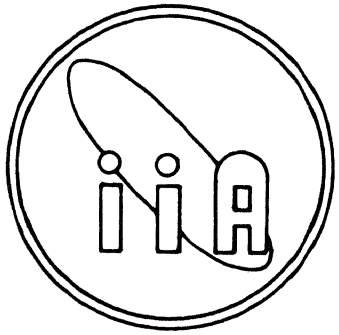
Indian Institute of Astrophysics

Annual Report 1998-99

INDIAN INSTITUTE OF ASTROPHYSICS



ACADEMIC REPORT
1998-1999

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Back Cover	:	The Summit Hall, Kodaikanal Observatory, IIA.
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Professor Cohen-Tannoudji at the Hoskote Campus

The year in review

The year 1998-99 was as eventful and productive from the point of view of research and overall scientific development as the previous few years. Consolidation of several projects, initiated in the earlier years, took place. Some new initiatives were taken. The various campuses of the Indian Institute of Astrophysics, flung practically across the entire length of India, from Leh and Hanle in Ladakh to Kavalur and Kodaikanal in Tamil Nadu, witnessed all-round growth. Two highly successful international conferences were organised by IIA in Bangalore, one in the field of Astronomy and the other in the field of fundamental Physics. Several topical mini-symposia were organised on the occasion of the visits of some renowned scientists, in subject matters of common interest. Scientists from IIA as well as other neigthbourhood institutes participated in these and gave talks on their work in overlapping areas. Several graduate students were able to finish their doctoral work and many of them left the Institute with well-earned fellowships to pursue further work elsewhere in their areas of specialisation. With excellent facilities for research in astronomy, astrophysics and nonaccelerator particle physics, with the imminent prospect of the availability of new telescopes at the Indian Astronomical Observatory in Hanle, and with career prospects and pay scales on a par with other academic institutions carrying out fundamental research, IIA is attracting senior research scientists and graduate students alike in good numbers. With so much young talent dedicating themselves to astronomy and astrophysics, the prospects are indeed great for making significant contributions in the coming years.

Some of the highlights of the scientific work are enumerated below. This is followed by a more detailed description of the research, development and other activities of the institute that have taken place during the year.

Research

A new radioheliograph for obtaining two-dimensional images of the solar corona, sequentially at many frequencies in the range 40 - 150 MHz, was put into operation at the Gauribidanur Radio Observatory near Bangalore. This radioheliograph fulfils a long-felt need for a dedicated instrument to observe the solar corona at low frequencies. With the Nobeyama and the Nancay radioheliographs carrying out regular observations of the Sun at centimetre and decimetre-metre wavelength ranges, it has now become possible to extend the range up to decametre wavelengths with the operation of this new radioheliograph. A multi-wavelength collaborative study using the data obtained with the ground-based instruments and those on board space missions like Yohkoh, WIND, SOHO, is expected to provide new insights into the Sun. A new physical interpretation of the Poynting-Robertson effect has been given. By studying the effect as a two-parameter process, it has been concluded that the motion of dust in circumsolar orbit is governed only by solar radiation absorption and not by the asymmetry of re-emission, even when viewed in the rest frame of the Sun.

A new asteroid was serendipitously discovered by a research scholar in March 1999, while she was imaging a GRB field with a 1 K by 1 K CCD system and broadband filters, at the 102 cm Zeiss Telescope at VBO, as part of a regular observing run. A quick-look analysis of the CCD images revealed a faint moving object. A search through the 'Minor Planet Catalogue' did not indicate the presence of any known object in that area and confirmed that a new asteroid had been discovered. The precise astrometric positions as well as the magnitude of the asteroid were computed and reported to the Minor Planet Centre. Follow-up observations of the asteroid were carried out in April using the 102 cm telescope again. It is interesting to note that at a V magnitude level of 21 there could be about 50 asteroids per square degree of the sky. It is not surprising, therefore, to catch one or two of them once in a way while imaging at faint levels with large telescopes.

The problem of the high mass of the hot component in the recurrent nova T CrB was solved after 38 years through a major collaborative effort involving long-term spectroscopic monitoring of the nova with the 102 and 234 cm telescopes at VBO and photoelectric photometry of the object obtained at the Skalnate Pleso Observatory and the Hlohovec Observatory in Slovakia. The

mass of the hot component is estimated to be $1.2 \pm 0.2\ M_{\odot}$ assuming an orbital inclination of 68° for the binary system. There is thus no difficulty in reconciling the mass of the white dwarf with Chandrasekhar's theory. In another collaborative effort involving polarimetry at VBO and spectroscopy with the NICMOS3 array at Gurushikhar Observatory of PRL, the prototype and one of the brightest Herbig Ae/Be stars, AB Aurigae, has been monitored and it is found that the star entered an unusually inactive phase during January - February 1999. The optical linear polarization measurements indicated that the degree of polarization was at its highest while the spectroscopy showed that the Pβ line was marginally in absorption and the Brγ emission was absent. The V magnitude was at its brightest but the J,H,K magnitudes were at their faintest.

Formation of massive stars in the infrared-bright galaxy NGC 972 was studied through optical broadband and narrowband Hα imaging. The broadband images revealed a peculiar morphology and complex dust distribution. Continum-subtracted Hα images showed the presence of circumnuclear activity and disk star formation within a radius of 3.4 kpc from the centre. It was found that the circumnuclear starforming regions are distributed in a ring of radius 0.630 kpc and are closely associated with an inner dust ring. Evolutionary synthesis models were used to derive an age < 5.4 Myr for the nuclear starburst activity. The star formation rate has been estimated as $0.32\ M_{\odot}\ yr^{-1}$ in the nuclear region and $2.1 - 2.7\ M_{\odot}\ yr^{-1}$ in the inner 3.4 kpc of the galaxy.

The recent discovery of kHz quazi-periodic brightness oscillations (kHz QPOs) in some x-ray binaries have led to suggestions that these represent the orbital frequencies of the innermost Keplerian orbits around accreting neutron stars. Attempts have been made to derive constraints on the mass and the equation of state of a neutron star, by identifying the highest observed QPO frequency with the Keplerian frequency at the marginally stable orbit according to the general theory of relativity. These estimates have either neglected the effect of neutron star rotation or have used an approximate treatment of rotation in general relativity. However, there is a need for a fully general relativistic treatment of the rotation in deriving constraints on the neutron star structure using the kHz QPO data. This has been accomplished and new constraints have been derived on the mass and the equation of state of the neutron star. Constraints have also been derived corresponding to the case where the innermost stable orbit touches the neutron star surface. In another paper, the role of orthogonal polarization modes in pulsar emission has been re-examined in the light of high time-resolution data obtained at 1.41 GHz of the pulsar PSR B1133+16 with the Effelsburg Radiotelescope near Bonn. Orthogonal modes appeared better separated in the high-resolution dataset. The emission appears highly polarized. Further, the linear polarization becomes higher when the circular polarization is at minimum, an observation which is in agreement with the predictions of curvature emission.

Notable advances were made in the area of Non-Accelerator Particle Physics using parity nonconservation (PNC) in atoms and electric dipole moments (EDM) as two of the important probes of physics beyond the Standard Model. An experiment to observe PNC due to neutral weak currents in atomic Yb is currently under way at the University of California, Berkeley. Theoretical calculations were carried out in IIA to explore whether the same atom would be a good candidate for observing the nuclear anapole moment. The results suggest that two transitions $6s^2\ (^1S_0) — 6s\ 5d\ (^3D_1$ and $^1D_2)$ would be suitable for this purpose. Equally important is the Ra^+ ion, whose transitions were calculated in detail in IIA to show that the PNC signals in this ion are more than 20 times stronger than the corresponding transitions in Ba^+. An experimental effort to measure these transitions by trapping the ions in Paul Traps and addressing them through laser spectroscopy, is under way at IIA. The transitions are especially interesting, as they arise solely due to the nuclear anapole moment.

Infrastructure Development

Substantial progress was made during the year in the project work of setting up the Indian Astronomical Observatory at Hanle, Ladakh. A major part of the fabrication of the 2-m telescope was completed at EOS Technologies Inc. in Tucson. The telescope building and enclosure have been under construction. In an important development, the Washington University, St. Louis, Missouri and IIA jointly proposed the setting up of an Antipodal Transient Observatory comprising two identical 50 cm telescopes, 180 degrees apart in longitude, to monitor the time variability of astronomical objects, in particular the variability of AGN. IIA has decided to place this telescope in Hanle while

the other one to be operated by Washington University will be placed near Kitt Peak in Arizona. Both the telescopes are under fabrication in the US. The enclosure for the ATO was designed and is being fabricated at VBO, Kavalur. A 12 inch Meade telescope was acquired and commissioned during the year. Routine site-characterisation exercises continued at Hanle. Major effort was invested in providing various infrastructure facilities such as electrical power, a LN_2 plant, satellite communication channel, road, accomodation, transport, etc.

The Pt-Si near-infrared CCD, developed jointly with the Japanese, was installed in the infrared dewar and the pumping and cryogenic performances of the solid nitrogen dewar were tested to satisfaction. The first trial images with this detector were successfully recorded at the VBT using JHK filters.

The Hoskote campus witnessed all-round development. Several construction works have been started. A satellite communication station has been set up to receive data from Hanle and to control the remote operation of the telescopes there. The campus has been beautified with the planting of various species of trees and conservation measures have been adopted. It is hoped that when fully developed, this campus will provide an ideal setting for education, research and training. A major proposal to develop Non-Accelerator Particle Physics in IIA has been approved by SERC.

Conferences and Visitors

IIA hosted the Second International Workshop on Solar Polarization which was held in Bangalore between October 12 and 16, 1998. Sixty one Scientists from sixteen countries attended the workshop. The main purpose of the workshop was to bring together specialists working in this newly emerging area of solar physics. The meeting was highly successful. The proceedings have been recently published by the Kluwer Academic Publishers in the series Astrophysics and Space Science Library.

The Indo-French Workshop on Probing Fundamental Problems with Lasers and Cold Atoms was held in IIA, Bangalore during January 4-8, 1999. The meeting was jointly sponsored by the Indo-French Centre for the Promotion of Advanced Research and IIA. The French delegation to the conference was led by Professor Claude Cohen-Tannoudji and Professor Madame Leduc of Laboratoire Kastler Brossel, ENS, Paris. A variety of frontline research topics were discussed. These included quantum and nonlinear optics, manipulation of atoms and ions with light, quantum electrodynamics etc. Besides the French delegates, more than a hundred Indian scientists participated in the workshop. The scientific programme was excellent and a touch of class was added to it by a dance performance during one of the evenings by the noted Bharatanatyam exponent Malavika Sarukkai.

Professor Cohen-Tannoudji delivered an Academy Lecture organised by the Indian Academy of Sciences, Bangalore to a packed audience. The title was, *Manipulating atoms by light.* Professor Alain Aspect of Insitut d' Optique. Orsay, France gave a public lecture at the Raman Research Institute on the *Experimental tests of the foundations of quantum mechanics.* The Thirteenth IIA Bicentennial Public Lecture was also delivered during this workshop by Professor Michele Leduc. She spoke on *Imaging the human lungs by magnetic resonance with polarised gases.* This technique is supposed to revolutionise the diagnostic aspects of pulmonary diseases.

Under the programme, *Bright Sparks - the Best of British Science* sponsored by *The British Council*, two distinguished visitors - Dr. David Malin of the Anglo-Australian Observatory, Epping, Australia and Alex Boksenberg, FRS and Professor of Experimental Astronomy, Institute of Astronomy, Cambridge, England, visited IIA in February 1999. David Malin gave a talk on *Faint structures in bright galaxies* which was illustrated, as expected, with the exquisite astronomical photographs for which Malin is justly famous. On the occasion of Professor Boksenberg's visit on February 26, 1999 a mini-symposium on Quasars was organised. The symposium started with an illuminating lecture by Boksenberg on *What the quasar absorption lines tell us about the Universe* and ended with a presentation on *Energetic radiations emerging from accretion flows around massive black holes* by Ramanath Cowsik.

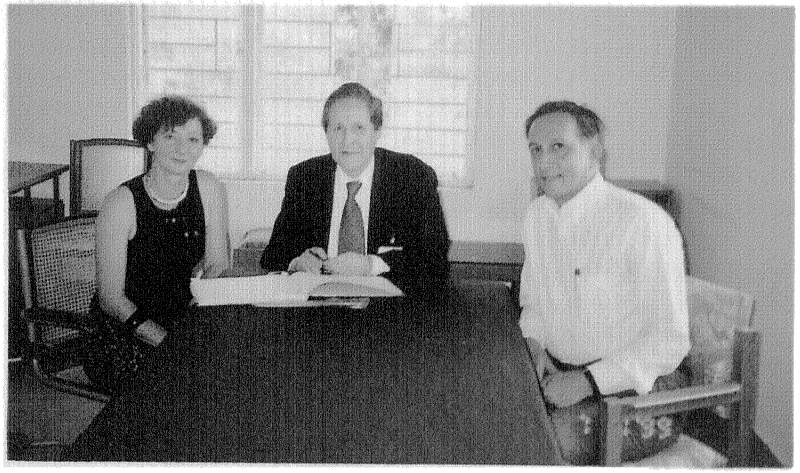
Nikos Prantzos of the Institut d' Astrophysique de Paris visited IIA in March, 1999 for about a week and a one-day workshop on The Galaxy and its Chemical Evolution was held in IIA on March 5. There has been a renewed interest

in this field, as with the high-resolution spectrographs attached to the Keck telescopes one is now able to probe chemically the Universe at high redshifts.

Graduate training

Five students, two under the Joint Astronomy Programme of the Indian Institute of Science and three directly recruited by IIA and registered with Bangalore University, completed their doctoral work and submitted their dissertations to the respective institutions. Two of them have already been awarded the Ph.D. degree while the formalities are nearing completion for the other three. The current student population in IIA is 32 strong.

The University of Calicut and IIA signed a Memorandum of Understanding in the area of their mutual interest of teaching and research in Astronomy, Astrophysics and related topics. As part of this MOU, IIA has agreed to install an 18 inch telescope at a suitable site in the University campus and the University has agreed to recognise IIA as one of its research centres for carrying out work leading to the Ph.D. degree. The University of Calicut has also agreed to recognise the course work done by IIA students in Bangalore and to consider the same to fulfil the requirements of a Master's degree. This solves a longstanding problem for those students admitted by IIA in the regular Ph.D. programme who have a B.E. or a B.Tech degree, since Bangalore University insisted on a Master's degree for Ph.D. registration and did not recognise the course work done at IIA.



Reaching for the Stars

IIA undertook to put up a tableau during the Republic Day Parade on behalf of the Ministry of Science and Technology. The theme was conceived by the IIA astronomers and the tableau designed by the Bangalore based firm Architecture Paradigm. The music used was from the cassette *Space* composed by Ustad Zakir Hussian in the series Music Today, the copyright of which is with Messrs Living Media India Ltd. The permission to use the music is gratefully acknowledged. The highlights of the tableau was a scale model of the sophisticated optical and infrared telescope that is to be installed at Hanle at an altitude of 15,000 ft. above the sea level.

Assessing the good progress that is being achieved in its fabrication, and also in building up the requisite infrastructure at Hanle, we have every hope of achieving "first light" by June 2000 at the Indian Astronomical Observatory, the highest of its kind in the world.

Ramanath Cowsik
Director

Solar physics

The Sun

Convection and torsional MHD oscillations in the Sun due to g modes excited by Post-Newtonian effects in solar-planetary gravitation.

Existence of common periodicities between various parameters of the solar cycle and those of solar system dynamics has led several authors to suspect the presence of some coupling between solar system dynamics and internal MHD of the Sun. (Wood, R.M. and Wood, K.D. 1965, Nature 208, 129; Wood, K.D. 1972, Nature 240, 91; Zaqarshvili, T.A. 1997, Ap. J. 487, 930). Earlier work (Gokhale, M.H. 1996, BASI 24, 121) had suggested that the torsional MHD oscillations of the Sun, which constitute the solar magnetic cycle (see Gokhale, M.H. and Javaraiah, J. 1995, Sol. Phys. 156, 157) are forced by the inertial torque due to the spin variations exerted on the Sun by planets.

It is pointed out that the gravitational exchange of energy and angular momentum between the Sun and Jupiter takes place basically on time scales of $\tau_j \sim$ 2596s and according to the parameterized Post-Newtonian (PPN) equations, this exchange is coupled to a large number of internal g modes of the Sun whose frequencies are crowded around 400 μHz. This coupling will lead to perpetual perturbations of durations $\sim \tau_j$ on the ephemeris orbits of the Sun and Jupiter and to the excitation of the coupled g mode waves, thus adding new degrees of freedom to solar system dynamics and the internal dynamics of the Sun. Using the extreme assumption of equipartition of energy, we estimate the perturbations in motions of the Sun and Jupiter to be observationally undetectable, and the wave amplitudes to be adequate to provide transport of the solar luminosity across the convective envelope. This might lead to a 'physical' model of solar convection.

Among the g mode waves so excited, the inward propagating 'prograde' waves would be absorbed in a thin layer at the base of the convective enveope and would exert on it a torque which could excite torsional MHD oscillations there. Details of these processes are being worked out.

(M.H. Gokhale)

Fossil magnetic fields on the Sun and stars

It is believed that stars might have retained in their interiors some part of the large-scale magnetic field from the protostellar phase. Such large-scale fields are conspicuous in many stars of the early and late spectral types on the main sequence and in white dwarfs. These large-scale magnetic fields play an important role in transferring angular momentum on long time scales and in the creation of stellar activity and activity cycles on short time scales. The aim of the present study has been to model the geometrical structure of the magnetic fields from the solutions of MHD equations and study their effects on the dynamics and the transfer of energy.

We first obtained a solution of Chandrasekhar's MHD equations for the steady part of the Sun's poloidal field which is embedded in an asymptotically uniform external field. In order to get the relative strengths of different components of the magnetic field in the solution, we have used the internal rotation recently inferred from the GONG data by Antia et. al. (1998, MNRAS 298, 543). In the radiative core (RC), our best fit gives the combination of the first two diffusion eigenmodes of the magnetic field. In the convective envelope (CE), the best fit yields a combination of dipole-like and hexapole-like magnetic fields. Magnetic field structure obtained from the present work is almost similar to our previous work. However, in the previous work, the uncertainties in the relative strengths of different components of the magnetic field were large (~20%), whereas in the present calculations, the uncertainties have been considerably reduced (~ 2%).

We have computed the radial and the latitudinal variations of the magnitude of the poloidal magnetic fields normalized to an asymptotic uniform magnetic field B_o. It is interesting to note that the strength of poloidal part of the magnetic field ($|B_p|$) varies substantially in the radial direction and appears to be nearly independent of the latitude. This profile of $|B_p| / B_o$ is almost similar to the rotation profile which is inferred by helioseismological studies. This work may give a clue to the evolutionary history of the internal rotation and mag-

netic field of the Sun. For example, in the early history of the Sun, a strong poloidal magnetic field might have played a dominant role in transferring angular momentum from the interior to the surface. In later stages, as the field decayed, the poloidal field might have reached isorotation with the present day solar rotation. Hence, it is not surprising that we obtain a striking similarity between the structure of the poloidal part of the magnetic field and the isorotation contours inferred from helioseismology.

It is tempting to extend this work to other stars. For example, for the early type main sequence stars, one may expect that the geometric structure of the poloidal magnetic field is similar to that of the steady part of the poloidal field in the Sun's radiative core. Similarly, the magnetic field structure of white dwarfs could be similar to the field structure in the radiative core of the Sun. In the case of G and K type main sequence stars, which have convective envelopes in the outer part and radiative core in the deep interior, one may expect the magnetic field structure to be similar to that of the field structure of the whole Sun. In the case of late type main sequence stars which are almost fully convective, we expect the magnetic field structure to be similar to the magnetic field structure in the convective envelope of the Sun.

(K.M. Hiremath and M.H. Gokhale)

Short-term periodicities in the Sun's 'mean' and differential rotation

Periodicities in the solar differential rotation on time scales shorter than the 11-yr solar cycle have been looked for through the power spectrum analysis of the differential rotation parameters determined from the Mt. Wilson velocity data (1969 - 1994) and the Greenwich sunspot group data (1879-1976). The differential rotation has been represented by a set of Gegenbauer polynomials $\omega(\phi) = \bar{A} + \bar{B}(5\sin^2\phi - 1) + C(21\sin^4\phi - 14\sin^2\phi + 1)$. For the Mt. Wilson data, observations obtained after 1981 were considered as they have reduced instrumental noise. The data were binned into intervals of 19 days. The annual averages of the 'mean' $\bar{A}$ and the differential coefficient $\bar{B}$ were calculated from the sunspot data. The abnormally high or low $\bar{A}$ and $\bar{B}$ values having large uncertainties during the years of solar minima were replaced by averages of values during the preceding and the following years. Considerable differences have been found in the temporal behaviour of the $\bar{A}$ and $\bar{B}$ determined from the velocity data and from the spot group data. In the Mt. Wilson velocity data, we found periods of 6.7 - 4.4 yr, 2.2 ± 0.4 yr, 1.2 ± 0.2 yr, and 243 ± 10 day in $\bar{A}$ and only the 11 yr period in $\bar{B}$ and $\bar{C}$. In the sunspot data, we found periods, which are most likely harmonics of the solar cycle, such as 18.3 ± 3.0 yr and 7.5 ± 0.5 yr in $\bar{A}$. In $\bar{B}$ we confirmed these periods and also the period 3.0 ± 0.1 yr found earlier. In addition, the 11 yr period is found to be present in $\bar{A}$ from the sunspot data, while it was found to be absent in $\bar{B}$. The differences in the periodicities in $\bar{A}$ and $\bar{B}$ determined from the sunspot data and the velocity data may be explained by assuming that the rotation rates determined from the velocity and the sunspot data represent respectively, the rotation rates of the Sun's surface layers and of somewhat deeper layers.

(J. Javaraiah, *R.W. Komm)

Depth dependence of the periodicites in the solar differential rotation

The temporal variations of the differential rotation coefficient B has been studied by determining it separately for the Greenwich data (1879-1939) samples defined as follows: (i) YLSG : young long-lived sunspot groups (YLSG1 : $t = 2, \tau = 7\text{-}12$, or YLSG2 : $t < 4, \tau = 10\text{-}12$), where τ and t represent respectively life span and age of a sunspot group in days, (ii) SLSG : short-lived sunspot groups ($\tau = 2\text{-}4$) and (iii) OLSG : old long-lived sunspot groups ($t > 4, \tau = 10\text{-}12$). To have sufficient data sizes, the calculations were done using moving time intervals (MTI) of lengths 5 yrs. Fig. 1 shows the power spectra of B determined from the YLSG, OLSG and SLSG for 5-yr MTI during 1879-1976. The power spectrum of B determined from YLSG shows the existence of a prominent periodicity of ~ 21 yr. Spectra determined from OLSG and SLSG show the existence of a prominent periodicity of ~ 11 yr. Comparing the mean rotation frequencies of YLSG, OLSG and SLSG with the radial dependence of solar plasma rotation frequency determined from helioseismology, it is suggested that the periodicities ~ 21 yr and ~ 11 yr in B are dominant in the rotational perturbations in the Sun's deeper layers (near base of the convective envelope, $r \sim 0.73\ R_\odot$) and in the shallower layers ($r > 0.95\ R_\odot$) respectively.

(J. Javaraiah)

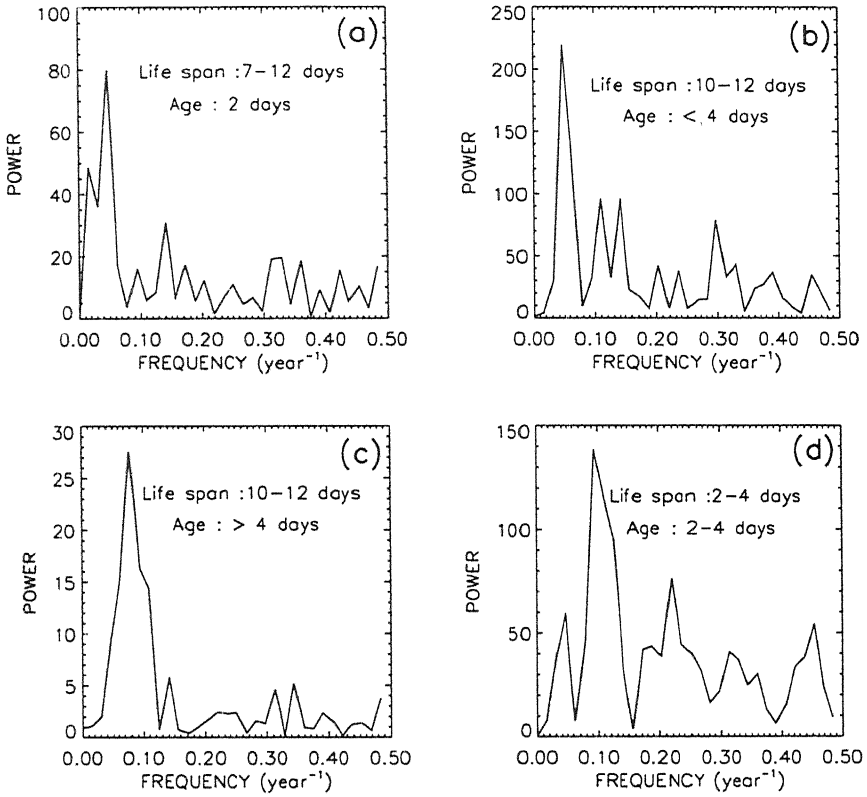


Figure 1. FFT spectra of the differential coefficient B determined from the (a) YLSG1, (b) YLSG2, (c) OLSG and (d) SLSG.

Variations of the Sun's 'mean' and differential rotation with the phase of the solar cycle

From the analysis of the Greenwich data on sunspot groups during 1879-1976, the average annual values of the rotation parameters $\bar{A}$ and $\bar{B}$ were determined according to the year relative to the nearest sunspot minimum (1923, 1934, 1944, 1955, 1965, 1975, 1986), to search for a solar cycle variation, as was done by Gilman & Howard in 1984 and Balthasar, Vazquez, and Wohl in 1986. Two data points (1932 and 1933) which had errors larger than three times the median error were excluded. A variation has been found with the cycle in the 'mean rotation' $\bar{A}$ which is slightly larger than the average during the cycle minimum and slightly smaller during the cycle maximum. The difference between the maximum and the minimum is about two standard deviations. No comparable cycle variation was found in the differential rotation coefficient $\bar{B}$. The variations in $\bar{A}$ and $\bar{B}$ were found to be very similar to the ones reported by Balthasar, Vazquez, and Wohl with the exception of the 9th year where they found a strong increase.

(J. Javaraiah, *R.W. Komm)

Dependence of the meridional motions of sunspot groups on their life spans and ages

Many solar physicists believe that the Sun's meridional flow can transfer angular momentum and magnetic flux across the solar latitudes and can even maintain the observed differential rotation. Tracking of tracers (sunspots, sunspot groups, faculae, plages, prominences, small magnetic features etc.) and direct Doppler measurements are the two principal methods used to measure the meridional flow. We have analyzed the data on sunspot groups compiled during 1874-1981 and investigated the following : (i) dependence of the 'initial' meridional motion of sunspot groups υ_{ini} (τ) on the life span τ of the groups in the range 2-12 and (ii) dependence of the mean meridional motion υ(t) of sunspot groups of life spans of life spans 10-12 on their age t. This investigation brings out the following trends.

In each of the latitude intervals 0° - 10°, 10° - 20° and 20° - 30°, the values of υ_{ini} (τ) and υ (t) often differ significantly from zero. In the latitude interval 20°

- 30°, the forms of υ_{ini} (τ) and υ (t) are largely systematic and mutually similar and this is true separately in the north and south hemispheres. In υ (t) there is a suggestion of the existence of periodic variation in solar meridional motion with a period of 4 days and an amplitude of 10-20 m s^{-1}. The meridional flows υ_e(t) determined from the data during the last few days of the life of spot groups of life spans 10-12 days are found to have magnitudes (10-20 m s^{-1}) and directions (poleward) similar to those of the surface meridional plasma flows determined earlier from the Dopplergrams and magnetograms. Existence of a north-south asymmetry in υ_e(t) is suggested. Using the anchoring depths of magnetic structures for spot groups of different τ and t estimated from the analysis of rotation rates of spot groups (Javaraiah J. and Gokhale M.H. 1997, A & A 327, 795), we suggest that the patterns of υ_{ini} (τ) and υ(t) may represent the spatial structure of the meridional flow in the Sun's convection zone, rather than its temporal variation.

