INDIAN INSTITUTE OF ASTROPHYSICS

ACADEMIC REPORT 2006-07

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Front Cover : High Altitude Gamma Ray (HAGAR) Telescope Array

Back Cover (outer) : A collage of various telescopes at IIA field stations

Back Cover (inner) : Participants of the second in-house meeting held at IIA, Bangalore

Printed at : Vykat Prints Pvt. Ltd., Airport Road Cross, Bangalore 560 017

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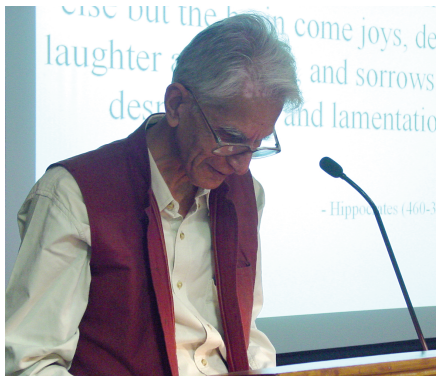
THE YEAR IN REVIEW

The year 2006-07 witnessed the installation of the High Altitude Gamma Ray (HAGAR) telescope array at the Indian Astronomical Observatory (IAO), Hanle and the initiation of site characterisation work for the National Large Solar Telescope (NLST). HAGAR is now in its commissioning phase. Five of the seven units are fully operational and the remaining two will be commissioned by October, 2007. With the severe Ladakh winter on its way out, work has commenced on laying the cables connecting the seven telescope units. The most promising regions for the NLST site appear to be in the high mountain desert of Ladakh. The existence of a fully functioning observatory at Hanle, and the support facility created at Leh by the Institute, are a major advantage in the reconnaissance process for the site characterisation work. Plans are underway to begin this activity in Hanle from May 2007 and at the Pangong lake by the end of 2007.

Turning to space related programmes, all the subsystems of the ultraviolet imaging telescope (UVIT), a payload on the first dedicated Indian space astronomy mission ASTROSAT, have reached the detailed design stage. Detector modules have been sent for integration and the engineering model of the high voltage supplies for these modules is nearing completion. The mirrors for the telescopes were partly figured and the design of the structure, in combination with the satellite, has been checked. The MGK Menon space sciences laboratory, equipped with a state-of-the-art clean room facility for assembly, testing and calibration of the payload is almost ready. The TAUVEX mission - an Indo-Israeli collaboration to observe the ultraviolet sky - is expected to be launched as part of the next GSLV mission (GSAT-4) in mid-2008. Software necessary to bring the satellite data to a format usable by individual scientists is being developed and is under rigorous testing.

Beginning 2007, a new lecture series was instituted by IIA, named after the Founder-Director, M K Vainu Bappu. The *Vainu Bappu Memorial Lecture* will be given each year by an eminent astrophysicist on a topic of broad interest. The first of this series was delivered by Professor E. N. Parker of the University of Chicago at IIA on January 4, 2007, on *The Sun, Space, Cosmic Rays & Climate*. He gave a broadbrush view of the physical properties of the Sun and of its interaction with the interplanetary space environment and its effect on the terrestrial climate. The eighteenth *IIA bicentennial*

Professor E. N. Parker delivering the First Vainu Bappu Memorial Lecture.



Professor O. Siddiqi delivering the Eighteenth Bicentennial Commemorative Public Lecture.

commemorative public lecture, held on March 2, 2007, was delivered by the renowned molecular biologist Professor Obaid Siddiqi, on *Biology of Learning and Memory*.

The Institute organized several national and international meetings, schools and workshops. An *in-house scientific meeting* was held at IIA on April 17th and 18th, 2006, where scientists and technical staff presented their contributions. As part of the International Heliophysical Year (IHY) the Institute hosted the *Second UN/NASA workshop on IHY and basic space science* at the Bangalore campus during November 27 - December 1, 2006. The main objective of the Workshop was to provide a forum to review preparations for IHY related recent scientific results and cross-disciplinary studies in heliospheric physics. More than 150 participants from 30 member states of the UN participated in the conference.

A new series of schools in various areas of astronomy and astrophysics was initiated to attract young researchers to this area as well as to promote excellence in the field. The Institute chose *Solar Physics* as the theme for the first school, which was held in Kodaikanal during December 10-22, 2006. The response was overwhelming with participation of over 38 students from several countries along with a distinguished international panel of lecturers.

In addition, the institute organised: *YAM-2007*, the tenth Young Astronomers' Meet (January 3-5, 2007); workshops on *UV and Multiwavelength Astronomy with ASTROSAT* (September 27-29, 2006) and *Physics and Astrophysics of Dust* (February 24-26, 2007); and the *Kodai Summer School in Physics* (June 2006).

Academic staff members continue to pursue their research vigorously in their respective fields. In solar physics, research on the dynamics of the magnetized chromosphere, viscosity in Alfvén waves, magnetic nature of coronal loops, energetics of coronal mass ejections, molecular lines in sunspots, coronal holes, detection of waves by statistical methods in the solar atmosphere were carried out. Studies of the diameter of the sun, solar irradiance, solar cycle effects on weather, radio observations of CMEs, global radio flux variations, and plasma processes in the Sun were among the investigations carried out towards understanding the sun. Between 2007 and 2008, Uranus passes through one of the nodes of its orbit on its equatorial plane for the first time since 1966. These mutual events of Uranian satellites will be observed after a span of forty years. Solar effects on the ionosphere would help to understand the interplanetary and near Earth environments.

Optical astronomers working in stellar and galactic astronomy are carrying out observations with the Institute's telescopes located at the Vainu Bappu Observatory (VBO), Kavalur and the Indian Astronomical Observatory (IAO), Hanle, Ladakh. The remotely controlled 2 m telescope at Hanle is being widely used by astronomers from various institutes from India and abroad. In observational astronomy, scientists have focussed their attention on star formation in the region of the open cluster, Cygnus, and NGC 1084, evolution of circumstellar disks in intermediate mass young stars, light variability of T Tauri stars, Hydrogen deficient stars, Fluorine abundances in evolved stars, stellar parameters, chemical composition of type II Cepheids, metal-poor stars, survey of Li-rich K giant stars, close binary stars, star clusters, variability of Na I lines in clouds, ISM-planetary nebulae, search for dwarf stars, exploding stars such as novae and supernovae. Studies on extragalactic objects such as Seyferts and quasars are also being carried out. A dynamical model of the narrow-line region in NGC 1068 has been developed.

The theoretical astrophysical group is engaged in pursuing research on various problems such as exact non-linear solutions for Hall-Alfvén wave in a uniformly rotating plasma, Magneto-rotational instabilities in Keplerian discs and effect of hybrid viscosity in two temperature discs, general treatment of Hanle-Zeeman redistribution for radiation scattering in magnetic fields and analysis of scattering polarisation, core structures for pulsar emission beam and relation between geometry of emission region and Stoke's parameter, numerical studies on the effect of changing impact parameters in galaxy collisions, and the effect of intergalactic medium on quasar motion in steady-state theory. The physics group is engaged in deriving rubidium and caesium electric dipole moments, oscillator strengths of ions of astrophysical importance. Other topics include effects of higher body excitations in relativistic coupled cluster calculations and *ab initio* calculations to characterise low lying states of selected isomers, isoscalar M1 contribution to deuteron photodisintegration and neutron polarisation.

Turning to the facilities at the observatories, it is a pleasure to note that the Vainu Bappu telescope, VBO, Kavalur, as well as the remote controlled Himalayan Chandra Telescope (HCT), Hanle, Ladakh, are extensively being used by astronomers from within the country and abroad. Honourable members of the Parliamentary Committee on Science & Technology, Environment & Forests visited the Indian Astronomical Observatory (IAO), Leh during June 10-14, 2006.

A 1.3 m telescope for the Vainu Bappu Observatory, Kavalur is being designed and fabricated by DFM, U.S.A. and a differential image motion monitoring (DIMM) telescope for continuous measurements on the sky is nearly ready at the same workshop. Both these equipment are expected to be delivered towards the end of 2007 and 2008 respectively. A detailed concept design for the proposed Hanle Echelle Spectro-Polarimeter (HESP) is being developed by the Anglo-Australian Observatory (AAO) and is expected to be ready by August 2007.

The Computer Centre is being further upgraded to provide facilities for high performance computing. The internet bandwidths of the Bangalore and Kodaikanal campuses have been significantly increased. A new data centre with 8 TB disk space has been set up to host data from various IIA and other facilities. The Library continues to make progress with the acquisition of new books and online subscription to many journals, and provides support to the research activities of the Institute through electronic document delivery and Open Access Repository. The collection and services of books and journals at Hosakote and the field stations have also been greatly enhanced.

Furthermore, the Library has made concerted efforts in setting up an archive of historical books and documents.

The Institute has a vibrant graduate studies programme with more than twenty five students. The Institute hosts a variety of programmes for man-power development by providing education in science and technology through a variety of programmes: (i) research and engineer trainee programme, (ii) projects as part of academic course work, (iii) visits of students and staff from other institutions, and (iv) summer project student programme.

