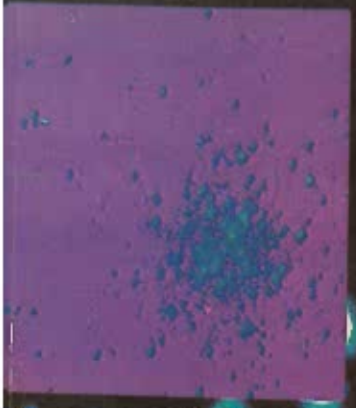
भौतिक अनुसंधान प्रयोगशाला
अहमदाबाद

PHYSICAL RESEARCH LABORATORY
AHMEDABAD



र्षिक रिपोर्ट
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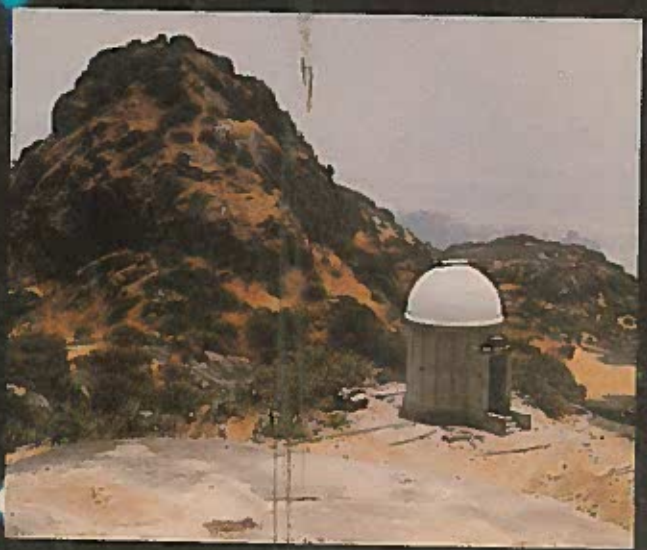
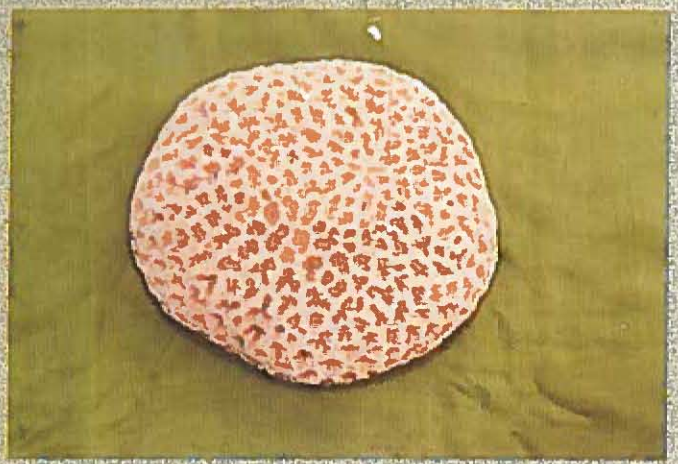
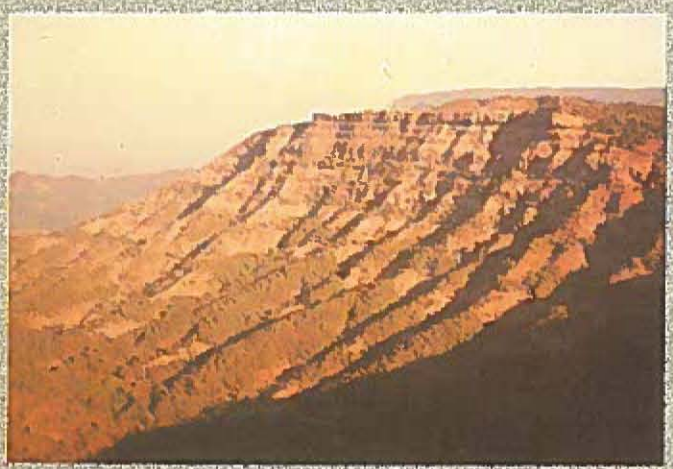
NUAL REPORT

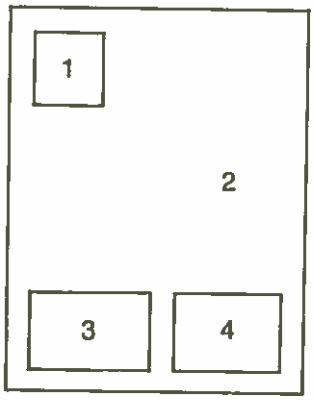






भौतिक अनुसंधान प्रयोगशाला
PHYSICAL RESEARCH LABORATORY

वार्षिक रिपोर्ट
Annual Report
1990–91



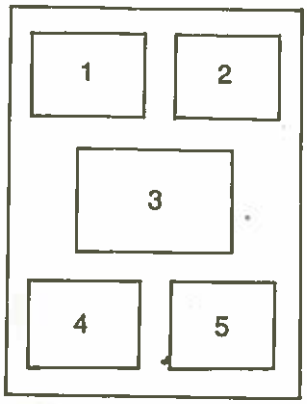
FRONT PAGE

Fig. 1 Globular cluster M-13 taken in near infrared band, with a CCD Camera. The white spotted stars are late type stars.

Fig. 2 Globular cluster M-13 taken with a CCD camera. The cluster contains more than one million stars with a pulsar in its centre.

Fig. 3 The observatory building for 1.2 m telescope at Gurushikhar, Mt. Abu.

Fig. 4 The observatory building for Schmidt Camera at Gurushikhar, Mt. Abu.



INNER BACK PAGE

Fig 1. All sky camera being assembled for 630 nm airglow observations at Mt. Abu.

Fig 2. Gas chromatograph laboratory for trace gas analysis.

Fig 3. Experimental device for Aharanov-Bohm analogue in classical mechanical domain (p. 15)

Fig 4. Computer facilities at IPS Station, Thaltej.

Fig 5. A balloon borne chemical release experiment at final check up prior to launch on 22 December, 1990.

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CONTENTS

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Introduction

In any scientific instituion, such as PRL, there are at least four major ingredients that are necessary so that the institution may continue its march towards the highest reaches of excellence. Perhaps, the foremost among these is the general academic ambience which continually feeds the scientists with a high degree of stimulation and challenge to achieve their best. It ought also to expose the scientists to the challenging problems of the day which they could try their hands on. (How many of us, for instance, in our younger school days, have been able to resist the temptation of trying to "trisect an angle" using a compass and a ruler?). However, the academic ambience is like a "self consistent field" in many body physics which can be contributed to only by the particles themselves which all move in it and are affected by it. It is, therefore, the academic community of the institution which ought to be individually and collectively responsible for the quality of the academic ambience. Of course, it is the senior members of the community who should, perhaps, bear a greater share of the responsibility, but unless the junior members also appreciate the importance of this ambience, it will not sustain.

However, as I have expressed on earlier occasions in the past, creation and sustenance of such an ambience where creativity flourishes, is a long and hard job which requires sustained effort over a long period of time and which requires continuing critical examination of scientific ideas and results in a process which may be termed as "scientific distillation". The collective aim of the scientific community ought to be to carry on the process of scientific distillation to finally be able to experience the fragrance of the final distillate.

What holds for scientific ideas and results holds for the evolution and development of individual scientist as well if only by virtue of the fact that they are the very participants in the process.

Of course, given the highly competitive nature of the scientific world today, it is important that an institution be equipped with the state-of-the-art facilities and scientific equipments. And this may be regarded as the second important ingredient for scientific excellence. It ought to be stated that the Laboratory has always tried to keep itself equipped with the best of equipment and technology. The acquisition recently of the Ion micro-probe for carrying out the isotopic analysis work for the solar system studies is an example. During the current Five-year plan P.R.L. has planned to equip itself with a laser facility both for the lidar studies of the strastopheric aerosols as well as for the laboratory studies of molecules.

In the same spirit, the Laboratory is now planning for a new computing environment which would replace the now 10-yr old DEC-10 system. The new computing environment will not be just another new computer, but will be a three level network system consisting of a set of high speed "compute-servers" supported at lower levels by a set of "work stations" and PC's. The system will also have a library node and an administrative node for the objective of complete computerisation of library services and administrative functions. Thus apart from the scientific computation that the new computer system will provide, it will also add new dimensions to administration and library services.

While the state of the art equipment and technologies are certainly very important to make high precision and sensitive measurements required in science research, these cannot be a replacement for the originality of ideas which alone make for excellence. An original idea must be there to be pursued using a precision equipment, if so needed. Indeed, an original idea, many a time, motivates its own original technology and instrumentation, while at times the idea may be so original that it can be carried out using only very simple equipment. The originality of ideas is thus the third of the ingredient (though should rank first in order of importance) for excellence.

Finally as the fourth point, one should mention, the individual's determination to excel and the choice of problems that one undertakes to address. There is something personal and private in a scientist that motivates him to undertake something unusual and challenging as against something of a standard variety which may yet be a high quality work. This would, of course, determine how a scientist would be classified among his peers! This will also eventually determine how an institution would be classified among the comity of institutions

New directions of research activities have been initiated in various areas in the continuing process of transformation whereby old activities which have lost their vigour are replaced by new ones on the advancing frontiers of science.

In the past few years a number of rocket and balloon experiments for the study of atmospheric chemistry, radiation and ionization parameters were

successfully conducted under the Indian Middle Atmosphere Programme. This year PRL was involved in a major international campaign called DYANA to study the interaction between chemistry and dynamics in the middle atmosphere. Furthermore a balloon flight with a joint PRL—MPAE (Max Planck Institute for Aeronomy) payload consisting of, a suntracking multichannel photometer of PRL and cryogenic air sampler of the MPAE was made successfully. Apart from the information on ozone and other minor species, the vertical distribution of methyl bromide, a major bromine containing gas has been obtained for the first time over the tropics.

A new programme of investigating the aerosol distribution in the stratosphere using lidar has been initiated. This study is an important component of understanding the radiation budget of the atmosphere. Along with the study of the minor constituents, such as ozone and nitric oxide whose studies have been carried out over the last eight years or so, the study of the aerosol distribution will provide an important data base for modelling the middle atmospheric processes.

In the upper atmosphere, attention has now been turned to the study of the structure and dynamics of its neutral component which has been so far ignored, partly because of difficult nature of the problem. Optical methods are being developed as an extension of the earlier night air glow photometry to include Fabry-Perot interferometry to study the temperature, structure and dynamics of the neutral component. A major breakthrough has been in the development of "day glow photometer" which has been successfully operated at PRL as a "first" in the world. This will serve as a very important instrument for the study of the neutral atmosphere during the day time as well.

In the area of Astronomy and Astrophysics, several interesting studies have been made. The arrival of Comet Austin in 1989 following the apparition of Comet Halley in 1985-86 gave us an opportunity of making a comparative study of the dust particles and the composition of the cometary environment. Polarimetric measurements of the coma have also revealed some very interesting phenomena, namely the existence in the entire coma of Comet Halley isolated pockets of high and low polarisation which should throw some light on the activity in the coma.

The visit of Comet Austin gave us another opportunity to also study the radio scintillation by its plasma tail as was done with Comet Halley earlier. Enhanced levels of scintillations as compared with that due to solar wind were confirmed when the radio source 2204+29 was occulted by Comet Austin.

Another important observation made during this year relates to the detection of rapid variability in polarisation in the BL LAC objects Mrk 421 with a periodicity of 19 min. A variation of flux was also recorded along with the variation of polarisation.

In Earth Sciences and Solar System Studies the story of the "Early Active Sun" continues to fascinate. PRL group has convincingly proposed an active early (the T-Tauri) phase for the Sun on the basis of the earlier noble gas studies. More work involving combined nitrogen, noble gas and nuclear track studies have been initiated to establish unambiguously or otherwise the presence of a T-Tauri phase.

Geomorphological investigations carried out along the cliffy coast of Saurashtra have provided valuable clues to past sea level changes and land movements (neotectonics). Two high sea-levels could be identified at 7m and 3m respectively after making corrections for an upthrow (neotectonic) of 8m. These are the first direct evidences demonstrating coastal instability and sea level change in Saurashtra.

Apart from the programmes belonging to the major areas and activities some of which have been highlighted here, some interesting laboratory studies carried out at PRL ought to be mentioned separately. Some of these studies belong to what has been designated as "Laboratory Astrophysics". These studies centre around measurements of photoabsorption and fluorescence cross-sections of some of the minor constituents that are important in atmospheric chemistry, for example, sulpher dioxide and cabon disulphide, which have been extensively studied this year. These studies will provide very important inputs for the modelling of the middle atmosphere.

Another laboratory study which has been carried out for quite a few years pertains to the properties of the motion of an ensemble of charged particles in magnetic fields. Though these studies have been giving rather unexpected and surprising results, the latest results are the most spectacular obtained so far. These show that the charged particles are affected by a magnetic vector potential even though the magnetic field in the space vanishes. This is a remarkable result because it apparently defies the well known, well established classical Lorentz equation of motion.

In the nuclear physics area a very successful

model has been developed for explaining the nucleon-nucleon scattering using the quark-gluon degrees of freedom. A single gluon exchange gives scattering phase shifts which are in excellent agreement with the experimental values.

In the meteorological studies, using a global atmospheric model with wave-CISK type of cumulus heating an eastward moving equatorial mode which resembles the observed 30-50 day monsoon oscillation has been generated. It has a two layer structure in the vertical, has global wave number one and is a composite of Kelvin and Rossby waves.

What has been given above is only a flavour of the work that has been carried out during the year 1990-91. There is of course, a certain amount of continuity in the work from one year to another. But there is also a certain degree of change, small changes of emphases and direction which must accompany a healthy evolving scientific programme.

There are two programmes of international significance which have already been launched. These are the International Geosphere Biosphere Programme (IGBP) and the Solar-Terrestrial Energy Programme (STEP). There is a strong overlap of PRL's scientific activities with both these programmes. While certainly the sweep of IGBP is very wide, it is possible to identify areas in PRL's scientific activities which could be meaningfully co-ordinated so as to constitute an effective component of the IGBP This is, in fact, much more true of the STEP

However, with respect to both these programmes, it is imperative to develop modelling activities which should be able to focus on the understanding of the inter-relationships among the different components constituting the programmes. No worthwhile understanding of the various complex interactive processes can be achieved without such a modelling activity. Though a beginning has been made the activity has yet to take off.

It is hoped that PRL scientists would be able to reorient some of their work plans so as to accommodate the objectives of the IGBP and the STEP over the next few years.

R K Varma

DIRECTOR

AWARDS AND HONOURS

Prof. Bimla Buti
Elected Fellow of the Third World Academy of Sciences

Prof. P. R. Pisharoty
Awarded the K.R. Ramanathan Medal (1990) for Atmospheric Sciences and Meteorology.

Prof. N. Bhandari
Selected for the National Mineral Award for the Year 1989-90 in Earth Science.

Dr. A. Sarkar
Awarded Young Scientist Medal 1990 in Earth Sciences

Prof. B.L.K. Somayajulu
Elected Fellow of the National Academy of Sciences, Allahabad.

Dr. A. K. Singhvi
Elected Fellow of the Indian Geophysical Union.

The research activities of the Astronomy and Astrophysics Division focusses on the studies of our Sun and exotic objects in our universe. The Infrared Astronomy group addresses to the various questions regarding active galactic nuclei, planetary nebulae and comets. The Solar and Plasma Astrophysics group studies various features of the solar wind plasma using the well-known interplanetary scintillations. The Udaipur Solar Observatory conducts studies on the Sun.

Infrared Astronomy

The focus of the scientific activity in the infrared astronomy area has been on (i) study of Active Galactic Nuclei (AGN), their short period variability in flux and polarization, and its implications on the energy production mechanism, (ii) investigating post asymptotic giant branch evolution of intermediate mass stars into the expanding shells of planetary nebulae (iii) exploring the environs of infrared bright stars at high spatial resolution using the technique of lunar occultations and (iv) study of the properties of Cometary dust grains.

Active Galactic Nuclei which include Quasars, BL Lac objects, Seyferts and Radio galaxies, are fascinating astrophysical objects producing enormous amount of energy about 10^{45} ergs/sec i.e. much more than our galaxy, from a much smaller region of space as implied by the time scale of quasi periodic variability in the flux emission rate. A detailed study of the short period flux variability in these objects should prove very valuable in understanding their true physical nature. Earlier, polarimetric observations by PRL scientists had established a 25 minute time scale of variability in the BL Lac object OJ 287. From observations made last year at Kavalur using 2.35 meter Vainu Bappu Telescope, PRL team now concludes on the basis of the power spectrum analysis that OJ 287 shows a flux and polarization variability on a time scale as short as 6 minutes. Six percent change in flux, observed during these short period variations amounts to a flux of about 300 billion suns ! This time scale of 6 minutes observed first by PRL scientists is now confirmed by a Finland group. This is the shortest time scale reported on such objects till now, at optical wavelengths.

During this year an imaging high resolution spectrometer was fabricated and tested with the 35cm Celestron telescope at Mt. Abu, and several interferograms on some HII regions and planetary nebulae were taken. The equipment uses a servo controlled and piezo electrically scanned Fabry Perot etalon and an imaging photon counting detector. Fabrication of this equipment has partly been supported financially by Department of Science & Technology, Govt. of India. The instrument will now be used for velocity mapping studies on planetary nebulae, HII regions and spiral galaxies.

An imaging polarimeter using CCD as a detector has been designed and constructed and is now operational. With this instrument spatial resolution down to seeing limit is possible on 1.2m telescope. Successful observations on Comet Austin and globular clusters have been made on a 6 inch telescope. From next season the instrument will be used on 1.2m telescope.

Study of Fresnel diffraction fringes, produced when a stellar source is occulted by a lunar limb, provides a means of achieving high spatial resolution without using the elaborate means of optical interferometry. The technique can especially be valuable in studying the morphology of circumstellar regions of infrared bright objects. The technique requires flux measurement on a millisecond time scale. PRL's near infrared photometer for lunar occultation studies has been fabricated and commissioned this year. In the realm of solar system physics, the group wants to continue the study of comets. A fascinating aspect of cometary plasma tails is the multitude of structural forms exhibited by them and their dynamical evolution, and it is only now that their relationships with the solar wind conditions are being properly understood. We are at present in the process of establishing a small Schmidt telescope camera, to record such events. The camera will be housed in a small building constructed for the purpose. The morphological pictures of plasma tail, together with Doppler shift informations provided by interferograms would be helpful in elucidating many aspects of solar wind cometary plasma interaction, especially when information provided on interplanetary solar wind conditions by the IPS observations are also available.

For any long term planning of astronomical activities at any site, careful quantitative evaluation of the site in terms of sky brightness, extinction and stellar scintillations, is very essential. A programme to this effect has been initiated to evaluate the Gurushikhar site.

In the following paragraphs these activities are

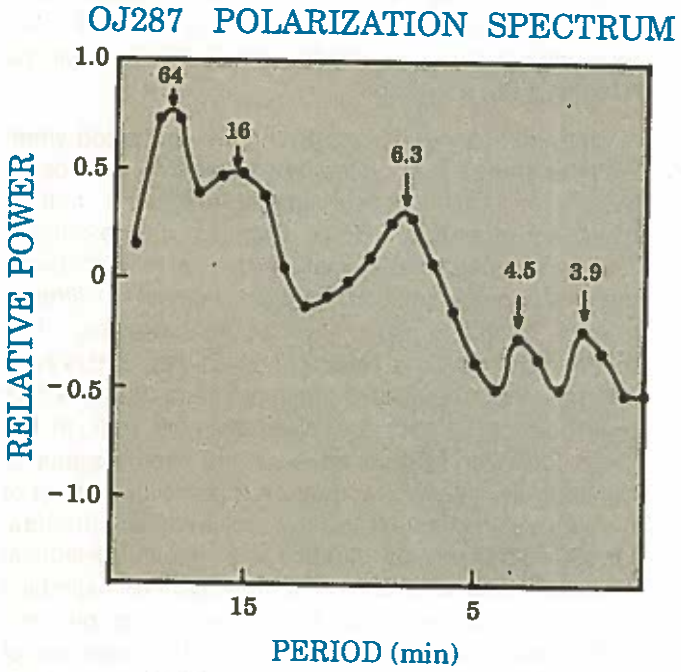
described in some detail.

Active Galactic Nuclei

Discovery of Shortest Period (6 minutes) Bursts in the BL Lac Object OJ287

As a part of our AGN (Active Galactic Nuclei) programme we have undertaken the study of BL Lac objects. The reason for selecting BL Lac objects is twofold :

(i) Amongst all AGNs BL Lacs show most rapid and large scale changes in flux and polarization.



The polarization spectrum of OJ 287 shows large energy at 6 min period, alongwith other periodicities. This is the shortest period burst observed so far. The short period variation suggest that shocked clumps of relativistic electrons are moving in the jet system of OJ 287. Recently Finland Astronomers have also confirmed the presence of 6 min variations in OJ 287.

(ii) The jets of BL Lac objects are directed towards the earth, hence we can have a close access to the central engine. Such a favourable situation does not exist for Quasars, Seyfert galaxies and Radio galaxies.

Our measurements of flux and polarization as a function of time are useful (a) in evaluating the size of the central engine (b) in evaluating the magnetic field around the central engine based on Eddington luminosity and the synchrotron life time calculations. Another important fact in BL Lac objects is that the observed luminosities are orders of magnitude greater than the theoretically calculated luminosities. This leads to one of the important conclusion that the relativistic beaming of plasma with large Doppler factor (usually more than 10) must be occuring in BL Lac objects. Of late the relativistic beaming model has received confirmation through VLBI (Very Long Baseline Interferometer) observations which show superluminal motions in some of the BL Lac objects.

In February 1991 we have made observations of three BL Lac objects OJ 287, MRK 421 and 0l90.4.

Out of.these three objects, which were observed on the same night only OJ 287 showed interesting burst activity in flux and polarization. The power spectrum analysis has shown clear periodicity of about 6 minutes. In these 6 minutes about 6 percent change in the flux of the galaxy was observed. This amounts to a release of energy equivalent to about 300 billion Suns. The period of 6 minute is the shortest burst period reported so far in the visual region of the spectrum.

The 6 minute period is now confirmed by the Finland astronomers. Our observations show other periodicities, in addition to 6 minute period. Another very important observational fact is that the burst variations in polarization and flux are well correlated (correlation coefficient about 0.72). Currently a model based on shock induced by a relativistic beams is being worked out.

(M.R. Deshpande, U.C. Joshi, A.K. Sen, J.S. Chauhan, N.M. Vadher, A.B. Shah and Chhaya. R. Shah).

Detection of Magneto - Bremmstrahlung Radiation from a Seyfert Galaxy NGC 2992

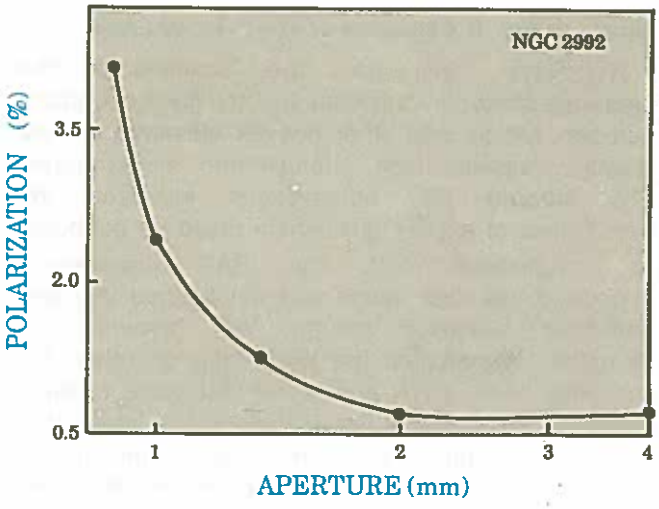
Seyfert galaxies are characterized by bright nucleus, broad emission lines and intense radiation in the infarred (nearly 100 times more radiation in the infrared than our galaxy emits in the visual). It is not yet known what is the exact physical process that leads to the release of intense radiation from the nucleus.

Two main processes are usually proposed.

(i) Thermal radiation

(ii) Magneto - Bremmashtrahlung (Synchrotron) radiation

If the radiation is of thermal origin one expects blackbody distribution in radiation with low or no polarization. On the otherhand if the radiation is of Magneto-Bremmastrahlung origin one expects large degree of polarization with a power law distribution in



The figure shows polarization in a Seyfert galaxy for different apertures (varying contributions from the galaxy). As the aperture is decreased, relative contribution from the galaxy, compared to the nucleus, decreases. This shows enhancement in polarization indicating the generation of synchrotron radiation from the nucleus of the galaxy. These conclusions are quite useful in deciding the processes of energy production in Seyfert galaxies.

the energy, but in actual practices what one has is a mixture of the two. The thermal radiation usually dominates the entire galaxy and is produced due to stellar light and the light scattered by the atoms, molecules and dust in the galaxy. On the other hand the Magneto - Bremmstrahlung radiation mainly originates from the nucleus. To decide which of the two mechanisms prevail it is important to do polarization measurements with different apertures. If one observes increase in polarization with the decrease in aperture then Magneto-Bremmstrahlung mechanism is operative. On the other hand if there is not much change in polarization with aperture variation one expects thermal radiation to dominate. With above facts in mind we have taken up the programme of Seyfert galaxies. In the galaxy NGC 2992 we have detected a strong evidence for Magneto - Brehmmstrahlung radiation. The observations were made on 2.35m telescope at Kavalur. Work on other galaxies is in progress.

(M.R. Deshpande, U.C. Joshi, A.K. Sen, J.S Chauhan, A.B. Shah, N.M. Vadher and Chhaya R. Shah).

Do cD Galaxies Harbour Active Nuclei?

Galaxies occur in clusters and super clusters in which majority of the galaxies are of eliptical type (about 80 percent). Towards the centre of these clusters of galaxies very luminous (10^{45} ergs/sec) supergiant elliptical galaxies called cD galaxies are found. cD galaxies are intrinsically quite rare, they are the most common optical counterparts of the double lobed radio surces. The questions are:do these cD galaxies have active nuclei? What is the mechanism for their large energy production? Do they show rapid variations? To find out answers to these questions we have taken up a systemetic study of cD galaxies. As a beginning, we have observed the galaxy 091833W3 in the Abell cluster A0779 and we have detected large amount of polarization (5 percent in U band). Another cD galaxy 3C465 in Abell cluster A2634 has also shown high degree polarization (6 percent in visual and 7 percent in red filter). The VLA maps at 1452 MHz show clear evidence of twin jets in both the galaxies. The position angle of the jets and the polarization angles are same for both the galaxies. cD galaxies are usually dustless (D in cD stands for it) and it is likely that the high degree of polarization may be of nonthermal origin. However further observations are being planned to explore a few more galaxies.

(M.R. Deshpande, U.C. Joshi, A.K. Sen, J.S. Chauhan, A.B. Shah, N.M. Vahder and Chhaya R. Shah).

Star Formation and Stellar Evolution

An Imaging Fabry-Perot Spectrometer for Velocity Field Mapping in Extended Astronomical Objects using a Two-dimensional Photon-counting Detector (IPD)

An Imaging Fabry Perot Spectrometer has been designed and constructed for the velocity field mapping from emission lines in extended astronomical objects like planetary nebulae, HII regions and spiral galaxies. Seeing limited (1-2 arc sec) imaging is expected in a field of view of 2-4 arc min with velocity resolution of 5-25 km/s (for different etalons). Etalons are scanned piezo electrically giving a wide spatial coverage within the field of view. The detector is a two dimensional photon counting detector (IPD) of diameter 18 mm. The instrument has been tested successfully in the laboratory and is expected to be used for scientific observations on large telescopes available in the country during the winter of 1991. A smaller version of the instrument which employs optically contacted etalons has been used to obtain interferograms in (OIII), H alpha and (NII) lines from some bright HII regions and Planetary Nebulae with a 35 cm Telescope at Mt. Abu. This project is funded partly by the Department of Science &

Technology, Government of India.

(B.G. Anandarao,P. Seema, D.Banerjee, J.N. Desai, N.S. Jog, H.I. Pandya and R.T. Patel)

Far-infrared Emission from a Sample of Starburst and Normal Spiral Galaxies observed by IRAS

Recently, analyses of IRAS observations have helped in understanding the possible physical processes behind the phenomenon of star formation in the nuclei of spiral galaxies. It had been shown that the late Hubble type galaxies exhibited larger infrared excesses than the early types. More recently a large sample of spiral galaxies have been analysed and divided into two broad categories (based upon certain morphological features) : (i) starburst galaxies and (ii) normal galaxies. The starburst galaxies are expected to show large infrared fluxes compared to the normal galaxies. An analysis of the IRAS photometric data (in 12, 25, 60 and 100 micron bands) on this particular sample of galaxies has been made by us with a view to find if there are marked differences in IR emission between these two classes.

Our analysis of a sample of high quality IRAS data shows that the starburst galaxies have larger excesses in 25 micron band than the normal ones. This can in general be attributed to the presence of a large or excess number of HII regions in the central or nuclear regions of starburst galaxies. In general, however, it appears that the IRAS data suffers from the drawback of large beam sizes (~a few arc mins.) due of which the contribution from the nuclear regions gets diluted with that from the disc component.

(P. Seema and B.G. Anandarao)

Variability of Emission Line Profiles in Be Stars

Be stars are emission peculiar among the B type stars with a circumstellar disc around them. Some of these stars are known to exhibit variability in the structure of their emission lines over time scales as short as a few minutes. It is possible to model the morphological structure of the circumstellar shell from emission line profiles. The variability in the line profiles would therefore put constraints on such models. A systematic high resolution spectroscopic study of this phenomenon would thus yield a better understanding of the underlying physical processes. We have initiated such a programme of observation of some of these Be stars namely Gamma Cassiopeae, Kappa Draconis etc in collaboration with Dr. R. Swaminathan of The Astronomy Department, Osmania University.

(B.G. Anandarao, D. Banerjee, N.S. Jog, K.S.B. Manian, R.T. Patel, F.M. Pathan, P. Seema and Mary Thomas)

Study of the IR Excesses of Wolf-Rayet Stars

Wolf-Rayet (WR) stars are identified by the presence of higher ionization spectral lines of carbon, nitrogen, helium and other heavier elements in their spectra, implying high photospheric temperatures. The infrared (IR) observations indicated the possibilities of excess flux, which could be attributed to circumstellar dust. The IRAS observations supported this idea and it was established that one particular subgroup namely WC favours dust formation. We studied the IRAS data on other WR subgroup namely WN and found that some of them also show excesses in the IR regions. We interpreted this excess in terms of the free-free and free-bound emission from the stellar wind. For this estimate the choice of the velocity law and the temperature gradient in the wind are very critical. We further noted that the observed excess in the Far IR region in some cases is not explained by the free-free emission alone. In four cases a definite indication of a cool blackbody contribution could be identified. The tempreture as estimated from the IRAS flux ratios is about 75 K. Curiously, these four cases are identified with ring nebulae and the estimated distances of the dust shells agree with the dimensions of the ring nebulae themselves.

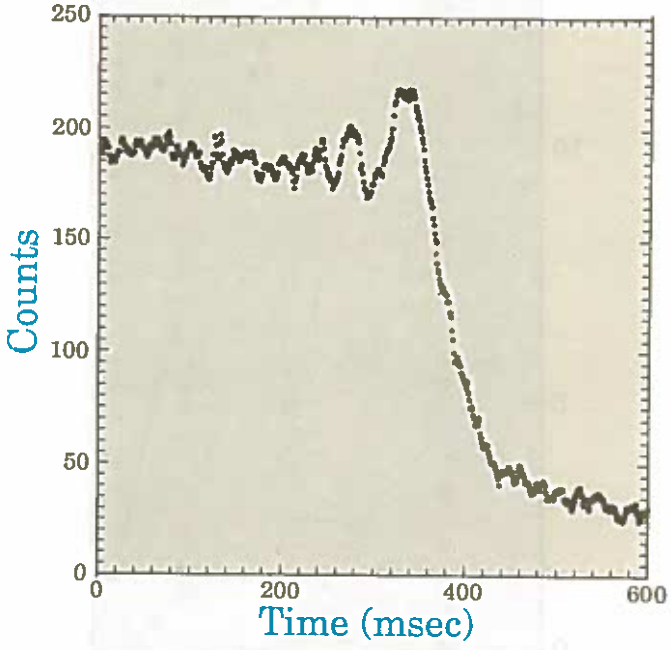
The study of the IR excesses were extended to the nearby galaxy namely the Large Magellanic Cloud (LMC), which contains only the earlier (hotter) subgroup. This means that the conterpart of the dust favouring WC does not exist in LMC. However, it was interesting to see that the IR fluxes of all stars were similar, irrespective of the subgroup and the binary nature. We identified some normal O type stars to establish this fact. The far infrared flux is contributed by atleast two distinct dust opacities (there may be more).The corresponding temperatures are about 30-35 K and 75-100 K. The cooler component agrees with the estimates of foreground contibution by other techniques. Therefore only the hotter component (75-100 K) has to be attributed to the circumstellar origin. The estimates of mass based on the observed flux leads to reasonably high values. This has to be attributed to the differences in the stellar luminosities and the environment as well. The stars of corresponding spectral types in the Galaxy do not indicate presence of dust.

(B.S. Shylaja and B.G. Anandarao)

Occultation Studies

Lunar Occultation

Observation of lunar occultations of stars and star forming regions of our galaxy is a powerful method which permits high angular resolutions down to milliarcsecond levels to be reached even with modest telescopes of 1 m size. The basic principle is to record the diffraction patterns produced when the source is occulted by the sharp limb of the moon and then analyse this pattern to recover source structure. Observations of lunar occultations in the visible region with a specially constructed photomultiplier based fast photometer were initiated last year at the 1.2m Gurushikhar telescope. During this year seveal occultation events involving stars SAO 98247, SAO 78557, SAO 78572 have been observed in the visible region. The emphasis during the year has been on observing lunar occultation in the near infrared region with a liquid nitrogen cooled InSb photometeric system. Good quality diffraction patterns have been successfully recorded at 2.2 microns from the following six sources, IRC 10578, IRC 10013, IRC 20034, IRC 30094, IRC 20190, IRC 20200. For several of these sources our observations provide the first lunar occulation light curves in the Infrared region.



The near infrared (2.2 micron) lunar occultation curve of IRC+10 013 obtained on 1990 December 26 using 1.2 m telescope at Gurushikhar, Mt. Abu.

The detailed analysis of the occultation traces involving fitting the data to a convolution of source profile and a point source diffraction (Fresnel) pattern is in progress to elucidate source structure.

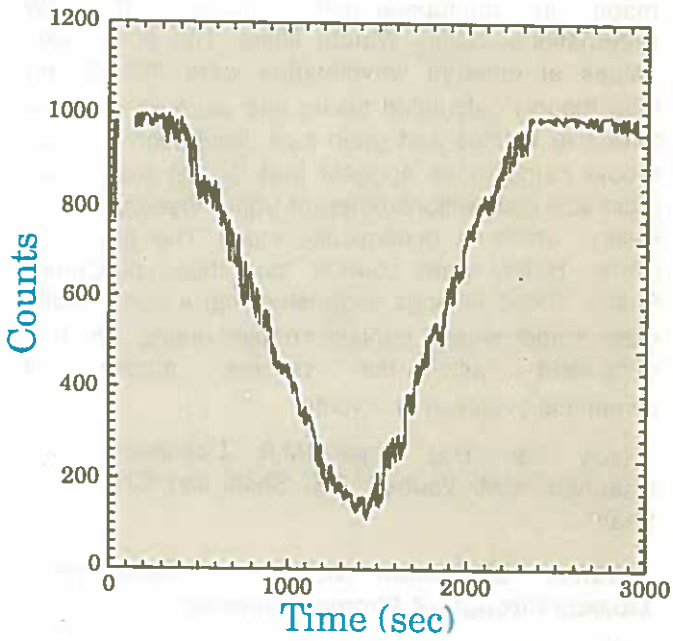
T. Chandrasekhar, N.M. Ashok and Sam Ragland).

Mutual Occultations of the Galilean Satellites of Jupiter

Every six years (half the orbital period of Jupiter) the equatorial plane of the planet sweeps across the earth and inner solar system. For a few months around this time the Galilean satellites which lie close to this equatorial plane of Jupiter undergo mutual occultations and eclipses as seen from the earth. Observations of these events are important on two counts.

(i) Ephemeris of the Jupiter system is known to an accuracy of only ~100 km while observations of mid times of mutual events can improve the accuracy to ~ 10 km. This is particularly important to precisely target the Galileo Space Probe which will reach the Jupiter system in 1995.

(ii) Observations at wavelength of 2.2 microns or



The near infrared (2.2 micron) light curve of occultation of Io by Europa on 1991 January 18 using 1.2 m telescope at Gurushikhar, Mt. Abu.

more of the occultation of Io by other satellites are important becasuse they allow us to pinpoint with the accuracy of ~ 10 km the position of volcanoes on Io's surface. The surface of Io is undergoing rapid changes. The volcanoes or hot spots are generally short lived features with time scales of a few years

and need to be monitored frequently to understand the geology of this most active object in the solar system.

As a part of the International Jupiter Watch program, during the period Jan-April 1991, a number of mutual events, both occultations and eclipses, were successfuly observed in the Infrared at 2.2 microns from the 1.2 m telescope at Gurushikhar. The data was sampled every 50 milliseconds. Presently analysis is in progress to determine mid times of events and also the precise drops in intensity during each event to compare it with theory. The large discrepancy between the observed and predicted drops in intensity during the 1985 events which is unexplained so far makes it an interesting aspect of this study.

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

On the Nature of Grains in Comet Austin

Comet Austin was observed during the pre and post perihelion phases on 2.35 m telescope at Kavalur and 1.2m telescope at Gurushikhar. Observations were made in photopolarimetric mode with IHW (International Halley Watch) filters. The polarisation values at different wavelengths were theoretically (Mie theory) calculated taking into account complex refractive indices and grain size distributions. These model calculations suggest that Comet Austin has grain size distributions different from those for Comet Halley, which is dynamically older. The grains in Comet Halley were coarser than those of Comet Austin. These findings suggested that a dynamically older comet should contain coarser grains, which is consistent with the present models of dynamical evolution of comets.

(A.K. Sen, U.C. Joshi, M.R. Deshpande, J.S. Chauhan, N.M. Vadher, A.B. Shah and Chhaya R. Shah)

Infrared Polarization Studies of Astrophysical Objects through IR Photopolarimeter

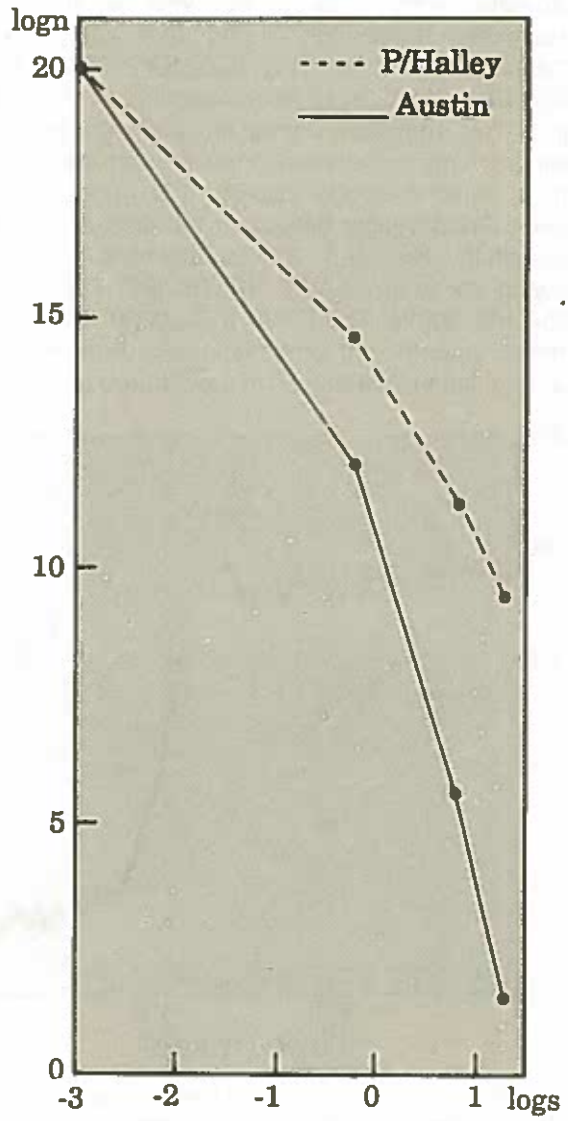
Polarization studies of certain astronomical objects in 1 - 5 micron band are important. The identification of the synchrotron process in active galactic nuclei, the dust shell around protostars, grain size distribution in Bok Globules and molecular cloud complexes etc. can be studied through IR polarization. To achieve these goals an IR polarimeter is being fabricated. The polarimeter has been designed and part of the fabrication work is also completed. In about a year's time the instrument is likely to be operational. The major part of the funding for this project has been made available by Department of Science & Technology, Govt. of India.

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

List of Papers published during 1990 - 91

1. Banerjee, D.P.K., Anandarao, B.G. Jain, S.K. and Mallik D.C.V., "Kinematic Studies of five galactic planetary nebulae", Astron. Astrophys., **240,** 137 - 141 (1990).

2. Chandrasekhar, T., Desai, J.N., Ashok, N.M., and Pasachoff, J.M., "Fabry Perot Line Profiles in 5303 A and 6374 A Coronal lines obtained during the 1983 Indonesian Eclipse", Solar Phys. **131,** 25(1991).



The grain size (radii) and population density (n) for Comet Austin derived through our model calculations are shown. These results are compared with the Comet Halley results. It is seen that Comet Austin shows enrichment of Coarser grains compared to Comet Halley. This difference can be explained due to the older dynamical age of Comet Halley.

3. Desai, J.N., Raju, K.P., Chandrasekhar T., Ashok, N.M., and Pasachoff, J.M., "Fabry Perot interferogram profiles in λ 5303 in relation to coronal structure 1980 and 1983 eclipses" in "Basic Plasma Processes on the Sun", pp. 251 - 252 IAU Symp. 142 Ed. V. Krishna and E. Priest (1990).

4. Sen, A.K., Joshi, U.C., Deshpande, M.R. and Debi Prasad C., "Imaging Polarimetry of Comet P/Halley", Icarus, **86**, 248 (1990).

5. Sen, A.K., Deshpande, M.R., Joshi, U.C., Rao, N.M., and Raveendran A.V., "Polarimetry of Comet P/Halley : Properties of dust", Astron. Astrophys **242**, 496 - 502 (1991).

6. Sen, A.K., Deshpande, M.R. and Joshi U.C., "Photometry of Comet P/Halley", Bull. Astron. Soc., Ind. (1991).

7. Vaidya, D.B. and Anandarao, B.G., "Circumstellar dust in Vega like stars : a detailed analysis of IRAS observations" in "Formation of stars and planets and the Evolution of the solar system", Proc. 24 ESLAB Symp. Ed. B. Battrick, ESA. SP 315, (1990).

SOLAR AND PLASMA ASTROPHYSICS

One of the main objectives of the Radio Astronomy group is to exploit the IPS technique for the studies of the density structure and its propagation in the interplanetary medium (IPM). At a frequency of 103 MHz this can be done over a range of distance of 0.3 to 1 AU from the Sun.

Using a reasonably large radio telescope observations of a number of scintillating radio galaxies enabled estimation of their angular diameters. This, in turn, led to the determination of the amount of ISS at the operating frequency, which broadens the sources.

Our earlier observations of enhanced scintillations of a radio galaxy by the ion-tail of Halley's comet were further supported by similar observations made at Thaltej of quasar 2204+29 swept over by the plasma tail of comet Austin on 13 May 1990.

The Radio Astronomy group has now embarked upon a project which further extends the IPS method to the study of solar-terrestrial relationship. Briefly, using the Thaltej 20,000 m² antenna array and a multi-receiver system, the scintillation behaviour of hundreds of sources will be used to map the varying turbulence in the IPM, presumably caused by solar transients, which might cause geomagnetic storms and Ionospheric disturbances.

Some of the scientific programmes in detail:

Source Diameter Measurements and Interstellar Scattering (ISS)

A consequence of 100-1000 km scale size rms density variations speeding at 400 km s^{-1} through the IPM is that the IPS phenomenon occurs in the case of compact radio galaxies with angular sizes in the range of about 0.1 to 2 arc sec. This fact can be used around to estimate angular diameters of scintillating radio sources. Diameters of 14 radio galaxies were measured at 103 MHz using IPS observations made with the 10,000 m² Thaltej radio telescope between mid-1984 and end of 1987. This was done by studying the variation of scintillation index as a function of solar elongation and assuming a spherically symmetric model of the solar atmosphere with Gaussian density irregularities. The results agreed well with those available at other frequencies and with VLBI measurements.

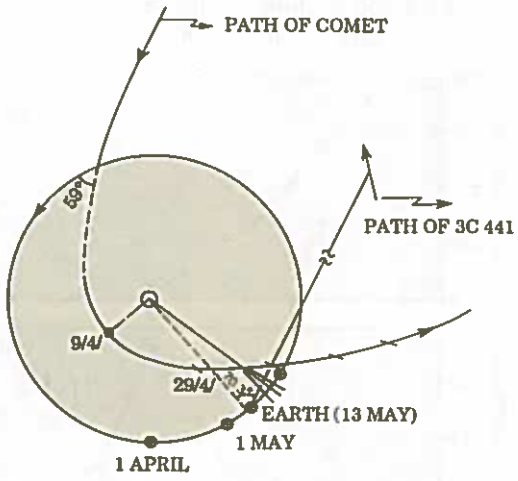
Using the measured diameters at 103 MHz and those available at 151.5 MHz, the interstellar scattering (ISS) at 103 MHz was estimated to be (0.07 ±0.01). The effect of ISS is to broaden a radio source. This sets a limit to high resolution observations or to the minimum detectable source diameter.

(P. Janardhan and S.K. Alurkar).

Enhanced Radio Source Scintillation due to Comet Austin (1989 c1)

Enhanced scintillations of quasar 2204+29 (3C 441) were observed with the Thaltej telescope at 103 MHz when the ion-tail of comet Austin swept across the source. Comparison with earlier observations of comet Halley at 103, 327 and 408 MHz and of comet Wilson at 408 MHz underscored the importance of the relative positions of the source, comet, sun and the observer. During the occultation by comet Austin the scintillation index increased by a factor of 3 over that

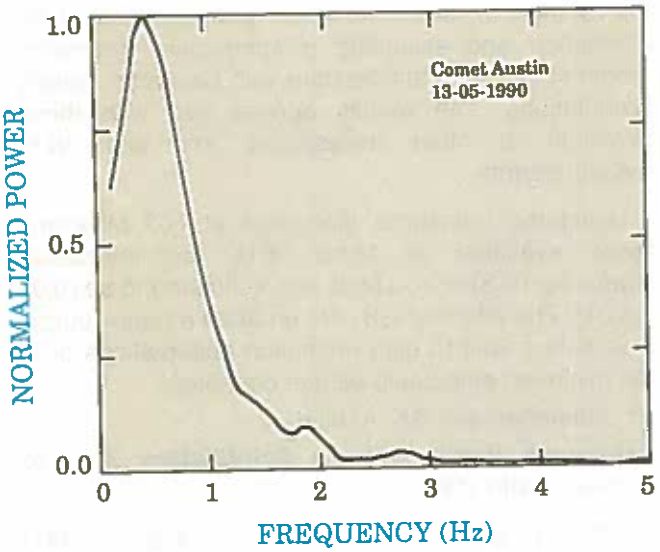
Relative Positions of Sun, Earth & Comet Austin - May 1990



Geometry during occultation of 3C 441 by Comet Austin, 13 May 1990

expected for 3C 441. The rms electron density at 0.9 AU from the Sun 7.3° downstream of the nucleus was 6 cm^{-3} whereas that for the normal solar wind at 1 AU

is 1 cm^{-3}. The corresponding scale sizes of plasma turbulence were much finer than normally found in IPS due to solar wind.