(J. Javaraiah)

Solar Rotation

An investigation was started some time ago with the aim of comparing the rotation of the Sun, the differential rotation and the variation of the rotation rate with the solar cycle derived from the measurements of the Kodaikanal white light images over 82 years (1906-1987) with similar data from Mt. Wilson. By combining the data sets from the two stations and deriving the rotation rate and other parameters, one hoped to enhance the precision to a level hitherto unachieved and to also look for systematic motions on the Sun for which there is only marginal evidence now from other sources. The rotation rates from the two stations when matched showed disagreements at a level of 0.6% which is too large considering the refined methods that were used for measuring the plates. This led to a series of unexpected problems. We ran the combined data sets through several newly devised diagnostic tests and finally traced the disagreement to optical aberrations in the imaging systems at both the stations. We then modelled these and the aberration corrected results from the two stations agree to within 0.08%.

(K.R. Sivaraman, *R. Howard, S.S. Gupta)

Evershed velocities in bipolar sunspots

Spectra taken at the solar tower telescope spectrograph, Kodaikanal, were analysed to find the line-of-sight velocities in regions between sunspots of opposite polarities. Velocities in opposite directions, in the range 1 - 2.5 km s^{-1}, were obtained in the regions between umbrae of opposite polarities having a common penumbra, which once again confirmed the Evershed flow falling back onto the sunspots. However, sunspots having separate opposite polarity structures did not show any appreciable velocity in the regions between them.

(K. Sundara Raman, P.S.M. Aleem, R. Thiagarajan)

Observational evidence for magnetic connection in bipolar spots

A study of photoheliograms, Hα spectroheliograms, and K_{pr} from Kodaikanal Observatory, the published soft x-ray data from OSO, and the magnetograms from KPNO, suggests that bipolar spots are magnetically connected through overlying loop structures. The result obtained for one year of data (1978) needs to be verified for a solar maximum period of activity.

(S.P. Bagare, S.S. Gupta)

Studies on the axial tilt angles of sunspot groups and chromospheric plages

The axial tilt angles were measured for selected sunspot groups observed during four years at Kodaikanal. The angles are examined for relation with other spot group characteristics such as group areas, latitude of occurrence etc. The results are compared with reported correlations obtained from magnetogram data.

(S.P. Bagare, S.S. Gupta)

Dynamics and heating of the solar chromosphere

The aim of this investigation is to reexamine the association or the lack of it of the bright points in the interior of the K-line network in the solar chromosphere with the underlying sub-arcsec magnetic elements at the photosphere.

The investigation is an important one as it can provide vital clues to settle the controversy between the two opposing sets of models in the literature (ones claiming magnetic association of the bright points and the others modelling them as of purely hydrodynamic origin) and the corrresponding role of the bright points in the heating of the chromosphere. Observationally the problem is a difficult one as it calls for observations to map the brightness field in the chromosphere and the magnetic fields at the photosphere level simultaneously using two big telescopes and under extremely good seeing as to resolve these sub-arcsecond structures. We have been observing for many seasons and the high quality data from this data bank have been used for the present analysis.

The important result of this investigation is that the magnetic association of the bright points is established. This confirms our earlier findings (Sivaraman, K.R. and Livingston, W.C. 1982 Sol. Phys. 80, 227) and has settled an important controversy. This result provides the long awaited observational confirmation in favour of the maneto-acoustic waves which are excited at the sites of the magnetic elements and propagated through the flux tubes represented by these bright points.

(K.R. Sivaraman, *W. Kalkofen, *W.C. Livingston, *C.U. Keller, *R. Smartt, S.S. Gupta, S.S. Hasan)

Search for solar g-modes from the Ca II H observations

An identification and clarification of the different modes of oscillations may eventually illuminate the solar neutrino problem. Particularly, the g-modes of the Sun are the most powerful tool for the investigation of the solar core, and a way to solve, for instance, the neutrino problem. We have used a high spatial and temporal resolution of long time sequence of spectra in the Ca II H-line obtained at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory, on a quiet region at the centre of the solar disk over a large number of bright points and network elements, to search for g-mode oscillations in the chromospheric level. We find an evidence for the existence of a long period of oscillations apart from a well known 3 minute oscillation in bright points and 5-7 minute oscillations in the network elements from an analysis of time series of these intensity variations in the H-line. We suggest that the longer period of oscillation may be related to g-mode oscillations of the Sun. However, further observations of longer period with high temporal and spatial resolution obtained particularly with SOHO/SUMER are required to confirm the results. The work is in progress.

(R. Kariyappa)

Period - brightness relationship in chromospheric bright points

The chromospheric bright points are the sites where an intense heating takes place by the 3 minute period waves. A 35 minute long time series of photospheric spectra in the Ca II H line on a quiet region at the centre of the solar disk observed under high spatial, spectral, and temporal resolution at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory is used to show that the period of intensity oscillations seen at the sites of a variety of bright points in the interior of the supergranulation cells is independent of their intensity enhancements. We find an evidence for the existence of the constant period of oscillations in bright points with their brightness and different period from network oscillations, and this suggests that the mode of heating may be identical (by 3 minute period waves) in any class of bright points and it may be an entirely different mechanism (by 5-7 minute period waves) in case of the network elements. In addition, it has been shown that the amplitudes of the main and the follower pulses of a variety of bright points decay exponentially with time and the decay rate is constant with their brightness in any class of bright points. We suggest that the physical process behind the cause for the bright points may be the interference of 3 minute period waves, and the 3 min bright points may be magnetic in origin, since they have been observed to bear a one-to-one correspondence with the underlying photospheric magnetic elements. (R. Kariyappa, *L. Dame, *F. Kneer and *M. Martic)

Application of non-linear analysis to intensity oscillations of the chromospheric bright points

New methods of periodic decomposition and nonlinear analysis have been applied to study the dynamical characteristics of intensity oscillations of the chromospheric bright points. A 35 minute time sequence spectrum in the Ca II H line over a quiet region at the centre of the solar disk under high spatial,

spectral, and temporal resolution observed at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory is used. The hidden periodic components are successively detected from the apparently irregular time series : the unique feature of this algorithm is that the constituent component can be non-sinusoidal in nature. It is shown that most of the bright points have two distinct non-sinusoidal periodic components with periodicity varying from 2.6 min to 5.8 min. With the help of multivariate spatial embedding technique, the correlation dimension has been computed which indicates that the complete underlying process can be approximated to a system with six independent degrees of freedom. The approximated entropy (ApEn) of each bright point has been computed to quantify the amount of regularity and it has been conjectured that the bright points with higher ApEn values are coupled with other bright points in the interior of the network in a random fashion. The overall nonlinearity of the process is also established with the surrogate analysis. The present analysis shows that the dynamical behaviour of the bright points is a nonlinear process and this corroborates the heating of the chromosphere at the sites of the bright points by dissipation of energy.

(R. Kariyappa, *J. Bhattacharya and *P.P. Kanjilal)

A heating mechanism based on electron acceleration in magnetic bipoles

The earlier work on He II excitation (based on SOHO/EIT data) identified enhanced excitation of He II with regions of mixed magnetic polarity. This has resulted in the present proposal for heating of the solar atmosphere. In this scenario, the time varying magnetic fields associated with emerging bipoles will produce electric fields which will accelerate electrons and ions. The less massive electron is accelerated to higher energies for a given electric field. Assuming that the acceleration will proceed only for the inverse of collision frequency, one can arrive at an expression for the electron's energy that scales with the plasma density in such a way that lower density leads to higher energy. This leads to a testable dependence of the heating, so produced, on the physical parameters of the bipolar loop.

(P. Venkatakrishnan)

Morphological relationship between G-band bright points and calcium bright points

High resolution images obtained at Canary Islands simultaneously in G-band and the Ca II K line showed interesting morphological relationship with each other. The most remarkable feature observed in a few cases was the association of a binary G-band source with an elongated Ca II K feature that appeared to connect the components of the binary source. This complex association also showed a coherent behaviour in time such that the motion of the photocentre of the binary source was correlated with the motion of the associated Ca II K feature. This suggests a bipolar origin for a few Ca II K bright points as opposed to the conventionally assumed heated flux tube models.

(V. Krishnakumar and P. Venkatakrishnan)

The chromospheric network : network evolution viewed as a diffusion process

The speed of magnetic network elements on the solar surface and the associated diffusion rates was estimated using correlation data derived from a time-series of Ca II K filtergrams. The speed is about 0.1 km/sec irrespective of the activity level. But because of lower step lengths in the active region, the diffusion coefficient here (150-230 km^2/sec) is lower than in quiet regions (360-500 km^2/sec). This difference is shown to quantitatively explain the longer correlation lifetimes in the active region.

(R. Srikanth, Jagdev Singh, K.P. Raju)

The chromospheric network : dependence of cell lifetime on length-scale

The functional relation between cell lifetime and size was derived by comparing their respective distributions. A linear dependence of cell lifetime on cell area with a slope of 3.34×10^8 km^2/hour is inferred. It is pointed out that this relation can be explained by assuming that the network evolves by means of a diffusion of network magnetic elements.

(R. Srikanth, K.P. Raju, Jagdev Singh)

The study of supergranular network on the Sun

We have obtained time sequences of Dopplergrams and magnetograms of the Sun with a cadence of one minute for 8 days from the space observatory SOHO. The aim of this work is to study the long-term oscillations which we had tentatively observed in the Ca II K filtergrams of solar chromosphere obtained from Antarctica. The advantage of space-based data is that it is devoid of the atmospheric modulations that can possibly affect the earth-based observations. Dopplergrams also show some evidence of long-term oscillations and a detailed analysis is under way.

(K.P. Raju, Jagdev Singh, R. Srikanth)

Estimation of magnetic field components in a prominence

In a recent work (Nagabhushan, B.S. 1998, A&A 333, 1043, hereafter referred to as Paper I) an attempt was made to construct a one-dimensional model of a solar prominence which is in magneto-hydrostatic and thermal equilibrium, by assuming that all the physical quantities and the magnetic field components vary only in the y-direction (across the width of the prominence). As an extension of this work, a quasi two-dimensional model for a prominence is constructed by assuming that all the physical quantities and magnetic field components vary along both y and z-directions (where z is along the vertical direction). It is found that in a "prominence type" of solution there is no abrupt variation of either dip angle θ or the width of the prominence W_o until the temperature at the edge of the prominence T_* reaches $12{,}000^\circ$ K. To satisfy this criteria, a specific relation between the values of total pressure C_1, the central temperature T_o and the ratio R of magnetic pressure at the centre of the prominence to the total pressure inside the prominence, is satisfied. It is found from our calculation that the shear angle ϕ varies from one field line to the other and it increases with R. In the equilibrium model it is found that the values of θ and gas pressure at the centre of prominence p_o decrease with an increase of R, while the value of shear angle ϕ and the strength of the magnetic field increase. The prominence width is minimum at R = 0.5. With the increase of total pressure C_1, the value of both p_o and horizontal component of the magnetic field B_H increase, while the value of θ and the width of the prominence decrease.

From this it is concluded that, for small values of R the value of p_o is high and the magnetic field strength is low. In order to maintain equilibrium, the value of θ should be high. The value of shear angle ϕ should also be low. These conclusions agree with the observations of Bommier et al. (1994, Solar Phys. 154, 231) for the inverse type prominence. On the other hand, for the larger values of R the value of p_o is low and the magnetic field strength is high. In order to maintain equilibrium, the value of θ should be low. The value of shear angle should also be high in this case. These conclusions agree with the observations of Bommier et al. (1994, op.cit) for normal type prominences. Thus we are able to model different types of prominences by changing the values of a single parameter R. The minimum and the maximum values of B which we have determined from our calculation are 2.5 G and 17.8 G respectively. The maximum and minimum values of θ which we determined from our calculation are 12.5° and 0.3° respectively. These values are in agreement with the results obtained from various observations as in Engvold et al. (1990), Bommier et al. (1994).

(B.S. Nagabhushana)

Line ratio technique for filter magnetograms

The discovery of intense magnetic flux tubes in the early seventies revolutionised the thinking about magnetic fields outside of active regions on the Sun. This discovery was based on the line ratio technique. The same technique was sought to be extended (in the present work) to vector magnetographs based on narrow band filters. It was shown that the current bandwidth of such filters preclude the use of the line ratio technique for fields weaker than a kilogauss. However, filter magnetographs operating at longer wavelengths (e.g. 1560 nm) in the near infrared would be able to exploit the technique for weaker fields.

(P. Venkatakrishnan)

Ellipsometry of Kodaikanal tower mirror surfaces

Ellipsometry of the three mirrors of the Kodaikanal solar tower clearly showed a well developed oxide layer superposed on the bare aluminium coating. The thickness of this layer was a small fraction of the wavelength of light.

(K. Sankarasubramanian, P. Venkatakrishnan, and J.P.A. Samson)

Solar polarimetry

A new polarimetric system was developed based on shifting of CCD charges in step with polarimetric modulation. The integrated twin images were seen to be quite free of noise induced by image motions. The telescope polarization measured using this system was seen to fit the model based on ellipsometric results very well.

(G. Srinivasulu, K. Sankarasubramanian, A.V. Ananth and P. Venkatakrishnan)

Interferometric imaging of solar features

Using a fizeau mask in the pupil plane of the 38 cm aperture lens of the Kodaikanal tunnel telescope, we were able to record the interference fringes produced by an exceptionally bright source in a sunspot region and reconstruct the image using the closure phase technique. A set of short exposure images obtained without the fizeau mask was also used for speckle reconstruction of tiny solar features.

(R. Sridharan and P. Venkatakrishnan)

Development of software for the archival and analysis of the Kodaikanal Solar Observatory data

A software to archive the Ca II K plage area data from Kodaikanal for about 100 years has been developed and installed at 'Spectro', Kodaikanal. The software is a user-friendly programme working in the MS-windows environment and has provisions for easy archival and fast retrieval of filtered and averaged data and plotting. This will be helpful in studying the synoptic changes in the Sun such as solar rotation, sunspot cycle and active region evolution. A software programme for the analysis of daily Ca K filtergrams from 'Spectro' is under way. The CCD images are flat fielded and corrected for rotation. Programmes are developed to determine the Ca II K index and plage.

(K.P. Raju, Jagdev Singh)

Solar Corona

Spectroscopic studies of the solar corona : spatial variations in line parameters of green and red coronal lines

Simultaneous profiles of the coronal green line ([Fe XIV] 5303 A) and the red line ([Fe X] 6374 A) were obtained on a number of days at several regions covering an area of about 200″ x 500″ in the solar corona. The intensity, velocity, and width for both of these lines were computed by making a Gaussian fit to the observed line profile. It was found that in coronal structures the spatial variations in the red and green line intensities are correlated. The ratio of green- to red-line intensities varies between 0.6-9.2 for different coronal structures. The value of the intensity ratio in an individual coronal structure also varies with height above the solar limb along the structure. The range of values of the intensity ratio observed implies that most of the structures under investigation had a temperature in the range of 1.2-1.6 x 10^6 K. It was also found that in coronal structures the width of the red line increases with height above the limb, whereas the green-line width in the same region decreases with height. This behaviour of the line widths can be explained if one assumes the mixing of plasma in the middle and higher portions of the coronal structures by microturbulence or travelling waves, which have been detected recently. No Hα loops and activity were seen in the regions during the periods of observation.

(Jagdev Singh, *Kiyoshi Ichimoto, *Hideki Imai, *Takashi Sakurai, *Aki Takeda)

The green coronal line activity

The green coronal line (5303 A) emission is, in general, intense around active regions with maxima appearing in the vicinity of sunspot latitudes. However, the coronal index derived from the limb observations of 5303 A line intensity does not seem to correlate well with the photospheric activity (Ramesh, K.B. 1998a, Sol. Phys. 177, 311; 1998b, Sol. Phys. 183, 295), while 5303 A emission was shown to be closely related to the underlying photospheric field strength (Wang et al. 1997, ApJ., 485, 419). Therefore, the enhancements in

the green line intensity remain to be studied in greater detail for their association with the underlying activity.

Analysis of the Homogeneous Data Set (HDS) of the green line intensity obtained from the limb observations of 5303 A coronal line, using ground-based coronagraphs, indicated that a threshold magnetic field strength of about 1500 Gauss was a more viable characteristic for a spot to be associated with the green line intensity enhancement. However, the peak intensity of the 5303 A line does not seem to depend on the strength of the spot magnetic field (Fig.2). Ca plages leading to green line intensity enhancement needs to have a threshold area of about 2000 millionths of the solar hemisphere with an associated spot in the current rotation or at least in the previous rotation. The magnetic signature associated with these spots or plages needs to have a polarity inversion line with moderate to high field gradients during their limb passages. It was indicated that a continuous watch on the progress of the level of gradients in a given magnetic signature during its disk passage can be used to foresee an associated coronal green line intensity enhancement at the west limb while, the observations of green line intensity enhanced features at the east limb can be used to foresee the new appearance or the recurrence of an active region at those latitudes with moderate to high field gradients associated with it. We suggest that some hidden process such as the reconnection accompanying flux cancellation at or near the level of photosphere might control the process of coronal heating which, in turn, might determine the measure of 5303 A line emission.

Further analysis is in progress to find a possible relation or the lack of it of 5303 A emission and the measure of the field gradients near the polarity inversion line.

(K.B. Ramesh, B.S. Nagabhushana and B.A. Varghese)

The modelling of coronal emission line profiles

The observed green coronal emission line profiles have been often found to have multi-components. Further examination reveals that the occurrence of multi-components in line profiles is related to the solar cycle variations as well as the activity of the coronal region. The spatial correspondence between

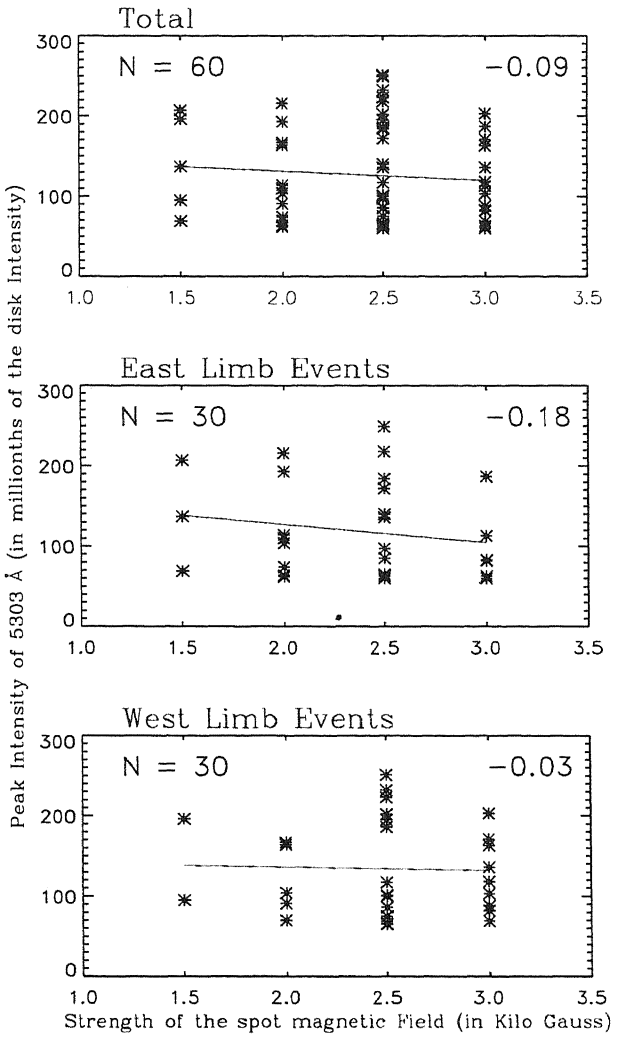


Figure 2. Dependence of the peak intensity of 5303 A coronal green line emission on the strength of the spot magnetic field. N is the total number of data points used in the analysis and is given at the top left corner of each plot. Coefficient of correlation is given at the top right corner. Note the absence of a systematic relation between them.

the intense loops in active regions and strong multi-components in line profiles suggests that the presence of loops affects the line shapes. The emission line profiles have been found to be fitted well with single or multi-Gaussians with line-of-sight velocities up to 70 km/s. A simple radiative transfer model of coronal emission line profiles has been developed which shows that coronal loops with mass motions inside may give rise to multi-components in line profiles. The effects of loop parameters such as electron density, flow velocity and kinetic temperature and the line-of-sight variations are studied. It is found that line profiles strongly reflect the physical conditions inside the loop.

(K.P. Raju)

Short period intensity oscillations in the solar corona observed during the total solar eclipse of 26 February 1998

Encouraged by the detection of high frequency, low amplitude continuum intensity oscillations in the solar corona during the total solar eclipse of 1995, a new six channel photometer incorporating low noise Hamamatsu R647 photomultipliers was designed and fabricated. Fast photometry at five different locations in the solar corona was performed at Don Bosco Mission, Venezuela during the total solar eclipse of February 26, 1998. Three interference filters with passbands of about 150A and centred around 4700, 4900 and 5000 A were used. The photometric data were recorded at the rate of 20 Hz in three channels and at 50 Hz in the remaining three channels. The power spectrum analysis of one of the channels that recorded appreciable counts indicates the existence of intensity oscillations in the frequency range 0.01 - 0.2 Hz. A least square analysis yields 90.1, 25.2 and 6.9s periods for three prominent components which have amplitudes in the range 0.5 - 3.5% of the coronal brightness. These periods and their amplitudes are similar to those detected in the coronal intensity oscillations during the 1995 eclipse.

(Ramanath Cowsik, Jagdev Singh, A.K. Saxena, R. Srinivasan and A.V. Raveendran)

Decametric observations of the solar corona

Multi frequency images of the outer solar corona in the frequency range of 40 - 150 MHz have been made regularly using the Gauribidanur radioheliograph. A 1024 channel one-bit digital correlator system is used to correlate the signals from the 32 groups of antennas. A calibration scheme based on closure and redundancy techniques is used for correcting the phase errors in the complex visibilities observed with the heliograph.

Two-dimensional maps of the Sun, obtained with the heliograph on the days when there was no solar activity, were used to study the thermal emission from the Sun. The effects of scattering on the radio emission by density inhomogenities, and coronal structures like holes and streamers and noise storm sources on the thermal emission were investigated.

Many Coronal Mass Ejections observed with SOHO (Solar and Heliospheric Observatory) were imaged at 103 MHz by the Gauribidanur radio heliograph. Possibility of predicting the forerunners of the CMEs using low frequency solar radio imaging was investigated. Mass of CMEs was derived from the Gauribidanur radio heliograms and it was found that the mass of slowly varying persistent features of CMEs was slightly higher compared to that ejected during the initial phase.

(R. Ramesh, K.R. Subramanian, M.S. Sundara Rajan and Ch.V. Sastry)

Eclipse observation of compact sources in the outer solar corona

It has been suggested that scattering of the radio radiation by density inhomogeneities increases the apparent sizes of coronal sources and this hypothesis is usually invoked by several authors to explain the low value of the observed radio brightness temperature of the outer solar corona. However, an upper limit for the scatter broadened image of a point source has not been obtained so far with good accuracy due to the lack of radio telescopes with sufficient angular resolution at frequencies less than 100 MHz, where the scattering is supposed to play a major role. It is well known that during a solar eclipse, radio observations of the Sun can be carried out with high angular resolution using the diffraction effects provided by the sharp limb of the Moon. During

the eclipse of October 24, 1995 we had carried out observations of the solar corona from the Gauribidanur radio observatory at a frequency of 75 MHz to check for the existence of discrete sources of small angular size. The angular resolution was 14″ which is the highest with which observations are ever made at this frequency. The smallest source size observed was 2.5″. This probably is the upper limit for scattering at 75 MHz.

(R. Ramesh, K.R. Subramanian and Ch.V. Sastry)

Solar Spectral fine structure in mm - wave

High sensitivity spectral observations of solar radio bursts carried out on June 30, 1989 exhibited a fine structure superimposed on the ongoing burst in its rising phase. The fine structure had a bandwidth of 2 GHz, a duration of 4 seconds and an intensity of 10 sfu and was interpreted as the thermal gyro - emission at the sixth harmonic of the gyro frequency originated from a hot kernel with short life time. Interaction of an emerging loop with an adjacent loop accelerated the particles in the loop from which the broadband burst was emitted due to the gyrosynchrotron emission. A temperature of 8×10^7 K, a magnetic field of 1250 G, and a density of 6×10^{12} cm^{-3} were derived for the hot kernel.

(K.R. Subramanian, *H.S. Sawant and *J.R. Cecatto)

X-ray studies

Long wavelength observations of jets from polar regions of the Sun

Recently there has been a report on the observation of jets from the polar coronal hole regions of the Sun by the EUV telescope and the LASCO coronagraph on board SOHO. These jets originate near flaring EUV bright points and they are triggered by magnetic reconnection between newly emerged bipolar magnetic fields and neighbouring unipolar flux. Though these jets are similar in appearance to those discovered earlier in soft x-rays wth Yohkoh, they are mainly confined to the polar coronal holes unlike the latter which occur predominantly in active regions and flaring soft x-ray bright points. Using the data obtained with the Gauribidanur radioheliograph and the statistics on radio bursts observed in different observatories all over the world published in Solar Geophysical Data, we searched for a possible temporal association between these jets and nonthermal radio burst emission since such an association would identify the flaring EUV bright points with the flare process. None of the events reported were accompanied by nonthermal emission, particularly Type III radio bursts, as was reported in the case of the soft x-ray jets. Since the observations of radio burst is a straightforward indicator of the presence of nonthermal population of energetic electrons, the lack of their association with EUV bright point flares raises the question regarding the nature of the latter as compared to the normal flares. However, one cannot also rule out the possibility of the bursts being very weak to be detected by the existing spectrographs in the present case. In that case, the upper limit for the flux density of these bursts is about 200 Jy, which is the sensitivity of the Gauribidanur radioheliograph.

(R. Ramesh)

Phenomenological dynamics for coronal loops by using a neural network approach

Simulation of x-ray 2D - coronal dynamics using an artificial neural network - multilayer backpropagation algorithm with inputs of Energy Fragmentation Patterns obtained from Yohkoh images parameters in soft and hard x-rays were carried out. Details of single loop structure have been investigated for the initial analysis. Using the square electron density gradient model, we have characterised the spatio - temporal loop dynamics concerning its twister - relaxation regime.

(K.R. Subramanian, the Brazilian Group)

On the formation of the helmet streamer on January 24, 1992 at the south-west limb of the Sun

Soft x-ray images of the Sun obtained with the Yohkoh satellite, were analysed along with white light coronal images observed at Mauna Loa and Hα pictures of the Sun taken at Mitaka and Kodaikanal to study helmet streamers.

Heating of a filament and subsequent brightening in x-rays and eruption in the region were found to lead to the formation of the helmet streamer on January 24, 1992. In an another event of February 24, 1993 only the brightening and eruption-like expansion of the brightening in soft x-ray led to the formation of the streamer. No Hα filament was seen in this region before and after the event of brightening in soft x-rays and formation of the streamer in this case. We, therefore, postulate that the plasma in the streamer comes from the solar surface during the x-ray eruption, and magnetic field of the region perhaps helps in containing the plasma and in the formation of the streamer.

(Jagdev Singh, *T. Sakurai, *K. Ichimoto, *E. Hiei)

On the disappearance of Hα filaments and soft x-ray enhancements as seen from Yohkoh SXT

Hα images of the Sun taken at Kodaikanal and Mitaka Observatories and soft x-ray images obtained by SXT on board Yohkoh for the years 1993 and 1994 were studied. From events of disappearing quiescent Hα filaments and associated soft x-ray brightenings, it has been found that in some cases the Hα filament appears broken and diffused about a day earlier than the beginning of the soft x-ray enhancement and it disappears completely during the event of soft x-ray transient brightening which lasts for 7 - 10 hours. Further, enhancements begin along filament channels and then move along arches which are inclined to the filament direction. From these observations we postulate that heating of plasma in the filament begins when it appears broken and less dark and continues till it triggers some physical process, responsible in initiating soft x-ray enhancement.