The construction of the new student hostel *Bhaskara* is making good progress and is expected to be ready by early 2008. Several public outreach activities took place during the year including *National Science Day* on February 28, 2007 which included several exhibitions, talks and viewing of the night sky with a 14 inch automated Meade telescope. 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 and takes care of the required translation of official documents. After a gap of more than a decade, the Institute organized an *Annual day function* on April 15, 2006 which was celebrated with great cheer and enthusiasm. A renowned touring company, Naya Theatre, headed by Habib Tanvir staged the play *Raj-rakt*, based on Tagore's *Visarjan* at IIA's Hosakote campus on February 11, 2007.

S. S. Hasan
Director

1 Sun and solar systems

1.1 Solar physics

Wave propagation in multiple flux tubes and heating of the chromosphere

It is well known that the magnetic network in the solar atmosphere consists of intense magnetic field elements, in which magnetohydrodynamic (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 *single* flux element due to motions at its base. The analysis is now extended to consider a more realistic model of the network consisting of multiple tubes. These tubes expand with height and merge with neighbouring tubes at a level of around 600 km above the photosphere. A transverse velocity perturbation with a period of 24 s is applied uniformly along the lower boundary located at the base of the photosphere. This excites (a) vertically propagating fast and slow MHD waves within the flux tube; and (b) acoustic waves generated at the flux tube edge near the lower boundary that propagate spherically outwards. These simulations enable one to study the complex wave pattern due to waves excited in the individual tubes as well as their interaction with waves emanating from adjacent tubes. The results show that the dominant heating of the chromosphere occurs due to slow magnetoacoustic waves in a region that is close to the flux tube axis. Various observational implications of these results are examined.

(S.S. Hasan, A. van Ballegooijen[1], & O. Steiner*)*

Effect of gravity on MHD waves

The gravitational stratification effect on magnetohydrodynamic waves at a single interface in the solar atmosphere has been studied in the penumbral region of the sunspot recently. The existence of slow and fast magneto acoustic gravity waves and their characteristics have been discussed. The effect of flows on magneto acoustic surface waves leads to modes called flow modes or v-modes. The present geometry is that of a plasma slab moving with uniform velocity surrounded by neutral gas. A critical width of the slab has been identified for both the surface modes at which the phase velocity is the same as with different density ratios. The dispersion characteristics change significantly with a change in the value of G (gravity).

(A. Satya Narayanan)

Variation of layer thickness on MHD waves

The magnetospheric boundary layer, which is the interface between the magneto sheath and the magnetosphere, has been considered to be the plasma slab surrounded by moving and static plasma media on either side. The compressibility effect on surface waves propagating along the slab has been discussed. The effect of variation of the boundary layer thickness is studied as a special case, since the observed variation of the boundary layer thickness leads to unstable modes due to Kelvin-Helmholtz instability. The solar wind driven magneto sheath plasma is considered as the moving plasma medium and the effect of the velocity of the solar wind is also taken into account.

(G. David Rathinavelu, M. Sivaraman*, A. Satya Narayanan & K. Somasundaram*)*

Viscous effects on Alfvén waves in the Sun

Viscous damping of Alfvén waves in the solar corona is studied in linear, viscous magnetohydrodynamics, since, viscosity is one of the main energy dissipative mechanisms among the other existing mechanisms such as resistivity, resonance absorption etc. The dispersion relation has been derived for waves propagating along the magnetic (sharp) interface separating the homogeneous, viscous, incompressible, moving and static plasma media on either side, permeated by a uniform magnetic field. This fundamental magnetic configuration can be modeled for many astrophysical coronal features as evidenced by many workers. The dispersion relation is solved numerically and the possible role of viscous damping of Alfvén waves in the heating of the solar corona is studied.

(G. David Rathinavelu, M. Sivaraman*, A. Satya Narayanan & K. Somasundaram*)*

Study of formation of prominences

Before the formation of the prominence, the fibrils aligned along the long axis of the prominence, which is an indicative of the horizontal motion only along the long axis of the prominence. In order to explain these types of flow, the basic equations of MHD are

[1] *Collaborators from other institutions

used, and they are solved, by assuming solar plasma is infinitely conducting and steady state, and quasi 2-D approximation. From the analysis the following results were obtained.

The flow along the long axis of the prominence is maintained by the current produced by the induction potential. The absence of flow in the other two direction is due to the balance of gravitational force, Lorentz force with the gas pressure. To achieve the above mentioned criteria, it is found that, the density of the fluid is proportional to the magnetic field strength the constant of proportionality, in turn depends on the geometry of the magnetic field.

In the cases where there is presence of flow in all the direction, it is found that a portion of the magnetic tension is responsible for the maintenance of the flow and the other portion is responsible for maintenance of equilibrium. During the eruption stages of the prominence, the material of the prominence escapes with a speed of the order of local Alfvén speed. It is mainly because the magnetic tension is completely participating in the maintenance of the flow. Thus there is a balance between total pressure and the gravitational force. Further work is progress in this direction.

(B. S. Nagabhushana)

Magnetic nature of coronal loops

The identity of the mechanism for coronal heating remains a very big puzzle even though the role of magnetic field has been accepted in heating the coronal plasma. It is necessary to study the nature of coronal loops to understand the heating of solar corona. Coronal loops are considered to be in hydrostatic equilibrium and isothermal in nature because of magnetic pressure being much larger than the gas pressure. Furthermore, the loops are thin and are magnetically shielded from other temperature loops. The authors have made systematic observations of four strong coronal emission lines in the visible [Fe X] 637.4 nm, [Fe XI] 789.2 nm, [Fe XIV] 530.3 nm and near infrared [Fe XIII] 1074.7 nm part of the spectrum for about 8 years. Two emission lines were observed at a time, making raster scans of a steady coronal region. The variation of line widths of these lines and intensity ratios as a function of height are being studied. The relationship between the widths of these lines and intensity ratio indicates that the steady coronal loops are not magnetically isolated. These findings put restrictions on coronal loops models and indicate that the magnetic pressure in coronal loops may be much less than assumed. These results strongly suggest that magnetic field strength in the corona needs to be measured accurately.

(Jagdev Singh, T. Sakurai & Kiyoshi Ichimoto*)*

Observations with 25 cm coronagraph at Norikura observatory

So far the authors have been making off the limb spectroscopic observations of coronal structures in two coronal emission lines choosing [FeX] and one from other three emission line namely [FeXI], [FeXIII] and [FeXIV]. Now several changes and additions in the experimental set up have been made, which permits to make the raster scans of the coronal structures in 4 coronal emission lines. So far it was not possible to study the intensity ratio of the [Fe XIV] 530.3 and [Fe XIII] 1074.7 nm emission lines. This will give a vital clue to the temperature structure in the coronal loops as it represents higher temperature plasma where as the other emission lines represent relatively low temperature plasma. In order to understand the physics involved in such a behaviour of coronal emission lines with height above the limb, they have made off the limb observations simultaneously in 4 coronal [Fe XI] 789.2, [Fe XIII] 1074.7, [Fe XIII] 1079.8 and [Fe XIV] 530.3 nm emission lines of the coronal structures on number of days during October, 2006 with 25-cm coronagraph at Norikura observatory in Japan.

The intensity ratio of two emission lines will yield kinetic temperature and using this temperature, the non-thermal velocity will be determined as a function of height above the limb. From these simultaneous observations, the authors can separate the thermal and non-thermal components to those which contribute to the line-widths of coronal emission lines. The variation of thermal or non-thermal component with height will yield clue to the physical and dynamical processes involved in the coronal loops. These findings will lead to delineate the role of various processes involved in heating of coronal structures and solar corona.

(Jagdev Singh)

Energetics of solar coronal mass ejections

The authors have recently completed an extensive survey of flux-rope coronal mass ejections (CMEs) observed by the LASCO instrument aboard SOHO, which firmly establishes the viability of energy associated with the advected CME magnetic field as

its primary driver. They have shown that the upper limit on the power that can be provided by the CME magnetic field can be upto an order of magnitude over what is required, while the lower limit is around 74 of what is required to drive the CME.

(Prasad Subramanian & Angelos Vourlidas)*

Transition region counterpart of a moving magnetic feature

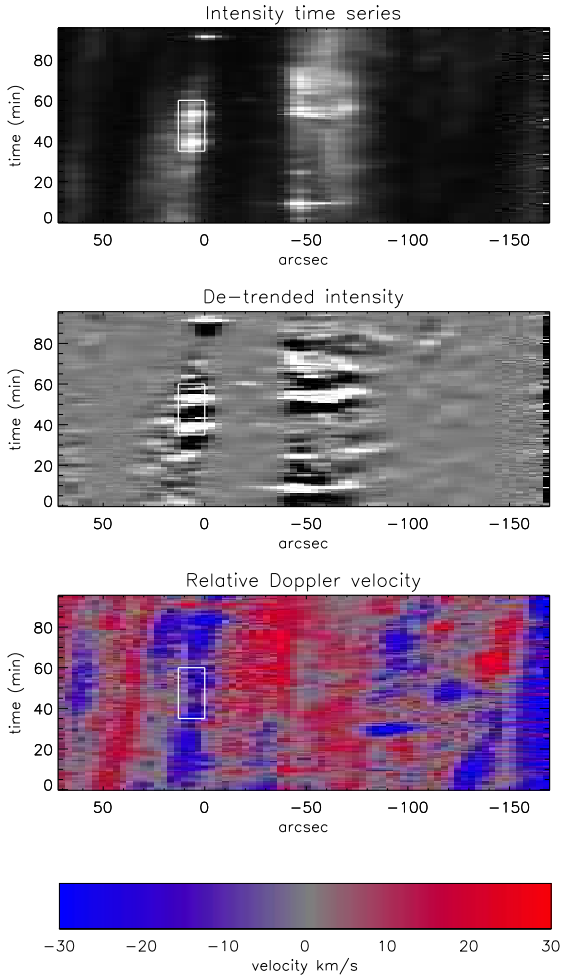


Figure 1: The O V 629.7 Å time series of the intensity variation (top), the de-trended intensity variation (middle), and the relative Doppler velocity with colour bar (bottom). The white rectangular marks the location of the MMF. The X axis corresponds to the solar Y coordinates of the pixels along the detector slit, and the Y axis shows the time.

