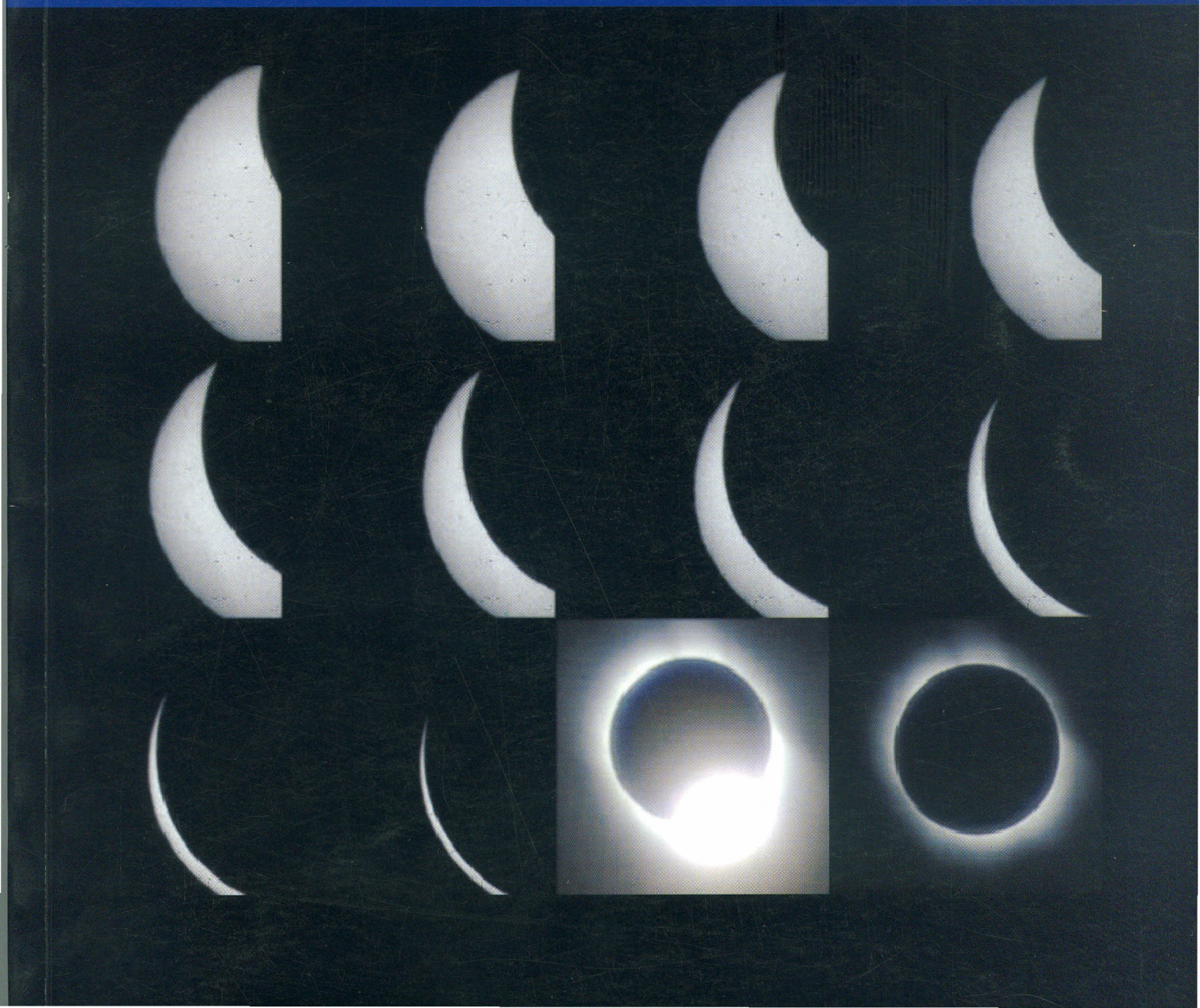
INDIAN INSTITUTE OF ASTROPHYSICS

Academic Report 2005–06



INDIAN INSTITUTE OF ASTROPHYSICS

ACADEMIC REPORT

2005–06

EDITED BY : **S.K. Saha**
EDITORIAL ASSISTANCE : **Sandra Rajiva**

Front Cover : A collage of photographs of the Sun taken during the Total Solar Eclipse of March 29, 2006 at Turkey.

Back Cover : 2-m HCT image (BVR colour) of the type II - Plateau supernova SN 2005 cs in the whirlpool galaxy M51.

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THE YEAR IN REVIEW

The year 2005-06 witnessed noteworthy developments on many fronts along with significant growth in many areas. A spectacular event in the form of a total solar eclipse lasting about 4 minutes was successfully observed from Antalya in Turkey on March 29, 2006 by a five member team of scientists from the Institute. High spatial resolution narrow band photometric images were recorded of the corona to investigate the nature of coronal waves and physical conditions in coronal structures.

Remarkable progress in various ongoing projects has been achieved during this period. The High Altitude Gamma Ray Telescope array (HAGAR) at the Indian Astronomical Observatory (IAO), Hanle, consisting of 7 telescopes, each with 7 mirrors having a total collection area of 4.4 sq. m is nearing completion. Two of these telescopes which were installed during the year received first light. The remaining five are expected to be commissioned soon. The design of the Ultra Violet Imaging Telescope (UVIT) payload for ASTROSAT, the first Indian astronomy space mission, is in its final stages. This payload, scheduled for launch in 2008, is being developed by IIA in collaboration with other institutes. It will be the first UV space telescope from India with three times better angular resolution than any similar telescope, providing new openings to Indian astronomers as well as paving the way for future national and international projects in UV and EUV astronomy. The Institute is a major partner in TAUVEX, an Indo-Israeli collaborative space-based ultraviolet imaging experiment, which is currently scheduled for launch in 2007. It consists of three UV telescopes that will provide a unique data set of the unexplored UV sky. The payload will be provided by Tel Aviv University, while IIA will contribute to mission planning, software development and data analysis.

The Institute organized various scientific conferences, workshops and schools during 2005-06. Continuing in the tradition of past years, a three-week summer school at the Kodaikanal campus was conducted for graduate and post graduate students on physics and astrophysics. Speakers from various reputed institutes delivered lectures in the school. A meeting was held at the Institute's Bangalore campus in the memory of Sir Hermann Bondi, KCB, FRS, a mathematician and cosmologist, who passed away on 10 September 2005. He was an honorary fellow of the Institute and is best known for developing the steady state cosmological theory with Fred Hoyle and Thomas Gold. His contributions to the theory of general relativity, the nature of

gravitational radiation, the introduction of Bondi radiation coordinates, the Bondi k-calculus, and the notion of Bondi mass are widely remembered. An Indo-Chinese workshop on *Recent advances in Solar Physics* was hosted at IIA, Bangalore, which provided a forum to exchange and discuss new results and plan collaborative observational programmes. The late A. Bhatnagar, a renowned solar physicist, delivered an evening public lecture entitled *Mysteries of our nearest star - the Sun*. Workshops on *Gamma-ray astronomy, Modern Trends in Atomic, Molecular and Optical Physics*, and *Science from the Himalayan Chandra Telescope* were also organized at IIA, Bangalore.

Academic staff members continue to pursue research in their respective fields. In solar physics, scientists are trying to measure variations of temperature, and non-thermal velocity in coronal loops, sunspot motions and waves, irradiance variability, activity and coronal holes. Other work includes theoretical modelling of the dynamics and nature of wave propagation in the magnetic network. The characteristics of type II radio bursts are being analyzed and efforts are in progress to estimate the coronal magnetic field. Some topical research problems in solar-terrestrial physics in the context of space weather are under investigation. Experiments continue at Hanle with a view to understanding the sources and distribution of carbon dioxide emission in the terrestrial atmosphere. In planetary science, the impact plume caused by the NASA's Deep-impact probe on comet Tempel 1 was recorded and is being studied.

Turning to stellar and galactic astronomy, it is satisfying to note that a large number of observations were carried out using the telescope facilities of the Institute. In-house built focal point instruments such as the fibre-coupled echelle spectrograph and speckle interferometer for the 2.34 m Vainu Bappu telescope (VBT), Vainu Bappu Observatory (VBO) in Kavalur, are producing new results. An auto-guider system was recently installed on the remotely operated 2 m Himalayan Chandra telescope (HCT) in Hanle. Both these telescopes are over subscribed. Research by the institute scientists has focussed on young stellar objects, evolved stars, star clusters, binary stars, chemical composition and abundance analysis, high resolution spectroscopy, interstellar matter, planetary nebulae, brown dwarfs, exo-solar planets, exploding stars, galactic disk, and active galaxies.

The Institute has an active theoretical group working on a range of problems in astrophysics and physics. Studies are being carried out on the magnetohydrodynamics of accretion disks, pulsars, radiative transfer, dynamics of galaxies, relativistic astrophysics particularly dark energy, and quasar redshift distribution. The physics group is exploring parity non-conservation effects in Ba^+ as a probe of physics beyond the standard model. Several calculations have been carried out in atomic and molecular physics as well as in nuclear physics.

In the area of instrumentation, the Institute proposes to acquire a high resolution spectropolarimeter for HCT in Hanle. Noteworthy progress has been achieved in the design and development of a wavefront sensor which is an integral part of an adaptive optics system. Experiments were performed in bacteriorhodospin (BR) films. A two-beam spectropolarimeter for Kodaikanal Tower telescope has also been developed. The primary mirror of the 1 m telescope has been successfully replaced by one developed in-house and the instrument is being used regularly for stellar observations. A new modern 1.3 m stellar telescope for imaging is being acquired for VBO, Kavalur.

The Institute has a vibrant graduate studies programme with students working towards their doctorates on a range of diverse research areas. Five new students joined this programme during the current year and one student was awarded a Ph.D. degree. In addition, 14 students participated in the visiting students' programme during the summer and carried out research projects on various topics.

A winter programme was organized for students of the international astronomy olympiad. The Institute faculty actively participates in teaching graduate courses. Several IIA scientists received awards in recognition for their achievements.

The library has created an Open Access Repository, which is a repository of IIA theses, publications (reprints and preprints), Bulletin of the Astronomical Society of India papers and archival collection. This resource is accessible on the internet through the institute website. Furthermore, the library is in the process of setting up an archive of old documents and manuscripts. More than 2000 books, which are out of copyright, have been digitized. The computer section has installed a new system for high performance computing that is ideally suited for parallel processing. The institute recently joined the national grid computing initiative GARUDA, that provides even higher levels of computational resources through a nation wide distributed network.

Turning to administrative restructuring and reform, various committees have been formed to strengthen the scientific and technical activities of the Institute as well as to address welfare issues. A new building equipped with a library, conference facilities and rooms for accommodating students and visitors is under construction. Welfare activities for SC/ST staff members is being looked into and taken care of in the best possible way. The Hindi cell is functioning efficiently, which takes care of required translation of official documents. As a part of the public outreach programme, the Institute celebrated National Science day on 28th February. Lectures on astronomy, and film shows on the laboratories and observatories of the Institute were among the several activities during the day, in which the public and school children participated. Science centres that showcase important developments in the Institute's history as well as communicate the excitement of astronomy to the general public are being planned at various centres of the Institute.

A proposal to build a two meter class National Large Solar Telescope (NLST) is under preparation. NLST will investigate the fundamental nature of solar magnetism down to the smallest scales that influence phenomena on the Sun such as the 11 year cycle, solar variability (that influences space weather) and activity that controls the heating of the sun's atmosphere. This will be a unique world-class facility that would bring new and exciting scientific results. In addition, efforts are being initiated to develop an adaptive optics system that corrects in real time the wavefront distortion caused by the atmospheric turbulence. These and several other initiatives that are on the anvil will pave the way for new and exciting projects in the forthcoming years.

S. S. Hasan
Director

SIRAJ HASAN TAKES OVER AS DIRECTOR OF IIA

Professor Siraj Hasan assumed charge on January 3, 2006 as Director of the Institute. Hasan, a Senior Professor and Chairman of the Group on Sun and Solar System Studies at the Institute, and Vice-President of the Astronomical Society of India is known in India and abroad for his distinguished academic and research work in astrophysics. He has held visiting faculty positions in many premier international institutions such as the Universities of Harvard, Oxford and London. His research publications are widely cited and have made a significant impact in solar astrophysics.

Hasan, a national science talent scholar, had his undergraduate and postgraduate education from the Aligarh and Delhi Universities. He received his doctorate in theoretical astrophysics from the University of Oxford, U.K. in 1977. Thereafter, he joined the Indian Institute of Astrophysics, Bangalore in the position of Fellow. He has been a recipient of the Commonwealth, Alexander von Humboldt and Smithsonian Fellowships and is an Associate of the Harvard College Observatory.

Hasan is a collaborator and principal investigator in several national and international research programmes. Some of his ongoing collaborations are with the Paris Observatory, the Center for Astrophysics, Harvard and the Kiepenheuer Institute, Germany.

1 Sun and Solar Systems

1.1 Solar physics

Observations of solar corona during total solar eclipse of March 29, 2006

A total solar eclipse of about 4-minute duration occurred over a belt covering Libya, Egypt, and Turkey on March 29, 2006. An expedition comprising of teams from IIA, Bangalore and ARIES, Nainital was organized jointly to carry out observations from a location in Turkey. The IIA team led by its Director obtained high spatial resolution narrowband photometric images of the coronal structure to investigate the nature of coronal waves. The data are being analysed to study intensity oscillations in the coronal green and red emission lines. Two 14-inch Meade telescopes equipped with 0.5 nm pass-band filters and CCD cameras with readout speed of 1 MHz were used to record the images in these emission lines at a frequency of about 0.5 Hz.

Figure 1: Narrow band image of a portion of the corona in green line at 5303 Å taken during totality on 29 March 2006.

Observations were also carried out for recording the shadow bands and the broadband images of the totality. It turned out that, in contrast to the record duration of shadow band phenomenon observed for several minutes in Antarctica on 23 November 2003, the bands were extremely elusive at this solar eclipse. Two screens and video cameras were used to simultaneously record the phenomenon at a separation of 10 meters. The records show very faint movement of the bands for just a few seconds. Contrast enhancement is being attempted to study these bands. Broad band digital images were also obtained during different phases of the totality. The diamond ring and the inner corona could be recorded with the short duration exposures.

(Jagdev Singh, S. S. Hasan, S. P. Bagare, R. Srinivasan & F. Gabriel)

Variation of temperature and non-thermal velocity in the coronal loops

In earlier studies, the authors have obtained off-the-limb spectroscopic observations in a number of forbidden emission lines ([Fe X]–[XIV]) to study the physical properties and temporal variations in steady coronal structures. Short exposure times adopted in these observations permitted them to study the variation in line-widths up to about 100″ above the limb. With a view to investigate variations in parameters of coronal emission lines to larger heights up to about 500″, the raster scans with 10 times longer exposure were made, compared to the earlier exposure times, on several days during September-October, 2003. The plot of FWHM's as a function of height indicates that the rate of increase/decrease of FWHM varies with height above the limb. Therefore, the gradients of FWHM with height for each coronal emission line in sub-intervals of 100″, namely, 0″ − 100″, 100″−200″, 200″−300″, 300″−400″, and 400″−500″ are computed. In most of the coronal structures, the FWHM of the [Fe XIV] 5303 Å line decreases up to 350″±50″, first with faster and then at slower rates, and later the FWHM remains same up to 500″. The FWHM of the [Fe X] 6374 Å line increases up to about 200″ and then appears to remain unchanged with height. The variations in FWHM of the [Fe XI] 7892 Å and [Fe XIII] 10747 Å lines with height show an intermediate trend. Further, the ratio of FWHM of 6374 Å to 5303 Å increases from 0.93 at the limb to 1.18 at 200″ height above the limb. From the FWHM ratio of 1.18 and intensity ratio of 5303 Å to 6374 Å lines about 2 around 200″, it is inferred that the plasma in steady coronal structures at this height is at a common temperature of about 1.5 MK and with a common non-thermal velocity around 17 km s^{-1}. Observations also show that non-homogeneous temperatures and non-thermal velocities largely exist in the lower corona up to heights 300″±100″ above the limb. The lack of variations in the FWHM of emission lines at heights 300″ above the limb in steady coronal structures does not support the general prevailing view that the non-thermal velocity increases with height due to coronal waves

or due to high velocity of solar wind. These findings are surprising and cannot be explained by the existing coronal loop models. The authors are proposing a new model for coronal loops which predicts the loops to be highly dynamic and also assumes that plasmas at different temperatures in the loops are not isolated magnetically. This implies that magnetic pressure is not very large compared to gas pressure. All the coronal models assume that the magnetic pressure is more than gas pressure. These findings need to be verified with space based spectroscopic observations with high spectral and spatial resolution in EUV and X-ray emission lines as the same imply serious restrictions on the coronal loop models and the location of origin of solar wind.

(Jagdev Singh, T. Sakurai[1], K. Ichimoto*, S. Muneer & A. V. Raveendran)*

Identification of AlF molecular lines in sunspot umbral spectra

A careful search was conducted for the presence of AlF molecular lines by the method of coincidences for five transition systems of the molecule, using high dispersion Fourier Transform Spectra. The presence of a large number of lines was confirmed. The equivalent width measurements were carried out and the effective temperature of the umbral source was estimated. One of the two values obtained is among the lowest reported so far from similar studies for molecules in sunspots. It is found that a 10Å window at 5764-5774Å has a predominant presence of the lines due to AlF, and this could serve as a useful pass band for study of temperature distribution in umbral atmospheres.

(S. P. Bagare, K. Balachandra Kumar, & N. Raja manickam*)*

Sunspot motion associated with solar flare

Studies on flare triggering mechanisms were carried out by using the optical observations taken at Kodaikanal. The structure and evolution of photospheric magnetic fields observed in the active regions were analyzed using Kodaikanal photoheliogram and spectroheliogram data. The shear angle changes were evaluated by carefully observing the sunspot motions from the changes in the orientation of the prominent umbrae that were evolved in this delta type sunspot groups. Both the flux and shear angle changes were found to be related to triggering of the flares observed in these active regions.

(K. Sundara Raman, K. B. Ramesh & R. Selvendran)

Solar X-ray spectral irradiance variability

Solar spectral irradiance at X-ray wavelengths shows large variations over the period of a solar cycle. The authors used X-ray irradiance data in three narrow spectral regimes deduced from Yohkoh SXT measurements to study coronal irradiance and its possible association with the activity in the lower atmosphere. Time variation of the X-ray irradiance is important in understanding the emergence of magnetic flux and the effects of such variation on the upper atmosphere of the Earth. It is noted that about 66% of the total (2-30 Å) X-ray irradiance arises from the 10-20 Å spectral range while the 2-10 Å band contributes only about 3% of the total. The time variation in the 2-10Åand 10-20 Å ranges follows each other closely. Further they closely follow the solar indices such as sunspot, $F_{10.7}$, and plage indices, and the similarity in the variation at 10-20 Å is quite apparent. However, the variation in the other spectral band (20-30 A) differs to a large extent, except for the solar cycle-dependent variation. The authors infer that, in addition to the active regions, the remnants of active regions contribute considerably to the emission in this spectral range.

(K. B. Ramesh & K. Sundara Raman)

Observations of second solar spectrum

The observations of the "Second Solar Spectrum", using ZIMPOL polarimeter in Locarno, Switzerland, were continued in late 2005, with extensive data obtained on the Hanle effect in Ca I 4227, and other important diagnostic lines. The analysis of the data is partly completed.

(K. N. Nagendra, Michele Bianda, & M. Sampoorna)*

Stokes profiles from the newly installed spectropolarimeter

Figure 2 shows the Stokes profiles I, Q, U, and V in the Fe I lines observed using the in-house built spectropolarimeter at Kodaikanal Solar telescope. The observations are dark subtracted, bias corrected and flat fielded. The profiles are from a row cut in a typ-

[1]*From other institutions

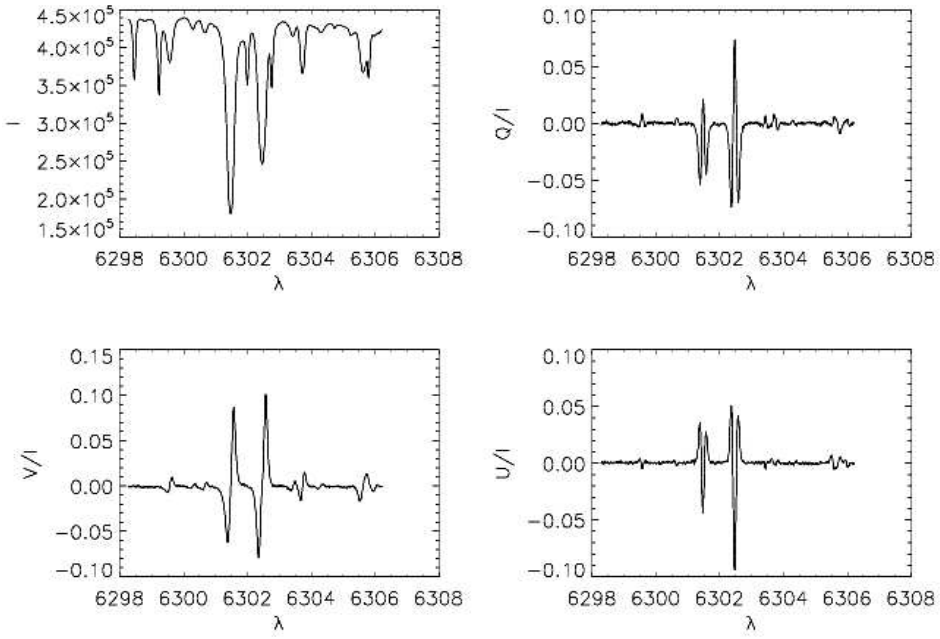


Figure 2: The Stokes profiles shown are at a typical point in the umbra of the sunspot NOAA0756 observed using the in-house developed spectropolarimeter on 26th April 2005. The profiles of magnetically sensitive Fe I lines are prominent.

ical sunspot umbral region. The Q and U profiles show the linear polarization and the orientation. V profiles indicate the circular polarization. Stokes I profile gives the total intensity. Calibration and removal of telescope polarization are in progress. The present two-beam arrangement is expected to yield a polarization accuracy of 0.1%.

(K.E. Rangarajan, K. Nagaraju & K.B. Ramesh)

Formation of filament channels

Process of the formation of a filament channel is initiated by the emergence of a new magnetic complex in the neighbourhood of a decaying or old active region. The subsequent diffusion of the new magnetic complex, convergence and cancellation and the concentration of the magnetic fluxes of these two regions lead to the formation of the filament channel.

Author had modeled the above process by using the basic equations of MHD. This is a kinematic study for a given magnetic configuration for which one can determine the solution. To determine the observed properties of the filament channel one has to use the observed configurations of the magnetic elements which are the building blocks of large scale structure.

The continued existence of a magnetic structure in the solar atmosphere, which has negligible mass and in the equilibrium state demands that the magnetic field will be in the force free state. The observations showed that the force-free-parameter α is predominantly positive (negative) in the southern (northern) hemisphere.

From the analysis the following results were obtained. If the sign of the α, is same for the remnant region and newly emerged region and it should be according to the rule mentioned above, then the chirality of the resulting field will be according to the one as observed. The concentration of the magnetic field is by the flow induced by the Lorentz force. For a given input condition, the maximum and the minimum value of the axial field is determined. The condition for the disruption of the filament as well as for the null chanels were discussed.

(B.S. Nagabhushana)

Wave propagation in the magnetic network

It is well known that the magnetic network in the solar atmosphere consists of intense magnetic field elements, in which MHD waves are likely to play an important role in their dynamics and energy transport. Recent studies by Hasan et. al. (2005, ApJ **631**, 1270) examined the wave propagation in a net-

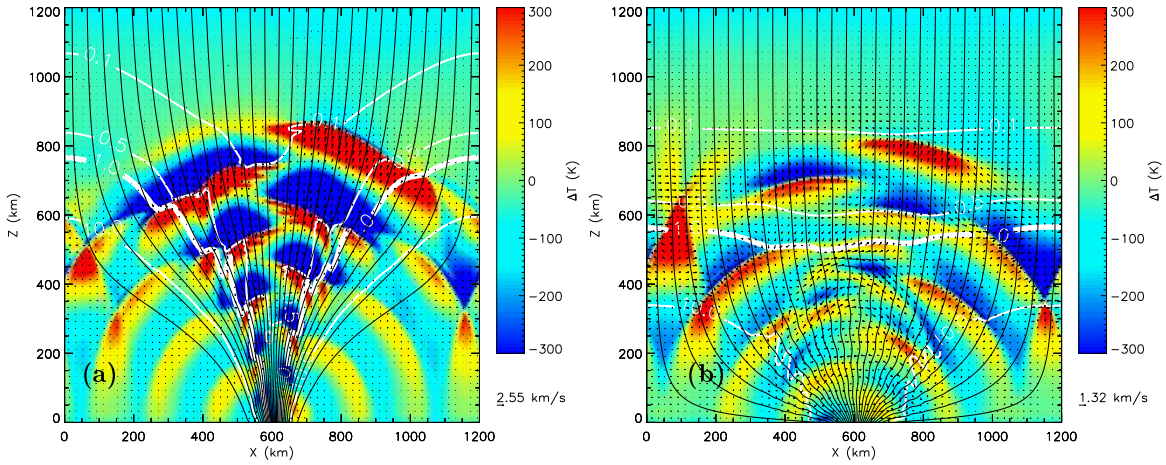


Figure 3: Flow pattern (arrows) and temperature perturbation (colours) at 110 s in (a) a configuration with a non-potential field and (b) potential field due to a periodic horizontal motion at the lower boundary with an amplitude of 750 m s^{-1} and a period of 24 s. The thin black curves represent the magnetic field lines and the heavy white curves contours of constant β corresponding to $\beta = 0.1$, 0.5, 1.0 (thick curve), and 10.

work element due to periodic motions at its base. These elements or flux tubes are modelled as non-potential structures in which the field drops sharply at the interface with the ambient medium. An alternative model of the network is examined where the magnetic field is potential to investigate how sensitive the dynamics is to the form of the initial configuration. This is carried out by comparing the wave excitation in both types of field geometry due to periodic transverse motions of the lower boundary. The time dependent evolution of these configurations is followed using a numerical method to solve the time dependent MHD equations. From Figure 3(a) the footpoint motions of the flux tube are an efficient source of acoustic waves at the tube-ambient medium interface. In the ambient medium they are visible as a semicircular pattern that propagates outwards at the local sound speed. Close to the tube axis, the pattern is dominated by slow longitudinal acoustic-like waves with large temperature fluctuations. As expected, the flow is essentially along the field lines.

The authors now turn to the case of a potential field configuration for the network. Using the same periodic excitation as before, they find from Figure 3(b), that below the surface corresponding to $\beta = 1$, the wave pattern generated by horizontal displacements at the flux tube base consists essentially of slow modes (Alfvénic in character), where the motions are transverse to the field and produce distortions in the field lines. The motions at the lower boundary also produce compressions and rarefactions (180° out of phase on opposite sides of the axis) that generate fast mode (acoustic like) waves that propagate ahead of the slow wave front. Above the $\beta = 1$ layer, where the Alfvén speed is significantly higher than the sound speed, the authors see a longitudinal slow wave that is acoustic in nature, propagating at the acoustic speed.

In summary, the authors find that the nature of wave propagation is different for the flux tube and potential field configurations. In the latter, the lower part of the atmosphere (where $\beta > 1$), has both Alfvénic (transverse) and acoustic waves travelling almost isotropically, whereas in the former, the pattern in the central regions of the flux tube is dominated by acoustic waves that produce larger temperature fluctuations, stronger shocks and consequently greater heating in the higher layers of the atmosphere. Thus, flux tubes appear to be promising in transporting energy to the upper chromosphere.

(*S.S. Hasan, A. van Ballegooijen*, & G. Vigeesh*)

3-minute oscillations in and around Sunspot

The detection of waves in the solar atmosphere has been of great interest to both solar and plasma physicists. The active region, AR0554, was observed with NIS/CDS on board SOHO (Solar and Heliospheric Observatory) to examine the extent and range of oscillations from a range of features. Among all the NIS spectral lines analysed, significant oscillations were found in Si XII 520 Å, Mg X 625 Å, O V 629 Å and He I 522 Å. The periods of the strongest oscillations in these lines were ≈ 10–20 min. After the dominant 10–20 min oscillations were filtered out from

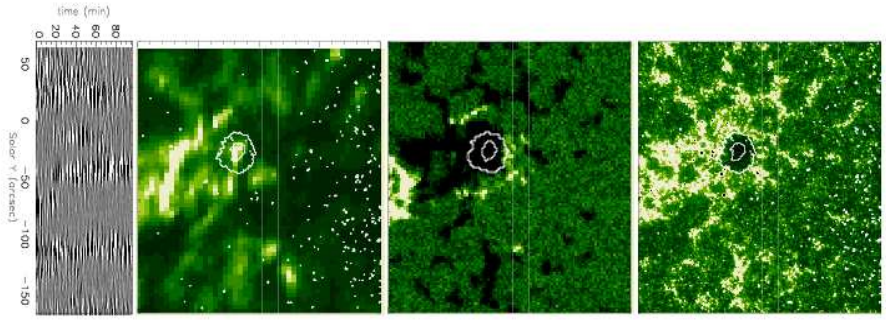


Figure 4: A comparison of the TRACE 1600 Å wavelength band image, MDI magnetogram, NIS O v 629 Å image from CDS and the P300-filtered space versus time slice (from left to right). The contours show the location of umbra and penumbra and the horizontal lines indicate the initial and final location of the CDS slit respectively. In the magnetogram, the white dots around the sunspot correspond to the moving magnetic features. The supergranulation cell boundaries are visible in the TRACE image as bright regions. The locations of these boundaries match the locations of the 3-min oscillation stripes.

these lines, only O v 629 Å showed significant (*i.e* above the 95% significance level) shorter-period oscillations. Specifically, the authors found that weak but significant 3-min oscillations are *not* confined to the umbra/plume but can be seen in many bright locations. The duration of these non-umbral 3-min oscillations is mostly ≈ 20 min. In contrast, the 3-min oscillations within the umbra are strong and stable for longer than 50 min. To find the possible sources of these 3-min oscillations outside of the umbra, the authors compared the oscillations of single pixels in different regions. The results of their comparison indicate a possible connection between the magnetic fields and the oscillation. Therefore, the authors suggest that 3-min oscillations may exist in many magnetic structures, but are often too weak to be seen in an unfiltered signal.

(Lin, Chia-Hsien, D. Banerjee, J. G. Doyle,*, & E. O'Shea*)*

Wave propagation in off-limb polar regions

Evidence for waves in the outer atmosphere of the Sun comes from measurements of radiance in a range of frequencies including visible, ultraviolet, X-ray and radio in addition to Doppler oscillations in visible and ultraviolet light given off by different solar structures at chromospheric, transition region and coronal temperatures. Using temporal series data from the Coronal Diagnostic Spectrometer (CDS) on SOHO the authors study oscillations found in transition region and coronal lines in off-limb polar regions. From a study of the phase delays between flux and velocity measurements (I-V) they have found evidence for fast magnetoacoustic waves to be predominantly present at coronal temperatures, while at transition region temperatures slow magnetoacoustic waves are more common. Measurements of phase delays between different line pairs reveals that the measured phases tend to line up along diagonal lines corresponding to fixed time delays. From the orientation of the slopes of these diagonal lines the authors can infer that the higher temperature lines lag the cooler temperature lines, suggesting the outward propagation of waves. From estimates of the formation heights of the lines, and using the measured time delays, they estimate propagation speeds for the different line pairs that indicates that the waves producing the observed phase delays are magnetoacoustic waves propagating at speeds close to the sound speed.