(Jagdev Singh, *T. Sakurai, *K. Ichimoto)

Solar system studies

Modeling the jets from comet Hale-Bopp

Possible scenarios were investigated to explain the intricate shell and jet structures of the comet observed from the Vainu Bappu Observatory, incorporating the recently published values of the period of rotation of the comet and its size. During early April 1997 three sets of shell structures are inferred (Fig.3) : one from the high latitude active source at $+65^{\circ}$ and two near-equatorial sources at $+5^{\circ}$ and -5°. On April 10, the rotation averaged values of the cosine of the Sun's zenith distance $< \cos z_{\odot} >$ as seen by these sources were 0.913, 0.092 and 0.003 respectively. To assess the contribution from these sources to the observed water production rate during early April, it may be noted that while the equatorial sources were illuminated by the Sun at near-grazing incidence, the source at $+65^{\circ}$ must be small in size. The constraint on the size of the high latitude source is evident because the total area north of the latitude for a spherically symmetric comet is $0.5\,(1-\sin\phi)$ of the total surface area of the comet. We assume that this source spans between 60° and 70° in latitude, and that it occupies 36° in longitude. The total production of water from this source will then be 29% of the total observed production rate of 4×10^{30} molecules s^{-1} from the entire comet near perihelion reported by Schleicher et al. in 1997. In addition to the contribution from the equatorial sources, several smaller unresolved jet sources, distributed sources of water from evaporation of the grains in flight and outgassing from the inactive regions of the comet may contribute to the total observed water production rate.

In spite of the near-grazing incidence of sunlight, the shells from the equatorial sources appear comparable in intensity to the high latitude source at $+65^{\circ}$. It is difficult to comprehend the reason for the near equal brightness of the two sets of shells when the values of $< \cos z_{\odot} >$ at the respective sources differed by a large factor. The high latitude source at 65° explains the shells expanding in the south-westerly direction corresponding to the apparent anti-clockwise rotation of the nucleus during April. On the other hand, the projected cometocentric separation of the observed shells from the equatorial sources match better for a clockwise motion of the source. The interwoven shells observed during February 1997 also appear too complex to be explained using a single nucleus. Thus there appears to be the need for two separate bodies with opposite sense of rotation, one hosting the high latitude source and the other the near-equatorial source. This is in conformity with the binary model by Sekanina (1998) with the two nuclei having their spin vectors subtending an angle $> 90^{\circ}$ with each other to explain the complex shell structures in the images of late February, 1997 and late March, 1997.

(R. Vasundhara, P. Chakraborty)

A photometric-dynamic model to investigate jets and shells from comets

The model developed during 1996-97 to simulate jet and shell features from comets was further improved. The earlier model considered only the location of the grains on the shell and the intensity was taken to be proportional to its projected area. The revised version now computes the intensity and polarization of light scattered by the dust grains in the shells.

The intensity profile across a shell and its shape are found to be dependent on the size distribution, density and the optical constants of the grains. Presence of submicron silicate grains has been inferred from mid-infrared observations by Crovisier et al. (1996, A & A 315, L385) and in particular, olivine was confirmed in the 6-45 μm spectra by Crovisier et al. (1996, Science 275, 1904). Based on these published results, the simulations were carried out for spherical, nonporous grains of Mg-Fe silicate glasses with pyroxene stoichiometry ($Mg_x\,Fe_{1-x}\,SiO_3$) and olivine stoichiometry ($Mg_{2y}\,Fe_{2-2y}\,SiO_4$) (Dorschner et al. 1995, A & A 300, 503) and also amorphous magnesium silicates with compositions similar to enstatite ($MgSiO_3$) and forsterite (Mg_2SiO_4) (Scot and Duley 1996, ApJ 105, 401). The intensity of light scattered by a grain was estimated using Mie scattering using the computer code developed by Shah (1977, Kodaikanal Obs. Bull. Ser. A 2, 42). Detailed modeling using multicolour data is required to determine the relative Mg-Fe fractions in the silicates. In the present study, which aims at demonstrating the capabilities of the model, x

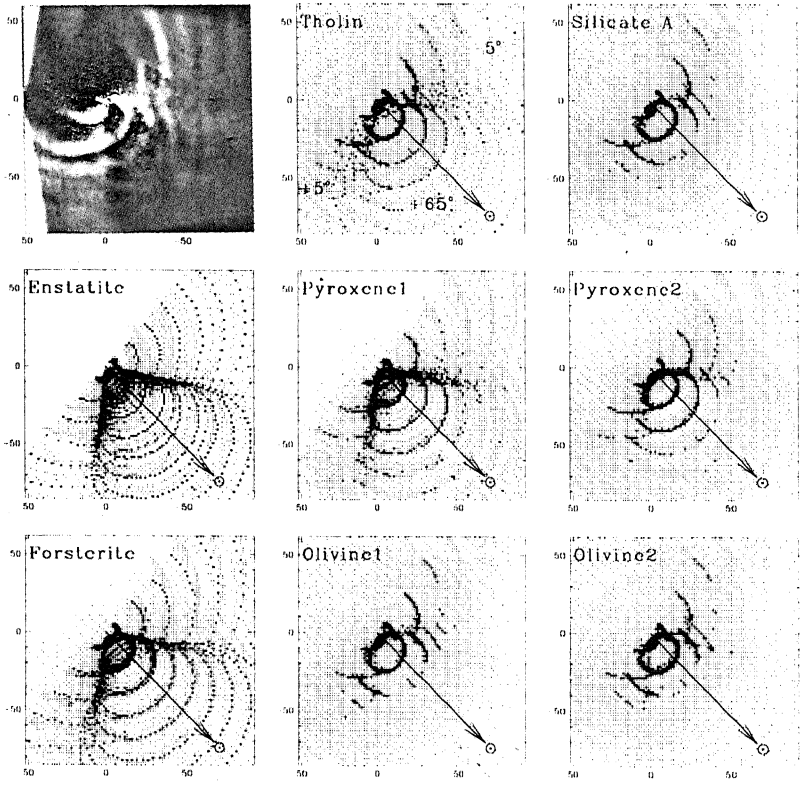


Figure 3. Comparison of the simulated jets using different grain materials with the processed image (top-left panel) obtained at the prime focus of the 2.34 m telescope at the VBO through a standard R filter. Each frame spans 147 arcsec on a side. North is up and East is to the left. Projected direction of the Sun is indicated by the arrow. The simulated shells expanding towards S-W of the comet centre are from the source at 65°. The simulated features in the N-W and S-E are from the sources at -5° and $+5^{\circ}$ respectively as indicated in top-middle panel. Grain sizes used in the simulation vary from 0.1μ to 30μ with a power law distribution of index –3.0.

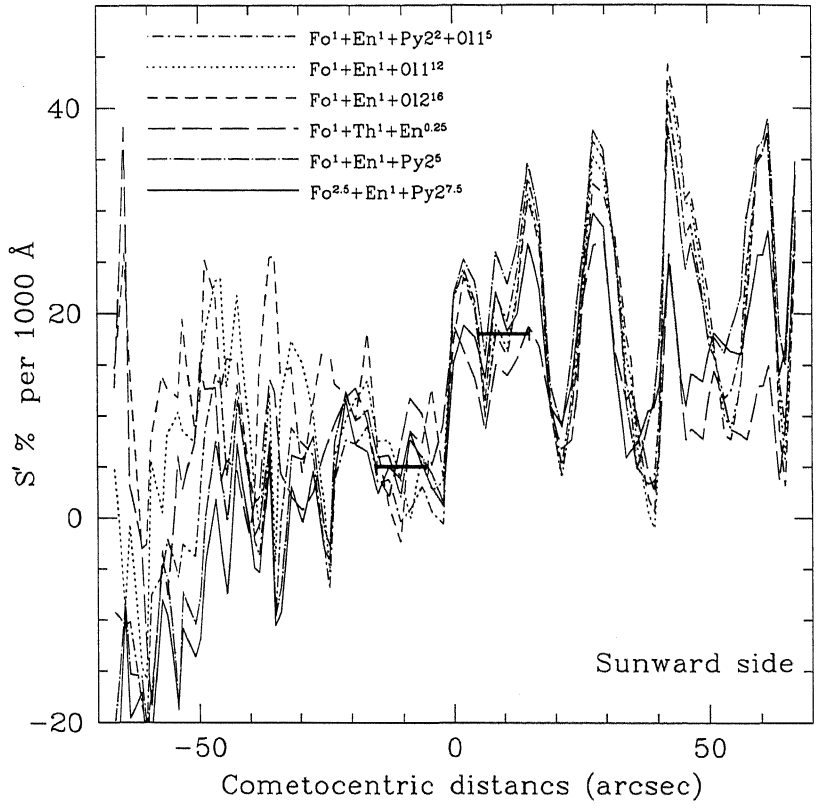


Figure 4. Colour, defined as $S'(\lambda_1, \lambda_2) = (dS/d\lambda)/S_{mean}$ (in % per 1000Å) defined by Jewitt & Meech (1986), across the comet along the projected comet – Sun direction, for different grain compositions of the ejected shells on 10 April, 1997. The line types for different compositions are given in the box. The symbols *Fo, En, Py2, Ol1, Ol2* indicate forsterite, enstatite, pyroxene2, olivine1 and olivine2 respectively. The superscripts indicate relative proportion by number. The observed color reported by Bellucci (1998) is indicated as the bars at ±10 arcsec from the comet centre.

= 0.95 (pyroxene 1), x = 0.5 (pyroxene 2), y = 0.4 (olivine 1) and y = 0.5 (olivine 2) have been used as representative cases. Astronomical silicate, the dielectric function of which has been constructed by Draine (1985, ApJS 57, 587) to match astronomical observations and tholin as representative of the class of organic grains (Khare et al. 1984, Icarus 60, 127) have also been included in the simulations Fig. 3.

Stringent constraints can be placed by comparing the predicted colour, expressed per 10^3 A according to the relation by Jewitt & Meech (1986, ApJ 310, 937) :

$$S'(\lambda_1, \lambda_2) = (ds/d\lambda)/S_{mean} \quad (1)$$

where $dS/d\lambda$ is the rate of change of reflectivity with wavelength (Fig. 4). In the present study, we use the reported values of colour by Bellucci (1998, A & A 333, 369) of S′ = 18% per 10^3 A on the Sun-ward side and S′ = 5% per 10^3 A on the anti Sun-ward side from his observations of 20 March, 1997.

Results of the preliminary investigations using compact isolated spherical grains indicate that predicted shells of grains of forsterite and pyroxene have shapes closely resembling the observed structures and colour. Enstatite, tholin, olivine (1 & 2) and 'silicate A' grains which yield diffuse shell structures are unlikely candidates. However, in reality, a cometary grain is an agglomeration of several submicron sized grains of heterogeneous composition and is therefore porous. A more detailed investigation has been started which uses the discrete dipole approximation theory (DDA) by Draine and Flatau and the Effective Medium Theory (EMT) to calculate the scattered light by the porous grains.

(R. Vasundhara)

Modeling spectropolarimetric observations of comet Hale-Bopp

Calibration of the optical components of the polarimetric unit used with the B & C spectrograph was completed. This calibration was applied to the spectropolarimetric observations of comet Hale-Bopp obtained on April 24, 1997.

Cometary polarization is dependent mainly on the complex refractive index of the grain material. However, the colour dependence of polarization is different for grains of different sizes. The dynamics of a grain of radius s depends on the radiation pressure parameter Q_{pr} (s, λ). As this parameter also depends strongly on the optical constants of the grain material, a comparison of the observed polarization and its dependence on colour with the simulated values is a powerful tool for investigating the nature of the grain material.

The present photometric-dynamic model assuming compact grains was used to compute the expected polarization at a given point on the sky plane by summing the contribution of all the grains along the line of sight. The polarization at a particular region on the coma was calculated using the expression : $P(\Sigma i_i - \Sigma i_{ii}) / (\Sigma i_i + \Sigma i_{ii})$ where (i_i) and (i_{ii}) indicate the intensity components scattered by a grain polarized perpendicular and parallel to the scattering plane. The summation was carried out over the grain sizes from $S_{min} = 0.1\ \mu$ to $S_{max} = 30\ \mu$ with a size distribution law given by $n(S)\ dS = S^{-3.0}\ ds$. The real (n) and absorptive (k) parts of the refractive indices of the grain material were varied and the predicted polarization of locations along the slit were computed.

Preliminary results of the comparison of the measured polarization in the coma within an aperture of 5.8 arcsec, at the respective values of 4.4%, 5.7% and 8.5% at λ4840, λ6200 and λ7300, with the model indicates that the refractive indices of the grain range between 1.6 - 1.8 for the real part and 0.4 - 0.5 for the absorptive part. A relatively large value of the absorptive component is required to explain the observed high value of polarization of this comet. This indicates a high Fe content (y < 0.4) of the grains of olivine stoichiometry corresponding to the formula $Mg_{2y} Fe_{2-2y} SiO_4$. These results will be improved when DDA and EMT are used to calculate the scattered light from the grains.

(P. Chakraborty, R. Vasundhara)

Discovery of two new asteroids

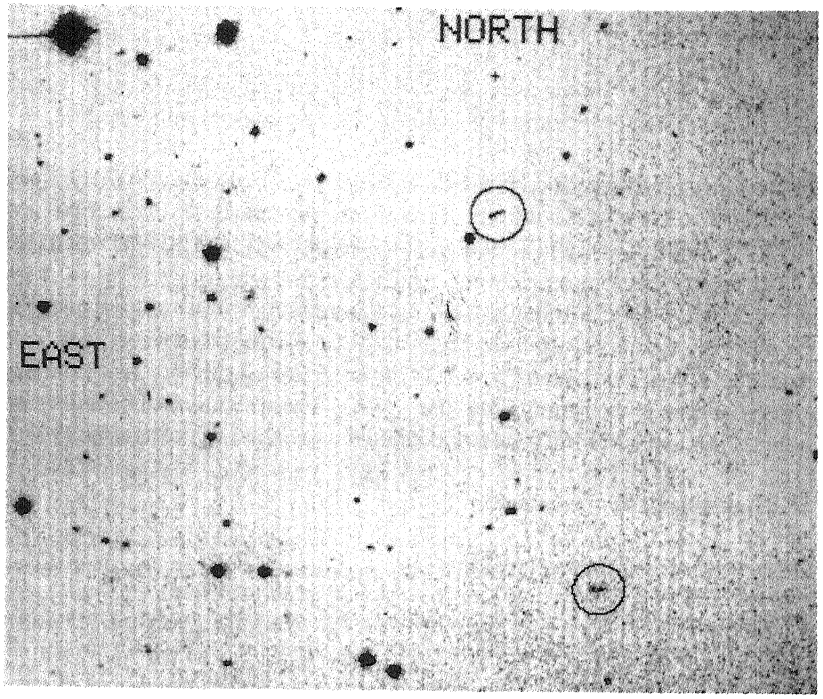
On March 17, 1999 two new asteroids were discovered in a single CCD frame within the FOV of 6′ x 6′ at the 102 cm Zeiss telescope of the Vainu Bappu Observatory. The asteroids were detected while observing the field of a recent Gamma Ray Burst, GRB990308, to search for the optical transient. One of the

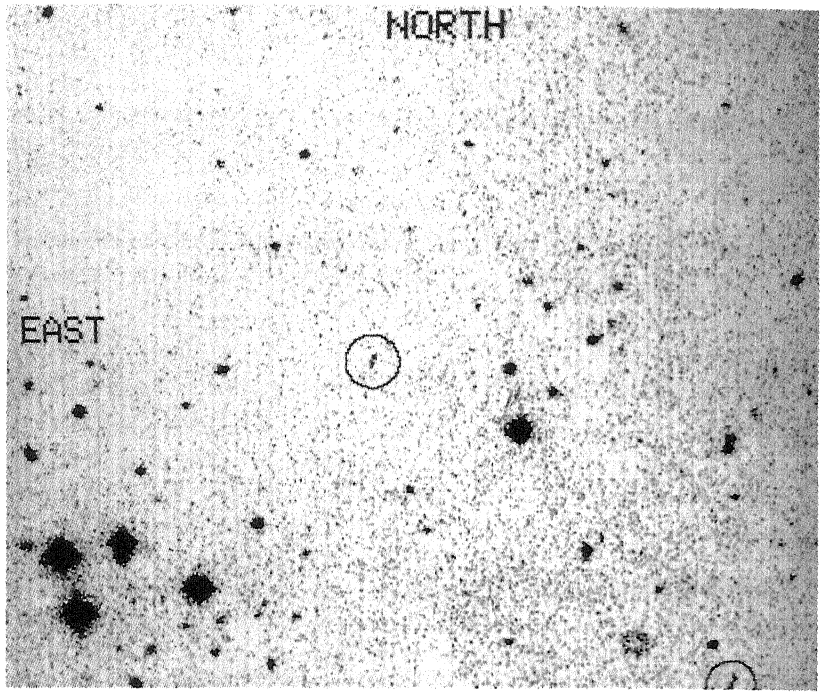
asteroids appeared in all the 6 frames taken successively having magnitude R = 20.5 and V = 21.2 while the second one was seen only in 2 of the frames with R = 20.6 both heading in the NW direction almost in parallel.

The future positions of these asteroids were predicted and follow-up observations were made on April 11, 1999. Both the Asteroids were recovered again within a single CCD FOV of the telescope. The R-band magnitudes were 21.5 and 21.2 for the first and the second asteroid respectively. The astrometric positions have been reported to the Minor Planet Center.

Follow-up observations are planned during the next opposition.

(S.G. Bhargavi)





Physical interpretation of the Poynting - Robertson effect

A General Relativistic weak field derivation of the Poynting-Robertson effect has been given to study the physical interpretation of the effect, which has historically been a bit controversial as regards the origin of the drag. It is pointed out that although the equations used to describe the effect are correct, the conventional interpretation, that the drag is caused by the forward-backward asymmetry of the dust re-radiation as seen in the heliocentric frame, is erroneous. The effect arises purely as a result of the solar irradiation combined with angular momentum conservation and is independent of dust re-emission.

(R. Srikanth)

Solar-terrestrial physics and geophysics

Solar-terrestrial physics

At dip equatorial stations in the Indian region, spread-F conditions are known to develop preferentially after midnight during the June solstice months of low solar acitvity, in association with a distinct increase in F layer height. This onset of spread-F faraway from the sunset terminator is currently believed to be due to a Rayleigh-Taylor (RT) plasma instability mechanism, with the gravitational and cross-field terms (hence F layer height) playing important roles. It is not yet known, however, whether the increase in layer height is a sufficient condition for post-midnight onset of spread-F. This question was addressed through an analysis of the ionogram database of Kodaikanal for Northern Summer months of 1994 and 1995. It was found that a conspicuous increase in F layer height occurred around midnight on nights with or without spread-F. This feature strongly suggests that the F layer height does not play a pivotal role and is not a sufficient condition for midnight onset of spread-F. Several possibilities exist that could account for this finding. First, although the F layer height condition is conducive to the growth of RT instability, other factors (e.g., day-to-day variability of neutral wind field due to MTM and ion drag, seed perturbations) that inhibit the instability growth may be operative on individual nights. Second, the onset of spread-F may not be due to destabilisation of local plasma but to overhead passage of patches of irregularities formed elsewhere (East or West of the station). Observations with Advanced Ionospheric Sounder (AIS) with directional and Doppler capabilities will help ascertain the relevance of the physical situation.

Measurements made with the HF Doppler sounder at Kodaikanal on the night of December 23/24, 1991 revealed conspicuous quasi-periodic fluctuations (period 25-35 min) in F region vertical plasma drift (hence in the equatorial zonal electric field) just after midnight. We have explored whether this drift perturbation is due to DP2 electric fields. The results are affirmative as they showed that the fluctuations in vertical drift are coherent with variations in North-South (B_z) component of the Interplanetary Magnetic Field (IMF) and with H_x components of the geomagnetic field at high-middle latitude locations both in the sunlit and dark hemispheres. They are also coherent with H-field variations in the dip equatorial region on the day side. The vertical drift perturbation recorded at Kodaikanal thus constitutes the first ever evidence for DP2 electric fields in the midnight dip equatorial ionosphere.

The latitudinal dependence of the characteristics of solar flare effect (sfe) in geomagnetic field is studied using data from the Indo-USSR chain of magnetometer stations covering magnetic latitudes 0° to 45° N. The results which cover a variety of equatorial electrojet conditions (normal electrojet/ counter electrojet) showed the latitudinal patterns of sfe to be quite complex. This could be due to the interplay of the effects of global Sq currents and zonal and meridional currents associated with the electrojet fields. The unique magnetometer database is also used to work out the latitudinal profiles of storm sudden commencements (ssc). It is seen that while during the daytime, the amplitude of ssc (H) is largest at the dip equator and progressively decreases with an increase of latitude, the opposite situation prevails during the nighttime when the amplitude shows a small but progressive decrease from Sq focus towards the dip equator. This behaviour is not seen in the amplitude of ssc (Z) which is large over the dip equator during both day and night times.

IIA participated in the observational equatorial spread-F (ESF) campaign held in April 1998 and March 1999 under the activities of WG3 of I-STEP.

(J.H. Sastri and STP team)

GPS receiver installed on a specially constructed monument at Leh.

Correlative study of solar cycle and activity phenomena with the Indian climate and monsoon rainfall

An overwhelming evidence is building up that the solar cycle and related acitivity phenomena have a good correlation with the global climate and temperature of the Earth. Aims of the present study are twofold. Firstly, we would like to investigate the correlative analysis of the solar cycle and activity phenomena with the Indian climate and monsoon rainfall. The second aim of this study is to understand the physical mechanism that links the Sun's radiative flux with the Earth's global climate and rainfall.

To start with, 120 years (1871-1990) of sunspot and Indian monsoon rainfall data were considered for the correlative analyses. The Homogeneous Indian Monsoon Rainfall data obtained by Parthasarathy et al (1993, Proc. Indian. Acad. Sci, Earth. Planet Sci. 102, 121) were used. The data was divided into 11 cycles which are binned according to one solar maximum to the next solar maximum year. For each cycle, the correlation coefficients (CC) for the months of Jan-Feb (JF), March-May (MM), June-September (JS) and October-December (OD) were computed. We found that : (i) for the months JF, CC vary from -0.209 to 0.5162 (ii) for the months MM, CC vary from -0.268 to 0.5775, (iii) for the months JS, CC vary from -0.549 to 0.4857 and (iv) for the months OD, CC vary from -0.397 to 0.4642. It is interesting to note that for the months of JS which are dominated by the south-west monsoon rainfall, present analyses show for the years 1871-1918 a positive correlation and a negative one for 1918-1958. Except for the cycle 1969-1980, this trend has been repeated. For the months OD, which are dominated by the north-east monsoon, present analyses show a negative correlation during the years 1871-1884, a positive correlation during the years 1884-1969 and a negative correlation after successive cycles. The results presented here are preliminary and definite conclusions cannot be drawn regarding the strong (either positive or negative) correlation of sunspot numbers and the Indian monsoon rainfall data.

(K.M. Hiremath, *P.I. Mandi)

Geodynamics of The Indian Continent

The Indian continent and adjoining terranes to the north of the Himalaya are one of the Earth's most highly stressed lithospheric intraplate regions separated by the Himalayan Cothsion plate boundary, plates sustained by the persistent northward underthrusting of the Indian plate beneath Tibet. But, whilst the 58 mm/year rate of Indo-Eurasian convergence is now well constrained, the details of the style and partitioning of deformation along this 6000 km long stretch is less definitive. Within the continent itself, different crustal units from south to north respond to the prevailing stresses variously, depending on the structure of the underlying lithosphere (crust and upper mantle), whilst across the Himalayan plate boundary, this convergence is accommodated both through NE directed compression and E-W extension right up to Lake Baikal, as well as through eastward extrusion of Tibet along a series of dextral strike slip faults.

In order, therefore, to understand fully the tectonic implications of the moving Indian plate, it is necessary to characterize the behaviour of the strain reservoir and the lithospheric structure in each of its distinctive tectonic units. A project designed to address these questions was initiated in the following two areas favoured by their dramatically anomalous character and, equally important, by the availability of substantial logistic and infrastructure support from the Observatories of the Indian Institute of Astrophysics.

The Nilgiris

These variously elevated mountaineous region of the south Indian granulite terrane stretches for over 400 kms roughly paralleling the passive continental margin of the western coast of India. Geological investigations of the region indicate pervasive rejuvenation of the terrain in recent times (personal communication with Professor K.S.Valdiya), all the way down to the southern high at Kodaikanal. Teleseismic waves that emerge almost vertically at Kodaikanal also show substantial delays pointing to its low velocity undercarriage. A knowledge of the rheological structure with depth is a prerequisite

for realistically modelling surface strains in terms of the causative sub-surface mechanism. It was, therefore, considered desirable to experimentally determine at Kodaikanal, the (i) strain rate with an accuracy of better than 0.1 microstrain per year that is now possible using GPS receivers and (ii) lithospheric velocity structure with a resolution of 2 km using broadband P-waveform receiver functions, as recently obtained for Hyderabad.

The Karakoram

The NW-SE trending Karakoram fault in northern Ladakh appearing on satellite imageries as a highly conspicuous lineament over a 1000 km long, is identified as a major intraplate slip plane that facilitates eastward extrusion of Tibet, out of the way of the advancing Indian plate at the rate of over 30 mm/yr (Fig. 6). However, the concepts of the kinematic models of this trans-Himalayan region primarily powered by this advance, which would be consistent with the known seismicity of the Himalayan arc, is still only qualitative. The spatial loci of moderate Himalayan earthquakes that are recognized as marking the leading edge of the understanding Indian plate, in turn, describe the arc of a small circle of 1696 km radius centred in northern Tibet and coinciding with the 4 km elevation contour that also demarcates the southern boundary of the Great Himalaya. The figure shows how the resulting convergence along this arc must cause along-arc extension by dextral slip of the Great Himalaya at an equal strain rate (Bilham et al 1998). This predicted value can be tested by actual measurements along the northwestern edge of the arc that fortunately lies within the Indian territory. Although experimental data in the accessible region just southwest of the Karakoram fault will reduce the signal to half the total shear along the fault, it is well within the limits of GPS geodesy to resolve the shearing rate within 3-6 years. This part of the project is accordingly addressed to constrain the geodynamic model of this northwestern edge of the trans-Himalayan region through (i) GPS based strain measurements and (ii) lithospheric velocity structure definition, using broadband teleseismic receiver functions. The latter part of the work will be undertaken in 1999.

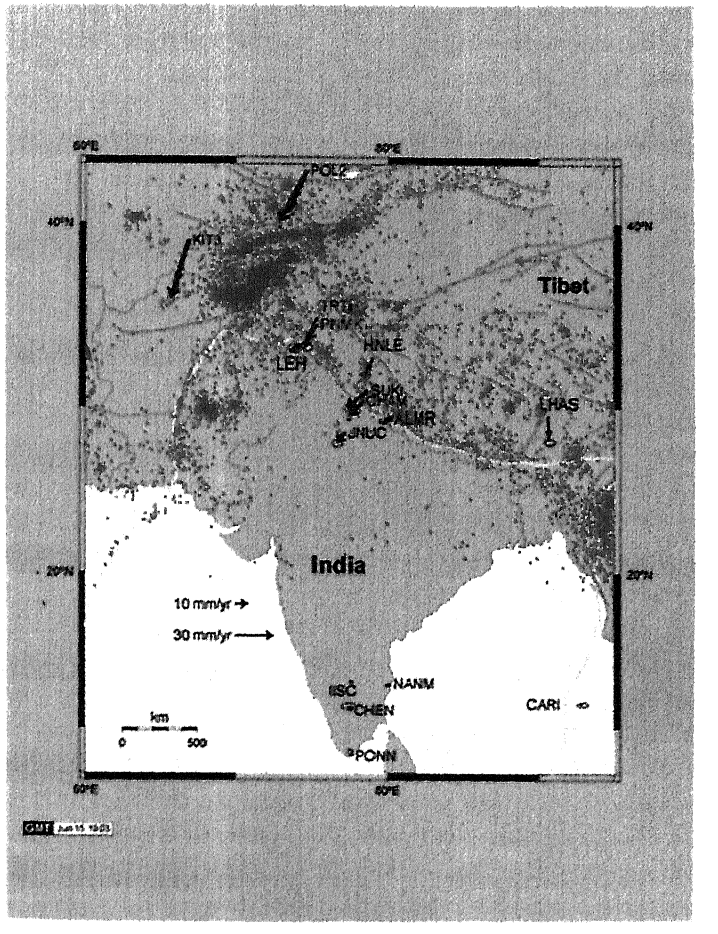


Figure 6. The arrows at Leh and Hanle show their annual relative velocity vectors with respect to the Indian shield (Kodaikanal). The dots show earthquake epicentres. Note the near absence of seismicity around Hanle.

