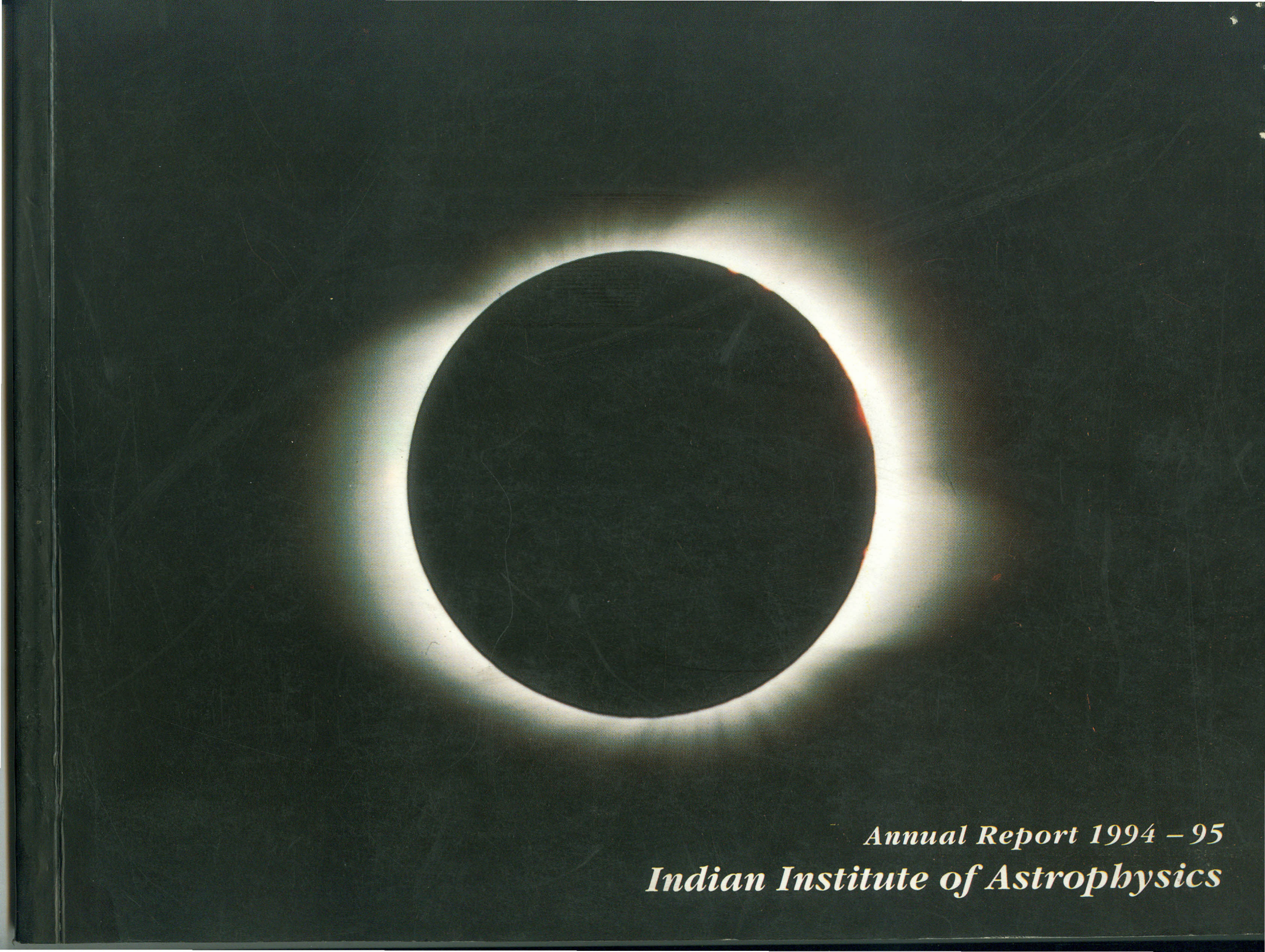
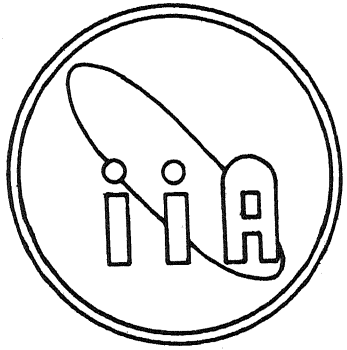


Annual Report 1994 – 95

Indian Institute of Astrophysics

INDIAN INSTITUTE OF ASTROPHYSICS



Annual Report
1994–95

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Front cover : Solar corona photographed during the 1994 eclipse in Chile

Back cover : The Great Nebula in Orion, NGC 1976
(Picture taken at VBO, Kavalur)

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Highlights

The year 1994-95 proved to be a wonderful year for the Indian Institute of Astrophysics with several significant developments :

1. Hanle in south-eastern Ladakh was identified as a good site for astronomy.

2. The Government of India identified the Institute as an important centre for instrumentation and provided funds for its development programmes in the years 1995-1997.

3. Work started at Hoskote where the Government of Karnataka had gifted 35 acres of fine land to the Institute for setting up a *Centre for Advanced Science and Technology* (CAST).

4. As a first step to the setting up of a *High altitude Infrared and Optical Telescope* (HIROT) as a National Facility, the Institute started its efforts to deploy a somewhat smaller telescope of aperture 2 metres.

5. One more set of polished sun-shield panels was delivered to ISRO for passively cooling the radiometers aboard the INSAT II series satellites.

6. FASTEST COMPUTER in India with a capability of 2.5 GFLOPS was installed in the Institute using the GRAPE-board developed by Professor D. Sugimoto of the University of Tokyo.

7. Controllers and cryogenics for a sensitive CCD-based image acquisition system were developed indigenously; this should result in a major financial saving for the Indian scientific establishments and industry.

8. The impact of the *Comet Shoemaker-Levy 9* with *Jupiter* was well covered by our observations and we observed an intense flash of infrared emission when the fragment S collided with the Jovian atmosphere.

9. An expedition from the Institute also covered the *Total Solar Eclipse* in *Chile,* in November 1994.

10. Considerable amount of work was done in various areas of astronomy, astrophysics and physics leading to more than 70 publications.

11. Three scientists were accorded recognition for outstanding achievements in their respective areas of study. ***R. Cowsik*** received the Professor A.C. Banerjee Memorial Award for 1995 from the National Academy of Sciences, Allahabad and also the Professor S. Chatterjee Endowment Lecture Award for 1995 from the Indian Physical Society, Calcutta. ***V.Krishan*** was awarded the Senior Associateship of the International Centre for Theoretical Physics (ICTP), Trieste, Italy for a period of six years. ***B.Datta*** was elected a Fellow of the Indian Academy of Sciences, Bangalore.

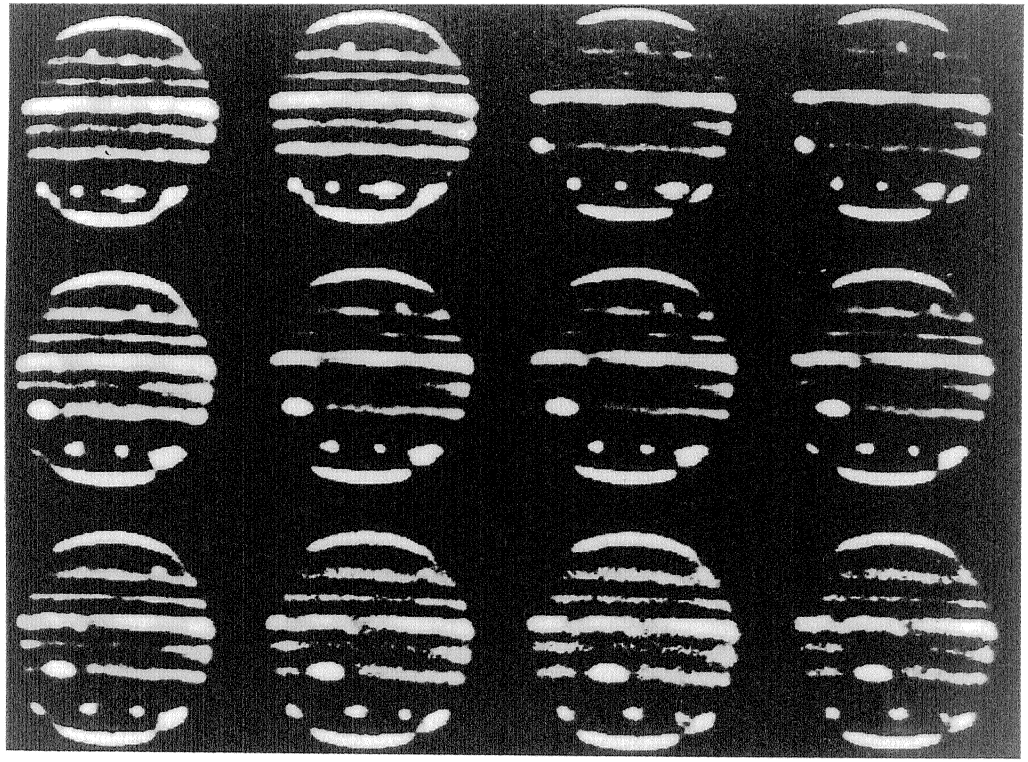


Fig.1. Series of images of Jupiter through the methane band at 8930 Å, obtained 1994 July 22 from IST: 19:30 to 21: 23. The first frame shows spots H, Q, and the D, G, S, R complex.

The Year in Review

The year started with the appointment of a number of scientists at different levels expanding further the scope of the research activities in physics, astrophysics and related areas. Regular site survey work began in Hanle, south-eastern Ladakh with a view to establishing there a centre for IIA's astronomical activities. Many of the administrative kinks and difficulties of operation, at this remote location, were straightened out by Mr. M. Ramani, the Senior Administrative Officer, who spent considerable amount of time during the year in Ladakh. The site survey is being carried out by a team of about twenty people in a rotatory system. Four senior scientists of the Institute are designated team leaders and one of them is usually always present at the site.

The Government of India intimated its approval of funding the early installation of a 2-m class telescope at an appropriate location that will provide the astronomers high quality data on a more regular basis so that the on-going programmes are not hampered by vagaries of the weather. The science advisors also felt that the procurement, the deployment and the operation of such a telescope using techniques of remote control may further help the scientists gain valuable experience for future needs.

The Institute planned and executed several experiments to study the impact of the encounter of Comet Shoemaker-Levy 9 with Jupiter in 1994 July. While imaging, spectroscopy and infrared photometry were done from the Vainu Bappu Observatory (VBO), Kavalur, a team from IIA used the techniques of speckle imaging to cover the event from Japal Rangapur Observatory (JRO) of the Osmania University, Hyderabad. Valuable cooperation was obtained from the astronomers of O.U. and JRO. IIA sent a team of four to Chile in November to observe the total solar eclipse. Two experiments were successfully carried out. Plans are afoot for a wider range of experiments involving a much larger team of observers for the 1995 October 24 eclipse that will be visible from parts of northern India. The Institute is expected to play a lead role in the organisation of the scientific expeditions - both national and international, to this eclipse event.

The first India-Japan Seminar on Astronomy and Astrophysics was held in IIA 1995 January 17-20. The Japanese delegation at this conference was led by Professor Daiichiro Sugimoto of the University of Tokyo. About twenty astronomers from Japan attended the conference. All the leading institutions in India, actively engaged in research in astronomy and astrophysics, sent their delegates to this conference. A number of important areas ranging from helioseismology to gamma-ray astronomy were covered during the deliberations at this meeting. Various exchange programmes were mooted and finalised. As a spin-off, a number of IIA scientists visited Japan in the succeeding months and carried out collaborative research in a wide range of topics.

A committee consisting of *Members of Parliament on Papers laid on the table, Rajya Sabha* visited the Institute and its laboratories on July 15. It commented very favourably on the activities of the Institute and expressed its support to the HIROT and CAST programmes.

Professor Virendra Singh, Director, Tata Institute of Fundamental Research, Bombay delivered the Ninth Bicentennial Commemorative Lecture on March 9, 1995. The theme of his talk was *S.N.Bose and the problem of blackbody radiation.* IIA and the Indian Academy of Sciences, Bangalore jointly organised a four day workshop on *Computational fluid dynamics and astrophysical applications* in Kodaikanal 1994 December 12-15.

Several distinguished scientists visited the Institute and interacted closely with the scientific and technical staff. A vigorous programme of seminars and colloquia was pursued.

Several new students joined the Ph.D. programme of IIA. The Institute initiated moves to obtain recognition from Birla Institute of Technology and Science (BITS), Pilani for the purpose of the registration and award of the Ph.D. degree to its students. A total of 24 students are currently enrolled for Ph.D. Of these 5 belong to the Joint Astronomy Programme of the Indian Institute of Science. The rest are registered at Bangalore University. Members of the staff continued to teach the M.Sc.

Astrophysics Special papers of Bangalore University and some of the courses in JAP, IISc. Several new courses in physics and mathematics and advanced level courses in astrophysics were offered in the Institute itself.

Development of the Hoskote land by fencing, planting trees, drilling bore wells and by landscaping has just started as a prelude to establishing a Centre for Advanced Science and Technology there.

It is a matter of great pride that the fastest computer in India has been set up at the Indian Institute of Astrophysics. This was accomplished by means of the GRAPE board with the conveyor belt architecture developed by Prof.D.Sugimoto. This computer is well suited for carrying out simulations of N-body systems interacting through gravitation.

A brief description of the important scientific work done during the year follows.

1. The Sun

A new theory of the solar cycle has been proposed that couples the internal rotation of the Sun to its orbital motion around the barycentre of the solar system. The inertial torque imposed by the spin-orbit coupling is found to force the torsional MHD oscillations whose interference causes the sporadic emergence of toroidal magnetic flux tubes which then manifests as solar activity. Supporting empirical evidence of the coupling of the Sun's internal MHD to solar system dynamics is obtained from a study of the variation of the annual mean values of the spin torque and the orbital torque, determined from solar system ephemerides, and the variation of the annual sunspot activity, which show a close correlation.

An extensive and accurate study of solar rotation using sunspots as tracers was completed from 82 years of data available in the plate vaults of Kodaikanal. The sidereal rotation rates, the differential rotation with latitude and meridional motions have been evaluated. The measurements have a high degree of consistency and the error bars on the estimated rotation rates are less than a percent.

Important theoretical studies on flux tubes were carried out which include a study of the response of a magnetic flux tube to buffeting by external p-modes, a study of the spectral line radiation from small-scale flux tubes and a numerical simulation of the equilibrium of sunspots.

During the solar eclipse in November high resolution multislit spectroscopy of the corona in the [Fe XI] 7892 Å and [Fe X] 6374 Å and narrow band photometry in selected emission lines were carried out. The data are supposed to elucidate further the temperature and density distributions in the corona and coronal structures.

2. Solar system studies

The main thrust of activity was the planning and carrying out of observations related to the encounter of Comet SL-9 with Jupiter and then analysing the collected data on this rather extraordinary event.

The infrared photometer on the 75 cm telescope in Kavalur recorded an intense infrared flash in the H band as fragment S crashed onto the cloud surface of Jupiter at UT 15:19:20 on July 21. The flash lasted about half a minute and the total energy in it is estimated to be ~ 3 x 10^{25} erg. In the direct imaging mode with a CCD photometer at the 102 cm telescope narrow band imaging was done in five different wavelengths during July 18-22. A broad band filter centered at λ 8900 was also used. The planet was reimaged in some of the filters again on August 13-14. The data throw valuable light on the morphology of the impact spots and their evolution. The 234 cm VBT was used in the cassegrain mode for spectroscopic observations. The long slit of the B & C spectrograph was placed parallel to the equator at the crash latitude 42° - 45° S. The spectra are being analysed to derive the wavelength dependence of scattering from the spots, the limb

darkening on and outside the spots and to estimate the ratio of the equivalent widths of pairs of NH_3 and CH_4 bands.

In addition speckle imaging was done in three wavelengths with band passes between 100-300 Å using a newly acquired 1024 x 1024 pixel CCD system. No less than 550 speckle images of Jupiter were recorded on July 17 after fragment E crashed on the planet. Another 80 images were recorded on July 24. The images are being processed using appropriate algorithms and they will be used to study disturbances in the cloud structure and the vortex structure in Jupiter's atmosphere.

3. Solar-terrestrial physics

The question of the response of ionospheric F region plasma motion near the magnetic equator to short-term changes of solar electromagnetic radiation was investigated experimentally. The results show that the equatorial F layer vertical drift is sensitive to the short-term variability of solar radiative output.

During the national campaign 1993 December — 1994 January simultaneous measurements of F region vertical plasma drift were done in the evening hours at the ionospheric stations in Trivandrum and Kodaikanal. The data obtained during this campaign were used to derive the height dependence of the vertical plasma drift in the dusk time equatorial F region during the winter solstice.

Measurements of the F region vertical drift under nonequatorial spread-F conditions were studied. The spectral content of the fluctuations in the drift was found to depend on local time. The results obtained in this study support the view that the short period variations are due to the polarization electric fields generated by the commonly occurring atmospheric gravity waves.

4. Stellar and Galactic physics

Spectroscopic investigations of Be stars, Be x-ray binaries, and spectroscopy and photometry of strong and weak emission T Tauri stars were carried out. Several interesting features were noticed and these are being analysed to learn more about the physical processes in these stars.

Further progress was made in the study of the chemical composition of RCB stars. Model Atmospheres specific to the physical properties of these stars with appropriate choices of the input parameters, have been constructed by astronomers at the University of Uppsala, Sweden. These are being used to systematically analyse the high quality high resolution data of these stars collected over the previous years. For R Cr B a study of the Na I absorption spectra suggests that the ejection of mass occurs even outside the large light drops. A detailed study of the RS CVn binary UX Ari was completed. A new programme of surveying the Li I 6707 Å line in late type giants and supergiants has been started. Extensive data on the Ca II triplet lines in these stars have already been collected. Relationship between chromospheric activity and the weakening of the triplet absorption in these stars has also been explored.

The remarkable post AGB star, SAO 244567, which was discovered to have produced à planetary nebula within the last twenty years, has been showing signs of fading during the last several years. One is perhaps actually seeing the evolution of a star in this critical phase in real time. HD 105262, a high latitude star with a large proper motion, was studied using spectra obtained with the VBT in Kavalur. Its status as a metal poor post AGB A supergiant has been confirmed. Several other studies on post AGB stars and on A and F main sequence stars with circumstellar dust shells are in progress. The work on M 4-18, the prototype of a planetary nebula with a WC 11 type central star, was completed. The final model derived for this object compares well with observations over the span of electromagnetic spectrum from the uv to the radio wavelengths. The excess near infrared radiation perhaps

indicates the existence of tiny dust grains in the nebula.

Photometry was done on several star clusters in the Galaxy. Probable binarity of open clusters in the Galaxy was explored and 18 pairs have been identified. From a consideration of the tidal disruption time scale and the average cluster life time it is conjectured that about 8% of the open clusters are members of binary cluster systems. NGC 2453, an open cluster in Puppis was studied in detail. Its great distance from us (~ 6 kpc) precludes the possibility of its physical association with the Type I planetary nebula NGC 2452 ($d \leq 3.5$ kpc) which appears close to it in the sky. The nebula is most likely a foreground object. An analytical expression was derived for the dynamical friction tensor in an anisotropic system and the consequences of anisotropy were explored. The study shows that the orbits of globular clusters tend to flatten out in time scales of the order of 10^9 yrs.

A polarization map of the cometary globule CG22 in the Gum Nebula was produced. The polarization vectors are found to be aligned parallel to the cometary tail of the globule. A self consistent analysis of the visible and dark matter components of the Galaxy was done. The velocity dispersion of the dark matter particles found from this study is about 600 km s^{-1} which is a factor of two higher than what is normally assumed in the laboratory searches of these particles.

5. Extragalactic studies

Soft x-ray data on 8 Seyfert galaxies obtained from the ROSAT database were analysed. A new emission line at 0.35 keV, suspected to be the C VI Kα line, was detected. A comparative study of radio-selected blazars (RBLs) and x-ray-selected blazars (XBLs) was carried out. Photometric monitoring of blazars to detect variability on short, medium and long time scales was continued. Broad band surface photometry of the radiogalaxy 3C 270 showed the presence of a dust lane oriented close to the major axis of the galaxy. The integral stellar spectrum of galaxies with circumnuclear 'hot spots' was synthesized. The 'hot spots' were interpreted as sites of self regulatory star formation activity. A variety of data on these galaxies seemed to support this thesis.

A nonstandard interpretation was given of discordant redshifts, quasar-galaxy associations and luminous connections on the basis of the Variable Mass Hypothesis (VMH) scenario within the framework of the Hoyle-Narlikar theory of conformal gravitation. The quasar-galaxy pair 3C 232 and NGC 3067 with discordant redshifts of 0.534 and 0.005 respectively was successfully explained this way.

A project to deploy a dedicated telescope to identify the optical counterparts of gamma-ray burst sources (GRBs) made further progress. Optics, the drive system and associated electronics were redesigned for the existing Schmidt telescope with this specific aim in view and fabrication of the system was taken up by the technical staff.

6. Theoretical astrophysics and astroparticle physics

The nuclear de-excitation lines of $^{12}C^*$ and $^{16}O^*$ observed from the Orion-complex with the COMPTEL instrument was analysed to estimate the flux of low energy cosmic rays and the observations of GeV gamma rays yielded the flux of high energy cosmis rays. The two-point spectrum thus obtained was much steeper than that in the general interstellar medium. These cosmic rays were shown to deposit ~ 10^{39} ergs per second in the nebula, an amount of energy adequate to generate the observed infrared luminosity of the complex.

Various problems in radiative transfer were studied. The problem of transfer of x-rays in a plane parallel atmosphere was solved and an emergent x-ray spectrum in the range 1-125 keV was calculated. The scope of the calculations on line driven winds in hot O and B stars was expanded by including the species HI, HeI and C III, C IV, Mg II, N V etc. Various partial frequency redistribution functions were studied to explore the effects of sphericity on emerging line profiles. The effects of

acoustic waves on resonance line polarization in solar type stars were also investigated.

Equilibrium of a charged test particle in the field of a rotating charged black hole (Kerr-Newman spacetime) was studied. The combined effects of the gravitational and electromagnetic fields were thereby probed. Scattering by black holes was studied using a simulated potential approach that rendered the problem amenable to analytical solutions.

The topological defect scenario of the origin of the highest energy cosmic rays was further explored with the identification of the monopole annihilation as a promising process. Other aspects of the topological defect scenario were also investigated. Other studies in astroparticle physics included the origin of nonlinear baryon density inhomogeneities, a chromogravity approach to strong interactions and quark confinement, the origin of primordial magnetic fields, baryogenesis etc. Based on the COBE data on anisotropy of the cosmic microwave background, a stringent upper limit on the electric charge asymmetry over a cosmological time scale was found. A stringent upper limit was also placed on the photon electric charge using the COBE data.

Acceleration of ultra high energy cosmic rays by conducting cosmic strings and the collision of these particles in intergalactic space were investigated.

7. Physics

Efforts have been on to set up state-of-the-art experimental facilities to study various fundamental aspects. During the year the design of an atomic beam apparatus was taken up. The apparatus is planned to be used for conducting cavity quantum electrodynamic experiments to measure in particular the weak Casimir-Polder force. Atomic physics experiments are also planned that will probe various aspects of physics beyond the Standard Model of particle physics. These are interference experiments involving a tunneling junction to test violations of time reversal and parity symmetries.

Theoretical work on atomic parity nonconservation, the electric dipole moments, time reversal etc is also being carried out. Some work on the nuclear anapole moment was also done. In addition, theoretical work on particle physics and nonlinear dynamics was added to the research activities of the Institute.

8. Optics, electronics and instrumentation

The rotational shearing interferometer was redesigned and refabricated incorporating a tilt mirror assembly. It was used on VBT to image the M supergiant α Ori. IIA signed an MOU with ISRO to provide the latter with polished sun shield panels of the very high resolution radiometer cooler to be deployed on the INSAT II series of satellites. One set of panels was handed over to ISRO in March.

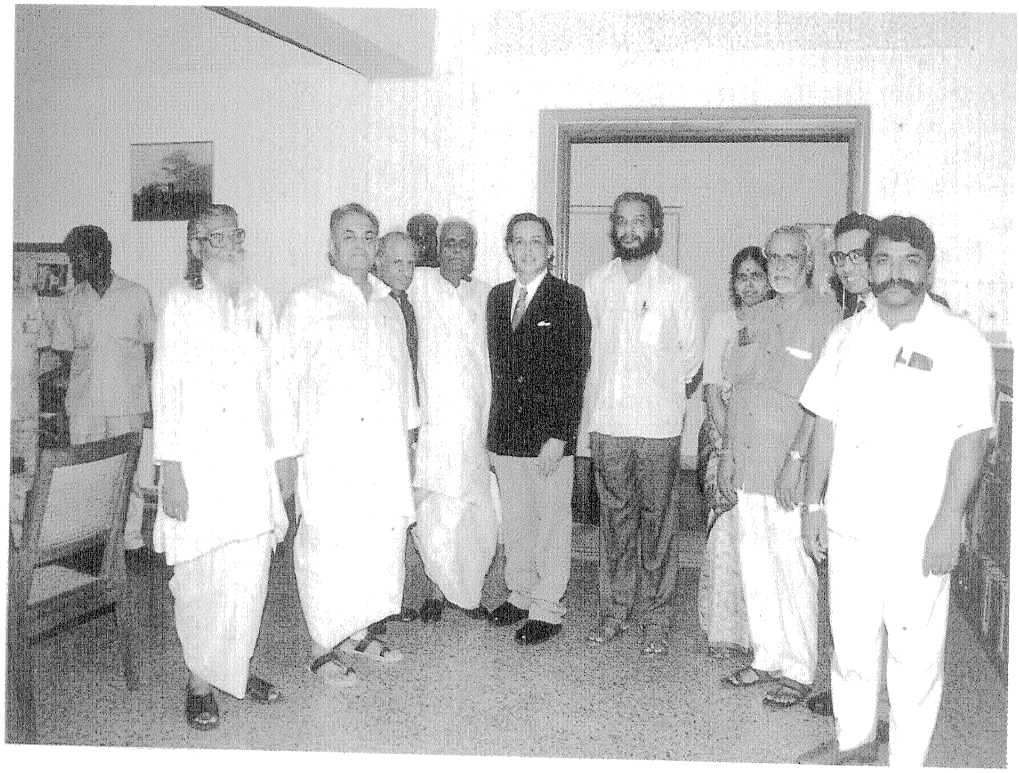
Progress was made in developing a new CCD controller based on Motorola's DSP 56002. A three litre liquid nitrogen Dewar is under fabrication. It is modular in design and is fabricated in two parts. Initial calculations show that the liquid nitrogen hold time of the Dewar will exceed 24 hours for a single fill. Two new 1024 x 1024 pixel CCD systems were procured from Photometrics Inc., USA. These were tested and then installed in VBO and JRO. The latter system will be used for the asteroid search programme.

A Local Area Network (LAN) comprising about 100 nodes was set up. Users are now able to work from their offices, receive and send e-mail through LAN as well as carry out work in the central facility. Upgradation of the existing computing facilities was also done. Several new PC 486's were procured. Laser printing facilities were further augmented.

As this year ends we are looking forward with great excitement to the major programmes in Physics, Mathematics, Astronomy and Technology which we will be undertaking in the coming year.

R. Cowsik
Director

Visit of the Members of Parliament



A new theory for the solar cycle

Excitation of torsional MHD modes in the sun by the inertial torques exerted on the sun by the solar system dynamics

In the conventional models of the solar cycle the equations for magnetohydrodynamics (MHD) within the sun are used ignoring the coupling of the sun's internal rotation to its 'orbital' motion around the centre of mass of the solar system. The authors have now shown that in the relevant magnetohydrodynamic problem the equation for angular momentum must include a new term representing the inertial torque imposed by the sun's 'spin-orbit coupling'. The total inertial torque is found to be stronger than the total electromagnetic torque, and varies with frequencies imposed by the solar system dynamics. Thus the inertial torque has been identified as the mechanism that forces the torsional MHD oscillations. As was shown by the authors earlier, it is the interference of these oscillations that causes the sporadic emergence of toroidal magnetic flux tubes that produce solar activity.

Empirical verification of the coupling between the sun's internal MHD and the solar system dynamics

The following similarities have been found between the temporal variations of the solar magnetic cycle during 1880-1976 and the variations of T_{spin} (or T_{orb}) (See Fig.2) :

(i) The most dominant period-band is same, viz., 17-25 yr.

(ii) During some cycles the profiles of the temporal variations are similar.

(iii) The amplitude modulations over the whole sequence are similar.

(iv) Prominent variations on time scales of a few years are also similar during some sunspot cycles.

By comparing the real variations of T_{spin} and T_{orb} with appropriate simulated variations, the authors have shown that the similarities listed above are not due to a chance coincidence of the periodicity of the solar magnetic cycle with the Jupiter-Saturn synodic periodicity alone. The above similarities between the solar magnetic cycle and the temporal variation of T_{spin} and T_{orb} indeed provide an empirical evidence for the coupling between the internal MHD of the solar cycle and the Solar System Dynamics (SSD).

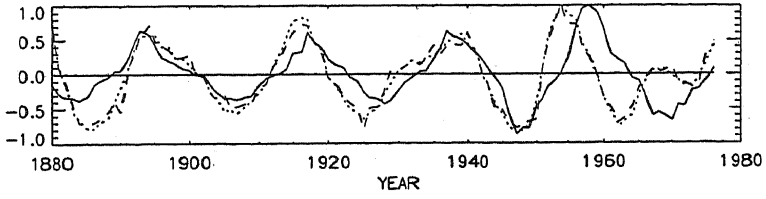


Fig.2. Variation of the annual mean values of T_{spin} (dashed line) and T_{orb} (dotted line), determined from solar system ephemerides, and the rate of emergence of toroidal magnetic flux from the sun (continuous line) as determined from the annual measure of sunspot activity with appropriate signs. The units for the three quantities are their maximum values during 1880-1976, viz, $|T_{spin}|$: 8.54×10^{30} dyne cm, $|T_{orb}|$: 2.34×10^{30} dyne cm, annual solar activity : value in 1958.

Maintenance of solar activity by the gravitational energy of the solar system and the 'gravitational loosening' of the sun

It has been found that in the above mechanism the rate of work done by the inertial torque, and its energy source, viz. the total gravitational energy of the solar system (which is ~10^{48} erg, concentrated in the sun), is adequate to maintain the torsional MHD oscillations against the loss of energy in the form of solar activity at the observed rate of ~ 10^{30} - 10^{31} erg s^{-1} throughout the sun's life.

Such an energy supply would imply 'slow loosening' of the gravitational binding of the sun. The authors point out that this 'loosening' may indeed be manifesting as the 'magnetic buoyancy' of the toroidal flux tubes, which lifts them into the sun's atmosphere, and ultimately as the overall mass loss from the sun at the rate of about 10^{-14} $M_\odot$ yr^{-1}.

Potential applications of the theory to other problems in space physics and astrophysics

It has been realized that the above theory of the coupling between the internal MHD of a star and the dynamics of the gravitationally bound system to which it belongs, has potential for future applications in the research on the following problems in space physics and astrophysics.

1. Prediction of the solar activity : on time scales of a few months to centuries (including, for example, the prolonged minima such as the Maunder minimum).

2. Activity of other stars : studies of the relations between the activity of other stars and their gravitational environments (e.g. stellar companions, planetary companions, accretion discs etc).