(E. O'Shea, D. Banerjee, & J.G. Doyle*)*

High velocity event near a sunspot

Jets with velocities higher than 200 km/s are often observed in the X-ray spectral range in the solar atmosphere, however, very few such objects are observed in the EUV range. The authors report an eruptive event observed in the south-west side of a sunspot, within the active region, AR0554, in a range of spectral lines formed in the transition region and corona. The main data were time-series observations obtained with the Coronal Diagnostic Spectrometer, in addition to images from the Michelson Doppler Imager and Extreme ultraviolet Imaging Telescope on board SOHO. Additional high resolution images from TRACE were also used. The event brightened a loop connecting the sunspot and a bright-point structure, triggering both a high-speed flow in the loop and a transient, low-speed ambient flow into the sunspot. The energy released is quickly conducted to the chromosphere, as evident by TRACE 1600 Å images and the light curve of He i 522 Å as seen by

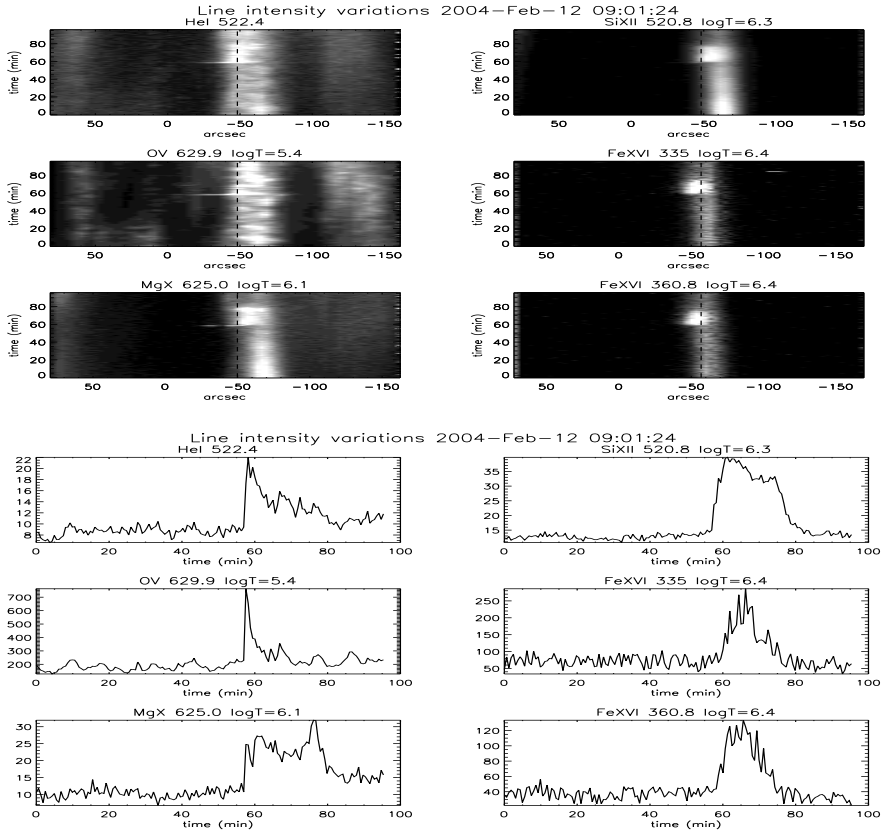


Figure 5: The top three rows are the X-T slices of the line intensities of the six lines analyzed. The X axis is the Solar Y coordinates along the slit, and the Y axis is the time. The lower three rows show the line intensity variation along the black dashed lines marked in the X-T slices (Solar Y$\approx -48''$). The unit of the intensity is photons/sec/area.

CDS. The results from our multi-wavelength study further indicates that the effect of the eruptive event may have reached temperatures higher than 2×10^6 K. Relative Doppler velocities of over 300 km/s were detected in the transition region line, O v 629Å. The multi-wavelength analysis indicates that the event is likely due to fast magnetic reconnection in the transition region. The velocities detected are consistent with the results obtained by the evaporation jet model.

(Lin, Chia-Hsien, D. Banerjee, J.G. Doyle* & E. O'Shea,*)*

Very long period activity at the base of solar wind streams

It is known that quasi-periodic fluctuations are present in open coronal structures. The authors report on the detection of very long (150-200 min) periodic intensity fluctuations, above the solar limb, close to an inter-plume. They use time series data of spectral lines originating from a wide range of temperatures in the solar transition region, above a polar coronal hole, from SUMER (Solar Ultraviolet Measurements of Emitted Radiation) on SOHO. The data also reveal long periodicities (15-100 min), interpreted in terms of slow magneto-acoustic waves, previously observed with other SOHO instruments. Along with the slow waves, the periodic intensity fluctuations which the authors have observed for the first time, could play a relevant role in accelerating the fast streams of particles leaking from the coronal holes, along open magnetic field lines.

(M. D. Popescu, D. Banerjee, E. O'Shea,* J. G. Doyle*, & L. D. Xia,*)*

High order atmospheric g-modes with large periods from TRACE observations

Internal g-modes of the Sun are the most powerful tools for the investigation of the solar core and the neutrino problem. The detection of atmospheric g-

mode oscillations are also equally important in order to know the role of different kinds of oscillations in the heating of the chromosphere and the corona. Six hours of time sequence of the ultraviolet images obtained on May 24, 2003 in 1600 Å continuum under high spatial and temporal resolution with TRACE Space Mission have been analysed. Fifteen UV bright points, 15 UV network elements and 15 UV background regions from the time sequence images for the detailed analysis have been chosen. The cumulative intensity values of all these features have been derived using SolarSoftware (SSW) in IDL. The light curves of all the features have been generated for the total duration of the observations. The power spectrum analysis using their time series data has been done. It is found that the UV bright points, the UV network and UV background regions will exhibit longer periods of intensity oscillations namely, 5.5 hours, 4.6 hours and 3.4 hours respectively, in addition to smallscale intensity fluctuations. These periods may be related to very high order atmospheric g-modes showing large periods at the transition region.

(R. Kariyappa, L. Damé, & B.A. Varghese)*

Observational searches for chromospheric g-mode oscillations from CaII H-line observations

A high spatial and temporal resolution of long time sequence spectra in Ca H-line, obtained at the Vacuum Tower Telescope (VTT), Sacramento Peak Observatory, on a quiet region at the center of the solar disk over a large number of bright points and network elements has been used to search for atmospheric (chromospheric) g-mode oscillations. An important parameter of the H-line profile, intensity at H_{2V} ($I_{H_{2V}}$), has been derived from a large number of line profiles. The light curves of all the bright points and network elements have been derived. The light curves represent the main pulse with large intensity amplitude followed by several smaller pulses with lower intensity amplitudes. The light curves of these bright points would give an impression that one can as well draw curves towards and away to the highest peak (main pulse) showing an exponential growth and decay of the amplitudes. An exponential decaying function has been fitted for all the light curves of the bright points and found that the slopes of decay are more or less the same, and one value of the coefficient of exponent can represent reasonably well the decay for all the cases. From an exponential fit, the authors find that there is an indication of the existence of a longer period of oscillations around 80-90 min. The FFT analysis of temporal variation of both the bright points and the network elements indicates around 10-min periodicity. It is speculated that these longer periods of oscillations may be related to chromospheric g-mode oscillations.

(R. Kariyappa, L. Damé, & K. M. Hiremath)*

Magnetic flux in the solar convective envelope inferred from the sunspots

Earlier, the authors have made an attempt to infer the toroidal magnetic flux in the convective envelope from measurements of the areas of the sunspot groups that appear first on the surface. However, in the present study, six years (1999-2004) SOHO/MDI magnetograms are used for the measurement of *initial* magnetic flux and preliminary results are: (i) majority of the spot groups that have *initial* appearance on the surface are bipolar, (ii) irrespective of their sizes, the bipolar spots with different life spans have similar magnetic field strengths of ~ 50 G during their first appearance on the surface, (iii) the field strength at the site of anchoring depths of the sunspots is estimated to be $\sim 10^5$ G near base and $\sim 10^4$ G near the surface, (iv) the dynamo–a source of sunspot activity– distributed through out the convective envelope and, (v) the rate of flux emergence of such a distributed dynamo is large near the base of the convective envelope compared to near the surface.

(K. M. Hiremath & M. R. Lovely)

Simulations of the Long-term behaviour of the solar activity cycle

The short-term (11yr, 22yr) and the long-term (Maunder minimum activity of ~ 100 yrs) behaviour of the solar activity cycle as a *coupled oscillator* due to coupling of the poloidal and toroidal MHD oscillations is modelled. The equations of coupled oscillations in the dissipative medium are considered and in order to closely match with the short-term and the long-term observations, the fundamental period due to poloidal oscillations is 22 years, the dissipation factor must be 0.185 and the coupling frequency should be 0.11 rad/yr. The oscillations of such a coupled oscillator are presented in Figure 6. It is seen from the figure that during 500 years simulated time interval, oscillations of the poloidal field with a fundamental period of 22 yrs are coupled with the toroidal field oscillations. The toroidal field oscillates in conso-

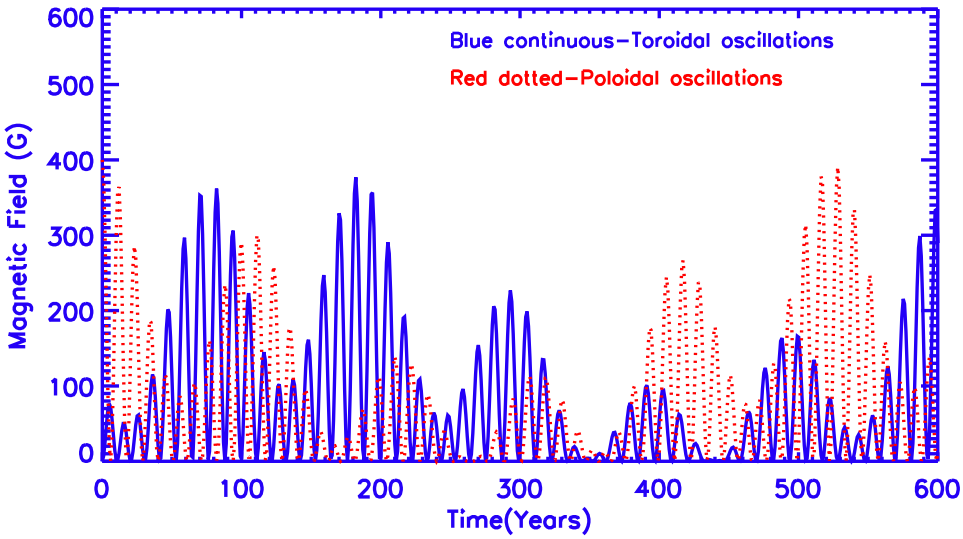


Figure 6: The oscillations of the poloidal field with a fundamental period of 22 yrs directly coupled with the toroidal field such that toroidal field oscillates in consonance with the poloidal field oscillations resulting in short-term ($\sim$ 11 yrs) and long-term (*Maunder minimum type oscillations of* $\sim$ *100 yr*) with a deep Maunder minimum around 350 years during the simulated time. The sunspot activity that results from the superposition of toroidal field oscillation modes is represented by blue continuous line and the poloidal field oscillations is represented by the red dotted line.

nance with the poloidal field. This simulation also reproduces the observed cyclic periodicities of 11 and 100 yrs with a very deep minimum around 350 years when both the strengths of poloidal and toroidal oscillations have very low amplitudes.

(K. M. Hiremath)

Influence of the solar activity on the Indian rainfall

Previously, the sunspot occurrence activity (Hiremath and Mandi, *New Astronomy*, 9, 651, 2004) and the irradiance occurrence activity was used and it was found that both these activities have very good positive correlation especially with the log-term ($\geq$ 10 yrs) Indian Monsoon rainfall. Presently the solar occurrence activity of polar faculae was used and it was found that there was strong negative correlation especially with the Indian Monsoon rainfall. The cause of the negative correlation of the solar polar activity with the rainfall activity must be due to anticorrelation of the polar activity with the sunspot activity. Since polar activity is considered to be a precursor of both the sunspot and the irradiance activities (and both these activities have long-term positive correlation), it can also be considered as a precursor for the prediction of the long-term rainfall activity.

(K. M. Hiremath)

Influence of the solar activity on the terrestrial lightning

The conventional idea is that lightning is due to pent-up charges stored in the electric field that are generated from the thunder clouds by collisions of the ice particles. During this process, clouds eventually attain the negative charges that induce positive charge near the ground leading to ionization of the air molecules (that are situated between the cloud and the ground) ultimately resulting in flow of current and hence lightning bolt. However, the air ionizes in the spontaneous electric field $\sim$ 2500 kilovolts per meter contrary to the *in-situ* field measurements of 100-400 kilovolts per meter. The question arises that how to achieve such a high electric field in order to ionize the air spontaneously. The two sources that seed the lightning are the cosmic rays and the solar high energy particles. In order to confirm the influence of solar activity, the author used the lightning data of the Indian subcontinent that are compiled by Indian Meteorology Department. The intensity of the lightning is measured as follows. Total number of injuries and deaths of the living beings on the ground are assumed to be directly proportional to the number of occurrences of the lightnings in the atmosphere. That means the increase in the high energy particle events that might seed the atmospheric lightning are correspondingly proportional to increase in solar activity. Preliminary results are in accordance with this expectation. The gist of this

problem is that the cosmic rays alone are not the seeds of energy and the influence of solar activity on the seeding of the terrestrial lightning should also be considered.

(K. M. Hiremath)

Studies of coronal holes using SOHO Data

Intensities, Doppler velocities and linewidths of EUV emission lines in a coronal hole and the nearby quiet Sun region have been obtained from Coronal Diagnostic Spectrometer (CDS) observations on board SOHO. The field of view is 1 × 4 square arc min, with a series of observations made at different spatial locations on the boundary of the north polar hole and its large equatorial extension, the 'Elephant's Trunk'. The formation temperatures of the observed lines vary from 0.083 MK to 1.10 MK and hence they represent increasing heights in the solar atmosphere from the upper chromosphere and transition region to the low corona.

The authors have examined the linewidths and Doppler velocities. A very high signal-to-noise ratio is essential for the reliable estimation of linewidths and Doppler velocities, so they have used only the strongest five emission lines, namely, OIII 599 Å, OV 630 Å, NeVI 562.8 Å, HeII 304(2) Å, and MgIX 368 Å. It has been found that all lines have larger widths in the coronal hole than in the quiet Sun outside. Also polar coronal hole have larger linewidths than that in the equatorial extension. Doppler velocities in the coronal hole are generally blue-shifted with respect to the quiet Sun, and the magnitude of the blueshifts increases with the height. Evidences of localized jets have also been found mainly in the vicinity of coronal hole boundaries. The findings have implications to the problems of the acceleration of the fast solar wind and coronal heating. Further analysis is under way.

(K.P. Raju & B.J.I. Bromage)*

Signatures of coronal holes in Kodaikanal Ca K data

It is generally accepted that the coronal holes show up their signatures as weak emission regions only very close to the corona. This means that there is no significant difference between line intensities inside and outside the coronal holes up to temperatures of about 0.8 MK. Some recent observations, however, indicate that line intensities in coronal holes are affected in the lower transition region and even in the chromosphere. The polar coronal holes have been found to be actually brighter than the nearby quiet Sun in the lower transition region. Hence it is interesting to see how coronal holes affect line intensities in the chromosphere and in the lower transition region, and also to know its consequences to the energy balance in the solar atmosphere. In this study, the authors examine the Ca K filtergrams from Kodaikanal for signatures of coronal holes. The daily Extreme-Ultraviolet Imaging Telescope (EIT) pictures from SOHO are used to identify the coronal holes. A comparison of EIT pictures with Ca K filtergrams enable the authors to study the possible differences, if any, between coronal hole regions and outside in the chromosphere.

Identification of coronal hole boundaries has been found to be easier at the disk centre than at polar regions. For this reason, the authors have selected only a few prominent equatorial coronal holes in our preliminary study. The intensity distribution of such coronal holes is compared with that of the quiet regions outside.

(K.P. Raju & J. Singh)

1.2 Solar radio astronomy

Occultation of a solar active region at 1.5 GHz during the eclipse of November 3, 1994

Data obtained during the the solar eclipse of November 3, 1994 with a 4- meter diameter antenna and a radio spectrograph operating at 1.5 ± 0.05 GHz with a time resolution of 100 msec were used to derive the size of a source in the solar active region AR 7798. The one-dimensional spatial resolution obtained in this case is $\approx$ 3.2 arsec. The radio observations of the occultation of the solar active region AR 7798 by the lunar limb during the above eclipse are presented. From the derivative of the eclipse curve, the authors found a source with an angular size of $\approx$12 arcsecs associated with this active region. It is found from the YOHKOH and Nobeyama heliograph images at 17 GHz, that the occulted source lies in the loop structures.

(K. R. Subramanian, H. S. Sawant, F. C. R. Fernandes* & J. R. Cecatto*)*

A statistical study of the characteristics of type-II doublet radio bursts

The characteristics of doublet type-II radio bursts have been studied, in which two type-II bursts oc-

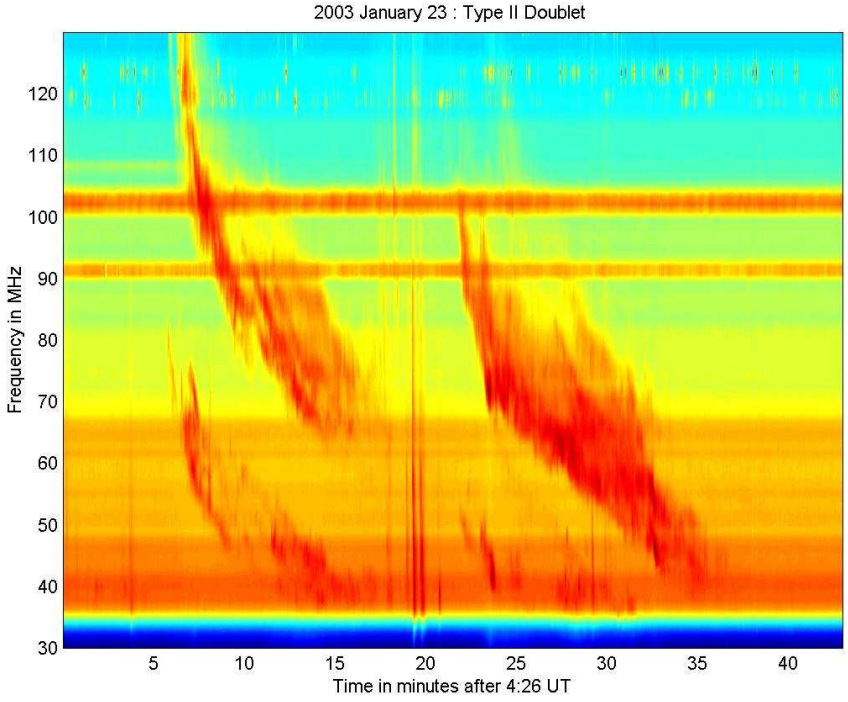


Figure 7: Typical example of a type-II doublet radio burst observed with the Gauribidanur digital radio spectrograph. Two type-II bursts can be seen in sequence, one starting at 04:32:00 UT and the second one at 04:49:00 UT. Both the bursts shows fundamental/harmonic structure.

cur in sequence and have investigated their drivers. 37 type-II bursts reported by the Culgoora radio observatory in the Solar Geophysical data for the period September 1994 - July 2004 were used to determine their time and frequency characteristics. Figure 7 shows a typical example of the type-II doublet burst observed with the Gauribidanur Solar radio spectrograph. In order to investigate their association with flares and Coronal Mass Ejections, flare data from NOAA and Coronal Mass Ejection data from Center for Solar Physics and Space Weather, Catholic University of America were used. The following results have been found: The second type-II radio burst starts at a lower frequency than the first one. The normalized drift rate of the first type II burst is found to be nearly twice that of the second type-II burst. For both the first and second type-II bursts, their start frequencies and the drift rates are found to be correlated. The mean time difference between the start of the first and second type-II bursts is 8.1 minutes. Only in two cases, there were reports of two flares or CMEs. The first and second type-II bursts start 5 and 15 minutes after the start of the GOES X-ray flares. The time difference between the CME onset and start of the first and second type-II bursts is also close to the above values. The type-II doublet bursts have the following association with flares: B class 11%; C class 25%; M class 40% and X class 25%. The Coronal Mass Ejections associated with type-II doublet bursts have an acceleration of -10 m/s^2 and angular width of more than 270 degrees.

(K.R.Subramanian & E.Ebenzer)

An estimation of the coronal magnetic field using type II doublet radio bursts

Multiple type-II bursts observed on January 23, 2003 in the band 30 - 130 MHz were used to estimate the strength of the magnetic field in the solar corona. From the observed bandwidths and drift rates of the two bursts and relating the instantaneous bandwidths to the density jump across the shock front and the drift rate to the velocity of the shocks, the authors have derived the strength of the magnetic field at 1.50 and 1.66 solar radii as 1.80 and 1.44 Gauss. The variation of magnetic field strength with height can be expressed as $\mathrm{B(R)} = 1.5\ \mathrm{R}^{-2.2\pm0.2}$. Assuming a coronal temperature of 10^6 K, the derived value of

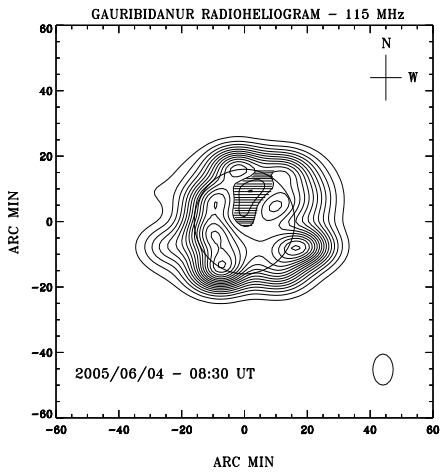


Figure 8: Radioheliogram of the solar corona at 115 MHz obtained with the GRH on June 4, 2005 around 08:30 UT. The peak T_b is $\sim 1.1 \times 10^6$ K and it corresponds to the discrete source near the limb in the south-west quadrant. The contour interval is 5.5×10^4 K. The open circle at the centre represents the solar limb. The instrument beam is shown near the bottom right corner of the figure. The hatched region in the northern hemisphere is the CH under study.

plasma beta is 0.14 at 1.50 solar radii and 0.11 at 1.66 solar radii.

(K.R.Subramanian & E.Ebenezer)

Observations of solar coronal holes

Coronal Holes (CHs) are large-scale structures in the solar atmosphere with a lower temperature and density than their surroundings. They appear brighter/ fainter compared to the 'background' corona, depending on whether the observations are in emission/absorption. The CHs trace the large scale structure of the 'open' magnetic field in the corona and are of great importance for the Sun-Earth relationships and space weather. The high-speed solar wind streams as well as the intermittent flow of energetic particles that give rise to large-scale interplanetary shocks are known to originate from the CH region in the solar atmosphere.

Recent solar observations with the Giant Metrewave Radio Telescope (GMRT) at 150 MHz show evidence for a radio counterpart to a CH observed as a depression in the radio brightness distribution on the solar disk. The multiwavelength imaging of the CH using data from different instruments over the low- and high-energy bands of the electromagnectic spectrum is shown to be a straightforward tool to study the properties of CHs. The structural details of the radio CH using the GMRT observations and the Extreme Ultra Violet (EUV) and Soft X-Ray (SXR) images obtained with the SOHO/EIT and GOES/SXI, respectively are compared. The density/temperature inside the same CH using 115 MHz data from the Gauribidanur Radioheliograph (GRH) are also studied.

From the superposition of the maps, it was shown that the difference in the position of the CH at 150 MHz and on Extreme Ultra-Violet and Soft X-Rays can be explained as a simple projection effect, with the radio layer lying 0.23 $R_\odot$ below the EUV layer at 1.6×10^6 K, and 0.28 $R_\odot$ below the X-Rays layer with temperatures ranging from 2 - 5×10^6 K in the GOES/SXI data. Making use of the first simultaneous observations using the GMRT and the GRH, the authors found that the average temperature of the 115 MHz counterpart to the CH is $\sim 7.70 \times 10^5$ K. The authors also derived the electron density, $n_e \approx 2.43 \times 10^7$ cm^{-3} at the location of the 115 MHz CH using the GRH data. This is less compared to the electron density of the 'background' corona at 115 MHz by a factor of ~ 6.

(F.R.H. Madsen⋆ & R. Ramesh, et al.)

1.3 Planetary sciences

Analysis of deep-impact data

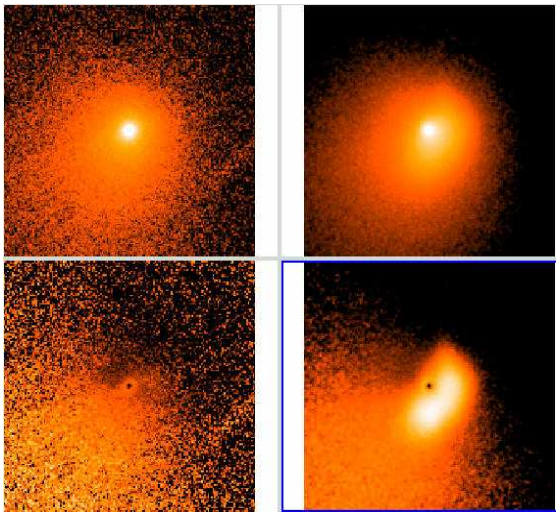


Figure 9: Images taken from the 102 cm telescope at VBO on 03 July at 14:26 UT IST(top left) and on 04 July at 13:47 UT IST(top right), 8.9 hour after the deep-impact. The field is 1 arcmin on a side, top is North and East is to the left. The impact ejecta is seen on the western side of the comet. This activity is suppressed by the normal coma the intensity of which falls off as the inverse of the distance from the comet centre. The lower panels show the images in which this gradation has been removed. Comparison of the processed images taken before (lower left) and after the impact (lower right) clearly shows the impact related activity on the comet.

NASA's deep-impact probe artificially created a crater on comet Tempel 1 on July 04 2005. In response to the International campaign for ground based observations to monitor this event, observations were carried out from the Vainu Bappu Observatory and the Indian Astronomical Observatory at Hanle. The impact plume was recorded in the images 8.9 hours after impact (Fig.8). This observation from the Indian subcontinent is considered very important, because of its geographic position. Analysis of the data using the working photometric-dynamic model is being carried out.

(R. Vasundhara, U. S. Kamath, G. Maheswar, S. Muneer, S. K. Pandey, & T. P. Prabhu)

Stellar occultation by the asteroid (423) Diotima

Analysis of the light curve of the occultation of 2UCAC 42376428 by (423) Diotima on 2005 March 06, from the 102 cm telescope at VBO was completed. A narrower projected size of 44.5 km along the occultation track than the predictions is implied from the observed duration. This information on the size, when combined with the results at other epoch will help in inferring the shape of this asteroid.

(R. Vasundhara)

Multi-observatory observations of night-side of Venus

Observations of Venus were made during 3-11 May 2004 (117.4 - 125.7 phase angle) and 3-10 July, 2004 (132.5 - 125.1 phase angle) from the 1.2 m Mt. Abu Telescope at Gurushikhar, Himalayan Chandra Telescope at Mt. Saraswati, Hanle and the Nordic Optical Telescope at La Palma, Canary Islands and the NASA/Infra Red Telescope Facility (IRTF) at Mauna Kea, Hawaii in J and K bands. While the sun-lit crescent portion was saturated in the detector, the night-side shows discrete cloud features. These features are seen to evolve over time and are markers of the atmospheric flow at or below 53 km altitude above the surface. By combining multi-site observations, measurements of zonal cloud velocities over baselines that are several hours long and get a better idea of the evolution of the features over time, are being made.

(S. S. Limaye, J. Warell, B. C. Bhatt, P. M. Fry*, & E. F. Young*)*

1.4 Atmospheric sciences

Atmospheric scintillation studies during total solar eclipse

The scintillation signatures observed as shadow bands during the total solar eclipse of 23 November 2003 was studied in further detail. The power spectrum shows a Kolmogorov type of slope with an index of about -2. The tail end of the spectrum shows a much steeper index of about -17/3. It was deciphered that it is important to examine the tail end portion of the spectrum by obtaining additional observations during future totalities.

(S.P.Bagare, S.M.Bhandari, & H.O.Vats*)*

Solar-terrestrial relationship

A few topical research problems in Solar-Terrestrial Physics (STP) relevant to Space Weather science are being addressed through analysis of appropriate data. One of them is the ground level geomagnetic signature of magnetospheric substorms at the dayside magnetic equator. The equatorial/low-latitude effects of substorms had been an integral part of substorm research in the pioneering days (1960s and 70s), and this aspect has again come into focus now because of the very recent divergent results. The conventional wisdom borne out of modeling efforts of 1970s and well supported by extensive observations is that the formation of the substorm current wedge at the expansion phase onset of substorms leads to a negative H-comp bay at the dayside dip equator with no contribution of ionospheric currents. But recent work done at IIA and elsewhere brought to light unambiguous evidence for the presence of an ionospheric component in the negative H-comp bay at the dayside dip equator, both during the growth phase and at expansion phase of IMF-triggered substorms. The ionospheric component is further found to prevail if there is a substantial and sudden reduction in magnetospheric convection (cross polar cap potential) at the expansion phase onset and not otherwise, rendering the convection changes induced by rapid transitions in IMF B_z component as the most important condition to be satisfied. But it is also reported by the MIT groups that the true signature of spontaneous or un-triggered magnetospheric substorms is a positive H-comp bay at the dayside dip equator, also with an ionospheric component. The origin of the positive bay and the ionospheric component, unlike that of the negative bay has remained obscure. This prevailing scenario necessitated a thorough eval-

uation of the equatorial manifestation of substorms (both on the day side and night side) through analysis of a large database of well-identified substorms, paying due attention to the type of substorm (triggered, spontaneous, storm-time and non-storm-time) and its phases. Such an effort is in progress in collaboration with groups within and outside the country. The results of this work will have an important bearing on the understanding of the solar wind-magnetosphere-high latitude ionosphere-low latitude coupling on substorm time scales.

(J. H. Sastri)

1.5 Geophysics

CO_2 measurements in the subcontinent

The Laboratoire des Sciences du Climat et de l'Envir onment (LSCE), CEA-Saclay, France is coordinating the measurement of green house gases (CO_2, CH_4, N_2O,SF_6) over an international network under the Raceau Atmospherique de Mesure des Composes a Effet de Serre (RAMCES) programme. The network includes more than 15 permanent sites in Europe and Asia, whereas flask sampling and in-situ measurements are also carried out on board air-crafts/ships. A survey of CO_2 and trace gases was conducted by LSCE at IAO, Hanle, in December 2000 with help of HCT staff. As expected, the site at IAO, Hanle, gives an opportunity to measure the composition of air masses coming preferentially from North-West India or from Central Asia, two regions which are poorly documented. The site is far away from the industrial areas and good logistic support is available.

IIA and LSCE are now collaborating on the IFCPAR project titled "Carbon Flux in India and Central Asia (CaFICA)" with the objective to improve our knowledge of the distribution of carbon sources and sinks in India and Central Asia, based on a synergy of atmospheric measurements and inverse model. The project is structured in two complementary poles with atmospheric survey of trace gases, CO_2, CH_4, N_2O, CO, SF_6 and $C^{18}O$ in Hanle-Ladakh and regional estimates of CO_2 sources and sinks using atmospheric transport model. Under this project, a very high precision CO_2 analyser will be installed at IAO, Hanle-Ladakh. A prototype Carbon dioxide analyzer for IAO, Hanle (Caribou2) dedicated to continuous CO_2 measurement with precision of 0.01 ppm was developed at LSCE with the help of its engineering branch Departement d'Astrophysique, de physique des Particles, de physique Nucleaire et de l'Instrumentation Associee (DAPNIA). The Caribou2 is made using nondispersive infrared (NDIR) analyzers. The Carbon Dioxide mole fraction measurements are calibrated with strict follow up of international monitoring protocol. The precision is improved through active control of pressure, flow rate and temperature of gases passing through the analyzer, the targets being $35 \pm 0.001^\circ$ C in temperature, 20 ± 0.005 ml/min in inlet flow rate, 1080 ± 0.04 mbar in gas tank/cell pressure.

The equipment was shipped to Hanle after rigorous tests in Paris during April-July 2005, and installed during August 2005 by a team of scientists and engineers from LSCE/DAPNIA with support of HCT scientists and engineers, inside a special enclosure that maintains a controlled environment. This system is producing data succesfully, and is available to LSCE/DAPNIA through internet.

(M. Ramonet, P. Bousquet,* D. Filippi,* M. Schmi dt,* B. Phillippe,* B. Jean,* P. Galdemard,* P. Ciala,*, O. Cloue,* J. Allard,* R. Azoulay,* D. Eppelle,* J. Bolorgey,* B. C. Bhatt, V. K. Gaur, S. K. Bhattacharya,* S. Gorka, D. Angchuk & R. R. Reddy)*

2 Stellar and Galactic Astronomy

2.1 Young stellar objects

Survey of T Tauri stars

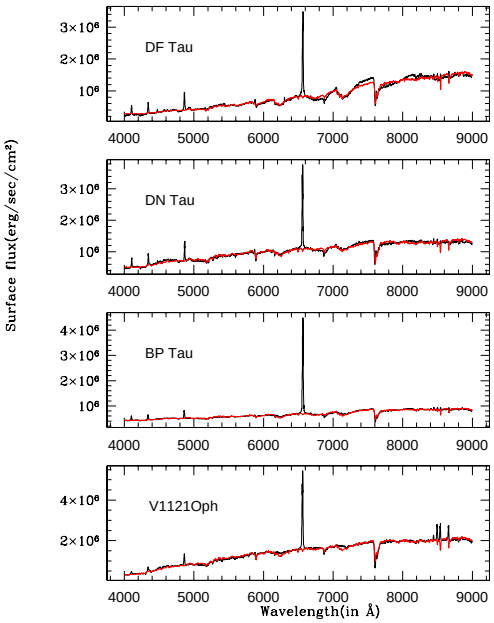


Figure 10: Modeling HCT optical spectrum of selected CTTS with the technique developed by us.