Sheeley (1969, Solar Physics, 9, 347) discovered, in spectroheliograms at $\lambda = 3883\AA$, a steady flow of bright points moving outward from a sunspot. These moving bright points were later seen in the magnetograms and was named as moving magnetic features (MMFs). It was suggested that the features were magnetic knots resulting from the interactions between the sunspot magnetic field and the mass motion of supergranules. MMFs are very small (< 1500 km), and can be either bipolar or unipolar. While moving magnetic features have been studied extensively at the photospheric level, the effect they have on the upper atmosphere remains largely unknown. In this work the chromospheric and transition-region dynamics associated with a moving magnetic monopole by using spectral time-series and images. The influence of a moving magnetic monopole, as recorded by magnetograms, up to transition region temperatures has been studied. This suggests that the magnetic monopole, despite being small, can influence dynamics in the upper atmospheric layers. Oscillations with a multitude of frequencies are found in the chromospheric and transition-region brightenings associated with a moving magnetic monopole (see Figure 1). The region of the brightenings shows a tendency to be blue-shifted when compared to the average motion of the entire field of view. The results indicate the presence of waves and/or flows carrying energy from the monopole to the higher atmosphere.

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

Detection of waves through statistical methods

Most of the methods of wave detection on the solar atmosphere have been restricted to a few specific case studies. A new approach has been taken up, where wavelets are used to measure oscillations in a statistical manner. A novel randomisation method was used to test their significance. This form of statistical testing is useful as it provides a more accurate picture of the processes at work in the atmosphere rather than a smaller number of discrete observations can. Recently, the authors have used measurements of spectral lines obtained from CDS to perform a statistical search for the presence of oscillations in off-limb polar regions and in coronal holes. Phase delays were measured using the technique of Athay & White (1979, ApJ, 229, 1147), in which phase delays are plotted over the full –180 degree to +180 degree range and as a function of frequency. An example of the result of this is shown in Figure **??**.

In this Figure (2), the combined phase delays mea-

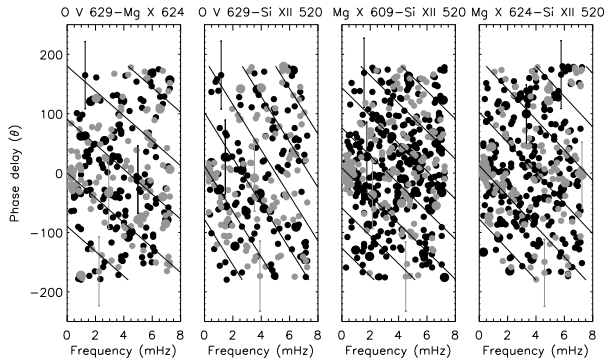


Figure 2: Phase delays measured between the oscillations in the different line pairs, as labeled, e.g., between Ov and Mgx 624 (left panel). Phase delays from radiant flux oscillations are shown as the black circle symbols, while phase delays from L.O.S. velocity oscillations are shown as the grey circle symbols. Phase delays were measured at the 95% and 99% significance levels. At the 99% significance level, they are indicated by the slightly larger symbols. Average uncertainties in the 95% and 99% phase delay estimates are shown by the representative error bars in each plot. Over-plotted on this plot are lines corresponding to fixed time delays

sured between different line pairs, e.g., between O V and Mg X, are shown. The results shown here are from a number of observations in the northern off-limb polar region, combined to obtain a more statistical overview of the processes at work in the Sun's atmosphere. From Figure **??**, it can be seen that the measured oscillations are present over the frequency range of ≈0–8 MHz and that the phases line up along roughly straight lines (there is a large scatter in the points around these 'straight' lines). This distribution of phases along straight lines indicates the presence of outwardly propagating waves. Measuring the slope of these lines allows one to obtain the time delays between the different lines, based on the phase equation; $\Delta\phi = 2\pi fT$ where f is the frequency and T the time delay in seconds. From this equation it can be seen that the phase difference will vary linearly with f, and will change by 360 degree over frequency intervals of $\Delta f{=}1/T$. In the case of Figure **??**, the time delay measured between the O V 629 line and Mg X 624 line (the first plot on the left) was found to be 58±7 s (17 MHz). Using the measured time delays, in conjunction with height differences measured between the different lines using limb brightening measurements, the authors calculated propagation speeds of 154±18 kms^{-1} between the O V 629 and Mg X 624 lines.

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

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 arc min wide by 4 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. Differences between the quiet Sun region and coronal hole on the one hand, and the polar hole and the equatorial extension on the other, have been examined. In the present study, intensity correlation coefficient of each line with the upper-most line Mg X 625 Å have been obtained. The behaviour of correlation coefficients as well as the intensity histograms in the polar and equatorial holes suggests that the depth of the transition region is less in the equatorial coronal hole than in the polar coronal hole.

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

Identification of molecular lines in sunspot umbral spectra

The estimation of transition probabilities was carried out for several molecules including some for which the presence in sunspot umbral spectra is suspect. A search and identification effort is on for some of these transitions. Preliminary results indicate the presence of a significant number of bands of Berelium series of diatoms in sunspot umbral spectra. Detailed work is in progress. It turns out that some of the results such as that for AlF, which was reported in 2006, are of interest in stellar physics. For instance, the presence of AlF bands and hence that of fluorine in some stellar sources is of particular interest in stellar evolution studies.

(S. P. Bagare, B. Karthikeyan & N. Rajamanickam*)*

Modeling GOES 1-8 Å spectral irradiance using sunspot areas

Solar 1-8 Å X-ray irradiance data is analyzed to investigate the anomalous increase during one of the solar maxima. Results show that the sunspot area

correlates very well with the 1-8 Å flux indicating the strong field regions, sunspots as the dominant source regions of the coronal emission. The author further finds that the mismatch of the sunspot numbers with X-ray flux during the later half of solar maximum of cycle 21 is due to the underestimation of the sunspot numbers by the Wolf's definition of sunspot numbers which assumes that a sunspot group contains on an average of 10 sunspots. It is concluded that the index of sunspot numbers needs a more refined version to represent precisely the solar activity.

(K. B. Ramesh)

Simultaneous measurements of magnetic field at different heights in solar atmosphere

Simultaneous observations of Hα line at 6562.8 Å and a nearby photospheric line at 6569.25 Å have been performed using the two-beam spectropolarimeter in order to compare the effects of magnetic field at both the heights. These observations have been obtained in the second order of the solar spectrum to obtain both the lines in the field of view of the detector with a spectral dispersion of 10.5 m Å per pixel. Basic data reductions have been completed and further analysis is in progress. A plot of the line-of-sight chromospheric magnetic field versus photospheric magnetic field for the region AR0875 on 30th April 2006 derived using the in-house built spectropolarimeter is shown in the Figure 3.

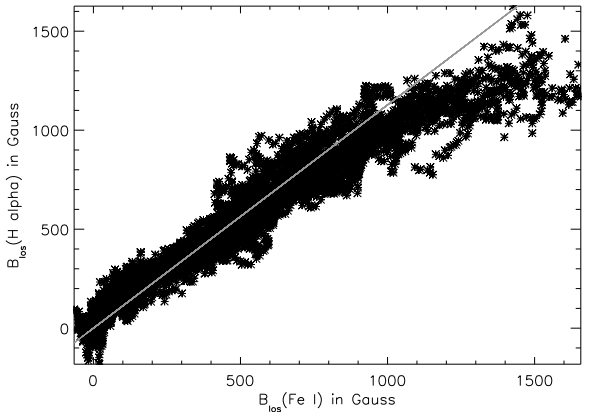


Figure 3: Line-of-sight chromospheric magnetic field versus photospheric magnetic field in the region AR0875 on 30th April 2006 observed using the in-house built spectropolarimeter.

