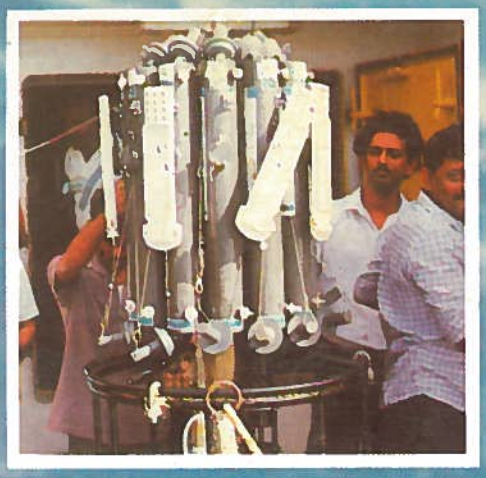

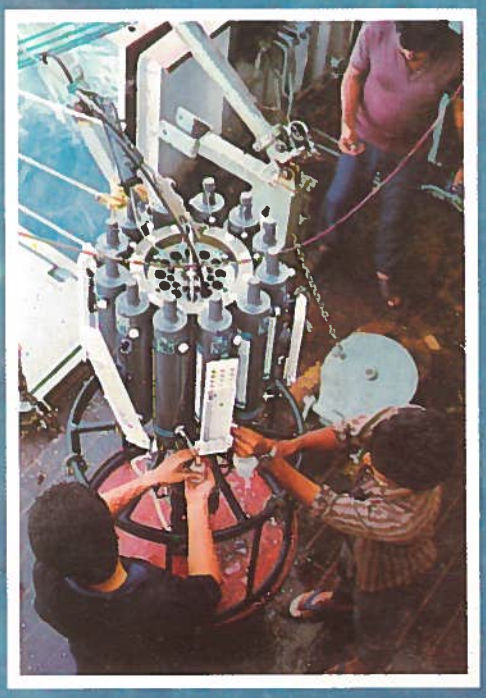

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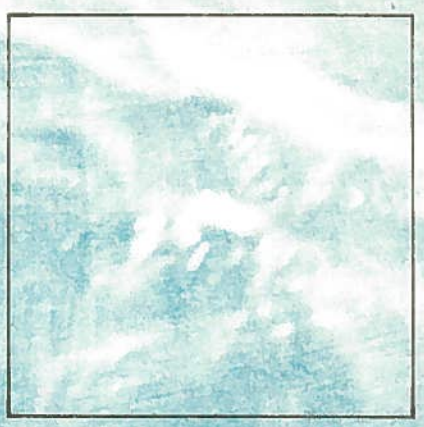
PHYSICAL RESEARCH LABORATORY, AHMEDABAD

वार्षिक रिपोर्ट
1991-92
ANNUAL REPORT



CTD (conductance,temperature depth recorder) rosette with 2l Niskin bottles getting checked before the Cast.

1991-92
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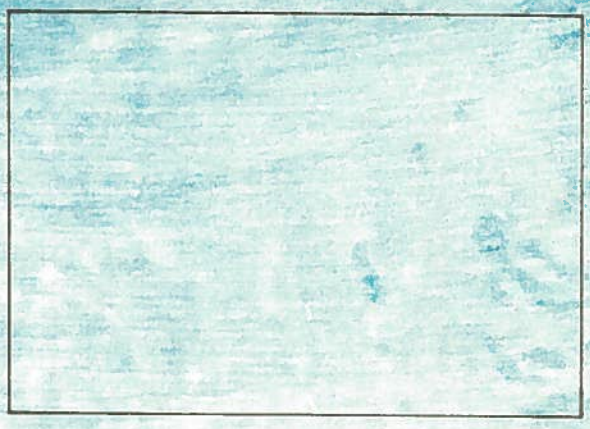
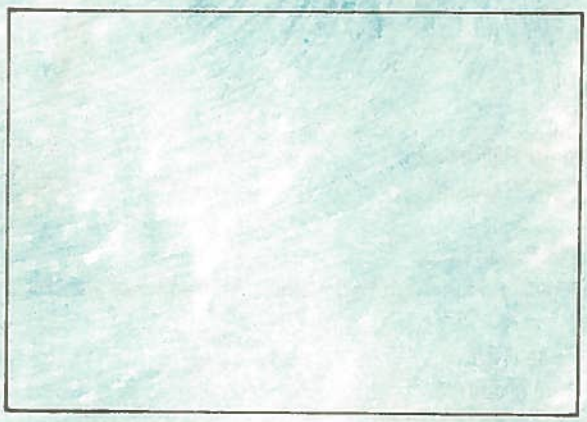
CTD rosette is secured after the Cast. Scientists are drawing water samples for analysis.

PHYSICAL RESEARCH LABORATORY
AHMEDABAD

View of a 30 l Niskin bottle in the open position before its descent to deeper depths for collection of water samples. Blackline across the figure is the hydrographic winchwire to which the sampler is fixed.



Large Volumes (20-100l) of water are passed through MnO_2 coated acrilan fibre at a slow rate for quantitative Ra extraction from sea water.



30 l Niskin bottles are secured after the Cast for drawing samples for radioisotope studies.

All Photographs are taken by
B.L.K. Somayajulu onboard DOD research vessel
FORV Sagar Sampada in a cruise to the Arabian Sea during February 1992.

Inner Pictures by :
D. R. Ranpura

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Introduction

An institution, such as PRL, which wishes to continue its march towards excellence ought to undertake periodically an exercise of a critical self assessment in relation to its scientific achievements. This includes not only an assessment of its past and present achievements, but also a consideration of possible future plans and directions. The scientific programmes of the institution have to display a dynamism of evolution so as to be constantly at the frontiers which have been advancing faster than ever before.

If we look at our achievements over the past five years, for example, we have good reason to be gratified not only with respect to the scientific results obtained, but also the new instrumentation developed in the various areas. However, as will be pointed out later, we ought also to give serious consideration at a given point in time, what new activities should be seeded which will take a centre-stage a decade hence, for example, when the present programmes would have outlived their scientific importance.

In the area of "*Atomospheric Sciences and Aeronomy*", PRL has undertaken two new thrust programmes apart from the continuation of the remnants of the earlier ones, such as the Spread-F.

First, in continuation of the IMAP (Indian Middle Atmopheric Programme), PRL has undertaken a comprehensive programme for the studies of the middle atmosphere. PRL scientists have made pioneering investigations on aerosols, ozone and other trace gases as well as green-house gases, such as CO_2, methane and water vapour. The balloon experiments conducted so far have yielded very valuable results, e.g. the first full set of trace gas profiles over the tropics, first mesurements of some of the bromine compounds in the stratosphere and trend estimates for some of the trace gases. One of the fall-outs of this programme for the coming years is our contribution to IGBP in trace gas studies in the tropics which includes methane and N_2O flux measurements, trace gas monitoring and troposphere chemistry.

The programme to study the Radiation Budget, which consists in the determination, *inter-alia*, of aerosol size distribution and optical depths in the troposphere and stratosphere and their role in radiation budget was initiated in the eighties. The hieght distribution/variation of size spectrum was studied for the first time using radiation techniques.

Radiation mesurements have also been used during the last few years both on balloon and from ground for minor constituent studies. While balloon programme give insight into the details of the aerosol parameters/processes in the atmosphere from the atmospheric radiation budget point of view, what is needed is a regular monitoring of the tropospheric and stratospheric aerosol optical depth. For this purpose, a Laser programme has been recently initiated with the acquisition of a Nd-Yag laser. Mie scattering measurements for aerosol studies have begun this year and the programme is being expanded for Rayleigh scattering measurements for the study of the structure and dynamics of the stratosphere and mesosphere.

The second thrust area which is, in some sense, a resurrection of the *airglow studies* of the yesteryears, is what may be called as the *Optical Aeronomy*. This consists in the studies of the ionosphere- thermosphere coupled structure and dynamics, using ground based optical techniques. During the last three to four years, since this programme was undertaken, several technological innovations have been effected: New state-of-the-art (and some times better than what is existing else where) instruments have been built and made operational : High resolution Fabry-Peort Spectrometer for line profile measurements of the Oxygen 630 nm emission to study thermospheric parameters, Doppler measurements for winds, multi-wavelength Fabry-Perot Spectrometer, the Dayglow Photometer (the realisation of this instrument has been a technological challenge for almost two decades which PRL scientists have been able to meet) and Image Intensifier CCD Camera systems for mapping the emission system.

Multi-station, multi-technique campaign have also been recently undertaken. Some of these have yielded first results and the next few years should be a period of intense observational activity which should be highly rewarding scientifically.

A very important supplementary activity to the middle atmospheric chemistry studies is the experimental determination of cross sections of atomic and molecular reaction of relevance to the atmospheric

chemistry. Such reaction cross sections have been determined by PRL'S Laboratory Astrophysics group. This laboratory, which was initiated in the seventies, is the only one of its kind in India and its efforts in the determination of important cross sections have given good scientific results which are well appreciated. This includes, over the last five years, photo- absorption and fluorescence cross sections for sulphur dioxide and carbon disulphide in a few spectral regions, as well as other molecules, such as methane, CCl_4 and chlorofluorocarbons, etc. which will be carried out in the near future.

An excimer laser pumped dye laser has recently been installed. This will give a spectral range of 320-990 nm and an energy of about 100- 200 m Joule/pulse. This will be used to study fluorescence spectra of different molecules as a function of incident photon wavelength and temperature. The radiative life times of molecules in different excited states can also be measured in this experiment.

In the area of *Astronomy and Astrophysics*, the group has earned a distinction for itself in the country for fabricating instrumentation for certain studies which were not undertaken in the country so far. The Fabry - Perot spectroscopy was initiated at PRL, both in the fields of astronomy and aeronomy. It was first used for the study of Doppler widths for upper atmospheric temperatures. The instrumentation was later developed for line profile studies in planetary nebulae. A state of the art imaging high resolution spectrometer has now been fabricated.

Fabry-Perot spectroscopy has also been used in carrying out innovative studies of solar coronae during total eclipse and on cometary plasma. Ours is one of the few groups the world over and only one in this country which has made this kind of observations.

A state-of-the-art polarimeter for astronomical observations has been fabricated at PRL. Important results have been obtained on time scales of variability of polarization in the AGN. An IR polarimeter is also being developed.

A CCD Camera (optical) has been fabricated which can enable us to study the extragalactic weak sources even with the 1.2 m class telescope, such as the Gurushikhar one. An IR - CCD camera is also under fabrication.

To achieve high spatial resolution in the infra - red (IR), a fast IR photometer, suitable for lunar occultation studies (that is, with a response time of ~ 1 ms), has been developed. High spatial resolution in the near IR can give clues to the nature of the circumstellar shells surrounding young stars and protostars and is, therefore, very useful in understanding star formatiom processes.

While many interesting investigations on planetary nebulae, comets and solar corona and active galactic nuclei (AGN) have already been made using these instruments, studies in the coming years will be addressed to (i) investigate and understand post asymptotic giant branch evolution of intermediate stars, (ii) probe astrophysical plasmas in diverse conditions, (iii) to study the nature of energetic processes occuring in nuclear regions of the AGNs and (iv) to study star formation processes; in particular, to probe the circumstellar environs of protostellar objects, their morphology and related aspects, including mapping polarization of stars behind dense dark clouds and globules.

In the radio astronomy area, PRL has made the first observation, using the IPS telescope, of the scintillation of radio source, 3C459, caused by the plasma tail of the Comet Halley. The observation was later confirmed by the Australian group while scintillations were also later recorded by the PRL group on Comet Austin, thus confirming and validating the scintillations by the plasma tails of comets. More recently, the IPS group has also recorded a rather spectacular event, what appears to be a burst emanating from the pulsar, 0950+08. Concomitant ionospheric absorption of the radio waves as observed from the ionosonde data point to the possible existence of also the X-ray emission burst from the pulsar.

In the area of *Theoretical Physics*, where we have had a number of disciplines: plasma physics, nuclear physics, atomic and molecular physics, monsoon dynamics and astrophysics, we have added a small group on particle physics during the last five years. This group is to have a specific orientation towards high energy astrophysics and cosmology. Significant

achievements have been made in all the various disciplines over the last five years.

Nuclear Physics group is historically the oldest group at PRL which has made pioneering contributions in nuclear structure and spectroscopy as well as in statistical theory of nuclear energy levels. While activity in low energy nuclear physics has continued with the most significant work being the development and application of the sdgIBM (Interacting Boson Model), the group has taken on new lines of investigation of nuclear behaviour at high energies. This involves quark gluon plasmas which have been investigated with special emphasis on the study of collective plasma properties. Very interesting modes of oscillations have been obtained arising from the nonabelian nature of the problem. Another significant investigation is the highly sucessful determination of nucleon- nucleon interaction (phase shifts) from the fundamental quark degrees of freedom, thus dispensing with the need of involving pions to mediate the interaction.

In high energy physics, the group has made important contribution in the construction of neutrino masses and mixings which explain almost all the experimental features inc uding the solar nutrino flux, a possible 17KeV neutrino with its cosmological and astrophysical implications.

In the area of atomic and molecular physics, in a work of fundamental importance, a proper formulation, referred to us *the boundary corrected formulation,* has been advanced for the problem of high electron capture. The earlier OBK formulation (Oppenheimer (1928) and Brinkman and Kramers (1930) was plagued by a singularity problem due to the long range nature of Coulomb interaction.

The two fundamental disciplines of physics which are essentially the cornerstones of physical sciences are classical and quantum mechanics. While quantum mechanics continues to be an enigma, we do not yet fully appreciate the structure of even classical mechanics and its implications. Furthermore, even now, the precise nature of relationship between classical and quantum mechanics continues to evade us. In the course of a search for such a relationship, some quite astonishing wave-like properties of a particular classical mechanical system (charged particles in a magnetic field) have been discovered. Indeed, evidence has been found for the existence of discrete energy states in the classical mechanical domain, the prediction for which has, in fact, been made by a theory which has been developed at PRL.

The plasma physics group at PRL has traditionally been the strongest plasma group in the country. However, subsequent to the parting of the fusion-oriented plasma physicists, the plasma activity has been concentrated on the space and astrophysical aspects. The group has made very interesting investigations on the behaviour of nonlinear Alfven waves in relation to the phenomena observed in solar wind plasmas. The effect of external sources is found to lead to chaos. The group has also now taken up studies of dusty plasmas which is a new and highly promising field of investigation and has already obtained a few very interesting results on dust acoustic waves and dust magnetosonic waves.

In the plasma astrophysical domain, a self-consistent dynamical theory has been given for the first time for the global galactic magnetic field. A problem of great astrophysical significance is the question of the origin of the magnetic field in the Universe which poses a great challenge.

In astrophysics, studies have been made of the structure and dynamics of the magnetospheres of compact objects and associated accretion disc, both in the Newtonian as well as general relativistic framework. Plasma instabilities have been identified which enable an accreting plasma to enter into the magnetosphere in a magnetically closed model.

Important contributions have been made in the area of monsoon variability on the intra-seasonal time scale. In particular, a good understanding has been achieved on the physical mechanism of the 30- 50 day oscillation and its northward propagation.

In the *Earth Sciences* area, PRL scientists have focussed their studies on ancient and contemporary processes that have shaped the surface of the planet earth since its formation. This naturally includes processes involving the lithosphere, the hydrosphere and the atmosphere and interactions among them. PRL is one of the very few institutions in the world

where active research in various earth system components is being pursued and it has made some highly significant contributions over the last five years.

Among the questions that have been addressed relating to the evolution of the lithosphere, are those relating to the Deccan volcanism (one of the largest known continental volcanic episode in the world) and the K/T boundary and the possible cause of the mass faunal extinction during the K/T transition. While a K/T section has been identified in Meghalaya, through the Ir anomaly, dating of the Deccan basalts have revealed the existence of three distinct volcanic episodes, all of which, however, predate the K/T event by about 2 Ma. The obvious conclusion that follows from these investigations is that mass extinction in, at least, the Indian peninsula could not have been caused by Deccan Volcanism.

In studies relating to the hydrosphere, there are questions concerning the chemical river inputs to the oceans as well as vertical mixing of the ocean waters and deep ocean circulation. Chemical interaction (one way) between the lithosphere and hydrosphere (the oceans) takes place through the river systems, while the interaction between the atmosphere and the oceans is mediated through both physical and biological processes. All these processes have their signatures with their respective time markers. Their evolution can be deciphered using appropriate *clocks*, such as the cosmic ray produced ^{32}Si for ocean circulation. The deep ocean sediments provide records over ~ 100 Ma or more. Because, partly of their biological origin and because the organisms respond in their chemical uptake differently at different temperatures over the aeons, these deposits contain in them, records of past climate changes (temperature changes, in particular). We thus have chemical and biochemical interactions involving the lithosphere, the hydrosphere and the atmosphere with the past climate changes convoluted in the records of these interactions locked up in such deposits, which can be on the ocean floor, on the continents, in the trees, or in some deposits in the continental shelves.

The major findings of these studies are that (i) the major Indian river system (the Ganga, the Brahmaputra and the Indus) -- the Himalayan rivers, have U concentrations an order of magnitude larger than in other major world rivers and are enriched ^{87}Sr / ^{86}Sr and thus would account for a significant fraction of the observed increase of these elements in the oceans over the past ~ 40 Ma. (ii) Using the ^{18}O /^{16}O ratio in the ocean sediments, it has been concluded, for instance, that the salinity in the Arabian Sea was higher during the last glacial period (as a result of weak SW monsoon and stronger NE monsoon). Conclusions have similarly been drawn about the sea surface temperatures and upwelling conditions and their correlation with the strength of monsoon at various geological epochs.

Deserts represent an important component of palaeoclimatic signatures. Theromoluminescence dating of the Thar desert sands suggest that the (Thar) desert is at least 200 Ka old, discounting its anthropogenic origin, but highlighting the role that the global climate changes play in the evolution of deserts.

On small time scales (1 - 10 yrs.), the analysis of tree rings, corals and glaciers provide the necessary climatic information.

However, for time scale of the order of 5000 - 20000 years, the records buried in the lake sediments and other continental deposits provide valuable information of climatic changes over these important time scales. Studies of the loess profile of Kashmir using the geochemical and mineral magnetic techniques and dating by ^{14}C and thermoluminescence, PRL scientists have been able to identify Milankovitch periodicities in the climatic signatures and, in fact, have been able to construct a detailed climatic sequence; the dominance of 20 Kyr Milankovitch periodicity, the onset of deglaciation at 18,000 B.P. as well as the role of Tibet in climatic forcing, and correlation between major magnetic reversals and climatic episodes.

Another major area of investigation has been the studies relating to the early solar system. Here one tries to understand the time evolution of the Sun and the solar system bodies, using meteorites and moon samples as the repository of the information regarding the early solar system processes in the form of various critical isotopic signatures. Using the recently acquired highly sophisticated mass spectrometer, the Ion Probe, significant new results have been obtained which suggest, *inter alia*, a relatively homogeneous isotopic com-

position for select elements in the solar nebula as against the standard view of an isotopically heterogeneous nebula. These and other results serve to provide tight constraints on the models of formation of solar system bodies. Apart from these results, PRL scientists have also found evidence for the existence of an early active phase of the Sun-the T-tauri phase.

While the achievements made by PRL over the last five years are quite gratifying, there are yet areas which require greater attention. For example, while we have acquired very valuable data by painstaking experimental work, we have not developed a good modelling activity which involves a meaningful analysis of the data. The need for such a data analysis and modelling group cannot be over-emphasized particularly in disciplines which involve globally inter-related processes, such as those pertaining to the atmosphere and the oceans, and the earth system processes, in general.

Again, while the current programmes would continue for the next 3-5 years and some even beyond, the challenge that an institution always faces is to think of programmes of futuristic importance which ought to be seeded today and which should occupy the centre stage a decade hence. The choice of such programmes requires a sense of prespective and vision which may not be easy to acquire, but which is, nevertheless, very essential to keep an institution on its march towards excellence. It is imperative that such programmes should now be identified for PRL.

(DIRECTOR)

Awards and Honours

Dr. S. C. Tripathy
Awarded the URSI Young Scientist Award for 1990

Dr. R. K. Varma
Elected Fellow of the Astronautical Society of India.

Dr. Hari Om Vats
Elected member of the International Astronomical Union.

Prof. D. P. Agarawal
Elected Fellow of the National Academy of Sciences, Allahabad.

Dr. J. N. Goswami
Elected Fellow of the Indian Academy of Sciences, Bangalore.

Prof. Bimla Buti
Elected President of Commission 49 of International Astronomical Union and President of Plasma Science Society of India.

Scientific studies undertaken by the Astronomy Astrophysics division cover a rather wide spectrum ranging from the phenomena occuring on the Sun and their influence on its immediate neighbourhood, to those occuring in distant galaxies.

Solar activity cycle and the transient energetic phenomena occuring on the Sun influence not only the corona and the interplanetary space, but also shape the cometary ion tails and generate disturbances. Nature of these interactions are studied using the techniques like H-alpha observations on the Sun, the interplanetary scintillations and observations made on special occasions like total eclipses and cometary appearances.

At the other end of the spectrum are the phenomena occuring near the central regions of active galactic nuclei; where accretion on massive black holes may be powering immense energy output and driving plasma jets to billions of kilometers. These give their signatures in the form of polarization of the radiation and its variability, and are being studied by polarimeteric methods.

Dark molecular cloud complexes are the locations of star formation. Birth of massive stars give rise to immense output of extreme ultraviolet radiations which ionize the surrounding medium and give rise to the ionized hydrogen (HII) regions. Line profile studies on the emission lines of the radiations emerging from these regions can be used to understand the velocity flow patterns and the turbulence. Such studies are important for the understanding of star formation processes.

Imaging high resolution Fabry-Perot spectrometer, recently completed, is used for such studies. In mass exchange binary systems, phenomena like novae eruptions give rise to subsequent formation of dust envelopes surrounding the system. Spatial and temporal time scales of the dust shell formation are studied by following the events by the infrared photometric studies.

During the previous year PRL scientists made very interesting observations pertaining to dust formation after novae eruption. Classical novae are mass exchange binaries in which a white dwarf is accreting matter from a companion exhibiting mass loss. The thermonuclear flash from accreted matter is believed to cause sudden increase in brightness upto 15 magnitudes (i.e. million times). Material ejected in the eruption subsequently leads to formation of dust envelopes.

PRL scientists studied two of such novae recently; Nova Herculis 1991 & Nova Cygni 1992 especially in their infrared brightness variations after eruption. Increased infrared brightness occurs sometime after eruption and is a signature of dust formation in circumstellar region.

Nova Herculis 1991 was a fast nova (i.e. brightness drop was 3 magnitude in 6 days). In this case dust formation signature was seen after 7 days. Normally, fast novae do not produce substantial dust and in this respect this observation is novel and surprising.

Nova Cygni 1992 which is a slow nova, is still being followed (100 days after eruption) and no substantial dust formation is noticed as yet.

Although theoretically a large telescope permits high spatial resolution (i.e. sharp images), distortions in wavefront caused by atmospheric refractive index inhomogeneities do not allow this in practice, e.g. a one meter telescope which should give a point object image of ~ 0.1 arc sec in the visible, rarely can give even a 1 arc sec image. One of the method that is followed at PRL is to observe diffraction fringes formed when lunar limb occults a stellar object - the method of lunar occultation. This can especially be useful in the infrared to resolve close binaries and circumstellar shells.

A more general method is that of speckle interferometry in which large number of short exposure (< 30 millisecond) speckled images are processed to recover high resolution image. PRL is shortly acquiring an array detector for the infrared (Hg-Cd-Te 256x256) which should enable it to undertake speckle interferometric work. However, signal to noise ratio in speckle interferometric image recovery is a very sensitive function of atmospheric seeing conditions. This makes quantitative evaluation of the seeing conditions imperative; in terms of what is commonly known as the Fried seeing parameter "r_o".

For this purpose a stellar intensity scintillometer with 0.5 millisecond sampling time has been made. Stellar scintillation measurements made with this will enable understanding the nature of scintillations and height of turbulent lavers over the Gurushikhar observatory site.

In the following paragraphs various scientific activities of the division are given in more details.

Solar Physics at Udaipur Solar Observatory

Solar prominences when seen against the solar disk are generally called as dark filaments. Their stability and eruption has strong effect on the interplanetary and geomagnetic field. From a detailed study of several erupting filaments the criteria for their stability have been established. To provide the required stability, it has been observed that the role of their "feet" anchored deep in the chromosphere, plays the most important part. Any change in the "Anchorage" due to either magnetic field variation or flare disturbance can cause filament eruption. For prediction of filament eruption detailed understanding of the magnetic field configuration is required.

For almost real time acquisition and analysis of digital solar images, a sophisticated digital image processing unit called Image Digital Analysis System (IDAS) has been commissioned in conjunction with the solar telescopes. Heliographic coordinates, area of active regions, height, length and width of the various solar features and integration of images, are now readily and rapidly obtained on real time basis, using IDAS.

The Udaipur Solar Observatory has been selected as one of the sites for Global Oscillation Network Group (GONG) programme for the study of helioseismology. It has been found from 6 years of site survey data, that Udaipur is clearly the best choice in the longitude band, however, Urumqi in China, complements Udaipur well during the deep and prolonged monsoon period in India.

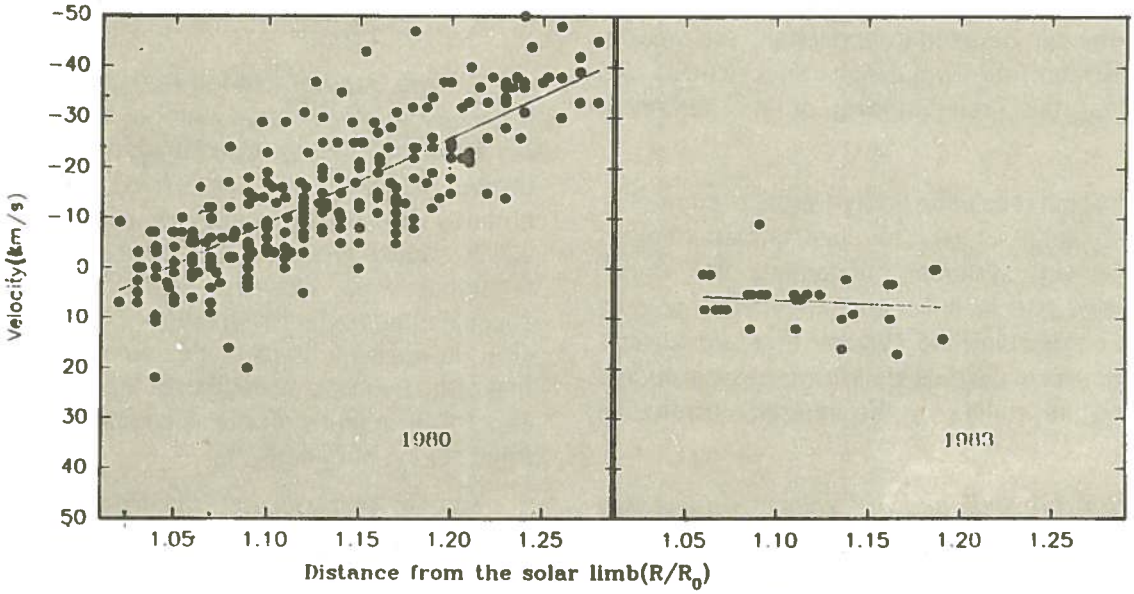
Three - Dimensional Orientation of Prominences, Filaments and Flare Loops

In order to visualise the structure, stability and evolution of loop like features such as prominences, filaments and flare loops, a code has been developed to reconstruct their 3 dimensional configuration as seen on the curved solar surface. The technique is purely geometrical and does not depend on the presence of magnetic field. Using this technique on full disk H-alpha photographs, the true height of the loops above the solar surface, their footpoint separation, the azimuthal angle of the loop-plane, the inclination to the vertical and the tilt of the axis of symmetry of the loop can be computed. These parameters define the orientation of loops in 3-dimension.

(A.Bhatnagar, A.Ambastha and N.Srivastava)

Coronal Loop Flows and Heating

Although it is generally accepted that solar corona attains its high temperature (> 2×10^6 degrees) by action of photospheric magnetic fields pervading



Line of sight velocity in corona (in km/s) vs. radial distance from solar limb (in $\frac{R}{R_\odot}$) (negative values indicate velocity towards observer).

corona, exact mechanism remains still elusive. Two broad classes of mechanisms are likely i) energy carried & dissipated by Alfvenic waves, ii)currents associated with reconnections. Observational clues as to the specific mechanism operating over a region could be obtained through understanding coronal loop flows through emission line profiles. PRL scientists obtained very high quality interferograms in 5303 A emission in [FeXIV] during 1980 & '83 eclipses. A statistical study of interferogram fringe diameter variation with height from the solar limb has recently brought out a very curious feature. In 1980 eclipse (which was in near maximum activity phase), there exists a definite statistical trend for increasing blue shift (i.e. flow towards observer) with height over the solar limb. The tendency is particularly strong over active regions. During 1983 eclipse, which was in declining activity phase, the trend is almost absent.

Although it is clear that this feature must be associated with average property of plasma flow in coronal loops, the exact significance remains to be understood. We propose to study this aspect more closely during 1995 eclipse, over northern India.

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

Radio Astronomy and Interplanetary Medium

The main scientific goal of the radio astronomy and interplanetary scintillation programme is the study of solar wind. For this we have a large radio telescope located at Thaltej and the observations of several compact radio sources e.g. quasars, radio galaxies have been regularly taken since 1984. All these observations have been analyzed to obtain solar wind velocity maps. In addition to this main experimental programme, study of high speed solar plasma streams was also undertaken mainly to understand their origin and effect on the terrestrial environment. These programmes are described below in detail.

Solar Wind Measurements for the Period 1984-90

There is now widespread evidence of the existence of solar wind, although gusty and variable, blows continuously from the solar corona into the interplanetary space. There are two basic approaches for the measurement of solar wind velocity, namely, insitu measurements by satellite and space probes and indirect measurements by radio astronomical observations of the phenomenon of interplanetary scintillation (IPS). The former, provides measurements only near the earth i.e. in the ecliptic plane whereas the latter method provides good spatial coverage both in and out of ecliptic plane. Radio astronomical observations of IPS using the Thaltej radio telescope were mainly used to estimate solar wind velocity and to make its maps (called V-maps).

Intensive observations of several compact radio sources using an array radio telescope operating at 103 MHz were made at Thaltej since 1984. Recently a method for determining the solar wind velocity using single station interplanetary scintillation observations has been developed by TIFR radio astronomers. Using this method we analyzed data for the period 1984-1990 and prepared velocity maps (V-maps). These maps are made by back projecting the observed velocity using the expression shown below:

$$\phi - \phi_o = \frac{\omega R}{V}$$

where ϕ is the heliolongitude of the point closest approach (at a distance R from the Sun) at which the solar wind V is measured, ω is the angular solar rotation velolcity and ϕ_o is heliolongitude from which the observed solar plasma must have emanated. The heliolongitude (ϕ_o) for each observation during a year is converted into the Carrington longitude and the V-maps are prepared for each year.

An attempt was made to study these observed velocity maps in terms of the evolution of the solar corona as well as the neutral magnetic line structures which strongly depends on the solar activity cycle. Almost all high speed regions correspond to the coronal holes and low-speed regions appear in the vicinity of the neutral magnetic lines. During solar minimum (1986) very low-speed are seen to emanate from the giant bipolar magnetic regions (GBMR) derived from line of sight (LOS) component of the photospheric magnetic field.

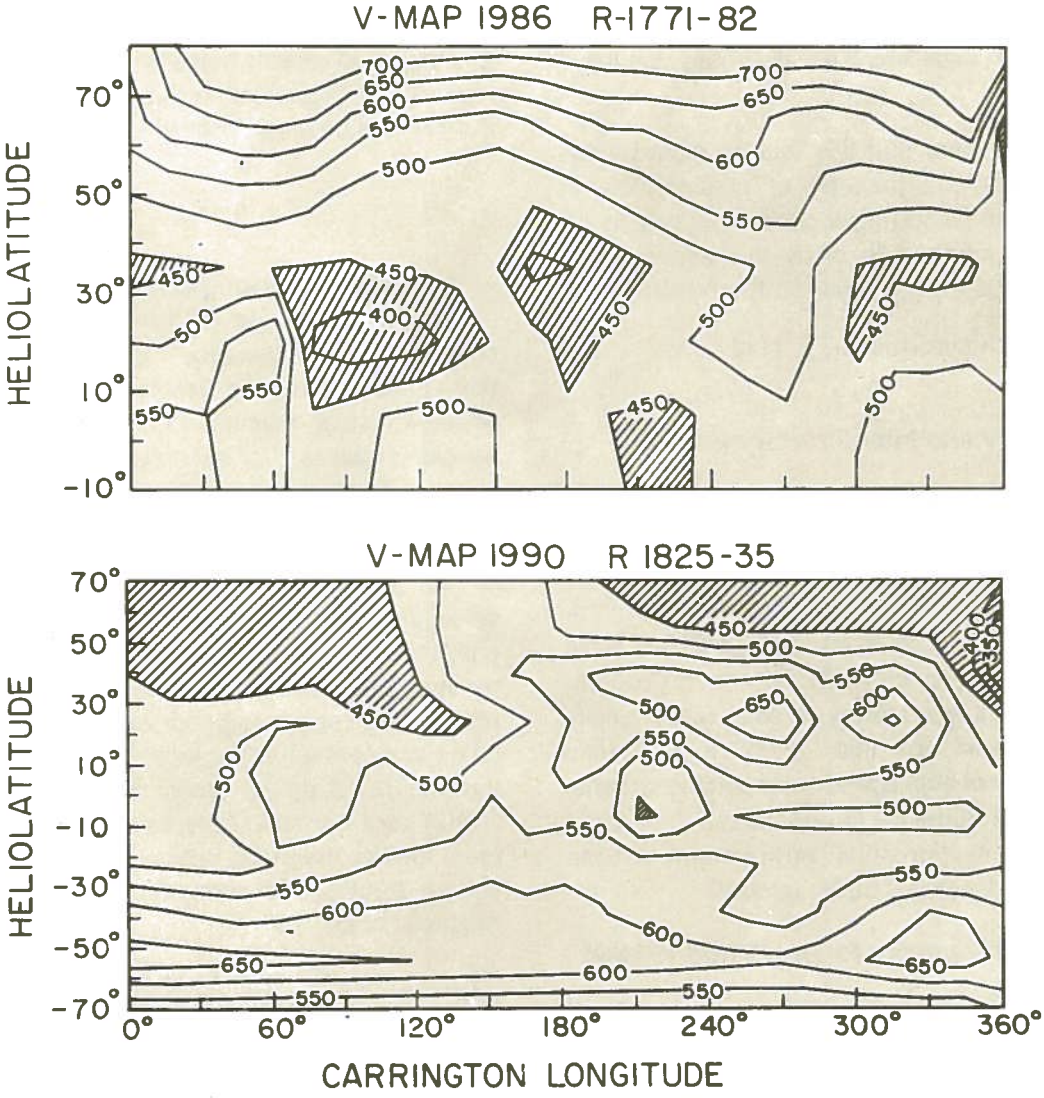
(Hari Om Vats, P. Janardhan, A. D. Bobra, A. K. Sharma, S.K.Alurkar, and K.J.Shah).

Coronal Hole and Solar Flare Associated High Speed Plasma Streams

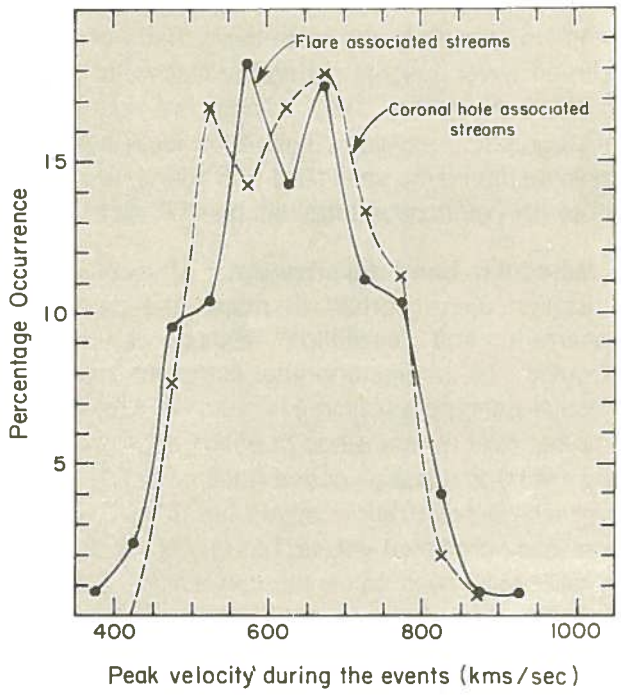
Solar wind can be organized into well defined high and low speed streams. The high speed stream originate

either from coronal holes or from solar flare regions. A study was undertaken to investigate the characteristics of these streams. It is found that the occurrence of the peak observed velocity of the streams associated with coronal holes and solar flares have comparable distribution. The peak observed velocity of the streams ranges from 400 kms/sec to 900 kms/sec and peak probability for 600 kms/sec. Similarly the stream duration for both the types ranges from 3 to 15 days with a peak occurrence of 5 days. Thus flare and coronal hole associated streams have comparable occurrence probability of peak observed velocity and duration of the events. The two types of high speed streams differ significantly in their solar cycle dependence. The occurrence of flare associated streams increase with the sunspot numbers whereas the occurrence of coronal hole associated streams is anti-correlated with the sunspot numbers. However, the total number of coronal hole associated streams is 2.2 times more than the flare associated streams. During high solar activity periods the number of flare associated streams becomes almost equal to the number of coronal hole associated streams.

(Hari Om Vats)



Typical examples of solar wind velocity maps obtained using IPS data of Thaltej Radio Telescope. Hatched portions mark the region of low speed and are found to be associated with neutral magnetic lines.



Comparison of peak velocity distribution for streams associated with coronal holes and solar flares.

Effect of Solar Wind Streams on the Geomagnetic Field

It is known that energetic processes on the Sun e.g. solar flares, coronal holes, mass ejections etc. have significant effects on the terrestrial environment specially the geomagnetic field. An attempt was made to investigate the effect of high speed solar streams and their associated polarity of the interplanetary magnetic field. It is found that whenever there is Earth passage of the high speed solar plasma stream Ap index registers an increase indicating that passage of these streams causes geomagnetic disturbance. There appears to be a linear relationship between the average enhanced Ap and the average peak velocity of the streams. The classification according to coronal hole and flare association brings out the fact that the rate of Ap enhancement is about 2.7 times more for flare associated streams than that for coronal hole associated streams. This fact makes the solar flares as the most important putative cause of geomagnetic enhancement, specially in high solar activity period. However, the polarity of interplanetary magnetic field seems to play no significant role in producing geomagnetic disturbances.

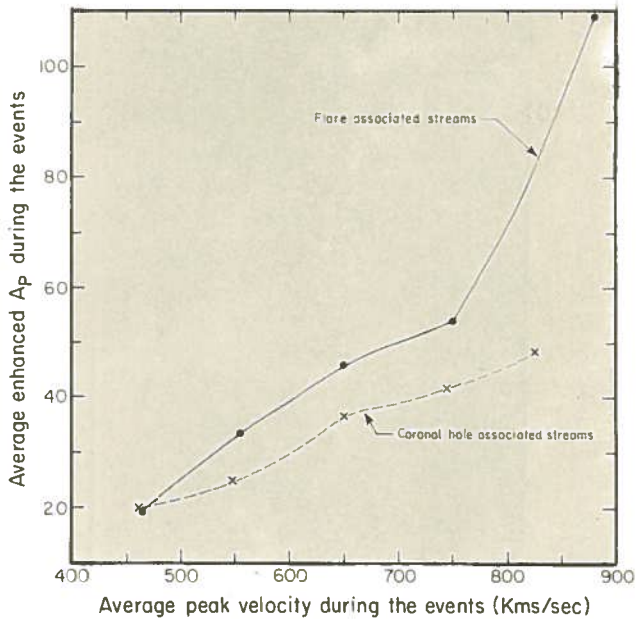
(Hari Om Vats and V. R. Chokshi)

Cometary Studies : Comet Halley and Comet Austin

The comet Austin has been studied along with the comet Halley and comparison of their dust properties has been made. This study is aimed to understand the dynamical evolution of comets. In the following paragraphs some of the new results are summarized.

Dust composition and size distribution :The problem which we have addressed is the composition and size distribution of cometary dust. This is vital to understand the origin and dynamical evolution of comets. Through the model based calculations we have studied the composition of comet grains (in terms of its complex values of refractive indices). We have obtained very interesting results on comet Austin. The calculations, being based on wide coverage of the phase angles, give unique solutions. This kind of detailed calculations were performed for the first time in the sense that very wide phase coverage of polarimetric observations have been taken into consideration and a least square solution has been sought. Some of the results are discussed in the following:

a) The dust size distribution of comet Halley (dynamically older comet) is different than that of comet Austin (a new comet) in the sense that Halley is relatively richer in coarser grains than Austin. There

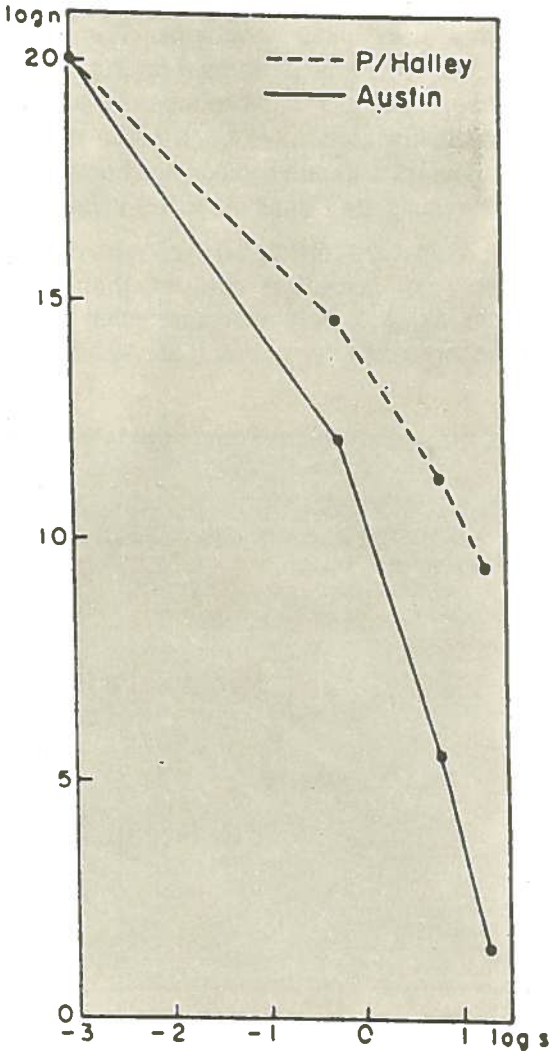


Dependence of Ap on the average peak velocity of the solar plasma streams.

were conjectures that dynamically older comet may be richer in coarser grains due to dynamical evolution. For the first time it has been demonstrated experimentally that dynamically older comets are richer in coarser grains. A paper has already been published in MNRAS 1991.

b) The composition of comet Austin does not seem to be very much different than that of comet Halley.

Imaging Polarimetry of Comet Austin : Imaging polarimetry is very powerful tool to understand the nuclear jet activity and the dust distribution in the comets. Imaging polarimetry on comet Halley carried out by us showed the pockets/blobs of high and low polarization. In order to study the motion of such blobs (which are connected with nuclear jets) and dust



Comparison of size distribution of dust grains in comet P/Halley and comet Austin as obtained using our polarimetric data through IHW filters

dynamics (synchrone and syndyne) repeated imaging polarimetric observations have been made on comet Austin on several nights during the last week of April and first week of May, 1991. Images are recorded on a photographic emulsion. Digitization work has been completed during the year 1991 and image processing work to get polarization map has been initiated.

Molecular band polarization : Molecular band polarization are important to model the production mechanism and excitation states of different molecules. To understand the complete nature of molecular band polarization it is necessary to observe the comet over a wide range of phase angles. Such a study has been made on comet Austin. For CN and C_2 the observed polarization values agree well with the theoretically predicted values, but for C_3 the polarization value falls much below the theoretically predicted value. Also the observed polarization values for C_3 show significant variation from night to night. Neither theoretical nor experimental works are available on the molecular band polarization of these two molecules. These values can be used for appropriate modeling of the different excitation states and mechanisms for these molecules.

Detection of Faint Filamentary structure in Coma of Comet p/Halley : An image processing technique has been developed to detect faint structures in images of extended astronomical objects. Such faint structures are not visible against the bright background of an image. This has been applied to comet p/Halley image taken by us. Results show very interesting structure in comet coma.

We plan to apply this technique to study the structures in galaxies.

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

Circumstellar Dust in Mira Variables and the Mass Loss Mechanisms

Infrared Astronomical Satellite (IRAS) data on 92 oxygen-rich Mira variables are analysed to evaluate the role of pulsations in mass loss among these stars. Using a radiative model equilibrium temperature, size, mass and optical depth of circumstellar dust shells have been estimated. A two-component dust shell model was found necessary to explain the photometric data. The mass of the inner shell shows a positive

correlation with the pulsation period while that of the outer shell does not. We suggested that the outer shell is a result of mass loss during the pre- asymptotic giant branch (AGB) stage while the inner shell represents the AGB mass loss caused by pulsations with the possible support from the radiation pressure. Dust seems to condense at 3-10 stellar radii which puts important constraints on the alternative mass loss processes like the one driven by acoustic waves. This work was done in collaboration with Prof.S.R.Pottasch, University of Groningen, Groningen, Holland.

(B.G.Anandarao and D.B.Vaidya)

IR Emission from Chemically Peculiar (CP) Stars

Some stars of spectral type A in the effective temperature range 7500 < T_{eff} < 10000 K show anomalous abundances of certain elements like Si, Sr, Hg, Mn and Eu. These are generally called as chemically peculiar (CP) stars and subgrouped into CP1 (also called as.Am, metallic line stars), CP2, CP3 and CP4, depending on the type of peculiarity. The sharp absorption lines in their optical spectra prevent the application of any standard technique to estimate the T_{eff}, by comparing it with the theoretical models. To overcome this difficulty, the data from the Point Source Catalog of the IRAS on these objects were searched with the idea of extending the energy distribution to the longer wavelengths. This study showed that slight excesses in flux above the theoretical models are present for some cases.

In cases where the UV observations are available, it was found that a single temperature energy distribution is difficult to match from UV through IR. The main reason for this is the redistribution of flux into the IR. Noting that many Am stars had long gaps in the near IR regions in their energy distributions, K band (2.2 micron) observations of some Am stars were obtained with the 1.2 m telescope at Gurushikhar during March-April, 1991 and at Kavalur during January- March 1992, with the 1m telescope. This established that the flux redistribution starts in the near IR region itself. Putting the results on 24 Am stars together it was possible to identify that the T_{eff} represented by the Paschen continuum is more realistic.

We further compared the various color indices like the (B-V), (V- K), (R-I) and (V-[12μ]) of the Am stars with the normal A stars. This brought out the important results 1) (R-I) is least affected by the flux suppression and 2) some Am stars have a clear excess flux in the IR. The source of this may be the free-free emission from the stellar wind (although weak) or possible circumstellar dust shells.