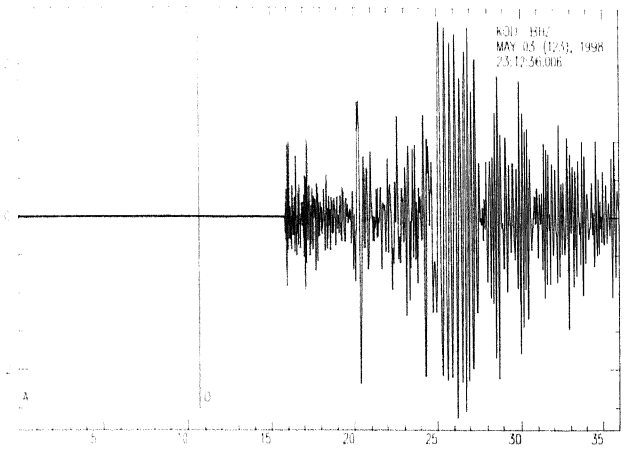


Figure 7. A part of the broad band seismogram (only the vertical component is shown here) recorded by the IIA 3-component Seismic Station at Kodaikanal. The ordinate denotes groundmotion levels in relative terms, while the abcissa denotes time in hundreds of seconds.

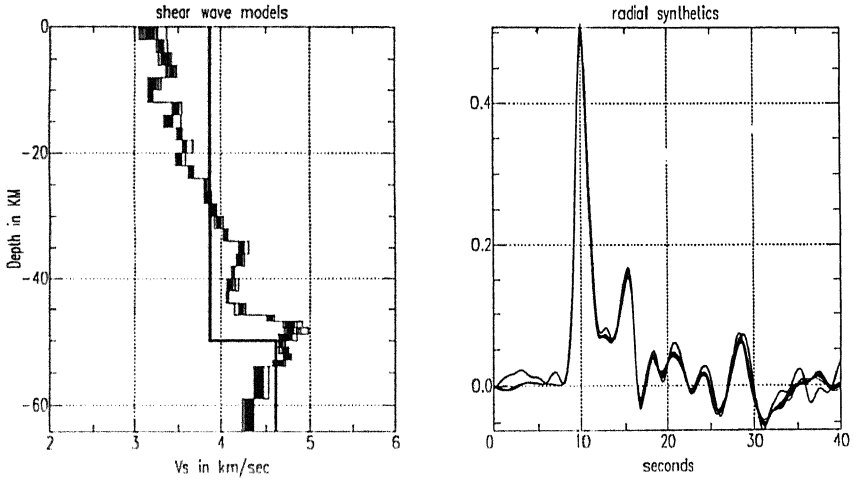


Figure 8. The figure on the right hand shows the radial receiver function (deconvolved P-wave-form which retains only the shear-converted phases) along with those reproduced by the suite of models (figure on the left hand) of the inverted shear velocity structure beneath Kodaikanal.

A related objective of the overall project is aimed at evolving some directive bases for quantifying earthquake hazard in the Himalayan plate boundary region which includes the heavily populated northern Gangetic planes. This 2400 km long accurate boundary is transversally segmented, apparently by several pre-existing ridges of the underthrusting Indian plate, thereby providing decoupled mechanical boundaries for the occurrence of characteristic earthquakes such as the 4 Great Himalayan earthquakes of the past 10 decades. Yet, characteristic lengths have no recognizable meaning in the phenomenology of statistical physics of composite systems. The current pattern of mantle features delineated by seismic tomography and geoid mapping by gravity and satellite altimetry is, however, reasonably well matched with plate tectonic reconstructions by subduction extrapolated backwards over the last 100 million years, pointing to the existence of a stationary state of plate tectonic processes. This part of the research is accordingly aimed at estimating future seismic hazard using this long-term metastability of a near critical state lithosphere together with the knowledge of seismicity and GPS derived estimates of the tectonic slip.

(V.K.Gaur)

Stars

Herbig Ae/Be and Vega-type stars : polarization observations

Herbig Ae/Be stars are pre main sequence stars of intermediate masses. They are generally associated with substantial amount of circumstellar gas and dust from the parent cloud. They are characterized by relatively large and variable linear polarization. Vega-type stars are main sequence (or close to zero-age main sequence) stars of similar masses that still have circumstellar dust but much less gas around them. It is not yet clear whether the Vega-type stars are a later evolutionary phase of the Herbig Ae/Be stars. Also, the survival of dust and preferential removal of gas from these systems is not well understood. An investigation has been undertaken to address this question.

Circumstellar matter around stars causes polarization of light from the system, due to scattering, if the geometrical distribution of the material is asymmetric (e.g. matter confined to a flat disk). Also, the degree of polarization depends on the amount of circumstellar matter. This may systematically decrease with time as the star evolves. Polarization measureements have been carried out on a sample of Herbig Ae/Be and Vega-type stars. They will be monitored for variability too. Also, spectroscopic observations are being made to look for any nebular emission from the gas around the Vega-type stars. About 10 stars have been observed so far. The project is continuing.

(P. Manoj and H.C. Bhatt)

Photometric and polarimetric variability of the T Tauri star TW Hya

An investigation of the long term photometric and polarimetric behaviour of the isolated T Tauri star TW Hya was completed. It is found that a period of 2.196 days derived from the present data satisfies all the available photometry. The steep increase in the amplitude towards shorter wavelengths indicates that the light variation is caused by hot spots. Apart from the periodic variations, sudden increases in brightness of the order of 0.2 mag lasting one or two days were also noticed.

A low resolution study of the Hα emission and Li I 6708 A absorption shows that the line strengths do not have any correlation with the rotational phase in TW Hya.

Since the synoptic linear polarization measurements obtained during 1990, 1991 and 1992 showed that TW Hya had variable polarization, further measurements were obtained over nine consecutive nights. The data indicate that the linear polarization in TW Hya has two components, namely, a low amplitude component which is present throughout and a large amplitude short-lived component which occurs randomly.

(M.V. Mekkaden)

Polarimetric and Spectroscopic study of the T Tauri star V410 Tau

A detailed analysis of the polarimetric, spectroscopic and photometric observations of the weak-emission T Tauri star V410 Tau was completed. The linear polarization and position angle are found to show variability with a period corresponding to the rotational period of the star. It is also found that the polarization reaches a maximum near the light minimum. Modelling of the V and R light curves shows that two adjacent spots, occupying a total fractional area of 0.23 and with a temperature 750 K cooler than the photosphere could account for the observed light variability. The periodic variability in linear polarization is attributed to the variable illumination of an optically thin circumstellar envelope by the rotating spotted star.

The Hα line is found to vary from shallow absorption to emission with the maximum emission strength at the minimum light, and vice versa. The Li I 6708 A absorption equivalent width, which is consistent with that of other T Tauri stars, does not show any appreciable variation with the photometric phase.

(M.V. Mekkaden)

Starspot distribution in RS CVn objects

Almost all RS CVn systems, for that matter all rotating variables, usually exhibit continuously varying light over the photometric cycle; flat-topped curves are seldom observed. Even in the case of eclipsing RS CVn variables, with the inclinations of the rotational axis $i \sim 90^{\circ}$, variation arising from the spotted nature of the active star outside the eclipse is nearly sinusoidal. This implies that the spots which modulate the observed flux have a large longitudinal spread, on the order of 180°.

For an inclination of the rotational axis i the main contribution to the rotational modulation comes from the spots present in the $\pm i^{\circ}$ latitudinal belt and the maximum possible amplitude increases drastically with the inclination. For example, for a spot-to-photosphere temperature different of 1000 K an increase in i from 40° to 60° increases the maximum possible amplitude from 0.5 to 1.2 mag, a range of about 0.7 mag. For a temperature difference of 1500 K, the range would be more than 1 mag. However, the spread in the maximum observed amplitude, for the four active, well-observed, single-lined systems - DM UMa, II Peg, HD 12545, and HD 81410 - is only around 0.25 mag. If spots are confined to $\pm 40^{\circ}$ latitude, the increase in amplitude when seen at $i = 60^{\circ}$ instead of $i = 40^{\circ}$ is about 0.2 mag. The corresponding increase is around 0.3 mag if the spots are cooler than the photosphere by 1500 K. Hence it appears that the longitudinal asymmetry in the distribution of spots, which causes the observed light modulation, is largely restricted to around 40° in latitude. Such a conclusion, of course, depends on the followoing assumptions : (i) the inclinations of all the four active stars are different and they show at least a spread of about 20°; it is highly unlikely that all of them have the same inclination of the rotational axis, (ii) all these objects show similar levels of spot activity, which is quite possible in view of their similar spectral types, and (iii) spots form on both sides of the stellar equator with equal probability as in the case of the Sun.

The total range of photometric periods ($\Delta P = P_{max} - P_{min}$) derived from long-term photometry will be a rough measure of the total latitudinal extent of spots on its surface, since the higher the latitude of spot occurrence, the larger will be the P. There are nine objects - λ And, σ Gem, II Peg, V711 Tau, HR7275, V350 Lac, V478 Lyr, BM Cam and V1149 Ori - for which the total range of rotational periods ΔP is well determined. It is found that in the log ($\Delta P/P$) vs log P diagram λ And, σ Gem, HR 7275, BM Cam, and V1149 Ori lie close to the position of the Sun with P_{max} corresponding to the rotational period at 30° latitude; the mean position occupied by the above nine objects in the diagram is well above the position with P_{max} corresponding to that at 60° latitude. This result is also consistent with the above suggestion that in spotted stars, in general, the spots occur mainly within around $\pm 40^{\circ}$ effective latitudes.

(M.V. Mekkadden and A.V. Raveendran)

New orbital solutions for the RS CVn binary IL Hydrae

The orbital parameters of the primary of IL Hya (=HD81410) were first derived by Raveendran et al. (1982, MNRAS 199, 707) from the eight radial velocity measurements that were available in the literature at that time. By combining his own radial velocity measurements with those of Collier Cameron (1987, S. Afr. Astr. Obs. Circ. 11, 1), Balona (1987, S. Afr. Astr. Obs. Circ. 11, 13) obtained an orbital period of 12.908 days, which is slightly longer than that obtained by the above authors. Balona also derived an eccentricity of 0.05 for the orbit. Recently, Weber & Strassmeier (1998, A & A 330, 1029) presented the orbital parameters based on 21 new radial velocities obtained by them and the 34 velocity measurements made by Balona assuming a circular orbit. A total of 85 radial velocity measurements are available for IL Hya dating from 1959 till 1995, and Weber & Strassmeier had used only 55 of them covering a time span of only 15 years. Fresh orbital solutions, for both circular and elliptical orbits, have been obtained for IL Hya combining all the published radial velocity measurements. The standard deviation is found to reduce only marginally to 2.440 km s^{-1} from 2.444 km $^{-1}$ for an elliptical orbit instead of a circular one. The eccentricity is found to be 0.013 - 0.005. The observed velocities are plotted along with the computed curve corresponding to the circular orbit in Figure 9. Six measurements, which show residuals larger than 5 km s^{-1}, have been excluded from the solutions, and these are indicated in the figure by arrows.

(A.V. Raveendran and M.V. Mekkaden)

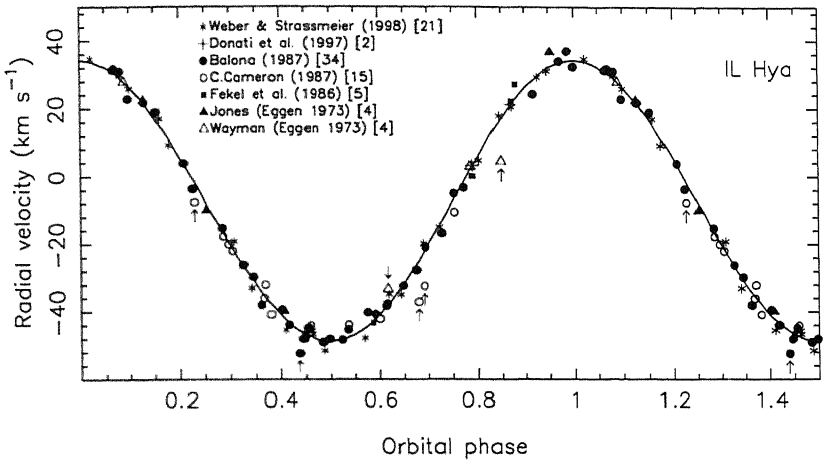


Figure 9. Radial velocity curve of IL Hya. The numbers inside the square brackets indicate the number of observations, and the arrows the observations excluded in the solutions. The orbital phases are computed using the ephemeris, zero phase = JD 2449390.607+12. 90522 xE. The uncertainty in the period is ± 0. 00005.

Internal rotation and toroidal part of the magnetic field of the AB Doradus

The K0 dwarf AB Doradus is studied extensively by different authors (Donati and Cameron 1997, MNRAS 291, 1 and references therein) for different purposes. The observations show that it is a low mass rapidly rotating star (V_{rot} ~ 50 times the equatorial rotation of the Sun), which possesses a complex spot distribution over its surface. The magnetic field of this star is time dependent, and the time scales of variations are found to be 1 day. Observations also show that the star's surface rotation is differential. Aim of the present work is to understand the steady and time dependent parts of the internal rotation and the toroidal component of the magnetic field of AB Doradus. Using the observed boundary conditions at the surface and assuming that the base of the convection zone rotates rigidly, we solve analytically Chandrasekhar's MHD equations for the steady part of the internal rotation and the toroidal component of the magnetic field of AB Doradus. We compute the radial variation of internal rotation for the three latitude zones (the equator, $40^{\circ}.5$ and $71^{\circ}.8$). It is interesting to note that the radial variation is similar to the radial variation of the Sun's rotation in the region of the convective envelope. This solution also yields a lower limit on the radiative core rotation at 1.42×10^{-4} rad sec $^{-1}$. Using the limit on the core rotation as the boundary condition at the base of the convection zone, we obtain the rotation in the convective envelope. For a consistent solution and for a radius of AB Dor equal to 5.95×10^{10} cms we estimate the size of the convective envelope to be 40% of the radius. The solution also yields an estimate of the toroidal part of the magnetic field (T). In this solution, T is normalized to the mean density 1.78 gmcm^{-3}. It may be noted that the field structure thus obtained is steady and we can not compare with the observed magnetic field. However, we can make some conjectures on the time dependent part of the toroidal magnetic field.

One of the ways to study the problem is to think that the dynamo is operating at the base of the convective envelope. However, the present calculation raises doubts about the applicability of the so-called dynamo theories for the explanation of the time-dependent part of the magnetic field of a fast rotating star such as AB Dor. An alternative way is to think that the toroidal field (which may be of primordial origin) is distributed throughout the convective envelope. In fact, the present study indicates that the toroidal field is distributed everywhere in the convective envelope. The active regions are formed from the toroidal perturbations of the underlying field leading to instabilities and bringing the toroidal field to the surface. For example, if the resulting Alfvén type perturbations have strengths similar to those of the ambient steady magnetic field, then the observed fields of 800 gauss might have formed just beneath the surface. However. the validity and other details of such a mechanism remain to be worked out.

(K.M. Hiremath)

Linear polarization in the RV Tauri star AR Puppis

The simultaneous photometry (20 nights) and polarimetry (30 nights) in V band obtained during December 1997-April 1998, which cover about a pulsational cycle and a half, clearly establish the polarization-light curve connection in AR Pup : both go through the maximum and minimum at about the same time. The polarization measurements in V between two successive light

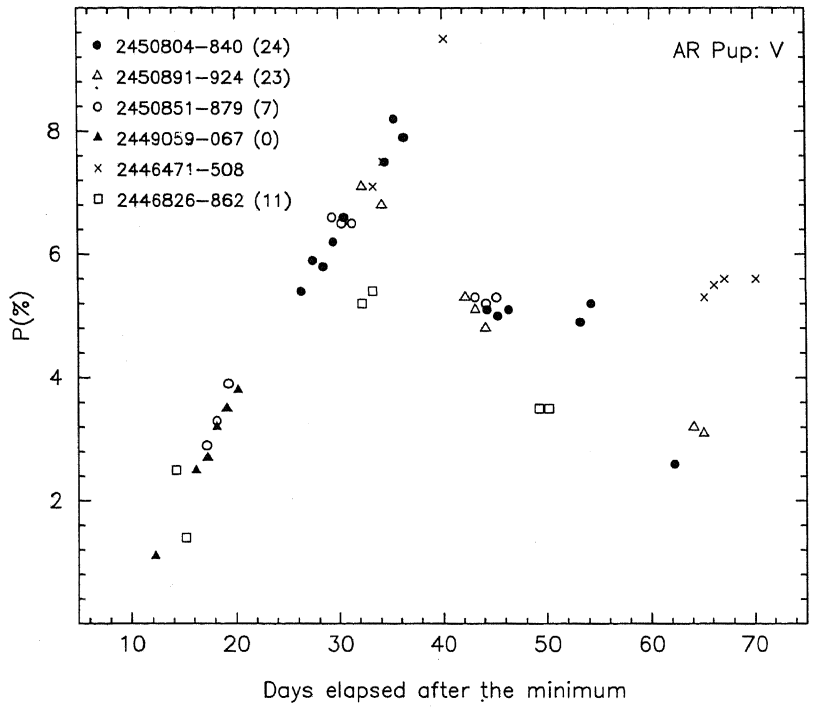


Figure 10. Plot of linear polarization in V against the number of days elapsed after a minimum. The observations between two connective light minima are grouped together and shifted along the time axis by the number of days indicated in parantheses.

minima, which constitute a polarization cycle, are grouped together and plotted in Figure 10 against the corresponding times elapsed after the first minimum; the data were obtained at Kavalur during the years 1984-98. Before plotting, the observations in each group were laterally shifted along the time axis by the number of days indicated in the figure. Since the time of minimum preceding the observations during JD 2446471-2446508 is uncertain, they were shifted by an arbitrary number of days along the time axis to align them with the other observations during the increasing phase. It is interesting to see that all the observations during the increasing phase of polarization lie on a near-straight line, implying that irrespective of the maximum level reached, the rate of increase in polarization was almost the same during the different cycles considered. Though the decline phase of the polarization shows a larger scatter, the average rate of decay, which is significantly smaller than that during the increasing phase, was also the same during different cycles. This indicates that the level to which the polarization drops before the onset of the next increase depends upon the level to which the polarization increased during the current cycle. Hence, it is quite possible that a residual polarization component, which decreases comparatively slowly, is superposed on that produced during the rise in the subsequent cycle, making the observed polarization a resultant of these two independently varying components; it is possible that the slow-varying component itself could be comprising two or more independently varying components.

The mechanism that produces the exceptionally large polarization in AR Pup is, mostly likely, selective absorption by non-spherical grains, which condense with a certain amount of alignment after each light minimum during a pulsational cycle. Position angle of the polarization in AR Pup does not show any correlation with its mean light level which is found to vary nearly-sinusoidally with a 1165 ± 4 day period.

(A.V. Raveendran)

Lithium abundance and mass

Observations of cool giants have shown that there exists a large range in their lithium abundances even for apparently similar stars. The depletions are large in a majority of them, far in excess of the predictions of the stardard stellar evolution models. In order to explore whether the large spread in Li I abundances observed in giants can be interpreted in terms of mass, moderately high resolution CCD spectra of the Li I line at 6707.8 A have been obtained in 65 subgiants, giants and supergiants and the lithium abundances derived. The absolute magnitudes of the sample stars have been estimated from the Hipparcos data. The stars have been plotted on the HR diagram and compared with the theoretical evolutionary tracks of Bressan et al. with initial masses ranging from 1 $M_\odot$ to 7 $M_\odot$ for a chemical composition typical of the solar neighbourhood : X = 0.70, Y = 0.28, Z = 0.02. This study shows that stars of low mass (< 2 $M_\odot$) span all ranges of Li abundances, perhaps reminiscent of the large

range in abundances observed in their main sequence progenitors. Higher mass stars show a different behaviour. Most of the giants of masses between 2.5 and 4.0 $M_\odot$ and hotter than 5000 K have Li abundances close to what is predicted by the standard stellar models. On the other hand, there are several high mass giants (>2.5$M_\odot$)cooler than T_{eff} = 5000 K with Li abundances as low as those of low mass stars of similar effective temperature. There must be parameters other than mass and the evolutionary status of a star, that control its Li abundance. Since there are several theoretical and observational uncertainties modifying the interpretation of the data, we are extending the above analysis to a much larger sample of stars of various masses to confirm whether the more massive stars indeed preserve their initial lithium.

(S.V. Mallik)

Lithium in F and G subgiants and giants

In order to assess how much lithium depletion occurs in the main sequence phase before the giant branch dilution sets in, it is important to study lithium in stars that have just evolved off the main sequence. With this in mind a large number of F and G dwarfs, subgiants and giants have been observed spectroscopically using the coudé echelle spectrograph at the 102 cm Zeiss telescope of VBO. We obtain a resolution of 0.35 A. Lithium abundances have been derived using standard techniques. A preliminary analysis has shown that lithium is by and large preserved in the early F dwarfs, subgiants and giants (log N(Li) = 3.0), whereas it is heavily depleted in late G stars often by as much as two orders of magnitude. However, there are a couple of G giants which show lithium-richness although they were actually expected to show dilution of their initial lithium. This suggests that there may exist additional lithium production mechanisms during the evolved stages of these stars. To test this and to establish a more definite connection between lithium abundance and its relation to rotation and activity, the sample is being further enlarged.

(S.V. Mallik, M. Parthasarathy, A.K. Pati)

Late-type giants with infrared excess - lithium abundances

De la Reza et al. suggested that all K giants become Li-rich for a short time. During this period the giants are associated with an expanding thin cirucmstellar shell supposedly triggered by an abrupt internal mixing mechanism resulting in the surface Li enrichment. In order to test this hypothesis twenty nine late-type giants with far-infrared excess from the list of Zuckerman et al. were observed in the Li-region to study the connection between the circumstellar shells and Li abundance. Eight giants have been found to have log N (Li) > 1.0. In the remaining giants the Li abundance is found to be much lower.

HD 219025 is found to be a rapidly rotating dusty and Li-rich K giant with Log N (Li) = 3.0 ± 0.2. Absolute magnitude derived from the Hipparcos parallax reveals that it is a giant and not a pre-main-sequence star. The evolutionary status of HD 219025 seems to be similar to that of HDE 233517 which is also a rapidly rotating, dusty Li-rich K giant.

The Hipparcos parallaxes of all the well studied Li-rich K giants show that most of them are brighter than the "clump" giants. Their position in the H-R diagram indicates that they have gone through mixing and the initial abundance of Li is not preserved. There seems to be no correlations between Li abundances, rotational velocities and carbon isotope ratios. The only satisfactory explanation for the overabundance of lithium in these gaints is the creation of Li by the extra deep mixing and the associated "cool bottom processing".

(M. Parthasarathy, *G. Jasniewicz, *P. de Laverny, *F. Thevenin)

Survey of high proper-motion stars : search for metal-poor stars

A programme to search metal-poor stars among the high proper-motion stars has been taken up. Of the stars studied so far, CS 22877-1 is most likely a metal-poor object. It shows a large radial velocity. From the strengths of the hydrogen lines it appears to have a spectral type of K0 but the strong metallic features normally present at this spectral type are extremely weak. More detailed analysis using high resolution data is in progress.

(Sunetra Giridhar and Gajendra Pandey)

Chemical composition of SRd variables : WY And, VW Eri and UW Lib

Spectroscopic abundances using high resolution spectra are derived for large number of elements in three SRd variables - WY And, UW Eri and UW Lib. The high velocity members of SRd type variables are distinctly different from the disk members. The high velocity members show a relative enrichment of oxygen and other elements seen in halo stars. WY And and VW Eri show Na and Al to be anticorrelated with Fe. VW Eri which is the most metal-poor member shows a remarkably large number of lines of neutron capture elements. Among these r-process elements are significantly enriched relative to s-process elements. All these derived abundances point to the enrichment of the interstellar medium by massive SNe of type II in the early Galaxy.

(Sunetra Giridhar, *D.L. Lambert and *G. Gonzalez)

Hydrogen - deficient stars

Extreme helium stars

Extreme helium stars are characterized by strong neutral helium lines, singly ionized carbon lines and weak or absent Balmer lines. Previous studies of extreme helium stars have revealed that their photospheres are rich in helium and carbon, which are the products of CNO cycle and triple - alpha burning respectively. Extreme helium stars in the temperature range 8000 K to 13000 K are termed as 'cool' extreme helium stars. Their spectra are characterized by neutral carbon lines, singly ionized carbon lines and neutral helium lines. Cool extreme helium stars are very similar to R Cr B stars in their photospheric abundances and luminosity to mass ratio.

We have observed four hydrogen-deficient stars classified as cool extreme helium stars, which are hotter than R Cr B stars but cooler than hot extreme helium stars. We believe our programme stars to be the transition objects which might evolve to R Cr B or to hot extreme helium stars. Also these stars cover a good range in effective temperature. Their distribution in log g - T_{eff} plane, along with R Cr B stars and hot extreme helium stars, would give us clues to their evolutionary status, when combined with photospheric elemental abundances. We have carried out abundance analysis of FQ Aqr, LS IV-14^{o} 109, BD -1^{o} 3438 and LS IV -1^{o} 002. The s-process abundances provide us with additional clues to examine the possibility of these stars evolving to R Cr B stars or to hot extreme helium stars.

(G. Pandey, N.K. Rao, *D.L. Lambert, * S. Jeffery and * M. Asplund)

We are also working on emission and absorption line spectra of MV Sgr, a EHe star with R Cr B characteristics. Work is also in progress on high resolution spectra of V1920 Cyg (a EHe star) which shows emission lines in the red region of the spectrum and asymmetric absorption line profiles, implying the presence of an expanded envelope.

(G. Pandey, N.K. Rao, *D.L. Lambert)

The 1995-96 deep minimum of R Cr B

A series of high resolution spectra obtained during the 1995-96 deep minimum of R Cr B, during which the star reached a V of 13.8 from around V ~ 6, has been analysed in detail. The mysterious spectral phenomenon, which plunges the star into a faintness by several orders rather irregularly and which has been a puzzle, is now more amenable to interpretation because of the high quality of these observations. The spectrum consists of two kinds of emission and an absorption-line spectrum that is similar to the one at maximum but rather indistinct or washed out at this phase. In addition, a broader emission spectrum containing high excitation lines of He I, Ca II H & K, Na I D etc is also seen. After a careful scrutiny of the radial velocities and the line intensities, it is suggested that the broad lines arise from an accretion disk around a low-mass compact object. The sharp emission spectrum consists of high excitation lines arising from shock propagation in the atmosphere of R Cr B and the other emission spectrum consisting of low-excitation lines comes from the circumstellar environment of the star. These spectra are interpreted in the context of dust formation occuring close to the star – high velocity ejection of cool gas is also seen.

(N.K. Rao, *D.L. Lambert)

Is DZ Andromedae an R Coronae Borealis variable ?

The variable star DZ Andromeda (DZ And) has been suspected to be a R Coronae Borealis variable. Our analysis of a high-resolution spectrum shows that the star has been misclassified : the spectrum resembles that of a K giant. We have determined the stellar parameters - effective temperature, surface gravity and microturbulence - using model atmospheres. Abundances derived for a range of light elements, many Fe-peak elements and a few s– process elements indicate a near-solar composition for DZ And.