(M.H.Gokhale, J.Javaraiah, R.Vasundhara)

Sun's internal magnetic field and rotation

A model of the 'steady' parts of rotation and magnetic field in the sun's convective envelope

Using Nakagawa's boundary conditions for the rotation and magnetic field at the base and top of the convective envelope (see Nakagawa,Y. 1969, ApJ **157,** 881) a model for the 'steady' parts of rotation and magnetic field in the sun's convective envelope was computed. The resulting rotation is similar to that given by helioseismology and the poloidal field is same as was computed by the authors earlier. For the toroidal field the model yields a field distribution with the strength varying from about 1 Gauss near the surface to about 10^4 Gauss near the base of the convective envelope. (K.M.Hiremath, M.H.Gokhale)

Relation between the solar magnetic cycle and the phase and amplitude of the dominant torsional oscillation

The authors have found that the deviations of the coefficient 'B' of the sun's photospheric differential rotation from its average value are larger in the neighbourhood of the sunspot minima than at other times. Thus there is a phase difference of 90° between the dominant torsional oscillation and the solar magnetic cycle. On the longer time scales, the variations in the amount of sunspot activity per unit time are well anti-correlated with the variations in the amplitude of the torsional oscillation represented by the variation of 'B' with the '22 yr' periodicity. (J.Javaraiah, M.H.Gokhale)

A turbulent model of the solar granulation

The turbulent nature of the motions on the solar photosphere is being emphasized more and more due to the improved quality of high

resolution observations. The processes of inverse cascade of energy in a turbulent medium are being explored for modeling the hierarchical flow patterns on the solar surface. Here, the development of large scale flows is studied using the Kolmogorovic arguments for a statistically stationary turbulent fluid as well as through the solution of the Navier-Stokes equations including the Reynolds stresses generated by the small-scale flows, in a manner akin to the dynamo problem. Some of the testable predictions of the model are being discussed. (V.Krishan)

Magnetic flux tubes

The response of a magnetic flux tube to buffeting by external p-modes

The response of a thin vertical magnetic flux tube to buffeting by p-modes in the ambient atmosphere is considered. Assuming that the atmosphere in the flux tube is isothermal with the same temperature as the external gas, the differential equation for the vertical displacement in the tube is solved analytically in the linear case. For rigid boundary conditions, there is a resonance when the frequency of the external p-mode matches one of the natural frequencies of the tube. However, in the more realistic case of the tube wave being allowed to leak out of the lower boundary, the response of the tube is more complicated. In general a sharply peaked resonance condition does not exist. The response and absorption cross-section are evaluated for different values of the external horizontal wave number, mode order and β (β is the ratio of the gas pressure to magnetic pressure in the tube and is assumed to be constant). It is found that the response of the tube is maximum at low values of k_x (the horizontal wave number in the external medium) and drops off very sharply as k_x increases. For a fixed value of k_x, the response increases with frequency and then decreases after reaching a maximum. At low values of β, the response increases with β till $\beta \approx 1.0$, and thereafter decreases. The depth variation of the total energy and its various components are calculated. In general, the calculations show that at large depths, the thermobaric wave energy (i.e., the sum of the kinetic and gravitational energies) dominates. The nonlinear response is also examined by solving the time dependent MHD equations. The nonlinear calculations confirm the predictions of the linear analysis that the response of the tube drops as k_x increases. The velocity and total energy are oscillatory with maximum power at the natural tube frequency close to the frequency of the driving p-mode. In addition, there is power at higher harmonics of the tube modes. The implications of these results for the sun are pointed out. (S.S.Hasan, *T.J.Bogdan)

Spectral line radiation from solar small-scale magnetic flux tubes

Spectral line radiation from small-scale model magnetic flux tubes in the solar atmosphere has been considered. The structure of the tube is determined by solving the magnetostatic equations in the thin flux tube approximation. It is assumed that the tube is in energy equilibrium and in pressure balance with the ambient medium. For the latter, a quiet sun model is constructed, using an additional heating term to reproduce the VAL C model, treating the medium as a plane-parallel atmosphere. The flux tube models are parametrized by plasma β_0 (ratio of gas pressure to magnetic pressure), the convective efficiency parameter α, and the radius R_0 at height $z = 0$ ($\tau_{5000} = 1$ in the quiet sun). The Stokes I and V profiles emerging from the models and averaged over areas that include the neighbourhood of the flux tube are calculated for various spectral lines with different sensitivity on magnetic field strength and temperature. The profiles are compared with high spatial resolution observations of plages near the disc centre obtained with the Gregory Coudé Telescope at the Observatorio del Teide, Tenerife. The information contained in both I and V profiles is found to be very useful in constraining the theoretical models. The best match of models with observations is achieved for values of β_0 between 0.3 and 0.5. For a sufficiently wide separation of the V extrema of the strongly split lines, a broadening mechanism is required. Pure velocity (microturbulent) broadening compatible with observations of strongly split lines gives too much broadening for the weakly split lines. A broadening that is proportional

to the Landé factor, i.e. magnetic broadening, appears more appropriate. This suggests dynamic models with temporary enhancement of the magnetic field strength. The continuum intensity of these models is higher and the absorption and V amplitude in the Fe II 6149 Å line are stronger than observed. An improvement in the match between model predictions and observations is likely to come from models in which the ambient gas has a lower temperature as well as a lower temperature gradient than are found in the quiet, field-free sun. Such models are currently under development for cylindrical flux tubes. (*F.Kneer, S.S.Hasan, *W.Kalkofen)

Stability of intense flux tubes on the sun

Recently equilibrium model structures for intense magnetic flux tubes have been obtained (Hasan, S.S., Kalkofen, W. 1994, ApJ, **436**, 355) in the solar atmosphere with a comprehensive treatment of radiative transfer incorporating the radiative energy exchange between the flux tube and the ambient medium. The present work aims at examining the linear stabililty of the equilibrium structures to wave-like perturbations. The radiation field fluctuations are coupled to the thermodynamic and magnetohydrodynamical fluctuations; the equations governing these fluctuations were derived under the slender flux tube approximation to the MHD equations. A numerical algorithm is being developed to solve these equations. The procedure is basically an iterative scheme which employs the variable Eddington factor technique for the moments of the perturbed radiation field and solving the other coupled equations which together form a generalized eigenvalue problem for w, the wave frequency. As an initial step towards solving this full radiation-hydrodynamical problem, solutions are being generated for the above system with the assumption of the Eddington approximation to the radiation field. (S.Rajaguru, S.S.Hasan)

Numerical simulation of the equilibrium of sunspots

The coupling of magnetohydrodynamic (MHD) equations governing the structure of vertical flux tubes near the solar surface has imposed difficulties in finding analytical as well as numerical solutions. Here a numerical simulation is being developed to study the equilibrium of a flux tube starting from an arbitrary initial state, as a time dependent problem. Axial symmetry is assumed and the nonlinear boundary value problem solved to achieve equilibrium of the flux tube in the (r-z) plane of the cylindrical coordinate system. Using a hydrostatic atmosphere along each fieldline which is arbitrarily specified in lieu of a self-consistent treatment of force balance, the MHD equations are solved in space and time. A flux tube with smooth, continuous and cylindrically axisymmetric magnetic field has been considered. This method is applicable to both thin and thick flux tubes. It can readily be extended to any coordinate system with 2 or 3 coordinates, and to discontinuous configurations such as current sheets. An application of this technique is made to develop a model sunspot. In the equilibrium structure of the thick flux tubes, it is found that the field lines near the centre of a large spot assume a configuration close to that of a potential solution while those at the periphery are pushed in by the gas pressure. (R.T.Gangadhara, S.S.Hasan)

Line ratio techniques for filter magnetographs

The feasibility of the line ratio technique for filter based vector magnetographs was investigated using simulations. An optimization technique that minimizes a functional of the intrinsic field strength was tested in a few cases. The lack of convergence in some of these cases is being examined. (P.Venkatakrishnan, *G.S.Gary)

Solar rotation

This investigation aims at determining the solar rotation and the differential rates with high precision using sunspots as tracers, from the white light images of 82 years (1906 - 1987) available in the plate vaults of Kodaikanal. The measurements of positions and areas of 3,32,260 sunspots from 18,888 solar images pertaining to the 82 years, using a digital measuring pad with an accuracy of 1 arcsec, have been completed. The sidereal rotation rates, the differential rotation with latitude and the meridional motions have been worked out. The results show that the measurements have a high internal consistency and the error bars for the rotation rates are as small as 0.14% (~ 3 metres sec^{-1}).

Some of the salient features of this study are as follows:

1. The rotation rates in all latitude zones from all spots are faster by 0.75% than the rotation rates from the spotgroups.

2. The individual spots have been grouped into 3 classes – small, medium and large with umbral areas corresponding to < 5, 5-15 and > 15 millionths of the visible hemisphere respectively. The rotation rates for the three size groups in 5 degree latitude zones for the north and the south hemispheres of the sun are shown in Figure 3. It is seen that the rotation rates from the small spots are faster than those from the large spots by nearly 2% and the rotation rates from the medium sized spots fall in between these two extremes. These are explained as due to the different rotation rates prevailing at different depths within the sun at which the spots are anchored : small spots are supposed to be anchored at shallower depths and the bigger ones at deeper layers. Further, between the two hemispheres, the south rotates faster at all latitudes compared to the north by about 0.3%. This is conspicuous in the spots of the first two classes.

3. Rotation rates from the small and medium sized spots show positive peaks in the solar minimum years whereas the large spots show no positive peaks. It is inferred that the rotation rates are higher during the years of solar minimum than during the years of the maximum. This solar cycle dependence is explained as follows :
During the years of the solar minimum rotation rates are those derived from the small sized spots which alone appear on the sun, whereas during the solar maximum the rotation rates are from a sample that is predominantly of the large spots. Thus the samples available for determining the rotation during the maximum and minimum epochs are not the same. Since the small spots rotate

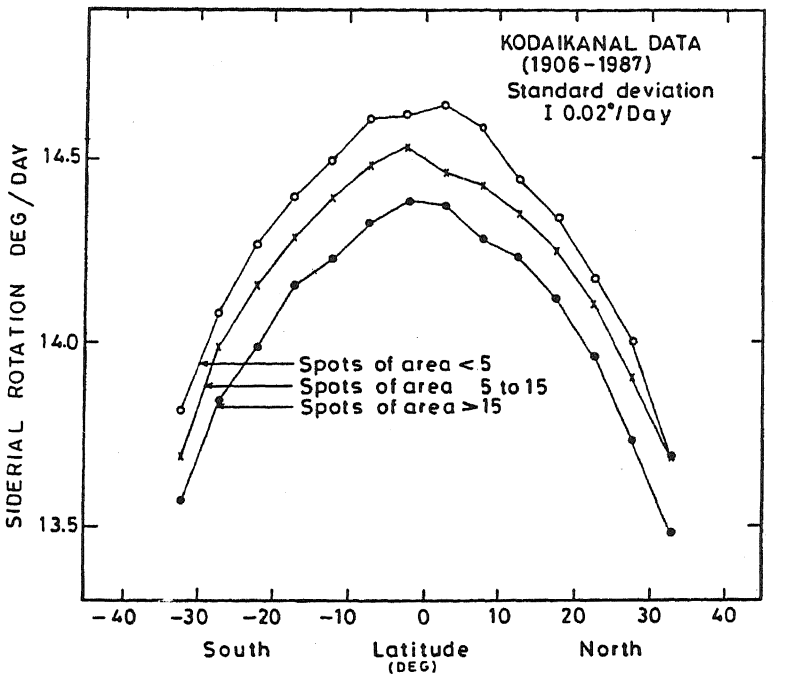


Fig.3. Rotation rates vs latitude in 5 degree bins from spots classified into 3 area groups (area < 5 millionths, 5 -15 millionths, > 15 millionths, of the visible hemisphere).

faster than the larger ones, the rotation rates will also appear to be higher during the period of the minimum than the maximum. The average amplitude of enhancement in the minimum is of the same order as the increase in rotation rate from the small spots (>5 millionths) over that from the large ones (> 15 millionths).

4. Comparing the rotation rates from the present study with the published rotation curve for the solar interior (from helioseismological data) it has been possible to estimate the depths at which the magnetic tubes of the spots of different umbral areas are anchored in the subsurface layers of the sun.

5. The meridional motions determined from the latitude drifts of the sunspots show that the motion is poleward at all latitudes in the northern hemisphere and is equatorward in the southern hemisphere in the mid latitudes and away from the equator at higher latitudes.

(K.R.Sivaraman, S.S.Gupta, A.V.Ananth, *R.F.Howard)

Diagnostics of the chromosphere-corona transition region and the corona

It has been found that under the assumption of constant electron pressure line intensity ratios of Si VII and Mg VII EUV lines can be used to determine simultaneously the electron density and the electron temperature within the chromosphere-corona transition region (CCTR) and the corona. In addition, line intensity ratios of Mg VII lines with respect to a reference Si VII line can be used to estimate the relative abundance of magnesium to silicon. This becomes possible because both these ions have equal maximum ionic concentration at the same temperature and for the other nearby temperature values the ratio of Mg VII ionic concentration to the Si VII ionic concentration remains practically constant. Theoretical intensities for these ions have also been computed using a model solar atmosphere and the reliable relevant atomic data currently available. Computed intensities have been compared with the available observed values pertaining to the average quiet sun conditions. The analysis suggests the need for future observations at high spectral resolutions to facilitate more detailed electron density and temperature diagnostics of CCTR and the corona. (P.K.Raju)

Non-equilibrium in helmet streamer flows

The onset of nonequilibrium in flows within helmet streamers was detected whenever the ratio of the height of the y-type singularity to the height of the Parker critical point in the solar wind exceeded unity. This has been suggested as a means to initiate a coronal mass ejection. (P.Venkatakrishnan)

He I λ10830 in active regions

Comparison of YOHKOH soft x-ray images with He I λ10830 images obtained at Norikura, Japan showed that the He I absorption is confined to the foot points of the x-ray loops. The correlation of the He I equivalent width with the line width is similar to that seen in quiet regions except for a larger range in the equivalent widths for the active regions. Thus, the equivalent width vs line width correlation seems to be a fundamental phenomenon independent of the location on the sun. (P.Venkatakrishnan, *T.Sakurai, *Y.Suematsu, *K.Ichimoto)

Solar flares

Flare trigger by onset of nonequilibrium in a flux tube

Recent observations of vector field changes during flares were interpreted as the onset of nonequilibrium in a pressure-confined tube

as it emerges into a low pressure atmosphere. The transition of the magnetic flux tube from a pressure-confined state to a force-free state is suggested as the mechanism that could trigger a flare. (P.Venkatakrishnan)

Search for flare-related changes in vector magnetic fields

A sequence of 42 vector magnetograms of AR 6659 obtained at MSFC on 10 June 1991 was examined to look for changes in the vector field azimuths associated with two M-class flares that occurred during the observations. No changes were found down to the sensitivity of the measurements, viz. 0.5 degree at the one sigma level. The fluctuations in transverse field strength showed a correlation with the mean transverse field, which is contrary to the expected behaviour of measurement noise. (P.Venkatakrishnan, *M.J.Hagyard, *E.A.West, *J.E.Smith)

The total solar eclipse of 1994 November 3

This total solar eclipse took place in South America where the moon's umbral shadow passed through Peru, Northern Chile, Bolivia, Paraguay, Argentina and Brazil. Most of the scientisits had made arrangements to observe this eclipse from northern Chile and Altiplano in Bolivia. An international camp was set up at Putre (18°11' S, 69° 33'W) near Arica in northern Chile at an altitude of about 3500 m with the help of army personnel. Prof. Hector Alvarez of the University of Chile was the National Coordinator. About 60 scientists belonging to 11 different teams from seven countries, USA, France, Japan, Korea, the Netherlands, Germany and India and about 500 amateur astronomers assembled at this camp to observe the eclipse.

A three-member team from the Institute went to Putre and set up a camp. Two experiments were conducted to study the temperature structure, turbulence and differences in open and closed field structures. Most of the time the sky conditions were excellent during their stay at Putre but thin clouds did appear at the time of the eclipse. Actual duration of the totality was one second less than the predicted value of 156 seconds by Espenak and Anderson (1993, NASA Reference Publication No.1318). (Jagdev Singh, Nagaraj Naidu, F.Gabriel)

High resolution multislit spectroscopy of solar corona in two lines

On an examination of the list of coronal emission lines in the visible, one finds that the two lines [Fe XI] 7892 Å and [Fe X] 6374 Å are best suited for observations. The ionization temperature for Fe X is about 1.0×10^6 K and it is about 1.2×10^6 for Fe XI.

The experimental setup consisted of a two-mirror 8 inch coelostat and an f/10 objective of 10cm aperture to form the solar image of 9.8 mm diameter on the multislit of the spectrograph. The field lens behind the multislit focussed the objective onto the spectrograph lens. The Littrow spectrograph with a f/10 lens of 4cm aperture and a 600 lines per mm grating provided a dispersion of 2 Å/mm in the 4th order red. Thus the 3rd order 7892 Å line and the 4th order red coronal line were separated by 162 mm. The 80 micron wide slit provided a resolution of 13 arc secs. The spectrograph was capable of giving a spectral resolution of 17 mÅ but the emulsion grain of 15 micron restricted the resolution to 37 mÅ which corresponds to a velocity of 2 km s^{-1}. The 25 mm diameter of the image intensifier allowed the observers to obtain the coronal spectra up to 2 solar radii from the centre of the sun. The spectrum was recorded on Kodak 2415 emulsion.

Preliminary analysis of the data has indicated that the strength of the emission lines was marginally above the continuum corona and the extent of the emission corona was much less extending up to only 1.3 solar radii from the centre of the disc. This may be due to the minimum phase of the solar cycle. (Jagdev Singh, R.Cowsik)

High resolution picture of the solar corona in [FeX] 6374Å obtained during the eclipse of 1994 November using a Peltier-cooled CCD camera.

Narrow band photometry in emission lines

To investigate the spatial variation of the temperature and density within coronal structures, narrow band photometry in two coronal emission lines was done. The ions Fe X and Fe XI are dominant emitters at temperatures of 1.0 x 10^6 K and 1.26 x 10^6 K respectively. The intensity ratio of [Fe X] λ6374 to [Fe XI] λ7892 enables a determination of temperatures, electron densities and relative abundances of elements within the coronal structures. A two-mirror coelostat was used to direct the coronal light to an objective of 15 cm aperture and 225 cm focal length. Narrow band filters of central pass band 6374 Å and 7892 Å and each of 5 Å band width were kept near the focal plane. The coronal pictures were recorded using a Peltier-cooled CCD detector. The optical setup provided a spatial resolution of about 4 arcsec. To obtain the large coverage of the solar corona, an arrangement was developed to move the CCD camera to a pre-determined position after each exposure.

Intensity ratio of the emission lines indicated a temperature of 0.9 x 10^6 K of the solar corona. A detailed analysis is being done to determine the temperature structure, and differences in open and closed field structures in terms of density and temperature and non-thermal broadening of the line profiles. (Jagdev Singh, R.Cowsik)

CIENTIFICOS INDIOS EN PUTRE

El doctor Jagdev Singh, del Instituto Indio de Astrofísica, explica a La Estrella los detalles de los experimentos que realizarán el próximo 3 de noviembre durante el eclipse. En la foto, dos de sus colegas preparan los reflectores que llevarán hasta el espectrógrafo la luz emanada de la corona solar. El trío de científicos indios es parte de los equipos de diversos países que han instalado su base de operaciones en el Regimiento de Caballería Blindada Granaderos, de Putre.

Investigations of the impacts of Comet Shoemaker-Levy 9 with Jupiter

The fate of the cometary fragments diving into the atmosphere of Jupiter at a speed of 60 km s^{-1} was investigated theoretically by Sekanina (1993, Science **262,** 382) and by Ahrens, Takata and O'Keefe (1994, Icarus **108,** 1). Their predictions of eruption of plumes rising to heights of about 3000 km following explosions at depths depending on the mass of the fragments were spectacularly confirmed by observations worldwide in the infrared wavelengths. The material in the plume consisted of evaporated cometary material and hot dissociated matter from the deep atmosphere. Subsequently, the matter in the hot plume recondensed and formed new localized dense clouds. The impacts occurred at a narrow latitude strip between 42° - 45°S, but spread over different longitudes due to the rotation of Jupiter.

Infrared flash from the impact of the fragment S

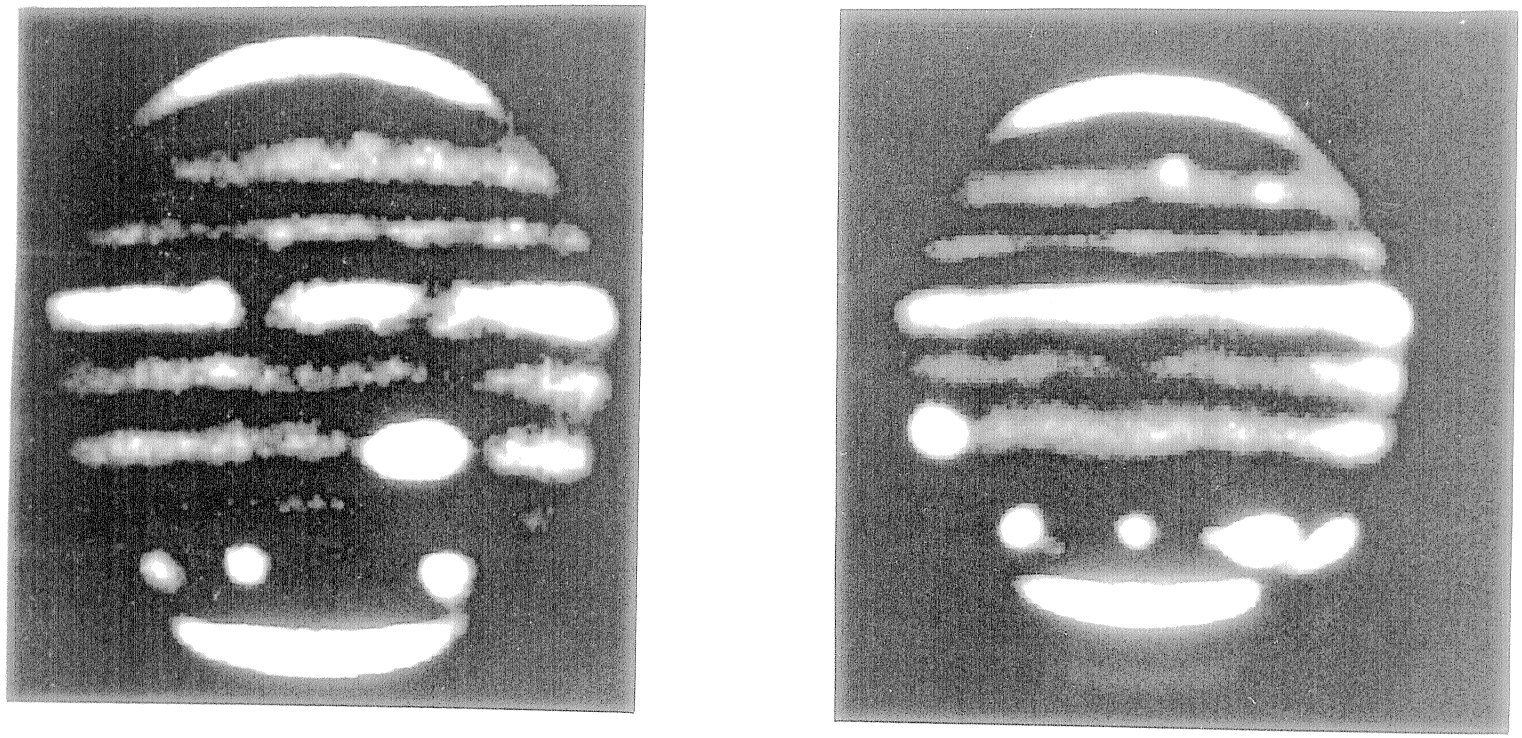
An intense infrared flash in the H band (1.65 μm) corresponding to the impact of the fragment 'S' on Jupiter on 1994 July 21 was detected at the Vainu Bappu Observatory, Kavalur. The infrared brightness began to increase sharply with a rise time of about 2 sec at 15:19:20 UT. The flash lasted for about 32 sec with a peak flux density of 8.2×10^{-6} erg cm^{-2} s^{-1} μm^{-1} at 1.65 μm. The total energy in the flash was $\gtrsim 3.6 \times 10^{25}$ erg. (H.C.Bhatt)

Direct imaging

To investigate the morphology of the impact spots and their evolution, direct imaging of the planet was carried out at the cassegrain focus of the 102 cm telescope. At the resolution of about 0.38 arcsec per pixel at the liquid nitrogen cooled CCD detector, the planet occupied 104 pixels across its equatorial diameter. Images were obtained during July 18 - 22 through five narrow band filters centred at λ4862, λ4935, λ5083, λ6581 and λ8930 (the methane band) with FWHM ranging between 50-100 Å and through a broad one with FWHM of 300 Å centred at λ8900. The planet was again observed on August 13-14 through filters centred at λ4862 and λ8930. The spots appeared bright (Fig.4 a & b, overleaf) in the λ8930 band relative to the Jovian background implying a shorter path length across the column of the methane gas. The recondensed impact ejecta are therefore much above the normal cloud top on Jupiter. The spots appeared darker in other wavelengths indicating that the material has lower albedo compared to the aerosols in a normal Jovian cloud. Fluxes in the methane band from the core of the impact regions within an aperture of 1".5 normalized with respect to that from the surrounding regions outside the spot were determined. This flux ratio follows a centre-to-limb variation as shown in Fig.5 for the impact spot K. Assuming a common limb-darkening law for the normal Jovian cloud and the impact debris, the fitted differential centre-to-limb profile is shown as the continuous lines. The parameters fitted using the method of least squares were R, the ratio of the single scattering albedo of the cloud of impact origin to that of the normal Jovian cloud and $\delta\tau$ the difference in the optical depths across the methane gas column to the two types of clouds. $\delta\tau$ is a measure of the light of the impact-related cloud over the Jovian cloud top. These parameters do not appear to have changed over a period of ~ 25 days (cf.Fig.5).

Outside the methane band the spots due to their lower albedo ($R < 1$) appear dark against the brighter Jovian background. Fig.6 shows intensity scans across the crash spots E, A and C on July 18 through the filters centred at λ4862 and λ8930.

A comparison of system III longitude of the spots (Fig.7) over the period of observations does not show evidence for drift within the observational scatter of 5°, except for the spot L which appears to have drifted westwards by about 10°.



(a) (b)

Fig.4. Images of Jupiter processed for contrast stretching to highlight the impact spots. North is to the top and East to the left. The crash spots from left to right are: (a) A,E, and H (b) H, Q_1, (G, D, S, R) complex and L. The Giant Red Spot is to the north of H in both the images.

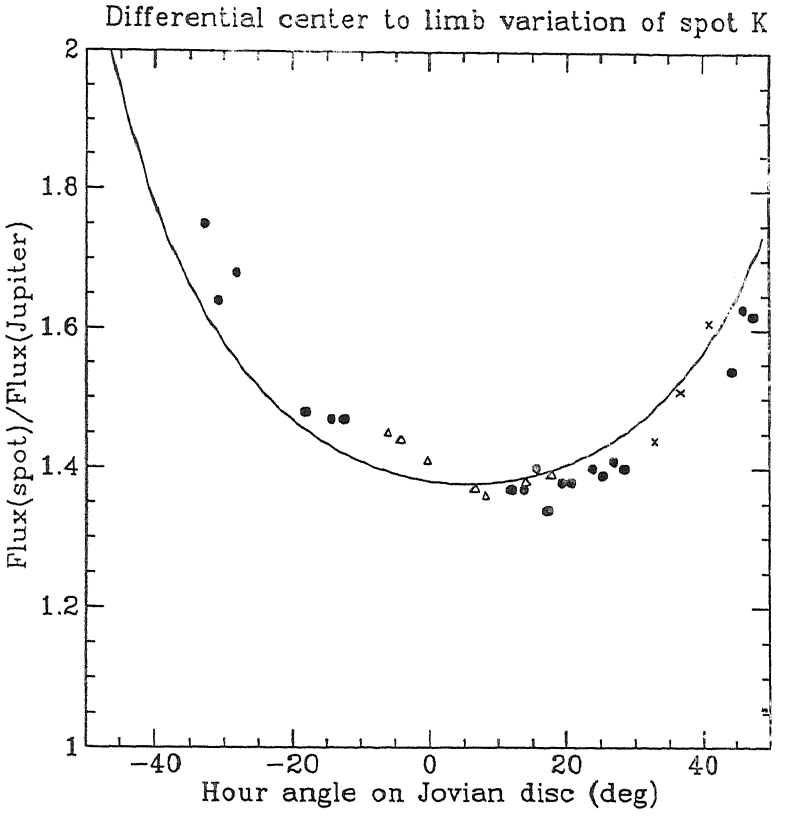


Fig.5. Centre-to-limb variation of the light scattered from the core of the spot K normalized with respect to that scattered from the surrounding regions on Jupiter in the methane band at λ8930. The crosses, filled circles and open triangles refer to observations on 19 July, 21 July and 14 Aug 1994. The fitted curve corresponds to an albedo ratio R (spot /Jupiter) of 0.77 at λ8930 and a lesser optical depth across the CH_4 column by $\Delta\tau = 0.21$.

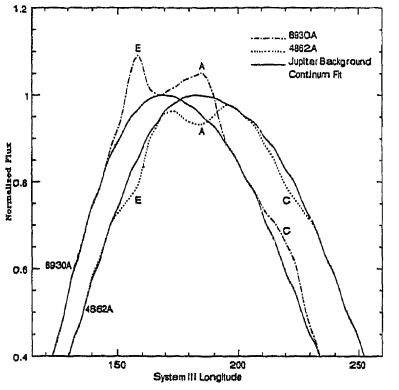


Fig.6. Intensity scans across the crash latitude of the Jovian disc on 18 July 1994 taken through two narrow band filters: one is centred on the deep methane band at λ8930 (dot - dashed curve) and the other centred at λ4862. The respective continuous lines for both the images refer to the Jovian background. The impact regions of fragments E, A and C stand out above the background at l8930 but are fainter at λ4862. The shift of the two background curves is due to the increase in the central meridian longitude of Jupiter by 15° between the two exposures.

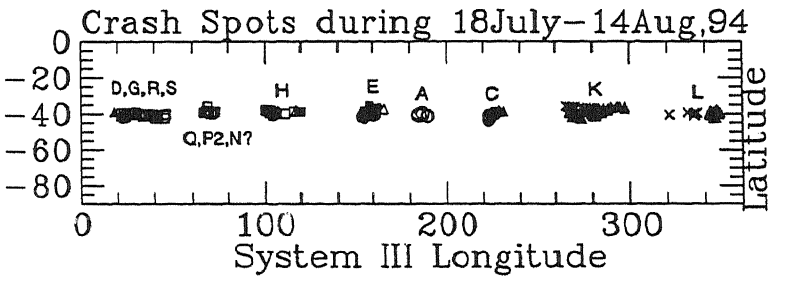


Fig.7. Latitude and system III longitude of the spots measured from the images taken on July 18 (crosses), July 19 (filled circles), July 20 (open triangles), July 21 (filled triangles), July 22 (open squares), Aug 13 (filled squares) and Aug 12 (circles).

Spectroscopy of the crash events

A series of low resolution spectra of the spots were obtained using the Boller & Chivens spectrograph at the cassegrain focus of the 234 cm telescope. The long slit of the spectrograph was placed parallel to the equator at the crash latitude of 42°-45° S. This arrangement permitted spectra of several crash spots in a single run. On July 18 and 19 the spectra were obtained at a resolution of 4.2 Å per pixel on the CCD detector covering a range of 4830 - 7400Å. Wavelength dependence of the scattering from the spots, limb darkening on and outside the spots, and the equivalent widths of the pairs of CH_4/NH_3 bands at λ5520/λ5430 and at λ6190/λ6475 will be investigated from the data.

Spectroscopic observations on July 20 - 22 were carried out in the wavelength region 8200 - 9200 Å with a resolution of 1.2 Å per pixel. The ratio of the spectrum from the spot region to the one from the surrounding region on Jupiter shows an excess of flux in the deep methane band (Fig.8). The series of spectra will be analysed to investigate the centre-to-limb variations of the equivalent width of this band.

(R.Vasundhara, Pavan Chakraborty, K.K.Ghosh, K.Jayakumar)

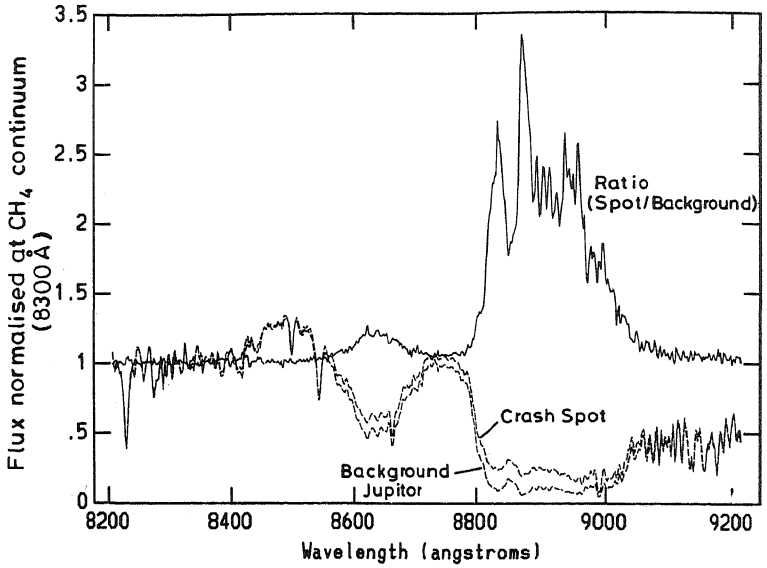


Fig.8. Spectral scans obtained using the Boller and Chivens spectrograph at the VBT. The dashed and continuous curves are the spectra of the spot group 'G, D, S, R' and the neighbouring region on Jupiter respectively. The divided spectrum (spot/Jupiter) shown as dot-dashed line indicates lesser absorption in the methane bands peaked at λ8640 and λ8870.

Interferometry

The technique of speckle interferometry was used to obtain the image of the entire planetary disk of Jupiter in the optical band, using the 1.2 metre telescope at Japal-Rangapur Observatory of Osmania University, Hyderabad, in collaboration with the Department of Astronomy, Osmania University. The image scale at the Nasmyth focus (f/13.7) of this telescope was further enlarged by a Barlow lens to enable sampling 0.11 arc sec/pixel of the CCD (at 0.55 micron) which is essentially the diffraction limit of the JRO telescope. A set of 3 filters (a) centred at 5500 Å, with FWHM of 300 Å, (b) centred at 6110 Å, with FWHM of 99 Å and (c) RG9, were used to image Jupiter. A 1024 x 1024 pixel water-cooled CCD with a pixel size of 22 micron was used as a detector. Necessary hardware was developed at the IIA Mechanical Workshop to

meet the requirements of the observations. Fifty speckle frames were sequentially recorded (each of 100 m sec exposure) in each of the 3 filters. The exposure time was chosen to obtain a good signal-to-noise ratio. Since the smearing due to the equatorial rotation of Jupiter is about 0.15 arc sec/min, one can afford to accumulate speckle frames for 2-3 minutes, if one expected to attain a resolution of 0.5 arc sec. In this experiment, it was possible to save 10 speckle frames/min. Twenty to thirty frames with good enough signal-to-noise ratio at the desired spatial frequencies are required to do speckle reconstruction. 550 images were recorded on 1994 July 17 soon after the fragment E of the Comet Shoemaker-Levy 9 collided with Jupiter. On 1994 July 24, 80 more images were recorded. A liquid nitrogen cooled 512 x 512 CCD was used to record 3 images of Jupiter in integrated light on 1994 July 22.