(B.S.Shylaja and N.M.Ashok)

IR Observations of Novae

Nova Herculis 1991: A nova is a violent astrophysical phenomenon brought about by a thermonuclear runaway in a degenerate layer of the surface of a white dwarf in a binary system. Infrared observations bring out the importance of novae as astrophysical laboratories for studying the formation of circumstellar grains and as possible sources of short lived radioactive isotopes which also figure in early solar system scenarios. In particular IR observations help in a) describing physical processes that characterise posteruptive development of novae, b) constraining theories of close binary system evolution and c) describing dust condensation processes. It is necessary to begin observations of nova at the earliest possible time after its eruption and continue regular observations for many weeks to get a good picture of the different processes.

On 24th March 1991 Nova Herculis 1991 erupted. PRL IR observations at the 1.2 m Gurushikhar telescope began on 5th April 1991 and continued regularly till the end of May when the nova became too faint to be observable. IR Photometry at J(1.2 micron), H(1.65 micron), K(2.2 micron) and circular variable filter photometry with a resolving power $\lambda/\delta\lambda$ ~70 between 1.7-3.4 microns constituted the observations.

The brightening of K band intensity seen in our data constitute the first signs of early dust formation in the system. The intial observations have been communicated in IAU circular (No.5254 dated 29 April 1991). Detailed analysis of our IR data in conjunction with other available data on the nova has led to the following conclusions:

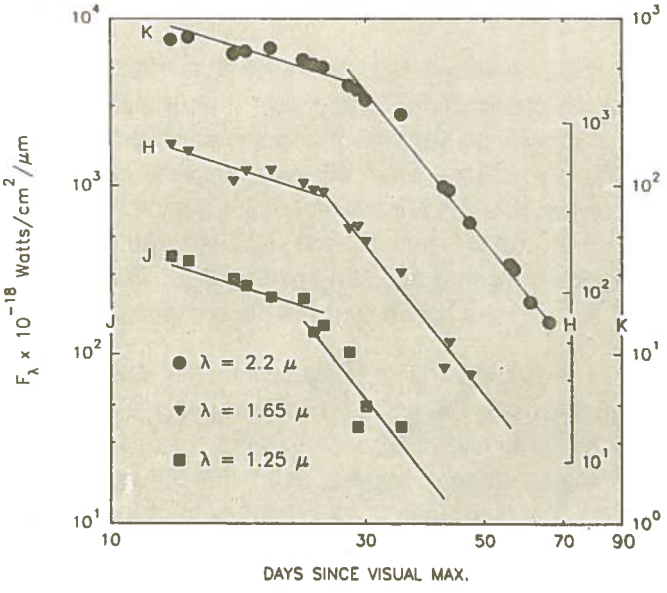
Nova Herculis 1991 was an unusually fast nova in which grain formation processes began as early as day 7 after eruption at a dust temperature of ~ 2000K. Maximum near infrared luminosity was reached on day 14 with L_{IR} ~ 5×10^4 $L_\odot$ at a blackbody temperature of ~ 1400K. Thereafter the dust cooled at a slow

rate $T_{BB} \propto t^{-1/2}$ consistent with a constant luminosity expansion phase. It is also possible to estimate, from the IR luminosity the Mass of dust condensed - $M_{dust} \sim 2 \times 10^{-8} M_{\odot}$.

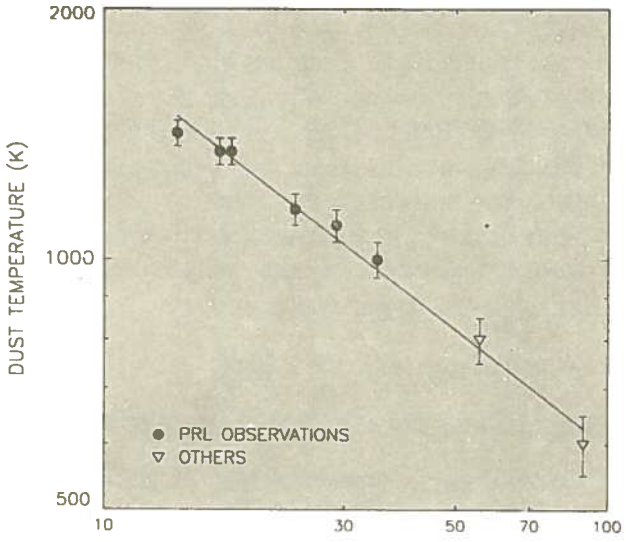
The blackbody angular diameter of the dust shell increased linearly with time reaching a peak value of 6 milli arcseconds, about 30 days after the eruption. The infrared light curve sharply steepened from a slope of -1 to -4 at about the same time, indicating the onset of optical thinness and the completion of the dust formation phase.

A detailed study of the Nova Herculis 1991 system is presented in our paper in Mon. Not. R. Astron. Soc. **255**, 412-418 (1992).

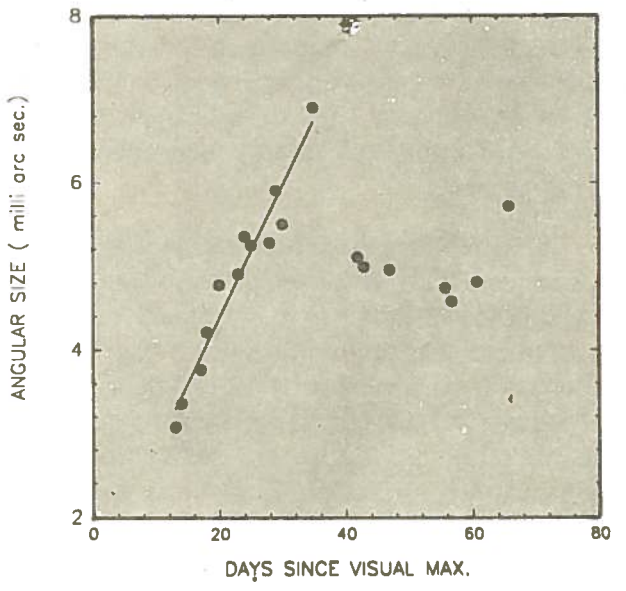
During the period of observations of Nova Her 1991 another nova in Ophiuchus also erupted and was observed. It was comparatively fainter and our observations on 4 May 1991 yield a K magnitude of ~ 8.0. Near IR observations of several novae have also been carried out by us at the 1 m telescope at Kavalur observatory during 1991-92. Novae studied are Nova Puppis, Nova Sgr.1992, Nova Cyg 1992, Nova Sco



Light curve of Nova Her 1991 in J,H,K filter bands. Observations in K (2.2 μm) cover the period day 13 to day 66 since visual maximum. In H (1.65 μm) the coverage is from day 13 to day 47 while in J (1.25 μm) it is from day 13 to day 35. The data shows a sharp change ~ day 25. Power laws of t^{-1} before day 25 and t^{-4} afterwards are superposed on the observation points.



The cooling curve of the dust in Nova Her 1991. A least square fit to the data gives a slope of ~ 0.5 signifying a constant IR luminosity phase. Maximum temperature observed ~ 1420 ± 50 K.



The variation of angular size (in milli arc seconds) with time since visual maximum. Angular size increases linearly with time till ~ day 30 implying expansion of the dust shell with uniform velocity. The abrupt change after day 30 could be attributed to the onset of optical thickness and the end of the dust formation stage.

1992. Due to limited telescope time available, the temporal coverage is not as extensive as in case of Nova Her 1991. Detailed study is in progress.

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

Co-ordinated observations of Flare Star AD Leonis: A campaign to comprehensively study the dynamics and energetics of stellar flares utilising high time resolution spectroscopy and photometry was organised on the AD Leonis system on May 8 and May 9, 1991. Satellite observations like Hubble Space Telescope, International Ultraviolet Explorer (IUE), ROSAT, GINGA and many ground based facilities including VLA and Arecibo participated in the multiwavelength campaign. At the 1.2 m Gurushikhar Telescope, AD Leonis was observed in the near infrared (1-3 microns) on the night of May 9, 1991. Observed magnitudes were J=5.7, H=4.80, K=4.60. Monitoring at 1 second interval nearly continuously was done in K band (2.2 microns) from 1558 UT to 1820 UT. Data shows possible flares around 1759 UT and 1806 UT lasting a few seconds with atleast 0.3 magnitude increase in intensity.

(N.M.Ashoκ and T.Chandrasekhar)

Co-ordinated observations of Cyg X-1: During the Space Shuttle (Discovery) STS-89 mission in April-May 1991 the URA instrument was to observe several X-ray sources in the sky and co-ordinated radio observations with Very Large Array (VLA) were arranged. Observations at other wavelengths was also requested. PRL observations at 2.2 microns at 1 second intervals on the intriguing binary X-ray source Cyg X-1 were carried out at the 1.2 m telescope on May 4, 1991 between 2230 and 2255 UT. The IR magnitudes of Cyg X-1 obtained were J=6.89, H=6.67, K=6.52. It was learnt later that the URA experiment developed low voltage power supply problems (LVPs) during the Cyg X-1 block but VLA observations of the source had continued.

(N.M.Ashok and T.Chandrasekhar)

Lunar occultations in the near Infrared

The technique of lunar occultations of stars and star forming regions is a simple yet powerful method of reaching high angular resolutions of a few milli arc seconds even with modest telescopes of the 1 m class. The near Infrared region offers the advantage of lower background intensity compared to the visible region thereby providing good signal to noise ratio in fringe resolution. The scaling of the pattern as $\sqrt{\lambda}$ also permits a more relaxed criterion for system time constant.

In the observations carried out this year at the 1 m telescope of Vainu Bappu Observatory, Kavalur two good IR occultation traces on IRC 20073 and IRC 00198 have been recorded in the K band (2.2 microns). The total of eight good occultation traces obtained so far in the last two years have together been taken up for source structure studies. The observed light curve I (t) can be given by

$$I(t) = \int_{-\infty}^{+\infty} F(w)\, s(\phi)\, d\phi + \beta$$

β defines background light level depending on the phase of the moon. F(w) is the point spread diffraction pattern while $s(\phi)$ is the brightness profile of the source in the direction of occultation. Detailed analysis to recover the source structure $s(\phi)$ taking into account system time constant, telescope aperture, spectral bandwidth is in progress.

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

Close Binary Systems

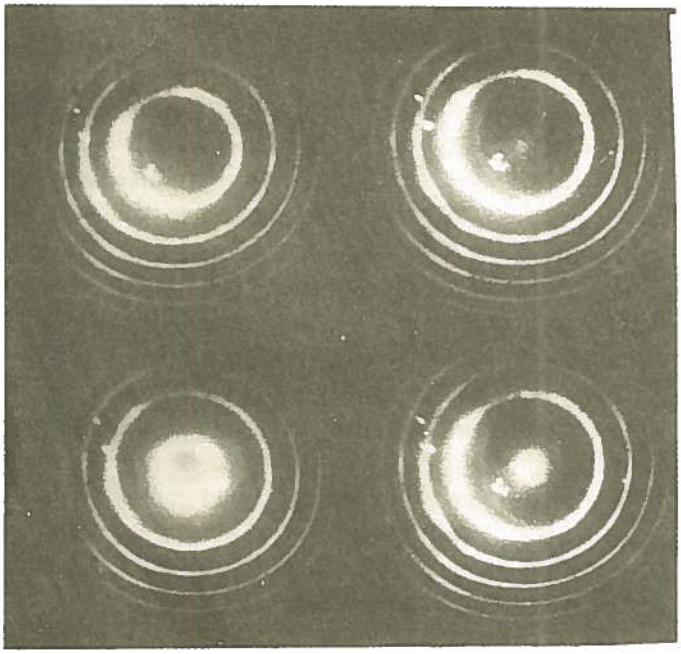
The stellar evolution in a binary system is very different than that of single isolated stars because of the mass transfer taking place between the individual stars of a binary system. The mass transfer leads to the formation of circumstellar rings or disks as well as mass loss from the binary system. The mass transfer rate is one of the important parameters in the models of binary star evolution. Further, distribution of the matter within the binary system provides important constraints for these models. An observational programme of near infrared photometry of close binary systems has been initiated with the objective of obtaining these parameters. JHK photometry of five binary systems UV Cnt, U CrB, TT Hya, UX Mon and DL Vir has been done and the data analysis is in progress.

This work is carried out in collaboration with Dr.H.C.Bhatt of Indian Institute of Astrophysics, Bangalore.

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

Velocity Field Mapping in Extended Astronomical Objects using an Imaging Fabry-Perot Spectrometer (IFPS)

Velocity fields in fine scale in Galactic HII regions : Using the newly built Imaging Fabry-Perot Spectrometer (IFPS) observations have been made on the Orion Nebula (M 42) at Gurushikhar, Mt. Abu with the C-14 telescope. A region of about 10.5 arc min centered around the θ^1 Orionis (Trapezium) has been mapped in the emission line [OIII] 5007 A with a spatial resolution of 3 arc sec and a spectral resolution of < 10 kms/s. Scanning was done by using a piezo-scanned servo-controlled etalon having an FSR of 3 A at 5007 A. The data (a total of 32 interferograms) are being analysed at present for obtaining detailed structure of kinematics and turbulence at fine scale. It is now believed that HII regions present an extremely complex velocity field structure. Our aim is to find out from the line profiles at each spatial point the spatial scales of turbulence in the region close to the star forming activity in order to understand the mechanisms responsible for the sustenance of turbulence in HII regions. We also aim to find out possible kinematic flows around the newly formed massive stars.



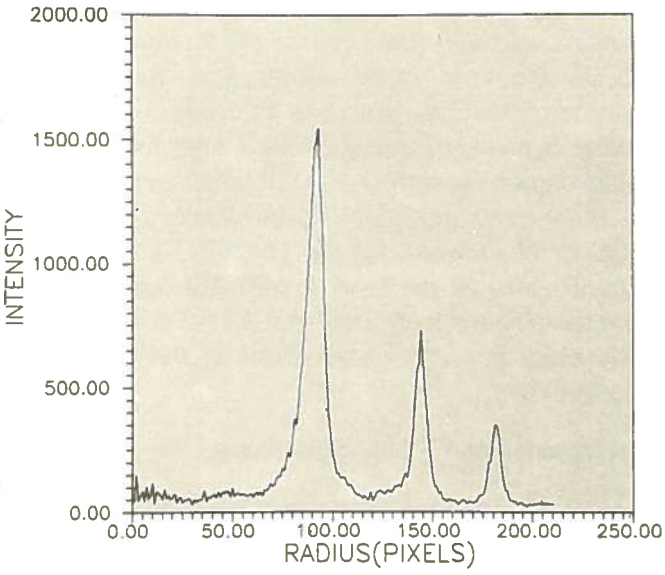
A mosaic of four interferograms of the Orion nebula (M 42) of 5 mt. integration in [OIII] 5007 A line taken at different etalon spacings. The expansion of the fringe pattern as the elaton is scanned (anticlockwise from bottom left) can be noted.)

A single interferogram in the [OIII] 5007 A emission line was also obtained on the HII region called Trifid nebula (NGC 6514) and has been analysed. The preliminary results show that there exist signatures of expansion around a group of newly formed massive stars probably driven by stellar winds. The velocity field shows low radial velocities all over except where there are newly formed massive stars. More observations are being planned with the 1 m telescope at Kavalur in collaboration with S.K.Saha of Indian Institute of Astrophysics, Bangalore.

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

Velocity fields in spiral Galaxies : Performance of the IFPS on large telescopes like the 2.34 m Vainu Bappu Telescope (VBT) and the 1 m telescope at Kavalur has been evaluated in order to estimate integration times necessary for obtaining high quality interferograms on spiral galaxies. These estimates tallied with those made theoretically. Several bright galaxies with flux upto 1.0 $X10^{-16}$ ergs/sec/sq.cm/sq.arcsec are possible to be mapped using this instrument with reasonably short integration times (10-40 mts.). Our first attempts to obtain interferograms were thwarted by bad weather at Kavalur. Our efforts will continue in the coming season.

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

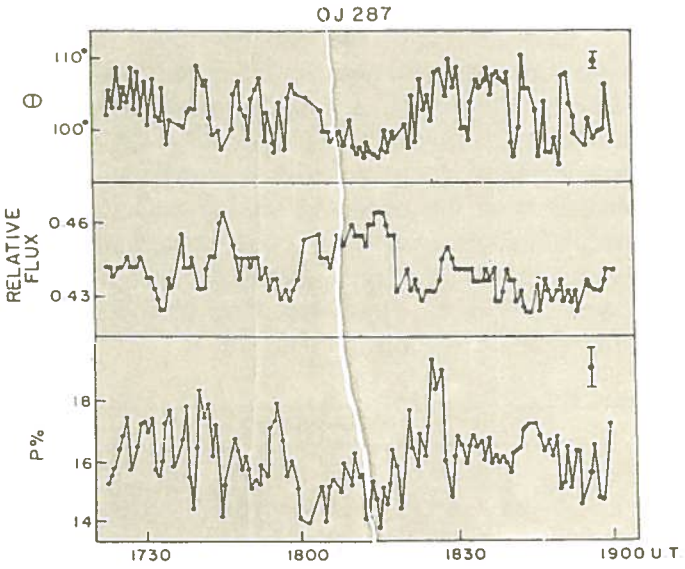


Line profiles of the Orion nebula in [OIII] 5007 A line, taken in a particular direction from the centre of the fringe system in an interferogram.

Studies related to Active Galactic Nuclei

Burst activity in BL Lac objects : Polarimetric and photometric observations were made for BL Lac objects: OJ287, OI90.4 and Mrk 421 on 2.34m Vainu Bappu Telescope of IIA at Kavalur. As a part of a program for seeking the evidence of rapid optical variability in BL Lac objects and AGNs we have carried out observations of OJ287 and Mrk 421. Although there is keen observational interest in short time scale variability, such data is lacking. Variability study is very important to understand the nature of the central engine. Micro variability has been detected in OJ287 and Mrk 421 in observations carried out on January-March 1991 and February 1992. Our observations show the presence of ultra rapid variability in flux and polarization in time scale of about 6.3 minutes in OJ287. This is the shortest time scale of variability detected so far internationally and it has great implication in understanding the physics of these energetic sources.

Study of cD galaxies : Our polarimetric observations made on a cD galaxy A-0779, shows the presence of strong synchrotron radiation in the nucleus. This is for the first time that such observations have been made on cD galaxy. The result will put constraints on the various models regarding the formation and evolution of these galaxies.



Variation in degree of percent polarization, polarization angle (θ) and flux. Observations are made on 2.3m VBT.

Study of Seyfert galaxies : To understand the nature of the nuclei of Seyfert galaxies, observations have been made on 2.3m VBT through different size apertures for: NGC 2992, NGC 3081, NGC 3227 and NGC 4388 galaxies. The apertures used are from 5 to 26 arcsec. There is a very sharp increase in degree of polarization in small aperture 5" showing the presence of strong non thermal source at the nuclei. Modeling work is in progress.

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

Evaluation of "Seeing" conditions at Gurushikhar Observatory Site

Astronomical image degradation due to atmospheric turbulence can be described by a statistical theory in terms of refractive index structure constant parameter $C^2_N(h)dh$; h being the height of turbulent layer. Ranging in "h" can be achieved by combining measurements like

- Study of power spectra of stellar scintillations with different apertures
- Study of star trail distortions and
- Correlation study of dual telescope scintillations

Such a study has been initiated for Gurushikhar site. Instruments used are

- Photon counting scintillometer with 0.5 millisecond sampling time, made at PRL
- Simple camera with high resolution film
- Equipment made by TIFR for Leh site survey programme, which was subsequently transferred to IUCAA (obtained on Loan).

This work was done in collaboration with Dr. S. N. Tandon of IUCAA, Pune.

(L. Mishra, J. N.Desai and R.Bisht)

List of Papers Published During 1991-92

1. Ambastha, A and Bhatnagar A. "Gong Site Evaluation Programme at the Udaipur Solar Observatory", Bull. Astron. Soc. Ind. **19,** 37 (1991).
2. Anandarao, B.G., " Zonal and Meridional Winds in the Earth's Atmosphere ", Encyclopedia of Earth System Science Vol. 4 , pp. 513-523, Ed. W. Nirenberg, Acad. Press (1992).

3. Banerjee, D.P.K. and Anandarao, B.G." A spatio-kinematic model for the multiple shell planetary nebula NGC 1535" Astron. Astroph. **250,** 165-170 (1991).

4. Chandrasekhar, T., Ashok, N.M. and Sam Ragland "Near-infrared observations of Nova Herculis 1991" M. N. R. A. S., **255,** 412-415 (1992).

5. Debi Prasad C. and Desai, J.N. "The plasma condensation Region in the Coma of Halley's Comet", Earth, Moon and Planets., **52,** 213-232 (1991).

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8. Joshi, U.C. and Deshpande, M.R. "Microvariability in Mrk 421", Proceedings of the Conference "Variability in Blazars", Turku, Finland.

9. Raju, K.P., Desai, J.N., Chandrasekhar, T. and Ashok, N.M., "The Excitation Mechanism of [Fe XIV] 5303 A line in the Inner Region of Solar Corona, J. Astron. Astroph. **12,** 311-317 (1991).

10. Sen A.K., Deshpande M.R. and Joshi, U.C."Photometry of Comet P/Halley on 19 March, 1986", Bull. Ast. Soc. Ind.**19,** 47 (1991).

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12. Sen, A.K., Joshi, U.C. and Deshpande, M.R., "Polarimetric Properties of Comet Austin", M.N.R.A.S., **253,** 738-742, 1991.

13. Srivastava, N., Ambastha, A, and Bhatnagar, A. "Evolution of Hellically Twisted Prominence Structure of March 11, 1979", Sol. Phys. **133,** 339-335 (1991).

14. Shylaja, B.S., "Spectrophotometric observations of γ^2 Vel", Bull. Ast. Soc. Ind.**18,** 305 (1991).

Behaviour of Charged Particle Motion Along an Inhomogeneous Magnetic Field and a Retarding Electric Field - Evidence for the Existance of Discrete Energy States

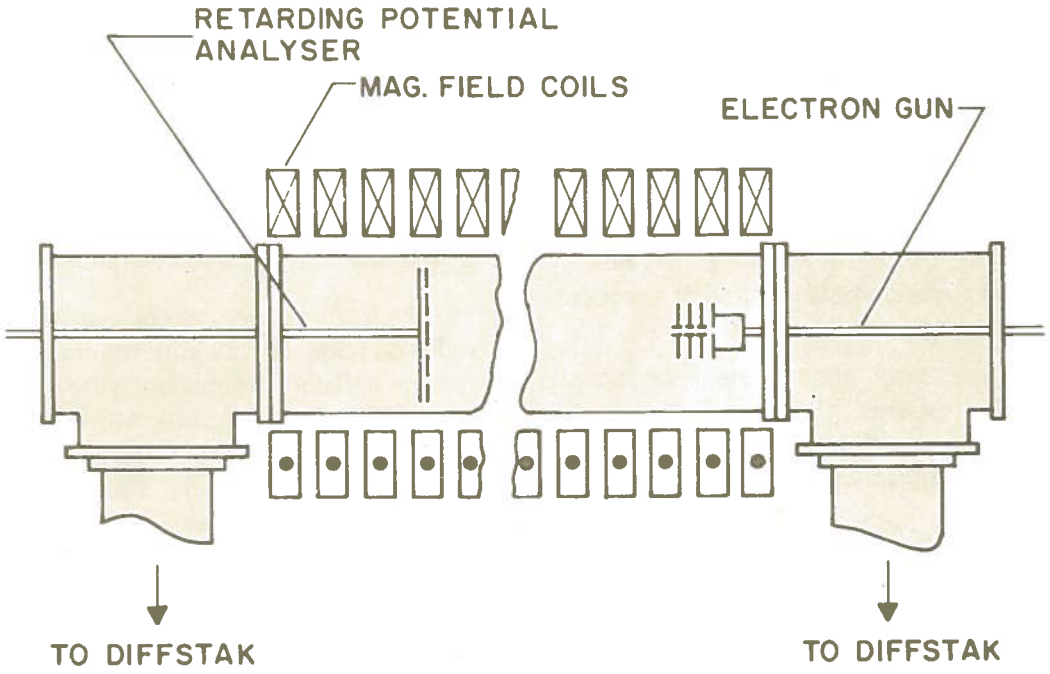
Electrons from an electron gun with a low beam current ~ 100 nA and energy in the range 0 - 3 KeV are injected from one end of an SS vacuum chamber (3m long and 0.27m dia) permeated by an axial magnetic field, with a small pitch angle (<5°) to it. The Faraday cup, movable along the axis of the chamber consists of a grounded collector plate with a grid, 10mm in front of it, which can be raised to any desired potential. The magnetic field in the chamber is produced by a set of 35 current carrying coils.

The experiment is carried out by first fixing a certain distance L, between the gun and the detector and choosing an electron energy E, and a spatially averaged magnetic field $\bar{B}$. The detector grid is then raised to a negative potential, slightly higher than the beam energy. The electrons moving along the potential drop between the gun and the detector get stopped by the retarding potential. The plate current is then recorded as the grid voltage is allowed to drop to zero.

According to the predictions of adiabatic theory the plate current as a function of the negative potential applied to the grid, should be a monotonically decreasing function and any increase in the potential could only lead to a decrease in the plate current.

We have recorded the plate current profiles for various values of $\bar{B}$ and L for beam energy E = 650 eV. The recorded plate and grid current profiles are found to be far from monotonic and indeed exhibit a number of maxima and minima whose separation decreases monotonically with the retarding potential. We have attempted to fit the observed energy peaks in the above plots into the relation (1) given below which is supposed to describe these peaks according to the theory (Varma R. K., Phys. Rev.,1985 and Varma R. K., Proc. Intl. Conf. Plasma Phys., 1991).

Peaks	Energy E_j (eV)			$j + 1/4 - \phi/2\pi$		
	plot 2a	plot 2b	plot 2c	plot 2a	plot 2b	plot 2c
N(↓)	417	453	438	41+0.15	31+0.32	36+0.56
N+3	357	377	373	44+0.48	34+0.36	39+0.62
N+6	313	317	323	47+0.45	37+0.47	42+0.57
N+9	277	272	283	50+0.50	40+0.46	45+0.47
N+12	247	237	250	53+0.48	43+0.35	48+0.41



A schematic of the experimental device.

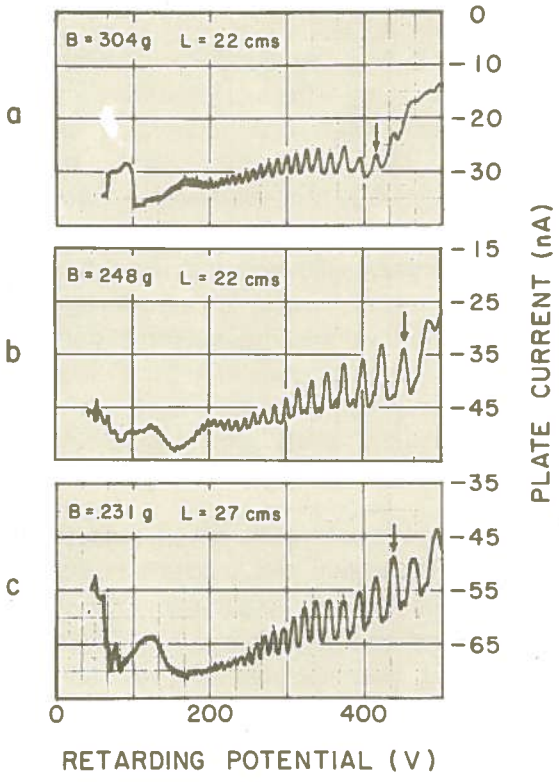


Plate current versus the retarding potential for beam energy = 650 eV and various values of $\bar{B}$ and L as shown in the plots.

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

where E_j is the energy corresponding to an integer j labelling the peak, (j is an analogue of a quantum number), ϕ is an undetermined phase. The energies E_j corresponding to these peaks and the values of $(j + 1/4 - \phi / 2\pi)$ as calculated from (1) and the j (integer) values so identified in the various cases are given in the Table

It is found that, the integers j do differ from each other by *three* in surprising conformity with the choices of the peaks made. This looks quite remarkable as it shows that the observed peaks do follow the relationship (1) and the hydrogen- like dependence on j, that it gives.

Another striking feature of the observed results, as indeed of the relation (1), is the dependence of the allowed energy peaks on the length L of the box - the distance between the gun and the detector, which signifies a wave-like nonlocality and which is contained in the formalism of Varma(1985), and hence the relation (1).

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

Planetary Atmospheres and Aeronomy

The research activities of the Planetary Atmospheres and Aeronomy Division are aimed to understand the radiative, chemical, ionization and dynamical processes in the atmosphere. The studies are based on balloon and rocket-borne in-situ measurements, radio and optical remote probing of the atmosphere, laboratory experiments and modelling. The activities cover the following three headings :

(i) Studies of the middle atmosphere - chemistry, aerosols and radiation balance, role of minor constituents, ionization and dynamics.

(ii) Studies of the upper atmosphere - ionospheric phenomena, plasma density irregularities asociated with equatorial spread-F and sporadic E, Ionosphere- thermosphere coupling.

(iii) Laboratory Astrophysics - Measurement of absorption and resonance fluorescence cross sections for various gases to understand the reactions that occur in the atmosphere/ionosphere and of interest in the investigation of planetary and astrophysical phenomena.

Ozone depletion and the global warming due to the enhanced greenhouse effect has been of great concern in recent times. Methane plays an important role in the greenhouse warming and in the tropospheric and stratospheric chemistry. Emissions from the paddy fields is considered to be one of the major sources of atmospheric methane. India has one of the largest paddy growing area in the world. To obtain quantitative budget of methane in the atmosphere it is necessary to measure its flux from various geographical regions. With this goal a programme was initiated to measure methane flux from Thanjavur area. The air samples collected were analysed at PRL using gas chromatographic technique.

A major achievement this year has been the commissioning of a powerful Nd-YAG lidar for probing earth's atmosphere. The system operates at 532 nm. At present a 40 cm telescope is being used to collect the backscattered light and the photon counter data used to derive the aerosol profiles in the altitude region upto about 35 km. A bigger telescope, of about a meter size, is planned for operation of the system to study the density and temperature upto 70 km from the weaker Rayleigh scatter.

With the commissioning of the Indian MST Radar in the ST mode, efforts have been made to make use of this powerful tool for atmospheric studies. In the first programme of the ST mode of operation, observations were made in February 1992 to study the winds and turbulence parameters from the pre-pocessed radar data. In another campaign data have been collected to study the nature of the irregularities/structures in troposphere from the signal echo statistics and from the aspect sensitive nature of echoes. Scans at every 2^{o} step of the beam position were taken for this study.

Stratospheric aerosols play an important role in the radiation budget of the atmosphere. Volcanic activities provide a major perturbation in the aerosol abundance and their size distribution. Mt. Pinatubo eruption in Phillipines during June 1991, is believed to be the strongest in this century. Balloon- borne auto-sun-tracking photometer and sky-scan-photometer were launched from the Hyderabad Balloon Facility on 26 October 1991 to study the increased aerosol abundance caused by this eruption. Studies of the stratospheric aerosol layers were also made from the ground based twilight brightness measurements in the near IR region.

In the upper atmospheric studies, development of sophisticated optical experiments continued and enabled indepth study of the thermosphere-ionosphere coupling. Neutral winds and temperature measurements from Mt. Abu using high resolution spectrometers at 630 nm alongwith F-layer height determined by ionosonde at Ahmedabad have shown that the F-layer peak estimated from neutral winds and temperature parameters using servo model agrees well with the measured values. The method of determining neutral winds at low latitudes from the F-layer height changes was validated from the unique in-situ measurements of neutral winds and electric fields from SHAR earlier.

An important step towards optical measurements has been the fabrication and successful operation of an all sky imaging FP spectrometer to map the temperature and wind field. One of the first result from this instrument has revealed the reversal of the equatorial fountain during nighttime.

As part of the national AICPITS programme scintillation observations were made at Ahmedabad from March 1991 to February 1992. The digital data recorded at Ahmedabad has enabled to study the power spectral features of scintillations from the

anomaly peak region in India for the first time. Compilation of the data at sixteen stations of the scintillation chain under AICPITS programme has been carried out for the March-April 1991 campaign. The temporal variation of the width of the equatorial scintillation zone has been brought out by this study.

During the year, the research activities of the Laboratory Astrophysics group focussed on the study of fluorescence spectroscopy of water vapour by photon impact. In addition, major effort was on the design and fabrication of two new experiments which include the photoabsorption cross section measurements of polyatomic molecules at different temperatures (200 to 300 K) in the spectral region varying from 180 to 330 nm and the study of fluorescence spectra of molecules at different temperatures ranging from 200 to 300 K at the incident photon wavelengths in the VUV region. In both cases, it is planned to carry out the above measurements with molecules of planetary and astrophysical interest.

The fluorescence spectrum of water vapour has been studied at the incident photon wavelength of 121.6 nm and relative production cross sections for different product states have been measured. The fluorescence spectrum at 121.6 nm wavelength was obtained in the emission wavelength region from 280 to 330 nm at the instrumental resolution of around 1 nm.

MIDDLE ATMOSPHERE

Minor Constituents in the Middle Atmosphere

Methane

Flux Measurements : Methane plays an important role in the greenhouse warming and in the tropospheric and stratospheric chemistry. It absorbs the outgoing earth's infrared radiation at 7.6 μm wavelength band. Further, its radiative forcing per unit molecules change is about 21 times that of CO_2. Methane is the sink for the OH radical in the troposphere and it is a source of water vapour in the stratosphere. Estimates of its global budget has many uncertainties. Methane emission from paddy fields, which is considered as one of the major sources, is uncertain due to lack of data from India and China, the two major rice producing countries. A programme to measure methane flux has been undertaken recently in Thanjavur area, situated

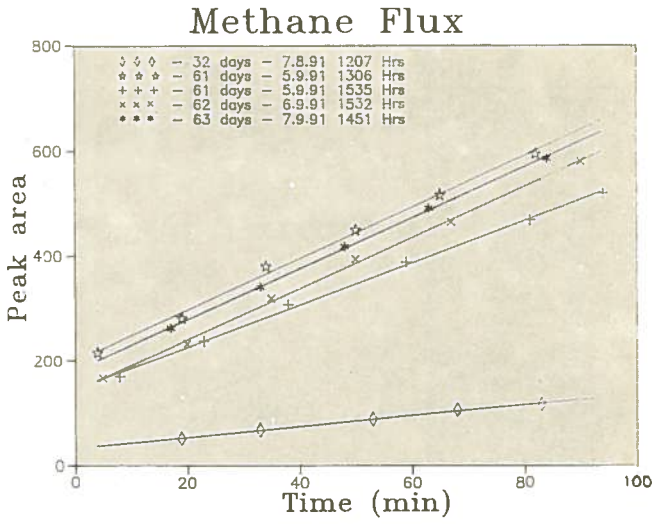


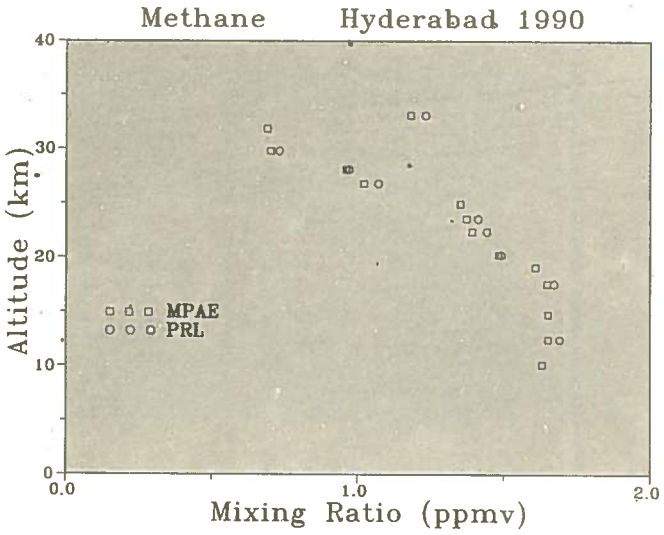
Fig. Typical trends of increase in methane inside the chamber

Typical increase in the concentration of methane (expressed in peak area units) inside the chamber. X-axis represents time after closing the plants by the chamber.

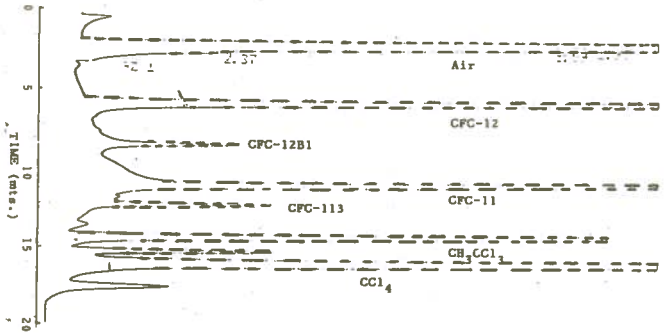
in Kaveri basin in Southern India. This area represents one of the major rice growing regions.A perspex chamber is used to cover the paddies and the air samples from the chamber are collected at different time intervals. These samples are analysed at PRL using gas chromatographic technique. Figure shows typical increase in the concentration of methane in the chamber. Slopes of these lines are used to estimate methane flux. Measurements have been made to cover different crop age and different fields. The estimated flux varies in the range of 15 to 25 mg $(CH_4)/m^2/hr$. This is much more than the reported values of 0.1 to 1.0 mg $(CH_4)/m^2/hr$ in the Northern Indian region measured. Our measurements also show that when fresh water is filled in the field methane flux is reduced. This is due to the fact that fresh water contains dissolved oxygen and the bacterial process does not produce methane in the presence of oxygen. Extensive measurements are planned during the year 1992/93 to cover different physical conditions and to confirm the higher flux rates.

(S. Venkatramani, Shyam Lal and B.H. Subbaraya)

Vertical Distribution : Alaquates of the samples collected during the collaborative balloon flight on April 9, 1990 from Hyderabad have been analysed at PRL for CH_4. Figure shows the comparison of the results of the analysis made at Max Planck Institute for Aeronomie (MPAE), Lindau, Germany and at PRL, Ah-



A comparison of the analysis results of the samples of April, 1990 Hyderabad balloon flight. Analyses are made at Max Planck Institute for Aeronomy, Germany and at PRL.



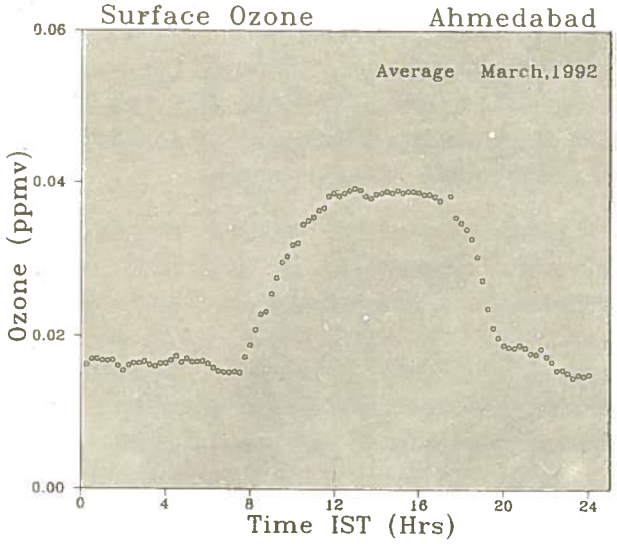
Chromatogram of an air sample of the balloon flight analysed at PRL showing separation and detection of various CFCs in the pptv range.

medabad. The results are in good agreement. A chromatogram obtained for samples collected from a balloon flight conducted from Hyderabad shows unambiguous detection and separation of several chlorinated and brominated hydrocarbons the concentrations of which are in the pptv range. More detailed analysis are in progress.

(Shyam Lal)

Tropospheric Chemistry

Increasing abundances of various trace gases including O_3 and its precursors like NO_x, CO, CH_4 etc. in the troposphere as a result of human activities are likely to alter the chemical and radiative property of this



Average diurnal variation of surface ozone observed at Ahmedabad using the new ozone analyser.

region. High levels of NO_x alongwith CO, CH_4 and non methane hydrocarbons give rise to the production of ozone at the earth's surface and also in the troposphere. A programme has been initiated to monitor concentration of a number of species from a few selected locations in India. As a first step a surface ozone monitor has been set up and made operational at PRL since November 1991. Figure shows typical diurnal variation of ozone with a maximum around noon. Significant day to day variability has also been observed during winter months especially under meteorologically disturbed conditions. A systematic long term monitoring programme would reveal seasonal and other longer term trends. Simultaneous measurements of other trace gases involved in ozone production and NO_x as well as total solar radiation flux would help study relative role of in situ chemistry and transport in tropospheric ozone abundances. Such a study is planned for the coming years.

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

NO_2 Column Density

NO_2 is a minor constituent of the earth's atmosphere. It plays an important role in the chemistry of atmospheric ozone. Several observations of this species have been reported, most of which are for mid and high latitude stations. The distribution of this species will be different at tropical region due to special features like strong upwelling motion, low tropopause temperature, high level of tropopause and less cosmic ray flux variability.

The method we have used to measure NO_2 column densities is based on its absorption feature of near 439 and 445 nm wavelength region. This region of solar spectra is parted with Fraunhofer lines. Fraunhofer component has been removed by taking observation during twilight hours and during noon hours. Also the effect of aerosol has been removed by equalizing absorption values at two wavelengths where absorption cross sections due to NO_2 are equal. Values of vertical NO_2 column density since November 1989 have been obtained. Observations could not be taken during monsoon months and during the periods when sky was not clear. The abundance of NO_2 appear to be between $1 - 5 \times 10^{15}$ cm^{-2} except after September 1991 when a slightly higher values of NO_2 were seen.

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

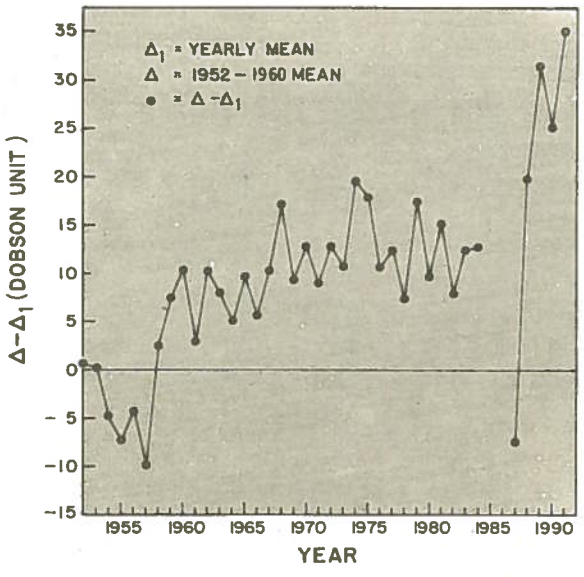
Long Term Trend of Total Ozone at Ahmedabad seen by PRL Dobson Instrument

There is concern about the long term trend of ozone abundance in our atmosphere all over the world. To study this problem, data for a long period of time is needed. PRL has been operating a Dobson spectrophotometer for the past 40 years at Ahmedabad (for some years it was operated at Mt. Abu). Observations are taken daily around 2 P.M. There is tendency of an increase in total ozone as the year advances. From 1952 to 1960 there has been a sharp increase of ozone. This could be due to the two reasons - (i) during this period a number of nuclear detonation tests were made by various countries. (2) prior to January 1961, CC' wavelength pair was used and from January 1961, AD wavelength pair was used for the measurements of O_3. We did not have sufficient data for 1985 to 1987 period. Again after 1988 a sharp increase of total ozone is discernable.

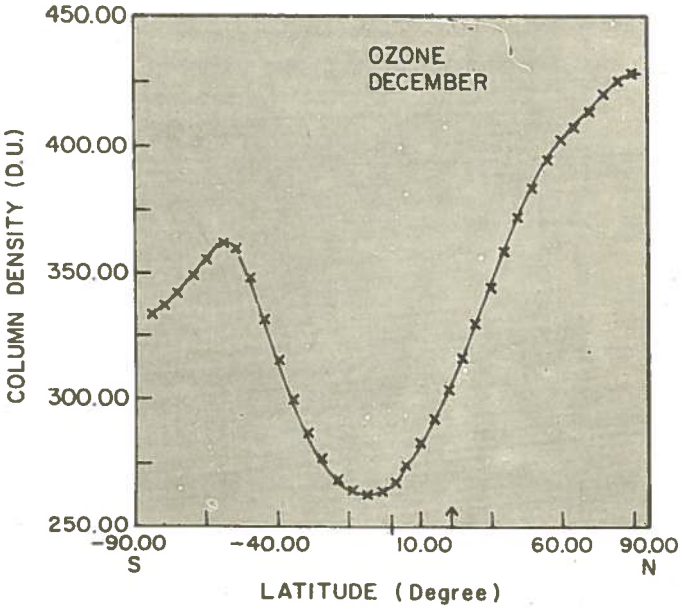
(D.K. Chakrabarty and K.V. Pandya)

2-D Model of Atmospheric Minor Constituents

We have been measuring NO_2 and O_3 column densities over Ahmedabad. It was of interest to examine how far our measured values agree with the theoretical model profiles. We have a collaborative programme with NCAR, Boulder. Under this collaboration, we have access to NCAR 2-D programme from PRL itself. Using this programme, we have calculated densities of various atmospheric minor species. Calculations have been done from 90° S to 90° N latitude for every 5° and at 1 km interval. Two model profiles are shown in Figure for the month of December (for O_3 and for NO_2). It is seen that at the equator, the column



Trend of total ozone over Ahmedabad - Mt. Abu seen by a Dobson Instrument.

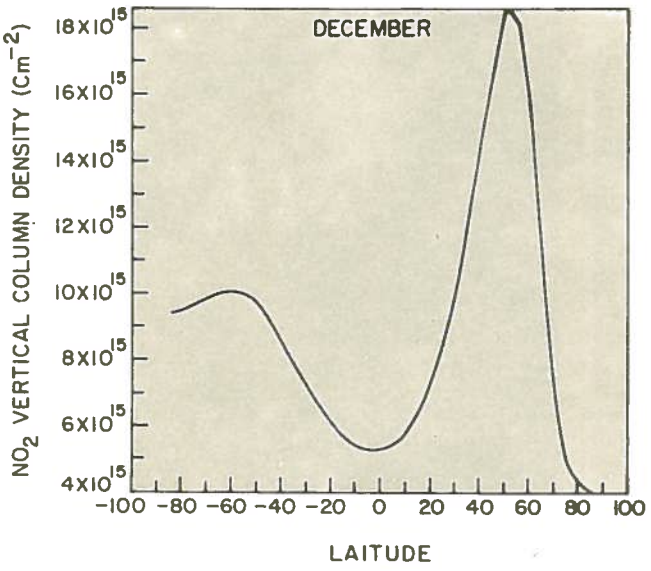


A calculation of 2-D model of ozone for winter.

density of O_3 is minimum. As we move away from the equator, the value of O_3 starts increasing . While in the northern hemisphere, this increase continues upto the pole, in the southern hemisphere, the increase is upto about 50°S, after which O_3 column starts decreasing and continue to decrease upto the pole. For Ahmedabad latitude, modelled value of O_3 is 285 D.U. The measured value of O_3 by our Dobson Instrument is about 250 D.U.