The T Tauri stars survey work, using optical slitless spectroscopy and broadband BVRI observations of selected Galactic Star Forming Regions (GSFRs) beyond one kpc is being carried out. In the HCT-Cycle-8 & 9 part of the star forming regions M17 and NGC 6820 were surveyed. The data reduction is being completed.

(P.S. Parihar & D. K. Ojha)*

Accretion process in classical T Tauri & DF Tau stars

Nearly simultaneous optical and near-infrared band observations provide effective tools to explore the mechanisms responsible for the variability observed in T Tauri Stars. Several classical T Tauri stars have been observed, to study the nature and time variation of the disk accretion process. Furthermore, to extract valuable accretion related information from observed optical spectrum, a code has been developed based on a physical model due to Calvet & Gullbring (1998). The modeling technique gives very encouraging results which closely matches with the previous findings obtained with very fragmented and complex approach.

High quality photometric and spectroscopic data of DF Tau stars have been collected over the last two years. Both the photometric and spectroscopic data have been reduced and the author has looked for variations in some emission lines strengths, which may represent the variation in the mass accretion process.

(P.S. Parihar)

V 410 Tau

The spectroscopic observations of the weak emission T Tauri star V410 Tau obtained over 1999/2000, 2002/2003 and seasons have been analyzed. The Hα emission strength showed rotational modulation during the 1999/2000 season in such a way that the emission strength is maximum at light minimum and vice versa. But the observations obtained during the 2003/2004 season do not follow the trend observed at earlier seasons. This can be due to the change in the location of chromospheric active regions.

It is planned to continue the observations of a few T Tauri stars over the coming seasons using the 2.3m VBT.

(M. V. Mekkaden & S. Muneer)

Post-outburst phase studies of McNeil's nebula

A detailed study of the post-outburst phase of McNeil's nebula (V1647 Orionis) showed a general decline of the brightness of exciting source. There is a significant variation of brightness about the mean decline, similar to other eruptive variables like EXors and FUors. The absorption component of Ca II infrared triplet shows general weakening of stellar wind. While the optical nebula is extended widely and predominantly to the north, the infrared nebula is relatively confined, and definitely extended to the south too, suggesting a large-scale disk-like structure surrounding the central source that hides the optical nebula. It is concluded that the central source is a pre-main-sequence star with its current outburst more like EXor rather than FUor event.

(D. K. Ojha, S. K. Ghosh*, A. Tej*, R. P. Verma*, S. Vig*, G. C. Anupama, D. K. Sahu, P. S. Parihar, B. C. Bhatt, T. P. Prabhu, G. Maheswar*, H. C. Bhatt, B. G. Anandarao*, & V. Venkataraman*)*

2.2 Evolved stars

R Coronae Borealis at the 2003 light minimum

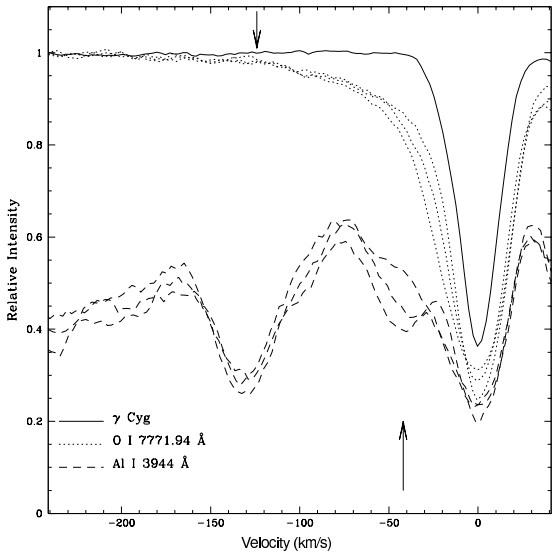


Figure 11: Seven spectra of the OI 7772 Å(top) and the AlI 3944 Åline of R CrB at maximum light from 1995 May 18 and September 30. The OI line from γ Cyg is shown (solid line). The velocity zero point is set at the centres of the OI and AlI lines.

A set of five high-resolution optical spectra of R CrB obtained in 2003 March is discussed. At the time of the first spectrum (March 8) the star was at V = 12.6, a decline of more than six magnitudes. By March 31, the date of the last observation, the star was at V = 9.3 was on the recovery to maximum light (V = 6). The 2003 spectra are compared with the extensive collection of spectra from the 1995-1996 minimum presented previously. Spectroscopic features common to the two minima include the familiar ones also seen in spectra of other RCBs in decline: sharp emission lines of neutral and singly-ionized atoms, broad emission lines including He I, [N II] 6583 Å, Na D, and Ca II H & K lines, and blueshifted aborption lines of Na D, and K I resonance lines. Prominent differences are seen between the 2003 and 1995-1996 spectra. The broad Na D and Ca H & K lines in 2003 and 1995-1996 are centred approximately on the mean stellar velocity. The 2003 profiles are fitted by a single Gaussian but in 1995-1996 two Gaussians separated by about 200 km s^{-1} were required. However, the He I broad emission lines are fitted by a single Gaussian at all times; the emitting He and Na-Ca atoms are probably not colocated. The C_2 Phillips 2-0 lines are detected as sharp absorption lines and the C_2 Swan band lines as sharp emission lines in 2003 but in 1995-1996 the Swan band emission lines were broad and the Phillips lines were undetected. The 2003 spectra show C I sharp emission lines at minimum light with a velocity changing in five days by about 20 km s^{-1} when the velocity of sharp metal lines is unchanged; the C I emission may arise from shock-heated gas. Reexamination of spectra obtained at maximum light in 1995 shows extended blue wings to strong lines with the extension dependent on a line's lower excitation potential; this is the signature of a stellar wind, also revealed by published observations of the He I 10830 Å line at maximum light. Changes in the cores of the resonance lines of Al I and Na D (variable blue shifts) and the Ca II IR lines (variable blue and red shifts) suggest complex flow patterns near the photosphere. The spectroscopic differences at the two mimima show the importance of continued scrutiny of the declines of R CrB (and other RCBs). Thorough understanding of the outer atmosphere and circumstellar regions of R CrB will require such continued scrutiny.

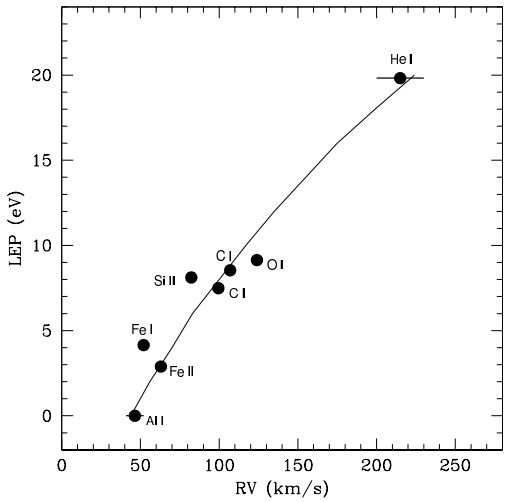


Figure 12: Wind velocity versus lower excitation potential of the line for spectra at maximum light from 1995 May to September. The data point for HeI is from Clayton et al. (2003)

(N. Kameswara Rao, David L. Lambert & M. D. Shetrone*)*

An analysis of the ultraviolet spectra of extreme helium stars and new clues to their origins

Abundances of about 18 elements including the heavy elements Y and Zr are determined from Hubble Space Telescope Imaging Spectrograph. Ultraviolet spectra of seven extreme helium stars (EHes):

LSE 78, BD +10 2179, V1920 Cyg, HD 124448, PV Tel, LS IV-1 2, and FQ Aqr. New optical spectra of BD +10 2179, V1920 Cyg, and HD 124448 were analyzed, and the published line lists of LSE 78, HD 124448, and PV Tel were analyzed afresh. The abundance analyses are done using LTE line formation and LTE model atmospheres especially constructed for these EHes. The stellar parameters derived from an EHe's UV spectrum are in satisfactory agreement with those derived from its optical spectrum. Adopted abundances for the seven EHes are from a combination of the UV and optical analyses. Published results for an additional 10 EHes provide abundances obtained in a nearly uniform manner for a total of 17 EHes, the largest sample on record. The initial metallicity of an EHe is indicated by the abundance of elements from Al to Ni; Fe is adopted to be the representative of initial metallicity. Iron abundances range from approximately solar to about 1/100 solar. Clues to EHe evolution are contained within the H, He, C, N, O, Y, and Zr abundances. Two novel results are (1) the O abundance for some stars is close to the predicted initial abundance yet the N abundance indicates almost complete conversion of initial C, N, and O to N by the CNO cycles; and (2) three of the seven stars with UV spectra show a strong enhancement of Y and Zr attributable to an s-process.

The observed compositions are discussed in light of expectations from accretion of an He white dwarf by a C-O white dwarf. Qualitative agreement seems likely except that a problem may be presented by those stars in which the O abundance is close to the initial O abundance.

(Gajendra Pandey, David Lambert, Simon Jeffery*, & N. Kameswara Rao)*

FIP effect in evolved stars semi-regular variables and RV Tauri stars

The First Ionization Potential (FIP) effect, i.e., the surface abundances of elements are strongly correlated with their first ionization potential, in the sense that elements with lower ionization potential are depleted more than the elements with highier ionization potential, was first discovered in the evolved stars of RV Tauri type from the analysis of spectra obtained from VBT Echelle Spectrometer (Rao & Reddy, MNRAS, 2005). This is an indication of the magnetically controlled stellar wind operating from the photosheres of these evolved stars, a phenomenon similar to that on the Sun. The authors have surveyed systematically several other cool semi-regular variables and RV Tauri stars (of T_{eff} around 4000 K) for the presence of FIP effect from their derived surface elemental abundances using high resolution spectra from VBT echelle spectrometer complimented by spectra from McDonald Observatory.

Stars V Pyx and possibly Z Aur show the presence of FIP effect operating. Spectra at different phase (in pulsation) have been obtained for V Pyx and CE Vir. The analysis is in progress.

(N. Kameswara Rao, Eswar Reddy & D. Lambert)*

Hydrogen deficient stars

VBT Echelle spectrometer has been extensively used to obtain high resolution spectra of several RCB stars at maximum, to study their stellar wind properties. Two hydrogen deficient binaries KS Per and Upsilon Sgr have also been monitored with echelle spectra to study orbit related changes and abundances.

The variable hydrogen deficient stars that suddenly undergo drops of several magnitude in light due to circumstellar dust condensation have been monitored spectroscopically with HCT using HFOSC. Several stars, e.g., DY Per, SU Tau, SV Sge, FG Sge etc., during light minima have been studied. They have also been observed at maximum light to compare and moniter the changes. ES Aql, U Aqr, Z Umi, HD 182040, HD 137613 etc.

Some of the hydrogen deficient nebulae have also been observed. The planetary nebula around FG Sge has been extensively observed when the star is faint and undergoing a deep minimum -thus providing uncontaminated spectra of the nebula.

Several carbon stars at high galactic latitude have also been observed with HCT. This programme has been going on for a few years in order to cover sufficient numbers for the study. It is hoped to observe fainter members in the coming seasons since the autoguider is operating on HCT now.

(N. Kameswara Rao, Gajendra Pandey & Eswar Reddy)

High resolution spectroscopy of weak G-band stars and other interesting objects

Several high resolution spectra have been obtained with VBT echelle of weak G- band stars in the field, particularly the objects in the southern hemisphere with a view to study their abundance patterns and to understand the phenomenon of this weak G-band

nature (carbon depletion). It is planned to study a large number of these objects utilizing the spectra already obtained at McDonald observatory of the northern and fainter objects.

(N. Kameswara Rao, Gajendra Pandey, Eswar Reddy & David Lambert)*

Abundance analysis of the cool extreme helium star LSS 3378

Abundance analysis of the cool extreme helium (EHe) star LSS 3378 is presented. The abundance analysis is done using local thermodynamic equilibrium (LTE) line formation and LTE model atmospheres constructed for EHe stars. The atmosphere of LSS 3378 shows effects of dredge-up due to H-burning, He-burning, and s-process nucleosynthesis. The derived abundances of iron peak and alpha-elements indicate the absence of selective fractionation or any other processes that can distort chemical composition of these elements. Hence, the Fe abundance $[\log(Fe) = 6.1]$ is adopted as an initial metallicity indicator. The measured abundances of LSS 3378 are compared with those of R Coronae Borealis (RCB) stars and with rest of the EHe stars as a group.

(Gajendra Pandey & B. Eswar Reddy)

Abundance analysis of evolved stars of high galactic latitude

Abundance analysis of a sample of high galactic latitude supergiants have been carried out in search of evolved stars. It is found that HD 27381 has atmospheric parameters and an abundance pattern particularly C,N,O very similar to that of the post-AGB star HD 107369. These two stars with striking carbon deficiency [C/Fe] nearly -1.0 provide an observational link with hot Post-AGB stars showing very large carbon deficiency of -2.0 dex or more. Another Post-AGB candidate HD 137569 shows selective depletion of refractory elements Si, Mg and Fe while sulfur exhibits near solar abundance. Considering the fact that HD 137569 is known to be a spectroscopic binary, the observed chemical peculiarities could be explained by the dust-gas separation occurring in circumbinary envelope. Other candidate post-AGB stars HD 10285 and HD 25291 are moderately metal-poor and show the influence of mixing that has brought the products of NeNa cycle to the surface. It is found that the high velocity B type star HD 172324 shows moderate deficiency of Fe group elements but the CNO abundances are very similar to that of disk B supergiants. The observed variations in the radial velocities, transient appearance of emission components in hydrogen line profiles, and doubling of O I lines at 7774Å support the possibility of this star being a pulsating variable or a binary star.

(Sunetra Giridhar & Armando Arellano Ferro)*

A high resolution spectral analysis of three carbon enhanced metal-poor stars

The results of an analysis of high-resolution spectra ($R \sim 50\,000$) of two Carbon-Enhanced Metal-Poor (CEMP) stars, HE 1305+0007 and HE 1152−0355, selected from the Hamburg/ESO prism survey, and of the classical CH star HD 5223, obtained with the Subaru Telescope High Dispersion Spectrograph, are presented. All of these stars have relatively low effective temperatures (4000K – 4750K) and high carbon abundances, which result in the presence of very strong molecular carbon bands in their spectra. The stellar atmospheric parameters for these stars indicate that they have surface gravities consistent with present location on the red-giant branch, and metallicities of [Fe/H] = −2.0 (HE 1305 + 0007, HD 5223) and [Fe/H] = −1.3 (HE 1152−0355). In addition to their large enhancements of carbon ([C/Fe] = +1.8, +1.6 and +0.6. respectively), all three stars exhibit strong enhancements of the $s-$process elements relative to iron.

HE 1305+0007 exhibits a large enhancement of the 3rd-peak $s-$process element lead, with [Pb/Fe] = +2.37, as well as a high abundance of the $r-$process element europium, [Eu/Fe] = +1.97. The 2nd-peak s-process elements Ba, La, Ce, Nd, and Sm are found to be more enhanced than the 1st-peak s-process elements Zr, Sr and Y. Thus, HE 1305+0007 joins the growing class of the so-called "LeadStars", and also the class of objects that exhibit the presence of both $r-$process and $s-$process elements, the CEMP-r/s stars. The large enhancement of n-capture elements exhibited by HE 1152−0355 and HD 5223 are more consistent with the abundance patterns generally noticed in CH stars, essentially arising from pure $s-$process nucleosynthesis. The elemental abundance distributions observed in these stars are discussed in the light of existing theories of CH star formation, as well as the suggested formation scenarios of the CEMP-r/s group.

(A.Goswami, A. Wako, T.C. Beers*, N. Christlieb*, J. Norris*, S.G. Ryan* & S. Tsangarides*)*

Lithium abundances for early F stars : New observational constraints for lithium dilution

To investigate possible correlation between Li abundances and rotational velocities among evolved F-G stars, the authors studied a large sample of early F stars. They obtained high resolution spectra centred on the Li 6707A of 73 early F stars with the Aurelie spectrograph on the 1.52m telescope of the Observatoire de Haute Provence, France. Physical parameters and lithium abundances are derived for 73 early F stars, often for the first time using spectrum synthesis and LTE model atmospheres. The authors have analysed the position of these stars in the H-R diagram based on Hipparcos data using stellar evolutionary tracks and we discuss their lithium abundances and projected rotational velocities.

The observed stars are mostly on the turn-off, with masses between 1.5 and 2.0 solar masses. The stars with measured A(Li) abundance show high lithium content, most of them with abundance near the cosmic value. The A(Li) versus $V \sin i$ diagram shows the same trend as reported in previous studies: fast rotators ($V \sin i > 30$ km/sec) are also stars with high lithium content, whereas slow rotators present a wide range of values of A(Li), ranging from no detected lithium to the cosmic value.

(G. Jasniewiciz, A. Recio-Blanco*, P. de Laverny*, M. Parthasarathy & J. R. De Medeiros*)*

High resolution spectroscopy of the high velocity hot post-AGB star LS III +52°24 (IRAS 22023+5249)

The authors present the high resolution spectrum of the high velocity hot post-AGB star LS III +52°24 (IRAS 22023+5249). The spectrum covers the wavelength range from 4290−9015Å at a resolution of R = 52000. They identify absorption lines of He I, C II, C III, N II, O II, Al III and Si III and emission lines of He II, C II, N II, O I, Al III, Si II, Fe I, Fe II, Fe III and [Fe III] in the spectrum. The presence of [N II], [O I] and [S II] lines and the absence of [O III] indicate the presence of a low excitation nebula around the central hot post-AGB star. Four absorption components were identified in the profile of the Na I lines of which one may be of circumstellar origin and the rest interstellar. The Balmer lines show P-Cygni profiles indicating ongoing post-AGB mass loss. The absorption line spectrum has been analysed using both LTE and non-LTE model atmosphere techniques to determine stellar atmospheric parameters and chemical composition of the star. From the absorption lines, we derived heliocentric radial velocity of −145 kms^{-1}. The authors conclude that LS III +52°24 is a high velocity hot post-AGB star rapidly evolving into a young low excitation planetary nebula.

(G. Sarkar, M. Parthasarathy & P. García-Lario*)*

2.3 Star cluster

NGC 7419 - A cluster with episodic star formation

A photometric and spectroscopic study of the young open cluster NGC 7419 was done, which is known to host a large number of classical Be stars for reasons not well understood. Based on CCD photometric observations of 327 stars in UBV passbands, the reddening of the cluster is estimated to be, E(B−V) = 1.65±0.15 mag and the distance = 2900 ± 400 pc. The turn-off age of the cluster was estimated as 25± 5 Myr using isochrone fits. A large fraction of stars (42%) was found to have NIR excess and their location in the diagram was used to identify them as intermediate mass pre-MS stars. The isochrone fits to pre-MS stars in the optical colour-magnitude diagram showed that the turn-on age of the cluster is 0.3 –3 Myr. The stars with H_α emission were found to have NIR excess and occupied the location of Herbig Be stars in the NIR colour-colour diagram. This raised the suspicion that these stars may be intermediate mass pre-MS stars and not classical Be stars. The spectra of the emission line stars were also found to be very similar to the Herbig Be stars and their pre-MS age was estimated to be between 0.2 to 1 Myr. Thus the emission line stars are more likely to be the Herbig Be type intermediate mass pre-MS stars and not classical Be stars. These stars are found in the 25 Myr old cluster due to a recent star formation in the vicinity of the cluster, which is also responsible for the large fraction of pre-MS stars in the cluser. Thus NGC 7419 is an open cluster with episodic star formation.

(A. Subramaniam, Blesson Mathew, B.C. Bhatt & S. Ramya)

Stellar content of two young open clusters: NGC 663 and NGC 654

UBVRI CCD photometry in a wide field around two young open clusters NGC 663 and NGC 654 have been carried out. The photometric data is used to

construct the colour-colour and colour-magnitude diagrams, from which the authors investigate the reddening, age, mass, and evolutionary states of stellar contents in these clusters. The reddening across the cluster regions is found to be variable. Both clusters are situated at the same distance of 2.4 kpc. Star formation in both clusters is found to be a continuous process. In the case of NGC 663, star formation seems to have taken place sequentially, in the sense that formation of low-mass stars precedes the formation of most massive stars. Whereas, in the case of NGC 654, formation of low mass stars did not cease after the formation of most massive stars in the cluster.

(A. K. Pandey, K. Upadhyay*, K. Ogura*, R. Sagar*, V. Mohan*, H. Mito*, H. C. Bhatt & B. C. Bhatt)*

Colour-magnitude diagram for the α Per cluster

With the recent SuperCOSMOS survey, the membership of the young, nearby open cluster α Per has now risen to over 500 stars with a rich assemblage of low mass stars reaching faint magnitudes down to V = 21.0. An attempt is made to construct a colour-magnitude diagram for these stars corrected for reddening individually. This has been effected by using a scheme evolved by Maheswar Gopinathan to determine distance to dark clouds/cometary globules based on photometry of stars lying in their line of sight. Treating A_v as a free parameter over a large range in small steps, intrinsic colours (V-R), (V-I), (V-J), (V-H), (V-K) are computed from the observed ones and compared with the intrinsic colours known for unreddened main sequence stars of various spectral types from theory/observations.The best fit with a minimum value of χ^2 then yields A_v, spectral type, M_v and distance for each star. Using the same methodology, an HR diagram for the α Per cluster has been reconstructed which clearly has a much reduced observed spread in V-M_v. However, theoretical isochrones for various ages superposed on the finite spread still persisting on the HR diagram strongly suggest that star formation must have taken place in α Per over an extended time interval; a large number of low mass stars perhaps formed as recently as 10-20 Myrs ago in contrast to the estimated age of the cluster of 50-80 Myr.

(Sushma Mallik & G. Maheswar)

2.4 RR Lyrae

RR Lyrae stars in the inner Large Magellanic Cloud: A new puzzle

RR Lyrae stars belong to the Population-II objects and are thought to be older than 9 Gyr. These stars thus trace the halo structure of any galaxy. Since the Large Magellanic Cloud (LMC) is a face-on galaxy, its halo has evaded any detection so far. The distribution of these stars, projected on the inner LMC, has been studied with the aim of estimating the LMC halo properties. They were expected to show a spherical distribution, but the author found an elongated distribution, similar to the stellar distribution in the bar of the LMC, fitted better. This result directly indicated that the RR Lyrae stars are located in the disk/bar and not in the halo. The scale-height of the RR Lyrae stars, is estimated to be 3.0 $\pm$ 0.9 kpc, which on the other hand showed that these stars are located in the halo. Thus the RR Lyrae stars in the inner LMC show a puzzling combination of disk-like distribution and halo-like location. This can arise if the LMC went through early mergers. This would still require the RR Lyrea stars to have formed in the disk and then dispersed in the halo.

(A. Subramaniam)

CCD photometry of RR Lyrae in globular clusters

CCD photometry has been carried out on Globular cluster M2 using data from 2-m HCT at IAO, 1-m of VBO, and 2-m of SPM, Mexico during 2004-2005. CCD photometry in V and R filters of globular cluster M2 has been used to calculate accurate periods for most variables and new Ephemerids have been calculated. The authors have detected clear light variations in eight stars in the field of M2 not previously reported as variables. The locations of variables in M2 is shown in Figure 13. The images were obtained with 2 m HCT of the IAO, India. Pipeline procedure of Dan Bramich involving differential photometry by the image subtraction method has enabled detection of new faint variables. Detailed identification of new variables are shown in individual image stamps contained in Figure 14.

The light curve decomposition of RR Lyra stars has been used to derive the mean physical parameters [Fe/H] of -1.5, Log L of 1.65 $L_\odot$ and M_V of 0.71. The estimated mean distance to the cluster is 10.49$\pm$ 0.15 kpc. With these results, M2 appears to follow the general globular cluster sequence Oost-

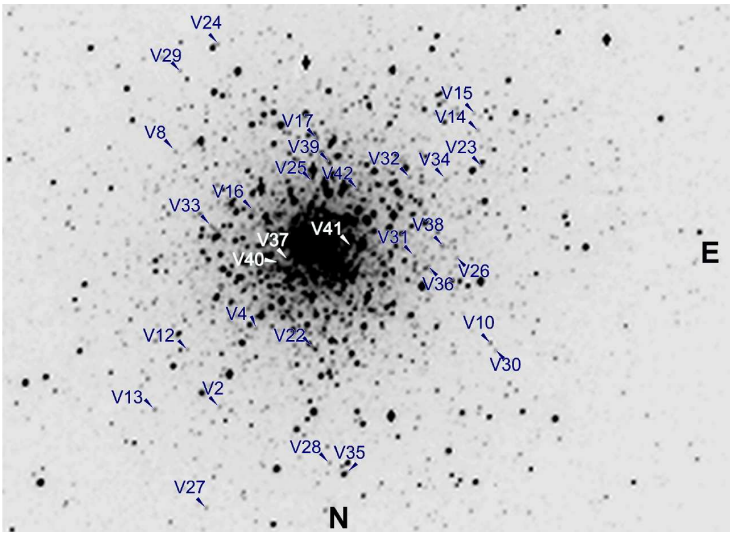


Figure 13: The image of M2 in V filter obtained with the 2m HCT showing the location of RR Lyra variables.

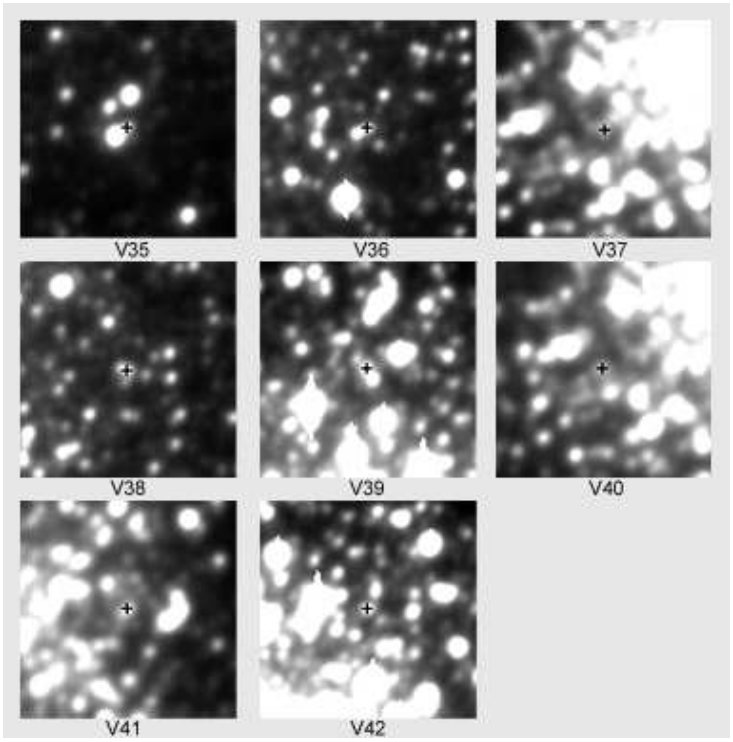


Figure 14: The individual stamps for the new variables in M2.

erhoff type, mass, luminosity and temperature all as a function of metallicity. Mean relationships for masses, luminosities, T_{eff} and M_V as a function of the metallicity for a family of globular clusters are derived.

(C. Lázaro, A. Arellano Ferro*, M. J. Arévalo*, D. M. Bramich*, S. Giridhar, & E. Poretti*)*

2.5 X-ray binary, binaries, RS CVn

SS 433: Results of a Recent Multi-wavelength Campaign

A multiwavelength campaign was conducted in 2002 September-October, to observe SS 433 using the Gi-

ant Meter Radio Telescope, Pune, the Infrared (IR) telescope, Mt. Abu, the ARIES telescope, Nainital for optical photometry, the 2.34 meter Vainu Bappu Telescope, Kavalur for spectral measurements and the Rossi X-ray Timing Explorer for X-ray observations. The sharp variations in intensity on time scale of a few minutes in the X-ray, IR, and radio wavelengths have been noticed. Differential photometry in the IR observations clearly indicates significant intrinsic variations on short time-scales of minutes throughout campaign. Combining the results for these wavelengths, a signature of delay of about two days between IR and radio signals was noticed. The X-ray spectrum yielded double Fe line profiles corresponding to red and blue components of the relativistic jet. The broad band spectrum averaged over the campaign duration is also presented.

(S. K. Chakrabarti, B. G. Anandarao*, S. Pal*, S. Mondal*, A. Nandi*, A. Bhattacharyya*, Ram Sagar*, J. C. Pandey*, A. Pati, & S K Saha)*

Close binary stars

The speckle interferometer is being used at the 2.34 meter Vainu Bappu Telescope (VBT), Kavalur regularly to record speckle-grams of close binary stars ($\rho < 1''$). Data analysis of a few close binary stars along with the respective reference stars have been carried out. Hundreds of frames of each of these stars are scanned carefully and are analyzed with the power spectrum followed by the autocorrelation algorithms developed by Saha and Maitra (2001, Ind. J. Phys. **75B**, 391) to determine the separation between the primary and its companion.

(S.K. Saha)

Obtaining binary star orbits from interferometric data

Speckle interferometry can be efficiently used to obtain diffraction limited images of close binary systems. An algorithm based on least square technique and Cracovian matrix elimination developed by A. V. Raveendran is used to obtain orbits of several close binary systems. These orbits have been constructed from the interferometric data obtained from various telescopes across the world since 1953, to illustrate utility of this method.

(S. K. Saha & D. Som)*

Search for new eclipsing RS CVn binaries

About fifty eclipsing binaries are classified as eclipsing RS CVn stars and identifying more candidates using eclipse mapping will undoubtedly help to explore star-spot related activities. One spectroscopic survey program has been started to search for new eclipsing RS CVn candidates from the recently released ASAS survey results. A sample of 180 most likely RS CVn candidates have been observed using medium resolution spectrograph available with HCT and VBT. The data reduction of 180 stars has just been completed and more than 30 stars have been identified as chromospherically active, based on the H_α observations. One star from the sample, HD69820 turns out to be an eclipsing Ae type star, an interesting candidate to explore circumstellar disk.

(P.S. Parihar)

2.6 ISM

Interstellar gas and dust

The authors have focused around their continuing interest in interstellar gas and dust and on the diffuse ultraviolet radiation field. Using data from the Far Ultraviolet Spectroscopic Explorer, they have placed the first constraints on the optical properties of interstellar grains in the far ultraviolet, where most of the energy of the interstellar radiation field lies.

The authors have obtained data from the Galaxy Evolution Explorer and are using them to study the properties of interstellar dust in the near ultraviolet. When distant galaxies are looked at, only their integrated light, including direct starlight as well as starlight reprocessed by interstellar dust are seen. Observations will be used as a template for the emission from other galaxies.

(Jayant Murthy, N. Sujatha, & P. Shalima)

Galactic star forming regions

A programme is initiated to study galactic star-forming regions, using HCT data in the optical-infrared, far-infrared data from the TIFR balloon-borne telescope, radio data from the GMRT, and data from archives and other sources.

A multiwavelength study of IRAS 06055+2039 showed that it is a typical embedded cluster with several high-density clumps. The shocked molecular hydrogen forms an arc towards north-east of the cen-

tral IRAS point source. The total mass of the cloud is estimated to be 7000-9000 $M_\odot$.

(A. Tej, D. K. Ojha*, S. K. Ghosh*, V. K. Kulkarni*, R. P. Verma*, S. Vig* & T. P. Prabhu)*

Bipolar planetary nebulae

The bipolar planetary nebula Menzel 3 has been modelled in an open geometric configuration for the first time using new Infrared Space Observatory observations along with all other available data.

The bipolar planetary nebula Hubble 5 is being currently modelled. New observations from the Infrared Space Observatory are being analyzed along with other available data. A new approach to interpret the complete spectrum is being undertaken.