The data are being processed using appropriate image processing algorithms to study the disturbances in the cloud structure as well as the local vortex structure which forms at the impact sites. Photometric analysis of a few images is also being taken up. (S.K.Saha, R.Rajamohan, B.Nagaraj Naidu, M.J.Rosario)

Low frequency radio observations

An array operating around 22 MHz was constructed for observing the radio emission from Jupiter during the impact of Comet Shoemaker-Levy on Jupiter. An acousto-optic spectrograph was used along with the above array for the observation of radio bursts from Jupiter during the crash period. The observations show no enhanced radio emission due to the collision. (E.Ebenezer, K.R.Subramanian, Ch.V.Sastry)

Stars

Herbig Ae/Be stars

In continuation of the previous work (AR 1993-94) multi-epoch spectra in the region 5950-7000 Å of another 28 Herbig Ae/Be stars (in the magnitude range 9-14) were obtained using the B & C spectrograph at the cassegrain focus of VBT with a CCD detector. Now, a total of 43 Herbig Ae/Be stars have been thus covered. From the spectra of these stars, it is found that 16 stars display the presence of both [OI] λλ6300, 6363 and the double-peak P Cygni Hα profiles and the rest of the 27 stars display only single-peak Hα profiles in their spectra. These results can be explained on the basis of a model assuming that the forbidden lines are formed in a geometrically thin region near a circumstellar disc. An alternative explanation is based on another model in which the forbidden lines are formed in the outer part of the stellar wind in these stars. (K.K.Ghosh, S.Pukalenthi)

Be stars

High resolution (0.17 Å per pixel at Hα) spectroscopy of Be stars, using the 102 cm Zeiss reflector of VBO with the coudé echelle spectrograph and a CCD detector was continued. Data on 143 Be stars have been collected. From multi-epoch observations the authors have detected phase changes (from B to Be or from Be to Be-shell) of 18 Be stars. It is suggested that the phase changes from B to Be may be due to the ejection of matter via nonradial pulsations and the phase changes from Be to Be-shell phase may be due to a major outburst from the star as indicated by P Cygni profiles of Hβ, He I 5876 Å and the profiles of Hα. The major outburst may, in turn, be a result of infall of matter on the surface of the star. Inverse P Cygni profiles of Hβ, He I 5876 Å and Hα have often been observed before an outburst. Further observations and detail modeling are in progress. The authors are also measuring different spectral properties (violet and red peak separation, FWHM, equivalent width, radial velocities etc) of the above mentioned profiles of Be stars. These results along with the rotational velocities and spectral types of the 143 stars will be used to understand the dynamics of the envelopes of these stars. (K.K.Ghosh, *K.R.Radhakrishnan, *R.Krishnamoorthy, *K.C.Srinivasan, G.Selvakumar and M.J.Rosario)

Polarimetry

Recently data analysis of quasi-simultaneous spectroscopic (between Hβ and Hα region) and polarimetric (B, V, R and I bands) observations of 43 Be stars have been completed, along with the observations of a few polarized and unpolarized standard stars. From the polarimetric data of the programme stars, no frequency dependence of polarization could be detected. On the other hand a weak correlation between the equivalent width of Hα and the R band polarization of Be stars was found. The authors are planning to correct the emission equivalent width of Hα due to photospheric absorption and to carry out further statistical tests that may help elucidate the physics of the envelopes of Be stars. (K.K.Ghosh, K.V.K.Iyengar, *K.C.Srinivasan, *K.R.Radhakrishnan)

Be x-ray binaries

Be x-ray binaries comprise a good fraction of high mass x-ray binaries. To understand the evolution of these binaries, it is important to measure the orbital periods of the compact component. The best way to measure the orbital periods of these binaries is to regularly monitor these objects in x-rays and detect the successive x-ray flares when the compact object enters into the envelope of the component. However, due to the great demand of observing time and the short life time of x-ray satellites it is difficult to regularly monitor the Be x-ray binaries in x-rays.

In 1989 the authors suggested (Ghosh et al. 1989, ApJ. **344**, 437) that

by carrying out optical spectroscopy in Hα, CII λλ6578, 6583 and He I λ6678 of Be x-ray binaries, it would be possible to detect x-ray flares. Based on the optical observations of HDE 245770 (A0535+26) the appearance of an x-ray flare in this object was predicted (cf. IAUC 4913) and later confirmed (cf. IAUC 4915). During 1994-1995, several optical spectra of 10 Be x-ray binaries were obtained and x-ray flares in two such objects were detected. The programme will be continued. (K.K.Ghosh)

T Tauri and active chromosphere stars

The broad band UBVRI photometry of the active chromosphere stars HD 81410, HD 127535, HD 139084 and HD 155555 obtained at ESO, Chile and VBO, Kavalur between 1987 and 1993 was analysed. This programme was carried out mainly to study the short as well as the long term changes in the formation and disintegration of spot groups. Strömgren photometry was also carried out for a few programme stars. The analysis showed that in very active stars, like HD 127535 and HD 155555, sudden changes take place in the formation and location of spot groups. This was inferred from the sudden variation in amplitudes and phase minima of light curves. The light curves at times, showed the presence of two or more spot groups also.

Broad band photometric observations of weak emission T Tauri stars V 410 Tau and HD 288313 and of strong emission stars TW Hya and V 4046 Sgr were also done. The light curves of weak emission T Tauri stars showed only gradual changes in the phase minima and amplitudes while in the case of strong emission T Tauri stars sudden changes in the shape and amplitude in light curves were noted.

The analysis of the simultaneous broad band photometry and polarimetry of weak emission and strong emission T Tauri stars showed the following results. In the weak emission T Tauri star, V 410 Tau, a periodic variation in polarization is observed in anticorrelation to its photometric light curve in the sense that larger polarization was observed at the light minimum and low polarization at the light maximum. In the strong emission T Tauri stars no appreciable correlation was noted between the photometric light curve and polarization. The strong emission T Tauri stars showed sudden changes and large polarization compared to the weak emission stars.
(M.V.Mekkaden)

RS Canum Venaticorum stars

BV photometry and Hα spectroscopy of UX Arietis

BV photometry of UX Ari was obtained on 76 nights during 1989-94. An analysis of this data together with the data available in the literature was made and the following results emerged. Appreciable changes in the light curves occurred over a time scale as short as a couple of rotation cycles. The light curves available during 1988.76-1989.10 showed that the amplitude increased by 0.06 mag entirely due to an increase in the brightness at light maximum by the same amount. The increase in brightness at light maximum was continuous, and probably resulted from a reduction in the spot coverage on the hemisphere visible around that phase. Four major spot groups could be identified in the 22 years of photometric data on UX Ari. The spots located at synchronous latitudes were found to have lifetimes longer than 20 years while for those located at the faster rotating latitudes they were in the range 2-8 years. From the results of a recent Doppler imaging study Vogt & Hatzes (1991, IAU Colloq. 130, p.297) have argued that in UX Ari the equator is synchronized to the orbital motion and that the angular velocity increases towards the poles. However, the light curves obtained close to the epoch of the observations used for the Doppler imaging study are not consistent with the Doppler images derived. The amplitude varies cyclically with a period around 10-13 years. The highest value of 0.3 mag occurred around 1984-85. If allowances for the presence of a bright secondary are made, this implies a remarkably large intrinsic variation 0.65 mag for the active star. Intervals of lower amplitudes are found associated with the intervals of evener longitudinal distribution of

spots on the stellar surface rather than with intervals of low level spot activity. Apparently, the amplitude is anticorrelated with the brightness at light minimum. The ΔV_{min} probably has a saturation value around 0.34 mag below the highest ΔV_{max} observed so far.

The B–V colour shows a phase modulation with the system appearing bluer at light minimum than at light maximum. A quantitative consideration of the numbers involved showed that this resulted from an increased fractional contribution to the total light in the blue region from the hotter secondary when the active star became faint.

The Hα line in UX Ari is highly variable; it varies from pure absorption to pure emission. The equivalent width does not show any significant phase modulation. Study of the Hα variability of UX Ari is complicated by the presence of the secondary whose relative contribution to the continuum level varies out of phase with the brightness of the active star. If the contribution to the continuum level from the secondary were not properly taken into account, then there would be excess absorption at the velocity of the G-type star as the cool star becomes faint. Detailed spectral analysis incorporating the variation in the continuum levels is required to confirm the reported Hα excess absorption in UX Ari and the inferred mass transfer from the active K star to the G star. (A.V.Raveendran, S.Mohin)

Zeta Geminorum

Behaviour of O I 7774 Å feature

Zeta Geminorum is a classical Cepheid variable with a period of about 10 days. The O I triplet near 7774Å in this star has been monitored using the 102 cm Zeiss telescope of Vainu Bappu Observatory, Kavalur, India. The O I triplet is a good luminosity indicator for yellow supergiants and may therefore be used for luminosity calibration of Cepheids. Although a well known P-L relation exists for classical Cepheids, the use of the O I triplet has at least two advantages. A colour excess estimate is not required when this line is used as a diagnostic. Secondly, since it is a strong feature, the triplet can be measured even from medium resolution spectra. It is important to know how the line varies during the pulsation cycle. With this in view it was decided to have a very extensive phase coverage of this line at high resolution. The spectra were obtained at 22 epochs enabling a good phase coverage. The authors also monitored the strength of a few metallic lines in that spectral region to understand and account for the variation of the atmospheric parameters over the pulsation cycle. It is found that the O I line strength varies with phase but it does not follow the light curve pattern. Its strength attains a maximum value between phase 0.7 to 0.9. This maximum value used with an $M_V - W_\lambda$ (O I) relation calibrated for F-G supergiants predicts a fairly accurate M_V for the star. A study of the behaviour of this feature in other classical Cepheids is to be undertaken. (Aruna Goswami, Sunetra Giridhar)

Hydrogen deficient stars

Abundances

In a collaborative programme with Martin Asplund and Bengt Gustafsson of the Astronomical Observatory of the University of Uppsala, abundance analyses of several RCB stars have been done using new hydrogen-deficient line-blanketed Model Atmospheres incorporating new opacities, a range of molecules etc. The atmospheres have been constructed by the Uppsala group especially for this programme. (N.K.Rao, *D.L.Lambert)

R Cr B

High resolution spectra at $\lambda/\Delta\lambda = 6 \times 10^4$ and 10^5 have been obtained of R Cr B at normal light maximum with the Mc Donald 2.1 m and 2.7 m telescopes in the region of 5150-7800 Å on several occasions. The spectra show several absorption components in the Na I D lines. Some

of them appear rather suddenly. Dramatic appearance of some components in the spectrum obtained on 1994 March 26 which were not present in 1990, suggests ejection of gas even outside the large light drops.

The spectra cover both pulsation (?) maximum as well as minimum. The spectra at pulsation minimum show strong enhancement of C_2 Swan bands in absorption. The analysis of these spectra using Schönberner's Model Atmospheres indicate a change in T_{eff} from 7750 K (at maximum) to 7000 K (at minimum). The spectra at some phases show Hα emission. The spectra obtained close to the maximum show velocity gradients. The radial velocity of the lines indicate that the outer layers are lagging behind the inner layers on one occasion while the reverse is true on the other occasion. Further study is in progress using the improved Model Atmospheres of Martin Asplund and Bengt Gustafsson, referred to above. (N.K.Rao, *D.L.Lambert)

Z UMi

The star Z UMi was recently discovered as a probable RCB star. High resolution spectra of it in the region 5100–7800Å were obtained at the McDonald Observatory. The star is a cool carbon star. Analysis of the spectra indicates the presence of the Li I feature at 6707 Å. Since high excitation lines like Hα are anyway weak even in normal cool carbon stars, the hydrogen deficiency - a characteristic feature of RCB stars, cannot be inferred easily. The spectra in the region of the CH bands at 4300 Å are proposed to be obtained. Comparison with other cool RCB stars is in progress. (A.Goswami, N.K.Rao, *G.Gonzalez, *D.L.Lambert)

FG Sge

Several high resolution spectra of FG Sge, the famous born - again red giant central star, associated with a planetary nebula, have been obtained during a deep light minimum. It is suspected that the star is slowly turning into an RCB star. The Na I D line profiles look very similar to those of R Cr B at minimum. Further analysis is being done in collaboration with astronomers at the University of Texas. (N.K.Rao)

RV Tauri stars

In continuation of earlier novel findings about the abundances in the carbon rich RV Tauri star IW Car, several other carbon rich RV Tauri stars (e.g. EP Lys, AR Pup etc) are being observed at high spectral resolution in the red region. Abundance analyses of some of them are in progress. (S.Giridhar, N.K.Rao, *D.L.Lambert)

Ca II triplet lines in cool stars

In continuation of the detailed survey of the Ca II triplet lines λ8498, λ8542, λ8662 as sensitive indicators of luminosity, metallicity and chromospheric activity in cool stars, the λ8662 line was observed during 1994-95 in about 40 stars with the coudé echelle spectrograph at the 102 cm telescope. These data have been reduced and analysed using the IRAF package. High dispersion CCD spectra now exist for 130 stars of all luminosity types in all the 3 lines spanning a spectral type range from F8 to M4 and a large range in [Fe/H] from +1.1 to – 3.0. The analysis corroborated the earlier result that the correlation between the Ca II strengths and luminosity is very strong, especially for the metal-rich stars. It is nonlinear in nature. A few superluminous supergiants have also been observed and they fit with this relation very well. Sensitivity to metallicity is also striking, especially for supergiants. A detailed inspection of the above stars has shown about 14 of them to be chromospherically active. The central depth in each of the three Ca II lines in such a star is found to be significantly less than in the others of the same luminosity, metallicity and temperature, perhaps owing to the emission filling into the absorption. The spectrum of a chromospherically active star divided by that of a quiet star shows net emission at the Ca II triplet wavelengths. This emission is found to be stronger in supergiants than in dwarfs, in analogy with the behaviour of the Ca II H and K emission observed in cool stars. (Sushma V. Mallik)

Li I 6707 line in cool stars

Chromospheric activity is usually related to the age of a star - more active the chromosphere younger is the star. One would expect in such stars the lithium line to be rather strong, for in older stars it is likely to be weakened due to the depletion of Li. In order to explore this, a study of the Li I line at 6707.83 Å was undertaken in both chromospherically active and quiet stars from the above sample. It is a weak line, the equivalent width (EQW) ranging from a few mA to a few tens of mA and is blended with an Fe I line at 6707.45 Å of comparable strength. The EQW of the Fe I blend was estimated from the EQWs of 5 other Fe I lines of the same lower excitation potential computed using the well known software package LINES (Sneden 1974, Ph.D thesis, UT) and Model Atmospheres with an appropriate choice of atmospheric parameters. A close look at the corrected Li I strengths reveals that only half of the chromospherically active stars have a fairly strong Li line. The rest have the Li line as weak as the quiet stars implying that Li abundance and age may not have a one-to-one correlation. In fact, lithium is expected to be largely depleted/diluted in evolved stars, yet some of the late K and M giants and supergiants observed show a strong Li line. A larger sample of stars is being studied to explore various mechanisms of production and destruction of lithium. (Sushma V. Mallik)

Post-AGB stars

Fading and variations in the spectrum of the central star of the very young planetary nebula SAO 244567 (Hen 1357)

The optical spectrum of SAO 244567 obtained in 1971 shows that it was a post-AGB B1 or B2 supergiant at that time. It has turned into a planetary nebula (PN) within the last 20 years.

The IUE ultraviolet spectra obtained during the last seven years show that the central star is rapidly evolving. It is found that the central star of this young PN has faded by a factor of 2.83 within the last seven years. The terminal velocity of the stellar wind has decreased from –3500 km s^{-1} in 1988 to almost zero in 1994. In 1988 the C IV (1550Å) line had a P Cygni profile with a strong absorption component but by 1994 the line almost vanished. The UV absorption and nebular features show variations in strength. This may be due to the fading of the central star and also possibly to the expansion of the nebula.

These results suggest that in the central star the nuclear fuel is almost extinct as a result of post-AGB mass loss. The main stellar energy may be gravothermal in nature. A very fast drop in luminosity by almost an order of magnitude when the burning cannot be sustained any longer is typical of hydrogen-burning AGB remnants. These results suggest that the central star of this young PN is rapidly evolving to become a DA white dwarf.

An alternative interpretation is that the present fading is due to an episode of high mass loss, which is now just completed. If the ultraviolet fading was a factor of 2.83 from 1988 to 1995, the luminosity would remain the same if the temperature increased from 37,500 K to 47,500 K in the same period. It may be that these changes occur in steps which are triggered by periods of episodic mass loss during the post-AGB evolution, and that the hydrogen burning has not stopped or only stopped temporarily. (M.Parthasarathy, *P.Garcia-Lario, *D.de Martino, *S.R.Pottasch, *D.Kilkenny, *P.Martinez, *K.C.Sahu, B.E.Reddy, *B.T.Sewell)

Spectroscopy of carbon-rich Post-AGB supergiants

High resolution and high S/N ratio spectra of several carbon-rich post-AGB F,G,K supergiants were obtained with the Isaac Newton Telescope (INT) at La Palma. Analysis of the spectra indicates the overabundance of carbon and s-process elements. This result suggests that matter rich

in carbon and the s-process elements is dredged up to the surface during the AGB stage of evolution of these stars. (M.Parthasarathy, *P.Garcia-Lario, B.E.Reddy, *A.Manchado)

Post-AGB A and F supergiants and high c_1-index stars

Several post-AGB A and F supergiants show high c_1-indices indicating very low surface gravities and extended atmospheres. Recently Bidelman compiled a list of several A and F supergiants with high c_1-indices and shell features and suggested that some of these may be unrecognized post-AGB objects. In order to detect new post-AGB candidates among the high c_1-index stars the authors have obtained 1.1Å resolution CCD spectra of 18 selected A and F supergiants with very high c_1-indices with the VBT at Kavalur. The atmospheric parameters, T_{eff}, log g, [Fe/H] and CNO abundances, are being determined. The abundances of the high c_1-index stars will be compared with the abundance patterns of post-AGB A and F supergiants. (B.E.Reddy, M.Parthasarathy, T.Sivarani)

HD105262: a high latitude metal-poor post-AGB A supergiant with large proper motion

Large proper motion post-AGB stars are very rare. HD 105262 is a high galactic latitutde (+73°) A-type star with large proper motion and high c_1-index. Earlier it was classified as a Field Horizontal Branch (FHB) star. Recently Abt suggested that it may be a star similar to HR 4049. In order to further understand the evolutionary status and chemical composition of HD 105262, 1.1Å resolution spectra of the star were obtained with the VBT, Kavalur. Analysis of the spectra reveal that HD 105262 is metal poor ([Fe/H]=—2.2). However, the CNO abundances are nearly solar. The absolute magnitude of HD 105262 is estimated to be $M_v = -5.0$. The Hα and Hγ profiles are similar to those of HR 4049 and other post-AGB A supergiants. The Hα and Hγ profiles, the absolute magnitude, the high galactic latitude, the kinematics and chemical composition clearly indicate that HD 105262 is a metal poor post-AGB A supergiant. It is not an FHB star. (B.E.Reddy, M.Parthasarathy, T.Sivarani)

Hot post-AGB stars

Ultraviolet spectra of several hot post-AGB stars were obtained with the IUE satellite to study the stellar UV continuum, nebular lines and stellar wind profiles and their variation. Effective temperatures were determined using the IUE ultraviolet fluxes. Stellar wind P Cygni profiles of N V and C IV are detected in the IUE spectra of IRAS 18033-5101 and IRAS 18523-3219. They also show the C III] 1909Å nebular lines. These hot post-AGB stars are losing mass and may be evolving rapidly towards higher temperatures similar to SAO 224567. (M.Parthasarathy, *D.de. Martino, *P.Garcia-Lario)

SAO 165175

SAO 165175 is a high galactic latitude object (b = 57°) with large radial velocity. It is a long period variable (Whitelock et al. 1989, MNRAS **241**, 393) with a period of 254 days and light amplitude = 0.29 in K filter. There is some evidence of amplitude variability from cycle to cycle.

The spectrum taken in the 5490-7000 Å spectral region reveals many interesting aspects. Generally the metallic lines are shifted by −1.8Å indicating a radial velocity of 85 km s^{-1}. The spectrum contains very few lines and the existing lines are very weak. Only a few lines of Fe II, Fe I, Si I, Si II and O I and one line each of Ca I and Mg I could be detected. Fe II lines at 5534.8Å, 6238.4Å, 6247.6Å, 6416.9Å and 6516.2Å show line doubling. They all have weaker components that are nearly half as strong as the original line. These weaker components are blue shifted by 0.6 Å and they correspond to a velocity of −112 km s^{-1}.

The only strong lines in the spectrum are Na I D lines and the Hα line. Si II lines at λλ6347, 6371 are of moderate strength. All these features exhibit multiple components. The D lines have strongest components at radial velocity –85 km s^{-1} with FWHM ~0.45Å. Other photospheric lines also show this velocity. The D lines have another pair of components marginally weaker than the strongest components which correspond to a radial velocity of –45 km s^{-1}. They are almost symmetrical with FWHM ~0.48 Å. In addition there is a blue shifted asymmetric shallow component with a FWHM ~0.72 Å corresponding to a radial velocity of –127 km s^{-1}.

The Hα line has two strong emission components. The first one with a peak intensity of 1.95 corresponds to a radial velocity of –86 km s^{-1}. The second emission component with a peak intensity of 1.30 corresponds to a radial velocity of 16.4 km s^{-1}. In between these two emission components there lies a deep absorption corresponding to a radial velocity of –31.0 km s^{-1} and a central depth 0.55. The Hα feature has broad absorption wings extending up to 10 Å on either side.

A spectral type of A2 Ia has been suggested by Waelkens et al. (1987, A & A **181,** L5) from the photometry, the continuum energy distribution and a few spectra. A few more spectra at moderate dispersion were obtained by Whitelock et al. (1989) which support the same. However, when compared to the A0 supergiant υ Leo the metal lines in SAO 165175 are rather weak and hence the star is likely to be metal poor. (S.Giridhar, N.Kameswara Rao, *D.L.Lambert)

Main sequence A and F stars surrounded by dust shells

The Infrared Astronomical Satellite (IRAS) data revealed cold dust disks around several main sequence A and F stars. At least 30% of the nearby main sequence stars show evidence for dust discs at the IRAS sensitivity limit. A programme of spectroscopic study was initiated of main sequence A and F stars with dust shells to determine their chemical composition and to detect circumstellar neutral gas shells. High resolution (0.4Å) spectra of α PsA, β Pic, 51 Oph and related stars were obtained with the 102 cm telescope and the coudé echelle spectrograph.

Some spectral features indicating the presence of circumstellar neutral gas shells around these stars have been detected. An analysis of the spectra to study the nature and composition of circumstellar matter in these stars is in progress. (T.Sivarani, M.Parthasarathy)

Oscillator strengths for ultraviolet Ga II and Ga III lines

Ultraviolet spectra of B-type stars are very crowded with lines, which may be even more numerous in the peculiar stars, owing to the overabundances of some elements in their atmospheres. Despite the availability of large line lists, atomic data are still missing for many transitions. In particular, Ga II and Ga III lines are very poorly represented. In this work log gf values from laboratory intensity data for all the ultraviolet Ga II and Ga III transitions observed by Isberg & Litzen have been derived. The authors used lifetime measurements when available and the Cowley method for the remaining transitions. (*F.Castelli, M.Parthasarathy)

Novae

The programme on optical spectroscopy of novae was continued during the year. The quiescent novae T CrB, RS Oph and GK Per were monitored periodically. The post-outburst spectra were recorded for Novae Cyg 1992, Cas 1993, Oph 1994, Sgr 1994 # 2. A suspected nova in Sagittarius was also observed and shown to be a peculiar variable star. (*G.C.Anupama, T.P.Prabhu)

Galaxy and the Interstellar Medium

Dynamical evolution of protostar clusters in molecular clouds

Star forming molecular clouds contain protostars and more massive clumps of gas. The system of protostars and clumps interact gravitationally and the individual objects also suffer gas drag. The lower mass protostars are gravitationally scattered by the more massive clumps. Energy is transferred from the clumps to the protostars. A significant fraction of the protostars attain velocities large enough to enable them to escape from the cloud. Thus young stellar objects can be found even in the low density surroundings of the molecular clouds as is found observationally. The dynamical evolution of such systems has been studied numerically. (U.Gorti, H.C.Bhatt)

Star clusters

Probable binary open star clusters

The existence of binary clusters in the Magellanic Clouds is fairly well established, whereas only one such pair, h & χ Persei, is known in the Galaxy. From the catalogues of open clusters of the Galaxy, 18 probable pairs of clusters (with known distances) have been identified, with spatial separations less than 20 pc. The tidal disruption timescales for these pairs, due to Galactic differential rotation are calculated. In some cases, these timescales are larger than the average cluster life time of about 10^8 yr. About 8% of the open clusters appear to be members of binary systems and hence binary cluster systems may not be very uncommon in the Galaxy. (A.Subramaniam, U.Gorti, R.Sagar, H.C.Bhatt)

UBVRI CCD photometry of the two southern clusters Berkeley 79 and Trumpler 11

CCD observations in U,B,V,R and I pass bands have been made down to V = 18.5 mag for the southern galactic star clusters Berkeley 79 and Trumpler 11. The sample consists of 60 and 358 stars respectively. Berkeley 79 seems to have non-uniform extinction over the observed region with a median value of E (B–V) = 1.19 ± 0.05 mag, while a uniform reddening with E (B–V) = 0.21 ± 0.02 mag appears to be present over the face of Trumpler 11. The distances of the clusters Berkeley 79 and Trumpler 11 have been estimated as 2.3 ± 0.2 kpc and 3.1 ± 0.3 kpc respectively. Based on isochrone fitting of the bright stars, an age of 65 Myr has been assigned to Berkeley 79, while the age of Trumpler 11 has been estimated to be in the range of 100 to 250 Myr. (R.Sagar, *R.D.Cannon)

A deep photometric study of the open cluster NGC 2453

The complete CCD data on NGC 2453 and its adjoining fields in the three bands B,V, and I were analysed using the latest version of the DAOPHOT software on the VAX 11/780 installation at VBO, Kavalur. A total of 356 stars were included and the field covered had an area of about 4.' x 6.' of the sky centred on the cluster. The membership of the stars is difficult to determine for lack of kinematic information. The authors have therefore used certain statistical criteria by dividing the field into a cluster core region and an outer region, counting the number densities of stars in the two regions and then assessing the field star contamination. Further, a radial density distribution of the stars was also obtained. The data show that the vast majority of the stars belong to the cluster sequence, the field star population contributing less than 40% to the total and that the cluster radius extends to about 2.'5.

The V, B–V and V, V–I colour magnitude diagrams have been generated down to V = 20. The mean true distance modulus derived from these diagrams is 13.85 ± 0.2 mag yielding a distance of 5.9 ± 0.2 kpc. Model isochrones due to Schaller et al (1992, A & A **96,** 269) that include the effects of mass loss and convective core overshooting have been fitted to the cluster sequence and a mean age of 25 Myr has been obtained. As had been already concluded the distance of approximately 6 kpc puts the cluster much beyond the planetary nebula NGC 2452 whose largest estimated distance is about 3.5 kpc. The nebula is most probably a foreground object and is not physically associated with the cluster. (D.C.V.Mallik, Ram Sagar, A.K.Pati)

Cometary globule CG 22 in the Gum nebula

About 15 stars in the region of the cometary globule CG 22 have been measured polarimetrically. From these observations a polarization map has been produced. It is found that the polarization vectors are more or less parallel to the cometary tail of the globule. The average level of polarization is 1%. The results suggest that the magnetic field in the globule has been shaped by the radiation pressure effects of a central source and the present magnetic field plays an important role in confining the material in the cometary tail of the globule. (H.C.Bhatt, *T.K.Sridharan, *Jayadev Rajagopal)

Nebulae around WC 11 type stars

M 4-18

The nebula around this star has been modelled taking into account both its gas and dust content. The model compares well with observations ranging from UV to radio wavelengths that include optical observations obtained at VBO,Kavalur. This work has led to the very interesting possibility that tiny grains (dimension ≤10 Å) might be responsible for the excess near IR radiation. (R.Surendiranath, N.Kameswara Rao)

It has been planned to include stochastically heated tiny grains in the photoionization model code developed for the work on WC 11 objects. (R.Surendiranath, P.Bhattacharjee)

Observations

CCD spectral observations of select WC 11 type nebulae were continued in the wavelength range of 4000 - 10000Å with the B & C spectrograph on VBT. Fabry-Perot observations of x-ray emitting planetary nebulae are planned for the detection of the [Fe X] line at 6374Å. (R.Surendiranath)

Dark matter

A self-consistent analysis of the visible and the dark matter components constituting the Galaxy has been done. In particular, the velocity dispersion of the dark matter particles has been obtained. The resulting value of the velocity dispersion, 600 km s^{-1}, is about a factor of two higher than what is usually assumed. The implications of this result for the ongoing laboratory search for the dark matter particles are being studied. The above method of analysis is now being applied to other galaxies for which sufficient data on the characteristics of the visible components are available. (P.Bhattacharjee, R.Cowsik, C.Ratnam)

Galaxies and Active Galactic Nuclei

Galaxies

Dynamics

The important parameters in a galaxy collision are the impact parameter, the velocity of collision and the mass ratio of the galaxies. The dynamically significant quantity is the distance of closest approach p. The effect of changing the distance of closest approach in collisions of galaxies of comparable mass is investigated by numerical simulations. The simulations include both merging and non-merging collisions. The value of p has been chosen from the range $0 \leq p/R_h \leq 10$ where R_h is the half-mass radius of the galaxy and the initial relative orbit is assumed to be parabolic. The pair of galaxies is expected to merge if they become strongly bound and the distance between their centres is comparable to the half-mass radius. This is seen to happen when $v_p < v_e$ and $p/R_h < 3$ (v_p is the relative velocity at closest approach and v_e is the escape velocity at that distance). Merging takes place in two or more close encounters. The merging time is seen to depend strongly first on the distance of closest approach and then on the velocity at closest approach. The analytically estimated merging times show fairly good agreement with those obtained from numerical simulation. The merging phenomenon becomes less and less imporant if $p/R_h > 3$. For the most wide encounter ($p/R_h = 10$), the galaxies retain their initial structure. (P.M.S.Namboodiri)

Star formation in central regions of galaxies

The circumnuclear 'hot spots' in galaxies are explained as sites of self-regulated star formation activity with the uv flux acting as the trigger and regulator. Strong ultraviolet radiation from newborn massive stars compresses nearby dense inhomogeneities, triggering further star formation. Once initiated, the star formation wave propagates with a velocity determined by the parameters of cloud inhomogeneities. The total uv flux increases as a result of continued star formation leading to enhanced heating and evaporation of protostellar inhomogeneities. Once the uv flux reaches a critical value, propagation of star formation has to stop. Thus the star formation in such a scenario has a built-in self-regulatory mechanism. The integral stellar spectrum has been synthesized in this scenario and compared with the photometric data. The observed optical colours and low equivalent widths of hot spots cannot be explained with an instantaneous burst, but agree well with the self-regulated sequential star formation lasting for a few to several tens of million years. (*V.Korchagin, *A.Kembhavi, *Y.D.Mayya, T.P.Prabhu)

Dust in the radio galaxy 3C 270

Broad band surface photometry of the radio galaxy 3C 270 (NGC 4261) shows the presence of a dust lane oriented close to the major axis of the galaxy. The dust lane may be interpreted as the projection of a disc inclined at 75° to the plane of the sky and perpendicular to the radio axis. It is suggested that the disc is the reservoir of gas supply to the nucleus that has triggered the nuclear activity. (*A.Mahabal, *A.Kembhavi, *K.P.Singh, *P.N.Bhat, T.P.Prabhu)

Stimulated Raman scattering of water maser lines in astrophysical plasmas

The radiative transfer equations for the stimulated Raman scattering of water maser lines in astrophysical plasmas have been derived and solved. An electron density of about 10^6-10^7 cm^{-3} has been assumed. In stimulated Raman scattering, the energy of the water maser line is transferred to the side band modes: Stokes mode and anti-Stokes mode. These side band modes are proposed as an explanation for the

occurrence of the extreme features observed in the galaxy NGC 4258. The threshold value of the brightness temperature for Raman scattering is about 10^{16} - 10^{19} K, and this is satisfied. For simplicity, here only the Stokes mode has been considered and the anti-Stokes mode neglected, it being nonresonant in the case of backward Raman scattering. (R.T.Gangadhara, *Shuji Deguchi)

Active galactic nuclei

Rapid polarization variability in intense sources

The authors have recently reported the polarization changes of the intense electromagnetic radiation, in active galactic nuclei and pulsars, due to stimulated Raman scattering. In the present work it is shown that the incident and the Raman scattered radiation, when superimposed, exhibit highly complex and variable polarization patterns, some of which could account for the observed polarization variability in intense sources. Further, if the ratio of the frequencies of the incident and the scattered radiation is an irrational number, the electric field of the superimposed radiation traces a quasiperiodic rotation. The modulation of the Raman scattered sideband modes with even small perturbations due to the thermal radiation or the Raman cascade, would lead to chaotic rotation of electric field of the superimposed radiation. (R.T.Gangadhara, V.Krishan)

Intranight optical variability in optically selected QSOs

In a continuing programme to search for intranight optical variability in one radio-moderate and six radio-quiet (but all optically bright and luminous) quasi-stellar objects, using the 2.34-m Vainu Bappu Telescope, the data have clearly shown microvariability for the radio-moderate QSO, 0838 + 359, and provide strong indications of microvariability for two of the radio-quiet QSOs, 0946 + 301 and 1049 – 006, and possibly also for a third, 1206 + 459. Additional observations of these and other QSOs could provide a powerful means of discriminating among various theoretical mechanisms proposed for the energy source and, in particular, the origin of optical microvariability in active galactic nuclei. These apparent detections of microvariability in radio-quiet QSOs seem to favour models where flares on accretion discs are responsible for the microvariability. (*Gopal-Krishna, Ram Sagar, *P.J. Wiita)

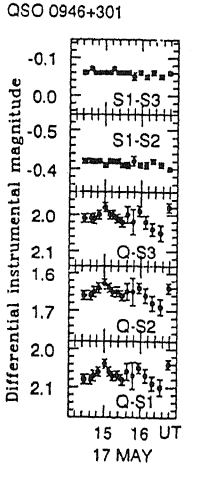


Fig.9. *R*-band observations for 0946 + 301.