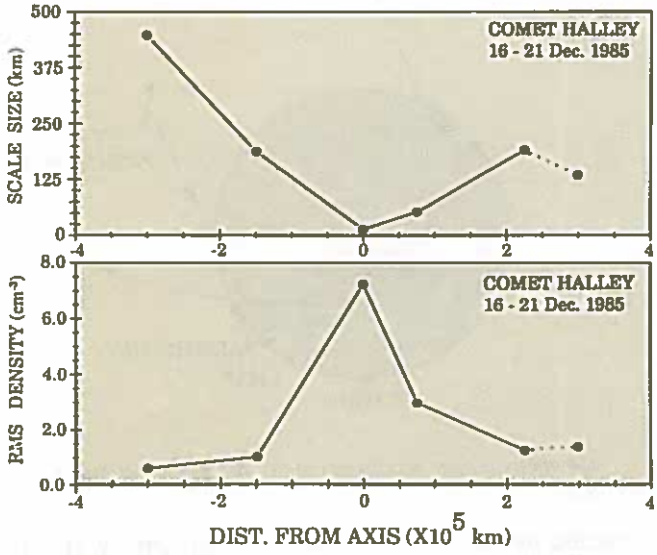
Typical IPS power spectrum of enhanced scintillations of 3C 441.

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

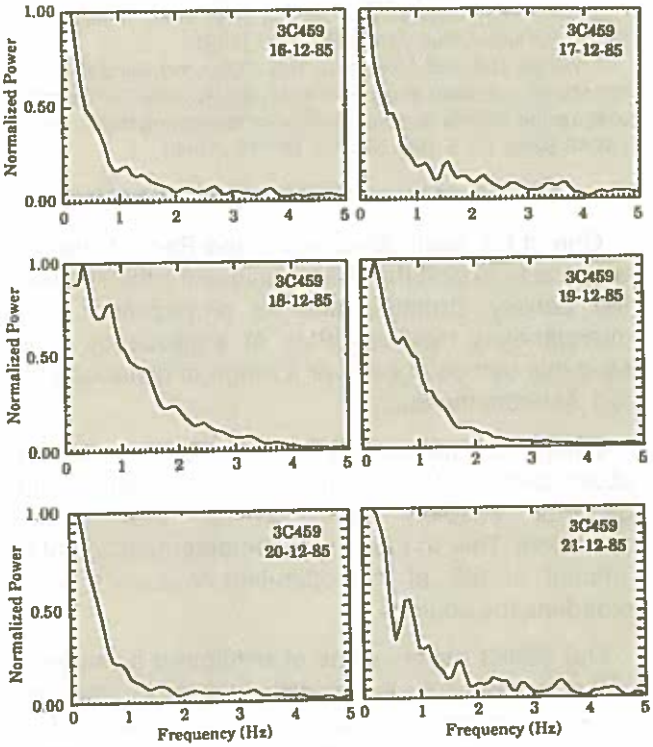
Spectral Analysis of Enhanced IPS of 3C 459 caused by Comet Halley

A critical look at the observations of enhanced scintillations of quasar 3C 459 during its occultation on 16-21 December 1985 yielded interesting results.

Assuming a linear increase of the ion velocities in the cometary tail from 100 km s^{-1} at the tail axis to 400 km s^{-1} at the edges where the tail merges with the normal solar wind, power spectral analysis of the scintillations shows a range of rms electron density variations and their scale sizes. From about 3-6 cm^{-3} and 10-30 km respectively near the axis they change to 0.6 to 2 cm^{-3} and 100-270 km near the edges of the tail.



Variation of scale size of density irregularities and rms density with distance from the axis of plasma tail of Halley's comet.



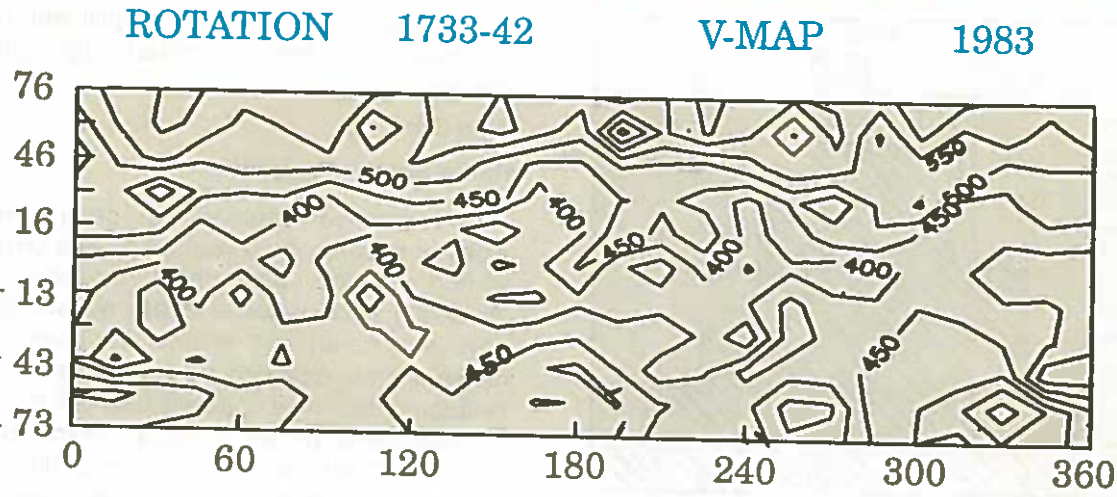
IPS spectra of enhanced scintillations of 3C 459 during its occultation by Halley's comet on 16-21 December, 1985.

The IPS spectra on consecutive days during the period 16-21 December 1985 indicate systematic shift of the peak of the power spectra at 0.16, 0.34, 0.24 and 0.16 Hz on 16/17, 18, 19 and 20/21 respectively. The tail-lag played a very crucial role in deciding the correct occultation geometry and path of the source through the tail.

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

Solar Wind Velocity Maps

Unlike spacecraft and comet tail observations IPS observations are capable of providing a large-scale, 3-dimensional and global view of the solar wind. It is worthwhile attempting to construct a picture of IPM by averaging together IPS observations of solar wind velocity over many sources on several solar rotations, during which the solar wind is quite stable.



Specimen V-map for Carrington rotations 1733-42 in 1983 based on published values.

Measured solar wind speed is mapped back along an Archimedean spiral or a stream line on the source surface, resulting in a latitudinal and longitudinal solar wind structure, called a "v-map". Such 2-dimensional maps are useful in correlating gross features of the velocity structure with large-scale solar features, such as neutral line, coronal holes, solar activity, etc.

The work on production of such velocity-maps has been initiated. The test results of the velocity-mapping procedure are indicated in the diagram, which is based on the published velocity values of the Japanese IPS Observatory.

(S.K. Alurkar, Medha Alurkar and P. Janardhan).

Use of Spectral Simulation for Evaluation of Plasma Parameters of the Interplanetary Medium

Based on four major variables, namely, solar wind velocity, solar elongation angle, power law index of the distribution of plasma irregularities in the interplanetary medium and radio source size and two minor variables; axial ratio and inner scale of the irregularities, a numerical scheme has been evolved to compute the theoretical spectrum of IPS. Comparison of these spectra with the IPS observations of a large number of radio sources enabled us to evaluate parameters of the interplanetary medium including solar wind velocity. The solar wind velocity thus obtained, certainly depends on the model parameters and assumptions, but seems to provide insight into the dynamics of the solar plasma. We will use these solar wind values for V-map and subsequent comparison with large scale features of the solar corona.

(Hari Om Vats, K.J. Shah, S.K. Alurkar and Medha Alurkar)

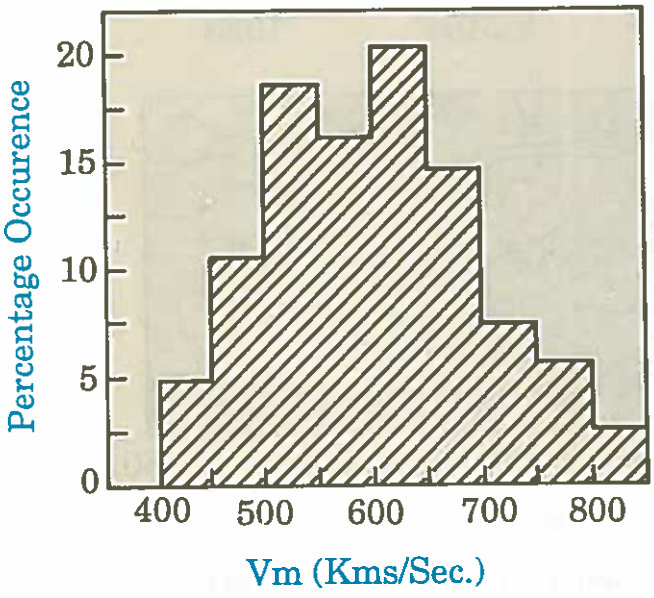
Statistics of Plasma Blobs and Holes

IPS observations at Thaltej now amply indicate the presence of plasma blobs and holes of dimension 10^5 kms or so. Because of large dimension, these do not contribute significantly in the process of scattering of radio waves of the compact radio sources; instead they tilt the passing wavefront. The origin of these blobs and holes is yet not understood. We calculated the magnitude of angular refraction which is found to be several arc minutes. This angular refraction means that the plasma density deviations in the blobs and holes could be upto about 10%. We are now analysing many more sources and would make a two dimensional map of the plasma density departures projected back to the solar surface.

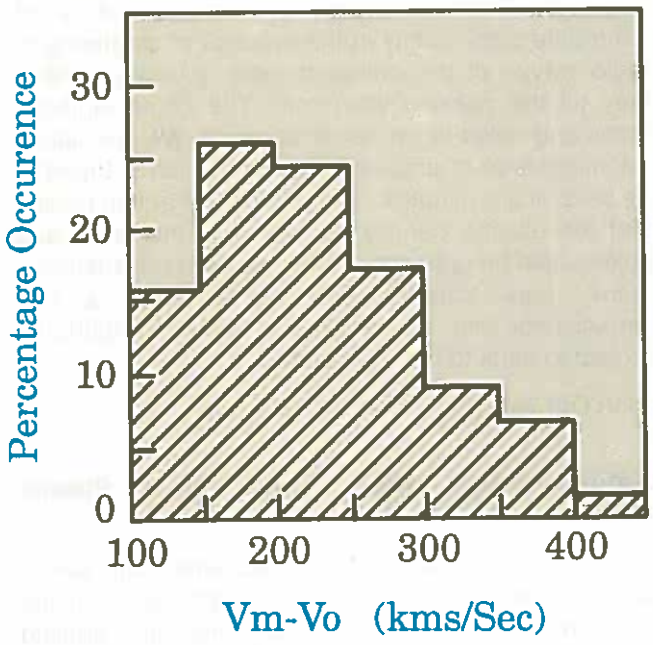
(Hari Om Vats and S.K. Alurkar).

Flare-associated High Speed Solar Plasma Streams

Characteristics of the flare-associated high speed solar plasma streams are investigated using measurements from space probes and earth-orbiting spacecraft for the period 1964-82. The maximum observed velocity V of these streams ranges from 400 to 850 kms/sec with peak probability for about 600 kms/sec. These last for 1-10 days with the peak occurrence for about 3 days. The difference between the pre-stream velocity (V_o) and the maximum velocity (V_m) of any high speed stream serves as the measure of its intensity. For about 60% of these flare associated streams, (V_m-V_o) is well in excess of 200 kms/sec and in some cases becomes as large as 450 kms/sec. The most remarkable inferences from the present study are the following :



Percentage occurrence of maximum velocity Vm of high speed solar plasma streams during the period 1964-82.



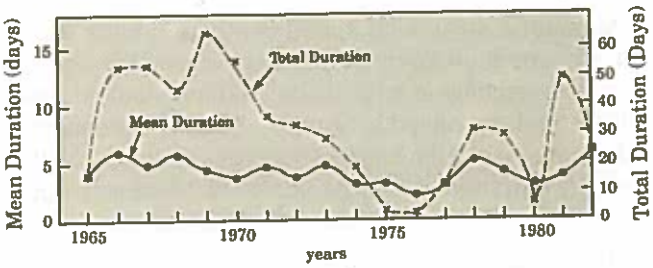
Percentage occurrence of the difference (V_m-V_o). V_o being the pre-stream velocity.

The yearly percentage occurence, total duration and the product of mean (V_m-V_o) with total duration of the high speed streams during the year correlate well with the solar activity, e.g. maximum during high solar activity period with sole exception of the year 1980 and minimum during low solar activity. The yearly means of maximum velocity (V_m), duration and (V_m-V_o) do not show any systematic variation with the solar activity. The study implies that the presence of sunspot number plays a significant role in the generation of flare-associated high speed solar streams.

(Hari Om Vats)

Radio Source Variability

An extensive observational programme for the study of variable radio sources at 103 MHz has been started. In this programme we are at present observing each antenna beam on two consecutive days and central 24 beams are used. Thus each observation is repeated after 48 days. The system is calibrated daily by a specially built unit consisting of a standard signal generator and a transmitting dipole on top of the Thaltej building. This procedure will enable determination of source flux in arbitrary units. This programme will require large data base and is expected to provide variabilities of temporal scale larger than a month. Smaller periodicities (about a day) will be investigated once the 32 receiver system becomes operational.



Variation of total duration of high speed streams and yearly mean with years.

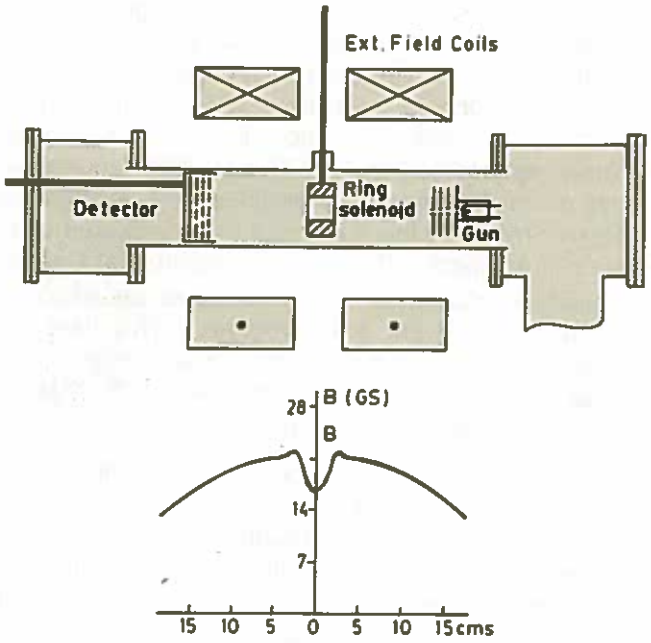
Comparison of source sizes at 103 & 151.5 MHz

Source	0" 103 MHz	Error	0" 151.5 MHz	G. Lat b
3C119	0.72	+0.14	0.20	4
3C144	0.34	-0.10	—	6
3C147	0.30	+0.06	0.3	10
3C48	0.35	+0.04	0.25	29
3C196	0.84	+0.27	1.00	33
CTA21	0.21	+0.04	0.25	34
3C222	0.33	+0.08	0.30	38
3C237	0.58	+0.13	0.40	47
3C446	0.25	+0.05	0.10	49
3C459	0.41	+0.09	0.40	51
3C2	0.49	+0.10	0.40	61
3C298	0.59	+0.07	0.40	61
3C273	0.55	+0.06	0.50	64
3C287	0.45	+0.09	0.40	81

(Hari Om Vats, A.K. Sharma, P. Janardhan, A.D. Bobra, S.K. Alurkar, S.L. Kayasth, H.T. Rangooni and C.K. Viswanath)

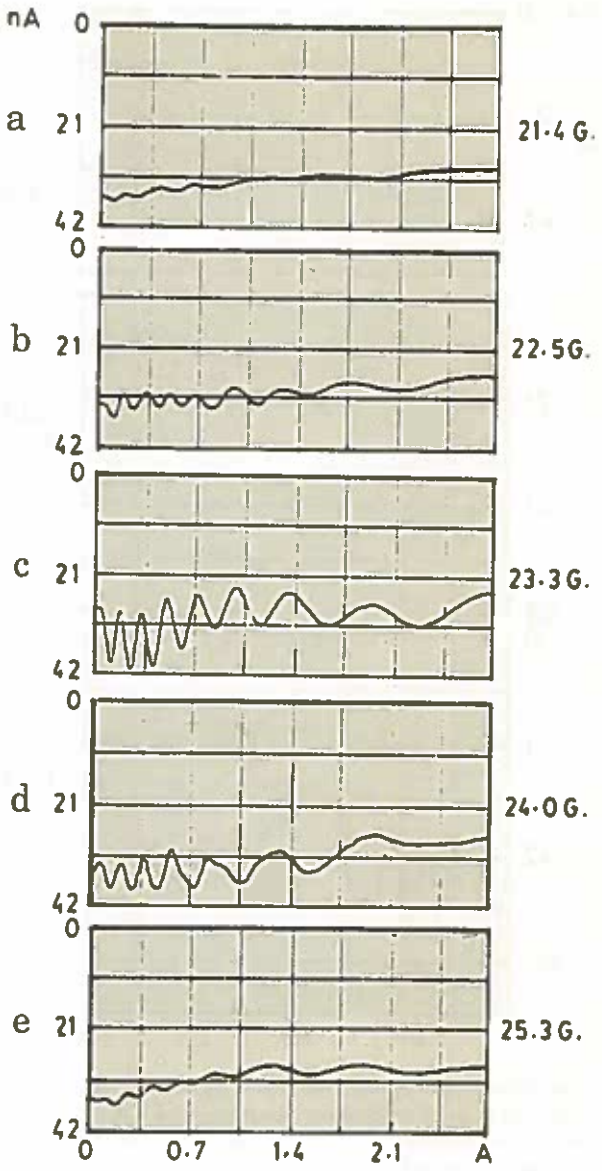
Observation of the Magnetic Vector Potential a la' Aharonov-Bohm in the Classical Mechanical Regime

Following the prediction made on the observability of the vector potential a la Aharonov-Bohm in the classical mechanical regime (Vide contribution by RK Varma on page 61 of this report), an experiment has been carried out to examine whether a curl free vector potential in space does affect the electrons in accordance with the prediction.



Schematic of the experiment for the observation of magnetic vector potential in the classical mechanical domain.

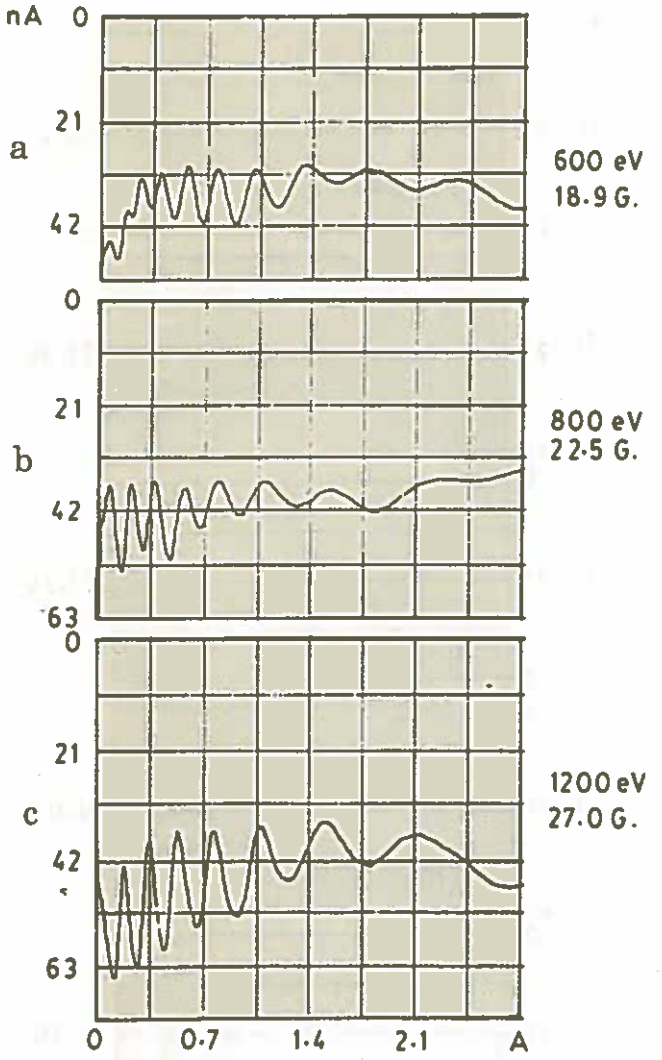
The desired situation is obtained by a ring solenoid (a Rowland ring) which has a magnetic induction field confined entirely in the solenoid with, ideally, a zero magnetic field outside, and thus the corresponding vector potential field being curl free outside. The ring solenoid is immersed in a nearly axisymmetric external magnetic field with the axis along the axis of the vacuum chamber and coaxial with that of the ring. If now an electron beam of a given energy is shot through the ring along the magnetic field and the transmitted current is collected by a Faraday cup, the theory predicts that the transmitted electron current



Transmitted electron current (Y-axis) as a function of current in the solenoid (X-axis) for an electron beam energy 800 eV.

Scale : Y-axis 10 nA/div.
X-axis 0.35 A/div.
(a), (b), (c), (d), (e) correspond to the external magnetic field values 21.4 g, 22.5 g, 23.3 g, 24.0 g and 25.3 g respectively. Note that (c) corresponding to the optimal field value 23.3g gives the most prominent pattern.

would suffer oscillations as the magnetic flux inside the solenoid increases (or decreases). The flux change, $\Delta \Phi$ corresponding to the consecutive peaks, according to theory varies as $\varepsilon^{1/2}$ with the energy ε of the electron beam, apart from the other dependences : on the distance L between the gun and the detector and the pitch angle of injection etc.



Transmitted electron current (Y-axis) as a function of current in the solenoid (X-axis) for different beam energies = 600, 800 and 1200 eV. The respective magnetic field values, namely 18.9 g, 22.5 g and 27.0 g, are the optimal values corresponding to the relation (1a) of the text.

Scale : Y-axis 10 nA/div.
X-axis 0.35 A/div.

The transmitted electron current does, in fact, exhibit oscillation with the flux Φ in the experiment in accordance with the predictions as shown in the figure. This is astonishing indeed because no effect of any sort is expected to be produced on the electron dynamics in the classical domain by the vector potential with a vanishing curl in the space accessible to the electrons. Such an effect is entirely new and is contrary to the expectations from the classical Lorentz equation of motion. The importance of the implications of this effect is obvious.

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

List of Papers Published During 1990 - 91

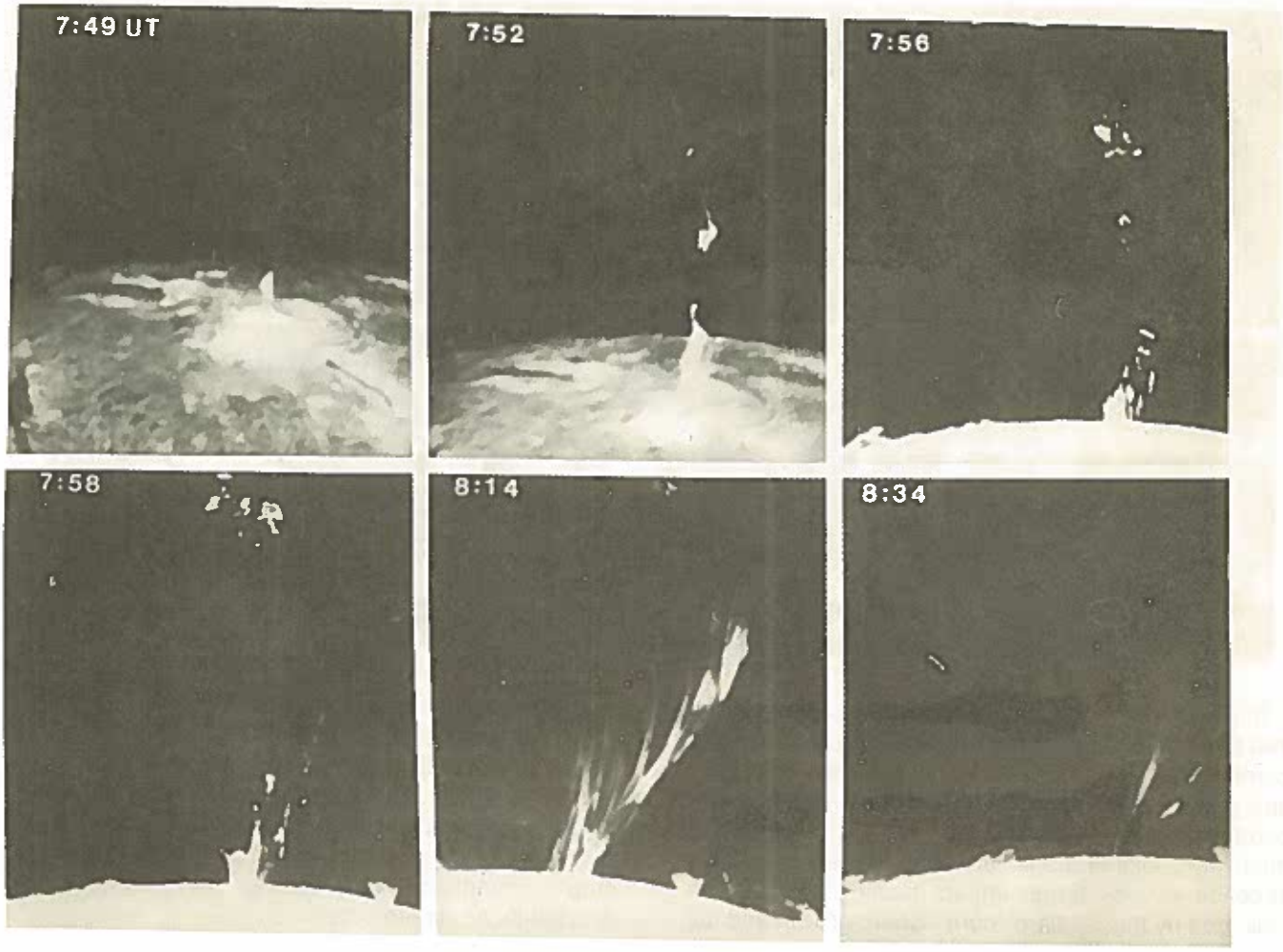
1. Slee, O. B., Bobra, A.D., Waldron, D. and Lim, J., "Flare associated high speed scintillations through Comet tails revisited : Comet Wilson (1987), Austr. J. Phys.(1990).

SOLAR PHYSICS AT UDAIPUR SOLAR OBSERVATORY

An extremely energetic and unusual series of homologous flaring arches were observed during 5-7 March, 1991, on the eastern limb of the Sun in Boulder active region No. 6538. Almost identical flaring arches were triggered by energetic flares on 5, 6 and 7 March 1991. The most remarkable activity occurred on 7 th March. Initially a huge flaring arch occurred which was preceded by a small flare. A few minutes after this flare subsided, another class 3B flare occurred at 07:49 UT in the same region, this flare continued for more than 2 hours, giving rise to extremely energetic mass ejection activity. The solar material shot out with a maximum speed of about 800 km per second to more than 700,000 km from the Sun. Such active mass ejection events have been rarely reported earlier. At USO, complete sequence of this event has been photographed. A well registered 16 mm movie of this event has been prepared using special equipment (Megavision) available at Caltech, Pasadena, California, U.S.A. Detailed analysis and study of this event is in progress . This flare and associated mass ejections gave rise to type II and type IV radio emissions and on 9 March at 22:46 UT an intense geomagnetic storm.

For a twentyfour hour coverage of solar activity, two observational campaigns were conducted during the year. Under this collaborative programme solar observations were made from the Udaipur Solar Observatory, the Big Bear Solar Observatory in California and the National Solar Observatory, Arizona, USA. From the observations taken from India and USA, a twentyfour hours continuous movie of solar region and filament activation has been prepared.

USO, Udaipur has been selected as one of the six stations for Global oscillations studies, out of potential 15 sites, distributed around the globe. With Udaipur site in the network the duty cycle of observations reaches even upto 94 % of the time otherwise it drops to 85 % only which is unsatisfactory for helioseismology. USO is planning to participate in an International programme of Global Oscillation Network Group (GONG) for the study of solar interior using the technique of helioseismology.

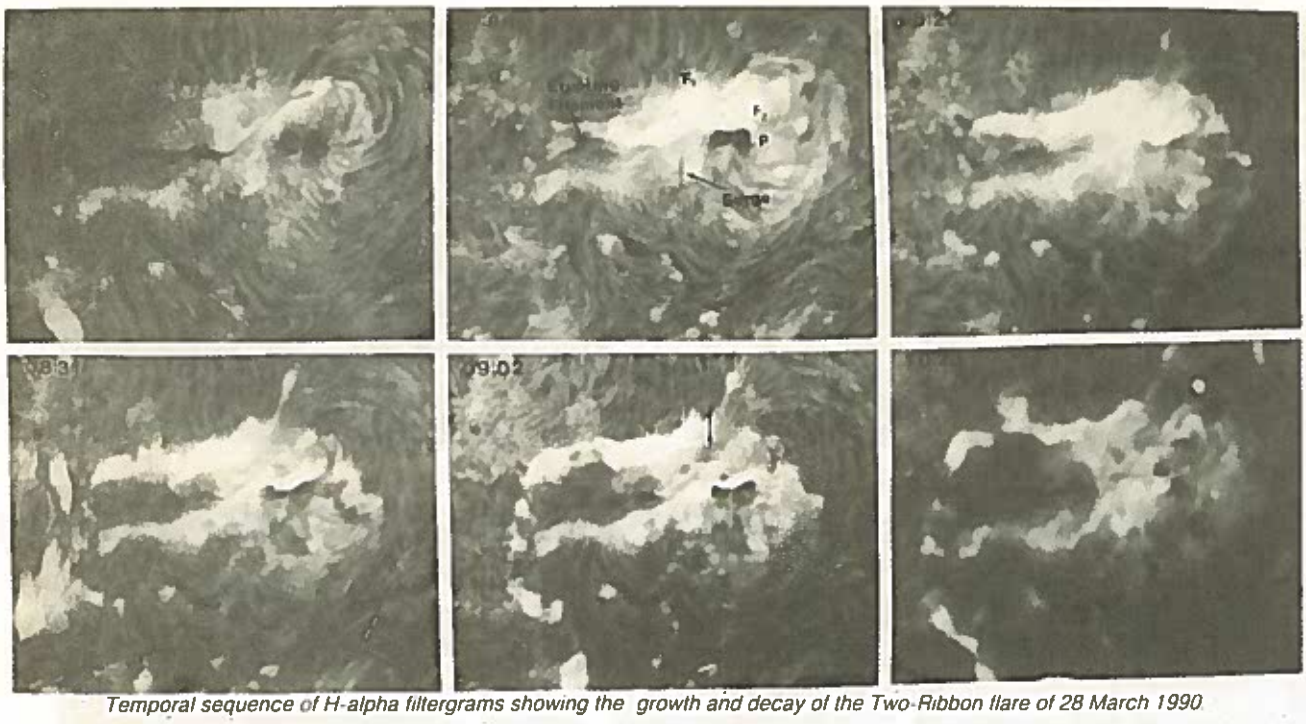


An energetic solar mass ejection observed from USO in association with an X5/3B Ten flare in Boulder region No. 6538 (S20E66) on 7 March 1991/0749 UT.

Large Two-Ribbon Flare of March 28, 1990

Two-ribbon solar flares belong to the class of more energetic flares. They are believed to be caused by an instability of the magnetic configuration which erupts outward along with the filament situated in it. An extensive two-ribbon solar flare in H-alpha line center (6563 A) was observed on March 28,1990/07:30 UT in the Active Region No. 5988 The main flare emission ribbons formed around the magnetic line of inversion, delineated by a dark filament. This filament was observed to have blown off during the initial "flash" phase and reformed later in the decay phase of the flare. The eruptive instability may have been caused by an "emerging flux" observed at the neighborhood of the filament in NOAA 5988 which is perhaps the "trigger" for the flare onset.

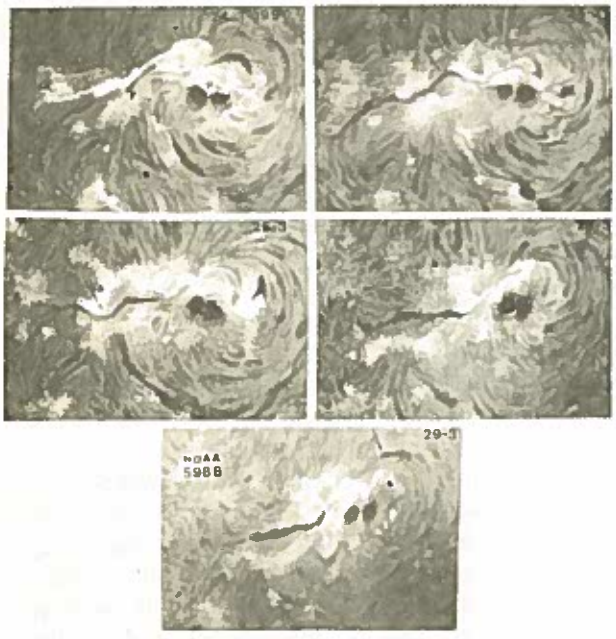
In order to study the development of flare intensity, we obtained high resolution, 512x512 pixel digital H-alpha filtergrams at 8-bit depth using the Digital Image Processing Facility at USO. Various steps of image processing and analysis were carried out to obtain iso-intensity (density) contour levels of the flare and areas were plotted for the contours . The resulting growth-decay profiles indicate the following : (i) the brightest features wers relatively short-lived at around 20 min, as compared to 200 minutes for the main phase of the flare, (ii) a second maximum was seen in the areas of outer (and fainter) flare- contours, much later after the "core" of H-alpha emission, marked by "8", had subsided, (iii) growth/decay of contour-areas occurred at varying rates. From these results, we may draw some interesting inferences about the chromospheric heating associated with the flare.



Temporal sequence of H-alpha filtergrams showing the growth and decay of the Two-Ribbon flare of 28 March 1990

It is known from X-ray and microwave observations that the primary flare energy-release site is situated at coronal heights. At this site, particles are energized and guided along magnetic loops downward to lower chromospheric regions. In the chromosphere relatively cooler H-alpha flare kernels are formed by a secondary, thick target impact heating process, as indicated by the flare "core". Sharp growth and fall of the core area is suggestive of the impulsive and short-lived nature of the flare energy-release process at the "primary" flare location, i.e., the corona. A rapid cut-off in supply of energetic particles is also inferred. We suggest that the second maximum observed in the areas of outer contours occurred due to a "third step" chromospheric heating by the energy dissipation around the core.

(A. Ambastha).



The emergence of new flux in the Active Region No. 5988 during March 24-29, 1990. The rotational motion of the emerging flux region (EFR) marked "δ" is evident.

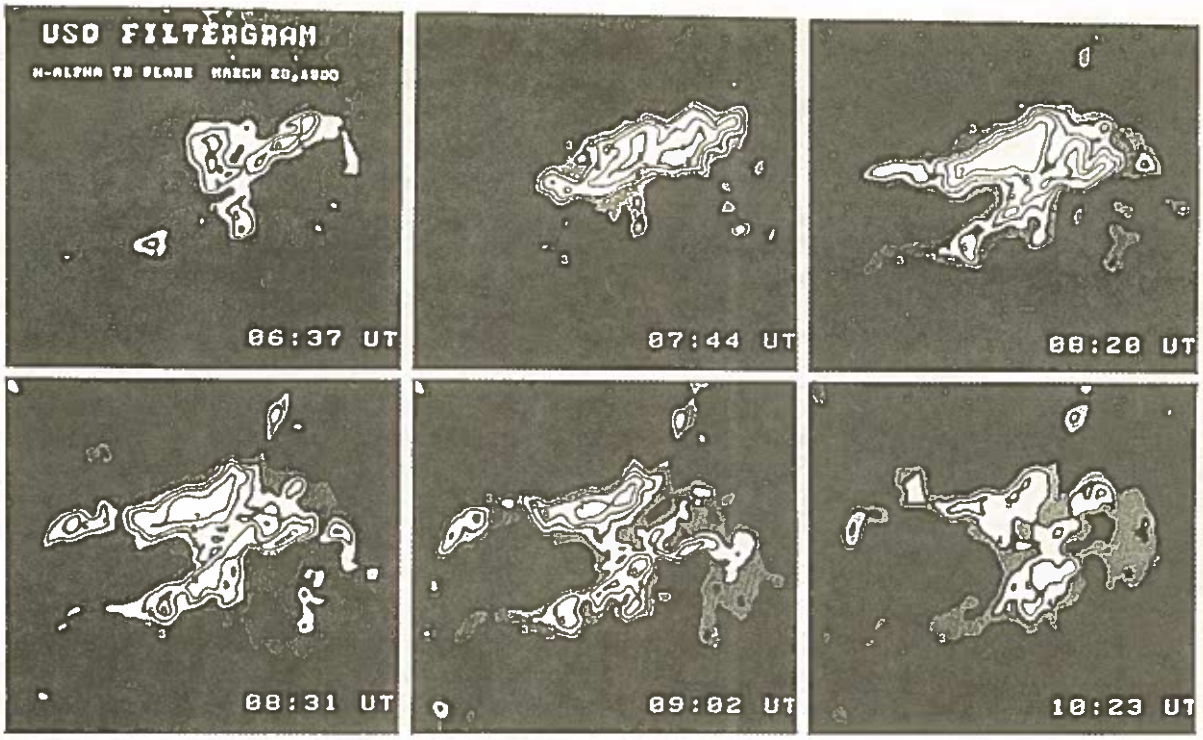
Cosmic Ray Flare of 29 September 1989

At the Udaipur Solar Observatory an intense cosmic ray flare was observed on 29 September 1989. This flare gave rise to strong geomagnetic activity and particle emissions. In the figure is shown the development observed at USO of this flare in H - alpha radiation.

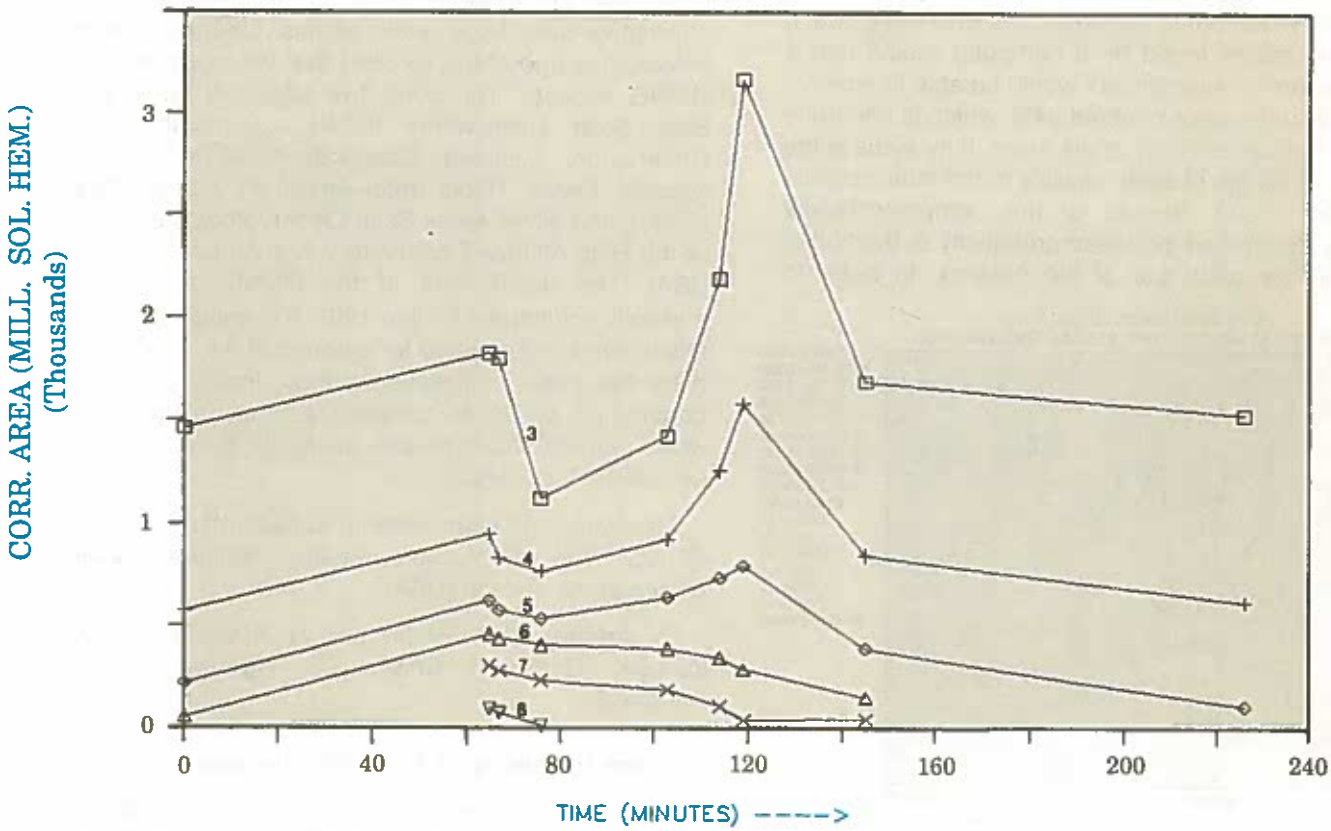
(R.M. Jain, A. Bhatnagar and R. Sharma).

GONG Site Survey Program

Helioseismology provides a very good tool for probing the internal structure and dynamics of the Sun. For its success, it is required to observe the sun on near continuous basis during 24-hour period over many days. In order to reduce the problem posed by the diurnal cycle at a single location, an international scientific community-based project, the Global Oscillations Network Group (GONG) has been proposed by the National Solar Observatory, USA.

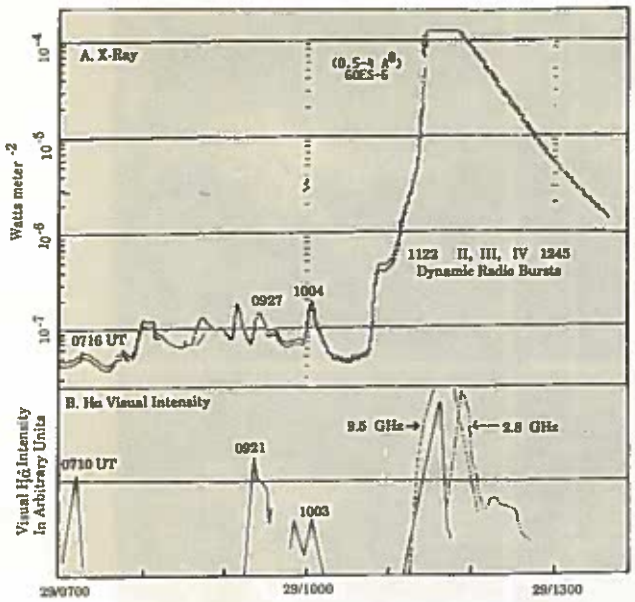


A



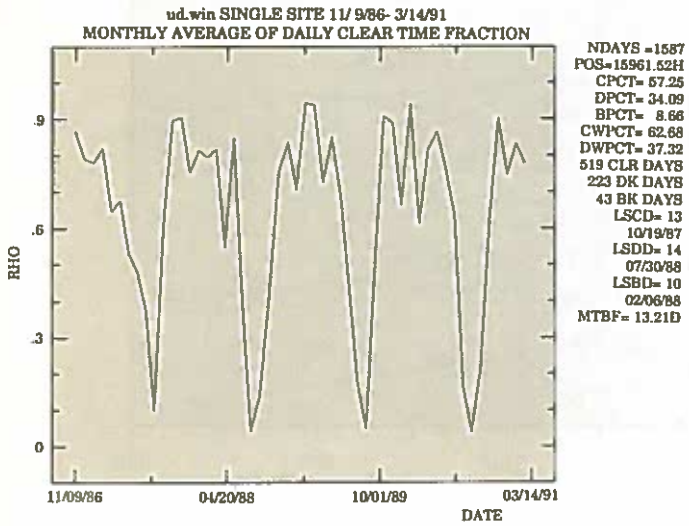
(A) Iso-intensity (density) contours of the flare as obtained from the digitized images. (B) Area-profiles for various isointensity contour-levels of (A).

B



Variation of X-ray, H-alpha and Microwave emissions associated with 29 September, 1989 cosmic ray flare.

Under the GONG project, it is intended to take spatially resolved digital dopplergrams of the Sun from six suitably distributed observatories over the globe. It has been earlier found by a computer model that a well-chosen six-site network would be able to achieve an overall duty-cycle of about 94%, which is adequate to meet helioseismology goals. Here, duty cycle is the ratio of the length of solar visibility to the total possible time (24 hours). Results of the computer model critically depend on the mean probability or fraction of clear sky for each site of the network. In order to obtain accurate values of this parameter, a site evaluation program has been conducted at fifteen GONG candidate sites, including the Udaipur Solar Observatory (USO). Under this program, a Normal Incidence Pyroheliometer along with a data acquisition system was placed at USO in November 1986. Using the large database covering the period November 8, 1986—March 14, 1991, an average duty cycle of around 63% has been obtained for Udaipur, with 519 completely clear days having duty cycle greater than 95% from a total of 1587 days of observation. Not surprisingly, prominent seasonal variation in the duty cycle is observed, sharply marked by the dips corresponding to Indian monsoon. Average extinction coefficient for Udaipur is obtained around 0.2071. Further, average transparency powers for the g-modes and p-modes are calculated as 8.19 x 10^{-5} and 3.43 x 10^{-7} respectively.



Monthly averages of daily clear time fraction, or the duty cycle, for Udaipur during November 9, 1986 - March 14, 1991. The prominent dips correspond to the months of monsoon activity.

From the fifteen candidate sites participating in the GONG Site Evaluation Program, there were 192 reasonably distributed six site networks possible. Statistical comparison of the duty cycles for all these networks has shown that the networks containing USO are superior to networks with an alternative site. As a result of this, USO has been selected as one of the six sites that will comprise the GONG network. The other five sites will be at Big Bear Solar Observatory (USA), Learmonth Solar Observatory (Australia), Observatorio del Tiede, Izana (Spain), Cerro Tololo Inter-American Observatory (Chile), and either Mees Solar Observatory, Haleakala or the High Altitude Observatory, Mauna Loa (Hawaii, USA). The deployment of the GONG network is currently schelduled for late 1993. It is anticipated that this network will observe for a period of 3 to 6 years to meet the goals of helioseismology. Indian scientific community will have complete access to the data, which is expected to be also useful for the other non-helioseismic studies.

This work has been done in collaboration with the GONG Site Evaluation Team, National Solar Observatory, Tucson (USA).

(A. Ambastha, A. Bhatnagar, N. Srivastava, R.M. Jain,S.K. Gupta, R. Sharma, G. Agarwal and V. Kumawat)

Eruption Instability of Solar Prominences

Soalr prominences may be represented by a uniformly twisted, curved, magnetic tube anchored at both ends in the photosphere. Prior to the eruption, these prominences evolve through a series of

equilibrium states ascending with a slow velocity due to an increase in the electric current or mass loss through legs.