(R. Surendiranath & S. R. Pottasch)*

Planetary Nebulae in Clusters

Although more than 90% stars in the Galaxy have evolved through a Planetary Nebula phase, and a substantial number of stars are members of Star Clusters, the incidence of Planetary Nebulae in Clusters is a rare phenomenon. A theoretical analysis of the probability of incidence of PN in Clusters shows that the rate of incidence is crucially dependent on the age and mass of the Cluster. While the rate is directly proportional to the mass of the Cluster, the sense of the dependence on the age is quite the opposite. It is less likely to find a PN in an old Cluster. Our theoretical estimates agree with the observed number of PN found in the Globular Clusters of our Galaxy and in the Galactic Halo.

(J. K. Baliga & D. C. V. Mallik)

The case of NGC 2818

In view of the rarity of the incidence of a PN in an Open Cluster, the case of NGC 2818, a PN associated with an Open Cluster of the same name is rather exceptional. The Cluster with its associated nebula was spotted first by John Herschel. In 1972 Tifft et al. (1972, MNRAS, **158**, 47) undertook a photometric and spectroscopic study of the Cluster and the Nebula. They derived a distance to the Cluster of 3.2 kpc. Independent radial velocity measurements of the PN and the members of the Cluster seemed to agree with the view that the nebula is associated with the Cluster.

There has been no independent distance measurement of the PN to establish its membership of the Cluster. At $b = 8.6°$, it is far out of the plane of the Galaxy to preclude the application of either the *Extinction Method* or the *H I Absorption Method* to an estimate of its distance. A recent paper by Mermilliod et al (2001, A&A, **375**, 30), which gave the most accurate distance and radial velocity determinations to the Cluster has cast some doubt on the association of the PN with the Cluster, based on discrepancies in the radial velocity estimates. But there are doubts about the radial velocity they attribute to the PN.

Using a new method due to Maheswar & Bhatt, the authors have re-estimated the distance to the Cluster NGC 2818 making use of six-colour photometry. They confirm the distance determined by Mermilliod et al.

The only way to settle the issue of the membership of the PN to the Cluster is to make an independent distance estimate to the Planetary Nebula. The only method that seems feasible is the *Expansion Parallax Method* using radiocontinuum images of the PN to detect its angular expansion. Since the nebular expansion velocity is large, there should be detectable angular expansion over a reasonable time base-line. Work is in progress to obtain VLA data to determine the expansion parallax of PN NGC 2818.

(D. C. V. Mallik & J. K. Baliga)

2.7 Brown dwarfs and extra-solar planets

Polarization from extra-solar planets

The authors calculate the degree of linear polarization of radiation from stars having planets that may not be resolved spatially. They assume single scattering by water and silicate particles in the planetary atmosphere. The dilution of the reflected polarized radiation of the planet by the unpolarized stellar radiation and the effect of oblateness of the planet as well as its elliptical orbit are included. A chemical equilibrium model is employed to estimate the number density of water and silicate condensates and the degree of linear polarization at R band of starlight is calculated as a function of (1) mean size of condensates, (2) planetary oblateness, (3) inclination angle, (4) phase angle, (5) orbital eccentricity e and (6) the epoch of periastron passage. It is shown that the polarization profile alters significantly at all inclination

angles when an elliptical orbit is considered and the degree of polarization peaks at the epoch of periastron passage. The authors predict that detectable amount of linear polarization may arise if the planetary atmosphere is optically thin, the mean size of the condensates is not greater than a few microns and the oblateness of the planet is as high as that of Jupiter.

(*Sujan Sengupta & Malay Maiti*)

Polarization from Brown dwarfs

Degree of polarization resulting from dust scattering in a rotation-induced oblate photosphere of an L dwarfs for dwarfs of spectral types L0 to L6 is calculated. Assuming that forsterite is the main condensate, the atmospheric dust distribution is derived for different spectral types based on a chemical equilibrium model. The degree of polarization at optical is then calculated using a single scattering model. The expected linear polarization at optical is found to peak at around spectral type L1. For a fixed rotational velocity, the degree of polarization decreases from hotter to cooler objects. However, with the increase in mean grain size, the degree of linear polarization reduces significantly. The authors fit the recently observed linear polarimetric data of L dwarfs and find that single dust scattering model coupled with the chemical equilibrium models of condensates is consistent with the observational results.

(*Sujan Sengupta & Sun Kwok**)

Differential photometry of Brown Dwarfs : observation of variability at R band

Photometric variability of L dwarfs in R band is reported for the first time. Out of three L1 dwarfs (2MASS 1300+19, 2MASS 1439+19, and 2MASS 1658+70) observed, R band variability has been detected in 2MASS 1300+19 and 2MASS 1439+19. The observations were made using the 2 m Himalayan Chandra Telescope. The objects exhibit variability of amplitude ranging from 0.01 mag to 0.02 mag. Object 2MASS 1658+70, turns out to be non-variable in both R and I band. However, more observations are needed to infer its variability. No periodic behaviour in the variability is found from the two L1 dwarfs that are variable. All the three L1 dwarfs have either negligible or no H_α activity. In the absence of any direct evidence for the presence of sufficiently strong magnetic field, the detection of polarization in the optical band suggest the presence of dust in the atmosphere of L dwarfs. The authors suggest that the observed R band photometric variability is most likely due to atmospheric dust activity.

(*Malay Maiti, Sujan Sengupta, P. S. Parihar & G. C. Anupama*)

2.8 Exploding stars

Nova V1494 Aquilae 1999 no. 2

The optical and near-IR spectra of the fast nova V1494 Aquilae 1999 no. 2 obtained during the early decline, transition and nebular phases were analysed. During this period, the nova evolved in the $P_{fe}P^{o}_{fe}C_{o}$ sequence. The transition from the optically thick wind to a polar blob-equatorial ring geometry was seen in the evolution of the spectral line profiles. Evidence of density and temperature stratification in the nova ejecta was found from the spectra.

(U. S. Kamath, G. C. Anupama, N. M. Ashok, Y. D. Mayya*, & D. K. Sahu)*

2006 outburst of RS Ophiuchi

The recurrent nova RS Oph was detected in outburst on 2006 Feb 12.9 and monitored using the VBT as well as the HCT. Monitoring the radio emission from the source was initiated using the GMRT. The radio observations are concerted with observations at frequencies > 1.5 GHz using the VLA, MERLIN and EVN. For the first time, radio emission was detected in frequencies below 1 GHz. Observations in the optical and radio are continuing.

(G. C. Anupama, N. G. Kantharia , D. K. Sahu, S. Muneer, G. Pandey, B. C. Bhatt, P. S. Parihar, & G. Selvakumar)*

Monitoring low redshift supernovae

The programme to monitor low-redshift supernovae is continuing on the HCT. The type Ia supernovae SN 2005cf, SN 2005hk, SN 2006D and SN 2006X, the type II P supernova SN 2005cs, the type Ib SN 2005bf and the type IIn supernova SN 2005kd were monitored. The monitoring of SN 2005kd is continuing. Data are being analysed.

(G. C. Anupama, D. K. Sahu, G. Uday Kumar, T. P. Prabhu)

SN 2004et

The type II P supernova SN 2004et that occurred in the nearby galaxy NGC 6946 was monitored both spectroscopically and photometrically using the 2m HCT. A few spectra were also obtained with the 1m Carl Zeiss telescope. The observations span a time range of 8 days to 541 days after explosion. The late time bolometric luminosity and the Hα luminosity in the nebular phase indicate that $0.056 \pm 0.02 M_{\odot}$ of ^{56}Ni was synthesised during the explosion. The plateau luminosity, its duration and the expansion velocity of the supernova at the middle of the plateau indicate an explosion energy of $E_{\rm exp} = 1.20^{+0.38}_{-0.30} \times 10^{51}$ ergs, with $20^{+7}_{-5} M_{\odot}$ mass ejected during the explosion. The pre-supernova radius $R_{\rm psn}$ is estimated to be $496^{+93}_{-74} R_{\odot}$. The estimate of the ejected mass, along with some conservative assumptions about mass loss and the mass of neutron star indicate the mass of the progenitor star to be $22 \pm 7\, M_{\odot}$. The late time light curve and the evolution of the [OI] and Hα emission line profiles indicate the possibility of an early dust formation in the supernova ejecta.

(D. K. Sahu, G. C. Anupama, S. Srividya & S. Muneer)

SN 2005bf

The peculiar type Ib supernova, SN 2005bf, was observed around maximum using the 2-m HCT. It was found to be unique and peculiar. The maximum phase was broad and occurred around 2005 May 7, about forty days after the shock breakout. SN 2005bf had a peak bolometric magnitude $M_{\rm bol} = -18.0 \pm 0.2$: while this was not particularly bright, it occurred at an epoch significantly later than other SNe Ibc, indicating that the SN possibly ejected ~ 0.25 M$_{\odot}$ of ^{56}Ni, which is more than the typical amount. The spectra of SN 2005bf around maximum were very similar to those of the Type Ib SNe 1999ex and 1984L about 25-35 days after explosion, displaying prominent He I, Fe II, Ca II H & K and the near-IR triplet P Cygni lines. Except for the strongest lines, He I absorptions were blueshifted by < 6500 km s^{-1}, while Fe II by $\sim 7500 - 8000$ km s^{-1}. No other SN Ib has been reported to have their Fe II absorptions blueshifted more than He I ones. Relatively weak Hα and very weak Hβ also possibly existed, blueshifted by $\sim 15,000$ km s^{-1}. It was suggested that SN 2005bf was the result of an explosion of a massive He star, possibly with a trace of hydrogen envelope. Detailed theoretical modelling of the light curve evolution and the spectra (Tominaga et al. 2005, *ApJ*,**633,** L97) suggest that the progenitor was initially massive (25-30 $M_{\odot}$), possibly a WN star. The properties of SN 2005bf resemble those of the explosion of Cassiopeia A.

(G. C. Anupama, D. K. Sahu, J. Deng, K. Nomoto*, N. Tominaga*, M. Tanaka*, P. A. Mazzalli* & T. P. Prabhu)*

γ-ray burst sources

Monitoring of the optical afterglows of GRB events using the 2 m HCT initiated with participants from IIA, RRI and ARIES, Naini Tal is continuing.

The optical counterparts of several gamma-ray burst sources detected by SWIFT have been observed using the HCT. These include GRB 050502B, GRB 050525A, GRB 050730, GRB 050828, GRB 051021, GRB 051022, GRB 051028, GRB 051109A, GRB 051111A, GRB 051117B and GRB 060218.

(G. C. Anupama, Ram Sagar, D. Bhattacharya*, D. K. Sahu, P. S. Parihar, B. C. Bhatt, T. P. Prabhu, P. Bama, S. Srividya, N. K. Chakradhari & S. Vanniarajan)*

2.9 Galactic disk

Decomposition of the galactic disk: Clues to its formation

Observational spectroscopy and the analysis of quantitative abundances in stellar atmospheres of large number of stars in the Milky Way have obvious advantages to understand the Galaxy formation. Our recent studies in two parts (Reddy et al. 2003; Reddy et al. 2006) form a major contribution to the field. So far this is the largest survey of high resolution spectroscopic analysis of 26 elemental species in 400 unevolved F-G-K disk stars.

Abundances have been obtained for 25-27 elements representing the major sites of stellar nucleosynthesis (Type-II SN, Type Ia SN, and AGB stars). In Figure 15, average abundance of four α elements (Mg, Si, Ca, and Ti) relative to Fe is plotted as a function of [Fe/H]. α- elements are known to be produced only in the short-lived SN II. On the other hand Fe is primarily synthesized in long-lived SN I. The ratio of the SN I and SN II products trace the Galactic chemical evolution. Note the clear distinction in ratios of [α/Fe] for thin and thick disk stars.

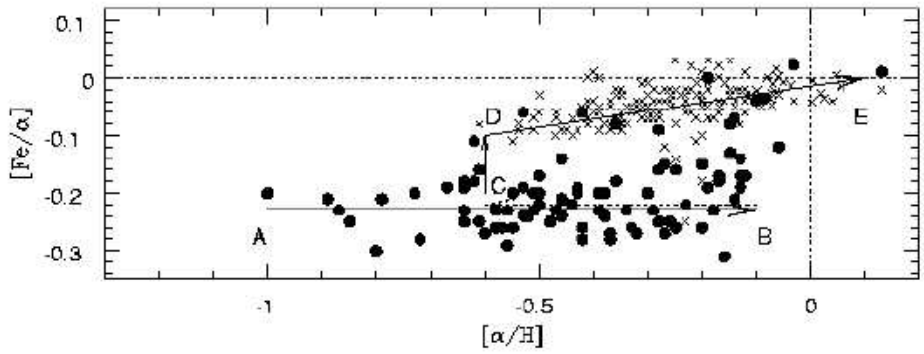


Figure 15: Plot of [Fe/α] versus [α/H] for thick disk stars (filled symbols) and the thin disk stars (crosses). Horizontal and the vertical lines in the plot represents solar ratios.

Thick disk stars at given [Fe/H] are found to have larger ratios compared to thin disk in the [Fe/H] range of -1.0 to -0.3 dex. Thus, the results unambiguously rule out the theories that thick disk is a mere metal-poor extension of the thin disk. The ratios [α/Fe] (Figure 15) show no trend with [Fe/H] suggesting thick disk formed much faster in about 1-2 Gyrs (no evidence of mixing of products produced in long lived SN I).

A novel result regarding Galactic disk formation and evolution is shown in Figure 15. The track "A-B" represent thick disk evolution from point "A" to "B". Near horizontal line, without trend, may suggest thick disk formed much quicker. The authors suppose merger event (when the Galaxy was just 4-5 Gyrs old) took place at point "B". The composition of thick disk gas was diluted by a merger of very metal-poor ([Fe/H] ≈ -2.0) but gas rich dwarf galaxy. The point "C" corresponds to the initial composition of the thin disk. The track "C-D" represents the pollution by delayed SN I products (more Fe little/no α elements) prior to the star formation in the thin disk. Finally, the composition of the gas (and stars) of the new thin disk evolves along the track D to E in response to contributions by the SN II, SN I, and AGB stars.

(B. Eswar Reddy, David L. Lambert, & Carlos Allende Prieto*)*

Stellar streams in the galactic disk

The authors continue to study the chemical composition of samples of a few hundred stars belonging to various kinematic groups in the Galaxy. Following the recent elemental abundance surveys of Galactic thin and thick disk components, the authors had proposed to study stellar streams in the Galaxy to understand its formation, and evolution in a more comprehensive way. Our proposal to obtain the required high resolution spectra was accepted by McDonald observatory.

Observational scrutiny of the Galactic disk offers many advantages which are not available when examining external spiral galaxies. In particular, it is possible to obtain chemical compositions for stars in the solar neighborhood with different kinematical properties. The stars are sufficiently bright so that detailed abundance analyses is possible and they are close enough for accurate proper motions (and radial velocities) to be obtained from which to derive the space velocities. Combining compositions and kinematics enables the chemical history of distinct populations to be traced. Our principal goal here is to make a more detailed chemical mapping of the disk, and in particular, to explore the compositions of stars in stellar streams, also called moving groups and super clusters.

(B. Eswar Reddy & David L. Lambert)*

2.10 Active galaxies

Hot gaseous outflows in Seyfert galaxies

The hot gaseous outflows in Seyfert galaxies are being studied via spectroscopic observations in the far-ultraviolet regime using the Far-Ultraviolet Spectroscopic Explorer telescope. The authors particularly targeted the Seyfert galaxies of type 2, which are those purportedly obscured by optically thick material in the line of sight, in order to contrast their properties with those of type 1. The authors find that the OVI line width is narrow in them, as would be expected for Seyferts with obscured nuclei, and also that the doublet ratio appears to differ from that in the Seyferts purportedly oriented pole-on.

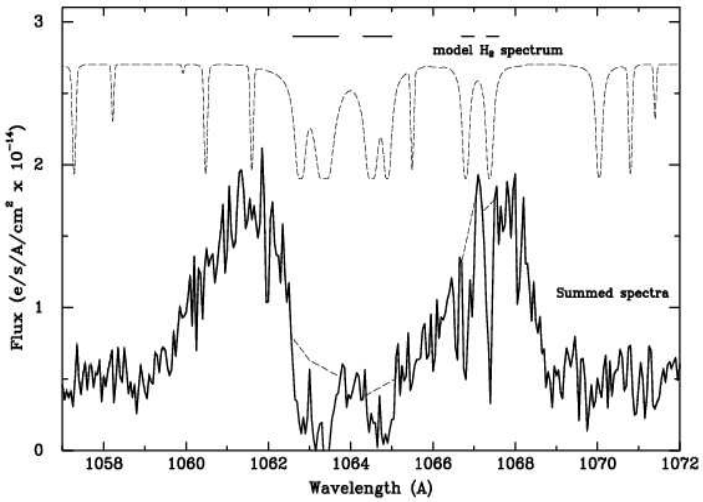


Figure 16: The O VI doublet region of the *FUSE* spectrum of Mrk 533. Data from the *FUSE* detectors LiF1A & LiF2B which give redundant coverage of this region have been combined in the plot (lower panel). On top in this panel, an example of a model absorption spectrum of Galactic H_2 at zero redshift that corresponds to a H_2 column density of $5\times\ 10^{19} cm^{-2}$ is illustrated, showing that several of the dips in the Mrk 533 spectra are contamination from absorption in the Galaxy. The positions of the strongest absorptions are indicated by horizontal lines above the upper H_2 spectrum. The dashed lines marked on the O VI spectrum indicate a rough removal of the effects of this absorption. The O VI doublet lines are strong and relatively narrow, consistent with their origin in the narrow-line region. This is in predicted contrast to the very broad O VI line reported in Seyferts of type 1 which are purportedly pole-on. The profiles of the two doublet lines are very well matched, implying a line ratio of $\sim$ 1, and thus optically thick emission.

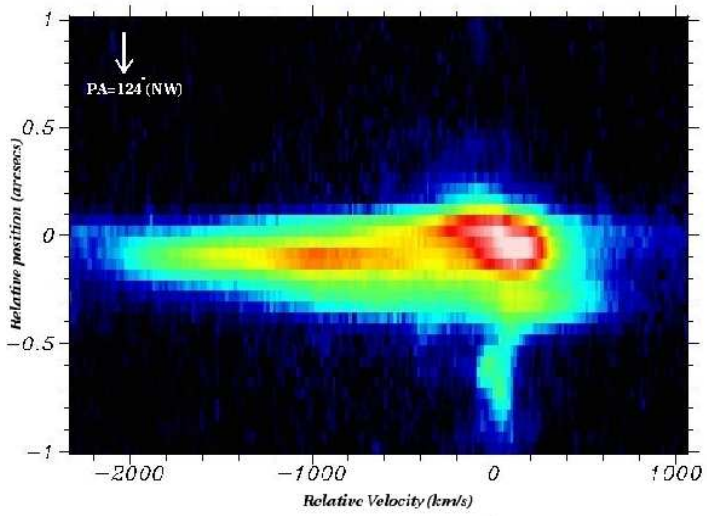


Figure 17: The *HST STIS* spectral image of the Seyfert galaxy Mrk 533 in the region of [O III]λ5007 line is plotted here in velocity space. The vertical spatial axis is along the *STIS* slit which is at a PA of 124°, *i.e.*, along the radio jet axis of the Seyfert. The zero position of this axis corresponds to the peak of the continuum in the off-line region. The zero position of the horizontal dispersion axis corresponds to the systemic velocity of 8659km s^{-1}The very nuclear [O III]λ5007 profile (from the innermost pixel, *i.e.*, <0$''$.05, or <30pc) matches well with the O VI profile. However, moving only slightly off nucleus (0$''$.1–0.$''$2 or 50-100pc), the [O III]λ5007 profile peak shifts to +100 km s^{-1}and the shortward side gains a strong wing extending to $\sim$−2000 km s^{-1}. The difference between the O VI and [O III]λ5007 profiles is consistent with a picture in which the most nuclear region exhibits velocities $\sim$ 500 km s^{-1}in mild outflow with the receding part hidden from view; however, beyond this inner region, the gas is strongly accelerated by a nuclear wind or jet flow.

In the case of the Seyfert 2 galaxy Mrk 533, its FUV spectra show narrow asymmetrical O VI $\lambda\lambda$1032, 1038 emission lines with stronger wings shortward of the peak wavelength, but the degree of asymmetry of these wings in velocity is much lower than that of the wings of the lines of lower ionization. The C III λ977 line is seen weakly with a similar profile, but with very low signal to noise. These *FUV* spectra are among the first for a purportedly obscured Seyfert. The *HST STIS* spectral image of Mrk 533 allows delineation of the various components of the outflow, and the authors infer that the outflow is accelerated.

The difference between the O VI and [O III]λ5007 profiles is consistent with a picture in which the most nuclear region exhibits velocities $\sim$ 500 km s^{-1} in mild outflow with the receding part hidden from view, and a strong acceleration of the gas beyond this inner region. The absence of O VI emission in the highly accelerated [O III]λ5007 -emitting gas argues in support of this gas being photoionized rather than shock-ionized.

(P. Shastri, J. Hutchings, J. Murthy, M. Whittle* & B. Wills*)*

The magnetic fields in the nuclear jets of radio galaxies

Based on the detections of polarisation on the pc-scale in the nuclei of four Fanaroff-Riley I galaxies from a pilot study, the authors have obtained VLBI polarisation data for a larger sample of radio galaxies. Using these data they are investigating the systematics of the magnetic field geometry in their nuclei, and the connection with the Fanaroff-Riley divide.

(P. Kharb, P. Shastri & D. Gabuzda*, S. Baum* & C. O'dea*)*

Multiwavelength monitoring of beamed AGN (Blazars)

Participation in the Whole Earth Blazar Telescope (WEBT), constituted to monitor Blazars (highly relativistically beamed AGN) simultaneously with observations at X-ray, gamma-ray and TeV energies is continued. The goal is to discriminate between competing models for the emission mechanisms of the highly relativistic jets, by tracking the time-lag between the variations in intensity at different wavelengths, the chromaticity of the variability on different time-scales and possible periodicities in the variability.

(P. Shastri, A. K. Pati, M. Villata & the WEBT team*)*

3 Theoretical Astrophysics and Physics

3.1 Inverse problem

Extended matched filter method

The periodic structure hidden behind randomness is undetectable if the coherence length of the randomness r_0 is small compared with the wavelength Λ of the periodic part. The limit (existing) beyond which the periodic part is undetectable, from purely intensity measurements is $(r_0/\Lambda) < 0.33$. To cross the above limit of detectability, one has to perform more complicated intensity interferometry. In the extended matched filtering method developed by us, it is shown that it is possible to detect the grating structure even for $(r_0/\Lambda) \sim 0.11$, by intensity measurements alone, being thus a considerable advance over the existing limits of detection. This method begins with the assumption that the scattered intensity must consist of a train of identical peaks, located at $\pm nQ$, where $Q = (2\pi/\Lambda)$. The method is now being applied to detect angular separations of closely spaced binaries.

(S. Chatterjee)

3.2 MHD

Astrophysical magnetic fields: MHD theory

Helicity conservation imposes constraints on dynamo action. The minimal field strength of the large scale magnetic field that could result given the constraints has been studied using a quasi linear model. The calculation of helicity is technically complicated because of open boundaries and the usual form for the MHD invariant is modified to take this into account. Further, the helicity fluxes at the boundaries are accounted for approximately. In a paper in preparation, a simple application of the quasi linear model to the solar and galactic dynamos are presented.

(A. Mangalam)

MHD of accretion disks

Authors describe the formation of accretion disks in diverse astrophysical situations. These systems, though controlled by the gravitational forces, have embedded in them a host of magnetohydrodynamic (MHD) and plasma-physical mechanisms without which many an observed phenomena would be hard to account for. The essential role of the MHD turbulence has been well emphasized. The authors give a critical review of the ways and means of generating it through the magnetorotational instability and in the process correct the erroneous premise on which the local analysis continues to be carried out. The problem is complex and the present level of its understanding leaves much that needs novel techniques to fully capture its entire range of processes.

(V. Krishan, Z. Yoshida & S. M. Mahajan*)*

Existence of the magnetorotational instability

By posing and solving a global axisymmetric eigenvalue problem on an infinite domain with modes vanishing at zero and infinity for a differentially-rotating MHD plasma, the conditions for the occurrence of a purely growing low-frequency mode known as the magnetorotational instability (MRI) are mapped. It is shown that the MRI criterion drawn from the "local dispersion relation" is at best inadequate, and may even be misleading. The physics of the MRI is rather nuanced. It is dictated by the details of the radial profile of the rotation velocity $\Omega(r)$ and not just by the sign and the magnitude of its gradient, Ω'. The salient features of the class of profiles for which the MRI-like eigenmodes may occur are given along with the eigenspectrum. For a variety of other profiles, it is shown that an unstable magnetorotational mode is not a valid eigensolution.

(S. M. Mahajan & V.Krishan)*

Equilibrium structures in partially ionized rotating plasmas - Accretion disks

The formation of equilibrium structures in partially ionized rotating plasmas, consisting of electrons, ions and neutral molecules, including the Hall-effect, is studied in order to diagnose the possible velocity and the magnetic field configurations in a self consistent manner. A class of equilibria with unit magnetic Prandtl number and equal values of the fractional ion mass density $\alpha = \rho_i/\rho_n$ and the Hall parameter $\epsilon = \lambda_i/L$ emerges where ρ's are the uniform mass densities, λ_i is the ion inertial scale of the structure. A few simple examples show that the linear and the nonlinear force free magnetic configurations along with essentially nonlinear Beltrami flow field seem to be the general features of plasmas in the special case of the Keplerian rotation relevant for astrophysical plasmas. However, the equilibrium con-

ditions permit more general flow and the magnetic field profiles which can perhaps be fully explored numerically with the Grad-Shafranov type of formulation. Further by expressing the not so well known ionization fraction in terms of the temperature of the system , assuming thermal equilibrium, relationships amongst the extensive parameters such as the scale, the neutral particle density, the flow velocity, the temperature and the magnetic field of the equilibrium structure can be determined. There seems to be a good overlap between the Hall- and the thermal equilibria. The validity of the neglect of the ion dynamics is discussed.

(V. Krishan & Z. Yoshida)*

3.3 Pulsar

Millisecond pulsar emission altitude from relativistic phase shift: PSR J0437-4715

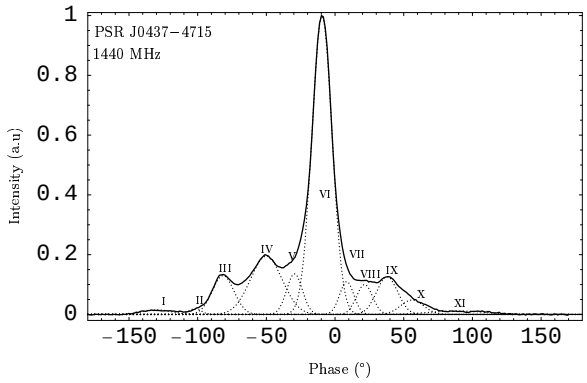


Figure 18: Average pulse of PSR J0437-4715 at 1440 MHz and the model Gaussians (dotted line curves)fitted to emission components. Due to A/R effects, the core (VI) peak is shifted to the phase $\sim -9.5^\circ$ from the meridional plane (M) which is at 0°.

The authors have analyzed the profile of the millisecond pulsar PSR J0437-4715 at 1440 MHz by fitting the Gaussians to pulse components, and identified its 11 emission components, as indicated by Figure 18. They propose that the components form and emission beam with 5 nested cones centred on the core. Using the phase location of component peaks, they have estimated the aberration–retardation (A/R) phase shift. Due to A/R phase shift, the centroid of intensity profile and the inflection point of polarization angle swing are symmetrically shifted in the opposite directions with respect to the meridional plane, which is defined by the rotation and magnetic axes. Figure 19 shows a typical pulse profile with relativistic phase shift of pulse components and polarization angle in the opposite directions with respect to the meridional plane. By recognizing this fact, the authors have been able to locate the phase location of meridional plane and estimate the absolute altitude of emission of core and conal components relative to the neutron star centre. Using the more exact expression for phase shift given recently by Gangadhara (2005), the authors find that the radio emission comes from a range of altitudes from the core at 7% to outer most cone at 30% of light cylinder radius.

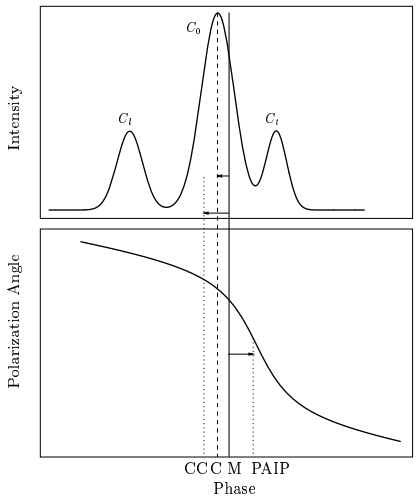


Figure 19: A typical pulse profile. C_0 is the core. C_l and C_t are the components on leading and trailing sides, respectively. The dotted lines represent the phase of cone centre (CC) and polarization angle inflection point (PAIP). The thick line marks the phase of meridional plane (M), and the broken line marks the phase of core peak (C). Arrows indicate direction of phase shift of CC, C and PAIP with respect to M.

(R. T. Gangadhara & R. M. C. Thomas)

Dynamics of charged particles in the radio emission region of pulsar magnetosphere

The authors consider the classical picture of three dimensional motion of charged particles in pulsar magnetosphere. They adopt a perturbative method to solve the equation of motion, and find the trajectory of particles as they move along the rotating dipolar magnetic field lines. Our main aim is to study the influence of rotation on the pulsar radio emission by considering the constrained motion of particles along the open field lines. The authors find that the rotation induces a significant curvature into the particle trajectories. Our model predicts that the intensity on leading side dominates over that of trailing side. They expect that if there is any curvature induced radio emission from the region close to the magnetic axis then it must be due to the rotation induced curvature. The authors find the evidences for radius–

to–frequency mapping in the conal as well as core emissions.

(R. M. C. Thomas & R.T. Gangadhara)

Emission altitudes in radio pulsars with triple profiles

The authors have been developing an independent method to explain emission altitudes in radio pulsars with triple profiles which display centres of core and conal components non-coincident in longitude. Different emission altitudes are attributed to these components and explain the offsets resulting from aberration, retardation and the magnetic fieldline sweepback. This allowed to determine difference between core and conal altitudes which are much less uncertain than the individual altitudes derived by other methods. Individual altitudes can also be found by enlarging the framework to interpret pulse widths. However, only the altitude difference by itself leads to many interesting and surprising consequences. Our main findings are: the core emission altitudes, r_{core} may be smaller, larger than or same as r_{cone}, the conal ones and that the core emission cannot always come from the stellar surface. More importantly, both core and conal emissions may not come from the full available part of the polar flux tube and their filling factors vary with the altitudes in a specific manner.

The authors are carrying out a detailed analysis of observations of triple profiles at different frequencies and derive emission altitudes. They compare these with the altitudes derived from the offsets between intensity and polarization centroids of the pulse profiles so that a more definite radius to frequency mapping can be arrived at. This apart, the authors study variation in the filling factor with frequency. The authors believe that these considerations will have implications for pulsar radio emission mechanisms. The work is in progress.

(R.C. Kapoor & C.S. Shukre)*

3.4 Radiative transfer

OGLE-II data analysis for deriving physical parameters of a binary system

The work on the OGLE-II project is being continued. All the photometric data presented in the catalog of eclipsing stars were collected. The authors have selected about 100 EA (Algol type) binaries based on the shape of the light curve in each star-field with secondary minimum at phase, in the range of 0.49 - 0.51. The data of I-band is considered because the B and V data points are not enough to produce a proper light curve. In the next step, the intensity is converted into flux for the above set of data. The code based on Bin Maker 3 depends on the input parameters like, latitude grid, longitude grid, mass ratio, potentials as a omega, wavelength, temperatures of both the components etc. In the final step, the Wilson-Devinney code will be used for deriving the physical parameters of the components of the close binary systems.

(M. Srinivasa Rao, B. A. Varghese, D. Kjurkchieva, & Valentin P. Ivanov*)*

Line profiles from stars with circumstellar shells

O and B supergiants and red giants are commonly observed to have circumstellar shells. High resolution observations of the emission lines formed in these shells are rarely available. The authors are trying to compute the emission line profiles of the KI line formed the circumstellar envelope of the N-type star R Scl and compared these with those observed by Gustafsson et al., (1996, *A&A* **318**, 535). The authors have used the data given in the above paper regarding the expansion velocity, mass loss rate and radii etc for obtaining the line profiles at different radii.