Reflection of radio radiation at ionization fronts in emission line regions and accretion disks of active galactic nuclei

It is known that high frequency short duration electromagnetic pulses can be generated by reflection of low frequency radiation of relativistically

moving ionization fronts. In addition, a part of the incident electromagnetic energy is converted into a spatially periodic static magnetic field. Here, we investigate this phenomenon in the emission line region (ELR) and accretion disks of active galactic nuclei where relativistically moving ionization fronts are created by the ionization continuum. It is suggested that this process may play an essential role in (1) causing rapid correlated variability in radio radiation and high frequency parts of the nonthermal spectrum; (2) generating high frequency radiation through scattering of relativistic electrons off the spatially periodic magnetic field, a byproduct of the reflection process; (3) the diagnostic of the emission line region; and (4) absorption of the radio radiation. The anomalous absorption of radio radiation in ELR through parametric decay instabilities has been pointed out earlier. Interaction of radio radiation with ionization fronts further strengthens the case for the existence of strong correlation between the nonthermal radio continuum and the ELR phenomena as the multiwavelength observations of AGN are beginning to show. (V.Krishan)

Detection of a new emission line, C VI Kα in the soft x-ray spectra of Seyfert galaxies

Majority of the Seyfert galaxies emit excess soft x-rays (below 2 keV) and the cause of such soft excess is mostly unknown. It has been suggested that excess emission may be due either to the second power-law emission, or due to the thermal emission from the outer part of the accretion disk, or due to the leakage of soft photons from the ionized medium. To understand the cause of such soft excess emission, the authors have collected high signal-to-noise ratio spectra of 8 Seyfert galaxies from the ROSAT database. Detailed spectral analysis of these spectra were carried out using complex models and a new emission line, C VI Kα, around 0.35 keV (Figure 10) has been detected and this may be due to absorption from O VIII. These results are being modelled using the programme CLOUDY, to understand the nature and origin of soft x-rays from Seyfert galaxies. (K.K.Ghosh, S.Soundararajaperumal)

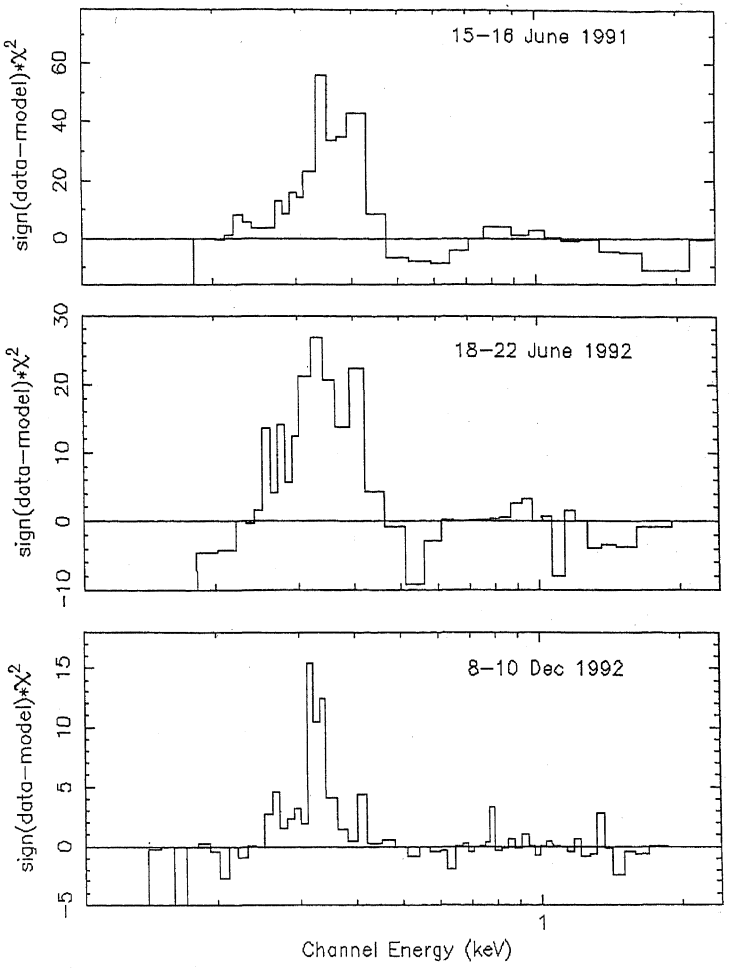


Fig.10. Residual plots (observed spectrum minus model) of the ROSAT spectra of Seyfert galaxy, MKN 766. The emission is clearly present in all spectra.

UV studies of radio-quiet and radio-loud quasars

If the ratio of the radio flux to the optical flux of a quasar is smaller than 10, the quasar is called a radio-quiet quasar while if it is greater than 10, the quasar is a radio-loud one. Most of the problems of AGN can be understood if we can find out the cause of radio-quietness and radio-loudness. To search for such causes, the authors have obtained UV spectra of more than 300 radio-quiet and radio-loud quasars observed with the Hubble Space Telescope and with the International Ultraviolet Explorer. After reddening corrections of these spectra the uv spectral indices (α_{uv}) of these quasars have been computed. From the results obtained it is found that the uv spectral index of a radio-loud quasar is much steeper than that of a radio-quiet quasar. The radio-loudness is found to be correlated with the uv spectral indices. The equivalent widths and the FWHM of the emission lines of these quasars are being measured. With these the authors propose to look for different statistical relations between the measured parameters of these objects which may throw some light on the differences between radio-quiet and radio-loud quasars. (K.K.Ghosh, S.Soundararajaperumal)

Blazars

In continuation of the work on blazars reported last year, these objects were classified into two groups based on their detection technique, since most of the blazars have been discovered either at radio or at x-ray frequencies. Blazars detected at radio frequencies are called radio-selected blazars (RBLs) and those detected at x-ray frequencies are x-ray selected blazars (XBLs). Both RBLs and XBLs have common characteristics, but important differences have also been found in their core-dominance, optical polarization, radio-luminosity and variability properties. The authors have suggested that the continuum radiations emitted from both the RBLs and XBLs over the entire electromagnetic range can be represented by either a single or a double parabola (see Figure 11). Attempts are being made using different relativistic jet models to fit the data on these objects which may give an understanding of the physics of blazar activity. (K.K.Ghosh)

Photometric monitoring of blazars

The programme aims at studying the pattern of variability in a sample of blazars over different time scales, from hours to months to years. Attempts are being made to observe changes not only in magnitude but also in colour. Fairly extensive data have been obtained for four objects over two and a half years; for a few other objects some observations have been obtained. The data are being reduced and an analysis of the actually achieved temporal coverage will be done before attempting to interpret the variability in terms of physical models. (A.K.Pati, K.K.Ghosh)

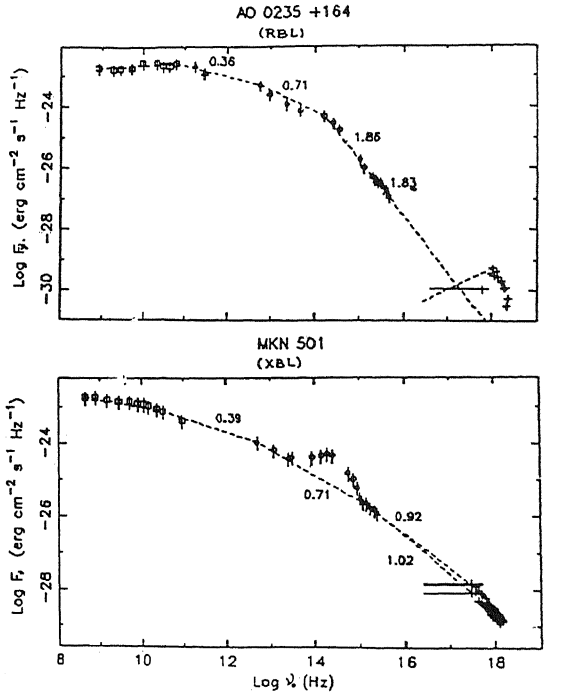


Fig.11. Multifrequency spectra of Radio-Selected (RBL) and X-ray selected (XBL) blazars. Two parabolas are needed to fit the spectrum of RBLs and a single parabola can fit the spectra of XBLs.

Application of the Hoyle-Narlikar theory of conformal gravitation

In the theory propounded by F.Hoyle and J.V.Narlikar, the standard k = o Friedmann Cosmology can be described in a conformal frame with static Minkowskian spacetime where the systematic epochal increase of particle masses (Variable Mass Hypothesis, VMH) gives rise to the usual cosmological redshifts.

Discordant redshifts, quasar-galaxy associations and luminous connections

In the VMH scenario, quasars are interpreted as 'young nearby' objects whose particle masses lag behind the universal mass function (Narlikar, J.V., Das, P.K. 1980, in IAU Symposium 92, ed. G.O.Abell and P.J.E.Peebles, p. 127, hereafter ND). The ND model could adequately explain the discordant (anomalous) redshifts of quasars as well as various observed features of quasar-galaxy association. In particular, an elegant interpretation is obtained for the phenomenon of luminous connections between objects with vastly dissimilar redshifts. The ND model was used to explain the recently observed bridge of matter apparently connecting the quasar-galaxy pair 3C232/NGC 3067 with z = 0.534 and 0.005 respectively. Work is in progress to construct a more detailed model for this pair. Also an attempt is being made to interpret some other known examples such as Markarian 205/NGC 4319 along similar lines.

Hubble relation

In VMH, the Hubble law obtains naturally as an 'age-redshift' effect. Objects of same age show a dispersionless relation and the observed deviations from the Hubble line can be quantitatively accounted for without the addition of epicycles of evolution.

Quantization of redshifts

The observed quantization (periodicities) in the redshift distributions of quasars and galaxies does not have an explanation in the expanding universe scenario. It has been suggested that the quantization can occur in VMH due to the emergence of matter from zero mass quantum-mechanical realm in discrete bursts spaced at discrete intervals. This interesting idea is being pursued.

'Missing Mass' problem and rotation curves

The 'missing mass' problem arises from the inferred peculiar velocities and velocity dispersions of galaxies. Since in VMH, the galaxy redshifts are not indicative of velocities, in principle, the mass requirements can be reduced and the missing mass problem rendered less severe. On a suggestion of J.V.Narlikar, the author is trying to explain the flat rotation curves of spiral galaxies using the fact that the equations of motion in the HN theory contain a mass dependent term which may give rise to an extra force over and above gravity.

Statistical analysis of quasar-galaxy associations

The well-known inverse relation between the angular separations and the galaxy redshifts in quasar-galaxy associations, which implies a constant physical separation, can be satisfactorily explained by the ND model. An attempt was made earlier to study whether a similar correlation exists between the angular separations and the quasar redshifts. Since the results were inconclusive, the analysis is being redone in the light of the more recent data.
(P.K.Das)

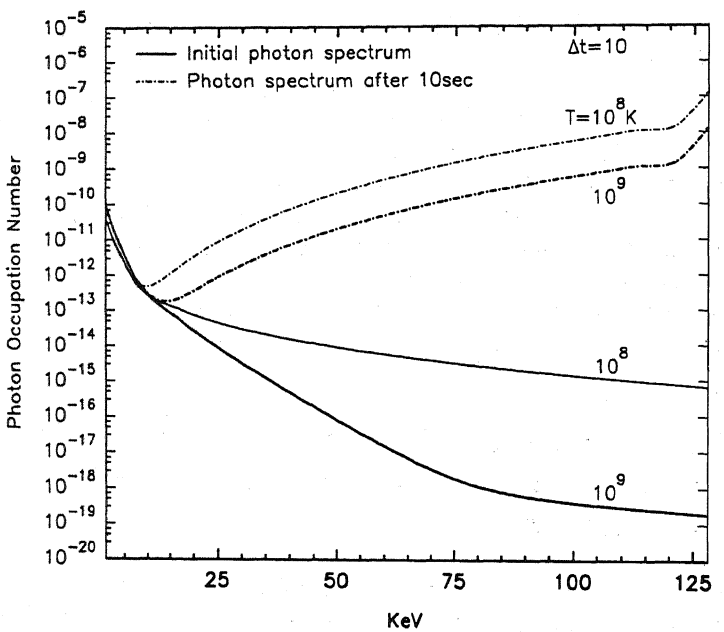


Fig.12. Emergent photon spectrum.

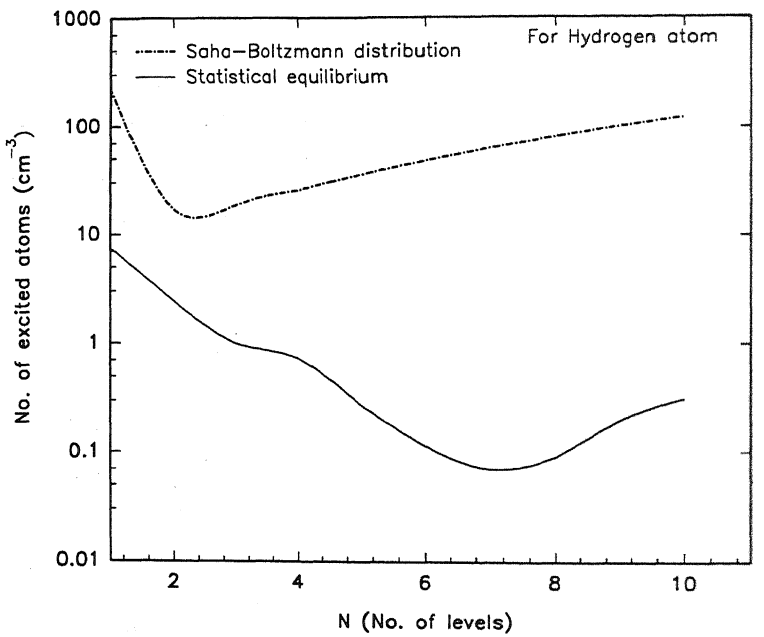


Fig.13. Number density of line forming atoms.

Theoretical Astrophysics and Cosmology

Radiative transfer

Radiative transfer in x-rays

The equation of radiative transfer of x-rays and the Kompaneets equation have been solved simultaneously. This gives the time evolution of the initial x-ray spectrum. The equation of transfer in plane parallel geometry is given by

$$\mu \frac{dI}{d\tau} = S - I$$

where μ is the cosine of the angle between the ray and the normal to the plane parallel layer, I the specific intensity and S the source function which contains the free-free emission and the emissivity from hot electrons to cold photons and a redistribution function relating the redistribution of photon energies at different frequencies. The quantity $d\tau = \sigma n_e dz$ where $\sigma = \sigma_s + \sigma_a + \sigma_a^{ff}$. σ_s, σ_a and σ_a^{ff} are the scattering, absorption and free-free absorption coefficients respectively. The Kompaneets equation is given by

$$\frac{\delta n}{\delta y} = \frac{1}{x_k^2} \frac{\delta}{\delta x_k} \left[x_k^4 \left(n + n^2 + \frac{\delta n}{\delta x_k} \right) \right]$$

where n is the photon occupation number in the phase space given by

$$n = \frac{c^2}{2h\nu^3} I, \quad x_k = h\nu/kT \qquad \text{and} \qquad y = \int \frac{kT}{m_e c^2} \sigma_T n_e c\, dt.$$

The specific intensity is obtained from the transfer equation which is used in the Kompaneets equation to get time evolution of the initial spectrum which is taken as a 'Modified Black Body' spectrum

$$I^{MB}(x) = 8.4 \times 10^{-4} T^{5/4} \rho \bar{g}_{ff}^{1/2} x_k^{3/2} \frac{e^{-x_k/2}}{\sqrt{e^{x_k}-1}} \text{ erg s}^{-1} \text{cm}^{-2} \text{Hz}^{-1} \text{ster}^{-1}$$

where ρ is the density, g_{ff} the Gaunt factor for free-free emission.

$$x_k = \frac{h\nu}{kT} = \frac{5.92647 \times 10^9}{T} x, \quad x = \frac{h\nu}{m_e c^2}$$

In Figure 12, an emergent spectrum at Δt = 10 sec, for T = 10^8 K, 10^9 K is displayed for the spectral range of 1 — 125 keV. (A.Peraiah, B.A.Varghese, M.Srinivasa Rao)

Stellar winds in O and B stars

Work on the radiatively driven wind problem in O and B stars was continued. In obtaining the radiation pressure in the line one needs to calculate the line producing ions which is obtained in two ways : (1) Saha-Boltzmann distribution and (2) by the statistical equilibrium equation. During the current year the species H I, He I, C III, C IV, Mg II, N V have been included in the calculations. In Figure 13 a plot of the hydrogen occupation numbers obtained from the Saha-Boltzmann distribution and the statistical equilibrium distribution are shown for comparison. The radiation pressure in the line depends on the occupation number and this affects the velocity profiles of the expanding medium. (A.Peraiah, B.A.Varghese, M.Srinivasa Rao)

Effects of redistribution functions R_{II} and R_V on emergent flux profiles in spherically symmetric stellar atmospheres

The influence of partial frequency redistribution (PRD) is expected to become more pronounced in the extended atmospheres of supergiant stars because of low densities. Therefore, the dependence of the emergent flux profiles on the form of the angle-averaged partial frequency distribution functions (R_{II} and R_V) is examined for extended stellar atmospheres. The line transfer equation is solved for a two-level

atom in spherical symmetry. In order to investigate the influence of the extension alone on the emergent flux profiles, velocity fields have been neglected.

This work establishes that sphericity enhances the PRD effects. This result is shown in Fig. 14 where the emergent flux profiles resulting from R_{II} and R_V are plotted in comparison to those resulting from the assumption of complete redistribution (CRD). Since the profiles are symmetric in the absence of velocity fields, only half of the frequency grid is shown here.

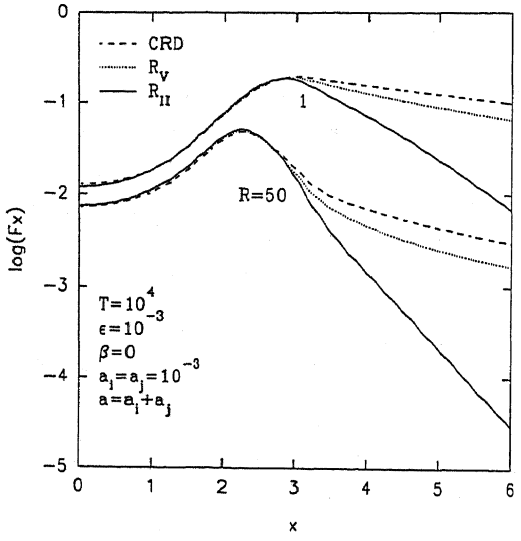


Fig.14. R denotes the stellar atmospheric extent in units of the photospheric radius. R = 1 corresponds to the plane-parallel case. T is the total optical depth; ε is the thermalization parameter, β is the ratio of continuum to line opacity; β = 0 implies the absence of any background continuum; a_i and a_j are damping parameters of the lower and upper levels of a two-level atom.

The effects of R_{II} and R_V on emergent flux profiles are much more pronounced for an extended atmosphere (R = 50) than for the corresponding plane-parallel (R = 1) case. (Prabhjot Singh, A.Peraiah)

Resonance line polarization in the presence of acoustic waves

Observations of several resonance lines in the solar atmosphere indicate the presence of wave motions, acoustic waves being one of them. The effects of acoustic waves on resonance line polarization have been investigated. This helps in the diagnostics of the type of waves present in the atmosphere and other properties of the medium through which the radiation is propagating. The radiative transfer equation is solved using the "Discrete space theory technique". A plane parallel geometry is used that adequately represents the solar type of atmospheres. The preliminary calculations show that, at different phases during the propagation of the acoustic wave, the percentage of polarization is enhanced compared to the case when no wave is present. This result is illustrated in Fig.15. Comparison is also made between the results of sinusoidal type of waves and saw-tooth type of waves. These calculations were made using only the complete redistribution of frequency as a scattering mechanism in the resonance line. Extensive work is proposed to be undertaken using different types of redistribition functions for different spectral lines. (K.E.Rangarajan, A.Peraiah)

Effects of aberration and advection on line formation

Aberration and advection terms in the radiative transfer equation are important when a medium is expanding with near relativistic velocity. We are investigating the effects of these terms on the spectral line formation with various types of velocity gradients of the medium. Changes in the spectral lines are studied by considering complete and partial frequency redistributions during the scattering process. These results will be of importance for line formation in supernovae, Seyfert galaxies etc. (D.Mohan Rao, A.Peraiah)

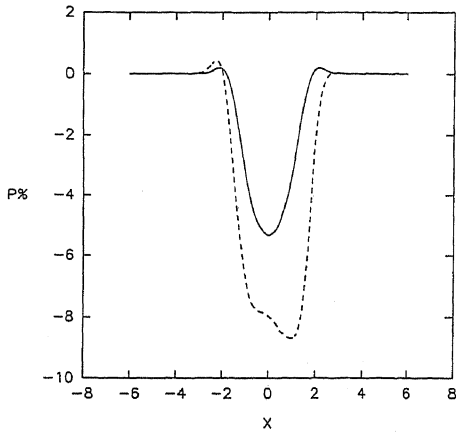


Fig.15 The percentage of polarization in a typical resonance line when no depolarizing mechanism is present, is shown against the frequency $x = \frac{(\nu-\nu_0)}{\Delta\nu_D}$ where $\Delta\nu_D$ is the Doppler width. The solid line indicates the result for a static atmosphere when no acoustic wave is present and the dotted line when such a wave is present at a certain phase. The negative values show that the polarization is parallel to the surface. The viewing angle is 84° from the normal to the surface.

Dynamical friction in anisotropic systems

Dynamical friction on moving masses arises due to the scattering of these moving bodies from their original direction of motion. This scattering process is determined by the magnitude of the impact parameter and the momentum transfer. In anisotropic systems anisotropy in dynamical friction may appear due to anisotropy in the impact parameter as well as in the velocity distribution of the scattering particles. In this work an exact analytical expression has been obtained in the form of a converging series for the dynamical friction tensor for an anisotropic system, which exactly coincides with the well known Chandrasekhar formula when the system is isotropic. Approximate expressions have also been obtained for the above series, which make computations amenable through simple numerical steps. The same formula can also be used to calculate the gravitational field due to anisotropic distribution of matter.

A consequence of the anisotropy in dynamical friction is that orbital motion in such systems become anisotropic. Thus, for the case of our Galaxy, it is found that the orbits of globular clusters of mass ~10^6 $M_\odot$ would flatten out in time scales on the order of 10^9 years. (S.Chatterjee, U.Gorti, H.C.Bhatt)

Nuclear astrophysics

Formulation and theoretical investigation of nuclear reaction networks : synthesis of ^{19}F and ^{26}Al

The author has attempted to formulate and investigate several nuclear reaction paths leading to the production of low mass elements with emphasis on ^{19}F and ^{26}Al. The nucleosynthetic origin of flourine whose only stable isotope is ^{19}F and the production mechanisms of ^{26}Al are still uncertain. This study has been made in the context of combined hydrogen and helium burning processes. Mixing of protons in a He-burning zone with appropriate temperature-density profile can initiate such a combined burning process. Such stellar environments may be prevalent in various astrophysical objects like Asymptotic Giant Branch stars and gamma-ray burst sources. (Aruna Goswami)

Nuclear partition function

For a description of matter undergoing gravitational collapse, a quantity of importance is the partition function of iron-peak nuclei. This is because the collapse hydrodynamics and the subsequent bounce (if any) of the stellar core depend critically on the value of the partition

function of the constituent nuclei. The authors have calculated the thermodynamical properties of excited ^{56}Ni nuclei (for temperatures up to 10 MeV) in the framework of a self-consistent temperature-dependent Hartree-Fock theory. This approach represents an improvement over other approaches that have been used such as modified versions of the simple Fermi-gas model of the nucleus and Thomas-Fermi type statistical calculations. For the effective interaction, the most recent models for the Skyrme interaction have been used. (B.Datta, *P.K.Sahu, *S.M.Chitre)

Compact Objects

Pulsars

Extensive analyses of pulsar observations in the framework of the polar cap model have led to a classification of the radio pulse components into the core and conal emissions based on various criteria such as morphology, polarization, spectral index etc. In this model the core emission should originate from the central region of the polar cap and the conal emission from its periphery, the dynamics of which is not yet understood. To gain an insight into such characteristics the dipole magnetic field geometry has been analysed for the general case of an oblique rotator revealing the existence of two branches of magnetic field lines with which the core and conal emissions are identified. One of these branches defines the conventional polar cap boundary giving rise to the conal emission. The region of the polar cap defined by the other branch is contained inside the polar cap but has a peculiar shape, giving rise to core emission. The analysis suggests that the conal emission originates from a region close to the stellar surface whereas for the core component to be noticeable, its emission height must be much greater. The conal beam shows a latitudinal compression whereas the core emission region shows a peculiar latitudinally elongated shape, both varying with the angle of inclination. Without involving any detailed dynamics, it is possible to reconcile and unify many apparently inconsistent features brought out by different analyses of the same pulsar pulse observations and to successfully accomodate a large number of characteristics of the pulsar radio emission. (R.C.Kapoor, *C.S.Shukre)

Neutron stars

Magnetic field decay

Theoretical investigation of the problem of evolution of neutron star crustal magnetic fields was continued. The field evolution mechanism is assumed to be pure diffusion, that is, Ohmic decay. In order to achieve realistic conclusions, the temperature distribution in the star was incorporated in the calculations and the best available model for the electrical conductivity of the crustal material adopted. The magnetic fields are assumed to be initially confined entirely to the crust and of Gaussian nature (other possibilities such as non-exponential form for the assumed initial magnetic field will be investigated as a follow-up study).

It is found that a major factor in the field evolution is the impurity parameter in the crustal composition. Therefore, the calculations are done for a wide range in the parameter space for the impurity factor. A new feature of these calculations is that the dependence of the field evolution on the equation of state of neutron star matter has been studied. Preliminary results of the computations show that, quite independently of the initial conditions, the ohmic dissipation timescales of the expelled magnetic flux lie in the range $10^{8\text{-}9}$ years. (B.Datta, *D.Bhattacharya)

Black holes

Equilibrium of a charged test particle in the Kerr-Newman spacetime

In the classical theory, the equilibrium condition for two particles of masses M and m carrying charges Q and q respectively is extremely simple, namely GMm = Qq where G is the gravitational constant. The question arises as to how this would be modified within the framework of the general theory of relativity. This was investigated by Bonnor by replacing one of the particles by a Reissner-Nordstrom black hole while the other was considered to be a test particle. The interesting results that emerged demonstrated how general relativity substantially altered a rather simple classical problem. This study has been extended by considering the equilibrium of a charged test particle placed in the field of a rotating charged black hole, namely the Kerr-Newman spacetime. It is a well known fact that rotation engenders novel general relativistic effects. Replacing one of the particles by a Kerr-Newman black hole would reveal the influence of rotation on the problem. At the same time the equilibrium of a charged test particle can act as a probe to study the combined effects of the gravitational and electromagnetic fields of the charged black holes. Equilibrium positions and their stability against small perturbations were studied in detail both when the horizon exists and when the spacetime represents a naked singularity. As expected rotation influences the situation to a considerable degree. (C.V.Vishveshwara, *M.Aguirregabiria, *A.Chamorro, *J.Suingaga)

Scattering by black holes : a simulated potential approach

The theory of scattering by black holes of zero mass fields—scalar, electromagnetic and gravitational, yields a Schrödinger type equation with different equivalent potentials. The solution to this equation can only be obtained by numerical integration. The authors have explored the possibility of replacing the exact equivalent potential by an approximate one which fits the former closely and possesses known analytical solutions. The approximation is justified in view of the fact in a real physical situation the potential may be modified by mass distributions around the black hole. The final result should not crucially depend on the minute details of the potential. Use of approximate potentials would simplify the solution of the problem. Since solutions are in the form of known analytical functions their study is more straightforward than handling numerical solutions. Also a knowledge of their analytical properties would be important in the investigation of scattering problems. A simple single potential as well as a combination of three potentials patched together to simulate the actual potential have been used. Employing this technique the authors have studied the scattering of monochromatic waves and the evolutions of wavepackets revealing the generation of quasinormal modes. (C.V.Vishveshwara, *J.M.Aguirregabiria)

Plasma physics and magnetohydrodynamics

MHD waves

The study of hydromagnetic surface waves in plasmas has acquired increased interest in the recent years. The dispersion equation for the hydromagnetic surface waves along the interface between two plasma media of different densities has been derived. The magnetic field has been assumed to be inclined at an angle to the interface. The propagation vector is also inclined to the interface whose angle is different from that of the magnetic field. The dispersive characteristics of these waves have been studied under the assumption that the Alfvén speed is much larger than the sound speed (low β plasma).

The properties and resonant absorption of the Alfvén compressional surface waves have been studied for a cold plasma when the uniform magnetic field is inclined at an angle to the vertical. For a given direction of propagation, a relation which depends critically on the densities of the plasma medium has been derived for the existence of the surface waves. This is in contrast to the incompressible case wherein surface waves can exist for any density discontinuity.
(A.Satya Narayanan)

Cosmology

MOND and the cosmological constant

A possible connection between MOND (Modification of Newtonian Dynamics) proposed as an alternative hypothesis to dark matter (DM) in galaxies and clusters and a residual cosmological constant term dominating cosmological dynamics in a $\Omega = 1$ universe was explored. Some of the coincidences pointed out by Weinberg were found to follow from this picture. It also provides a basis for the fundamental acceleration assumed in MOND. Implications for the early universe and for galaxy formation are being studied. (C.Sivaram)

Astroparticle Physics and the Early Universe

Limit on photon electric charge

From the COBE data on the anisotropy of the microwave background a very stringent upper limit of $q < 10^{-34}$ e (e being the electron charge) was placed on the photon electric charge, putting constraints on some nonstandard models. This improves earlier limits by orders of magnitude. (C.Sivaram)

Detection of thermal neutrino background

Various methods to detect a thermal neutrino background (predicted by standard cosmology) including anomalous forces exerted in sensitive devices, rotation of polarised laser beams, etc are being critically studied. Interactions of UHE neutrinos with the DM neutrino galactic halos as a possible detection method is also considered. (C.Sivaram)

Constraints on cosmic charge asymmetry and neutrino charge from the microwave background

Considering the observed anisotropy in cosmic microwave background radiation ($\Delta T/T \leq 10^{-4}$) an upper limit on the electric charge asymmetry over a cosmological scale is found which is several orders more stringent than those found earlier. The same argument constrains the charge of massless degenerate neutrinos. (P.B.Pal, S.Sengupta)

Origin of the highest-energy cosmic rays

Work on the topological defect scenario of the origin of the highest energy cosmic rays has been continued. Monopole-antimonopole annihilation has been identified as a promising candidate process for generating the observed highest-energy cosmic ray events. (P.Bhattacharjee, *G.Sigl)

The possibility that there may be a break in the highest-energy cosmic ray spectrum is being investigated. The observed "gap" near the so-called Greisen-Zatsepin-Kuzmin cutoff energy ~ 6×10^{19} eV in the Fly's Eye as well as Akeno data seems to be statistically significant. It is found that, if the "gap" in the spectrum persists even after the exposure factors of the two experiments increase by a factor of four in the coming years, then this can be used to rule out pure power-law models (with power-law index > 2 as expected in the shock acceleration mechanisms) of origin of the highest-energy cosmic ray events at high confidence levels. Theoretical implications of this result are being studied. (P.Bhattacharjee, *S.Lee, *D.Schramm, *G.Sigl)

The topological defect scenario, in which the cosmic ray injection spectrum is determined by the theory of quark jet fragmentation, can indeed give rise to non-power law injection spectra. The data gathered from the highest-energy collider experiments are being analyzed to determine the trend of evolution of the fragmentation function of quarks into hadrons with increasing energy. This knowledge of the evolution of the fragmentation function can then be used to calculate the injection

spectra of the cosmic ray particles in the topological defect scenario. (P.Bhattacharjee)

Primordial magnetic fields

It was shown that the field equations of massive vector fields (invoked by some authors to generate inflation) in spaces with torsion gave rise to London type equations with Meissner-like effects. The effective vector field mass was related to a time-varying torsion background in the early universe. Present values of the field are consistent with microwave background anisotropies. (C.Sivaram, *L.G. de Andrade)

Baryogenesis

It was pointed out that gravity can cause CP-violation if isospin couples to the torsion of spacetime. This suggests a possible mechanism for production of excess baryons over antibaryons in the early universe in a spin dominated phase. Violation of both CP and baryon number conservation by torsion interactions in a spin dominated phase of the expanding early universe in an isospin-modified Einstein-Cartan theory enables one to satisfy Sakharov's conditions for baryogenesis. Preliminary estimates give an asymmetry of 10^{-9}. (C.Sivaram, *V. de Sabbata)

Nonlinear baryon density inhomogeneities in the Early Universe

Certain processes in the early universe could have given rise to large nonlinear density inhomogeneities in baryons. One possible process is associated with evaporating dense quark nuggets which could be formed during a first-order phase transition from quark-gluon plasma to hadronic matter in the early universe. The role of neutrinos in erasing density enhancements before the epoch of neutrino decoupling has been incorporated. It is found that density inhomogeneities of amplitudes larger than $\sim 10^4$, created due to baryon evaporation from quark nuggets, are reduced down to $\sim 10^4$ due to 'neutrino inflation'. Implications of these results for primordial nucleosynthesis are being studied. (P.Bhattacharjee, *J. Alam, *B.Sinha, *S.Raha)

High Energy Astrophysics

Optical identification of gamma-ray burst sources

Sources of bursts of gamma-rays (GRBs) lasting for a few tens of seconds on an average, have been known and observed for over twenty years. They seem to be isotropically distributed all over the sky and are not known to repeat. The BATSE (Burst and Transient Source Experiment) instrument on board the Compton Gamma Ray Observatory (CGRO), designed to perform a full sky survey in gamma rays, has been detecting, on an average, a new source every day. The nature of the objects producing these bursts is not known and no identification in any other wavelength band, either during the gamma ray burst or at any other time has been made. Several alternative theoretical models for these objects have been proposed, ranging from galactic neutron stars to objects at cosmological distances. The fundamental questions of the identity of these objects, the origin of the energy source, the triggering of the burst and the physical processes involved remain a mystery.