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

Measurement of solar diameter from Kodaikanal white-light images

One of the most important motivating factor for the search of changes in the diameter of the sun is that it holds the clues to explain the solar irradiance variations of an amplitude of $\sim 0.1\%$ in phase with the sunspot activity that have been recorded by solar irradiance monitors on board from space crafts for more than two decades. It is certain that this variation in irradiance that occur over the solar cycle timescale cannot be due to changes in the nuclear reaction rates as the photons take nearly a million years to diffuse out of the core region. If so, the cause of the luminosity changes possibly has to reside in a region between the core and photosphere and it is reasonable to look for variations in the solar radius as the possible cause for the irradiance variability. The most plausible mechanism for storing energy is magnetic field that could modulate the heat transfer processes in the very subsurface layers in such a way as to cause the change in radius and hence the consequent change in luminosity without involving the deeper layers. Measurement of the radius of the sun is an age old problem and several methods have been employed over the past decades by various groups to determine the radius. Precise determination of the absolute radius is indeed a difficult problem but, the determination of the changes in radius can be determined with reasonable accuracy. Evaluation of radius from radio data or from spectroheliograms in chromospheric lines gives a value for radius far above the photosphere while recent determinations using the helioseismology data give a value for radius somewhere below the photosphere by $\sim 5\ Mm$ and is model dependent. Between these locations lie the photospheric radius which is of direct relevance to explain the irradiance variations. The most obvious way to determine the photospheric radius is from the white light images that are available in the archives of a very few observatories in the world. The program of obtaining white light images of the sun at the Kodaikanal observatory started in 1904 continues to the present day. The daily photoheliograms are obtained with a 6 - inch telescope of focal length 2.44 m, where the solar image is magnified to size of 8 inches. The 8 inch diameter solar image is photographed on a plate or a film of size $10''$ $10''$. The diameter of the solar image on the photoheliogram of every day for the period 1906 - 1987 was measured along the N- S and the E- W diameters of the sun using a CalComp digitizing board that has a spatial resolution of $0.2''$ on the sun. The measurements of

diameter that is done plate by plate has been completed. The reduction of the data for 4 half solar cycles have also been completed and the work on the rest of the data is in progress.

The authors find from the small sample that has been analysed that the solar diameter during sunspot activity minimum is larger than during sunspot maximum by 500 milli arcsec and this variation in diameter can explain satisfactorily the observed variation in solar luminosity between the sunspot maximum and minimum.

(K. R. Sivaraman, S. S. Gupta & A. V. Ananth)

Contribution of solar chromospheric fine scale features to UV irradiance variability

The Sun is the primary source of energy responsible for governing both the weather and the climate of the Earth. For that reason alone one would expect that changes in the amount and type of energy the Earth received from the Sun could alter both the weather and climate. The variations in the UV irradiance are produced by surface manifestations of solar magnetic activity. The variations in the solar UV flux may cause significant changes in the Earth's climate. Understanding the physical origin of UV irradiance changes is an extremely important issue in Solar and Space Physics.

The plages, magnetic network, internetwork and the background regions from the CaII K spectroheliograms of 1980 and 1992, observed at the National Solar Observatory at Sacramento Peak, using their histograms taken for the full-disk have been segregated. The different parameters like the intensity and area of the chromospheric features, the full-disk intensity (spatial K index), and the Full Width at Half Maximum (FWHM) of the histograms have been derived from the images. The spatial K index, FWHM, and the intensity of various features have been compared to the UV irradiance measured in the MgII h and k lines by Nimbus7 and NOAA9 satellites and it has been found that they are correlated with the MgII h and k c/w ratio. It has been established, for the first time, from the results of 1992 images and of 1980 that the FWHM can be used as a good index for measuring and describing the chromospheric activity in the K-line. The results of both 1980 and 1992 images show an anticorrelation between the intensity and area of the network elements, which confirm the earlier findings derived entirely from different data sets from Kodaikanal CaII K spectroheliograms analyzed for the center of the solar disc in a quiet regions for a longer time interval of 1957 to 1983 (Kariyappa & Sivaraman, 1994, Solar Phys. 152, 139). During solar minimum the network is fainter but covers a larger area than during solar maximum. These results suggest that the variations in both the intensity and area of the various chromospheric features have to be taken into account in irradiance models. A similar analysis technique has also been applied to HeII 304 Å images obtained from SOHO/EIT instrument. The work is in progress.

(R. Kariyappa, L. Damé & K. Tobiska*)*

Toroidal component of the magnetic field structure of the sunspots during their first appearances

The genesis of solar cycle and activity phenomena and the formation of sunspots that emerge from the solar interior are not yet understood completely. The sunspots are supposed to be formed by the perturbation of steady part of the underlying toroidal components of the sun's large-scale magnetic field. Hence, by measuring toroidal component of the magnetic field of the sunspots for different life spans over the surface during their first appearances, one can estimate toroidal component of the sun's large-scale magnetic field in the convective envelope. With this aim in mind, the study of probing of internal magnetic field structure of the convective envelope is continued. In the previous academic year, using six years (1999-2004) of SOHO MDI magnetograms, the magnetic flux in the solar convective envelope was estimated at different anchoring depths of the sunspots from the surface measurements of the *initial* magnetic flux of the individual spots. However, the magnetograms yield only line-of-sight component of the magnetic field, i.e., the sum of projection of east-west (toroidal) and meridional components. These two components are separately estimated by least-square fit to the observed magnetic flux of the sunspots that have first appearance on the surface. Preliminary results, for different life spans, indicate that strength of toroidal component of the magnetic field structure is weaker than strength of the meridional component of the magnetic field structure in contrast with the expectations.

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

Solar cycle as a forced and damped harmonic oscillator: prediction of future 15 cycles

Deviating from the traditional dynamo mechanism,

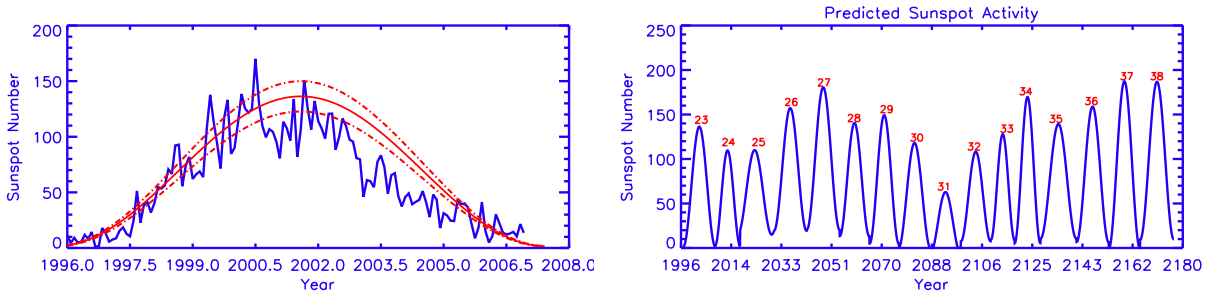


Figure 4: Prediction of the future solar cycles. (a) The left plot illustrates the predicted (red continuous) curve over plotted on the observed (blue curve) sunspot cycle 23. The dashed red curves represents uncertainty in the prediction. (b) The right plot illustrates predicted future 15 solar cycles. The red numbers over different solar cycle maximum are the cycle numbers.

the solar cycle is modeled as a forced and damped harmonic oscillator (Hiremath, K. M., 2006, A&A, 452, 591) and from all the 22 cycles (1755-1996), the long-term physical parameters such as amplitudes, frequencies, phases and decay factors are estimated. In the present study, with an *autoregressive* model and by using these physical parameters of 22 cycles, the amplitudes and periods of future 16 solar cycles are predicted.

Predicted amplitude of the present solar cycle (23) with a period of 11.73 yr matches very well with the observations. With these encouraging results, the profiles of future 15 solar cycles are predicted and are illustrated in the adjacent Figure 4. Important predictions are: (i) the period and amplitude of the cycle 24 are 9.34 years and 110 (±11), (ii) the period and amplitude of the cycle 25 are 12.49 years and 110 (± 11), (iii) during the cycles 26 (2030-2042 AD), 27 (2042-2054 AD), 34 (2118-2127 AD), 37 (2152-2163 AD) and 38 (2163-2176 AD), the sun might experience a very high sunspot activity, (iv) the sun might also experience a very low (around 60) sunspot activity during cycle 31 (2089-2100 AD) and, (v) length of the solar predicted cycles vary from 8.65 yr for the cycle 33 to maximum of 13.07 yr for the cycle 35.

(K. M. Hiremath)

Solar and astronomical forcing on the Indian monsoon rainfall

The study of influence of solar activity on the Indian monsoon rainfall is continued. In the previous studies, the sunspot occurrence activity (Hiremath & Mandi, 2004, New Astronomy, 9, 651) and the irradiance occurrence activity (Hiremath, 2006, ILWS workshop, p.178) were used and it was found that both the activities have positive, moderate and yet significant correlations with the Indian Monsoon rainfall activity. In those studies, in order to remove the long-term trends, average of the whole data set used to be subtracted and normalized with their respective standard deviations.

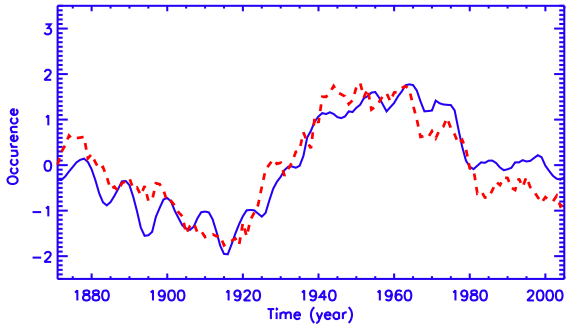


Figure 5: The annual sunspot (blue) and Indian Monsoon rainfall (red) occurrence variabilities. Both the data sets are detrended and normalized to their respective standard deviations.