Like O_3, NO_2 content is also minimum over the equator. Its value also starts increasing as we move away from the equator. NO_2 content is maximum around 50°N and 50°S. The peak value of NO_2 content in the northern hemisphere, however, is about double of that in the southern hemisphere. Also, in the northern hemisphere, after 50° latitude, NO_2 content decreases very rapidly and becomes almost zero near the pole. This is consistent with the expectation. Because in December month, in the northern hemisphere, pole will have nighttime condition. And at night, NO_2 is destroyed by O_3, first to form NO_3 and then to form N_2O_5. The modelled value of NO_2 for the Ahmedabad latitude is about 8×10^{15} cm^{-2} whereas the measured value lies in the range of $2\text{-}5 \times 10^{15}$ cm^{-2}.

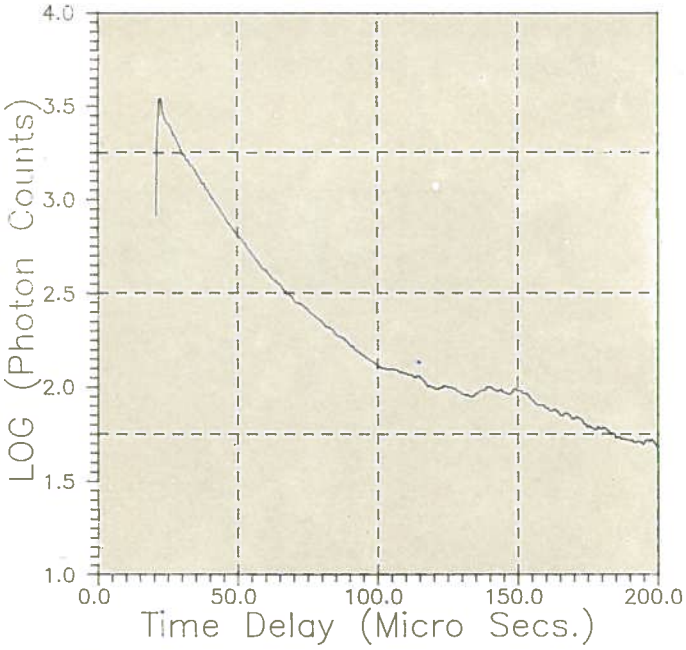
(G. Beig and D.K. Chakrabarty)



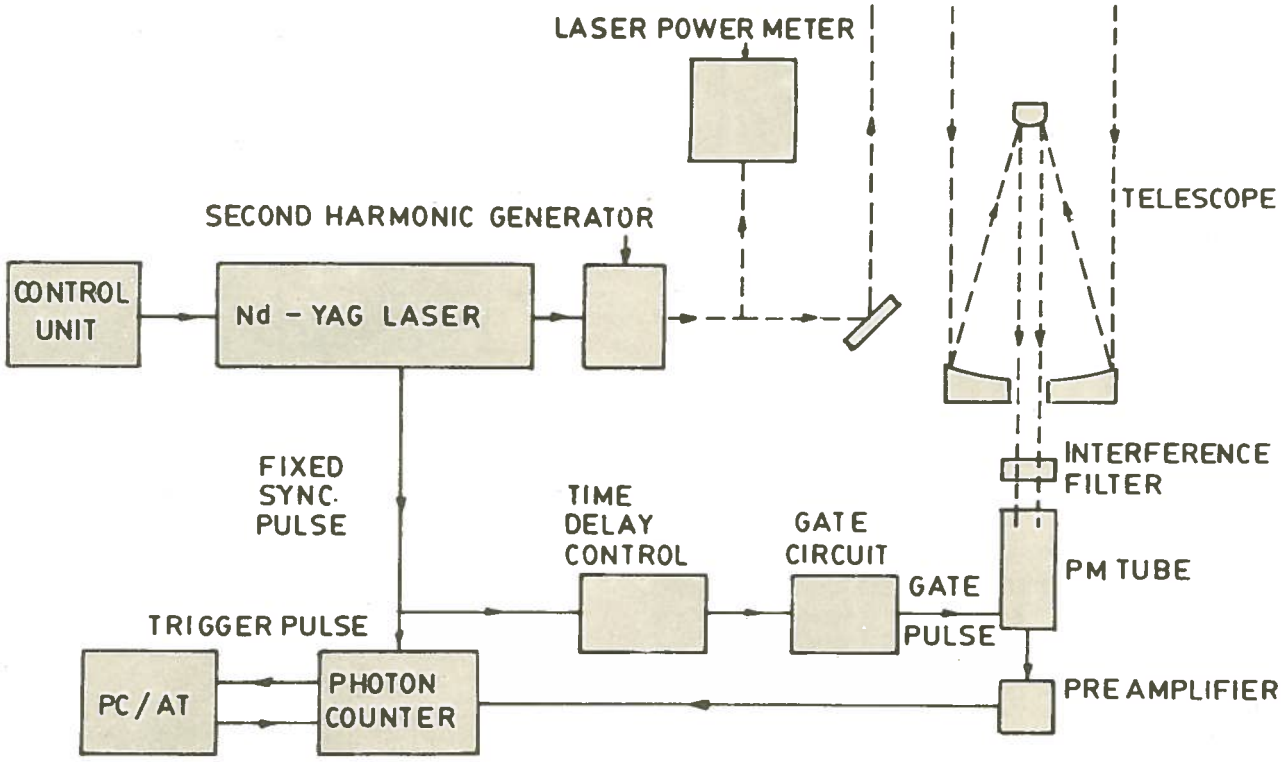
A calculation of 2-D model of NO_2 for winter.

Aeros ol Studies Nd-YAG Laser Based LIDAR System for Atmospheric Studies

A LIDAR system is being set up at the Physical Research Laboratory for atmospheric studies. The system is based on a high power Nd-YAG pulsed laser, operating at the second harmonic (532 nm). The laser has an average energy of 400 mJ at this wavelength with a pulse duration (FWHM) of 7 nsec and a pulse repetition rate of 10 Hz. In the first phase of operation, designed for aerosol studies, a 40 cm cassegrain telescope is used to collect the backscattered signals and a EMI 9813 gated and cooled photomultiplier tube operating in the photon counting mode is used to detect the signals. A time delay generator is used to select the appropriate time intervals for data sampling, corresponding to different altitude regions of interest. The different components of the system have been integrated and some test firings have been made. The received echoes show enhancements in the scattered signal strength seen as multiple layers in the altitude region of about 18 to 25 km. These scattering layers have been caused by the Mt. Pinatubo volcanic eruption at Philippines in June last year. The system is being made ready for a systematic monitoring of the aerosol layers upto an altitude of about 35 km.



Back scattered laser light intensity as a function of the time delay between the transmitted and the received laser pulse (Raw data). The increase in the signal strength around 150 μsec, corresponding to 22.5 km is due to the enhanced scattering from the aerosol layer formed after the Mt. Pinatubo volcanic eruption.



Block diagram of the PRL Lidar system for atmospheric studies.

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

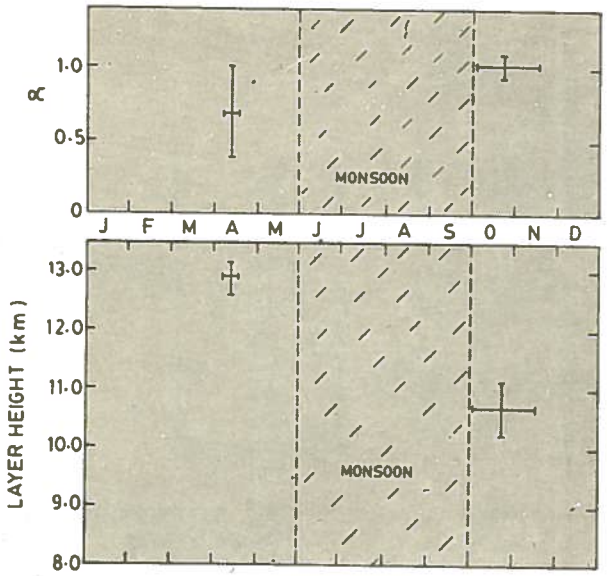
Balloon-borne Studies of Mt. Pinatubo Volcanic Aerosol over Hyderabad

On 26th October 1991 a 0.5 million cubic meter hydrogen filled balloon was launched from Hyderabad Balloon Facility carrying the Auto-Sun-tracking photometer and a sky-scan-photometer systems developed at PRL to study mainly the stratospheric aerosol layer and the variation induced by the Mt. Pinatubo eruption, during June 1991, at Philippines believed to be the strongest in this century. The aerosol extinction coefficient profiles obtained at ten different wavelength regions from UV to IR all show a large increase in values at all altitude levels compared to previous results obtained over Hyderabad in 1985. The maximum increase, by about two orders of magnitude is found at the stratospheric altitudes. While the detailed analysis of the data to determine the aerosol size distribution parameter is in progress, the preliminary analysis indicates that the aerosol layers formed due to the eruption were found to exist between 19 and 27 km with the maximum concentration of particles around 22-24 km during the observation period over Hyderabad. Also the estimated ozone number densities in the altitude region of 16 to 32 km give large values, larger by about a factor of four higher than the 310 nm absorption data than to any previous results. While the ozone concentrations are expected to decrease by about 10% due to the ejecta, this fictitious increase can be attributed to the enhanced SO_2 absorption in the 310 nm wavelength region used for the estimation of O_3 concentration. Further analysis is in progress to estimate the SO_2 abundances in this altitude region from the observations.

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

Tropospheric Aerosol Extinction Profiles and their Seasonal Variability

About 28 aerosol extinction profiles obtained over Thumba and Hyderabad from rocket and balloon experiments during the last few years are classified into two main groups, those obtained before the Indian

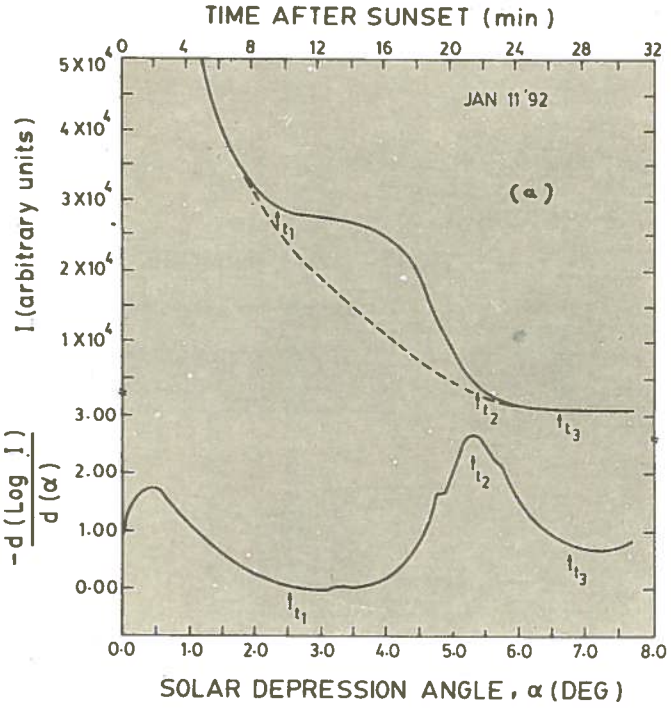


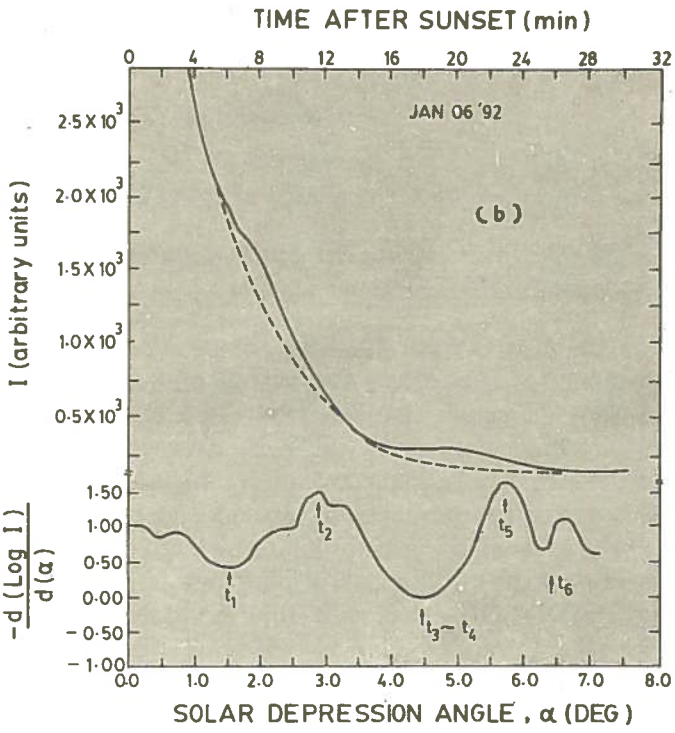
Variations in tropospheric aerosol characteristics before and after the Indian Monsoon. While the mean wavelength exponent of scattering, increases from a value of 0.6 to 1.0 (top) the layer height comes down from 13 km to 10.5 km (bottom) after the monsoon.

Monsoon period and those obtained after, with an aim to study the monsoon induced variations in tropospheric aerosol profiles and vis-a-vis. The main parameters used for the study are the wavelength exponent of aerosol scattering, α, which is also a measure of the aerosol size distribution function and the aerosol extinction coefficients. In general it is seen that the aerosol extinction coefficients are higher (a factor of two in many cases) during the premonsoon period compared to that of the postmonsoon periods. α is found to be altitude dependent with low values, indicative of bigger particles, near the ground level as well as in the altitude region of 11 to 16 km, just below the tropopause level. Analysis of the individual flight result show that the value also exhibits a systematic variation from the premonsoon to post monsoon period with the layer characterised by the low value coming down from 13 km to 11 km after the monsoon. The results indicate that the residence time of tropospheric aerosol particles are of the order of few months and is mainly controlled by gravitational settling and rain wash.

(A. Jayaraman and B.H. Subbaraya)

The Stratospheric Aerosol Effects of the 1991 Mt. Pinatubo Eruption





(a) Variation of twilight intensity, I, with solar depression angle, α (a), and variation of d (log I)/d α with solar depression angle, α (b) for the case of a single aerosol layer due to Pinatubo eruption. (b) for the case of a double layer due to Pinatubo eruption.

It has been reported earlier that twilight brightness occurs after volcanic eruption and monitoring of the brightness can shed light on the properties of stratospheric aerosols. On June 15- 16, 1991 eruption of Mt. Pinatubo took place, which ejected a large amount of dust into the stratosphere. Spectacular twilight intensity brightness was observed since November 1991 over Ahmedabad. This intensity has been monitored at 800 nm. The variation of twilight intensity with solar depression angle for 11 January 1992 shows a clear departure from the normal pattern of the drop in the twilight intensity with the increase of solar depression angle.

An interesting observation (in Pinatubo eruption) is the presence of two or more aerosol layers. The aerosol strength, represented by a factor Q, has been obtained by taking the ratio of twilight intensity at maximum departure time and the sunset twilight intensity. The value of Q has not monotonically decreased with the passage of time as expected. For the month of November 1991, the average value of Q is -0.7 ± 0.1. This value increased after November 1991. In the last week of December 1991 and first week of January 1992, the value of Q has reached maximum - 0.45 ± 0.05. This could be due to another volcanic eruption which took place at Andaman Nicobar island in the month of November 1991.

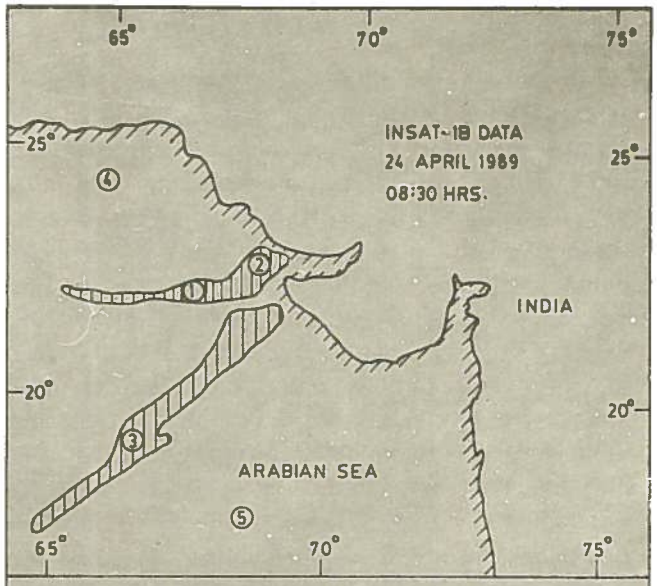
From the above observations, it is also possible to determine the lower and upper heights of the aerosol layer. The analysis shows that the lower boundary of the aerosol layer lies around 25.7 ± 5.8 km.

(M. Lal and D.K. Chakrabarty)

Sun-Photometer Measurements of Spectral Extinctions over Ahmedabad

An experimental programme was undertaken to study aerosol optical depth variations in six different wavelength regions for a period of about 10 weeks in early 1991 over Ahmedabad. An automatic multichannel suntracking photometer assembly and data acquisition system were used to measure solar radiation intensities at 310, 440, 500, 750, 850 and 950 nm wavelength regions. The calibration of the instrument was carried at a relatively clean atmosphere at Guru Shikhar in Mt. Abu and the system constant was evaluated. This value was further used in analysing the Ahmedabad data.

The observations showed that apart from large day to day variations, aerosol optical depths also showed diurnal variations at all wavelengths with maximum around noon hours. Also the optical depth values are found to increase from January to March at all wavelengths. The mean monthly value of aerosol optical depth (for 850 nm as an example) during January is found to be 0.16 which increases to 0.31 in February and reaches a maximum value of 0.44 in March. The wavelength exponent of scattering is found to vary from 0.4 to 1.5 during this period indicating that the aerosol size distribution parameter also undergoes variations. The wavelength versus optical depth plots indicate that the tropospheric aerosols in general exhibit bimodel size distribution.



LOCATION	VIS. COUNT	IR. COUNT	TEMP. °K
1	56	89	292
2	26	89	292
3	14	81	293
4	7	89	292
5	5	81	293

Observation of dust plumes over the Arabian Sea, shown by the hatched area. The visible and IR photometer counts for the selected five locations are shown in the table below. Note while the visible counts show marked difference, the IR channel does not distinguish the plume from the background.

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

Feasibility Study on using INSAT Data for Monitor-

ing Aerosol Content over Ocean Surfaces

More than 80% of the land mass surrounding the Arabian Sea viz. Saudi Arabia, Iran, Afganistan, Pakistan and North-west India are arid or semi-arid regions with high incidents of dust storms. Satellite pictures show transport of these particles over Arabian Sea and Indian Ocean. These desert aerosols mix with the maritime aerosols found over ocean surfaces and can grow bigger depending on the ambient humidity. To explore the possibility of using INSAT data to monitor aerosols over Indian seas a trial study was undertaken in which INSAT 1B data for the period March to May 1989 were examined. Among the few cases which indicated the presence of dust clouds, data corresponding to 08:30 IST on 24 April 1984 is selected for a detailed study which shows atleast two large dust plumes extending few hundred kilometers over the Arabian sea. While the visible channel (0.5 to 0.7 m) photometer counts are found to be as high as 56, over the plume location compared to 5 counts for the background sea surface, the IR channel (10-12 m) data for the same locations does not show any difference and is found to be around 89, corresponding to a temperature of 292° K. Analysis of wind data shows that the wind directions were mainly north and north westerly during the observation period, indicating that the plumes might have originated from Afganistan/Pakistan.

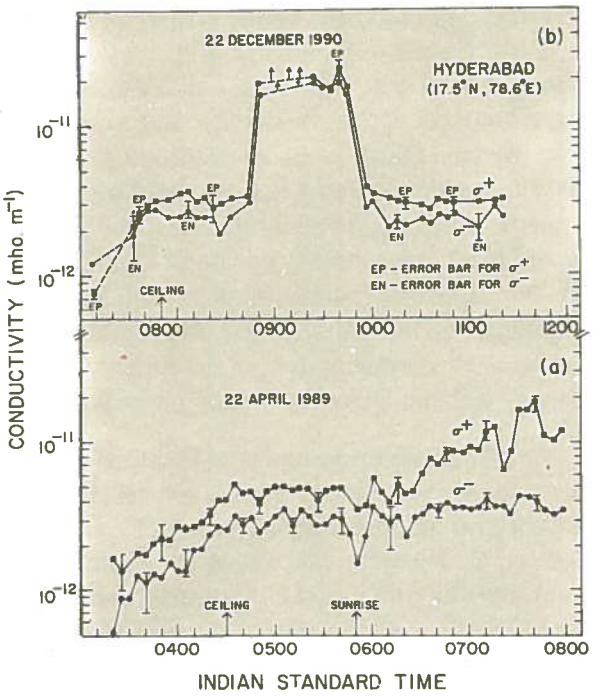
A detailed study on desert aerosol climatology is planned under the ISRO-GBP programme.

(A. Jayaraman and B.H. Subbaraya)

Studies on Electrical Parameters

Seasonal and Solar Zenith Angle Dependence of Stratospheric Conductivity over Hyderabad

During the last ten years (1982-91) six balloon flights have been conducted from Hyderabad to measure polar conductivity during different seasons and different times of the day. The vertical electric field merasurements were also carried out on three balloon flights. Three balloon flights were incorporated with apex valve. By opening the apex valve we could float the balloon at different altitudes for about one hour. During April months three balloon flights were conducted while during October- December period three more balloon flights were conducted. It was found that during night time positive ion conductivity and negative ion conductivity were same in altitude region 10 km to



Variation of positive and negative ion conductivities with time in two balloon flights at Hyderabad.

32 km height region. During day the positive ion conductivity was more than negative ion conductivity above 28 km. Below 28 km both the conductivity values are nearly same during day time. We also found more fluctuations in conductivity values in April months compared to October-December months.

Further it was found that the vertical electric field measurements were also affected by the solar radiation. At the float altitude of 32 km the vertical electric field in night was about 1 v/m while at 10.00 hrs the electric field values were 0.2 v/m. These measurements were carried out on 17 October, 1989.

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

Thunderstorm Related Variations in Stratospheric Ion Conductivity

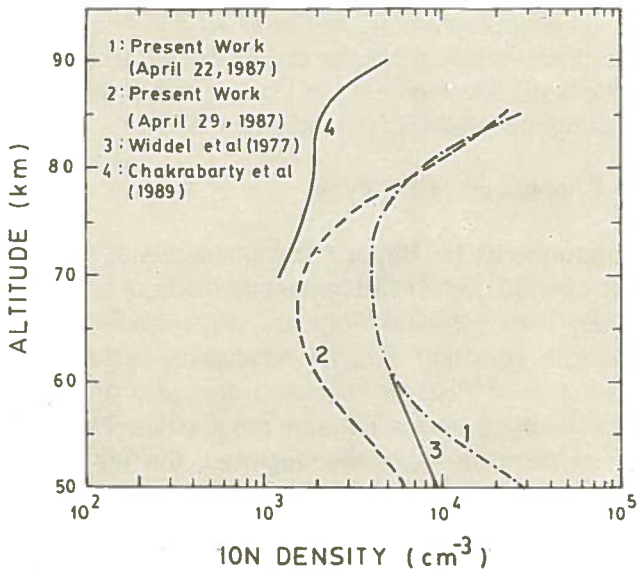
Several balloon measurements of ion conductivity have been made from Hyderabad during the IMAP and IMAP-C periods. One of them, made on 22 December 1990, was during thunderstorm activity. The sensor was a hollow gold plated metal sphere to which fixed bias was applied. The balloon was launched around 6 A.M. and data were obtained till 11.30 A.M. Both positive and negative ion conductivities were measured. It has been found that during thunderstorm acctivity, both

positive and negative ion conductivities increase by a factor of about 10 from their fair weather values which is 10^{-12} mho cm^{-1}. This increase was seen for about an hour. Such an increase was also detected at mid latitude stations but to a lesser extent (by a factor of maximum about 5). This is the first measurement of ionic conductivity at low latitude during thunderstorm activities. An interesting point to note is that in this whole flight both positive and negative ion conductivities are approximately equal, i.e $\sigma^+ \approx \sigma^-$ In contrast, on 22 April 1989, during daytime $\sigma^+ > \sigma^-$ with σ^+ increasing with the increase of solar elevation angle at 37 km.

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

First Parachute Measurements of Mesospheric Positive Ion Density over the Dip Equator

As a part of Indo-Soviet collaborative programme total positive ion density of the mesosphere was measured by parachute dropped from a Soviet M-100 rocket at Thumba. Two flights, one on 22 April 1987 and the other on 29 April 1987, were conducted. Sensors were gridded spherical probe and were identical in both the flights. Preliminary results were presented earlier. A detailed analysis has been completed now.



First parachute measurements of mesospheric positive ion density at Thumba.

We find that below about 80 km, the value of N^+ (the total positive ion density) for 22 April 1987 is higher than that of 29 April 1987. At 50 km, this turns out to be by a factor of about 5. This is in the cosmic ray region where the ion production rate should change very little with time. Physically, this would require a change by a factor of 25 in the recombination coefficient which is very hard to accept. A theoretical ion density profile obtained by us is also shown in this figure. A comparison indicates that theoretical ion density values are smaller than the measured values eg. at 80 km, the factor comes out to be about 5. Such a high value and large variability of ion density below about 80 km have also been reported earlier by Aikin et al (1981). They attribute this to be due to meteoric debris.

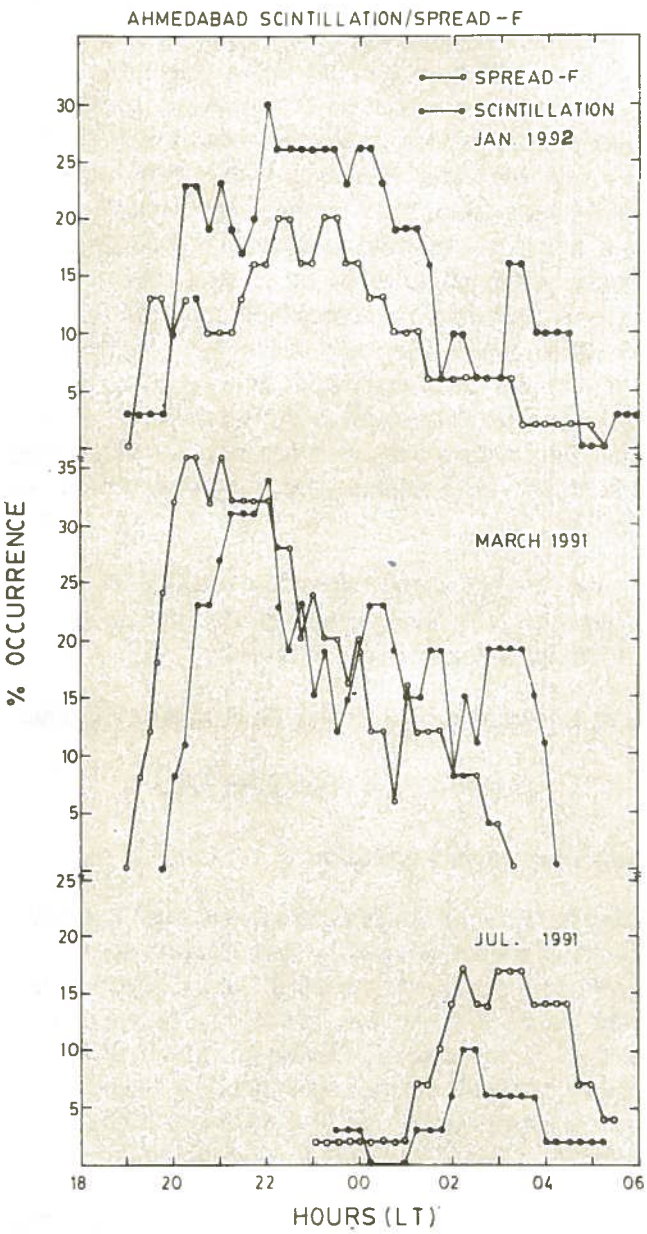
We also see a broad maximum around 60 km. This is, probably, the level above which ionization due to Lyman-alpha becomes predominant.

(D.K. Chakrabarty, J.S. Sidhu, G. Beig and S.R. Das)

UPPER ATMOSPHERE

Ionization Layer Formation

The Life Time of Sporadic-E Layers over Thumba : We have shown earlier that over Thumba sporadic-E layers were observed during night hours, provided they were meteor shower days. In day time during counter electrojet conditions such layers have been observed. Incidentally those counter electrojet days happen to be meteor shower days also. The thickness of the layers were about 5 km which are comparable to the vertical wavelength of gravity waves. Since the gravity wave periods are about 3 hours to 4 hours, we expect that these layers should also have same period. To find the life time of these layers we have examined data from three rocket flights during the night 12-13 March, 1967, two flights on 21 April 1975 (day and night) and two flights during the night 15-16, March 1975 and two flights on 21 December (night). All these days were meteor shower days. The interval between these two flights were more than 3 hours but less than 12 hours. It was found that layers decayed after 3 hours. Of the three flights during the night of 12-13 March 1967, the layers were observed at 1900 hrs but disappeared at 2200 hrs and reappeared again at 0600 hrs. These results show that the life time of these layers is couple



Occurrence of scintillations and Spread-F over Ahmedabad for the months of January, March and July during the year 1991.

of hours which is same as life time of gravity waves.

(S.P. Gupta)

Ionospheric Irregularities

Spread-F and Scintillation over Anomaly Crest Region : Continuous monitoring of VHF scintillations at 244 MHz was started over Ahmedabad from March 1991 as part of the AICPITS programme. On several nights data were recorded digitally for quantitative studies of scintillation parameters. Simultaneous scintillations and ionosonde observations have been analysed for the period March 1991 - February 1992 to study the occurrence patterns of irregularities over the anomaly crest latitude. Occurrence of spread-F and scintillations was highest during equinoxes and lowest during summer. The maximum hourly percentage occurrence of scintillations/spread-F were 35 percent during March, 25 percent during winter and 10-15 percent during July. The peak occurring around 21-22 hr during equinoxes, around 23 hr during winter and around 03 hr during summer. The scintillations at Ahmedabad occur in patches of short duration. Scintillation index and the power spectra have also been computed for few nights which are the first such studies over tropical latitudes in the Indian zone.

(G.D. Vyas, H. Chandra, M.B. Dadhania and R.N. Misra)

Scintillation Campaign of March-April 1991 : As part of the All India Co-ordinated Programme of Ionospheric and Thermospheric Studies programme a campaign of extensive scintillation observations was conducted covering about twenty stations right from dip equator to the latitude beyond the anomaly peak. The data were compiled jointly at a workshop held specifically for this purpose at Kolhapur during June, 1991. In addition, ionosonde data from Thumba, SHAR, Waltair and Ahmedabad were studied for spread-F. This multi-institutional programme, first of its kind in magnitude, has given valuable results on the temporal and the latitudinal development of the phenomenon of equatorial spread-F in the Indian zone.

(H. Chandra and G.D. Vyas)

Ionosonde as HF Radar : The ionosonde at Thumba was operated on a fixed frequency mode of operation during few nights of February 1991 under strong spread-F condition. A data acquisition system was developed at PRL for recording the echo amplitude data simultaneously at different range gates. The number of samples to be preintegrated, the number of range gates to be used and the starting height could be selected for this mode of data recording. The system can be interfaced to any ionosonde or radar and has applications in studies of ionosphere (equatorial spread-F) or the middle atmosphere (MST radar). The data recorded from Thumba are being analysed to study the echo fading characteristics like the fading

period, autocorrelation and power spectrum at different altitudes.

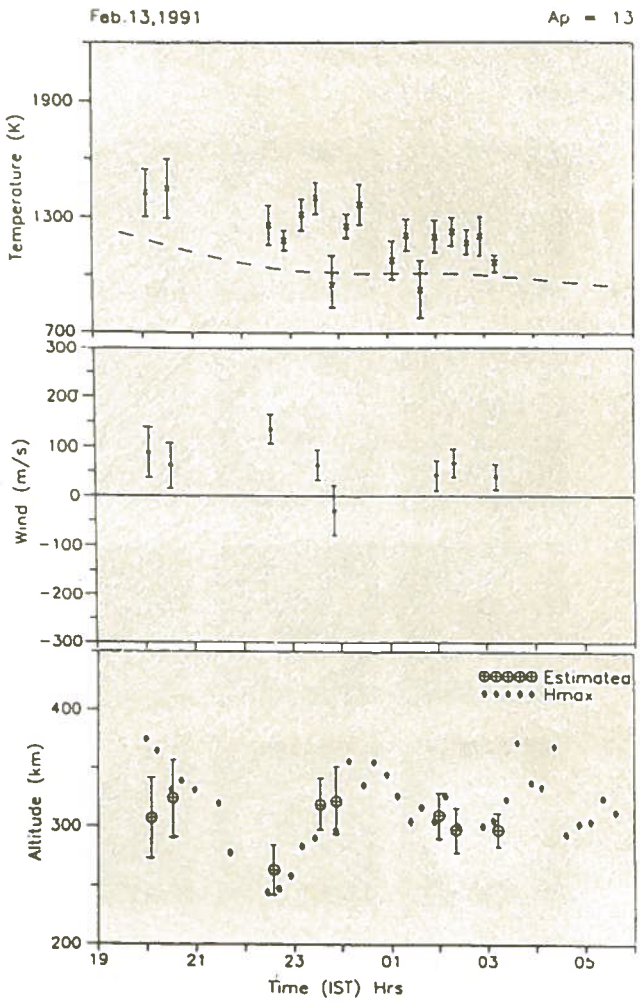
(R.N. Misra and H. Chandra)

Thermospheric Studies

Thermosphere-Ionosphere System : Systematic investigation of the Thermosphere-Ionosphere system is being carried out using both ground based optical and radio sounding techniques. Co- ordinated measurements are carried out to this effect. The high resolution optical spectrometers operating on OI 630.0 nm provides data on the kinetic temperatures and line of sight winds at ionospheric heights while the ionosonde provides data on base level F-region. The results from these measurements reveal a quantitative measure of the extent to which the neutral thermosphere and the F-region behave as a closely coupled system. Our earlier results revealed the role of neutral temperature on the F-region heights while the new results show the relative importance of meridional winds as well. Measured neutral temperatures and meridional winds were plugged into the basic servo equations and the height of maximum electron density, viz., H_{max} has been estimated and compared with that independently obtained from ionosondes. It had been shown that the estimated and measured values agree fairly well. The small deviati ons have successfully been used to derive the electric field and its variability. These results bring out the need for correcting the neutral temperature effects while making use of the existing ionosonde data base for deriving meridional winds.

(S. Gurubaran, R. Sridharan, R. Sekar, R. Narayanan, N.K. Modi and Manisha Pandya).

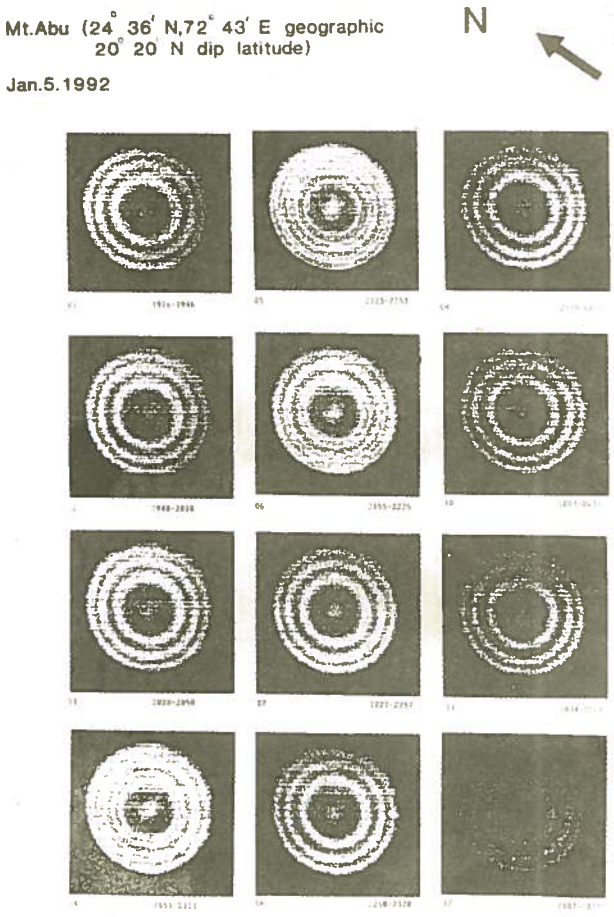
Validation of Meridional Wind Determination using Ground Based Ionosonde : As meridional winds play a crucial role in transporting energy and momentum, their determination is considered important for any study in the thermosphere-ionosphere system. Attempts are made to derive this parameter using the ground based ionosonde data. Validation of this method has been done by making use of a unique data set obtained from one of our earlier rocket experiments. Insitu measured electric fields and ground based ionosonde data were made use of in deriving meridional winds and this has been compared with the insitu determined winds. The agreement had been found to be very good thus validating the method for very low and equatorial latitudes.



Example of strong interaction between the thermosphere and the F-region of the ionosphere.a) measured neutral temperatures; b) measured meridional winds and; c) the estimated height of maximum electron densities in the F- region along with those measured independently by means of ground based ionosonde at Ahmedabad.

(R. Sekar and R. Sridharan)

The Doppler Imaging Spectrometer (DIS) : Under AICPITS, the all India co-ordinated programme for Ionosphere-Thermosphere studies, a DST sponsored project, the fabrication of an all sky imaging FP spectrometer was undertaken with an aim, to be able to map the temperature and wind fields of the airglow emitting regions. This project has successfully been completed and the first such imaging spectrometer, in the whole of the equatorial/low latitude zone has been



Sequence of interferograms depicting the reverse fountain effect, the north to south movement of the region of enhanced airglow corresponding to region of enhanced F-region plasma densities ie. the crest of ionization formed due to the equatorial ionization anomaly (EIA).

commissioned since December, 1991. Excellent Imageries of airglow emissions in the high resolution spectrometric mode are being obtained . One of the first results from this DIS has revealed clearly the reversal of the equatorial fountain during nighttime. Further, the extended field of view of the spectrometer enables us to lay constraints on the lower limit of the equatorial ionization anomaly (EIA) crest, which turns out to be 6° in latitude and longitude. More systematic studies are under way.

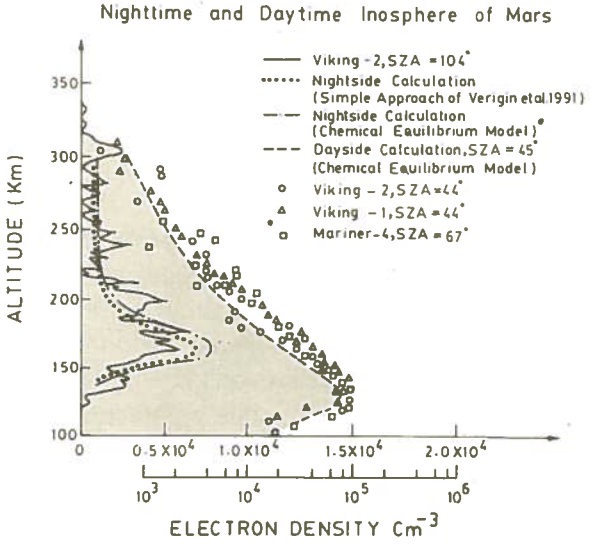
(R. Sridharan, R. Sekar, S. Gurubaran, D.P. Raju, R. Narayanan, N.K. Modi and Ranna Patel)

Further Results from Dayglow Measurements : The dayglow measurements are combined to augment the studies on the thermosphere-ionosphere system. A coordinated campaign was carried out from Waltair with a view to get clues about the daytime thermospheric conditions on days of equatorial spread-F, a nighttime phenomenon. Based on our earlier results, wherein it had been shown that the plasma densities in the F-region do contribute 35% of the total intensity and are totally responsible for the temporal variation exhibited by the same, clues to ESF triggering were sought in these measurements from Waltair. It had been observed that on days when there is a steep bite-out during prenoon hours in the overhead dayglow intensity and also, a cross-over in the intensity magnitudes as seen overhead and at a low elevation of 30°N, spread-F occurred over the equator. More detailed studies are in progress.

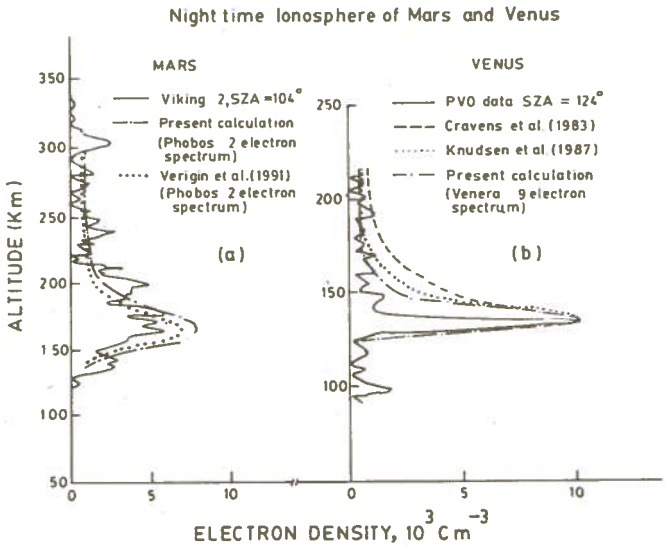
(D.P. Raju, R. Sridharan, R. Sekar, R. Narayanan and N.K. Modi)

Planetary Ionospheres

Ionospheres of Mars and Venus : A comparative study of nighttime and daytime ionospheres of Mars during solar minimum condition is made by calculating electron fluxes, ion production rates, ion and electron densities for the nightside and dayside ionosphere of Mars. For the study of nighttime ionosphere we have used the primary electron spectra measured in mag-



Comparative study of calculated and measured electron density profiles for the nightside and dayside ionospheres of Mars



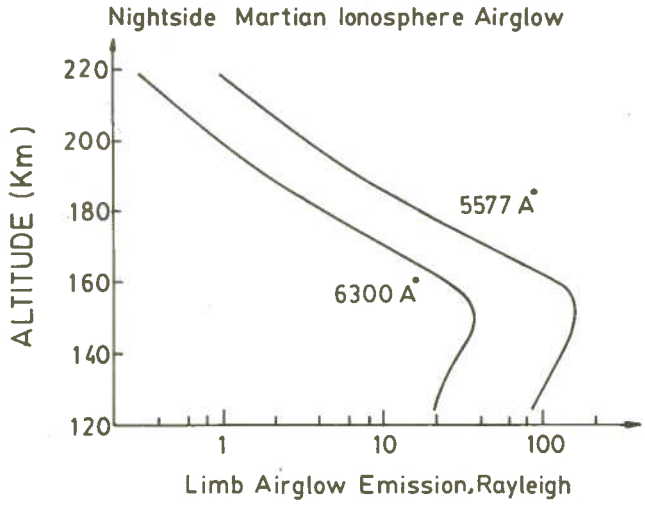
Electron density profiles for the nighttime ionospheres of Mars and Venus. Solid line (-------) shows the Viking 2 and Pioneer Venus Orbiter data for Mars and Venus. Dash dot (-.-) line shows present calculation, dotted line (....) shows the theoretical calculation of Verigin et al (1991) and Knud Sen et al (1987). Dashed (----) line shows the calculation of Cravens et al (1983).

netotail of Mars by Hyperbolic Electrostatic Analyser (HARP) experiment onboard the Phobos-2 martian orbiter. These electron spectra are averaged for 20 min time interval before using in the calculation. Calculations for monoenergetic (unit flux) ion production rates in the nightside are also carried out. Two different analytical approaches are used to carry out this calculation. The electron densities calculated for daytime and nighttime are compared with all possible measurements carried out by radio occultation and retarding potential analyser experiments on Mariner 4, Viking 1 and 2 during solar minimum condition. It is found that the energy of electron spectra observed by HARP experiment in martian magnetosphere is sufficient for impact ionization of planetary neutral gas and the characteristic flux could produce the nightside ionospheric layer with a peak density of few thousands of electrons per cubic centimeter. This corresponds to densities earlier observed by radio occultation experiment of Viking 2. The electron density for nighttime is found 20 times less than those of daytime and peaks at 30 km above the daytime ionosphere.

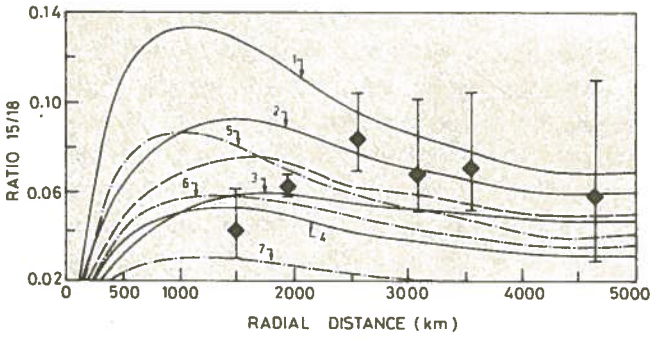
Mars and Venus have extended atmospheres with CO_2 dominating in the lower thermosphere and O at higher altitudes. The source of ionization during nighttime over Venus during solar minimum is reported to be electron precipitation. We have already seen in our previous study that HARP electron spectra precipitating in the nighttime ionosphere of Mars is sufficient for impact ionization. Thus both the planets have similar source of ionization in the nighttime. Much can be learnt from the comparative study of nighttime ionospheres of Venus and Mars. Therefore, we have also calculated the ion production rates, ion density and electron density for the nighttime ionosphere of Venus during solar minimum condition, using the Venera 9 electron spectra pricipitating into the upper atmosphere of Venus. These results are compared with the experimental and other theoretical calculations. From this comparative study we have found that the density of the nighttime ionosphere of Venus is factor of 2 more than the nighttime ionosphere of Mars during solar minimum condition.

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

630 and 557.7 nm Airglow Emissions in the Nighttime Ionosphere of Mars : From the above nighttime ionospheric studies of Mars it is now accepted that the electron spectra of few hundred eV observed by Phobos-2 is sufficient to explain the nighttime ionospheric layer. These electron spectra are used to calculate the 630 nm ($O\ ^1D - O\ ^3P$) and 557.7



Limb airglow emission intensities of 6300 A and 5577 A lines .



Calculated radial profiles of ratio m/q = 15/18 for different relative abundances of NH_3 and CH_4 compared with Giotto data (with error bars). Key: 1 - NH_3 = 0.5%, CH_4 = 2%; 2 - NH_3 = 1%, CH_4 = 2%; 3 - NH_3 = 2%, CH_4 = 2%; 4 - NH_3 = 1%, CH_4 = 1%; 5 - NH_3 = 1%, CH_4 = 5%; 6 - NH_3 = 2%; CH_4 = 5%; 7 - NH_3 = 2%, CH_4 = 5%; Long dashes - NH_3 = 1%, CH_4 = 1% (Photoionization source is taken into account only).

nm ($O\ ^1S$ - $O\ ^1D$) airglow emissions for the nighttime ionosphere of Mars. The mechanisms (i) electron impact excitation of O, (ii) dissociative recombination of O_2^+ and (iii) dissociative excitation of CO_2 are used in the present calculation for the production of $O(^1D)$ and $O(^1S)$ atoms. The loss rates of excited atoms is determined by radiation and quenching of CO_2. These emission rates are used to calculate the limb airglow intensities of 557.7 nm (~100 Rayleigh) and 630 nm (30 Rayleigh) lines which are in reasonable agreement with Mars 5 airglow observation. In this study the dissociative excitation of CO_2 is found to be the main excitation process of $O(^1S)$ atoms while dissociative recombination of O_2^+ is the major source of the production of O(1D) atoms.