It is essential to be able to identify the objects producing these gamma ray bursts, as a class, preferably in the optical domain, before further detailed studies can be performed. Optical identification can be attempted in near-simultaneity to the gamma ray burst as well as in the quiescent phase. Searches have been made in the past to detect optical transients in archival plates; there has been no confirmed detection. In the case of the quiescent phase, there are no criteria available, to allow a choice of a candidate, at the faint limits of the archival plate material (e.g. POSS), given that the better determined GRB positions have errors of a few arc minutes.

A project to deploy a dedicated telescope to identify the optical counterparts of GRBs has been started over the past year. The optics of the existing 18 inch Schmidt telescope will be mounted in a newly designed mount capable of slewing to any position in the sky within a few seconds. It is expected that GRB positions will be available over electronic networks within a short time of the actual burst detection. The telescope will be able to immediately slew to the position and take a rapid sequence of CCD images to determine the occurrence of an optical transient. Confirmed detection of an optical transient with adequate positional accuracy will allow follow-up deep imaging to identify the quiescent object, if any, associated with the sources.

A simulation of the experiment has been done using the telescope parameters and alternative CCD detectors to determine the feasibility of detection (to a given magnitude limit) for rapid repetitive imaging. If an optical transient occurs, it can be detected with 10 second integrations down to a magnitude limit of 17 to 18, depending on the photometric band used.

The technical groups are doing the initial assembly of the telescope, which is to be finally deployed at the high altitude site at Hanle.

A programme of deep imaging of fields in the GRB error boxes has been taken up with the VBT. This is an attempt to identify all known objects in the regions and to ascertain whether any unusual objects i.e. of unusual photometric colour or variability, exist in them. This data will form a valuable comparison database, going beyond the standard archival data such as the POSS, to enable the detection, if any, of new objects with the Schmidt telescope. (R.Cowsik, S.G.Bhargavi, A.K.Pati)

Gamma ray lines from the Orion complex

The observation of intense gamma-ray line emission from the Orion complex, attributed by Bloemen et al.(1994, A&A **281**, L5) to de-excitation of cosmic-ray carbon and oxygen nuclei, has important implications for emission from Orion in the infrared and in high-energy gamma rays, and also for the theories of cosmic-ray origins. Some of these implications are briefly pointed out. (R. Cowsik, *M.W. Friedlander)

Acceleration of UHE cosmic rays

The analogy between vortex lines in a type II superconductor and conducting cosmic strings is used to calculate the eiectric field and critical current carried by such objects using a modified Ginzburg-Landau theory. These quantities are related to the string tension and it is shown that these objects can accelerate protons to about 10^{22} eV or higher with a rough E^{-3} spectrum. (C.Sivaram)

Collisions of UHE cosmic rays

The collision frequency of UHE particles in intergalactic space in the energy range from 10^{21} eV and extrapolated to 10^{27} eV is estimated by integrating the flux over the range. The collision frequency near possible sources producing such particles is also estimated. (C.Sivaram, *A.W.Wolfendale)

Solar-Terrestrial Physics

Electrodynamics of equatorial F region Plasma

The question whether the ionospheric F region plasma motion near the magnetic equator responds to short-term changes in solar electromagnetic radiation is addressed through a study of the effect of the rapid and large decline in the solar radiative output that occurred from March through May 1992, on the postsunset maximum in F layer vertical drift (V_{zp}) over Kodaikanal. The reality of the decline is confirmed from independent ground and space measurements of solar UV spectral irradiance and conventional indicators of solar activity such as 10.7 cm radio flux, 1-8 Å x-ray flux, Mg II core/wing index and Ca II K index. Between the periods July 1991 through February 1992 and June 1992 through February 1993, there is a 35% decrease in the mean amplitude of the postsunset peak in F layer vertical drift (V_{zp}) over Kodaikanal, corresponding to a 40% decrease in the mean level of the 10.7 cm solar radio flux. Changes of the same magnitude are also seen when the comparison is restricted to a shorter interval of two local winter months preceding and following the rapid decline in the 10.7 cm flux. The results illustrate the sensitivity of the equatorial F layer vertical drift in the dusk sector to the short-term variability in the solar radiative output. Based partly on the zonal plasma drift measurements with the VHF incoherent scatter radar at Jicamarca (dip 2°N), it is suggested that the solar flux related changes in the F region zonal winds as well as in the longitudinal (local time) gradient in E region conductivity are responsible for the positive response of the dusktime peak in F layer vertical drift to the rapid decline in the solar radiative output that occurred in early 1992. (J.H.Sastri)

During the National campaign held in 1993 December - 1994 January, simultaneous measurements of F-region vertical plasma drift are made in the evening hours (1700-2100) IST) at Trivandrum (dip 0.6°N) and Kodaikanal (dip 4°N) with HF doppler radars (on two different probing frequencies). The data are used to derive the height dependence of vertical plasma drift in the dusktime equatorial bottomside F-region during the winter solstice. The height gradient of vertical drift is found in general to be positive and to vary with local time in a manner very similar to that of the ambient upward vertical drift, i.e. sunset enhancement and decay. As a function of altitude the height gradient, though highly variable, is mostly positive and large (average value 0.05 - 0.10 m/sec/km) in the height range 240-360 km and is very small in the height range 360-380 km. The positive height gradient of vertical plasma drift below the F layer peak is interpreted in terms of the altitude dependence of the relative contributions of E and F region dynamos to the electric fields responsible for plasma drifts (vertical and zonal) of the dusktime equatorial F-region. We hold the view that the observed large positive height gradient of equatorial F-region vertical drift at altitudes below 360 km is an additional facet integral to the complex electrodynamics of the dusktime equatorial ionosphere. The simultaneous measurements at Trivandrum and Kodaikanal are being extended to zonal plasma drifts particularly during the equinox season to substantiate the interpretation by verifying (a) the close association between the positive height gradient of vertical drift and vertical shear in the zonal plasma drift in lower F region and (b) the cessation of the positive gradient above 400 km. Effort is also being made to assess the possible preferential contribution of meridional neutral winds to F layer vertical drift over Kodaikanal and hence to the height gradient of the vertical drift. (J.H.Sastri, *V.K.Meena Varma, *S.R.P.Nayar)

Measurements of F region vertical drift, V_z made at Kodaikanal (dip 4°N) on 133 days during March 1991-February 1992 under non-equatorial spread-F (ESF) conditions, are studied for the characteristics of short-period (5-33 min) variations in V_z in the evening hours (1630-0130 IST). The spectral content of the fluctuations in V_z is found to depend on local time. The amplitude of the fluctuations, quantified in terms of the variance (σ^2), increases during the period of postsunset enhancement of upward vertical drift and decreases thereafter reaching a minimum during 2200-0000 IST. In consonance with this, while fluctuations in V_z in the entire band 5-33 min manifest in the postsunset hours, the longer-

period (13-33 min) components dominate thereafter (2200-0000 IST). The amplitude of the fluctuations and its day-to-day variability are higher in the local summer than in the local winter. On a day-to-day basis, the amplitude of V_z fluctuations increases with peak height in the interval 1756-2004 IST corresponding to the epoch of the evening enhancement in V_z. The results support the view that the short-period variations in F region vertical drift near the dip equator during the evening hours could be due to the polarization electric fields generated by the commonly occurring atmospheric gravity waves. (J.H.Sastri)

Observational programmes

The experimental facilities of the group at Kodaikanal (digital ionosonde, HF Doppler Radar and Magnetometer) and Kavalur (High-resolution pressure scanned Fabry-Perot Interferometer) have been used for synoptic monitoring of the equatorial upper atmosphere. In addition, the experiments have been run during the campaign periods of national and international cooperative programmes like AICPITS and STEP. The analysis of the campaign data is in progress. (J.H.Sastri, D.Karunakaran, K.B.Ramesh, J.V.S.V.Rao and staff of I & M and STR Lab).

Physics

Atomic probes of physics beyond the Standard Model

Atomic parity nonconservation (PNC) arising from neutral weak currents and electric dipole moments (EDMs) due to parity and time-reversal violation are two important non-accelerator probes of physics beyond the Standard Model of elementary particle physics. PNC in atomic thallium was recently measured to an accuracy of one per cent by a group at the University of Washington, Seattle, U.S.A. Theoretical work was done here to clarify certain issues related to that experiment.

Following the previous work on PNC in singly ionized barium, medium-sized relativistic many-body calculations have been carried out that highlight the importance of the low-lying configurations for that ion. The combined results of PNC experiment and theory for the two aforementioned cases can yield crucial information about the validity of the Standard Model.

Considerable progress has been made in the theoretical and computational aspects of atomic EDMs. The authors intend to calculate the EDM of atomic mercury using their recent theoretical formulations based on the configuration interaction and the linearized coupled-cluster methods. (A.D.K.Singh, S.Malhotra, B.P.Das, *D.Mukherjee, *W.F.Perger)

Problems in the atomic-nuclear interface

The observation of a nuclear anapole moment which arises from parity violating interactions in the nucleus will have profound implications for nuclear physics.

Preliminary estimates have been made of the contributions to PNC in thallium and caesium due to the interaction of the nuclear anapole moment with atomic electrons. This work suggests that many-body effects are important in both cases. It is clear that for thallium, which appears to be the best candidate for detecting an anapole moment, we need to develop a theory which can cope with strongly interacting configurations. (A.D.K.Singh, S.Malhotra, B.P.Das, *S.Bhagwat).

Particle Physics

In general the zero momentum limit of thermal self-energies calculated in perturbation theory depends on the order in which the time and the space components of the momentum are taken to zero. The authors show that this is an artifact of the perturbative calculation and in fact the non-analyticity of the one-loop self-energy disappears when it is calculated with improved vertices and/or improved propagators that incorporate the imaginary part of the self-energy. (P.B.Pal, *J.Nieves)

The precise statement of the equivalence theorem between the longitudinally polarized states of a massive gauge boson and the corresponding goldstone mode is discussed when the amplitude in question depends on masses of other particles (e.g. the Higgs boson) in the theory. It is shown that in such cases, one obtains two theorems which are inequivalent in general. (P.B.Pal)

The CP-violating form factor of the ZZZ and ZZγ vertices in the pair production of Z° bosons has been studied. Useful observables in azimuthal distributions are constructed to probe CP - nonconservation which may originate from these vertices. A simple two Higgs Model of CP-violation is used as an illustration. (P.B.Pal, *D.Chang,*W.Y.Keung)

The author analyzes two recent models based on the gauge group $SU(3)_c \times SU(3)_L \times U(1)_N$ where each generation is not anomaly-free, but the anomaly cancels when three generations are taken into account. It is shown that the most general Yukawa couplings of these models

admit of a Peccei-Quinn symmetry. This symmetry can be extended to the entire Lagrangian by using extra fields in a very elegant way so that the resulting axion can be made invisible. (P.B.Pal)

Chromogravity approach to strong interactions and quark confinement

This is an extension of the earlier work (C.Sivaram and Abdus Salam 1993, Mod.Phys.Lett. **A8,** 321) where a Weyl type of action for strong gravity in which colour symmetry is built into the gauge group was suggested. Here two-gluon exchanges induce the chromogravity metric at hadronic scales. The curvature and torsion are constructed. It is shown that interactions of virtual quark-antiquarks with the torsion of the colour gauge field leads to a polarization of the field tensor giving modified non-abelian field equations which imply a colour analogue of the Meissner effect. This is analogous to magnetic vortex lines trapping colour flux. The finite range of strong interaction is induced through London-type field equations. Interaction with colour axial vector torsion field gives rise to chromogravimagnetic spin-spin quark forces. (C.Sivaram, *Yuval Ne'eman)

Nonlinear dynamics

Adaptive dynamics on circle maps

A model of adaptive dynamics on a lattice of circle maps was studied. The model revealed two remarkable features: first, even when the individual local elements were regular, the adaptive dynamics could give rise to chaotic lattice dynamics. Secondly, the adaptive relaxation time between chaotic updates determined the nature of the power spectrum. In the limit of small relaxation times (when the tails of adaptive processes interfere) 1/f characteristics were obtained. (Sudeshna Sinha)

Transient 1/f noise

We reported the existence of transient (non asymptotic) "1/f noise" occurring over reasonably long time scales, in certain extended nonlinear systems. These studies contribute towards establishing that transient phenomena, which are often quite relevant in numerical and laboratory experiments, can hold a wealth of interesting dynamical features. (Sudeshna Sinha)

Self-regulatory spatio-temporal dynamics

A prototype of spatio-temporal self-regulation is proposed and its efficacy on chaotic lattices demonstrated. It is found that the suggested control mechanism was remarkably effective in bringing the extended nonlinear system to temporal invariance. Further the systematic effects of various parameters on the regulatory dynamics were shown. (Sudeshna Sinha)

Molecular collision dynamics

We are developing a code to calculate the nascent branching to the various near-resonant collisionally redistributed states in the interaction,

$$Sr(5s6p)^1\ P_1 + He \rightarrow (Sr(5s6p)^1\ P_1,\ ^3P_{2,1,0}) + He$$

$$Sr(5s6p)^1\ P_1 + He \rightarrow (Sr(5p4d)^3\ F_{4,3,2},\ ^1\ D_2) + He.$$

By integrating the coupled kinetic rate equations, we can obtain the branching ratios and fit the data measured previously. From these fits, we can extrapolate to determine the nascent branching ratios. We have also calculated the theoretical branchings, by a semiclassical method. (Sharath Ananthamurthy, *P.D.Kleiber ,*K.M.Sando)

Cavity quantum electrodynamics experiment using an atomic beam

Efforts are under way to build an atomic beam apparatus to conduct cavity quantum electrodynamical experimental work. In particular, the authors propose to measure the weak Casimir-Polder force that is experienced by atoms in a highly reflective narrow cavity (cavity width 0.7-7μm). The apparatus is to be designed as modular components and will consist of a source which is an effusive beam of xenon atoms in the ground state cooled to liquid nitrogen temperature, a mechanical slotted disk velocity selector (SDVS), a collimator and cavity plates designed so that the cavity width is variable. The atoms emerging from the cavity are ionized by electron impact and detected by ion-detection hardware. By measuring the transmission intensity as a function of cavity width, one can determine the Casimir-Polder force. Additionally, mass-dependent effects on the Casimir-Polder interaction are to be examined by spatially resolving the isotopes of xenon in a B-field.

Atomic beam chamber designs are being finalised before fabrication. Vacuum generation in the chamber is achieved by a turbo-molecular pump backed by an oil-free diaphragm pump. (Sharath Ananthamurthy, R.Cowsik, A.K.Saxena, R.Srinivasan)

Atomic physics experiments

Preparations for setting up fundamental atomic physics experiments are on. These are interference experiments involving a tunneling junction to test violations of time reversal and parity symmetries. The procurement, fabrication and preliminary testing of many subsystems (e.g.electronics, mechanical parts for the external cavity and optics) which are required for making a tunable laser diode system, have been completed. This and similar diodes will be used for the Stark shift experiments as well as the EDM experiments. This laser diode will be used in some spectroscopic studies and later in the fabrication of the neutral atom trap. Testing the full laser diode assembly and fabrication and testing of the trap are expected to take less than a year. A tunneling junction using two prisms with an air gap of a few microns is being made in the Photonics Division of IIA. (Sudha A. Murthy, A.S.Babu, P.K.Mahesh, *Simon Pereira, A.K.Saxena, J.P.Lancelot, J.P.A.Samson)

Some theoretical studies relevant to wave-particle duality have been completed and an experiment with down converted photons has been proposed to clarify the issue of induced coherence in interference experiments involving multiple down conversions. It has been found that the indistinguishability of interfering paths alone is sufficient to explain all the previous experimental results and the proposed comments on the context dependence of the notion of wave particle duality. Quantifying wave and particle information in interference experiments is based on the fact that the coherence (wave information) is proportional to the overlapping probability amplitudes and particle information (or "which path") is proportional to the square of the amplitudes. Situations have been discussed where there is wave and particle information with proportions very different from what is encountered in interference experiments. (Sudha A.Murthy, *C.S.Unnikrishnan)

Optics

High resolution astronomical imaging using rotational shearing interferometer

The rotational shearing interferometer was redesigned and refabricated incorporating a tilt mirror assembly and test runs at 234 cm VBT were carried out. The interferometer with a complete on-line correction for atmospheric turbulence is being developed for further observations. (A.K.Saxena, *N.Udaya Shankar, *R.Jayadev, *M.Selvamani, J.P.A.Samson)

Synchrotron radiation beam line optics

A machine for grinding and polishing spheroidal surfaces has been designed and fabricated. A pair of zerodur blanks of dimensions 300mm x 50mm x 50mm and 500mm x 50mm x 50mm for a spheroidal and a flat mirror respectively, have been prepared and the surface generated. The polishing and figuring of the spheroidal mirrors are nearing completion. The profile of the spheroidal mirror thus shaped is close to the theoretically calculated values. The flat mirror is being polished and figured to the required accuracy. Interferometric tests are being used for monitoring the surface. (R.Cowsik, A.K.Saxena and Optics Staff)

Sun shield panels of very high resolution radiometer cooler

In continuation of the work on VHRR sun shield panels an MOU was signed between IIA and the Indian Space Research Organisation for another two sets of sun shield panels for INSAT II C,D,E satellites. One set of panels was already polished and handed over to ISRO on March 10, 1995 on schedule. The panels were received by Sri R.Aravamudan, Director, ISRO Satellite Centre, Bangalore. (A.K.Saxena and Optics team)

The precision optical components of a Null lens optical system of LEOS-ISRO were evaluated in the optical testing shop using Zygo Interferometer and delivered with the supporting documents. (A.K. Saxena)

Telescope for the Comet SL-9 Jupiter encounter

An 8 inch achromat telescope tube was designed and fabricated with HDPE light weight material especially for the observation of Jupiter-Shoemaker-Levy 9 collision. The 6 inch Carl Zeiss telescope mount was modified to adopt the 8 inch telescope tube. J.P.A.Samson participated in the expedition to Hanle, Ladakh to install the telescope at that high altitude site. Performance of the telescope was tested successfully in the high altitude conditions for a period of 8 days. (A.K.Saxena, J.P.A.Samson)

Echelle spectrograph

To meet the need for the interim period and to gain experiences in building the proposed high resolution echelle spectrograph, an optical layout for the echelle spectrograph was optimised for use on the 234 cm telescope using a new grating and other existing optics — a collimator, prisms and a camera. Configuration details of this moderate resolution spectrograph have been worked out and fabrication of the spectrograph has been taken up. (R.Cowsik, A.K.Saxena, A.V.Raveendran, J.P.Lancelot)

In connection with the fiberlinked high resolution echelle spectrograph project for VBT, a large echelle grating of 52 gr/mm blazed at 70 degrees has been procured from Milton-Roy. A cross dispersion prism has also been obtained. Alternative designs of the collimator camera system are being evaluated. (N.K.Rao, A.V.Raveendran, A.K.Saxena, Unnikrishnan Nair)

In a project aimed at obtaining low resolution spectra a Jobin Yvon concave grating has been obtained. It is proposed to use an optical fiber with a 100 micron core drawn from the prime focus of VBT to couple to the concave grating spectrograph. Initial mechanical arrangements are complete and experiments are in progress. (N.K.Rao, F.Gabriel, ..Jayakumar)

Spot deflection cube

High precision optics employing a 35 mm cube with a central hole for accurate spot deflection measurements of the order of 10^{-6} to 10^{-7} radian for the gravitation experiment at Gauribidanur, was fabricated in the workshop. All the four sides required figuring to 1/10 wavelength accuracy and better than 1 arc minute parallelism between the sides. A through hole at the centre with dimensional accuracy of less than 10 micron was provided. (Optics Staff)

Small tilt measurements using prism

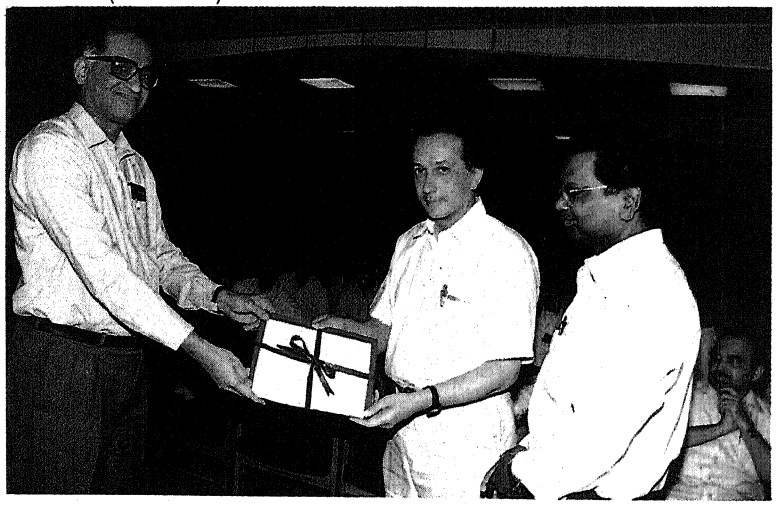
A simple theoretical study was undertaken to measure small local tilts in the wavefront, exploiting the large changes in the angle of emergence for small changes in the angle of incidence in a prism. A rigorous theoretical and experimental study is in progress. (J.P.Lancelot, V.Krishnakumar)

Aluminising

The vacuum coating facility at Kavalur and Bangalore is being used for aluminium coating of various optics of the Institute. The 24 inch solar tunnel mirror, the 12 inch eclipse mirrors and about 20 mirrors of the Bangalore Amateur Astronomers Association were aluminised during the current period. The RSI beam-splitting surface was coated with 50% reflectivity at the 12 inch plant in Bangalore. A simple arrangement was set up for winding the tungsten filaments which are used in the plants. (K. Ramankutty)

Speckle interferometer

Significant progress has been made in the fabrication of the speckle interferometer to be used on the 234 cm Vainu Bappu Telescope (VBT), Kavalur. The Centre for Manufacturing Technology Institute (CMTI), Bangalore, has undertaken the job of fabricating this sensitive instrument. The mechanical design had been tested by CMTI using FEM analysis to find any deflections, distortions, stress, flexure etc. Based on this report, the design was modified using CAD to suit the requirement of the CNC wire cut EDM and CAM. A computer simulated test has shown that the instrutment can hold any detector of 10 kg weight kept at a distance of 200 mm from the back plate of this interferometer with a flexure of 1.3 micron. Welding technology has been avoided to maintain finer accuracies. Mechanical fabrication using 410 stainless steel whose thermal expansion is less than that of crown glass is in progress and it is hoped that the performance of this interferometer will be tested in June 1995, at the cassegrain focus of VBT. We have been able to maintain the surface accuracies of the plates and mounts within the tolerance limit (~ 5 micron). A mechanical spacer of 450 mm is also being made to keep the focal point instrument sufficiently away from the backend of the mechanical adaptor of VBT to obtain the best focus at the cassegrain end. Efforts have been made to keep both the flanges equidistant at all points with a tolerance of ~ 25 microns. (S.K.Saha)



Handing over of the VHRR sun shield panels

Electronics and Instrumentation

Mosaic-CCDs

CCD wafer run

In order to meet the mosaic CCD requirement, a wafer run has been initiated with Thomson CSF of France. This batch will consist of 44, four inch silicon wafers, with each wafer having two dices of 2048 x 2048 pixel three side buttable CCDs. These CCDs have four readout registers enabling fast readout of an image. The devices operate in the MPP mode with a very low dark current. On-chip temperature sensors are available on the device. The CCDs are three side buttable with 200 μ dead zone on two sides and 100 μ on the third side. This feature enables the arrangement of CCDs in 2 x n mosaic configuration. The wafer run has yielded 8 Thomson "S" grade devices and 12 devices in other grades. (S.Muralishankar, R.Srinivasan, R.Cowsik)

CCD controller

A new controller design based on Motorola's Digital Signal Processor, DSP 56002, has been taken up recently for use in the mosaic CCDs (THX 7897). This controller will be capable of reading 16 CCD readouts at 40 KHz with a PC-AT 486 forming the host. Data transmission between the controller and the PC is configured on a three-wire high speed link. (S.Muralishankar, B.Nagaraja Naidu, R.Srinivasan)

Liquid nitrogen Dewar

A three litre liquid nitrogen CCD Dewar is under fabrication in IIA workshop. The Dewar design is modular and is fabricated in two parts. The lower part houses the copper can having a three litre LN_2 capacity with its associated fill and vent structures, vaccum port for evacuation of the Dewar and Graniville Philips convectron vacuum gauge for on-line monitoring of the vacum status. A stainless steel bellow is used to support the LN_2 copper can to take into account the axial load on the thin neck tube. The upper portion of the Dewar houses the detector, its electrical connections and the optical port. The cold finger is implemented through a spring loaded copper block so that the chip reaches the required thermal equilibrium. The upper housing can easily be changed to accommodate a change in the CCD type. The upper and lower parts of the Dewar are joined with an O ring port providing vacuum integrity. The inner body of the Dewar and the copper can will be gold-plated to achieve low emissivity and will act as a radiation shield. Initial calculations show that the liquid nitrogen hold time of this Dewar would exceed 24 hours for a single fill. (S.Muralishankar, R.Srinivasan, P.U.Kamath, Sagaya Nathan)

Data acquisition system

Window based CCD data acquisition system

A MS-Windows based image data acquisition system is currently under development and is likely to be ready for field testing shortly.

The highlights of the new system are:

1) Single monitor operation

2) Capacity for handling large format (e.g. 2 K x 2 K) CCDs

3) More user-friendly graphic interface.
(Faseehana, A.V.Ananth)

Counter timer card

A PC based multi counter/timer card has been implemented. The card uses the Intel programmable 8254 ICs as timers to generate multimode

timing functions and to generate timing wave forms. This card is useful in generating the time delay function for the CCD scanner programme. (B.Nagaraja Naidu)

Analog-digital I/O card

A PC based analog-digital I/O card has been designed and developed in the Electronics Laboratory. The card incorporates the following features:

1) 32 single ended input channels

2) 12 bit ADC 35 µsec conversion time

3) Two 12 bit DACs, 3 µsec settling time

The ADC and DACs can operate either in unipolar or bipolar mode with a voltage range covering ± 10V or ± 5V. The digital Input/Output lines are TTL compatible and are configured as 16 bit inputs organised as two bytes and 16 bit outputs, also organised, as two bytes.
(B.Nagaraja Naidu)

On-line selection of images:

An electronic image selector was designed and fabricated. This device counts the number of pixels having brightness above a threshold value, which can be pre-selected. The best image (based on this number) amongst a sequence of a given number of images is stored on a buffer. This image is written on the hard disk of a computer, and a new image (again the best from a new sequence of images) is written on the buffer. The present device can handle only small images, but the same principle can be extended to bigger images in the future. (V. Krishnakumar, P. Venkatakrishnan)

The Photometrics 1K x 1K CCD system

Two new Photometrics 1K x 1K systems have been installed and tested. One of these is for use at VBT and the other for the asteroid scanning project. These two systems are identical and each is configured with SUN Sparc LC as a host system and a VME bus.

While testing the Time Delay Integration (TDI) mode of operation it was found that the CCD VME controller board needed more memory than the existing 4 megabytes to scan a large field. The problem was intimated to and sorted out in consultation with the vendors when they supplied two controller boards with 8 megabytes of memory. During imaging with the VBT a nonuniform dark integration was noticed over the surface of the CCD. It was realised that the serial clocks could cause a glow during the integration. A new set of EPROMs obtained from Photometrics which avoids serial clocking during exposure, solved the problem.

The SUN Sparc workstations acquired for the CCDs were tested in the laboratory in Bangalore and subsequently relocated to VBO and Japal Rangapur Observatory of Osmania University. The data acquisition software for the above systems were supplied by Inovision Corporation, USA. Initially the software had many bugs as it was developed to operate under Suntools and was then ported to Openwin environment. The bugs were fixed through a dialogue with Inovision Corpn. Initially the software did not support TDI and FITS format of data storage, which were later supplied by Inovision Corpn. as command line routines. These routines were then linked to the main operating software in Bangalore. Satisfactory observations have been carried out using the system at VBT, Kavalur (S.Muralishankar, A.K.Pati, R.Srinivasan)

A linear CCD camera system

A linear Charge Coupled Device (CCD) based data acquisition system has been designed and built to replace the existing photographic recording at the Spectroheliograph facility in Kodaikanal. A CCD of

6000 pixels and 10 by 10 microns in size (Fairchild CCD 191) has been used. The camera system digitises a 60 mm solar image with high resolution. The data acquisition is implemented with a PC/AT 486 system. The two-dimensional image data is acquired by scanning the camera across the image. The data acquisition software synchronises the 12 bit pixel data readout to the scan speed. The image is displayed on the computer monitor with an 8 bit resolution. The 12 bit digital data is stored in the hard disk of the computer and a software routine converts the data to FITS format, enabling easy portability to other computers. The software is user friendly and menu driven. Initial field trial of the system is planned with the Tunnel Telescope and the mechanical interface design has been initiated. (R.Srinivasan, G.Srinivasulu)

Ellipsometry with a Babinet compensator

The complex refractive index of an aluminium layer deposited on a mirror surface is sought to be determined using the value of the phase shift between two orthogonal polarisations, after reflection from the surface. The effect of measurement noise on the convergence to the required values of the refractive index is now being simulated. This programme is aimed at determining the instrumental polarisation of the Kodaikanal solar tower. (K. Sankarsubramaniam, P. Venkatakrishnan)

Digital display system for UPSO, Nainital

The digital display unit for the 1 metre telescope at UPSO, Nainital, has been installed successfully in 1994 August. The system is modular and consists of the following subsystems.

a) Hardware:

1) PC-interface electronics

2) Sidereal clock

3) Power supply

4) A PC/XT host

The PC-interface electronics bin consists of the following hardware:

(i) Two synchro to digital converter cards one each for RA and DEC axis,

(ii) A data multiplexer card to multiplex the UT and ST data,

(iii) A line driver/receiver card to send/receive digital signals to/from the host computer

(iv) Provision for the necessary hardware to implement star changing function

A sidereal clock procured from Raman Research Institute, Bangalore provides display of UT and ST and BCD output for the computer interface. All these subsystems are housed in a standard 19" rack which is located in the control room. The host PC/XT is positioned on the observing floor along with a line driver/receiver unit. The whole system has been wired such that either the digital or analog (dial) display can be selected with the flip of a toggle switch.

b) Software :

The driver software is developed in Turbo-Pascal and the programme execution flows through a set of procedures. A three-speed synchronising algorithm is implemented in software to combine the three synchro outputs to form a single 20 bit for RA and 19 bit for DEC. The initial offset corrections are implemented in software with reference to the dial display system. The coordinates of HA, DEC and RA, the ST, UT and the derived parameters like zenith distance and air mass are computed and displayed on the monitor continuously. The software has also provision for the finer corrections in the coordinates with reference to stars. (R.Srinivasan, B.Nagaraja Naidu)

Seeing monitor

The seeing monitor developed during the last two years (AR 1993-94) consists of a pair of detectors placed next to each other, mounted on the focal plane of a telescope. Transit of a star across the field of view of a telescope would also involve the transit of the blurred stellar image across the two detectors. Thus the outputs V_1 and V_2 from the two detectors give the differential and sum outputs:

$$\delta V(t) = V_1(t) - V_2(t)$$

and

$$V_+(t) = V_1(t) + V_2(t)$$

whose typical pulse shapes are as given in Figures 16 and 17 respectively. Thus the angular diameter of the stellar image is given by, $\delta\dot{\theta} = \dot{\theta}\delta\tau$ where $\dot{\theta}$ is the angular velocity of the star in its transit across the sky. Since $\dot{\theta}$ = 15 arcsec/sec, a one arc sec seeing requires an accurate measurement of $\delta\tau \approx 0.06$ second. With our system we have accurately determined the diameter of the moon ≈0.5 degree. For the determination of the angular diameter of a second magnitude star a further amplification of the signal by 10^5 is also needed with noise suppression, which is now being pursued. (S.Chatterjee, K.C.Thulasidharan, V.Krishnakumar, K.Sankara Subramaniam)