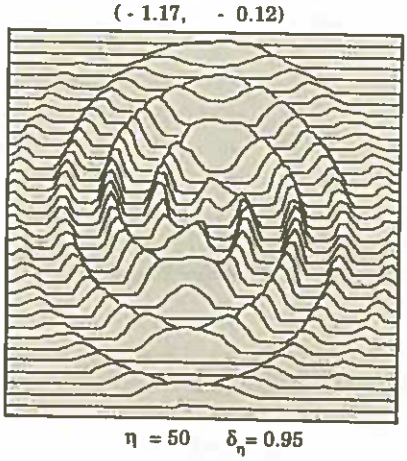
For the later phases of twisted prominence eruption event of March 11, 1979, various instability criteria were examined using the observed physical quantities. We found that instability criterion for the onset of a class of micro-instabilities was not satisfied for the prominence. However, the prominence was found unstable against macroscopic deformation into helical shape as the threshold condition given by $B_\phi > 2\pi r B_Z / l$ was satisfied. As prominence eruption evolved, B_ϕ reduced and the threshold condition became more difficult to satisfy. Consistent with this we observed twist-free prominence structures in the post eruptive phase. In order to establish results obtained from the analysis of 11 March 1979 event, more prominence eruption events observed from USO are being studied during pre-eruptive phase, onset of instability and the later phases. It is hoped that the analysis will enable us to determine the equilibrium height of the prominences, separation of the foot-points and in understanding the role played by twists in the eruption of the prominences.

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

Stability of a Multi-Component, Self-Gravitating Finite Disk Galaxy

It is well known that disk galaxies are complex astronomical objects consisting of several components with widely varying properties, such as, (i) a flat rotating disk of dust, gas and young population I stars, (ii) a central spheroidal bulge of mostly old, population II stars, and (iii) a large "invisible" spherical halo surrounding the disk and the bulge. Although the visible spiral structures of a galaxy are characteristic features of the disk, their physical appearance seems to be governed by the spatial extent and mass of the central bulge. A massive halo, surrounding both the disk and the bulge would also influence the dynamics and structure of the disk. Indeed it is difficult to construct kinematically stable model disk galaxies with a reasonable pressure distribution when there is no halo present. Further, unphysically large thermal energy, of the order of rotational energy, is required to stabilize the disk against all explosive modes. An eigenvalue problem for a disk-halo model gives a set of complex global eigenmodes, some of them "explosively" unstable when the halo is not sufficiently massive as compared to the disk. Many unstable modes are stabilized when the mass of halo is increased. Smooth spiral structure is obtained for dominant eigenmodes when the core radius of the halo is equal or larger than the radius of the disk. It is also found that while "cold" disks in absence of halo mostly allow "leading" spiral patterns, smooth "trailing" spirals are permitted for a disk-halo system.

(A. Ambastha)



Eigen-pattern associated with perturbed surface density of the disk component corresponding to the most dominant eigenmode for $\eta = 50$. δ_n = halo-mass/total mass $\doteq$ 0.95. A smooth, trailing spiral structure is evident.

List of Publications during 1990-91

1. Ambastha, A., Stability of Self-Gravitating Finite Disks, IAU Colloquium No. 132 "Instability, Chaos and Predictability in Celestial Mechanics and Stellar Dynamics", Nova Science Publ. Co., USA, 1991.

Planetary Atmospheres and Aeronomy

The research activities of the Planetary Atmospheres and Aeronomy Division are aimed to provide an understanding of the radiative, chemical and dynamical processes in the atmosphere. The studies are based on in-situ and ground based remote probing of the atmosphere using radio and optical techniques, laboratory experiments and modelling. The activities can be broadly grouped into the following three headings :

1. Studies of the Middle Atmosphere — chemistry and radiation balance, role of trace gases and minor constituents, ionisation phenomena and dynamics.
2. Studies of the Upper Atmosphere — ionospheric phenomena, plasma density irregularities and structures associated with equatorial spread-F and sporadic E and ionosphere-thermosphere coupling.
3. Laboratory Astrophysics — Measurement of absorption and resonance fluorescence cross sections for various gases to understand the reactions that occur in the atmosphere/ionosphere and those of interest in the investigation of planetary and astrophysical phenomena.

Recent developments related to the ozone depletion phenomenon and the possible global warming due to enhanced greenhouse effect has given further impetus to the study of the middle atmosphere. We have the advantage of being in a tropical region characterised by a strong upwelling motion which couples the troposphere and the stratosphere.

Studies of the vertical distribution of trace gases is one of the major programmes for understanding the chemical-dynamical processes. As a part of a collaborative programme between PRL and Max Planck Institute for Aeronomy, Lindau, Germany, which was initiated in 1985, a balloon flight was conducted during this year from Hyderabad. For, the first time vertical distribution profile of CH_3Br, a major bromine contributing gas, has been obtained. The results show lower mixing ratios of various trace gases in the stratosphere as compared to those obtained in 1987 and give very high growth rate of CFC-13 B1 (18% per year). Water vapour is a natural gas forming a part of the basic water/ice/vapour cycle. However, it is the major source of the most important radical (OH) in the atmosphere. More importantly, it has a crucial role in the greenhouse warming. A balloon borne fluorescence hygrometer has been developed at PRL and measurements made during the year.

Ozone measurements were made during March-April 1990 from Thumba as a part of the International DYANA campaign. The results show larger ozone increase during night time as compared to the theoretical computation and also show wave like perturbation which grows in amplitude with increasing height. The typical wavelength is about 8.5 km at 40 km which grows to 13.5 km at 50 km. The disturbance is found to propagate upward with a typical velocity of about 0.15 meter per second.

Aerosols which influence the energetics of the atmosphere have been measured using in-situ optical technique from Trivandrum and Hyderabad. These results have been compiled this year to study the basic features and their variability. The aerosol size distribution factor derived from the spectral distribution of aerosol extinction shows presence of a layer characterised by larger number of bigger particles just below the tropopause region. The layer height is found to come down from 13 km to 11 km after the Indian monsoon indicating that these particles are soil derived and have a residence time of few months.

Transport of gases in the atmosphere is controlled by the eddy diffusion in addition to large scale motions. An empirical model for the 10 to 100 km height region has been developed based on balloon and rocket measurements from Hyderabad and Thumba respectively. The eddy diffusion coefficient increases with altitude by three orders of magnitude between 10 and 100 km.

Turbulence parameters have been derived from the electron density fluctuations observed on the daytime Langmuir probe flights conducted from Thumba. From the power spectra of the fluctuations in the scale size range of 1 - 300 m it was observed that the spectral index was -5/3 upto 80 km altitude and much steeper at higher altitudes. This indicates that irregularities in the inertial subrange are observed below 80 km only. Turbulence parameters, energy dissipation rate, eddy diffusion coefficient and vertical turbulent velocity were obtained in the altitude region of 60 - 80 km.

Major emphasis in upper atmospheric studies during the year was on co-ordinated measurements, using ground based optical and radio experiments, to study the ionosphere-thermosphere coupling and the phenomenon of equatorial spread-F.

A high resolution Fabry-Perot Spectrometer had been operated from Mt.Abu to measure neutral winds and temperatures in the altitude region 250-300 km

by recording the 630 nm night airglow emission Ionosonde and HF Doppler were operated from Ahmedabad simultaneously and case studies are being made during magnetically quiet and disturbed periods to understand the energetics of the low latitude thermosphere and coupling to high latitude regions. Direct experimental evidence for the control of neutral temperatures and wind field on the F-region base height has been obtained.

The all sky imaging camera to map the 630 nm emissions to study the large scale plasma depletions associated with the phenomenon of equatorial spread-F was modified to improve the quality of the picture. The system was operated from Thumba during the campaign of February 1991 and the plasma depletions were photographed for the first time in India. The depletions had E-W dimension of about 50 km and extended to several hundred km along N-S.

The evaluation of the various processes that are responsible for the 630 nm dayglow emission supported by measurements reveals that the dissociative recombination is responsible for 50% of the dayglow intensity and is solely responsible for its temporal variabilities.

The research activities under Laboratory Astrophysics include (i) the measurement of photoabsorption cross sections of molecules in the vacuum ultra-violet and ultra-violet regions, (ii) electron scattering cross sections of atoms and molecules in gas at low electron energies and (iii) the study of fluorescence spectra of polyatomic molecules by photon impact. A new experiment has been designed during the year to measure absorption cross sections of atmospheric molecules at different temperatures ranging from 200 to 500 K.

The fluoresence spectra of sulphur dioxide and carbon disulphide have been studied at three incident photon wavelengths of 121.6, 73.6-74.4 and 58.4 nm and relative production cross sections for different product states have been measured. The fluorescence spectra at these three wavelengths were obtained in the emission wavelength region from 238 to 432 nm for sulphur dioxide and 240 to 555 nm for carbon disulphide at the spectral resolution of about 1 nm.

Work on measurement of photoabsorption cross sections for ammonia has recently been initiated and the cross sections are being measured in the spectral region 180 to 205 nm with an instrumental resolution of 0.08 nm. Also, a new experiment has been designed to measure photoabsorption cross sections for some atmospheric molecules at different tempretures ranging from 200 to 500 K. The measurements would be carried out in the spectral region 180-320 nm. The molecules like NO, NO_2, CO_2, CS_2, SO_2 and chlorofluoromethanes would be investigated using the new set up being fabricated in the laboratory.

MIDDLE ATMOSPHERIC STUDIES

Vertical Distribution of Trace Gases

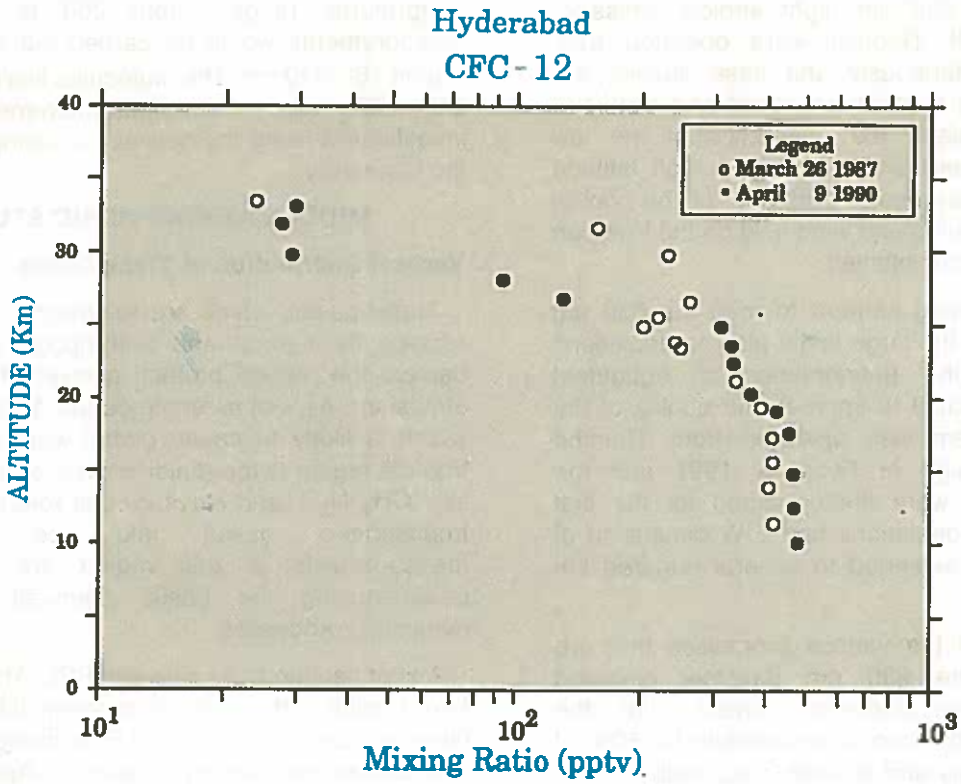
Trace gases, which are released from the earth's surface by natural and anthropogenic processess deplete the natural protective layer of ozone in the atmoshere as well as enhance the greenhouse effect which is likely to cause global warming. Since the tropical region is the major source of biogenic gases like CH_4, N_2O and plays crucial role in transporting tropospheric gases into the stratosphere, measurements in this region are important in understanding the basic chemical-physical and dynamical processes.

A joint balloon flight between PRL, Ahmedabad and Max Planck Institute for Aeronomie (MPAE), Lindau, Germany under the ISRO-DLR exchange programme was conducted from Hyderabad on April 9, 1990. As in earlier exeriments, the balloon carried the sun tracking multichannel photometer of PRL and the cryogenic air sampler of the MPAE. Fifteen air samples were collected between 10 and 35 km altitude during the ascent and slow valve controlled descent trajectory of the balloon.

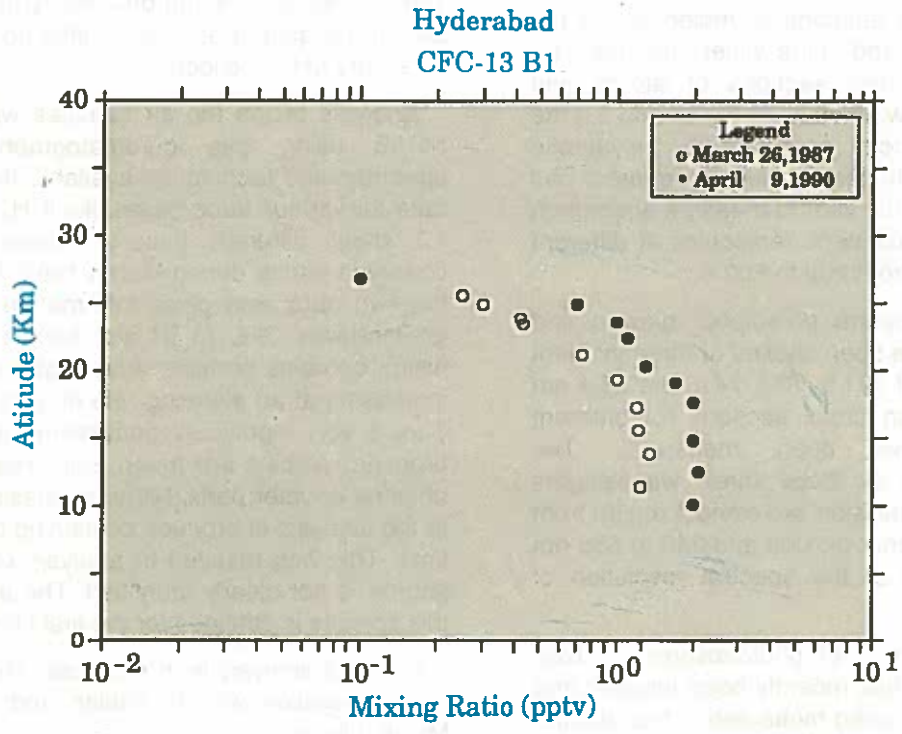
Analysis of the the air samples was made at the MPAE using gas chromatographic and mass spectrometric techniques available there. Preliminary data for various trace gases like CH_4, N_2O, and CFC-12 show different features above 20 km than observed earlier during March 1987. A comparison of the two data sets gives information regarding their growth rates. CFC-13, B1 also known as Halon 1301, which contains bromine atom, has been found to be increasing at an alarming rate of about 18% per year. This is very significant considering the fact that the bromine radicals are much more reactive than their chlorine counter parts. More emphasis has been paid to the analysis of bromine containing compounds, this time. This has resulted in analysis of CH_3Br whose source is not clearly identified. The altitude profile of this species is obtained for the first time.

Detailed analysis is in progress. This work is done in collaboration with P. Fabian and R. Borchers of MPAE, Lindau.

(S. Lal, B.H. Subbaraya and S. V. Ramani)



Vertical distribution of CFC-12 as measured on April 9, 1990 from Hyderabad (solid circles) compared with measurement made on March 26, 1987 (open circles).



Vertical distribution of CFC-13B1 as measured on April 9, 1990 (solid circles) and on March 26, 1987 (open circles) from Hyderabad.

Methane Flux Measurement

Methane is an important greenhouse gas. Its contribution to the greenhouse effect is next to carbon dioxide among the anthropogenic gases. However, the sources of methane are biogenic in nature such as paddy fields, natural wetlands and enteric fermentation. With about 30% of global paddy fields, Indian region is a potential source of methane to the atmosphere. However, there are no systematic measurements of methane flux from India. We have initiated a programme for measuring methane flux from Southern India. Methane was found to be increasing in the chamber covering the rice paddies. However, the number of samples was not sufficient to make a quantitative estimate of the methane flux. A detailed programme is being planned for 1991.

(S. V. Ramani, Suchita Desai, S. Lal and B. H. Subbaraya)

Water Vapour Measurements using Lyman-alpha Hygrometer

Water vapour is the major source of the key OH radical which dominates the chemistry in the earth's middle atmosphere. Further, water vapour is the most effective natural greenhouse gas in the earth's atmosphere. Due to its positive feedback in the global warming, accurate measurements of its distribution have become very important. The Lyman-alpha hygrometer developed at PRL was flown on a balloon flight conducted from Hyderabad on March 18, 1991. The flight has given good signal upto about 24 km. The data are being processed to get the vertical distribution of water vapour.

(Y. B. Acharya, J. T. Vinchhi, S. V. Ramani and S. Lal)

Balloon-borne Water Vapour Measurements using Photometers

The absorption of solar radiation in the 950 nm wavelength region by the $\rho\sigma\tau$ band of water vapour is measured using a balloon-borne spectrophotometer. Measurements were made in six different wavelength regions centered around 300, 310, 500, 670, 800 and 950 nm with a typical band width of 10 nm, to get profiles of water vapour concentration alongwith ozone and aerosol. A sun tracking mechanism is used to align the photometers towards the sun during balloon ascent. The instrument was flown twice on 11 April 1988 and on 5 November 1988 from Hyderabad. As the contributions due to Rayleigh and aerosol scattering are very small in the 950 nm compared to water vapour absorption, water vapour concentrations could be obtained more accurately (with an error of less than 4% at all altitudes) compared to our earlier attempt, in which measurements were made in the 800 nm absorption band. The present technique is capable of measuring water vapour concentrations from few ppmv to few thousand ppmv. The obtained results show that water vapour mixing ratio varies from few thousand ppmv at 4 km to few hundred ppmv at 8 km. In the 10 to 20 km range the mixing ratio is of only few ppmv. The conventional radiosonde routinely employed in the Meteorology Department is not sensitive above an altitude region of about 8 km.

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

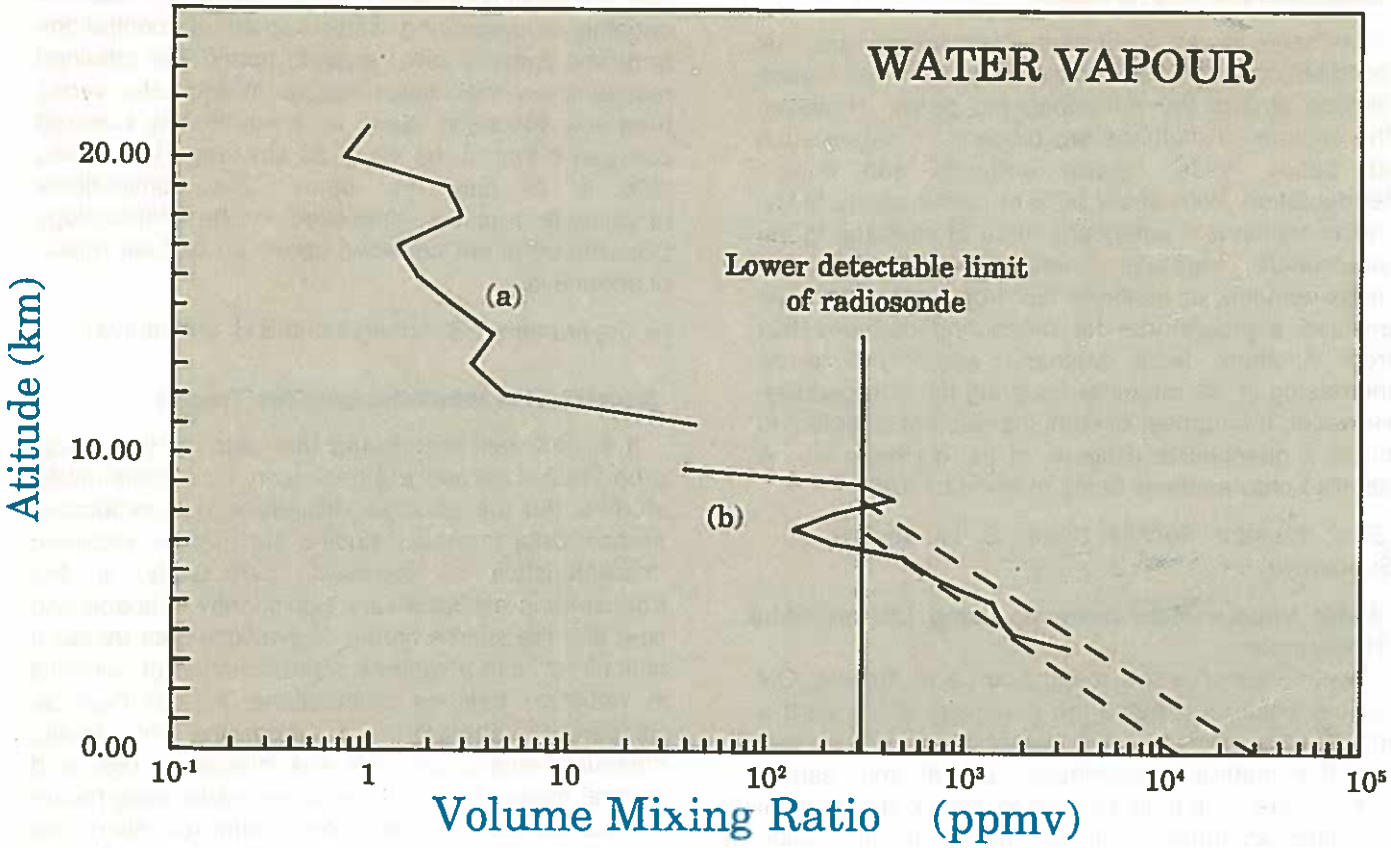
Aerosol Characteristics over the Tropics

It is now well recognised that data on the optical properties of aerosol are necessary for climate model studies. But the principal difficulties in incorporating aerosol data in model studies are that the radiative characteristics of aerosols, particularly of the tropospheric aerosols vary significantly in space and time and the sparse nature of available data makes it difficult to have a realistic representation of aerosols in radiation balance calculations. At the Physical Research Laboratory, a programe of in-situ measurements of aerosols was initiated in 1980 and several measurements have been made using rocket and balloon-borne photometers. Data from six rocket experiments conducted from Thumba and four balloon experiments from Hyderabad during the last ten years on the aerosol optical properties in the UV to IR region and upto an altitude of about 30 km are compiled to study the salient features of the aerosol characteristics in the tropical middle atmosphere. Tropospheric aerosols show a seasonal variation both in terms of their abundance and size distribution before and after the Indian monsoon. The attenuation of the incoming solar radiation by aerosol is found to be significant both in the visible and IR region which contributes to the heating of the lower atmosphere particularly before the onset of monsoon. Also a layer of aerosol particles characterised by larger number of bigger particles is found to exist just below the tropopause level. The height of the layer is found to come down from 13 to 11 km after the monsoon, indicating that the particles are soil derived and have a residence time of few months in the troposphere. The stratopsheric aerosols are found to have a different behaviour and are influenced mainly by major volcanic eruptions.

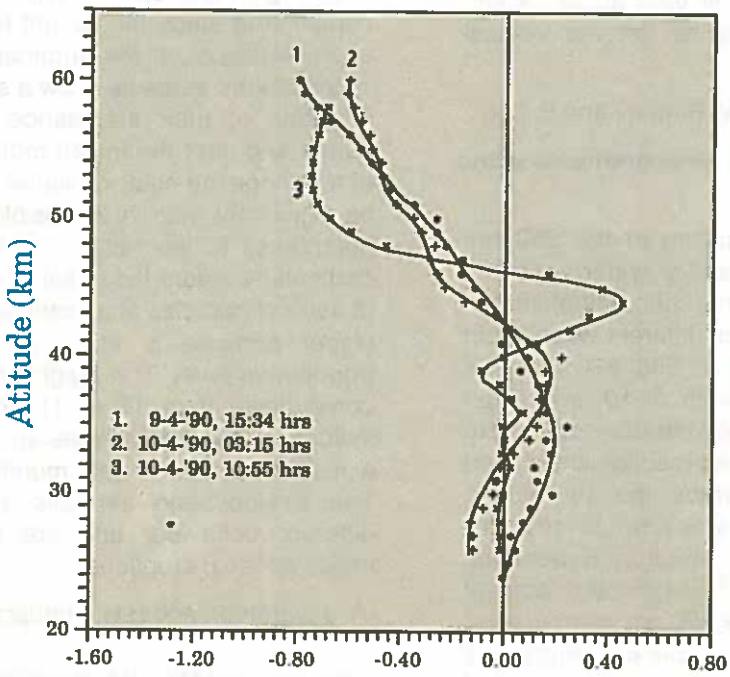
(A. Jayaraman and B.H. Subbaraya)

International DYANA Experiment

As a part of the International DYANA (Dynamics Adopted Network for the Atmosphere) campaign and



Water vapour concentrations measured over Hyderabad using balloon-borne Sun-Photometer on (a) 11 April 1988 and (b) 5 November 1988. Dashed lines represent the range of values, typical of central India, measured using radiosonde by India Meteorological Department.



Variations in ozone number densities (x) obtained from the three rocket measurements made in April 1990 under DYANA.

under the ISRO-SCHM collaboration measurements of ozone vertical distribution were made over Thumba during March-April 1990 with the main objectives to study (i) the effect of dynamical perturbations on the ozone vertical distribution and (ii) the day to night time variation in ozone concentration at higher altitudes PRL's contribution in the campaign was limited to twc day time and two night time rocket experiments. All the four measurements gave good quality data. Preliminary analysis of the data show higher night time increase in ozone concentrations above 50 km as compared to theoretical predictions. Further the profiles obtained during the April Salvo exhibit superimposed wave like perturbations which are found to grow in amplitude with increasing height.

(K.S. Modh, S.K. Banerjee, A. Jayaraman, B.H. Subbaraya and J.T. Vinchhi).

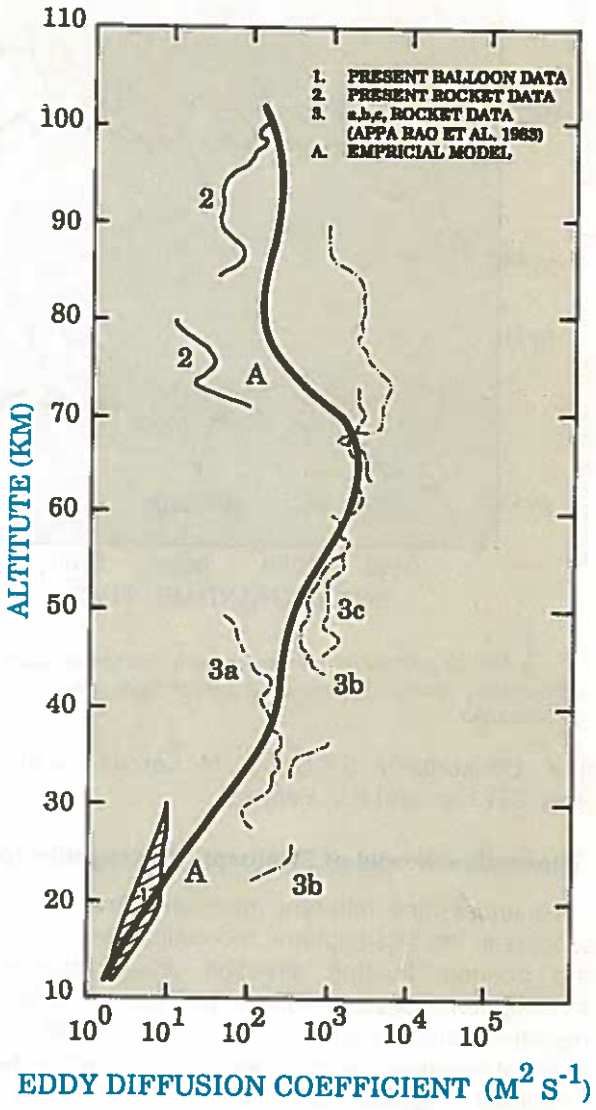
Empirical Model for the Eddy Diffusion Coefficient for Low Latitude Middle Atmosphere

Eddy diffusion is a phenomenon which determines the distribution of minor neutral species in the Middle Atmosphere. During the Middle Atmosphere Programme, the coefficient of eddy diffusion of the Middle Atmosphere was measured using high altitude balloon from Hyderabad (17,5° N, 78.6° E) and using rockets from Thumba (8° N , 76° E). Using these data and also the data available from the Soviet chaff release experiments using M-100 rockets from Thumba, an empirical model of the eddy diffusion coefficient in the altitude range of 10 to 100 km has been made for the Indian subcontinent. The value of this parameter is found to vary from 1 m^2s^{-1} to about 1000 m^2s^{-1} in the above altitude range, with a dip around 80 km.

(G. Beig and D.K. Chakrabarty)

Day-night Variation of Positive Ion Conductivities in the Stratosphere

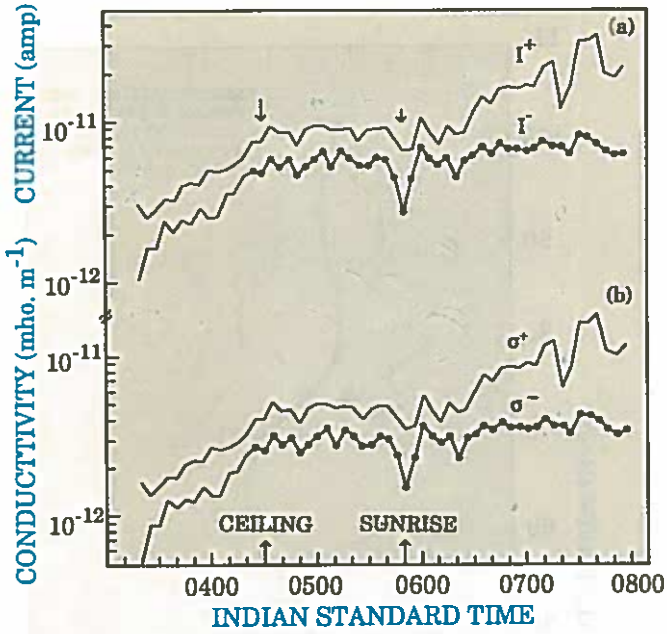
Balloon borne measurements during the IMAP period have given intriguing results on the day-night variability of positive ion conductivity in the stratosphere. It has been found that sometimes $\sigma_d^+ > \sigma_d^-$ (here suffixes d and n represent day and time conditions and σ^+ and σ^- are positive and negative ion conductivities). To sort out this problem, a balloon was launched on April 22, 1989 from Hyderabad at 0150 hrs IST. In this flight, conductivity values of both positive and negative ions were measured by a spherical probe. It has been unambigously found that $\sigma_n^- \sim \sigma_d^- \sim \sigma_n^+$ before sunrise. After sunrise, the value of σ_d^+ starts increasing with



An empirical model (profile marked as A) of the eddy diffusion for the low latitude middle atmosphere

the increase of solar elevation.

The value of σ_d^-, however, does not significantly change from that of σ_n^-. This monotonic increase of σ_d^+ with sunrise has been found to be due to the increase of ion current when negative bias was applied to the probes. These results confirm the earlier measurements of conductivities from Hyderabad during 18 April 1984 by means of conductivity probes. While this feature could be explained by the photoelectric effect on the probe, the possibility of increased mobility due to photodissociation of heavier species eventually increasing σ_d^+ could not be ruled out. This aspect is being investigated further.



Altitude profiles of both ion currents and ion conductivities measured by spherical probe in the balloon flight of April 22, 1989 at Hyderabad.

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

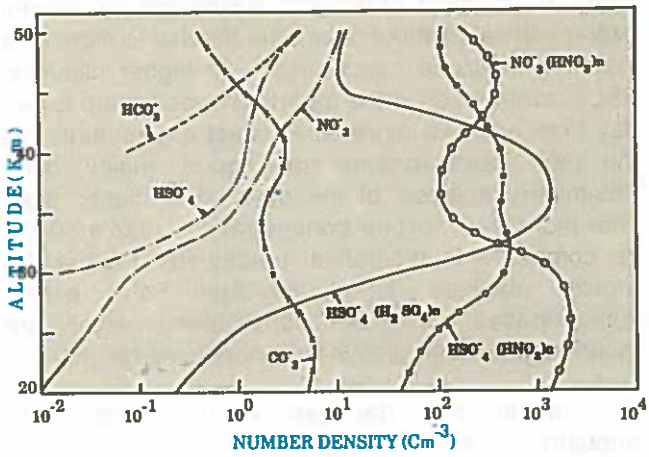
Theoretical Model of Stratospheric Negative Ions

To understand different processes involving ionic species in the stratosphere, theoretical model studies are needed. In that direction, model studies of stratospheric positive ions have been made and reported earlier. To make the picture complete, model study of negative ions has been initiated and a quasi-simplified negative ion chemical scheme for the stratosphere has been proposed. The constraints in this model are (1) the total negative ion density profiles measured by us at Hyderabad by balloons must be reproduced and (2) the measured features of negative ion cmposition should be satisfied. Present study shows that $NO_3^-(HNO_3)n$, $HSO_4^-(HNO_3)n$ and $HSO_4^-(H_2SO_4)n$ with N = 2 to 4 are the dominant negative ions of the stratosphere. Of these, the most dominant ion below about 32 km and above about 42 km is $NO_3^-(HNO_3)n$. $HSO_4^-(H_2SO_4)n$ remains the most prominent ion between 32 and 42 km.

(G. Beig and D.K. Chakrabarty)

Response of Electrons to a Gravity Wave in the Upper Mesosphere

Rocket and ground based measurements during quiet daytime condition have shown the existence of a sharp gradient in electron density around 85 km



A theoretical model of stratospheric negative ion composition.

altitude called 'ledge'. Recently, the ledge has been reproduced by a gravity wave of period larger than 2 hours. A highly temperature dependent reaction channel for the formation of positive cluster ions in the mesosphere was assumed. It was shown that a fluctuation in temperature of the order of 9 K produced by the gravity wave could create the ledge in the upper mesosphere. However, we have shown that as per the latest information of the laboratory measured reaction channels of positive ions, such a small fluctuation in temperature cannot reproduce the ledge. The ledge is suggested to be due to the peculiarity of the height distribution of electron production rate in that altitude region.

(D.K. Chakrabarty)

Measurement of NO_3 by Ground Based Visible Absorption Spectroscopy

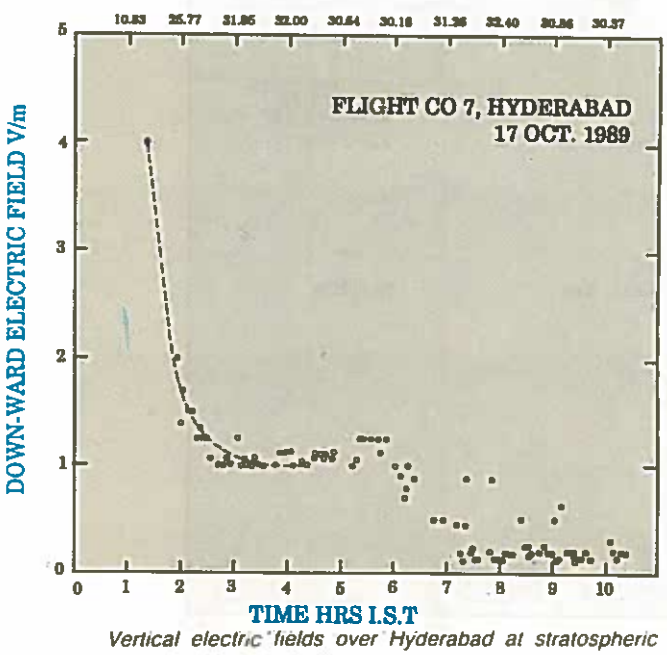
NO_3 is an important minor neutral constituent belonging to NO_x group in the earth's atmosphere. The data on this species at low latitude is sparse. It has a strong absorption feature near 662 nm. During the day, NO_3 is rapidly destroyed by sunlight and hence will have a much lower abundance than at night. In this connection a new experimental set up has been developed featuring a PC-AT based digital data acquisition (12 bit), accurate control of monochromator wavelength and fast scanning speed (30 A per second). This has resulted in fast and

accurate measurements with a large dynamic range. With this system it has been possible to get the signature of this species in the spectrum of the reflected moonlight. We have considered the ratio of this spectrum at two different elevations of the moon. This removes the weak Fraunhofer structure present in the above spectrum. Some observations were taken near the full moon days during the months of February and March, 1991. Analysis shows that the vertical column abundance at nighttime would be in the range of 1 to 4 x 10^{14}cm ^{2}.

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

Vertical Electric Field, Air Earth Current and Conductivity in Stratosphere

The stratospheric electric field and conductivity were measured in altitude region 15 to 33 km. The balloon was launched half an hour past midnight and reached floating altitude of 33 km at 2.30 A.M., and remained afloat till 10.30 A.M. Electric field and conductivity measurements carried out from Hyderabad on 17 October 1989 show that conductivity increases with height while the electric field decreases with height from 15 to 32 km. The product of these two parameters known as air-earth current density remains nearly constant but clearly shows variations with time at float altitude. Such variations can be explained due to local causes like local winds, though the exact cause of these variations is still to investigated.



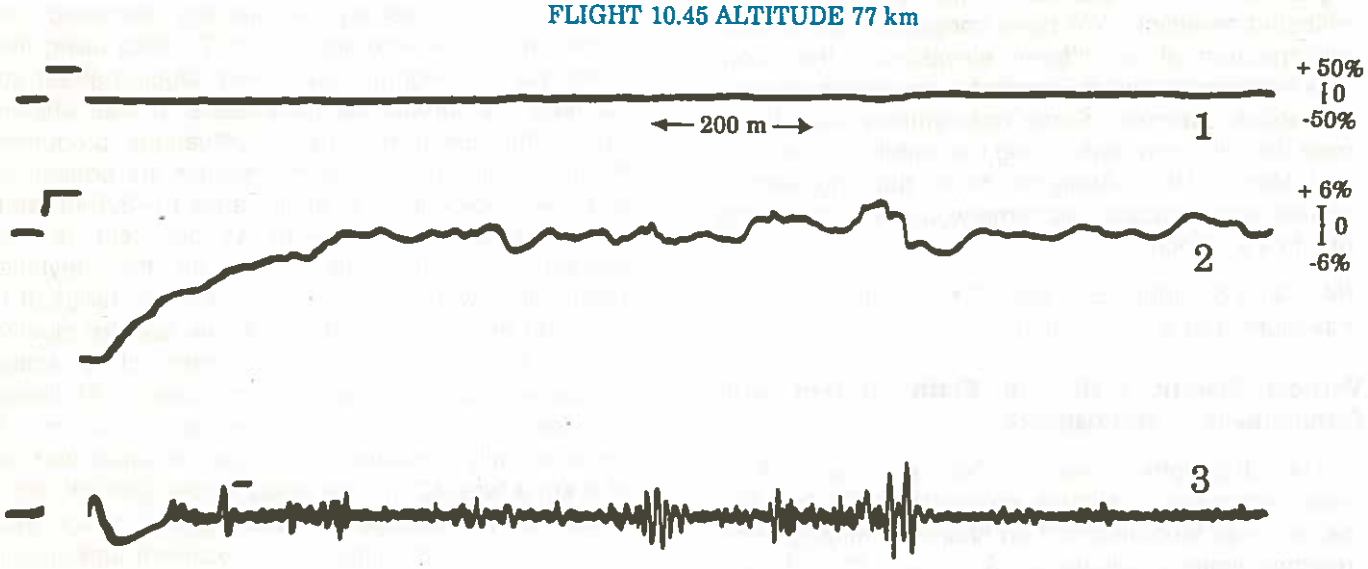
Vertical electric fields over Hyderabad at stratospheric altitudes. Sun rise effect is clearly seen after 0600 hrs IST

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

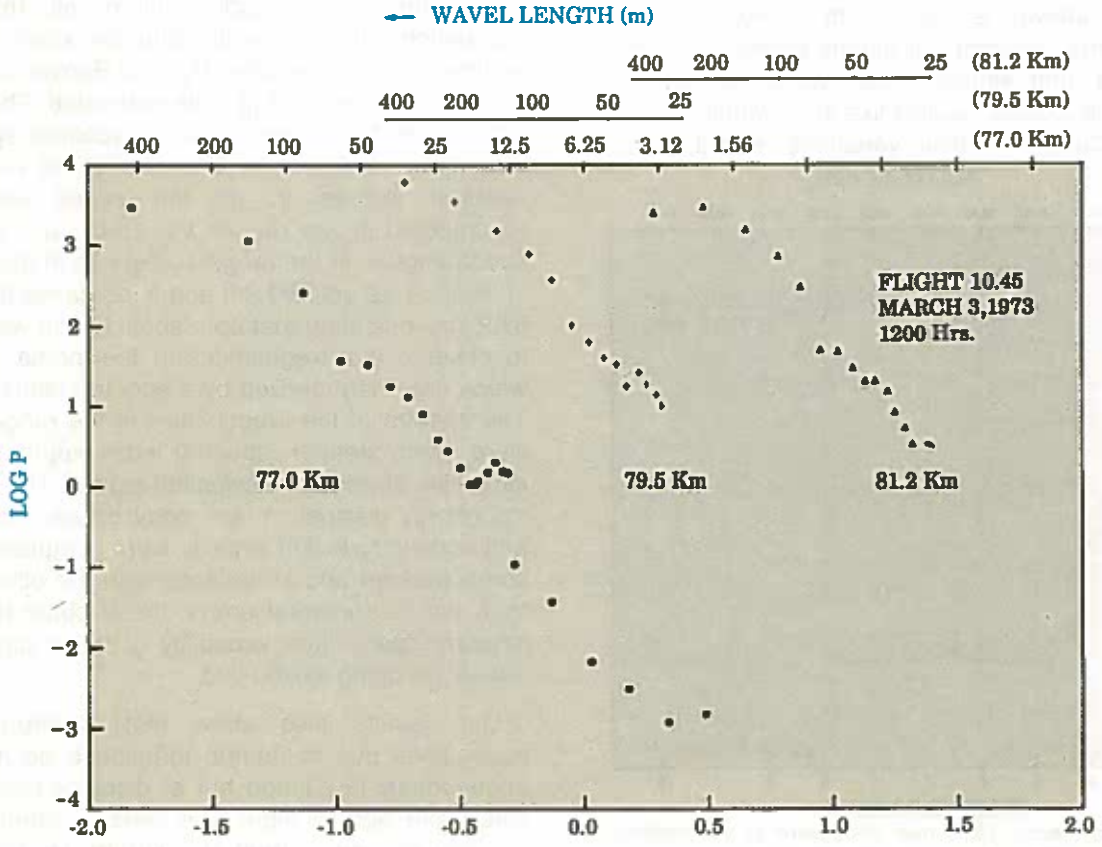
Estimation of Turbulence Parameters from the Fluctuations in the Electron Density

The electron density fluctuations observed on almost all the daytime flights from Thumba using the rocket borne Langmuir probe were studied afresh to estimate the turbulence parameters. It was shown earlier that electron density fluctuations produced through neutral turbulence mechanism are present in 60-82 km region in large scale range (1-300 m) and have amplitudes as large as 15 per cent. In the present study the spectra of all the daytime irregularities were studied in the scale size range of 1 m to 300 m. It was found that all the spectra clearly exhibit a change in spectral index at a scale corresponding to a few tens of meters. At lower altitudes (67.5 km) this scale was 17.2 m, it systematically increased at higher altitudes and at 81.2 km it was 42 m. The break in the spectral slope as well as the change of wavelength (at which this break occurs) with altitude is in excellent agreement with other experimental as well as theoretical estimates of the inner scale of turbulence. Hence this scale was taken as l_o, the inner scale of turbulence. Using this value of l_o, a standard atmospheric model and in-situ neutral temperatures the other turbulence parameters viz Kolmogorav microscale (η), energy dissipation rate (E), eddy diffusion coefficient (K), vertical turbulent velocity (U_z) and Buoyancy or outer scale of turbulence (L_B) were estimated. The altitude variation of η, l_o and L_B is in excellent agreement with other experimental and theoretical works. The spectral indices in all the cases were then recomputed in two ranges viz. l_o-L_B and l_o-η The spectral index in the range l_o-L_B was in the range of -1.76 to -1.92 upto 80 km and it increases to -2.27 at 81.2 km, indicating that upto about 80 km we are able to observe the irregularities in the inertia subrange which are characterized by a spectral index of - 5/3. The spectra of the irregularities in the range of l_o-η were much steeper (spectral index approaching -7) indicative of viscous dissipation regime. The values of the energy dissipation rate, eddy diffusion coefficient and vertical turbulent velocity were in agreement with some workers and at variance with the others. Apart from the instrumental errors, these could be due to inherent space-time variability of these parameters. These are being looked into.

Our results also show that electron density fluctuations due to neutral turbulence do not occur continuously in altitude but at discrete levels which differ from flight to flight. The vertical extent of these fluctuations range from 0.5 km to 15 km. In the daytime these irregularities cannot be observed in 85-100 km region using the in-situ probing. This is so



Flight record showing the presence of Neutral Turbulence generated 15-300 m electron density irregularities in the Main channel (1) and the Duct channel (2) and 1-15 meter irregularities in the high frequency channel (3).



Spectra of 1-300 m electron density irregularities at 77.0, 79.5 and 81.2 km.

because the region of 85 - 100 km is the one where theoretically the CFI (Cross-field instability) generated irregularities are present in their full strength (due to steep gradients and the vertical electric field) and neutral turbulence generated irregularities, if at all present, will be very weak and hence will be masked almost completely by CFI generated irregularities.

(H.S.S. Sinha)

UPPER ATMOSPHERIC STUDIES

Investigations on Thermospheric/Ionospheric System (TIS)

The investigations of Thermospheric/Ionospheric System (TIS) are being carried out using ground based optical and radiosounding techniques. The high resolution Fabry-Perot Spectrometer is operated from Mt. Abu for the measurements of both temperature and winds. The Thermospheric/Ionospheric Coupling is being investigated by means of co-ordinated optical measurements from Mt. Abu and the ionospheric measurements from Ahmedabad. Case studies are being performed during magnetically disturbed and quiet periods in order to understand the energetics of the low latitude thermosphere and its mode of coupling to the high latitude regions. In order to understand the spatial variabilities in the thermospheric temperature and winds a second identical Fabry-Perot Spectrometer was fabricated and operated successfully for the first time in a co-ordinated campaign from Thumba.

The unique dayglow photometer is also operated for the investigation of daytime thermosphere. Significant strides have also been made in the identification of the emssion processes.

Further investigation of the equatorial spread-F by means of numerical stimulation has been carried out to identify the response of the nighttime F-region to the various neutral dynamical parameters.

Co-ordinated Measurements on TIS

Successful co-ordinated campaign from Thumba for the investigation of low and equatorial Thermosphere/Ionosphere System was conducted. This was a multi-institute and multi-technique campaign and is first of its kind and magnitude. Four experiments namely Fabry-Perot Spectrometer, Dayglow Photometer, All sky Imaging camera and VHF scintillations recorder were operated by PRL while Space Physics Laboratory, VSSC, Trivandrum operated their Digital Ionosonde, Magnetometer and VHF backscatter from Thumba. The ground based Ionosonde and HF Doppler were operated from Kodaikanal by Indian Institute of Astrophysics, Bangalore. The Mt. Abu FP Spectrometer and the ionosonde/HF Doppler from Ahmedabad were also operated by PRL.