(Aruna Goswami, N.K. Rao and *D.L. Lambert)

The spectrum of the cool R Coronae Borealis variable Z Ursae Minoris at minimum

We present a high-resolution spectrum of the cool R Coronae Borealis variable Z Ursae Minoris (Z UMi) in its 1997 decline. In addition to the photospheric absorption lines, the spectrum exhibits narrow emission lines of Na I, Ti I, Fe I and Ba II. Broad emission lines of He I and Na I D, which are generally seen in warmer R Cr Bs in decline, are not noticed in Z UMi's decline spectra at this phase. This absence is the principal novel feature of the Z UMi spectrum.

(Aruna Goswami, N.K. Rao and *D.L. Lambert)

Post – AGB Stars

Spectroscopy of the post-AGB star HD 101584 (IRAS 11385-5517)

From an analysis of the spectrum (4000A to 8800A) of HD 101584 it is found that most of the neutral and singly ionized metallic lines are in emission. The forbidden emission lines of [O I] 6300A and 6363A and [C I] 8727A are detected, which indicate the presence of a very low excitation nebula. The Hα, Fe II 6383A, Na I D_1, D_2 lines and the Ca II IR triplet lines show P-Cygni profiles indicating a mass outflow. The Hα line shows many velocity components in the profile. The Fe II 6383A also has almost the same line profile as the Hα line indicating that they are formed in the same region. From the spectrum synthesis analysis we find the atmospheric parameters to be T_{eff} = 8500 K, log g = 1.5, V_{trb} = 13 km s^{-1} and [Fe/H] = 0.0. From an analysis of the absorption lines the photospheric abundances of some of the elements are derived. Carbon and nitrogen are found to be overabundant. From the analysis of Fe emission lines we derive T_{exi} = 6100 ± 200k for the emission line region.

(T. Sivarani, M. Parthasarathy, *P. Garcia-Lario, *A. Manchado and *S.R. Pottasch)

Chemical composition of HD 179821 (IRAS 19114+0002)

An LTE analysis of medium-resolution spectra of HD 179821 has been made. The atmospheric parameters have been derived : T_{eff} = 5660 K, log g = -1.0 and [Fe/H] = -0.5. The position of the star in the H-R diagram, its high radial velocity V_r = 100 km s^{-1}, its far infrared excess similar to planetary nebulae and its chemical composition suggest that HD 179821 is a low-mass carbon-poor post AGB supergiant and not a massive Pop I red supergiant. The underabundance of carbon and of the s-process element zirconium suggest that HD 179821 has not undergone the third dredge-up phase. Its chemical pattern is similar to the carbon-poor halo PN DDDM-1.

(M.Parthasarathy, *F.Th'evemin, *G.Jasniewicz)

Planetary Nebulae - white dwarf connection

The evolutionary connection between the central stars of planetary nebulae and white dwarfs has been known for years. Recent work with high-resolution spectra of the post-AGB stars and protoplanetary nebulae has further firmed up this connection. A distinct evolutionary connection between the C-rich AGB stars and C-rich central stars of planetary nebulae has been established by studying the C/O ratios in the stars.

(M. Parthasarathy)

Planetary Nebulae with binary central stars

It is estimated that at least 10% of the planetary nebula nuclei (PNNi) are

detectable close binaries. The common envelope phase of their evolution is not well understood. The morphology of asymmetric as well as bipolar planetary nebulae are thought to be either due to binarity or rotation of PNNi. In order to study the properties and evolutionary status of PNe with binary nuclei, we have taken up 28 objects for a detailed research. We have gathered all the available IUE NEWSIPS spectra of all these objects and extracted various astrophysical parameters. Our aim is to plot them on the HR diagram and compare them with the evolutionary tracks predicted by theory and thus gain new insights into their evolution. Analysis of Sp 3, PC 11 and Hb 7 are nearing completion.

(R. Surendiranath and M. Parthasarathy)

Interferometric studies

Close Binary Stars

Thousands of speckle-grams of several close binary stars (separation < 1 arc second) and of reference stars (unresolved) were successfully recorded, with the new speckle interferometer at the Cassegrain focus of the 2.34 meter VBT, at VBO, Kavalur, through narrow band filters, using a EEV uncooled intensified CCD (ICCD) camera, as well as with the newly acquired Peltier-cooled ICCD. Two binary stars, viz., HR4689, HR4757, have been reconstructed (Saha et al., 1999) using a powerful algorithm – the triple correlation technique. The power spectrum, as well as the phase from the average bispectrum of the images of these stars have been derived.

(S.K. Saha and V. Chinnappan)

Novae and supernovae

Recurrent Novae

Recurrent novae (RNe) form a small, but heterogeneous group of cataclysmic variable stars that undergo classical nova-like outbursts at intervals of the order of decades. Some RNe are short period binaries similar to a classical nova and consist of an accreting white dwarf and a mass losing main sequence secondary. In contrast, other members of this group are long period binaries with periods of the order of several hundred days and consist of a hot white dwarf and a red giant, similar to the symbiotic stars. The nova outbursts in RNe are thought to be powered by a thermonuclear runaway in the layer formed on the white dwarf following accretion of mass from the companion.

Recurrent novae at quiescence : systems with giant secondaries

A comprehensive study of the recurrent novae with giant secondaries was made based on spectra obtained primarily from VBO and published photometric data. Although current thoughts favour a thermonuclear runaway on a massive white dwaft as the energy source for the RNe, the lack of high ionization lines in the UV spectra of RS Oph and in the optical spectra of T Cr B, RS Oph, V3890 Sgr and V745 Sco points to an inconsistency with the idea of the presence of a hot white dwarf. Further, the hot component's luminosity and effective temperature are inconsistent with standard white dwarf tracks in the H-R diagram.

The quiescence data indicate the hot component in these systems is variable, with the variability manifesting as a variability in the ultraviolet luminosity, the UV and optical emission line fluxes and in the UV/visual magnitudes. The variations are uncorrelated with the binary orbital motion. The observed UV and optical spectral characteristrics of the hot component in these systems can be explained by a white dwarf+accretion disc embedded in an envelope of wind from the M giant secondary. We suggest the observed variations are a result of (a) the fluctuations in the mass accretion rate; (b) changes in the column density of the absorbing wind envelope, which is optically thick.

(G.C. Anupama and *J. Mikolajewska)

The problem of the high mass of the hot component in T Coronae Borealis

Long-term spectroscopic observations are presented of the recurrent nova (RN) TCrB. These were obtained between the years 1985 and 1996 using 1.02 m and 2.34 m telescopes of the Vainu Bappu Observatory in India and the long-

term photoelectric photometry of the object obtained mainly at the Skalnaté Pleso Observatory and at the Hlohovec Observatory in Solvakia. On the basis of our results, we have returned to a reanalysis of the old radial-velocity measurements published by Kraft (1958). The results obtained solve unambiguously the problem of the apparently too high a mass of the hot component of T CrB, unacceptable if it has to be a white dwarf (WD), as several independent lines of evidence suggest.

(* L.Hric, * K. Petrik, * Z. Urban, * P. Niarchos, G.C. Anupama)

The 1999 outburst of U Scorpii

The recurrent nova U Scorpii is of particular interest as the object may be evolving towards a Type I supernova outburst. U Sco underwent its sixth record outburst in February 1999. From a visual magnitude fainter than 14.2 on Feb 25.040, 1999 the nova rose to a visual maximum of 9.5 on Feb 25.154, reaching a peak of 7.6 mag on Feb 25.562. The nova steadily declined thereafter at an extremely fast rate of 0.67 mag/day, similar to the previous outbursts.

Spectra of the nova in the wavelength range of 3500-9000 were obtained from VBO using the OMR spectrograph at VBT during the maximum, early and late decline phases on Feb 26.011, 27.015, Mar 8.989, 9.953 and Apr 8.925. The spectra during maximum show strong, extremely broad emission blends due to N III, C III, C IV and hydrogen lines. Helium line could also be present. The FWHM of these blends is 4000-5000 km/s.

(G.C. Anupama and *G.C. Dewangan)

SN 1998S

The supernova SN 1998S was discovered in the Sc II 2 galaxy NGC3877 on March 3, 1998 at a discovery magnitude of 15.2 at a pre-maximum phase. Early spectra indicated the supernova was of Type IIn.

SN 1998S was observed from VBO during March 13 - Arpil 15, 1998 covering the pre-maximum and the early decline phases. Spectra during the maximum phase indicate a blue continuum with weak Balmer emission lines. The emission lines showed a narrow P-Cygni profile and a blue shifted broad, shallow absorption trough. As the supernova declined, the emission lines developed a broad profile with the centroid blue-shifted by 900 km/s. The narrow P-Cyg feature was superimposed on this broad feature. Fe II lines began to develop and strengthen. The continuum which was extremely blue during the pre-maximum and maximum phases got redder with time.

(G.C. Anupama, T. Sivarani and G. Pandey)

Recent Supernovae

Spectra of the recent supernova SN 1999aa were obtained close to the optical maximum in February-March, 1999 using the OMR spectrograph on the VBT.

(G.C. Anupama & *G.C. Dewangan)

Pulsar observations

Detection of new emission components from PSR B0329+54

New emission components of the strong PSR BO329+54 have been detected. For this pulsar high-quality single pulse data are readily observable, and hence it has become an excellent laboratory for an in-depth study of the neutron star emission physics. Based on Rankin's pulse profile classification scheme, this pulsar is classified as one of the triple component variety.

We have obtained single pulse data of PSR B0329+54 at 606 MHz with a time resolution of 0.25 ms in August 1996 using the 76m Lovell Telescope at Jodrell Bank, U.K. The average pulse obtained from the data is shown in Fig11.

To estimate the average pulse profiles which clearly showed the presence of weaker components, we have developed a 'window-threshold' technique. In this technique, a window is set on the longitude and an intensity threshold in employed while considering the single pulses for making average profiles, i.e., we consider all those pulses, which have emissions above the threshold within the window. In Fig. 12a, we have plotted the average pulse profiles, which are obtained by applying this technique to each component window.

The average profile obtained from all those pulses is plotted in Fig12b. which clearly shows the presence 9 emission components in PSR BO329+54.

By applying this new technique three new emission components (VII, VIII and IX) of this pulsar have been detected and we have also confirmed the presence of a component (VI) proposed by Kuzmin and Izvekova. This pulsar is now known to have nine components, which is among the highest of all the known pulsars. Our findings favour the idea that the pulsar emission is annular or conal.

(R.T. Gangadhara, * Y. Gupta, * D. Lorimer)

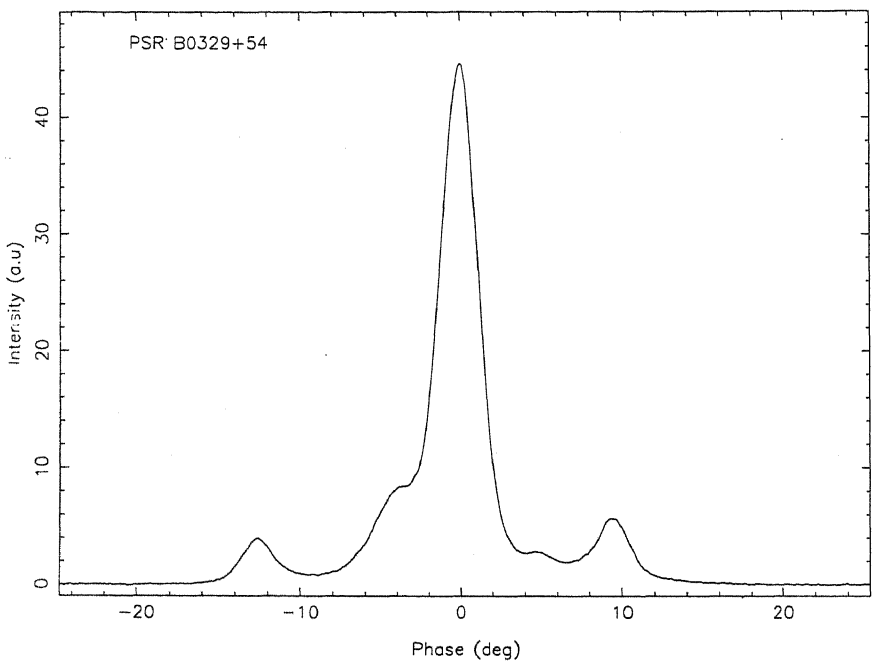


Figure 11. Average pulse profiles of PSR B0329+54 obtained from the data at frequency 606 MHz, where the intensity I plotted in an arbitrary unit, designated a.u.

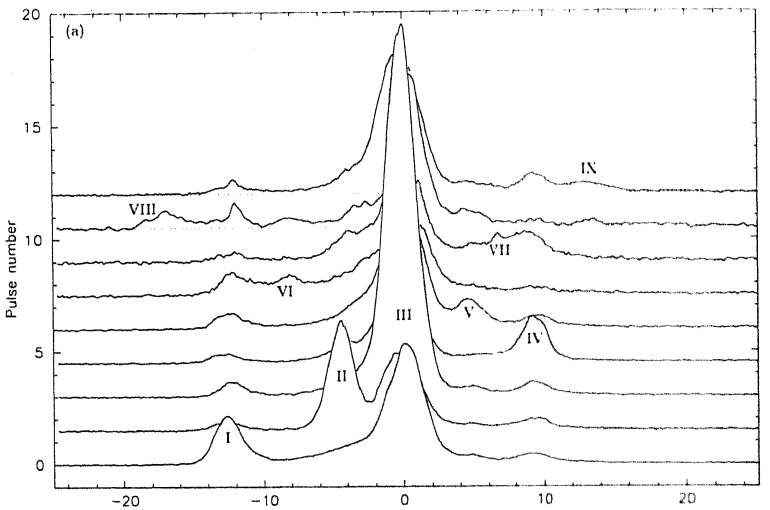


Figure 12(a). Average pulse profiles at 606 MHz obtained by using the window threshold technique over each component's longitude.

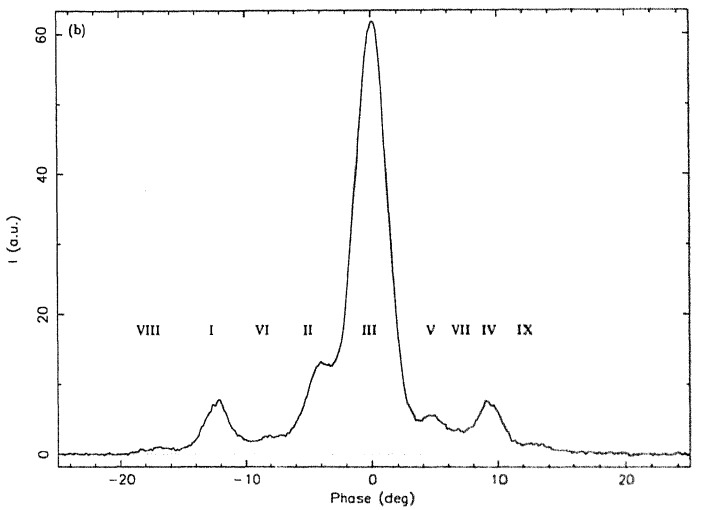


Figure 12(b). Average profile obtained by averaging those that show the presence of the nine emission components.

The galaxy, galaxies and active galactic nuclei

The Galaxy

Magnetic fields in cometary globules

Magnetic fields play an important role in the dynamics of interstellar clouds and the process of star formation. Cometary globules (CGs) are small dense molecular clouds found in regions of massive star formation. Radiation and stellar winds from nearby luminous stars cause the formation of comet-like tails in these objects. The CG 30-31 complex in the Gum Nebula represents an active region of star formation involving cometary globules. Embedded in the core of CG 30 is a young star, IRS 4, that drives a bipolar molecular outflow. To study the geometry of the magnetic field in this CG complex, especially in relation to the cloud morphology and the molecular outflow, we have made polarization measurements of stars in the region. A polarization map representing the geometry of the magnetic field is produced. The magnetic field is found to be nearly perpendicular to the cometary tail. The observed direction of the magnetic field is more or less parallel to the bipolar molecular outflow from the young stellar object IRS 4. The cloud magnetic field perhaps allows gravitational collapse preferentially along the field lines and formation of a protostellar accretion disk perpendicular to it. The molecular outflow is also channelised parallel to the ambient magnetic field.

(H.C. Bhatt)

OB associations and star clusters in the Puppis-Vela region

As there are many early type stars present in the Puppis-Vela region along with the IRAS-Vela shell and the Gum nebula, it is presumed a recent star formation event has taken place here. To study various aspects related to this we have used the parallax and proper motion data available in the Hipparcos catalogue. We have identified the kinematic members of 2 OB associations and 6 star clusters. We have determined the mean distance, location, age and space velocities of these groups. The clusters and OB associations show similar age and space velocity. The field stars also show ages similar to that of the clusters. From the velocity, location and age, we find that VOB2, Col 140, Tr 10, NGC 2516 and NGC 2547 could have been formed from the same star formation event.

(A. Subramaniam, H.C. Bhatt)

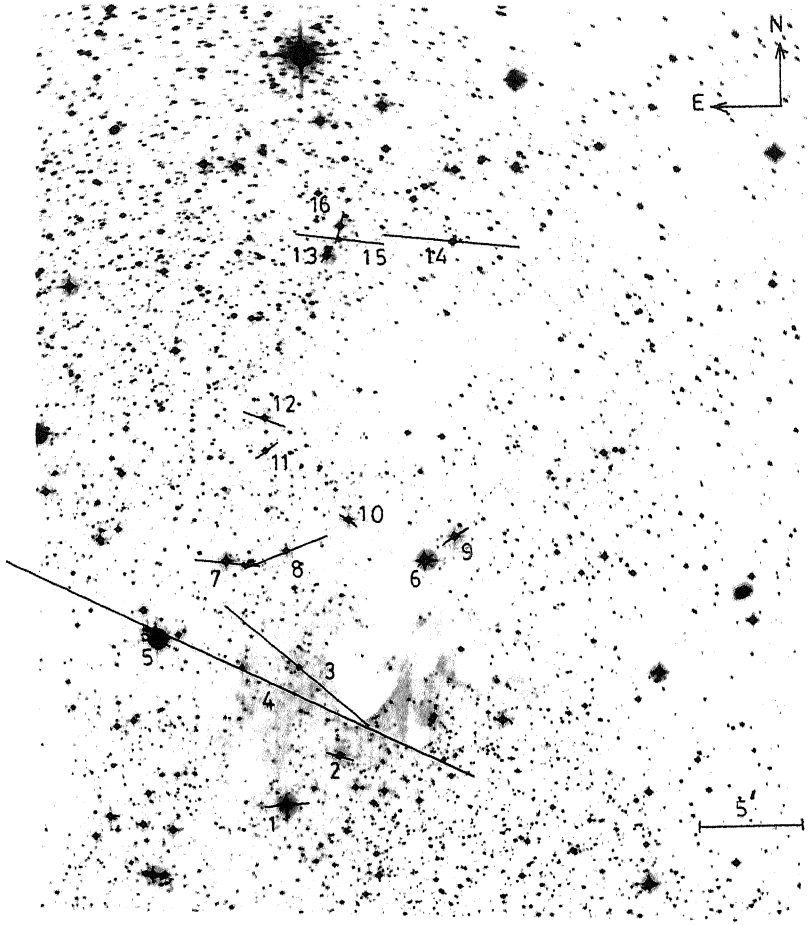
Chemical evolution of intermediate mass nuclei in solar neighbourhood and the halo of our Galaxy

Recent observations of Fe group elements in very low metallicity stars show an evolutionary trend very different from that of Fe, implying divergent paths of chemical evolution for these elements. Since the initial input yields in a chemical evolution model implicitly contain a physical scenario of evolution, improved input yields along with a realistic model of chemical evolution should result in a better simulation of the observed abundances. The present work investigates this hypothesis with a two-zone model of Galactic chemical evolution using a comprehensive set of theoretically computed yields covering the entire range from H to Fe. It is shown that with a two-zone model the main observational constraints of the solar neighbourhood can be satisfied. The abundances of the iron group elements with a few exceptions, are also found to be in good agreement with the stellar abundance data. The model simulates chemical compositions at solar birth, and the age-metallicity relation close to observation.

(Aruna Goswami and *N.Prantzos)

Production and evolution of heavy elements in the Galaxy

The origin of the various chemical species in the universe and the evolution of their abundances (in particular, in the Galaxy) is one of the major themes of modern astronomy. However, current models of stellar nucleosynthesis face several difficulties in calculating the amount of heavy elements, the s- and r-



CG 30-31

nuclei, synthesized by stars of various masses. With the goal of obtaining a clearer picture of the production and evolution of heavy elements in the Galaxy, we have undertaken to evaluate on the basis of stellar nucleosynthesis models, the amounts of s-nuclei produced by stars of various masses and metallicities and hence calculate the evolution of the heavy element abundances in our Galaxy on the basis of existing models of galactic chemical evolution.

(Aruna Goswami and *N.Prantzos)

Galaxies

A study of the emission line spectra and the stellar populations of starburst galaxies

Starburst galaxies are those galaxies which exhibit very high rates of star formation over a small region of about 1-2 kpc, that cannot be sustained for more than one tenth of the Hubble time. Optical to near-IR spectroscopy has been carried out on a sample of starburst galaxies with an aim to study the properties of the ionized gas and thereby infer the nature of the embedded ionizing stellar cluster. Since the nebular lines do not provide information about the evolved population which are no longer sources of ionizing radiation, the stellar absorption features of the red supergiant stars have been used to infer the presence of an evolved population.

From the optical emission line diagnostics, we infer higher electron densities, and higher excitations in starburst nuclei compared to low luminosity H II nuclei. We find through the use of the radiation softness parameter, that the temperatures of ionizing stars decrease with increasing metallicities and is less than 40,000K for all our sample starburst regions. This would place the upper mass limit of the IMF in these regions at $M_u < 25\ M_\odot$. We find that the low ionization lines are considerably enhanced in these nuclei, which could possibly indicate the presence of shocks or a modification of the thermal properties of the photoionized nebula by dust.

The starburst regions show star formation rates of about 0.757 $M_\odot\ yr^{-1}$ and from a comparison of the SFR in the inner regions with that for the whole galaxy, most of the star formation activity appears to be concentrated in the central few kiloparsec radius. From $^{12}CO(1\text{-}0)$ measurements available in the literature, it is known that most of these galaxies have huge reservoir of molecular hydrogen gas concentrated towards the nuclear region, within a few hundred parsec radius.

From the observed Hα luminosity, Hα equivalent widths and Ca II triplet equivalent widths, it appears that the nuclear starbursts have a composite population, consisting of young, massive stars which are less than 3 Myrs old, coexisting with an evolved population. We have measured the Ca II triplet equivalent widths in the nuclear regions of starburst galaxies and used these to infer the presence of evolved massive stars which are in the non-ionizing, RSG phase. We use diagnostic diagrams based on evolutionary synthesis modelling of starbursts, involving Ca II triplet equivalent widths and Hα equivalent widths to infer ages of 6 - 8 Myrs for the evolved population.

(Swara Ravindranath and Tushar P.Prabhu)

Properties of H II regions in NGC 1365 – the luminosity function and size distribution)

H II regions serve as the best probes to study star formation in external galaxies. The luminosity function of H II regions essentially reflects the luminosity and mass functions of the embedded stellar clusters.

We present in this work, the statistical properties of H II regions in the barred galaxy NGC 1365. We have catalogued 98 H II regions, and obtained the luminosity function (LF) of these regions. The H II LF can be expressed by a power law of slope $\alpha = -2.29 \pm 0.11$, and this is consistent with the steep slopes expected for galaxies of early Hubble type. Spiral galaxies of late Hubble type are known to have shallower slopes since they have sufficiently large numbers of H II regions contributing to the high luminosity end of the H II LF. We find that the size distribution of H II regions can be well-approximated by an exponential law, and that NGC 1365, like other early type spirals, has very few giant H II regions. From the steep slopes of the H II LF and the diameter distribution of H II regions in early-type galaxies, it appears that some dynamical phenomena are responsible for inhibiting the formation of

large star-forming complexes in these galaxies. A simple linear least square fit to the luminosity versus the radius of the H II regions, in logarithmic units, yields a slope close to 3, as is expected for ionization-bounded Strömgren spheres. However, at higher luminosities, there is an upward trend indicating a deviation from this relation. This probably indicates that the higher luminosity H II regions are density-bounded.

(Swara Ravindranath and Tushar P.Prabhu)

Active Galactic Nuclei

High resolution optical imaging in the light of emission lines on sub-arcsecond scales can reveal the structure of the narrow-line gas in active galactic nuclei (AGN). Recently, the high spatial resolution observations of emission lines of the AGN NGC 4151 have been successfully carried out at the Cassegrain focus of the 2.34 meter VBT, Kavalur. The new intensified CCD camera system (cooled) has been used as a detector for the speckle interferometer to record 2000 specklegrams of this object through a narrow band filter centred on Hα (FWHM = 50 A). Data are being processed. If a photon counting detector system is made available, where it can reach $m_v > 14$, the present speckle interferometric programme can be made competitive with programmes elsewhere. A study of the time variability of AGN emission is also being planned.

(S.K.Saha and V.Chinnappan)

The phenomenon of reprocessed high energy emission in a radio-quiet quasar analogous to that seen in lower luminosity radio-quiet AGN, and the implications for high-luminosity radio-quiet AGN are being investigated. The parsec-scale radio structure of radio-quiet AGN of low-luminosity is being investigated for a sample of such objects in order to test predictions of Unified Schemes. A collaborative effort has begun under the ILTP scheme. AGN that are highly variable are being monitored at the Vainu Bappu Observatory as part of multi-wavelength campaigns that study these objects in both the flare and the quiescent state.

(P. Shastri)

High-energy astrophysics

High-energy Astrophysics

Gamma Ray Bursts : deep CCD imaging of GRB fields

The observational programme of deep CCD imaging of Gamma Ray Burst (GRB) fields has been continued with the 1m and 2.34m telescopes of Vainu Bappu Observatory. Targets were chosen from the Interplanetary Network (IPN) Catalog and COMPTEL/CGRO as well as Beppo SAX triggered GRBs. Besides making an extensive photometric and astrometric database we are trying to establish the properties of GRB hosts in quiescence by identifying their unusual photometric colours and/or variabilities in our deep CCD images. The data analysis is in progress.

Rapid follow-up observations

It was realized long ago that multi-waveband observations of a GRB event would play a major role in the understanding of the GRB phenomenon and its origin. The problems of large error boxes of GRB localizations and of timelag between the GRB event and the follow-up observations in other wavebands have been now relaxed after the launch of BeppoSAX. The procedures developed for the precise and quick localizations of GRBs enabled the discovery of optical counterparts of over a dozen GRBs since early 1997.

One of us has been the member of the GRB co-ordinate distribution network and has been receiving the burst alarms since mid-1994. We have been attempting the rapid follow-up of GRBs since then. Unfortunately, so far we have not had success in finding the counterparts, mostly due to the bad weather in Kavalur. Many of the bursts could not be followed up either because they were too close to the Sun's position or were in the southern hemisphere.

(S.G. Bhargavi, R. Cowsik)

The simultaneous gamma ray and optical observations of GRB 990124 were used to put stringent constraints on the equivalence principle for ultrarelativistic particles and on the mass and other properties of the photon.

(C. Sivaram)

Early Universe and Astroparticle Physics

The Top-Down scenario of origin of the Extremely High Energy Cosmic Rays (EHECR):

The existence of Extremely High Energy Cosmic Rays (EHECR) — cosmic ray particles of energies above 10^{20} eV – is difficult to explain within the context of conventional acceleration mechanisms operating in astrophysical sources. Continuing on with our earlier work on the subject, we have made detailed calculation of the expected spectra of nucleons, photons and neutrinos in the "Top-Down" scenario of origin of EHECR in which these energetic particles arise from decay of sufficiently massive X particles originating from certain processes in the early Universe rather than from any "bottom-up" acceleration mechanisms operating in powerful astrophysical sources. The massive X particles in question could arise from collapse or annihilation of topological defects (such as cosmic strings and/or magnetic monopoles) associated with some Grand Unified Theory (GUT) and formed during a symmetry breaking phase transition in the early Universe. Alternatively, the X particles could be some long-lived metastable relic particles of lifetime comparable to or greater than the age of the Universe, which could be produced in the early Universe through particle production processes associated with inflation.