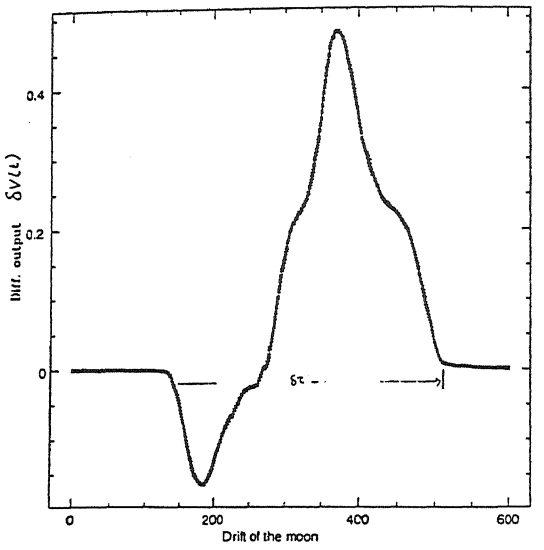


Figure 16

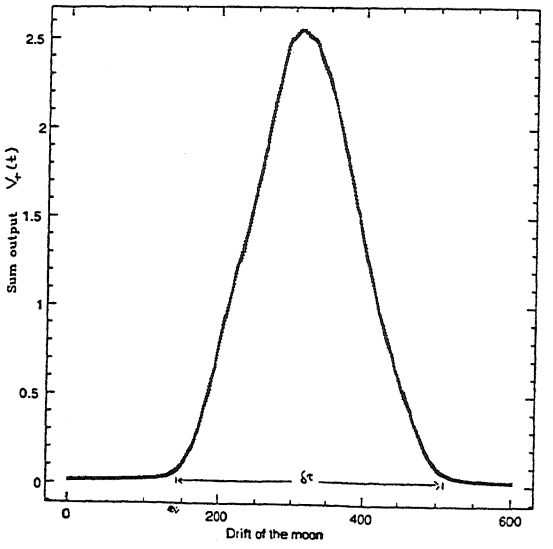


Figure 17

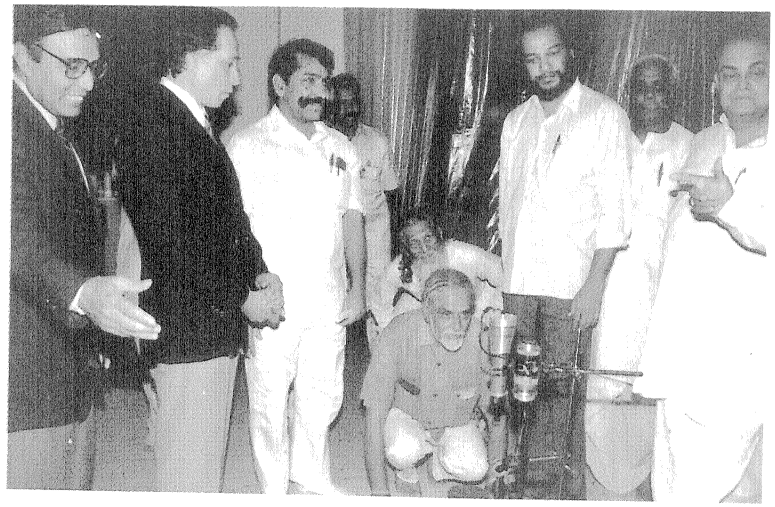
Schmidt Telescope

Mechanical work

This telescope is intended for observations of the optical counterparts of gamma ray sources and other stars in the optical wavelengths. The drive system consisting of ground helical gear trains driven by a special type of heavy duty DC motor with built-in E.M.brake is suitable for the high speed required for quick acquisition of the optical counterparts of gamma ray sources in the sky. This is a compact light weight telescope designed for good structural rigidity and high natural frequency from the point of view of fine tuned control system. The telescope design has been completed after discussion with optical, electrical, electronics and mechanical engineers. The fabrication, machining and other processes have been arranged through the technical facility available at IIA workshop and specialised small scale engineering industry in and around Bangalore. Some of the major components such as the centre piece, the upper tube and the lower tube, north and south beams, side members, R.A. and Dec bearing housing, helical gears, gear boxes, trunnions, steel piers needed careful monitoring during the manufacturing process and to assure the quality at each step. No single engineering industry had all the facilites and the work was distributed to about six work centres with high level interaction by the Mechanical Engineering group. The trial assembly of the mount and its drive system is completed. The manufacture of a few more subassemblies such as focussing, reimaging, counter weight, CCD mounting etc are to be completed. Drive system is ready for testing the servo system. (B.R.Madhava Rao, Mechanical Division Staff)

Electronics

A drive and display system has been designed for the telescope. The components of the drive are configured to operate at extremely low temperature which are experienced in the Himalayan high altitude sites. To reduce maintenance and to increase the reliability, brushless DC servo drive with Pulse Width Modulation (PWM) amplifiers have been chosen. PTFE insulated power and signal cables have been selected to withstand the low temperature. Sinusoidal commutation using a resolver mounted on the axis is chosen to obtain uniform motion even at low speeds. A pair of motors on each axis will control all the speeds required. One motor serves as drive motor and the second motor is used in the counter torque mode to eliminate backlash. A 17 bit absolute encoder has been chosen to provide 10 arcsec position information. An incremental encoder with 25,000 counts per revolution provides the velocity feedback. The control logic function is implemented in a personal computer incorporating suitable interface cards. The control console for the telescope was designed in house and fabricated by a small scale industry. (V.Chinnappan, A.S.Babu, N.Jayavel)



MP's visit IIA Instruments Laboratory

Radio astronomy

Gauribidanur radioheliograph

The E-W arm of the heliograph was divided into 8 groups of 16 elements each. A 64 channel digital correlator was used to get all possible correlations. Phase corrected outputs are used to synthesize the E-W one-dimensional scans of the sun at 51 and 77 MHz. These scans were calibrated using the radiosources Tau A and Cas A and CLEANed with the observed E-W beam on a point source. During the period 1995 January-February the sun was relatively quiet and no transient burst activity was seen. The observed flux densities varied from about 2700 Jy to 8800 Jy at 51 MHz and from about 8000 Jy to 17000 Jy at 77 MHz. The E-W half-power diameter varied from about 43' to 56' at 51 MHz and from 33' to 44' at 77 MHz. The brightness temperature varied from about 0.3×10^6 K to 0.6×10^6 K at 51 MHz and from about 0.5×10^6 K to 0.8×10^6 K at 77 MHz. The half-power widths of the observed scans remained approximately constant at both 51 and 77 MHz during the above period. The variations in the brightness temperature and the variations in the integrated flux densities are correlated. There is no correlation between the variations in the brightness temperature and the half-power widths. (K.R.Subramanian, R.Ramesh, M.S.Sundara Rajan, Ch.V.Sastry)

Digital correlator system

Switching circuits were installed for the 64 channel correlator system to make observations of the sun at two frequencies (55 MHz, 75 MHz) simultaneously.

A prototype was built using NRO (Nobeyama Radio Observatory) correlator chips. Design of the 1024 channel correlator system to correlate signals from EW antennas with signals from NS antennas using NRO correlator chips has been completed. Fabrication of the system has been taken up and the system is expected to become operational by the end of this year. Test circuit has also been built to test NRO corrector chips. (M.S.Sundara Rajan)

Mass positioning system for Gravitation Experiment

In order to move and position the weights required in the Gravitation Experiment at Gauribidanur a micro stepping stepper motor drive has been built. This approach eliminates the need for tachogenerators and the closed loop control normally required with DC servo motors. The mass system was brought from Gauribidanur and a test setup has been created in our workshop to test the slow motions. (R.Cowsik, V.Chinnappan, N.Jayavel, B.Nagaraja Naidu)

Electrical work

a) Efforts are on to have a new indoor substation in lieu of the existing outdoor unit. This work is carried out in close interaction with the CPWD.

b) The electrical distribution system at Japal Rangapur observatory, Hyderabad was improved, to take care of proper earthing and lightning protection.

c) A 75 KVA diesel generator set was commissioned at Bangalore campus for backup power. A 37.5 KVA DG set was commissioned at Kodaikanal.

(K.Padmanabhan, K.Rangaswamy, Narasimhappa, V.Chinnappan)

Work at Mechanical Workshop

The following fabrication jobs were undertaken and completed:

(i) Some components of the 61 cm Schimdt Telescope.

(ii) Tool for synchrotron radiation beam line project.

(iii) Base and filter holder for 8 inch telescope intended for the observation of the collision of Comet Shoemaker-Levy with Jupiter.

(iv) Base for the 18 inch telescope at Hanle.

(v) A mechanical rig for moving the source mass around the gravitational experimental setup.

(vi) Manufacture of CCD Dewar for mounting a mosaic CCD.

(vii) Servicing of dome wheels at Nehru Planetarium, Bangalore.

(viii) Machining of VBT dome drive axles.

(x) Maintenance of pipelines of central air-conditioning units at Bangalore campus.

(Staff of the Mechanical Engineering division)

Computing Facilities

Bangalore Computer Centre

Local Area Network

A Local Area Network comprising about 100 nodes has been set up in the Institute. This network will enable users to work from their offices in addition to working at the central facility. The main feature of the network is a thick ethernet backbone to which most of the workstation class equipment is connected and 12 thin ethernet segments. Individual personal computers or similar equipment can be hooked on to the thin ethernet. An uninterrupted power supply connection is also provided to the individual offices.

A Sparc Classic workstation

A Sparc Classic workstation was added to the existing ones at Bangalore.

Expansion on Sparc-10

The following items have been ordered and installed on Sparc-10:

1) a 2 GB hard disk,

2) a 14 GB 8 mm tape,

3) Solaris 2.4 operating system is going to be installed in place of the existing SUN OS.

A VME interface for Sparc-10 also has been procured to install a special purpose board called GRAPE. This is to be used for solving N-Body problems. The board was procured under the India-Japan collaborative program.

Expansion on DEC-ALPHA

The following add-ons have been ordered for the DEC-ALPHA machine:

1) a 2.1 GB hard disk,

2) a 4 GB DAT,

3) 32 MB RAM,

4) a terminal server for 8 asynchronous lines.

A mathematical and statistical package (IMSL) is also being procured for DEC-ALPHA. These are likely to be installed shortly. To help the scientific community with word processing applications four IBM-PC 486 computers and a laser printer have been procured.

A set of programmes were developed to feed the PC based data into the IRAF format for analysing the Jupiter images using Blind Iterative Deconvolution technique (BID).

Several utility programs have also been developed for converting image data from the existing CCD image data acquisition systems at VBT, the 102 cm telescope and also PDS tapes to the standard formats for further processing on Sparc systems.

A wide area connectivity has also been established for remote logging and file transfer facilities through a dedicated leased line to the Indian Institute of Science, Bangalore. (J.S.Nathan, S.S.Chandramouli, A.V.Ananth)

Vainu Bappu Observatory

Vainu Bappu Telescope

Replacement of guide rod for focus assembly

The original guide rods had worn out due to extensive usage resulting in alignment error during observation. Tightening of the linearly moving pillow blocks had reached the extreme limit. Hence action was taken to manufacture 8 new guide rods. Out of these 4 are kept as spare. They were manufactured through a small scale industry after ensuring the following quality assurance proceedures.

(i) Chemical analysis of EN 36 raw material in the form of long rod,

(ii) Case hardening of guide rods to attain 60 - 65 HRC hardness with a case depth of 1 mm after premachining,

(iii) Carburizing the ends of the guide rods where threads are present,

(iv) Finish grinding of the guide rod and ensuring straightness over a length of 600 mm and diametral tolerance within 10 micron.

The new guide rods were fixed on VBT before the observing season started in 1994. The error in alignment while focussing was eliminated at the testing stage.

New prime focus camera

This is made out of stainless steel grade 304. This has provision to mount CCDs CH 260 and P 8603 without disturbing the alignment. It has all the mechanism for guiding to the same specification as the earlier one which was catering to only CH 260.

Balancing of the telescope

A standard method of balancing telescopes using strain gauges mounted on the drive trunnions of the telescope, which has been reported earlier, has been made operational on the VBT.

Efforts are on to interface the signal output from the strain gauge bridges to a PC to reduce errors introduced by operation of the system. Using this system, tests are being conducted for different configurations of the telescope in both axes to study the behaviour of the structure.

Fixtures for thermal probes inside the dome

Fixtures were designed and mounted for locating temperature probes at various selected points inside the dome for conducting studies on the effect of temperature differential on seeing.

Preventive maintenance work

The EM brakes, tachogenerators, helical compound gear trains, torque motors, incremental and absolute encoders were cleaned, lubricated and aligned. The horseshoe spherical surface, filters, pressure pads, nozzles, pressure gauge manifold and pumping systems were cleaned and filled with dust free oil. The damaged CCD shutter was repaired. The dome bogie axle which was broken after long service was replaced by the spare recently manufactured. (B.R.Madhava Rao, Mechanical Division Staff)

40 cm telescope

Design modificatiens were carried out and the performance of the drive system and focussing system was checked. Design changes were

necessary to make the length of the R.A. axis shorter without functionally derating the telescope and to make it suitable for observation at Hanle, Ladakh (latitude ~ 32 degree N) and Burdwan (latitude ~ 21 degree N). Length of the polar axis was reduced from 1250 mm to 750 mm. This involved extensive machining of the R.A. bearing housing at Kavalur and Bangalore workshops. The design changes resulted in obtaining a vibration-free telescope that now requires a compact building and dome. Two interface adapters were designed and fabricated and mounted to locate a 17 bit encoder assembly for the R.A. and Dec axis. One 6 inch f/15 guide telescope was mounted. Interface adapters with filter holder and focussing system were designed and fabricated to mount the auto-guides along with the guide telescope and to mount the CCD with main telescope. (B.R.Madhava Rao, Mechanical division Staff)

Electronics

The electronics for the modified 40 cm telescope was completed in a record time of 27 days at VBO. The units made include translator cards for HS-50 and FD-16 stepper motors, display system, power supplies, handsets and link cables. The entire system was checked at VBO, Kavalur and the reinstalled system at Bangalore worked satisfactorily. (K.S.Ramamoorthy, N.Sivaraj, A.Ramachandran, K.Ravi, S.Ramamoorthy J.Manoharan)

Kavalur Computer Centre

Two Sparc Classic computers were installed at Kavalur to help CCD image data acquisition and analysis of images. A laser printer has also been acquired for image/graph/text printing requirements. (K.N.Kutty, A.V.Ananth, S.Muralishankar)

National Facilities

The Hanle Project

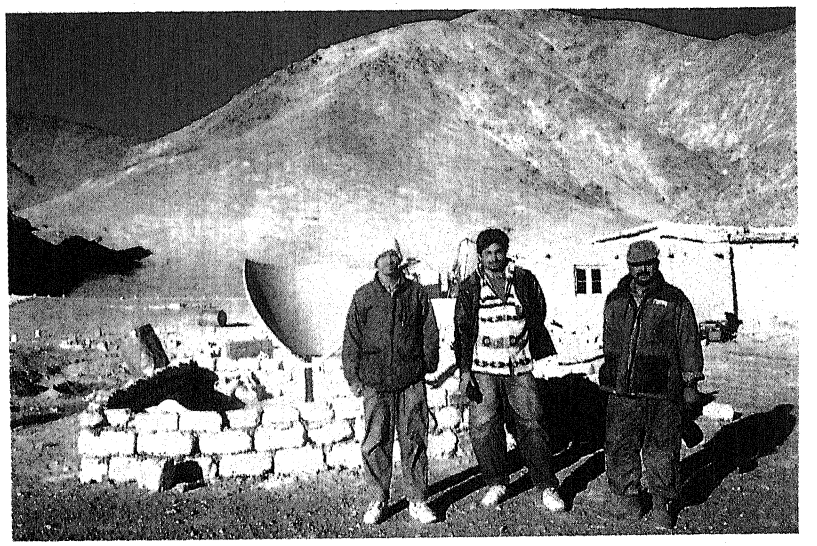
An astronomical site survey has been initiated at Hanle, Ladakh, since 1994 December. The aspects covered so far include visual monitoring of cloud cover, monitoring of ambient temperature and relative humidity at hourly intervals of day and night. For logistic reasons, the survey is undertaken at the outskirts of the Hanle river basin and plans are afoot for shifting the location to the top of the hill, Dikpa Raza Ree. A mobile 18-inch Newtonian reflector has been acquired from Jim's Mobile Inc., Colorado, U.S.A. The telescope is installed at the present location of the site survey, together with an ST-6 Peltier-cooled CCD detector and standard UBVRI filters for measurement of atmospheric extinction. The CCD could operate at –50° C during winter when the ambient temperature ranged between –10° and –27° C.

During their stint at Hanle, Jagdev Singh and V.Moorthy obtained stellar trails near zenith using the 18-inch telescope. The data was recorded on Kodak 2415 fine grain film. These trails are being analysed to evaluate the seeing conditions at Hanle. Images of the sky were also obtained near zenith and at 45 degrees above the horizon in the north, the east, the south and the west with long exposures of 15 minutes to determine the brightness. The data are being analysed. Jagdev Singh used a water vapour meter obtained from the Physical Research Laboratory, Ahmedabad, to measure the water vapour content of the atmosphere during the day. The photometer readings were obtained every one hour during the day, whenever sky conditions were favourable. This dataset is also being analysed.

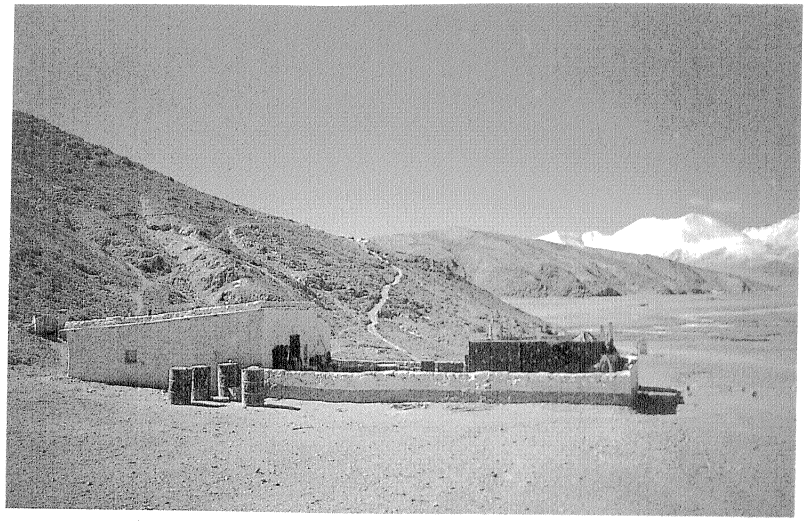
Plans to install a solar telescope at the site to obtain calcium K-line pictures of the sun did not materialise as the telescope did not reach Leh in time. The coelostat and the telescope were fabricated in Kavalur.

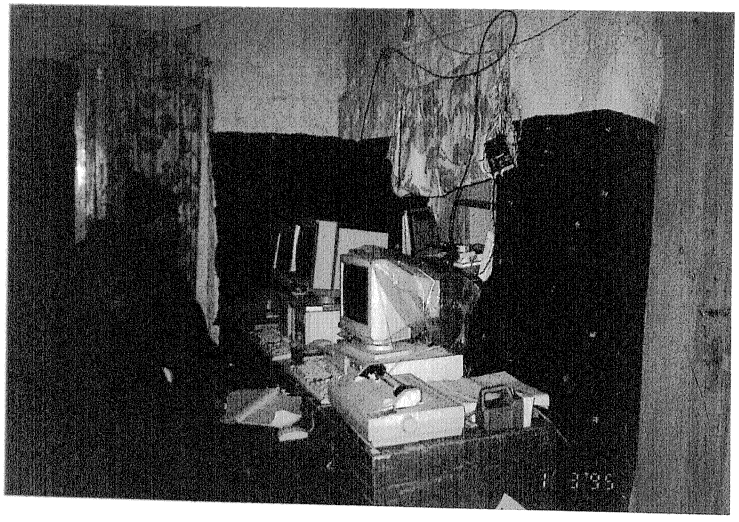
The observers who have spent considerable time observing at Hanle during this period have been : T.P.Prabhu, J.Singh, B.C.Bhatt, K.Kuppuswamy, C.Velu, N. Selva Kumar and V.Moorthy. The technical personnel who spent considerable time with them during the setting up of the field station in the severe winter were J.P.A. Samson and K.Ravi. As the person responsible for administrative coordination, M.Ramani spent long periods at Leh, with visits to Hanle in between, during this critical phase. The site survey will be continued initially for a year in order to obtain statistics on the average cloud cover over the year as well as the seasonal distribution of cloud cover.

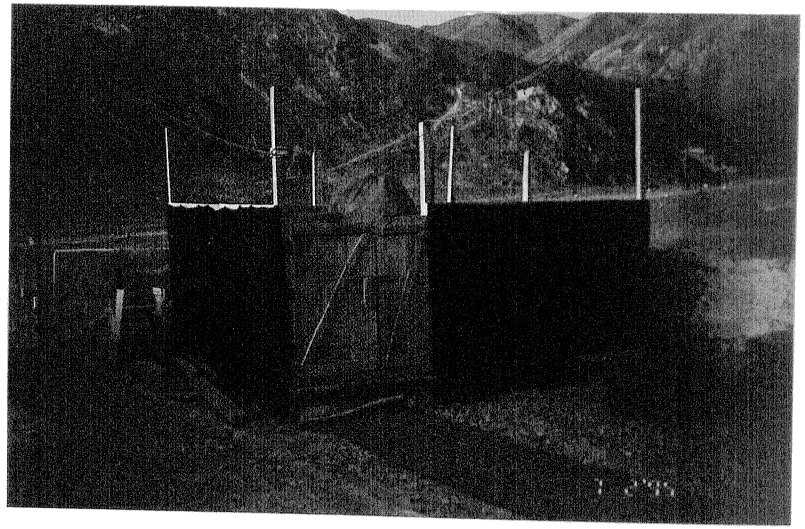
Organisation of the long term activity at Hanle has been an eye-opener in many ways and has provided invaluable inputs for any large scale activity that may be taken up in the future. The critical areas in which valuable expertise has been gained are : clothing and footwear, food supplies, transportation, medical supplies and emergency situations. The administration and purchase departments have been continuously involved in taking innovative measures for tackling problems in maintaining this activity at such a remote location.



Site Survey at Hanle





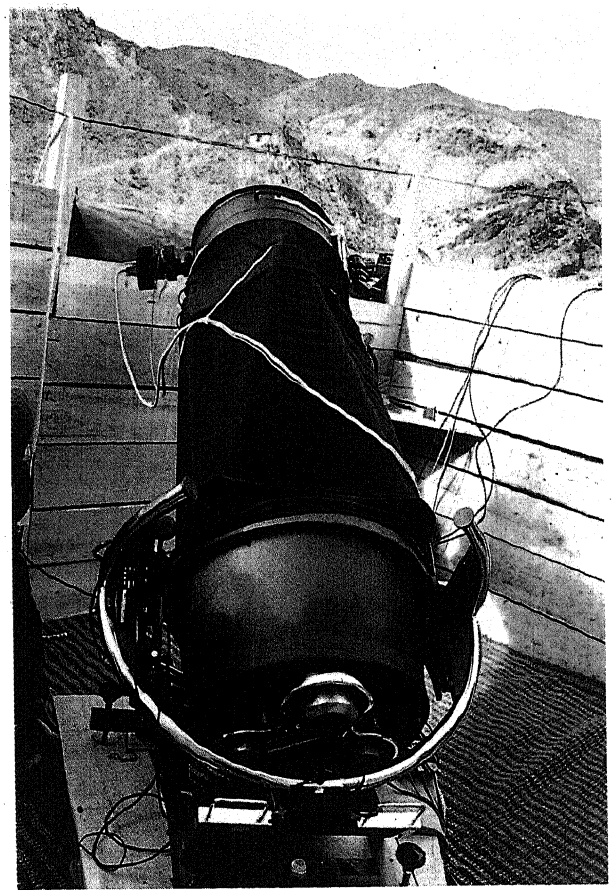


The HIROT Project

The efforts initiated the previous year (AR 1993-94) continued in 1994-95 and yielded positive results. The Science and Engineering Research Council (SERC) approved the project and funded the writing of the Detailed Project Report (DPR). An Advisory Committee was constituted consisting of Dr. K.Kasturirangan (Chairman, Space Commission) as the Chairman, Dr. R.Chidambaram (Chairman, Atomic Energy Commission), Professor G.Swarup (Project Director, GMRT), Dr.K.R.Sharma (Director, CSIO, Chandigarh), Professor S.K. Khanna (Chairman, AICTE), Dr V. Rao Aiyagiri (DST), Professor B.V.Sreenkantan (Visiting Professor, NIAS) as members with Professor R.Cowsik as the member-secretary. They recommended the setting up of three Working Groups in three crucial areas related to the project viz. Science and Astronomy, Engineering, and Logistics and Operations. Professor R.Cowsik formed these Working Groups in 1994 November with a very wide membership involving astronomers, physicists, highly skilled technical personnel and administrators from various leading institutions in the country. Many of the senior academic and technical staff members of the Institute have been co-opted into the WGs.

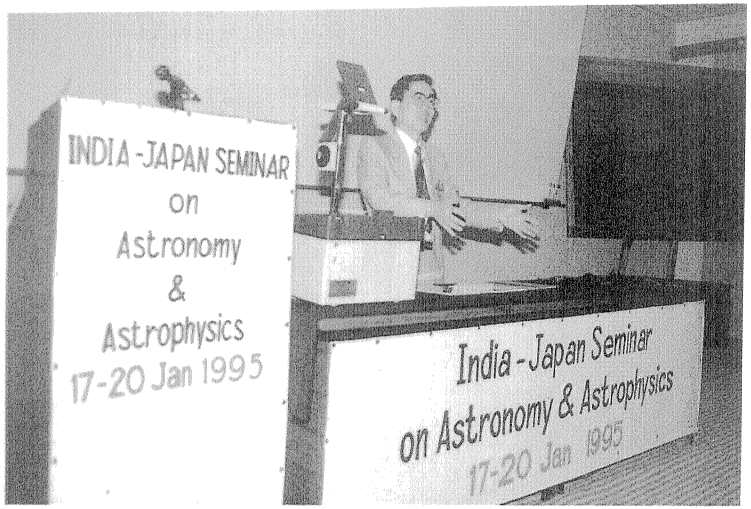
To enable the Working Groups to identify and focus on the diverse problems inherent in such a high technology project as HIROT, a draft explanatory report was prepared, both to familiarise the Working Group members with the technology of telescopes as well as to form a base report which would then evolve into the DPR. A visit was arranged for a team of four members to key institutions in Europe and the USA, to make a preliminary study of the technical and scientific issues involved in the building of a 4 m class optical telescope facility. The visit, covering the period 1995 February 18 - March 10 was to the Padova Observatory (the 3.5-m Galileo telescope), the European Southern Observatory Headquarters in Munich (the 3.5 m NTT), the facilities of Messrs Carl Zeiss in Germany, the facilities of Messrs Autoscope in the USA, and the National Optical Astronomy Observatories, Tucson, Arizona, USA (3.5 m WIYN telescope). Members of the team were Ram Sagar, A.K.Pati, V.Chinnappan and N.Viswanathan (ISRO).

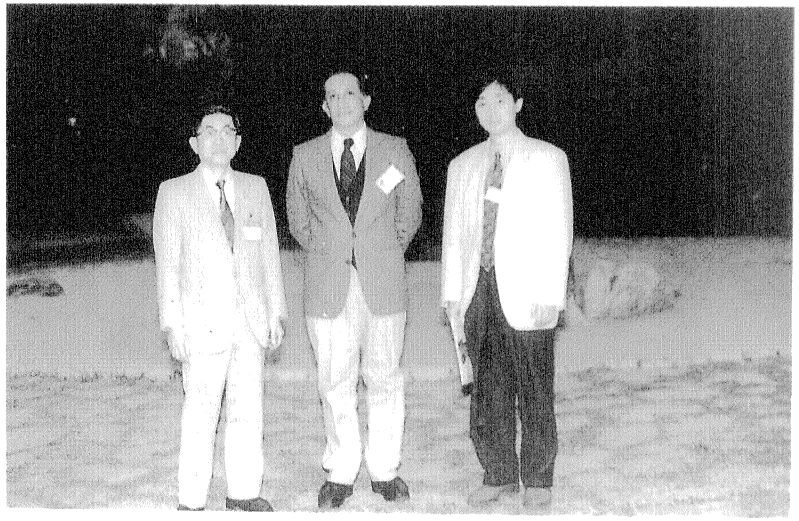
The first combined meeting of the Working Groups was held in IIA on 1995 March 11 soon after the return of the team from the U.S.A. Well over fifty scientists, including the WG members and invited participants attended the meeting. A detailed report of the meeting has been



18" telescope at Hanle station

India Japan seminar





Miscellaneous

India-Japan Seminar on Astronomy and Astrophysics

The India-Japan Seminar on Astronomy and Astrophysics was held in IIA during 1995 January 17-20. The initiative was taken by Professor R.Cowsik as the Indian Coordinator in the thrust area of Astronomy and Astrophysics. The seminar was attended by a large delegation from Japan and a corresponding group of Indian astronomers and scientists from leading scientific institutions in the country. It was inaugurated by Professor C.N.R.Rao, the Co-chairman of the India-Japan Science Council. Professor B.V.Sreekantan delivered the keynote address. The valedictory address was delivered by Professor Daiichiro Sugimoto. The proceedings of the meeting have been published as 1995, Volume 23, No.3 of Bulletin of ASI. Professor R.Cowsik and Professor D.Sugimoto are the guest editors.

VHRR Sun shield panels

In a simple ceremony on March 10, 1995 VHRR sun shield panels for the INSAT 2 series of satellites were handed over by Professor R.Cowsik to Dr. R.Aravamudan, Director, ISAC. The panels were prepared at the Photonics Workshop, IIA.

Computational Fluid Dynamics and Astrophyhsical Applications

A workshop on Computational Fluid Dynamics and Astrophysical Applications was organised in Kodaikanal during December 12-15, 1994. Professor S.S.Hasan was the organizer.

Bicentennial Commemorative Public Lecture

The Ninth IIA Bicentennial Commemorative Public Lecture was delivered on March 9, 1995 by Professor Virendra Singh, Director, TIFR. Professor Singh spoke on *S.N.Bose and the problem of black body radiation.* The bicentennial lecture series was started in 1987.

Historical studies

It is known that the earliest astronomical instruments used in prehistoric times in India are the water clock and gnomon. It is suggested that some of the Harappan pots with holes and circularly laidout brickwork with a hole for a wooden peg found in Harappan sites might correspond to these instruments. In the context of some suggestions regarding the animal figures in Indus seals as representing astronomical constellations the huge animal figures at Bhimbhetka and other rockshelters in central India have been examined. It is possible that such animals could have been the basis to denote constellations in mesolithic times in India.

The preliminary investigation of the megalithic stone alignments at Hanamsagar (Karnataka) of fifty rows of fifty stones suggests that these arrangements have alignments towards the directions of the solstice sun rises and sunsets. (N.K. Rao)

The astronomical contributions of N.R.Pogson, the Government Astronomer at Madras observatory from 1860-93 and a renowned variable star observer, are being studied in the context of the development of observational astronomy during those years, particularly the work done at Madras and the general developments at that time. A brief account of this was presented at the Workshop on Heritage of Ancient Indian Astronomy held in Pune in November 1994. (N.K.Rao, A.Vagiswari and C.Louis)

Work of the Hindi Cell

The Annual Report 1993-94 and the Audited Accounts of the Institute were produced in Hindi. Praveen classes were started at the Bangalore Campus, and in Kodaikanal Observatory. Ten staff members appeared for the Praveen Examination and some of the successful candidates won cash awards. Dictionaries and other literature of assistance were distributed among those attending Hindi classes.

Hindi Diwas was celebrated on September 14, 1994. Hindi books on various subjects worth Rs.8,683.51 were acquired for the Hindi Cell Library. A PC 386 with accessories has also been acquired for the Hindi Cell. (R.C.Kapoor, Saroj Ishwarlal)

VBO

Like every year, August 10, 1994 was celebrated at VBO to coincide with the 67th birthday of the late Professor M.K.Vainu Bappu. Around 400 College/University students from different parts of Tamil Nadu, attended the function. A talk on "Near-Earth Asteroids" was given by Prof.R.Rajamohan. The students were taken around the observatory and the nightsky was shown to them through the visitors' telescope.