The main objective of the campaign was to investigate the low/equatorial Thermosphere/Ionosphere System during magnetically quiet and disturbed periods and also a special emphasis was given to the equatorial spread-F phenomenon. The data are being analysed.

(R. Sridharan, R. Sekar, S. Gurubaran, R. Narayanan, N.K. Modi, S.R. Das, H. Chandra, H.S.S. Sinha, G.D. Vyas, R.N. Misra, V.K. Parmar and M.B. Dadhania)

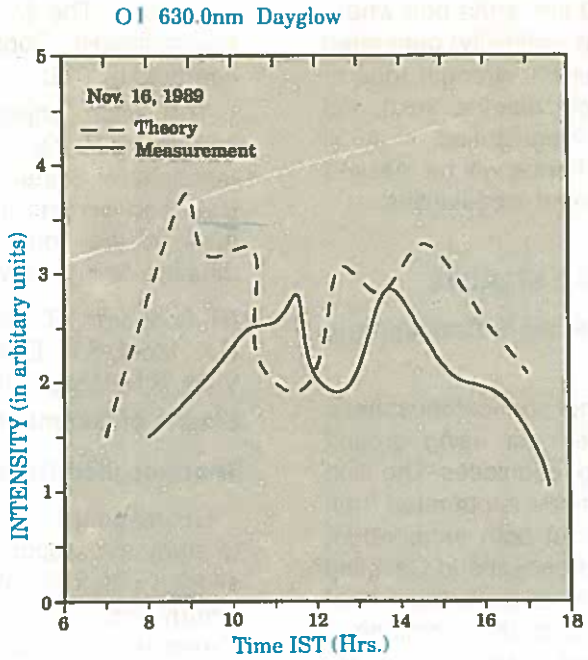
Effects of Geomagnetic Storms in the Low Latitude Thermosphere/Ionosphere System

Geomagnetic storms provide unique opportunities to study the response of the upper atmosphere for a sudden external input of energy. Since most of the energy input is concentrated at polar regions the transport of energy and momentum to other regions has been an important aspect of investigation. Case studies of individual storm events by following the response of the TIS system day by day provide us vital clues to the overall energetics of the system. One such study carried out using the FP spectrometer data from Mt. Abu reveals that thermospheric neutral temperatures on magnetically disturbed days are about 300-500 K larger than on quiet days. Further the effects of these disturbances take about a day to get registered at low latitudes. This result suggests the possibility of (i) meridional wind circulation and/or effective transportation of energy by means of gravity waves.

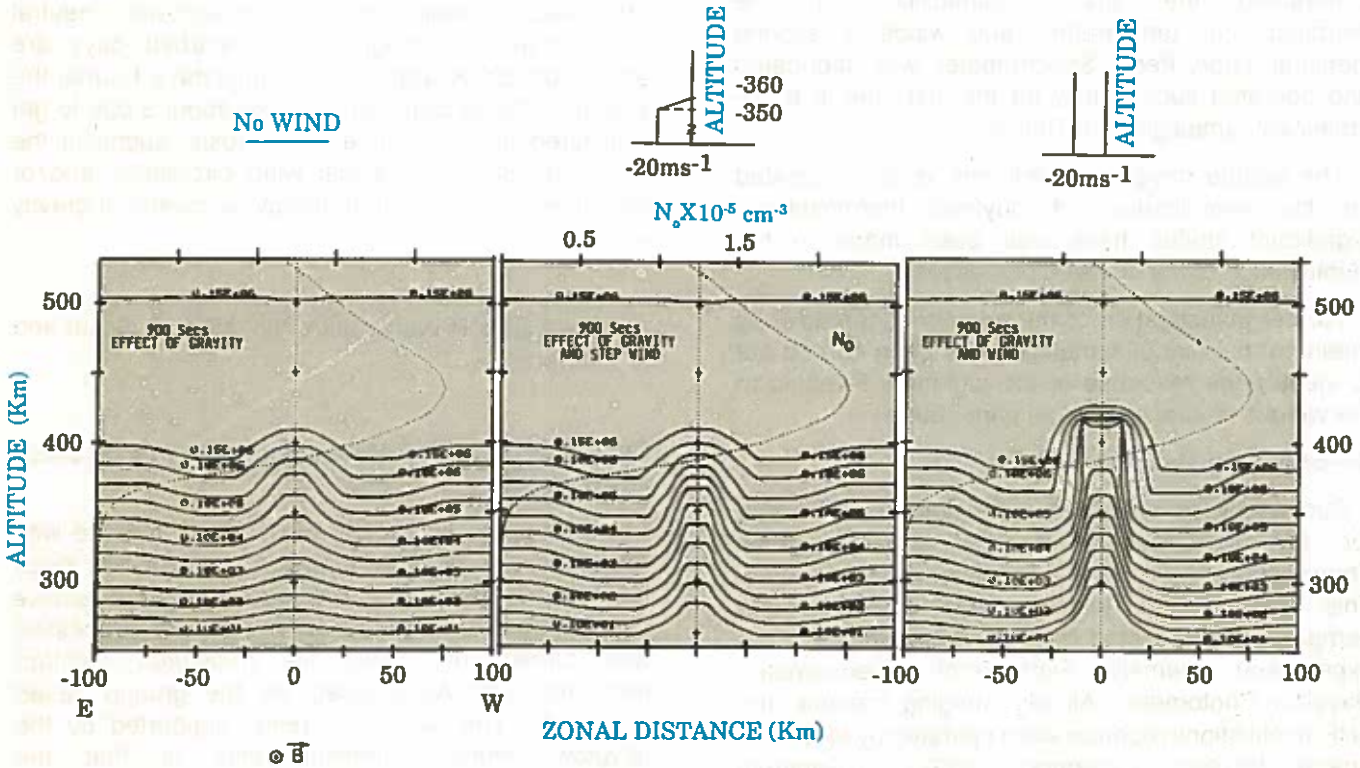
(S. Gurubaran, R. Narayanan, N.K. Modi, R. Sekar and R. Sridharan)

Contribution of the Mechanisms for the OI 630.0 nm Dayglow

A new result confirming our earlier inference with regard to the dayglow emission process has been obtained. A theoretical investigation on the relative importance of the various known emission processes was carried out using the measured electron densities, over Ahmedabad, by the ground based ionosonde. The significant result supported by the dayglow intensity measurements is that the dissociative recombinnation of O_2 ions with ambient electrons is comparable to the photodissociation of O_2 and further, all the temporal variabilities recorded are solely due to the temporal variation of the electron densities. The significance of these measurements



Temporal variations of OI 630.0 nm dayglow intensities as measured over Mt. Abu (continuous curve) and theoretically estimated (dashed curve) using the electron density obtained by ionosonde operated from Ahmedabad. The values are normalised to the measured noon time minimum.



Isoelectron density contours in zonal and vertical plane at 900 sec for three cases where the driving agencies are (i) gravity, (ii) gravity plus downward wind (20 m/s) upto 350 and zero beyond 360 km, (iii) gravity plus downward wind (20 m/s) all through the altitude region of simulation. This figure brings out the significance of 'insitu' effects of the destablising agency.

from a location under the crest of the equatorial ionisation anomaly has also been shown for the first time.

(R. Sridharan, S.A. Haider, S. Gurubaran, R. Sekar, R. Narayanan and N.K. Modi)

Equatorial Spread-F Investigation

The significant role of neutral dynamical parameters especially the vertical winds in accelerating/decelerating the evolution of plasma depletions was successfully demonstrated by the development of nonlinear numerical simulation method. In continuation to that, an exercise was carried out to investigate whether these effects are of 'insitu' origin or communicated from lower altitudes. A case study was performed by introducing a step wind i.e. an altitude independent downward wind (20 ms $^{-1}$) upto 350 km which drops down to zero at 360 km. This result when compared with a case of (i) no wind and (ii) altitude independent downward wind, revealed that the nonlinear effects of insitu winds and electric fields are important even beyond 350 km. Further, the effect of dominant advection term in the evolution of plasma density irregularities are found to be highly localised and not very significant. This work has been carried out in collaboration with Prof. R. Raghavarao and Dr. R. Suhasini.

(R. Sekar and Ranna Patel)

Imaging of Plasma Depletions over Trivandrum

Ground-based measurements of 630.0 nm brightness distribution of the night airglow emanating from the bottomside of the F-region shows large depletions. These deplétions are the manifestations of the plasma bubbles which are believed to be produced by the generalized Raleigh Taylor Instability.

An all sky optical imaging system capable of measuring very weak airgolw was developed in PRL during the last year to study the plasma depletions associated with the equatorial spread-F. This system consists of an interference filter, a fish-eyed lens (for 180° FOV) or a standard lens (for 51° FOV), an image intensifier and a 35 mm camera. This imaging system was operated from SHAR during February 1990. The analysis of these preliminary data indicated that the system needs some tuning. As a result the optical design of the system was significantly improved during 1990-91 to ensure that the image quality is excellent.

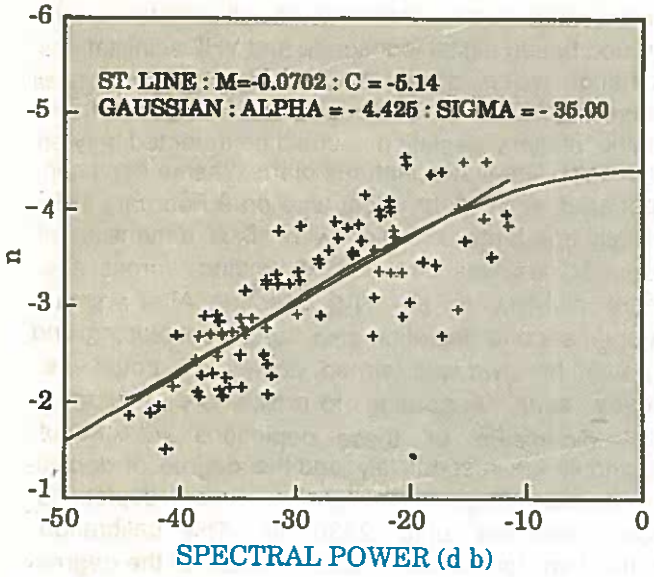
The imaging system was operated from Trivandrum during February 1991 for 10 nights. The spread-F irregularities were detected on all nights by the ground based digital ionosonde and VHF scintillations. Although we could map the 630 nm nightglow on all these nights, the much sought for plasma signatures of the plasma depletion could be detected only on one night. The first signatures of the plasma depletion appeared at 1930 hr. local time on 9 February 1991. Initially one large depletion with E-W dimension of about 50 km was observed extending across the entire nightsky in the N-S direction. After a small interval second depletion also started developing and by 2230 hrs. two well formed depletions could be clearly seen. According to preliminary estimates E-W dimension of these depletions were about 80 and 40 km, respectively, and the degree of depletion was much larger for the former. These depletions were observed upto 2330 hr. The calibration of the film, for absolute determination of the degree of depletion, and the digitization of images is now nearing completion. The processing of these images is currently in progress to take care of the effects such as background illumination, phosphor noise of the intensifier, etc.

(H.S.S. Sinha,, H. Chandra, R.N. Misra, G.D. Vyas, V.K Parmar, Nikhil Shah N. Dutt and G.A. Panchal)

Rocketborne in-situ and Radio Scintillation Studies of Ionospheric Irregularities

In situ measurement of the electron density irregularities associated with equatorial spread-F were made by Langmuir probe flown on a RH-560 from SHAR during November 1982. Spectral studies in the scale size range of 20 m to 200 m (transition scale) for over 200 samples of data have shown the spectral slope increasing with spectral power P_t. The spectral index values varied between -1.5 to -4.6 and the relationship of the exponent (power law index n, represented as $P(f) \propto f^n$ with power was shown to be best described by a Gaussian function as $n = -4.425 \exp(-P_t^2/2x35^2)$) where P_t is the power $(\Delta n_e / n_e)^2$ in db. The mamimum value of the index n thus comes out to be -4.425. This is in fair agreement with the results obtained in laboratory experiments for the study of drift waves i.e. between -4.5 to -5.0.

Spectral characteristics of the irregularities were



Variation of the spectral index (n) with spectral power of the F-region irregularities in the wavelength region 20-200 m determined from the in-situ measurements conducted from SHAR.

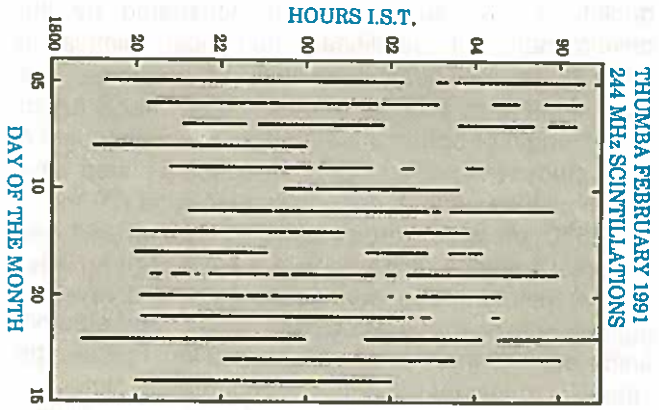
also studied from radio scintillation observations made from SHAR during October 1988. About 225 samples of scintillations during the night of 4-5 October were analysed for spectral indices in the frequency range of .3 to 3 Hz (spatial scale 30 m - 300 m for an assumed drift of 100 m/s). The power law exponents obtained from temporal scintillation spectra varied between - 2.4 to - 6.0 which would correspond to -1.4 to -5.0 for one dimensional spatial spectra. These values are very close to the exponent values obtained from in-situ measurements. The variation of the spectral index with scintillation index S_4 also showed an increase and later approaching to a constant value. Since the scintillation index is directly related to n_e the results obtained from scintillation studies also support the result of the dependence of spectral exponent on spectral power obtained from in-situ studies.

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

Ionospheric Scintillation Studies

As part of a preliminary multi-technique campaign to study equatorial spread-F, VHF scintillation observations at 136.1 MHz were made from SHAR during March 1990. Later the experiment was conducted from IIT Madras till 14 December 1990 when the radio beacon from satellite ETS-2 was shut down.

A new receiver at 244 MHz was built to record the beacon from the Fleetsat satellite and operated from Thumba during February 1991 as part of Thermosphere-Ionosphere System studies with emphasis to the equatorial spread-F. Strong scintillations were recorded on all the nights during the period of campaign.



The occurrence of scintillation over Thumba shown for each day during the period 5 to 20 February 1991.

(G.D. Vyas, H. Chandra, H.S.S. Sinha, R.N. Misra, M.B. Dadhania and V.K. Parmar)

Solar EUV and Solar Wind Electron Interaction with Comet Halley's Ionosphere : Ion Composition

The ion and neutral mass spectrometer results obtained from Giotto and Vega spacecrafts have attracted a great deal of attention to a large number of observations in situ in the inner coma of Comet Halley. The early studies reported in the literature were concentrated on the chemistry and dynamics of cometary ionosphere. In these studies the ionization in the vicinity of comet Halley resulting from the interaction of post-shock solar wind electrons was not included. We have conducted a study which includes this process and find that this is indeed one of the dominant processes.

A model calculation for the production rate due to sources (i) solar EUV (ii) photoelectron and (iii) solar wind electrons for different ionic species are carried out in the inner coma of Comet Halley.To perform the

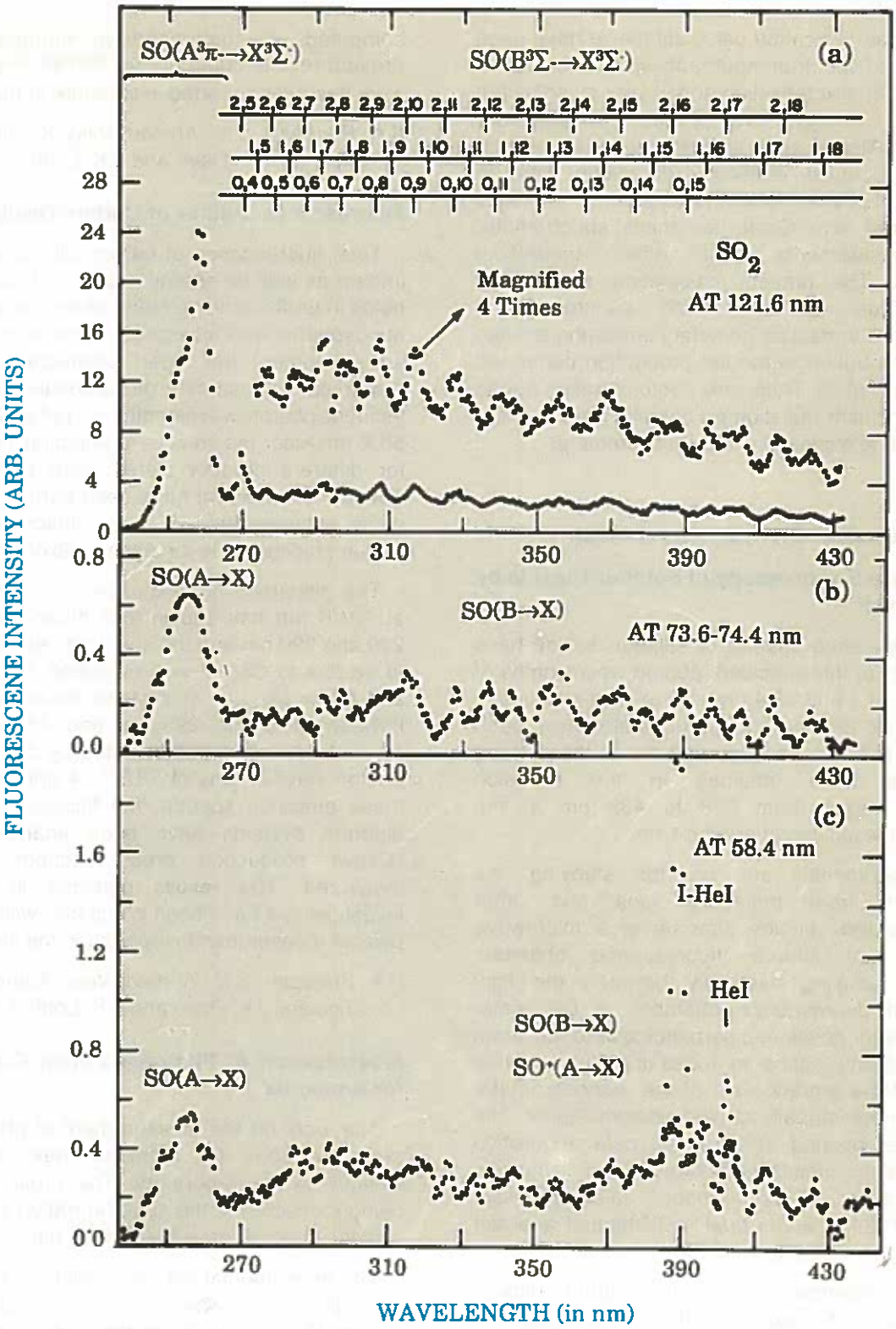


Fig. 15. The fluorescence spectra of sulphur dioxide at incident photon wavelengths of (a) 121.6 nm (b) 73.6-74.4 nm and (c) 58.4 nm. Fig (c) shows the fluorescence spectrum alongwith scattered radiation of helium lines (solid points) whereas fluorescence spectrum after proper subtraction of scattered radiation has been shown by open points.

electron impact ionization calculations we have used analytical yield spectrum approach which is based on Monte Carlo characterization and is very much suited for electron energy loss process in planetary atmosphere. Steady state ion densities are obtained by solving coupled continuity equations with an assumption of photo chemical equilibrium. The results are compared with Giotto ion mass spectrometer (IMS) measurements and other theoretical calculations. The present calculation shows that ionization due to solar wind electrons and photoelectrons impact on cometary atmosphere make a larger contribution to the ion production compared with photoionization. Thus, only photoionization due to solar EUV incident radiation on cometary atmosphere is insufficient to explain the IMS measurements.

(S.A. Haider)

LABORATORY ASTROPHYSICS

Fluorescence Spectroscopy of Sulphur Dioxide by Photon Impact

The fluorescence spectra of sulphur dioxide have been studied at three incident photon wavelengths of 121.6, 73.6-74.4 and 58.4 nm and relative production cross sections for different product states have been measured. The fluorescence spectra at these three wavelengths were obtained in the emission wavelength region from 238 to 432 nm at the instrumental resolution of around 1 nm.

The experimental set up for studying the fluorescence from molecular ions and other photofragmented species consists of a microwave discharge light source, fluorescence chamber, differential pumping assembly between the light source and fluorescence 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 which include appropriate pre-amplifier, amplifier and a home-made microprocessor controlled 1024 channel dual multichannel analyzer operated in the multiscaling mode.

The fluorescence spectra of sulphur dioxide obtained using the experimental set up described above consists of SO (A $\rightarrow$ and B $\rightarrow$ X) systems at 121.6 nm and 73.6-74.4 nm and SO (A $\rightarrow$ X) system at incident photon wavelength of 58.4 nm along with the two SO systems. In all these emission spectra, the relative production cross sections for fluorescence bands of different systems have been computed. A comprehensive comparison of the present results could not be carried out as not much work has been reported in literature in this direction.

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

Fluorescence Studies of Carbon Disulphide

Total fluorescence of carbon disulphide by photon impact as well as energy analysis of such emissions helps in understanding many phenomena in planetary atmospheres and interstellar medium. In view of this, an experiment has been conducted to study the dispersed fluorescence of carbondisulphide at three incident photon wavelengths of 121.6, 73.6-74.4 and 58.4 nm.Also, the relative production cross sections for different product states have been measured. These measurement have been carried out using the same experimental set up as described in case of similar studies made for sulphur dioxide.

The dispersed fluorescence for carbon disulphide at 121.6 nm has shown four broad peaks between 240 and 290 nm and the spectrum has been identified to be due to CS(A $\rightarrow$ X) transition. CS_2^+ (B $\rightarrow$ X) and CS_2^+ (A $\rightarrow$ X) systems have been produced between 276 and 295 nm and 437 and 555 nm respectively when photoexcited by both the incident photon wavelengths of 73.6-74.4 and 58.4 nm. In all these emission spectra, the fluorescence bands of different systems have been analyzed and their relative production cross sections have been measured. The results obtained in the present investigations have been compared with a few recent reliable measurements reported in the literature.

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

Measurement of Photoabsorption Cross Sections for Ammonia

The work on the measurement of photoabsorption cross sections for ammonia has recently been initiated in the laboratory. The cross sections are being measured in the spectral region 180 to 205 nm with the specral resolution of 0.08 nm.

The experimental set up consists of an argon mini-arc light source which produces a continuum from 115 to 350 nm, an one-meter near normal incidence monochromator to obtain monochromatic photon beam, a beam splitter to monitor the intensity of the incident photon beam during the experiment, an absorption chamber to carry out absorption studies, two thermoelectrically cooled photomultipliers (one to measure intensity at the beam splitter and the other to

measure intensity of the beam transmitted through the target gas) and a fast data acquisition system. Using this set up, the preliminary data on photoabsorption cross sections of ammonia has been obtained. Work is being continued in this direction.

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

Photoabsorption Cross Section Measurement of Molecules at Different Tempretures.

A new experiment is being set up in the laboratory to measure photoabsorption cross sections for some atmospheric molecules at different temperatures varying from 200 to 500 K. These measurements would be carried out in the spectral region 180-320 nm at the instrumental resolution of about 0.1 nm. The molecules like NO, NO_2, CO, CO_2, SO_2, CS_2 chlorofluoromethanes etc. would be investigated with an accuracy of ±5 percent.

The photoabsorption cross sections for a molecule would be different at different temperatures. The number of molecules at room temperature are maximum in the zeroth vibrational level of the groupd electronic state. As the temperature increases, the number of molecules in the zeroth vibrational level gets reduced and the higher vibrational states get more and more populated. Also, for different initial vibrational states, the transition probabilities for photoabsorption change drastically. Hence the absorption cross sections at a certain incident photon wavelength may be appreciably different for different gas temperatures. This experiment has been designed and is being fabricated right now in the laboratory. Some of the sub-systems are ready while some others would be ready in the near future.

(S.M. Ahmed, V. Prahlad and Vijay Kumar)

Electron Scattering Cross Sections for Carbon Monoxide

Work on the measurement of absolute total electron scattering cross sections for carbon monoxide has recently been initiated in the laboratory. The cross sections are being measured at low electron energies ranging from 0 to 10 eV using a photoelectron source. In this experiment, the electrons produced conventionally from electron guns have been replaced by photoelectrons produced by interaction of monochromatic vacuum ultra violet photons with source gases.

The total electron scattering cross sections for carbon monoxide have so far been measured at only a few electron energies. Work is being continued in this direction.

(M.K. Jayaraj, K.P. Subramaninan and Vijay Kumar)

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10. Parmar, V.K., "A precise timer", Electronics for You, 23, 137 (1991).
11. Prajapati, I.A., Ahmed, S.M. and Vijay Kumar, "Fluorescence studies of CS_2 and SO_2 at 121.6, 173.6-74.4 and 58.4 nm", Pramana - J. Physics, 36, 191 (1991).
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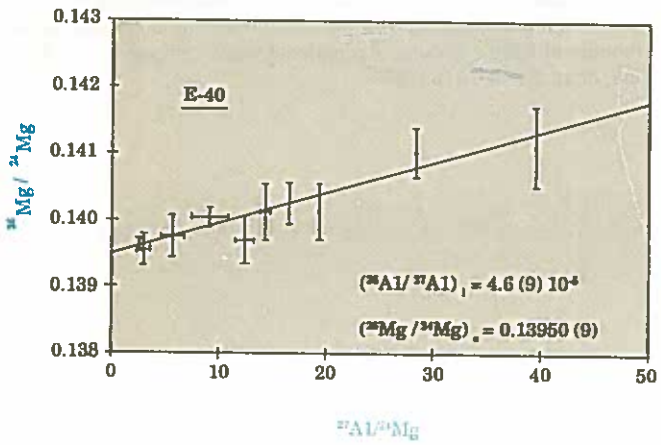
Earth Science and Solar System Studies

The Earth Science and Solar System Division comprises of two areas (i) Geocosmophysics and (ii) Continental Palaeoclimate Studies. In the Geocosmophysics area the focus is on understanding processes that have shaped the solar system from its infancy and to the ones that are currently taking place on one of its members, our planet Earth. The focus of Continental Palaeoclimate Studies area is to derive palaeoclimatic information from study of lake sediments using a multi-disciplinary approach.

GEOCOSMOPHYSICS

The Geocosmophysics area has two main fields of research (i) those based on meteorites and moon samples to derive information about the Sun in its early stages and the formation of the solar system objects and (ii) those based on samples from the Earth to obtain information on mountain building, weathering and erosion, ocean circulation and palaeoenvironment.

Magnesium isotopic compositional studies have been completed in a set of pristine solar system materials contained in the primitive carbonaceous meteorite Efremovka using the Ion Probe. The results are : (i) the presence of ^{26}Mg excess (from the decay of now-extinct short-lived radionuclide ^{26}Al) in all the refractory inclusions irrespective of their petrographic type and well defined Mg-Al isochrons and (ii) in one of the inclusions a sympathetic behaviour in isotopic and petrographic systematics are seen that enable us to understand the processes responsible for its formation.



Presence of radioactive ^{26}Al as seen through excess ^{26}Mg. The initial $^{26}Al/^{27}Al$ and $^{26}Mg/^{24}Mg$ ratios at the time of formation are indicated.

Two meteorites collected from the Antarctica that are established to be of lunar origin have been studied for their noble gases, nitrogen and nuclear track records. The very similar noble gas exposure ages for both the meteorites suggest that they belong to the same fall. The track and the radionuclide data allow us to estimate the Moon-Earth transit time of this meteorite to be between 0.2-0.6 million years and to delineate the major episodes of exposure, burial and ejection from the moon in the history of this sample.

Geochemical studies of Permian-Triassic boundary section in the Spiti Valley, Himachal Pradesh indicate two horizons with small enhancement of iridium having concentrations of 73 and 113 pg/g in sharp contrast to a strong Ir anomaly of 12100 pg/g at the Cretaceous-Tertiary boundary in Meghalaya suggesting that asteroidal impact need not be invoked to bring about mass extinction.

The Ganga-Brahmaputra (G-B) is one of the largest river systems of the world which has been extensively studied to determine its role in erosion of the Indian subcontinent and transport of materials to the Bay of Bengal. The G-B river system annually transports about 910 million moles of Sr with a $^{87}Sr/^{86}Sr$ of 0.7213. The G-B system contributes significantly (30%) to the Sr isotope evolution of seawater during the past 20 million years and reinforces the major impact of Himalayan orogeny on the marine geochemistry of Sr isotopes.

Intense biological productivity, high particulate concentrations and associated denitrification at intermediate depths are resulting in extensive removal of ^{210}Po and ^{210}Pb throughout the water column of the eastern Arabian sea. The continental margin sediments which are in contact with the core of the denitrification layer (200 - 700 m) are acting as sink for ^{210}Pb and U and as a source for Mn to the Arabian sea.

Cosmic Rays and Solar System Studies

Further Results from the 'Anuradha Spacelab-3 Experiment

The main objective of Anuradha experiment onboard the spacelab was to determine the ionisation state of the Anomalous Cosmic Rays (ACR). This has been achieved, but the data acquisition is continued to enlarge the data base which has increased the event statistics by 40%. The singly ionised state of the ACR having local interstellar neutrals as their source is now well established from the expanded data base.

The new observation of the partially ionised low energy (30-125 Mev/n) galactic cosmic ray (GCR) iron-group particles reported by us last year was a completely unexpected result and efforts were made to substantiate this observation. A total of sixteen such events (as against three reported last year) have been observed in a total of 55 low energy iron group particles detected in this experiment. The upper-limit ionization state for these events are :

Ti (6^+) V(10^+, 16^+), Cr(5^+, 8^+), Mn(4^+), Fe(3^+, 3^+, 10^+, 11^+, 14^+, 14^+ 20^+, 20^+) and Ni(8^+, 14^+).

We propose that the low-energy (1-10 MeV/n) component of the steady-state local interstellar cosmic rays may themselves be the source of the partially ionized heavy particles. The GCR heavy ions at these energies, following their interstellar travel are expected to be partially ionized, with their equilibrium ionization state being a function of their energy. As regards the acceleration of this partially ionized low energy (1-10 MeV/n) component to observed energies (30-125 MeV/n) at 1 A.U. the solar wind termination shock as the most plausible site is still preferred. This work is carried out in collaboration with the TIFR group led by Profs. S. Biswas and N. Durgaprasad.

(A. Dutta, J.N. Goswami and N. Sinha)

Xe Isotope Production in Ba Targets

This program of determining the production rates of Xenon isotopes to understand its isotopic composition in moon and meteorites is continued at proton energies of 800 MeV, 1200 MeV and 2600 MeV. These studies were carried out as part of a collaboration with Universities of Cologne and Hannover, F.R.G. The irradiations at 800 MeV were carried out at the Los Alamos accelerator whereas those at 1200 MeV and 2600 MeV were carried out at Saclay. Our results show that the earlier assumption of a constant production cross-section for Xe isotopes for proton energies above 600 MeV is no longer valid. The measured cross sections show significant variations. More importantly our results prove that the relative yields of the Xe isotopes (spallation spectrum) change systematically as the proton energy increases from 600 MeV to 2600 MeV with enhanced production of the heavier isotopes eg. ^{131}Xe and ^{132}Xe, in comparison to the lighter isotopes, ^{124}Xe and ^{126}Xe. These results provide important constraints for explaining the GCR-Xe production in extraterrestrial matter.

The measured Xe amounts in samples taken from documented depths of anorthositic lunar rocks 61016, 64435 and 79215 have been separated into constituent components to look for SCR produced Xe isotopes. The results from all the three rocks show marginal excesses of SCR produced Xe. The excesses observed are more prominent for the isotopes ^{129}Xe, ^{131}Xe and ^{132}Xe. The excesses observed here and the resultant isotopic composition are significantly different from the Xe components inferred from the studies of Xe in Apollo samples by other groups.

(K.J. Mathew and M.N. Rao)

Exposure History and Trapped Gases in Lunar Meteorites

Eleven meteorites of lunar origin have been identified so far from Antarctic meteorite collection. Since only a small region of the lunar surface has been sampled by the Apollo and Luna missions, it is desirable to have access to samples from other regions of the moon. These meteorites hopefully provide such samples.

Nitrogen, noble gases and nuclear tracks are studied in two recently identified lunar meteorites to understand : (a) their cosmic ray exposure history and (b) the origin of the trapped gas cmponents. Our results show that the (i) K-Ar ages of these samples are 3.2 ± 0.6 Ga, (ii) concentrations of the solar wind gases in these samples are very small, implying a short residence time on lunar surface, (iii) the $(^{40}Ar/^{36}Ar)_{tr}$ = 7.2 ± 0.7 indicating the duration of solar wind loading to be ≥ 3 Ga and (iv) the noble gases are dominated by cosmogenic component while nitrogen is dominated by a trapped component which is upto two orders of magnitude higher than can be explained by solar wind. The results allow us to characterise this 'excess N' component to have $\delta^{15}N$ = 17 ± 13.5 ‰. This value is in good agreement with the recently reported idigenous lunar nitrogen ($\delta^{15}N$ = 13 ± 1.5‰). No solar flare track records are observed which is consistent with the presence of very low solar wind gases in these samples. The track data along with published cosmogenic radio nuclide data constrain the space exposure age (moon-earth transit time) to within 0.2 - 0.6 Ma suggesting that the stable cosmogenic nuclide (^{21}Ne, ^{38}Ar, ^{83}Kr, ^{126}Xe etc.) are entirely produced when the sample was exposed on the lunar surface. The cosmic ray exposure ages derived from the noble gas isotopes are consistent with each other and are same for both the meteorites (225 ± 45 Ma), clearly supporting the pairing of these two meteorites as earlier suggested from chemical and petrological

observations.

(J. N. Goswami and S.V.S. Murty)

Production Rate of Cosmogenic Nitrogen

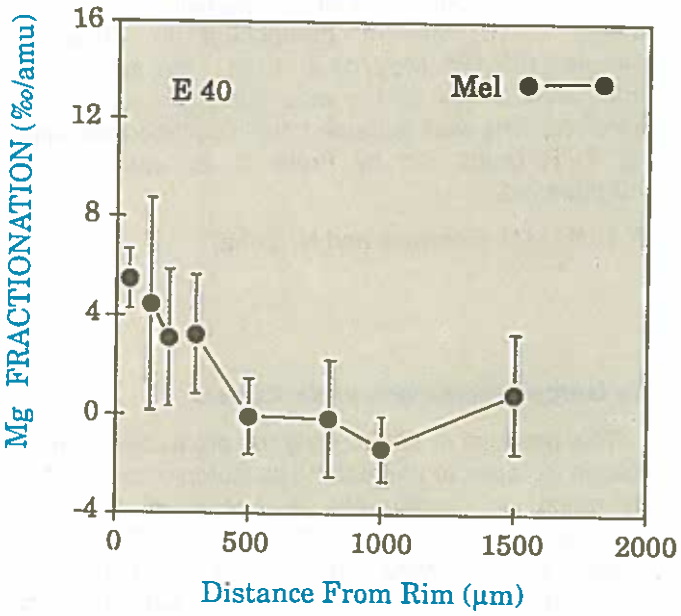
Oxygen is the principal target element for the production of ^{15}N and ~45% of most of the silicate minerals are made of oxygen. Inspite of its ubiquitous production in all silicate material that were exposed to cosmic rays, it has not been easy to decipher the cosmogenic N component due mainly to a preponderance of large indigenous N which is most often ill-defined. One approach that has been adopted to circumvent this difficulty was to theoretically calculate the production ratios $^{15}N/^{21}Ne$ or $^{15}N/^{38}Ar$ and use the easily measurable ^{21}Ne or ^{38}Ar to derive the cosmogenic $\delta\ ^{15}N$. Nevertheless it is desirable to idependently derive the cosmogenic ^{15}N. Aubrites which have well defined indigenous N component with $\delta\ ^{15}N = -33$ ‰ are good candidates for such studies.

As a first step, Norton County, an aubrite with a high exposure age is analysed for N, Ne and Ar. The cosmogenic components (in units 10^{-8} ccSTP/g) are $^{15}N = 236 \pm 30$; $^{21}Ne = 62 \pm 6$; $^{38}Ar = 2.1 \pm 2$. Both ^{21}Ne and ^{38}Ar yield an exposure age of 121 ± 15 Ma, resulting in a nitrogen production rate $P_{15} = (1.95 \pm .35) \times 10^{-8}$ cc STP/g Ma.
(S.V.S. Murty)

Ion-Probe Studies

a) Mg-isotopic systematics in early solar system objects : We have studied a set of petrographically well characterized coarse-grained-refractory inclusions (CGIs) from the Efremovka CV3 chondrite for their magnesium, calcium, titanium and oxygen isotopic compositions using the ion probe. The absence of secondary alteration products in the Efremovka CGIs compared to those in Allende makes them one of the most pristine solar system material available for laboratory analysis. Of the six CGIs analysed for magnesium isotopic compositions three can be classified as type B1, one as type B2, one as compact type A and one is a hibonite-rich inclusion.

The magnesium isotopic compositions in the different mineral phases of these inclusions are determined by the ion probe at a nominal mass resolution of ~4000. A measurement precision of ≤ 2‰ (2 σ m) could be achieved during these analysis. ^{26}Mg excess due to in-situ decay of now-extinct short-lived radionuclide ^{26}Al (half-life = 7×10^5 years is present in all the Efremovka inclusions studied by us. Further all of them yield well defined magnesium-aluminium isochrons irrespective of the inclusion type. This is unlike in Allende the most widely studied CV 3 meteorite for isotopic systematics where except for the type B1 inclusions, the Mg-Al correlation is mostly disturbed. The isotopic data for the Efremovka CGIs must be a reflection of their pristine nature as inferred from their petrographic characteristics. The Efremovka data do show a spread in the initial $(^{26}Al/^{27}Al)$ ratio $[(3.6\text{-}5.9)\times10^{-5})]$ around the canonical value of ~5×10^{-5} The initial $(^{26}Mg/^{24}Mg)$ ratios for the source material of the Efremovka inclusions are higher than the normal solar system value (0.13932) for atleast three CGIs. The variations in both the initial Al and Mg isotopic compositions in the Efremovka CGIs support the presence of isotopic inhomogeneity over small scale sizes in the solar nebula.



Intrinisic Mg fractionation in melilite (inclusion E40) as measured from rim to the core.

The magnesium isotopic fractionation in both melilite and spinels from the inclusions favours the heavier isotopes as is expected for coarse grained refractory inclusions that are considered to be evaporative residues. However, the fractionation trend varies from inclusion to inclusion. The pattern seen in inclusion E 40 which has been observed for the first time in a normal refractory inclusion is of particular interest. The chemical composition of melilite in this inclusion grades from 10 % Ak° near the edge to 80% Ak° in the core and both the fractionation trend and the compositional variation can be best explained by

postulating rapid volatilization loss during solidification of this inclusion from the molten droplet. Such observations of sympathetic behaviour in both petrographic and isotopic systematics have been sought for quite sometime as they allow one to pinpoint, with confidence, the process affecting the formation of these early solar system objects. The Efremovka inclusions thus seem to be extremely promising samples in this context. This work was carried out in collaboration with Dr. A.A. Ulyanov of the Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow.

(b) Software and hardware support for the Ion Probe : The need for developing certain software and hardware support systems for appropriate data handling and synthesis, as well as environment and subsystem monitoring was identified last year and some of these were implemented during the year. The data handling software mainly pertains to isotopic analysis. The design of a 68000 microprocessor-based-system, to continuosly monitor and display several instrument as well as environmental parameter has been completed during the year.

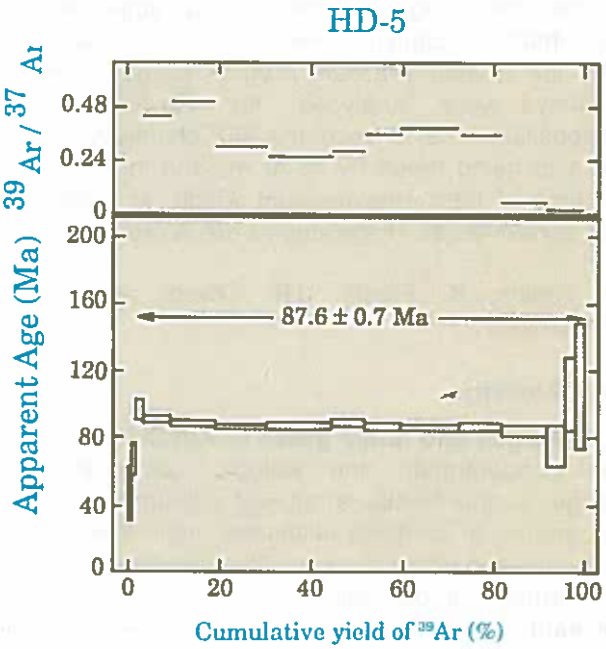
(M.P. Deomurari, J.N. Goswami, V.G. Shah and G. Srinivasan)

EARTH SCIENCES

Geochronology

Geochronological studies were focussed on two main areas - the Deccan and the Himalaya. Both these are on-going programmes.

(a) Ar-Ar ages of Deccan trap basalts and associate dykes : The Ar-Ar geochronology of Deccan basalts is being carried out to evaluate the exact timing and duration of their eruption to address the twin problems of the origin of these continental flood basalts and their relation to the K/T events. An important study carried out this year was to test the consistency of Ar-Ar ages obtained in our laboratory with those reported by other international laboratories. An international standard SB-3 was dated precisely at 162.1± 0.6 Ma which is in excellent agreement with the reported and accepted value of 162.9± 0.8 Ma. Basalt samples with palaeontological/stratigraphic control of intertrappean sediments like the occurrence of dinasour eggs were dated. In two such sections samples were analysed. While in one section the flows immediately above and below the fossiliferous intertrappean give identical plateau ages, (65.5± 0.7 and 65.4± 0.4 Ma), in the other section the sample below the fossiliferous horizon gives a plateau age of 63.7± 0.7 Ma. These results are very significant because they imply the existence of dinasours in the Tertiary. These findings require further confirmation by dating some more samples from other sections.



Age spectrum for dyke sample HD-5 from south Indian craton.

In addition to these, samples from tholeitic dykes from the south Indian craton were dated. These dykes were thought to have been coeval with the Deccan episode based on chemical, Sr isotopic, magnetic, and K-Ar data. The significance of such dykes to elucidate the tectono-magmatic regime at the time of emplacement led us to undertake this study. Two such dykes yielded Ar-Ar ages of 89± 1 Ma and indicate that these dykes predate the Deccan main episode. Their significance in the context of Deccan volcanism is being investigated.

(b) Dating Himalayan Granitoids : In the Himalaya, Rb-Sr dating of two important granite gneissic units - the Munsiari and the Amritpur of the Kumaun sector were undertaken. The Amritpur granite, in the vicinity of the Main Boundary Thrust (MBT) gives an isochron age of 1888 ± 46 Ma and confirms the hypothesis that it is a part of the crystalline Ramgarh nappe (1770 ± 56 Ma) tectonically brought in juxtaposition with the MBT. The Munsiari gneisses also give an isochron age of 1815 ± 128 Ma and lend support to the idea that these infact are the root zones of the Lesser Himalayan Crystalline nappes. These ages, coupled with our previous studies have led to a fairly comprehensive scenario of Kumaun Lesser Himalayan tectonic set up.

An important study, in the context of the evolution and tectonics of Himalaya, which was initiated this year in collaboration with the scientists of the Wadia Institute of Himalayan Geology, Dehradun, was the isotopic, chronologic and chemical characterisation of basic-mafic volcanism in Himalaya. Basic volcanics from the Bhimtal-Bhowale area of Kumaun Lesser Himalaya were analysed for Rb-Sr isotopic composition, major, trace and REE chemistry. These are also being dated by Ar-Ar method to determine the time of their emplacement which, at present is very controversial. These studies are in progress.

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

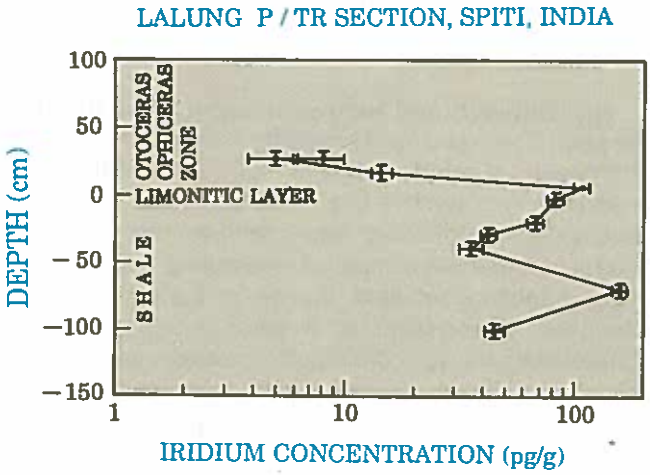
Geochemistry

(a) Nitrogen and noble gases in Kutch Xenoliths : The concentration and isotopic composition of nitrogen in the mantle is not well constrained. Noble gas studies in samples of mantle origin like MORB, diamonds and ultramafic xenoliths have provided a lot of information about their distribution in the interior of the earth. Similar data for nitrogen are very scarce mainly due to experimental difficulties. Some recent nitrogen studies in diamonds and MORB have yielded both +ve and -ve $\delta^{15}N$ making an unambiguous assignment of $\delta^{15}N$ for mantle nitrogen difficult. In an effort to understand the nitrogen reservoirs of the deep earth, two spinel-peridotite-xenoliths (clinopyroxene (CPX) separates) from Kutch and their host basalt were analysed for nitrogen and noble gases.

The two CPX samples of Kutch have different N contents as well as $\delta^{15}N$ values. Both the CPX samples have the same $^{4}He/^{40}Ar$ and $^{40}Ar/^{36}Ar$ ratio, but differ in their noble gas contents. One sample has clear excesses of ^{21}Ne and ^{38}Ar due to (α , n) reactions on ^{18}O and ^{35}Cl respectively. These differences in N and noble gas systematics might be due to heterogeneity in the sub-lithospheric mantle, as suggested from the Nd-Sm systematics of these xenoliths. Different degrees of degassing could generate such a heterogeneity as suggested from the nitrogen results of MORB.

(S.V.S. Murty and K. Pande)

(b) Geochemical characterisation of Permo - Triassic(P-Tr) boundary : The most severe stress on life occured at the Permo-Triassic (P-Tr) boundary which resulted in heavy mass mortality on land and in the oceans. A good exposure of P-Tr sediments exist in Lalung section of the Lingti river basin in the Spiti Valley, Himachal Pradesh. Conflicting results on iridium anomaly in P-Tr section of Shangs in China have been reported during the past few years. We have therefore analysed the Spiti sediments for diagnostic geochemical elements like Ir, Fe, CO, etc.



Iridium profile in the Lalung section.