(M. Srinivasa Rao, L. S. Cidale & M. L. Arias*)*

Hanle-Zeeman effect

The work on Classical and Quantum formulation of line scattering theory in the presence of arbitrarily strong magnetic fields (the so called theory of Hanle-Zeeman effect, Magnetic Raman Scattering) is partly completed. This work represents one of the most sophisticated classical/quantum theoretical frameworks ever developed to handle these problems of radiation scattering on atomic levels.

(K. N. Nagendra, M. Sampoorna, & J. O. Stenflo)*

Stochastic polarized line formation: Zeeman line transfer in a random magnetic field

The analytic and numerical techniques are developed to solve Zeeman line transfer in a stochastic media. Earlier, this problem was usually treated in

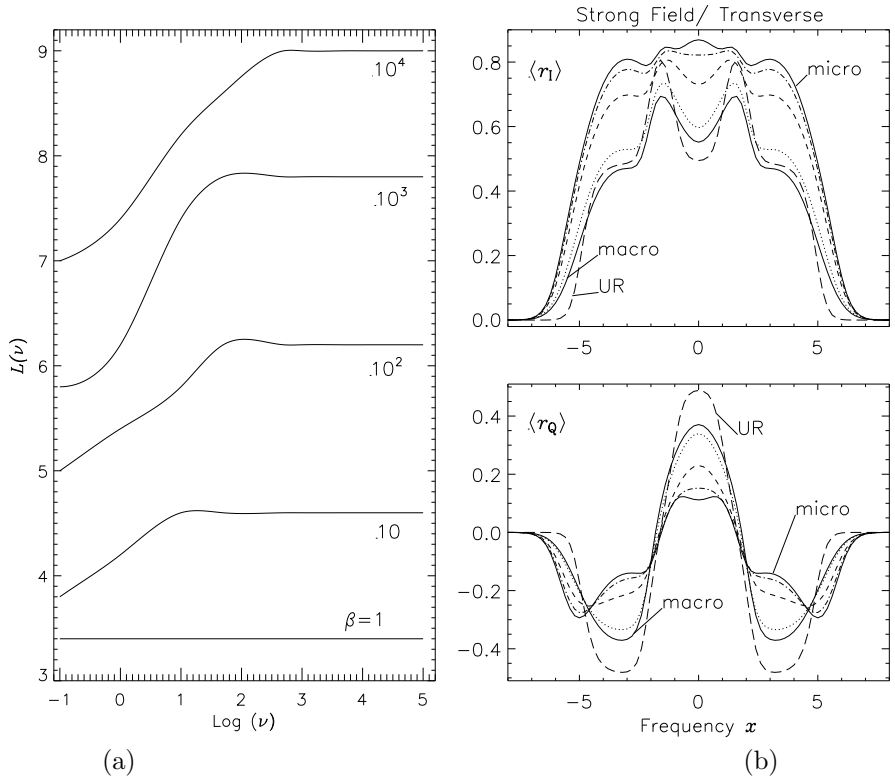


Figure 20: (a) Left panel: Variation of the full width at half maximum $L(\nu)$ of the emergent Stokes I profile with ν for various values of β. The model parameters employed are mean magnetic shift $y_o = \Delta H_o = 0.1$; dispersion around the mean value H_o is $\gamma_{\rm H} = 1$; the orientation of the mean field w.r.t. LOS $\theta_o = 0^\circ$; $\phi_o = 0^\circ$ damping parameter and $a = 0$. (b) Right panels: Dependence of the mean Stokes parameters on the correlation length $1/\nu$ of the magnetic field for a strong line: $\beta = 100$. The other model parameters are $\Delta H_o = 3$; $\gamma_{\rm H} = 1$ and $\theta_o = 90^\circ$. LOS. The full lines show the macro ($\nu = 0$) and micro limits. The line types are: dotted ($\nu = 1$); dashed ($\nu = 10$); dot-dashed ($\nu = 50$). The long-dashed lines correspond to the Unno–Rachkovsky (UR) solution calculated with $\boldsymbol{H}_o$.

the 'micro-turbulent/ macro-turbulent' limits where the Zeeman propagation matrix/ Stokes parameters, respectively, were averaged over the probability distribution function of the magnetic field. In reality, a stochastic medium is considered by the authors, where the field is random with a finite correlation length, i.e. characteristic scale of field variation, comparable to radiative transfer characteristic scale (photon mean free path).

The vector magnetic field is modeled by a Kubo-Anderson Process (KAP). The idea of the KAP is to describe the atmosphere in a number of "eddies" having lengths distributed according to a Poisson distribution with given density. It is assumed that in each eddy the magnetic field is constant and its value drawn at random from a probability distribution function. A KAP is thus characterized by a correlation length and a distribution function. The mean polarized radiation field is obtained by averaging over this distribution and the distribution of the length of the eddies.

KAP, when associated to a simple atmospheric model like the Milne–Eddington model, yields explicit expressions for the mean and RMS fluctuations of the Stokes parameters at the surface of the atmosphere. Numerical investigations of mean residual Stokes vector and their RMS fluctuations are carried out for a magnetic field distribution function $P(\boldsymbol{H})$ that describes a random magnetic field with a mean value $\boldsymbol{H}_o$ and an isotropic Gaussian fluctuations with a dispersion $\sqrt{3}\sigma$. From Fig. 20a (left panel), the authors notice that weak lines are quite insensitive to the value of the number of jumps ν of the magnetic field per unit optical thickness of the medium, and depend only on $P(\boldsymbol{H})$. For strong lines sensitive to the value of ν, the micro-turbulent regime is reached when $\beta/\nu < 1$, where β is the line strength parameter. From Fig.20b (right panel), the authors notice that: (i) the mean Stokes I parameter for any value of ν always lies between micro and macro turbulent limits, (ii) for Stokes Q, the line centre is quite sensitive to ν, only when $\boldsymbol{H}_o$ is in the transverse direction with respect to the line of sight (LOS) or close to it.

(M. Sampoorna, K.N. Nagendra, & H. Frisch)*

Generalized Voigt Functions (GVF) and their derivatives

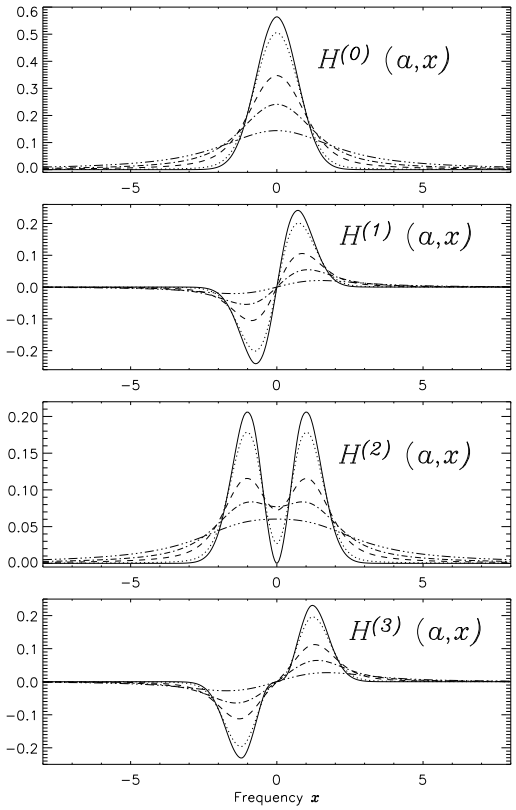


Figure 21: $H^{(n)}$ functions for $n = 0$ to 3. The solid line: $a = 0$; dotted line: $a = 0.1$; dashed line: $a = 0.5$; dot-dashed line: $a = 1$; and dash-triple dotted line: $a = 2$. $H^{(n)}$ ($n = 1, 3, 5, 7\ldots$) have positive and negative maxima, while $H^{(n)}$ ($n = 2, 4, 6\ldots$) are entirely positive valued functions.

In the theory of Stochastic polarized spectral line formation one encounters a special class of functions called generalized Voigt functions $H^{(n)}(a, x)$ and $G^{(n)}(a, x)$. The quantity x is the non-dimensional frequency and a is the damping parameter. The authors note that for $n = 0$, the usual Voigt $H^{(0)}$ and Faraday-Voigt $G^{(0)}$ functions are obtained. Efficient and simple recurrence relations are derived, suitable for high speed computation of these GVF. Nature of these $H^{(n)}$ and $G^{(n)}$ functions has been studied in detail for $n = 0\,\text{to}\,3$ and a large range of damping parameter values (see Figs. 21 and 22). $H^{(n)}$ is an even/odd function of x for even/odd values of n respectively, whereas $G^{(n)}$ is an even/odd function of x for odd/even values of n respectively. The recurrence relations for the 'partial derivatives of GVF' are also derived. The authors have further expressed the partial derivative of $H^{(0)}$ and $G^{(0)}$ as a series expansion involving $H^{(n)}$ and $G^{(n)}$.

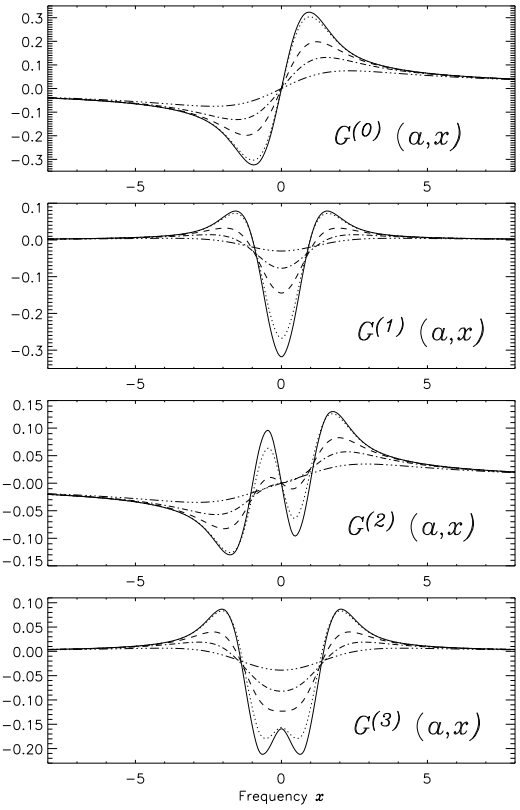


Figure 22: Same as Fig. 21, but for $G^{(n)}$ functions. Notice that all the functions have positive and negative values.

(M.Sampoorna, H. Frisch & K.N. Nagendra)*

Effect of electric quadrupole field on the Stokes profiles of Na I D2 line

The observed Stokes profiles of Na I D lines reported by Stenflo et al., (1997, *A&A*, **321**, 355) had attracted considerable attention and a qualitative explanation of the shape of the Na I D2 line has been given [Holzreuter et al., 2005, *A&A*, **434**, 713] based on the anisotropy of the radiation field and PRD effects, but the core polarization still appears to be an unresolved issue. Recent studies by Yee Yee Oo et al., (2004, *JQSRT*, **84**, 35) have shown that the Stokes parameters in polarization of the line radiation are modified due to the introduction of external electric quadrupole fields in addition to the presence of uniform magnetic fields. The present investigation aims to study the effect of electric quadrupole field on the Stokes profiles of the Na I D2 line as the upper level with $j = 3/2$ is quite sensitive to the presence of electric quadrupole fields.

(*K. Nagaraju, K. E. Rangarajan, K. N. Nagendra, Yee Yee Oo* & G. Ramachandran*)

Atomic polarization due to scattering of radiation

With the advent of the second solar spectrum (A. Gandofer, The Second Solar Spectrum (Zurich, Vdf, 2000, 2002, 2005)) considerable amount of activity is directed towards the interpretation of the observed Stokes parameters. In this context, Hanle effect has been invoked when the external magnetic field strength is less than 100 Gauss, while the region above upto 1000 Gauss is generally referred to as Hanle-Zeeman regime. When the field strength is less than 1 Gauss, hyperfine interactions are invoked to study the effects of lower level atomic polarization. It is shown, in this theoretical study, that an atom (left in a state of non-zero angular momentum j) is polarized when radiation is scattered on it, even if the initial state of the atom is unpolarized before scattering. Moreover, it is shown that scattering itself modifies the lower level polarization in a two-level problem.

(*G. Padmanabha*, Yee Yee Oo*, K. N. Nagendra & G. Ramachandran*)

3.5 Interacting galaxies

Dynamics of the galaxies

The fact that most of the galaxies are found in pairs and multiple systems implies that they are bound to interact with each other frequently. Gravitational interactions can transform the morphology of the galaxies. While sphere - sphere and disk - disk collisions have been studied extensively through N-body simulations, collisions between disk - sphere pair of galaxies have been explored in a limited number of studies. In such collisions, the tidal effects have maximum intensity and the simulation result gives us an upper limit for the tidal damage and distortions produced in the colliding galaxies. Numerical simulations have been performed to study the tidal effects produced in a disk galaxy by the passage of an elliptical galaxy. The disk galaxy is modelled as a three component system - a disk, a bulge and a halo - and the elliptical galaxy is a Plummer model. The interaction parameters are chosen such that the galaxies move in a rectilinear orbit which does not culminate in a merger. The results indicate that even though the tidal effects are sensitive to both the mass ratio and the inclination of the disk to the orbital plane, it is the mass ratio which is more important in producing tidal damage to the less massive galaxy. The spherical galaxy undergoes maximum tidal damage if the mass of the disk is same or larger. Collisions, in which the mass of the spherical galaxy is more, result in the formation of a ring structure around the disk after the closest approach and it disappears after a few crossing times.

(P.M.S. Namboodiri)

3.6 Relativistic astrophysics

Dark energy may link the numbers of Rees

There is increasing evidence that the universe is dominated by dark energy of the type given by an invariant cosmological constant. Latest data also indicates that fundamental interaction couplings and particle masses have remained remarkably constant from the earliest epochs. It is natural to connect these two "steady state" features of the evolving universe, suggesting a role for the cosmic vacuum energy in fixing these interaction constants. Advances in high precision cosmology have revealed that dark matter of an unknown type constitutes about one-fourth of cosmic matter while baryons account for just four per cent. These various cosmic parameters are enumerated by the six numbers of Rees. With the dark energy as a unifying link, it has been shown by the author that these numbers can be all connected and their values estimated. Further work on this is in progress.

(*C. Sivaram*)

Cosmological constant as a unifying link

With the cosmological constant as an underlying and unifying link, attempts are made to understand the dark matter to dark energy ratio and the fact that the baryon fraction is only four per cent. Various equations for dark energy are explored to understand how the various other cosmological parameters acquire their present values.

(*C. Sivaram*)

Phase space constraints on neutrino luminosity

Neutrinos being fermions are subject to quantum phase space constraints. Many discussions of inverse neutrino bursts and emissions, for example from gamma ray bursts (resulting from hypernovae or neutron star mergers) do not seem to consider this aspect. While the importance of phase space constraints for gravitational clustering of neutrinos is

well recognised the explicit use of such constraints to limit neutrino emission from ultraenergetic sources has not been highlighted. Special relativistic and general relativistic phase space constraints are shown to limit neutrino luminosity from compact sources in various situations.

(*C. Sivaram*)

Periodicity in quasar redshift distribution

The author continues to investigate various astrophysical and cosmological implications of the variable mass hypothesis (VMH) scenario of Hoyle-Narlikar theory of conformal gravitation. The standard model in cosmology does not have a satisfactory explanation for the observed peaks in the redshift distribution of quasars. A modified version of the Narlikar-Das (N-D) model for quasars could adequately explain the observed parameters in some typical cases. Work is in progress to provide a more sound theoretical basis for the modified N-D model by considering a quantum version of the classical scenario. The qualitative picture is as follows: Assuming that the creation mechanism produces a local scalar field of negative energy and stresses it can be argued that the nucleus of the parent galaxy becomes unstable whenever the newly created mass attains one of the discrete set of values and ejects the same. Work is in progress to quantify this idea and in particular obtain a theoretical explanation for the geometric series of Karlesson for redshift periodicity.

(*P. K. Das*)

Braking effect of intergalactic clouds

Investigations are in progress to study the braking effect of intergalactic clouds on a newly created plasmoid ejected from a galaxy in the VMH scenario and to see how it can be related to the observations of quasar-galaxy associations.

(*P. K. Das, J. V. Narlikar* & H. C. Arp**)

Absorption redshift systems in quasars

The detection of absorption systems at redshifts lower than the emission redshifts of high redshift quasars is usually cited as evidence for the cosmological nature of quasar redshifts. However it is entirely possible that absorption systems are intrinsic to the quasars which need not be at the distances implied by their redshifts. Recent measurements of the cosmic background radiation temperatures in the absorption systems of some high red shift quasars have been cited as a further confirmation of the cosmological nature of quasars. An attempt is being made to provide an alternative explanation for these observations.

(*P. K. Das*)

3.7 Non-accelerator particle physics

Ba^+ PNC and its implications

The authors have worked on two important probes of physics beyond the Standard Model–parity nonconservation (PNC) in atoms and electric dipole moments (EDMs) of atoms. They work on PNC in Ba^+ has reached an accuracy of less than one per cent.If this is matched by the accuracy of the experiment on this ion, then the combined theoretical and experimental results of Ba^+ PNC will provide an independent test of the Standard Model of particle physics.

(B. K. Sahoo, H. S. Nataraj, C. Sur, R. K. Chaudhuri, B. P. Das, Angom Dilip & D. Mukherjee*)*

Application of unitary coupled-cluster theory

The authors have worked on a new approach to the high precision calculation of ground and excited state atomic properties that are relevant in the study of fundamental symmetries and different astrophysical processes. This approach is an extension of the well known many-body theory known as coupled-cluster theory and is called the unitary coupled-cluster theory. The authors have shown that the latter theory is very well suited for the accurate determination of a wide variety of properties.

(B. K. Sahoo, K. V. P. Latha, H. S. Nataraj, C. Sur, R. K. Chaudhuri, B. P. Das, Angom Dilip & D. Mukherjee*)*

Many-body theory calculation related to optical frequency standards

The electric quadrupole moment for the 4d $^2D_{5/2}$ state of $^{88}Sr^+$; one of the most important candidates for an optical clock, has been calculated using the relativistic coupled-cluster theory. This is the

first application of this theory to determine atomic electric quadrupole moments. The result of the calculation is presented and the important many-body contributions are highlighted. The calculated electric quadrupole moment is $(2.94 \pm 0.07)ea^2$, where a_0 is the Bohr radius and the electronic charge while the measured value is $(2.6 \pm 0.3)ea^2$. This is so far the most accurate determination of the electric quadrupole moment for the above mentioned state. The author has also calculated the electric quadrupole moments for the metastable 4d $^2D_{3/2}$ state of $^{88}Sr^+$ and for the 3d $^2D_{3/2,5/2}$and 5d $^2D^{3/2,5/2}$ states of $^{43}Ca^+$ and $^{138}Ba^+$, respectively.

(Chiranjib Sur, K. V. P. Latha, B. K. Sahoo, Rajat K. Chaudhuri, B. P. Das & D. Mukherjee)*

Transition rates of Pb^+

The authors have considered certain transitions in Pb^+ which are of astrophysical importance and calculated their rates by an ab initio relativistic many-body theory. A significant part of the work this year has been on hyperfine interactions in atoms. Such interactions are important in many different astrophysical processes.

(B. K. Sahoo, H. S. Nataraj, C. Sur, R. K. Chaudhuri, B. P. Das, Angom Dilip & D. Mukherjee*)*

3.8 Atomic and molecular physics

Excitation and ionization energies of Sr and Yb atoms

Relativistic coupled cluster method (CCM) is applied to compute the low lying excited and ion states of Strontium and Ytterbium atom. The resulting excitation and ionization energies are in excellent agreement with experimental data and with other correlated calculations. The nuclear magnetic dipole hyperfine constants (A) and electric quadrupole hyperfine constants (B) of excited states are also evaluated and are in accord with experiment.

(Malaya K. Nayak & Rajat K. Chaudhuri)

Calculation of P,T-odd interaction constant in BaF and YbF :

A fully-relativistic restricted active space (RAS) configuration interaction (CI) approach is employed to compute the P,T-odd interaction constant $W_{\rm d}$ of the ground $^2\Sigma$ state of YbF and BaF molecules. A series of increasingly sophisticated CI space yields a best estimate of $W_{\rm d}$= -1.088×10^{25} Hz/e-cm and $W_{\rm d}$ = -0.352×10^{25} Hz/e-cm for YbF and BaF, respectively. The CI space that yields the best estimate of $W_{\rm d}$ is also used to compute other molecular properties, all of which are found to be in good agreement with experiment.

(Malaya K. Nayak & Rajat K. Chaudhuri)

Theoretical determination of hyperfine matrix elements

Molecular spectroscopy is a sensitive probe of fundamental interactions because of close energy spacing of hyperfine spin-rotational levels. The authors calculate the hyperfine constants (A) and anisotropy using restricted active space configuration interaction method (RASCI).

(Malaya K. Nayak & Rajat K. Chaudhuri)

Applications of multi-reference coupled cluster theory

The single reference coupled cluster based linear response theory (CCLRT) and valence-universal multi-reference coupled cluster (VU-MRCC) theory for direct difference energy calculations have been presented. The similarities and differences in the structure of these two formalisms have also been addressed. The core-extensive CCLRT is applied to compute the ionization potentials (IPs) of HCl and excitation energies of CuH using Hartree-Fock (HF) orbitals. The authors further report the relativistic applications of the VU-MRCC theory through the computation of the ground and excited/ionized state energies and related properties of Ag and Hg atoms using Dirac-Hartree-Fock (DHF) orbitals. The IPs, excitation energies, and the spectroscopic constants reported here are in favorable agreement with experiment and with other correlated calculations.

(Malaya K. Nayak, Rajat K. Chaudhuri, Sudip K. Chaudhuri & Uttam Kumar Sinha Mahapatra*)*

Ground and excited states of cyanogen isomers

Ab initio calculations are used to characterize the ground and low lying excited electronic states of several *linear* and *cyclic* isomers of cyanogen. In partic-

ular, the calculations consider the excitation energies for selected singlet and triplet Σ states of cyanogen (NCCN), isocyanogen (CNCN), di-isocyanogen (CNNC), diaza-dicarbon (NNCC), and corresponding states of three cyclic cyanogen isomers, including many predictions that are presented here for the first time. Our calculations for the linear structures agree well with available experimental data, thereby providing a benchmark for assessing the predictions for other isomers, such as the cyclic isomers. The present calculations are also used to identify the possible emitting species for some unexplained bands in the emission observed from certain low temperature matrices. Since the emitter could not be assigned to any of the cyanogen isomers, some other molecule must be responsible for the emission in low temperature matrices.

(Rajat K. Chaudhuri, S. L. N. G. Krishnamachari & Karl F. Freed*)*

Ground and excited states of C_3N_2 and its isomers

Ab initio calculations are used to characterize the ground and low lying excited electronic states of selected dicayanocarbene (C_3N_2) isomers. In particular, the present calculations are used to identify the possible emitting species for some unexplained bands observed in certain low temperature matrices. Our calculated ground state geometries and the corresponding vibrational frequencies agree well with available experimental and theoretical data, thereby providing the reliability of the predicted parameters. The present calculation explains all the observed spectral features of the above mentioned band system satisfactorily and assigns this to the $1^3A' \leftarrow X^1A'$ transition of cyclic C_3N_2.

(Rajat K. Chaudhuri & S. L. N. G. Krishnamachari)*

3.9 Nuclear physics

Photodisintegration of polarized deuterons at astrophysical energies

The model independent irreducible tensor formalism developed earlier to discuss n-p fusion (Ramachandran et al. 2003, *J. Phys. G: Nucl. Part. Phys.*, **29**, L45) is extended to discuss photodisintegration of polarized deuterons at astrophysical energies, as precise knowledge of $n + p \rightleftharpoons d + \gamma$ at neutron kinetic energies, E_n between 25 and 200 keV in centre of mass is crucial (Burles et al., 1999, *Phys. Rev. Lett.* **82**, 4176) to sharpen the predictions of Big Bang Nucleosynthesis (BBN). It is shown that laboratory measurement of target analyzing power in photodisintegration of polarized deuterons at c.m angle $\theta = 90^o$ provides a sensitive test to the contribution of the isoscalar $M1$ and $E2$ amplitudes, in addition to the dominant isovector $M1$ and $E1$ amplitudes. It is also pointed out that the relative strength of the isoscalar amplitudes could be estimated empirically through experimental measurements of the difference between the differential cross-sections at θ and $180^o - \theta$.

(*G. Ramachandran, Yee Yee Oo* & S. P. Shilpashree*)

Deuteron photodissociation with 100% linearly polarized photons

Following recent experimental studies using the High-Intensity Gamma-ray Source (HIGS) at the Duke Free-Electron Laser Laboratory, a theoretical study has been taken up to analyze the data incisively, in view of their relevance to Big Bang Nucleosynthesis (BBN). Since the isovector $M1$ amplitude is dominant at thermal neutron energies of order 10^{-5} keV and the isovector $E1$ amplitude is known to be dominant in photodissociation at photon energies above 2.62 MeV, attention has been focussed in these experiments to study the interplay between these two amplitudes in the keV range of interest to astrophysics. An analysis carried out by the authors of the experimental result for γ-ray anisotropy (Müller et al., Nucl. Inst. Meth. A **440** (2000) 736) employing polarized thermal neutron capture by polarized protons revealed that the contribution of the isoscalar amplitudes to thermal neutron cross section is of the same order as the measured cross sections (Suzuki et al., ApJ. **439** (1995) L59) for capture at astrophysical energies. The present investigation aims to focus attention on the relevance of isoscalar amplitudes in polarized photon studies.

(*G. Ramachandran & S. P. Shilpashree*)

Polarization of ω-meson produced in proton-proton collisions

Studies on meson production in nucleon-nucleon collisions have evoked considerable interest experimentally as well as theoretically, during the last decade and a half, and a model independent approach was developed by G. Ramachandran et al. (2002), for

pion production and more recently (Ramachandran et al., 2005, *Phys. Rev. C*, **72**, 031001(R)] for ω production, which is more interesting since omega is a spin-1 particle. Polarization of *omega* is an important observable, which can be studied experimentally by measuring the angular distribution and circular polarization of the photon emitted as omega decays into a neutral pion and a photon. A detailed theoretical study of the Fano statistical tensors characterising the vector and tensor polarization has been taken up, which can lead to the empirical determination of the threshold amplitudes.

(*G. Ramachandran, J. Balasubramanyam*, M. S. Vidya* & Venkataraya**)

Unified approach to photo and electro production of mesons

Recent experimental studies on photo and electro production of mesons beyond the first resonance region is of considerable interest to study higher resonance contributions and to verify predictions based on quark models for the hadrons. For example, attention was focussed on η production since it facilitates study of nucleon resonances free from Δ contributions as η is an isoscalar in contrast to the isovector pion. As the photon energy increases further the thresholds are reached for production of mesons like ρ, ω and ϕ which are spin-1 particles. As the energy at Jefferson laboratory, Virginia, USA, can go upto 6 GeV, production of mesons with spin upto 4 can be envisaged. In view of these developments on the experimental side, a unified theoretical approach to discuss photo and electro production of mesons with arbitrary spin s has been developed for the first time, which can facilitate elegant discussion of resonance contributions as well. Work aimed at deriving formulae for hadron spin observables as well as beam analyzing powers is in progress.

(*G. Ramachandran, M. S. Vidya* & J. Balasubra manyam**)

Phase matrix for scattering of polarized radiation in external fields

Following recent theoretical studies (Yee Yee Oo et al. 2005, *JQSRT*, **90**, 343) on polarization of line radiation in the presence of external electric quadrupole and uniform magnetic fields, a quantum electrodynamical approach to scattering of radiation by atoms was developed and an elegant expression was derived for the phase matrix for scattering, under such external environments. Numerical studies are in progress considering the simplest case of two level atoms, where the upper level has spin 1 and the lower level has spin 0.

(*Yee Yee Oo*, K. N. Nagendra, S. Anathamurthy* & G. Ramachandran*)

4 Experimental astronomy

4.1 High resolution techniques

100 years of Photon counting: the quest for the perfect eye

The photoelectric effect discovered by Einstein has revolutionized how ultra-sensitive light detectors can be conceived of and has led to a quest, through the 20th century (and still going on), for the 'perfect detector' which is asymptotically feasible. Light detectors based on the photon counting systems have been much used in astronomy. This article reviewed such detectors.

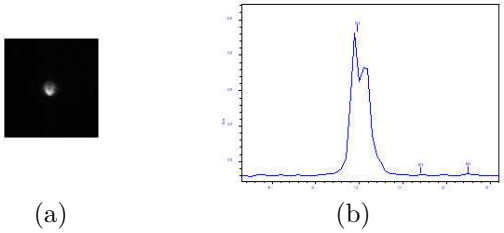
(S. K. Saha)

Laser guide artificial star for high resolution imaging

A large telescope encodes the information about the source, but is unable to get the diffraction-limited informations. Due to the inhomogeneity of the propagating medium that carries the light to the Earth's surface, the image of a point source (unresolved stars) cannot be smaller than a limit at the focal plane of the telescope. In order to estimate the point spread function of both the atmosphere and the telescope, observation of a bright unresolved star is needed. Astronomers do face difficulties in locating such an object within isoplanatic patch. Over the years, several observatories have developed the laser guide artificial star in order to palliate the limitations of low sky coverage (the probability of finding a suitable reference star within isoplanatic patch). The article discussed the utility of such an instrument.

(S.K. Saha)

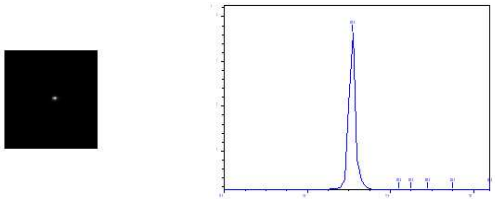
Design and development of wavefront sensor system and wavefront correction system for atmospherically degraded images



(a) (b)

Figure 23: (a) Un-corrected image and (b) its cross section.

The authors have investigated and built a wave-front error measurement and correction system in the laboratory to remove the degradation caused by atmospheric turbulence. A fast wave-front sensor was designed and built with shack-Hartmann lenslet array, CMOS imager and custom made software. Peltier cooled low light level CCD camera was used for comparison and calibration. For wave-front contra tilt mirror an adaptive mirror was used. Finite Element Analysis and In-house developed Long Trace Profilometer tests were conducted for evaluation of surfaces created by the adaptive mirror for various actuator control voltages. PCI based interface card having 40 channels of digital to analog converter were developed for control. Using the new wave-front sensor output data, and the characteristics of the control mirrors measured, correction of the aberrated wavefront was achieved by controlling 37 actuators of the adaptive mirror and 3 actuators of the tip-tilt mirror.



(a) (b)

Figure 24: (a) Corrected image with a tip-tilt mirror for tilt error correction and other high frequency errors with a micromachined deformable mirror (MMDM), and (b) its cross section; images are twice magnified for better visibility.

Examples of corrections and image improvement are displayed in Figure 24. Images captured by ANDOR Peltier cooled low light level CCD camera with 10 msec exposure time It is found that an aberrated image having 6.4 pixel Full Width at Half Maximum can be sharpened to have 3.5 pixel and the peak intensity has increased from 5610 counts to 36500 counts.

(V. Chinnappan & A. K. Saxena)

Adaptive optics

Research work continues towards building a low cost adaptive optics system, a new approach to stellar image correction for atmospherically degraded images, for astronomical applications.

The research work on the development of a new wavefront sensing technique using polarization shearing interferometer for Adaptive Optics applications

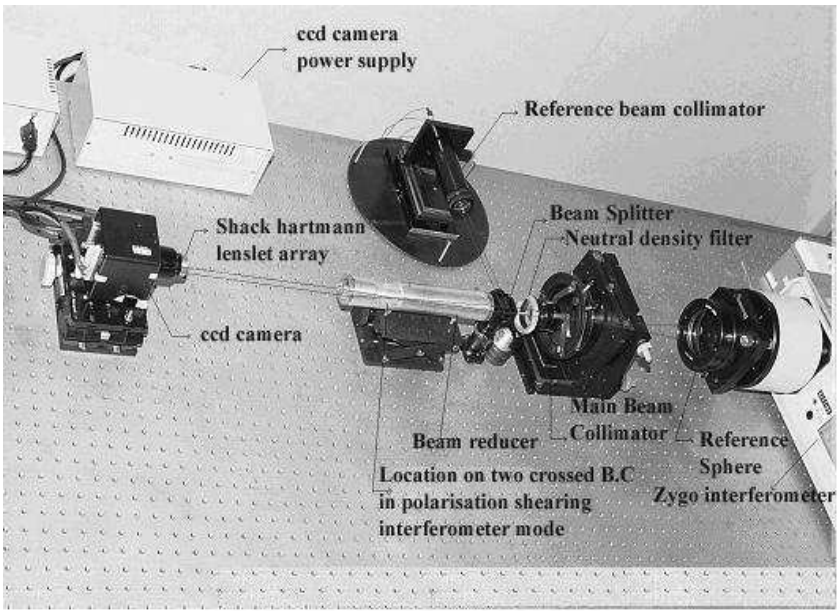


Figure 25: Wavefront sensing experimental setup in the laboratory.

has been completed. Conventional wavefront sensing techniques, employing shearing interferometers, require two orthogonal records for processing of the data and to retrieve the Wavefront. The new Wavefront sensing method developed here utilizes a single record for Wavefront retrieval. The method uses Fourier Transform technique and efficient data reduction procedure. This is quite simplified and a unique approach to use a single record for this purpose. Laboratory experiments were conducted and found to match with the results obtained from Shack Hartmann wavefront sensor.