Using detailed numerical simulations of propagation of extragalactic nucleons, γ-rays, and neutrinos in the Universe, we have studied the sensitivity of the predicted particle spectra to particle physics uncertainties such as the mass and decay modes of the X particles, the QCD quark fragmentation functions which determine the injection spectra of particles, and so on, as well as to

astrophysical uncertainties associated with the strength of the universal radio and infrared backgrounds and the extragalactic magnetic fields. Based on this detailed study, we have identified an interesting range of relevant parameters for which the Top-Down scenario explains the EHECR data without violating any observational constraints such as those imposed by the measured extragalactic diffuse gamma ray background, the COBE measured microwave background anisotropy, the light element abundance, and so on.

In addition, spurred by recent independent experimental indications of a possible small neutrinos mass, we have included the effects of a few eV range neutrino mass in the particle propagation calculations. In particular, we include the effects of excitation of the Z-boson resonance in the interaction of sufficiently energetic neutrinos with the cosmic thermal background neutrinos, and study its signature in the predicted particle spectra which will be testable in the up-coming Auger detector. Thus, accurate measurement of the EHECR spectrum in the upcoming large area detectors may give indirect signatures of massive neutrinos dark matter and their large-scale distribution in the Universe.

(P.Bhattacharjee,*S. Lee, *G.Sig 1 and *S.Yoshida.)

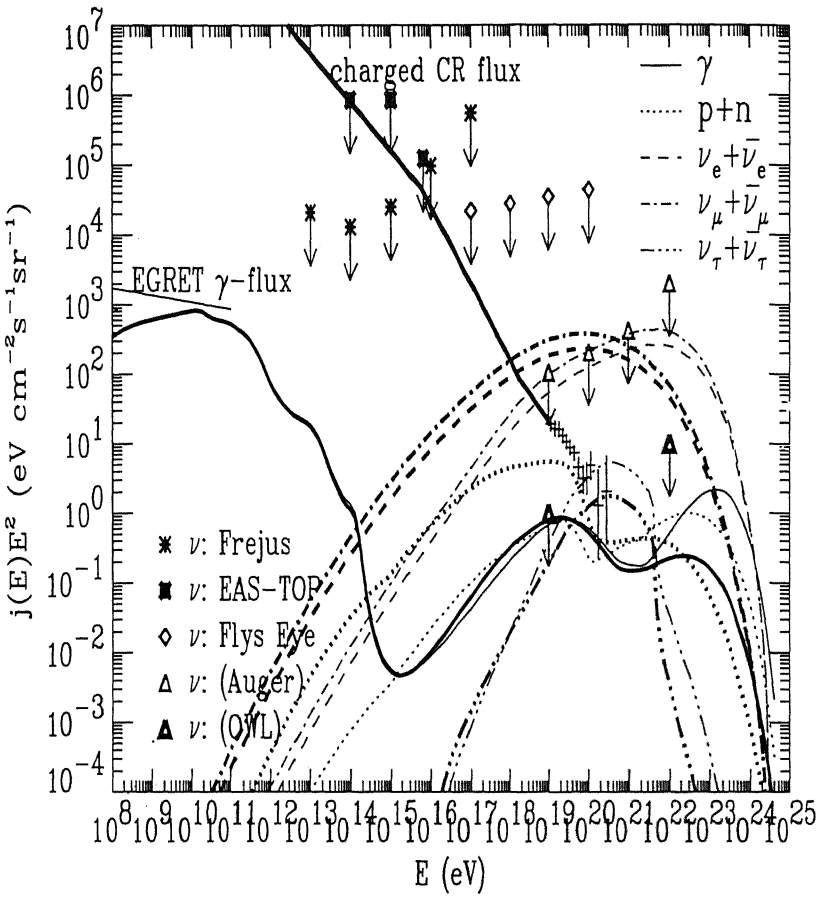


Figure 13. Energy spectra of nucleons, γ-rays and neutrions for the TD model with $m_X = 10^{16}$ GeV, $p = 1$, and the decay mode $X \rightarrow q + q$, assuming the high URB version and an EGMF of 10^{-10}G. Thick and thin lines represent the SUSY and no-SUSY FFs, respectively. 1 sigma error bars are the combined data from the Haverah Park, Fly's Eye and AGASA experiments above 10 EeV. Also shown are piecewise power law fits to the observed charged cosmic ray flux below 10 EeV, the EGRET measurement of the diffuse γ-ray flux between 30 MeV and 100 GeV (37), and experimental neutrino flux limits from Frejus (38) and Fly's Eye (39), as well as projected neutrino sensitivities of the future Pierre Auger (40) and NASA's OWL (42) projects.

Theoretical astrophysics and cosmology

Radiative Transfer

Polarized line transfer

A new operator perturbation method for polarized line transfer has been formulated. An important generalization of this method to the case of Hanle effect with partial frequency redistribution has been also achieved. Work is in progress on further development of this method.

In recent years, realistic frequency redistribution matrices considering the full angle, frequency, and polarization coupling are derived, based on quantum electrodynamics. Work on incorporating these exact relations in our "operator perturbation method" is in progress. This involves developing an extremely accurate radiative transfer solution, in order to decipher the unknown landscape of QED effects in polarized line formation theory.

(K.N. Nagendra)

Molecular polarization in the solar atmosphere

The second solar spectrum shows unexpected and surprising features of polarization in molecular lines (e.g., C_2 and MgH). These lines are almost invisible in the intensity spectrum. We conjectured that the polarization of these lines is due to resonance scattering in the lower solar atmosphere. To test our hypothesis, we considered the VAL model for the solar atmosphere. By modeling the MgH lines, we could determine the oscillator strength and the collisional de-excitation parameter of the transition. This work is one of the first few to explain molecular line polarization as due to resonance scattering in the solar atmosphere.

(D. Mohan Rao and K.E. Rangarajan)

Effect of waves on resonance scattering polarization in solar atmosphere

Polarization profiles of resonance lines formed in the presence of various types of waves propagating in a non-magnetic atmosphere were investigated. The input solar atmospheric model was VAL-C. We found that the type of wave present in the atmosphere influences the time – averaged emergent polarization profile in spite of the stratification of physical parameters present in the atmosphere. By this study we have shown that the polarization is a better diagnostic tool to identify the characteristics of waves present in the solar atmosphere than the specific intensity. Further theoretical developments should include partial frequency redistribution (PRD) effects. PRD is expected to give variations in the wings of line profiles which is essential for finding the conditions in the deeper layers of the atmosphere.

(K.E. Rangarajan)

Resonance polarization with collisional redistribution

In an earlier paper the effect of depolarizing collisions on resonance polarization in the absence of magnetic field was studied. We investigated whether the partial frequency redistribution function R_{III} (which describes the frequency redistribution due to collisions) can be replaced by complete redistribution in resonance polarization calculations. It was found that the R_{III} function gave different polarization in the Doppler core compared to CRD when depolarizing collisions were neglected. When depolarizing collisions were included, the approximation (i.e $R_{III} \approx \phi(x)\,\phi(x')$) gave significant underestimation of the polarization in the intermediate frequency domain between the line core and wings when the coherence parameter, γ was smaller than 0.9.

Since the above calculations pertain only to parameterized models, a more realistic model atmosphere has now been considered. In our present calculations, the resonance polarization of Ca I 4227 A in solar atmosphere has been studied using the exact R_{III} and with the approximate form $\phi(x)\,\phi(x')$.

We do not find any differences in the percentage of polarization between the two cases. It is proposed that for the photospheric lines with small value of γ, differences may be found in the polarization when R_{III} and CRD functions are used in the radiative transfer calculations.

(D. Mohan Rao)

Distorted surface due to self rotation and tidal effect

The atmospheres of the components of a close binary system are distorted mainly by two physical effects (1) rotation of the components and (2) the tidal effects on one due to the presence of its companion. These effects make the atmospheres of these stars nonspherical. Nonsphericity changes the density distribution of the matter through which the radiation passes and as a consequence, the line radiation in such a medium is modified. In addition, the light of the secondary falling on such a distorted atmosphere affects the line profiles formed in these atmospheres. In this work, the equation of a distorted surface has been solved along with the equation of radiative transfer to study the effects of rotation and tidal effects of a close binary system.

(M. Srinivasa Rao, *A. Peraiah)

Effect of gravity darkening on spectral line formation

Theoretical line profiles from the extended atmospheres of the components of a close binary system, whose surfaces are distorted due to rotation and tidal effects, have been computed. The line profiles have been calculated in terms of mass ratio of the two components m_2/m_1, ratio of the equatorial radius of the primary to the distance between the centres of gravity of the two components, r_e/R, ratio of the centrifugal to gravity forces at equator, f and the ratio of angular velocities at the equator and at the pole, x . The line profiles are calculated for different velocity laws, and different temperatures and their fluxes are compared.

(M. Srinivasa Rao, *A. Peraiah)

Reflection Effect in Close Binaries

In an earlier piece of work, the reflection effect in 2-dimensional geometry was studied to see how the radiation field changes, if the reflected radiation were calculated correctly by employing the radiative transfer equation. It was shown that even a 2-dimensional calculation of reflected radiation changes the radiation field considerably.

This work is now being extended to calculate the reflected radiation from the extended surface of the components of a close binary system assuming 3-dimensional Cartesian geometry. The specific intensity of the radiation field can be estimated along the line of sight for an observer at infinity. As a preliminary step the calculation was done in a purely scattering medium. While calculating the radiation field, I excluded the radiation occulted by the central star and the radiation in the shadow cone. The secondary component is assumed to be kept at different points in its orbit which is assumed to be circular. The amount of radiation received by the observer at infinity depends on the position of the secondary.

(M. Srinivasa Rao)

Effect of dust on polarization of line radiation

The effect of dust on line polarization is studied. We have assumed an atmosphere with spherical symmetry and have used the Discrete Space Theory to solve the polarized radiative transfer in the presence of dust and under the assumption of complete redistribution. We assumed that the dust scatters radiation isotropically. We considered a uniform distribition of the dust in the medium. The calculations are done in the comoving frame of the fluid assuming a two-level atom in the non-LTE approximation. In a spherically symmetric atmosphere with azimuthal symmetry in the radiation field, it is sufficient to consider the Stokes parameters I_l and I_r to represent the polarization state of the radiation field. The total intensity is defined as $I = I_l + I_r$ and the Stokes parameter Q is defined as $Q = I_l - I_r$. I_l and I_r denote the intensities of linearly

polarized radiation along two perpendicular directions l and r. The linear polarization is defined as p = (Q/I). With the above definitions, the vector transfer equation for a two-level atom in the comoving frame was solved. We considered 15 frequency points in the domain [-7,7]. In the static cases, the Doppler core extends from -3 to +3 Doppler widths. In the presence of an acoustic wave with amplitude equal to 3 times the Doppler width one should perform the calculations to cover the entire [-7,7] frequency range.

(B.A. Varghese, *A. Peraiah)

Atomic Astrophysics

We have used non-relativistic multi-reference many-body perturbation theory to calculate excitation energies and oscillator strengths of several radiative transitions in neutral calcium that are of importance in astrophysics. We have also studied the allowed and intercombination transitions in doubly ionized carbon which is of great astrophysical interest.

(B.P.Das)

Stellar dynamics

Angular momentum plays an important role in shaping a galaxy during its evolution. The behaviour of angular momentum transfer to the internal degrees of freedom of the remnants of a pair of galaxies undergoing collisions has been studied by numerical simulations. The simulations have been continued for more than 50 dynamical times. The transfer of orbital angular momentum and energy to the internal degrees of freedom takes place essentially after the galaxies pass through the perigalactic point. At the end of the simulations, the remnants are fairly relaxed systems whose potentials are deeper than their progenitors. The change in the orbital angular momentum shows fluctuation in the case of merging simulations and smooth variation in the case of nonmerging simulations. Even though the precise shape of the remnants are difficult to derive from these simulations, the inner and outer parts show tendency to respectively evolve into prolate and oblate systems.

The analytical investigation of the stability of a stellar system is often restricted to simple cases like homogeneous spherical systems. The study of stability of non-homogeneous systems can be achieved only by numerical simulations. A dynamical system, such as a galaxy, if perturbed oscillates about its equilibrium position. The first numerical simulations of this phenomenon was done by Miller and Smith (1994) who modelled a galaxy as a polytrope of index n = 3. Oscillations in the kinetic energy are considered as signatures of galactic oscillations. We performed a series of simulations in which the galaxy was represented as that corresponding to a polytrope of index n = 0, 1,2 and 3. In all these cases the evolution of the galaxy was followed for more than 70 dynamical times and the kinetic energy showed a very regular undamped oscillatory pattern. Fourier Transform of the data showed an oscillation period of 3.6 times the dynamical time. Further analysis of the data is in progress.

(P.M.S.Namboodiri)

An algorithm is being developed for solving the coupled nonlinear partial differential equation for the dark matter potential. An iterative procedure is used to solve the nonlinear equation along with the boundary conditions. Using an initial value the nonlinear elliptic equation reduces to a linear equation which is solved using successive overrelaxation method.

(B.A. Varghese, R. Cowsik)

Turbulence

Hydrodynamical turbulence is present in a variety of astrophysical situations, be it stellar, galactic and intergalactic. The kinetic helicity is believed to be the most crucial characteristic of turbulence as it is needed for the generation of large scale magnetic and velocity fields. The mechanisms of converting longitudinal motion associated with compressible motions into vortical motions responsible for generating kinetic helicity have been discussed. Passage

of acoustic waves in a turbulent medium and incidence of oblique acoustic waves on a shear flow present themselves as favourable circumstances for the production of kinetic helicity.

(V. Krishan)

Plasma physics

Dusty Plasmas

Grains in various astrophysical sites are commonly electrically charged. Presence of such grains in a plasma gives rise to new wave modes which can manifest themselves as time variability in the observed radiation. Further the discerning feature of a charged grain is that its charge is variable. We are investigating the consequences of charge variability in a dusty plasma.

(V.Krishan, *R.K. Varma, *P.K. Shukla)

Pair production and annihilation in a plasma

A photon becomes a massive particle in a plasma. We are exploring effects of photon mass on electron-positron pair production and annihilation cross sections. Preliminary results show that the cross sections are reduced significantly. We further plan to replace one of the photons in a two photon process for pair formation and annihilation by a plasma wave and determine the corresponding cross sections. These processes acquire a great importance in high energy compact objects.

(V.Krishan)

Magnetohydrodynamics

The effect of uniform flows on the characteristics of magnetoacoustic-gravity surface waves at a single interface when both the magnetic field and propagation vector are parallel to each other is studied. The region above the interface is permeated by a uniform horizontal magnetic field. The lower region is field free. The temperature on both sides of the interface is assumed to be uniform, with a discontinuity along the interface. The dispersion relation for the fluid which is compressible and having a large conductivity is derived in the linear context. Depending on the temperature structure, the interface supports one or two surface modes in the absence of gravity. Certain limiting cases are discussed. It is proposed to continue this work by assuming that the magnetic field and propagation vector are inclined to the interface. This work has been started and will be completed shortly.

(A. Satya Narayanan)

The study of dynamical phenomena in sunspots is being carried out computationally using the ZEUS2D MHD numerical code developed by Norman and Stone (1992). Gangadhara and Hasan (1997) have adapted a time-dependent 2-D code to study dynamical phenomena in sunspots. In this study they have solved the MHD equations in cylindrical geometry to examine the evolution of a sunspot towards equilibrium, starting from an arbitrary initial state. They have chosen a potential magnetic field which is in hydrostatic equilibrium. We propose to study the dynamics of sunspots by assuming a more general form of the magnetic field while the fluid is assumed to be in hydrostatic equilibrium.

(A. Satya Narayanan, P. Joarder, R.T. Gangadhara, S.S. Hasan)

Recently, Nakariakov et al. (1997) have investigated the interaction of longitudinal and transverse waves in thin magnetic flux tubes. They show that the nonlinear terms give rise to shock formation which are isolated. The growth and decay behaviour of the nonlinear resonant three-wave interaction has been studied. We propose to extend this study by incorporating the effect of uniform gravity.

(A. Satya Narayanan, P. Joarder, S.S. Hasan)

The nonlinear dynamics of a three-dimensional jet is being studied. In this study, the jet is being driven by a small-amplitude precession to break the symmetry and excite helical modes of the Kelvin-Helmholtz instability. Using the method of multiple scales we study the nonlinear evolution of the Kelvin-Helmholtz instabililty when the flow reaches the speed of light. For relativistic cases, numerical simulations are rather hard to obtain. The basic equations of MHD taking into account relativistic effects have been linearized using transformed variables for space and time. The lowest order equations give the conventional dispersion relation which can be solved in the usual way. The higher order equations have been derived and the solutions for them will be sought either analytically or numerically.

(A. Satya Narayanan, R.K. Kochhar)

Based on the axisymmetric MHD equilibrium of an incompressible fluid which was derived by Satya Narayanan (1996) we formulate the general equations for the non-radial oscillations. These sets of linearized equations which are infinite in order are closed by assuming that the power spectrum of the oscillations is dominant up to order 7 in the Legendre polynomials. Certain limiting cases of this formulation are presented and their stability is also discussed.

(A. Satya Narayanan)

Neutron stars and pulsars

Neutron stars in low mass x-ray binaries (LMXBs)

Kilohertz quasi-periodic oscillations (QPOs) in LMXBs may represent the orbital frequencies of the innermost Keplerian orbits around accreting neutron stars. We have derived constraints on the mass and equation of state of the neutron stars, by identifying the highest observed QPO frequency with the Keplerian frequency at the marginally stable orbit given by general relativity. Our treatment is fully general relativistic and includes the effects of rapid rotation.

The results of the study are as follows. If the neutron star radius is less than the marginally stable orbit radius (i.e. $R < r_{ms}$), then with the additional assumption that the highest observed QPO frequency are produced at $r = r_{ms}$, soft equation of state models for neutron star interiors will be disfavoured. If the highest observed QPO frequencies are produced at the innermost allowed orbit, which can be either at $r = r_{ms}$ or $r - R$, then the neutron star mass will be constrained to (0.6-1.8) $M_{\odot}$ or (1.8-2.2) $M_{\odot}$. These results are of sufficient generality as we have considered equation of state models ranging from very soft to very stiff.

(A.V.Thampan, *D.Bhattacharya, B. Datta.)

Geometry of pulsar beams

Kapoor has continued with his study of the geometry of pulsar beams delineated by an open field line structure of an oblique dipole rotator in the polar cap model of pulsar emission. The division of open field lines into two branches lends itself to the idea that the branches may be the arena where the core and conal components of a pulsar beam are generated, at relatively different altitudes such that the core emission comes from a region far above the conal one. This allows one to relate in an average manner the ratio of two emission altitudes with the inclination angle alpha between the rotation and the magnetic axes. Comparison with data however does not seem to support this unless the alpha values derived from observations are incorrect.

In the conventional models, the core emission emanates from the full polar cap at or very near the surface whereas the conal components are produced at an altitude of about 10 R_{*}. If this is so, then due to aberration, one should observe the conal component advanced in phase with respect to the fiducial centre of the pulse (cone leading the core). Observationally, both the lead and

its reverse - 'the lag' - are seen ($\Delta\phi \simeq \pm 1$ deg.). At all altitudes, the contribution of toroidal components of the magnetic field of a pulsar works in a sense opposite to that of stellar rotation and tend to overcome the lead. This magnetic field line sweepback has been studied by Shitov (1983, 1985). Taking this into account we have calculated the phase shift of a pulse component centre with respect to the magnetic axis of a pulsar as a function of the corotational velocity of the conal emission zone using our and Shitov's formulations. The following points emerge :

1. The phase difference, $\phi_{abb} - \phi_{mfs}$ first rises up to about half the distance to the light cylinder and then slopes down, rising again at v around 0.8c. The picture is more or less the same for all inclination angles above about 20 deg.

2. Observationally, the phase difference is about + or -1 deg though the maximum calculated value can be in excess of say, 25 deg. This implies that the two emission regions have to be closeby and possibly core and conal emission regions are far away from the stellar surface.

3. In order to get a clearer picture a detailed investigation is necessary. We are in the process of calculating precisely the change in the pulsar emission region structure with altitude using the Deutsch solution for the magnetic field of an oblique rotator.

(R.C. Kapoor)

Nuclear astrophysics

Nuclear Partition Functions

Nuclear partition functions are of interest in a number of astrophysical situations, such as pre-supernova stellar collapse and nucleosynthesis. Both the nuclear level density and continuum nucleon state substraction are necessary to obtain realistic estimates of the nuclear partition function. A non-divergent prescription for calculating nuclear partition functions was suggested by Fowler, Engelbrecht and Woosley (1978, ApJ 226, 984), introducing a truncation of the level density integral near the nucleon separation energies; for the level density they used the back-shifted Fermi-gas formula. A similar calculation but without continuum subtraction was done by Mazurek, Lattimer and Brown (1979, ApJ 229, 713). Tubbs and Koonin (1979, ApJ Lett 232, L59) calculated nuclear partition function using a semi-classical treatment for the level density in a Fermi-gas model of the nucleus. We have calculated partition functions of iron-peak nuclei using thermal Hartree-Fock formalism, which constitutes a more microscopic and realistic approach to describe nuclei. For the interaction we have used the newly suggested modern versions of the Skyrme model.

Numerical results for iron-peak nuclei with temperatures less than 5 MeV indicate that partition functions are smaller than those given by the conventional formulation. We also find that the entropy per nucleon to be quite low, suggestive of an orderly collapse of pre-supernova matter.

(B.Datta and *I.Bombaci)

General relativity and Cosmology

Inertial forces in general relativity

Earlier we had established covariant relations among the general relativistic analogues of inertial forces, gyroscopic precession and gravitoelectromagnetic forces in axially symmetric stationary spacetimes such as those of black holes. This facilitated significantly the understanding of several phenomena occuring in these spacetimes. We have now recast Einstein's field equations in terms of the inertial forces. This should enable one to analyze the solutions, interpret them physically and study source configurations.

(Rajesh Nayak and C.V. Vishveshwara)

Black holes in non-flat backgrounds

Whereas a great deal of research has been carried out on the properties of black holes in isolation, hardly any information is available in case they are in non-flat backgrounds such as those associated with cosmological spacetimes. This is a very important problem, since one should know whether the properties are still valid, modified or totally altered. Towards this end we have been studying black holes in the background of the static Einstein universe as obtained by Vaidya. We have investigated the location and the properties of the event horizon and the ergosphere as well as some physical phenomena taking place in these spacetimes.

(Rajesh Nayak, B.S. Ramachandra and C.V. Vishveshwara)

Studies were made on possible connections between vacuum zero-point fluctuations (fields), known as ZPF, with a non-zero cosmolgical constant now treated as a cosmological free variable to be determined by observations. It was pointed out that there were several distinct differences between these entities, i.e. ZPF and a cosmical constant. Attempts to relate ZPF and a cosmical constant to a graviton mass in flat space were shown to be inconsistent. Flat space propagators for both massless and massive spin-2 particles in the context of flat space wave equations do not correspond to the full FR (general relativity) with a graviton mass. The interrelation between ZPF (as defined above) the cosmical constant and dark matter has been explored and inferences deduced for the early universe.

The possibility of symmetry breaking in the early universe (either at the electroweak dominant stage or at the quark-gluon stage) giving rise to a small residual cosmical constant of the observed magnitude (as implied by luminosities of distant supernovae etc.) has been studied.

The incorporation of a discrete scale invariance in particle physics (following the earlier approach in a cosmological context) was shown to imply some interesting results for the spectrum of particle masses around TeV scale and beyond.

(C. Sivaram)

Physics

Quantum effects

Recently Coleman and Glashow have developed a model which allows the introduction of a small violation of Lorentz invariance. Observational signatures arise because this interaction also violates flavour conservation and allows the radiative decay of muon, $\mu \rightarrow e+\gamma$, whose branching ratio increases as $b\gamma^4$ where γ is the Lorentz factor for the muon with respect to the reference frame in which the dipole anisotropy of the universal microwave radiation vanishes. A bound on the Lorentz invariance violating parameter b, of $b < 10^{-25}$ was calculated based on observations of horizontal air showers with number of electrons, $n_e \geq 5 \times 10^6$. Similar consideration of cosmic ray neutrinos in the atmosphere improve these bounds by twenty orders of magnitude!

(R.Cowsik, G.Rajalakshmi, B.V.Sreekantan)

Tunneling between two BEC

Laser cooled and Bose condensed neutral alkali atoms in magnetic traps are macroscopic quantum systems. That is, the behaviour of about 10^5 BEC atoms can be characterised by a single wavefunction with a definite amplitude and phase. The robustness of this phase has been experimentally demonstrated by several groups in the world through interference experiments. Tunneling between two condensates (single and multi-component) is yet another way to visualise the phase coherence between two similarly prepared condensates.

A self-consistent mathematical formalism describing time evolution of two condensates with a tunneling barrier induced by an external driving laser has been derived. This formalism takes into account the change in the shape of the initial wavefunction as a function of the fractional population difference between the two condensates. The calculation gives a realistic limit to the amplitude of Josephson-like oscillations between the two condensates. Further calculation including damping of the condensates amplitude due to spontaneous emission is in progress and the effects of confining such a system inside a high Q cavity are being investigated.

(Andal Narayanan)

Photon down conversion

Nonlinear optical technique such as Photon Down Conversion is being developed to study the coherence and correlation properties of single photon and entangled photon states. Efforts are on to generate and characterize down converted photons in type-I phase matched Barium Borate crystal using the 351 nm line of Argon Ion laser. The down-converted, entangled photons will be employed for several experiments on the foundational aspects of quantum physics. Light sensitive and protected power supply assemblies for sensitive single photon detectors are fabricated and tested.

(Kaustuv Das, B. Raghavendra Prasad, C.S.Unnikrishnan and *Simon Periera)

Test of a quantum-like theory

A series of experiments were performed to test a quantum-like theory (proposed by R.K. Varma of PRL) and relevant earlier observations by Varma and Punithavelu, which seemed to support the theory in a remarkable way. The theory pertains to a system of thermal electrons with a narrow energy distribution propagating in a uniform axial magnetic field, to a detector with an analysing retarding potential in front. Both the theory and earlier results supported the possibility that there are quantum-like effects on a macroscopic scale which could not be explained within concepts of classical physics. Our results rule out the possibility that the quantum-like theory has observable consequences that are beyond the standard classical paradigm, thereby more or less completely solving a puzzle which was outstanding for more than 15 years.

(C.S. Unnikrishnan *C.P. Safvan)

Gravitation Experiments

Hermetic sealing of the gravitation experiments laboratory at Gauribidanur for suppression of the diurnal component of the atmospheric pressure variations was tried and further necessary improvements are in progress to achieve the required isolation. UHV compatible near-zero length optical windows were fabricated and tested.

(R.Cowsik, N.Krishnan, and P.U.Kamat)

Low angular divergence, ultrahigh brightness LED source was used in an existing autocollimator based on position sensitive linear detector to improve the sensitivity to 3×10^{-8} rad/$\sqrt{\text{Hz}}$. This autocollimator, with a dynamic range exceeding 104 will be employed for measuring the Casimir force and finite temperature corrections.

(R.Cowsik, C.S.Unnikrishnan, G.Rajalakshmi)

A torsion balance with a thin and wide metal strip as its suspension has the dominant contribution to its restoring force coming from the gravitational attraction of the Earth on the balance mass element. This property was utilised in designing a torsion balance to measure the changes in the local gravitational acceleration of the Earth to an accuracy exceeding 1 part in 10^8. This is the first ever design for a micro-gravimeter based on a torsion balance. The measurement requires determination of the changes in the period of the balance to an accuracy of 10^{-8} over an observation time smaller than the tidal frequencies of interest, which has been demonstrated as feasible even without extraordinarily stringent technological requirements. The fabrication will be taken up this year.

Some earlier analysis of certain experimental results on gravitational shielding is being expanded to include many old and new experiments. A unified phenomenological basis for analysis and design of such experiments is also being discussed. A review article on gravitational shielding is being prepared stressing the phenomenological and experimental aspects.

(C.S.Unnikrishnan, *G.T. Gillies)

Nonaccelerator particle physics

Atomic probes of physics beyond the standard model

Parity Nonconservation (PNC) in atoms and Electric Dipole Moments (EDMs) are two important non-accelerator probes of physics beyond the Standard Model. We have made many significant advances in these two areas during the past year.