Our results show that Ir occurs below 50 pg/g level in the Spiti black shales and below 10 pg/g in the overlying limestone. However, at the contact of the two, where a 5cm thick limonitic layer occurs, a high concentration of 73 pg/g has been measured. Again 72 cm below the limonitic layer a slightly stronger peak of Ir at 113 pg/g level has been found in shales. These two peaks confirm that iridium anomaly is only marginal at P-Tr boundary and is atleast two orders of magnitude lower than the Ir levels found at Cretaceous-Tertiary boundary in marine sediments. The small enhancement of Ir at P-Tr boundary can be understood in terms of terrestrial enrichment processes and extra terrestrial impact of asteroid or comet need not be invoked for P-Tr extinctions. Dr. R.J. Azmi of the Wadia Institute of Himalayan Geology is collaborating in this study.

(N. Bhandari and P.N. Shukla)

(c) Isotope Geochemistry of Himalayan Streams : To understand weathering processes occurring in Himalaya, the source waters of Ganga have been sampled in collaboration with Dr. K.K. Sharma of the Wadia Institute of Himalayan Geology, Dehradun.

Towards this a detailed geochemical and isotopic study (radioactive and stable) was carried out. A brief account of the major ion chemistry was presented last year. The programme has since then been completed and the salient features of the isotope study are presented below.

(i) $^{87}Sr/^{86}Sr$

The concentrations of Rb and Sr and $^{87}Sr/^{86}Sr$ isotopic ratios have ben measured in the Ganga-Brahmputra (G-B) river system. Our emphasis has been to determine : (i) the $^{87}Sr/^{86}Sr$ of the source waters of the Ganga (ii) the fluxes of Sr isotopes through the G-B river system during high discharge stages and (iii) the role of G-B system on the marine geochemistry of Sr isotopes. Towards this, the Ganga has been sampled extensively from its source at Gangotri (in the Higher Himalaya) to Patna (in the alluvial plains). The average Sr concentration of the Ganga (at Patna) and the Brahmaputra (at Goalpara) are 1197 and 728 nmol/l and the corresponding $^{87}Sr/^{86}Sr$ are 0.7239 and 0.7192 respectively. The $^{87}Sr/^{86}Sr$ of the source waters of the Ganga (the Alaknanda, the Bhagirathi and their tributaries) range between 0.7300 to 0.7986, considerably higher than the global run-off value of 0.7119. The high $^{87}Sr/^{86}Sr$ in the source waters of the Ganga results from the intense weathering of Precambrian granites and gneisses having high radiogenic Sr.

The G-B system transports annually about 910 million moles of Sr with a $^{87}Sr/^{86}Sr$ of 0.7213 to the Bay of Bengal. Our results show that the G-B system could contribute significantly(~30%) to the Sr isotope evolution of sea water during past ~20 Ma and reinforces the major impact of Himalayan Orogeny on the marine geochemistry of Sr isotopes.

(ii) Stable isotopes of H and O

High altitude streams (Ganga headwaters) show a δD- $\delta^{18}O$ relationship close to that of the global meteoric water line. Samples from the lowland regions show a significant effect of evaporation, indicated by a reduced slope(~6) in the δD- $\delta^{18}O$ plot. There is a progressive enrichment of the values downstream Ganga. The values of the Ganga headwaters show a change of -0.19‰ ($\delta^{18}O$) and -1.6‰ (δD) per 100m increase in altitude ("altitude effect")which is shown by a simple theoretical calculation to be half that in the original precipitation.

(iii) U and Ra isotopes :

Extensive measurements of ^{238}U, ^{226}Ra concentrations and $(^{234}U/^{238}U)$ activity ratios have been made in the source waters of the Ganga to determine (i) the sources of U and Ra to the Ganga and (ii) the weatherig rate of uranium in the Himalaya. The ^{238}U and ^{226}Ra concentrations in these high altitude streams are typically ~2 and ~0.2 dpm/l, respectively. The high uranium concentration results from intense chemical weathering processes and/or contrubutions from uraniferous zones. The uranium weathering rate derived for these rivers is ~2 kg/km^2/yr, comparable to some of the other Himalayan rivers, but orders of magnitude higher than that of the other major world rivers. These results suggest that uranium mobilization in the Himalaya by rivers is ubiquitious. The low ^{226}Ra concentration relative to ^{238}U in the waters indicate that Ra is more particle reactive in these environments.

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

Quaternary Climate and Evolution

(a) Arid - semiarid regions through TL studies :

(i) Arid regions :

Studies on the evolution and climate of the Thar desert have been continued in collaboration with Dr. R.P. Dhir, CAZRI,Jodhpur and Profs. V.N. Misra and S.N. Rajaguru of the Deccan College, Pune and scientists from the Geological Survey of India. Studies carried out so far from the north west and north east regions suggest that sand mobilization post dates glacial aridity by a couple of thousand years. It also appears that aeolian activity can be used to reconstruct palaeomonsoon during the past 10^5 years.

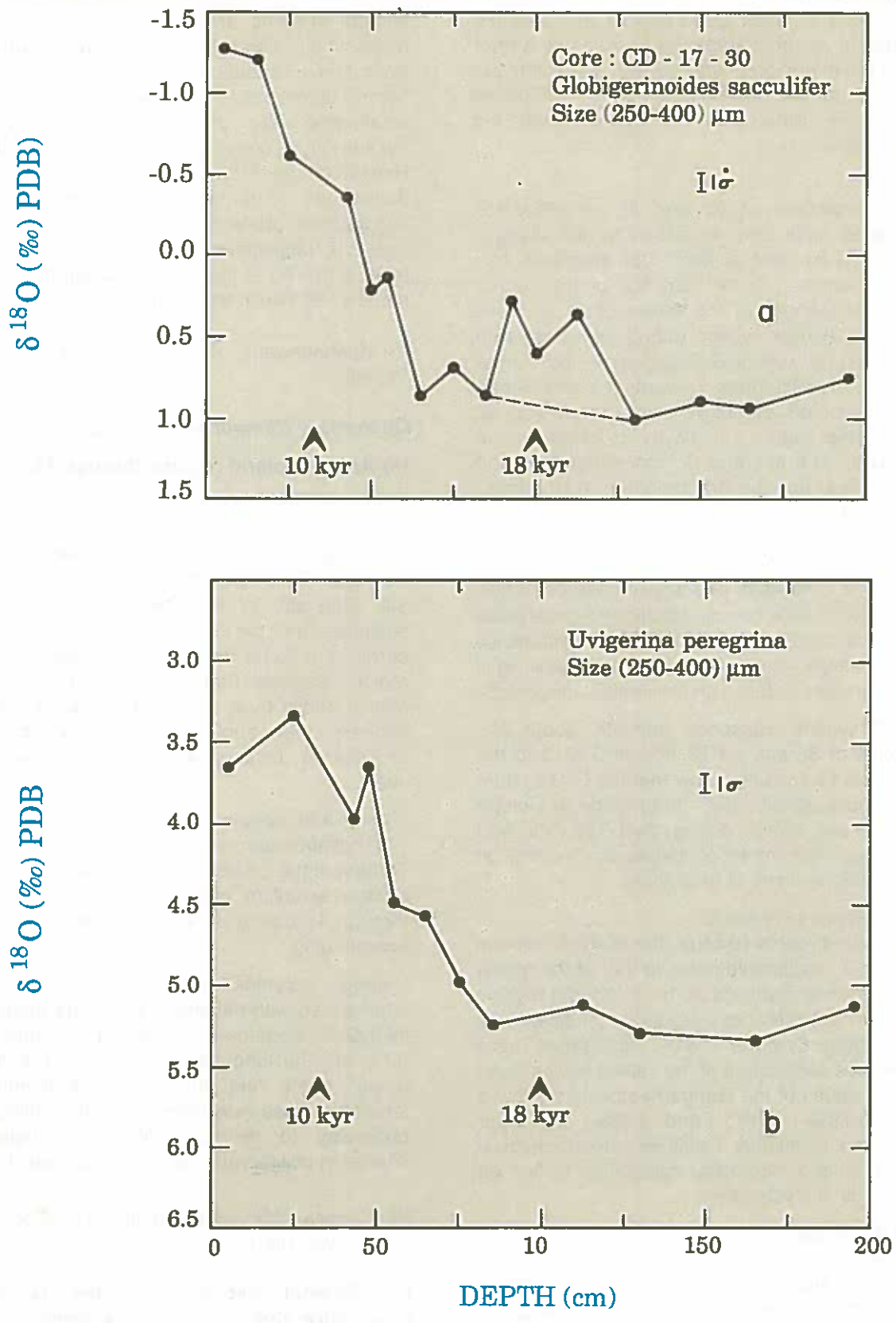
(ii) Semiarid regions :

In collaboration with Dr. N.K. Sareen and Prof. S.K. Tandon of the Geology Dept., Delhi University, studies on the evolution of the Sabarmati drainage basin through TL dating is taken up. The initial results are encouraging.

Long columns of Chinese loess deposits interspaced with palaeosol layers are being analysed for their TL signatures to (i) evolve their chronology and (ii) study the long term variation of the nonthermal decay dose rate effects (environmental versus laboratory dose rate measurements). Efforts are also underway to develop optically simulated dating studies in collaboration with Mr. S.D. Rawat.

(S. Chawla, V.S. Kishankumar, A.K. Singhvi and M. Someshwar Rao)

(b) Coastal Evolution in the Quaternary : Saurashtra Coast : Saurashtra coast has provided evidences both for neotectonics and sea level changes during the Quaternary. Significantly, these features are engraved on 200 ky old calcarenites



Oxygen isotopic composition expressed as $\delta^{18}O$ in calcarious shells of foraminifera U. peregrina (bottom-water-living) and G. Sacculifer (surface-water-living) from the Arabian sea as a function of depth. The variations indicate that the bottom water (~ 4000m) was cooler by at least 1.5°C during the last glacial maximum (18 kyr ago) whereas the surface water was more saline.

commonly known as miliolite. The coastal geomorphological features are recorded along the cliffy coast as raised intertidal platforms and wave-cut notches. As such, two high sea level stands at +7 m and +3 m could be discerned and their complimentary strand features have been traced between Jafarabad and Porbandar. Associated with these strands are relict oyester beds and coral reefs which are being dated using ^{14}C and U/Th methods to determine the chronology of high sea levels.

(Navin Juyal and R.K. Pant)

(c) Deep Arabian Sea Sediments : A multidisciplinary study to decipher climatic and environmental records stored in the Arabian Sea Sediments was taken up a few years ago which is being continued. Some of the new results obtained this year are discussed below :

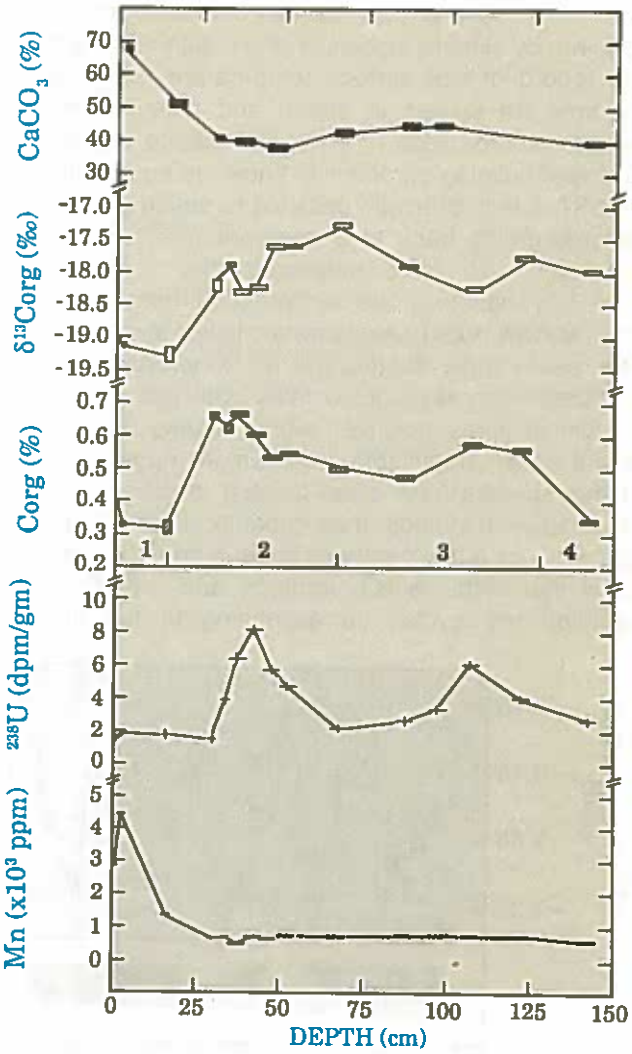
The oxygen isotopic composition of formaminifera the calcareous organisms in the oceans depend on the ambient temperature and salinity of the water. For example, an increase of 1°C in the water temperature causes a decrease of 0.2‰ in the $^{18}O/^{16}O$ ratio in the $CaCO_3$ shell. Consequently the planktonic forminifera (surface dwelling) record the temperature and salinity of the mixed layer of the ocean whereas the benthic foraminifera which live near the sediment water interface monitor the bottom temperature and salinity. Thus a study of the $^{18}O/^{16}O$ ratio in these two types of foraminifera from sediment cores can be used to decipher past changes of these two parameters in the surface and bottom of the ocean respectively.

The carbon isotopic composition of these organisms is determined by the $\delta^{13}C$ of ΣCO_2 of the ocean water. So the processes which modify the composition of ΣCO_2 are recorded in the shell of the forams. The important results are :

(i) The salinity in the Arabian sea was higher during the last glacial period as a result of weak SW monsoon and stronger NE monsoon. During the peak of the glacial period sea surface temperature rose by ~2°C as a result of weak upwelling condition due to reduced SW monsoon.

(ii) Deep water in the Arabian sea was cooler by atleast 1.5°C and was characterised by a CO_2 rich - O_2 poor water mass, probably due to a change in the deep water circulation.

(iii) There is a positive correlation between the organic matter (OM) and U concentrations in the core;

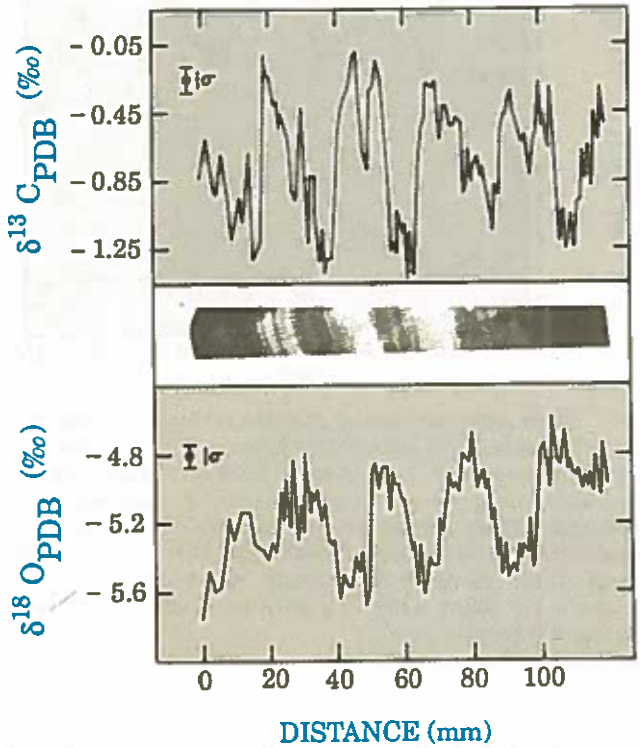


Depth profile of $CaCO_3$, Corganic, $\delta^{13}Corg$, ^{238}U and Mn-content in the sediment core SK-20-185 from the deep Arabian sea (lat. 10°N, long 72°E, water depth : 2523 m). $CaCO_3$ content decreases during the glacial period (stage 2) indicating lower productivity. There are marked increases of ^{238}U content during stages 2 and 3 which are correlated with total organic carbon (Corg). These increases are probably due to lowered oxygen content in the bottom water as a result of sluggish bottom water circulation in the glacial period.

high U and OM concentrations occuring during glacial periods (eg. $\delta^{18}O$ stages 2, 3 and 4, see figure). These high concentrations of U and OM are probably due to either the prevalence of anoxic conditions especially at the sediment water interface or enhanced preservation of OM (and associated U) which would have deposited from seawater. These as well as other possibilities are being evaluated to construct a possible scenario.

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

. One of the important boundary conditions required by climate models on the Indian monsoons is the record of sea surface temperature (SST). Such records are sparse in space and time. Since the oxygen isotope ratio ($\delta^{18}O$) of marine organisms (like reef building corals) is to known to be dependent on SST, it is in principle possible to obtain proxy SST records dating back to a few centuries with a high resolution. We have measured the $\delta^{18}O$ and $\delta^{13}C$ variations in the banded coral (Porites 1) from the Karavatti Island, Lakshadweep to test this possibility. Our results show that this species, widely distributed in Lakshadweep, lays down fairly well defined bands (visible in X-ray positive), which makes the annual layers easily identifiable. Furthermore huge colonies of this species have been located in several of the Lakshadweep islands, thus capable of yielding proxy SST data for a few centuries back in time. Our results show that both $\delta^{18}O$ (bottom) and $\delta^{13}C$ (top) variation are cyclic, corresponding to the annual



$\delta^{18}O$ (bottom) and $\delta^{13}C$ (top) variations in a banded coral (Porites 1) from the Karavatti Island, Lakshadweep. Xray picture shows clear annual bands (centre).

density bands (centre). The $\delta^{18}O$ variations are interpretable in terms of temperature and salinity changes associated with the monsoon. For example, during June to September, SST reduces by 3°C in the Lakshadweep region. This is shown by a decrease in $\delta^{18}O$ of -0.7‰ The $\delta^{13}C$ variations are indicative of the changes in productivity caused by the upwelling induced by the monsoon. Further studies are in progress using corals from this and other (e.g. Gulf of Kutch) regions.

(S. Chakraborty, S. Krishnaswami and R. Ramesh)

Hydrospheric Studies

In this section are described the results of experiments conducted in Himalayan glaciers, shallow groundwaters and in the ocean using environmental isotopes and some major and trace elements.

(a) Himalayan Glaciers : This year our activities were mainly confined to the detection of radioactivity that could be attributed to the Chernobyl accident of April 1986 in USSR. In addition, a suite of samples were collected from a Himalayan glacier.

The measurement of total and ^{137}Cs radioactivities in snow samples collected from the hump region (4150 to 4650 m) of the Chhota Shigri glacier in 1987 have been completed. A factor of 15 higher activities in the hump regions compared to older samples provide direct evidence for the deposition of Chernobyl fallout on the Indian Himalaya. The activities, due to the long distances involved, are smaller compared to similar samples from the region close to the accident site eg. the Alps.

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

(b) Oxygen and Hydrogen isotope systematics in surficial waters from Gaula Catchment area : Over a hundred samples (springs, streams, lakes, rain and snow) from the catchment area of the Gaula river in the Kumaun Himalaya were collected and analysed for δD and $\delta^{18}O$ alongwith major ions. The 600 km^2 area encompasses an altitude range of 1600m (545 m to 2150 m AMSL) an annual rainfall and temperature range of 100 - 250 cm and -1.5°C to 35°C respectively and rocks (granites, gneisses and metamorphics) ranging in age from Tertiary to Precambrian. Significant negative correlations exist between altitude (> 1000 m) and $\delta^{18}O$ (r = -0.58 to -0.78) which yield an altitude effect of 0.2 - 0.3‰ decrease in $\delta^{18}O$ per 100 m increase in altitude. This agrees with such studies made in other parts of Himalayan and in other regions in the world.

The positive correlation (r = 0.68) between δD and $\delta^{18}O$ i.e.

$$\delta D = (5.8 \pm 0.4)\ \delta^{18}O + (2.3 \pm 0.3)$$

which has smaller slope compared to a similar correlation obtained for meteoric waters indicates that the waters in this study have undergone significant

evaporation. The mean value of deuterium excess comes out to be 15‰ consistent with the drier conditions leading to evaporation. This study was carried in collaboration with Dr. S.K. Bartarya of the Wadia Institute of Himalayan Geology.

(S.K. Bhattacharya, R. Ramesh and B.L.K. Somayajulu)

Origin of Groundwater in Lakshadweep Island : Lakshadweep is a group of about 37 small islands with a total area of 28.5 km^2 situated between 8^{0}N and 12^0 30'N, 71^0 and 74^0 E. These are coral islands built on a submarine ridge off the west coast of India. Shallow ground water is present in these islands the origin of which has been assumed to be meteoric. We have collected ground water samples from 10 major islands and measured the stable isotope ratios of hydrogen and oxygen (δ D and δ ^{18}O respectively). They show a relation

$$\delta D = (6.8 \pm 2.0)\ \delta\ ^{18}O + (5.6 \pm 4.8)$$

with a correlation coefficient of 0.6 significant at 0.01 level. Within errors, this relation is similar to that obtained from precipitation world-wide, proving that the origin of these shallow ground waters is indeed meteoric. The sea water intrusion into these ground waters has been calculated using a simple mixing model and is found to be 7 ± 5%.

(R.A. Jani and R. Ramesh)

Oceanographic Studies

(a) Arabian sea particle scavenging rates through ^{238}U disequilibria measurements : The Arabian sea is known for its high biological productivity and particulate concentrations and associated denitrification at intermediate depths. With a view to obtain rates of particle - associated processes, depth profiles of dissolved ^{234}Th, ^{238}U, ^{210}Po, ^{210}Pb and ^{226}Ra concentrations were measured in the Eastern Arabian Sea between 7^{0}N to 21^{0}N, at water depths ranging from surface to 4000 m.

Dissolved ^{234}Th is deficient relative to its parent ^{238}U in the surface 300 m, the ^{234}Th/^{238}U activity ratio ranging from 0.4 to 0.8. This deficiency interpreted in terms of irreversible adsorption of ^{234}Th on to particulate phases, yields a residence time of about 50 days for dissolved Th in these waters. The depth profiles of ^{210}Po/^{210}Pb show a maximum around 100 m with activity ratios ~ 1.5. Above and below this maximum there is deficiency of dissolved ^{210}Po with respect to ^{210}Pb. The residence time of dissolved ^{210}Po is deduced to be 160 and 300 days respectively in surface and deep waters. Recycling of Po in the surface waters most probably accounts for its longer residence time compared to that of Th.

The ^{210}Pb/^{226}Ra activity ratios in deep waters ($\geq$ 500m) range between 0.3 to 0.5 indicating its intense removal by scavenging proceses, the mean residence time of dissolved Pb in deep waters is 20 years. These studies indicate that particle reactivity decreases as Pb < Po < Th and that the time scales of scavenging of dissolved species of these elements on to particulate phases range from a few months in the mixed layer to a few years in the year in the deep sea.

Another intersting observation is that the ^{210}Pb deficiency in deep waters is more pronounced in samples closest to the slope and shelf regions. This larger deficiency suggests more intensified scavenging near the continental margins. This is consistent with our observations on the ^{210}Pb inventory in the underlying bottom sediments as indicated below .

(b) Western continental margins of India - Are they sink or source of trace elements to the Arabian sea? : Geochemical and geochronological studies on spade cores, collected from the western continental shelf and slope regions of India (during ORV Sagar Kanya Cruise-47), are being carried out to assess the role of continental margins as a sink or source for trace elements to the open ocean. We present data from three cores, L-8 (20^{0}N, 69^{0}E, water depth : 375m); J-7 (17^{0}N, 72^{0}E, water depth : 340m) and I-5 (15^{0}N, 72^{0}E, water depth : 353m). These samples contain 43 to 73.2% $CaCO_3$ and the weight loss on ignition at 400^0 C (index of organic matter) ranges from 7.3 to 15.4%. The ^{210}Pb activity vs depth profile in these cores yield sediment accumulation rates of 0.8, 2.0 and 0.8 mm/yr respectively, on a $CaCO_3$ free basis The standing crop of ^{210}Pb (Σ dpm/cm^2) ranged from 79 and 400 dpm/cm^2 respectively, significantly higher than that estimated (40-50 dpm/cm^2) from its atmospheric supply and production in the overlying water column. A possible mechanism for this large excess in the ^{210}Pb inventory is its removal at the continental margin sites. This removal mechanism appears to be consistent with the ^{210}Pb -^{226}Ra systematics in the over head water column. Uranium is another element which shows a large removal at this site. The U concentration in the analysed cores range from ~6 to 25 ppm on $CaCO_3$ free basic yielding authigenic U deposition rates of 0.1 - 2.5 mg/cm^2.kyr which are the highest so far reported for any part of the major world oceans. Mn is grossly depleted in these anoxic sediments. The studies indicate the continental margins are a sink for U and ^{210}Pb and source for Mn. Similar studies are being carried out in the Bay of Bengal.

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

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1. Baskaran M. and Somayajulu B.L.K., "Clay mineral distributions in dated miliolites of the Late Quaternary from Saurashtra and Kutch, Gujarat", J. Geol. Soc. India, **35,** 471, 1990.

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3. Bhandari N. and Shukla P.N., "K/T Boundaries in India and geochemical contributions of Deccan volcanism", in "Cretaceous event stratigraphy and the correlation of the Indian nonmarine strata", (Eds.) Sahni A. and Jolly A., Punjab University, Chandigarh, India, 22, 1990.

4. Biswas S., Durgaprasad N., Mitra B., Singh R.K., Dutta A. and Goswami J.N., "Observation of low energy (30 - 100 MeV nucleon^{-1}) partially ionised heavy ions in galactic cosmic rays", Ap. J. (Letters), **359,** L5 - L9, 1990.

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7. Durgaprasad N., Biswas S., Mitra B., Singh R.K., Vahia M.N., Dutta A. and Goswami J.N., "Cosmic ray propogation studies from sub - iron and iron abundances in Spacelab-3 Anuradha experiment", Ind. J. Phys., **64A,** 175, 1990.

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10. Murty S.V.S. and Marti K., "Search for solar type nitrogen in gas rich Pesyanoe meteorite", Meteoritics, **25,** 227, 1990.

11. Nijampurkar V.N. and Rao D.K., "Evidence of Chernobyl fallout on a temperate Himalayan glacier", Curr. Sci. **59,** 1239, 1990.

12. Pant R.K. and Chamyal L.S., "Quaternary sedimentation pattern and terrain evolution in Mahi river basin, Gujarat, India", Proc. Ind. Natl. Sci. Acad., **56A,** 501, 1990.

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14. Sarkar A., Ramesh R. and Bhattacharya S.K., "Effect of sample pretreatment and size fraction on the $\delta^{18}O$ and $\delta^{13}C$ values of foraminifera in Arabian sea sediment," Terra Nova, 489, 1990.

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CONTINENTAL PALAEOCLIMATE STUDIES

Primary focus of the area is towards reconstruction of the climatic history of the continental earth from the study of sedimentary deposits of fluvial, aeolian and lacustrine origin. Climatic information is obtained by studying imprints on the sediments of the changing depositional environment (e.g. within a lake) or the source area of the sediment. A variety of characteristic indicators of climatic change are used. These include, among others, study of (i) grain size distribution; (ii) magnetic minerals; (iii) organic matter; (iv) trace elements; (v) isotopic ratios; (vi) pollen and diatom content of sediments. The period of past climatic change is estimated by isotopic geochronological methods. Radiocarbon dating being the principal chronological tool for sediments deposited during the last 30-40 thousand years. Other geochronological tools include thermoluminescence and uranium/thorium isotopic ratio methods for older sediments in the 1-100 thousand year time range and ^{137}Cs, ^{210}Pb - fallout identification for younger sediments on 1-150 year time scale.

Lake Sediments from Manasbal, Kashmir

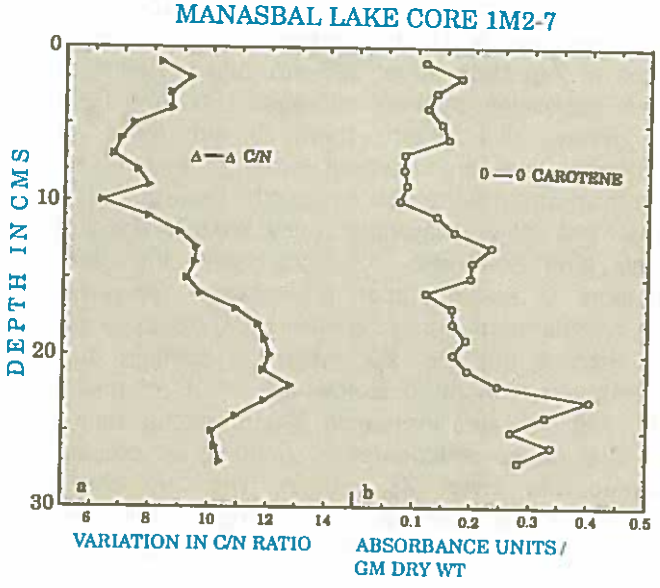
Several short (1m) and long (6m) cores were raised using an indigenously developed piston type lake sediment corer from Manasbal lake (34°9'N, 74°52'E; elevation 1584m), 25 km northwest of Srinagar in Kashmir. This closed basin lake derives its water both from the catchment surface runoff as well as several subterranean springs.

The short cores were sampled at 1cm interval and long ones at 4cm. Magnetic susceptibility χ and its frequency dependent component (χ_{fd}, carbon/nitrogen (C/N) ratios and pigment variations down the core have been used to estimate the varying sources of sediments and organic matter in terms of components produced in-situ within the lake (autocthonous) and those derived from outside the lake (allocthonous) from the catchment areas. The pigments were measured spectrophotometrically while the C/N ratios were determined by means of CHN analyser.

Following representative values of C/N ratios have been used as indicators of the source of organic matter.

Source	C/N Ratio (W/W)
Lake water planktons	~ 7
Land plants	> 30
Sedimentary rocks	< 5

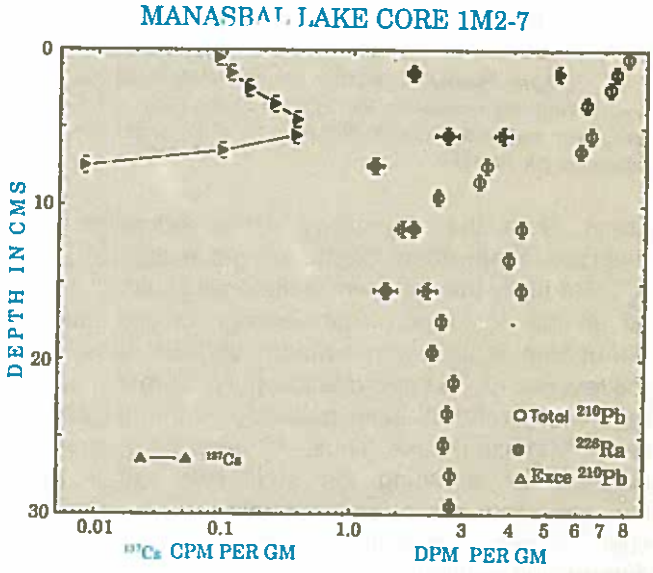
Generally, it is found that increased terrestrial organic material is accompanied by an increase in carotene (a pigment) in lacustrine sediments. This increase in carotene is not primarily derived from the land plants but is due largely to increase in plant productivity in the lake as a result of significant inputs of terrestrial nutrient rich material. Therefore increase of carotene, even though derived essentially from increased productivity within the lake, is an indicator of relative increase of allocthonous input into the lake.



(a,b) Variation in C/N ratio (Fig. 1a) and carotene (Fig. 1b) against the depth in one metre Manasbal lake core 1M2-7. Note the increase of both the parameters below about 12 cm depth indicating increase of allochthonous source of organic matter into the lake below this depth.

Figure shows that upto 10 cm depth C/N ratio is less than 9 increasing downward upto a depth of 27cm and reaches maximum value of 13 at about 22 cm depth, thus showing an increase in allocthonous terrestrial plant debris into the lake from about 12cm downwards. Carotene variation also shows a similar trend and therefore supports the inference that from a depth of 12 cm downwards the allocthonous source of organic matter input into the lake became dominant.

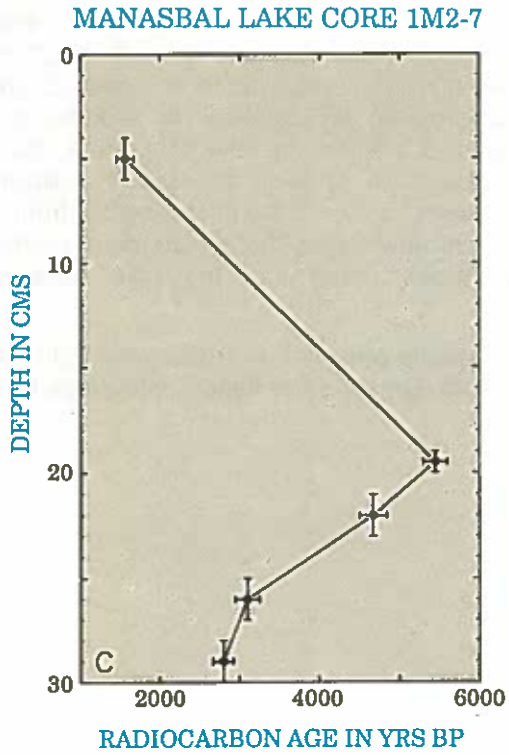
Figure shows the presence of ^{137}Cs in the top 6cm part of the core. On the other hand, ^{210}Pb drops to a



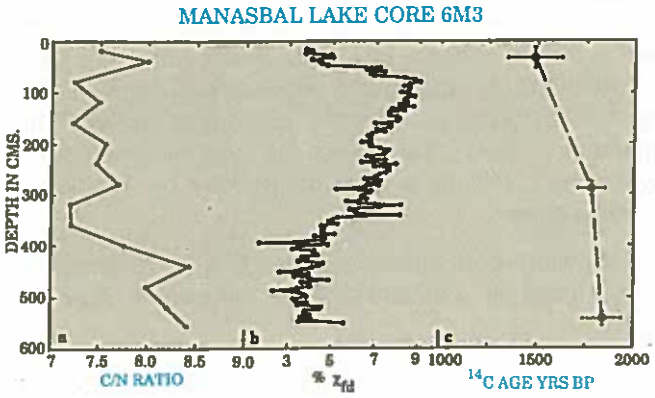
^{210}Pb and ^{137}Cs variation against the depth in one metre Manasbal lake core 1M2-7, yielding average sedimentation rate of about 4.8 mm/year for the top 17 cm of the profile.

background value at depth of 17cm. This gives an average sedimentation rate of about 4.8mm/yr. The top 6cm would therefore correspond to only about 12 years. The higher activity level of ^{137} Cs, in this case compared to that observed in glacial snow of Changme Khangpu could be an artifact of ^{137}Cs rich allochtonous soil of a particular stratum.

Figure gives the apparent radiocarbon ages of the sediments at different depths, one finds that from



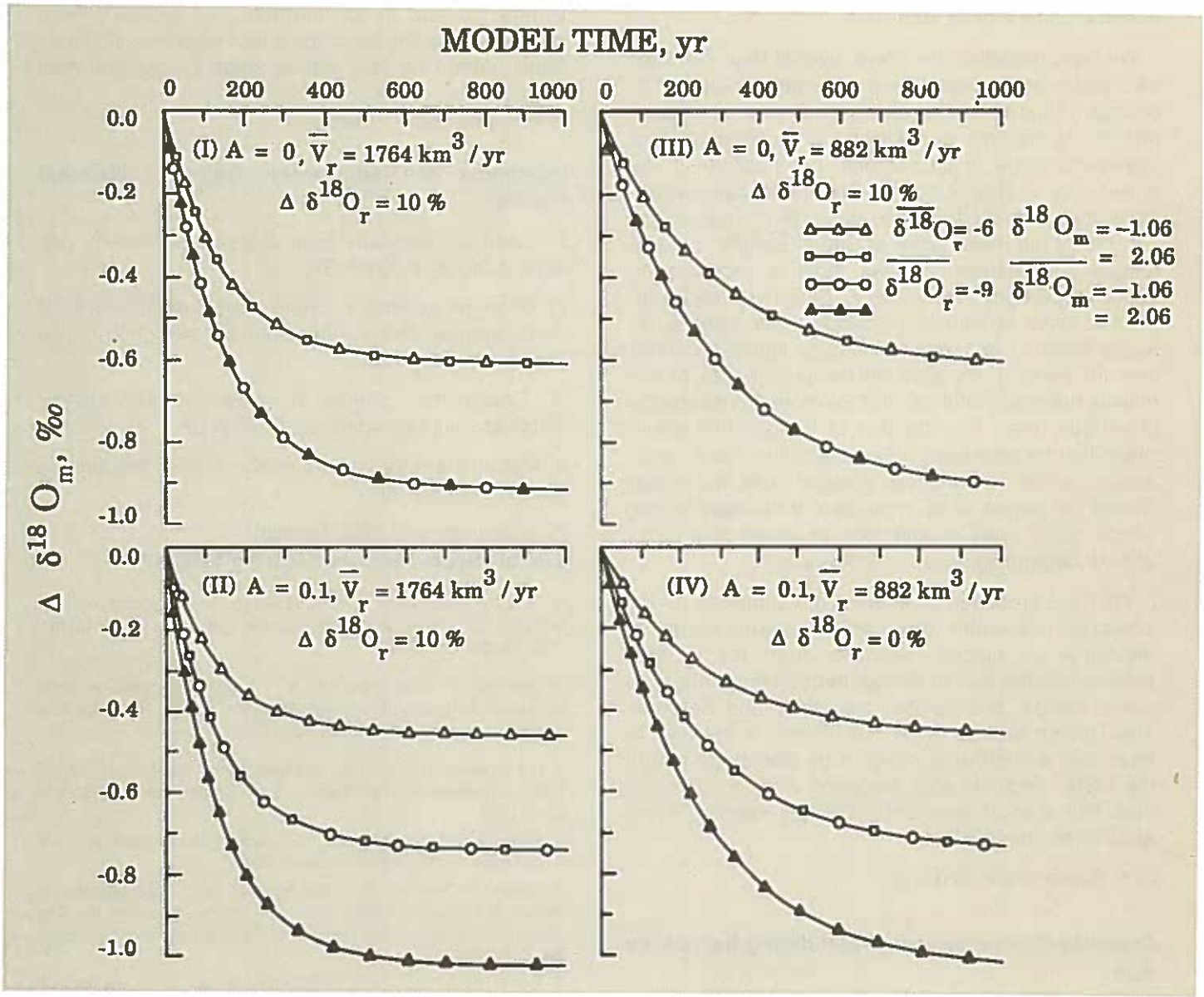
^{14}C ages against the depth in one metre Manasbal lake core 1M2-7. Note the reversal in the ^{14}C age below 19cm depth which has been interpreted due to the erosion of an upper (younger) palaeosol into the lake.



Variation in C/N ratio χ_{fd} and ^{14}C ages against depth in six metre Manasbal lake core 6M3. Note that upto about 400cm depth fine material (high χ_{fd}) with C/N. < 8 indicates autochthonous deposition. But below 400cm coarser material (low χ_{fd} and high C/N ratio (> 8) indicates allochthonous source of the sediments.

about 19cm, the chronology of the sediments gets reversed. From 30cm depth, we get a date of 2900 BP. Gradually the sediment is becoming "older" as we go up the core upto 19cm. except for one date at about 5cm depth which is about 1500 BP. We explain the reversal of ^{14}C dates due to input of carbon material by erosion from an upper palaeosol in the catchment of the Manasbal Lake. Thus, ^{14}C ages here serve as markers for sourcing the sediments rather than indicating the rate of sedimentation of the lakes. In such cases radiocarbon cannot be used for determining sedimentation rate but only to source (by correlating with rocks of known age) the incoming allochthonous organic material into the lake basin. In addition to C/N ratio, χ and χ_{fd} were also measured. It is now established that an enhancement of both χ and χ_{fd} is indicative of soil derived materials. The extent of enhancement depends upon the soil development. In figure we have plotted depth variation of C/N ratio, χ_{fd} and ^{14}C dates of 6M3 core. For about top 400 cm, the C/N ratio remains within 8, ranging between 7.2 to 8.0, thus indicating predominantly autochthonous input. This trend is anticorrelated with the enhancement of χ and χ_{fd} upto a depth of 400 cm where it is more than 5 and below 400 cms, it is less than 4. This indicates a normal type of slack depositional regime where fine material was being deposited upto a depth of 40 cms. But below 400 cm, there is an indication of rapid influx of coarser material which is characterised by smaller values of χ_{fd}. Upto about 300 cm, one is getting a steady deposition, between ^{14}C ages 1500 and 1750 B.P. Below this depth, there is an influx of allochthonous organic material showing the same ^{14}C ages from about300to 550 cm depth. Thus the three parameters show concordant trends. We thus find that in this long core also ^{14}C ages follow the other indicators of sedimentation processese. Whenever finer material comes into the lake, the C/N ratios are less than 8 but the χ_{fd}, which is particle size dependent is enhanced. Below 400 cm depth,the≥8 C/N ratio indicates increased allochthonous inputs, therefore faster sedimentation, bringing in coarser material with lower χ_{fa} values. The ^{14}C dates, therefore, show practically no change within one standard deviation between 300 to 550 cm depth.

(D.P. Agrawal, N. Bhandari, R.D. Deshpande, S. Kusumgar, A. Raina, C. Sharma and M.G. Yadav)



Model computed change ($\Delta\delta^{18}O_m$) in the mixed layer of Bay of Bengal resulting from a 10 percent step change in the isotopic composition ($\Delta\delta^{18}O_r$) for two steady state values of the total river inflow $\bar{V}_r$ 1764km³/yr; Case I and $\bar{V}_r$ = 882 km³/yr; Case III). Similar plots for a 10 percent step change (A = 0.1) in the volume of the river inflow, $\bar{V}_r$ = 1764 km³/yr; Case II and $\bar{V}_r$ 882 km³/yr, Case IV are shown in the lower half of the diagram. In each case only one of the two parameters, either $\bar{V}_r$ or $\delta^{18}O_r$ is changed, the other being constant

Source of Freshwater Spike in the Indian Ocean

A negative excursion of about -1% in $\delta^{18}O$ of the planktonic foraminifera around the Last Glacial Maximum (LGM) based on the analysis of a sediment core in the eastern Arabian sea has been reported recently. The negative spike has been interpreted to have been caused by increased runoff from the east-flowing south Indian rivers into the Bay of Bengal due to enhancement of NE monsoon.

We have modelled the mixed layer of Bay of Bengal as a well-mixed box and have estimated the degree of change required in the quantum of river discharge and/or its isotopic composition to account for the observed change in the isotopic composition of the mixed layer of Bay of Bengal. The model calculations show that in order to cause the -1% change in the $\delta^{18}O$ of the mixed layer of Bay of Bengal, it would require the quantum of river input to increase by about 10 percent. Alternatively, if the river discharge were to have remained unchanged, the input water would have to become isotopically lighter by more than 10 percent. Considering the preset data of the relative magnitudes of NE and SW monsoon discharge of various rivers into the Bay of Bengal, this would mean that for increased NE monsoon to have been reponsible for the observed spike at LGM, the rainfall during the period of NE monsoon of the east flowing south Indian rivers should have changed by a factor of 5-10 depending on its $\delta^{18}O$ value.

We have proposed an alternative hypothesis for the observed freshwater spike which invokes increased discharge of glacial meltwater from the Tibetan plateau into the Bay of Bengal through the Himalayan rivers Ganga, Brahmputra, Irrawaddy and Salween. The Tibetan plateau (area $2.5 \times 10^6 km^2$) is believed to have had a large area covered by glacial ice before the LGM. There is also evidence showing that this area had a short duration(~1000 yr) warming event around the time of LGM.

(S.K. Gupta and P. Sharma)

Snowline Depression over Tibet during the last Ice Age

The role of Tibetian plateau in global palaeoclimate has been highlighted in recent years. A considerable debate, however, persists on the nature of ice cap on the Tibetan plateau during the Late Quaternary. Matthias Kuhle of the University of Gottingen, based on the interpretation of sediments, sedimentary sequences and landforms in the margins of the plateau, has estimated the depression of equilibrium line altitude (ELA) between 1100-1500m during the last ice age. Such a lowering of ELA would have formed an extensive ice sheet of $2\text{-}2.4 \times 10^6 km^2$ area over Tibet. These observations and interpretation have, however, recently been questioned by some Chinese geomorphologists.

We have for the first time attempted to estimate this parameter from the observed $\delta^{18}O$ shift (average -2‰ maximum -3%) of the glacial ice age from the Dunde ice cap in the northern part of the Tibetan plateau. Our estimate of the snowline depression over Tibet during the last glacial stage ranges between 700-1200m.

(S.K. Gupta and P. Sharma)

Highlights of Radiocarbon Dating : National Facility

1. Lustrous Redware from Bhavnagar district has been dated to 3570 yrs BP.

2. Offshore sediment dating from kerala coast of Ambalapuzha shows sedimentation rate of 2.5cm/yr (water depth 8 mts).

3. Chalcolithic period in West Bengal, District Burdwan, has been dated to 2870 yr BP.

4. Mature Harappa culture in Kutch, site Dholavira is dated to 4273 yr BP.

(S. Kusumgar and M.G. Yadava)

List of Papers Published During 1990-91

1. Sharma, P., Gupta, S.K. and Juyal, N. "Heating induced enhancement of ultrafine ferrimagnetic grains in soils", Current Science, **59**, 789, (1990).

2. Sharma, P. and Bhandari, N. "Augmenting surface water infiltration by means of recharge channels", Bhujal-News (Quat. J. Central Groundwater Board), **5**, 12, (1990).

3. D.P. Agrawal, Rekha Dodia and Mala Seth, "South Asian climate and environment at c 18000 BP" Vol. II, O.Sofer and Clive Gamble (Ed.), 1990.

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5. Singh, G., Wasson, R.J. and Agrawal, D.P., "Vegetational and seasonal climatic changes since the last full glacial in the Thar Desert, orthwestern India", Review of Palaeobotany and Palynology, **64**, 351 (1990).

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7. Gupta, S.K., Sharma, P., Juyal, N. and Agrawal, D.P., "Loess-palaeosol sequence in Kashmir : correlation of mineral magnetic stratigraphy with the marine palaeoclimatic record", Journal of Quaternary Science **6**, 13 (1991).

8. Agrawal, D.P., "Past climatic changes in India and their relevance to IGBP 1", Indian Geosphere Biosphere Programme : Some Aspects (Eds.) T.N. Khoshoo, M. Sharma, Har-Anand Publications, New Delhi, 57, (1991).

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

One of the most interesting and important aspects in astrophysics that has recently received considerable attention with regard to formation of binary radio pulsars and the origin of quasiperiodic oscillations from low mass X-ray binaries is the interactions between the magnetosphere of a neutron star and a surrounding accretion disc. The different plasma instabilities that arise due to this interaction seem to play an interesting role in understanding some of the processes in these compact objects. During this year the instabilities of different modes that could be supported by the plasma in the accretion disc particularly near the inner edge of the disc have been studied including the effects of finite conductivity. One of the key features of this investigation is the existence of plasma instabilities like Kelvin-Helmholtz, Rayleigh-Taylor and resistive electromagnetic modes. The effect of finite conductivity is found to decrease the K-H and resistive electromagnetic mode while there is no such effect on magnetic modes. As a result of these instabilities the accreting plasma can enter directly into the magnetosphere in a magnetically closed model and enhance the luminosity.

Meteorology and Climate Studies

One of the dominant features of monsoon variability within a season is the 30-50 day oscillation. A more accurate expression for the northward phase speed of this oscillation has now been derived using a simple analytical formulation including the effect of cumulus heating. Speeds of a couple of metres per second have been obtained. In another study this has been formulated as an eigenvalue problem and low frequency modes have been obtained. Further studies of the equatorial 30 day mode using linear and non-linear global spectral models indicate that nonlinearity has significant impact on these modes.