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

Cometary Studies

The Study of the Coma of Comet Halley A comparative study of ionization rates due to sources (i) solar EUV radiation, (ii) photoelectrons, and (iii) auroral electrons for different ionic species is carried out in the ionosphere of comet Halley. It is found that in the vicinity of ionization peak, the photoelectron impact ionization rate is higher than photoionization rate. However, at all radial distances auroral electron impact ionization is always greater than either of the two. Coupled continuity equations for chemical steady state conditions are solved to compute densities of water group ions (H_3O^+, H_2O^+, OH^+, H^+), ammonia group ions (NH^+_4, NH^+_3, NH^+_2, NH^+), and methane group ions (CH^+_5, CH^+_4, CH^+_3, CH^+_2). Mass to charge ratios m/q = 19/18, 17/18, 15/18, 15/19) are determined and compared with Giotto ion mass spectrometer data to derive the relative abundances of NH_3 and CH_4 in the coma of comet Halley. The effect of different ionization sources with varying NH_3 and CH_4 abundances on the ratio profiles of m/q and ion-electron densities are studied in detail. To find a reasonable fit to all of the m/q ratio profiles about 1.5% NH_3 and 2% CH_4 (relative to H_2O) is required in 'normal' ionization condition (photoionization + photoelectron impact ionization). In 'enhanced' ionization condition (when auroral electron source is added to solar EUV and photoelectron source of ionization) the required concentration of NH_3 remains almost same while requirement of CH_4 increases to 5%. Photoelectron ionization source is found to play a significant role in determining the ion densities in cometary ionospheres. Figure shows the calculated radial profile of ratio m/q = 15/18 for different relative abundances of NH_3 and CH_4 compared with Giotto data.

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

LABORATORY ASTROPHYSICS

Fluorescence Spectroscopy of Water Vapour by Photon Impact

Fluorescence spectrum of water vapour has been studied at the incident photon wavelength of 121.6 nm and relative production cross sections for different product states have been measured. The fluorescence spectrum at 121.6 nm wavelength was obtained in the emission wavelength region from 280 to 330 nm at the instrumental resolution of around 1 nm. Work is going on to obtain the fluorescence spectra of water vapour at other incident photon wavelengths of 58.4 and 73.6-74.4 nm. Also, the total undispersed fluorescence intensity measurements were carried out at these three wavelengths as a function of pressure of the target gas. This provides information regarding relative fluorescence quantum yield of water vapour at these wavelengths provided the intensity of the incident photon beam is kept constant.

The experimental set up for studying the fluoresence spectroscopy of molecules at the VUV photon wavelengths consists of a microwave discharge light source, fluorescence chamber, differential pumping assembly between the light source and the chamber, a 0.2 meter monochromator positioned perpendicular to the beam axis, appropriate optics to focus the fluorescence emission at the entrance slit of the monochromator and a thermoelectrically cooled photomultiplier. The spectra are obtained using a fast data acquisition system. The total undispersed fluorescence spectra at different incident photon wavelengths are obtained at different pressures of the target gas by using the monochromator in the zero order.

The fluorescence spectrum of water vapour obtained using the experimental set up described above consists of (1,0) and (0,0) vibrational bands of $A \rightarrow X$ system of photofragmented specie OH. The relative production cross sections for different vibrational bands of this system have been measured.

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

Fluorescence Spectroscopy of Molecules at Different Temperatures

A new experiment is being set up in the laboratory to study the fluorescence spectroscopy of molecules at different temperatures. The measurement would be 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 would be obtained as a function of temperatures ranging from 200 to 300 K. The fluorescence spectra would be studied in the emission wavelength region from 200 to 700 nm depending upon the target gas used at the instrumental resolution of about 0.5 to 1 nm.

The experimental set up would essentially be the same as described earlier for the study of fluorescence spectra of molecules at room temperature. The only difference would be that the fluorescence chamber would be immersed in the methyl alcohol bath and would be cooled to the required temperature by a mechanical refrigeration system. The temperature of the fluorescence chamber can be maintained to a degree of accuracy of better than $\pm$ 1 K for hours together.

It is expected that the relative production cross sections would be different at different temperatures. The experimental set up for carrying out such measurements is ready and work would be taken up shortly using CS_2 and SO_2 molecules respectively.

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

Photoabsorption Cross Section Measurement of Molecules at Different Temperatures

A new experiment was proposed last year to measure photoabsorption cross sections for some atmospheric molecules at different temperatures varying from 200 to 300 K. These measurements were proposed to be carried out in the spectral region ranging from 180 to 350 nm at the spectral resolution of about 0.1 nm. A lot of progress has been made during the year and most of the sub-assemblies of the total experimental system have already been fabricated in the laboratory.

The experimental set up for measuring the photoabsorption and fluorescence cross sections for molecules at different temperatures consists of an argon mini-arc light source, an one meter near normal incidence monochromator, a beam splitter, an absorption/fluorescence chamber with appropriate temperature bath and controller, thermoelectrically cooled photomultipliers and a fast data acquisition system. The argon mini-arc source produces a continuum from 115 to 350 nm and a monochromatic photon beam is obtained by using the normal incidence monochromator. The intensity of the incident photon beam is monitored during the experiment by the beam splitter whereas photoabsorption/fluorescence measurements are carried out in the absorption chamber. This chamber is cooled by the external refrigeration system which involves cooling methyl alcohol in the temperature bath.

Most of the new experimental system is ready and all sub- assemblies fabricated in our laboratory have been integrated and tested for vacuum, beam alignment etc. The actual measurements for obtaining photoabsorption /fluorescence cross section of molecules would start in a short time. To start with, SO_2 molecule would be investigated.

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

Low Voltage, High Current Power Supply

A low voltage, high current power supply capable of supplying a constant current of 80 amperes has been designed and is being fabricated in the laboratory. This power supply is used to strike an argon mini-arc light source operated at an argon gas pressure of about one atmosphere.

The argon mini-arc light source emits a continuum covering the spectral range from 115 to 350 nm. The light intensity of this source is extremely large between 230 and 350 nm and for the photoabsorption studies, most of the times, one has to use light attenuators in this spectral region. But the spectral region between 115 to 230nm is rather weak in intensity. Previously, a home-made 40 ampere constant current power supply has been used for absorption studies. The new 80 ampere power supply is being fabricated to obtain increased light intensity in the spectral region 115 to 230 nm. This would help to study fluorescence from neutral molecules with better signal-to-noise ratio.

(I.T. Kripalani and J.K. Dave)

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14. Sridharan, R., Narayanan, R. and Modi, N.K., An improved chopper mask for the dayglow photometer", Applied Optics, **31,** 425 (1992).

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16. Vyas, G.D. and Chandra, H., "Ionospheric zonal drift reversal and equatorial spread-F' Ann. Geophys. **9,** 299 (1991).

layer at the base of *Otoceras-Ophiceras* beds and the lower one occurs 70 cm below it in the *Productus* shale. Present geochemical study revealed that the limonitic layer also shows a significant positive europium anomaly (Eu^*/Eu)=1.9 and Ce anomaly (Ce/La)N = 1.4. La/Th and Th/Yb in the Lower Triassic limestones are similar to those found in basalts, suggesting volcanic contribution of some elements during the Lower Triassic. The REE, siderophile and Ca abundance patterns at the base of Griesbachian can possibly be explained by known terrestrial processes but the data also have important implications to the extraterrestrial hypothesis for the Permo-Triassic transition. This work was carried out in collaboration with Dr. R.J. Azmi of the Wadia Institute of Himalayan Geology, Dehra Dun.

(N. Bhandari and P.N. Shukla)

Isotopic studies of Dinosaur Egg Shells : Well preserved clutches of dinosaur (Sauropod) egg shells and skeletal remains discovered in the Upper Cretaceous Lameta limestones of Kheda district, Gujarat were studied for their oxygen isotopic composition. Various lines of evidences suggest that the location of discovery could have been a nesting site for the dinosaurs. The oxygen isotopic data of the egg shell carbonate show that the source water for the dinosaurs was rivers, small evaporative pools and similar freshwater reservoirs. The carbon isotope data suggest that the reptiles were consuming plants that utilize the C_3 photosynthetic pathway e.g. small palms, shrubs, conifers etc. Similar analyses of the host limestones suggest that they were deposited in a fresh water environment that provided the niche for the large scale breeding and nesting of the dinosaurs.

(S. K. Bhattacharya and A. Sarkar)

Quaternary Climates and Evolution

Detailed understanding of the climate of our planet since Quaternary times is a major topic of current interest since it would help in the development and testing of models for global change. Our group has been carrying out extensive studies in this direction using both land and sea based samples primarily collected in and around India. The ultimate goal of these studies is to develop an integrated climate evolution comprising the land and sea regions of the Indian subcontinent.

Studies on Thar desert, Sabarmati basin and Chinese Loess : The basic objective of the research was to delineate climatic record from deserts and desert margins which being climatically stressed, record the fluctuation in ambient climate on an amplified scale.

In studies on Thar desert, the focus was to reconstruct the chronology of arid phases via the dating of aeolian sands and intervening selenites. During the past year extensive studies on the NE track of Thar were undertaken with the help of Geological Survey of India and the results confirmed our earlier observation of peak aeolian activity at ~14 KaBP. This post dates the peak of glacial aridity during the last glacial maximum of 18 kaBP. A study of spatial distribution of TL ages (indicating accretion episodes) tends to suggest that at present the Thar is in a substantially contracted phase compared to its expense at ~14 ka B.P. In the western region, several selenite beds sandwiched between aeolian sands were located indicating significant changes in ambient hydrology.

The chronology of aeolian sands suggest that these beds were formed sometime during the glacial maxima. Further studies are in progress to quantity and understand the implication of such beds on hydrological regimes at that time. In a related exercise, the detailed study of the feasibility of dating proximally transmitted fluvial deposits was carried out. This was taken up to understand the shifting of drainage pattern of River Sabarmati, which at present does not follow the paleoslopes indicating a drainage shift due to a possible neotectonic event. Dating of quartz extracts from conglomerates and fans indicated stratigraphically consistent ages of 40-200 ka B.P. These results suggest that the change in the drainage should have occurred ~40 ka or later. The dating of conglomerate deposits also provide an age of ~200 ka to the lower paleolithe that is consistent with the other dating evidences from the Thar desert and Hiran Valley. Presently the experiments are being refined further and efforts to date the sample via optically stimulated luminescence are being made.

Extensive studies were also taken up last year on a long 2.5 Ma column of Chinese loess/paleosol sequence. Based on soil stratigraphy, magnetostratigraphy and comparisons with oxygen isotopic stages an approximate estimate on the loess deposition rate has

been worked out. The TL ages on these are compared with the above estimate to examine the presence of any long term fading component in TL signal that could explain age underestimation in some of the loess-paleosol sequences. Preliminary results indicate such a fading process and more effort is being put to characterize the process.

The collaborations for the programmes cited above are with CAZRI, Jodhpur, Deccan College, Pune, Geological Survey of India, Jaipur, Dept. of Geology, Delhi, Dept. of Physics, Guj. University and RSIC, IIT, Bombay.

(V. Kishan Kumar, S. Prasad, M. Someswar Rao and A.K. Singhvi)

Sea level and neotectonism in Saurashtra Coast : The Saurashtra peninsula is presently being investigated for Quaternary sea- level changes and neotectonism. It has been demonstrated that the coastal tract remained unstable throughout the late Quaternary times. The evidence for tectonic instability comes from intricately related geomorphological features such as the symmetrical open folding of the miliolite beds, block faulting along the fracture lineaments which consequently control the drainage pattern in the study area.

Last interglacial high sea stand has been identified at 7 meter above the present day sea level (asl) after making necessary corrections for neotectonism. The dates for this stand ranges between 110-125 ka whereas another sea stand at - 13m asl was identified which gave an age of 84 ka. This level has come to surface as a result of the emergence of land mass. These high sea stands are in conformity with the deep sea oxygen isotope stages of 5e and 5a respectively.

(N. Juyal and R.K. Pant)

Climatic records in Himalayan Glaciers : Surface snow and ice samples collected at different altitudes from 3700 to 4700 m on Tiprabank glacier indicate the continuous trend of cooler period during last 400 years. The snout ice shows the most depleted values of δ D and $\delta\ ^{18}O$ to be –109‰ and –15.3‰ respectively.

The depth profiles of snow/ice collected from two shallow pits in the accumulation and ablation zones of Tiprabank glacier show cyclic variations and these could be used in dating annual snow layers from accumulation zone of the glaciers. Other studies are in progress.

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

Stable isotope studies on Indian Corals : This study initiated about a couple of years ago has been continued. Corals are shallow marine organisms that deposit aragonitic $CaCO_3$ with seasonally varying density that shows up as annual bands in an X- ray photograph. The age of a live coral can be determined by counting the bands, as each band is deposited in one year. Further, as the stable oxygen isotopic composition of coral $CaCO_3$ depends on the sea surface temperature (SST) when salinity variations are small, corals can be used to obtain a high resolution proxy SST record that will be useful for validating climatic models aimed at predicting the Indian monsoon rainfall. We have shown that the sea surface cooling of 3° to 4°C induced by monsoon winds in the Arabian Sea is faithfully recorded as changes in $\delta\ ^{18}O$ of two corals of Porites species collected from two of the Lakshadweep islands (Amini and Kavaratti), separated by about half a degree latitude. We have also shown that the disequilibrium isotopic fractionation in these corals remains constant at ~4.5 ‰ by comparing the coral $\delta\ ^{18}O$ record with that of a clam (Tridacna maxima) that grew within 1m of the coral. We have used the SST data from the Daily Weather Reports to derive an empirical relationship between the coral $\delta\ ^{18}O$ and SST.

$$t(^{\circ}C) = 8.60 - 3.89\ \delta\ ^{18}O \text{ coral}$$

Though interannual variations in SST are small (~0.5° C in ~100 years), the seasonal dip in SST during the monsoon (~3° to 4°C) is large enough to be detected by the corals. Analysis of long coral sequences will be able to provide proxy SST data for the past few hundred years. Work in this direction is in progress.

(S. Chakraborty and R. Ramesh)

Environmental reconstruction through sediments from continental margins : Ascertaining past environmental conditions with high resolution can in principle be conveniently done through geochronological and geochemical studies of fast depositing coastal ocean sediments. Undisturbed spade cores of ~30 cm in length collected from the continental margins of Western India (i.e. in eastern Arabian Sea) have been

GEOCOSMOPHYSICS

Study of the two major reservoirs of the earth, the lithosphere and the hydrosphere, to get insights into the processes that controlled its evolution through time forms the major focus of the Geophysics aspects of our Area activities. The "cosmo" part deals with the study of the remnants of extraterrestrial matter that our planet has been collecting from time to time, mostly in the form of meteorites which helps us to understand the evolution of the Solar System of which our planet earth is a member.

Highlights

The Ar-Ar geochronologic studies of the Deccan trap basalts have yielded very useful information. It is shown that bulk of the lava erupted at 67.1 ± 0.1 Ma ago whereas the Cretaceous-Tertiary transition occurred 65 Ma before present (BP) indicating that Deccan Volcanism could not have been responsible for K/T mass extinctions.

In the Quaternary Climate Studies, one thing appears significant - the TL chronology of the aeolean sand columns of Thar desert indicates that the peak of aeolian activity centered around 14 KaBP which predates the last glacial maximum (LGM,18 KaBP) by about 4 Ka.

Contemporary studies on the isotopic composition of C and O in atmospheric CO_2 collected in ground level air appears to have the potential for quantifying the monsoon induced productivity changes on land.

The isotopic signatures measured in one refractory object isolated from a primitive meteorite suggest that such objects could have formed in hot and dense regions of the solar nebula. Efficient gas-dust fractionation and localized heating in the solar nebula can provide such settings that will obviate the need for an uniformly hot solar nebula in the meteorite forming zone, with temperatures much higher than the predicted ones, for the formation of the primitive refractory solids in the solar system.

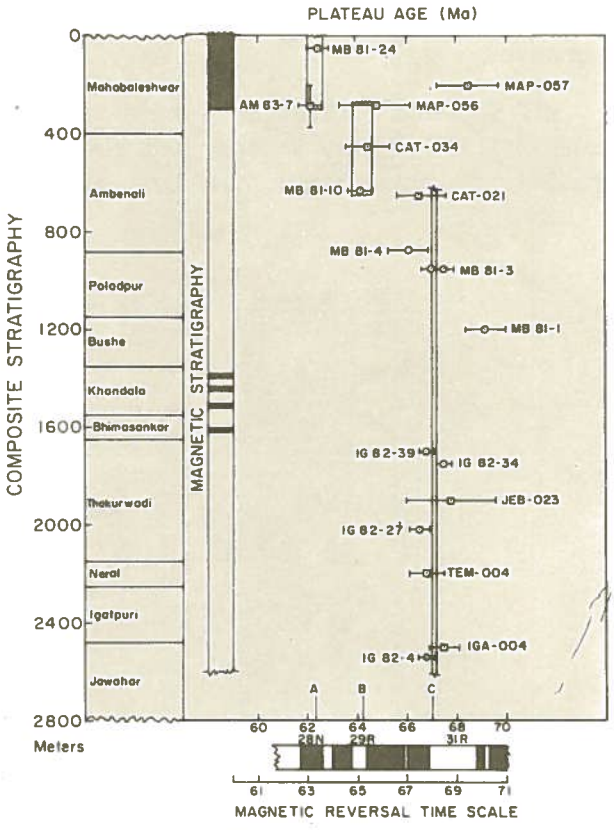
Micro diamonds were successfully isolated from a primitive meteorite and their interstellar origin was established from isotopic studies of noble gases and nitrogen. The isotopic data also suggest the presence of a small component of silicon-carbide of interstellar origin in the sample. Isolation and studies of interstellar grains from several meteorites are being planned as these will allow the testing of several astrophysical theories.

Significant results obtained during the year under report are described in the following sections.

Earth Sciences

Geochronology and Geochemistry

Deccan Volcanism : Basalts have erupted on the earth's surface throughout its geological history and in a variety of tectonic environments. Continental Flood Basalts (CFB) are voluminous lavas that have periodically blanketted the continents and are associated with either a continental break-up and/or the passage of continent over a hotspot. Such stupendous outpouring of basalts have been cited as a possible cause for the mass faunal extinctions that have occurred during the past. For example, the Deccan volcanism is thought to have been the cause for the Cretaceous/Tertiary (K/T) extinctions 65 Ma ago. Our preliminary studies two years back suggested that the



Plot of plateau ^{40}Ar-^{39}Ar ages versus composite stratigraphy of Deccan traps from Western Ghats. Modified magnetic stratigraphy of this section is also shown. The magnetic reversal time scale is shown at the bottom.

Deccan volcanism might have predated the K/T event. Precise geochronology of basalts from stratigraphically correlated flows of the western ghats of the Deccan Province have been carried out. The present results alongwith the published ones for the western ghats show that the main/peak eruptions took place at 67.1 ± 0.1Ma ago, 64.2 ± 0.4 and 62.3 ± 0.1 Ma ago, the bulk of the lava erupted at 67.1 ± 0.1 Ma. This predates the K/T events by 2 Ma suggesting that the Deccan volcanism might not have caused the K/T extinctions.

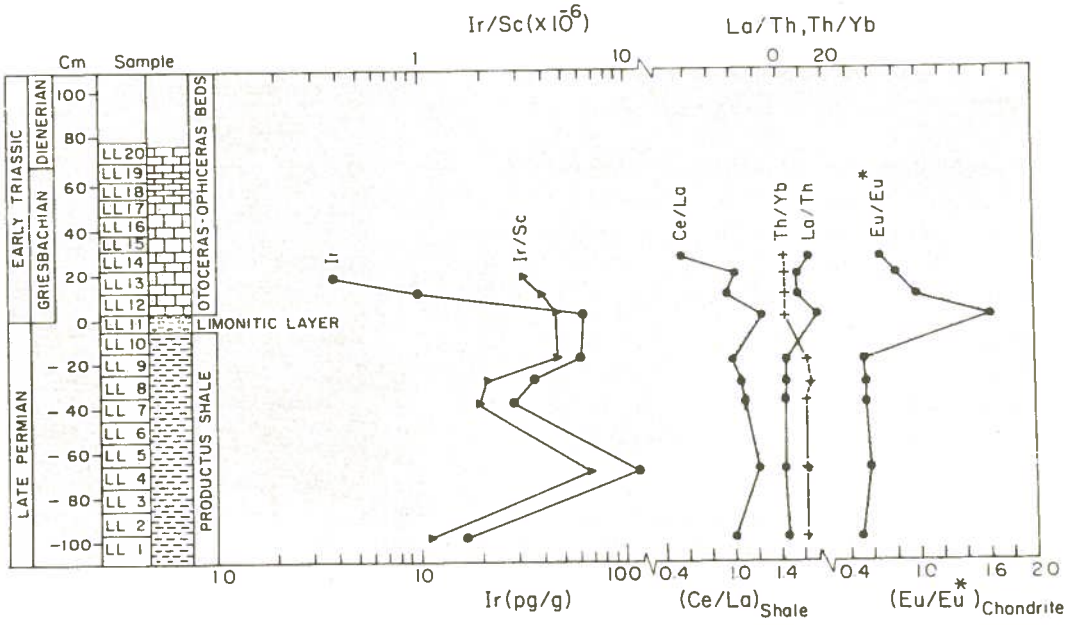
(R. Jadeja, K. Pande, J.R. Trivedi and T.R. Venkatesan)

Geochemical Studies at the Cretaceous-Tertiary (K/T) and Permo-Triassic (P/Tr) Boundaries in India.

It is known that extinctions of life have taken place during transitions/boundaries such as K/T and P/Tr. Both these boundaries are well preserved in some of the Indian Geological formations. A detailed geochemical study of these sections was undertaken to infer the cause for the extinctions and associated geochemical signatures.

K/T Sections : A number of marine as well as continental K/T sections in India, particularly around the Deccan volcanic region, have been analyzed to obtain concentration profiles of some platinum group and other trace elements, specifically to search for anomalous levels of iridium. Except for the Um Sohryngkew River (USR) section in Meghalaya, where iridium is found to occur at anomalously high level in the K/T boundary layer, all other sections show low levels in the range of 10 to ~120 pg/g. The iridium profile in USR section is characterized by a sharp peak of 12.1 ng/g in a 1.5 cm thick limonitic layer, superimposed on a broad band of ~0.2 ng/g extending over a 50 ± 20 cm thick section, on either side of which Ir decreases to the base level of ~0.02 ng/g.High Ir is accompanied by high Os but Os/Ir ratio in the peak (0.37) is different from ~2 measured in the broad band. The Ir profile in the USR section seems to be consistent with fallout of cometary debris preceding and following the main impact. The measurements at other sites in the Deccan suggest that the iridium inventory of the Deccan is too low to account for the high iridium observed in KTB layer all over the world, but may be sufficient to give rise to its enhancement adjacent to the KTB peak.

P/Tr Section in Spiti, Tethys Himalaya : Last year we reported that at two horizons in the P/Tr boundary interval of Spiti, Tethys Himalaya, containing Ir at 73 and 114 pg/g, about a factor or 2 above the background level.The upper one occurs in a limonitic



Positive Eu anomaly (EU/Eu) and the accompaying Ir excess observed in the limonitic layer at the Permo-Triassic boundary of Spiti. Ir is normalised to Sc to correct for changes in sedimentation rate. Ce/La indicates redox conditions whereas Th/Yb and La/Th characterises the presence of Volcanic contributions during Triassic.*

dated using ^{210}Pb and analysed for U, Mn, Al and $CaCO_3$ contents as well as $\delta\ ^{18}O$ in the surface dwelling foraminifer G. ruber separated from different depths. The sedimentation rates ranged from 0.8 to 2.5 mm/yr which allowed the construction of time (years) versus parameter plots that yielded the following information :

- The $CaCO_3$ abundance, an indicator of primary productivity varied from ~20 to 75% during the past ~250 yrs.
- In the near-coastal regions the environment at sediment-water-interface had been anoxic as evidenced by low Mn/Al < 70×10^{-4} and high U/Al (> 2×10^{-4}) weight ratios.
- In deep water regions at some locations, the environment was anoxic between ~120 yrs and ~60 yrs BP. From 60 yrs BP till present it turned oxic as evidenced by high Mn/Al and low U/Al weight ratios.
- In general the $\delta\ ^{18}O$ values were more negative (by ~0.4‰)during the past ~70 yrs. compared to the previous period. Also $\delta\ ^{18}O$ is inversely correlated to the rainfall anamoly. Increase in rainfall (which reduces surface salinity of sea water) and/or increase in temperature are the most likely causes for decrease in $\delta\ ^{18}O$. The high resolution studies described above are directly relevant for ascertaining the Past Global Environmental Changes (PAGES).Such studies form an important part of the IGBP.

(M.M. Sarin, A. Sarkar, B.L.K. Somayajulu and D.N. Yadav)

In the following sections are described the studies to understand the present state of the climatic system with regard to the cause-effect relationships.

$\delta\ ^{13}C$ and $\delta\ ^{18}O$ of CO_2 in ground-level-air : The Indian subcontinent and the adjoining seas (the Arabian Sea and the Bay of Bengal) experience seasonal reversal of wind systems and associated weather changes resulting from summer and winter monsoons. The monsoons are associated with significant changes in the oceanic and continental biosphere and are therefore expected to have considerable effect on the content and isotopic composition of atmospheric carbon dioxide. We have attempted to measure this effect in ground-level carbon dioxide samples collected in the city of Ahmedabad during 1990. The CO_2 content is in general agreement with values obtained elsewhere. The $\delta\ ^{13}C$ values of air CO_2 show a minor effect due to the increase of productivity on land during the southwest monsoon season. The $\delta\ ^{18}O$ value of CO_2 is slightly enriched compared to northern high- latitude values owing to the equilibration of CO_2 with enriched leaf water expected in a tropical country like India.

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

Study of evapotranspiration during the Indian monsoon using stable isotope data from shallow groundwaters : We have earlier measured the δ D and $\delta\ ^{18}O$ values of shallow ground waters (which are very young otherwise) along a traverse in the east-north west parts of India that come under the direct influence of the Indian monsoon. On the premise that shallow ground waters represent an "averaged contemporary precipitation", their isotopic ratios can be interpreted as proxy indicators of the δD and $\delta\ ^{18}O$ values of the local precipitation. We have now modelled the rain-out events and their effects on the isotopic ratios as a first order Rayleigh-distillation process leading to a spatial $\delta\ ^{18}O$ gradient (coast to inland) of about –2‰ per 1000 km distance between coastal Calcutta and inland Delhi. The moisture bearing wind systems enter the land near Calcutta and propagate north-westerly towards Delhi with successive stages of precipitation. However, the gradient appears to be smaller than what would be expected for a pure Rayleigh process, where the vapour reduction factor in Delhi is more than half. This reduced gradient can arise if the original parcel of water vapour is augmented by additional vapour transport through evapotransipration. A 10 chamber/box model has been employed to take the evapotransipration effect into account. This model suggests that upto 40% of water that has precipitated has to be put back into the vapour phase to explain the observed isotopic trend. This estimate is close to values expected based on hydrological balance calculations and is also similar to the value of 35% obtained in European precipitation. This work was carried out in collaboration with Dr. R.V. Krishnamurthy of Water Researches Institute, Kalamazoo, Michigan, USA.

(S.K. Bhattacharya)

Aqueous Geochemistry

The aqueous geochemical studies include measurements of stable and radioactive isotopes, major ion and a few other select trace elements in water bodies on land and in the oceans. These studies are aimed at understanding the source of water to the fresh water systems, their movement, fluxes of elements/isotopes to the oceans via rivers and geochemical behaviour of nuclides in ocean systems.

Salt lakes of Rajasthan and Gujarat : There are a number of salt lakes in and around Rajasthan, the origin of which (especially their salt) has been a subject of speculation. One of the hypotheses for their origin is that they are remnants of the Tethys Sea that existed before the collision of the Indian and Tibetan plates around 70 Ma ago. We have collected more than 50 fresh and salt water samples from and around some of the major salt lakes (Sambhar, Didwana and Kutchaman in Rajasthan, and Kharaghoda in Gujarat) and determined their stable isotopic composition (δ D and $\delta\ ^{18}O$) to verify the above hypothesis. Our results show that the δD and $\delta\ ^{18}O$ follow a linear relationship:

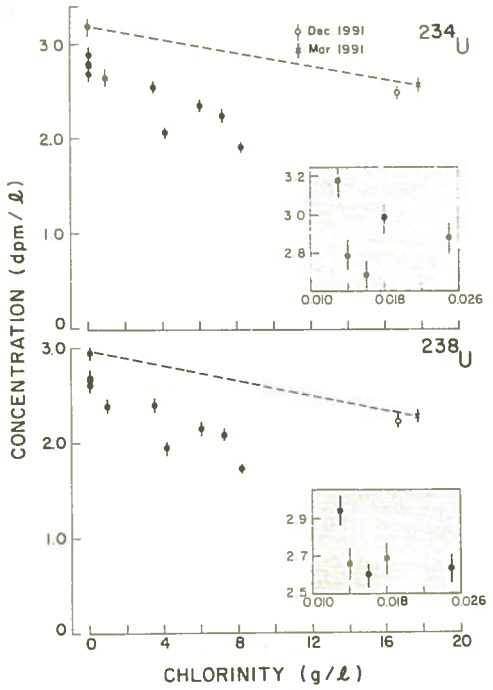
$$D = (3.86 \pm 0.07)\ \delta\ ^{18}O - (17.81 \pm 0.31)$$

with a correlation coefficient of 0.97, significant at 0.01 level, implying that these waters are essentially of meteoric origin. They are evaporated products of the local precipitation. There is therefore no evidence for the seawater inundation hypothesis for the origin of water in these lakes. It is also possible, however, that these lakes were originally of marine origin , but over the geological past, they were flushed with meteoric waters. Attempts are being made to look into the origin of salt.

(R. Bhushan, R.A. Jani and R. Ramesh)

Hooghly estuary : The flux of uranium,and associated $^{234}U/^{238}U$ ratios through rivers, is a topic of considerable interest to geochemists. The group has pioneered in some of these studies. In less polluted estuaries of the major rivers of India as well as those of other countries, its behaviour is found to be conservative with the notable exception of the Meghna estuary (of the Ganga-Brahmaputra river systems) in Bangladesh where evidences for its non-conservative behaviour were reported.

Amongst the Indian estuaries, river Hooghly which is a part of the Ganga system and its estuary surrounded by the metropolis of Calcutta is known to be polluted. With the aim of understanding the behaviour of uranium and some of its daughter nuclides in a polluted estuary, a study was conducted in December 1991 through the Mooriganga channel of the Hooghly. Major ions, Si, U and its daughter nuclides are being measured. Whereas the major ions Na, K, Ca and Mg do not show any significant departure from the expected conservative behaviour, Si behaves non-conservatively. It is most likely removed in the Hooghly estuary primarily through biological productivity.



Concentrations of ^{234}U (top) and ^{238}U (bottom) in the estuarine waters of Hooghly. All data points fall below the conservative (dotted) line indicating U removal in this polluted estuary which amounts to about 20%. In all other Indian estuaries U isotopes behave conservatively.

The U concentration in the freshwater region of the Hooghly ranged from 2.66 to 2.94 dpm/l,the high value was measured near the Outram Ghat in Calcutta (fresh water-end-member of the Hooghly estuary).This decreases to 1.72 dpm/l near the mouth of the river (chlorinity = 8.2 g/l) and then show an increase to 2.2 dpm/l, with increasing chlorinity. Both ^{234}U and ^{238}U behave identically. The $^{234}U/^{238}U$ activity ratios in the fresh water region are in the range of 1.02 - 1.08 similar to the values reported by us in Ganga at Farakka and beyond upstream. In the region spanning a chlorinity of 0.9 to 8.2 g/l, the concentrations of ^{234}U and ^{238}U

are lower compared to either of the end members strongly suggesting the estuarine removal of uranium. If the non-conservative behaviour is attributed to U removal entirely, it is estimated that about 20% of the dissolved U transported through the Hooghly river is removed in regions close to the river mouth.

Modelling of some of the aqueous-system processes : Over the past two years, attempts have been made to model some of our results such as those on (i) the role of Himalayan orogeny on the variation of $^{87}Sr/^{86}Sr$ in the ocean, (ii) the use of ^{210} Po to obtain "new production" in the Arabian Sea euphotic zone (iii) the transport of Ra isotopes from continental boundaries to open ocean and (iv) the stable isotopic variation in terminal lakes. Some of these studies are briefly described below:

- The steady increase of $^{87}Sr/^{86}Sr$ in the oceans during the past 40 Ma has been attributed to the uplift and consequent erosion of the Himalaya. Recently detailed measurements of these isotopes in the Ganges and Brahmaputra (GB) rivers has been completed by our group and we could test the above hypothesis by setting up a model for the evolution of Sr isotopes in the ocean resulting from its supply via GB rivers. The model takes into account the input of Sr by rivers into the ocean by hydrothermal exchange and by diffusion from pore waters. Assuming a perturbation in the supply of Sr isotopes, we have determined the extent of the contribution via GB system to the changes observed in the ocean record. This contribution turns out to be ~15% over the past 40 Ma or ~30% during the last 20 Ma.
- Using a one dimensional-advection diffusion model and the data on dissolved ^{210}Po, NO_3 and PO_4 in the Arabian sea water column, we have calculated the upper limit for new production in the north east Arabian Sea to be ~0.3 gC m^{-2} d^{-1}. New production is the net transport of carbon from the surface to the deep ocean and its determination is important to understand marine carbon budgets.
- The lateral transport of carbon from the coastal shelf sediments to the deep sea is important in the global carbon budget. We have set up a two dimensional advection–diffusion tracer transport model for Ra isotopes and evaluated the horizontal eddy diffusivities between coast and open ocean in the eastern Arabian Sea both at surface and 300m depth which is the core of the perenneal denitrification layer.
- The stable isotope systematics of a terminal lake have been modelled. A terminal lake is one in which the input of water is through direct precipitation and run-off and the output is through evaporation alone (there is no outflow). Salt lakes in Rajasthan and Gujarat behave like terminal lakes as they receive water only during the monsoon and evaporation proceeds throughout the year. Taking the data on humidity, temperature and the isotopic composition of precipitation in this region, we calculated the steady state δ D ^{18}O value for these lakes to be 4.65‰, which is in good agreement with the measured value of 4.8‰.

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

Solar System Studies

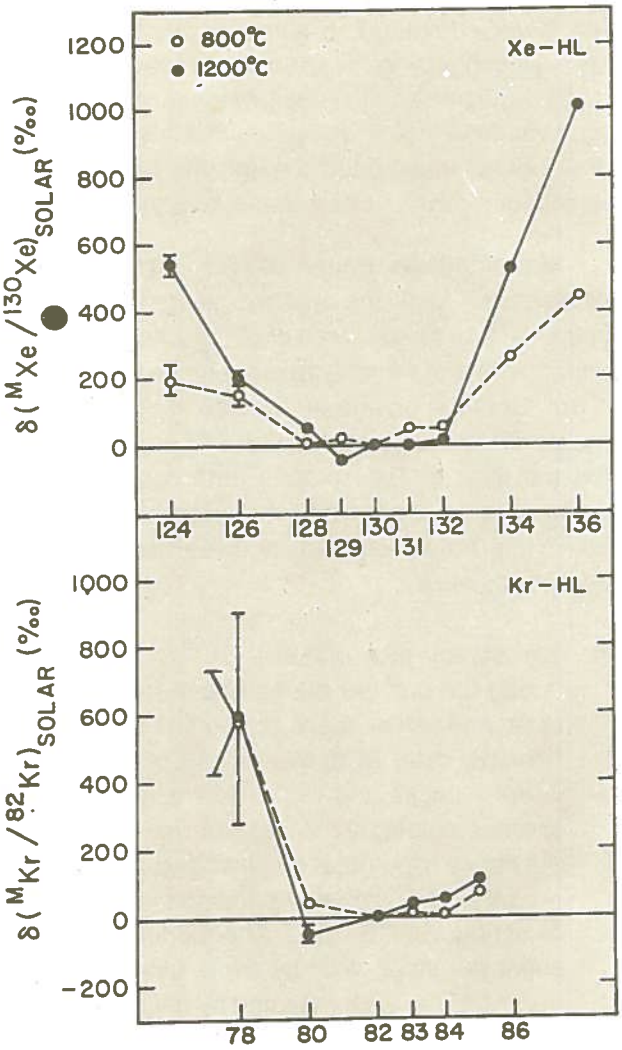
Relict Grains in Refractory Inclusions

The proposed formation temperatures of the coarse grained refractory inclusions are predicted to be in excess of 1700°K much higher than 1000 °K predicted for meteorite forming zone (2-4 A.U.) by solar nebula models. However, some laboratory experiments aimed at the above problem suggested the possible presence of relict phases within the molten refractory inclusions.

Using the concept of isotopic disequilibrium between co-existing mineral phases as a signature of relict grains several refractory inclusions from the Efremovka meteorite having distinct textural and isotopic signatures indicative of their crystallization from a melt were studied. In one of these inclusions, E40, evidence for magnesium isotopic disequilibrium between spinels and melilites, two coexisting mineral phases, was obtained suggesting that some of the spinels in the interior of the inclusion are indeed relict grains. These grains were extraneous to the inclusion and did not undergo complete isotopic exchange with the surroundings i.e. source melt. Using the recent laboratory data on magnesium self-diffusion in spinels at high temperature a cooling rate of few tens of

degrees per hour is derived which is much higher than that of the nebula as a whole (< 1 degree/yr), and much lower than that of a radiating droplet in the low density nebula (few tens of degrees per second). The only setting that will be compatible with both the high initial temperature and the needed cooling rate are the localized dense and hot regions in the solar nebula. While efficient gas-dust fractionation can also lead to localized dense region in the nebula, a unique source for localized heating is difficult to identify. However, a host of possibilities do exist.

Isotopic heterogeneity in the Solar nebula : A second look : Isotopic heterogeneity in the solar nebula is now considered well established as a large suite of data on anomalous isotopic compositions in meteoritic phases show widespread variations in the magnitude of these anomalies, even for the same element. In the case of magnesium, the presence of excess ^{26}Mg in many refractory phases in meteorites, that correlates well with ^{27}Al content of the phases, suggests that the excess is due to in-situ decay of now-extinct ^{26}Al [$^{26}Al^{*}$; half life = $7x10^{5}$ years], present in the solar nebula at the time of formation of these refractory objects. Magnesium isotopic studies in a set of six refractory inclusions that includes several types of objects from the Efremovka meteorite have been completed.All the inclusions have ^{26}Mg excess and in five of these inclusions, we obtained initial ($^{26}Al/^{27}Al$) values close to $5x10^{-5}$, a value found primarily in type B1 inclusion during the earlier studies. Our observations of similar initial ($^{26}Al/^{27}Al$) for a set of Eremovka refractory inclusions do not support heterogeneous distribution of $^{26}Al^{*}$ in the solar nebula. An important feature that distinguishes the Efremovka inclusions from those in other meteorites, is the lack of secondary alteration suggesting them to be more pristine samples of the solar system.It is likely that the observed variation in the initial ($^{26}Al/^{27}Al$) in many refractory objects in primitive meteorites results from secondary processes affecting these objects. Evidence for such an affect was also found in one of the Efremovka inclusions studied by us, where data for two co- existing mineral phases suggested different initial ($^{26}Al/^{27}Al$) for this object. This can be best explained as due to exchange of Mg and Al between these two phases during a secondary event affecting this object, early in its history, when ^{26}Al was still extant.



Deviation in the isotopic ratios of the Xe and Kr with respect to solar composition are plotted for 800°C and 1200°C fractions of the micro diamond seperate from Murchison.

Interstellar Grains in Primitive Meteorites

Our knowledge about the interstellar grains is based mostly on astronomical observations, theoretical modelling and deductions. The recent discovery of preserved interstellar grains (microdiamond, silicon carbide, graphite) in certain primitive meteorites has opened up the prospect of laboratory investigation of these exotic grains. Such studies will help us in understanding the stellar environment in which solar nebula originated, and also to check several astrophysical theories regarding formation, destruction, relative abundance, size distribution and life-time of interstellar grains.

Following rigorous procedures, we have successfully separated microdiamonds from a 6 gm sample of the carbonaceous chondrite Murchison and proved them to be of interstellar origin from a study of nitrogen and noble gases isotopic compositions.

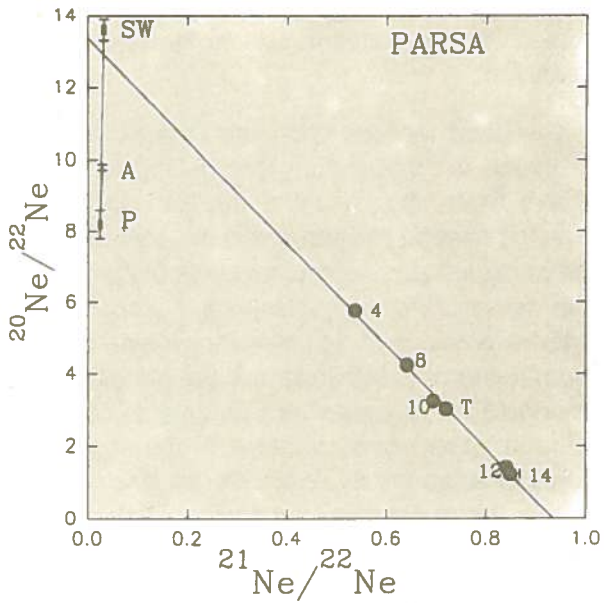
The isotopic composition of nitrogen and noble gases, particularly neon, krypton and xenon, show typical values (characteristic of interstellar diamonds) [$\delta^{15}N = -310‰$, $^{20}Ne/^{22}Ne = 8.4$ (Ne – A2); depletion in light isotope of krypton and enrichment in its heavy isotopes; enrichment of both light and heavy isotopes of Xe (Xe – HL;)], at the 1200°C extraction, where ~90% of the total nitrogen was released. At higher temperature, there is a depletion in ^{15}N, coupled with an excess of ^{22}Ne [Ne – E(H)] which is indicative of a small admixture of interstellar silicon carbide in the separate. Another interesting feature, not previously seen, is the possible enrichment of both light and heavy isotope of Kr (Kr – H.L.?) at 800° C extraction step. This result needs further confirmation.

Light Nitrogen in Lehrauli Urelite

Urelites are an enigmatic group of meteorites (achondrites) mainly consisting of olivine, pigeonite and elemental carbon, including diamonds whose origin is controversial. While petrological studies indicate a magmatic origin, oxygen isotope data suggest a heterogenous accretion. Lahrauli urelite which fell in Uttar Pradesh in 1955 was studied for nitrogen and noble gases. A step-wise release study of a bulk sample revealed two components in the nitrogen. A heavy component with $\delta^{15}N = 5.5‰$ that progressively decreased to – 107‰ at 1400°C (light component) which then increased to – 89‰ in the 1700° fraction. The light-N-component in Lehrauli is the lightest nitrogen found in a bulk stone meteorite till todate. If carbonaceous chondrites which have $\delta^{15}N > 40‰$ are the precursors for Ureilites the high nitrogen cannot be accounted for. As Urelites are supposed to have been formed during a magmatic process, preservation of such distinct N-components is not possible.Heterogenous accretion appears to be more favourable.

Records of CR Interaction in Meteorites

Two meteorites Parsa, an enstatite chondrite, and Orgueil, a carbonaceous chondrite, have been studied for their solar-wind, sclar-flare and galactic cosmic ray



Neon isotopic data for the different temperature fractions of Parsa are plotted in the three isotopic diagram. Temperatures indicated are multiples of 100°C. T is total. A, P and S.W indicate compositions of air, planetary and solar components. The least square fit to data yields the trapped $^{20}Ne/^{22}Ne = 12.6$.

interaction records. The special features of these meteorites and the results obtained from our study are described here.

Trapped noble gases in enstatite chondrites have two main features that are different from other chondritic classes : (i) independence of noble gas amounts on the petrologic class, and, (ii) presence of an "Ar-rich" component, characterized by the ratio $^{36}Ar/^{132}Xe$ intermediate between the planetary (~80) and solar (25,000) values. Further, there is no E-chondrite belonging to the "gas-rich" group, that is enriched in solar noble gases. We have studied the noble gases in Parsa enstatite chondrite (EH3).The least square fit to the neon isotopic data extrapolates to the solar-wind value of $^{20}Ne/^{22}Ne = 12.9$. The ^{4}He content of the sample is also in excess of the expected radiogenic component due to decay of Th and U, and the $^{4}He/^{20}Ne$ ratio (corrected for radiogenic and cosmic ray produced components) of ~450 is similar to the solar value suggesting the presence of a solar type gases in Parsa. Surprisingly, this signature is not obvious for the heavier noble gases, with $^{36}Ar/^{132}Xe$ ratio of ~90 being close to the planetary value. Thus the "gas-rich" component comprises only a minor part of its total noble-gas inventory. This is also supported by

the negative result in our search for enstatite grains (< 0.5 %) in this meteorite with solar flare irradiation records.

The carbonaceous chondrite Orgueil, represents one of the five meteorites that belong to the most primitive types, the C1 chondrite. Isotopic studies of separated mineral phases of this meteorite have suggested that its compaction has taken place very early in the history of the solar system, and, probably in < 10 Ma of the formation of the first solar system solids. This meteorite has also individual mineral grains with solar flare irradiation records which predate its compaction time, and, thus, represent some of the earliest fossil records of solar activity. We have analysed individual grains of this meteorite using nuclear track and mass-spectrometry techniques to further understand the activity of the Sun during its very early stages of evolution. The ^{21}Ne contents of the solar flare irradiated grains are higher than ^{21}Ne found in unirradiated grains but the difference is not as large as that found in C2 carbonaceous chondrites. This study is in progress.

Production of Cosmogenic Nuclides in Meteorites:

^{3}He, ^{21,22}Ne, ^{10}Be and ^{26}Al in chondrites : Depth profiles of the cosmogenic isotopes ^{3}He,^{21} Ne, ^{22}Ne, ^{10}Be and ^{26}Al have been measured in the chondrites, Madhipura, Udaipur and Bansur. The shielding depths of the samples and meteorite sizes were derived from cosmic ray track density data and from ^{21}Ne exposure ages. In addition ^{10}Be and ^{26}Al were measured in 7 fragments in Dhajala. The measured data, together with the existing ^{53}Mn profiles in these meteorites and with other well investigated depth profiles of cosmogenic radionuclides and rare gas isotopes in ALHA 78084, Keyes, St. Severin, Jilin and Knyahinya, now provide an experimental data base describing the depth and size dependence of cosmogenic nuclides in ordinary chondrites for preatmospheric radii between 8.5 cm and about 100 cm.