We have proposed experiments to observe PNC arising from neutral weak currents and the nuclear anapole moment in singly ionized radium. The former would be a very good probe of physics beyond the Standard Model and the latter uses the techniques of ion trapping and laser cooling to observe the nuclear anapole moment (a new fundamental property of the nucleus) in an unambiguous way. We have also carried out preliminary many-body calculations to determine the size of PNC in Ra^+. The results suggest that Ra^+ is indeed a very promising candidate for observing PNC. Experiments to observe these effects are being planned in our institute.

We have developed new many-body formalisms based on the coupled-cluster method to calculate the PNC induced electric dipole transition amplitude in atomic caesium. The result of this calculation in combination with atomic PNC experiments yields a value for the Weinberg angle that is consistent with the Standard Model and in excellent agreement with high-energy data from CERN and other laboratories. We can begin to look for new physics beyond the Standard Model by including more many-body effects in our calculation, but that would require the use of a state-of-the-art parallel computer with a large memory.

An important step in our caesium PNC work was the development of new relativistic atomic basis functions. These basis functions are among the best available for doing relativistic many-body calculations. We have also formulated new relativistic coupled- cluster approaches and applied them to calculate the ionization potential of a variety of closed and open shell atoms.

Our work on atomic EDMs has centred around developing suitable theoretical models for EDM of atomic ytterbium which is sensitive to nuclear effects.

The experiment related to this work is in progress in Kyoto, Japan. The combined result of that experiment and our theoretical work promises to throw light on the origin of hadronic CP violation.

(B.P.Das)

An alternative route has been developed to compute the parity nonconserving transition along with parity-conserving properties like, transition energies, oscillator strengths, dipole and hyperfine transition matrix elements. The approach is based on open-shell coupled cluster (CC) method.

All the relevant CC codes to compute the above-mentioned atomic properties have been developed and applied to a wide variety of atomic systems (Lithium to Thallium). The author has also developed relativistic second order MBPT and CC code (linear response version as well as an open-shell version) to compute the ionization potentials and electron affinities of atomic systems ranging from small to large Z values. Our linearized version of relativistic CC method (CCLRT) not only provides accurate ionization potentials for the principal states but also for 2h-1p satellite states. This is perhaps the first application of relativistic CCLRT for the computation of satellite ionization potentials.

An alternative MBPT theory has been developed to compute non-adiabatic coupling elements. The method can also be applied to ascertain the ground and excited state geometry of chemically interesting molecular systems. It is important to note that the optimization of excited state geometry always proceeds via difficulties and is still a major area of research. Our method, in fact, is particularly suitable to handle those troublesome cases.

(R.K. Chaudhuri)

Trapping and cooling of ions and atoms

A concerted effort is being made to equip the NAPP laboratory to start experiments on trapping and cooling of atoms and ions. The two proposed activities are studies in atomic parity nonconservation in Ra^+ and Yb^+ and measurement of atomic electric dipole moment in Yb. These studies can provide important information on physics beyond the Standard Model. A cylindrical Paul trap has already been built, and initial tests are under way.

(B.Raghavendra Prasad, Kaustav Das and *A.G. Menon)

Measurement of Casimir-Polder Effect

An apparatus for generating a nitrogen atomic beam was set up. An electron gun of the type in computer monitors was used to ionize this atomic beam and efforts are on to detect the ions generated. An alternate electron gun is under design and a pair of Helmholtz coils to collimate the electron beam have been completed.

(D.Suresh, C.S.Unnikrishnan, G.Rajalakshmi, J.P.A.Samson)

An interferometric method was used to measure the gap between two Fabry-Perot plates held a few microns apart. The method used the tunable Ti-Sapphire laser and the wave meter to locate the Fabry-Perot fringes in the frequency space. From the separation of the fringes the plate gap was computed. An IDL program which corrects for the instrumental profile and fits the theoretical curve to the experimental data was developed and used to analyse data.

(D.Suresh, C.S.Unnikrishnan, G. Rajalakshmi, B.Raghavendra Prasad, Kaustuv Das, Andal Narayanan)

Instrumentation and facilities

Speckle Interferometer

The newly developed speckle interferometer has been in operation at the Cassegrain end of the 2.34 meter Vainu Bappu Telescope (VBT), Kavalur to record speckle-gram of various objects since September, 1996. Further development of this incorporates a nano-adjusting mechanism which helps in ultrafine focusing of the microscope objective. Flexure mechanism is being developed to achieve the nano-metric motion of the same. An arrangement for the micro-metric x - y movement of the detector to ensure its position precisely has been developed.

(S.K.Saha)

Measurement of r_0

The flat wavefront enters the telescope warped significantly by virtue of its passage through a turbulent atmosphere containing a distribution of cells differing in size and refractive index. If the exposure time is shorter (< 20 msec) than the evolution time of the phase inhomogeneities, then each patch of the wavefront with diameter r_0 – Fried's parameter – would act independently of the rest of the wavefront resulting in multiple images (speckles) of the source. The night time variations of Fried's parameter at the 2.34 meter VBT site were computed (Saha and Chinnappan, 1999) using the speckle interferometric technique. Speckle-grams of 15 point sources (unresolved stars) in and around 30° of the zenith were analyzed. The form of transfer function $< | P(r) |^2 >$ is obtained by calculating Wiener spectrum of the instantaneous intensity distribution from each of these stars. Here, p is the transfer function , r = (x,y) is 2-dimensional space vector, < > indicates the ensemble average and | | stands for the modulus. Further analysis is being carried out for measuring the size of r_0 at an interval of 0.1 sec.

(S.K.Saha and V.Chinnappan)

Image Processing

The newly developed algorithm (Saha et al., 1999), based on triple correlation technique, is being used to reconstruct the close binary stars. This method is based on the closure phase that remains uncorrupted in the presence of atmospheric turbulence. The notable advantage of this is that of providing information about the object phases with better signal-to-ratio from a limited number of frames. But the disadvantge is that of demanding severe constraints on the computing facilities with 2-dimensional data since the calculations are 4-dimensional. It requires extensive evaluation-time and data storage requirements, if the correlations are performed by using digitised images on a computer. This code has been developed based on unit amplitude phasor recursive re-constructor. The algorithm written in Interactive Data Language (IDL) takes an hour for processing 10 frames of size 128 x 128 at SPARC ULTRA computer, the fastest one available at IIA. The memory needed for the calculation exceeds 160 MB if the array size is more than the said numbers. Since the bispectrum is a 4-dimensional function it is difficult to represent it in a 3-dimensional co-ordinate system. Therefore, Saha et al., (1999) have stored the calculated values in 1-dimensional array and used later to calculate the phase by keeping track of the component freqeuncies.

(S.K.Saha, R.Sridharan, K.Sankarasubramanian).

Instruments

Fibre-linked coudé enhelle spectrograph

Work on the spectrograph is going on very actively. The f/5 collimotor-camera system fabrication, contracted to the University College London, has been completed. The system has been tested by Dr. Raghavendra Prasad at UCL and received in Bangalore. Now the assembling and installation of the whole system is in progress. A few items that are needed to complete, e.g. fibres, mechanical stages and mounts etc are being designed and orders for manufacture have been given.

(N.K. Rao, S. Giridhar, R. Prasad, F. Gabriel, P.K. Mahesh, Samson)

Pt-Si IR Camera

The Pt-Si near IR CCD has been installed in the IR dewar and the pumping and cryogenic performances of the solid nitrogen dewar have been satisfactorily tested. The various clock and bias voltages have been tuned and the gain of the output amplifier has been set. This camera was obtained under the Indo-Japanese collaborative programme. Dr. M. Ueno from the University of Tokyo visited IIA and VBO in this connection. The first trial images under JHK filters were successfully recorded using the VBT.

(R. Srinivasan, T.P. Prabhu, G. Srinivasulu, A.V. Ananth, *M. Ueno)

Mosai-CCD Controller

A mosaiced CCD camera controller is built for operating four Thomson-CSF THX 7897 2K x 2K CCD. The controller card works in a PC/AT based host environment on Windows 95/NT platform. The host interface card, DSP card, clocks and bias module analog processing card and the back-plane mother board have been implemented and testing is under progress.

(R. Srinivasan)

Mount for polarization measurement rig

The measurement of the polarization state of light from the Sun was done using a Stokes polarimeter at the solar tower-tunnel telescope, Kodaikanal. Since the amount of inherent polarization of the light from the Sun is comparable to the instrumental/telescopic polarization, it is necessary to quantify the instrumental/telescopic polarization. In order to do this, a rig for measuring the instrumental polarization in situ was devised.

The instrument consists of two parts viz. the input beam part and the detector part, both of which can be mounted on the top of the mirror cell of the coelostat. The first, second and third mirrors of the coelostat are similar in dimensions.

The input beam part consists of a laser source, the light of which is passed through a prism for changing the direction of the beam from vertical to horizontal and another glass plate is used to split the beam into two portions, one of which is taken as the reference beam. The beam emerging straight through the glass plate (the one that is not taken for reference) then falls on an optical wedge. The optical wedge then bends the beam to an angle of about 5° and by rotating the wedge, the angle of incidence of the beam on the mirror can be changed. A polaroid with its axis 45° to the wedge direction is pasted with the wedge to make the beam polarized at 45° to the plane of incidence. The reflected beam from the mirror is detected by a unit which consists of an insertable polarizer, a Babinet Compensator and a rotatable polaroid, together forming the analyser. The output beam from this is detected by a CCD detector which is in the frame grabbing mode.

The change in the polarization state of the input linearly polarized beam is analysed using the BC, rotatable polaroid combination. In general, the linearly polarized light will become elliptically polarised after reflection. The BC, polaroid combination gives two dimensional fringes, the contrast of the fringes and the position of the fringes can then be used to analyse the polarization state of the beam. From these two parameters, the instrumental polarization of a single mirror can be calculated. Similar measurement is done for all three mirrors and the combined instrument polarization is then estimated.

(P.K. Mahesh, K. Sankarasubramanian and K. Sagayanathan)

Photonics

Adaptive optics

In order to incorporate the polarization shearing interferometer as a wavefront sensing device in an adaptive optics system, an extensive study on adaptive optics has been undertaken. The study is modeled based on VBO site (Fried's parameter $r_0 = 5$ cm, wind velocity = 5 m/s) and the typical parameters of 90″, 40″ & 30″ telescopes. The requirements on the controller bandwidth and the tracking frequencies are computed for the existing telescopes at VBO, Kavalur. Optimal design of the wavefront sensor subaperture for effective adaptive optical imaging is in progress.

(A.K. Saxena, J.P. Lancelot and V. Chinnappan)

Wavefront Sensing

As reported above, we are planning to use polarization shearing interferometer as a wavefront sensing device for adapative optical imaging system. Considering few ms duty cycle / time constant requirements in the AO system, we are exploring the possibilities of using a single interferometric record for the evaluation of the wavefront. Work in this direction is in progress.

(A.K. Saxena and J.P. Lancelot)

Synchrotron radiation beam line (SRBL) optics

A new polarization shearing interferometer based Long Trace Profilometer (LTP) setup has been designed and prototype of the instrument has been built and tested for its efficacy. This has been achieved adopting a milling machine table for reasons of sturdiness and availability of long table travel required for the existing SRBL mirrors. The necessary software for the data reduction has been incorporated. A master flat was tested with this instrument and the results were compared with the results obtained from zygo interferometer. The two profiles are in very close agreement.

(A.K. Saxena, R. Cowsik and R. Ismail)

A project on building a complete Long Trace Profilometer (LTP) capable of measuring mirrors up to 1 meter length, entitled "Towards setting up metrology facilities required for the optics for using synchrotron radiation beamlines" has been sanctioned by BRNS. The instrument will be built in IIA.

(A.K. Saxena, R. Cowsik, *V.C. Sahni and *R. Mukund)

HIROT Project, Hanle

Substantial progress was made during the year on all aspects of setting up the Indian Astronomical Observatory at Hanle, Ladakh. A major part of the 2-m telescope was completed at EOST, Tucson, and a major fraction of the enclosure parts was fabricated. The enclosure for 50-cm Antipodal Transient Observatory telescope was designed. A 12-inch Meade telescope was acquired and commissioned during the year and routine seeing measurements were undertaken. The enclosure for the Meade telescope was also designed and fabrication commenced. Major effort was invested in various infrastructure facilities such as electrical power, liquid nitrogen plant, satellite communication channel, road, acquisition of land, accommodation, transport, etc. All these aspects are summarized below.

Site Characterization

Monitoring of Cloud Cover continued in its fifth year. Automated Weather Station monitored the meteorological parameters through the third year.

A Meade 12-inch telescope was procured and configured as differential image motion monitor (DIMM). Using this equipment, seeing measurements at the telescope site were initiated in July 1998, and have been made periodically (August, December 1998 and March 1999). The median seeing recorded at 2-m above ground was 0.83 arcsec. A permanent housing is being built and when completed, the DIMM will be installed there for continuous monitoring and also as an aid to flexible scheduling of 2-m telescope observing programmes.

Initial experiments were undertaken for microthermal measurements.

A 220-GHz Radiometer was build collaboratively with the Raman Research Institute and the University of Tokyo, for site characterization of Hanle. The instrument will be transported from Tokyo to Bangalore, then taken to Hanle and installed for continuous monitoring. This will also help in flexible scheduling of IR observational programmes with the 2-m telescope in addition to characterizing the site for sub-millimeter to near-infrared region.

2-m Telescope

A detailed design review was held in IIA, Bangalore in May 1998.

The telescope fabrication is progressing at Tucson without signifcant delay in the schedule, except for some slippage on the grinding and polishing of the

primary mirror blank. Attempts were continuously made to contain all the slippages within the final target of 2 October 1999 for the first light.

The major milestones related to fabrication of the telescope were completed during the current year. These were : Milestone 3, Mirror Blank Delivered, Milestone 4, Yoke and Base Complete, Milestone 5, Tube, mirror cell and servo complete. The assembly work is progressing at Tucson and the subassembly and assembly tests are scheduled for May 1999.

Enclosure

M/s STUP consultants, who were awarded the task of designing the enclosure, visited the shortlisted manufacturers and also the site in April 1998. After receiving detailed quotations, M/s Mengi Engineering Works, Jammu, were awarded contract for the fabrication and erection of the enclosure in May 1998. The telescope pier was cast during the working season of 1998. It needs some rectification work which is scheduled for May 1999. The foundation for columns was also completed by September 1998, and the columns were fabricated at Jammu and delivered at site in October 1998. The dome is being assembled in Jammu and will be ready for tests in April/May 1999 after which it will be transported to the site and erected.

Focal Plane Instruments

Three focal plane instruments are planned during the initial stage.

CCD Imager

Quotations were sought from different firms. However, no useful proposal was forthcoming to meet the science requirements as well as the time schedule. Hence it was decided to build it in house, and orders were placed for a 2K by 4K thinned, back-illuminated, VISAR coated chip from SITe Ltd in March 1999.

The Filter Assembly, dewar, controller, etc are being designed. This instrument is planned to be the First Light Instrument.

HFOSC

The fabrication of mechanical components as well as electronic controls is proceeding at Copenhagen University Observatory. The design of grisms is complete and the substrates will be ordered soon. The designs of the collimator and the camera are being finalized. An extension agreement for fabrication of CCD detector unit was finalized between CUO and IIA, and a SITe Ltd 2K by 4K thinned, back-illuminated, VISAR-coated chip was ordered. The interface unit to house filters and calibration lamps is being designed. This instrument is scheduled to be available by January 2000.

Near-IR Camera

A 512 x 512 pixel HgCdTe based IR camera with two choices of image scales, broad and narrow band filters in the JHK region, was designed by IR Labs, Tucson. The award for its fabrication is planned to be given to the same firm. The instrument is expected to be available by May 2000.

Phase II instruments

Some planning was also made on Phase II instruments which include a mosaic CCD camera, a high-resolution spectrograph, and an InSb-array based Near-Infrared Imager Spectrograph. The last of these is planned to be built in collaboration with Dr. M. Ueno, University of Tokyo. This will extend the capabilities of the telescope for imaging up to 5 μm wavelength and spectroscopy in the range of 1-5 μm.

50-cm Antipodal Transient Observatory

The specifications for the two 50-cm telescopes were finalized and orders were placed by Washington University, St.Louis, with M/s Torus Precision Optics Ltd. The telescopes are expected to be delivered in May 1999 after which one of them will be transported to Hanle for installation. The enclosure

for the telescope was designed in house and is being fabricated in the mechanical workshops of IIA. The civil works at site will commence in June 1999, at which time the structural parts will be transported to the site for subsequent erection.

Infrastructure Development

Power

Three DG sets were procured from M/s Greaves Ltd., transported to the site and installed during the working season of 1998. M/s CEL and M/s TATA BP Solar Ltd began installing their 30 KWP SPV power stations, but could not complete the installations due to various factors. The remaining work is scheduled for May/June 1999. Two 1.05 KWP SPV power plants were also produced from M/s TATA BP Solar Ltd to power RABMN communication equipment. These were in use, but final commissioning tests were postponed by the firm for May/June 1999.

Land

Nearly 600 acres of land at Hanle, including the Digpa-ratsa Ri mountain range and some surrounding flat land, was transferred by the J & K Government to IAO during this period. A few acres of land at Choglamsar near Leh were also identified for the purpose of transfer for the proposed Science Centre.

Roads

The work on the unsurfaced link road between Hanle Monastery and observatory campus was continued by the BRO. On request by Director, IIA, the BRO took up the work of levelling the area around the peak. Some additional FRP shelters were procured through BRO to accommodate additional staff visiting the site for infrastructure development.

Liquid Nitrogen Plant

A 5 lit/hr capacity Liquid Nitrogen plant specifically designed for the high-altitude environment, was ordered from M/s Stirling Cryogenics and Refrigeration, the Netherlands. Two staff members of IIA were trained at the works on operation and routine maintenance. The plant arrived in Delhi in November 1998 and has been stored in Jammu since the road to Leh was closed. It will be sent to Hanle as soon as the roads open in May 1999 and installation and commissioning will follow.

Vehicles

A second Maruti Gypsy vehicle was sent to Leh since the movement of personnel between Leh and Hanle had increased and medical emergencies require a vehicle to be always available at Hanle. Action was also taken to procure a TATA 407 vehicle which will reduce the requirement of hiring local trucks at considerable expense for moving material between Leh and Hanle.

Satellite Communication Link

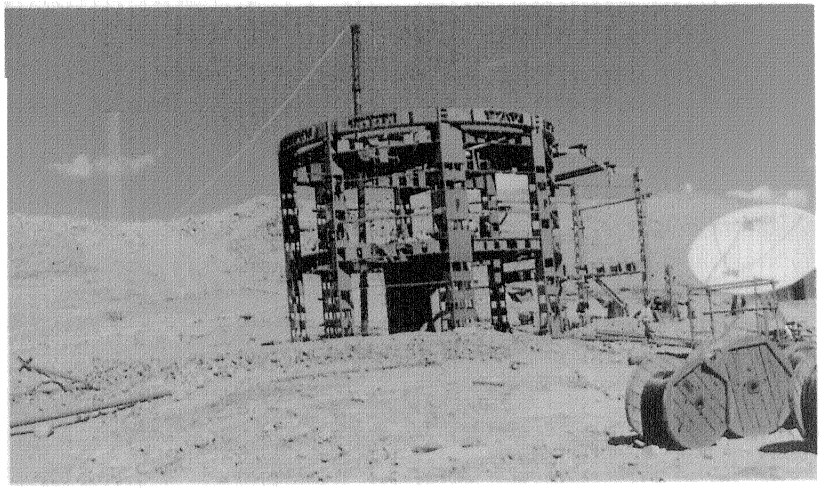
The NOCC tests of 3.8-m communication dish antenna were attempted in April, July and October 1998. A bandwidth of 64 kbps was procured from M/s ITI Ltd for the purpose. The tests could not go through due to various factors. The original 3.8-m dish was replaced by a new one after two failures of NOCC tests. The mount of the dish is being redesigned by IIA so that it can comply with the wind specifications after which another attempt will be made to clear the NOCC tests.

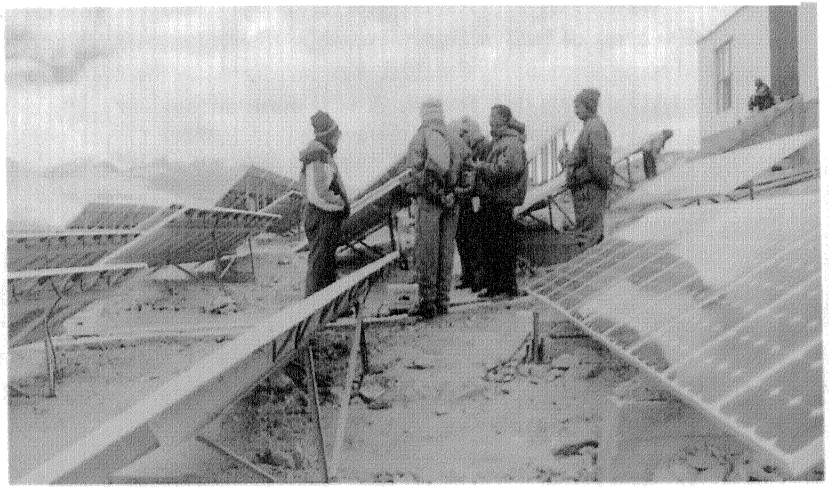
Additional bandwidth will be procured from M/s ITI Ltd so that the 128 kbps rate planned originally will be possible at first light. Attempts are being made to obtain an assured bandwidth from the Department of Telecommunication, and also to augment it with the help of various government agencies.

Personnel

Five engineers joined the project on 3-year contract during the current year. They were posted at CREST campus, Hosakote. One of them, an electrical engineer was transferred to the site in Ladakh. The site in Ladakh is manned by an astronomer in his capacity as Project Officer. One senior mechanical

Indian Astronomical Observatory





engineer from IIA, Bangalore was also transferred to the site during the current year. One mechanical engineer and one electronics engineer from Ladakh were identified and appointed on temporary basis at the site. The involvement of the existing staff at IIA Bangalore and VBO Kavalur was also enhanced during the current year.

Astronomy from Hanle

Considerable efforts were made and results achieved in developing groups of astronomers who will closely associate with instrument development and then make science verification as well as guaranteed time proposals for the telescope.

Two students undertook seeing measurements as their course work project and and made the first sets of measurements with the DIMM.

(T.P.Prabhu)

Vainu Bappu Observatory, Kavalur

40 Inch Telescope

The work on the 40″ telescope primary mirror has been taken up. After backside grinding and polishing, the surface generation has been done in the front side using diamond wheel. Before taking up the surface generation, the surface generation machine has been overhauled and reconditioned. Grinding is in progress with a full size tool.

(A.K. Saxena, J.P. Lancelot, V. Gopinath and V. Robert)

Technical report on vibration tests

Vibration studies were conducted using an Analog Devices capacitance based accelerometer on all the telescope structures at the Vainu Bappu Observatory, Kavalur and a technical report on the same has been published.

The design for the mounts for the grating and prism for the coudé echelle spectrograph were completed.

VHRR Sunshield Panels

The work on the sixth set of the Very High Resolution Radiometer (VHRR) sunshield panels continues. The set will be delivered some time in the middle of the year.

(A.K. Saxena and Optics team)

Computer Centre

The computer centre provided support to the scientific community in the form of hardware and software installation, maintenance of the LAN and other equipment.

The major addition to the Computer centre was a SUN ultrasparc and a network Laser printer.

Recent versions of IRAF and STSDAS were made available on SUN solaris and Linux platforms. The latest IDL 5.0 was installed on SUN ultrasparc system. A few more SUN ultra sparc systems will become available to users shortly.

(A.V. Ananth, J.S. Nathan, K.N. Kutty, S.S. Chandra Mouli)

Library

The Library added a record number of 517 books and subscribed to 166 journals. It continued to receive 100 observatory publications, newsletters and annual reports. Around 300 interlibrary loan requests were handled during the year. More than 300 journals were bound. The Library continued its graduate training program. The Library made special efforts to merge the book catalogues of TIFR, Bombay, PRL, Ahmedabad, RRI and IIA, Bangalore during this period. In May 1998, Christina Louis attended the Third Meeting of the Library and Information Services in Astronomy held in Puerto de La Cruz, Tenerife and presented a paper on the Networking of Astronomy Libraries in India.

Physics, Astronomy and Mathematics (PAM) Division of the Special Library Association of USA, launched an Asia-Pacific Forum, in October 1998, and IIA became a member of this organisation for closer cooperation among libraries in this region. Christina Louis has been invited to be a member of the International Relations Committee of this PAM Asia-Pacific Forum. During the 19th meeting of the Astronomical Society of India meeting held at Raman Research Institute, Bangalore, A.Vagiswari presented an update on networking of all the astronomy libraries in India. Ms. K.Revathi, Senior Documentation Assistant and R.Krishnamurthy, Senior Mechanical Assistant retired after 40 years of service in the Institute. Their valuable contribution to the binding section is recorded with appreciation.

Student affairs

Five students finished their doctoral work and submitted their theses.

Charu Ratnam (JAP) worked on *Distribution of dark matter in the Galaxy* and R. Srikanth (JAP) on *Studies on the solar chromospheric network*. They were both registered at the Indian Institute of Science.

Three students registered at Bangalore University also submitted their theses. Angom Dilip Kumar Singh worked on *A study on the electric dipole moment of atoms*. He was awarded the Ph.D. degree in March 1999. V.Krishnakumar submitted his thesis on *High angular resolution imaging of the Sun* in August 1998. R.Ramesh submitted his thesis titled *Multifrequency observations of the outer solar corona with the Gauribidanur radioheliograph* in October 1998. Ramesh's presentation of his thesis at the 19th meeting of ASI was adjudged the best.

Seven students were trained under the Summer Projects Programme during May - July 1998.

Two new students joined the Ph.D. programme in 1998-99.

K. Sundara Raman, Scientist B, Kodaikanal was awarded the Ph.D. degree in Physics, in 1999 February, by Bharathidasan University, Tiruchirapalli for his thesis *studies on dynamics of active regions and sumpots*.

Conference reports

Second International Workshop on Solar Polarization

The workshop was held in Bangalore during October 12-16, 1998. The place and time chosen for holding such an important meeting have some significance - namely the recognition by the international community, of the growing contributions from Indian solar physicists to this specialised area of research. The ultimate goal of all the studies in this area is to measure the solar magnetic fields at all spatial scales, and to understand the physics of the interaction of matter with radiation in the presence of oriented and turbulent magnetic fields. The Sun presents us with an entirely new world of hitherto unknown aspects, when one looks at the "polarized solar spectrum". The amazing richness of information contained in the polarized line spectrum (now called Second Solar Spectrum because of its strangeness and its lack of resemblance to the conventional unpolarized solar spectrum), has led to an intense research activity in theory, observations, modeling and the instrumentation. However many challenging problems of Solar Polarization are yet to be solved.

The workshop had a large participation. 61 scientists from 16 countries participated in the workshop. 50 oral papers and 22 poster papers were presented during 7 scientific sessions and segregated panel discussions. The scientific discussions and presentations were of the highest quality. During the workshop week, excellent concerts, and other cultural events and visits were organized, to expose the invitees to the cultural heritage of India. They also visited famous monuments nearby. Other important activities at the workshop were a book exhibition, a book release ceremony, and the accompanying guests' programmes. The proceedings of the workshop published as a book ("Solar Polarization" Eds. K.N. Nagendra and J.O. Stenflo : ASSL Vol. 243, 1999, Kluwer Academic Publishers, The Netherlands) gives an exciting account of the scientific deliberations of the workshop.

The first Solar Polarization Workshop (SPW) was held in Russia (1994), the second in India (1998) while the third one is proposed to be held in Spain (2002). SPW's are becoming a regular affair giving the specialists working in this area an excellent opportunity to congregate and exchange their ideas. Many scientists wish to come back to India for another SPW.