A newly emerging important area of study in which work has begun is that of interannual variability and atmosphere-ocean interaction. An investigation has been initiated to understand the dynamics of the Walker Circulation. Using a simple analytical model and linear and nonlinear global spectral models it has been shown that the intensity and geometry of the equatorial heat source and sink control the strength and scale of Walker Circulation. It was also found that nonlinear effects significantly increase the strength of the Walker Circulation.

Plasma Physics

The study of nonlinear Alfven waves in inhomogeneous as well as in multi-species plasmas has been one of the most important activities in plasma physics group. Large amplitude Alfven waves propagating along the magnetic field in an inhomogeneous plasma with nonuniform streaming are shown to be governed by the Derivative nonlinear Schrodinger equation (DNLS) modified by the inhomogeneity and the streaming. The inhomogeneity leads to acceleration of Alfven soliton. The acceleration gets further modified due to streaming. In another study the nonlinear Alfven waves in a multi-species plasma are shown to be chaotic in presence of a driver when its amplitude exceeds a certain threshold.

MICROSCOPIC PHYSICS

Foundation of Classical and Quantum Physics

The aspect of the correspondence, namely, the role of discrete Hamiltonian systems, between classical and quantum mechanics, is still not well understood even for systems with a few degrees of freedom. In quantum systems the role and importance of discrete symmetries is well understood and a systematic procedure to allow for them has been developed. In semiclassical quantization schemes the procedure for the allowance of discrete symmetries is not so well developed. We have developed a procedure to allow for discrete Hamiltonian symmetries in a semiclassical quantization scheme. The proposed procedure gives symmetry labeled eigenvalues even in situation where the classical dynamics is dominated by chaos.

Nuclear Physics

Much has been learnt in the past about quadrupole and octupole collective modes in nuclei and our knowledge about hexadecupole states is still in its infancy. Over the past five years the scientists at PRL developed a model with interacting bosons carrying monopole, quadrupole and hexadecupole degrees of freedom. Detailed spectroscopic calculations for Sm isotopes and for ^{194}, ^{198} Pt by employing a Hamiltonian

interpolating the dynamical symmetries (classified by the group) are carried out in the above model which is known as sdg model. The observed hexadecupole matrix elements (E4 data) in ^{152,154}Sm are well reproduced and E4 strength distributions are predicted. In addition the so called M1-excited scissors configurations are classified (with and without hexadecupole g boson) for the nucleus ^{185}W and their location and the corresponding M1 strengths are predicted. These recent results together with the investigations carried out earlier establish that the sdg model is a simple and yet powerful tool in analyzing E4 properties in nuclei.

Particles and Fields

The mass of the neutrino plays an important role in cosmology and particle physics. Recently some earlier observations of a massive 17 keV state emitted in beta decay were reconfirmed. Different theoretical schemes have been suggested to understand the origin of this 17 keV neutrino, which are consistent with laboratory constraints and at the same time can provide the bulk of the dark matter. In a different scheme, the 17 keV neutrino and all the other neutrinos turn out to be Dirac particles but the 17 keV state decays and becomes cosmologically irrelevant. Models were also proposed in which the 17 keV mass for the neutrino can be naturally understood without fine tuning of parameters.The solar neutrino problem also gets solved in some of the above models through the magnetic moment of the neutrinos.

Formation and study of quark-gluon plasma (QGP) is the frontier of modern sub-nuclear physics. A search for this exotic state of matter is being carried out. both experimentally (using relativistic ion beams) and theoretically using bag models, lattice quantum chromodynamics (QCD). However the crucial property of colour confinement which is empirically established is not adequately treated in these theories. The relativistic harmonic confinement models developed at PRL which incorporate overall confinement even for QGP are successful in describing low energy strong interaction. The inclusion of these models for QGP equation of state predicts a T^7 temperature-dependence for pressure and energy density of QGP in contrast to T^4 dependence in the bag model and the lattice - QCD. The implication of T^7 dependence on QGP evolution especially in quark stars and early universe are quite novel whose details are being worked out.

The detailed scientific programmes are described below :

MACROSCOPIC PHYSICS

Astrophysics

Centrifugal Force Reversal in Ernst Space Time

To understand the possible role of magnetic field in the study of centrifugal force reversal, we considered the projection of time like curves onto the conformal 3-space in optical reference geometry of Ernst space time which is an exact solution of Einstein's equations for a mass embedded in an otherwise uniform magnetic field. In this space time there are two circular photon orbits one very close to r + 3m (unstable) and the other far away, depending upon the strengths of the central mass M and of the magnetic field B, which is stable. The centrifugal force acting on a test particle in circular orbit reverses its direction twice, once at each of the photon orbits. Thus in the region below r = 3m and away from r = r_{ph} (stable) the centrifugal force acts in the same direction as gravitation thus rendering Keplarian motion impossible. Hence it appears that when the effects of magnetic field (however weak) is included in the metric then there is a natural cutoff region for the application of Keplarian law for motion of bodies in the space time.

(A. R. Prasanna)

Radial Force on a Charged Test Particle in Superimposed Magnetic Fields on Schwarzschild space time.

Using the formal approach of optical reference geometry we derived an expression for the total radial force acting on a charged test particle (gravitational + centrifugal + Lorentz) in dipole and uniform magnetic fields superimposed on the Schwarzschild space time. As the centrifugal force reverses at r = 3m, it is clear that for a given strength of B, the magnetic field,the existence of bound orbits depends crucially on the location. Further it is shown that bound orbits can exist for certain angular momentum values in the case of ultra compact objects (R $\leq$ 3m) whereas for the same values there may not be bound orbits in the case of normal neutron stars. This indicates that the dynamics of plasma in the vicinity of ultra compact object with magnetic field could be very different from what it would be in the case of ordinary neutron stars.

(A. R. Prasanna and Sai B. Iyer)

Non-minimal Coupling of Electromagnetism and Gravitation and its Consequence on Equivalence Principle

Several years ago we had introduced a Lagrangian having non-minimal term of the form $R_{hijk}F^{hi}F^{jk}$ and derived the consequent field equations which are generalization of Einstein-Maxwell equation. One of the interesting consequences of this as noted by others is that this non-minimal term introduces gravitational birefringence for electromagnetic rays passing through very strong gravitational fields. More recently it was pointed out that this non-minimal term in the Maxwell's equations is equivalent to introducing a new dielectric and permeability tensor which would be anisotropic. One of the way of understanding this is to look for any observable feature that could arise due to cumulative effect even in the gravitational field of the Sun. In order to analyse any such effect, one needs to solve the Dirac equation with vector potential including the non-minimal term. The formalism has been set up for the required study and further work is in progress.

(A. R. Prasanna and S. D. Rindani)

Plasma Instability at the Inner Edge of the Accretion Disc

The interaction between the magnetosphere of a neutron star and a surrounding accretion disc has recently received considerable attention with regard to formation of binary radio pulsars and the origin of quasi-periodic oscillations from low mass X-ray binaries. Hence, it is important to understand the different modes of instabilities that could arise in discs supported by the gas and magnetic pressure around compact objects under general perturbations.

In this context, we have analyzed the instabilities of different modes that could be supported by the plasma in accretion discs. Including the effects of finite conductivity of the plasma in the disc dynamics, a local stability analysis is performed. One of the key features of this investigation is the existence of plasma instabilities like Kelvin-Helmholtz (K-H), Rayleigh-Taylor and resistive electromagnetic modes. It was observed that the finite conductivity lowers the growth rates of the K-H and resistive electromagnetic instabilities whereas the magnetic mode is independent of conductivity. As a result of these instabilities, the incoming matter can penetrate the magnetic field of the central star and can push the inner edge of the disc nearer to the compact object enhancing the luminosity.

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

Higher Dimensional Theories

Solutions to Einstein's equations in higher dimensions are of interest in the study of the low-energy limit of string theories. We have investigated the scalar perturbations of a higher-dimensional Kerr black hole. The perturbation equations have been separated by employing a higher-dimensional analogue of the Carter constant. The eigenvalues of the angular equations are determined perturbatively in terms of Gegenbauer polynomials, and the radial equation is solved numerically. Scattering of scalar waves and the normal modes of oscillation are investigated. This work was done in collaboration with C. V. Vishveshwara, and B. R. Iyer.

(Sai Iyer)

Meteorology and Climate Studies

Analytical study of the Northward Propagation of the 30-50 Day Mode in the Indian Monsoon Region

We have been studying the physical mechanisms of the northward propagation of the 30-50 day mode in the Indian monsoon region. We used linearised zonally symmetric equations in a two level formulation. As the meridional refractive index was found to be complex, we had concluded that there is a possibility of meridional propagation. We had also calculated the meridional phase speed using highly simplified equations. We have now derived a more accurate expression for the meridional phase speed. Our calculation of the phase speed yields values of a couple of metres per second. The amplitude of the wave decays as we move away from the equator.

(R. N. Keshavamurty and V. Krishnakumar)

The Northward Propagation of the Low Frequency Mode in the Monsoon Region as an Eigenvalue Problem

We have been trying to understand this phenomenon using a linear two-level model based on the quasigeostrophic equations on an equatorial beta-plane. We had earlier formulated the problem as an eigenvalue problem associated with a two point

boundary value problem. This problem has been solved using the shooting method. Preliminary results indicate that several low frequency modes are possible. Further work is in progress.

(V. Satyan and R. N. Keshavamurty)

Dynamics of the Equatorial Low-frequency Mode

The dynamics of the equatorial low frequency (30-50 day period) oscillation has been studied using a global atmospheric model. Both the linear and the nonlinear versions of the model were used, the former obtained by dropping the nonlinear terms. This linear model is superior to the one used earlier. The purpose of the study was to investigate the role of nonlinearity in the dynamics of the low frequency mode. A symmetric forcing in the form of an equatorial heat source with a latitudinal speed of $\pm$ 6° and longitudinal extent of 35° and having a sinusoidal vertical profile was used to generate the low frequency mode. Using a drag of 10 days both the linear and nonlinear models were integrated for 10 days. The equatorial heating was then switched off and cumulus heating in the form of wave-CISK was switched on and the models integrated for 40 days. Results show that the phase speed of the moist Kelvin wave in the nonlinear model is slightly less than that in the linear model. We also find that the growing mode in the linear model has a larger amplitude than that in the nonlinear model.

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

Dynamics of the Walker Circulation

The tropical atmosphere is characterized by deep convective heat sources and heat sinks. These zonal asymmetries drive the large scale Walker Circulation. We have studied the intraseasonal and interannual variability of the Walker Circulation, using linear and nonlinear models.

By carrying out idealized numerical experiments, we have studied :

a) The role of the Indonesian heat source and the Pacific heat sink in driving the Walker Circulation.

b) Role of nonlinear advective terms, in maintaining the time-mean Walker Circulation.

Our preliminary results indicate that the geometry of the source-sink combination, is very important in controlling the scale and strength of the Walker Circulation. Nonlinearities are found to strengthen the Walker Circulation induced by the source-sink combination. This is because, nonlinearities enhance the stationary Rossby wave response. In particular, the Rossby waves to the west of the sink is enhanced by about ten percent, amounting to the strengthening of the Walker Cell.

(R. Krishnan)

Downward Propagation of the Upper Tropospheric Modes in a Global Spectral Model

In our earlier linear studies, we have theoretically shown that the upper tropospheric easterly waves in the monsoon region can propagate downwards under certain conditions. An expression for the complex 'vertical refractive index' for such a mode was derived analytically. Observations in the monsoon region do show that the upper tropospheric modes may propagate downward and may act as triggering mechanisms for the genesis of lower tropospheric monsoon disturbances.

We are now examining the above possibility in the framework of a nonlinear global spectral model. In this study we would like to address the following questions: (i) What are the conditions favourable for the downward propagation ? (ii) Do these modes act as triggering mechanisms for the formation of monsoon disturbances in the lower levels ? (iii) What are the energy mechanisms involved in the downward propagation ? The objective of this study is to understand the dynamics of formation of the synoptic monsoon disturbances. This work is in progress.

(V. Krishnakumar and R. N. Keshavamurty)

Growth and Energetics of Pulse Perturbations in the Monsoon Flow

We have been studying this problem using a 5 level, 35 wave resolution atmospheric model in which a boundary layer CISK scheme is used for the heat released by cumulus clouds. A balanced pulse perturbation was superposed on the basic flow at 900 mb level. CISK heating was switched on and the model integrated for two days. Analysis of the model results shows that the pulse grows in amplitude under the action of CISK.

We have also computed the energetics and it is found that there is conversion of zonal available potential energy into eddy available potential energy and eddy available potential energy to eddy kinetic energy. Both these conversions are found to be comparable indicating significant baroclinic energy exchange.

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

Energetics of Monsoon onset Vortex and Monsoon Depressions

We have investigated the nonlinear growth and the detailed energetics of the monsoon onset vortex and monsoon depressions in the frame work of a nonlinear global spectral model incorporating the effects of cumulus convection. The most important achievements and conclusions of these studies can be summarized as follows :

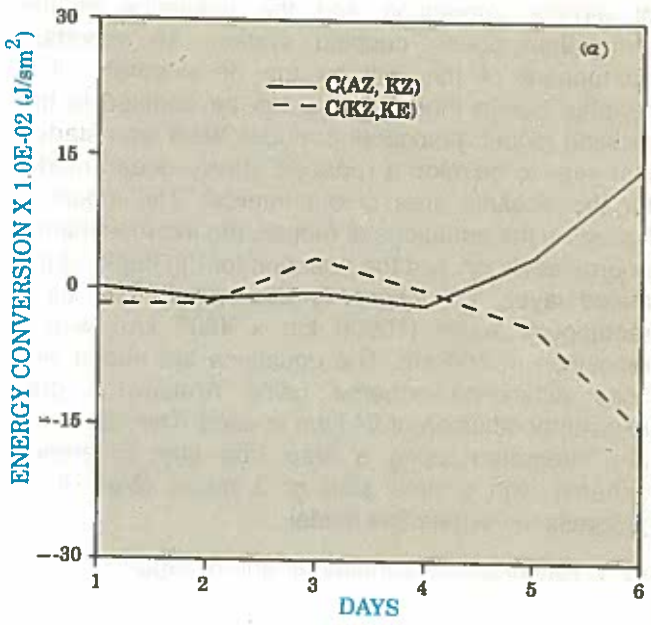
In a nonlinear study, we started from an idealized north-south temperature contrast (resembling the heating distribution during monsoon). Using a nonlinear global spectral model and including the effects of cumulus heating, we generated the onset vortex around 13°N and the monsoon depression around 23°N. The nonlinear model was integrated for a period of six days. Our studies have shown that the onset vortex grows by wave-CISK type of cumulus heating and the monsoon depression grows by boundary layer CISK type of cumulus heating. The onset vortex has the structure of an equatorial Rossby wave.

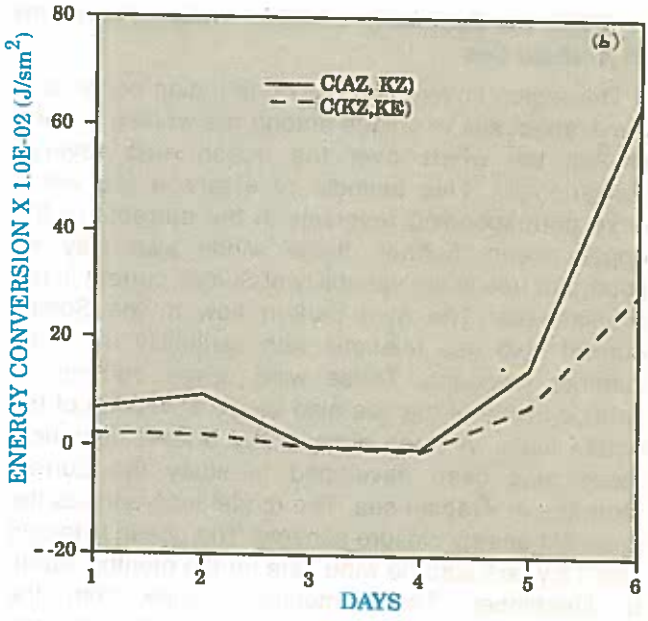
We have carried out detailed energetics calculations of the simulated monsoon onset vortex and monsoon depressions. The time variation of vertically integrated energy conversion of Zonal Available Potential Energy (A_Z) to Zonal Kinetic Energy (K_Z) represented by C (A_Z, K_Z) and of K_Z to Eddy Kinetic Energy (K_E) given by C (K_Z, K_E) i.e. Barotropic Exchange, in the case of monsoon onset vortex are shown in figure. It can be seen that the barotropic exchange of energy shows positive exchange from Day 1 to Day 3 and later on the baroclinic conversion in the presence of cumulus heating becomes quite conspicuous.

Figure shows the time variation of vertically integrated energy conversion of A_Z to Eddy Available Potential Energy (A_E) represented by C (A_Z, A_E) and of A_E to K_E represented by C (A_E, K_E) i.e. Baroclinic Exchange in the case of the simulated onset vortex.

The calculations of energetics of the simulated monsoon depression show that baroclinic exchange is the primary exchange process in the presence of cumulus heating. Barotropic conversion here is rather small.

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





Time variation of vertically integrated enery conversion in the case of monsoon onset vortex.
(a) C(A_Z, K_Z) and C(K_Z, K_E)
(b) C(A_Z, A_E) and C(A_E, K_E)

Ocean Modelling

A major activity planned for the future is the study of air-sea interaction and the dynamics of the atmosphere-ocean coupled system. An important component of this will be the development of a suitable ocean model which can be coupled to the existing global atmospheric model. Work was started last year to develop a reduced gravity ocean model for the oceanic area of our interest. The model is based on the equations of motion, the thermodynamic energy equation and the equation for the depth of the mixed layer. The ocean is considered here as a rectangular basin (10000 km x 4500 km) with a resolution of 100 km. The equations are coded with finite difference scheme using Arakawa C-grid. Horizontal diffusion of ∇^2 type is used. The equations are integrated using a leap frog time difference scheme with a time step of 3 hours. Work is in progress to validate this model.

(S. V. Kasture, V. Krishnakumar and S. Jaggi)

A Study on Variability of Wind Induced Currents in Arabian Sea

The region covered by the north Indian ocean and the Arabian sea is unique among the world's oceans in that the winds over the ocean area reverse semiannually. This periodic reversals in the winds drive corresponding reversals in the currents of the upper ocean. Further, these winds also play an important role in the variability of Somali current in the Arabian sea. The gyre pattern flow in the Somali current also has relations with variability of Indian summer monsoon. These wind driven currents at various levels of the sea also cause advection of the ocean mass. A three dimensional 5-level numerical model has been developed to study the current structure in Arabian sea. The model incorporates the turbulent energy closure scheme. The ocean is forced with 12 years surface wind data for the months March to December. These months include both the transition phases of monsoons (Southwest and Northeast monsoon). Surface current structure of the year 1977 for the months of March and April has been shown in figures. The model realistically simulates the major features of large scale upper ocean circulation. A comparison of the results with those of the mean climatological or observed circulation is very encouraging.

(Sunil Jaggi)

Plasma Physics

Nonlinear Alfven Waves in Inhomogeneous Plasmas

Nonlinear Alfven Waves, in homogeneous plasmas, are shown to be governed by the MDNLS (Modified Derivative Nonlinear Schrödinger) equation. The inhomogeneity leads to acceleration (deceleration) of the Alfven solitons depending upon plasma (kinetic pressure/magnetic pressure) and on density gradients vis-a-vis direction of wave propagation.

(B. Buti)

Solitary Alfven Waves in Inhomogeneous Streaming Plasma

Large amplitude Alfven waves, propagating along the magnetic field in an inhomogeneous plasma with nonuniform streaming, are shown to be governed by DNLS equation modified by the inhomogeneity and the streaming. For weak but arbitrary inhomogeneity, this modified DNLS leads to accelerated solitary Alfven waves. The acceleration gets further modified due to the streaming. For certain values of plasma , streaming can change the accelerating solitons into decelerating solitons and vice versa.

(B. Buti)

Parallel Solitary Alfven Waves in Warm Multispecies Beam-Plasma Systems

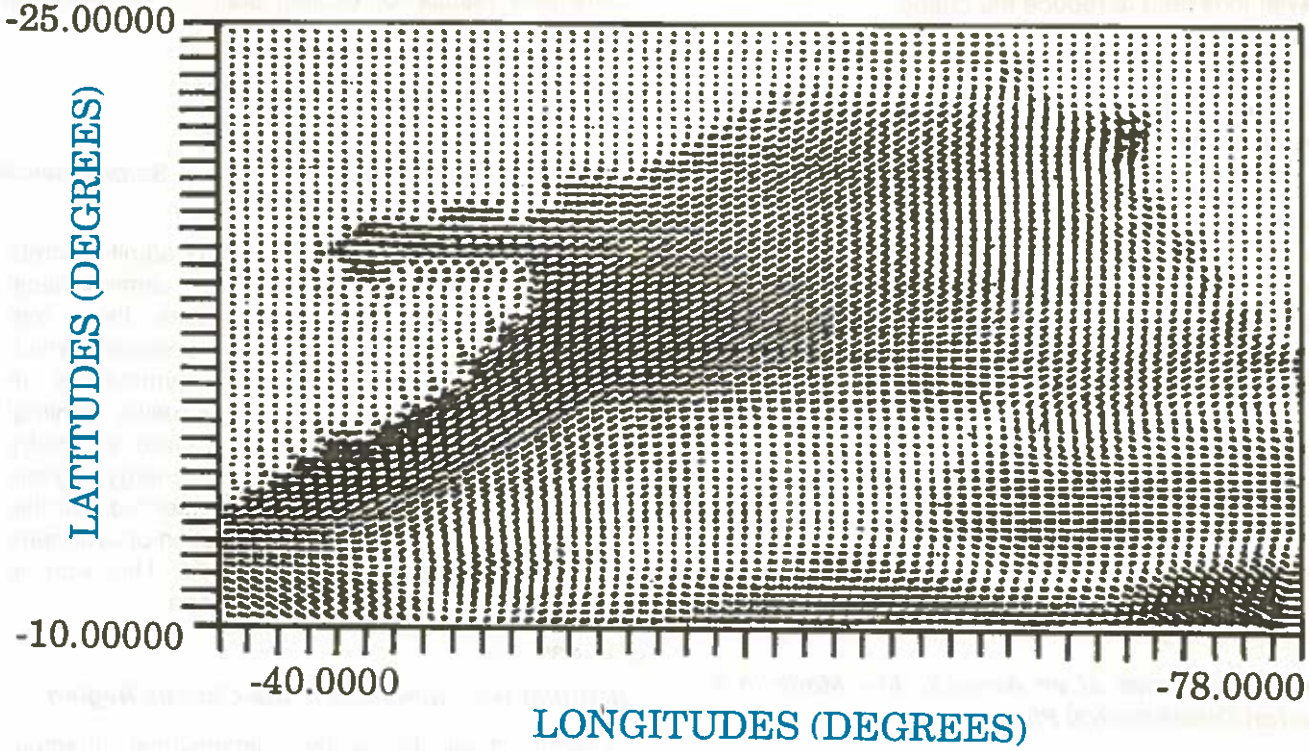
A self-consistent reductive perturbation treatment is given for parallel propagation of MHD waves in warm plasmas, with the emphasis on a multispecies plasma description and in which different constituents can have differing equilibrium drifts. The wave magnetic field is shown to obey a derivative nonlinear Schrödinger equation. Soliton solutions to this equation are discussed, including applications to plasmas with two ion species. Such solitons are larger (in amplitude) and wider than in the non-streaming case, other parameters being equal. This work is done in collaboration with F. Verheest of Institut voor Theoretische Mechanika, Rijksuniversitoit Gent.

(B. Buti)

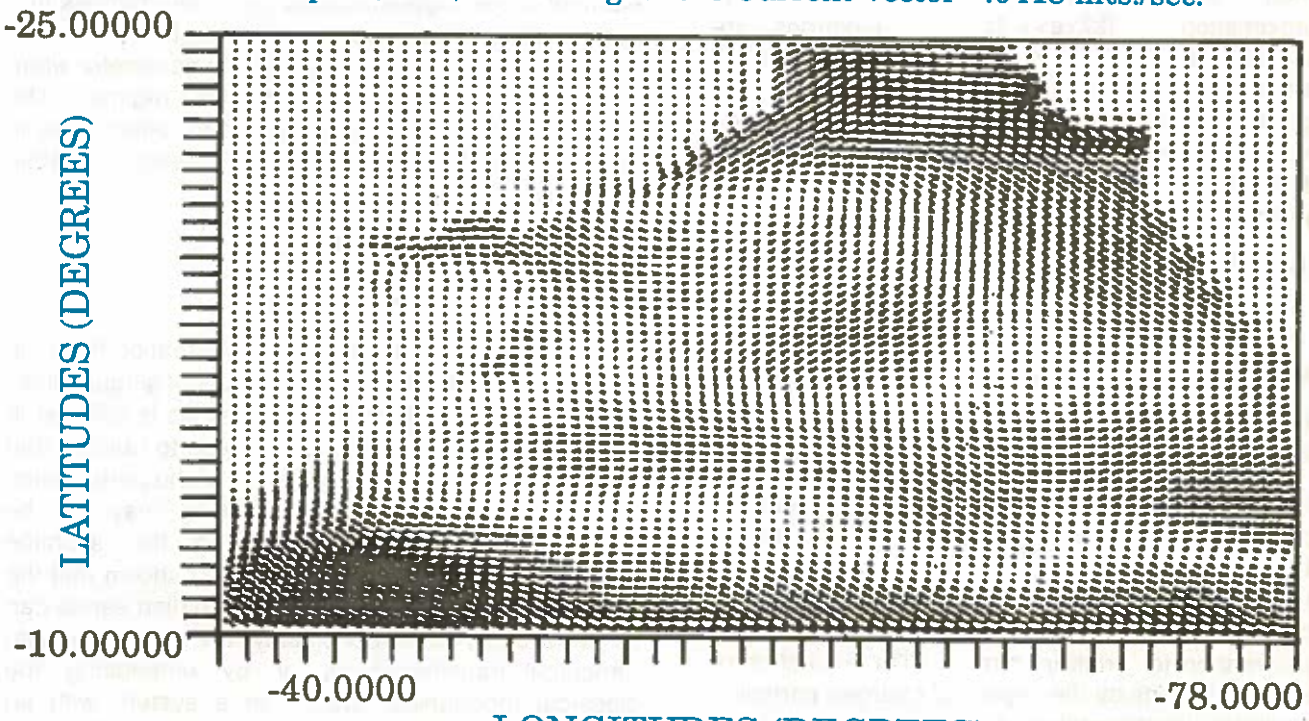
Chaotic Alfven Waves in Multi-Species Plasmas

By means of Hamiltonian formalism, it is shown that the nonlinear Alfven waves, in a multispecies plasma, in the presence of a driver can be chaotic provided the amplitude of the driver exceeds certain threshold. In the presence of heavier ions, e.g., oxygen in case of comets and helium in case of solar wind, this threshold is larger compared to the case of plasma

March (1977) Max. Mag. of the Current Vector =.0413 mts./sec.



April (1977) Max. Mag. of the Current Vector =.0418 mts./sec.



WIND INDUCED SURFACE CURRENTS IN ARABIAN SEA

with only two species. The latter clearly shows that heavier ions tend to reduce the chaos.

(B. Buti)

Instability of Electrostatic Waves in Non-uniform Weakly Ionised Magnetised Plasma

A novel electrostatic instability is shown to exist in a weakly ionised magnetised plasma having equilibrium density and electron temperature gradients. The growth rate of the instability depends on $\eta_e(=L_n/L_T)$, a physical parameter measuring the relative strength of temperature and density inhomogeneity, as well as charged particle-neutral collisions. It is suggested that the present result could help in understanding the origin of non thermal electrostatic fluctuations that have been seen in the EISCAT observations during the heating experiments of the E-region of earth's ionosphere. This work is done in collaboration with P. K. Shukla.

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

Kinetic Properties of an Acoustic-like Mode in a Two Ion Quasi-neutral Plasma

Kinetic analysis of an acoustic-like mode in a plasma with hot and cold ion components has been carried out. Under the short wavelength approximation ($k\lambda ve >> 1$), electrons are assumed to form a dynamic neutralising background and their contribution to the perturbation is justifiably neglected. The significant role of hot ions in the Landau damping of the aforesaid mode is highlighted and a novel concept of plasma experiment is suggested.

(C. B. Dwivedi)

MICROSCOPIC PHYSICS

Atomic and Molecular Physics

Arbitrary nlm → n'l'm' Excitations of Atoms and Ions by Electron Impact

It is believed that the Glauber cross sections become more and more accurate with increasing quantum numbers for atomic targets. We derive a one-dimensional integral representation of the scattering amplitude in the Coulomb-modified Glauber approximation for arbitrary nlm → n'l'm' excitation of hydrogen-like ions by the impact of charged particles. The integral representation is found to be useful for efficient computation of cross sections. We present some new results for excited state to excited state transitions.

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

Classical and Quantum Mechanics

Discrete Symmetries and Semiclassical Quantization

Most quantum Hamiltonian systems admit discrete symmetries and, in general, semiclassical quantization procedures do not take them into account. A technique has been developed which allows for discrete Hamiltonian symmetries in semiclassical quantization schemes using minimal quantum input. It is shown that accurate symmetry labelled eigenvalues are obtained in energy regions dominated by classical chaos. It is expected that this work will provide insight into construction of symmetry labelled semiclassical wave functions. This work is being done in collaboration with S. Sinha.

(V.B. Sheorey)

Quantum Wavefunctions in the Chaotic Region

Eigenfunctions for a two dimensional quantum system which is known to be classically chaotic have been obtained. At present time the overlap matrix element of the eigenfunctions for small changes in a system parameter have been evaluated and show extreme sensitivity to changes in the parameter when the system is in the chaotic regime. The wavefunctions are being subjected to other tests in order to study the imprint of classical chaotic dynamics in them.

(V.B. Sheorey and J.C. Parikh)

Canonical Perturbation Theory

It is well known that canonical perturbation theory in classical mechanics has two sources of singularities : (a) Each term in the perturbation series is singular in certain regions of phase space (close to rational tori) and (b) Even if the individual terms of the perturbation theory are finite, the overall series may not be convergent. We have reanalysed the situation prevailing in classical mechanics and shown that the singularity in each term in the perturbation series can be removed by either considering the time dependent canonical transformations or by embedding the classical mechanical system in a system with an extra degree of freedom with noncompact motion.

Numerical studies on example Hamiltonians in a 2 degrees of freedom are being carried out.

(B.R. Sitaram)

On the Observability of the Magnetic Vector Potential a la' Aharonov-Bohm in the Classical Mechanical Regime

An earlier quantum-like theory by the author on the motion of the charged particles in magnetic fields has been generalized to include a vector potential component along the field line. The resulting Schrödinger-like equation turns out to be analogous to the quantum-mechanic Schrödinger equation for a charged particle in a magnetic field except that our equation is one-dimensional along the magnetic field and involves, therefore, only the parallel component $A_{\parallel}$ of the vector potential :

$$i\mu \frac{\partial \Psi}{\partial t} = \frac{1}{2m}\left(\frac{\mu \partial}{i \partial x} - \frac{e}{c} A_{\parallel}\right)^2 + (\mu\Omega)\Psi$$

Here, μ appears in the role of $\hbar$ and the adiabatic potential $\mu\Omega$ appears in the place of the potential in the Schrödinger equation.

The above equation which is supposed to describe a classical mechanical system micro-ensemble makes some unusual predictions, namely the observability of $A_{\parallel}$ in the manner of the Aharonov-Bohm effect in quantum mechanics. This comes about because of its analogous structure to the quantum mechanic Schrödinger equation for a particle in a magnetic field. This yields the "quantum-like condition"

$$\int_0^L \left(m v_{\parallel} + \frac{e}{c} A_{\parallel}\right) dx = 2\pi n \mu$$

for the allowed status of motion. Clearly the presence of $A_{\parallel}$ in this condition implies its observability a la Aharonov-Bohm. Such a prediction as to its observability would appear to be heretical as it implies effects which are not covered by the classical equation of motion, if the vector potential is curl-free everywhere in the region accessible to the electrons except for a small region which is not.

(R.K. Varma)

Nuclear Physics

Nuclear Level Densities with Interactions

The state and level densities in ^{28}Si, ^{168}Er, ^{181}W and ^{234}U nuclei are calculated using the convolution theory based on Central Limit Theorem described in the last two years annual reports. The spin cut-off factors calculated via the spin cut-off density are used to decompose state densities into level desities in a given spin range. In the case of ^{28}Si a 0+2 $\hbar\omega$ space with realistic single particle energies and the (sd+fp) part of the Kuo 10-orbit interaction is employed while in heavy nuclei (^{168}Er, ^{181}W, ^{234}U) a few single particle levels around the fermi surface (with zero deformation Nilsson energies) and the phenomenological surface delta interaction with a free parameter G (the force constant) are used. The level densities at the neutron resonance energy are well reproduced in the case of ^{168}Er, ^{181}W and ^{234}U with G = 0.193, 0.155 and 0.135 MeV respectively which should be compared with the estimate G ~ A/25 MeV derived from spectroscopy of low-lying levels. In the case of ^{28}Si the calculations predict 1000 states per MeV at 19 MeV excitation which is in good agreement with other calculations. The predicted densities in the four nuclei are in good accord with the fermi gas forms and they show that the theory is good upto 20 MeV in light nuclei (Si) and ~8-10 MeV in heavy nuclei (Er, W, U). The fermi gas parameter 'a' turns out to be 2.24, 18.19, 19 05 and 26.19 MeV^{-1} and the back shifting parameter Δ is 1.27, 0.51, -0.28 and 0.73 MeV for ^{28}Si, ^{168}Er, ^{181}W and ^{234}U respectively. The value of 'a' should be compared with the fermi gas estimate a~A/10 MeV^{-1}

Systematic calculations of level densities and spin cut-off factors in many regions of the periodic table are under progress. The work is done in collaboration with J.B. French and R.U. Haq.

(V.K.B. Kota)

Spectroscopy of Samarium Isotopes in the sdg Interacting Boson Model

Successful spectroscopic calculations for the 0^+_1, 2^+_1 and 4^+_1 levels in $^{146-158}$Sm are carried out in sdg boson space with the restriction that the s- boson number $n_s \geq 2$ and the g- boson number $n_g \leq 2$.. Observed energies, quadrupole and magnetic moments, E2 and E4 transition strengths, nuclear radii and two nucleon transfer intensities are reproduced with a simple two-parameter Hamiltonian. For a good simultaneous description of ground, β and γ bands, a Hamiltonian interpolating the dynamical symmetries

in the sdg model is employed. Using the resulting wavefunctions, in ^{152,154}Sm, the observed B (E4; $0^+_1 \longrightarrow 4^+_\gamma$) values are well reproduced and E4 strength distributions are predicted. Moreover, a particular ratio R involving two nucleon - transfer strengths which show a peak at neutron number 90 is well described by the calculations.

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

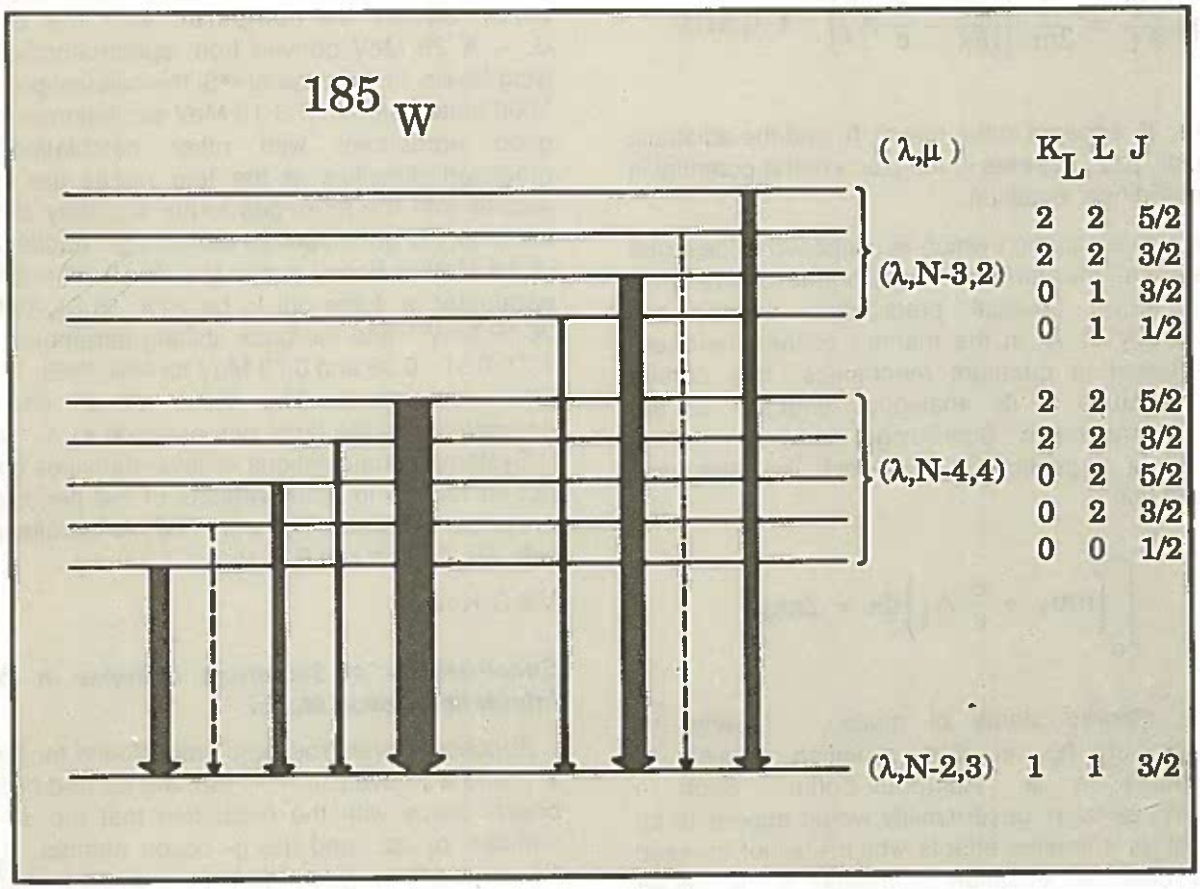
Scissors States with and without g-Bosons in the Interacting Boson Model for ^{185}W

The M1 excited scissors states in ^{185}W are studied in the SU(3) limit of the proton-neutron interacting boson fermion model with sd and sdg bosons (there is good evidence for the applicability of the $SU_{sdg}(3)$ limit for ^{184}W nucleus and E4 collectivity in odd W isotopes). The sd results are recovered as a special case of the sdg model and the latter model admits two different (SU(3) ⊗ U(2) and U(15) ⊗ U(2)) coupling schemes and has two pieces (that behave as (11) and (33) SU(3) tensors) in M1 operator, unlike one each in the sd case. The scissors M1 states in the SU(3) ⊗ U(2) and U(15) ⊗ U(2) limits are classified and the location of these states and the corresponding B(M1) values (M1 strengths) are predicted for the SU(3) ⊗ U(2) limit. As shown in the figures, the M1 strength is concentrated in just two SU(3) representations (η N-4,4) and (η N-3,2) where η=2 for sd and η=4 for sdg. The results obtained for ^{185}W apply directly to the nucleus ^{187}OS and extend easily to all even-odd nuclei with the odd-neutron in the 82-126 shell.

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

Shear Instability and Entropy Generation in Heavy Ion Collisions

An instability, known as Kelvin-Helmholtz instability



M1 strengths from scissors states (ηN-3,2)k_L LJ, (η N-4,4)k_L LJ to the ground state(ηN-2,3)k_L= 1 L=1 J=3/2 in ^{185}W nucleus. Note that (λ, μ) denotes SU(3) representation and k_L is the orbital band head quantum number. The ratio of the widths of the transition lines give the ratio of the M1 strengths. Approximately (ηN-4,4)states appear at 2.75 MeV and (ηN-3,2)states appear at 3.32 MeV. Note that η=2 for sd and η=4 for sdg. All the pedictions are in the SU(3) ⊗ U(2) limit.

(shear instability), well known in fluid theory and plasma physics is studied in heavy ion collisions (HIC) to study the process of entropy generation. The source of this instability is the transverse gradient of longitudinal velocity which is quite likely to arise when the collisions are somewhat peripheral (non-central). Relativistic equations describing this instability are derived here. A set of coupled partial differential equations in three dependent and three independent variables are obtained. It is difficult to solve them analytically. In order to get a qualitative idea, we have solved the non-relativistic version of the above equations with some approximations. We find that in boost invariant unperturbed state the growth rate of this instability competes with damping due to the boost invariant expansion of the unperturbed system. We also analyze low energy nuclear collisions, where there is no boost invariance, using a simple equilibrium flow with shear.

We made some rough estimate of eddy or turbulent viscosity. It is well known in fluid theory that shear instability leads to eddy formation and hence turbulence. The larger eddies are less dissipative through viscous dissipation, but they can transfer energy to smaller eddies through nonlinear inertia which dissipates faster through viscous force. So one can replace this nonlinear term in the equation for larger eddies by an eddy viscosity term.

We found that for reasonable parameters in HIC the eddy viscosity coefficient is of the same order as shear viscosity coefficient quoted by Danielewicz and Gyulassy. Therefore, shear instability can generate entropy of the same order as that of viscous dissipation. This work was done in collaboration with V.M. Bannur and P.K. Kaw

(J.C. Parikh)

IBM and the Dynamic (HF) Fermion Basis

We propose a prescription to construct the boson wave functions (BWF) in microscopic (fermion) basis dynamically for different nuclei from the corresponding Hartree-Fock (HF) solutions. The HF calculations are done with Surface Delta Interaction (SDI) as the residual interaction. From the occupancy occp(i) of the ith model orbit for neutrons and protons (calculated from the HF orbits) we construct effective single particle (s.p.)$|\ k\ = \pm 1/2>_{(n,p)}$ deformed orbit. We, then, project out good angular momentum states of $|\ J^{\pi}; T, T_3> = |\ 0^+, 1, \pm 1>, |\ 2^+, 1, \pm 1>$, and $|\ 4^+, 1, \pm 1>$ from the 2-particle determinant constructed out of the effective s.p. deformed orbits and call them $s_{n(p)}$, $d_{n(p)}$ and $g_{n(p)}$, the s, d and g neutron ($_n$) and proton ($_p$) BWFs respectively. Being constructed out of the occupancies of the s.p. Shell Model (SM) orbits, their structure is clearly microscopic and dynamic. The approximation involved is that we have bosons of only identical fermions (T = 1) and no np bosons (T = 0).

The BWFs and the SDI are then used to calculate the boson single particle energy (s.p.e.) and the two body matrix elements (t.b.m.e.). The t.b.m.e. calculation is rather involved and is done in np basis employing Complex Spectroscopy techniques. The s.p.e. and t.b.m.e. thus obtained define the Interacting Boson Model (IBM) Hamiltonian for the nucleus considered. The total IBM Hamiltonian is the sum of boson s.p.e. ε_s, ε_d, ε_g and the t.b.m.e. of V_{nn}, V_{pp}, and V_{np} (the 2 body n-n, p-p, n-p boson interaction) operators. In our approximation we drop the V_n and V_{pp} terms but carry out the V_{np} calculations exactly in multi j-shell. Diagonalisation of this Hamiltonian gives us the spectrum of the nucleus

The study of the spectra of 1n-1p boson systems (such as Zn^{60}, Ne^{20}, Ti^{44}) strongly suggests that the boson space should be extended to include g bosons to the space of s and d bosons in order to achieve good agreement with the SM results for these nuclei.

We plan to carry out spectroscopic studies of other even-even nuclei with higher number of bosons using SDGIBM1 boson Shell Model code developed by Y.D. Devi and V.K.B. Kota.

(S. Sarangi, J.C. Parikh and S.P. Pandya)

Particle and Fields

17 keV Neutrino

Experimental observations made at the end of the last year confirmed earlier observation of a 17 keV neutrino emitted in some ß decays. A phenomenologically consistent scheme to accommodate this neutrino into theoretical framework was proposed. Unlike most of the related models, the 17 keV neutrino does not decay in this scheme. Instead it can remain in the present universe with the relic density large enough to solve the dark matter problem.

(A.S. Joshipura)

Electric Dipole Moments

Electric dipole moments (edm) of fermions provide important test of theories of CP violation. It was shown that if this violation is generated by exotic variety of fermions called mirror fermions, then one ends up

getting too large edm for the electron and the neutron unless the mixing between the ordinary and exotic fermion is very small. The experimental limit on the edm of the electron and the neutron leads to limits on the relevant mixing which are five to six orders of magnitude than the existing limits.

(A.S. Joshipura)

Two-Higgs-doublet Model with Natural Suppression of Flavour Violation

An extension of the standard SU(2) x U(1) model of weak and electromagnetic interactions to include two Higgs doublet is proposed. Unlike well studied models, this model has a discrete symmetry which suppresses rather than forbids flavour violation. This allows the possbility of light Higgs bosons, without conflict with experiment. A scenario where only a neutral Higgs boson is light is shown to be in agreement with results on $B\bar{B}$ mixing CP violation. Another scenario with a light charged Higgs boson, while being consistent with the above results, also allows for a light top quark, which might have escaped detection at Fermilab.

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

Leptonic CP Violation in Z Decay

CP violation has so far been seen only in the KK system. To understand the mechanism of CP violation one has to consider various theoretical possibilities which might lead to observable CP violation in other experiments. CP violation in high-energy leptonic processes has received very little attention, mainly because it is negligible in the standard model. We consider extensions of the standard model to include extra leptons with non-standard SU(2)xU(1) transformation properties, where CP violation can arise in flavour-violating Z couplings. The possibility of using flavour asymmetry in leptonic Z decays to observe CP violation is studied. It is found that constraints coming from flavour-conserving Z decays can be used to predict that CP violation would be observable only if one can accumulate about 10^9 Z, beyond the capability of present machines.

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

Yukawa Couplings of N = 2 Superconformal Theories

Evidence that compactifications of the heterotic string on certain Calabi-Yau manifolds are connected in a deep and intricate way with compactifications on tensor products of minimal N = 2 superconformal field theories has been the subject of much recent attention. It has recently been shown by exploiting various relationships among coset conformal field theories that the entire massless spectra for the D4, E10 and E28 models are the same as A1 x A1, A1 x A2 and A1 x A3 respectively. We carried out the analysis a step further by investigating the Yukawa couplings of such models. We first consider the singularity structure and hence the Landau-Ginzburg potential of these models, which then give us the defining polynomials of the corresponding Calab-Yau manifold. We then consider deformations of these polynomials which do not change the metric of the manifold. This will identify various Gepner models which corresponds to topologically equivalent Calabi-Yau spaces. We further show that by proper identification of the fields with appropriate normalization these models also have the same Yukawa couplings and discrete symmetries and hence they give rise to the same fermion masses and mixing and related phenomenology when embedded in an N = 2 superconformal field theory. These identifications reduce the independent Gepner models by a factor of two. This work was done in collaboration with H.B. Zheng, M. Leblanc and R.B. Mann.

(U. Sarkar)

QCD Effect on the CP-Violating Operator

Recently it has been shown that the electron dipole moment (edm) of the neutron can receive a large contribution through the dimension six CP-violating gluonic operator, which is not suppressed by mixing angles or quark masses. This operator can be induced by a wide variety of models, which will then be ruled out from the present experimental limit on the edm of the neutron. This conclusion depends strongly on the QCD renormalisation group evolution of this operator, since its anomalous dimension can significantly enhance or supress its contribution to the edm of the neutron. We addressed this question using a non-zero momentum insertion of the composite operator, explicitly accounting for operator mixing in the renormalization of this operator. Calculation of the gauge parameter from the anomalous dimension of this operator is used as a consistency check on the final results. A strong QCD suppression of the CP-violation effects in the neutron edm is confirmed, contrary to initial claims of an enhancement. This work was done in collaboration with E. Bagan, R.B. Mann and T.G. Steele.