However, in the present study, after removing the decreasing trend from the annual Monsoon rainfall data and increasing trend from the sunspot data during the months of Monsoon period, compared to the previous studies, the correlation coefficient improves substantially. On the other hand, for both the detrended data sets that have moving average of greater than ten years (Figure 5), the correlation is found to be very high (70-90%) suggesting 10-100 yr of solar forcing and a long-term ∼25,000 yr of astronomical forcing that is attributed to change in the solar radiation (insolation) of ∼25,000 yr periodicity that is mainly considered to be precession of the earth's rotation axis due to torque of the sun and the moon on the earth's equatorial bulge. Owing to strong solar and astronomical forcing and predictive capability of future solar activity cycles, one can predict the long-term Indian Monsoon rainfall activity 10-100 years in advance.

(K. M. Hiremath)

1.2 Solar radio astronomy

Post-CME solar corona and radio noise storm activity

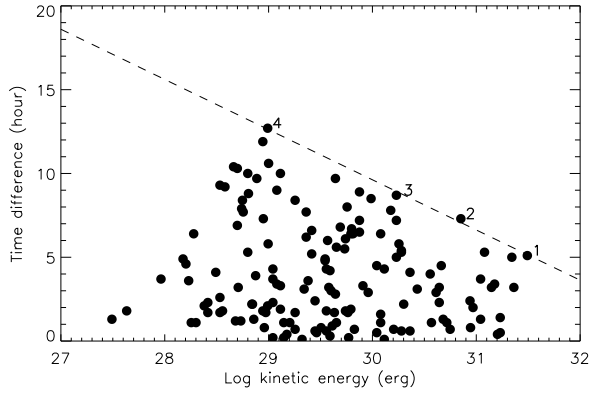


Figure 6: Variation of the CME-noise storm onset time difference with kinetic energy of the CME. The straight line (obtained using points numbered 1, 2, 3 & 4) indicates the cut-off in the above time interval for different values of CME kinetic energy.

Noise storms are the most frequently observed solar activity at meter wavelengths. They consist of occasional short-lived (0.1 - 1 s) narrowband radio enhancements (type I or noise storm bursts), superimposed on often observed continuous, slowly varying, long lasting (hours - days) broadband background emission called type I or more usually as noise storm continuum. The early phase of noise storms is generally associated with a global brightening in soft X-rays. But the latter are not due to X-ray flare occurring anywhere on the Sun. Correlative studies with Hα flares also indicate that they are not necessarily related to noise storms. The post-CME corona has received relatively little attention so far. Therefore, the authors performed a statistical study of solar radio noise storms whose onset was in the aftermath of CMEs reported during the period 1997-2004. Details about start time and location was available for 340 radio events during the above period. To verify the association between the above two phenomena, they had imposed conditions that the noise storm must have occurred $\leq$24 h from the onset of a CME. And the CME central position angle must be located inside an angular span of $\pm 45^\circ$ with respect to the noise storm. The main results are: (i) 196/340 noise storms considered were associated with a CME; (ii) the mean separation between the position angle of noise storm and CME leading edge was $\approx 25^\circ$; (iii) the sky-plane speed of CMEs was in the range 100-800 km/s, with peak around 350 km/s; (iv) the angular extent of a vast majority of the CMEs was $< 120^\circ$; (v) depending on the kinetic energy of the preceding CME, each one of the 196 radio events occurred within a specific time interval from the CME onset. Overall, the onset of all the noise storms was $\leq$ 13 h from the CME lift-off time; (vi) the above cut-off for a particular CME depends on its kinetic energy and varies inversely with the logarithm of the latter (Figure 6). The corresponding numbers are $\approx$ 4 & 19 h for CMEs with kinetic energy $\sim 10^{32}$ & 10^{27} ergs, respectively.

(R. Ramesh, C. Kathiravan & H. S. Nataraj)

Observational constraints on the efficiency of plasma emission

The authors have applied the theoretical formalism of Subramanian & Becker (2004, Solar Physics, 225, 91; 2006, Solar Physics, 237, 185) to investigate the power budget for electron acceleration in a post-flare decimetric continuum source observed with the Giant Metrewave Radio Telescope (GMRT). This yields the best observationally deduced estimate of the efficiency of the plasma emission process.

(Prasad Subramanian, S. M. White, M. Karlicky*, R. Sych*, H. S. Sawant* & S. Ananthakrishnan*)*

Anomalous resistivity in the solar corona

Several observations of reconnection events in the solar corona seem to mandate much lower Lundquist numbers than what can be accommodated by classical collisional resistivity. The authors have applied the novel model for anomalous resistivity of Numata & Yoshida (2002, Phys. Rev. Lett., 88, 45003) to solar flare reconnection events observed with the YOHKOH telescope. They have found that the resistivity needs not only to be enhanced, but also needs to be localized over length scales of the order of an ion skin depth in order to explain the observations.

(K.A.P. Singh & Prasad Subramanian)*

Forbush decreases and cosmic ray diffusion

Forbush decreases are cosmic-ray manifestations of the near-earth effects of solar transients. The authors have been exploring data from the GRAPES-3 muon tracking telescope at Ooty, with a view to understanding this phenomenon better. Some important unresolved theoretical problems such as the perpendicular diffusion of cosmic rays and the level of MHD

turbulence near solar ejecta can be addressed in a unique manner with this data. Furthermore, powerful near-earth space weather diagnostics/predictors can be developed using this data. Taken together, the GRAPES-3 instrument and the Ooty Radio Telescope next door have the potential to become one of the most important space weather instrument suites in the world.

(Prasad Subramanian, Sunil Gupta & H. M. Antia*)*

Global solar radio flux density variations during October - November 2003

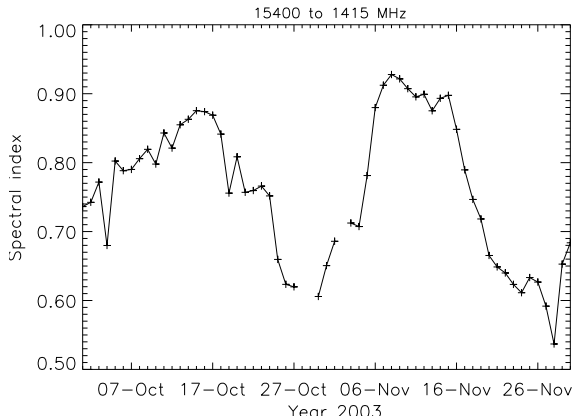


Figure 7: Variations in the spectral indices as a function of days during October-November 2003 for the two bands 15400-1415 MHz and 610-245 MHZ.

The variations in the spectral indices of the global solar radio flux during the solar eruptive events of October - November 2003 were studied. Daily values of the global solar radio flux at 15400, 8800, 4995, 2995 2880, 1415, 610, 480 and 245 MHz given in the solar geophysical data during the period October - November 2003 were used to derive the spectral indices of the radio emission in the high (15400 - 1415 MHz) and low (610 - 245 MHz) bands (Figure 7). The spectral index of the solar radio emission during the above period varied from 0.93 to 0.54 in the 15400 - 1415 MHz band and from 1.54 to -1.64 in the 610 - 245 MHz band showing more non-thermal activity. Correlation between the spectral indices in the high and low frequency bands was found to be weak suggesting the emission processes are different. It was found that the spectral indices in the low frequency (610 - 245 MHz) band are better correlated with the flare indices than the spectral indices in the high band (15400 - 1415 MHz) with the flare index.

(K. R. Subramanian, Prasad Subramanian, E. Ebenezer & Ravish)*

1.3 Planetary sciences

Analysis of pre-deep-impact data of comet Tempel 1

NASA's deep-impact probe artificially created a crater on comet 9P/Tempel 1 on July 04 2005. Images obtained from the Vainu Bappu Observatory and the Indian Astronomical Observatory have been modeled. The results indicate that the pre-impact jets from comet Tempel 1 are due to broad active regions at latitudes $+50^o$, $+05^o$ and an extensive southern region between -35^o and -65^o. As the orientation of the jets are dependent on the direction of the rotation pole of the comet, this direction was also determined during the fit. The direction of the north pole is found to be RA = $290^o \pm 10^o$ and DEC = $+75^o \pm 10^o$. The grains are found to have an initial velocity of 0.02- 0.12 km s^{-1} and are of sizes 0.1 - 2 μm. The ground based images show structures spanning to about 40,000 km. The structures in the vicinity of the nucleus are affected by seeing and are therefore not delineated. Recent published images of this comet obtained by camera on board the deep-impact spacecraft show significant details. The fitted parameters using the ground based data are being used to simulate the high resolution near nuclear images. This will help to better constrain the grain sizes, initial velocities and the grain size distributions.