(*J. P. Lancelot & A. K. Saxena*)

4.2 Space astronomical telescope

Ultra Violet Imaging Telescope (UVIT) payload on Astrosat

UltraViolet Imaging Telescope (UVIT) is one of the payloads on satellite Astrosat. Astrosat carries several telescopes, most of which are X-ray telescopes, while UVIT is used for simultaneous wide field (about one half of a degree) imaging in three channels: FUV (1200 Åto 1800 Å), NUV (1800 Åto 3000 Å), and VIS (3500 Åto 5500 Å), with an angular resolution of $< 2''$. Apart from observations of ultraviolet objects, e.g. hot stars and star forming galaxies, UVIT would be used to study temporal variations of X-ray objects simultaneously with the X-ray telescopes.

UVIT is configured as twin Cassegrain telescopes, each of aperture 375 mm diameter; one of these observes in FUV (1200 Åto 1800 Å), and the other in NUV (1800 Åto 3000 Å) and VIS (3500 Åto 5500 Å). Each of the three channels uses intensified imaging detectors, which are being developed as a collaboration between ISRO and CSA. This project is being done at IIA in collaboration with IUCAA, PRL, and TIFR. In each channel a set of filters are mounted on a wheel for selection of a narrow band.

The basic design of the instrument has reached an advanced stage, and a Preliminary Design Review of the payload was held in the month of March. The tubes for intensified imaging detectors are being developed by a company in UK, and these are expected to be completed in a few months. The high voltage supplies for these tubes too are being developed in UK. The mirrors are being done by LEOS, ISRO, and the engineering model of these are expected to be ready in a few months.

The payload would be assembled in MGK Menon Laboaratory at CREST; this clean laboratory is specially being developed to high standards of cleanliness required by ultraviolet optics. The laboratory is expected to be ready by the month of July. Engineering model of the payload is expected to be assembled in this laboratory by the end of this year.

Astrosat is expected to be launched in 2008, and UVIT is expected to be ready, with all the tests, to

go on Astrosat by beginning of 2008.

UVIT team

Tauvex

Work on the Indo-Israeli collaboration on TAUVEX is proceeding well. TAUVEX is a set of three imagers which is planned to launch on an ISRO GSLV rocket in February, 2007 as part of the GSAT-4 mission. The team from Tel Aviv University headed by Dr. Noah Brosch will be providing the instrument hardware, ISAC is handling issues dealing with spacecraft integration. The TAUVEX group at IIA is responsible for almost everything else.

Activities over the last year include the creation of a set of tools for the TAUVEX users including a simulation package, an exposure time calculator and miscellaneous FITS tools. The TAUVEX pipeline has been completed and testing is now underway.

TAUVEX group

4.3 Laboratory physics

High-contrast, all-optical switching in bacteriorhodopsin

High speed photonic switching, which forms an essential component of optics based communication networks and data processing systems, can be achiev ed with electro-optic, opto-mechanical, magneto-op tic, and acousto-optic devices. The current rapid development of high data-rate fiber-optic communication and real-time information processing system has created a need for all-optical, ultrahigh-speed photonic switches, which will eliminate the need to convert the photonic signal to an electrical signal and vice-versa. An all-optical switching action can be accomplished by use of one optical pulse (pump beam) to control the transmission of a second optical pulse (signal or probe beam) by virtue of their interaction in a nonlinear medium.

In this project, the authors carried out experiments with the nonlinear-absorption-based, high-contrast, all-optical switching in the photochromic bacteriorhodopsin (bR) films. The switching action is accomplished by control of the transmission of a weak probe beam through a bR sample with the help of strong pump beam illumination at 532nm wavelength. The authors found that the switching properties of bR films depend on several experimentally controllable parameters such as probe wavelength, pump-beam intensity and excitation rate. A comparative study of the switching behaviour and other parameters were carried out at three different probe wavelengths (543, 594 and 633nm) and various beam powers and excitation rates. The experiments were carried out on commercially available D85N and D96N mutants.

(Ravinder Kumar Banyal & B. Raghavendra Prasad)

Study of refractive index variations with temperature using automated interferometric techniques

Refractive index is the most important parameter of a material. It helps in determining its application for optical devices, or for a material being studied via optical method. This can be measured very precisely by using interferometric techniques. Here, the authors use the interference of waves to produce a measure of optical phase or equivalently optical path length between two interfering wave fronts. These path length differences may be a result of a physical length difference traversed by the two beams or as a result of the two waves traversing materials with different propagation velocities or equivalently with different indices of refraction. It is possible to measure the change in index of refraction of a material as a function of temperature by interferometric methods. Because of their high sensitivity, interferometers have been used to measure very small displacements, small surface roughness, quality of optical components indices of refraction wavelengths of waves interfering etc. The authors used Mach-Zehnder interferometer which consists of two beam splitters and two totally reflecting mirrors for measuring temperature dependent variations in refractive index. Temperature dependent refractive index changes were measured in alkali halide filters like BaF_2 and MgF_2 which are widely used in FUV and NUV. They have extremely sharp transmission cutoff edges in the ultraviolet region. These filters are good for solar observations and the study of variation refractive index with temperature is very important for the same. Here an effort is made to incorporate advanced control and data acquisition techniques with interferometry, which enabled high degree of accuracy in measurements. The entire experimental setup including motion stages, detectors, temperature control etc is implemented on Lab VIEW platform.

(T. Ramachandran & B. Raghavendra Prasad)*

5 Telescopes and Observatories

5.1 Kodaikanal Observatory

HF Doppler radar and digital magnetometer

Regular data acquisition in the monitoring mode continued with the HF Doppler radar and digital magnetometer. A new digital data acquisition system (DAS) is an advanced stage of realization for use with the HF Doppler radar; this facility permits acquisition of data even during conditions of plasma destabilization such as ESF and facilitates fast reductions of the digital data.

(J. V. S. V. Rao, J. H. Sastri and staff of I&M section and STR Laboratory)

Synoptic and solar activity observation

The Kodaikanal observatory has a distinction of having broadband Ca K-line and H-alpha images of the Sun for over a period of 100 years. Solar activity, which sometimes affects the earth's environment and satellites in space, is monitored on a daily basis. These data are on photographic records and it is now being recorded in digital mode. A new set up is now in place to obtain Ca K-line full disk images of the Sun as filtergrams. A new setup comprising of a stand alone mode H-alpha telescope to record full disk filtergrams at high cadence is underway.

(Jagdev Singh)

Digitization of Kodaikanal data

A project to digitize the invaluable solar data of a hundred years at the Kodaikanal Observatory has been taken up. Highly stable light sources and large format 4K × 4K CCD detectors together with high quality optics to minimize the vignetting effects are being procured for the purpose. These will provide the necessary resolution of the photographic records to be fully transferred to the digitized mode. The mechanical design of the digitizer has been finalized and the fabrication work is in progress. In order to speed up the process, two digitizers will be set up and used simultaneously.

The digitized data will enable the studies of long-term variations on the Sun and its impact on the earth's environment. It is proposed to study the development of sunspots, sunspot cycle, solar dynamo, variations in solar diameter with time, variation in solar rotation rate, differential rotation, filaments, prominences, large convective cells and such other phenomena on the Sun.

(Jagadev Singh & S. P. Bagare)

Solar image limb tracker for KTT

A colour image limb tracker system for Kodaikanal tunnel telescope (KTT) based on SPOT - 2D bi-cell sensor is developed at the Institute. SPOT-2D is a two segmented photo detector with dimension 1.3 mm × 2.5 mm with a gap of 0.127 mm. The system is installed at Kodaikanal tunnel and initial tests have indicated that the system is tracking for 10 minutes and is undergoing further test for optimization.

(Thulasidharen K.C, & A.V. Ananth)

WARM telescope

The white light active region monitor (WARM) Telescope is a three mirror (8 inches) coelostat proposed to be setup at Kodaikanal. In this connection the control hardware has been configured and procurement process is on. The major control components are: (i) BSM63N - 133 AA brushless AC servomotor from Baldor, USA, (ii) Microflex brushless AC servo drive, (iii) Servorated gearhead GBSM63 - MRP070 (10), (iv) Next move PCI card (4 axis servo motion controller) with MINT software, and (v) Absolute encoder ROC 417 from Heidenhain. The mechanical system has also been designed.

(K. C. Thulasidharen, A. V. Ananth, K. B.Ramesh & J. P. A. Samson)

Two-beam spectropolarimeter for Kodaikanal Tower Telescope

A two beam Spectropolarimeter has been developed using a polarizing beam displacer for the measurement of the vector magnetic field of sunspots. Recording two orthogonal states of polarization simultaneously helps to reduce the seeing induced effects considerably. The figure shows the white disc of the Sun's image at the slit of the spectrograph and the polarimeter in front. The polarimeter consists of quarter wave plate, half wave plate, a polarizing beam displacer followed by a compensator. The angular graduations indicate the position of the optic

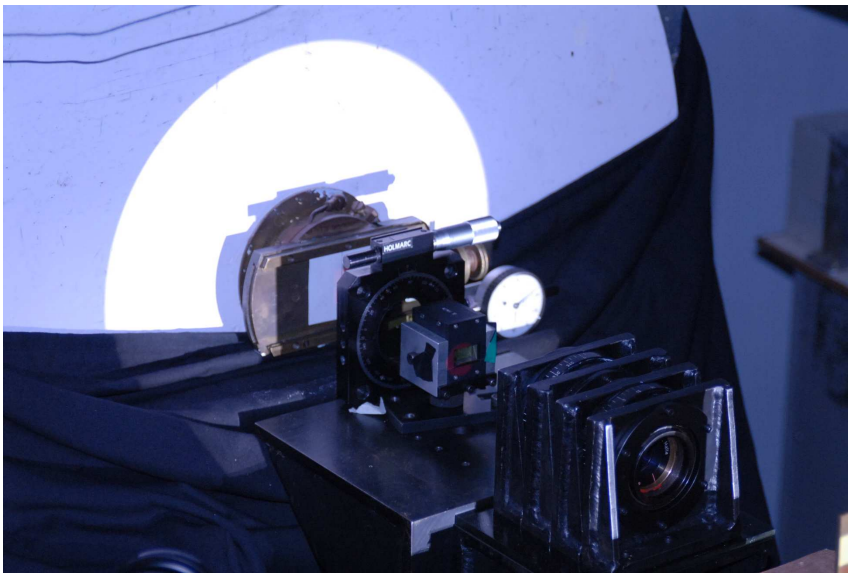


Figure 26: Spectropolarimeter setup at Kodaikanal tower telescope.

axis of the components with respect to the spectrograph slit.

(*K. E. Rangarajan, K. B. Ramesh, K. Nagaraju, K. Sankarasubramanian*, J. Singh, P. Kamath & P. K. Mahesh*)

5.2 Vainu Bappu Observatory, Kavalur

Stellar photo-polarimeter

The various mechanical parts of the polarimeter were tested for their stability and repeatability in their movements. Those parts which did not meet the requirements were re-designed and fabricated. The testing and alignment of the various optical parts, after loading them, are in progress.

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

Upgradation of high resolution Echelle spectrometer for VBT

As the performance of the spectrometer depends mainly on the fiber coupling efficiency of the telescope beam into the optical fiber, a new fiber interfacing unit was designed, fabricated and installed in VBT. The fiber interfacing unit works for the fiber with tapered end and is mounted in the prime focus of VBT.

The f/3 from the primary mirror is focused onto the tip of the optical fiber. The input end of the optical fiber has a stainless steel metal ferrule of size 6.35 mm diameter and its front face is polished and tapered to 15-deg angle. The optical fiber (core 100 micron size) is centred in the metal ferrule. When the starlight falls on the metal ferrule of the fiber input end it reflects back the light at an angle of 30 deg from the optical axis of the telescope.

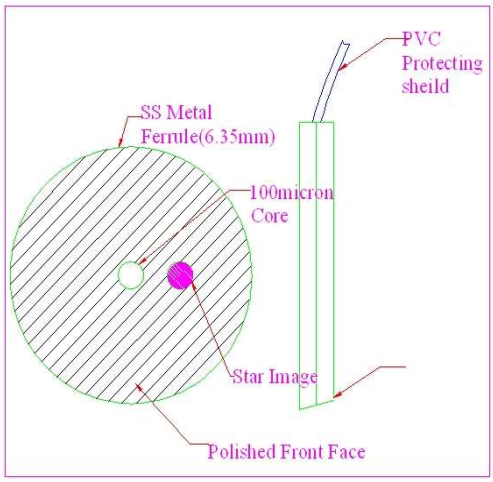


Figure 27: Schematic of optical fiber input end.

The reflected light is converted into a collimated beam by a collimating lens and then falls on a folding mirror placed in a lens housing. The folding mirror sends the light on a focusing lens and finally the light comes to focus on the ICCD. The ICCD output can be seen on video monitor, which is placed in the con-

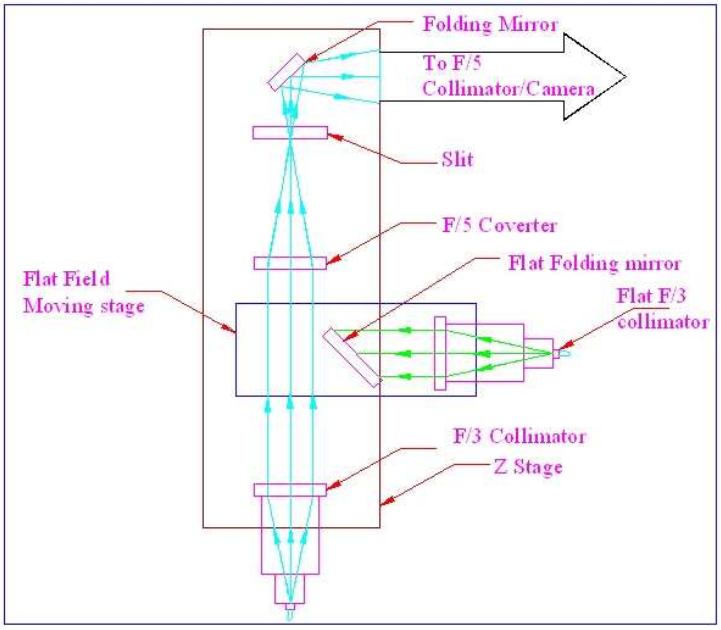


Figure 28: Schematic of flat field fiber output end selection fiber transmission measurement.

sole room for guiding. With a very small movement of the telescope the starlight falling on the metal ferrule is centred on the fibre core. When the starlight falls on the fiber core, the ICCD captures the images of the starlight and the fiber core and both will be displayed on the monitor. In this condition the starlight is coupled into the fiber and is transmitted to the other end of the fiber. The focus of the image can be adjusted by moving the telescope prime gauge.

In this unit a field mirror is introduced to see the star field directly on the ICCD. When the field mirror is introduced into the path of the beam it will be converged onto the ICCD or otherwise the converging lens will focus the star image reflected which is from the metal ferrule.

In the earlier fiber interfacing unit, the same 100 micron fiber which is used for object was used to take flat fielding. As the flat needs to cover more pixels than the object for accurate flat field correction, it was decided to use 200 micron fiber for flat fielding and was routed in the telescope. The output end of the optical fiber is converted into a collimated beam by a fiber collimator and the collimated beam is fed into the f/5 focuser with the help of 45 deg folding mirror. The folding mirror and the fiber collimator is mounted on moving stage so that when the flat field is taken, this folding mirror will be brought in between the F/3 VF/5 converter. The flat and object selection can be done and it can be controlled remotely from the computer. The control software is updated for this additional facility. The schematic of the flat field fiber output end mounting on the moving stage is shown in Figure 28.

(N. Kameswara Rao, S. Sriram, R. Srinivasan, K. Jayakumar & F. Gabriel)

Aluminisation for Vainu Bappu Telescope

The primary mirror of the 2.34 m Vainu Bappu Telescope has been given a fresh aluminium coating. After alignment the telescope has been released for observation. There has been great improvement in the light gathering power.

(Photonics Division)

1 m Telescope

The primary mirror of the 1 m telescope has been replaced with the new zerodur mirror fabricated at the Photonics Division, IIA, Bangalore. Necessary modifications in the support system and balancing of the telescope have been incorporated suitably. The alignment has been carried out close to the perfection. The inside focus and outside focus images are seen quite circular and spider shadows are clearly visible, well focused long exposure images produced seeing limited images. The telescope has been re-

leased for trial observations.

A matching zerodur secondary is under fabrication. A concave secondary with matching eccentricity has been polished and matched well with the existing secondary mirror. The work on the zerodur convex secondary is in progress.

(Photonics Division)

Vacuum and thin film coating

The 1.2 m and 2.8 m vacuum plants have been made fully functional by undertaking suitable alternative repairs. The 2.34 m primary mirror of the VBT was aluminized. An excellent coating has been achieved. The 0.9 m HAGAR telescope mirrors were aluminized at the 1.2 m vacuum coating plant. Periodic aluminizing of the mirrors is being done on regular basis. Major repairs of the coating plant are being planned in the coming financial year.

(Photonics Division)

Dome automation work for 75 cm telescope

In connection with the dome control software for the 75 cm telescope at VBT, Kavalur. The design of the software is planned to be similar to the 2m dome control software.

A power coupler which replaces the conventional heavy, difficult to maintain bus bars has been tested in lab. The dome incorporates a shutter with a full open slit width of 2200 mm and is driven by a 1/8th hp, 3F, ac motor. The power for the shutter is fed through a coupler. A 3 phase electric motor facilitates the linear travel of 60 mm through a screw and nut mechanism. This linear motion allows the coupler to engage. Limit switches are used to indicate the status of the coupler i.e. engaged or disengaged.

(Faseehana Saleem & A.V.Ananth)

New mount 75 cm telescope

Detailed design and analysis has been carried out for a new mount, tube and drives for the 75 cm telescope at VBO, IIA, Kavalur.

(Mechanical Division)

5.3 Indian Astronomical Observatory, Hanle

HFOSC Autoguider System (AUGUS)

Developed collaboratively by the Copenhagen University Observatory, Niels Bohr Institute, Copenhagen, Denmark, and IIA, and installed on HCT in September 2005, the system is in regular use. AUGUS has enabled long spectroscopic exposures and facilitates continuous monitoring of any desired field by locking on to the object with an accuracy of < 0.1 arcsec.

Continuous all-sky camera (CONCAM)

The CONCAM, developed by Michigan Technological University, USA, and installed at Hanle May 2005, is part of international network of all-sky cameras operating at night and available on the web. This has enabled online viewing of night sky at Hanle from anywhere in the world.

(*HCT team*)

High Altitude GAmma Ray telescope (HAGAR) Control system

Two telescopes have been installed at Hanle during this year. The telescopes work in a host environment of a Pentium PC and INTEL 8951 microcontrollers serving as the front-ends for the telescope motion control interface. The host obtains information about the telescope-coordinates from absolute encoders and determines position errors, based on a telescope modeling for an alt-azimuth system. In order to improve the response time, a faster and better microcontroller was identified to replace the present 8951 controller. In the new development, Microchip Technology Rs PIC microcontroller (PIC16F877) has been identified as the Embedded Controller and the new motion control interface system has been implemented with this controller as the front-end system.

The PC calculates the position and velocity errors of the telescopes and sends the frequency of operation of the stepper motors and the direction informations to the micro-controllers. The PC operates in a Round-Robin fashion to obtain position information from Absolute Encoders and also the status of the telescopes. The PC sends command to the microcontroller with the drive-frequency information. The loop time per one cycle of scanning for all seven telescopes is about 100 milliseconds. This through-

put permits proper tracking of the telescope up to a blind spot of 1.5-degree radius cone.

(Faseehana Saleem, G. Srinivasulu & R. Srinivasan)

Mechanical fabrication of HAGAR

After incorporating changes in design as noted from the performance of the prototypes, five more telescope units are being fabricated to complete the array of HAGAR. Presently the fabrication of the five units is under progress with a target of installation at Hanle in this season.

(Mechanical Section)

GPS measurements of crustal deformation and atmospheric water vapour over the Indian subcontinent

The Department of Science & Technology has established a NAVSTAR Global Positioning System Network over the Indian subcontinent with a few permanent stations and several campaign sites to study the crustal deformation over the Indian subcontinent with a view to provide eventual support for earthquake prediction. IIA is collaborating with CMMACS, Bangalore, on this project, and has hosted three permanent stations at Kodaikanal, Leh and Hanle. An accurate sub-millimetric estimation of three dimensional coordinates of each location also requires accurate correction for tropospheric delays in the signal. A fraction of the delay (less than 15%) is caused by water vapour and hence the GPS network can also be used to estimate atmospheric water vapour. A study of atmospheric water vapour is of interest in monsoon prediction, and the results for a particular site are of great importance for infrared astronomy since this is the main atmospheric absorbant in the infrared region of electromagnetic spectrum.

An analysis of data accumulated over the last decade indicates 14-20 mm/yr convergence between South India and the Himalayas, 80% of which is accommodated in the Himalayas and the rest in central India. The data was also used to study the effect of 26 December 2004 Sumatra-Andaman earthquake on the Indian subcontinent. The study indicates co-seismic displacements of 10-22 mm at south Indian sites and southward displacements of $\sim$ 7 mm at the north-easterm Indian stations. Andaman-Nicobar campaign sites sufferred as much as 1.6 - 6.5 m of west-southwestward displacement, 0.6 m uplift in north Andaman and 1-2 m subsidence in Port Blair and Car Nicobar.

A method has been devised to estimate water vapour from the GPS data over the entire Indian subcontinent, and used with the data for the period 2001-2003. No other measurements are available for most of the sites and hence the results are extremely valuable. The efforts are underway to improve the measurements using in-situ measurements of ambient temperature and atmospheric pressure, especially for sites with low atmospheric water vapour.

(S. Jade, M. S. M. Vijayan*, V. K. Gaur, T. P. Prabhu, S. C. Sahu, B. C. Bhatt, M. P. Singh, D. Angchuk, S. Gorka, & T. Thsering)*

5.4 CREST, Hosakote

Network upgradatation

The network between CREST and IAO was partially upgraded during May 2005 with new switches and routers. Apart from increasing the reliability of remote operations, it is now possible to access internet from IAO, Hanle, and also to access a few specific systems at Hanle such as CONCAM and CARIBOU. Further activity is scheduled during the next year.

HCT data archive

Necessary hardware for implementation of HCT Data Archive was procured during the current year. Front-end software to interface between the observations and data header upgradation as required for archiving, and also the software for accessing archival data, were developed in collaboration with Virtual Observatory India, IUCAA, Pune. The past data will be progressively archived during the next year.

(G.C. Anupama, B.C. Bhatt, P.S. Parihar, D.K. Sahu, D. Angchuk, T. Dorjai, S. Gorka, T. Thesring & Ravikumar Reddy)

5.5 Radio Telescope, Gauribidanur

Radio polarisation observations of the solar corona

The E-W one dimensional solar radio polarimeter for observations of solar corona in the height range $\sim 0.2 - 0.8$ $R_\odot$ (above the solar disk) is now in regular operation at the Gauribidanur observatory. The authors have been working on the implementation of multi-frequency observational capability for

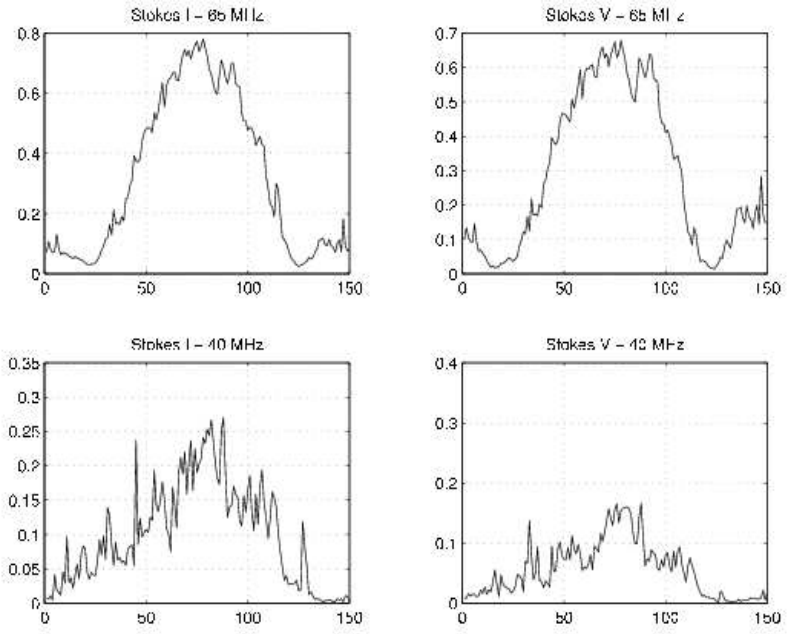


Figure 29: Observations of polarised radio emission from the solar corona on January 6, 2006. The abcissa is sample number and ordinate is correlation coefficient. The integration time is 512 ms.

the above antenna system over the last few months. The unit was readied recently and we are performing test run on Sun and other unpolarised sidereal radio sources in the aforementioned frequency range. The fully commissioned system is expected to provide near simultaneous information about magnetic field at different layers of the solar corona. The figure shows observations carried out with the above system on January 6, 2006 at 40 & 65 MHz ($\sim$ 0.6 & 0.4 $R_\odot$, respectively).

(*R.Ramesh, C. Kathiravan & M.S. Sundara Rajan*)

6 Activities at IIA, Bangalore campus

6.1 Electronics Division

Mosaiced 4K×4K camera system

With the successful operation of the Echelle Spectograph at VBT, with the indigenously developed 2K×4K CCD Camera System as the focal plane detector, a need has been expressed in the institute to develop a 4K×4K mosaiced camera system in order to cover a wider field. A good noise figure of 4-5 electron rms has been obtained with the Echelle Camera system with a read-out time of 4 min 30 sec per frame. Subsequently there has been a proposal to develop a similar system for wide field imaging for the DFM 1.3 M telescope chosen for the VBO, Kavalur. The design has been completed for the hardware implementation and the software work relating to the generation of clock and bias voltages and data-acquisition is in progress. The proposed target date for completion of the mosaiced camera system is December 2007, coinciding with the delivery of the DFM 1.3 M telescope.

(R. Srinivasan & G. Srinivasulu)

CCD image acquisition, analysis and processing software using IDL under linux

The present image acquisition software has been developed using Gtk(Graphics tool kit) libraries, with C++ under Linux. As the Gtk versions keep changing, maintaining software up to date is difficult.

The purpose of the software is to acquire, analyze and process the CCD images. This software has been developed using IDL under Linux platform. The software uses a client / server model where the client can be placed on the same machine as the server or at a remote site. The client / server communication programs as well as the Device Driver for the locally developed image acquisition board are written in C. IDL procedures call the C programs to establish connection between server and client. This software is equipped with standard file handling, image processing/analysis, graphics, and image acquisition facilities viz, Bias, Dark, and Image acquire. This software is being developed for 2K×4K CCD for 2.34 m telescope at VBO, Kavalur as well as 2K × 2K CCD proposed for 75 cm telescope.

(V.Arumugam & A.V.Ananth)

6.2 Computer Division

The Computer Centre has embarked on several initiatives. The internet bandwidth was increased from 768 kbps to 2 Mbps. and upgrading of the internet backbone of all campuses to 2 Mbps. Interconnectivity between campuses is also slated for a major upgrade such that one virtual campus will be set up.

A new Sunfire V20Z CPU Cluster was installed in the IIA, Computer Centre for high end computing. The Sun Cluster runs on NPACI ROCKS cluster software, Sun Grid Engine, RedHat Enterprise Linux version 4.0. It has 80 GB RAM, 1.1 TB of disk space. The hardware is distributed over a Master node and 7 compute nodes. It is meant for number crunching and ideally suited for parallel computing. The institute has also become part of the National Grid Initiative (GARUDA Network) where computers across the country are linked with a high speed network to take advantage of large computing projects.

(*Computer Section*)

6.3 Photonics Division

VHRR Sun Shield Panels for INSAT 3D Satellites

The Photonics Division is engaged in the polishing of the sunshield panels for INSAT 3D imager and sounder coolers Four sets of panels (10 Nos.each) along with the samples (200 Nos.) have been optically polished and delivered to ISRO. The microroughness of the surfaces was measured using Veeco profilometer and brought to less than 20A.

(Photonics division)

Optical Metrology Lab

The optical metrology laboratory equipped with the facilities: (i) Long Trace Profilometer (LTP), (ii) Digital Spherometer, (iii) Fiber Optic Spectrometer, (iv) Wyco Profilometer, and (v) Zygo Interferometer for optical testing is utilized on regular basis. In addition, the BRNS, DAE funded LTP, Version-II for the metrology of Synchrotron Beam Line Optics, has been designed and developed at IIA. The air bearing translation stage and the optical head have been designed built and integrated. Performance of the system has been tested. The final specifications of the instrument are: (i) Travel length = 1200 mm (48 inches), (ii) Minimum detectable slope error 0.25 arc sec or lower, (iii) Range -15 min, (iv) Measure-

Figure 30: Newly built Long Trace Profilometer (version II).

ment in step of 1 mm and above programmable, (v) Overall Positional accuracy = 5 mm, (vi) Resolution = 1.0 mm, (vii) Slide speed (Alignment mode) = 50 - 60 mm/sec, (viii) Roll error = <3 arc sec, (ix) Pitch = <3 arc sec, (x) Yaw = <3 arc sec, and (xi) Drive control and positioning, data acquisition and reduction through computer control.

The figure shows the version-II of the newly built LTP. This development has placed India in the world map of LTP builders.

(Photonics Division)

6.4 Board of Graduate Studies

The Summer Project Students' Programme 2005 was conducted during May 15-July 10, 2005. Applications were received from all over India and 14 students were selected. They were given a series of lectures, covering topics such as Stellar Astronomy, Astronomical Instrumentation, Solar Astronomy, Solar-Radio Astronomy, Astronomical Space Missions, Galactic Astronomy and Cosmology. These students were exposed to IIA facilities through visits to VBO, Kavalur and CREST, Hosakote. They carried out research projects under the supervision of their guides and gave presentations as well as submitted reports.

Five new students joined the IIA PhD Programme during August 2005. The students were selected through a written test conducted by JEST followed by interviews. The students who had qualified for JRF through UGC, CSIR exams were also called for interviews.

B. K. Sahoo submitted his thesis titled *Coupled-cluster theory of parity nonconservation in atoms*, to the Mangalore University and was awarded his degree in April 2006.

Veeresh Singh participated in the "European Radio Interferometry School, hosted by the University of Manchester/Jodrell Bank Observatory during 5 - 9 September, 2005.

A winter programme was organised for the students of the International Astronomy Olympiad under The Nurture Program at IIA, Bangalore, VBO, Kavalur and CREST Hosakote, during Dec. 09-20, 2005. The students were given a series of 15 lectures on a large number of topics in astronomy. The students were also given demonstrations and assignments using the existing observational data. They were given hands-on experience at the telescopes and various instruments at VBO, Kavalur and CREST, Hosakote. These 27 students carried out small research projects in groups under the supervisions and gave presentations at the concluding session.

(*S. Giridhar & H. C. Bhatt*)

6.5 Archeoastronomy

Zodiacal pillars

The monitoring of morning sunlight on the Zodiacal pillars in the mukha mandapa of Sringeri Sri Vidaya Sankara temple has been continued to cover all the months of the year properly. Several photographs of the pattern of sunlight on the pillars during various months (unless affected by clouds or rain) have been obtained. Still observations during some months (that have been affected by either clouds or rain) have to be obtained.

(N. Kameswara Rao, Muralidas, Bhaskara & A. V. Raveendran)

Aspects of prehistoric astronomy in India

Some archeoastronomical aspects regarding the development of observational astronomy in India during prehistoric times are discussed in a paper. A plea is made for preservation of megalithic monuments of possible astronomical significance. Investigations ranging from pre-historic rock paintings to megalithic stone structures have been discussed including artifacts from Indus sites.