(U. Sarkar)

A New Parameterization of the KM Matrix

In the standard electroweak model the quark masses, mixing angles and the CP-violating phase are the ten arbitrary parameters and so phenomenological study of this sector is highly advocated. For a better understanding of the mixing matrix (CKM matrix) recently a new parameterization has been proposed in terms of its eigenvalues and eigenvectors by Kielenowski. We generalized this idea and then reproduced a symmetric CKM matrix with only two angles while predicting a range in the amount of CP-violation. The relation between this parameterization and the standard one is studied. Some variations of this parameterization are worked out. This work was done in collaboration with H.G. Blundell and R.B. Mann.

(U. Sarkar)

Neutrino Mass and Horizontal Symmetry

To understand the problem of repetition of generations and the mass hierarchy structure of the fermions, continuous horizontal local gauge interactions have been proposed, as possible extension of the standard model. Several horizontal symmetric models have been proposed to understand the quark masses and mixing. We studied the neutrino mass matrices in these models with some minimal assumptions. We have shown that the different horizontal symmetries namely U(1), SU(2), SU(3) vector and SU(3) vector-like, will imply different structure for these mass matrices.

(K.N. Bandyopadhyay, D. Choudhury and U. Sarkar)

Calculation of the Neutrinoless Beta-beta Decay of ^{76}Ge using a Quark Model with Harmonic Confinement

The half life of the neutrinoless double beta decay of ^{76}Ge into the ground state of ^{76}Se is calculated in a relativistic quark confinement model. The proton-neutron quasi-particle random phase approximation is used to evaluate the s and p wave nuclear matrix elements contained in the decay amplitude. We avoid the closure approximation and the use of the effective vector and axialvector coupling constants in the hadronic currents. In our formulation,the recoil matrix element arises naturally from the quark recoil in the decaying neutrons. The recoil and the p-wave effect are discussed and compared with other calculations. From the experimental lower bound for the decay half life an upper limit for the effective Majorana mass of the neutrino is deduced and the right-handed contribution to the charged weak current estimated. This work was done in collaboration with J. Suhonen and A. Faessler.

(S.B. Khadkikar)

The Neutrinoless Double Beta Decay of ^{76}Ge, ^{82}Se, ^{86}Kr, ^{114}Cd, ^{128}, ^{130}TE and ^{134}, ^{136}Xe in the Framework of a Relativistic Quark Confinement Model

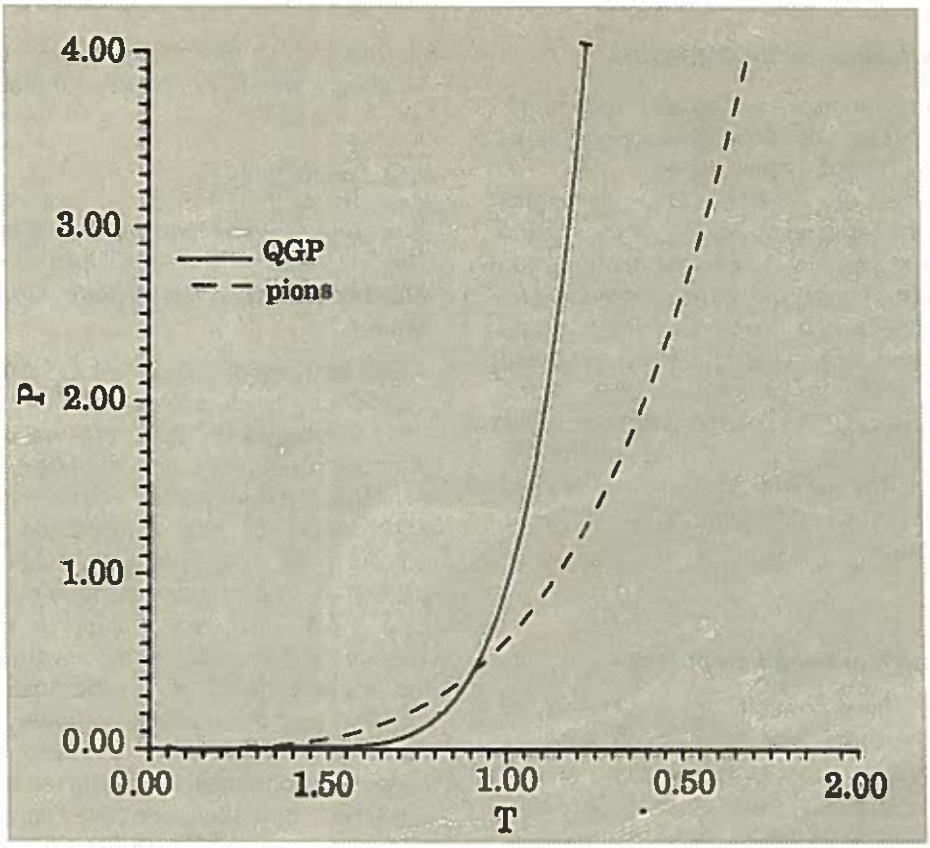
The half life of the $O^+ \rightarrow O^+$ neutrinoless double beta decay is calculated for ^{76}Ge, ^{82}Se, ^{86}Kr, ^{114}Cd, ^{126}, ^{130}Te and ^{134}, ^{136}Xe and the upper limit for the effective neutrino mass of 3.0eV is deduced from available experimental data. In addition, the contribution of the right-handed charged weak currents to the effective weak Hamiltonian is estimated. The relevant parameters attain the values $|(\lambda)| < 4.1 \cdot 10^{-6}$ and $|(\eta)| < 6.6 \cdot 10^{-8}$. The nucleonic weak current is treated starting from the current quark level and evaluating the quark current using relativistic quark wave functions obtained from a Dirac equation with a harmonic confineent potential. The nuclear matrix elements of the thus obtained effective weak operators are evaluated using the proton-neutron quasi-particle random phase approximation approach avoiding the use of closure and the accompanying singular neutrino potentials. The dependence of the decay half life on the recoil effects and the p-wave contribution is analysed. Detailed presentation of the theory is pursued. This work was done in collaboration with J. Suhonen and A. Faessler.

(S.B. Khadkikar)

Equation of State for Quark-Gluon Plasma in a Relativistic Harmonic Confinement

A Lorentz scalar + vector confining potential V(r) for quarks and a similar confinement model for gluons successfully used to describe hadron spectra and nucleon-nucleon phase shifts, is used to obtain equation of state of quark-gluon plasma. The potential V(r) can be viewed as a phenomenological representation of the overall confinement of quarks and gluons. This is essential because even from the deconfined phase one does not expect coloured partons to emerge as asymptotic states in the laboratory. The relativistic potential V(r) is consistent with the analytic lattice result concerning the nature of confinement (area law) with massive static quarks.

The transition temperature from pion-gas to quark gluon plasma is found to be 117 MeV. The model



Pressure in (fm^{-4}) versus Temperature (in fm^{-1}) for pions and quark gluon plasma.

gives a T^7 temperature dependence of pressure and energy density for quark gluon plasma. This is quite different from the ideal gas T^4 behaviour found in Bag model and lattice calculations. The differences are entirely due to the different treatment of the confinement property in these calculations. Of course only experimental results will finally establish the equation of state for quark matter.

(S.B. Khadkikar and J.C. Parikh)

Study of Nucleon-nucleon Interaction with Confinement Model for QCD

We have investigated the effect of exchange of confined gluons among relativistically confined quarks in nucleon-nucleon scattering calculations. For the quarks, we use the relativistic harmonic oscillator Lorentz scalar-vector confinement model (RHM) which explains the properties of light hadrons. A similar confinement scheme for gluons, the so called current confinement model (CCM) which describes glueballs, is employed to obtain confined-one-gluon-exchange potential (COGEP) which is used in these calculations.

The parameters in our model are fitted from Baryon Spectroscopy and from glueball spectra. With a single parameter α_s (strong coupling constant) we are able to obtain good agreement with experimental phase shifts for $^1S_0$, $^1P_1$ and $^1D_2$ phase shifts. The hard core radius for $^1S_0$ is found to be 0.621 fm. The effective range and scattering length are in good agreement with the experimental values. We have also investigated higher angular momentum phase shifts with tensor and spin orbit potentials with COGEP. There is fairly a good agreement with the phase shift for $^3S_1$ and $^3P_1$.

Our calculation clearly shows the role of confinement of gluons in giving rise to the crucial intermediate range attraction in the N-N force. Also the tensor and spin orbit forces are of right sign and have the right order of magnitude. In conclusion we have been able to obtain certain features of N-N interaction starting from the dynamics of quarks and gluons including confinement of color as a phenomenological input.

(S.B. Khadkikar and K.B. Vijaya Kumar)

LIST OF PAPERS PUBLISHED DURING 1990-91

MACROSCOPIC PHYSICS

ASTROPHYSICS

1. Tripathy, S.C., Prasanna, A.R. and Das, A.C., "Accreting magnetofluid around a compact object with a dipolar magnetic field. Newtonian analysis, Mon. Not. R. Astr. Soc. **246,** 348 (1990).

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6. Virbhadra, K.S., "Speed of a freely falling particle in Reissner-Nordstrom spacetime", Phys. Lett. A **147,** 351 (1990).

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2. Devi, Y.D. and Kota, V.K.B., "Band structure with a g-boson excitation in the interacting boson model", J. Phys. G : Nucl. part. Phys. **17,** 465 (1990).

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2. Choudhury, D. and Sarkar, U., "Naturally light Majorana neutrinos with no neutrinoless double beta decay", Phys. Rev. **D41,** 1591 (1990).

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COMPUTER CENTRE

The Computer Centre has the versatile DEC-1091 Computer System, a work station DN-3500 and HCL BUSYBEE AT. The Centre operates in two shifts on all days including Sundays. The storage capacity of the main frame is 512K words of 36 bits word length. The access time is 700 nano second. The main frame also has 2K words of cache memory with an access time of 133 nano second.

Five disk drives each of 40 mega words capacity are attached to the system. Four, high speed dual density of 800/1600 BPI magnetic tape drive units of nine track are also 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 RICOH RP3400 daisy wheel printer and one card reader are also attached to the system.

The time sharing, and highly user friendly TOPS-10 operating System supports the full configuration.

The work station DN-3500 has MC 68030, 32 bit VLSI Processor. It has 4 MB winchester disk drive and one 60 MB cartridge tape drive. The system is attached with colour display monitor with key board and mouse. It runs under UNIX/AEGIS Operating System. A versatile 8 pen dual port plotter and an NEC P5-XL Printer are also connected to the work station.

The main activities of the centre are software development and research in computer related areas of numerical methods, Statistics, Operations research, Neural Networks and Library science. The staff support by way of consultation to many internal projects as well as external projects of academic institutes and government bodies. The staff helps the users in designing and developing a new computer software systems. The staff also helps different areas and sections of PRL by installing and implementing software system.

Various other activities of the centre include in organising courses in computer and related topics to educate the users. Besides, the members of the centre support other academic activities like teaching, syllabus framing, staff and computer system selection for the universities and other educational institutes and government bodies. The faculty guide the students from academic institutes in their desertation work.

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

Hardware acquired

The centre has acquired a work station NEXUS-3000. It has MC 68020, 32 bit VLSI processor. It works at 25 MHz clock rate. It also has MC 68881 Co-processor which also works at 25 MHz. It has 4 MB Random Access memory (RAM). The auxiliary storage includes 155 MB winchester disk drive and one 1.2 MB Floppy drive. The system is attached with high resolution 19 inch (1024x800 pixels) colour monitor with keyboard and mouse.

The existing Apollo DN-3500 system is up graded by replacing 155 MB winchester disk drive by 348 MB winchester disk drive.

Software Acquired

DOMAIN-OS-SR10.1 operating system has been obtained. Both the work stations are now working under DOMAIN-OS-SR10.1 which support UNIX BSD 4.3, and 2 UNIX SYS V .2 and AEGIS, Both the systems are connected by APOLLO token ring network and they support SR 10 TCP/IP.

The centre also procured the MATHEMATICA Packages and is installed on DN3500 which runs under DOMAIN-OS-SR10.1. The package is very useful for Numerical calculations. The package provides highly accurate results and one can obtain to any number of decimal places practically. It provides symbolic calculations also which includes Calculus and can evaluate derivatives and integrals symbolically. It also provides graphics of 2D and 3D including shading, colour and lighting effects. MATHEMATICA produces graphics using POSTSCRIPT which can be rendered on many kinds of POSTSCRIPT devices to obtain hard copy. MATHEMATICA can also be used as a programming language.

The centre has also procured CHIWRITER software which is a scientific/multifont Word Processor and is installed on PC/AT.

Research, Development and Consultation

Some of the research and development activities during the year are

1. A new algorithm has been developed to estimate the Autoregressive parameters in a time series model to obtain the power spectrum. The method finds the parameters in a least square sense with the constraint that the sum of the coefficients is equal to one.

2. Developed Neural Network models for Discrimination.

3. Software development for neural computing using 'C' programming language.

4. Visualization programs using the MATHEMATICA.

List of papers published in 1990-91

1. C S R Murthy and P. N. Misra "On Structurally homogeneous clusters" ANVESAK, **18**, 117, 1988.

2. C S R Murthy and J. J. Trivedi "Detection of Kuznet s cycles through Maximum Entropy Method" ANVESAK, **19**, 37, 1989.

3. C S R Murthy "Complete information based Spectral Analysis" Indian Computing Congress Series; Computer Systems and Applications Recent Trends, Proc ICC, 1990, Tata McGraw Hill Publishing Co., New Delhi, pp. 321-327, 1990.

ELECTRONICS LABORATORY

The activities of Electronics Laboratory consists of fulfilling the computer based instrumentation needs for research groups in PRL and academic activities in the fields of artificial intelligence, computational techniques and computer hardware.

Artificial Neural Networks

A paradigm of artificial intelligence which exploits computational properties of neurons and their assembly or connection is known as artificial neural network or connectionism. The study undertaken deals with computations in connectionist system, learning algorithms, mapping of algorithm to the connectionist system, architecture of connectionist system and its hardware realisation and study of behavioural science such as speech and vision and simulating this behaviour in a computational model.

Hopfield Model

The collective computational properties of the Hopfield model of neural network are extensively studied and simulated with optimization problems such as task distribution and travelling salesman. Hopfield model of the neural networks have been found very useful in solving some of the optimization problems encountered in the day to day life.

In this architecture all the neurons are connected to each other with symmetric synaptic weights and external inputs are applied at an instant. The outputs of the neurons continually change due to feedback connections and finally come to a stable state. In doing so it can solve an optimization problem if a proper energy function is formulated to determine the strength of the excitatory or inhibitory connections between the neurons.

Since all the neurons act upon each other simultaneously the circuit acts as a parallel processor and hence is able to solve the problems very rapidly. The performance of the circuit improves if graded input output response is chosen instead of binary switching of states of the neurons.

Programs were written in PASCAL for simulating the electronic amplifiers in place of neurons and resistances and capacitances as synaptic connections for solving the following optimization problems :

1) Analog to binary converter

2) Library task optimization problem

3) Travelling salesman problem

Many of these problems are computationally very intensive but are solved within a few circuit time constants due to non-algorithmic nature of the way a neuronal architecture works. This research gives a better insight into the understanding of the biological neural network in the human brain and its high speed computational capabilities.

Another Hopfield model was used to study associative memory and recall capabilities limiting the number of neuron connection to the neighbouring few neurons. A network consisting of 16000 neurons used to store and recall images of human faces. It was possible to reconstruct the images from 33% missing or corrupted data. This model was simulated on PC/AT and also implemented in hardware.

Multilayered Neural Networks

Back propagation learning algorithm and its variations to speed up the learning process in multilayered networks are applied to variety of problems. The important factor affecting the learning mechanism is the non-linear transfer function of the neuron.

A simplified training strategy for feed forward multilayered network is developed in view of VLSI implementation. The standard back propagation technique is modified using stochastic logic to increase speed of learning with reduced circuit

complexity. The forward and reverse characteristics of the perceptron are generated using random threshold logic. The hardware consists of 32 layers working in sequential mode with each layer consisting of 31 perceptrons working in parallel. The inter-layer couplings are programmable with connection weightages being kept in external memory which is readable and reloadable from host computer.

Speech Synthesis and Recognition

The speech spectrograms are obtained using hardware based on DSP32 digital signal processor chip. The spectrograms are used to train the multilayered neural network for the task of word recognition based on the spectral data. Good results have been obtained for small vocabularies for speaker dependent recognition. The response time during task of recognition is of the order of few seconds which can be improved upon to almost real time by providing better front end hardware and software and reducing the communication between front end and host computer.

Speech synthesis is an important requirement in man machine interface. Among several techniques of coding speech for digital storage and synthesis the linear predictive coding is considered to be the best. The coding and reconstruction of speech waveform in real time requires computing speeds much higher than available PC/ATs and hence a transputer based system is under development.

A new algorithm for continuous autocorrelation of speech signal is developed in which total number of multiplication are reduced by two order of magnitudes. A neural network based continuous LPC coding algorithm is developed. The work is going on for large vocabulary speaker independent speech recognition.

Transputer Development

To implement functional computing hardware several transputer based boards were designed. These boards are being used for speech recognition algorithm in pipe line architecture. The software tools like assembler and disassembler are developed to aid the development of small dedicated transputer based applications. The Pascal and C language interfaces are being developed.

Coatings and Optical Filters

Design and fabrication of a somewhat newtype of induced transmission filters in the visible range of the spectrum is the most significant development of the year. These filters typically possess high transmittance of 60-70% as compared to our old design induced transmission filters, whose transmittance was typically about 25%. This apart we have fabricated a number of conventional type of dielectric narrow band filters for testing purpose.

As regards the routine work we have done several (about 180) jobs of vacuum-coatings, including bandpass-filter front surface mirrors, anti-reflection coatings beam splitters, neutral density filters, vacuum-UV-filters, AL+NaF coatings, aluminization of mylar and ceramics etc. Also we have provided high vacuum facility and services including technical advice to various PRL projects.

Papers Published in 1990-91

Rawat S.D., "The role of wave particle duality of light in optical computers", Science Focus Vol 1, p-5 (1990).
(1990)

LIBRARY

Collection

The PRL Library subscribes to 250 scientific and technical journals besides receiving a large number of scientific reports, data etc. Twelve important journals are subscribed by air-mail. During the year 485 books were added. The total stock of books and bound volumes of periodicals is about 38,500.

Services

Over 2,00,000 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 250 publications on Interlibrary Loan. Most of these books/reports/journals/articles were obtained on loan. 150 publications were given on loan by the PRL library to other libraries.

During the year 7000 books and journals were issued. A large number of reference queries were received and answered. The library could give more effective and better services by using several computerised systems developed inhouse.

Using these systems the following Finding Tools were prepared in the library :

- Astronomy Books in PRL Library.
- Conference Proceedings.
- Fast Facts - A guide to the Reference Collection.
- History of Science.
- One Line Keyword Index of Astronomy Books.
- Textbooks in PRL Library.
- Serial Publications.
- Bibliography of Reports.

- Periodical Holdings.

Current Contents - Physical, Chemical and Earth Science is being received in the library on floppy disks. Current Awareness Service using these floppy disks is being given to a few scientists after obtaining their current interest profiles. The response and feedback received shows that this service is found to be very useful, and the demand for it is growing.

Workshop on Library and Information Science in Astronomy and Astrophysics

Workshop on Library and Information Science in Astronomy and Astrophysics was held in PRL from January 29-31, 1991. Paritication was restricted to FORSA Members (Forum for Resource Sharing in Astronomy).

Prior to the Workshop the following four products were produced and displayed at the Joint Session held with the Astronomers.

- Union Catalogue of Astronomy & Astrophysics Serials available in the FORSA Libraries - Compiled by IIA
- Union Catalogue of Reference Tools in FORSA Libraries - Compiled by TIFR
- Astronomy Theses in FORSA Libraries - Compiled by RRI
- Directory of FORSA Libraries - Complied by PRL.

WORKSHOP

Workshop has assisted scientists and engineers in supporting research and development activities. The following major iobs were accomplished. We have carried out the repairing of the heavy and bulky 8 meter diameter FRP Dome and the drive mechanism at Udaipur. This was a challenging job and was executed very well.

Sample holder, Detector housing, various spherical probes for Balloon Flights and many other instruments were made for the planetary aeronomy division.

Maintenance work including making the required spare-parts for the Radio telescope at Thaltej was accomplished. Spacers, separators and insulators were made in thousands of numbers.

The one meter corer was modified and a three meter corer fabrication work is under progress. Floating platform and reaction vessel work is also under process for the continental palaeoclimatic group.

Textile Looms were assembled and attached to the Computer Control. This was displayed at Banaras and other places. For "Naya Gujarat" exhibition models of Sewage Plant and Robot were made.

For the Geocosmophysics group modification in the Mass Spectrometer, making few high vacuum s.s. valve, vacuum glow oven system and s.s. sample holders (thousands in number) were made.

Beam splitters, vacuum chamber, fluoresence chamber light baffle assembly work are the examples of precision work done in the workshop.

Infrared Photometer, C-14, camera attachment, Hertmann Diaphram and many highly precise assemblies were made for INF-RD project. Beside this workshop team was regularly sent to MT. Abu to assist scientists in experimental and maintenance work of the dome and the drive mechanism.

One hydraulic sheet cutting machine is installed in the workshop. This machine is designed on the latest concept and technique.

ENGINEERING SERVICES

The Engineering Services including all technical services pertains to civil engineering works and related building and laboratory services such as electrical, public health, airconditioning, intercommunication 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 planning, designing, estimating and execution of various works, horticulture development and maintenance and upkeepment of various building and campuses.

During the year following works have been undertaken.

- Modification works of Library block - under completion stage.
- Anodised aluminium doors & windows of Space Science Laboratory building at Thaltej Centre.
- Construction of New entrance of Laboratory premises.
- Contruction of Cement concrete road infront of space science laboratory.
- Construction of telescope house for 350mm celestron telescope with FRP dome at Gurushikar, under progress.

On August 9, 1990 the Physical Research Laboratory, celebrated the seventy-first birth anniversary of its founder, Dr. Vikram A. Sarabhai. Usually PRL celebrates Vikram Jayanti on August 12, the birthday of Dr. Sarabhai. But this year August 12 being Sunday, the celebrations were held on August 9. The celebrations started with the traditional tree planting ceremony at the PRL campus. This was followed by the presentation of the Hari Om Awards. The Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards, with funds generously provided by Shri Hari Om Ashram of Nadiad, Gujarat were instituted in 1973 at PRL in memory of its founder. This year the scientific disciplines for which the award was initially instituted have been modified. The disciplines are :

i) Space Sciences (including astronomy, astrophysics and planetary and atmospheric sciences).

ii) Space Applications (including meteorology, hydrology, remote sensing and related ground truths).

iii) Electronics, informatics, telematics and automation.

iv) Systems analysis or Management Problems.

The scientists who received the awards were Professors N. Kameshwar Rao of IIA, Bangalore and S. Bujarbarua of Institute of Advanced Study in Science and Technology (both for Space Sciences); Professor Sulochana Gadgil of IISc., Bangalore (for Space Applications); Dr. S. Pal of ISAC, Bangalore and Prof. L. M. Patnaik of IISc., Bangalore (both for Electronics, Telematics, Automation and Informatics) and Shri M. G. Chandrasekhar of ISRO Head Quarters, Bangalore (for Systems Analysis and Management Problems). Each award carries a medal and a cash prize of Rs. 8000/-. Professor B. V. Sreekantan gave away the awards to the distinguished recipients at an impressive ceremony held at the ATIRA auditorium.

A one day Workshop on Popularization of Astronomy for college teachers and amateur astronomers was organized in PRL on October 7, 1990. This was part of the popularization of astronomy program conducted on behalf of Astronomical society of India. The workshop was inaugurated by Professor P.C. Vaidya. More than eighty participants from other academic institutions like the Community Science Centre, Ahmedabad participated in the workshop.

Hari Om Awardees with Shrimati Mrinalini Sarabhai and the Chief Guest, Professor B. V. Sreekantan (l or r) Dr. S. Pal, Prof L.M.Patnaik, Shri M. G. Chandrasekhar, Dr. S. Bujarbarua, Prof. Sulochana Gadgil, Shrimati Mrinalini Sarabhai, Prof. B. V. Sreekantan, Prof. N. Kameshwar Rao and Prof. R. K. Varma.

On the occasion of Prof. P. V. Kulkarni's sixtieth birthday a felicitation function was held on November 1, 1990 at the Physical Research Laboratory. A one day symposium on 'Modern Trends in Astronomy' was also organised. The felicitation function was chaired by Prof. P. R. Pisharoty and the inaugural address was given by Prof. J. C. Bhattacharya. The scientific part of the day's proceedings consisted of four invited lectures covering scientific disciplines in which Prof. Kulkarni had been associated. The lectures covered topics like studies of the dynamics of the ionosphere using airglow emission, impact of new technology in the field of astronomy, the evolution of Fabry-Perot Spectroscopy in PRL and polarization studies of the Active Galactic Nuclei.

The Hindi week was celebrated at PRL during November 22-25, 1990. As before, the members of the staff and their families enthusiastically took part in the various competitions and the functions arranged during the week. The celebration started with a popular talk by Shri R. N. Misra in Hindi on November 22. On November 23, an essay competition was arranged for the staff members and their families. A panel of three judges from outside was invited for the evaluation of the speeches. Separate prizes were declared for Hindi speaking and non-Hindi speaking participants.

The Fifth National Symposium on Mass Spectrometry organised by the Indian Society for Mass Spectrometry was hosted by Physical Research Laboratory during January 7-9, 1991. Prof. R. K. Varma, Director, PRL delivered the inaugural address. About two hundred participants from India and thirteen from foreign countries have participated in this symposium. Fourteen review talks covering various aspects of developments in mass spectrometry techniques were presented by various experts. Apart from the invited talks a large number of scientific papers relating to application of mass spectrometric techniques in different fields were presented in three poster sessions. An exhibition of various instruments used in mass spectrometry was also organised by various manufacturing organisations. A special Bulletin by ISMAS was brought out to mark the symposium.

The Inter University Centre for Astronomy and Astrophysics at Poona, sponsors mini workshop in different aspects of Astronomy and Astrophysics to foster closer interaction between the research

Inauguration of the Fifth National Symposium on Mass Spectrometry

institutes and universities. Recognising the specialization available at PRL, IUCAA funded the holding of a mini workshop in Relativistic Astrophysics during 18-25 January 1991 which was directed by A. R. Prasanna. The meeting was restricted to a small group of people working in the area of Relativity and Astrophysics and few others wanting to get into the subject.

The fourteenth meeting of the Astronomical Society of India (ASI) was held at PRL during 29-31 January 1991. A one day symposium on 'The Sun and Helioseismology' was also organised under the auspices of ASI on 1 February 1991. About hundred delegates attended the ASI deliberations. The meeting was inaugurated by the eminent educationalist Prof. P. C. Vaidya which was followed by Presidential address. Prof. P. V. Kulkarni, presently the President of ASI spoke on 'Bok Globules'. The scientific session numbering over a dozen featured eight invited review talks and a large number of contributed papers. A visit to Thaltej Radio Astronomy Centre was also organised for the ASI delegates; the General Body Meeting of ASI was held there. In keeping with the ASI tradition, a popular lecture on 'Development of Bharatiya Panchangas' was delivered by Prof. K. D. Abhyankar at ATIRA auditorium on January 31.

Along with the ASI meeting a Workshop on Information Services in Astronomy and Astrophysics was also held at PRL. The participants were mostly members of FORSA (Forum for Resource Sharing in Astronomy and Astrophysics). The major aim was to discuss collaborative Resource Sharing projects and to have a Joint-session with the Astronomers so that the interaction would enable the FORSA members to ascertain the services and products needed by the Astronomers.

The National Science Day was celebrated at PRL on 23 February 1991. The celebration was jointly organised by Indian Physics Association, Ahmedabad Chapter and the Gujarat Science Academy. The programme consisted of Science Quiz for school children of class IX to XI and popular science lectures in Hindi and Gujarati. The Science Quiz was held in two phases. In the morning about two hundred children from about hundred schools in Ahmedabad and Gandhinagar district participated in the preliminary round which was of written type. The questions were in English and Gujarati. The first eighteen students were selected from the final round which was oral. Two popular lectures were arranged for the students and the teachers. Prof. S. P. Pandya gave a very fascinating talk on 'A Peep in the World of

Prof. P. V. Kulkarni delivering the Presidential Address at the Fourteenth Meeting of the Astronomical Society of India.

Atoms" in Gujarati. This was followed by another scintillating talk in Hindi on "Impact of Interplanetary Processes on Life on Earth" by Professor N. Bhandari. The final round of the Science Quiz was of oral type. The competition in this round was very close and exciting. For the encouragement of the young science students all the eighteen students were presented a science kit which were generously donated by M/s. Electric Control Gear (India) Ltd., Ahmedabad. The winners of first, second and third positions in the final round of the quiz were presented with a set of science books. All the participating students in the quiz programme were presented a popular science book.

Professor Roddam Narasimha, Director, National Aeronautical Laboratory, Bangalore delivered the fourth Professor K.R. Ramanathan Memorial Lecture on March 18, 1991. The title of his talk was "Climate near the Ground: The Ramdas Effect". Prof. Narasimha, an eminent and distinguished aerospace scientist, is also a Professor in the Department of Aerospace Engineering and Centre for Atmospheric Sciences, IISc., Bangalore. He has made outstanding contributions in the field of Fluid Mechanics and in particular in the area of Turbulence. His contributions in the field of Aerospace Engineering are well known.

This year three of our staff members retired from the laboratory. Mr. Mohinder Nath Sharma, Engineer SC, retired from PRL on June 30, 1990 after putting a dedicated service for about twenty two years. Mr. Mohinder Nath joined Electronics Laboratory of PRL on October 26, 1968 as a Scientific Assistant. In PRL he was always addressed as 'Mota Bhai' and he really lived as one. He had been an excellent maintenance man and specialized in repairing oscilloscopes, power supplies, public address systems for the laboratory. As the years went by he adopted to the fast changes in the world of electronics and by the time he retired from PRL he was successfully handling computer based inventory of electronic stores for items worth millions. He was single handedly laisoning with the stores and purchase section of the laboratory as it suited best to his temperament and the capacity to interact with all the staff members and colleagues — be it an elderly person or a young apprentice with equal ease. We wish him a very happy and contended life for years to come.

Professor P.V. Kulkarni retired from PRL on October 31, 1990 after twenty five years of dedicated service. Dr. Kulkarni joined PRL in 1965. It was at the suggestion of Dr. Ramanathan that an airglow programme was initiated and P.V. Kulkarni (then

Professor Roddam Narashima delivering the fourth Professor K R Ramanathan Memorial Lecture

working for his Ph.D. at Pune) was one of the first group of scientists in India who constructed their own equipments and began a series of photoelectric studies of airglow at Pune, Mt. Abu and Srinagar in 1957. During 1961-63, Dr. Kulkarni worked in P.M. Millman's group at NRL, Ottawa as a Post Doctoral Fellow. He continued studies of airglow emissions in 6300 A and 5577 A wavelengths. Also during this period he developed a novel method of calibration of low level light sources in the laboratory. This work earned Dr. Kulkarni the membership of IAGA Committee on Optical Calibration Standards. In 1963 he joined the Hawaii Institute of Geophysics as an Associate Professor where he not only continued his airglow work with distinction, but also shouldered teaching responsibilities for post graduate students. As a result of his observations he was the first to postulate the existence of two distinct emission layers for the green Oxygen radiation in the upper atmosphere at 100 kms and 250 kms. This prediction was later confirmed by rocket and satellite observations. At PRL for the first ten years he continued to work on airglow emissions and their importance in understanding the morphology and dynamics of the upper atmosphere and in particular the D, E and F layers. He also studied OH emissions and successfully determined the temperature of the neutral component of the atmosphere in the D-region. He showed that in this region, contrary to earlier beliefs there were temperature variations which led to inference of existence of gravity waves. A spectacular result obtained by Kulkarni was the optical mapping of the Appleton anomaly in the ionosphere and its progressive advance from tropics to the equator during the night. At the peak of his career in the field of optical aeronomy Prof. Kulkarni decided to embark on a new venture to set up an infrared research programme at PRL and to build a suitable observatory dedicated to this programme at Gurushikhar. He brought to this field his extensive experimental skill, experience and dedication and built a number of increasingly sophisticated near infrared photometers. With his students he used them at Nainital and Kavalur Observatories to carry out astronomical observations. His group was the first to observe near infrared bursts from the well known X-ray burster MXB 1730-33. The observatory at Gurushikhar is now ready and the telescope - specially constructed for IR observations - will become operational soon. Only those who have been closely in touch with this project - as we have been - can fully appreciate the amount of hard work, long time-spans, meticulous planning and dedicated effort that Prof. Kulkarni put in this project for nearly a decade of the most productive period of life. Prof. Kulkarni has been elected a Fellow of Indian Academy of Sciences, and is the present President of the Astronomical Society of India. After retirement Prof. Kulkarni has chosen to settle down in Sangli. We wish him many happy and peaceful years of active retirement.

Shri A. V. Bagayatkar retired from service on December 31, 1990 as Special Assistant to the Director. Shri Bagayatkar came along with Prof. D. Lal's group at TIFR and joined PRL on January 1, 1973 as Personal Assistant to the Director. As an assistant to the Director, Shri Bagayatkar's job was quite challenging. It meant long hours in the office sacrificing his family time and personal comforts. A noteworthy feature of Shri Bagayatkar's working was his meticulous upkeepment of both office records as well as personal library of reprints/books of the Director. Any time one needed any reference material, Shri Bagayatkar would locate it in a minute's time. His office almost looked like a temple with everything clean and arranged neatly. A soft-spoken person, with few words and a characteristic smile are some of the things that we would remember Shri Bagayatkar for. We wish him a long, happy and healthy retired life with his family making up the time he would have missed being with them while he was in service.

Papers Presented at Symposia/Conferences in 1990-91

ASTRONOMY AND ASTROPHYSICS

Infrared Astronomy

a. Workshop on "Trends in computing in ISRO", Bangalore July, 1990.

1. Deshpande, M.R., Shah, A.B. and Jog N.S., "Computer and Image Processing system reqirements at IR Observatory P.R.L.".

b. First Kodai workshop on "Optical Interferometry" August, 1990.

1. Desai J.N., "High resolution Interferometric Spectroscopy" (Invited talk.)
2. Chandasekhar, T., "Infrared Detectors" (lead talk in a discussion session.)

c. IAU Colloquium 126 on "Origin and Evolution of Interplanetary dust", Kyoto, Japan, August 1990.

1. Sen A.K., Deshpande M.R., and Joshi U.C., "Polarimetric properties of Halley's dust."

d. 24th ESLAB Symposium on "Formation of Stars and Planets and the Evolution of the Solar System" at Friedrichaheffen, Germany, 17-19 September, 1990.

1. Vaidya, D.B. and Anandrao, B.G., "Circumstellar dust in Vega stars-detailed analysis of IRAS observations".

e. IUCCA minischool on Infrared Astrophysics (Jan 1-5, 1991), Madurai, Kamraj Univ.

1. Sam Ragland., "Lunar occultations in the Infrared" (a talk).

f. Conference on "Variability in Blazars", Turku, Finland, January 1991.

1. Joshi U.C. and Deshpande M.R., "Detection of microvariability in MRK 421."

g. Astronomical Society of India XIV meeting, Ahmedabad, January 29 - Feb. 1, 1991.

1. Ashok N.M., Chandrasekhar T. and Sam Ragland., "Lunar occultation observation from Gurushikhar.
2. Banerjee D.P.K. and Anandrao B.G., "A Physical mechanism for the structural development of planetary nebulae envelopes."
3. Banerjee D.P.K., Anandrao B.G., Mallik D.V.C., and Jain S.K., "Spatiokinematics of the bipolar plantery nebula NGC2440."
4. Joshi U.C., and Deshpande M.R., "Detection of short time Variability MRK 421".
5. Seema P., Anandrao B.G., Banerjee D.P.K., and Jog N.S., "An Imaging Fabry Perot Spectrometer using a 2-dimensional photon counting detector for kinematic studies of extended objects".
6. Sen A.K., Joshi U.C., and Deshpande M.R., "Photopolarimetric properties of comet Austin".
7. Shylaja B.S., and Anandrao B.G., "IR excesses in WR stars".
8. Shylaja B.S., "The wind structure of γ^2 vel".
9. Sheela P.K., and Joshi U.C., "Study of atmosphere aerosol at Gurushikhar".
10. Vaidya D.B. and Anandarao, B.G., "Circumstellar dust in vega like mainsequence stars — a detailed analysis of IRAS observations".

b. IEEE Seminar on "Imaging 90" (Kerala Section), December, 1990.

1. Jog N.S., Pandya H.I., Patel R.T., Seema P., and Anandrao B.G., "Imaging data acquisition using IPD detector for astronomical applications".

i. Minischool in "High Energy Astrophysics", P.R.L., Ahmedabad.

1. Desai J.N., "Observational Aspects of High energy Astrophysics" (invited talk).

Solar and Plasma Astrophysics

a. Workshop on Popularising Astronomy, PRL, Ahmedabad, October 1990.

1. Vats H.O., "Universe through the radio telescope".

b. XIV Astronomical Society of India Meeting, PRL, Ahmedabad, Jan, 29 - Feb. 1, 1991.

1. Janardhan P., Alurkar S.K., Bobra A.D., and Slee O.B., "Enhanced scintillation of radio source 2204+29 by Comet Austin (1989c1) at 103MHZ".
2. Sharma A.K., and Vats H.O., "On the relationship of solar wind and geophysical parameters".
3. Vats H.O., and Alurkar S.K., "Determination of source broadening during strong scattering in the interplanetary scintillation".
4. Vats H.O., Shah Y.V., and Alurkar S.K., "Statistic of Plasma blobs and holes".

Solar Physics at Udaipur Solar Observatory

a. XIV Astronomial Society of India Meeting, Ahmedabad (29 January - 1 February 1991).

1. Ambastha A. "Large Two-Ribbon Flare of 28 March 1990".

2. Ambastha A., Bhatnagar A., Srivastava N., Jain R.M., Gupta S.K., Sharma R., Agrawal G., "Results of GONG Site Survey Program at the Udaipur Solar Observatory."

3. Bhatnagar A., "Observational aspect of Helioseismology" (Invited review talk).

4. Jain R.M., Bhatnagar A. and Sharma R. "Cosmic Ray Flare of 29 September 1989".

5. Srivastava N., Ambastha A. and Bhatnagar A. "Helically twisted prominence eruption event of March 11, 1979".

b. I.A.U. Colloquium No. 132 "Instability Chaos and Predictability in Celestial Mechanics and Stellar Dynamics", Delhi (October 10-13, 1990).

1. Ambastha A. "Stability of Self-Gravitating Finite Disks."

c. XVII International School For Young Astronomers, Malaysia (May 28-June 15, 1990)

1. Srivastava N. "Udaipur Solar Observatory : Existing facilities and its objectives".

2. Srivastava N. "On the evolution of helically twisted prominence structures of March 11, 1979".

d. Amateur Astronomer's meet at IUCAA Pune (January 12-13, 1991)

1. Bhatnagar A. "Solar Astronomy by and for amateurs".

e. Workshop : Popularization of Astronomy (October 7, 1990)

1. Bhatnagar A. "Picturesque Sun".

f. Annual Conference of National Istitute of Personnel Management on "Integrative Approaches to Human Resources Management", Hyderabad (October 25-27, 1990)

1. Singh B.K. "Managing Human Resources : New Perspective".

PLANETARY ATMOSPHERES AND AERONOMY

a. XXVIII COSPAR Symposia and Associated Meetings at The Hague, The Netherlands, 25 June-6 July, 1990.

1. Gupta S.P., "Meteoric ions as tracers for gravity waves over the magnetic equator".

2. Gupta S.P., Acharya Y.B. and Narayan A., "Effect of charging of balloon on conductivity and electric field measurements".

3. Gurubaran S., Sridharan S., Suhasini R., and Raghavarao R., "Nighttime themospheric temperatures and associated F region dynamics from low latitudes."

4. Nagpal O.P., and Raghavarao R., "On the wave forcing of the semiannual zonal wind electric fields".

5. Raghavarao, R., Sekar, R. and Suhasini, R., "Non-linear numerical simulation of equatorial spread-F effects of winds and electric fields".

6. Sridharan R., Rahghavarao R., Gurubaran R., and Narayanan R., "Pre dusk enhancements of OI 630.0 nm dayglow intensities from low latitude".

7. Sridharan R., "Recent developments in ground based optical ivestigation of equatorial electrojet (Invited Paper).

b. Seventh International Symposium of the Commission on Atmospheric Chemistry and Global Pollution (CACGP), Chamrousse, France. 5-11 September, 1990.

1. Lal M., Beig G., and Chakrabarty D.K., "Observations of columnar density of nitrogen dioxide and ozone over the tropics".

2. Lal S., Ramani S.V., and Subbaraya B.H., "Biogenic trace gases in the tropical region".

c. Symposium on "30 years of scientific ballooning in India", Hyderabad 22-24 October, 1990.

1. Gupta S.P., "Conductivity and vertical electric field measurements by balloonborne probe from Hyderabad" (Invited talk).

2. Jayaraman A., "Results on Aerosols from balloon measurements".

d. International symposium on "Optical and Radio Remote Sensing of the Atmospheric Environment", New Delhi, 24-26 October, 1990.

1. Beig G., and Chakrabarty D.K., "Models of the Antarctica mesospheric positive ions."

2. Beig G., and Chakrabarty D.K., "A theoretical model of negative ion composition in the stratosphere".

3. 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".

4. Prakash S., Chandra H., Vyas G.D., Sinha H.S.S. and Misra R.N., "Equatorial spread F campaign of October, 1988.

5. Raghavarao R., Sekar R., and Suhasini R., "The effects of electric fields, winds and advection in the nonlinear stimulation of equatorial spread-F ".

6. Sridharan R., Gurubaran S., and Tewari A.K., "Dayglow photometry promise and future".

e. Workshop on ozone layer and atmospheric changes. Trichur, 29-30 November, 1990.

1. Lal S., "Vertical distribution of trace gases and their role in atmospheric chemistry".

f. Eight National Workshop on Atomic and Molecular Physics, Hyderabad, 6-12 December, 1990.

1. Ahmed S.M., and Vijay Kumar, "Measurement of photoabsorption and fluorescene cross sections for Carbon Disulphide".
2. Ahmed S.M., and Vijay Kumar, "Quantitative photoabsorption and fluorescene spectroscopy of Sulphur Dioxide".
3. Prajapati I.A., Ahmed S.M., and Vijay Kumar, "Fluorescene studies of carbon disulphide and sulphur dioxide at 121.6, 73.6-74.4 and 58.4 nm".
4. Vijay Kumar, "Space vehicle glow and its possible sources", (Invited talk).

g. Fourteenth meeting of Astronomical Society of India, Ahmedabad, 28 - January 1, 1991.

1. Haider S.A., Bhardwaj A., and Singhal R.P., "A model calculation of ionic composition in the coma of Halley's comet".

h. Winter school on MST Radar application, Tirupati, 28 January - 4 February, 1991.

1. Chandra H., "Spaced antenna drift and interferometric technique with application to MST Radar" (Invited talk).
2. Sridharan R., "Optical and radar investigations of the equatorial spread F" (Invited talk).
3. Subbaraya B.H., "Structure and Energetics of the middle atmosphere" (Invited talk).

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

a. International Archaeometry Symposium, Heidelberg, W. Germany, April 2-6, 1990.

1. Singhvi A.K., Chawla S., Misra V.N., Rajguru S.N., Deraniyagala S.U., and Sauer W., "Thermoluminescene dating of sediments and Archaeological chronology".

b. Sixth specialist Seminar on TL/ESR dating, Clairmont Ferrand, France, July 6-10, 1990.

1. Chawla S., and Singhvi A.K., "Implications of dose rate effects in quartz based TL dating".
2. Singhvi A.K., Dhir R.P., Rajguru S.N., Misra V.N., and Chawlas "Palaeoclimatic and archaeological implications".

c. 53rd Meteoritical Society Meeting, Perth, 17-21 September, 1990.

1. Goswami J.N., Srinivasan G., and Ulyanov A.A., "Ion probe studies of magnesium isotope compositons in Efremovka CAI's".
2. Nishizumi K., Nagai M., Imamura M., Honda M., Kobayashi K., Kubic P.W., Shava P., Wheler R., Signer P., Goswami J.N., Sinha N., Reedy R.C., and Arnold J.R., "Solar cosmic ray produced nuclides in Salem meteorite".
3. Rao M.N., Garrison D.H., and Bogard D.D., "Elemental and isotopic composition of solar flare noble gases in Kapoeta : Implications for charged particle acceleration from Sun".

d. IAEA/RCA Training Course on Isotope Techniques in Hydrology, Bhabha Atomic Research Centre, Bombay, September 17 - October 5, 1990.

1. Nijampurkar V.N., "Isotopes in snow and glacier hydrology".
2. Somyajulu B.L.K., "Studies of lakes using naturally occurring radioactive nuclides".

e. Seventh International Conference on Geochronology, Cosmochronology and Isotope Geology, Canberra, Australia, September 24-29, 1990.

1. Bhattacharya S.K., Sarkar A., and Naidin D.O., "Evidence of rapid temperature change across K/T boundary : ^{18}O signature in Mangyshlak sediments".
2. Goswami J.N., and Srinivasan G., "Magnesium isotope systematics in refractory inclusions from CV3 chondrite Efremovka".
3. Sarin M.M., Trivedi J.R., Krishnaswami S., and Sharma K.K., "Weathering in Himalayas : Inferences from chemical and isotopic analysis of high altitude streams".
4. Sarkar A., Bhattacharya S.K., Sarin M.M., "Correlated enrichment of uranium and organic carbon in an eastern Arabian Sea Core during the Last Glacial Maximum (LGM)".
5. Venkatesan T.R., Rathore S.S., and Srivastava R.K., "Ar-Ar Studies of Malani Complex in Rajasthan, India : Evidences for different magmatic espisodes".

f. DST Workshop on Coastal Geomorphology, Department of Geography, Andhra University, Waltair, November 14-16, 1990.

1. Somyajulu B.L.K., "Dating Sediments and events in coastal areas" (Invited talk).

g. American Geophysical Union Fall Meeting, December 1990.

1. Copenhaver S.A., Krishnaswami S., and Turekian K.K., "Retardation of ^{238}U and ^{232}Th Chain

Radionuclides in Long Island, Connecticut and Nevada test site aquifers".

h. International seminar on Rising trends in palaeoanthropology : Environmental change and human response during the last 2 m.y., Dept. of Archaeology, Deccan College, Pune, Dec. 19-23, 1990.

1. Singhvi A.K., Chawla S., Rajguru S.N., Misra V.N., and Dhir R.P., "Significance of TL dating of fossil dunes in the study of Stone Age chronology and environment in the Thar desert".
2. Venkatesan T.R., Somyajulu B.L.K., Rajguru S.N., Mishra, Sheila, Korisettar R., and Ganjoo R.K., "Further investigations on Bori Volcanic ash for age and composition".

i. Fifth National symposium on Mass Spectrometry, Physical Research Laboratory, Ahmedabad, Jan. 7-9, 1991.