(R. Vasundhara)

Mutual events of the Uranian satellites

In 2007-2008, the planet Uranus passes through one of the nodes of its orbit on its equatorial plane for the first time since 1966. For a few years around this time, its satellites will eclipse and occult each other whenever any two of them are aligned with the Sun or the Earth respectively. It is planned to observe these events from VBO and IAO. Due to the faintness of the satellites and their apparent proximity to Uranus, careful planning of the events is required. Theoretical simulations of the light curves have been carried out for deciding the best observing strategy. The simulations indicate that albedo variations on the satellites will produce noticeable signatures on the mutual event light curves. It is found that the partial events of the upcoming mutual event series of the Uranian satellites can be modeled taking into account the albedo variations inferred from the maps of the southern regions imaged by Voyager 2 when only these regions are occulted/eclipsed. This

will enable a robust determination of the astrometric parameters. The shape and asymmetry of the mutual event light curves along with the rotational light curves of the satellites obtained simultaneously during the planet's equinox crossing period can be utilized to obtain a coarse albedo map of the northern hemisphere of the satellites which were under polar darkness during the Voyager encounter and hence hitherto unknown. These studies will also help in investigating possible changes in the known southern regions since the 1986 encounter of Voyager 2.

(R. Vasundhara)

1.4 Solar-terrestrial relationship

Plasma-neutral coupling in the equatorial upper atmosphere

The various coupling processes, namely plasma-neutral coupling, high and low latitude dynamical and electrodynamical coupling manifest in the day-to-day behavior of the equatorial upper atmosphere parameters. Well thought-out studies are in progress, which may lead to better understanding of the role of the coupling processes with reference to the times of substorms of various types and magnetic storms due to different structures in the solar wind plasma and interplanetary magnetic field and their solar sources.

(J. H. Sastri, J. V. S. V. Rao & collaborators)

Characterization of the ionospheric storm of November 20-21, 2003 at low and equatorial latitudes in the south Asian region

The super geomagnetic storm of November 20-21, 2003, the second largest storm to occur between 1957 and 2004 has been the subject of extensive studies since its occurrence as regards the global ionospheric-thermospheric storm associated with it. Nonetheless, the authors feel that the evaluation of the storm-time ionospheric disturbances in the east Asian sector is not yet comprehensive for this geomagnetic storm. With this perception, they have revisited the storm event to bring out new information of the ionospheric disturbances. Data of the ionosonde network in India (75° E) and Japan (135° E) have been used to characterize the ionospheric storm at low and mid-latitudes at the Indian and Japanese meridians, respectively. Data form the Indian magnetometer network is used to assess the disturbances in the equatorial electrojet (EEJ) and hence in the zonal electric field that drives it. Information on equatorial zonal electric field for the evening-night period is derived from HF Doppler radar observations of F region vertical plasma drift (v_z) at Kodaikanal (dip 4° N). It is found that the super-geomagnetic storm is accompanied, during its well-defined main phase and recovery phases, by significant perturbations in F region height and peak electron density at mid-latitudes in the Japanese sector, and in the equatorial anomaly region, as well as in EEJ/nighttime Vz in the Indian sector. Good examples of these are the longitudinal confinement of the negative F-layer storm effect due to the disturbance in the chemical composition (molecule enriched air) in the Asian sector and the prevalence of a seemingly strong equatorial ionization anomaly (EIA) at the time counter-electrojet (CEJ) conditions in the Indian sector. Both these occurred during the storm recovery phase. These and other ionospheric disturbances that were observed further strengthen the steadily growing view that, in some geomagnetic storms, disturbances in the neutral thermosphere contribute significantly to the behaviour of the equatorial ionospheric F region, in addition to the those in the zonal electric field.

(J. H. Sastri, K. Niranjan, R. S. Dabas*, C. V. Devasia*, S. Alex* & B. Sreevani*)*

Solar wind-magnetosphere-ionosphere coupling at the time of storm sudden commencements (ssc)

The effect of the impact of rapid step-like changes in the solar wind dynamic pressure, Pd on the subsolar magnetopause is known to manifest as the geomagnetic storm sudden commencement (ssc) or sudden positive impulse (si+) everywhere within the magnetospheric cavity. The ssc manifests quite distinctly in the ground-level geomagnetic field of the day-side dip equatorial region, primarily because of the prevalence of an external electric field(s) and current(s) of polar origin in addition to that due to the enhancement of Chapman-Ferraro currents induced by the sudden magnetospheric compression. The reason(s) as to why the ssc appears in two distinct forms, namely, without and with a preliminary reverse impulse (pri) with more or less equal frequency, remained a puzzle. Against this background, an in-depth study is being attempted to quantify, for the first time, the response, as a function of local time, of the day-side equatorial geomagnetic field (ssc) in terms of the characteristics (absolute and relative to the ambient of the amplitude of the step-like change in Pd, and ambient polarity of the North-South com-

ponent of the interplanetary magnetic field, IMF) of the causative fast forward interplanetary shock. Simultaneous data from the equatorial magnetometer stations of CPMN/MAGDAS project and of Kodaikanal are used for the purpose with reference to a large number of carefully identified and well defined IP shocks. This effort is hoped to provide answer(s) to the fundamental question as to the origin of the bi-modal response (with and without a pri) of the day-side equatorial geomagnetic field to sudden magnetospheric compression induced by IP shocks, and the solar wind-magnetosphere-ionosphere couplings underlying it.

(J. H. Sastri, K. Yumoto & C. -S. Huang*)*

2 Stellar and Galactic Astronomy

2.1 Star formation

Star formation in the region of the open cluster - NGC 225

NGC 225 is believed to be a 120 Myr old open cluster located at $\sim$ 650 pc. Eight stars with Hα emission are found to be located around the cluster, of which two are probable Herbig Be stars, indicating a very young age for the cluster. To explore whether the Herbig Be stars, which are pre-main sequence (PMS) stars are part of this cluster, the authors re-estimated the cluster parameters using optical (UBV)pg and 2MASS JHK photometry. The above data was combined to detect the presence of any possible PMS stars in the cluster region. Among the identified 28 proper motion members, 15 stars were found to have near-infrared (NIR) excess indicating that they are PMS stars. Also, most of the upper main sequence (MS) stars were found to show NIR excess, suggesting that the brighter proper motion member stars have not yet reached the main sequence. PMS isochrones were used to estimate the age of stars with NIR excess and is found to be between 0.5–10 Myr. Thus, the cluster NGC 225 is a very young cluster, younger than 10 Myr and its age is not 120 Myr as previously believed. It is proposed that a recent star formation has resulted in the formation of NGC 225, two Herbig Be stars, stars with Hα emission, dust lanes and nebulosity in the vicinity of the cluster.

(Annapurni Subramaniam, Blesson Mathew & S. R. Kartha)*

Understanding the star formation history in the Cygnus region

In the Cygnus OB region 5 clusters (IC4996, NGC 6910, Be 87, Biurakan 2 and Be 86) are studied. The optical data from the literature is combined with the 2MASS data to identify the PMS stars as stars with near IR excess. The authors identified 93 PMS stars, 7 candidate Herbig Ae/Be stars and 9 stars with Hα emission spectra. The identified PMS stars are used to estimate the turn-on age of the cluster. The duration of star formation of the clusters (difference between the turn-on and turn-off age) is found to be about the cluster age itself (6 Myr) for three clusters. There is evidence for multiple star formation in two other clusters. The spectra of 9 stars were obtained and these stars are classified based on the spectral and the evolutionary properties. In most of the stars, the rotational velocity of the disk is less than that of the star. One star is likely to be a Herbig Ae/Be star and the rest are likely to be classical Be stars.

(Annapurni Subramaniam, B. Bhavya & Blesson Mathew)*

2.2 Young stellar objects

Temporal evolution of circumstellar disks in intermediate-mass young stars

Optical spectra of 45 intermediate-mass Herbig Ae/Be stars were taken with the VBO telescopes. Together with the multi-epoch spectroscopic and photometric data compiled for a large sample of these stars and ages estimated for individual stars by using pre-main sequence evolutionary tracks, the authors have studied the evolution of emission-line activity in them. They find that, on an average, the Hα emission line strength decreases with increasing stellar age in Herbig Ae/Be stars, indicating that the accretion activity gradually declines during the PMS phase. This would hint at a relatively long-lived (a few Myr) process being responsible for the cessation of accretion in Herbig Ae/Be stars. It is also found that the accretion activity in these stars drops substantially by 3 Myr. This is comparable to the timescale in which most intermediate-mass stars are thought to lose their inner disks, suggesting that inner disks in intermediate-mass stars are dissipated rapidly after the accretion activity has fallen below a certain level. The authors also further find a relatively tight correlation between the strength of the emission line and near-infrared excess due to inner disks in Herbig Ae/Be stars, indicating that the disks around Herbig Ae/Be stars cannot be entirely passive. It is suggested that this correlation can be understood within the framework of the puffed-up inner rim disk models if the radiation from the accretion shock is also responsible for the disk heating.