Production rates are found to change only slightly with depth in small meteorites (R ≤ 15 cm). For large bodies (15 cm ≤ R ≤ 65 cm) the profiles show significant depth dependence, the cosmogenic production increases from the surface to the center by about 30%. The production rates at center increase with meteoroid size and show a broad maximum for radii between 25 and 65 cm. For R ≤ 70 cm, a significant decrease of center production rate is seen for ^{10}Be, ^{26}Al, ^{53}Mn and ^{21} Ne, the individual depth profiles being essentially flat with shallow transition maxima.

The observed depth profiles and the dependence of the center production rates on meteoroid size are well reproduced by model deductions based on Monte Carlo calculations of the intra- and inter-nuclear cascade of galactic protons in meteoritic matter and on experimental and theoretical excitation functions of the underlying nuclear reactions.

The model calculations provide a basis for the identification of meteorites with anomalous levels of radioisotopes and give information about their irradiation history and changes in the cosmic ray intensity with time and orbital space of the meteoroid.

This work was carried out in collaboration with the Cologne and Hannover groups in Germany.

^{15}N in Oxygen : Cosmogenic ^{15}N is produced from oxygen. There are two channels for this production : (i) direct production $^{16}O \rightarrow {}^{15}N$. and (ii) via the short lived isobar $^{16}O \rightarrow {}^{15}O \rightarrow {}^{15}N$. In the earlier production rate estimates only channel (ii) contribution was calculated and the total ^{15}N production was estimated using an emperically derived scaling factor due to the non-availability of cross section data for the direct ^{15}N production. With the recent availability of several cross section measurements for channel (i), the calculations for ^{15}N production by SCR and GCR in moon and meteorites were repeated and compared with the previous data.

Ion Probe and tracks : (M.P.Deomurari, J.N.Goswami, V.G.Shah, N.Sinha and G.Srinivasan)

Mass Spectrometry : (K.J.Mathew, S.V.S.Murty, M.N.Rao)

Radioactiviity : (N. Bhandari and K.M. Suthar)

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1. Bhandari, N.,"Collisions with the earth over geological times and their consequences to the terrestrial environment", Curr. Sci., 61-97, 1991.

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Continental Palaeoclimate Studies

The group continued to focus its research activity on palaeoclimate related problems. In this connection, several ^{14}C dates were measured besides carrying out mineral magnetic and organic geochemical analysis on the lake samples. Some oxygen and carbon isotope ratios on the East Arabian sea cores were also made. Calcium carbonate content variation were also made on this core. To achieve higher resolution we have carried out a variety of experiments to improve the techniques employed.

In addition to the experimental work, our group has continued mathematical modelling studies, initiated last year, with the objective of assessing the significance of the regional palaeoclimatic data to understand the processes affecting global climate change during the Late Quaternary.

The highlights of the year's work are: The role of continental carbonate as a major sink of carbondioxide during warmer periods has been identified, which could have lowered the carbondioxide peak of the last inter-glacial (125 kyr).

A one-dimensional parameterised form of a snow balance model has been developed which enables one to understand evolution of ice cover over Tibet, based on the yearly balance of ice accumulation. This model has been used to constrain the possible thickness of the ice cover over Tibet during the last 40 kyr.

An anomalous warming of 0°–45°N at the time of last glacial maximum (LGM), 18 kyr ago has been inferred from a reinterpretation on the published palaeoclimatic data. Based on the observation of an unusual volcanic quiescence during this period, a long lasting relationship between climate and volcanicity has been proposed.

Oxygen and carbon isotope analysis on foraminifera from east Arabian sea core indicate a cooling at 10-11 kyr which can be correlated with Younger Dryas event.

Carbondioxide Problem and Continental Carbonates

The greenhouse gases have created great alarm about the future of this planet.

From the palaeoclimatic data we feel that such a scare is not called for as at c.125 kyr B.P. and also earlier there was a high CO_2 level but it was taken care of by the self-adjusting mechanisms of the planet.

We have now collected data on the removal of CO_2, as immobile $CaCO_3$, in the form of calcite, Kankar, calcrete etc., through a variety of processes including pedogenesis, fluctuations of water table etc. The data suggests that beyond a certain threshold, this sub-tropical sink gets activated and keeps removing the CO_2 from the atmosphere till the earth cools down again. This tropical reservoir of CO_2 has a major role to play in CO_2 budgeting of the globe. We hope to bring out the role of this major reservoir for the first time in triggering self-adjusting mechanisms of our planet.

(D.P. Agrawal)

Constraints on the Thickness of Ice Sheet over Tibet during the Last 40 kyr

The Quaternary glaciation of Tibet has received considerable attention in recent years due to its role in regional climate especially the Asian summer monsoon. Recently, however, it has been argued that the Tibetan ice sheet might have played an important role in initiating global scale climatic changes in the past. A controversy, however, exists about the nature of late Quaternary ice cover over Tibet. We have examined this problem in the light of available high resolution isotopic data from the Dunde ice cores on the northern flank of Tibet and palaeovegetational data from the Indian sub-continent during the last 40,000 years. The isotopic data from Dunde ice cores was interpreted to indicate a temperature lowering of 4°–6°C under a limiting assumption that precipitation change did not influence the ELA position. The temperature lowering was translated to equilibrium line altitude (ELA) depression of 700-850m during the Last Glacial Stage (LGS). This ELA depression could have caused the snow line to be lower than the mean altitude of the Tibetan plateau resulting in an ice sheet over a large area (approximately 2.4 million km^2). We have now developed a simple 1–dimensional parameterised form of a snow balance model that enables us to calculate the ice thickness depending on the yearly balance of ice accumulation alone.

We combined this model with the estimated snow line depression derived from the $\delta\ ^{18}O$ data of the

Dunde ice cap to place constraints on the maximum possible thickness of the ice cover over Tibet during the last 40 kyr. We concluded that ice sheet having thickness in excess of 250m or so could not have existed over the Tibetan plateau during the last 40 kyr period.

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

Anomalous warming of 0°– 45°N latitude during the Last Glacial Maximum

Over the last two decades palaeoclimatic data both from continental as well as oceanic regions have been accumulating which suggests that high altitude regions from tropical/subtropical parts of the earth lying in the latitudinal belt 0°– 45°N may have had an anomalous warming episode around 18 kyr B.P., a period commonly identified as the Last Glacial Maximum.

We have compiled the available evidence with this new perspective. The evidence consists of isotopic records from well dated ocean cores, ice cores from the Dunde ice cap, palaeovegetational data from the Indian sub-continent and Africa, palaeolake level data from Asia, Africa and the American west. We speculate that this anomalous event was caused by a possible relationship between long lasting volcanic quiescence and the northern hemispheric temperature. The existence of such a relationship has been shown by earlier workers, using the northern hemisphere temperature index and the Greenland ice core activity levels (primarily reflecting volcanic activity index). The period of Little Ice Age (A.D. 1350 – 1700) coinciding with increased ice activity and the Medieval warmth of A.D. 1000-1300 correlates with decreased ice activity. We show that the period of anomalous warmth around 18 kyr B.P. correlates with the period of unusual volcanic quiescence in the Bryson's volcanic index series.

(S.K. Gupta and P. Sharma)

Signature of Younger Dryas Cooling in the Arabian Sea Sediments

Younger Dryas event of the earth's history represents a unique episode in the last deglaciation period when there was a temporary halt in the melting of the ice sheets for about 1000 years (from 11 kyr to 10 kyr ago). This event is most clearly reflected in the oxygen isotope record of the deep sea sediments in the form of a temporary excursion in the ^{18}O data towards more positive values. The cause of this event is still not clear and can be better understood by studying the synchroneity and amplitude of its isotopic signature in different ocean basins.

In this context we have measured the oxygen and carbon isotope ratios of four species of planktonic foraminifera (which are known to have different depth habitats) from a sediment core in the eastern Arabian sea. The core SM-3283 was raised from a depth of 2077m at 14°N, 71°E and sampled at 1cm interval upto 50cm. The sedimentation rate (determined by ^{14}C method) is uniform between 18cm to 50cm with a value of 2.3cm/kyr. The $CaCO_3$ content varies from about 64% (Holocene) to 40% (Last Glacial Maximum).

There is a clear signal of Younger Dryas event in terms of 0.75% excursion in the $\delta^{18}O$ values of *G. sacculifer*, the maximum value occurring at 10 kyr. Interestingly the excursion in $\delta^{18}O$ values of *G. Ruber* start earlier by about 500 yrs but the two maxima occur at the same time. These results along with the data on *G. menardii* and *Orbulina universa* have interesting implications regarding the propagation of melt water signal across different depths of the Arabian sea water.

(S.K. Bhattacharya, A. Sarkar, N. Juyal and M.G. Yadava)

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1. Agrawal, D.P., Bhatt, Diva, Malaiya, Sudha and Kharakwal, Jeewan, "Archaeology of Kumaon: Problems and Prospects", Man and Environment, Vol. XVI, 1991, pp.59-61.

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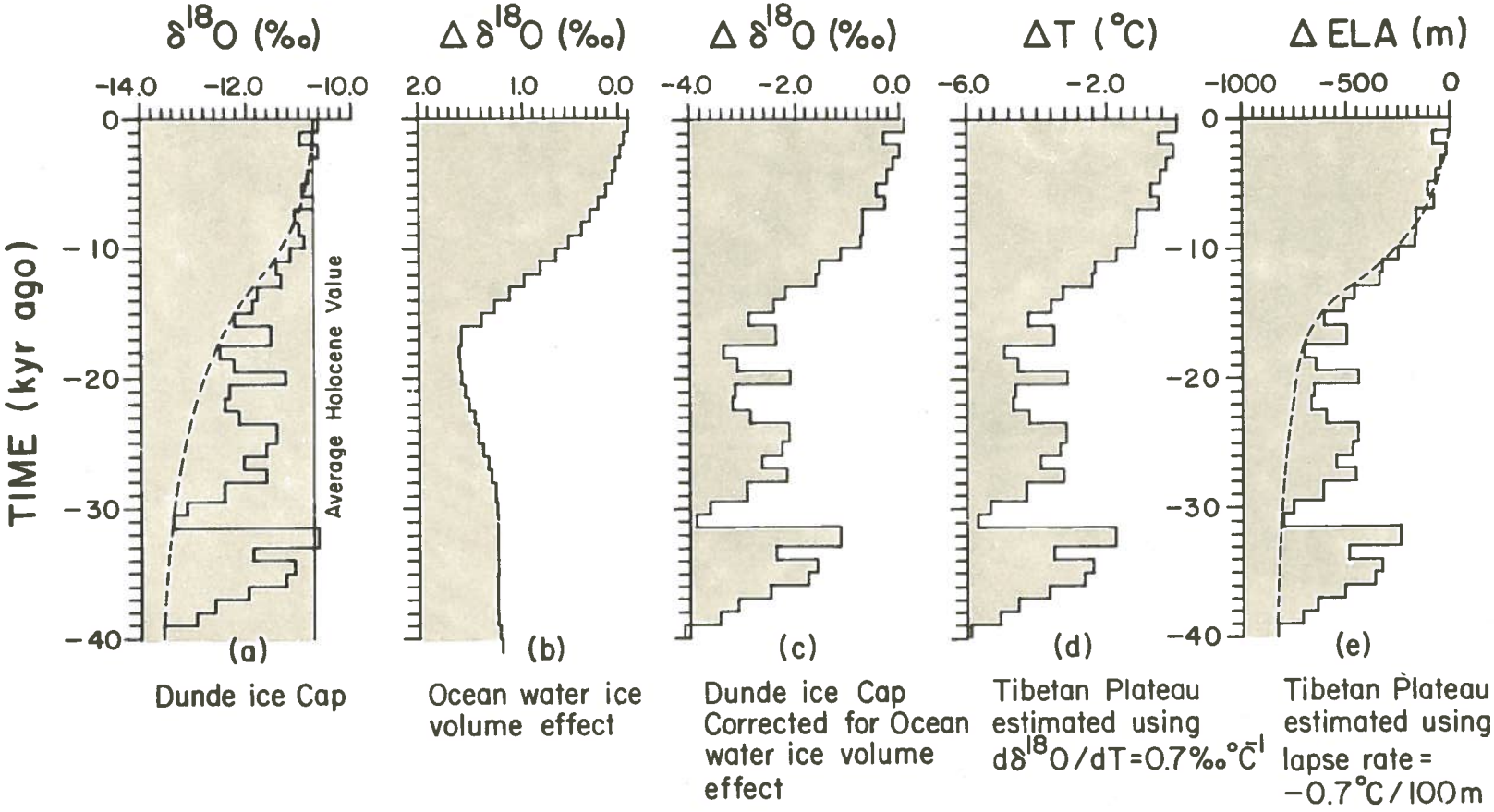
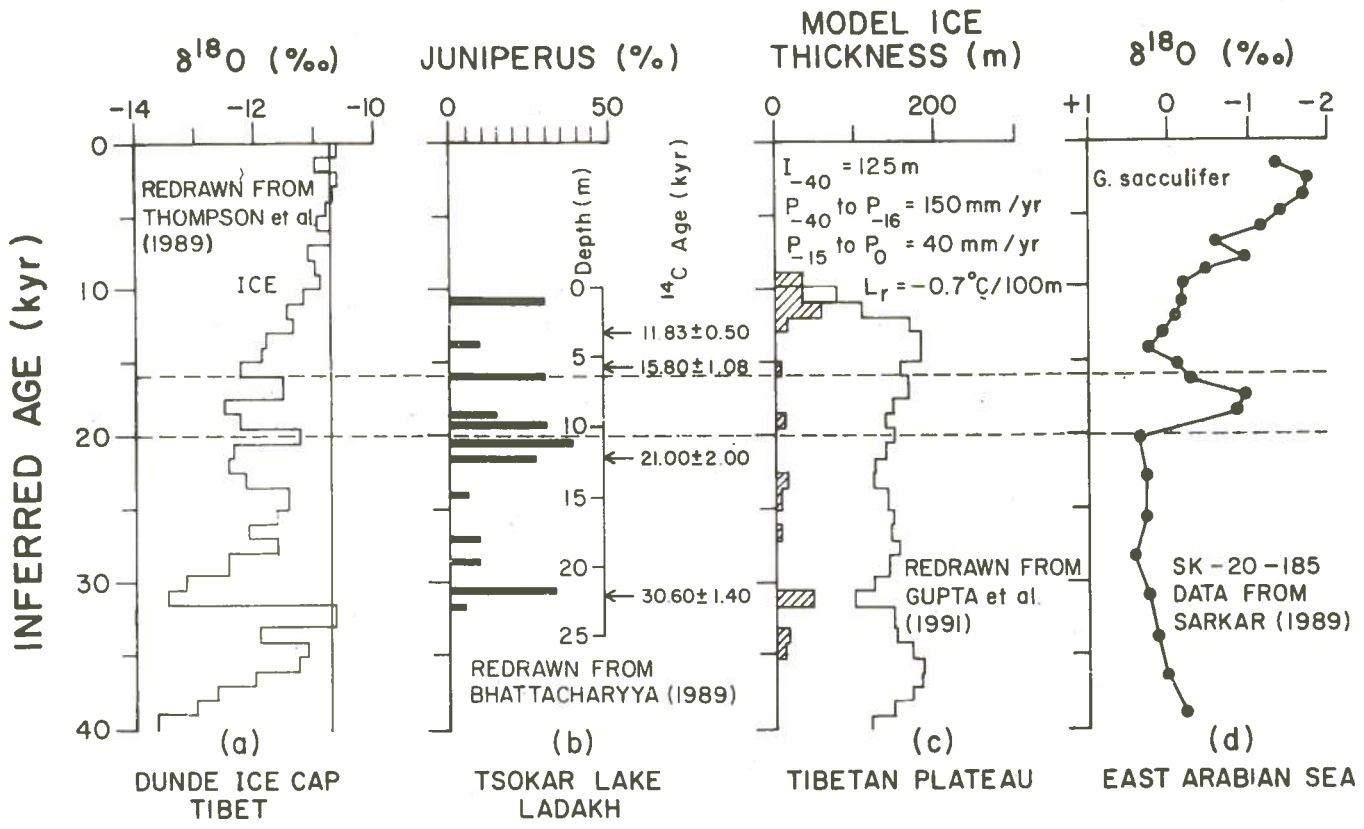
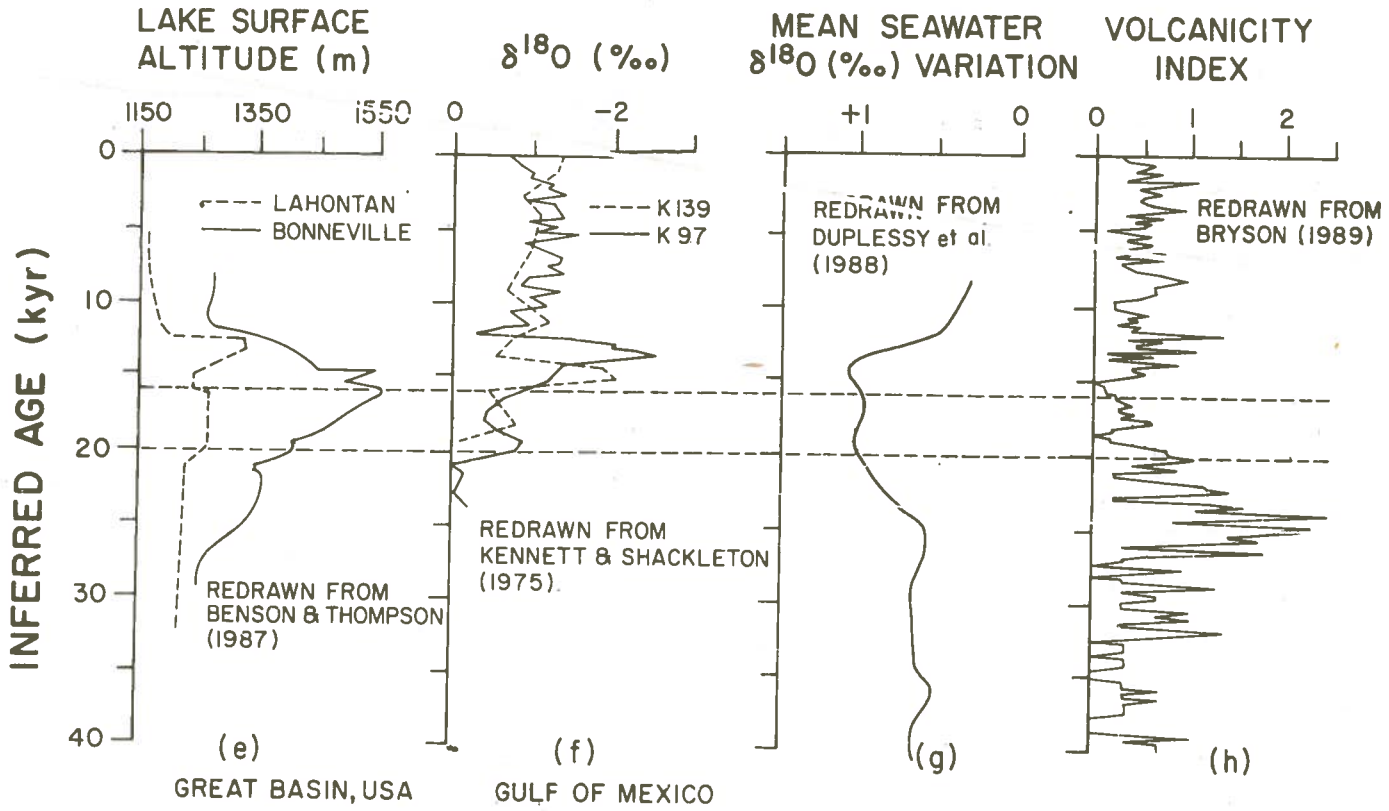


The steps (a-e) involved in the translation of the Dunde ice core $\delta^{18}O$ shifts to the ΔELA. The intermediate steps (b-d) are: (b) estimation of the ocean water ice volume effect;(c) Dunde ice cap $\delta^{18}O$ data corrected for the ocean water ice volume effect; and (d) estimation of the change in mean annual surface air temperature (ΔT) from the ocean water ice volume effect corrected $\delta^{18}O$ shift using the Dansgaard (1964) $\delta^{18}O$-T relationship. The ΔT values are converted to the ΔELA values using the atmospheric lapse rate. The dashed lines in (a) and (e) are for a hypothetical $\delta^{18}O$ profile of the Dunde ice cap obtained by drawing an envelope joining the most negative $\delta^{18}O$ values in (a). All Δ-values refer to the change in the past values of the parameters ($\delta^{18}O$, T and ELA) with respect to their long term present day averages.



a. $\delta^{18}O$ profile of the Dunde ice cap of Tibet ; b. Juniperus abundance profile from the Tsokar lake, Ladakh. Note correspondence between the increased abundance of Juniperus pollen in Ladakh during the 21-18 kyr period and the increase in $\delta^{18}O$ of about 1‰ both indicating warming during the same period ; c. Model computed ice thickness (solid line) and glacial melting (hatched curve) for the Tibetan plateau under assumed values of the various parameters : I_{40}, the thickness of ice sheet on the Tibetan plateau 40 kyr ago P_{-40}, P_{-16}, P_{-15} and P_0, precipitation over the Tibetan plateau at 40 kyr, 16 kyr, 15 kyr and at present respectively ; L_r = atmospheric lapse rate. Note the glacial melting associated with the warming event around 18 kyr; d. $\delta^{18}O$ curve of the foraminifera G. sacculifer from the East Arabian Sea core SK-20-185. The -1‰ excursion during the 19-16 kyr interval indicative of freshwater influx at the core location has been interpreted by Gupta et al (1992) in terms of increased discharge of glacial melt from Tibetan plateau into the Bay of Bengal through the Himalayan river system as indicated in Fig c.



e. Lake surface altitude of Lahontan lake (solid line) and Bonneville lake (dashed line) during the last 30 kyr. Both the lakes show a high level during 20-16 kyr period ; f. $\delta^{18}O$ record of planktonic formanifera G. sacculifer from the sub-tropical Orca basin, Gulf of Mexico of core K-97 and K-139 showing a negative spike of about 0.8‰ amplitude during 20-18 kyr. The spike is indicative of meltwater discharge from the Laurentide ice sheet into the Gulf of Mexico due to warming event around the LGM. g. Mean seawater $\delta^{18}O$ variation obtained by patching together the Norwegian sea benthic $\delta^{18}O$ variation with that of Pacific Ocean core V-19-30. The curve shows an excursion of -0.07‰ around 18 kyr equivalent to a 5-6 m eustatic sea level rise ; h. Volcanicity index chronology for the last 40 kyr. Note the conspicuous minimum in the volcanicity index curve during the 20- 16 kyr period.

The research activities of the theory group can be broadly divided into macroscopic and microscopic physics. The research programmes in Astrophysics, Meteorology and Climate Studies and Plasma Physics belong to macrophysics while those of Atomic and Molecular Physics, Foundation of Classical and Quantum Mechanics, Nuclear Physics and Particle Physics are in the microphysics division. Some of the highlights of the work done during the past year are given in the following :

MACROSCOPIC PHYSICS

Astrophysics

On the astrophysics front, studies are being carried out to understand the role of magnetic fields in the structure formation during the early phase of the Universe on one hand and in the analysis of plasma instabilities arising in magnetised accretion disc around compact gravitating objects on the other. Further the dynamical effects of the reversal of centrifugal forces on collapsing rotating stellar configuration, are being considered in the framework of Kerr- geometry. Some of the significant results in these contexts are; the importance of the role of the toroidal magnetic field in the disc structure (for equilibria with physically meaningful density distribution), and the role of the Kerr-parameter 'a' in the analysis of the ellipticity maximum of slowly rotating Macclaurian Spheroids, caused due to centrifugal reversal.

Meteorology and Climate Studies

Fluctuations of the Walker circulation, one of the major circulations in the tropical atmosphere, have far reaching effects on the global weather and climate as well as on the performance of the Indian summer monsoon. During this year several dynamical studies are conducted by using both 2-level linear model and a 5-level nonlinear model to understand the role of the Indonesian heat source (ascending limb of Walker circulation) and the eastern Pacific cooling (descending limb) on the intensity of the Walker circulation. It is shown that as the distance between heat source and heat sink increases the intensity of the Walker circulation decreases. It is also found that the nonlinear advection terms contribute to the strengthening of the Walker circulation to the west of the heat sink.

Some of the recent model studies made during this year have thrown considerable light on the problem of the northward propagation of the shear zone (a part of 30-50 days oscillations) in the monsoon region. A more accurate expression has been derived for the northward phase speed. In a more realistic study using both symmetric and three dimensional models, northward propagation with a phase speed of half a degree latitude per day has been obtained.

Plasma Physics

Plasma, whether in space or laboratory, is capable of supporting a large number of spontaneous and externally induced waves and instabilities. These are believed to be responsible for many complex phenomena observed in space and astrophysical plasma and therefore it is quite natural that the theory group has been concentrating on the studies of these waves and instabilities. Some of the very important contributions made during this year are given below.

A new mode of plasma instability in a weakly ionized inhomogeneous magnetoplasma has been proposed to understand the nature and cause of the irregularities observed in the lower region of earth's ionosphere. This novel instability which is electromechanical in nature is seeded by the neutrals and is driven by electromechanical coupling through frictional force between plasma and neutral fluids.

Large amplitude Alfven waves have been observed in the interplanetary medium. Earlier it was shown that these nonlinear Alfven waves are governed by the Derivative Nonlinear Schrodinger (DNLS) equation, which in presence of external source, like a plane wave, can under certain conditions lead to chaos in the medium. In the presence of pulse type disturbance e.g. solar bursts, it is shown that the solitary Alfven waves will get accelerated but there is no possibility of chaos in such cases.

MICROSCOPIC PHYSICS

Atomic and Molecular Physics

In Atomic and Molecular Physics, a fundamental problem in the study of charge-exchange processes that are relevant to both laboratory and astrophysical phenomena has been considered during this year. Perturbative approaches based on an expansion of the

transition amplitude in power of weak nuclear charge Z have been frequently employed to study charge transfer in one-electron collision system. A fundamental question is: how rapidly does this Z-expansion converge. It is shown that the Z-expansion converges rather slowly in comparison with certain other expansions which, owing to the inclusion of the Coulomb boundary conditions, are not expansions in powers of Z.

Foundation of Classical and Quantum Mechanics

It is well known that, while the statistical properties of the eigenvalues of a classically chaotic quantum system provide a signature for the underlying chaos, information of the detailed behaviour of the system is contained in its eigenfunctions. We have studied wavefunctions for a two- dimensional system which is classically chaotic. A set of highly localized states, effectively one dimensional, was identified and shown to exist in the chaotic region. Furthermore, it was shown that eigenenergies for localized states are accurately predicted by a WKB-like expression.

Nuclear Physics

The sdg interacting boson model with monopole (s), quadrupole (d) and hexadecupole (g) degrees of freedom which was developed, in considerable detail by carrying out large number of investigations, by PRL scientists is now being applied in describing a variety of observed hexadecupole (E4) data. The observed systematics of hexadecupole deformation parameter (β_4) in rare-earth and actinide nuclei which show sign change with mass number A are reproduced using the coherent state formalism. The hexadecupole transition matrix elements in ^{196}Pt that are measured last year are described by employing a symmetry defined Hamiltonian and E4 operator. Distribution of hexadecupole strength (with energy) in ^{150}Nd is studied using a quadrupole-quadrupole plus hexadecupole- hexadecupole force whose structure is determined by a microscopic (shell model based) procedure. Finally, the systematics of E4 matrix elements connecting ground state to 4^+ state of γ-band in rare-earth nuclei that give information about hexadecupole component in the asymmetry of nuclear shape, is studied using the SU(3) limit of the model. All these analyses of E4 properties, which showed good agreement with data, demonstrate that the sdg model opens up a new possibility of enriching our understanding of hexadecupole degree of freedom in atomic nuclei.

Particles and Fields

The e^+e^- colliding machine LEP (Large Electron Positron collider) at CERN has given important information on the basic structure of electroweak interactions. Due to large statistics, precision tests have become possible. This can be used to discover new physics. One such possibility is CP violation. It is shown that CP violation in the decay of Z boson can be tested with a little improvement in the available statistics at LEP. A new mechanism to theoretically generate CP violation in Z decay was proposed and its consequences were analyzed.

The LEP data can also provide a crucial test of the ideas of the unified theories which unify basic forces namely weak, electromagnetic and strong. It is shown that unified models which allow for light right-handed gauge bosons are not consistent with the available data at LEP.

MACROPHYSICS

Astrophysics

Role of Magnetic Fields in Structure Formation

One of the most hotly discussed problems in Astrophysics today is the formation of structure of the Universe. There have been several studies in this context particularly using the role of dark matter both hot and cold. One of the important features that needs understanding in this context is the role of magnetic fields. In fact the existence of magnetic fields at the galactic scales is itself an enigmatic problem which has drawn attention of physicists for over fifty years. With almost entire matter distribution in the Universe being in plasma state it is interesting to consider the problem of structure formation and the existence of magnetic fields together in a self-consistent scenario. Using the usual m.h.d. approximation we are considering the dynamics of magnetofluid in the background of expanding Universe. As the presence of magnetic field could disturb the isotropy, we are looking for a self-consistent treatment of fluid with anisotropic stresses and magnetic field locally but with a possibility of having global isotropy.

(A.R. Prasanna and Sai Iyer)

Inertial Forces in Kerr Spacetime

Viewing a given spacetime geometry in a 3+1 splitting often yields substance to intuitive approaches for dynamics as in Newtonian formalism. Conformal splitting of the Schwarzschild spacetime resulting in the optical reference geometry has shown the reversal of centrifugal force at r = 3m, the last photon orbit. When a similar splitting is tried for the Kerr geometry which describes a rotating star, the conformal factor changes sign at the ergosurface and thus in the region between the event horizon and ergosurface the discussion of forces would not be the same as outside the ergoregion. As rotation also brings in the Coriolis force which again has both signs only outside the ergoregion, the region within the ergosphere but outside event horizon needs a detailed discussion with respect to both these inertial forces. Studies are being carried out to discuss the correct conformal splitting one needs to do for giving unambiguously the role of forces in the Kerr space time beyond the event horizon. However confining to region beyond the ergosurface and considering the case of slowly rotating McClaurin Spheroid, using the expression for velocity V and angular momentum J as given by Kerr geometry we have evaluated the ellipticity ε with $a \neq 0$ and find that the maximum occurs at a value larger than R = 6m.

(A.R. Prasanna and Sai Iyer)

Quasi-Normal Modes of Black Holes

The late-time behaviour of black hole perturbations is dominated by the quasi-normal modes, which satisfy outgoing wave boundary conditions and are characterized by complex frequencies. Recently, while studying the stability of the Kerr black hole, Whiting introduced a new effective potential to describe the perturbations. The quasi-normal modes corresponding to the models corresponding to the stability of the Kerr black hole, Whiting introduced a new effective potential to describe the perturbations. The quasi-normal modes corresponding to this potential and their relationship to the modes corresponding to the standard (Teukolosky) potential are being studied.

(Sai Iyer)

Radial-Azimuthal Instability at the Inner-Edge of the Accretion Disc

With a view to understand the physical processes leading to time variation of the pulse period of X-ray sources, attention has recently been focussed on the various plasma instabilities that can arise as a result of the interaction between the magnetic field of a neutron star and the matter in an accretion disc. A stability analysis of a resistive plasma configurations around a compact object has been carried out using the eigenvalue techniques. The two-dimensional analyses reveal the existence of Kelvin-Helmholtz (KH), magnetosonic and resistive electromagnetic modes. In the case of magnetosonic waves, both slow and fast modes exist depending on the values of sound speed and Alfven velocity. The dispersive characteristic of both the modes are also found to be different. The fast mode is non-dispersive along the radial direction but dispersive in the azimuthal direction where the slow mode has the opposite nature i.e. they are weakly dispersive in the radial direction but non-dispersive in the azimuthal direction. The other two modes, within local approximation are found to be stable. The novelty of this calculation lies in the fact that the perturbation analysis corresponds to physically more relevant and self- consistent equilibrium solution. Unlike in many other equilibrium solutions which considered a jump condition either in magnetic or velocity fields, we have considered smooth profiles. However, we have used a body mode formalism under local approximation and it is desired to include surface effects through boundary condition which will account for the coupling of the magnetosphere and the disc.

(S.C. Tripathi, C.B. Dwivedi, A.C. Das and A.R. Prasanna)

The Effect of Toroidal Field on the Accretion Disk Dynamics

The structure of the magnetic field, resulting from the distortion of the stellar field by currents flowing through the disc, plays an important role in accretion dynamics. The toroidal magnetic field which is generated due to the plasma motion in the presence of the poloidal magnetic field, is an important agent to exchange the angular momentum between the star and the disc. It is also emphasized that the toroidal magnetic field plays an important role in the generation and collimation of jets in astrophysical objects. In this connection a self-consistent equilibrium structure of the disc including toroidal magnetic field both in definite and infinite conductivity is being carried out. The preliminary results, for a physically meaningful density

and pressure distribution, suggests bounds on the different components of the magnetic field.

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

A Comment on the Energy-Momentum Pseudotensor of Landau and Lifshitz

In previous investigations we learned that the energy-momentum pseudotensors of Einstein, Tolman, Landau and Lifshitz and Moller give sensible results for the energy density in the Kerr-Newman spacetime when calculations are accomplished in the Kerr-Schild Cartesian coordinates. We have now found that the well known pseudotensor of Landau and Lifshitz, having privilege over others of providing angular momentum in asymptotically flat spacetimes, suffers from a relative drawback as it gives a negative energy density in the Schwarzschild spacetime when calculations are carried out in the quasi-Cartesian coordinates but the line-element not being in the Kerr-Schild form.

(K.S. Virbhadra)

Gravitational and Electromagnetic Fields of a Charged Tachyon

We have obtained a static and axially symmetric exact solution of Einstein-Maxwell equations. The solution has been interpreted to give the gravitational and electromagnetic fields of a charged tachyon. Switching off the charge parameter yields the solution for the uncharged tachyon which was earlier obtained by Vaidya.

(K.S. Virbhadra)

Energy and Momentum Ion Vaidya Spacetime

The components of the well known energy-momentum pseudotensors of Einstein, Tolman, Landau and Lifshitz, and Moller are evaluated for the Vaidya radiating spacetime. These pseudotensors are found to be traceless for this spacetime. The pseudotensors of Einstein and Tolman give exactly same result for all their components. Unlike the case of the Kerr-Newman field, the pseudotensor of Moller gives exactly the same energy distribution as given by that of the Einstein, Tolman, or Landau and Lifshitz.

(K.S. Virbhadra)

Meteorology and Climate Studies

Studies of the Dynamics of Walker Circulation

The tropical atmosphere is characterized by deep convective heating over the regions of Indonesia, equatorial South America and equatorial Africa. A substantial cooling in the east equatorial Pacific is also observed. We have studied the influence of the heat source over Indonesia and the heat sink over the equatorial east Pacific in controlling the scale and strength of the time-mean Walker Circulation using a 5-level nonlinear global spectral model and also a simple 2-level linear equatorial β-plane model. It has been shown that the longitudinal extent and the intensity of the Walker Circulation is crucially controlled by the combination of the Indonesian heating and the cooling in the central-eastern Pacific. It is shown that as the distance between the heat source and the sink is increased the intensity of the Walker circulation decreases. When the cooling rate in the equatorial Pacific region is large, it is shown that the circulation becomes stronger. The role of nonlinear advection terms in the time-mean east-west circulation is also investigated. Nonlinear terms affect the Kelvin and Rossby waves near the region of strong heating. It has been shown using the 5-level nonlinear global spectral model, that nonlinear advection terms contribute to the strengthening of the Walker Circulation mainly to the west of the heat sink.

(R. Krishnan, R.N. Keshavamurty and S.V.Kasture)

Diagnostic Studies of the Vorticity Balance in the Tropical Upper Atmosphere of a Nonlinear Global Spectral Model

The time mean vorticity balance in the tropical atmosphere at 300 mb of a nonlinear global spectral model is diagnosed. The model was forced by an idealized heat source and a heat sink representing the observed convective heating over the Indonesian region and the cooling in the eastern Pacific. The model is integrated until a steady state is attained. A vorticity budget study at 300 mb, using the model generated fields has been carried out. Similar studies were also performed by forcing the model with the observed diabatic heating for the summer and winter climatologies.

Earlier there have been a few linear and nonlinear studies of the vorticity balance. The linear calculations consisted of forcing the barotropic vorticity equation linearized about the mean zonal flow, with the observed time-mean divergence. It was found that the model generated flow matched with the observed flow, only when a strong vorticity damping term was included in the equation. This strong damping was associated with cumulus friction. However, nonlinear calculations that did not include any vorticity dissipation still could generate realistic flows. This suggests that nonlinearities play a role that is similar to that of strong damping used in linear models.

It is found from our studies that it is essentially the nonlinear terms that contribute to vorticity balance in the tropical upper atmosphere. More precisely, the dominant vorticity balance in the tropics is between the stretching and vorticity advection by the time-mean horizontal flow. It is also found that transients do not contribute much to the balance.

(R. Krishnan, R.N. Keshavamurty and S.V. Kasture)

Northward Movement of the 30-40 Day Oscillation in an Axisymmetric Global Spectral Model

In the Indian Monsoon region during summer large thermal contrast is set up in the meridional direction which in turn sets up a meridional circulation.

There are studies that relate the low frequency fluctuations of monsoon activity with the well known 30-40 day oscillation. Analysis of MONEX Data reveals a northward propagation of the 30- 40 day mode over India with a meridional speed of roughly 1^0 per day and having a meridional scale of 2000-3000 kms. Similarly studies of satellite observations show that cloud patches propagate northward over the Indian longitudes on the time scale of the intraseasonal oscillation. Kasture and Keshavamurty (1987) did a power spectrum analysis of the zonal wind and found a large power occurred on time scales of 30-50 days. Keshavamurty et. al. (1986) calculated the 'meridional refractive index' of this mode and showed that it propagates in the meridional direction. Keshavamurty et.al. (1988) obtained a rough theoretical estimate of the northward phase speed of this mode to be around a couple of degrees per day.

The motivation behind this work is to model the northward propagation of the 30-40 day mode using axisymmetric version of a 5-level nonlinear global spectral model. To begin with we generate monsoonal type of flows in the model using an appropriate heating distribution. After a steady basic state is attained we switch on an equatorial heat source and integrate the model for a few days. The equatorial heating is then turned off and cumulus heating due to CISK formalism by Charney and Eliassen is introduced. We have examined the evolution of the perturbations superposed on the basic flow.

It is found that the perturbations become unstable and start growing under the influence of CISK. A northward migration of the convective zone is clearly obtained. The convective zone propagates meridionally with a speed of about 0.5^0 per day. This resembles the observed northward propagation of the 30-40 day intraseasonal oscillation in the Indian Monsoon region.

(R. Krishnan, R.N. Keshavamurty and S.V. Kasture)

Northward Propagation of Zonal Wind Shear Zone in the Monsoon Region

By imposing a south to north diabatic heating gradient in a global spectral model, summer monsoon type of basic flow was generated. It had westerlies in the lower troposphere and easterlies in the upper troposphere. The spectral model had rhomboidal truncation at 35 waves and five levels in the vertical. Then a symmetrical equatorial heat source was used to generate Rossby and Kelvin waves. This perturbation was superimposed on the basic flow. By incorporating boundary layer CISK the model was integrated for 30 days. It was found that the equatorial zonal wind system propagates northwards with a speed of about 1^0 latitude per day. It has many features similar to the observed 30-50 day oscillation in the monsoon region.

(S.V. Kasture, R. Krishnan, R.N. Keshavamurty and V. Satyan)

Northward Propagation of the Low Frequency Oscillation - Further Studies

Using zonally symmetric perturbation equations on monsoon zonal flow, we have shown that 30-50 day equatorial mode shows meridional propagation with speeds of a few meters per second. A more accurate analytical expression for the meridional phase speed of this oscillation has also been obtained. Our theoretically computed phase speeds show reasonable agree-

ment with the observed phase speed of this mode. The complete WKB solution as well as the much simpler solution of this mode, both show fast meridional decay with respect to latitude.

(V. Krishnakumar and R.N. Keshavamurty)

Growth of Monsoon Disturbances

Using an appropriate north-south distribution of diabatic heating in a global spectral model we have generated summer monsoon type of basic flow. It has westerlies in the lower troposphere and easterlies in the upper troposphere. Then we superimposed a pulse at the point of inflexion to the north of the jet at 900 mb level. Using Charney & Eliassen type of cumulus heating we integrated the model for five days keeping the basic flow fixed. We found that the pulse grows into observed type of monsoon depression. When cumulus heating was absent the pulse did not show any appreciable growth. The detailed computations of energetics show that the main growth mechanism of the pulse is by baroclinic energy exchange in the presence of cumulus heating.

(S.V. Kasture, R.N. Keshavamurty and V. Satyan)

Nonlinear Studies of the Growth of Monsoon Disturbances

The southwest summer monsoon is characterized by a westerly current in the lower troposphere and strong easterly current in the upper troposphere. We have generated the basic monsoon flow in a nonlinear global spectral model by imposing idealized heating gradients. We then simulated a feeble monsoon vortex around 21^0 N starting from an asymmetric heating distribution (with respect to the equator) and with a specific vertical structure. The simulated cyclonic vortex was superposed on monsoon basic flow and with the resulting total flow the model was integrated for a period of five days, incorporating a simple form of cumulus heating. It was found that the perturbation, in the presence of basic flow grows into depression under the influence of cumulus heating.

(V. Krishnakumar, S.V. Kasture and R.N. Keshavamurty)

Downward Propagation of Upper Tropospheric Modes in the Nonlinear Global Spectral Model - Further Studies

We have generated basic characteristics of the monsoon flows i.e. westerlies in the lower levels and strong easterlies in the upper levels, using an idealized diabatic heating distribution in global spectral model. The steady state response of this heating distribution was obtained. On this basic flow a pulse type perturbation was superposed at 300 mb and at 21^0 N latitude. A disturbance of scale around 6000 km was generated due to the pulse perturbation.

The model was further integrated for four days. It was found that the upper tropospheric disturbance slowly propagates downward upto 900 mb. It is also interesting to note that the amplitude of the perturbation at 900 mb on the fourth day is quite significant. This perturbation may act as a triggering mechanism and it can grow into a monsoonal type of disturbance. The study on conditions favourable/unfavourable for downward propagation is in progress.

(V. Krishnakumar, S.V. Kasture and R.N. Keshavamurty)

Study of Break Monsoon Condition over Western India

In the summer monsoon, there are large scale divergent circulations due to the presence of large scale convective heating over the eastern and adjoining parts of India and a substantial cooling over the regions of north-west India and further west. Observations do indicate that the rainfall distribution over central and western India crucially depends on the east-west shift of this convective zone. During drought years, it has been observed that the convective zone shifts more eastwards than in normal years.

It has been our objective to simulate the large scale features in a typical drought year (1979). A five level nonlinear global spectral model was forced with the observed diabatic heating distribution for summer 1979 based on ECMWF analyses. The steady state response was obtained by integrating the model for 100 days. The simulated large scale circulations over India such as the cross equatorial south westerlies in the lower troposphere and upper tropospheric Tibetan anticyclone indicate a significant eastward shift as compared to the normal monsoon. The computed velocity potential patterns at 300 & 900 mb in the year 1979 show that the region of subsidence lies more eastwards compared to a normal year.

(V. Krishnakumar, R. Krishnan and S.V. Kasture)

Non-linear Evolution of Dissipative Multispecies Magneto Plasmas

In the study of evolution of two-species plasma like hydrogen, we had demonstrated that the dissipation in the system is responsible for producing chaos through two distinct channels (Buti, Solar and Planetary Plasma Physics, 1990). However, very often in solar wind, cometary plasma etc., we encounter plasmas with more than two species. We have derived the governing nonlinear equation for the multispecies dissipative plasma. The numerical computations are in progress.

(B. Buti)

Role of Propagating Solar Disturbances in Interplanetary Plasma

Large amplitude Alfven waves have been observed in the interplanetary medium. Earlier we had shown that these nonlinear Alfven waves are governed by the Derivative Nonlinear Schrodinger (DNLS) equation which in the presence of an external source, like a plane wave, can under certain conditions lead to chaos in the medium. In the presence of a pulse type disturbance e.g., solar burst, we have shown that the solitary Alfven waves will get accelerated but there is no possibility of chaos in such cases. However, in case of propagating solar disturbances like series of pulses or a wave packet, the driven DNLS can not be reduced to ODE and we have to solve nonlinear coupled partial differential equations. This is in progress.

(B. Buti)

Solitary Alfven Waves in Inhomogeneous Multispecies Plasmas

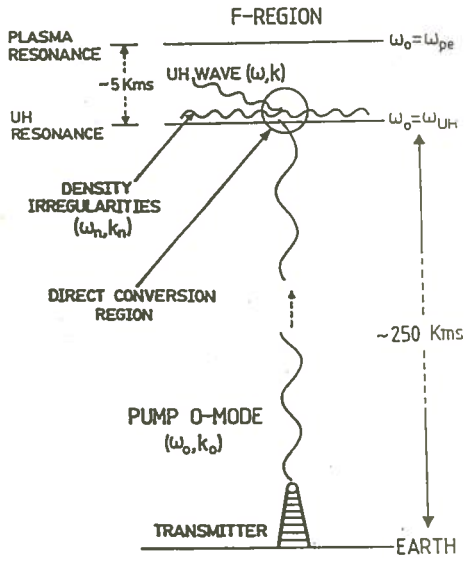
In homogeneous plasma, we had shown (Buti B., JGR, 1992) that the presence of heavy ions, in the multispecies plasmas, leads to reduction of chaos in the system. In an undriven inhomogeneous plasma however, the solitary waves get accelerated (Buti B., GRL, 1991). We are looking into the role of heavy ions on the evolution of nonlinear Alfven waves in an inhomogeneous plasma with an arbitrary inhomogeneity.

(B. Buti)

O-Mode Electromagnetic Wave Conversion into Upper-Hybrid Waves

There are strong reasons to believe that the various features in the "Stimulated Electromagnetic Emission" (SEE) spectra from the ionosphere as observed in the recent experiments at Tromso (Norway) and Arecibo (Puerto Rico) originate due to the wave-wave interactions involving upper-hybrid waves as a dominant component. However, the details of a mechanism responsible for the upper-hybrid wave excitation from the incident pump O-mode electromagnetic wave has not been worked out so far. We have suggested that pre- existing density irregularities in the irradiation region can produce upper-hybrid waves by means of a "direct conversion" process. The process is basically linear in nature (i.e., no feedback involved), has no threshold power requirement, and leads to initial secular growth that is linear in time. It is different from the conventional linear mode conversion process in that it occurs independent of any standard plasma resonances like cyclotron harmonics. For the typical ionospheric parameters, the process is very fast whereas the pump power absorption rate crucially depends on the nature of the density irregularities, being maximum for the coherent fluctuations. This work has been carried out in collaboration with S.N. Antani and D.J. Kaup.