Indo-French Workshop on "Probing Fundamental problems with lasers and cold atoms"

The workshop was held under the joint sponsorship of the Indo-French Centre for the Promotion of Advanced Research (IFCPAR) and IIA. Several Institutes in Bangalore participated in organizational matters in an active manner, providing support and forums for lectures and cultural programmes. It was inaugurated on January 3 by Prof. B. V. Sreekantan, Chairman, IIA Council, known for his important contributions in Cosmic Ray based particle physics research. The workshop continued at a hectic pace with a large number of lectures, discussions, and interactions till January 9, 1999.

Tremendous progress has been made in the field of laser manipulation of atoms and ions over the past two decades or so. Slow atomic beams, fountains and dense clouds of atoms serve as convenient physical systems where ultrahigh precision measurements can be made. Spectacular physical phenomena like the Bose-Einstein Condensation has been observed. It is also possible to trap a single charged atom (an ion) and then freeze its motion using laser light. Cold atoms and ions also serve as ideal systems of atomic clocks of unprecedented precision exceeding a part in 10^{17}. Some of the pioneering ideas which led to these remarkable developments in the last two decades were conceived and elaborated by French physicists, under the leadership of Prof. Claude Cohen-Tannoudji who was awarded the Nobel Prize in 1997. Prof. Michèle Leduc, the present Director of the Laboratoire Kastler Brossel (LKB), Ecole Normale Superieure, Paris where many of these discoveries were made, and Ramanath Cowsik, who has been actively advocating the need for a new era of NAPP activity in the country, were the

major motivating force behind the organization of the workshop, with a clear idea to foster collaborative research in this important area.

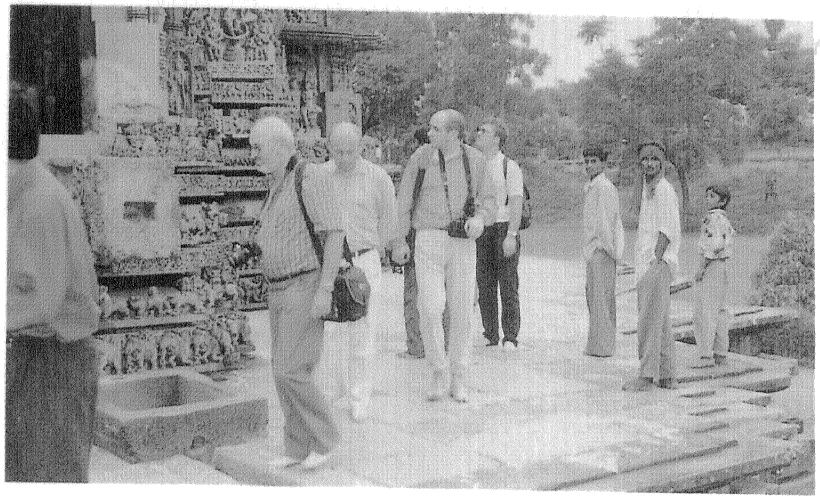
IIA has plans to probe the fundamental issues like parity and time reversal symmetry in particle physics and the nature of the electromagnetic vacuum.

There are other institutions like IISc and RRI in Bangalore, BARC, Mumbai and CAT, Indore, and NPL, Delhi where laser cooling experiments have been started with goals ranging from observation of Bose-Einstein condensation to realization of high precision atomic clocks. The expertise on laser cooling of atoms and ions is only starting to be developed in India. However, there exists a rich research tradition in modern optics and laser physics. Therefore it was gratifying to bring together about 130 physicists from all parts of India, representing all the major institutions interested in modern atomic physics and optics for this weeklong workshop.

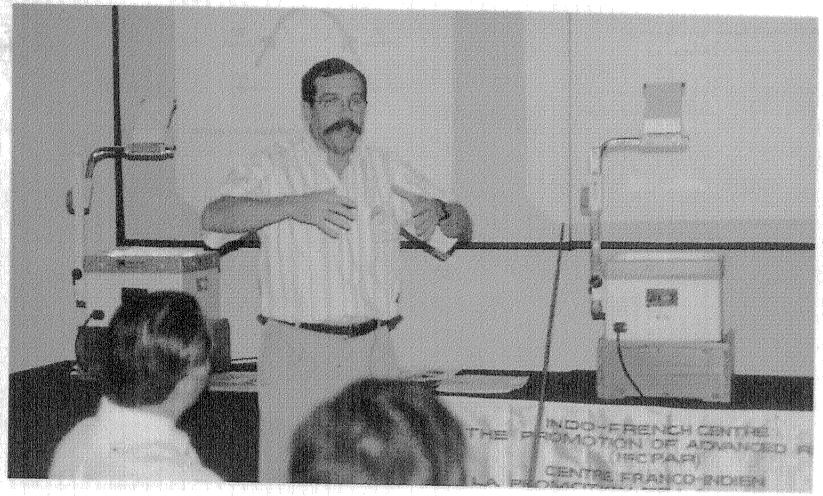
The scientific session which was started with an overview lecture by R.Cowsik on the Paradigm of Non-accelerator Particle Physics was followed by several lucid and illuminating lectures both on the fundamental and applied aspects of laser cooled atoms by the French and Indian physicists working in the field. From the NAPP group at IIA, Bhanu Das talked on violations of the fundamental discrete symmetries, especially parity violation and related effects in atomic systems. Angom Dilip Kumar Singh gave a talk on calculations of the EDM and on some new experiments on EDM employing laser-cooled Ytterbium atoms. The Indian ambitions in the area of laser cooling and trapping were represented by several institutions including IIA, BARC, IISc, RRI, NPL and CAT.

The afternoon of the last day of the workshop was dedicated to a discussion on future collaborative research between Indian and French laboratories. P.G.S.Mony, Director, IFCPAR described the procedure for proposing collaborative programs and offered cooperation and support. Several definite proposals were discussed, which are expected to be followed up in the coming year and these will be fulfilling the goals of organising the workshop.

SPW 2



Indo French Workshop



Personnel

The academic and technical staff as on 31 March 1999 include the following :

Director : R. Cowsik.

Senior Professor : M. H. Gokhale (up to 30 June 1998),V. Krishan, N. K. Rao, J. H. Sastri.

Professor : B. P. Das, B. Datta, S. S. Hasan, R. K. Kochhar, D. C. V. Mallik, M. Parthasarathy, T. P. Prabhu, R. Sagar*, C. Sivaram, P. Venkatakrishnan.

Scientist E : G. S. D. Babu, H. C. Bhatt, K. K. Ghosh, R. C. Kapoor, A. K. Pati, R. Rajamohan, J. Singh.

Associate Professor : A. V. Raveendran.

Scientist D : P. Bhattacharjee, S. Chatterjee, S. Giridhar, S. S. Gupta, S. Mohin, K. N. Nagendra, P. M. S. Namboodiri, K. R. Subramanian, R. Vasundhara.

Reader : S. P. Bagare, P. K. Das, D. Mohan Rao, K. E. Rangarajan.

Senior Research Scientist : Kaustuv Das, B. Raghavendra Prasad.

Scientist C : G. C. Anupama, R. Kariyappa, M. V. Mekkaden, K. P. Raju, K. B. Ramesh, P. Shastri.

Scientist : K. M. Hiremath.

Fellow : R. K. Chaudhuri, S. V. Mallik, A. Satya Narayanan.

Research Scientist : R. T. Gangadhara, P. Joarder.

Scientist B : B. S. Nagabhushana, K. Sundara Raman.

Research Associate : K. Jayakumar, K. Kuppuswamy, H. Joseph Rosario, S. Soundararaja Perumal.

Engineer G : R. Srinivasan.

Head, Photonics Division : A. K. Saxena.

Senior Principal Scientific Officer : A. V. Ananth.

Principal Scientific Officer : V. Chinnappan.

Engineer D : B. R. Madhava Rao, G. Srinivasulu, M. S. Sundara Rajan.

Scientific Officer SD : S. K. Saha, R. Surendiranath, J. P. L. C. Thangadurai.

Scientific Officer SC : P. S. M. Aleem, J. Javaraiah, D. Karunakaran, M. S. Rao, J. V. S. V. Rao, B. A. Varghese, L. Yeshwanth.

Senior Engineer (Civil Works & Estates) : N. Selvavinayagam.

Librarian : A. Vagiswari.

Assistant Librarian B : C. Louis.

Engineer B : S. S. Chandramouli, Faseehana Saleem, A. T. A. Hameed, J. S. Nathan, K. Narayanankutty, K. Padmanabhan, K. S. Ramamoorthy.

Technical Officer : M. Mohd Abbas, N. Jayavel, P. K. Mahesh, S. Muthukrishnan, B. Nagaraja Naidu, R. Muralidharan Nair, K. G. Unnikrishnan Nair, J. P. A. Samson.

Technical Associate : P. Anbazhagan, A. M. Batcha, E. Chellasamy, F. Gabriel, P. U. Kamath, G. N. Rajasekhara, K. Rangaswamy, A. Selvaraj, R. Selvendran, N. Sivaraj, K. S. Subramanian, G. S. Suryanarayana, K. C. Thulasidharan, A. V. Velayuthan Kutty.

Documentation Associate : S. Rajiva.

Mechanical Associate : T. Johnson.

Project Officer : B. C. Bhatt.

Engineer : 2m Telescope Project : P. M. M. Kemkar (Mechanical), P. Misar (Electronics & Computer), A. N. Raut (Electrical), R. R. Reddy (Civil), H. R. Sharma (Optics).

Engineer SC : 2m Telescope Project : M. P. Singh (Electrical).

Distinguished Professor : V. K. Gaur, K. R. Sivaraman.

Visiting Senior Professor : M. H. Gokhale (w. e. f. 1 July 1998), C. V. Vishveshwara.

Senior Scientist (Honorary) : A. Krishnan.

Adjunct Scientist : N. Krishnan, C. S. Unnikrishnan.

Visiting Fellow : Andal Narayanan, Annapurni Subramanian, J. Bagchi+, Holger Merlitz, Manoj K. Samal, J. Vijapurkar+.

Visiting Research Associate : P. K. Panda.

Senior Research Associate (CSIR) : Aruna Goswani.

Graduate Students : S. Banerjee (JAP), S. Bhattacharya (JAP), S. G. Bhargavi, P. J. Chakraborty, G. Gauba, K. P. Geetha, M. Gopinathan, A. D. Jana, C. Kathiravan, P. Kharb, V. Krishnakumar, D. V. Lal (JAP), S. Majumdar, S. Mazumdar (JAP), P. Manoj, R. Nayak, G. Pandey, G. Rajalakshmi, S. P. K. Rajaguru (JAP), B. S. Ramachandra, R. Ramesh, C. Ratnam (JAP), B. Ravindra, S. Ravindranath, M. Sharma, A. D. K. Singh#, T. Sivarani, R. Sridharan, K. Sankarasubramanian, R. Srikanth (JAP), D. Suresh, A. V. Thampan.

* on lien to UPSO, Naini Tal.

+ left in June 1998.

left in March 1999.

Involvement in the Community

P. Bhattacharjee is the PI of the Indo-US(NSF) collaborative research project on 'Phase Transitions in the Early Universe and Probes of Large-scale Distribution of Matter in the Universe'. The participating institutions in this project are the University of Chicago, USA, TIFR, Mumbai and IIA, Bangalore. The participating Indian scientists in the project are R. Cowsik, S. M. Chitre and D. Narasimha. **R. Cowsik** continued as the Area Coordinator in the fields of Astronomy & Astrophysics and allied topics under the India-Japan Cooperative Research Programme of the DST and JSPS. He also shouldered the responsibility as the Chairman, National Scientific Steering Committee for I-STEP. He has been elected Secretary, the Cosmic Ray Commission (C4) of IUPAP for the triennium 1999-2002. **K.K. Ghosh** was awarded an NRC Research Associateship tenable at MSFC, Huntsville, Alabama, USA. He has been on sabbatical leave from IIA since April 1, 1998. **Vinod Krishan** continued as Editor, BASI. She was the Director of the School on Plasma Astrophysics held jointly by IIA and IISc in Bangalore between June 21 and July 15, 1998 under the aegis of DST. She is also a member of the Physics Panel of UGC and a member of the Scientific Advisory Committee of IUCAA 1997-2000. **K.N. Nagendra** organized the second International Workshop on Solar Polarization (ital) in Bangalore in 1998 October. He was a member of the SOC and co-chaired the LOC. He also edited the proceedings of the meeting with J.O. Stenflo.

Appendixes

APPENDIX A

PUBLICATIONS

In Journals

Angom Dilip Singh, Das B.P. (1999) *J. Phys.B*, in press.
Parity Nonconservation in Atomic Yb Arising from the Nuclear Anapole Moment.

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Krishan, V.
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Paper Presentations at Meetings

Anupama, G. C.
Spectroscopy of Supernovae
XIX ASI Meeting, Bangalore
1999 February 1-4

Anupama, G. C., Pandey, G., Sivarani, T.
Optical Spectroscopy of the Supernova SN1998S
XIX ASI Meeting, Bangalore
1999 February 1-4

Bhatt, B.C., Prabhu, T.P., Anupama, G.C.
Site Characteristics of Indian Astronomical Observatory, Hanle
XIX ASI Meeting, Bangalore
1999 Feburary 1-4

Chakraborty, P., Andreas Hänel, Erwin Heiser, Vasundhara, R.
Modeling Dust Jets and Shells from Comet Hale-Bopp - Observations
Observatory of the Naturwissenschaftlicher Verein Osnabrück.
Conference of the Astronomische Gesellschaft in Heidelberg, Heidelberg
1998 September 15-19

Chakraborty, P., Vasundhara, R.
Spectropolarimetry of Comet Hale-Bopp
XIX ASI Meeting, Bangalore
1999 February 1-4

Gangadhara, R. T.
Window Threshold Technique for Detecting Pulse Components
XIX ASI Meeting, Bangalore
1999 February 1-4

Giridhar, S.
High Resolution Spectroscopy with a 10-m Class Telescope
XIX ASI Meeting, Bangalore
1999 February 1-4

Goswami, A., Prantzos, N.
Chemical Evolution of Intermediate Mass Nuclei in Solar Neighbourhood and the Halo of the Galaxy
XIX ASI Meeting, Bangalore
1999 February 1-4

Goswami, A.
Modelling the Chemical Evolution of the Galaxy
Workshop on the Chemical Evolution of the Galaxy, IIA, Bangalore
1999 March 5

Javaraiah, J.
Depth Dependence of Periodicities in Solar Differential Rotation
SOHO 6/GONG 98 WORKSHOP : Structure and Dynamics of the Interior of the Sun and Sun-like Stars, Boston, U.S.A.
1998 June 1-4
4-Day Periodic Variation in the Sun's Meridional Flow
XIX ASI Meeting, Bangalore
1999 February 1-4

Krishnakumar, V., Venkatakrishnan, P.
Morphology of Ca II K Bright Points and their link with G Band Bright Points
XIX ASI Meeting, Bangalore
1999 February 1-4

Lal, D. V., Shastri, P., Gabuzda, D.
Seyferts at milliarcsec scales
XIX ASI Meeting, Bangalore
1999 February 1-4

Mallik, S. V.
Lithium Abundance and Mass
XIX ASI Meeting, Bangalore
1999 Feburary 1-4

Raju, K. P.
Modelling of the Coronal Green Emission Line Profile
XIX ASI Meeting, Bangalore
1999 February 1-4

Ramesh, R., Subramanian, K.R., Sastry, Ch.V.
High Angular Resolution Observations of Solar Noise Storms
32nd Scientific Assembly of COSPAR, Nagoya, Japan
1998 July 12-18

Ramesh, K.B., Nagabhushana, B.S., Varghese, B.A.,
Green Coronal Intensity enhancement and its relation to the underlying Active Region Magnetic Field.
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1998 October 12-16.

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Science from "Solar X-Ray Spectrometer (SOXS)" - Proposed Payload On Board Indian Satellite
XIX ASI Meeting, Bangalore
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Rao, D. Mohan
Resonance Polarization with Collisional Redistribution
Second International Workshop on Solar Polarization, Bangalore,
1998 October 12-16.

Saha, S. K., Sridharan, K., Sankarasubramanian, K.
Speckle Image Reconstruction of Binary Stars
XIX ASI Meeting, Bangalore
1999 February 1-4

Satya Narayanan, A.
Magnetoacoustic-Gravity Surface Waves with Flows
XIX ASI Meeting, Bangalore
1999 February 1-4

Srinivasalu, G., Ananth, A. V., Sankarasubramanian, K., Venkatakrishnan, P.
A CCD Based Polarimeter for Solar Observations
Second Internatinal Workshop on Solar Polarization, Bangalore
1998 October 12-16

Sridharan, R., Venkatakrishnan, P.
Speckle Image Reconstruction of Solar Features
XIX ASI Meeting, Bangalore
1999 February 1-4

Subramaniam, A.
V, I CCD Photometry of NGC 6553
X Canary Islands Winter School on Globular Clusters, Tenerife 1998 November 16-28.
A New Look at the OB Association and Starclusters in the Puppis-Vela Region using Hipparcos Data.
XIX ASI Meeting, Bangalore, 1999 February 1-4

Binary Star Clusters in Galaxies: our Galaxy.
XIX ASI Meeting, Bangalore, 1999 February 1-4

Globular cluster systems in Giant Elliptical Galaxies.
XIX ASI Meeting, Bangalore
1999 February 1-4

Sundara Raman, K.
Role of spectroscopy in predicting the transient events in the solar atmosphere
Physics Department, TBML College, Panayar, Tamil Nadu
1999, March 20

Venkatakrishnan, P.
Magnetic Bipoles and Electron Acceleration : A Common Theme for Chromospheric and Coronal Heating
XIX ASI Meeting, Bangalore
1999 February 1-4

APPENDIX B

Colloquia and Invited Talks at Conferences, Workshops and Seminars

Anupama, G. C
Recurrent Novae with Giant Secondaries
Nicolaus Copernicus Astronomical Centre, Torun, Poland
1998 June

An Overview of Astronomical Software
Mini-Symposium on 'Software in Astronomy', IIA
1999 Feburary 15

Optical Microvariablity in Active Galactic Nuclei
Mini-symposium on 'Quasars', IIA
1999 Feburary 26

Contribution of Novae and Supernovae to the Enrichment of the Interstellar Medium
Workshop on The Chemical Evolution of the Galaxy, IIA
1999 March 5

Bagare, S.P.
A new look at the Umbral Depression and a few related phenomena in Sunspots
TIFR, Mumbai
1998 November 17

Bhattacharjee, P.
Cosmic Topological Defects and Extremely High Energy Cosmic Rays,
Seminar at Physics Dept., Case Western Reserve University,
Cleveland, Ohio, USA,
1998 September 15

Extremely High Energy Cosmic Rays : The Top-Down Scenario
Astronomy and Astrophysics Center, Enrico Fermi Institute, Univ. of Chicago, Chicao, IL, USA,
1998 October 8

Probing New Physics with Extremely High Energy Cosmic Rays,
Symposium on Future Projects of Cosmic Ray Physics in Japan,
Institute for Cosmic Ray Research (ICRR), Univ. of Tokyo, Tokyo, Japan,
1999 March 2-4

Bhatt, H. C.
Dust in HII Regions
Bhavnagar University, Bhavnagar, Gujarat,
1998 August 18-20

Magnetic Fields in Cometary Globules
PRL, Ahmedabad,
1998 September 4-6

Star Formation
Indian Institute of Science
1998 May

Cowsik, R.
The Universe of High Energy Particles
Inaugural Address, Summer School on 'Plasma Astronphysics'
Indian Institute of Science, Bangalore
1998 June 22

Ultrahigh Energy Particles in Space
National College, Bangalore
1998 July 6

Dark matter in the Universe : Perspectives and Prospects
CSIR Foundation Day Lecture, CSIO, Chandigarh
1998 September 26

Physics and Astrophysic of the Elusive Neutrinos
National Workshop on 'Neutrino Physics'
Central University, Hyderabad
1998 November 6

The Paradigm of Non-Accelerator Particle Physics
Indo-French Workshop on Fundamental Problems using Lasers
IIA, Bangalore
1999 January 4
The Early Universe

National Insitute of Advance Studies, Bangalore
1999 January 16

An introduction to Physics and Astrophysics of Neutrinos
XIX ASI Meeting, Bangalore
1999 February 3

Energetic Radiations emerging from Accretion Flows around Massive Black Holes
Mini-symposium on 'Quasars'
IIA, Bangalore
1999 February 26

Torsion Balance as a Sensitive Probe of Fundamental Physics
Indian Physics Association, Bangalore
1999 February 27

Wave particle Duality of Light
ISRO Satellite Centre, Bangalore
1999 March 1

Isotopic Anomalies in Stardust
Workshop on The Chemical Evolution of the Galaxy
IIA, Bangalore
1999 March 5

Das, B.P.
Theory of Atomic Electric Dipole Moments
International Workshops on CP Violation, Trento, Italy
1998

Application of Laser Cooling and Ion Trapping to Parity Nonconservation in Atoms
National Laser Symposium, Kanpur
1998

New Directions in Atomic Parity Violation
Indo-French Workshop on Fundamental Problems Using Lasers, Bangalore
1999 January 3-9

Relativistic Effects in Intense Fields
SERC School on Intense Fields in Atoms and Molecules, Ahmedabad
1999

Gokhale, M.H.
Sun's Activity and Magnetic Field
UPSO, Nainital
1998 April 16

Solar Physics (2)
Solar System Dynamics (2)
UGC Refresher Course on 'Space Mathematics'
University of Pune
1998 August 17-22

Giridhar, S.
The Chemical histoy of the Galaxy as inferred from the Observed Abundance Patterns in Different Stellar Groups
Workshop on The Chemical Evolution of the Galaxy,
IIA, Bangalore
1999 March 5

Krishan, V.
Role of Inverse Cascade on Solar Granulation
International meeting on Astrophysical Fluids - from Atomic Nuclei to Stars and Galaxies, Haifa, Israel,
1998 January 12-15

Coronal Loops - the Building Blocks of the Solar Corona
Solar Physics meeting, IIA, Bangalore
1998 February 23-24

Radiative Processes, and Solar Flares
DST workshop on High Energy Astrophysical Plasmas,
PRL Ahmedabad,
1999 January

Generation of Large Scale Magnetic Field
Current Trends in Plasma Physics,
PRL, Ahmedabad
1999 Feburary

Prabhu, T. P.
Indian Astronomical Observatory, Hanle
XIX ASI meeting, Bangalore
1999 Feburary 1-4

Rangarajan, K.E.
Understanding the Solar Interior
Workshop on Astrophysics, Lady Doak College, Madurai Kamaraj University
1999 February 24-25

Rao, N. Kameswara
The High-resolution Spectroscopic Study of the recent 1995-96 Minimum of R Cr B
Workshop on R Cr B and RV Tauri and other post-AGB stars
University of Canterbury, Christchurch, New Zealand
1998 November 16-17

Galactic Astronomy with 10-m Telescopes
XIX ASI Meeting, Bangalore
1999 February 1-4

Saha, S. K.
Unconventional imaging in Optical Astronomy
S N Bose Institute of Basic Sciences, Salt Lake City, Calcutta,
1999 January 8

Shastri, P.
Relativistic Beaming in AGN
XIX ASI Meeting, Bangalore
1999 February 4

Vishveshwara, C.V.
Spacetime and Rotation
Max Planck Institute for the History of science, Berlin
1998 July

Visits

G. C. Anupama visited the Nicolaus Copernicus Astronomical Center, Warsaw & Torun, Poland during 1998 June-August under the INSA-Polish Academy of Sciences Exchange Programme. The visit was supported by INSA, IIA and the Polish Academy of Sciences. **P. Bhattacharjee** visited the Laboratory for High Energy Astrophysics, NASA/ Goddard Space Flight Center, Greenbelt, Maryland, USA as a NAS/NRC Resident Senior Research Associate, January 1997-January 1999. **R. Cowsik** attended the IUPAP General Assembly and the inaugural ceremony of the Centennial Meeting of the American Physical Society in Atlanta, USA during March 17-21, 1999. **B. Datta** visited Variable Energy Cyclotron Centre, Calcutta, June 1998 for collaborative work with Dr. B. Sihna. He also visited the Department of Phys, Univ. of Pisa, Italy on a research invitation supported by INFN, Italy Oct-Nov 1998 for collaborative work with Dr. I. Bombaci. **R. T. Gangadhara** visited the National Centre for Radio Astrophysics, Pune, during March 26 - April 10, 1999. **A Goswami** visited the Institut d'Astrophysique de Paris, Paris, France from 1.4.1998 to 15.7.1998. The visit was part of a collaboration with Prof. N. Prantzos of IAP, Paris, France. **J. Javaraiah** visited National Solar Observatory (NSO), Tucson, U.S.A. June 4 - August 4, 1998 and worked with Dr. R. W. Komm (GONG/NSO) to determine the solar surface meridional motion from small magnetic features observed on high resolution SOHO magnetograms. **T. P. Prabhu** visited the University of Tokyo, Hongo Campus, Tokyo, 1999 February 8-26, for the construction of a 220-GHz radiometer for site characterization of Hanle and for discussion on other possible collaborations on Indian Astronomical Observatory, Hanle. **B. Raghavendra Prasad** visited the Optical Science Laboratory at the University College, London in October 1998 to test the f/5 collimator of the proposed high-resolution fibre-optic echelle spectrograph of IIA. He also visited the Clarendon Laboratory of the University of Oxford and other physical laboratories in UK and the Laboratoire Kastler Brossel, ENS, Paris during his trip Oct-Nov 1998. **R. Ramesh** visited the University of Maryland, USA June 13-14, 1998, Goddard Space Flight Center (NASA), USA June 15,1998, the VLA, New Mexico June 17-23, 1998. He also visited the Nobeyama Radio Observatory, Japan June 27 to July 10, 1998. **P. Shastri** visited the Astro Space Centre, Lebedev Physical Insitute, Moscow, during July-August, 1998 as part of the ILTP project titled 'Seyfert galaxies and unified schemes'. **Jagdev Singh** visited the National Astronomical Observatory, Mitaka, Japan between June and December 1998.

APPENDIX C

Vainu Bappu Observatory

Sky Conditions at VBO

Year	Month	Spectroscopic (hrs)	Photometric (hrs)
1998	April	145	26
	May	92	18
	June	88	13
	July	15	0
	August	29	7
	September	45	9
	October	79	10
	November	26	3
	December	125	22
1999	January	243	41
	February	221	38
	March	254	81
	Total	1362	259

Kodaikanal Observatory

Spectroheliograms / Photoheliograms and seeing conditions at Kodaikanal

Year	Month	No. of photographs in				SEEING*				
		Hα	Kfl	HαPR	PHGM	5	4	3	2	1
1998	April	24	9	17	23	-	2	10	10	1
	May	23	11	14	17	-	3	12	2	-
	June	5	7	3	8	-	1	3	2	2
	July	1	1	2	2	-	-	2	-	-
	August	1	2	2	5	-	1	3	1	-
	September	7	9	4	12	-	-	2	7	3
	October	5	5	4	6	-	-	1	1	4
	November	10	15	7	13	-	-	8	2	3
	December	14	15	10	14	-	2	9	1	2
1999	January	29	27	18	20	-	3	7	8	2
	February	26	27	22	24	-	6	14	3	1
	March	30	28	25	30	-	12	13	3	2
	Total	175	156	128	174	-	29	85	40	20

Kfl = K–flocculus
HαPR = Hα Prominence
PHGM = Photoheliogram

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

Solar Tower Tunnel Observations

Year	Month	Total number of days of observations	Seeing (in arcsec)								
			1 to 2	2	2 to 3	3	3 to 4	4	4 to 5	5	> 5 (poor)
1997	April	17	-	1	1	13	1	1	-	-	-
	May	12	-	-	2	8	1	1	-	-	-
	June	2	-	1	1	-	-	-	-	-	-
	July	1	-	-	1	-	-	-	-	-	-
	August	8	-	-	1	5	2	-	-	-	-
	September	9	-	1	1	6	1	-	-	-	-
	October	4	-	-	1	3	-	-	-	-	-
	November	5	-	-	-	2	3	-	-	-	-
	December	7	-	-	-	5	2	-	-	-	-
1998	January	24	-	-	4	16	2	2	-	-	-
	February	21	-	-	-	20	-	1	-	-	-
	March	20	-	1	6	11	2	-	-	-	-
	Total	130	-	4	18	89	14	5	-	-	-