1. Bartarya S.K., Bhattacharya S.K., Ramesh R., and Somyajulu B.L.K., " $\delta^{18}O$ and δD systematics in the surficial waters of the Gaula catchment area, Kumaun Himalaya".
2. Bhandari N., "Study of long lived radiosotopes in extraterrestrial samples using accelerator mass spectrometry" (Invited talk).
3. Bhandari N., Mathew K.J., Rao M.N., Herpers U., Vogts S., Wolfli W., Hofmann H.J., Michel R., and Bodeman R., "Production rates of cosmogenic nuclides in meteorites determind by accelerator and conventional mass spectrometry".
4. Bhattacharya S.K., and Jani R.A., "Monsoon effect on atmospheric CO_2 ".
5. Chakraborty S., Ramesh R., and Lough J.M., "Covariance of density and stable isotope ratios of carbon and oxygen in a hermatypic coral".
6. Goswami J.N., "Ion microprobe : Applications to solar system studies" (Invited talk).
7. Goswami J.N., Shah V.G., and Srinivasan R., "Isotopic studies by a secondary ion mass spectrometer : Parametric, investigations".
8. Goswami J.N., Srinivasan R., and Ulyanov A.A., "Ion probe studies of magnesium isotopic compositions in early solar system objects".
9. Murty S.V.S., "Nitrogen and light noble gases from Gujarat".
10. Murty S.V.S., and Pande K., "Nitrogen in Kutch Xenoliths".
11. Murty S.V.S., and Sinha B., "Helium and neon isotopes in Bakreshwar hot spring".
12. Ramesh R., and Sarin N.M., "Stable isotope systematics of north Indian rivers".
13. Rathore S.S., Trivedi J.R., and Venkatesan T.R., "Rb-Sr age of Jalore and Siwana granites : Revelation of thermal event by ^{40}Ar-^{39}Ar study".
14. Rathore S.S., and Venkatesan T.R., "^{40}Ar-^{39}Ar age of essexite from Mundwara alkaline complex, Rajasthan".
15. Sarkar A., Ramesh R., and Bhattacharya S.K., "Carbon isotopes in planktonic foraminifera and palaeomonsoon change".
16. Trivedi J.R., M.M. Sarin, Krishnaswami S., and Sharma K.K., "Strontium isotopes in the Ganga-Brahmaputra river system : weathering in the Himalayas and fluxes to the Bay of Bengal".

j. International Symposium on the Oceanography of the Indian Ocean, National Institute of Oceanography, Goa, January 14-16, 1991.

1. Chakraborty S., and Ramesh R., "Stable isotope studies of corals from Lakshadweep islands".
2. Sarin M.M., Krishnaswami S., and Rengarajan R., "Water column processes in the Arabian Sea : Inferences from vertical distributions of ^{210}Po, ^{210}Pb and ^{226}Ra".
3. Sarin M.M., Krishnaswami S., Somyajulu B.L.K., and Bhushan R., "Comparative geochemistries of Th, Po and Pb in the upper 300m of the Arabian Sea".
4. Sarkar A., and Bhattacharya S.K., "Glacial to interglacial isotopic changes in the benthic and planktonic foraminifera from the western Arabian Sea".
5. Yadav D.N., Sarin M.M., and Somyajulu B.L.K., "Western continental margins of India : Are they sink or source for trace elements to the Arabian Sea".

k. Fourteenth Meeting of the Astronomical Society of India, PRL, Ahmedabad, January 29 - February 1, 1991.

1. Mitra B., Durgaprasad N., Singh R.K., Biswas S., Dutta A., and Goswami J.N., "Low energy cosmic rays and molecular clouds".
2. Goswami J.N., "Cosmic Ray Studies", (Review talk).

l. National Seminar on Isotopes in Earth Sciences, Calcutta, February 5, 1991.

1. Singhvi A.K., "Luminescene Geochronology : Present status" (Invited talk).

m. National Seminar on Thermoluminescene and Applications, M.S. University, Baroda, February 7-9, 1991.

1. Singhvi A.K., Someswar Rao, M. and Chawla S., "Thermoluminescene dating : Implications in Physics" (Invited talk).

2. Chawla S., Kishan Kumar V.S., and Singhvi A.K., "Preheat procedures in TL dating".

n. Asian IGBP Workshop, NPL, Delhi, February 11-15, 1991.

1. Ramesh R., and Somayajulu B.L.K., "Study of palaeoclimates using trees, corals and marine sediments from the Arabian Sea and Bay of Bengal regions".

2. Singhvi A.K., Dhir R.P., Rajguru S.N., Mishra V.N., and Chawla S., "Chronology of climatic changes in the Thar desert, Rajasthan".

o. Annual Meeting cum Seminar of the Geological Society of India, IIT, Powai, March 11-12, 1991.

1. Somayajulu B.L.K., "Recent studies on the Quaternary Carbonate deposits of Saurashtra and Kutch".

p. Twenty second Lunar and Planetary Science Conference, LPI, Houston, Texas, USA, March 18-22, 1991.

1. Goswami J.N., Srinivasan G., and Ulyanov A.A., "Ion probe studies of Efremovka CAI'sI : Magnesium isotopic composition".

2. Murali A.V., Blanchard D.P., Somayajulu B.L.K., and Parekh P.P., "K/T Boundary signatures in Manganese Nodule Zetes 3D".

3. Murty S.V.S., and Goswami J.N., "Nitrogen noble gases and nuclear tracks in lunar meteorites MAC 88104/88105".

4. Rao M.N., Garrison D.H., and Bogard D.D., "Solar flare noble gases preserved in lunar Rock 61016."

5. Rao M.N., Garrison D.H., and Bogard D.D., "Xenon isotope systematics in Kapoeta and Ancient Solar activity.".

THEORETICAL PHYSICS

Astrophysics

a. In Miniworkshop on Relativistic Astrophysics, PRL, Ahmedabad January 21-25, 1991.

1. S.C. Tripathy, "Time dependence and stability of accretion discs".

Meteorology and Climate Studies

a. Indo US Seminar on Parameterization of subgrid scale processes in dynamical models of medium range prediction and global climate, Pune, August 6-10, 1990.

1. Kasture S.V., Satyan V., and Keshavmurty R.N., "Sensitivity of equatorial waves to moisture availability in cumulus parameterization".

b. WMO Regional Workshop on Asian and African Monsoons, 4-8 February, 1991, Pune.

1. Keshavamurty R.N., "Mid tropospheric cyclones".

Plasma Physics

a. Miniworkshop on Relativistic Astrophysics, PRL, Ahmedabad January, 21-25, 1991.

1. A.C. Das, presented two invited talks on Magnetospheric plasma processes.

b. 23rd General Assembly of International Union of Radio Science, Prague, August 28- September 5, 1990.

1. S.C. Tripathy, "Plasma discs around rotating compact objects".

Atomic and Molecular Physics

a. VIII National Workshop on Atomic and Molecular Physics, University of Hyderabad, Hyderabad, December 6-12, 1990.

1. H.S. Chakraborty, "Arbitrary nlm $\rightarrow$ n'l'm' atoms and ions by electron impact".

Classical and Quantum Mechanics

a. Miniworkshop on Quantum Chaos and Adriatico Research Conferences, International Centre for Theoretical Physics, Trieste, Italy, 4 June-6 July, 1990.

1. V. B. Sheorey, "Some studies on a classically chaotic quantum system" (Invited talk).

2. V. B. Sheorey, "Numerical methods for Eigenvalues and Eigenfunctions of chaotic quantum systems" (Invited talk).

b. VIII National Workshop on Atomic and Molecular Physics, University of Hyderabad, Hyderabad, 6-12 December 1990.

1. V.B. Sheorey, "Eigenvalues and Eigenfunctions of chaotic quantum systems" (Invited talk).

c. National Symposium on Plasma Science and Technology and National Seminar on Plasma Science, December 4-8, 1990, Jadavpur University, Calcutta.

1. R. K. Varma, "Nonlinear Dynamics-Chaos and Structures" (Keynote address).

d. International Workshop on the Application of Statistical Methods in Theoretical Physics and Fluid Mechanics, January 8-15, 1991, ISI, Calcutta.

1. R. K. Varma, "Wave mechanics of Classical Mechanical Ensemble : A New Paradigm".

Nuclear Physics

a. DAE symposium on Nuclear Physics, Madras, December 1-4, 1990.

1. Devi Y.D., and Kota V.K.B., "Samarium isotopes in gIBM : Weak Coupling calculations", contributed paper.
2. Sarangi S., Parikh J.C., "IBM and the Dynamic (HF) Fermion Basis for Zn Isotopes".
3. S.B. Khadkikar, Invited talk on "Neutrinoless double beta decay using harmonic confinement model for quarks".

b. International Conference on "High spin physics and Gamma soft nuclei", Pittsburgh, USA, September 17-21, 1990.

1. Devi Y.D. and Kota V.K.B., "Some studies in the interacting boson model including g bosons : two nucleon transfer and g boson bands".

c. VII International Symposium on "Capture Gamma Ray Spectroscopy and related topics", Asilomar, California, USA, October 14-19, 1990.

1. Kota V.K.B., "Level densities, expectation values and strengths with interactions : convolution forms and applications", Invited paper.

Particles and Fields

a. Workshop in High Energy Physics Phenomenology II, Calcutta, January 2-15, 1991.

1. U. Sarkar, "Models of 17 keV neutrino".

COMPUTER CENTRE

a. Workshop on Trends of computing in ISRO, Bangalore, July 24-26, 1990.

1. D.R. Kulkarni, "Proposal for new computing environment at PRL".

THESES SUBMITTED DURING 1990-91

Ahmed S. M.

Neutral and ionic fluorescence of molecular gases by photon impact (July 1990).

Banerjee D. P. K.

Kinematic studies of extended objects in astrophysics using high-resolution spectroscopy (August 1990).

Krishnakumar V.

Instability studies of monsoon and equatorial flows (February 1991).

Sekar R.

Plasma instabilities and the dynamics of the equatorial F-region (January 1990).

Sen A. K.

Photopolarimetric studies of comet P/Halley and some astronomical objects (July 1990).

PRL Technical Notes

TN-90-70

An assembly language program for implementation of fast fourier transform on 8086/8088 microprocessor by R. N. Misra and Akhilesh kumar

TN-91-71

Four channel audio cassette based data recorder by R. N. Misra

TN-90-69/1

Windowing capability with HDS terminal by Surangi Shah & D. R. Kulkarni

TN-90-69/2

A programming system for Stepwise Discriminant Analysis by C.S.R. Murty and J. J. Trivedi

Symposia/Workshop Organised at PRL

1. Workshop on Popularising Astronomy, October 7, 1990

2. Modern Trends in Astronomy, November 1, 1990

3. Workshops on Relativistic Astrophysics, January 18-25, 1991

4. Workshop on Library and Information Services in Astronomy and Astrophysics, January 29-31, 1991

5. XIV Astronomical Society of India, January 29-31, 1991

6. Fifth National Symposium on Mass Spectrometry, January 7-9, 1991

Conferences/Symposia attended during 1990-91

ASTRONOMY AND ASTROPHYSICS

Infrared Astronomy

Dr. M. R. Deshpande
Mr. N. S. Jog
Mr. A. B. Shah

Bangalore

Workshop on Trends of computing in ISRO, July, 1990.

Dr. J. N. Desai
Dr. T. Chandrasekhar
Kodaikanal

First Kodai workshop on Optical Interferometry, August 10 - 17, 1990.

Dr. A. K. Sen

Kyoto, Japan

IAU Colloquium 126 on Origin and Evolution of Interplanetary dust, August, 1990.

Mr. N. S. Jog
Mr. H. I. Pandya

Trivandrum

IEEE Seminar on Imaging 90, December, 1990.

Dr. U. C. Joshi

Turku, Finland

Conference on Variability in Blazars 4, January, 1991.

Mr. Sam Ragland

Pune

IUCAA minischool on Infrared Physics, January, 8 -19, 1991.
Winter school, January 8 - 12, 1991.

Dr. J. N. Desai
Dr. B. S. Shylaja

Ahmedabad

IUCCA Miniworkshop on Relativistic Astrophysics, January 20 - 25, 1991.

All members of Astronomy and Astrophysics Division

PRL, Ahmedabad

XIV ASI meeting, and a one day symposium on The Sun and Helio Seismology January 29 - February 1, 1991.

Solar And Plasma Astrophysics

Hari Om Vats

Ahmedabad

Workshop on Popularising Astronomy, PRL, October, 1990.

Dr. S. K. Alurkar
Dr. S. S. Dagaonkar

Ahmedabad

Fifth National Symposium on Mass Spectrometry, PRL January 7-9, 1991.

Dr. Hari Om Vats
Dr. A. K. Sharma

Pune

GMRT Winter School at National Center for Radio Astrophysics, January 8 - 18, 1991.

Dr. S. K. Alurkar
Dr. S. S. Degaonkar
Dr. Hari Om Vats
Dr. A. K. Sharma
Mr. P. Janardhan
Mr. A. D. Bobra
Mr. K. S. Lali
Mr. N. S. Nirman
Mr. R. C. Shah
Mr. P. Venat

Ahmedabad

XIV Astronomical Society of India Meeting, PRL, January 29 - February 1991.

Solar Physics At Udaipur Solar Observatory

Dr. A. Ambastha

Udaipur, India

Computer Society of India (CSI) sponsored "National Seminar on Operating Systems and Standards", April 29 - 30, 1990.

Dr. A. Ambasth

Delhi, India.

I.A.U. Colloquium No. 132 on "Instability, Chaos and Predictability in Celestial Mechanics and Stellar Dynamics", October 10 - 13, 1990.

Dr. A. Ambastha
Dr. A. Bhatnagar
Dr. R. M. Jain
Ms. N. Srivastava

Ahmedabad, India.

XIV Astronomical Society of India Meeting January 29 - February 1, 1990.

Dr. A. Bhatnagar

Calcutta, India.

National Seminar on the Sun and our Environment February 7 - 8, 1991.

Pune, India.

Amateur Astronomers Meet, January 12 - 13, 1991.

Ahmedabad, India.

Workshop : Popularization of Astronomy, October 7, 1990.

Ms. N. Srivastava

Malaysia

XVII International School For Young Astronomers, May 28 - June 15, 1990.

Mr. B. K. Singh

Hyderabad

X Annual Conference of National Institute of Personnel Management on "Integrative Approaches to Human Resources Management", October 25 - 27, 1990.

New Delhi

Institute of Secretariat Training and Management, Dept. of Personnel and Training, Govt. of India sponsored programme on "Establishment Rules" February 4-8, 1991.

Mr. R. Koshy

New Delhi

Institute of Secretarial Training and Management, Dept. of Personnel and Training, Govt. of India sponsored programme on "Induction course for stenographers : New Recruitment", December 14 - 20, 1990.

PLANETARY ATMOSPHERE AND AERONOMY

Dr. S. P. Gupta
Dr. R. Sekar
Dr. R. Sridharan

The Hague, The Netherlands

XXVII COSPAR Plenary and VII Quadrenial STP Symposium, 25 June - 6 July, 1990.

Dr. G. Beig
Dr. S. Lal

Chamrousse, France

The International Symposium of the Commission on Atmospheric Chemistry and Global Pollution, September 5 - 11, 1990.

Dr. S. P. Gupta
Dr. A. Jayaraman

Hyderabad

Symposium On "30 Years of Scientific Ballooning in India", October 22 - 24, 1990.

Dr. S. M. Ahmed
Dr. M. K. Jayaraj
Mr. L. A. Prajapati
Dr. Vijay Kumar

Hyderabad

Eighth National Workshop on Atomic and Molecular Physics, December 6-12, 1990.

Dr. G. Beig
Dr. D. K. Chakrabarty
Dr. H. Chandra
Mr. S. Gurubaran
Mr. M. Lal
Dr. R. Sekar

New Delhi

International Symposium on Optical and Radio Remote Sensing of the Atomospheric Environment, October 24 26, 1990.

Dr. R. Sekar
Dr. R. Sridharan

Pune

First Group Monitoring Workshop on Atmospheric Science, December 17 - 21, 1990.

Mr. Y. B. Acharya
Dr. S. M. Ahmed
Dr. H. Chandra
Mr. S. R. Das
Dr. S. Lal
Mr. R. N. Misra
Dr. H. S. S. Sinha
Dr. R. Sridharan
Dr. Vijay Kumar

Ahmedabad

Fifth National Symposium on Mass Spectroscopy, January, 7 - 9, 1991.

Dr. S. M. Ahmed
Dr. S. A. Haider
Dr. A. Jayaraman
Dr. S. Lal
Dr. Vijay Kumar

Ahmedabad

Fourteenth Meeting of Astronomical Society of India, January 29 - February 1, 1991.

Dr. G. Beig
Dr. H. Chandra
Mr. S. Gurubaran
Mr. S. V. Ramani
Dr. R. Sridharan
Dr. B. H. Subbaraya

Tirupati

First Winter School on MST Radar Applications, January 28 - February 4, 1991.

Dr. B. H. Subbaraya

New Delhi

Asian Workshop on The International Geosphere Biosphere Programme, February 11 - 15, 1991.

Mr. R. N. Misra

Indore

National Conference on Real Time Systems, February 24 - 26, 1991.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

Dr. N. Bhandari

Nottingham, UK.

International Sedimentology Congress and International Geological, Correlation Program 293 held in August 1990.

Dr. N. Bhandari
Dr. S. K. Bhattacharya
Mr. S. Chakraborty
Dr. J. N. Goswami
Dr. S. Krishnaswami
Mr. N. R. Manchanda
Mr. K. J. Mathew
Dr. S. V. S. Murty
Dr. V. N. Nijampurkar
Mr. J. T. Padia
Dr. K. Pande
Dr. R. K. Pant
Dr. R. Ramesh
Dr. M. M. Sarin
Dr. A. Sarkar
Mr. V. G. Shah
Dr. P. N. Shukla
Dr. A. K. Singhvi
Dr. B. L. K. Somayajulu
Mr. G. Srinivasan
Mr. J. R. Trivedi
Dr. T. R. Venkatesan

Ahmedabad

Fifth National Symposium on Mass Spectrometry held in PRL, January 7 - 9, 1991.

Dr. S. K. Bhattacharya
Mr. S. Chakraborty
Dr. S. Krishnaswami
Dr. R. Ramesh
Dr. M. M. Sarin
Dr. A. Sarkar
Dr. B. L. K. Somayajulu

Goa

International Symposium on the Oceanography of the Indian ocean held at the National Institute of Oceanography during January 14 - 16, 1991.

Dr. S. K. Bhattacharya
Dr. M. M. Sarin
Dr. T. R. Venkatesan

Canberra, Australia

Seventh International Conference on Geochronology, Cosmochronology and Isotope Geology held during September 24 - 29, 1990.

Dr. S. Chawla

Clermont Ferrand, France.

Sixth Specilaist Seminar on TL/ESR Dating, July 6 - 10, 1990.

Mr. A. Dutta
Dr. J. N. Goswami

Ahmedabad

Fourteenth Meeting of the Astronomical Society of India, PRL, held during January 29 - February 1, 1991.

Dr. V. N. Nijampurkar
Dr. B. L. K. Somayajulu

Bombay

IAEA/RCA, Training Course on Isotope Techniques in Hydrology, BARC, September 17 - October 5, 1990.

Dr. R. Ramesh
Dr. A. K. Singhvi
Dr. B. L. K. Somayajulu

New Delhi

Asian IGBP Workshop held at the National Physical Laboratory during February 11-15, 1991.

Dr. V. S. Kishankumar
Dr. A. K. Singhvi
Mr. M. Someswar Rao

Vadodara

National Seminar on Thermoluminescence dating held at the M. S. University, Vadodara, February 7 - 9, 1991.

Dr. A. K. Singhvi

Heidelberg, Germany.

International Archaeometry Symposium, April 2 - 6, 1990.

Calcutta

National Seminar on Isotopes in Earth Sciences, February 5, 1991.

Dr. A. K. Singhvi
Dr. T. R. Venkatesan

Pune

International Seminar on Rising trends in Paleoanthropology : Environmental change and human response during the last 2 m.y., held at the Deccan College, during December 19 - 23, 1990.

Dr. B. L. K. Somayajulu

Bombay

Annual Meeting of the Geological Society of India, held at the Indian Institue of Technology, Powai, during March 1 - 12, 1991.

Paris, France

Second scientific Advisory Council Meeting of the International Geosphere Biosphere Program held during September 3 - 7, 1990.

Waltair

DST Workshop on Coastal Geomorphology held at the Dept. of Geography, Andhra University, during November 14 - 16, 1990.

Continental Palaeoclimate Studies

Dr. P. Sharma

Beijing, China.

Workshop on Global Environmental Changes since the Last Glacial Maximum, held at Institute of Geology, Academia Sinica, November 11 - 20, 1990.

Bangalore

Intensive course on Free and Moving Boundary Value Problems held at CSIR Centre for Mathematical Modelling and Computer Simulation (CMMACS) December 3 - 7, 1990.

Dr. D. P. Agrawal

New Delhi

Geological and Archeological time - Some concepts and their applications, International Seminar on Time, IGCNA, November 1990.

Poona

Human Response to Climatic Change in Kashmir, Deccan College, December 1990.

Ahmedabad

^{14}C Dating Materials and Contamination, ^{14}C Workshop, Physical Research Laboratory, February 1991.

Poona

Review of Palaeoclimatic data from Kashmir, DST Workshop December 1990.

THEORETICAL PHYSICS

Dr. B. Buti

Baltimore, MD, USA

American Geophysical Union, in May 1990.

New Hampshire, USA.

Gorden Research Conference on Space Physics in July 1990.

Mr. H. S. Chakraborty

Hyderabad

VII National Workshop on Atomic and Molecular Physics, School of Physics, University of Hyderabad, December 6 - 12, 1990.

Dr. A. C. Das

Ahmedabad

Miniworkshop on Relativistic Astrophysics, PRL, January 21 - 25, 1991.

Ahmedabad

XIV ASI meeting, PRL, January 29 - February 1, 1991.

Ms. Y. D. Devi

DAE symposium on Nuclear Physics, Madras, India, December 1 - 4, 1990.

Dr. Sai Iyer

Bombay

Workshop on Galaxy Formation, TIFR, September 3 - 7, 1990.

Hyderabad

IUCAA Workshop on N body simulations in galactic dynamics, Osmania University, January 16 - 21, 1991.

Dr. A. S. Joshipura

Calcutta

Workshop on High Energy Physics Phenomenology, S. N. Bose Centre for Basic Sciences, January 2 - 15, 1991.

Ahmedabad

XIV ASI meeting, Physical Research Laboratory, January 1991.

Mr. S. V. Kasture
Mr. V. Krishnakumar
Mr. R. Krishnan
Dr. V. Satyan

Pune

Indo US Seminar on Parameterization of subgrid scale processes in dynamical models of medium range prediction and global climate, 6 - 10 August, 1990.

Dr. R. N. Keshavamurty

New Delhi.

Asian Workshop on IGBP, A Study of Global Change, February, 1991.

Pune

WMO Regional Workshop on Asian and African Monsoons, February, 1991.

Dr. V. K. B. Kota

Pittusburgh, USA.

International conference on High spin Physics and Gamma Soft nuclei, 17 - 21 September, 1990.

Asilomar, California, USA.

VII International symposium on Capture Gamma Ray Spectroscopy and related topics, 14 - 19 October, 1990.

Mr. V. Krishnakumar

Pune

WMO Regional Workshop on Asian and African Monsoons, Pune, 4 - 8 February, 1991.

Mr. R. Krishnan

Pune

WMO Regional Workshop on Asian and African Monsoons, 4 - 8 February, 1991.

Dr. J. C. Parikh

Menton, France.

Quark Matter '90, May 7 - 11, 1990.

Cambridge (Mass), U S A

International Conference on Particles and Nuclei, June 25 - 29, 1990.

Dr. A. R. Prasanna

Kavalur

Second VBT Workshop at VBO, 19 - 20 April, 1990.

PRL, Ahmedabad.

Mini Workshop on Relativistic Astrophysics, Jan. 20 - 26, 1991.

Dr. S. D. Rindani

Trieste, Italy.

Summer School on High Energy Physics and Cosmology International Centre for Theoretical Physics, June - July, 1990.

Calcutta

Workshop on High Energy Physics Phenomenology (WHEPP II), S. N. Bose National Centre for Basic Science, January 2 - 15, 1991.

Dr. U. Sarkar

New York, USA

From Symmetries to Strings: Forty years of Rochester Conference, Rochester, May 4 - 5, 1990.

Calcutta,

Mini Workshop in P-P collider physics, India, November 26 - 29, 1990.

Calcutta

Workshop in High Energy Physics Phenomenology II, India, Jan. 2 - 15, 1991.

Dr. V. Satyan

New Delhi

Asian Workshop on IGBP; A study of Global change, New Delhi, 11 - 15 February, 1991.

Dr. V. B. Sheorey

Trieste, Italy.

Miniworkshop on Quantum Chaos and Adriation Research Conferences, International Centre for Theoretical Physics, 4 June - 6 July, 1990.

Hyderabad

VIII National Workshop on Atomic and Molecular Physics, University of Hyderabad, December 6 - 12, 1990.

Dr. B. R. Sitaram

Cochin

VI SERC School in High Energy Physics, as Guest Faculty, December, 1990.

Mr. S. C. Tripathy

Prague

23rd General Assembly of International Union of Radio Science, August 28 - September 5, 1990.

Ahmedabad

Mini Workshop on Relativistic Astrophysics, January 21 - 25, 1991.

Ahmedabad

XIV ASI meeting, January 29 - February 1, 1991.

Dr. R.K. Varma
Iowa, USA

4th National Workshop on the Physics of Dusty Plasmas, September 10-12, 1990.

Jadavpur

National Symposium on Plasma Science and Technology and National Seminar on Plasma Science, December 4-8, 1990.

Calcutta

International Workshop on the Application of Statistical Methods in Theoretical Physics and Fluid Mechanics, January 8-15, 1991.

ELECTRONICS LABORATORY

H. S. Mazumdar
S. N. Pradhan

Bangalore

"Trends of computting in ISRO", July 24 - 26, 1990.

COMPUTER CENTRE

Mr. P. S. Shah

Bangalore

24th CSI Annual Convention, 20 - 23 September, 1989.

C. S. R. Murthy

Hyderabad

First Indian Computing Congress, November 22 - 24, 1990.

Dr. D. R. Kulkarni

Delhi

Course on System Software ' Admn. of APOLLO Dn 3500 Workstation,July 1989.

Bangalore

Workshop on "Trends of computing in ISRO Head Quarters,"July 24 - 26, 1990.

Mr. G. G. Dholakia

Delhi

Course on System Software & Admn. of APOLLO DN 3500 Workstation July, 1989.

Mr. M. S. Patel

Ahmedabad

Seminar on "UNIX Operating System" jointly organised by La Salle University, USA and CCIT, Ahmedabad, Sept. '89.

Calcutta

25th CSI Annual Convention October 31 - November 3, 1990.

Mrs. J. J. Trivedi

Ahmedabad

Seminar on "UNIX Operating System" jointly organised by La Salle University, USA and CCIT, Ahmedabad, Sept. '89.

Mrs. B. H. Shah

Ahmedabad

National Seminar on Computer and remote sensing applications in Agriculture, Rural Management and Water Management by CSI Feb. 21 - 22, 1991.

Mr. P. R. Shah

Calcutta

25th CSI Annual Convention October 31 - November 3, 1990.

Visits to Universities/Research Organization and Talks given there during 1990-91

ASTRONOMY AND ASTROPHYSICS

Infrared Astronomy

Dr. J. N. Desai

Ahmedabad

Gujarat University, gave two lectures on Astronomy at, "Summer School for Physics Teachers", arranged by Administrative staff college. Community Science Center, gave a Popular lecture on "Light and Universe" February, 1991.

Bhavnagar

Bhavnagar University, gave two public lectures on "Stellar evolution and Nuclearsynthesis" and "Origin of Universe", March, 1991.

Dr. M. R. Deshpande

Bangalore

Indian Institute of Astrophysics, gave a talk on "Rapid Variability in BL Lac objects".

Mr. A. K. Sen

Japan

Nagoya University, gave a colloquium on "Star formation in dark clouds", August, 1990.

Mitaka, Tokyo, Japan.

National Astronomical Observatory, presented a seminar on "Imaging polarimetry of Comet P/Halley".

Solar and Plasma Astrophysics

Dr. Hari Om Vats

Kolhapur

Visited Physics Department, Shivaji University, and gave two lectures (May 22 - 25, 1990) on : "Scintillation Phenomenon and its Application" and "Our Place in the Universe".

Solar Physics At Udaipur Solar Observatory

Dr. A. Bhatnagar

Calcutta, India

Visited Variable Energy Cyclotron Centre and gave colloquium on "The Active Sun", September 11, 1990.

Dr. R. M. Jain

Nainital

Visited Uttar Pradesh State Observatory, and gave talks on "Solar Flares and Associated Emissions in the Electromagnetic Spectrum" on 17 February 1990, and "Variation of Solar Granulation over a Solar Cycle" on 19 February 1990.

PLANETARY ATMOSPHERE AND AERONOMY

Dr. G. Beig

Buisson, France

Visited Service d'Aeronomie, CNRS and gave a talk on "Ground based measurements of NO_3 over Ahmedabad (PRL), India" (September 12 - 15, 1990).

Dr. D. K. Chakrabarty

Ahmedabad

Visited Physics Department, Gujarat University and gave a talk on "Global change and middle atmosphere" (November 17, 1990).

Dr. S. P. Gupta

Lindau, Germany

Visited Max Planck Institute for Aeronomy and gave a talk on "Sporadic E layers during meteor shower days over the magnetic equator" (May 22, 1990).

Pune

Visited IUCAA and gave a talk on "Balloon charging effect" (February 15, 1991).

Pune

Visited the Giant Meter Wave Radio Telescope Project (GMRT), TIFR and gave a talk on "The electrical structure in the near earth enviroment by balloon and rocket experiment" (February 16, 1991).

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

Dr. N. Bhandari

Torino, Italy.

Visited the Institute di Cosmogeophysics and gave a talk on "Impacts versus volcanism" on 12th September 1990.

Bangalore

Attended the meeting of the Indian Academy of Sciences and gave a talk on "Collisions with the Earth over geological times". Visited the Indian Institute of Astrophysics and gave a lecture on "Cometary impacts and stress on life on earth" in November 1990.

Dr. S. K. Bhattacharya

Melbourne, Australia.

Visited the CSIRO Division of Atomospheric Research during Sept. 30 to October 1, 1990 and gave two talks on "Isotopic studies on atmospheric CO_2".

Dr. J. N. Goswami

Ahmedabad

Attended Gujarat Science Academy Meeting and gave a talk.

Dr. R. Ramesh

Ahmedabad

Gave a talk on "Isotope Dendrochronology" in the Botany Dept. of the Gujarat University, February 1991.

Dr. A. K. Singhvi

Tubingon, W. Germany.

Visited the Geography Department during 28 - 31 March 1991 and gave a talk on "Luminescence Geochronology : Methodology".

Dr. B. L. K. Somayajulu

Torino, Italy.

Visited the Institute di Cosmogeofisica and gave talk on "Applications of Cosmogenic beryllium-10 in Earth Sciences" on September 11, 1991.

Goa

Gave the Silver Jubilee lecture on "Mixing in the oceans using cosmogenic silicon-32" on Nov. 26, 1990.

Continental Palaeoclimate Studies

Dr. D. P. Agrawal

Bangalore

Visited Indian Institute of Science and gave a talk on "Indian Palaeoclimatic data and modelling requirements", January 1991.

THEORETICAL PHYSICS

Dr. P. Bhaskaran

Bangalore

Indian Institute of Astrophysics, March 27 - April 27, 1991, and gave a talk on "Dynamics of Plasma Discs Around Compact Objects".

Dr. B. Buti

California

Jet Propulsion Laboratory/NASA, California, during February-July, 1990 and gave a seminar on "Chaotic Alfven Waves" in April 1990.

Washington DC

Naval Research Laboratory, Washington DC and gave a seminar on "Coherent and Chaotic Alfven Waves" in May 1990.

Cornell University and gave a seminar on "Nonlinear and Chaotic Alfven Waves in Inhomogeneous Plasma" in August 1990.

Alaska

Institute of Geophysics and Planetary Physics, University of Alaska and gave a seminar on 'Some Nonlinear and Chaotic Processes in Space Plasma' in August 1990.

Delhi

Indian Institute of Technology, Delhi and gave a seminar on "Chaotic Alfven Waves in Inhomogeneous Streaming Plasmas", in December 1990.

Bombay

Indian Institute of Geomagnetiam, Bombay, and gave a seminar on "Coherent Alfven Waves in Inhomogeneous Plasmas" in March 1991.

Dr. Sai Iyer

IUCAA, December 31, 1990 January 12, 1991 and gave an invited talk on "Centrifugal force reversal in GR".

Dr. Sunil Jaggi

New Delhi

Centre for Atmospheric Sciences, IIT Delhi and gave a talk on "Wind induced circulation in Arabian Sea and Bay of Bengal", October 1990.

Dr. R.N. Keshavamurty

Cochin

Cochin University and gave ten lectures on "General Circulation".

Dr. S. B. Khadkikar

Bombay

Tata Institute for Fundamental Research during January 2 - 4, 1991, and delivered a seminar in Theoretical Physics on "N-N scattering from confined QCD".

Dr. V. K. B. Kota

Brighton, England

University of Sussex at Brighton and gave a seminar on "Two nucleon transfer in sdg interacting boson model", December 10 - 12, 1990.

Dr. J. C. Parikh

Washington

Institute for Nuclear Theory, University of Washington, Seattle, June 11 - 12, 1990, and given a seminar on

"Collective Behaviour in Classical Quark Matter".

Minneapolies

Insitute for Theoretical Physics, University of Minneapolies, June 13 - 15, 1990 and given a seminar on "Collective Behaviour in Classical Quark Matter".

Texas

Department of Physics, Texas, A & M University, College Stations, June 18 - 22, 1990 and given a seminar on "Collective Behaviour in Classical Quark Matter".

Bhubaneswar

Institute of Physics, January 1 - 8, 1991 and gave two seminars on (1) Collective Behaviour in Classical Quark Matter. (2) Time Series Analysis.

Calcutta

Variable Energy Cyclotron Centre (Bhabha Atomic Research Centre), Jan. 9 - 11, 1991 and gave a seminar on "Collective Behaviour in Classical Quark Matter".

Dr. A. R. Prasanna

Trieste, Italy.

International Centre for Theoretical Physics, May 8 -Sep. 8, 1990. Gave a seminar on "Motion of spinning charged particle in curved space time", SISSA June 21.

Vienna, Austria

Institute for Theoretische Physik, June 24 - 27 1990. Gave seminar on "Centrifugal force reversal in curved space time".

Pavia Italy.

Institute di fisica Teorica et Nucleare University of Pavia, July 2 - 8, 1990. Gave a seminar on "Relativistic accretion disks".

Dr. S. D. Rindani

Trieste, Italy

International Centre for Theoretical Physics, June 1 - August 5, 1990 and gave a talk on "light top quark revisited".

Geneva, Switzerland

CERN, and gave a talk on "Natural suppression of flavour violation in two Higgs doublet models", July 1990.

Dideol, U. K.

Rutherford Appleton Laboratory, and gave a talk on "Light top quark and light charged Higgs revisited", August 1990.

Dr. U. Sarkar

Ontario, Canada.

Physics Department, University of Waterloo, Waterloo, gave a colloquium on "Neutrino Physics" on June 14, 1990.

Santiniketan

Physics Department, Visva Bharati University, gave a seminar on "Massive Neutrinos" on July 13, 1990.

Calcutta

ECC, gave a talk on "Neutrino Mass and Solar Neutrino Puzzle" on December 6, 1990.

Dr. V. Satyan

Ahmedabad

Department of Physics, Gujarat University and gave a course on 'General Meterology' to students of Post M. Sc. Diploma Course in Space Sciences during November-December 1990.

Dr. V. B. Sheoray

Trieste, Italy.

International Centre for Theoretical Physics and gave two talks, June 8 - July 9, 1990.

Richmond, Virginia, USA

Department of Physics, Virginia Commonwealth University and gave a seminar on "A Signature for Quantum Chaos", August 16 - 31 1990.

Mr. S. C. Tripathy

Prague

Charles University, Prague, September 1990. Gave a talk on "The role of magnetic field in Plasma discs".

Dr. R.K. Varma

Bochum, Germany

Visited Ruhr University, Bochum, Germany and gave a lecture on "Wave Mechanics of an ensemble of charged particles in inhomogeneous magnetic fields - Theory and Experiment", 17-22 August, 1990.

Maryland, USA

Visited University of Maryland and gave a talk on "Interference like effects in the motion of charged particles in inhomogeneous magnetic fields", 6-7 September, 1990.

Japan

Visited University of Nihon, Japan and gave a talk on "Wavelike interference phenomena in the motion of charged particles in inhomogeneous magnetic fields", 24-26 September, 1990.

COMPUTER CENTRE

Dr. D. R. Kulkarni

Ahmedabad

An invited talk on "parallel processing" to the participants of six week diploma course in computer applications. Teachers training program at Vikram A. Sarabhai community Science Centre, June 1990.

PHYSICAL RESEARCH LABORATORY
Ahmedabad-380 009

Audited Statement of Accounts as on 31 March 1991

C. R. SHAREDALAL & CO.
CHARTERED ACCOUNTANTS

PHYSICAL RESEARCH LABORATORY
AHMEDABAD-380 009.

Trust Regn. No. E/1371/Ahmedabad

AUDITOR'S REPORT

We have audited the Accounts of the above referred Trust for the year ended 31st March, 1991 and beg to report as under :

1. That the accounts are maintained regularly and in accordance with the provisions of the Act, and the Rules.
2. That Receipts and disbursements are properly and correctly shown in the account.
3. That the Cash Balance and Vouchers were in the custody of the cashier on the date of the audit and were in the agreement with the accounts.
4. That books, Deeds, Accounts, Vouchers and other documents and records required by us were produced before us.
5. That an inventory, certified by the Registrar, of the moveables of the Trust has been maintained,
6. That the Head Accounts and IFA and Accounts Officer appeared before us and furnished the necessary information required by us,
7. That no property of Fund of the Trust were applied for any objects or purposes other than the objects or purposes of the Trust,
8. That the amounts outstanding for more than one year are Rs.7,56,481/- (including doubtful Rs. 53,150/-and the amount written off are Rs.30,492/-,
9. That tenders were invited for repairs or construction as the expenditure involved did exceed Rs.5,000/-,
10. That no money of Public Trust has been invested contrary to the provisions of section 35.
11. That no alienations of immovable property have been made contrary to the provisions of section 36.
12. We have further to report that :-
    (i) The immovable and movable properties are acquired out of Central Government grants and hence no provision is made for the depreciation.

For C. R. SHAREDALAL & CO.
CHARTERED ACCOUNTANTS
(C. R. SHAREDALAL)
Partner

Place : AHMEDABAD
Date : 19-11-91

C. R. SHAREDALAL & CO.
Chartered Accountants

PHYSICAL RESEARCH LABORATORY
Ahmedabad-380 009.
Trust Regn. No. E/1371/Ahmedabad.

Balance Sheet as at 31st March, 1991

FUNDS & LIABILITIES	Rupees	Rupees	PROPERTY & ASSETS	Rupees	Rupees
TRUST FUND CORPUS			IMMOVABLE PROPERTIES		
Grant and contribution		15,71,21,588	(AT COST)		2,85,69,444
OTHER EARMARKED FUNDS			INVESTMENTS (AT COST)		13,57,000
Depreciation Fund	—		MOVABLE PROPERTIES		
Reserve Fund			(AT COST)		
Any Other Fund	10,07,785				
		10,07,785	Furnitures, Fixtures, Equipments		
LOANS (SECURED OR UNSECURED)			Dead Stock & Vehicles	11,28,64,765	
From Trustees	—		Stock of Stores (At cost)	10,46,043	
From Others	—	—	Stock of Medicine (at cost)	38,004	
PROJECTS BALANCES		76,77,861	(As per inventory certified by the management)		11,39,48,812
			LOANS (UNSECURED)		
			Staff members		
LIABILITIES			Vehicle loan (Including		
Civil Engineering Division SAC	1,30,321		accrued interest Rs. 1,81,584)	14,57,945	
For Expenses	3,15,463		House building advance (Including		
For Materials & Contracts	26,25,941		accrued interest		
Miscellaneous Liabilities	12,62,476		Rs. 23,31,649)	1,05,18,433	1,19,76,378
Other Deposits	1,20,636		Sundry Debtors		82,613
Recoverable P.F. Contribution	72,46,964		(including Rs. 82,091 outstanding		
		1,17,01,801	for more than one year and		
			Rs. 37,887 considered doubtful)		
INCOME & EXPENDITURE ACCOUNT					
Balance as per last					
Balance Sheet Dr.	15,43,450				
Less: Surplus as per INC & EXP A/C	18,62,201	3,18,751			
TOTAL C/F Rs.		17,78,27,786	TOTAL C/F Rs.		15,59,34,247

FUNDS & LIABILITIES	Rupees	Rupees	PROPERTY & ASSETS	Rupees	Rupees
TOTAL B/F Rs.		17,78,27,786	TOTAL B/F Rs.		15,59,34,247
			ADVANCES		
			To Employees (including Rs. 22,229 more than one year)	3,21,396	
			To Contractors & Suppliers (including Rs. 5,04,489 for more than one year and Rs. 13,737 considered doubtful)	9,71,896	
			To Other Projects Project Balances (Including Rs. 1,37,696 for more than one year)	2,54,573	
			To Others (including Rs. 3,92,335 as deposit with others) (Rs. 9,985 for more than one year & Rs. 1,526 considered doubtful)	4,69,245	
					20,17,110
			INCOME OUTSTANDING		
			KEF Grant Receivable	1,20,000	
			DOS Grant Receivable	25,90,000	
			PRL EMPLOYEES PROVIDENT FUND	72,46,964	99,56,964
			CASH & BANK BALANCES		99,19,465
TOTAL Rs.		17,78,27,786	TOTAL Rs.		17,78,27,786

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

As per our report of even date

Place : Ahmedabad
Dtd. 19th Nov., 1991

C. R. Sharedalal & Co.
Chartered Accountants

S. M. Modi
Head A/Cs & IFA
PRL

G. N. Nagori
Accounts Officer
PRL

Dinesh Patel
Secretary
PRL Council

C. R. SHAREDALAL & CO.
Chartered Accountants

PHYSICAL RESEARCH LABORATORY
Ahmedabad-380 009.
Trust Regn. No. E/1371/Ahmedabad.

Income & Expenditure Account for the year ended on 31st March, 1991

EXPENDITURE	Rupees	Rupees	INCOME	Rupees	Rupees
EXPENDITURE IN RESPECT OF PROPERTIES			RENT (Accrued/Realised) :		
Rates, Taxes & Cesses	71,896		Realised	2,29,063	
Repairs & Maintenance	1,59,462				2,29,063
Salaries	—		INTEREST (Accrued/Realised) :		
Insurance	—		On Security	—	
Depreciation	—		On Loan : Vehicle Loan	91,602	
Other expenses	—	2,31,358	House Building Loan	6,71,111	
			On Retirement Benefits	28,812	
ESTABLISHMENT EXPENSES :			On Security Deposits	—	
Remuneration (in case of a Math to the Head of a Math, including his household expenses if any.	—	—	On Bank Accounts	—	
					7,91,525
LEGAL EXPENSES :		89,072	DONATION (In cash or kind) :		—
AUDIT FEES :			GRANTS :		5,69,80,000
Statutory Audit Fees	30,000		INCOME FROM OTHER SOURCES :		
Internal Audit Fees	30,000		In details as far as possible		
		60,000	Computer other use service etc.	36,732	
Contribution and fees :		—	Miscellaneous Income (sale of scrap, Liquid Nitrogen job work income etc.)	1,47,808	
AMOUNT WRITTEN OFF :			Administrative expenses		
(a) Bad Debts	393		recovery	1,83,848	3,68,388
(b) Loan Scholarship	—		Sale of Capital Assets		1,12,040
(c) Irrecoverable Rent	—		Previous Year Adjustment (net)		3,416
(d) Other items	—				
Irrecoverable Proj Balance W/O.	30,099				
		30,492	Provident Fund Contribution		
MISCELLANEOUS EXPENSES :		—	Received back from PRL Employee's		
DEPRECIATION :		—	Provident Fund Trust (on A/C)		10,00,000
AMOUNT TRANSFERRED TO RESERVE FUND OR SPECIFIC FUND IN BALANCE SHEET :					
To DOS non-recurring capital grant for addition to movable properties (furniture fixtures, dead stock, library books & journals & vehicle & Previous year adjustment)	35,06,603				
To House Building advance grant (Including Interest Rs. 6,75,125)	16,75,125				
To Vehicle advance grant (Including Interest Rs. 91,406)	5,91,406				
		57,73,134			
TOTAL C/F Rs.		61,84,056	TOTAL C/F Rs.		5,94,84,432

EXPENDITURE	Rupees	Rupees	INCOME	Rupees	Rupees
TOTAL B/F Rs.		61,84,056	TOTAL B/F Rs.		5,94,84,432
EXPENDITURE ON OBJECTS OF TRUST :					
(a) Religious	—				
(b) Educational & Research	5,14,38,175				
(c) Medical Relief	—				
(d) Relief of Poverties	—				
(e) Other Charitable object	—				
		5,14,38,175			
Surplus carried over to Balance Sheet		18,62,201			
TOTAL Rs.		5,94,84,432	TOTAL Rs.		5,94,84,432

As per our report of even date

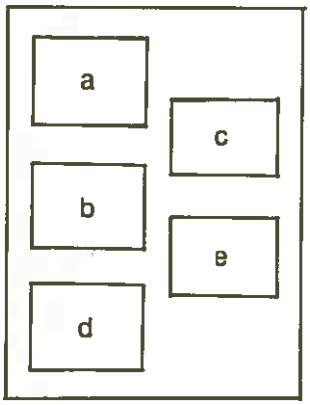
Place : Ahmedabad
Dtd. 19th Nov., 1991

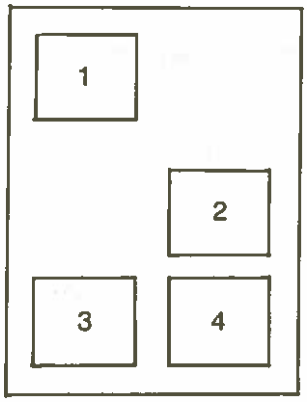
C. R. Sharedalal & Co.
Chartered Accountants

S. M. Modi
Head A/Cs & IFA
PRL

G. N. Nagori
Accounts Officer
PRL

Dinesh Patel
Secretary
PRL Council





INNER FRONT PAGE

a,b,c. Corals from the Arabian Sea and Bay of Bengal which are studied for past sea surface temperatures.

d. Deccan basalts of Mahabaleshwar.

e. Seismically affected lake sediments from Ladakh area.

BACK PAGE

Fig. 1 Interferogram of the planetary nebula NGC 6853 obtained in the oxygen green line (500 7A)

Fig. 2 CCD camera on 15 cm telescope at Gurushikhar observatory.

Fig. 3 The near infrared fast photometer used in lunar occultation studies and observations of mutual events of Jovian satellites.

Fig. 4 The imaging Fabry-Perot spectrometer used in studies of extended astronomical objects like planetary nebulae and H II regions. *(p 5).*