(N.N. Rao)



Schematic diagram showing the details in a typical ionospheric heating situation.

Linear and Nonlinear Waves in Dusty Plasmas

We have started work on waves and instabilities in dusty plasmas, the study of which is fast emerging as a new field of intense activity in space plasma physics. While most of the existing analyses only consider various aspects of individual dust particles (like, their creation, shape and size, charging processes, impact parameters, etc.), there are indications that waves and instabilities arising due to the collective dynamics of the dust particles may be responsible for the phenomena such as radial transport and radial structure in the dusty plasma systems like planetary rings (i.e. Saturn's). We have suggested a dusty plasma model which is suitable for describing low frequency waves. Our model predicts the existence of a new type of acoustic waves which we have called "dust acoustic" waves. The waves are driven by electron thermal pressure whereas the inertia is provided by the dust particles. Both linear and nonlinear aspects of the new waves have been investigated. We show that unlike the usual ion acoustic waves in a two component electron ion (dust free) plasma, nonlinear dust-acoustic waves can propagate as solitons of either positive or negative electrostatic potential, corresponding to a hump or a depletion in the electron density, respectively. As discussed recently by Lonngren, these waves seem to play an important role in dusty-plasma expansion into vacuum regions. Further work is in progress.This work has been carried out in collaboration with P.K. Shukla and M.Y. Yu.

(N.N. Rao)

Low Frequency Drift-like Fluctuation in a Weakly Ionised Magnetoplasmas.

This is a continuation of our earlier work on the instability of electrostatic waves in a non- uniform weakly ionized magneto-plasma where it was shown that the growth of the instability depends on the vaiue of η_e (L_T /L_N), the ratio of temperature scale length to density scale length and the measure of collisions between plasma and neutrals. In the present study, the instability is examined in the limit of strong parallel diffusion of electrons. It is seen that a drift-like instability can be excited. Its growth rates are shown to depend on the ratio between ion-neutral collision frequency and ion-cyclotron frequency. This produces temperature fluctuation in addition to density and potential fluctuations and has relevance to low-temperature laboratory plasma experiment in which there exists a large fraction of neutrals. Temperature fluctuations are its distinguished features and therefore the theory can be verified by the measurements of temperature fluctuation. This work is done in collaboration with P.K. Shukla.

(C.B. Dwivedi and A.C. Das)

Neutral Induced Low-Frequency Instability in a Weakly Ionised Inhomogeneous Magnetoplasma

A new physical mechanism is proposed to understand the nature and cause of the irregularities observed in the lower region (D-Region?) of earth's ionosphere. Based on three fluids model, a self consistent linear local analysis has been made in a partially ionised inhomogeneous magnetoplasma. It is found that a new instability exists. This instability, electromechanical in nature, is seeded by the neutrals and is driven by electro-mechanical coupling through strong frictional force between plasma and neutral fluids. The onset of this instability requires a finite neutral diffusion flow. For typical values of D-region ionospheric plasma parameters, the range of scale length is found to lie between a few tens of meter to about a kilometer. The time scale of the instability is found to be of the order of one hour.

(C.B. Dwivedi and A.C.Das)

Particle Acceleration by Kinetic Alfven Waves in the Io Plasma Torus

The generation of surface waves due to strong gradient in density and its coupling to kinetic Alfven waves near the Io plasma torus are found to be a viable mechanism for particle acceleration leading to a beam of energetic electrons along the magnetic field. It is shown that the acceleration to a few KeV is possible and this might explain the intense auroral hiss observed near the inner edge of plasma torus by Voyager 1. This work has been done in collaboration with W.-H.Ip.

(A.C. Das)

MICROPHYSICS

Atomic and Molecular Physics

Excited State to Excited State Transition of Hydrogen- like Ions by Impact of Charged Particles

Cross sections for excited-state to excited-state transition of hydrogen like ions induced by the impact of charged particles are needed in astrophysical applications. These cross sections are very difficult to determine experimentally. Therefore, we have started a study of collisions involving hydrogen-like ions in their excited states. We have derived a one- dimensional integral representation of the coulomb- modified Glauber amplitude for nlm - n'l'm' transition. An attractive feature of the integral representation is that it incorporates all detailed structures of the initial and final state wavefunctions via the form factor. A computer code has also been developed. Numeral calculations of cross sections for some collision systems, important in astrophysics are in progress.

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

Charge Transfer

The discovery of singularities in the standard T-matrix elements for charge transfer in 1985 led to the realisation of importance of a proper treatment of the long-range of the coulomb interactions to obtain a divergence-free perturbation models. This stimulated the development of the boundary corrected formulation which preserves the coulomb boundary conditions. In a recent development, a perturbation scheme, called the z-expansion method, based on a modified transition matrix elements obtained by cancelling the singularities of the standard T-matrix elements, is proposed. In the z-expansion method, the modified T-matrix element is expanded in powers of smaller one of the target and projectile nuclear charges. We have critically examined the basic features of the z- expansion method and have shown that its various order perturbative models can be derived by introducing further approximation in the corresponding models of the boundary corrected perturbation formulations. This work is done in collaboration with J. Eichler of Hahn-Meitner-Institute, Berlin, Germany.

(D.P. Dewangan)

Classical and Quantum Mechanics

Investigations in Canonical Perturbation Theory

Given a Hamiltonian $H = H_0 + \varepsilon H_1$, where ε is a parameter, canonical perturbation theory attempts to determine a canonical transformation as a power series in e, which will transform H to H_0 . It is well known that such series do not exist globally over phase space but can exist and be well defined locally (on the KAM tori). Last year, we had analysed the causes for such singular behaviour and had shown that the singularities could be removed by considering time dependent canonical perturbation theory. We are analysing the modified perturbation theory in greater detail, especially in systems with 1 degree of freedom. Our studies show the relevance of the modifications that we have suggested in canonical perturbation theory. In particular, we have shown that for a large number of 1 degree of freedom systems, the canonical transformations derived from our theory agree with those obtained from independent (non-perturbative) methods. Further investigations in this direction are in progress.

(B. R. Sitaram and M. Mehta)

No-Go theorems and Classification theory of Hamiltonian Systems

Two Hamiltonians H_1 and H_2 are said to be equivalent if there exists a canonical transformation which takes H_1 to H_2. In general, the problem of deciding whether two Hamiltonians are equivalent requires the solution of a non-linear partial differential equation for the generator of the transformation. We have shown that it is possible to convert the problem into a geometric one using the notion of dynamical forms: Given a Hamiltonian H, the usual symplectic 2 form induces a 2 form and a 1 form on the constant H surfaces. This pair of forms is called the dynamical forms associated with H. Two Hamiltonians H_1 and H_2 are equivalent if and only if the corresponding constant H-surfaces are diffeomorphic and if the diffeomorphism preserves the dynamical forms. In particular, the topology of the constant H-surfaces enables us to prove "no-go theorems"; for example, such a theorem can be used to show that certain canonical perturbation theories necessarily have zero radius of convergence, as in the Hamiltonian $H = p^2/2 + f*q^4/4 + e*q^2/2$, with e or f as the perturbation parameter.

(B. R. Sitaram)

Localized Wavefunctions in Chaotic Quantum Systems

In several physical problems (from diverse fields) wavefunction localization is known to be significant. For example, the observed spectrum of an atom in an external magnetic field, as a function of the external field strength, displays rich structure and exhibits certain features which are indicative of wave function localization in configuration space. Such features are also present in the eigenvalue spectrum of a bounded Hamiltonian system consisting of two coupled quartic oscillators which we have been investigating. Wave function localization is also known to play a key role in the physics of disordered media in condensed matter physics. The nature of individual eigenfunctions of chaotic quantum is still, to our knowledge, largely unexplored. It has, however, been observed that many of the quantum eigenfunctions appear to localize around the classical periodic orbits of the system. We have visually identified eigenfunctions which are localized by plotting the density, $P_n(x,y) = |\psi_n(x,y)|^2$, where the integer, n, numbers the eigenstate sequentially from the ground state. These special states were used to obtain a semiclassical expression for the energy of all such localized states. Since these states are essentially one dimensional, a WKB type expression of the form,

$$E(\Gamma, \alpha; N) = a_0(\Gamma, \alpha) + a_1(\Gamma, \alpha)(N + 1/2)^{4/3}$$

is employed. The label Γ refers to the symmetry type and for the A_1 symmetry N is an even integer and α is a system parameter. The coefficients a_0 and a_1 are obtained by a least squares fit to a few of the lower eigenenergies of the localized states. This expression accurately predicts eigenvalues for the highly excited localized states. Furthermore, the coefficients a_0 and a_1 are slowly varying functions of α and thus energies for other α values can be calculated. The role of the localized states in the spectrum is being investigated. Some of this work is being done in collaboration with S. Sinha.

(V.B. Sheorey)

Nature of the Quantum Density Surface in the Chaotic Region

We have obtained eigenfunctions for a two dimensional quantum system which known to be classical chaotic. The quantum density defined by $P_n(x,y) = |\psi_n(x,y)|^2$, has been plotted using a very fast visualization scheme. These plots show that while the density is usually a smooth function for the lower quantum states it describes a crinkled surface for eigenfunctions in the chaotic region. A criteria for chaotic states based on the nature of this surface is being developed. The changes in the nature of the surface for small changes in a system parameter are also being investigated.

(V.B. Sheorey)

Information Theory and Chaotic Quantum States

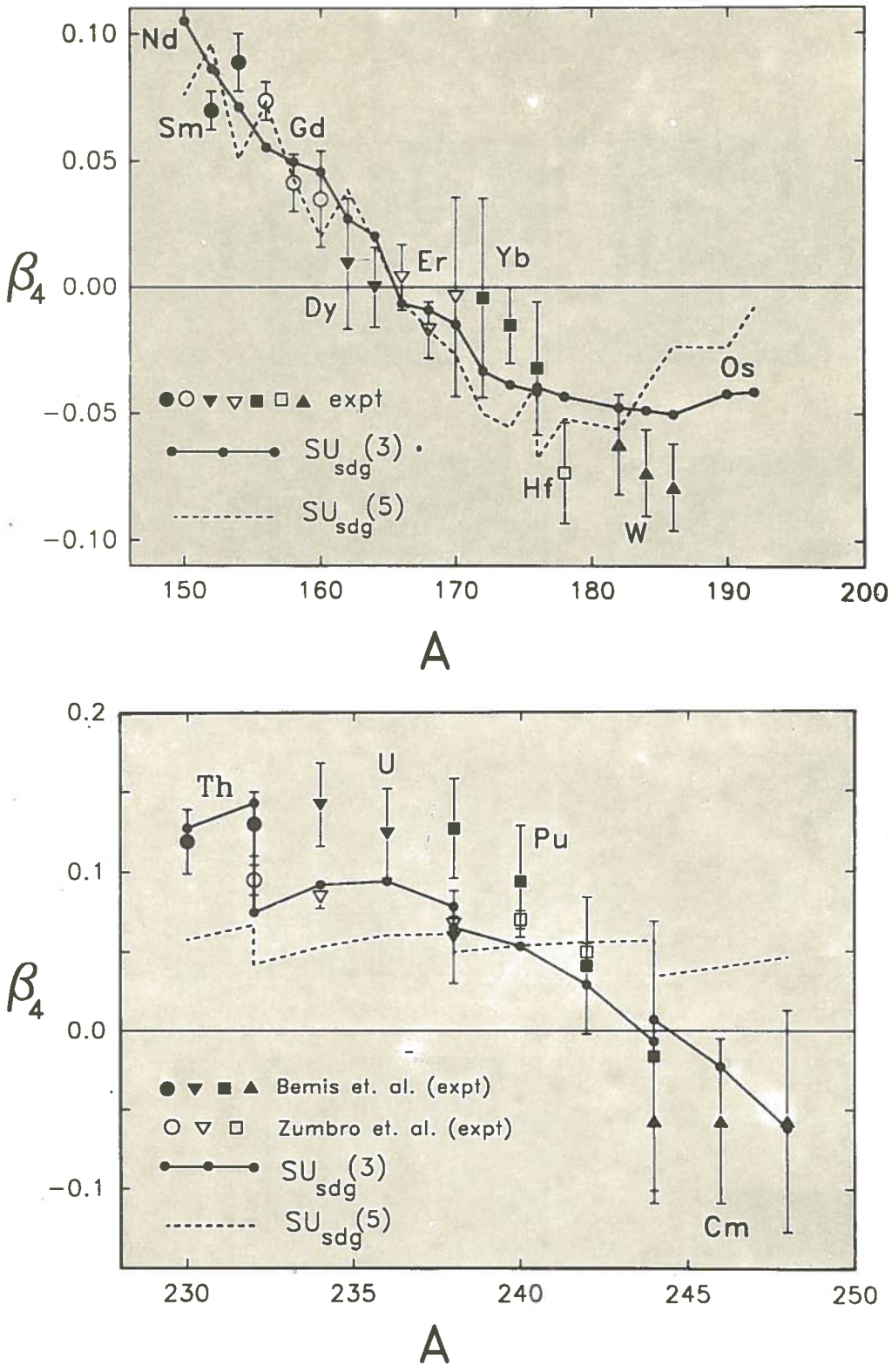
We have obtained configuration space eigenfunctions for a two dimensional quantum system consisting of two coupled quartic oscillators. This system is known to be classically chaotic. The Fourier transform of this eigenfunction defines a function in the conjugate space, i.e., the momentum space. These wave functions in the canonically conjugate variables are used to define corresponding information entropies. The sum of the entropies calculated in the conjugate spaces can be written as an uncertainty relation. The nature of these entropies is being investigated with a view to study the imprint of classical chaotic dynamics in them.

(V.B. Sheorey)

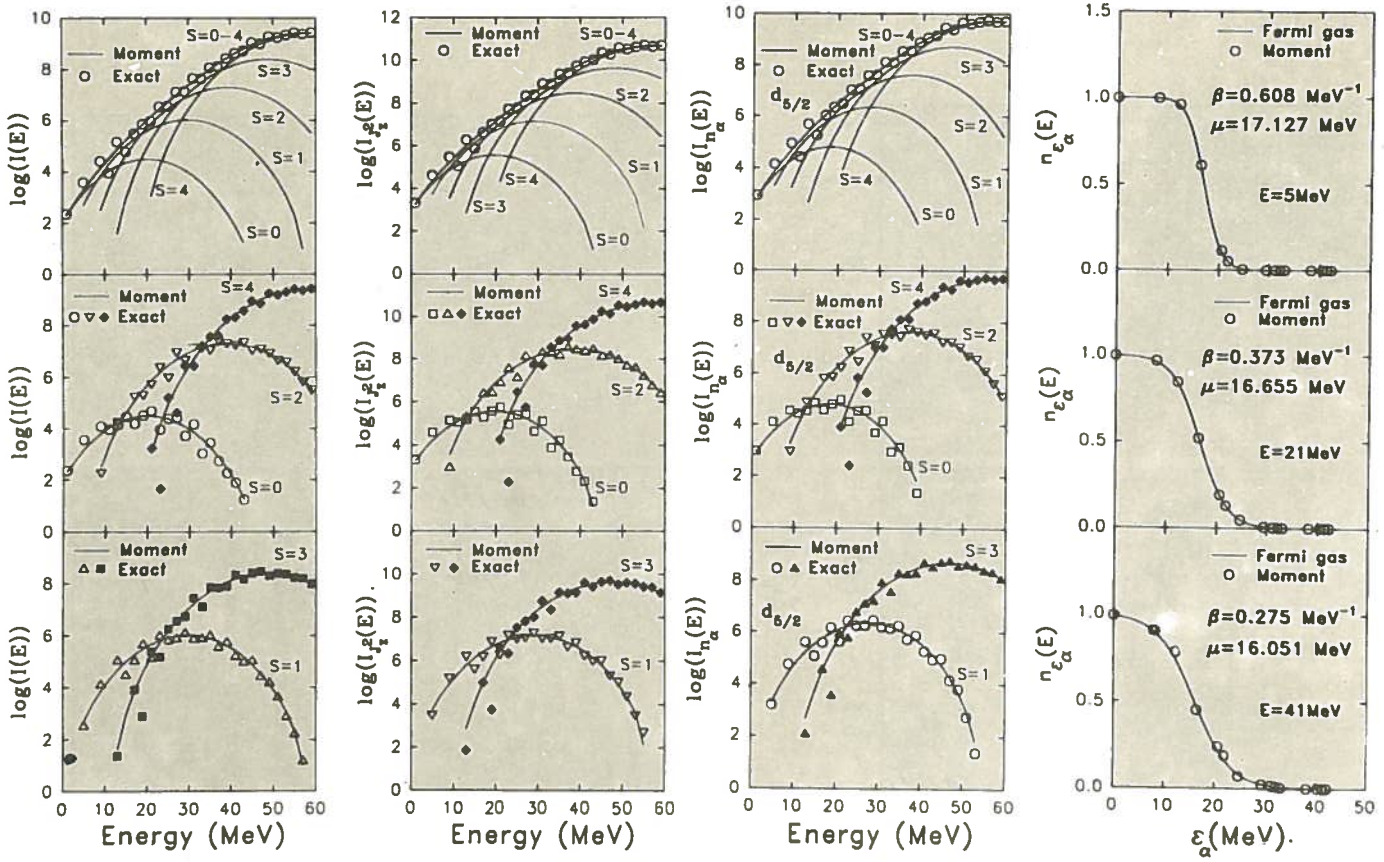
A Boundary-value Paradigm for Classical Mechanics

Classical Mechanics is well known to be essentially an initial value problem. The solution of the problem of classical mechanics consists in determining the trajectory of a system whereby the initial conditions are advanced by means of the equations of motion which are second order in time for the position coordinate and thereby require initial conditions on position and velocity.

Some recent experimental results obtained by us (Varma, R. K., Phys. Rev., 1985 and Varma R. K., Proc. Intl. Conf. Plasma Phys., 1991) motivated by the predictions of a theory point to a rather astonishing feature that the relative positions of the boundaries appear to play a role in determining the properties of motion as revealed in the experiment. This appears to point to the existence of a boundary value paradigm in classical mechanics very much like in quantum mechanics and in classical wave motion, and manifesting a wave- like nonlocality.



Comparison of sdgIBM predictions with experimental data for hexadecupole deformation β_4 vs. mass number A for (a) rare-earth nuclei, (b) actinide nuclei.



Comparison of exact counting results with moment theory for state densities I(E), spin cut-off densities $I_{J_z^2}(E)$ *and occupancy densities* $I_{n_\alpha}(E)$*. Occupancy densities are shown for* $1d_{5/2}$ *orbit and similar results are obtained for other orbits. Last column shows comparison of fractional occupancies (for protons)* $n_{\varepsilon_\alpha}(E)$ *calculated using moment theory with Fermi-Dirac form for E = 5, 21 and 41 MeV. The deduced thermodynamics temperature (*β*) and chemical potential (*μ*) are given in the figure.*

While the standard equation of motion paradigm offers no possibility of viewing classical mechanics as a boundary value problem, the Hamilton-Jacobi formalism does offer such a possibility. The momentum in this formalism can be viewed as a vector-field which is derivable as the gradient of a scalar field S, the Hamilton principal function. The subject under discussion is being explored using these ideas and some new and interesting insights are gained.

(R. K. Varma)

Nuclear Physics

sdgIBM description of E4 matrix elements in γ-unstable nuclei in Os-Pt region

Last year we reported sdgIBM calculations for Samarium isotopes that exhibit spherical-deformed phase transition and there the boson shell model code we developed as well as our knowledge on sdgIBM dynamical symmetrics are put to use. Using the same, this year studies are carried out for γ- unstable Pt-Os isotopes ^{192}Os, ^{194,196,198}Pt. These are of specific interest as hexadecupole (E4) transition matrix elements in these nuclei have become available recently (for ^{192}Os the matrix elements corresponding to the decay of the first three 4^+ levels to ground state are measured in 1985, for ^{194,198}Pt the matrix elements corresponding to the decay of the first three 4^+ levels to ground state are measured in 1990 and for ^{196}Pt the matrix elements corresponding to the decay of the first four 4^+ levels are measured in 1991). A hamiltonian and E2 and E4 transition operators interpolating sdgIBM dynamical symmetries and a truncated space which includes upto two g-bosons (the zero and one g-boson calculations reported in literature fail to describe E4 data) are used to obtain a consistent description of spectra, E2 matrix elements and the above mentioned E4 data. Thus demonstrating that sdgIBM is well suited for describing E4 properties of γ-unstable nuclei.

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

M1-Distributions for p-n sdgIBM for odd-A Nuclei

Recently considerable attention (both theoretical and experimental) is being paid to the question of fragmentation of M1 strength in even-even nuclei. It is demonstrated that in order to address this problem in the framework of IBM, one has to include 'g' bosons. Although there is no data so far, a priori, one knows that there will be more fragmentation of M1 strength in odd-mass nuclei. Therefore we studied the distribution of magnetic dipole strength in even-odd nuclei in N = 82-126 shell employing the SU(3) ⊗ U(2) limit (U(2) generates pseudo-spin) of proton-neutron sdg interacting boson fermion model. The group theory corresponding to the above symmetry limit is worked out in detail. Using this, compact expression for M1 matrix elements are derived and the corresponding strength distribution is constructed for ^{187}Os which is a good pseudo-spin nucleus. It is essential that these predictions be confronted with data; this clearly calls for new experiments.

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

E4 Strength Distribution in ^{150}Nd: A Microscopic sdgIBM Description

In order to explore, apply and establish sdgIBM we employed in our previous studies, hamiltonian and transition operators based on symmetry considerations. To understand E4 properties in more detail an attempt is made to construct operators based on microscopic (shell model) consideration. To this end we developed a simple procedure where it is assumed that single boson energies derived from identical particle (proton-proton or neutron-neutron) interactions and the two-body matrix elements of the boson-boson interaction derived from proton- neutron interaction. In the first study reported here the interaction is assumed to be of quadrupole-quadrupole and hexadecupole-hexadecupole ($K_2Q^2 .Q^2 + K_4Q^4 .Q^4$) form using single - j shell OAI (Otsuka, Arima and Iachello) mapped effective charges of quadrupole (Q^2_p, Q^2_n) and hexadecupole (Q^4_p, Q^4_n) operators in proton (p) and neutron (n) spaces separately and then carrying out pnIBM to IBM projection of $[K_2 Q^2_p . Q^2_n + K_4 Q^4_p . Q^4_n]$ operator, boson-boson interaction is constructed. The same $Q^2_{p(n)}$ and $Q^4_{p(n)}$ operators are used together with pnIBM to IBM projection to obtain the IBM E2 and E4 transition operators. Using the above hamiltonian and transition operators observed spectrum and E2 matrix elements for ^{150}Nd are well reproduced. The wave functions are then used

to construct E4 distribution and it is in reasonably good agreement with the observed strength distribution.

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

β_4 Systematics in Rare-Earth and Actinide Nuclei: sdgIBM Description

The observed variation of hexadecupole deformation parameter β_4 with mass number A in rare - earth and actinide nuclei is studied in the sdg interacting boson model using the $SU_{sdg}(3)$ and $SU_{sdg}(5)$ coherent states and a mapped hexadecupole transition operator as described in ^{150}Nd example, (i.e) using a single-j shell OAI mapping and pnIBM to IBM projection. The data is well described and in particular the change in sign of β_4 with mass number A, both in rare - earths and actinides, is well reproduced by the $SU_{sdg}(3)$ limit as can be seen from the figures.

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

Test of Moment Methods for Spin Cut-off and Occupancy Densities for Non-interacting Particle Systems

Spin cut-off factors $\left[\sigma_J^2(E) = < J_z^2 >^E\right]$ and occupation numbers $\left[< n_\alpha >^E\right]$, α, denotes a spherical orbit, are important physical quantities in statistical nuclear physics as the former decomposes state densities (I(E)) into observable level densities and the latter determines much of the thermodynamic behaviour of the nucleus. The moment methods developed by French and collaborators, which involve convolution function of various kinds, for calculating spin cut-off and occupancy densities (they are spin cut-off factor and occupancy weighted state densities) for non-interacting particle system in large spaces are tested in the example of twelve protons and twelve neutrons in sixteen spherical orbits ($1s_{1/2}$, $1p_{3/2}$, $1p_{1/2}$, $1d_{5/2}$, $2s_{1/2}$, $1d_{3/2}$, $1f_{7/2}$, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$, $1g_{9/2}$, $2d_{5/2}$, $1g_{7/2}$, $3s_{1/2}$, $2d_{3/2}$, $1h_{11/2}$) each, including upto $5\hbar\omega = 4\hbar\omega$ excitations. The results are shown in the figures and the exact densities obtained by direct counting (i.e. distributing particles in all possible ways in the given set of orbits subjected to Pauli restrictions). The densities as well as their S-decompositions are in good agreement with exact results. The agreements shown in the figures for the S-decompositions of the densities will allow one to apply, with confidence, the extended moment theory with interactions. Moreover the spin cut-off factors and spherical orbit occupation numbers, which follow by dividing corresponding densities by the state density, are also well described by moment theory. Comparisons with Fermi gas forms

$$I(E) \propto \exp 2\sqrt{a(E-\Delta)},\quad \sigma_J^2(E) \alpha \sqrt{a(E-\Delta)},$$

$$n_{\varepsilon_\alpha}(E) = \left(2j_\alpha + 1\right)^{-1} < n_\alpha >^E = \left[1 + exp\left[\beta(E)\left\{\varepsilon_\alpha - \mu(E)\right\}\right]\right]^{-1}$$

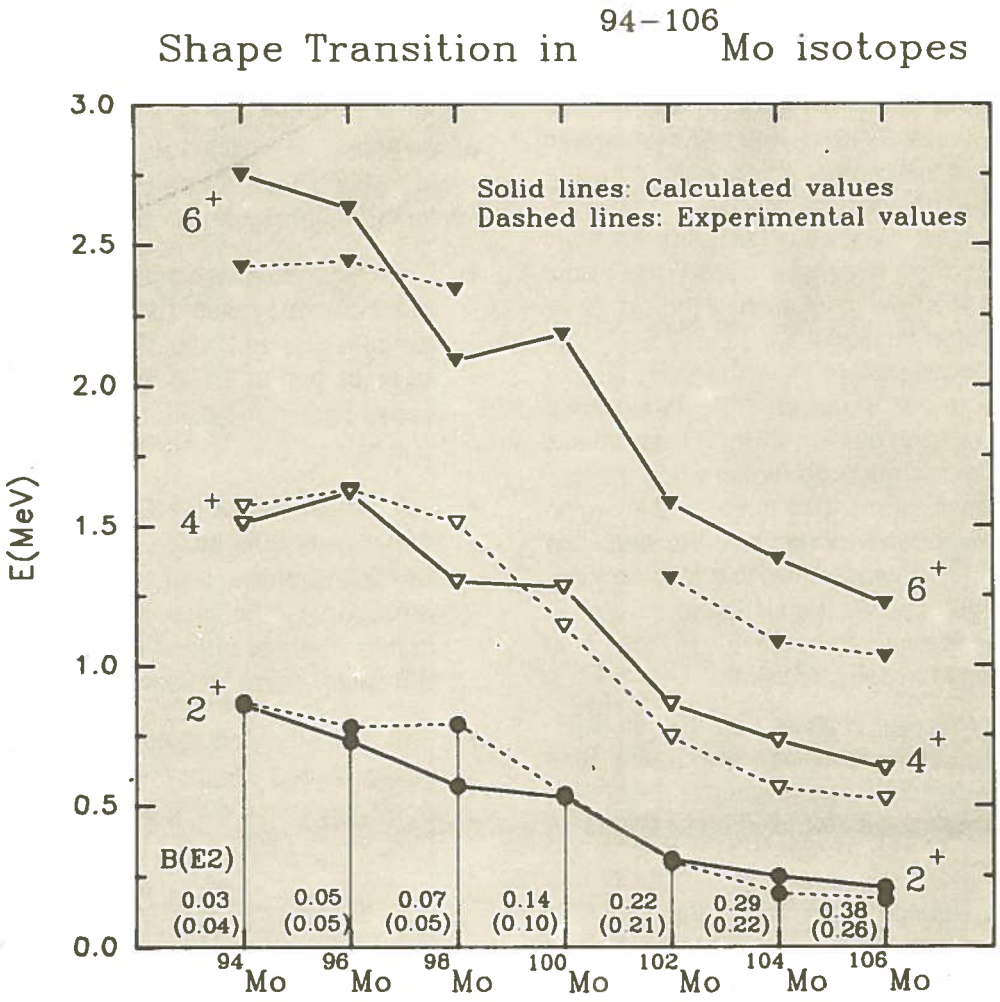
are made and thermodynamic temperatures (β) and chemical potentials (μ) are deduced at different excitation energies from the calculated occupation numbers. The results presented in the figures represent the first complete set of calculations demonstrating the application of moment methods for state, spin cut-off and occupancy densities for noninteracting particle systems.

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

Shape Transition of Even-Even $^{94-106}$Mo and $^{146-154}$Sm Isotopes in Dynamic Microscopic IBM

A new scheme developed earlier to derive the IBM–2 Hamiltonian in dynamic microscopic basis has been applied to carry out spectroscopy of even-even Mo and Sm isotopes. The observed transitions from spherical (vibrational) to deformed (rotational) shapes in these isotopes have been reproduced and studied.

Following this scheme, first the correlated identical nucleon pair states S_ρ, D_ρ and G_ρ (ρ = ν or π for neutrons and protons respectively) for each nucleus are constructed from the corresponding lowest energy, axially symmetric, good parity and prolate deformed Hartree-Fock (HF) solutions. The identical nucleon pair energies ε^{ρ}_{j} and the interaction matrix elements between neutron and proton pairs $V_{\nu\pi}$ are derived using standard shell model techniques. These matrix elements, through Marumori mapping of one- and "two-body" correlated pair states to the corresponding boson states, define the IBM-2 Hamiltonian. This Hamiltonian is dynamic (varying from nucleus to nucleus) and microscopic (being derived from nucleonic degrees of freedom). The approximation involved here is that the twobody interaction $V_{\rho\rho}$ between identical bosons is ignored.



The calculated and experimental excitation energies of the J = 2,4,6 Yrast levels are plotted for $^{94\text{-}106}$Mo isotopes. The calculated and experimental (in parentheses) (B(E2); $2^+ \rightarrow 0^+$) values are given alongside the vertical lines indicating the quadrupole transition $2^+ \rightarrow 0^+$. The spectra and the sudden enhancement of B(E2) for $^{100\text{-}102}$Mo indicate the shape transition.

The matrix elements of IBM-1, used in the SDGIBM1 boson shell model package developed by Y.D. Devi and V.K.B. Kota, are then determined from the IBM-2 matrix elements by a projection technique based on the F-spin symmetry amongst the ν and Π bosons.

The IBM-1 Hamiltonian for each of the even-even $^{94\text{-}106}$Mo and $^{146\text{-}156}$Sm isotopes is then uniquely defined. Using these IBM-1 Hamiltonians together with the SDGIBM1 boson shell model package we obtain the energy spectra of the various isotopes. The spectra exhibit the observed shape transition. In the adjoining figure, the calculated (solid lines) and the experimental (dashed lines) J =2,4,6 Yrast levels of the Mo isotopes are plotted with respect to the respective ground (J = 0) states. The energy ratios between $2^+ \rightarrow 4^+$ and $4^+ \rightarrow 6^+$ levels are close to unity for $^{94\text{-}98}$Mo isotopes which is characteristic of vibrational nuclei while those for the heavier ones ($^{104\text{-}106}$Mo) are proportional to J(J+1), characteristic of rotational nuclei. The transition from vibrational to rotational type occurs at A = 100 –102. The calculated E2 transition probabilities from the 2^+ to the ground state (B(E2;$2^+ \rightarrow 0^+$)) of the SU(3) $T^{(E2)}$ transition operator are also noted alongwith the corresponding experimental values in parentheses. The enhancement of these values at A = 100–102 also indicates the transition. Similar results are obtained for the Sm isotopes as also previously shown by Y.D. Devi and V.K.B. Kota.

(Subrata Sarangi and Jitendra C. Parikh)

Microscopic Study of Nuclear Spectroscopy at High Spins in A = 80 and Rare-Earth Region

Using axially deformed Hartree-Fock and Angular momentum projection techniques we have investigated the effects of rotation alignment on the band structure and signature dependence in ^{79}Rb, ^{73}Se, ^{147}La, ^{149}Pr, ^{151}Pm and ^{183}Ir nuclei. Experimentally known band structures in ^{151}Pm are fairly well reproduced in our calculation. In addition we have studied the signature effects in $h_{11/2}$ proton rotational bands in ^{147}La, ^{149}Pr and ^{151}Pm. We find signature inversion in B(E2; I $\rightarrow$ I-1) values in the K=3/2$^-$ band of ^{149}Pr, When three protons in the $h_{11/2}$ orbit rotation-align. Similar effects are also realised in the mass 80 region when the $g_{9/2}$ occupation increases from one to three. In this region studies are presently concentrated on ^{79}Rb and ^{73}Se nuclei. Studies on ^{183}Ir isotope show that rotation alignment of $h_{9/2}$ protons causes the signature splitting in the K=1/2$^-$ band. The unfavoured $\alpha = -1/2$ branch in this band is predicted in our calculation.

It is apparent from our analysis that rotation alignment of nucleons in high j like ($h_{9/2}$) orbits rather than gamma deformation (sometimes invoked in the empirical models) is responsible for signature effects in nuclei.

(A.K. Rath, C.R. Praharaj, S.B. Khadkikar and S.P. Pandya)

Particles and Fields

Study of Nucleon-Nucleon Scattering Angular Distribution with Confinement Model for QCD

We have investigated the effect of exchange of confined gluons among relativistically confined quarks in N-N scattering calculations. The existing phenomenological models have incorporated the confinement of quarks, but the effect of confinement of gluons has not been taken into account. In our previous study we obtained good agreement with the phase shift for the $^1S_0$ and $^1P_1$ state with the phase shifts of Arndt et al., (the phase shifts of Arndt et al., are extracted from the differential cross section [$\sigma(\theta)$] by the single energy analysis). Encouraged with this success we investigated the phase shifts of higher partial waves and the n-p and p-p [$\sigma(\theta)$]. There is no agreement with the phase shift of Arndt et al., for the $^3P_0$, $^3P_2$ $^1D_2$,$^3D_1$, $^3D_2$ and $^3D_3$ states. It is to be noted that the experimental phase shifts for higher angular momentum (L) partial waves ($L \geq 5$) are extracted from $\sigma(\theta)$, with the assumption that the contribution for all the partial waves comes from one pion exchange potential. Hence our phase shifts cannot be compared with the phase shifts of Arndt. But the calculated p-p and n-p $\sigma(\theta)$ using our phase shifts are qualitatively in agreement with $\sigma(\theta)$ of Arndt. While calculating p-p $\sigma(\theta)$ we have not taken coulomb scattering into account. The main results are:

- The colour-magnetic part of the COGEP gives substantial intermediate-range attraction and short-range repulsion in the $^1S_0$ and $^3S_1$ channels. The term in the COGEP which gives intermediate-range attraction arises out of the confinement of gluons.
- The tensor part of the COGEP has the right sign but is weak. The phase shift of the $^3S_1$ state falls below the phase shift of Arndt. The bulk of the attraction of the tensor force for the $^3S_1$ state comes from the term in the COGEP arising out of the confinement of gluons.
- The spin-orbit part of the COGEP has the correct signature and correct order of magnitude and is in good agreement with the phenomenological potentials.
- We have obtained good agreement with the experimental p-p and n-p $\sigma(\theta)$ without meson exchanges but using confined gluon exchange between relativistically confined quarks, even though phase shifts for higher L partial waves do not agree with Arndt.

(S.B. Khadkikar and K.B. Vijayakumar)

Baryon Meson Spectroscopy in COGEP

We are investigating the effect of confined gluons in baryon meson spectroscopy calculation. For the confinement of quarks we have made use of the relativistic harmonic oscillator Lorentz scalar + vector confinement model (RHM) which has been quite successful in obtaining the ground state properties of the low lying hadrons. For the confinement of gluons, we have made use of the current confinement model (CCM) developed in the spirit of the RHM. The confined gluon propagators (CGP) are derived in CCM. Making use of the CGP we have obtained confined-one-gluon-exchange potential (COGEP) between the quarks. In COGEP the central, tensor and spin-orbit

potentials in the limit $c \rightarrow 0$ (in CCM c fm^{-1} gives the range of gluons) goes over to the usual non relativistic quark model potentials (NRQM)). Making use of the tensor and spin-orbit part of the COGEP we plan to investigate the excited states of baryons and mesons. Since it is well known that the spin-orbit terms arising from the OGEP in NRQM is too strong and destroys the reasonably good correspondence between the observed and the calculated spectra we hope to overcome these shortcomings using COGEP.

(S.B. Khadkikar, K.B. Vijayakumar and A.K. Rath)

Magnetic Moments of Baryons and the Proton Structure Function

The recent result on the integrated spin dependent structure function for the proton has rekindled interest in the hadronic matrix elements of the neutral currents. Various explanations for the European Muon Collaboration (EMC) data have been put forward, including, amongst others, large gluonic contributions to the proton spin. A recent analysis of the magnetic moments of the baryons claims that between 60% and 80% of the spin is carried by the quarks. We show that the magnetic moments of the baryons are independent of the EMC measurement. The magnetic moments of the quarks can only be fixed if the precision of the EMC measurement can be improved by orders of magnitude. This work was done in collaboration with D. Choudhury and P.J. O'Donnell.

(U. Sarkar)

Study of Symmetric Quark Mixing Matrix

All the presently available data are consistent with the symmetric ansatz for the quark mixing matrix and this ansatz has been studied widely in recent times. We studied (with D. Choudhury, M.K. Samal and R.B. Mann) the phenomenological constraints due to CP violation in the K - $\overline{K}$ system and the extent of B - $\overline{B}$ mixing on the quark mixing matrix. We point out that this ansatz requires a very heavy top quark. A parameterization of the mixing matrix, which was proposed by us, is the most general parameterization for the symmetric ansatz. We (with M.K. Samal) then aim to find constraints on the quark mass matrices for the symmetric ansatz. We work in a few interesting bases and try to get the corresponding mass matrices from some symmetry requirement. We then give the symmetry constraint for the mixing matrix in terms of the mass eigenvalues in a basis-independent form.

(U. Sarkar)

Proton Decay and Low Energy Grand Unification

Recently a new paradigm has started in grand unified theories following an observation that an SU(15) GUT can be broken at very low energy, still satisfying proton decay constraints. We analyzed (with B. Brahmachary, R. B. Mann and T. Steele) proton decay and the choice of Higgs fields in GUTs, where baryon number is a gauge symmetry (including SU(15)). Although Higgs effect forbid low energy unification as claimed by others, there exists symmetry breaking patterns which allow low energy unification as well as chiral colour symmetry, quark-lepton ununified symmetry and baryon number symmetry breaking at the TeV scale, without any observable proton decay.

(U. Sarkar)

Physics of the 17 KeV Neutrino

Recent signatures of a 17 keV neutrino, which was first observed in 1985, have made the neutrino physics more complex. We (with M.K. Samal) studied the limits on the elements of the neutrino mixing matrix consistent with neutrinoless double beta decay and the neutrino oscillation experiments with only three neutrino species. Stringent limit on $m_{(nu)}$ is obtained. Allowed values of the various mixing angles are obtained. We (with D. Choudhury) also tried to accommodate the new find in a extension of the standard model by proposing a new mechanism to generate the 17 keV scale radiatively. The left- handed neutrinos combine with the only sterile neutrino of the model to form a 17 keV neutrino, which decays very fast into the lighter neutrinos and a singlet-doublet Majoron. The model is consistent with all the laboratory, astrophysical and cosmological constraints known so far.

(U. Sarkar)

Three Dirac Neutrinos

Many experiments have confirmed the existence of a 17 keV neutrino emitted in the beta decay. The question is not settled yet but it has been realized that it is not very easy to accommodate the 17 keV neutrino in

theoretical schemes. A model was proposed in which right-handed neutrinos are added to the standard model and a global unbroken $L_e + L_\tau - L_\mu$ symmetry is imposed. This generates three Dirac neutrinos, one of which can be identified with the reported 17 keV neutrino.

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

Leptonic CP-Violating Asymmetry in Electron-Positron Annihilation due to Z Width Effects

CP violation has so far not been seen outside the neutral K meson system, and hence our theoretical understanding of CP violation is far from complete. Search is on for an experimental observation of CP violation in other situations, including electron-positron annihilation at LEP energies. A scenario lying outside the standard SU(2) x U(1) theory has been studied here which predicts large CP- violating asymmetry in leptonic final states. The absorptive part for the CP-violating amplitude, essential for a non-zero rate asymmetry, is provided by the imaginary part of the Z propagator in the resonance region. After rejecting several popular extensions of the standard model, it is found that a model based on SU(2) x U(1) x U(1), where the extra U(1) symmetry is a gauged horizontal symmetry, corresponding to the difference between electron and tau lepton numbers, can give large CP violation, provided exotic charged leptons exist. This effect, if present, would be easily observable in future experiments.

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

Two Majoron Decay of Heavy Neutrinos

Heavy neutrinos are not favoured on cosmological ground if there is no mechanism for depleting their number density in the early universe. Models have been proposed in which heavy neutrino decays to a lighter neutrino and a massless boson called Majoron. But this decay rate is not fast in the simplest of these models. We have shown that in some models, the decay into the Majoron can be substantial and can even be faster than the decay to a single Majoron. Such models can therefore provide a viable description of heavy neutrinos.

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

Minimal Seesaw Model and Fast Neutrino Decay

The most attractive mechanism for generating neutrino masses is the so-called seesaw mechanism which invokes very heavy right-handed neutrinos. This can generate moderately heavy (keV to MeV) left-handed neutrinos. It was believed that minimal model of this type is unable to accommodate a heavy left-handed neutrino which decays fast on cosmological scale. We have shown this not to be the case. An explicit model is presented which can offer a consistent description of the 17 keV neutrino.

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

Antineutrinos from the Sun

The neutrino oscillations inside the sun or in the region between the sun and the earth can solve the solar neutrino problem. This problem can also be solved if one postulates a neutrino which decays on its ways to the Earth. In most models, the decay product is a right handed neutrino which cannot be detected. We have worked out a scenario where the decay product contains antineutrinos. The expected number of antineutrinos generated this way in the future detectors has been worked out in detail.

(A. Acker, A.S. Joshipura and S. Pakvasa)

Filamentation Instability and Nuclear Stopping in Heavy-Ion Collisions

One of the most interesting problems in the relativistic heavy- ion collision (RHIC) experiments is that of nuclear stopping. Various numerical models for RHIC have predicted that for collisions of very heavy nuclei like Pb-Pb (~ 200 GeVA) the nuclear stopping is higher than that in other lighter nuclear collisions at the same energy. These studies have also shown that the collective effects can play an important role in the collisions of such heavy nuclei. However, the collision models which have been used so far are extremely detailed and complicated and include all kinds of nuclear reactions. To get a better insight into the physical phenomena, it seems important to look for a simple mechanism which can explain this particular observed feature of RHIC. In the present work we consider one such mechanism - namely filamentation instability (below) which may influence the nuclear stopping.

Filamentation is the instability which leads to stratification of initially homogeneous and oppositely directed plasma fluxes which are interacting via mean vector field (gluon fields for QGP). Such a qualitative picture of filamentation is relevant for RHIC conditions as due to expected transparency in RHIC, the nuclear collisions can be regarded as two color fluxes counter streaming through each other. Under these conditions the instabilities related with plasma streaming might be important. However, it can be shown that only filamentation mode is the most important for RHIC conditions. Using SU(2) color hydrodynamic frame work to describe quark fluxes we have shown that the analysis of non-linear state generated by the filamentation is important. Numerical solutions of the special cases of the non-linear state have been investigated. Our study reveals that considerable fraction of the mean directed kinetic energy of the initial color fluxes have degraded ($\approx$ 60 - 80% into random motion and oscillating mean field energy. The auto-correlations of velocity profile suggest that the stream velocity becomes chaotic and the mean value is never restored to the original value of the directed velocity. Thus the generation of turbulent mean fields and velocity fields contribute to an enhanced level of nuclear stopping. This work is done in collaboration with Jitesh Bhatt and Predhiman Kaw from IPR.

(Jitendra Parikh)

Hydrodynamics of Classical Gluonic Plasma

In relativistic Heavy-Ion-Collision the plasma produced will pass through a pre-equilibrium phase. Since the number of degrees of freedom for gluons are more they will equilibrate faster than the quarks. To describe the pre-equilibrium evolution of gluons in the quark-gluon plasma one may start with the Gauge Covariant Kinetic equation of Elze-Gyulassy and Vasak, where one determines the evolution of a Gauge-Covariant distribution function, which is a 3 x 3 matrix in colour space with local SU(2) group symmetry. Taking the moment of the momentum equations, neglecting spin effects and terms of the order of one arrives at the hydrodynamic description of the gluonic plasma. This description may be justified when the gluons can be treated as a cold fluid (i.e if $V_{th} < V_{ph}$, the phase velocity of the considered wave) and the number density of particles inside the Debye sphere is much greater than one.

Physically this description involves collective phenomena in a gluon plasma in which the collective long wave length low frequency oscillations are described by the field equations and the short wavelength high frequency oscillations are described by the hydrodynamic equation.

With this picture in mind we have done a linearised calculation in (1+1) dimension. The result of our calculation shows that the background density of gluons which generates a self consistent background field can contribute to the plasma oscillations in the medium. If one assumes the background number density to be diagonal in colour space one can show that the system executes a simple harmonic oscillation.

On the other hand retaining the off-diagonal terms in the number density it turns out that the signature of instability or damping depends on the parameters e.g. equilibrium number density etc. It is worth mentioning that earlier workers using the so-called Abelian dominance approximation have always found the system to execute simple harmonic oscillations only. Because of non-abelian dynamics the off diagonal terms in the number density operator start mixing with each other which in turn is responsible for damping or instability. This work was done with P.K. Kaw.

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

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11. Sarkar, U. and Samal, M.K., "Symmetric CKM matrix and quark mass matrices", Phys. Rev. **D 45**, 2421 (1992)
12. Sarkar, U., Choudhury, D. and O'Donnell, P.J., "Magnetic moments and the structure function of the proton", Zeit. Phys. **C 54,** 307 (1992)
13. Sarkar, U., Brahmachari, B., Mann, R.B. and Steele, T., "Higs effect in SU(15) GUT", Phys. Rev. **D 45**, 2467 (1992)
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15. Bannur, V.M., Kaw, P.K. and Parikh, J.C., "Shear instability and entropy generation in heavy-ion collisions", Phys. Rev. **C 44**, 859 (1991).
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Computer Centre

The Computer Centre operates in two shifts including Saturdays and Sundays and has the versatile DEC-1091 Computer System with a storage capacity of 512K words of 36 bits word length. 700 nano second is the access time. It also has 2k words of cache memory with an access time of 133 nano seconds.

The auxiliary data storage and retrieval capacity is 200 mega words and is distributed equally over five disk drives. Also four, high speed dual density magnetic tape drive units of nine tracks are attached to the system.

At present, 48 terminals including four with graphic display out of which two with hard copy facility, two line printers of LP20 type with 132 print positions, one RICHO RP3400 daisy wheel printer and one card reader are attached to the system.