(P. Manoj, H.C. Bhatt, G. Maheswar* & S. Muneer)*

T Tauri stars: HD 288313

Photometric observations over three seasons show the weak emission T Tauri star HD 288313 to be a light variable with a 2.2636 day period. The observed V amplitudes lie in the range 0.06–0.15 mag. The star shows appreciable changes in the brightness

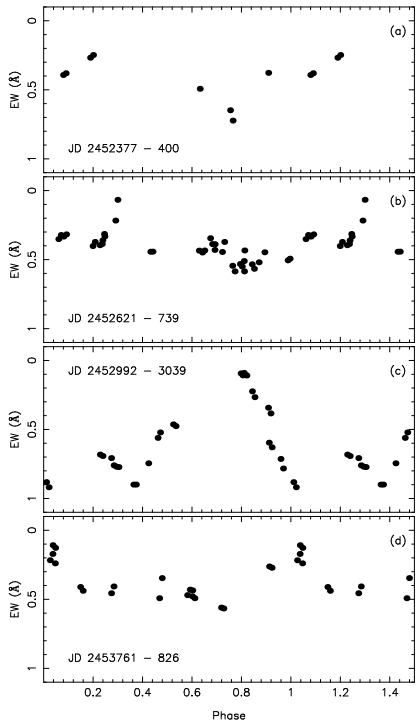


Figure 8: HD 288313: Plots of Hα equivalent widths against the corresponding photometric phases computed using JD = 2447911.567 + 2.^{d}2636. The observational period is indicated in the corresponding panel.

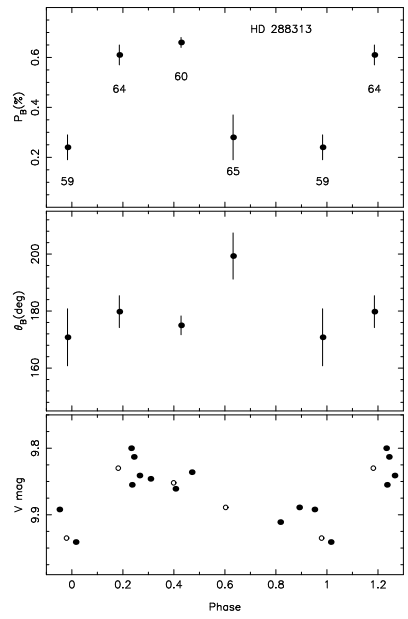


Figure 9: HD 288313: Plots of percentage linear polarization and position angle in B band observed during JD 2449059–65 against the corresponding photometric phases computed using JD = 2447911.567 + 2.^{d}2636. The numbers in the plot of P identify the Julian days of observation. The bottom panel shows the V observations overlapping with the polarimetry. The open circles indicate the V mag obtained on the nights of polarimetric observations.

at maximum and minimum of the light curve from season to season. The $(b - y)$ colour does not exhibit any significant variation during the photometric cycle. The light variation appears to be caused by the rotational modulation of stellar flux by cool starspots distributed asymmetrically across the stellar longitudes.

An analysis of the spectroscopic observations obtained during 2002–2006 shows that the Hα line strength in HD 288313 varies drastically from completely filled-in emission to almost full absorption that is typical of a normal star of similar spectral type. The Hα equivalent width is found to show a clear rotational modulation only occasionally. Most of the time chromospheric active regions are distributed well across the stellar longitudes, thereby suppressing obvious rotational modulations (Figure 8).

Broadband linear polarization measurements show HD 288313 to be a short period, low amplitude polarization variable. The polarization variation is, apparently, rotationally modulated (Figure 9). Dust grain scattering in a non-spherical circumstellar envelope of a star with inhomogeneities in the surface brightness distribution seems to be the mechanism operating in producing the observed polarization.

(M. V. Mekkaden, S. Muneer & A. V. Raveendran)

TW Hya

Spectroscopic observations of the classical T Tauri star TW Hya obtained in the region of Hα during the years 2000 to 2007 were analysed. The Hα emission equivalent widths show drastic changes and vary from 190 Å to 400 Å. The emission strength shows periodic variability corresponding to the star's rotation period and this trend is noticed only over durations less than a few months. The emission strengths when plotted over the entire period of observation show two distinct peaks indicating the presence of two accreting zones.

(M. V. Mekkaden, S. Muneer & A. V. Raveendran)

2.3 Hydrogen deficient stars

Parameters of the two helium-rich subdwarfs in the short period binary PG1544+488

Helium-rich subdwarf B (He-sdB) stars form a small group of chemically peculiar, early-type, low-mass stellar remnants. They are thought to be formed either as a result of mergers of white dwarfs or by con-

vective mixing of a helium white dwarf envelope after a late helium flash. PG1544+488 is the prototype of the He-sdB stars. It was serendipitously found to be a short period binary (P 0.5 day) comprising two helium-rich subdwarfs. Physical parameters and orbital solution for the two helium-rich subdwarfs in PG1544+488 from optical spectra obtained over a period of three years is reported. The physical parameters - effective temperature, surface gravity and helium abundances (by number) - for both subdwarfs were measured by fitting the observed spectra with LTE models using a chi-squared minimization procedure. The orbital solutions were obtained using radial velocities measured from the optical spectra. The implications of the discovery that PG1544+488 is a binary on the current understanding of the evolution of helium-rich subdwarf B stars and the possibility of a third formation channel for these stars involving a common-envelope in a close binary is also briefly discussed.

(A. Ahmad, C.S. Jeffery*, R. Napiwotzki*, & G. Pandey)*

Hydrogen deficient binary stars KS Per and υ SGR - spectroscopic monitoring

The long period hydrogen deficient binary stars KS Per and υ Sgr have been spectroscopically monitored from 2003 Dec. Both radial velocity changes and profile changes have been studied. The rich emission line spectrum of υ Sgr (and KS Per) has been listed. The [N II] lines have been seen to appear and disappear on occasion. The presence of [N II] in υ Sgr are reconfirmed. The changes in the radial velocities and profiles are interpreted in terms of the orbital motions.

(N. Kameswara Rao & Gajendra Pandey)

Studies of hot hydrogen deficient stars with UVIT

Just about 20 extreme helium (EHe) stars are known, and these were identified from optical studies. EHes are hydrogen deficient supergiants, and their origin and evolution is a mystery. EHes span a range in effective temperature: 8000 - 30,000 K, and in surface gravity : log(g) = 0.5 - 3.0 (cgs). The possibility of distinguishing hydrogen deficient stars from normal stars (hydrogen rich) using UVIT colours is also explored.

(Gajendra Pandey & N. Kameswara Rao)

Emission lines in high resolution spectra of EHe stars

The hydrogen-poor stars whose origins and evolution are not yet understood include hydrogen-deficient carbon stars (HdC), R CrB stars, Extreme helium (EHe) stars, He-rich sdOs, H-poor central stars of PN ([WC]), and non DA-white dwarfs. Three scenarios are predicted for the formation of R CrBs/EHes/[WC] stars; (i) involving a merger of two white dwarfs (DD), (ii) a He-shell flash in a post-AGB star, and (iii) close-binary evolution. The theory of stellar evolution predicts that about one-third of all white dwarfs which are of the non DA variety are the result of either DD scenario or final He-shell flash scenario making R CrBs/EHes/[WC] stars, an important segment of mainstream stellar evolution. Most of the EHes show absorption line spectra except for the hot R CrBs and [WC] stars which show emission lines. The hot EHes showing emissions overlap with [WC] stars and the cool EHes with R CrBs in their effective temperatures. High resolution spectra of couple of EHes and R CrBs have been obtained, to search for the presence of emission lines to determine the mass-loss rates and to test the evolutionary connections with [WC] stars and/or He-rich sdOs. The spectra are from VBT echelle spectrometer and McDonald. Surface composition of EHes show C/He about 0.01 (by number) similar to He-rich sdOs, whereas [WC] stars show C/He about 1 (by number). If EHes are to become [WC] stars they have to lose mass and alter their surface composition.

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

2.4 Fluorine in evolved stars

Discovery of fluorine in cool extreme helium stars

Neutral fluorine (F I) lines are identified in the optical spectra of cool extreme helium (EHe) stars. These are the first F I lines identified in a star's spectrum, and they provide the first measurement of fluorine abundances in EHe stars. The results show that fluorine is overabundant in EHe stars. The overabundance of fluorine provides with evidence for the synthesis of fluorine in these stars, which is discussed in light of asymptotic giant branch evolution and the expectation from accretion of an He white dwarf by a C-O white dwarf.

(G. Pandey)

Fluorine abundances in R CrB and EHe stars

Neutral fluorine lines are identified in the spectra of warm R CrB stars and cool EHe stars obtained from VBT echelle spectrometer and McDonald. The overabundance of fluorine in these H-deficient stars provides clues to their origin and evolutionary connection. Synthesis of fluorine is discussed in the light of single-star evolution, close-binary evolution, and double-degenerate mergers that results in H-deficiency in these stars.

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

Search for neutral fluorine lines in late B-and A-type supergiants

High resolution spectra of several late B- and A-type supergiants are obtained from the VBT echelle spectrometer. Aim is to determine the stellar parameters (effective temperature and surface gravity) and finally the chemical composition; in particular of key elements like s-process, and fluorine. These parameters will be used to identify the low mass late B- and A-type supergiants. The study of these stars will prove to be interesting and important in identifying new post-AGB stars of spectral type: late B, and A. This will further improve the understanding of stellar nucleosynthesis and post-AGB evolution.