(N. Kameswara Rao)

7 Library

The library enhanced its collection of books and Journal volumes during 2005-06. 287 books and 659 bound volumes of journals were added to the collection, which includes the books and journals bought for libraries at Bangalore, Hosakote, Kavalur and Kodaikanal. The library also subscribed to 243 journals out of which 134 titles can be accessed electronically from all the campuses of IIA and the field stations. The library continues to offer the two-year training programme for Post-Graduate students in Library Science from different universities. They are trained in all the sections of the library and also in the Digital library Project.

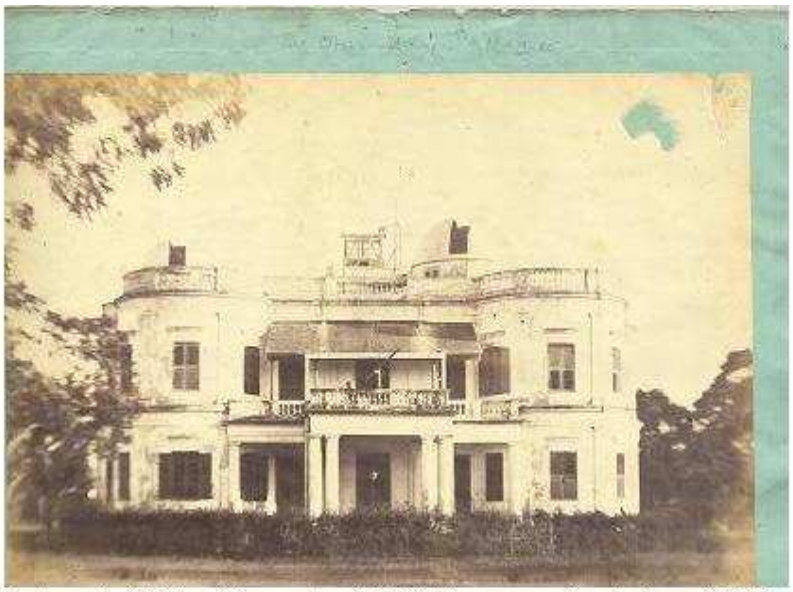
Additional journals for display are brought from RRI library regularly. Many Inter library loan requests from scientists and students were fulfilled during the period April 2005 - March 2006. The Institute has established a small library at Hosakote which is maintained by sending new books and journal issues regularly from the Bangalore campus. IIA library continues to be a member of FORSA (Forum for Resource Sharing in Astronomy) consortium and from this year Scientific American Online along with its archives is accessible as a consortium deal.

From August 2005 the following new Online Resources are added to the library collection, which are accessible from all the campuses of IIA.

1. ASP (Astronomical Society of Pacific) Conference Proceedings full text available online from volume 309, 2004.
2. PNAS (Proceedings of the National Academy of Sciences) available online from volume 1, issue 1, 1915.
3. JSTOR General Science Collection available online from volume 1, issuse 1.
4. Lecture Notes in Physics available from Volume 480, 2003.

Ms. Cherry Armstrong a descendant of a former Director Mr. Norman Pogson of Madras Observatory (1861-1891) visited the Kodaikanal Observatory in February 2006. An album of photographs depicting the work of Pogson in Madras Observatory during 1861-1891 was presented. These photographs are available on the Institutes web page.

Digitization of 350 old books which are out of copyright and 73 IIA theses have been completed with metadata. From the month of February 2006 the IIA Open Access Digital Repository is accessible on the Internet from the following URL.



Photograph of Madras Observatory in 1861. From personal collection of Ms.Cherry Armstrong, great-great grand daughter of N.R.Pogson, Director of Madras Observatory (1861-1891) presented to IIA Archives during her recent visit to Kodaikanal.

http://prints.iiap.res.in

IIA Open Access Repository has 73 theses, 84 historical papers in archival community and 850 research publications accessible on the internet.

(*Library staff*)

8 Welfare activities for SC/ST staff members

A senior officer of the Institute is functioning as the Liaison Officer to support the welfare of the SC/ST staff members.

Housing facilities have been extended to many SC/ST staff members on a priority basis. Special consideration as per the norms during the regular assessment was provided to these categories of employees.

The total staff strength of the Institute as on 31-03-2006 was 364. As per the orders of the Government, 51 posts in scientific and technical categories were exempted from the reservations. Out of 313 positions, 53 members belong to SC and 30 members belong to ST, forming 16.93% and 9.58%respectively.

Apart from this, reservations have been extended to OBCs and Physically Handicapped persons.

9 Implementation of Official Language

All round efforts have been made to ensure successful implementation of the official language. Section 3/3 of official language Act has been complied with, and the Administrative and other reports have been prepared bilingually. These include the Institutes Annual report, and other administrative reports. Letters received in hindi are replied in hindi. Official circulars have been brought out bilingually. Hindi Divas is celebrated in the Institute. Reference books in hindi have been made available to the staff members. Hindi books have been bought for Rs 5000/-. 28 bilingual rubber stamps have been prepared for the Institute and for the Hanle project.

(*R. C. Kapoor*)

10 Publications

10.1 Journals

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***Chakrabarti, S.K., *Anandarao, B. G., *Pal, S., *Mondal, S., *Nandi, A., *Bhattacharyya, A., *Mandal, S., *Ram Sagar, *Pandey, J C., Pati, A., Saha, S.K.,** 2005, *MNRAS,* **362,** 957.
SS 433: Results of a recent multi-wavelength campaign.

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Goswami, Aruna, *Wako, A., *Beers, T.C., *Christlieb, N., *Norris, J., *Ryan, S. G, *Tsangarides, S., 2006, *MNRAS,* in press.
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Shastri, P., 2005, Intl Astrophysics Conf., on *Relativistic Astrophysics & Cosmology - Einstein's Legacy* , Munich, Germany, 7-11 November, 2005.
Less is more? Are radiogalaxies below the Fanaroff-Riley break more polarised on pc-scales?

Sivaraman, K. R., Gupta, S. S., *__Howard, R. F.__,2005 Indo-China Workshop on *Recent Advances in Solar Physics*, 7–11 November 2005.
Tilt angles of the axes of bi-polar spot groups

Subramaniam, A., 2005, *BASI*, **33**, 343.
Is the Large Magellanic Cloud a double barred galaxy.
Conference on *Island Universes: Formation and evolution of disk galaxies,* July 2005, Netherlands
Counterrotating Core In The LMC: Accretion and/Or Merger?

Subramaniam, A., Bhatt, B. C., Ramya, S., 2005, *BASI*, **33**, 378.
Study of emission line stars in young open clusters using slit-less spectra: NGC 663.

Subramaniam, A., Prabhu, T.P., 2005, *BASI*, **33**, 406.
Kinematic evidence of counterrotation in the central region of the Large Magellanic Cloud.

Subramaniam, A., Sahu, D. K., *__Sagar, R.,__ *__Vijitha, P.,__ 2005, *BASI*, **33**, 378.
NGC 146: a young open cluster with different ages for the low and high mass stars.

Sundara Raman, K., Ramesh, K. B., Selvendran R.,2005, Indo-Chinese workshop on *Recent Advances in Solar Physics* held at Bangalore during 7-11 November 2005.
Evolutionary changes of sunspots and umbral rotation associated with flares

*__Yohkoh, Ramesh, K. B., Sundara Raman, K.__ 2005, Indo-Chinese Workshop on *Recent Advances in Solar Physics*, held at IIA Bangalore, during 7-11 November 2005
Coronal x-ray spectral irradiance variability

10.5 GCN Circulars, IAUC, CBET

Anupama, G. C., Sahu, D. K., Uday Kumar, G., 2006, *CBET 452.*
Supernova 2006be IN IC 4582.

Anupama, G. C., Kantharia, N. G., 2006, *IAUC 8687.*
RS Ophiuchi.

Bhatt, B. C. , Ramya, S., Anupama, G. C., 2005, *GCN 3346.*
GRB 050502b, optical observations.

Bhatt, B. C., Sahu, D. K., 2005, *GCN 3775.*
GRB 050730, optical observations.

Bhatt, B. C., Sahu, D. K., Srividya, S., Chakradhari, N. K., 2006, *GCN 4597.*
GRB 060124 optical observations.

Mishra, K., Kamble, A. P., Sahu,D. K., Srividya, S., Bama, P., Anupama, G. C., Vanniarajan, S., 2005, *GCN 4259.*
GRB 051109A Optical Observations.

Ramya, S., Sahu, D.K., Parihar, P.S., Prabhu, T.P., 2005, *GCN 3774.*
GRB 050803, optical observations.

Sahu D. K., Anupama, G. C., 2005, *CBET 319.*
SN 2005lt in MCG +03-30-51.

Sahu, D. K., Pandey G., Bama P., Chakradhari, N. K., 2005, *GCN 4294.*
GRB 051021 optical observations.

Sahu, D. K., Srividya, S., Vanniarajan, S., 2005, *GCN 4278.*
GRB 051028 optical observations.

10.6 Archeoastronomy

Rao, N. K., 2005, *BASI*, **33**, 499.
Aspects of pre-historic astronomy in India

10.7 Books edited

Das, B. P., *__Vasant, Natarajan,__ (Eds), Allied Publishers, *Precision spectroscopy of atoms, molecules and bose condensates*

Saha, S. K., *__Rastogi, V. K.,__ (Eds), Anita Publications, New Delhi, *21st Century Astrophysics*

10.8 Popular articles

C. Sivaram
Spacecraft to smash comet, Deccan Herald, 27th June 2006;
Danger from asteroids, Deccan Herald, 21st Feb 2006;
Giotto rendezvous with Comet Halley, Deccan Herald, 21st March, 2006;
Fading Star, New Scientist, 168, 81 (1 Oct 2005);
Dive, Dive, New Scientist, 189, 121 (18 Feb 2006).

11 Miscellaneous activities

11.1 Teaching and Guidance

S. P. Bagare continued to serve as a member of the PG Exams in Physics of the Bangalore University. He continued to guide students for Ph.D., with one of them, Mr. K. Balachandra Kumar submitting his thesis to the Madurai Kamaraj University in 2005. Bagare also served as external thesis examiner for Ph D degree of the University of Kerala.

D. Banerjee delivered a series of introductory lectures on Sun, for the summer project students at IIA, Bangalore and also for the Olympiad students at Kavalur.

B. P. Das has been guiding K.V.P. Latha on her thesis on *Many-Body Theory of Electric Dipole Moments of Atoms and Implications for Physics Beyond the Standard Model*; and H.S. Nataraj on his thesis on *Electric dipole moment of the electron and its implications for matter-antimatter symmetry.*

R. T. Gangadhara has been guiding Mr. Reji Mathew C. Thomas (JRF, IIA) for his Ph. D. thesis on *Pulsar radio emission*, since January 2003.

S. Giridhar gave two introductory lectures on "Introduction to Stellar Astronomy" to students of the summer school during May 30, 2005. Giridhar also gave two lectures and two demonstration sessions to first year students of IIA, as part of an additional course on "Stellar Atmospheres". She also guided a summer school student Jaya Sahu on her research project titled *Radial velocities and metallicity of F-G supergiants* during May 17-July 10, 2005.

A. Goswami supervised a group of four students, on a project on " Population-II Carbon stars" during Dec. 9-22, 2005 under the nurture program for International Astronomy Olympiad.

Mr. S. M. Vijayan, working under the guidance of **V. K. Gaur and S.S. Gupta** has submitted his thesis on *Estimation of tropospheric precipitable water vapour and crustal deformation using GPS,* to the Gandhigram Rural Instiitute, Tamil Nadu, during February 2006.

S. S. Hasan continued to guide G. Vigeesh towards Ph.D. He also taught JAP course on fluid dynamics.

R. Kariyappa guided an M.Sc., student under the SPSP-Program for her project: *Study of Chromospheric Variability of the Sun,* organized by the BGS. The duration of guidance was 3-months (May - July 2005). He also taught a course in Solar Physics for M.Sc. Astrophysics students as Guest Faculty at the Department of Physics, Bangalore University for 3 months during August 1 - October 31, 2005. In addition, he served as a member of PG exams in Physics at Bangalore University, Bangalore.

A. Mangalam taught a reading course in General Relativity and Cosmology at IIA in January–April 2005. He also taught a JAP course in High Energy Astrophysics during January to mid March 2006. He taught a semester long course in Mathematical Physics. He delivered 6 lectures on "Fluid dynamics" and conducted tutorials at the Kodai Summer School in Physics during July 2005. He guided Mr. V.L.N. Prasad, B.Tech (IIT Chennai) on a project on *Stellar distribution around Black Holes.*

K. N. Nagendra is guiding M. Sampoorna, a regular Ph D student of IIA, on a Ph D thesis project. K.N. Nagendra guided an M.Sc. Student under the SPSP-Program (the Summer Project Students Program) organized by the BGS.The duration of guidance was 2 months (May 2005-July 2005).

K. E. Rangarajan taught Stellar Atmospheres for Ph D. students at IIA. Rangarajan gave a refresher course on "Radiative processes in Astrophysics" to college lecturers and professors of Calicut university in the month of August, 2005.

E. Reddy guided a student from IIT, Guwahati towards his summer project. Mentored a group of olympiad students for a week at Vainu Bappu Obervatory, Kavalur.

S. K. Saha gave a series of 14 lectures on 'Astronomical techniques' to the Joint Astronomy Programme and IIA graduate students during October-December, 2005. He has guided D. Som, a summer school student from IIT, Delhi.

P. Shastri is supervising the Ph.D. thesis of Veeresh Singh, IIA PhD programme.

C. Sivaram gave 20 lectures for the first semester JAP course on High Energy Astrophysics. He gave a post-graduate course on General Relativity and Cosmology (24 lectures), January-April, 2006, at the Physics Dept., Bangalore University. He also taught

a one month course in astrobiology (15 lectures) at BIFR, Nov. 2005, and gave Introductory lectures on astrophysics and cosmology, for the students of the Astronomy Certificate course, held at BIFR, April, June, September, (ten lectures). C. Sivaram guided a summer school student Kiran Kumar, for a project on Black Hole Dynamics (May-July 2005). He also guided Chetan Srinivas, for summer internship, for six weeks. He was a final year EE, IIT Madras student and work on a project on *Foundation of quantum mechanics*. Short-time guidance was also provided to another student (Karthik) from Mysore univ. to work on *Quantum Information*.

K. R. Subramanian gave a hands-on training to the students of MSc Physics (Astronomy special) in Radio astronomy, at the Bangalore University with observation of the Sun and Jupiter using Radio Jove kit.

K. Sundara Raman guided 4 students of 2nd year BE (Electronics and Electrical Engineering) of Karunya Institute of Technology, Coimbatore for their Summer Project Programme in the field of Solar Physics.

11.2 Invited Talks/Lectures in Workshops /Conferences etc.

S. P. Bagare gave an invited talk titled *Solar optical facilities at the Kodaikanal Observatory* at the Indo-Chinese Workshop on *Recent Advances in Solar Physics,* held at IIA, Bangalore during 7 11, November 2005. He was also invited to talk on the participation of IIA in the IHY 2007 program at the Annual meeting of the Balkans, Black Sea, and Caspian Sea Regional Network on Space Weather Studies, held at Manavgat, Antalya, Turkey, during March 30–April 1, 2006.

B. C. Bhatt presented a seminar on *IAO-Hanle: High Altitude Site for Astronomy & Astrophysics* at the Department d'Astrophysique, de physique des Particles, de physique Nucleaire et de l'Instrumentation Associee (DAPNIA) on May 20, 2005.

Christina B. delivered a talk entitled *Consortia of libraries to Open Access: collaboration at different level*, at the meeting on *Special Libraries SLIB 2005*, KualaLumpur organized by Petronas Co., in the month of May 2005.

B. P. Das gave the following invited lectures : *Parity nonconservation in heavy ions, GSI, Darmstadt*, Germany, 23 May 2005 ; *Parity nonconservation in atomic systems*, University of Mainz, Germany, 1 June 2005 ; *Parity nonconservation in singly ionized barium, Indian Institute of Science,* Bangalore, 31 Aug 2005 ; *New limit for a time-reversal violating electron-nucleus interaction,* Topical Conference on Atomic,Molecular and Optical Physics, Indian Association for the Cultivation of Science, Kolkata, 14 Dec 2005 ; *Parity nonconseravtion in trapped ions,* University of California, Berkeley, USA, 20 March 2006 ; *Electric dipole moment in the electron-nucleus sector : Probe of Higgs Physics, University of California, Berkeley, USA, 27 March 2006* ; *Atomic parity nonconservation : A nonaccelerator probe of the unification of fundamental forces,* Washington State University, Pullman, USA, 18 April 2006; Coupled-cluster theory of parity nonconservation in Ba+, University of Washington, Seattle, USA, 12 April 2005 ; *Atomic parity nonconservation,* Michigan Technological University, Houghton, USA, 3 May 2006; Coupled-cluster theory of parity nonconservation in Ba+, Ohio State University, Columbus, USA, 5 May 2006.

R. T. Gangadhara gave an invited talk on *Radio Pulsars* during the workshop on Frontier Areas of Physics held during 7–8 November, 2005 at Kuvempu University, Shimoga.

K. M. Hiremath gave an invited talk entitled *The Flares associated with the dynamics of the suns pots*, during the International solar workshop on *Transient phenomena on the Sun and interplanetary medium*, held at ARIES, Nainital, India, 05-07 April, 2005.

V. Krishan gave invited lectures on *MHD of Accretion Disks* at the Autumn College on Plasma Physics, Sept.3-16, 2005, ASICTP, Italy.

P. M. S. Namboodiri gave an invited talk titled *The dynamics of colliding galaxies,* in the Indian National Science Congress symposium, at Hyderabad.

B. E. Reddy gave the following invited talks : *Elemental abundance survey of the galactic disk*, a colloquium : ASIAA, Taipei, Taiwan, 10 Feb 2006 ; *Do stars swallow palnets? Few spectroscopic tests* a seminar at ASIAA, Taipei, Taiwan, 13 March 2006; *Chemodynamics of the Galactic Disk: Clues to its evolution*; *Do stars swallow planets? Few spectro-*

scopic tests a Seminar: National Central University, Jungli, Taiwan, 17 March 2006.

S. K. Saha gave colloquiums entitled, (i) *Optical Aperture Synthesis,* at the Institute of Radio Physics & Electronics, Calcutta University, Calcutta, on 19 April, 2005 and (ii) entitled, *Interferometric imaging in optical astronomy,* at the Saha Institute of Nuclear Physics, Calcutta, on 20 April, 2005. He has also delivered an invited talk entitled, *High angular resolution spectroscopy* at the 2nd International conference on, *Current developments in atomic, molecular & optical physics with applications* CDAMOP, during March 21-23, 2006, at Delhi University.

J. H. Sastri gave an invited talk on *The current trends and future prospects of the physics of the Magnetosphere-ionosphere-thermosphere system pertaining to Space Weather-Science and Applications*, during the Plenary session-II on 'Space Weather' at the XIV National Space Science Symposium held in Andhra University, Visakhhapatnam in February 2006. J. H. Sastri gave an invited talk on *Effect of magnetic storms and substorms on the low latitude ionosphere*, at the ILWS workshop held in Goa in February 2006.

P. Shastri gave a seminar on *The Nuclear Structure of Radiogalaxies and the Fanaroff-Riley Divide,* on 31st October, 2005 at the Istituto di Radioastronomia, Bologna. She also delivered a talk on *Different Angles on Seyferts*, 4th November, 2005 at the *Astronomy Department, University of Bologna, Italy.* She also gave a talk at Tauvex meeting on *Active Galaxies and their importance: Results from imaging them.*

Sujan Sengupta gave an invited talk on *Polarimetric detection of earth like exoplanets* at the symposium, 'Star Formation', held at Theoretical Institute for Advanced Research in Astrophysics, Hsinchu, Taiwan during Nov. 28- Dec 08, 2005. He delivered another invited talk entitled *In search of extra-solar planet* at 24th National Space Science Symposium at Andhra University, Vishakapatnam during 9-12 February 2006.

C. Sivaram gave the following invited talks : *Einsteins four papers of 1905, Einsteins unified field theory* at the Phys. Dept., University of Mysore, on April 2, 2005; *Structures in the universe and current status of cosmology*at the Intl- Symposium on life and universe, SSRI, Bangalore (Central College) on August 17, 2005; *Signatures of life in space* Inaugural public talk, Seminar at Regional Science Centre and Planetarium, Calicut; *Scientific work of Hermann Bondi*, Memorial Meeting held at IIA, October 14, 2005;*Aspects of astrobiology,* J.N. Planetarium, Bangalore, October 15, 2005 ;*Einsteins work on General Relavity and Cosmology year of physics*, Bangalore University, on 12 November 2005; *New physics with gamma ray astronomy.* Mini workshop on Gamma ray astronomy, IIA; 75 years of the neutrinos, IIA, on 5 Dec. 2005; *Modern cosmology* 2 lectures,Invited plenary lectures at State level physics workshop, MGM College, Udupi and Mangalore University, on 10 December 2005; *Astrophysics of stars and galaxies 2 lectures. Invited plenary talks, at state level physics seminar, Kalpataru Science College, Kuvempu university, on 17 Dec 2005*; *2005 Nobel Prize in Physics*, Nobel Prizes Symposium, 2005, held at Faculty Hall, IISc; *Aspects of Dark Energy and Black Hole entropy* : Plenary talk, Seminar on Foundations of Science, Bangalore, on 2 February 2006; *Application of Physical principles to Biotechnology.* Plenary talk at Confluence Biospectrum 06, Central College and Indian Academy of Sciences on 13 February 2006; *String Theory 'TOE the line?* (Indian Physics Assoc. and Dept. of Physics Bangalore University) on 4 March 2006.

C. Sur gave the following invited talks : *Einstein's legacy-birth of a new era,* World year of Physics Celebration Meeting, IIA, Bangalore, March 14, 2005 ; *Accurate determination of electric quadrupole moment for optical frequency stadard in Sr+",* Workshop in Modern Trends in Atomic, Molecular and Optical Physics, IIA,Bangalore, Nov 23-24, 2005; *Optical frequency standard with* Sr^+*: A theoretic many-body approach*, Topical Conference in AMO Physics, Kolkata, December 2005 ; *Frequency shift in Optical frequency standard with* Sr^+*: A theoretic many-body approach*, Indo-French Workshop in AMO Physics, Raman Research Institute, Bangalore, January 2006.

11.3 Attendance in Meetings, Workshops, Seminars and Lectures

G. C. Anupama participated in the conference "India's Competitiveness and Preparedness in Science & Technology for the coming Decades" held at NIAS, Bangalore on 26 & 27 October 2005.

G. C. Anupama, D. Banerjee, S. Giridhar, A. Goswami, S. S. Hasan, R. C. Kapoor, R.

Kariyappa, T. P. Prabhu, S. K. Saha, Jagdev Singh attended the workshop on *Science from HCT*, during 21-22, January, 2006.

G.C. Anupama, H. C. Bhatt, R.T. Gangadhara, J. Murthy, G. Pandey, T.P. Prabhu, N.K. Rao, P. Shastri, A. Subramaniam, attended the TAUVEX Science Meeting, March 21-23, 2006, IIA, Bangalore.

D. Banerjee, S.S. Gupta, S.S. Hasan, K.P. Raju, K.B. Ramesh, K.E. Rangarajan, Jagdev Singh, K.R. Subramanian, K. Sundara Raman attended the Indo-Chinese workshop on *Solar physics* during 7-11 November, 2005.

B. C. Bhatt attended a six weeks programme on *Advanced Techno-Management Programme for Scientists/Technologists* sponsored by Dept. of Science & Technology, Govt. of India during March 07 - April 16, 2005 at Administrative Staff College of India, Hyderabad.

S. Giridhar attended a workshop on *Indo-French network in astronomy* which was organized at the IUCAA, during June 30-July 1,2005. She chaired a session of the above mentioned workshop.

Goswami, Aruna gave two lectures on Dec. 12 and 13, 2005 titled *Nucleosynthesis in stars,*, *Formation and evolution of elements in our Galaxy,* at the 2nd Nurture Camp for Indian Intl Astronomy and Physics Olympiad students, held at VBO, Kavalur, IIA, during 9-20 December 2005; *ESO/MPA Workshop on Carbon-rich Ultra Metal-poor, stars in the Galactic halo* : A Workshop Summary Group Committee II meeting, March 24, 2006.

S. S. Hasan was the co-chair of the SOC for the Indo-China Workshop on *Solar Physics*, November 7-11, 2005 at IIA. He had participated in the *International Living with a Star Workshop*, February 20-24, 2006 in Goa. He chaired two sessions and was the Working Group Leader in the sessions on the *Sun and Heliosphere.*

Hiremath K. M., attended the (i) 'ILWS workshop 2006' Goa, Feb 19-25, 2006, (ii) *International Solar Workshop On Transient Phenomena On the Sun And Interplanetary Medium*, held at (ARIES), Nainital, India, 05-07 April, 2005.

R. C. Kapoor attended the 14th National Space Science Symposium 9-12 Feb 2006 at Vishakapatnam.

V. Krishan attended the International Conference "On Plasma Simulation and Theory, Nara, Japan, July 5-9, 2005. She also attended the Conference on *Theoretical and Experimental Physics*, Feb, 8-9, 2006, Univ. of Tokyo and delivered a lecture on *Search for instabilities in accretion disks.* She has also given lectures on *Accretion Disks , Equilibrium and Instabilities*, at Universities of Osaka and Kyoto, Japan, November 2005. She also delivered a series of lectures on *MHD of accretion disks* at Abdus Salam International Center for Theoretical Physics, Italy, during 4 - 16 Sept., 2005.

P. M. S. Namboodiri attended the 93rd Indian Science Congress at Hyderabad during 3 - 7 January 2006.

E. Reddy gave a Colloquium: August 2005, IIA, Bangalore, on *Chemodynamics of the Galactic Disk: Clues to its evolution*

S. K. Saha attended the Mini workshop on 'Gamma Ray Astronomy', 17-18 Nov, 2005, at IIA, Bangalore ; Second International conference on, 'Current developments in atomic, molecular & optical physics with applications' CDAMOP, during March 21-23, 2006, at Delhi University.

J. H. Sastri participated in the *XIV National Space Science Symposium (NSSS-2006)* held in Andhra University, Visakhapatnam during 9-12 February 2006. He also participated in the *International Living With a Star (ILWS)* workshop held in Goa, during 19-24 February 2006.

P. Shastri attended the International Astrophysics Conference, *Relativistic Astrophysics and Cosmology - Einstein's Legacy* -, Munich, Germany, 7-11 November, 2005; 3rd ASTROSAT Workshop on *Active Galactic Nuclei*, M. L. Sukhadia University, Udaipur, 21-29 December, 2005; Talks: *1. AGN Classification and General Properties 2. Active Galaxies in the Ultra-Violet.*

Jagdev Singh attended the meeting at RRI to discuss the space based solar observational facility in January 2006 and gave a talk on *Proposal for space coronagraph in the visible part of the spectrum.* At the IHY meeting held at Manavgat, Turkey on March 30, 2006 Jagdev Singh spoke on the *Chromospheric*

variations with the solar cycle phase.

A. Subramaniam attended the conference on *Island Universes: Formation and evolution of disk galaxies,* July 2005, Netherlands.

K. R. Subramanian attended the *XVIIIth Union of Radio Science International* GA 2005, Oct 24 - 28, 2005 New Delhi; *XIV National Space science symposium,* Visakapatanam, Feb 9-12, 2005.

C. Sur attended the workshop in Modern Trends in AMO Physics, IIA, Bangalore, Nov, 2005 ; Topical Conference in AMO Physics (TC2005), Kolkata, Dec. 2005 ; Indo-French workshop in AMO Physics, RRI, Bangalore, January 2006.

11.4 Visits

D. Banerjee visited Armagh Observatory, UK for three weeks in September 2005.

Under the IFCPAR CaFICA Project, **B. C. Bhatt** visited the Laboratoire des Sciences du Climat et de l'Environement (LSCE)/Department d'Astrophysique, de physique des Particles, de physique Nucleaire et de l'Instrumentation Associee (DAPNIA), F-91198 Gif-sur-Yvette Cedex, France during May 8-June 4, 2005.

H. C. Bhatt visited Calicut University, Calicut, 2 December, 2005.

R. T. Gangadhara visited the NCRA, Pune, during April 2-8, 2006 and gave a seminar on *Pulsar emission altitude from relativistic phase shift* on 6th April 2006 at NCRA, Pune.

S. S. Hasan visited the Paris Observatory at Meudon, France (May-July 2005) and the Kiepenheuer Institute, Freiburg, Germany during June 12-16, 2005. S. S. Hasan led the IIA team to the Total Solar Eclipse on March 29, 2006 in Antalya, Turkey.

Ismail Jabilullah had been to M/s. Anorad, BV, Netherlands for the inspection and familiarization of the air bearing translation stage in connection with the LTP Project.

V. Krishan visited the Univ. of Tokyo as Visiting Professor for the period April, 2005 - Feb. 2006.

K. N. Nagendra visited the *Observatoire de Nice*, France, for Two months during Sept-Nov, 2005 and the *Istituto Ricerche Solari Locarno*, Switzerland, for a month during August 2005.

M. Parathasarathy spent six months (Jan 2005 - June 2005) as a visiting Professor at the department of Physics and Astronomy, University of Oklahoma, Norman, USA.

N. K. Rao spent 4 months at McDonald observatory University of Texas at Austin, Texas, USA, from late Dec 2005 to middle of April 2006.

B. E. Reddy spent 3 months (June - Aug) in 2005 at University of Texas, Austin, USA and McDonald Observatory, Fort Davis, USA. He was also a visiting scientist at Institute of Astronomy and Astrophysics, Taiwan during Jan-Mar, 2006.

P. Shastri visited the Istituto di Radioastronomia, Bologna, as well as the *Astronomy Department, University of Bologna, Italy.*

Sujan Sengupta visited Theoretical Institute for Advanced Research in Astrophysics (TIARA), Hsinchu at Taiwan twice during 2005 on invitation of Professor Ronald Taam and Academia Sinica, Institute of Astronomy and Astrophysics (ASIAA) at Taipei, Taiwan.

C. Sur visited the Indian Association for the Cultivation of Science, Kolkata, Dec. 2005. He also visited the Dept of Physics,Visva-Bharati, Santiniketan, West Bengal, December, 2005.

11.5 Involvement with Scientific Community

G.C. Anupama is the co-PI of the project *Symbiotic binary stars and related objects* approved under the Indo-Polish Exchange Programme. PI of the INSA-JSPS project *Physics of core collapse supernovae.* She is also the Editor of the Bulletin of the Astronomical Society of India since 2004 March and Member of the review committee for the project *Virtual Observatory India - The Next Generation*, (PI: A.K. Kembhavi, IUCAA), funded by the Ministry of Communications and Information Technology.

B. C. Bhatt has been awarded Life membership of Administrative Staff College of India, Bella Vista, Hyderabad during 2005.

H. C. Bhatt served as (i) Member of the GMRT Time Allocation Committee (ii) Refereed research proposals for DST and ISRO.

B. P. Das has the following research projects *Computational Many-Body Theories of Symmetry Violations in Atoms,* supported by BRNS-DAE ; *Tests of fundamental symmetries, theory and precision spectroscopy with complex atoms,* supported by Department of Science and Technology, India and National Science Foundation, U.S.A. Participating Institutions : Indian Institute of Astrophysics, Physical Research Laboratory and University of California, Berkeley, USA.

As Vice President of Commission 45, on Spectral Classification **S. Giridhar** will co-chair the SOC along with C. Corbally and Coryn Bailer-Jones for the Joint Discussion titled "Exploited Large Surveys for Galactic Astronomy" which has been alloted 1.5 days during GA-2006 (16-25 August 2006). Giridhar would also be co-editor of the Proceedings of the above mentioned JD. Giridhar has reviewed a research project for DST.

S. S. Hasan was the Indian Principal Investigator of an Indo-French programme on *Dynamics of Solar and Stellar interiors: Seismology and Activity* during the period October 1, 2001 to September 30, 2005. This is a collaborative programme between IIA and TIFR from the Indian side and Observatoire de Paris, Laboratoire d'Astrophysics (Toulouse) and Observatoire de Cote d'Azur (Nice) on the French side. He continued to be a member of the editorial board of Journal of Astrophysics and Astronomy. Since 1991, S. S. Hasan is an Associate of the Harvard College Observatory, Cambridge, U.S.A. He is also the Vice-President of the Astronomical Society of India.