The time sharing and higher user friendly TOPS-10 operating system supports the full configuration.

The Centre is also euipped with two work stations DN-3500 which has MC 68030, 32 bit VLST processor with 12 MB RAM and Weitek FPA and NEXUS-3000 which has MC 68020, 32 bit VLSI Processor. DN-3500 has 348 MB Winchester disk drive and one 60 MB cartridge tape drive. The system is attached with colour display monitor with key board and mouse, an eight pen dual port plotter and a NEC P5- X2 printer. The operating system under which it runs is UNIX. NEXUS-3000 also has MC 68881 Co-processor. Both work at 25 mhz clock rate. It has 4 MB Random Access Memory (RAM). It has an auxiliary storage of 155 MB winchester disk drive and one 1.2 MB floppy drive. The system is attached with colour monitor with key board and mouse. Both systems are connected with TOKEN ring network.

The Centre also possesses a PC/AT (BUSYBEE of HCL) consisting of 2 MB RAM, 40 MB winchester disk, 1.2 MB floppy and CGA monitor.

The main activities of the centre include research in computer related areas of Numerical Methods, Statistics, Operations Research, Neural Networks, Modelling & Simulation and Library Science and the relevant software development for general use. It also includes teaching to Visiting Members of PRL and Space Science students besides helping the users in designing and developing new computer software systems. The staff also support by way of consultation to many internal as well as external projects of academic institutes and government bodies. They also help in installing and implementing software systems for different areas and sections of PRL. Besides, the members of the centre support various academic activities like teaching, syllabus framing, staff selection and computer system selection of the universities and other educational institutes and government bodies. The faculty guide the students from academic institutes in their desertation work.

The Centre also organises courses in computer related topics to educate the users community.

The Centre develops and maintains a good library of various software packages and subroutines for general use to help PRL scientists and other scientists from various parts of the country. The Centre possesses MATHEMATICA packages and is available on the work-station DN 3500. The Centre also possesses IMSL.

The Centre is in the process of acquiring a large number crunching system for various scientific applications of the Laboratory.

Teaching and Educational Activities

A FORTRAN77 course has been organized in the Summer for the benefit of general student community.

Computer Centre recruited 2 fresh post graduates to be trained in Computer Programming and 4 fresh graduates to be trained in Computer Operation.

Research Development and Consultation

Some of the research and development activities during the year are :

- Neural network models for classification
- Modification of Back propagation algorithm for unsupervised learning
- Evolutive Neural Networks for Discrimination and classification
- Software for non-linear estimation by MarQuardt's Method

- Package for Univariate Stochastic Model Identification
- Development of a package for Univariate Stochastic Model Prelimaniry estimation
- Software for Univariate Stochastic Model Estimation
- Development of Software for Univariate Stochastic Model Forecasting
- Development of a perceptron-based pocket algorithm to obtain an optimum solution of non-separable problems
- Development of 'Unlearning algorithm' to make Hopfield nework well- behaved optimally
- Development of Hopfield network using the delta learning algorithm
- Development of number of useful programs using Mathematica

List of papers published in 1991-92

1. C.S.R. Murty "Evolutive Artificial Neural Networks for Discrimination and Classification", Indian Computing Series; Information Technology. The Tool for Productivity. Proc. ICC 1991. Tata Mcgraw Hill Publishing Co., New Delhi, pp.337-344, 1991.

Electronics Laboratory

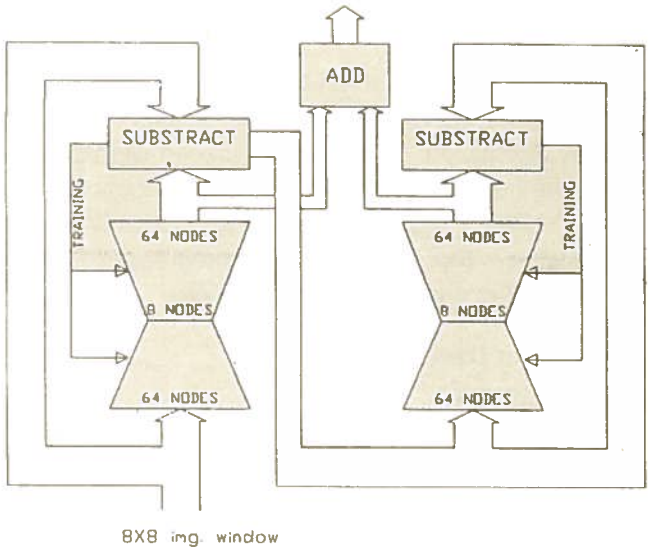
The research activities of the Electronics Laboratory are computer based instrumentation, artificial intelligence, computer hardware and computational techniques. The Appropriate Automation Promotion Program of DOE being carried out at Electronics Laboratory was transferred to ATIRA. The know how of computer aided textile design and fabrication generated under this program has been transferred to industry and a training centre based on this know how has been set up at Panipat (Haryana) by the National Handloom Development Corporation. The following were the major developments during the year :

Artificial Neural Network

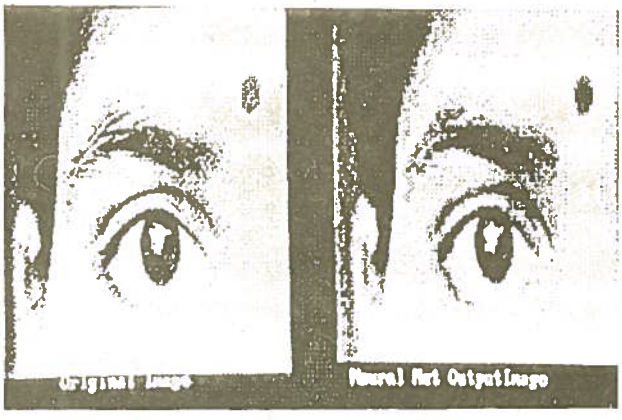
Various topologies of neural networks have been studied and applied for image and speech processing.

Image Processing

A multi layered network with its training algorithm has been designed to obtain image data compression and feature extraction (see figure). Two multi layered networks were used for the purpose. The output errors of the first network were applied to the second network and the sum of the outputs of both the networks are used as final output. This experiment showed that the 64 gray pixels could be represented by 16 binary hid-



Neural network configuration for image band compression. Compressed data is taken from 8+8 hidden nodes.



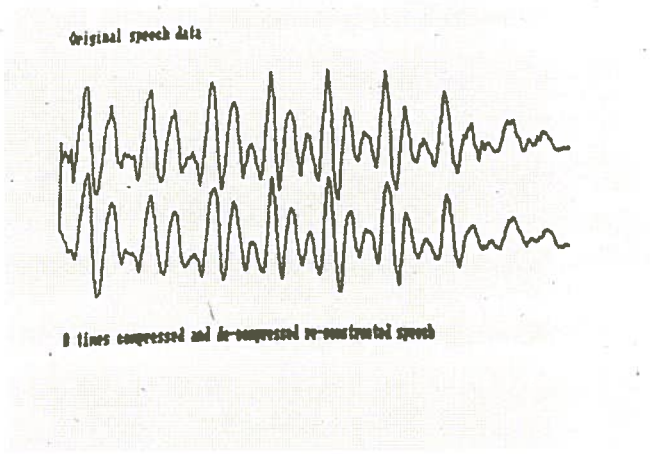
Reconstructed band compressed data is plotted in the right. The original picture of 256 x 256 x 8 is in the left.

den unit. From the data of these 16 units picture could be reconstructed using the weight achieved in the experiment output. A reconstructed image is shown.

Speech Processing

Multi layered Neural network has been used to achieve the task of speech (word) recognition. A DSP based hardware is used to obtain the spectrograms of speech data and train the network to recognize the words. The trained network is used with the test data. Good success rates have been obtained for small vocabularies (< 10 words). The work on Phoneme separation is in progress.

An algorithm based on NN has been developed to find Adaption coefficients in Adaptive Differential Pulse Code Modulation (ADPCM) of speech signal which reduces the storage requirements of speech signal in digital form. Also the hardware is developed to regenerate the speech. Decompressed speed alongwith the original speech is shown.



Waveform at the top is the actual digitized speech. The bottom waveform is decompressed output of ADPCM designed using Neural network.

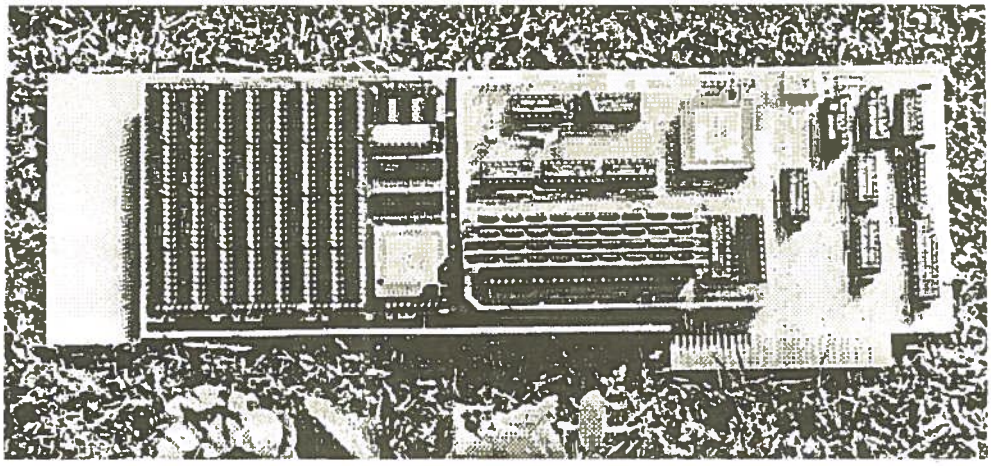
Transputer Development

The transputer (T800) based addon board has been developed for IBM PC compatible machine. Also the Transputer and RAM Module TRAM (T800 and 4 MB memory) with its mother board has been developed. More than one TRAM can be used on the Mother board for parallel processing. Parallel C, Pascal and FORTRAN compilers are made compatible with this hardware. The Graphics support is added to the INMOS compilers to increase graphics speed.

Multi Mirror Telescope (Modular)

A Multi Mirror Telescope with a modular construction is being designed. In the proposed design the aperture of the main reflector will be realized by a cluster of small mirrors with individual drives that will move all the reflectors in unison to track a stellar object. Two alternate schemes are being studied - a moving focus telescope and a fixed focus telescope.

Optical ray tracing algorithm has been developed for both the schemes for estimating their angular



T-800 Transputer mother board with 16 mb TRAM board (at right) developed at PRL works in parallel - processing mode.

resolution which will be mainly limited (to few arc minutes) by geometrical abberation rather than the diffraction limited resolution of the conventional large size single apertures being tried on very complex mounts and drives in Europe and USA.

Techniques Area

During the year a new project of making an Ion Cyclotron Resonance Type Fourier Transform Mass Spectrometer (ICR-FTMS) had been taken up. An ultra high vaccum (UHV) system for ICR-FTMS is under fabrications. A number of components of the same including various SS flanges, the main plumbing, a glass-to-metal UHV seal and supporting frame have been fabricated in our workshop. The system has been assembled and presently being leak tested. We have done several (approximately 100) routine and special type of coatings jobs for PRL projects and other institutes.

Library

The Library which was formerly housed on the first and second floors, has now acquired the ground floor of the building. Work on modification of the ground floor was completed in October 1991. Since then it is being used as the main reading hall.

The entire Library Collection which consists of 37,000 books and bound journals was reorganised. Since the Astronomy area has been shifted to the Thaltej Centre, books and bound journals on Astronomy have been shifted to Thaltej.

Collection

The PRL library subscribes to 241 scientific and technical journals besides receiving a large number of scientific reports, data etc. Nine important journals are subscribed by air-mail. During the year 273 books were added.

Services

Over 1,65,000 photocopies were made according to requests received from PRL personnel. Xerox copies of articles from our collection were also supplied to other libraries.

Requests were received for obtaining 550 publications on Inter- library loan. Most of these publications were obtained on loan for our readers. About 160 publications were given on loan by the PRL library to other libraries.

During the year 7500 books and journals were issued from the library.

The following Bibliographies were compiled according to requests received by the library :

1. Volcanic effects on climate change 1987-91

2. Refractory inclusions in chondrites 1981-91

Library Network

As publications on Science & Technology in Ahmedabad are available in the Space Applications Centre and Institute for Plasma Research Libraries, a local Library Network of PRL-SAC-IPR Libraries has been proposed. This network will enable effective Resource Sharing of the book collection which is in machine readable form in all these libraries and will also enable resource sharing of the journals subscribed by PRL, SAC and IPR Libraries.

Research Alert Service

The Current Awareness Service which was started last year from the Current Contents database is now being given to sixty scientists in PRL and also to a few scientists in IPR and SAC. A survey of this service was undertaken recently and it showed that the readers were solely dependant on this service for keeping abreast of the latest developments in their subject areas.

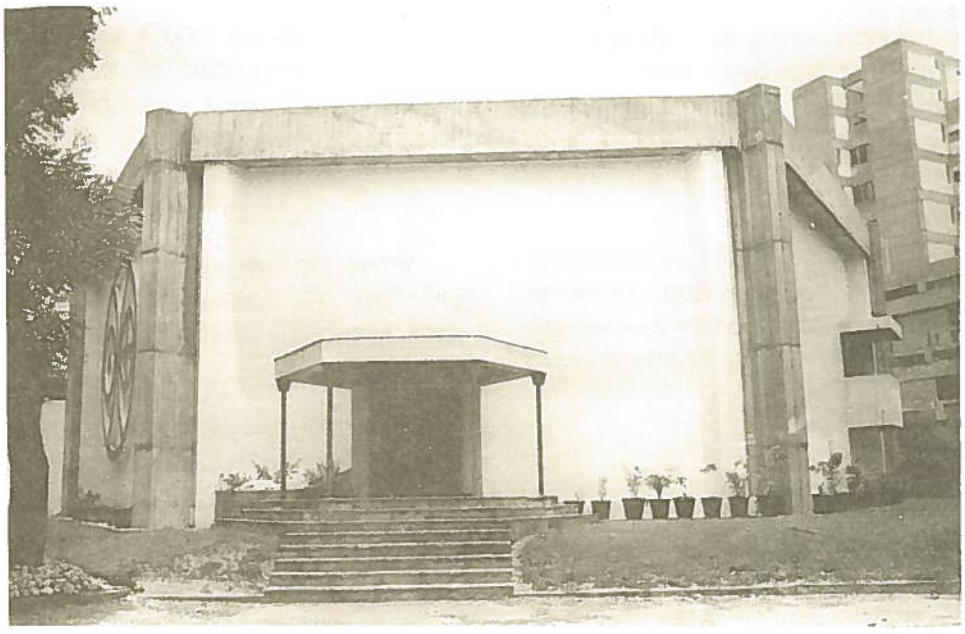
Workshop

Workshop has several achievements during the year 1991-92. Several jobs made by the mechanics were admired by users and many distinguished visitors from abroad.

Machining and precision assembly work of Doppler Imaging Spectrometer and Daytime Fabry Perot Spectrometer was carried out for PAR:TH project. NSS'92 award was given to the scientist for the development of this instrument.

A 3 meter corer was designed, developed and fabricated for CON:PC project. This instrument was handled in a deep water lake "mansar" near Jammu, in J&K State. This equipment is made much more

3 Meter Corer and a floating platform indigenously designed and fabricated in PRL Workshop is seen under operation at Mansar Lake near Jammu.



The newly built PRL auditorium.

lighter, compact and easy to operate. 1. meter Corer was serviced and repaired as and when needed. Dust collecting instrument was made to measure dew parameters of vetical winds.

For PAR-AP Project major jobs acomplished were: Coelostat Drive Unit, mirror mount, s.s container, sensor, detector mount and acrylic chamber. Our mechanics had joined the field trip to Madras to assist the scientist.

IR-Photometer and Stellar Scintillation Photometer are the examples of highly precise machining and assembly work. Several times this service was extended for maintenance and repairing work at Mt. Abu.

Optical fiber mounting, and other servicing work on Monochromater and high vaccum rotary filter chamber was carried out to the entire satisfaction of the users.

Fairly good amount of s.s. fabrication work was done for the project PAR-VK. Absorption chamber, Beam Splitter, Diffusion pump coupler and flanges are few of them.

Precision machining work was done for Mass Spectrometer and Ion Probe. Precise sample holder were made in large quantity for GEO-RS Project.

Telescope work, Yagi antena, Spherical Probe and many optical holders were made for the Sross project.

Our P C is now upgraded with a 40 MB hard disk and 640 K memory. In future we have plans to start making drawings with Auto Cad programm.

Three of our Engineers had been to Delhi and visited the International Mechine Tools Exhibition.

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 relating to horticultural development and maintenance and upkeepment of various buildings and campuses like PRL campus, Staff quarter campus, Thaltej campus, Gurushikar & Hill View campus, Udaipur Solar Observatory, etc. We also prepare sites for installation of sophisticated equipments meeting with clean room specifications.

During the year following works have been undertaken.

- Modification works of Library block
- Land scaping of PRL campus
- Construction of lecture hall with 300 seating capacity
- Construction of Vertical extension to stores building - under completion.
- Construction of telescope house for 350 mm celestron telescope with FRP dome at Gurushikar.
- Design & fabrication of aluminium framed display boards.

Events and Activities 1991-92

A one day symposium on perspective in solar system research was held in PRL on July 28, 1991 in honour of Prof. M.N. Rao who completed sixty years. The symposium began with the inaugural and felicitation session chaired by Prof. S.P. Pandya, former Director of PRL and inaugurated by Director, Prof. R.K. Varma after Prof. K. Gopalan's (Deputy Director, NGRI) and his addresses for which Prof. Rao made a gracious reply. The technical sessions, three in number, began after morning tea. During the first session two papers were presented. Prof. Gopalan described the various geochronometers in the U- (aplha) decay series as well as the Xe-U method based on Uranium fission. Prof. Rama Rao talked on noble gas radar in terrestrial settings and its use in ground water exploration. The second session consisted of three elegant talks by Dr. Utpal Sarkar, PRL on solar neutrino puzzle, Dr. N. Bhandari, PRL on past variability on different time scales and by Prof. P.S. Goel of IIT, Kanpur describing the unexplained results on meteorites obtained by neutron activation analysis. In the third session Dr. J.N. Desai, PRL talked on the interaction of cometary ion tails with solar wind irregularities; Dr. R. Sridharan elaborated on the high resolution spectroscopic studies of planetary atmospheres and Dr. V.S. Venkatavardan gave a popular concluding talk with good colour slides on Planets Today. The session concluded with brief narrations/speeches by Prof. Rao's present and past colleagues regarding their experiences of him.

The Hindi Day was celebrated at PRL from September 12 to 14, 1991. During the celebrations an essay competition, two popular lectures and elocution competition were organised for all the staff members. The elocution competition was also open to the families of our staff members. The essays and elocutions were evaluated seperately for Hindi and non-Hindi speaking participants.

An Indo-US Mini-Workshop on "Interplanetary Scintillation (IPS) and Propagating Solar Disturbances" was held during 25-26 September, 1991 at the Physical Research Laboratory. On 24 and 27 September 1991 there were working group meetings of the investigators of the Indo-US Collaborative Project entitled

Prof. J. C. Bhattacharya being welcomed at the INDO-US Mini Workshop on "Interplanetary Scintillation and Propagating Solar Disturbances".

"Co-ordinated Studies of Solar Radiations at Radio, X-ray and Optical Wave-lengths and Travelling Interplanetary Phenomena during Solar Maximum Year and Beyond." This project began on March 1987 between the Space Environment Laboratory (SEL) of NOAA, Boulder, USA and Radio Astronomy Group of Physical Research Laboratory, Ahmedabad. The Workshop was attended by five scientists from USA and fifty scientists from PRL and other research institutes in India. The Workshop had an inagural session followed by four scientific sessions. Prof. J.C. Bhattacharya, former Director of the Indian Institute of Astrophysics, Bangalore, in his inaugural address reminisced the beginning of solar research in India and presented its glorius achievements. He also focussed the attention of the participants on some challenging problems in Solar Physics. The three scientific sessions dealt mostly with topics on coronal and IPM structures from Velocity and G-maps, solar phenomena and geomagnetic field and interaction of solar wind with planets and comets. The Workshop concluded with panel discussion on the future course of the coordinated studies to be pursued jointly by the Indian and American investigators.

The second International Conference on Gravitation and Cosmology was held at the Physical Research Laboratory, Ahmedabad during December 13-18 1991. About one hundred and forty scientists participated from outside Ahmedabad amongst whom about forty were from abroad. The conference essentially concentrated on four aspects namely Quantum and Classical Gravity, Gravitation Radiation and Cosmology. As the participation in the conference was only by invitation, the paper presentations were restricted to workshops whose coordinators had preselected the papers for oral presentations while all the papers submitted were encourged to be displayed as posters. There were fifteen plenary lectures and three panel discussions covering various aspects of Gravitation Physics during the six working sessions, while the four working afternoons were devoted to four workshops.

The annual meeting of the Indian National Science Academy (INSA) was held at the Physical Research Laboratory, Ahmedabad from December 29-31, 1991. The Indian National Science Academy was established in January 1935 with the object of promot-

At the inaugural function of the second International Conference on Gravitation and Cosmology.

ing science in India. Six Awards were conferred this year in various disciplines. All the awardees received the awards from Professor P.N. Tandon, President, INSA and delivered lectures pertaining to their specialization.

The seventh SERC school in Theoretical High Energy Physics was hosted by PRL during December 23, 1991 - January 18, 1992. There were thirty six participants from all over the country mostly young students, including three of PRL students. The programme for the school was chalked out in every possible detail - the titles of courses, the syllabus for each course and the schedule of courses almost a year in advance. As a result, the students had an opportunity to listen to well-planned series of lectures from experts from all over the country. A special feature in the school this year was the presence of "Guest Faculty" who were experts in their respective fields. Their presence gave an opportunity to the students to hold discussions in an informal atmosphere. These experts also held regular tutorials for the students every afternoon. The schedule was a heavy one including Saturdays. After four weeks of hard work the participants returned with pleasant memories of PRL and of the useful contacts they had made among themselves and among the teachers.

This year we were fortunate to have two highly distinguished scientists with us. Professor William Ian Axford, F.R.S. and Professor Fritz Rohrlich visited PRL as the fifteenth and sixteenth Vikram Ambalal Sarabhai Professors respectively. Professor Axford, F.R.S., a distinguished space scientist is the Director of the Max Planck Institute for Aeronomie, Lindau, Germany. During his stay at PRL Professor Axford delivered two very stimulating scientific lectures and one popular lecture entitled "Halley's Comet" while he was with us.

Professor Fritz Rohrlich, an eminent and distinguished theoretical physicist visited PRL for three weeks in January 1992. During his stay Prof. Rohrlich gave a series of lectures on Relativistic Particle Electrodynamics : How its Problems got Resolved. The lectures were very informative and useful to our young scientists. The popular lecture entitled Scientific Revolutions and Our view of the World was interesting and thought provoking.

Professor W. I. Axford, F. R. S. visited PRL as the fifteenth VAS Professor.

Professor Fritz Rohrlich, visited PRL as the sixteenth VAS Professor.

A one day symposium on Solar Physics and Interplanetary Medium was organised on January, 1992 to felicitate Profs. S.K. Alurkar and S.S. Deagaonkar on their sixtieth birthday. There were two scientific sessions and an inaugural and felicitation session. The symposium was inaugurated by Prof. J.C. Bhattacharya, former Director of Indian Institute of Astrophysics, Bangalore. The two scientific sessions consisted of five talks by the scientists actively engaged in research related to the topic of the symposium. Highlights of the scientific contribution of Prof. S.K. Alurkar and Prof. S.S. Degaonkar were outlined at the felicitation.

An international symposium on the Evolution of Deserts was held at PRL during February 11-19, 1992. The hosts of the symposium were PRL, CAZRI, and GSI. Several international agencies such as UNEP, WMO, the Ford Foundation, the British Council besides a host of national agencies co-sponsored the symposium. An important aspect of the symposium was a very meticulously organised 1200km long field trip to some of the important sites in the Thar desert. This was organised with a view to exposing the international scientific community to the climate, geology, soils, minerals, water resources, fauna and flora of this interesting and unique desert region. Within the framework of the symposium two broad categories of papers were presented - one dealing with the records of past changes in the global climate based on proxy climate indicators, e.g., flora, fauna, chemical, isotopic and mineralogical variations preseved in natural archives such as lakes and marine sediments, aeolian deposits, ice sheets etc. The other set of papers addressed the desertification processes operative under the present day climate and their quantification.

The National Science Day celebration was jointly organised by the Physical Research Laboratory, Indian Physics Association and Gujarat Science Academy. The programme was planned with the sole aim of creating scientific awareness amongst the school students. Hence the programme included science quiz consisting of written and oral rounds and popular lectures in Hindi and Gujarati. About two hundred children from about hundred schools of Ahmedabad and Gandhinagar district participated in the preliminary round which was of written type. The winners of first, second and third position in final round of the quiz was

A field trip to Thar Desert was organised during the international symposium on the Evolution of Deserts.

presented with a set of science books. To encourage participation of these students in future scientific programmes and to instil in them the excitements of scientific pursuits the Gujarat Science Academy presented all the participants with a popular Science book. In addition, the first eighteen students were presented a science kit, which were generously donated by M/S. Electric Control Gear (India) Ltd., Ahmedabad.

On March 10, 1992 PRL celebrated the occasion of one of its most distinguished alumni, U. Ramachandra Rao completing 60 years of age. Normally when one of its senior scientists completes 60 years PRL celebrated it in the form of a one day symposium on a subject related to his research interest. But this was indeed a special occassion, unlike other celebrations of its kind. The large canvas of Prof. U.R. Rao's scientific and technological interests could not be contained on a single day. Many of his colleagues of yester years, both senior and junior gathered to greet him on this occasion, to give expression of their respect and affection. They joined hands with some very distinguished scientists from India and abroad.

The National Space Science Symposium, sponsored by the Department of Space, was held at the Physical Research Laboratory, Ahmedabad from March 11 to 14, 1992. The symposium was inaugurated by the renowned atmospheric scientist, Dr. A.P. Mitra, FRS and Bhatnagar Fellow, NPL. The inaugural function held at the ATIRA Auditorium, was presided over by Prof. U.R. Rao, Chairman, ISRO and Secretary, DOS. The plenery and other scientific sessions were held at the PRL's newly built Auditorium which was formally inaugurated by Prof. U.R. Rao on 10th March, 1992. About three hundred and fifty delegates attended the symposium which included two hundred delegates coming from outside Ahmedabad and representing various research institutions and university centres with space research activities. Nearly three hundred contributory papers were presented at the symposium, sixty of the them in oral presentation and the others in the poster sessions. There were nine plenery review talks on topical subjects and seventeen invited review talks covering different subjects in space sciences. The subjects covered included astronomy and astrophysics, cosmic rays, planetary ionospheres/magnetospheres, ionospheric structure and

Prof. U. R. Rao, Chairman, PRL Council of Management and one of PRL's most distinguished alumni being felicitated by Prof. R. K. Varma, Director, PRL, on the occasion of his sixtieth birthday.

dynamics, middle atmospheric studies (which covered chemistry, radiation, aerosols, meteorology, ionization and electrodynamics) satellite meteorology and satellite remote sensing. An evening session was conducted on the recently commissioned ST mode operation of the National MST radar facility near Tirupati. The system specifications, salient features of the system, design and preliminary results on tropospheric studies were described by the scientists and engineers from the National MST Radar Facility, MST radar project and the SAMEER group who are building the facility. As customary first, second and appreciation prizes were awarded to contributory papers in different categories. These were based on the quality of the subject material and its presentation. In addition, there were first, second and third prizes for best posters. The prizes were announced during the concluding session of the symposium and given away by Prof. R.K. Varma. The symposium also provided an opportunity to the participant scientists to discuss scientific activities to be undertaken in the country such as the upcoming Indian MST Radar, Indian Solar Terrestrial Energy Programme (ISTEP) and the International Geosphere-Biosphere Programme (IGBP).

This year six of our staff members retired from the laboratory. Professor M.N. Rao retired on July 31, 1991 after eighteen years of dedicated service at PRL. Professor Rao started his academic career as a Lecturer in the Andhra University, Waltair. Later he went to Mainz in the then West Germany and obtained his Dr. rer.nat from the University of Koln in 1962. After a brief stint at BARC, he went to the United States where he spent five years at the University of Arkansas, Fayetteville where he became an Assistant Professor. In 1969 Dr. Rao returned to TIFR and alongwith Prof. Gopalan, set up highly sensitive glass mass spectrometer for rare gas analysis and initiated research programmes on lunar and meteorite research. Dr. Rao moved to PRL in 1973 and built up one of the best Mass Spectrometry laboratories. During the next eighteen years Prof. Rao's group carried out wonderful work in earth sciences both in quality and quantity. Most recently, he spent a couple of years as a NSF-NRC Senior Scientist at the Johnson Space Centre, USA. From Waltair to premier institutions in the west to the NASA (where he had been recently) has been a long academic journey but he has done it extremely well.

Miss N.M. Davierwala, Assitant Account officer retired from PRL on September 30, 1991 after putting a dedicated service for about twenty years. After completing her Masters degree in Commerce Miss Davierwala joined the Mahila Mandal District Zilla Parishad in Surat District. She joined PRL in 1971. From that time onwards she had been a part of this laboratory, its activities, its growth and its history. She has proved herself as an excellent coordinator. Her main contribution was to assist the Accout Officer in auditing and finalising the accounts of the Laboratory. She had automated the income expenditure and balance sheet on computer and this has greatly benefitted the accounts section in speedy completion of the accounts. She was an asset to the organization. Her early retirement would undoubtedly be a great loss to the Accounts section and PRL as a whole

Mr. Jagdev Singh Sidhu joined PRL in January 1967 and retired in January 1992 after putting twenty five years of service. Before joining PRL, he was working in Indian Navy as Chief Electrician, Radio and Radar Unit. At PRL he joined the group under Prof. U.R. Rao and Dr. Kasturirangan and made X-ray payloads for them which were flown on board rockets and balloon from Thumba and Hyderabad respectively. After U.R. Rao's group moved to Bangalore in early 1970, Mr. Sidhu worked in various projects - notable among them were SOLRAD satellite, MONEX, Partial Reflection Radar, Indo-Soviet mass spectrometry, Indian Middle Atmosphere Programme Mr. Sidhu actively participated in a number of rocket and balloon experiments during this period. Mr. Sidhu not only made the payloads of these experiments, he was also very much involved in studying the kind of data obtained. Mr. Sidhu was an honest, simple, hardworking, disciplined and dependble man. He never compromised excellence with any other thing and to achieve this excellence he was ready to go to any extent. He always liked challenging job. One special quality in Mr. Sidhu was that one could entrust a

job to him and be assured that the job would be completed. Mr Sidhu is a fine hockey coach. Eversince he came to Ahmedabad, he has been coaching students in hockey. And it is for the sake of hockey that he did not move to Bangalore with Prof. U.R. Rao despite an invitation from him.

Dr. S.K. Alurkar completed sixty years on January 11, 1992 with more than three decades of dedicated scientific career in PRL. Prof. Alurkar joined PRL in 1957 after graduating from the Poona University. He studied the properties of D & E regions of the ionosphere through the absorption of Low Frequency radio waves from Tashkent. He later went to the Institute de Pesquisas Espaciasis (INPE), Sao Paulo, Brazil and the University of Adelaide, Australia, where he worked on solar plasma irregularities, plasma instabilities and IPS. After his return to PRL in 1973, Prof. Alurkar, in association with Prof. R.V. Bhonsle, embarked on a project relating to the study of the interplanetary medium using three spaced telescope system. This was a challenging project and Prof. Alurkar has very dedicatedly contributed to the installation of the system over the past fifteen years. In addition to carrying out a survey of radio sources, an interesting phenomenon of the scintillation of a radio source by the plasma tail of Comet Halley was also discovered using the Thaltej antenna array. This has enabled one to evaluate several plasma properties in the cometary tail.

Dr. S.S. Degaonkar completed sixty years on January 15, 1992, with a career in PRL running almost four decades. He joined PRL in 1952 and worked on the physics of the ionosphere with Prof. K.R. Ramanathan. His interests encompassed the study of protective ozone layer, various phenomena related to ionospheric D, E and F layers through the cosmic radio noise method which had just begun. Prof. Degaonkar used this method very effectively to study the properties of the ionosphere. Later he developed a High Frequency Capacitance Probe which was successfully launched to study the ionosphere. Prof. Degaonkar spent two years at the South West Centre for Advanced Studies at Dallas, Texas. On return to India, he continued his interest in solar-terrestrial relationship. Later he developed interest on Solar Radio Astronomy. He has done excellent work on solar corona using high resolution decametric observations. Besides his research publications Prof. Degaonkar has written a book entitled "Space Science and Earth's Environment" which has become a very popular book for ionospheric physicists.

Papers Presented at Symposia/Conference In 1991-92

ASTRONOMY AND ASTROPHYSICS

a. Symposium on "Solar Connection with Transient Interplanetary Processes (SOLTIP)", Liblice, Czechoslovakia, Septermber 30 - October 5, 1991.

1. Janardhan P. and Alurkar S.K., "Possible contribution of a solar transient to enhanced scintillation of a quasar".

b. Seventh Cambridge Workshop on "Cool Stars, Stellar Systems and the Sun" at Tucson, Arizona, USA , 9-12 October, 1991.

1. Anandarao, B.G., Pottasch S.R. and Vaidya D.B., "Infrared Emission in Mira Variables - Pulsational Mass Loss ".

c. IAU Colloquium No.133 on "Eruptive Solar Flares", Ituazu, Argentina, 2-6 August, 1991.

1. Bhatnagar, A., Ambastha, A., Srivastava N., "Filament Eruptions, Flaring Aches and Eruptive Flares".

d. National Space Science Symposium, PRL, Ahmedabad, 12-16 March,1992.

1. Ashok N.M., Ragland S., Desai J.N. and Chandrasekhar T., "Twilight near-infrared studies of the Mt.Pinatubo Volcanic dust over Ahmedabad, India".
2. Anandarao, B.G., Pottasch, S.R. and Vaidya, D.B., "Infrared Emission in Mira Variables - Mass Loss Mechanisms".
3. Chauhan, J.S., Joshi, U.C., Sen, A.K. and Deshpande, M.R., "Study of Comet Austin with Imaging Polarimetry".
4. Deshpande, M.R., Joshi, U.C., Sen A.K. and Chauhan, J.S., "Detection of microvariability in a BL Lac object OJ 287".
5. Joshi, U.C., Chauhan, J.S., Sen, A.K., Deshpande,M.R. and Shah, C.R., "Detection of high frequency features in comet Halley image".
6. Janardhan P., "Interplanetary scintillation - Recent Results" (invited talk).
7. Misra, L., Desai, J.N. and Ashok N.M., "Stellar Intensity Scintillations and Astronomical seeing over Gurushikhar, Mt.Abu".
8. Sen,A.K., Joshi, U.C., Chauhan J.S. and Deshpande, M.R., "On the nature of dust and gas properties of comets".
9. Shylaja B.S. and Anandarao, B.G.," IR Emission in WR Stars in LMC ".
10. Vats Hari Om, Alurkar S.K. and Janardhan P., "Solar wind measurement using Thaltej radio telescope for the period 1984-90".

e. GMRT Winter School on "Solar Radio Astronomy and Interplanetary Medium", Calcutta, January 10-18, 1992.

1. Alurkar, S.K., "Results from PRL multistation Experiment".
2. Bhatnagar A., "The Sun at Optical wavelengths" (Invited talk).
3. Bhatnagar, A., "Sun - Our nearest Star" (Evening talk).
4. Vats, H.O., "Characteristics of fast solar streams and their interaction with the geomagnetic field".

f. Conference on "Modern Trends in Geomagnetic Studies at Low Latitudes", Bombay, 2-4 December, 1991.

1. Vats Hari Om, "Solar wind and geomagnetic activity".

g. Mini Workshop on "Automated Photoelectric Telescopes," IUCAA Pune, October 21-25, 1991.

1. Ashok N.M. "Occultation studies of solar system objects" and "Spectroscopic studies using light weight spectrometers".

h. IUCAA Workshop on "Experimental techniques in Space Science and Astronomy", Gujarat University, February 24-28, 1992

1. Ashok N.M. "Infrared Photometry in Astronomy"
2. Chanderasekhar T., "Telescopes".
3. Desai J.N., "High Resolution Spectroscopy in Astronomy".

i. Indo-US Mini-workshop on "Interplanetary Scintillation and Propagating Solar Disturbances", Ahmedabad , 25-26 September, 1991.

1. Alurkar S.K., "Evolution of coronal and neutral line structures with solar cycle".
2. Alurkar S.K., "Solar wind speed structure".
3. Ambastha, A., "Eruptive Flare Events of March 5-9 Possible Source of Interplanetary disturbance".
4. Janardhan P., "A summary of 103 MHz observations of enhanced scintillation due to cometary ion tails".
5. Srivastav, N., "Filament Eruptions".

6. Vats H. O.. "Determination of solar wind speed by single station IPS observations".

7. Vats Hari Om, "High speed solar wind streams and geomagnetic activity".

j. Symposium on "Solar Physics and Interplanetary Medium", Ahmedabad, 28 January 1992.

1. Janardhan P., "Cometary studies at metre wavelengths".

2. Vats Hari Om, "Interplanetary Scintillation studies at PRL - Past, Present and Future".

k. Symposium on "Perspectives in Solar System Research", PRL, Ahmedabad, 29 July 1991.

1. Desai, J.N., "Interaction of cometary ion tails with solar wind irregularities".

l. Symposium in honour of Prof.U.R.Rao, PRL, Ahmedabad, 1992.

1. Desai, J.N., "High Spectral Resolution in Astronomy".

m. Summer School on "Upper Atmosphere Sciences"., Shivaji University, Kolhapur, 10 June - 1 July, 1991.

1. Ambhastha A., "Solar Radiations", (4 lectures).

2. Bhatnagar, A., "Sun in Action", (public lecture).

3. Desai, J.N., "Experimental Techniques for Airglow", (4 lectures).

PLANTERY ATMOSPHERE AND AERONOMY

a. SERC School on "Upper Atmospheric Studies", Shivaji University, Kolhapur, June 10 - July 1, 1991.

1. Chandra, H., - Gave four lectures.

b. Symposium on "Perspectives in Solar System Research", PRL, Ahmedabad, July 29, 1991.

1. Sridharan, R., "High resolution spectroscopic studies of planetay atmospheres" (Invited talk).

c. XX General Assembly of IUGG and Associated Symposia and Meetings at Vienna, Australia, August 11-24, 1991.

1. Chandra, H., Vyas, G.D., Sinha, H.S.S., Prakash, S. and Misra, R. N., "Spectral characteristics of the ionospheric irregularities obtained from VHF scintillations recorded over SHAR".

2. Prakash, S., Pal, S. and Chandra, H., "Spectral characteristics of the electron density irregularities associated with equatorial spread-F transitional wavelengths" .

3. Sinha, H.S.S., "Plasma density irregularities in the equatorial D-region produced by neutral turbulence".

4. Sinha, H.S.S., Chandra, H., Misra, R.N. and Prakash, S.,"Optical imaging of plasma depletions associated with equatorial spread-F".

5. Sinha, H.S.S., Prakash, S. and Pandey, R., "Modelling of sharp ionization layers over equator observed during counter electrojet".

d. Indo-US Mini-Workshop on "Interplanetary Scintillations and Propagating Solar Disturbances", PRL, Ahmedabad. September 25-26, 1991.

1. Chandra, H., "Interplanetary Disturbances and Ionospheric Effects" (invited talk).

e. First SERC School on "Atomic/Molecular Physics", Calcutta, November, 1991.

1. Vijay Kumar, Gave six lectures on "Elastic scattering of electrons and positrons by atoms and molecules"

f. Symposium on "Modern Trends in Geomagnetic Studies at Low Latitudes", December 2-4, 1991, IIG, Bombay.

1. Gupta, S.P. and Chandra, H., "Role of vertical electric field and neutral winds in the formation of sporadic-E layer over Thumba".

2. Chandra, H., "Equatorial electrojet and the ionospheric drifts at low latitudes".

g. Symposium on "Solar Physics and Interplanetary Medium", PRL, Ahmedabad, January 28, 1992.

1. Chandra, H., "Solar cycle and geomagnetic activity effects on equatorial spread-F" (invited talk).

h. International "Symposium on Evolution of Deserts", PRL, Ahmedabad, February 11-14, 1992.

1. Subbaraya, B.H. and Jayaraman, A., "Desert aerosols and their role in atmospheric radiative transfer".

i. All India Conference on "Applied Instrumentation", February 14-15, 1992, Roorkee University, Roorkee.

1. Misra, R.N. and Chandra, H., "Ionosonde Data Digitization".

2. Misra, R.N., "PC Printer Post as General Parallel I/O"

j. National Symposium on "Advances in Tropical Meteorology with emphasis on Satellite Applications", SAC, Ahmedabad, February 19-22, 1992.

1. Jayaraman, A, and Subbaraya, B.H., "Monitoring of Aerosol Content over Ocean Surfaces using INSAT data".
2. Subbaraya, B.H., "Tropical Atmospheric Chemistry - Special Significance for IGBP Studies".

k. National Space Science Symposium, March 11-14, 1992, PRL, Ahmedabad.

1. Haider, S.A., "A Comparative study of nighttime ionospheres of Mars and Venus during solar minimum condition"
2. Gupta S.P., Acharya, Y.B. and Narayan, A., "Balloonborne measurements of electrical parameters and their relevance to global electric circuit".
3. Gupta, S.P., Chandra, H. and Thiemann, H.,"Role of gravity waves and meteoric ions in the formation of layers over Thumba".
4. Lal, M., Sidhu, J.S., Chakrabarty, D.K. and Verma, S.D., "Some results of ground based measurements of atmospheric NO_2 at Ahmedabad by visible absorption spectroscopy".
5. Lal, M. and Chakrabarty, D.K., "Atmospheric NO_3 observations over low latitude northern hemisphere during night".
6. Beig, G., Chakrabarty, D.K., Lal, M., Sidhu, J.S. and Das, S.R., "In-situ measurements of eddy coefficient during 1985-1990"
7. Lal, M., Das, S.R. and Chakrabarty, D.K., "Volcanic disturbances in the stratospheric aerosol layers over Ahmedabad observed by visible and near IR spectroscopy"
8. Beig, G., "Model of sulfuric acid vapour for volcanically quiet and active conditions : Two dimensional simulations".
9. Beig, G., Chakrabarty, D.K., and Brasseur, G., "Two dimensional model of stratospheric negative in composition".
10. Chandra, H., Vyas, G.D., Sinha, H.S.S., Prakash, S. and Misra, R.M., "Equatorial spread-F campaign over SHAR".
11. Misra, R.N., "Four channel audio cassette based data recorder",
12. Misra, R.N., and Chandra, H., "Ionosonde data digitization".
13. Prakash, S. and Sinha, H.S.S., "Formation of electron density layers in E-region over low latitude".
14. Vyas, G.D. and Chandra, H., "VHF scintillations and spread-F in the anomaly crest region".
15. Chandra, H., Vyas, G.D., Rastogi, R.G. and Participants AICPITS Scintillation Network, "Coordinated VHF scintillation observations in India during March-April, 1991".
16. Sridharan, R.,"Thermopheric-Ionospheric coupling" (Invited talk)
17. Gurubaran, S., Sridharan, R., Narayanan, R., Sekar, R. and Modi, N.K., "The Low latitude thermosphere/ ionosphere system".
18. Sridharan, R., Sekar, R., Gurubaran, S., Narayanan, R. and Modi, N.K., "First results from a high resolution doppler imaging spectrometer (DIS) from Ahmedabad located under equatorial ionization anomaly (EIA)".
19. Sridharan, R., Narayanan, R., Modi, N.K., Raju, D.P. and Gurubaran, S., " Determination of emission line profiles of dayglow - an innovative approach".
20. Ramachandran, S., Jayaraman, A., Acharya, Y.B. and Subbaraya, B.H., "Sun photometer measurements of spectral extinctions over Ahmedabad".
21. Jayaraman, A. and Subbaraya, B.H., "In-siu measurements of Tropospheric aerosol extinctions and and their seasonal variability".
22. Subbaraya, B.H. and Shyam Lal, "Surface ozone monitoring at Ahmedabad".
23. Lal, S., Venkataramani, S. and Subbaraya, B.H., "Methane flux measurements from paddy fields in Southern India".
24. Subbaraya, B.H., "Middle Atmosphere Coupling Processes" - Invited Talk.

l. International 'Symposium on Global Change (IGBP)', Tokyo, Japan, March 27-29, 1992.

1. Lal, S., "Vertical distribution of trace gases in the tropical region over Hyderabad (Invited paper).

m. International Symposium on "Middle Atmosphere Science", March 1992, Kyoto, Japan.

1. Lal, M. and Chakrabarty, D.K., "Twilight brightening at near IR over Ahmedabad, India after Mt. Fugen and Mt. Pinatubo volcanic eruption in June, 1991".
2. Lal, M. and Chakrabarty, D.K., "Variability of atmospheric NO_2 at 23^oN".
3. Chakrabarty, D.K., Lal, M., Beig, G., Sidhu, J.S. and Das, S.R., "Balloon measurements of stratospheric ion conductivities over tropics".
4. Beig, G., Walters, S. and Brasseur, G., "Two dimensional model of stratospheric positive ion composition"

5. Lal, S., Borchers, R., Fabian, P. and Subbaraya, B.H., "Vertical distribution of halogenated hydrocarbons in the tropical middle atmosphere".

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

a. 2nd International Symposium on the Biogeochemistry of Model Estuaries; Estuarine processes and Global Change, Jekyll Island, Georgia, USA, April 14-20, 1991.

1. Somayajulu, B.L.K., Borole, D.V., Eisma, D., Martin, J.M., Rao, K.S. and Thomas, A.J. :Geochemical studies in the Godavari estuary, India".

b. XVI General Assembly of the European Geophysical Society, Wiesbaden, April 22-24, 1991.

1. Bhandari, N., Mathew, K.J., Rao, M.N., Herpers, U., Bremer, K., Vogt, S., Wolfli, W., Hofman, H.J., Michel, R., Bodeman, R. and Lange, H.J. "On the depth and size dependence of cosmogenic nuclide production rates in stony meteoroids".

2. Bonino G., Cini Castagnoli, G. and Bhandari, N., "Ti in meteorites : Investigation of century scale variations of solar activity".

c. 54th Meeting of the Meteoritical Society, Monterey, California, July 21-26, 1991.

1. Bhandari, N., Mathew, K.J., Rao, M.N., Herpers, U., Brewer, K., Vogt, S., Wolfli, W., Hofman, H.J., Michel, R., Bodeman, R. and Lange, H.J., "Depth and size dependence of cosmogenic nuclide production rates in stony meteoroids".

2. Goswami, J.N., "Meteoritic evidence for an early active Sun".

3. Goswami, J.N., Srinivasan, G. and Ulyanov, A.A. "Titanium, calcium and magnesium isotopic composition in a hibonite rich inclusion from Efremovka".