Colloquia by visiting scientists

Evolution of galactic magnetic fields
B.P.Pandey, Institute for Plasma Research, Ahmedabad
1994 April 5

OB association in galaxies
P.Battinelli, Osservatorio Astronomico, Roma, Italy
1994 April 27

The initial evolution of open clusters
R.Capuzzo Dolcetta, Instituto Astronomico, Roma, Italy
1994 April 27

Two-phase model of accretion disks in Active Galactic Nuclei
J.Poutanen, Observatory and Astrophysics Laboratory,
University of Helsinki, Finland
1994 May 3

Coherence in chaos
B.Buti, NPL, New Delhi
1994 June 2

Galaxies : shapes, cores and dust
Ajit Kembhavi, IUCAA, Pune
1994 June 2

Magnetic shear changes before and after solar flares
Ashok Ambastha, Udaipur Solar Observatory,
1994 July 14

Initial mass function and its relevance to dark matter
T.Richtler, Sternwarte der Universität, Bonn, Germany
1994 July 19

Optical solutions for high speed communication
R.K. Shevgaonkar, IIT, Bombay
1994 July 19

Nucleosynthesis by the s process in red giants - the neutron density
D.L.Lambert, University of Texas, Austin, USA
1994 July 25

Emission line variability in Active Galactic Nuclei
P.J. Wiita, Georgia State University, USA
1994 July 28

Hubble space telescope observations of H_2, C_2 and CO molecules in diffuse clouds towards σ Ophiuchi
D.L.Lambert, University of Texas, Austin, USA
1994 August 2

Microsecond universe
B.Sinha, SINP and VECC, Calcutta
1994 August 18

Imaging polarimetry
A.K.Sen, IUCAA, Pune
1994 August 30

Continuum millimeter observations of high redshift radio quiet QSOs
A.Omont, Institut d' Astrophysique, Paris, France
1994 November 21

What IRAF was, is and will be
F. Valdes, National Optical Astronomy Observatories
Tucson, Arizona, USA
1994 December 12

SNe Ia and the Hubble Constant
A. Saha, Space Telescope Science Institute, Baltimore, Maryland
1994 December 14

Stellar populations in nearby dwarf galaxies
A. Saha, Space Telescope Science Institute, Baltimore, Maryland, USA
1994 December 15

Unity of forces and understanding the origin of families and mass-scales
J.C.Pati, University of Maryland, USA
1995 January 5

Radiative transfer in the upper atmospheres of outer planets
R.N.Halthore, Hughes STX Corporation,
Goddard Space Flight Center, Greenbelt, MD, USA
1995 January 24

Some new results from Ulysses spacecraft
G.Thejappa, University of Maryland, USA
1995 January 31

Active spectrographs
Rajiv Bhatia, University of Padova, Italy
1995 February 7

Chromospheric structure and dynamics
W.Kalkofen, Harvard Smithsonian Center for Astrophysics, Cambridge, USA
1995 February 13

Soap films
A.Mackay, Birbeck College, London
1995 February 23

Global structures of discs around black holes
J.Artemova, Theoretical Astrophysics Centre, Copenhagen, Denmark
1995 February 24

Discovering the Alchemist Nagarjuna
D.Wujastyk, Welcome Institute for the History of Medicine, London
1995 March 21

Constraints on galaxy formation from the Lyman-alpha absorbers in front of quasars
K.Subramanian, GMRT, Pune
1995 March 31

Library

During the year the Library added 331 books to its stock and it subscribed to 140 journals and continued receiving 101 observatory publications, preprints, newsletters and annual reports. The Library borrowed journals from RRI and TIFR for display. One hundred and forty one interlibrary loan requests were handled during year. 1,55,000 xerox copies were made from the library books and journals. Two consignments of New Palomar Sky Survey charts were received.

The Library acquired a PC 486 and an integrated software called Libsys. The database available on CDS/ISIS was transferred to Libsys and now the library database of books, as well as circulation statistics of library documents, is available on Libsys. Since all the local PC's are connected through ethernet in the Institute, the database can be accessed through PCs. The Library also acquired a new xerox machine with enlargement and reduction facility and since it is easy to operate, the users themselves are encouraged to xerox their requirements.

Citation search was done for 15 scientists through the facility available at INSDOC, Bangalore.

The backlog of pending journals for binding was taken up with some private binders and the binding is being updated. 400 volumes of journals were bound during the year.

Ms.Christina Louis attended the EDM 94 (Effective Document Management 94) Seminar cum Workshop in Singapore 1994 July 7-10 organised by Minolta Co., Singapore. The theme of the seminar was Micrographs and Electronic Imaging. She was also given in-house training for 3 days in operating the various micrographic equipments at Minolta Company in Singapore. Shri Venkatesha from the Library has enrolled himself in the 2 year diploma course in Library and Information Sciences from July 1994. Ms.A.Vagiswari attended the Bangalore Science Library meetings held in GTRE, IISc and IIM, Bangalore.

The research students continue to help the library staff in the library routines and they have also become familiar with the library software. Mr.N.N.K. Murthy, retired Librarian LRDE, joined the Library to assist in library work.

Personnel

The academic and technical staff during the period 1994 April - 1995 March include the following :

Director : Ramanath Cowsik

Senior Professor : A.Peraiah, Ch.V.Sastry (up to 1994 July 31), C.V.Vishveshwara

Professor : B.P.Das, M.H.Gokhale, N.Kameswara Rao, R.K.Kochhar, V.Krishan, J.H.Sastri

Associate Professor : Bhaskar Datta, S.S.Hasan, R.C.Kapoor, D.C.V.Mallik, Palash B.Pal, M.Parthasarathy, T.P.Prabhu, R.Rajamohan, Ram Sagar, Jagdev Singh, C.Sivaram, P.Venkatakrishnan

Reader : S.P.Bagare, H.C.Bhatt, A.Chokshi, P.K.Das, K.K.Ghosh, S.K.Jain (deceased 1994 November 17), S.Mohin, P.M.S.Namboodiri, A.K.Pati, P.K.Raju, A.V.Raveendran, K.R.Subramaniam, Sudeshna Sinha

Fellow : P.Bhattacharjee, S.Chatterjee, Sunetra Giridhar, J.Javaraiah, R.Kariyappa, Sushma V.Mallik, M.V.Mekkaden, D.Mohan Rao, B.S.Nagabhushana, K.N.Nagendra, R.S.Narayanan (deceased 1994 August 12), K.E.Rangarajan, S.K.Saha, Lakshmi Saripalli, A.Satya Narayanan, Alok Shukla, K.Sundara Raman, R.Surendiranath. G.Thejappa (on leave), R.Vasundhara

Research Associate : K.M.Hiremath, K.Jayakumar, K.Kuppuswamy, Prabhjot Singh, J.V.S.V.Rao, M.J.Rosario, M.Srinivasa Rao, Baba A.Varghese, L.Yeshwant

Senior Principal Scientific Officer : R.Srinivasan

Head, Photonics Division : A.K.Saxena

Principal Scientific Officer : A.V.Ananth, G.S.D.Babu, V.Chinnappan, B.R.Madhava Rao

Scientific Officer 'SD' : M.S.Sundara Rajan, G.Srinivasulu

Scientific Officer 'SC' : P.S.M.Aleem, S.S.Gupta, D.Karunakaran, K.B.Ramesh, K.Sasidharan, J.P.L.C.Thangadurai

Senior Civil Engineer : N.Selvavinayagam

Senior Technical Officer : R. Sivashanmugam (up to 1994 May 2)

Librarian : A.Vagiswari

Assistant Librarian A : Christina Louis

Assistant Librarian B : H.N.Manjunath (on leave)

Technical Officer : A.T.Abdul Hameed, S.S.Chandramouli, M.Mohammed Abbas, A.Mohammad Ghouse, R.Muralidharan Nair, K.Narayanan Kutty, K.Padmanabhan, K.Ramankutty, K.S.Ramamoorthy, J.P.A.Samson, K.G.Unnikrishnan Nair

Technical Associate : A.M.Batcha, P.Chockalingam, F.Gabriel, N.Jayavel, P.K.Mahesh, S.Muralishankar, S.Muthukrishnan, J.S.Nathan, G.N.Rajasekharan, A.Selvaraj, N.Siva Raj, K.S.Subramanian, K.C.Thulasidharan, A.P.Velayuthan Kutty

Engineer Associate : Faseehana Saleem

Documentation Associate : Sandra D.Rajiva

Emeritus Professor : J.C.Bhattacharyya, K.R.Sivaraman

Emeritus Scientist (CSIR) : K.V.K.Iyengar

Professor (Projects) : Ch.V.Sastry (since 1994 August 1)

Post-doctoral Fellow (CSIR) : P.Bhaskaran

Visiting Fellow : S.Ananthamurthy, R.T.Gangadhara, H.Parthasarathy, K.P.Raju

Young Scientist (DST) : Aruna Goswami

Students : Angom Dilip Kumar Singh, S.Annapurni, Atish Dipankar Jana, D.Banerjee, S.Banerjee, S.G.Bhargavi, Charu Ratnam, M.Dikpati, B.Eswar Reddy, K.P.Geetha, V.Krishnakumar, Rajesh Kunnumpuram, Mangala Sharma, G.Pandey, S.Paul Kasper Rajaguru, Pavan Chakraborty, R.D.Prabhu, K.Rajesh Nayak, R.Ramesh, H.N.Ranganath Rao, K.Sankara Subramaniam, S.K.Sengupta (CSIR), T.Sivarani, Sonjoy Majumder, R.Sridharan, R.Srikanth, D.Suresh, Susheela Rajagopal, Swara Ravindranath, A.V.Thampan, G.Uma

Palash B.Pal joined IIA as Associate Professor 1994 June 13. **Sudeshna Sinha** joined as Reader 1994 June 7. **Lakshmi Saripalli**, **Prajval Sastri** and **K.P.Raju** joined as Fellow, 1994 December 15, 1995 March 22 and 27, respectively. **Ch.V.Sastry** retired as Senior Professor 1994 July 31. He was reappointed Professor, Radioastronomy Projects. **Harish Parthasarathy** left IIA in 1994 August to take up a position in IIT, Bombay. **Sharath Ananthamurthy** joined IIA as a Visiting Fellow 1994 October 3.

R. Sivashanmugam took voluntary retirement from service 1994 May 2 after 33 years of service. Mr. Sivashanmugam looked after the Kavalur Observatory as the resident officer right from its inception.

S.K.Jain died on 1994 November 17 of lung cancer. **R.S.Narayanan** met with an automobile accident on 1994 August 12 that resulted in his instantaneous death.

Involvement in the scientific community

G.S.D.Babu has been elected General Secretary of ASI for a three-year term. He continues to be an executive member of the National Committee for the Restoration of the Jantar Mantars in India. **R. Cowsik** has been elected to the Council of the Indian National Science Academy, New Delhi for a period of three years. He is also the Coordinator from the Indian side in Astronomy and Astrophysics for the India-Japan Collaborative Programme in Science. **B.Datta** has been elected Fellow of the Indian Academy of Sciences (1995). **S.S.Hasan** is the Principal Investigator of an Indo-US Project on 'Structure, Dynamics and Heating of the Solar Atmosphere' which is a collaborative programme between IIA and Harvard Smithsonian Centre for Astrophysics, Harvard University (U.S.A). He is also a member of the Managament Committee of the Centre for Mathematical Modelling and Advanced Computing (CMMACS), Bangalore. **Jagdev Singh** was nominated as the Convener of the National Coordination Committee for the Total Solar Eclipse of October 24, 1995 constituted by INSA, New Delhi. **V.Krishan** has assumed charge as Editor, Bulletin of the Astronomical Society of India. **A.K. Pati** was a member of the organizing Committee of the 2nd Indo-US Workshop on 'Array Detectors and Image Processing' held at IUCAA, Pune 1994 Nov 28 - Dec10. **Ram Sagar** is a member of the Organizing Committee of IAU Commission 37. He was also a member of the Scientific Organizing Committee of the XVI ASI meeting. **N.K.Rao** has been elected a member of the Scientific Organizing Committee of the IAU Commission 29 'The Stellar Spectra'. He is also a member of the Indian National Committee on Astronomy. N.K.Rao is a member of the Scientific Organizing Committee of the 2nd International Conf. on Hydrogan Deficient Stars to be held at Bamberg, Germany 1995 August 28 - Sept. 2 and a member of the National Committee for the 'Asundi memorial International Conference on Spectroscopy: Prospects and Frontiers' to be held at BARC, Bombay 1995 January 2-6. He was a member of the Science Advisory Committee of IUCAA till December 1994. **J.H.Sastri** served as a member of the Research Advisory Committee (RAC) of IIG, Bombay. He also acted as the Coordinator of the HF Doppler Radar Network of the National Programme AICPITS, funded by DST, New Delhi. **C.Sivaram** continued as Project Co-Director of the World Laboratory, Switzerland. **P.Venkatakrishnan** was nominated as the Organizing Committee member for Commission 12 of IAU for 1994-1997. He was also a Senior NRC Associate at NASA//MSFC from 1994 June 1 - November 30. **C.V.Vishveshwara** has been made a member of the Governing Council of IUCAA, Pune 1995 January 1 - 1997 December 31.

Visitors

J.Poutanen, Observatory, Helsinki, Finland
1994 April 21 - May 5

Roberto Capuzzo Dolcetta, Instituto Astronomico, Universita la Sapienza, Roma, Italy
1994 April 24 - 29

Paolo Battinelli, Osservatorio Astronomico, Roma, Italy
1994 April 24 - 29

R.K.Shevgaonkar, IIT, Bombay
1994 June 7 - 8

T.Richtler, Sternwarte der Universität, Bonn, Germany
1994 June 24 - July 27

D.L.Lambert, University of Texas, Austin, USA
1994 July 10 - August 3

C.V.Sukumar, Theoretical Physics, Oxford, U.K.
1994 August 29 - September 2

Tom Gehrels, Univ. of Arizona, USA
1994 November 9 - 11

Alain Omont, Institut d' Astrophysique de Paris, France
1994 November 21 - 23

C.L.Bhat, BARC, Bombay
1994 December 9 - 10

A.Das, IPR, Ahmedabad
1994 December 9 - 11

Abhijit Saha, STScI, Baltimore, Maryland, USA
1994 December 9 - 16

Francisco Valdes, NOAO, Tucson, USA
1994 December 10 - 13

Pranab Ghosh, TIFR, Bombay
1994 December 12-16

J.N.Prasad, IIG, Bombay
1994 December 14 - 19

A.Das, IPR, Ahmedabad
1994 December 15 - 16

S.Sarkar, Univ. of Oxford, U.K.
1994 December 15 - 24

K.Iwasaki, Kyoto Gakuen University, Japan
1994 December 24 - 1995 January 5

J.C. Pati, University of Maryland, USA
1994 January 5 - 6

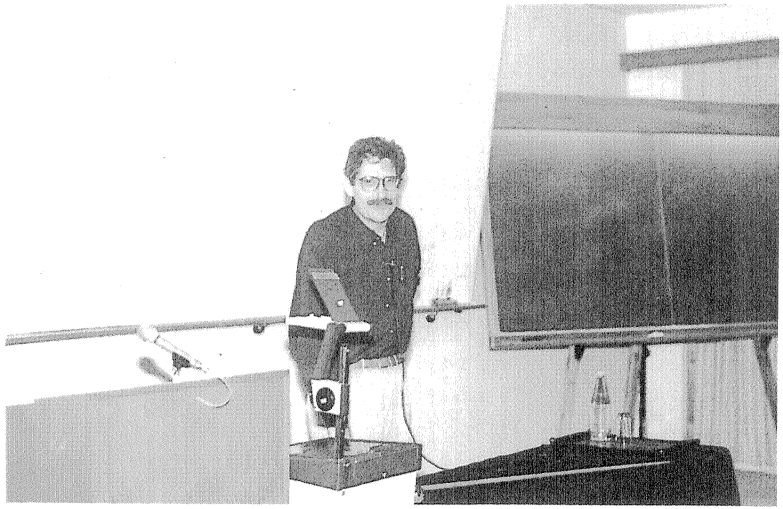
Sudha Murthy, KAI Science & Technology, Lancaster, PA, USA
1995 January 9 - March 31

G.Padmanabhan, Dept of Science & Tech., New Delhi
1995 January 17 - 19

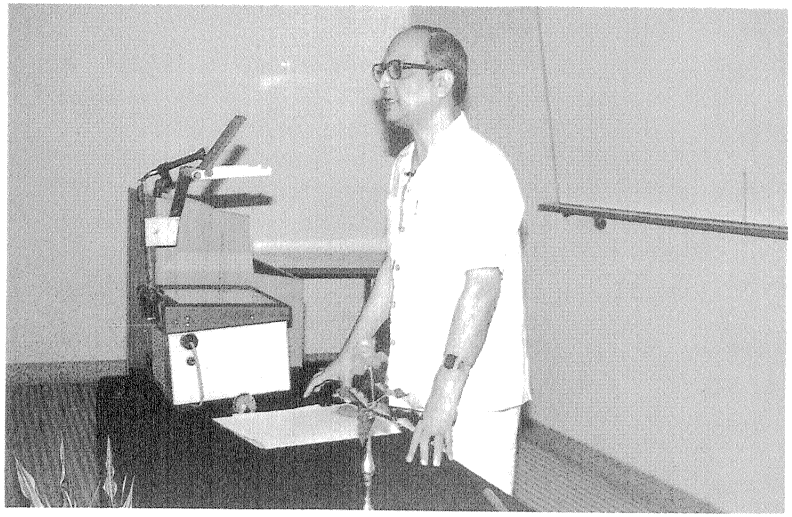
W.Kalkofen, Harvard Smithsonian Center for Astrophysics, Cambridge, MA, USA
1995 February 12 - March 4

N.Gopalswamy, University of Maryland, College Park, MD, USA
1995 February 12 - March 4

Visitors

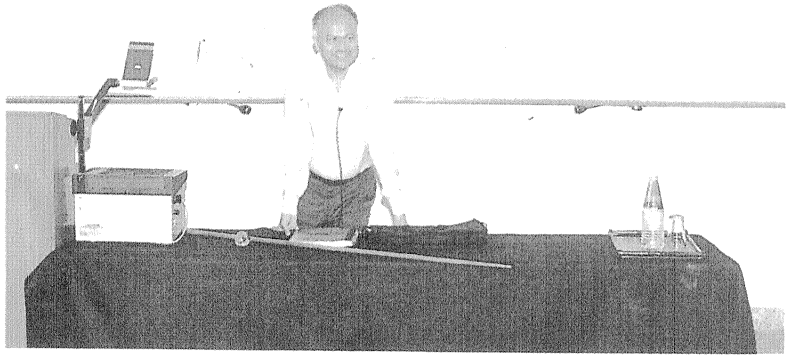


Professor A. Omont



Professor V. Singh

Professor J. Pati



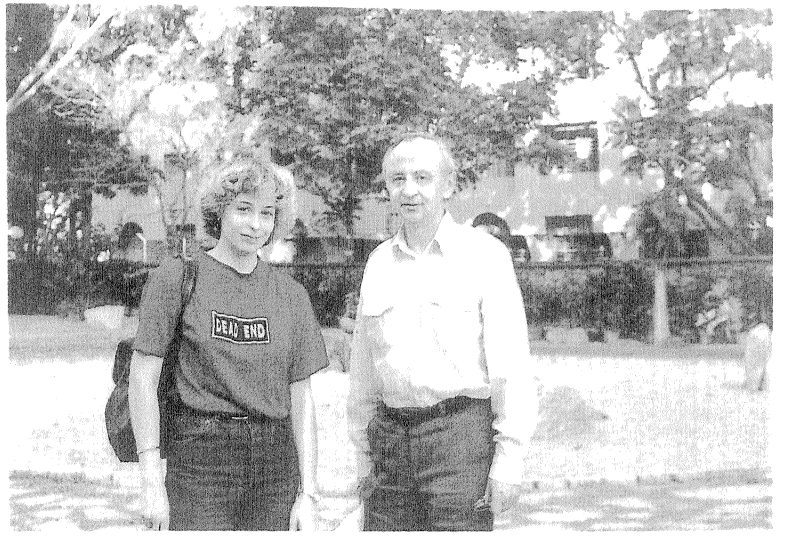
Professor J.V. Narlikar

R.K. Bhatia, University of Padova, Italy
1995 February 5 - 8

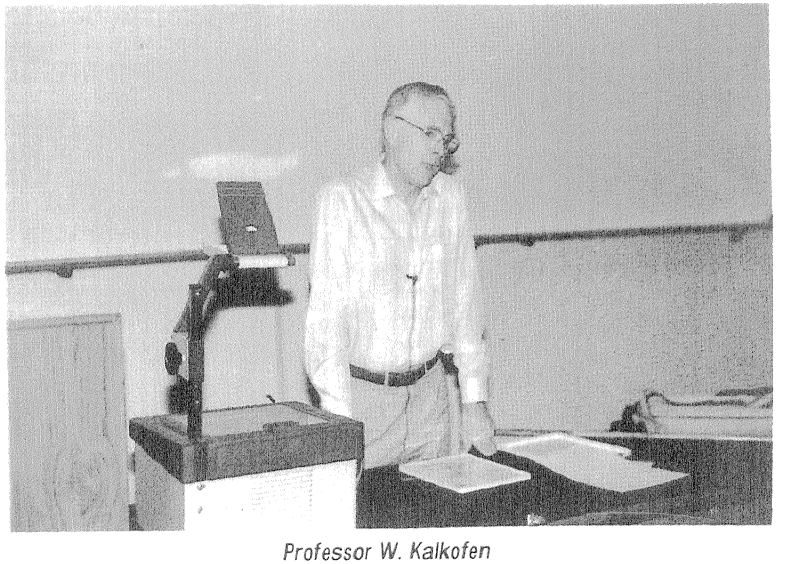
Janaki Dantuluru, Michigan Tech. Univ., MI, USA
1995 February 10 - 11

K.Iwasaki, Kyato Gakuen University, Japan
1995 February 14 - 27

C.S.Unnikrishnan, TIFR, Bombay
1995 March 11 - 13



Dr. J. Artemova, Professor I.D. Novikov



Professor W. Kalkofen

Professor Alan Mackay and Mrs. Mackay with
Professor R. Cowsik (left) and Professor S. Chandrasekhar (right)

Appendixes

Appendix - A

Publications

In Journals

*Aguirregabiria, J.M., *Chamorro, A., *Suinaga, J., Vishveshwara, C.V. (1995) *Class.Quant.Grav.*, **12**, 699.
Equilibrium of a charged test particle in the Kerr-Newman spacetime.

Ananthamurthy, S., *Kleiber, P.D. (1995) *J.Chem. Phys.* **102**, 5.
Collisional redistribution in Sr-He spin changing energy transfer collisions: final state alignment.

Ananthamurthy, S., *Sando, K.M., *Kleiber, P.D. (1994) *J.Chem.Phys.*, **101** 12,
A classical path theory of collisional redistribution in Catte spin-changing energy transfer collisions.

Banerjee, D., Hasan, S.S.,*Christensen-Dalsgaard, J. (1995) *ApJ,* **451**, 825.
The influence of a vertical magnetic field on the oscillations in an isothermal stratified atmosphere. II.

Bhattacharjee, P. (1995) *Bull.ASI,* **23,** 127.
On top.

Bhattacharjee, P., *Sigl, G. (1995) *Phys. Rev.D,* **51**, 4079.
Monopole annihilation and highest energy cosmic rays.

Chatterjee, S. (1995) *A&A,* **298,** 438.
Distribution of stars perpendicular to the plane.
of the Galaxy II.

*Names of collaborators from other institution

Cowsik, R., *Friedlander, M.W. (1995) Ap. *J. Lett.*, **444,** L 29.
Implications of gamma-ray lines observed from the Orion complex.

Datta, B., Thampan, A.V., *Bhattacharya, D. (1995) *JAA*, in press.
A numerical survey of neutron star crustal density profiles.

Gangadhara, R.T., Krishan, V. (1995) *ApJ,* **440,** 116.
Rapid polarization variability in intense sources.

Ghosh, K.K., Soundararajaperumal, S. (1995) *ApJS,* **100,** 37.
Multifrequency spectra of EXOSAT blazars.

Giridhar, S., *Arellano Ferro, A. (1995) *Rev. Mex.*, **31**, 23.
A critical compilation of oscillator strengths for Fe II lines.

*Gopal-Krishna, Ram Sagar, *Wiita, P.J. (1995) *MNRAS,* **274**, 701.
Intranight optical variability in optically selected QSOs.

Hiremath, K.M., Gokhale, M.H. (1995) *ApJ,* **448**, 437.
'Steady' and 'Fluctuating' parts of the sun's internal magnetic field.

Jain, S.K. Bhatt, H.C. (1995) *A&AS,* **111**, 339.
Study of variability of the polarization in Herbig Ae/Be stars.

Javaraiah, J., Gokhale, M.H. (1995) *Sol.Phys.*, **156**, 157.
Periodicities in solar differential rotation, surface magnetic field and planetary configurations.

*Kneer, F., Hasan, S.S., *Kalkofen, W. (1995) *A&A,* in press.
Spectral line radiation from small-scale magnetic flux tubes.

*Korchagin, V., *Kembhavi, A.K., *Mayya, Y.D., Prabhu, T.P. (1995) *ApJ,* **446,** 574.
Are nuclear hot spots in galaxies sites of sequential star formation?

*Krishan, V. (1995) *Physica Scripta,* **T52,** 115.
Reflection of radio radiation at ionization fronts in emission line regions and accretion disks of active galactic nuclei.

Malhotra, S., Singh, A.D.K., Das, B.P. (1995) *Phys.Rev. A,* **51,** R2665.
Relativistic configuration interaction analysis of parity nonconservation in Ba.

Mallik, D.C.V., Sagar, R., Pati, A.K. (1995) *A&AS,* **114**, 537.
A deep BVI photometric study of the open cluster NGC 2453.

Mayya, Y.D. (1994) *AJ,* **108,** 1276.
Embedded clusters in giant extragalactic HII regions.I. BVRHα photometry.

Mayya, Y.D. (1995) *AJ,* in press.
Embedded clusters in giant extragalactic H II regions.II. Evolutionary population synthesis model.

Mohan Rao, D., Rangarajan, K.E., Abhyankar, K.D. (1995) *Bull.ASI,* **23,** 211.
Non-conservative Rayleigh scattering in a finite atmosphere - II. Polarization in telluric lines.

Mohan Rao, D., Varghese, B.A., Srinivasa Rao, M. (1995) *JQSRT,* **53**, 639.
A comparative study of finite-difference methods for radiative transfer problems.

Namboodiri, P.M.S. (1995) *Bull.ASI,* **23,** 65.
Head-on collision of spherical galaxies.

Pal, P.B. (1995) *Bull.ASI,* **23,** 121.
Do neutrinos have mass?

Pal, P.B. (1995) *Phys.Rev. D,* in press.
The strong-CP question in $SU(3)_c \times SU(3)_L \times U(1)_N$ models.

Pal, P.B.,* Chang, D., *Keung, W.Y. (1995) *Phys.Rev. D,* **51,** 1326.
CP violation in the cubic coupling of neutral gauge bosons.

Pal, P.B., *Nieves, J.F. (1995) *Phys.Rev. D,* **51,** 5300.
The zero momentum limit of thermal Green functions.

Parthasarathy, M.*Garcia-Lario, P., *de Martino, D., *Pottasch, S.R., *Kilkenny, D., *Martinez, P., *Sahu, K.C., Reddy, B.E., *Sewell,B.T. (1995) *A&A,* **300**, L25.
Fading and variations in the spectrum of the central star of the very young planetary nebula SAO 244567 (Hen 1357).

Prabhu, T.P., *Mayya, Y.D., *Singh, K.P., Rao, N.K., Ghosh, K.K., Mekkaden, M.V., Pati, A.K., Raveendran, A.V., Reddy, B.E., Sagar, R., Subramaniam, A., Surendiranath, R. (1995) *A&A,* **295,** 403.
SN 1993J in M 81: the first two months in the optical region.

Rajamohan, R., Satyanarayanan, A. (1995) *Speculations in Science and Technology,* **18**, 51.
On light travel time delays.

Ramesh, K.B., Sastri, J.H. (1995) *Ann.Geophys.,* **13**, 633.
Solar and seasonal variations in F region vertical drifts over Kodaikanal, India.

Raveendran, A.V., Mohin, S. (1995) *A&A,* **301**, 788.
BV photometry and Hα spectroscopy of the RS Canum Venaticorum binary UX Arietis.

Reddy, B.E., Parthasarathy, M., Sivarani., T. (1995) *A&A,* in press.
HD 105262: a high latitude metal poor post-AGB A supergiant with large proper motion.

Sagar, R. (1995) *Bull.ASI,* **23**, 433.
Star clusters in the Magellanic clouds.

Sagar, R., *Cannon, R.D. (1994) *Bull.ASI,* **22,** 381.
UBVRI CCD photometry of the two southern galactic star clusters Berkeley 79 and Trumpler 11.

Sasidharan., K., *Sreedharan, T.D.,*Pratap, R., Krishan, V. (1995) *Sol. Phys.,* **157**, 121.
Temporal Evolution of pressure in solar coronal loops.

Sastri, J.H. (1995) *J.Geophys.Res.,* **100**, 9753.
Response of equatorial F-layer vertical drift in the dusk sector to the change in the radiative output of the Sun in 1992.

Sastri, J.H. (1995) *JGG,* in press.
Short-period (5-33 min) variations in vertical drift of F region plasma near the magnetic equator.

Singh, J. (1994) *Bull.ASI,* **22,** 239.
Total solar eclipses of 1994 and 1995.

Singh, J. (1995) *Bull. ASI,* **23,** 3.
Total solar eclipses of October 24, 1995 II.

Singh, J., Gupta, S.S. (1995) *Sol. Phys.,* **158**, 259.
On the eruption of prominences and disappearance of quiescent filaments.

Singh, J., Nagabhushana, B.S., Babu, G.S.D. *Wahab Uddin (1994) *Sol. Phys.,* **153,** 157.
Study of Calcium K network evolution from Antarctica.

Singh, Prabhjot (1995) *MNRAS,* in press.
A radiative transfer calculation using angle-averaged R_{II} and R_V in a static spherically symmetric stellar atmosphere.

Sinha, Sudeshna (1994) *Phys. Rev. E,* **49,** 4832.
Unidirectional adaptive dynamics.

Sinha, Sudeshna (1995) *Phys.Lett.A,* **199,** 365.
Adaptive dynamics on circle maps.

Sinha, Sudeshna (1995) *Int.Jour.Mod.Phys. B,* **9,** 875.
Chaos and regularity in adaptive lattice dynamics.

Sivaram, C. (1994) *Ap&SS,* **215**, 185.
Some aspects of MOND and its consequences for cosmology.

Sivaram, C. (1994) *Ap&SS,* **219,** 135.
MOND, dark matter and the cosmological constant.

Sivaram, C. (1995) *Bull.ASI,* **23,** 77.
The Hulse-Taylor binary pulsar PSR 1913+16.

Sivaram, C. (1995) *Am. J. Phys.,* **63,** 5.
Upper limit on photon electric charge from cosmic microwave background.

Sivaram, C., *de Andrade, G. (1994) *General Relativity and Gravitation,* **26,** 615.
Torsion and massive electrodynamics in the early universe.

Sivaram, C., *de Andrade, G. (1995) *J. Math. Phys.,* in press.
Torsion and quantized vortices in general relativity.

Sivaram, C., *de Sabbata, V. (1994) *Found. Phys.Lett.,* **7,** 475.
Gravity and CP-violation.

Sivaram, C., *de Sabbata, V., *Wang, D. (1994) *Acta Astrophysica Sinica,* **14**, 12.
On Born-Infeld type modifications of general relativity.

Subramaniam, A., Gorti, U., Sagar, R., Bhatt, H.C. (1995) *A&A,* in press.
Probable binary open star clusters in the Galaxy.

Surendiranath, R., Rao, N.K. (1995) *MNRAS,* **275**, 685.
A photoionization model of the nebula around WC11 star M4- 18.

In Proceedings

Bhattacharjee, P. (1995) in *Proceedings India-Japan Seminar on A&A,* ed. R.Cowsik and D.Sugimoto, *BASI*, **23**, 283.
Cosmic ray signatures of cosmic topological defects.

*Castelli, F., *Bonifacio, P. *Hack, Parthasarathy, M. (1995), *ASP Conference Series,* in press.
Unpredicted lines in the ultraviolet spectra of B-type stars.

*Castelli, F., Parthasarathy, M. (1995), *ASP Conference Series,* **78,** 151.
Oscillator strengths for ultraviolet Ga II and Ga III lines.

Cowsik, R. (1995) in *Proceedings India-Japan Seminar* on A&A, ed. R. Cowsik and D. Sugimoto, *BASI*, **23**, 273.
Neutrino properties derived from laboratory and astrophysical studies.

Cowsik, R., *Krishnan, N., *Tandon, S.N.M, *Unnikrishnan, C.S. (1995) in *Proceedings 7th Marcel Grossmann Meeting on GRG,* in press.
Equivalence principle and feeble Yukawa - like forces.

Cowsik, R., Ratnam, C., Bhattacharjee, P. (1995) in *Proceedings 7th Marcel Grossmann Meeting on GRG,* in press.
The velocity of particles of Galactic Dark Matter.

Datta, B. (1995) in *Proceedings of International Conference on Astrophysics and Cosmology,* ed. B. Sinha and R.K. Moitra, Calcutta, p.168.
Extended hadronic matter at high densities.

Datta, B. (1995) in *Proceedings of International Conference on Non-accelerator Particle Physics,* ed. R.Cowsik, World Scientific, p.364.
Neutron stars as non-accelerator hadron physics laboratory.

Hasan, S.S. (1995) *in Proceedings IAU Coll 154: Solar and Interplanetary Transients,* ed. S.Ananthakrishnan and A.P.Rao, in press.
Dynamical effects in solar photospheric flux tubes.

Hasan, S.S. (1995) *in Proceedings India-Japan Seminar on A&A,* ed. R.Cowsik and D.Sugimoto, *BASI*, **23**, 337.
Helioseismology : recent developments and new perspectives.

Krishan, V. (1995) in *Proceedings of XV Summer Workshop on IR Tools for Solar Astrophysics,* National Solar Observatory, p.327.
A turbulent model of solar granulation.

Malhotra, S., Singh, A.D.K., Das, B.P. (1995) in *Proceedings of the International Conference on Non-accelerator Particle Physics,* ed.R.Cowsik, World Scientific, p.520.
Parity non-conservation in Ba^{+}: A theoretical analysis of contributions from neutral weak currents and the nuclear anapole moment.

Pal, P.B. (1995) in *Proceedings of XI DAE Symp., Santiniketan,* in press.
Bounds on neutrino properties from astrophysics and cosmology.

Peraiah, A. (1995) in *Proceedings on 'Recent Trends in Methods of Radiation Transport',* Kalpakkam Chapter & Indira Gandhi Centre for Atomic Research, Kalpakkam.
A review of discrete space theory of radiative transfer in stellar atmospheres.

Raju, P.K. (1995) in *Proceedings of the IX National Symposium on Plasma Science and Technology,* ed. C.B. Dwivedi, Guwahati, p.108.
Electron density and temperature diagnostics of solar plasma using emission lines of Ne^{+4} and Mg^{+4}.