M. Parthasarathy continued to be Vice-President of *IAU Commission 29 : Stellar Spectra.*

R. Kariyappa continues to be a "Council Member for Karnataka State Council for Science & Technology", by Karnataka Government, Indian Institute of Science, Bangalore for 3 years (2004 - 2007). He continues to serve as co-investigator for SOLARNET space mission project under CNRS, France. NASA has selected him as "Mail-in-Reviewer" to review two research proposals which have been submitted to NASA for funding.

K. N. Nagendra continued to be a member of the SOC IAU Comm. 36, on Stellar Atmospheres. He continues to hold the position of visiting Professor at the Observatory of Nice, France. He continues as a Technical Specialist and collaborator in a major French CNRS project organized to be conducted at Observatory of Nice, and Observatory of Meudon, in France, for 3 years.

P. M. S. Namboodiri has been an external examiner for the M.Sc.(Astronomy) examination of Osmania University, Hyderabad.

B. Raghavendra Prasad is a member of DST (TSG) Project Review Committee on Molecular Electronics, conducting polymers, Non-invasive and other bio-sensors.

N. K. Rao is the member of the organising committee for the symposium *Life & Universe* organised by the SSRI (Science and Spiritualitay Research in India), Bangalore, during August 2005 held at Bangalore University Campus.

S. K. Saha continued to be the member of the Editorial Board, Asian Journal of Physics. He also continued to be a member of the Project Appraisal & Review Committee (PARC) of a project on 'Design & Development of Adaptive Optics System for Missile Imaging & Tracking and Long Range Surveillance', Instruments Research & Development Establishment (IRDE), Defence Research & Development Organisation (DRDO), Dehra Dun, India.

J. H. Sastri served as a Member of the Scientific Advisory Committee of Space Physics Laboratory (SPL) of VSSC/ISRO, Trivandrum. He also served as a Co-Chair of the Working Group (WG) for Space Weather: Science and Applications of CAWSES-India program funded by DOS/ISRO and as a member of the PAC-Atmospheric Sciences of DST, New Delhi.

A. K. Saxena continues to serve as an expert member of many national scientific project committees of ISRO, IRDE and BARC.

C. Sivaram brought out five more issues of the newsletter on Astrobiology in 2005-06 with the assistance of Mr.Ajay Sastry. C. Sivaram was examiner for the paper on Astrophysics for M Sc. final year, Bangalore Univ.

12 Public Outreach

12.1 Lectures, Talks

G. C. Anupama gave a talk on *Supernovae* on 17 Dec 2005 at the B.H.S. First Grade College, Bangalore. She also gave a talk on *Supernovae and other energetic phenomenon* on 13 January 2006 at Ninth NIAS Course for University and College Teachers on Integrated Approach to Knowledge and Information conducted at NIAS, Bangalore during 2005 December 28 - 17 January 2006.

S. P. Bagare gave an invited lecture titled *Contributions of total solar eclipse observations to Physics and Astrophysics* at the state level physics conference on "Contributions of Einstein and his contemporaries to physics and mankind", at S.J.M. College, Chitradurga, held during 30-31 December 2005.

R. T. Gangadhara attended a state level physics conference on *Contributions of Einstein and his contemporaries to Physics and Mankind* held during December 30-31, 2005 at S. J. M. College, Chitradurga. He made an oral presentation on *Stellar Evolution and Origin of Neutron Stars.* He also gave talks on (i) *White Dwarfs, Neutron Stars and Pulsars* at K.E.L. Society, S. Nijalingappa College, Rajajinagar, Bangalore on 17th December, 2005, (ii) *White Dwarfs and Neutron Stars*, during the Refresher Course in Physics, UGC Academic Staff College, Bangalore, on 7 March 2006, (iii) *Radio Pulsars* to them on the same day.

S. S. Gupta gave a valedictory address to the PG Physics students of the Alagappa University, Karaikudi, T.N., on the Rajiv Gandhi Renewable Energy Day Celebrations, 2005, Seminar on Renewable Energy for Society, on August 20, 2005.

R. C. Kapoor had organized an IIA exhibition on Sept 23-24, 2005 at Christ Junior College in Koramangala with displays of astronomical objects and the laboratories of the Institute.

R. Kariyappa has been invited as a Chief Guest to inaugurate the "Arts & Science Exhibition" and to address the students at R.S High School, Bangalore on December 28, 2005. He has been invited as one of the Judges to select the best Science Exhibition held at Christ College, Bangalore University, Bangalore on September 23, 2005.

J. P. Lancelot gave lectures at the M.P.Birla Institute of Fundamental Research for the Astronomy and Astrophysics course.

P. K. Mahesh gave an invited lecture at the Kongu Engineering College, Perundurai, Tamilnadu on 23-8-2005 titled *Design of Astronomical telescopes-Some aspects* and inaugurated their Mechanical Engineering Graduates Association (MEGA) for 2005.

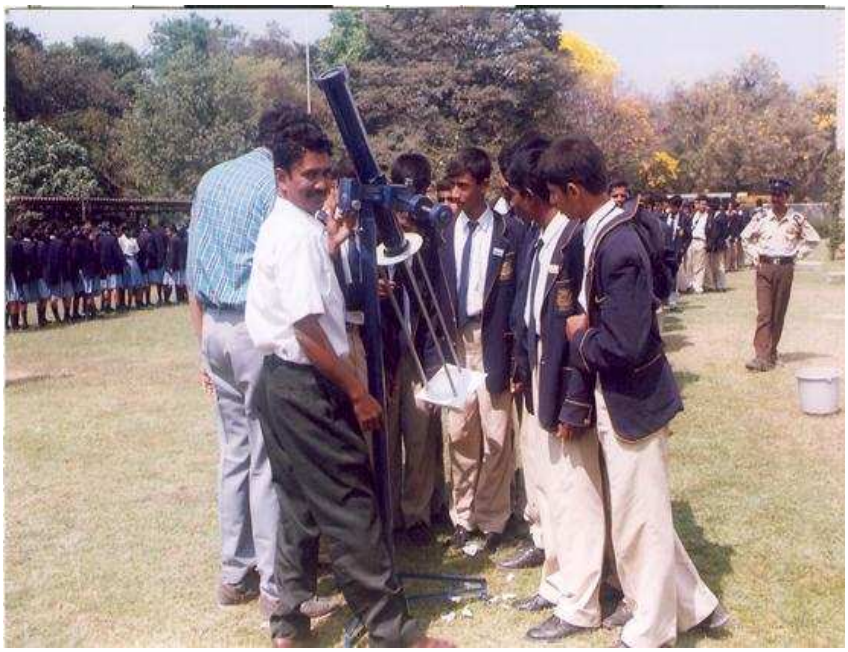
A. Mangalam gave a popular talk on 'Stellar Dynamics' to college students at the Nehru Planetarium in May 2005.

Jayant Murthy gave a talk on 'Space Astronomy' at National Institute of Technology (Karnataka) at Suratkal.

G. Ramachandran gave a talk at the BASE, JNU, Bangalore on "Special Theory of Relativity" on 1st June 2005 Wednesday at 11 A.M.

P. Shastri delivered a talk on *Supermassive black holes* at the Nehru Planetarium, Bangalore, June 2005.

C. Sivaram gave the following popular invited lectures : *Some universal aspects of language, information and communication CIL, Mysore, April 2, 2005*; *From Atoms to Quarks and Neutrinos* : Inaugural plenary lecture at the 14th Summer school of Science, Mahajana Education Society, Mysore, May 9, 2005 ; *Frontier areas in physics and astrophysics Inaugural plenary lecture*, in Refresher course at Mahaveer Jain College, Bangalore, June 8, 2005 ; *Einsteins papers at 1905 and his life and work.* Inaugural plenary Lecture, Year of physics, Christ College, Bangalore, on June 16, 2005; *Introduction to Astronomy and Astrophysics*, Lectures given to staff of Briggs of Burton (India) Ltd, on August 12, 2006; *Aspects of Bird Flight and Navigation,* National Seminar on Bird Ecology and Conservation, Bangalore on November 13, 2005 ; *Import of Einsteins work on science and technology.* Inaugural Plenary lecture, World year of Physics seminar at Bangalore Institute of Technology, 23 November 2005; *Modern cosmology* 2 lectures Invited plenary lectures at State level physics workshop, MGM College, Udupi and Mangalore University on December 10, 2005; *Cosmic Power Houses* Mico-Bosch Bangalore on 20 Dec. 2005; *Calendars through the ages*, BIFR, Bhartiya Vidya Bhavan on 27 Jan 2006; *Cosmology*, BIFR, Bangalore, 30 Jan 2006; *Stellar energetics, compact objects and the Cosmos*, Symposium on Frontiers of Physics, Ind.



Acad. Sci, and Phys. Dept. St. Philomenss College, Mysore, on 17 Feb 2006.

K. Sundara Raman gave popular lectures on the topics: *Sun, our Star* on the occasion of the Teachers day celebrations held at Labbaikudikadu, Perambalur District, Tamil Nadu on August 27, 2005 to school teachers belonging to the district. *To challenge the minds of today and pick the master tomorrow*, at the School of Management Studies, School of Computer Applications and School of English belonging to the various colleges of Madurai Kamaraj University on the occasion of MAGNACOM 2005. He addressed the assembly of the students belonging to most of the Engineering Colleges and Science Colleges in Erode at "Institute of Road Transport and Technology", Erode, on the occasion of National Science Day on February 28, 2006 and a keynote address on *Nurture the Nature for Our Future* and also presented a talk on *Solar and Astrophysics* and *Popular Astronomy* to the students of Brindavan Public School, Trichy on March 14, 2006.

12.2 National science day, 2006

The Institute celebrated the National Science Day on the 28th February with great enthusiasm. Lectures on astronomy and film shows on the Institute laboratories were arranged in the Auditorium whereas a 7.5 cm refractor specially modified to project the image of the Sun onto a screen attached to it was installed in the lawns for public to view. More than 600 students from nearby schools attended the sessions which included a short film (30 min) on eminent Indian scientists of the 20th Century. This film was specially made by PhD students of the Institute. A special lecture on the radio view of the universe was also given by Ebenezer.

(R. C. Kapoor)

13 Conferences, Workshops hosted at IIA

13.1 Kodai summer school in physics and astrophysics

A 3-week summer school on Quantum mechanics, Statistical Mechanics, Fluid Dynamics, Brownian Motion, Special relativity, Cosmography and Cosmohistory was organized at IIA, Kodaikanal, during June 06 - 25, 2005. The enrichment course consisted of course lectures and tutorials. Twentyfour final M.Sc., B.Sc., Physics and B.Tech., students from various Universities, Colleges attended the school. Experts in the field from different scientific and educational institutions were invited to give the course lectures and tutorials.

13.2 A meeting in memory of Sir Hermann Bondi

A special meeting was organized in IIA on 14 October 2005, in the memory of Prof. Sir Hermann Bondi, KCB, FRS. Bondi was an honorary fellow of the Institute. He was an eminent scientist who held several important positions such as Scientific Adviser to the British Govt., Head of European Space Research Organization and Master of Churchill College. C.V. Vishveshwara gave an account of some personal reminiscences and anectodes regarding Bondi and C. Sivaram elaborated on several of Bondi's scientific contributions, especially his seminal work on the steady state cosmological theory, various aspects of gravitational radiation, definition of mass in general relativity and well known solutions named after him. His important works which have much astrophysical relevance such as Bondi accretion models were also discussed.

13.3 Indo-Chinese workshop on recent advances in solar physics

The Indo-Chinese workshop on *recent advances in solar physics* was hosted by the Indian Institute of Astrophysics, Bangalore, India during Nov 7-11, 2005. Solar and Space Plasma Physics is a dynamic field of research in rapid development. This workshop on solar and space plasmas physics provided a forum to exchange and discuss recent results and ideas on the latest theoretical models and observational data. This was a historic first meeting of this kind, the Indian and Chinese solar physicists exchanged notes about the respective national facilities. This workshop also enabled the national solar community to exchange views. Recently we have hardly had any national level workshop of this kind. During the last day of the workshop, a specific session was set aside to discuss possible cooperations between the Chinese and Indians. There were invited oral presentations and contributed presentations in the form of posters. An Evening Pub-

lic Lecture titled '*Mysteries of our nearest star-the Sun* was also organised. It was delivered by Prof. Arvind Bhatnagar (formerly Director, Udaipur Solar Observatory). All the presentations are available in electronic form in the conference website (http://www.iiap.res.in/icw05/). The meetimg was well attended.

13.4 Workshop on gamma ray astronomy

A mini-workshop on gamma-ray astronomy was held at IIA on 17 November 2005. It was attended by scientists and engineers of IIA, TIFR, BARC, RRI and ISAC. There were review talks on gamma-ray astronomy from ground as well as space, celestial gamma-ray sources, gamma-ray production mechanisms and the impact of gamma-ray astronomy on physics.

Following the presentation and discussions, a panel discussion was held to review the ongoing activities and future plans of India in this field. It was concluded that the high-altitude advantage of Hanle provides us with an opportunity to develop a world class gamma-ray facility with a low energy threshold at much lower cost compared to the investments made in this direction by other countries. The ongoing HAGAR project at Hanle and planned MACE project are the first steps which will pave way to further augmentations at Hanle.

13.5 Workshop on modern trends in atomic, molecular and optical ph ysics

A workshop on the said topic was held at IIA on 23-24 November, 2005. There were about 50 participants from IIA, IISc, RRI, University of Goa, Bangalore University and University of California, Berkeley, USA. It covered topics at the cutting edge of atomic, moleculcular and optical (AMO) physics. Dmitry Budker, in his keynote address emphasized the applications of AMO physics to particle physics and astrophysics. Some of the talks were on the recent pathbreaking developments in cold atoms and molecules as well as quantum computation. A few talks highlighted some of the important advances in the theory of atomic and molecular structure and their applications to fundamental symmetries. Some interesting talks on optical physics were also presented. Budker also delivered a special lecture on *the Physics Nobel Prize 2005.*

13.6 Workshop on science from the Himalayan Chandra Telescope

A national meeting of users of the 2-m Himalayan Chandra Telescope (HCT) was organised at IIA on 21-22 January 2006. The meeting was attended by 20 users of HCT from IIA and 21 national users outside IIA, apart from 26 other interested scientists and engineers. A booklet on HCT was also released on the occasion.

The scientific program consisted of overview of HCT, facilities, and utilization, followed by several talks on the results from HCT since May 2003. There were also presentations on a few new programmes, proposals of second generation instruments, and other initiatives at Hanle in astronomy as well as other sciences. Considerable time was provided for discussions within the user community and a report was generated based on the discussions. The HCT user community strongly stressed the need for a large telescope at Hanle, further instrumentation for HCT, and further augmentation of the facilities around HCT and its remote control station. The meeting was well attended.

13.7 TAUVEX Meeting

A Workshop was held (Mar. 21 - 23, 2006) at IIA to plan for the science to be done with the TAUVEX mission. About 40 people attended from IIA and other institutions including Israeli collaborators. A number of presentations were made about instrument capabilities and the expected science (posted at http://tauvex.iiap.res.in). As a result of the meeting, it was decided that a science document would be put together to aid in mission planning. It was agreed that there would be equal participation of the Indian and Israeli scientists in the science with collaborative papers encouraged. Various software tools have been created to help the interested observer.

14 Colloquia given by visitors

15.4.2005
International Heliophysical Year 2007
N.Gopalswamy
NASA/Goddard Space Flight Center, Greenbelt, USA

30.5.2005
Constitution of ASP-2 on Space Weather-Science and Road Map for Space Weather Research : The Solar Connection
P. Venkatakrishnan
Udaipur Solar Observatory, PRL, Ahmedabad

14.6.2005
A Sounding Rocket Experiment for Direct Imaging of Epsilon Eridani b
07.3. 2006
Round-the-Clock Ground-based Imaging Spectroscopic Studies of the Solar Terrestrial Interactions
Supriya Chakrabarti
Center for Space Physics, Boston University, USA

20.6.2005
Solar Physics and Development of the BDA Project at INPE
H. S. Sawant
Dept. of Astrophysics, INPE, Brazil

23.6.2005
High Resolution Spectro-Polarimetry at the Dunn Solar Telescope
K. Sankarasubramanian
National Solar Observatory, Sunspot, New Mexico, USA

1.7.2005
Canonical Transformations
Subhashish Banerjeee
JNU, Delhi

7.7.2005
The Sloan Digital Sky Survey and the Virtual Observatory
26.7.2005
Virtual Observatory Tools at JHU
Anirudha Thakar
John Hopkins University, USA

13.7.2005
Overview of the Facilities at Lytkarino Optical Glass Factory
Maxim Yesipov
Lytkarino Optical Glass Factory Moscow, Russia

20.7.2005
Reddening Variation in Young Open Clusters
Brijesh Kumar
ARIES , Nainital

21.7.2005
Testing Fragmentation Models for Forming Binary / Multiple Protostars
22.7.2005
Scientific Opportunities at the ASIAA
Jermy Lin
Institute of Astronomy & Astrophysics Academia Sinica, Taiwan

9.8.2005
The Double Pulsar - An Odd Couple
G. Srinivasan
ISRO Satellite Centre, Bangalore

12.8.2005
What can we Learn from Gamma Rays and Neutrons about the Sun
James M. Ryan
University of New Hampshire, USA

18.8.2005
A Relativistic Equation of State for Neutron star
Prafulla Kumar Panda
University of Florianopolis, Brazil

5.9.2005
Caribou: Global Network for in-situ measurement of CO 2 concentration
Michel Ramonet
Laboratoire des Sciences du Climat et de 1 'Environment (LSCE), France

5.9.2005
Chemodynamics of the Galactic Disk: Clues to Formation and Evolution of the galaxy
6.9.2005
Analysis of Ultraviolet Spectra of Extreme Helium Stars and New Clues to their Origins
David L Lambert
McDonald Observatory, University of Texas, Austin, USA

14.10.2005
Cosmos & Culture
C. V. Vishveshwara
J.N. Planetarium, Bangalore

25.10.2005
M82: A Spiral Galaxy in Formation
Y. Divakara Mayya
INAOE, puebla, Mexico

26.10.2005
The Sardar Sarovar Narmada Project : An Engineeing Marvel
K.S. Srinivas
SS Narmada Nigam Ltd Gandhinagar, Gujarat

16.11.2005
Quasar host Galaxies : Recent Work and Puzzles
John Hutchings
NRC Herzberg Institute of Astrophysics,
Vancouver, Canada

19.12.2005
Resolving Extended Stellar Components in Nearby Galaxies
Anil Seth
Dept Astronomy, Univ. Washington, Seattle, USA

2.1.2006
Recent Developments in Magnetic Reconnection Theory : Applications to Space and Laboratory Plasmas
Amitava Bhattacharjee
Space Science Center, Inst. Study of Earth, Oceans and Space, University of New Hampshire, USA

3.1.2006
Detection of Waves in the Outer Solar Atmosphere
Eoghan O'Shea
Armagh Observatory , U.K.

16.1.2006
Synergy Between colliders and cosmology
CERN Sabine Kraml
Geneva, Switzerland

17.1. 2006
Origin of the most Energetic Cosmic Rays
S. Kawakami
Osaka City University, Japan

19.1. 2006
The Diffuse Ultraviolet Background
Richard Conn Henry
The Johns Hopkins University, USA

31.1. 2006
Observations of Radio Jets and Molecular Gas in Nearby Radio Loud Galaxies
Mousumi Das
Raman Research Institute, Bangalore

7.2. 2006
Is The Solar Chromosphere Always Hot?
Wolfgang Kalkofen
Harvard-Smithsonian Center for Astrophysics, USA

14.2. 2006
Spinning Black Holes - Which Way do they Point?
Jim E. Pringle
Institute of Astronomy, Cambridge, UK

28.2. 2006
Large-Scale Circulations of Prominences and the 530.3 nm Corona
Vojtech Rusin
Astronomical Institute, Slovak Academy of Sciences,
The Slovak Republic

1.3. 2006
The Ultimate High Resolution View of the Sun: the SOLARNET Mission
Luc Dame
Service d'Aeronomie du CNRS, France

14.3. 2006
Seismic View of the Solar Interior
Kumar Chitre
Dept. of Physics, University of Mumbai, India

28.3. 2006
Cosmic Evolution of Black Hole Mass and Metallicity in Active Galactic Nuclei
Hagai Netzer
Tel-Aviv University, Israel

15 Visitors at IIA

May 2005
U.J. Sofia
Whitman College, USA

24.5.05-2.6.05
S. Ramadurai
TIFR, Homi Bhabha Road, Mumbai

13.6.05-16.6.05 & 6.3.06-8.3.06
Supriya Chakravarthi
Center for Space Physics, Boston Univ., USA

13.6.05-20.6.05
F. Madsen
INPE, Brazil

18.6.05-23.6.05
H. S. Sawant
Dept. of Astrophysics, INPE, Brazil

June 2005-August 2005
P. K. Panda
Univ. Florianpolis, Brazil

1.7.05-29.7.05
A. Thakar
John Hopkins Univ., USA

13.7.05-15.7.05
Maxim Yesipov
Lytkarino Optical Glass Factory Moscow, Russia

17.7.05-21.7.05
Brijesh Kumar
ARIES , Nainital

20.7.05-23.7.05
Jermy Lin
Institute of Astronomy & Astrophysics Academia Sinica, Taiwan

10.8.05-13.8.05
James M. Ryan
University of New Hampshire, USA

11.8.05-09.9.05
David L Lambert
McDonald Observatory, University of Texas, Austin, USA

6.11.05-13.11.05
A. Bhatnagar
Udaipur Solar Observatory, India

6.11.05-12.11.05
Fang Cheng, Ding Minde & Tang Yuhua
Nanjing Univ., China

6.11.05-12.11.05
Wang Jingxiu, Bi Shaolan, Yan Yihua, Deng Yuanyong, & Qu Zhongquan
NAOC, Yunnan Observatory, China

6.11.05-12.11.05
Ji Haisheng, Li Hui & Gan Weiqun,
Purple Mountain Obs., China

6.11.05-12.11.05
Yang Zhiliang
Beijing Normal Univ., China

14.11.05-23.11.05 & 20.3.06-25.3.06
John Hutchings
Herzberg Institute of Astrophysics,
Vancouver, Canada

02.1.06-12.1.06
Eoghan O'Shea
Armagh Observatory , U.K.

16.1.06-19.1.06
S. Kawakami
Osaka City University, Japan

28.1.06-22.2.06
Wolfgang Kalkofen
Harvard-Smithsonian Center for Astrophysics,
USA

26.2.06 - 6.3.06
Luc Dame
Service d'Aeronomie du CNRS, France

16.3.06-18.3.06
K. Rathnatunga
Carnegie Mellon University, USA

14.2.06
Jim Pringle
Institute of Astronomy,
Cambridge, UK

2.2.06-22.3.06
E. Destefano
INAF - Catania Astrophysical Observatory,
Catania, Italy

20.3.06-29.3.06
Hagai Netzer
Dept of Phys. & Astronomy
Tel Aviv Univ., Israel

21.3.06-23.3.06
E. Almozonino & N. Brosch
Dept of Phys. & Astronomy
Tel Aviv Univ., Israel

16 National & International Programmes

16.1 Collaborations with other countries

1. The Indian Institute of Astrophysics has signed a MOU with INPE of Brazil in June 2002 for the development of digital correlator system for the Brazilian decimetric array (BDA) being constructed by INPE at Brazil. The first part of the system was interfaced in December 2003 for a 5 element interferometer at the INPE campus. A 1444 channel correlator system is being constructed at IIAP for the final phase of the BDA which will consist of 32 parabolic dishes of 4 m in diameter operating in the band 1.5 - 5 GHz with maximum baselines of 2 km.

2. TAUVEX mission, an Indo-Israeli ultraviolet imaging experiment that will image large parts of the sky in the wavelength region between 140 and 320 nm, is planned to be launched in 2006.

3. The faint object spectrograph and the auto guider for the 2-m HCT, Hanle, were developed in collaboration with the Copenhagen University Observatory, Denmark.

4. Indo-German collaborations on the study of dynamics and heating of the magnetized chromosphere of the Sun.

5. In order to set up an antipodal transient observatory, the IIA is collaborating with the McDonnell Center for Space Sciences, Washington University, St Louis to operate two 0.5-m optical telescopes for photometric monitoring of active galactic nuclei. One of these telescopes situated in Arizona is operational. The other one, nearly 180 deg apart in latitude, is installed at the Indian Astronomical Observatory, Hanle, and is currently undergoing commissioning tests.

6. A radio spectrograph operating from approximately 18-70 MHz is being developed for radio telescope at Gauribidanur under the UN Basic science initiated programme in collaboration with the University of Maryland, and the Naval Research Lab.

16.2 Collaborations with institutes within the country

1. IIA is collaborating with ISRO, Inter University Center for Astronomy and Astrophysics (IUCAA), Physical Research Laboratory (PRL), and Tata Institute of Fundamental Research (TIFR) to develop UltraViolet Imaging Telescope (UVIT), which is one of the payloads on satellite Astrosat.

2. IIA is also collaborating with TIFR in setting up a Gamma Ray Telescope array at IAO, Hanle, utilizing the atmospheric Cerenkov technique for detection. The high altitude will help in reducing the detection threshold to lower energies. The array consists of 7 telescopes, each with 7 mirrors of total area 4.4 square meters. The telescopes are deployed over a circle of radius 50 meters. The expected detection threshold is 50 GeV. Two of these telescopes were installed in 2005 and the remaining five are being installed in 2006.

17 Academic/ Scientific/ Technical staff

Director: S. Sirajul Hasan

Senior Professor: B. P. Das, Vinod Krishan, M. Parthasarathy, T. P. Prabhu, N. Kameswara Rao, J. H. Sastri, R. Srinivasan

Professor: H. C. Bhatt, D. C. V. Mallik, Jayant Murthy, R.C.Kapoor, Jagdev Singh, C. Sivaram

Head Photonics: A. K. Saxena

Sr.Principal Scientific Officer: A. V. Ananth

Associate Professor: P. Bhattacharjee, Sunetra Giridhar, S. Surendra Gupta, S. G. V. Mallik, K. N. Nagendra, K. E. Rangarajan, S. K. Saha, K. R. Subramanian

Scientist E: S. P. Bagare, P. M. S. Namboodiri, A. K. Pati, B. R. Prasad, A. V. Raveendran

Scientist D: Arun Mangalam, G. C. Anupama, S. Chatterjee, R. K. Chaudhuri, P. K. Das, R. T. Gangadhara, R. Kariyappa, M. V. Mekkaden, S. Mohin, K. P. Raju, K. B. Ramesh, A. Satyanarayanan, Prajval Shastri, R. Surendiranath

Engineer E: V. Chinnappan, G. Srinivasulu, M. S. Sundararajan

Sr.Civil Engineer: N. Selvavinayagam

Scientist C: S. Annapurni, D. Banerjee, B. C. Bhatt, A. Goswami, J. Javaraiah, U. S. Kamath, S. Muneer, G. Pandey, P. S. Parihar, R. Ramesh, B. Eswar Reddy, D. K. Sahu, S. K. Sengupta, M. Srinivasa Rao, K. Sundara Raman, B. A. Varghese

Scientist: K. M. Hiremath

Incharge Optical Workshop: J. P. L. C. Thangadurai

Senior Technical Officer: J. P. A. Samson

Technical Officer B: J. V. S. V. Rao

Engineer C: V. Arumugam, S. S. Chandramouli, Dorjai Angchuk, Faseehana Saleem, S. Kathiravan, P. M. M. Kemkar, P. K. Mahesh, S. Nagabhushana, J. S. Nathan, R. Ramachandra Reddy, B. Ravikumar Reddy, M. P. Singh, S. Sriram

Asst. Librarian C: Christina Birdie

Scientist B: P. Bama, E. Ebenezer, B. S. Nagabhushana, N. Shanthi Kumar Singh

Scientific Officer SC: P. S. M. Aleem, L. Yeshwanth

Engineer B: P. Anbazhagan, K. Anupama, K. Dhan anjay, P. U. Kamath, Sanjiv Gorkha, Sonal Torphil, Tashi Thsering Mahay, K. C. Thulasidharan, Tsewang Dorjai, Vellai Selvi

Technical Officer: S. Muthukrishan, R. Muraleedharan Nair, C. Nanje Gowda, K. Rangaswamy, R. Selvendran

Documentation Officer: Sandra Rajiva

Tech.Associate B: F. Gabriel, K. Jayakumar, M. Joseph Rosario, K. Kuppuswamy, G. N. Rajashekara, A. Selvaraj, N. Sivaraj, K. S. Subramanian, G. S. Suryanarayana

Technical Associate: A. S. Babu, D. Babu, Kumaravel, S. Pukalenthi, A. Ramachandran, S. Ramamoorthy, K. Ravi, M. R. Somashekar, C. V. Sriharsha, A. V. Velayuthan Kutty

Assistant Librarian A: B. S. Mohan, P. Prabahar.

Distinguished Professors: Ramanath Cowsik (Vainu Bappu Chair), V. K. Gaur, K. R. Sivaraman, S. N. Tandon (Adjunct)

Visiting Sr.Professor: G. Ramachandran, P. R. Vishwanath

Visiting Scientist: R. Vasundhara

Visiting Fellow/PDF: N. V. Sujatha, Chiranjib Sur

SRF: K. J. Baliga, R. K. Banyal, C. Kathiravan, K. V. P. Latha, Malay Maiti, K. Nagaraju, Malay K. Nayak, R. M. Thomas, M. Sampoorna, P. Shalima

JRF: Rumpa Choudhri, Abhay M. Karnataki, B. Mathew, Tapan Mishra, H. S. Nataraj, A. C. Pradhan, G. Vigeesh, Veeresh Singh, Bharat K. Yerra

Project Consultant: A. Vagiswari

Sky conditions

Vainu Bappu Observatory, Kavalur

Time Allocation during 1 April 2005 - 31 March 2006

I. VBT		Total No. of Proposals received	30
	a.	No. of Spectroscopic Proposals	27
	b.	No. of Photometric Proposals	3
	c.	No. of target of opportunity proposals	3
	d.	Total No. of Nights requested	223
	e.	No. of Nights requested for Spectroscopic work	21
	f.	No. of Nights requested for Photometric Work	202

*During 1 July 2005 - 11 January 2006 the telescope was not available for observations.

Vainu Bappu Observatory

Year	Month	Spectroscopic Hours	Photometric Hours
2005	April	83	0
	May	70	0
	June	45	7
	July	27	0
	August	42	0
	September	36	0
	October	39	0
	November	76	7
	December	93	24
2006	January	215	77
	February	244	97
	March		
	Total	970	212

Sky conditions at Indian Astronomical Observatory, Hanle

Year	Month	Photometric (night hrs)	Spectroscopic (night hrs)	Total (night hrs)
2005	April	77	126	240
	May	63	85	217
	June	93	126	210
	July	50	109	217
	August	128	193	248
	September	116	176	270
	October	248	269	310
	November	199	273	330
	December	227	271	341
2006	January	143	189	341
	February	111	162	280
	March	117	163	279
	Total	1572	2114	3283

Kodaikanal Observatory

Spectro / Photoheliograms and Seeing Conditions at Kodaikanal

Year	Month	No. of photographs in			Seeing Condition*				
		Kfl	PHGM	5	4	3	2	1	H
2005	April	17	14	21	–	2	9	10	–
	May	24	21	26	–	–	20	6	–
	June	9	9	16	–	–	4	11	1
	July	5	5	12	–	–	2	9	1
	August	10	10	24	–	–	15	8	1
	September	12	8	14	–	–	9	3	2
	October	7	8	17	–	–	7	10	–
	November	6	5	12	–	2	4	5	1
	December	19	22	23	–	–	19	4	–
2006	January	22	19	22	–	–	2	18	2
	February	22	20	23	–	–	13	9	1
	March	26	27	28	–	6	16	5	1
	Total	179	168	238	0	10	120	98	10

Kfl = K–flocculus
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) 2	2 to 3	3	3 to 4	4	>5 poor
2005	April	19	–	–	11	3	3	2
	May	21	–	2	7	4	2	6
	June	4	–	–	4	–	–	–
	July	2	–	–	2	–	–	–
	August	6	–	–	4	1	1	–
	September	6	–	–	5	1	–	–
	October	9	–	–	7	–	2	–
	November	14	–	–	9	–	5	–
	December	18	–	–	12	2	1	3
2006	January	16	–	–	11	–	5	–
	February	18	–	–	15	–	3	–
	March	24	–	–	18	4	2	–
	Total	157	–	2	105	15	24	11