4. Murty, S.V.S. and Sheel Varun. "Production rate of cosmogenic nitrogen from Norton Country aubrite".

5. Srinivasan, G., Ulyanov, A.A. and Goswami, J.N., "Magnesium isotopic fractionation in refractory inclusions : Indications for a mineralogic control".

d. Prof. M.N. Rao's 60th Birth Day Symposium on Perspectives in Solar System Research, PRL. July 29, 1991.

1. Bhandari, N., "Solar Variability".

e. XIII INQUA Congress, Beijing, China, August 2-9, 1991.

1. Chakraborty, S. and Ramesh, R. "Stable isotope studies of Indian corals".

2. Pant, R. K. and Juyal, N. "Late Quaternary land-sea interactions in Saurashtra, West Coast, India.

3. Sarkar, A., Ramesh, R. and Bhattacharya, S.K. "Late Pleistocene paleoclimate in the northern Indian ocean".

4. Singhvi, A.K., Bronger, A., Heinkiele and Someswar Rao, M., "Chronology of climatic change based on loess-paleosol sequences in Central Europe, India and China".

5. Singhvi, A.K., Dhir, R.P., Rajaguru, S.N., Misra, V.N. and Chawla, S. "Chronology of climatic change in the Thar desert, India.

f. 20th IUGG General Assembly, Vienna, Austria, August 11-24, 1991.

1. Nijampurkar, V.N., Sarin, M.M. and Rao, D.K. "Chemical composition of snow/ice of a high altitude Himalayan glacier".

2. Sarin, M.M., Krishnaswami, S. and Somayajulu, B.L.K. "Radioactive disequilibria of the U Series nuclides in the Arabian Sea : particle scavenging rates in surface and deep waters".

3. Somayajulu, B.L.K. and Sarin, M.M. "Radium isotopes in the northern Arabian Sea".

g. Twenty Second International Cosmic Ray Conference, Dublin, Ireland, August 11-23, 1991.

1. Biswas, S., Durgaprasad, N., Dutta, A., Goswami, J.N., Mitra, B. and Ramadurai, S."Implications of the observations of partially ionised states in galactic cosmic rays".

2. Dutta, A., Goswami, J.N., Biswas, S., Durgaprasad, N., Mitra, B. and Singh, R.K. "Further evidence for the presence of low energy partially ionized iron-group ions in galactic cosmic rays".

3. Dutta, A., Goswami, J.N., Biswas, S., Durgaprasad, N., Mitra, B. and Singh, R.K. "Ionization states of Anomalous Cosmic Rays".

h. IGCP No. 293 Meeting on Event Markers in Earths History, Calgary,Alberta, Canada, August 28-30, 1991.

1. Bhandari, N., Shukla, P.N. and Azmi, R.J. "Iridium profiles of the Permo-triassic boundary, Spiti, India".

2. Bhandari, N. and Shukla, P.N. "Geochemistry of K T boundary sections in India".

i. **International Symposium on Evolution of Desert Landscapes, University of Western Australia, Perth, October 7-10, 1991.**

1. Singhvi, A.K., Dhir, R.P., Rajaguru, S.N., Misra, V.N., Ramesh, R. and Chawla, S. "Luminescence geochronology of paleoclimatic changes in Thar desert".

j. **Seventh National Conference on Particle tracks in Solids, Jodhpur, October 9-11, 1991.**

1. Biswas, S., Durgaprasad, N., Mitra, B., Singh, R.K., Vahia, M.N., Yadav, J.S., Dutta, A. and Goswami, J.N., "Anomalous Cosmic Rays and their ionisation states".

2. Goswami, J.N., "Solar flare heavy ion tracks in extraterrestrial objects" (Invited talk).

k. **International Symposium on the Evolution of Deserts, PRL, Ahmedabad, February 10-14, 1992.**

1. Bhattacharya, S.K., Juyal, N. and Yadav, M.G., "Imprint of Younger Dryas cooling in a sediment core from the Arabian Sea".

2. Datta, P.S., Bhattacharya, S.K., Mookherjee, P. and Tyagi, S.K. "Study of groundwater occurrence and mixing in Pushkar (Ajmer) Valley, Rajasthan with O and hydrochemical data".

3. Dhir, R.P., Singhvi, A.K. and Rajaguru, S.N. "Evolutionary record of Thar desert".

4. Raghav, K.S., Pal, N.K., Pareek, S., Kishan Kumar, V.S. and Singhvi, A.K., "Stratigraphy and luminescence geochronology of aeolean sediments in north eastern Thar".

5. Ramesh, R. "Marine records of paleoclimatic changes : Evidence from oxygen isotopes.

6. Ramesh, R., Jani, R.A. and Bhushan, R. "Stable isotopic evidence for the origin of water in the salt lakes of Rajasthan and Gujarat".

7. Sareen, B.K., Someswar Rao, M., Tandon, S.K. and Singhvi, A.K., "A tentative chronological frame work for the Quaternary deposits of the Sabarmati basin of the semi- arid western India using Thermoluminescence".

8. Singhvi, A.K., Misra, V.N., Rajaguru, S.N., Raghavan,H., Chawla, S., Ramesh, R. and Dhir, R.P. "Chronology, paeoenvironment and geoarchaeology of a fossil dune (16R), Didwana, Rajasthan".

l. **National Space Science Symposium, PRL,Ahmedabad, March 11-14, 1992.**

1. Bhandari, N., "Variability of the energetic solar particle fluxes".

2. Dutta, A., Goswami, J.N., Biswas, S., Durgaprasad, N., Mitra, B. and Singh, R.K., "Ionisation states of low energy cosmic ray heavy ions in Anuradha experiment and their implications".

3. Goswami, J.N., "Further results from Anuradha".

4. Mathew, K.J. and Murty, S.V.S. "Cosmic ray produced nitrogen in extra-terrestrial matter".

5. Somayajulu, B.L.K., Yadav, D.N., Sarkar, A. and Sarin, M.M. "Environmental changes during the past few centuries based on geochemical studies of sediments from the north eastern Arabian Sea".

6. Venkatesan, T.R. and Pande, K., "Climatic perturbations, faunal crisis and volcanism : Evidence from the Deccan province".

m. **Workshop on Himalayan Glaciology Research Programme, WIHG, Dehradun, March 20-21, 1992.**

1. Nijampurkar, V.N. "Highlights of scientific contributions made on Himalayan glaciers during the last 15 years and future perspective for the next 5 years".

n. **23rd Lunar and Planetary Science Conference, Houston, Texas, USA, March 16-20 ,1992.**

1. Goswami, J.N., Srinivasan, G. and Ulyanov, A.A. "Isotopic disequilibrium in co-existing phases in an Efremovka CGI : An Ion Probe study".

2. Murty, S.V.S. "Solar gases in Parsa enstatite chondrite".

o. **International IGBP Conference, Tokyo, Japan, March 27-29, 1992.**

1. Chakraborty, S. and Ramesh, R. "Monsoon records in Indian Corals".

Continental Palaeoclimate Studies

a. **14th International Radiocarbon Conference, Tucson, Ariizona, USA, May 20-24, 1991.**

1. Kusumgar, Sheela, Agrawal, D.P., Bhandari, N., Deshpande, R.D., Raina, A., Sharma, C. and Yadava, M.G., "Lake sediments from the Kashmir Himalayas: Inverted ^{14}C chronology and its implications".

b. **XIII INQUA Congress, Beijing, China, August, 2-9, 1991.**

1. Agrawal, D.P., Kusumgar, Sheela, Deshpande, R.D. and Sharma, C., "Palaeoclimatic evidence from Kashmir: An update".

c. **National Seminar on "Indian Archaeometallurgy", Benaras Hindu University, Varanasi, October 2-4, 1991.**

1. Agrawal, D.P. and Seshadri, Rajam, "The Metallurgical Tradition of the Harappans".

d. **Papers presented at the International Symposium on "Evolution of Deserts", Physical Research Laboratory, Ahmedabad, February, 11-14, 1992.**

1. Agrawal, D.P., "Last 20 kyr of climate change and desertification in SE Asia".
2. Gupta, S.K. and Sharma, P., "Climate of high altitude tropics during last glacial maximum: A Puzzle".
3. Gupta, S.K. and Sharma, P., "Ice cover on Tibetan Plateau during Late Quaternary: A discussion".

e. **Poster paper presented at the National Space Science Symposium held at PRL, Ahmedabad, March 10-14, 1992.**

1. Sharma, P. and Gupta, S.K., "Late Quaternary ice cover on the Tibetan plateau and its palaeoclimatic implications".

THEORETICAL PHYSICS

Astrophysics

a. **International Conference on Gravitation and Cosmology, Ahmedabad, December 1991.**

1. Tripathy, S.C., Dwivedi, C.B., Das, A.C. and Prasanna, A.R., "The radial-azimuthal instability at the inner edge of the accretion disk".
2. Virbhadra, K.S., "An exact solution of Einstein's equations for a tachyon in a de Sitter universe".

b. **Workshop on Plasma Astrophysics, Bangalore, March 1992.**

1. Prasanna, A.R., "Dynamics of gravitating plasma" (gave two invited talks).

c. **XIVth Conference of the Indian Association of General Relativity and Gravitation, Anand, December 10-11, 1991.**

1. Virbhadra, K.S., "Energy-momentum localization in general relativity" (Invited Talk).

Meteorology and Climate Studies

a. **C-MMACS Meeting on Mathematical Modelling of the Ocean, National Aeronautical Laboratory, Bangalore, June 25-26, 1991.**

1. Krishnakumar, V., Kasture, S.V. and Keshavamurty, R.N., "Instabilities of monsoon and equatorial flows".
2. Krishnan, R., Keshavamurty, R.N. and Kasture, S.V., "Idealized studies of the dynamics of the Walker circulation".

b. **National Symposium on Advances in Tropical Meteorology with emphasis on Satellite Applications, Ahmedabad, February 19-22, 1992.**

1. Keshavamurty, R.N., "Monsoon variability - modelling and theoretical aspects".
2. Satyan, V., "Complex climate models".
3. Kasture, S.V., Krishnan, R., Keshavamurty, R.N. and Satyan, V., "A model study of the northward propagation of the zonal wind shear zone in the monsoon region".
4. Krishnan, R., Keshavamurty, R.N. and Kasture, S.V., "Diagnostic studies of the vorticity balance in the tropical upper atmosphere of a nonlinear global spectral model".
5. Krishnakumar, V., Kasture, S.V. and Keshavamurty, R.N., "Moist baroclinic instability and the growth of monsoon depressions - linear and nonlinear studies".

c. **International Symposium on Evolution of Deserts, Physical Research Laboratory, Ahmedabad, February 11-17, 1992.**

1. Krishnakumar, V., Krishnan, R. and Kasture, S.V., "A model study of active and break monsoon conditions over western India".

d. **National Space Science Symposium, Physical Research Laboratory, Ahmedabad, March 11-14, 1992.**

1. Krishnan, R., Keshavamurty, R.N. and Kasture, S.V., "Northward movement of the 30-40 day oscillation in an axisymmetric global spectral model".
2. Krishnakumar, V., Keshavamurty, R.N. and Kasture, S.V., "Growth mechanisms of the summer monsoon onset vortex - linear and nonlinear studies".

e. **Pre-Planning Meeting on Study of Land-Surface Processes, Indian Institute of Tropical Meteorology, Pune, February 25-26, 1992.**

1. Satyan, V. and Keshavamurty, R.N., "Modelling land surface processes".

Plasma Physics

a. **Plasma Physics College, International Centre for Theoretical Physics, Trieste, Italy, May 27-June 21, 1991.**

1. Buti, B., "Chaos in magnetoplasma" (organised the College as a Director and gave a lecture).

b. **Symposium on Plasma Dynamics - Theory and Applications, Trieste University, Trieste, Italy, June 26-28, 1991.**

1. Buti, B., "Nonlinear and chaotic Alfven waves" (invited talk).

c. **IAU Symposium No. 152, Chaos, Resonance and Collective Dynamical Phenomena in the Solar System, Angra dos Reis, Brazil, July 15-19, 1991.**

1. Buti, B., "Chaotic Alfven waves in solar and cometary plasmas" (invited talk).

d. **21st General Assembly of IAU, Beunos Aires, Argentina, July 23-August 1, 1991.**

1. Buti, B., "Chaos in Astrophysical Plasmas (organized a Commission Meeting on 'Plasma Astrophysics' and gave an invited talk).

e. **Mini Indo-US Workshop on IPS and Propagating Solar Disturbances, PRL, Ahmedabad, September 25-26, 1991.**

1. Buti, B., "Coherence and Chaos in Interplanetary Plasma" (invited talk).

f. **Sixth National Symposium on Science and Technology of Plasmas, Devi Ahilya Vishwavidyalaya, Indore, December 17-21, 1991.**

1. Buti, B., "Coherence and Chaos in Magnetoplasmas" (invited talk).

g. **61st Annual Meeting of the National Academy of Sciences, Meerut, December 19-21, 1991.**

1. Buti, B., "Coherence in Chaos" (invited talk).

h. **Workshop on Nonlinear Waves and Turbulence, JNU, Delhi, December 23-29, 1991.**

1. Buti, B., "Chaos in Magnetoplasmas" (invited talk).

i. **III Potsdam - V Kiev International Workshop on Nonlinear Processes in Physics, Clarkson University, Potsdam, New York, USA, August 1-11, 1991.**

1. Rao, N.N., "Mode conversions in ionospheric modification experiments (invited talk).

j. **National Space Science Symposium, PRL, Ahmedabad, March 11- 14, 1992.**

1. Das, A.C., "Planetary magnetosphre and the interaction with solar wind (Invited Talk).

2. Das, A.C. and Ip, W.-H., "Particle acceleration by kinetic Alfven waves in the Io plasma torus".

3. Rao, N.N. and Kaup, D.J., "Electron cyclotron harmonic waves during ionospheric modification experiments".

Atomic and Molecular Physics

a. **First SERC School in Atomic and Molecular Physics, Calcutta, November 11-30, 1991.**

1. Dewangan, D.P., Scattering of electrons and positrons at intermediate energies (lecture course).

Classical and Quantum Mechanics

a. **I SERC School on Plasma Physics : Nonlinear Waves and Dynamics, Jaipur, July 1-20, 1991.**

1. Sitaram, B.R., "Nonlinear Dynamics" (course of lectures).

b. **VII SERC School on Theoretical High Energy Physics, Ahmedabad, December 23, 1991 - January 18, 1992.**

1. Sitaram, B.R., "Group Theory" (invited talk). Conducted tutorials in Field Theory.

Nuclear Physics

a. **DAE Symposium on Nuclear Physics, Bombay, December 26-30, 1991.**

1. Devi, Y.D. and Kota, V.K.B., "E4 Strength Distributions in Sm : sdg IBM predictions".

2. Devi, Y.D. and Kota, V.K.B., "Scissors states in even-odd N=82-126 shell nuclei : enhancement in B(M1) strength due to g-bosons".

3. Devi, Y.D. and Kota, V.K.B., "E4 matrix elements in Pt : sdg IBM results".

4. Kota, V.K.B. and Majumdar, D., "Spin cut-off and occupancy densities and their S-decompositions : the non- interacting particle case".

5. Kota, V.K.B. and Majumdar, D., "Unitary decomposition of nucleon interactions all across the periodic table".

6. Rath, A.K. and Praharaj, C.R., "Band structure and signature effects in odd-Z rare-earth nuclei".

7. Khadkikar, S.B. and Parikh, J.C., "Quark-gluon plasma equation of state in a relativistic harmonic confinement model".

8. Khadkikar, S.B. and Vijayakumar, K.B., "Spin-orbit N-N interaction from COGEP".

9. Khadkikar, S.B. and Vijayakumar, K.B., "The spin-orbit interaction from COGEP".

10. Vijayakumar, K.B. and Khadkikar, S.B., "Tensor interaction from COGEP".

11. Khadkikar, S.B. and Vijayakumar, K.B., "The effect of confinement of gluons on N-N scattering, p-p and n-p differential cross section".

b. Group Theory and Special Symmetries in Nuclear Physics, Ann Arbor, Michigan, USA, September 19-21, 1991.

1. Devi, Y.D. and Kota, V.K.B., "Scissors states in SU(3) SU(2) limit of sdg IBM for even-odd nuclei in N=82-126 shell.

Particle and Fields

a. Workshop on Physics and Astrophysics of Quark Gluon Plasma, VECC, Calcutta, July 1991.

1. Parikh, J.C., "Equation of State for Quark Gluon Plasma" (Invited Talk).

b. Conference on Medium and High Energy Nuclear Physics, Saha Institute of Nuclear Physics, December 1991.

1. Parikh, J.C., "Equation of State for Quark Gluon Plasma" (Invited Talk)

c. Mini-Workhop on "Beyond the Standard Model and Supercollider Physics", University of Bombay, Bombay, February 10-13, 1992.

1. Rindani, S.D., "Workshop Summary" (Invited Talk).

Theses Submitted During 1991-92

Choudhury, D.

Fermion Masses and Mixing (May 1991).

Devi, Y.D.

Some Studies in the sdg Interacting Boson Model of Atomic Nuclei (June 1991).

Tripathy, S.C.

Plasma Magnetosphere around Compact Objects (June 1991).

Mathew, K.J.

Xenon production cross-sections on Barium targets by energetic protons from accelerators and simulation experiments on model meteoroids (July 1991).

Virbhadra, K.S.

Spin Precession of Charged Particles and Energy and Angular Momentum in Curved Spacetime (August 1991).

Vijayakumar, K.B.

Study of N-N Interaction with Confinement Model for QCD (December 1991).

Raju, K.P.

High resolution interferometry objects (February 1992).

PRL Technical Notes

TN-91-72

The fringes of the Thaltej Radiotelescope by Pramod Gupta.

TN-91-73

Group theoretical approach to nuclear collective motion, by V.K.B. Kota and J.C. Parikh

Symposia/Workshop Organised at PRL

1. Symposium on Persspective in Solar System Research, July 28, 1991.
2. INDO-US Mini Workshop on Interplanetary Scintillations and Propagating Solar Disturbances, 25-26 September, 1991.
3. International Conference on Gravitation and Cosmology, December 13-18, 1991.
4. VII SERC School on Theoretical High Energy Physics, December 23, 1991 - January 18, 1992.
5. Symposium on Solar Physics and Interplanetary medium, January 30, 1992.
6. International Symposium on Evolution of Deserts, February 11-19, 1992.
7. National Space Science Symposium March, 11-14, 1992.

Conferences/Symposia attended during 1991-92

ASTRONOMY AND ASTROPHYSICS

Dr.S.K.Alurkar

Liblice, Czechoslovakia

Symposium on "Solar Connection with Transient Interplanetary Processes (SOLTIP)", September 30 - October 5, 1991.

Dr.B.G.Anandarao

Tucson, Arizona, USA

Seventh Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, October 9-12 , 1991.

Dr.A.Bhatnagar

Ignazu, Argentina

IAU Colloquium No.133 "Erupting Solar Flares" August 2-6, 1991.

Tucson, Arizona, USA

Global oscillation Network group meeting, April 15-17, 1991.

Dr.S.K.Alurkar
Dr.A.Bhatnagar
Dr.A.Ambastha
Dr.S.S.Degaonkar
Dr.Hari Om Vats
Dr.A.K.Sharma
Dr.P.Janardhan
Dr.J.N.Desai
Mr.A.D.Bobra
Miss N.Srivastava
Mr.K.S.Lali
Mr.N.S.Nirman
Mr.R.C.Shah
Mr.P.Venat

Ahmedabad

Indo-Us Mini-Workshop on "Interplanetary Scintillation and Propagating Solar Disturbances", PRL, September 25-26, 1991.

Dr.J.N.Desai
Dr.M.R.Deshpande
Dr.B.G.Anandarao,
Dr.Hari Om Vats
Dr.U.C.Joshi
Dr.N.M.Ashok
Dr.T.Chandrasekhar
Dr.(Mrs.)B.S.Shylaja
Dr.P.Janardhan
Mr.A.D.Bobra
Mr.K.S.Lali
Mr.N.S.Nirman
Mr.R.C.Shah
Mr.P.Venat
Dr.D.P.K.Banerjee,
Ms.P.Seema
Mr.J.S.Chauhan
Mr.L.Misra
Mr.S.Ragland

Ahmedabad

National Space Science Symposium 1992 PRL, March 11-14, 1992.

Dr.B.G.Anandarao
Dr.N.M.Ashok
Dr.J.N.Desai
Dr.M.R.Deshpande
Dr.U.C.Joshi
Mr.L.Misra

Ahmedabad

International Conference on Gravitation and Cosmology, PRL, December 13-18, 1992,

Dr.S.K.Alurkar
Dr.Hari Om Vats
Dr.A.K.Sharma
Dr.P.Janardhan

Calcutta

GMRT Winter School on "Solar Radio Astronomy and Interplanetary Medium", January 10-18, 1992.

Dr.U.C.Joshi

Raipur

Workshop on 'Quasar Continuum and Emission Spectra' Ravi Shankar University, December 23-27, 1992; Sponsored by IUCAA.

Dr.N.M.Ashok

Pune

Mini Workshop on Automated Photoelectric Telescopes, IUCAA, Pune, October 21-25, 1991.

Dr.N.M.Ashok
Dr.T.Chandrasekhar
Dr.J.N.Desai

IUCAA Workshop on Experimental Techniques in Space Science and Astronomy, Gujarat University, February 24-28, 1992.

Dr.U.C.Joshi

Bangalore

UN/ESA Workshop on Basic Space Sciences ISAC, April 30 - May 3, 1991;

Dr.N.M.Ashok
Dr.U.C.Joshi
Ms.P.Seema

Pune

Image Processing in Astronomy, IUCAA, July 22-26, 1991.

Dr.A.Bhatnagar
Dr.J.N.Desai
Dr.B.G.Anandarao
Dr.U.C.Joshi
Miss P.Seema

Pune

Group Monitoring workshop on DST funded projects in Astronomy and Astrophysics, June 21-22, 1992.

Dr.Hari Om Vats

Bombay

Conference on "Modern trends in geomagnetic studies at low latitudes", December 2-4, 1991.

Mr.K.J.Shah

Delhi

XXVI Annual Convention of the Computer Society of India on "IT in every day life", September 29 - October 2, 1991.

PLANETARY ATMOSPHERE AND AERONOMY

Dr. H. Chandra
Dr. G.D. Vyas

Kolhapur Workshop on "AICPITS scintillation network - Data analysis of March-April 1991 campaign", Shivaji University, June 3-8, 1991.

Dr. H. Chandra
Mr. D.P. Raju

Kolhapur

SERC school on " upper atmospheric studies", Shivaji University, June 10 - July 1, 1991.

Dr. H. Chandra
Dr. H.S.S. Sinha
Dr. R. Sridharan

Dr. R. Sekar

Ahmedabad, PRL

Symposium on "Perspectives in Solar System Research", July 29, 1991.

Dr. H. Chandra
Dr. H.S.S. Sinha

Vienna, Austria

XX IUGG General Assembly and IAGA Symposium, August 11-24,1991.

Dr. H. Chandra
Dr. S.P. Gupta

Ahmedabad, India

Indo-US Mini Workshop on "Interplanetary Scintillations" and Propagating Solar Disturbances, September 25-26, 1991.

Prof. B.H. Subbaraya

Le Diableres, Switzerland

International Ozone Trends Panel Meeting, October 14-18, 1991.

Dr. S.M. Ahmed
Mr. V. Prahlad

First SERC Scool of "Atomic and Molecular Physics" held at IACS, Calcutta, November, 1991.

Dr. S.P. Gupta
Dr. H. Chandra

Bombay

Symposium on "Modern trends in geomagnetic studies at low latitudes", IIG Colaba, December 2-4, 1991.

Mr. V. Prahlad
Mr. S. Ramachandran

Ahmedabad

International Conference on "Gravitation and Cosmology, PRL, December 13-18, 1991.

Mr. Y.B. Acharya

Ahmedabad

ISRO-Electronics Industry Meeting, SAC, December 18-19, 1991.

Dr. H. Chandra
Dr. S.P. Gupta

Dr. A. Jayaraman
Dr. H.S.S. Sinha
Dr. Shyam Lal
Dr. R. Sridharan
Dr. R. Sekar
Dr. G. Subramanian
Dr. B.H. Subbaraya
Dr. Vijay Kumar

Ahmedabad, PRL

Symposium on "Solar Physics and Inter Planetary Medium", January 28, 1992.

Dr. A. Jayaraman
Mr. Y.B. Acharay

Ahmedabad

National Seminar on "Applications of Lasers", L.D. Engineering College, February 1, 1992.

Prof. B.H. Subbaraya
Dr. A. Jayaraman
Mr. S. Ramachandran

Ahmedabad

International Symposium on "Evolution of Deserts", PRL, February 11-14, 1992.

Mr. R.N. Misra

Roorkee

All India conference on "Applied Instrumentation", Roorkee University, February 14-15, 1992.

Prof. B.H. Subbaraya
Dr. H. Chandra
Dr. A. Jayaraman
Dr. H.S.S. Sinha
Dr. Shyam Lal
Mr. S. Ramachandran

Ahmedabad, India

National Symposium on "Advances in Tropical Meteorology with Emphasis on Satellite Applications", SAC, February 19-22, 1992.

Dr. B.H. Subbaraya
Mr. S. Ramachandran

Poona

Workshop cum Preplanning Meeting on "Study of Land Surface Process", IITM, February 25-26, 1992.

Dr. R. Sridharan

Bangalore

Third progressive group monitoring workshop of AICPITS, IIA, February 27-29, 1992.

Dr. D.K. Chakrabarty
Dr. M. Lal
Dr. H.S.S. Sinha

Ahmedabad,

Workshop on Experimental Techniques in Space Sciences & Astronomy, Gujarat University, February 1992.

Dr. B.H. Subbaraya
Dr. Vijay Kumar
Dr. S.P. Gupta
Dr. R. Sekar
Dr. A. Jayaraman
Dr. R. Sridharan
Dr. G. Subramanian
Dr. Shyam Lal
Dr. D.K. Chakrabarty
Dr. H.S.S. Sinha
Dr. Harish Chandra
Dr. K.P. Subramanian
Dr. G.D. Vyas
Dr. S.A. Haider
Mr. R. Narayanan
Mr. N.K. Modi
Mr. K.P. Raju
Mr. S.R. Das
Mr. S. Ramachandran
Mr. R. Gurubaran
Mr. Manohar Lal
Mr. Y.B. Acharya
Mr. S.K. Banerjee
Mr. R.N. Misra
Mr. V. Prahlad
Mr. I.T. Kripalani
Mr. A.P. Gohil
Mr. I.A. Prajapati
Mr. S. Venkatramani

National Space Science Symposium, PRL, March 11-14, 1992.

Dr. Shyam Lal
Mr. M. Lal

Kyoto, Japan

International Symposium on "Middle Atmosphere Science", March 23- 27, 1992.

Dr. Shyam Lal

Tokyo, Japan

International Symposium on "Global Change (IGBP)", March 27-29, 1992.

Dr. G. Beig
Mr. M. Lal

Kyoto, Japan

International Conference on Middle Atmosphere Science, March 1992.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

Dr. N. Bhandari

Calgary, Canada

International Geological Correlation Programme (IGCP) No. 293 on Geochemical Event Markers in the Phanerozoic, August 1991.

Dr. N. Bhandari
Dr. S.K. Bhattacharya
Dr. Kishan Kumar
Dr. S. Krishnaswami
Dr. R.K. Pant
Dr. R. Ramesh
Mr. Someswara Rao
Dr. A.K. Singhvi

Ahmedabad, India

International Symposium on the Evolution of deserts, PRL, Feb.1991.

Dr. N. Bhandari
Dr. A. Dutta
Dr. J.N. Goswami
Dr. S. Krishnaswami
Mr. K.J. Mathew
Dr. S.V.S. Murty
Dr. K. Pande
Dr. M.M. Sarin
Dr. P.N. Shukla
Dr. B.L.K. Somayajulu
Dr. T.R.Venkatesan
Mr. D.N. Yadav

Ahmedabad, India

National Space Science Symposium, PRL, March 1992.

GEO-CP Area

Ahmedabad

Perspectives in Solar System Research, One day Symposium in honour of Prof. M.N. Rao's 60th Birth Day, July 29, 1991.

Dr. A. Dutta
Dr. J.N. Goswami

Jodhpur, Rajasthan

7th National Seminar on Solid State Nuclear Track Detectors, Oct. 1991.

Dr. J.N. Goswami

Monterey, California

54th Meeting of the Meteoritical Society, July 21-26,1991. Los Alamos, California

Workshop on Nucleosynthesis and isotope anomalies, July 1991.

Dr. S. Krishnaswami

Cambridge, UK

Attended the JGOFS Special Meeting convened in the Cambridge University in July 1991.

Bermuda

Attended the JGOFS Steering Committee Meeting during Sept.30-Oct. 4 and the JGOFS Indian Ocean Planning Meeting during Oct. 4-5, 1991.

Goa

National JGOFS Planning Meeting, NIO, Jan. 22-23, 1992.

Dr. S. Krishnaswami
Dr. V.N. Nijampurkar
Dr. B.L.K. Somayajulu

Vienna, Austria

20th IUGG General Assembly, Aug. 11-24, 1991.

Dr. V.N. Nijampurkar

Vienna, Austria

IAEA consultants meeting on Isotopic indicators of palaeoclimate, February 17-20, 1992.

Dehradun, India

Workshop on Himalayan Glaciology Research Programme, Wadia Institute of Himalayan Geology, Mar. 20-21, 1992.

Dr. R. Ramesh

Tokyo, Japan

International IGBP Conference, Mar.27-29, 1992.

Dr. A.K. Singhvi

Perth, Australia

International Symposium on Evolution of desert landscapes, University of Western Australia, Oct. 7-10, 1991.

Dr. B.L.K. Somayajulu

Georgia, USA

Second International Symposium on the Biogeochemistry of Model estuaries : Estuarine processes and Global Change, Jekyll Island, April 14-20, 1991.

Continental Palaeoclimate Studies

Dr. Sheela Kusumgar

Tucson, USA

Liquid Scintillation Workshop, Application for Radio carbon dating. Pre-Conference Workshop, May 18-19, 1991.

14th International Radiocarbon Conference, May 20-24, 1991.

Dr. D.P. Agrawal

Beijing, China

XIII INQUA Congress, August 2-9, 1991. Varanasi National Seminar on Indian Archaeometallurgy, BHU, October 2-4, 1991.

Allahabad Birbal Sahni Centenary Confference, November 14-16, 1991.

International Symposium on Evolution of Deserts, PRL, February 11-14, 1992, Ahmedabad

Dr. D.P. Agrawal
Dr. S.K. Gupta
Dr. P. Sharma
Dr. Sheela Kusumgar
Dr. S.K. Gupta
Dr. P. Sharma

Ahmedabad

National Space Science Symposium - 1992, PRL, March 10-14, 1992.

THEORETICAL PHYSICS

Mr. B. Brahmachari
Dr. B. Buti
Mr. H.S. Chakraborty
Dr. A.C. Das
Mr. G. Datta
Dr. D.P. Dewangan
Dr. Sai Iyer
Dr. K. Jain
Dr. A.S. Joshipura
Mr. D. Majumdar
Mr. S.V. Kasture
Dr. R.N. Keshavamurty
Dr. S.B. Khadkikar
Dr. V. Krishnakumar
Mr. R. Krishnan
Dr. A.R. Prasanna
Dr. A.K. Rath
Dr. N.N. Rao
Mr. M.K. Samal
Dr. V. Satyan
Dr. V.B. Sheorey
Dr. B.R. Sitaram
Mr. S.C. Tripathy
Mr. K.S. Virbhadra

Ahmedabad

International Conference on Gravitation and Cosmology, PRL, December 13-18, 1991.

Mr. B. Brahmachari
Mr. G. Datta
Mr. M.K. Samal
Dr. B.R. Sitaram
Dr. A.S. Joshipura

Ahmedabad

VII SERC School on Theoretical High Energy Physics, PRL, December 23, 1991 - January 18, 1992.

Mr. H.S. Chakraborty
Dr. D.P. Dewangan

Calcutta

First SERC School in Atomic and Molecular Physics, November 11-30, 1991.

Dr. B. Buti

Ahmedabad

Mini Indo-US Workshop on IPS and Propagating Solar Disturbances, PRL, September 25-26, 1991.

Argentina

21st General Assembly of IAU, Buenos Aires, July 23-August 1, 1991.

Brazil

IAU Symposium No. 152 - Chaos, Resonance and Collective Dynamical Phenomena in the Solar System, Angra dos Reis, July 15- 19, 1991.

Madurai

Seminar on Behavioural Science-Scope and Limitations, Kamaraj University, May 16, 1991.

Meerut

61st Annual Meeting of the National Academy of Sciences, India, December 19-21, 1991.

New Delhi

Seminar on Geology and Environment Management, INSA, October 3, 1991.

Seminar on Evolution and Genetics : A Colloquium on Some Aspects of Current Interest, INSA, August 7, 1991.

Workshop on Nonlinear Waves and Turbulence, Jawaharlal Nehru Univrsity, December 23-29, 1991.

Trieste, Italy

Plasma Physics College, International Centre for Theoretical Physics. May 27-June 21, 1991.

Symposium on Plasma Dynamics - Theory and Applications, Trieste University, June 26-28, 1991.

Dr. A.C. Das

Austria

XX General Assembly, IUGG, Vienna, August 11-24, 1991.

Dr. A.C. Das
Dr. N.N. Rao

Ahmedabad

Solar Physics and Interplanetary Medium, PRL, January 28, 1992.

Dr. A.C. Das
Mr. S.V. Kasture
Dr. R.N. Keshavamurty
Dr. S.B. Khadkikar
Dr. V. Krishnakumar
Mr. R. Krishnan
Dr. N.N. Rao
Dr. V. Satyan
Mr. S.C. Tripathy

Ahmedabad

National Space Science Symposium, PRL, March 11-14, 1992.

Dr. Y.D. Devi
Dr. K. Jain
Mr. D. Majumdar
Dr. S.B. Khadkikar
Dr. V.K.B. Kota
Dr. A.K. Rath
Mr. K.B. Vijayakumar

Bombay

DAE Symposium on Nuclear Physics, December 26-30, 1991

Dr. B. Buti
Dr. C.B. Dwivedi

Indore

Sixth National Symposium on Science and Technology of Plasmas, Devi Ahilya Vishwavidyalaya, December 17-21, 1991.

Dr. Sai Iyer

Bombay

Workshop on Observational Cosmology, TIFR, April 14-18, 1992

Dr. R.N. Keshavamurty
Dr. V. Krishnakumar
Mr. R. Krishnan
Dr. V. Satyan

Ahmedabad

International Conference on Evolution of Deserts, February 11-19, 1992.

Mr. S.V. Kasture
Dr. R.N. Keshavamurty
Dr. V. Krishnakumar
Mr. R. Krishnan
Dr. V. Satyan

Ahmedabad

National Symposium on Advances in Tropical Meteorology with emphasis on Satellite Applications, February 19-22, 1992.

Dr. R.N. Keshavamurty

Bangalore

Workshop on Preliminary Scientific Results of MONTBLEX Programme, Indian Institute of Science, January 16-17, 1992.

Dr. J.C. Parikh

Calcutta

Workshop on Physics and Astrophysics of Quark Gluon Plasma, VECC, July 1991.

Conference on Medium and High Energy Nuclear Physics, Saha Institute of Nuclear Physics, December 1991.

Dr. N.N. Rao

New York, USA

III Potsdam - V Kiev International Workshop on Non-linear Process in Physics, Clarkson University, Potsdam, August 1-11, 1991.

Dr. S.D. Rindani

Bombay

Mini-Workshop on "Beyond the Standard Model and Su-percollider Physics", University of Bombay, February 10-13, 1992.

Dr. V. Satyan

Pune

Preplanning Meeting on Study of Land Surface Proces-ses, Indian Institute of Tropical Meteorology, February 25-26, 1992.

Dr. B.R. Sitaram
Mr. S.C. Tripathy

Jaipur

I SERC School on Plasma Physics : Nonlinear Waves and Dynamics, University of Rajasthan, July 1-20, 1991.

Mr. S.C. Tripathy

Calcutta

GMRT Winter School on Solar Radio Astronomy and Interplanetary Medium, Institute of Radio Physics and Electronics, January 10- 18, 1992.

Pune

Young Astronomers' Meet, GMRT, February 10-13, 1992. Gave an invited talk on "Dynamics of accretion disks".

Mr. K.S. Virbhadra

Anand

XVIth Conference of the Indian Association of General Relativity and Gravitation, Anand, December 10-11, 1991.

COMPUTER CENTRE

Dr. C.S.R. Murty

Hyderabad

Second Indian Computing Congress, Dec 26-29, 1991.

ELECTRONICS LABORATORY

Mr. H.S. Mazumdar
Mr. S.D. Rawat
Mr. D.V. Subhedar
Dr. S.N. Pradhan

Ahmedabad

National Space Science Symposium in March 1991.

LIBRARY

Rhoda Bharucha

NIO, Goa

Seminar on "Modern Trends in Marine Science Bibliog-raphic Information Handling, 28.2.1992.

Visits to Universities/Research Organizations and Talks given there during 1991-92

ASTONOMY AND ASTROPHYSICS

Dr. B.G.Anandarao

GSFC, Greenbelt, MD,USA

STX, Greenbelt,MD,USA

Gave a talk on Mass loss mechanisms in Mira Variables. October, 1991.

Dr. N. M. Ashok

Hyderabad

Department of Astronomy, Osmania University, gave talks on "Infrared Studies of Classical Novae" and "Stellar Evolution Studies of Intermediate Mass Stars using IRAS two colour plots".

Dr. A. Bhatnagar

California

Institute of Technology, gave a talk on "Happenings at Udaipur Solar Observatory", May 1991.

Bangalore

Indian Institute of Astrophysics, gave a talk on "GONG Project for Helio Seismology", January, 1992.

Bombay

Tata Institute of Fundamental Research, gave a talk on "Overview of Global Oscillation Network Group" project, February, 1992.

Gauhati

Gauhati University, gave a talk on "Helioseismology" March, 1992.

Dr. J. N. Desai

Hyderabad

Centre for Advanced Studies in Astronomy, gave five talks on "Experimental Techniques for Photometry & Spectroscopy in Astronomy", April 1991.

Dr. M. R. Deshpande

Bangalore

Indian Institute of Astrophysics, gave a talk on "On the nature of Central Engine in Active Galactic Nuclei".

Dr. U.C. Joshi

Hyderabad

Centre for Advance Study in Astronomy (CASA), Osmania University, gave three lectures on Scope of Polarization Study, Blazars- an Overview, Star Formation in Dark Globules, March 1991.

Bangalore

Indian Institute of Astrophysics, gave a Colloquium on Variability in BL Lac Objects, February 1991.

Ahmedabad

Community Sicence Centre, gave a talk on Journey to the Universe.

Physical Research Laboratory, gave a talk on Journey to the Universe: under "Popularization of Astronomy (ASI activity) program.

Rajkot

Amateur Astronomer Association, gave a talk on Variable stars under "Popularization of Astronomy" under Amateur Astronomy Club Programme.

PLANETARY ATMOSPHERE AND AERONOMY

Dr. Vijay Kumar

Kanpur

Visited IIT and gave a lecture on "Atomic Physics in PRL", February, 1992.

Dr. B.H. Subbaraya

Bombay

Visited Indian Institute of Geomagnetism and gave a talk on Middle Atmosphere-Thermosphere Coupling on April 11, 1991.

Dr. S.P. Gupta

Bangalore

Visited Indian Institute of Astrophysics and gave a talk on "Plasma instabilities in equatorial ionosphere" on May 8, 1991.

Dr. D.K. Chakrabarty

Calcutta

Visited Institute of Radio Physics and Electronics, University of Calcutta and gave a talk on "Turbulence in the Middle Atmosphere" April 25-30, 1991.

Mr. M. Lal

Nagoya University, Japan

Visited Solar Terrestrial Environment Laboratory, Nagoya University, Toyo Kawa, Japan. Had discussion

with Prof. Kondo and gave a talk on "Problems of NO_2 measurements at 23°N", March 30- April 4, 1992.

Dr. B.H. Subbaraya

Hyderabad

Visited NRSA and gave a talk on "Tropical Atmospheric Chemistry and Radiation Relevance for IGBP Studies", June 11, 1991.

Dr. G. Beig

Boulder, USA

Visited National Centre for Atmospheric Research and gave a seminar on "Stratospheric ion composition model with detailed and simplified scheme", July - August, 1991.

Dr. H.S.S. Sinha

Lindau, Germany

Visited Max Planck Institute fur Aeronomy and gave a talk on "Plasma density irregularities produced through neutral air turbulence", August 25 - September 8, 1991.

Dr. H. Chandra

Dehra Dun

Visited the Defence Electronics and Applications Laboratory (DEAL), Dehra Dun and gave a talk on "Research in Aeronomy at PRL", November 25, 1991.

EARTH SCIENCE AND SOLAR SYSTEM STUDIES

Geocosmophysics

Dr. S.K. Bhattacharya

Calcutta

Invited by the Jadavpur University, Geology Dept. twice and gave two lectures each time during August 1991 and another two during March 1992.

Dr. J. N. Goswami

Houston, Texas

Visited the Lunar & Planetary Science Institute during 10-20 July 1991 and gave a talk on "Did the Sun go through a T- Tauri phase?".

Bombay, India

Visited the Tata Institute of Fundamental Research and gave a Colloquium on "Ion Probe : Applications in Astrophysical and Planetary Sciences".

Dr. S. Krishnaswami

New Haven, CT, USA

Gave a talk at the Dept. of Geology and Geophysics, Yale University, on Sr isotopes in GB river system : Role in temporal variations in Sr/ Sr of the oceans during the past 30 m.y.

Dr. R. Ramesh

Ahmedabad,India

Gave a talk on climate and mass extinctions at the Nehru Centre for Environment Education on November 27, 1991.

New Delhi, India

Attended the IGBP Modelling meeting at NPL and gave a talk on Modelling under JGOFS on February 14, 1992.

Dr. A.K. Singhvi

Bombay, India

Gave a colloquium at BARC on TL dating : Present Status, Problems and Prospects in August 1991.

Dr. B.L.K. Somayajulu

Columbia,SC,USA

Gave a talk at the Dept. of Geological Sciences,University of South Carolina on the Radio isotope investigations in the Arabian Sea., on April 26, 1991.

Goa, India

Gave a talk on Paleoclimates at a Workshop on Marine Archaeology on 1st November 1991.

Continental Palaeoclimate Studies

Dr. P. Sharma

Bangalore

Visited Centre for Mathematical Modelling and Computer Simulation (CMMACS) and gave a talk entitled, "Role of Tibetan Plateau in the Quaternary Glaciation", August 25-September 5, 1991.

Dr. S.K. Gupta

Roorkee

Gave two lectures on "Isotope Application to Hydrology", National Institute of Hydrology, October, 21-25, 1991.

Ahmedabad

Viksat, Nehru Foundation for Development, gave five lectures on "Water as Resource and its crisis".

Dr. D.P. Agrawal

Allahabad

Gave lecture on "Philosophy of Archaeology", Allahabad Museum, November 1991.

Bombay

Nehru Planetarium, gave lecture on "The Concept of Time", December 1991.

Camp Dholavira.

Gave six talks on "Environment, Technology and Dating of the Past", Dholavira Institute of Archaeology, February 1992,

THEORETICAL PHYSICS

Dr. B. Buti

Italy

Visited International Centre for Theoretical Physics, Trieste, and gave a talk on "Chaos in magnetoplasmas", during May-June 1991.

Visited Instituto Di Cosmo Geofisica, Torino, and gave a talk on "Chaotic processes in magnetoplasmas", in July 1991.

Visited University of Pavia, Pavia, and gave a talk on "Nonlinear turbulent processes in plasmas", in July 1991.

Visited CNR Institute of Plasma Physics, Milan, and gave a talk on "Coherent and chaotic Alfven waves", in July 1991.

Brazil

Visited Instituto de Fisica, UNICAMP, and gave a talk on "Chaos in magnetoplasmas", in August 1991.

Visited Institute of Space Research, Sao Paulo, and gave a talk on "Coherent and chaotic phenomena in space plasmas", in August 1991.

Dr. Y.D. Devi

Calcutta

Visited S.N. Bose National Centre for Basic Sciences and gave a talk on "The Role of Hexadecupole Degree of Freedom in Nuclei and the sdg Interacting Boson Model", in July 1991.

Roorkee

Visited Physics Department, University of Roorkee, and gave a talk on "The Role of Hexadecupole Degree of Freedom in Nuclei and the sdg Interacting Boson Model", in July 1991.

Dr. Sai Iyer

Pune

Visited Inter-University Centre for Astronomy and Astrophysics and gave a talk on "Centrifugal Force Reversal in General Relativity", in January 1992.

Dr. V. Krishnakumar

Cochin

Visited Department of Meteorology and Oceanography, Cochin University of Science and Technology, and gave two talks on "Growth mechanisms of the monsoon depressions and onset vortex" and "Low frequency oscillation of the monsoon", during March 23-24, 1992.

Dr. J.C. Parikh

Hyderabad

Visited Centre for Cellular and Molecular Biology and gave a talk on Neural Nets, in July 1991.

Cochin

Visited Department of Physics, Cochin University, and gave a talk on "Physics of the Quark Gluon Plasma", in August 1991.

Oregon, USA

Visited Oregon State University and gave a colloquium on "Quark Gluon Plasma - Collective Dynamics", in November 1991.

Dr. N.N. Rao

New York, USA

Visited Clarkson University, Potsdam, and gave two seminars on "Ionospheric heating experiments near electron cyclotron harmonic frequencies", during September 1989-September 1991.

Dr. S.D. Rindani

Madras

Visited the Institute of Mathematical Sciences and gave two seminars on "Leptonic CP Violation in Z-decay" and "Global Symmetry and the 17 KeV Neutrino", in May 1991.

Dr. V. Satyan

Cochin

Visited Department of Meterology and Oceanography, Cochin University of Science and Technology, and gave

three talks on "Deterministic chaos and monsoon variability", "Low frequency variability of monsoon" and "Monsoon depressions", during August 12-14, 1991. Also gave a course of lectures on "General circulation at climate", in October 1991.

Mysore

Visited Department of Studies in Physics, Mysore University, and gave three talks on "Deterministic chaos and monsoon variability", "Low frequency variability of monsoon" and "Monsoon depressions", during August 18-22, 1991.

Ahmedabad

Visited Department of Physics. Gujarat University, and gave a course on "Dynamical Meteorology", in January 1992.

Dr. V.B. Sheorey

Calcutta

Visited Indian Association for the Cultivation of Science, Jadavpur, and gave six talks at the First SERC School on Atomic and Molecular Physics, during November 11-17, 1991.

Visited S.N. Bose National Centre for Basic Sciences and gave a seminar on "Localized quantum wavefunctions in chaotic systems", during November 26-30, 1991.

LIBRARY

Rhoda Bharucha

Gujarat Vidyapith, Ahmedabad

Refresher Course on 'Recent Developments in the Field of Information Science & Technology, September 19 - October 18, 1991 and gave two lectures on "Information Generation".

Refresher Course on Library & Information Science, January 16 - February 5, 1992 and gave one lecture on "CCF Standardization".