Singh, J. (1995) *in Proceedings India-Japan Seminar on A&A,* ed. R.Cowsik and D.Sugimoto,*BASI*, **23**, 333.
Total solar eclipse 1995.

Sivaram, C. (1995) in *Proceedings of the Symposium on Early Universe*, ed. V.Johri et al., World Sci., in press.
Alternatives to dark matter and consequences for the early universe.

Sivaram, C., Krishan, V. (1994) in *Instability, Chaos and Predictability*, Nova Sci.Publ., p.193.
Formation of large scale structures in the universe by inverse cascade : cosmosynergetics.

Subramanian, K.R., Ebenezer, E., Sastry, Ch.V. (1994) in *Proceedings CEOT 94*, p.96.
The Gauribidanur acousto-optic spectrometer.

Subramanian, K.R., Ramesh, R., Sundara Rajan, M.S., Sastry, Ch.V. (1995) in *Proceedings of IAU Coll.154 : Solar and Interplanetary Transients*, ed. S. Ananthakrishnan and A.P. Rao, in press.
First results from the Gauribidanur radio heliograph.

In Books

Sivaram, C. (1995) in *Current Trends in High Energy Astrophysics*, ed. M.M.Shapiro and R.Silberberg, Kluwer Academic Press.
Production and acceleration of ultra high energy particles by black holes and strings.

Circulars/Reports

Bhatt, H.C. (1994) IAU Circular 6039, Comet Shoemaker-Levy 9 : Infrared flash from the impact of fragments = 5 on Jupiter.

Singh, Jagdev, (1994) INSA Status report, ed. J.C.Bhattacharyya, Solar Corona.

Subramanian, K.R., Ramesh, R., Sundara Rajan, M.S., Sastry, Ch.V. (1995) STEP GBRSC News **4**, 13.
Gauribidanur radio heliograph.

Attendance in Conferences, Worskhops and other Scientific Meetings

NATO Advanced Course in Current Trends in High Energy Astrophysics
Erice, Italy
1994 May — C.Sivaram

Eighth International Symposium on Solar-Terestrial Physics,
Sendai, Japan
1994 June 5 - 10 — J.H.Sastri

Seventh Marcel Grossmann Meeting on General Relativity
Stanford University, USA
1994 July 24-29 — R. Cowsik

NATO ASI workshop on Formation and Interaction of Topological Defects
Isaac Newton Institute, University of Cambridge, UK
1994 August - September — P. Bhattacharjee

Workshop on Vacuum Technology
IISc, Bangalore
1994 August 22 - 27 — K. Ramankutty, A.K.Saxena

International School of Space Science
L'aquila, Italy
1994 August 29 - September 10 — D. Mohan Rao

Spanish Relativity Meeting
Menorca, Spain
1994 September 12 - 14 — C.V.Vishveshwara

XV Summer workshop on `IR tools for Solar Astrophysics'
National Solar Observatory, New Mexico
1994 September 19 - 23 — V.Krishan

Coupled Phenomena in Geoenvironment
National Physical Laboratory, New Delhi
1994 September 21 - 22 — J.H.Sastri

Workshop on Effective Field Theories and QCD
IISc, Bangalore
1994 October — P.B.Pal

Heidelberg workshop on TeV Gamma Ray Astrophysics
MPI für Kernphysik, Heidelberg, Germany
1994 October 3 - 7 — P. Bhattacharjee

NCSTC meeting
DST, New Delhi
1995 October 24 — Jagdev Singh

XVI Meeting of ASI
IUCAA, Pune
1994 October 25 - 28 — G.S.D.Babu, B.Datta, R.T.Gangadhara, R.C.Kapoor, V.Krishan, Ram Sagar, A.Satya Narayanan, A.K.Saxena, P.Singh

9th National Symposium on Plasma Science and Technology,
Guwahati, Assam
1994 November 14 - 17 — P.K.Raju

Diamond Jubilee Meeting of the
Indian Academy of Sciences
Bangalore
1994 November 28 - Dec 2 — R. Cowsik

Indo-US Workshop on Array Detectors and Image Processing
IUCAA, Pune
1994 November 28 - December 10 — A.K. Pati, R. Srinivasan, N.K.Rao, S. Murali Shankar, B. Nagaraja Naidu

UGC school on Large-scale structure in the Universe
Physics Department, Mysore University, Mysore
1994 December — P. Bhattacharjee

Symposium on Early Universe
IIT, Madras
1994 December — C.Sivaram

Symposium on Mathematical Methods and Applications
IIT, Madras
1994 December — C.Sivaram

VI Canary Islands Winter School of Astrophysics `The Structure of the Sun'
Spain
1994 December 5 - 16 — K.M.Hiremath

Third Kodai School on Computational Fluid Dynamics and Astrophysical Applications
Kodaikanal
1994 December 12 - 14 — R.T.Gangadhara, Vinod Krishan, S.S.Gupta, S.S.Hasan

Seminar on `Recent Trends in Methods of Radiation Transport'
Indian Society for Radiation Physics, Indira Gandhi Centre for Atomic Research, Kalpakkam
1994 December 20 — A. Peraiah, B.A. Varghese, M.S.Rao

National Space Science Symposium
Vikram Sarabhai Space Centre, Trivandrum
1994 December 20 - 24 — J.H.Sastri

11th DAE Symposium on High Energy Physics
Santiniketan
1994 December 28 - 1995 January 2 — R. Cowsik, P.B.Pal

V All India Amateur Astronomer's meet
Bhubaneswar
1995 January — Jagdev Singh

Workshop on Computer Networks
IUCAA, Pune
1995 January 1 - 14 — J.S. Nathan, K.E. Rangarajan

Diamond Jubilee Celebrations of INSA & Discussion Meeting on 'The New Global Order : role of science and technology
New Delhi
1995 January 7 - 8 — R. Cowsik

India-Japan Seminar on Astronomy and Astrophysics,
IIA, Bangalore
1995 January 17 - 26 — P. Bhattacharjee, R. Cowsik, R.T.Gangadhara, S.S.Gupta, S.S.Hasan, Jagdev Singh, V.Krishan, D. Mohan Rao, P.M.S.Namboodiri, P.B.Pal, N.K.Rao, S.K.Saha, A.Satya Narayanan, J.H.Sastri K.E. Rangarajan, P.K. Das

SERC School on Coherence and Correlations in Modern Optics and Quantum Physics
Madras
1995 January 23 - February 10 — Sudha Murthy

International Conference on Vacuum Science and Technology and SRS Vacuum Systems
CAT, Indore
1995 January 30 - February 2 — A.K.Saxena

International Conference on 'Differential Equations, Theory, Methods and Applications'
B.M.Birla Science Centre, Hyderabad
1995 February 20 - 23 — A.Satya Narayanan

Workshop on Advanced Laser Spectroscopy
IIT Kanpur
1995 February 25 - 28 — A.K. Saxena

First HIROT Working Group Meeting
IIA, Bangalore
1995 March 11 — R. Cowsik, R. Srinivasan, D.C.V.Mallik, T.P.Prabhu, H.C. Bhatt, N.K.Rao, S.K.Saha, A.K. Pati, Ram Sagar

Workshop on Physics and Astrophysics of Cosmic Rays above 10^{19}eV
Fermi National Accelerator Laboratory, Batavia, Illinois, USA
1995 March 13 - 15 — P. Bhattacharjee

Fundamentals of Physics and Astrophysics
PRL, Ahmedabad
1995 March 14 - 16 — V.Krishan

22nd OSI Sumposium
CSIO, Chandigarh
1995 March 29 - 31 — A.K. Saxena, J.P. Lancelot

Colloquia and Invited talks at Conferences, Workshops and Seminars

Bhattacharjee, P.

Ultra-high energy cosmic rays from cosmic topological defects
Isaac Newton Institute, Univ. of Cambridge, UK.
1994 September 8

Relic topological defects as sources of the highest-energy cosmic rays
Dept. of Theoretical Physics, Univ. of Oxford, UK.
1994 September 12

Cosmic topological defects and the origin of highest-energy cosmic rays
Physics Dept., Leeds University, UK.
1994 September 16

Cosmic topological defects and the origin of highest-energy cosmic rays
Max-Planck Institut für Radioastronomie, Bonn, Germany.
1994 September 30

Cosmic ray signatures of cosmic topological defects
India - Japan Seminar on Astronomy & Astrophysics, IIA, Bangalore.
1995 January 19

Cosmic topological defects as the sources of the highest-energy cosmic rays
Workshop on Physics & Astrophysics of Cosmic Rays above 10^{19} eV,
Fermi National Accelerator Laboratory, Batavia, Illinois, USA.
1995 March 15

Cowsik, R.

Equivalence principle and feeble Yukawa like forces
The velocity of particles of Galactic Dark Matter
Seventh Marcel Grossmann Meeting
Stanford University, USA
1994 July 24 - 29

Search for mesoscopic composition dependent forces
Eleventh DAE Symposium on High Energy Physics
Santiniketan
1995 January 2

Neutrino properties derived from laboratory and astrophysical studies
India-Japan Seminar on Astronomy and Astrophysics
Bangalore
1995 January 17 - 20

Einstein's equivalence principle and new forces in nature
NAL, Bangalore
1995 February 28

Einstein's equivalence principle
NRSA, Hyderabad
1995 March 1

Das,B.P.

Time reversal violation and the electric dipole moment of the electron
Institute of Physics, Bhubaneswar
1994 July

Datta,B.

New observational constraints on neutron star structure
XVI ASI meeting
IUCAA, Pune
1994 October 25 - 28

Gangadhara,R.T.

Numerical simulation of the equilibrium of sunspots
Third Kodaikanal Workshop on Computational Fluid Dynamics and Astrophysical Applications
Kodaikanal
1994 December 12 - 15

Pulsar radiation mechanism and polarization position angle
Waseda University, Japan
1995 March 1
Nobeyama Radio Observatory, Japan
1995 March 9

Numerical simulation of sunspot magnetic field configuration
Kyoto University, Japan
1995 March 4

Hasan,S.S.

Magnetohydrodynamics of the solar atmosphere
Third Kodaikanal Workshop on Computational Fluid Dynamics and Astrophysical Applications
Kodaikanal
1994 December 12 - 14

Helioseismology : Recent developments and new perspectives
India-Japan Seminar on Astronomy and Astrophysics
Bangalore
1995 January 17-20

New developments in numerical simulations of astrophysical plasmas
Defence and Research Laboratory, Hyderabad
1995 February

Hiremath,K.M.

Steady and fluctuating parts of the Sun's internal magnetic field
Institute of Astronomy, Zurich, Switzerland
1994 December 19

Krishan,V.

A turbulent model of solar granulation
XV Summer Workshop on `IR tools for Solar Astrophysics'
NSO, Sunspot, New Mexico
1994 September 19 - 23

Plasma processes in quasars
Astronomy Department, Georgia State University
1994 September 28

Inverse cascade in astrophyisical fluids
Third Kodaikanal Workshop on Computational Fluid Dynamics and Astrophysical Applications
Kodaikanal
1994 December 12 - 15

Rotation curves of galaxies, missing mass or missing physics
Meeting on Fundamentals of Physics and Astrophysics
PRL, Ahmedabad
1995 March 14 - 16

Namboodiri,P.M.S.

Collisions of unequal galaxies
Department of Earth Science and Astronomy,
University of Tokyo, Japan
1995 March 9

The influence of a large galaxy on a smaller companion
Dept. of Astronomy, Kyoto University
1995 March 14

Pal,P.B.

The gauge boson equivalence theorem
Conference on Effective Field Theories,
CTS, IISc, Bangalore
1994 October

The solar neutrino problem
Physics Dept., IISc, Bangalore
1994 November

Astrophysical and cosmological constraints on neutrino properties
11th DAE Symposium, Santiniketan
1994 December

The Implications of neutrino mass
India-Japan Seminar on Astronomy and Astrophysics
Bangalore
1995 January 17 - 26

Peraiah, A.

'Boltzmann and his work' (Keynote address)
Discrete Space theory of radiative transfer and its applications in stellar atmospheres and other subjects
Seminar on 'Recent Trends in Methods of Radiation Transport',
Kalpakkam Chapter and Indira Gandhi Centre for Atomic Research,
Kalpakkam
1994 December 20

Ram Sagar

Star clusters in the Magellanic clouds
XVI ASI meeting
IUCAA, Pune
1994 October 25 - 28

Rao,N.K.

Megalithic astronomy and before in India
Astronomical alignments of medieval temples
N.R. Pogson - the Madras years
Workshop on Heritage of Ancient Indian Astronomy,
IUCAA, Pune
1994 November 4 - 10

High resolution echelle spectroscopy
Indo US workshop on Array Detectors and Image Processing.
Pune
1994 December

Astronomy with Vainu Bappu Telescope
India-Japan Seminar on Astronomy and Astrophysics
Bangalore
1995 January

Sastri,J.H.

Thermospheric tides and related ionospheric phenomena
Physical Research Laboratory, Ahmedabad
1994 August

Dynamics of nighttime equatorial F region
Physical Research Laboratory, Ahmedabad
1994 August

Thermosphere-ionosphere coupling
Coupled Phenomena in Geoenvironment
National Physical Laboratory, New Delhi
1994 September

Equatorial F region dynamics
National Space Science Symposium, Vikram Sarabhai Space Centre.
Trivandrum
1994 December

Satya Narayanan, A.

A simple solution of the variational equation describing hydrodynamic flows
International Conference on `Differential Equations - Theory, Methods and Applications',
B.M. Birla Science Centre, Hyderabad
1995 February 20 - 23

Saxena,A.K.

Active and adaptive optics
22nd OSI Symposium on Optical and Optoelectronic Instrumentation, Chandigarh
1995 March 29 - 31

Sinha, Sudeshna

Chaos and regularity in adaptive lattice dynamics
Department of Physics, IISc, Bangalore
1994 October

Srinivasan, R.

IIA CCD systems
Indo-US Workshop on Array Detectors and Image Processing
IUCAA, Pune
1994 November 28 - December 10

Charge coupled devices - current advances
India-Japan Seminar on Astronomy and Astrophysics
Bangalore
1995 January 16 - 20

Indian plan for NEA study - scanning technique
Roppangi, Japan
1995 February 15

CCD projects in IIA
Department of Earth Science and Astronomy
Tokyo, Japan
1995 February 22

Sivaram,C.

Alternatives to dark matter and consequences for the early universe
Symposium on Early Universe,
IIT, Madras
1994 December 20

MOND and the cosmological constant
Symposium on Early Universe,
IIT, Madras
1994 December 21

Entropy in gravitational fields, black holes, strings and extended inflation
Dept. of Mathematics, IIT, Madras
1994 December 23

Acceleration and production of the highest energy cosmic rays by black holes and strings
NATO meeting on Current Trends in High Energy Astrophysics, Erice
1995 May 13

The binary pulsar PSR 1913+16 as a testing ground for general relativity
Dept. of Phys., Univ. of Ferrara
1995 May 26

Gravitational radiation from close binary systems
Department of Astronomy, Univ. of Bologna
1995 May 30

Possibility of detecting other long range force fields with modified gravitational wave detectors
Frascati
1995 June 16

Chromogravity approach to QCD and confinement
Theory Group, Dept. of Physics, Univ. of Bologna
1995 June 24

Venkatakrishnan,P.
Observational signatures of coronal heating
IAU Colloquium 154 : Solar and Interplanetary Transients
Pune
1995 January 24

Venkatakrishnan,P.
Observable signals of coronal heating processes
XXII General Assembly of IAU
The Hague, The Netherlands
1994 August 19

Vishveshwara,C.V.
Relativity and rotation
Universidad de Salamanca, Universidad
Complutense de Madrid and Universidad de Barcelona
1994 June

Gyroscopic precession in General Relativity
Spanish Relativity Meeting, Menorca, Spain
1994 September 12 - 14

Equilibrium of a charged test particle in the Kerr Newman Spacetime
Queen Mary and Westfield College, London
1994 December

Lectures

Bhattacharjee, P.
Astroparticle physics (7 talks)
UGC School on Large-scale Structures in the Universe
Mysore University
1994 December

Ram Sagar
IIA and HIROT, an introduction
Astronomical Observatory, Padova
Carl Zeiss, Oberkochen, Germany
1995 February 20 - 24

Sastri,J.H.
Equatorial Spread-F (ESF)
Second Winter School on Indian MST Radar,
S.V.University, Tirupati
1995 January - February

Paper presentations at Meetings

Chatterjee,S., Thulasidharan,K.C., Krishnakumar,V., Subramanian,K.S.
A simple system for the detection of wavefront tilt of the order of one arcsec
22nd OSI Symposium on Optical and Optoelectronic Instrumentation,
Chandigarh
1995 March 29 - 31

Gangadhara,R.T.
Nonlinear propagation of intense electromagnetic waves in quasar and pulsar plasmas
XVI ASI meeting
IUCAA, Pune
1994 October 25 - 28

Hiremath,K.M.
Steady and fluctuating parts of the Sun's internal magnetic fields
VI Canary Islands Winter School of Astrophysics "The Structure of the Sun"
Spain
1994 December 5 -16,

Kapoor,R.C., Shukre,C.S*
Geometrical constraints on pulsar emission
XVI ASI meeting
IUCAA, Pune
1994 October 25 - 28

Krishnakumar,V., Lancelot,J.P.
New technique for measuring wavefront tilt
22nd OSI Symposium on Optical and Optoelectronic Instrumentation, Chandigarh
1995 March 29 - 31

Krishnakumar,V., Venkatakrishnan,P.
An electronic image selector for solar observations
22nd OSI Symposium on Optical and Optoelectronic Instrumentation, Chandigarh
1995 March 29 - 31

Rajagopal,J., Saxena,A.K., Udaya Shankar,N., Selvamani,M., Samson,J.P.A.
Stellar observations using a rotational shear interferometer
XVI ASI meeting
IUCAA, Pune
1994 October 25 - 28

Saha,S.K., Rajamohan, R., Vivekananda Rao,P*., Swaminathan,R*., Somsunder,G*., Lokanadham,B.*
Observations of comet Shoemaker Levy-9 collision with Jupiter from Japal-Rangapur Observatory
IAU General Assembly, The Hague, The Netherlands
1994 August

Sastri,J.H.
Short-period (5-33 min) variations in vertical drift of F region plasma near the magnetic equator
Eighth International Symposium on Solar Terrestrial Physics, Sendai, Japan
1994 June 5 - 10

Sastri, J.H.,, Meena Varma, V.K.*, Nayar, S.R.P.*
Height gradient of F region vertical drift in the evening equatorial ionosphere
National Space Science Symposium, Vikram Sarabhai Space Centre, Trivandrum
1994 December 20 -24

Satya Narayanan, A.
On the steady part of the Sun's internal magnetic field
XVI ASI meeting
IUCAA, Pune
1994 October 25 - 28

Singh, Prabhjot
Effect of non-coherent subordinate line scattering in static spherically symmetric stellar atmospheres
XVI ASI Meeting
IUCAA, Pune
1994 October 25 - 28

Venkatakrishnan, P., *Sakurai, T. *Suematsu, Y., *Ichimoto, K, Venkatakrishnan, P.
He I 10830 in active regions
Winter meeting of Astronomical Society of Japan
1995 March 23

Visits to Scientific institutions

P. Bhattacharjee visited the Isaac Newton institute for Mathematical Sciences, University of Cambridge, U.K. as visiting physicist, during 1994 August 16 - September 19. He participated in the NATO ASI Workshop on Topological Defects and gave a talk. He also visited the Theoretical Physics department, University of Oxford, UK 1994 September 11-12; Physics Department, Leeds University, UK 1994 September 16 and gave a talk. He was also a visiting scientist at the Max-Planck Institut für Radioastronomic, Bonn, Germany 1994 September 20 - October 2. He visited Max-Planck Institut für Kernphysik, Heidelberg, Germany and attended the Workshop on TeV Gamma Ray Astrophysics, 1994 October 3 - 7. He was a visiting physicist at the Fermi National Accelerator Laboratory, Batavia, Illinois, USA 1995 March 13 - April 4. He also gave an invited talk at the workshop on Physics and Astrophysics of Cosmic Rays above 10^{19}eV. P. Bhattacharjee visited the Astronomy and Astrophysical Center, Enrico Ferni Institute during 1995 March and held discussions with Prof. D.N. Schramm and others on ongoing collaborative research programmes. *R. Cowsik* visited the McDonnell Center for the Space Sciences, Department of Physics, Washington University, St. Louis, USA as a Distinguished Visiting Professor for four months from 1994 February through June and also during 1995 March. *R.T. Gangadhara* visited Prof. S.Deguchi, Nobeyama Radio Observatory, Japan under the India-Japan Co-operative Research Programme during 1995 January 29 - March 16. He also had discussions with Prof. Makita, Kyoto University, Japan. *S.S.Gupta* visited the National Solar Observatory, NOAO, Tucson, USA 1994 September 1 - October 7. *S.S.Hasan* visited the Goddard Space Centre, Greenbelt (U.S.A.), the Space Telescope Institute, Baltimore (U.S.A.) and the Harvard-Smithsonian Centre for Astrophysics in May 1994. He also visited Saclay (France) in 1994 June. *K.M.Hiremath* visited the Institute of Astronomy, Zurich, Switzerland during 1994 December 17 - 20 and had discussions with Prof.Stenflo regarding his thesis. *V.Krishan* visited Georgia State University, Astronomy Department, 1994 September 26 - 30. *P.M.S.Namboodiri* visited Department of Earth Science and Astronomy, University of Tokyo, Japan from 1995 February 15 - March 30. He held discussions with Japanese counterparts on using the GRAPE computer for investigation of galaxy collissions and cluster dynamics. He also visited the Department of Astronomy, Kyoto University, Kyoto, Japan between 1995 March 13 - 15 and had discussions with Professor Shogo Inagaki on some interesting problems in cluster dynamics. In connection with the detailed project report for HIROT a team of 5 members headed by *Ram Sagar* visited The Astronomical Observatories, Padova and ANSALDO, Milan, Italy 1995 February 18 - 23; ESO, Münich, Carl Zeiss, Oberkochen 1995 February 24 - 28; Autoscope Corp, Fort Collins, NOAO, Tucson, WIYN Telescope at KPNO, 1995 March 1 - 6. *N.K.Rao* visited the Dept. of Astronomy, University of Texas at Austin during 1994 March 26-May 31 in connection with the collaborative program on evolved stars with Prof.Lambert. Observations of several hydrogen deficient stars and RV Tauri stars were obtained with the McDonald Observatory telescope. He also visited IUCAA, Pune in 1994 July in connection with the IUCAA Science Advisory Committee meeting; to participate in the workshop on 'Heritage of Ancient Indian Astronomy' 1994 November 4 - 10 and the Indo-US workshop on 'Array Detectors and Image Processing in Astronomy'. He also visited the Astronomical Observatory of Uppsala University, Sweden at the invitation of Prof. B.Gustafsson in connection with the collaborative programme on Hydrogen Deficient Stars, 1995 March 15 - 30. *J.H.Sastri* visited Physical Research Laboratory in 1994 August and gave an invited talk and colloquium. *C.Sivaram* visited the Departments of Physics and Astronomy, University of Bologna, 1994 March - June, as visiting Professor, and Department of Physics, University of Ferrara, 1994 June - September. *K.R.Sivaraman* spent about 5 weeks in 1994 September - October at the National Solar Observatory, Tucson, USA to reduce the Kodaikanal Measurements in collaboration with Dr.Howard. *R. Srinivasan* visited the Department of Earth Science and Astronomy, University of Tokyo 1995 February 7 - March 23. *G. Srinivasulu* visited the Department of Earth Science and Astronomy, University of Tokyo 1995 March 1 - 39. *P.Venkatakrishnan* spent 6 months in 1994 at NASA/MSFC as a senior NRC associate and gave seminars at MSFC 1994 June 13; University of Alabama in

Huntsville 1994 October 28; CSPAR 1994 November 23. He also visited National Astronomical Observatory, Mitaka, Japan between 1995 February 24 - March 9 under the India-Japan Collaborative Programme and gave talks at ISAS, Japan 1995 March 2 and Kyoto University 1995 March 4.*C.V.Vishveshwara* visited Universidad del Pais Vasco, Bilbao, Spain 1994 April - December on sabbatical leave. In 1994 June he visited Universidad de Salamanca, Salamanca, Spain; Universidad Complutense de Madrid, Madrid, Spain; Universidad de Barcelona, Barcelona, Spain. He also visited Queen Mary and Westfield College, University of London, England 1994 December.

Appendix B

Teaching

The Institute continued to give full support to the teaching programmes in JAP, IISc and the MSc Astrophysics special papers of the Bangalore University. In addition IIA introduced a few new courses at introductory and advanced levels. The JAP/IIA courses were semester-long. A list of these is given below :

Course	Lecturer
Survey of Astronomy (JAP)	H.C.Bhatt
Radiative Processes in Astrophysics (JAP)	V.Krishan
Fluid Dynamics and Plasma Physics (JAP)	S.S.Hasan
Astronomical technique (JAP)	Ram Sagar
Diffuse matter in space (JAP)	D.C.V.Mallik
General Relativity and Cosmology (JAP)	C.V.Vishveshwara
Mathematical methods (IIA)	S.Chatterjee
Physics I and II (IIA)	B.P. Das

In Bangalore University courses of fifteen to thirty lectures were given by S.P.Bagare, J.H.Sastri, R.K.Kochhar, R.Surendiranath and A.V.Raveendran. M.H.Gokhale continued to coordinate this programme. K.E.Rangarajan coordinated and supervised the summer projects of two IIA research scholars at NCRA, Ooty and Pune. Expert guidance was made available to the students by the NCRA staff. Ram Sagar supervised the summer projects for five engineering college students from PSG College of Technology on image processing. Ram Sagar and R.Srinivasan supervised the project of A.D.Jana on 'Temperature and seeing measurements at VBT'. A.V.Ananth taught a short-term course "Introduction to computers and FORTRAN programming". S.K.Saha gave a series of lectures on "Optical Interferometry in Astronomy" to the Ph D students of IIA. A.Satya Narayanan gave a course on 'Advanced Mathematical Methods'.

G.S.D.Babu taught a dissertation-oriented honours programme in Astronomy and Astrophysics to the undergraduate students of St Joseph's college, Bangalore. He also taught Spherical Trignometry and Astronomy at the Tangerine Geoscience Institute, Bangalore. P.Venkatakrishnan guided five students from PSG College of Technology in 1994 May under the IMPACT programme. He was assisted by V.Krishnakumar. R.Srinivasan offered a course on "Electronics and Instrumentation in Astronomy" to the undergraduate Honours Programme in St. Joseph's College, Bangalore. V.Chinnappan guided two batches of engineering students for their final year project work. Nagaraja Naidu guided students from PES Institute of Technology for their final year project work.

Ph D supervision

Bhaskar Datta supervised the Ph D thesis titled "A study of the properties of dense nuclear matter and application to some astrophysical systems" of P.K.Sahu submitted to Utkal University, Bhubaneswar. T.D.Sreedharan has submitted his Ph D thesis on 'MHD Turbulence in Solar Coronal Loops' to the Bangalore University under the guidance of V.Krishan. S.S.Hasan is supervising the research work of D.Banerjee and A.D.Jana towards their Ph D thesis.

Editing and Publishing

D.C.V. Mallik edited the Annual Report (1993-94) with the assistance of S.Rajiva on behalf of the Director. He also served as the Associate Editor of the Journal of Astrophysics and Astronomy, published by the Indian Academy of Sciences, till 1994 December 31. N.K.Rao continues to be on the Editorial Board of Journal of Astrophysics and Astronomy. T.P.Prabhu and A.K.Pati continued to edit the IIA Newsletter which entered its tenth year in 1995. Vinod Krishan assumed the duties of the Editor of the Bulletin of Astronomical Society of India since January 1995. Ram Sagar continues as the Associate Editor of the Bulletin. S.Rajiva is the Editorial Secretary. C.V.Vishveshwara is the co-editor of the Bulletin of Sciences, a quarterly journal published by Wiley Eastern.

Popular articles

Babu,G.S.D.
The collision of Comet Shoemaker-Levy (1993e) with planet Jupiter
Deccan Herald, Bangalore, 1994 June 20
The Week, Kochi, 1994 July 24

Pal, P.B.
Map-jokher itihas (A history of Measurements)
Prakriti
1995 January

Sourô-neutrino samasya (The solar neutrino problem)
Desh
1995 May 9

Singh,Jagdev
(1995) Souvenir, V All India Amateur Astronomers Meet
Bhubaneswar

Vishveshwara, C.V.
Matter and Magic
"Prakriti : The Nature of Matter"
ed. J.V.Narlikar
D.K. Prints World Ltd, New Delhi 1995

Popular Books

Pal, P.B.
Sal-tarikher Itihas (A history of Calendars)
Samata Prakashan, Calcutta, 1994

Bibartan : juge juge (Evolution through the ages)
(One of the contributing authors)
Breakthrough Publications, Calcutta, 1994

Radio/TV

Babu,G.S.D.
Collision of Comet Shoemaker-Levy (1993e) with planet Jupiter
AIR, Bangalore, 1994 July 8

G.S.D. Babu was the subject expert, script writer, narrator and presenter of the UGC Audio-visual programme on the collision of Comet Shoemaker-Levy (1993e) on the planet Jupiter titled "Cosmic Salute". It was produced by AVRC, Osmania University, Hyderabad in June 1994 for the County-wide Class Room Programmes of the University Grants Commission. This programme has subsequently won the award for the "Best Special Effects" in the All India Video Contest".

Popular Talks

Babu,G.S.D.
Crash of comet Shoemaker-Levy 9 (1993e) on planet Jupiter
Chemical Engineering Association, IISc, Bangalore,
1994 July 13
Vikram Sarabhai Space Centre, Trivandrum
1994 July 14
Lions Club of Bangalore North, Bangalore
1994 August 3
Technical Forum, BHEL, Bangalore
1994 August 4
National College, Jayanagar, Bangalore
1994 August 24

Indian Institute of Astrophysics

Central School, Indian Oil Refinery, Guwahati
1994 September 3
Cotton College, Guwahati,
1994 September 4
Guwahati Planetarium, Guwahati
1994 September 5
Indo-French Technical Association, Bangalore
1994 December 6

An introduction to Astronomy
Bishop Cotton Girl's High School, Bangalore
1994 August 5

Astronomical Observations of Maharaja Sawai Jai Singh
Birla Planetarium, Calcutta
1994 September 1
On the 9th Indian Scientific Expedition to Antarctica
CSI Council for Child Care, Regional Camp'94, Mandanapalle (AP)
1994 April 26
Vikram Sarabhai Space Centre, Trivandrum
1994 July 15
Indian Oil Refinery, Guwahati
1994 September 3
Cotton College, Guwahati
1994 September 5

Das,B.P.
Atomic probes of the unification of fundamental forces
Bangalore Science Forum
1994 November

Hasan,S.S.
New frontiers in the Physics of the Sun
Bangalore Planetarium
1994 September

Prabhu,T.P.
Supernovae
Bangalore Science Forum
1994 July 26

Saxena,A.K.
New technology telescope
Feroze Gandhi College, Rae Bareli, U.P.
1995 April 30

Singh, Jagdev
The Sun
Meeting of V All India Amateur Astronomer Meet
Bhubaneswar
1995 January

The total solar eclipse of October 24, 1995
Meeting of Bharath Gyan Vigyan Samithi
Karnataka
1994 October 24

Vishveshwara,C.V.
The cosmic vision : From myth to modern science
Life beyond the earth
Universidad del Pais Vasco, Bidbao, Spain
1994 April - December

Science and Society in Spain
Bangalore Science Forum
1995 February

Appendix C

Vainu Bappu Observatory

Sky conditions of VBO

Year	Month	Spectroscopic (hrs)	Photometric (hrs)
1994	April	118	15
	May	107	9
	June	69	5
	July	42	5
	August	29	1
	September	66	22
	October	38	0
	November	73	15
	December	188	100
1995	January	119	47
	February	172	71
	March	231	110
	Total	1252	400

Kodaikanal Observatory

Spectroheliograms/Photoheliograms (No. of plates and seeing condition)

Year	Month	Hα	KFL	HαPR	PHGM	Seeing*				
						5	4	3	2	1
1994	April	20	19	17	21	—	—	10	11	—
	May	20	25	14	24	—	—	11	12	1
	June	2	9	2	9	—	—	2	6	1
	July	6	4	5	6	—	—	3	3	—
	August	6	6	6	11	—	—	5	5	1
	September	16	15	13	18	—	—	6	11	1
	October	7	6	7	11	—	—	7	3	1
	November	8	10	7	8	—	—	2	6	—
	December	15	22	11	24	—	9	10	5	—
1995	January	17	16	11	17	—	—	15	2	—
	February	12	13	10	18	—	3	14	1	—
	March	24	24	17	24	—	11	11	2	—
Total		153	169	120	191	—	23	96	67	5

KFL = K-Flocculus, HαPR = Hα-Prominences,
PHGM = Photoheliograms

* (1-Very poor, 2-Poor, 3-Fair, 4-Good, 5-Excellent)

Solar tower observations

Year	Month	Total number of days of observations	Seeing (in arcsec)						
			2	2 to 3	3	3 to 4	4	4 to 5	5
1994	April	—	—	—	—	—	—	—	—
	May	8	—	1	7	—	—	—	—
	June	2	—	—	2	—	—	—	—
	July	1	—	—	1	—	—	—	—
	August	—	—	—	—	—	—	—	—
	September	5	—	1	4	—	—	—	—
	October	5	—	2	1	—	1	1	—
	November	4	—	—	2	1	1	—	—
	December	11	—	1	6	2	1	1	—
1995	January	3	—	—	3	—	—	—	—
	February	17	2	—	11	—	1	3	—
	March	19	—	3	13	—	2	1	—
	Total	75	2	8	50	3	6	6	—