(Gajendra Pandey)

2.5 Stellar parameters

Automated classification and stellar parameterization

Different approaches for automated spectral classification are critically reviewed. ANN based methods which are very efficient in quick handling of the large volumes of data generated by different surveys are described in detail. The application of ANN in various surveys covering UV, visual and IR spectral regions and the accuracies obtained is summarized. The preliminary results obtained with medium resolution spectra (R$\sim$1000) for a modest sample of stars using the 2.3 m VBT at Kavalur observatory, India are presented. The sample contains uniform distribution of stars in temperature range 4500 to 8000 K, log g range of 1.5 to 5.0 and [Fe/H] range of 0 to -3. The application of artificial neural network for parameterization of these stars have been explored. A set of stars with well determined atmospheric parameters for training the networks for temperature, gravity and metallicity estimations have been used. An accuracy of 200 K in temperature, 0.4 in log g and 0.3 dex in [Fe/H] in the preliminary efforts could be obtained.

(S. Giridhar, S.Muneer & A. Goswami)

Hα width and absolute magnitude relation in late type stars

Kraft et al. (1964, ApJ, 140, 235) have shown and established that the Hα line profile width at 0.1 central depth in late type stars in the spectral range F to M show strong correlation with absolute U magnitude. These studies were done using photographic plates. This relation with high resolution profiles using CCDs obtained with VBT echelle and Hipparcos parallaxes is re-examined.

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

Precision radial velocities with VBT Echelle - A global network of 2 m class telescopes

Many problems in stellar variability demand high precision radial velocities. VBT echelle is equipped with new iodine cell. Several new improvements are being made to obtain high precision radial velocities in the range of m/s. A global network of 2-m class telescopes with high resolution spectrographs have been formed to obtain better duty cycle in monitoring the variability in radial velocities.

(N. Kameswara Rao, Gajendra Pandey, B. E. Reddy, S. Sriram & K. Jayakumar)

2.6 Cepheids

Chemical compositions of the Type II Cepheids: BL Her & W Vir variables

Abundance analyses from high-resolution optical spectra are presented for 19 Type II Cepheids in the Galactic field. The sample includes both short-period (BL Her) and long-period (W Vir) stars. This is the first extensive abundance analysis of these variables. The C, N, and O abundances with similar spreads for the BL Her and W Vir show evidence for an atmosphere contaminated with 3α-process and CN-cycling products. A notable anomaly of the BL Her stars is an overabundance of Na by a factor of

about five relative to their presumed initial abundances. This overabundance is not seen in the W Vir stars. The abundance anomalies running from mild to extreme in W Vir stars but not seen in the BL Her stars are attributed to dust-gas separation that provides an atmosphere deficient in elements of high condensation temperature, notably Al, Ca, Sc, Ti, and *s*-process elements. Such anomalies have previously been seen among RV Tau stars which represent a long-period extension of the variability enjoyed by the Type II Cepheids. Comments are offered on how the contrasting abundance anomalies of BL Her and W Vir stars may be explained in terms of the stars' evolution from the blue horizontal branch.

(Thomas Mass, Sunetra Giridhar & D.L.Lambert*)*

2.7 Metal-poor stars

High resolution spectral analysis of three carbon enhanced metal-poor stars

The results of an analysis of high-resolution spectra (R ∼50,000), obtained with the Subaru Telescope High Dispersion Spectrograph, of two Carbon-Enhanced Metal-Poor (CEMP) stars selected from the Hamburg/ESO prism survey, HE 1305+0007 and HE 1152−0355, and of the classical CH star HD 5223 are presented. All of these stars have relatively low effective temperatures (4000 K - 4750 K) and high carbon abundances, which results in the presence of very strong molecular carbon bands in their spectra. The stellar atmospheric parameters for these stars indicate that they all 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 'Lead stars', 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.

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

2.8 Stellar survey

Search for Li-rich K giants

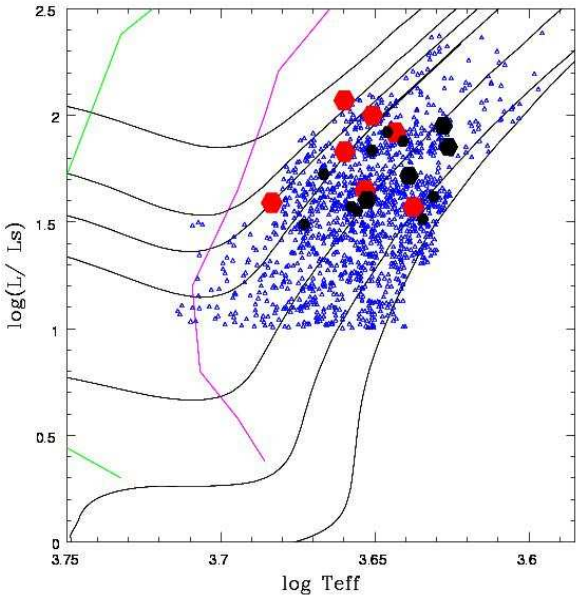


Figure 10: Sample stars (blue) are shown in the H-R diagram of luminosity versus $T_{\rm eff}$. A few known Li-rich K giants (red) and the new Li-rich K giants (black) from the survey are shown. Size of the symbols indicate amount of Li: bigger symbols represent super Li-rich (log ϵ(Li) $\geq$ 3.2) and smaller ones represent medium Li values (log ϵ(Li) = 1.5 - 3.0 dex). Also, shown are the evolutionary tracks for stars of masses between 0.8 - 2.5 $M_{\odot}$. The green line represents the beginning of the first dredge-up, and the magenta line indicates the start of the decrease in carbon isotopic ratio due to dilution.

There are a few K giants which are found to have, unexpectedly, large amount of Li in their photospheres. In some cases, Li abundance is 10-20 times more than the ISM (log ϵ(Li) = 3.2) value. Presently, there are less than two dozen K giants which may be classified as Li-rich K giants with an abundance of log ϵ(Li) $\geq$ 1.5 dex. Most of the Li-rich K giants were discovered serendipitously. It is not well understood how the handful of K giants happened to have such high Li. Is Li preserved, somehow, in some

stars? Are K giants able to produce Li, and dredge-up it to the photosphere? Or may be the Li in some of the K giants is due to swallowing of planets or dwarf stars with high Li but very low amount of hydrogen? These are some of the intriguing questions which need to be answered.

The authors initiated a search for Li-rich K giants among stars just above and below the red giant branch (RGB) clump region. Sample stars have been selected with the help of *Hipparcos* parallaxes (M_v) and the colour (B-V/b-y) (see Figure 10). There are around 1000 K giants which fall in this region of H-R diagram. Sample stars are being observed for low resolution spectra with the 2.0 m HCT and the 2.3 m VBT. The authors have deduced a relation, based on low resolution spectra, between the ratios of strengths of the Li at 6707 Å and a few similar low volt lines of Ca I and Fe I, and the actual Li abundance of known Li-rich K giants. So far, 400 K giants were observed and analyzed. A dozen K giants were found to be Li-rich, and for which high resolution spectra (R$\approx$ 60,000) are being obtained using an echelle spectrograph with 2.3 m VBT, Kavalur, and with the 2.7 m Harlan J. Smith telescope at McDonald observatory, USA.

(Y. Bharat Kumar & B. Eswar Reddy)

Low-resolution spectroscopy of high galactic latitude objects: Search for CH stars

Properties of CH stars like iron deficiency and enrichment of carbon and heavy elements can provide valuable inputs to understanding of nucleosynthesis. In particular, these parameters provide strong observational constraints for theoretical studies of nucleosynthesis of heavy elements at low-metallicity. Accurate identification and spectroscopic characterization of CH stars is therefore very essential. The authors have undertaken the program with the prime objective to search for these objects in a mixed sample of carbon stars taken from the Hamburg survey. The spectra of the objects were obtained using OMR at VBO Kavalur and HFOSC at HCT, IAO, Hanle, during 2005 and 2006. A detection of twenty-one CH stars from a sample of sixty objects based on low-resolution spectral analysis is reported. Estimated effective temperatures, $^{12}C/^{13}C$ isotopic ratios, and their location in the two colour J-H vs H-K plot support their identification with the class of CH stars.

(Aruna Goswami, P. Bama, Shanti Kumar Singh & Deepthi Devassy)

2.9 Binary system

Close binary stars

The speckle interferometer is used at the Cassegrain end of the 2.34 m Vainu Bappu Telescope (VBT), Vainu Bappu Observatory (VBO), Kavalur regularly to record specklegrams of a few close binary stars ($\rho < 1''$) along with the respective reference stars. Hundreds of frames of each of these stars are scanned carefully and are analyzed with the power spectrum using Matlab to remove the atmospherically induced point spread function from short exposure images of the binary stars, HD44112 (object) and HD46374 (reference). The speckle facility, after the end of each run, provides the accumulated power spectrum of the collected speckle frames. The averaged power spectrum of the object star is divided by the averaged power spectrum reference star obtained from observations of a nearby star, canceling out in this way the contribution of the atmospheric turbulence affecting the observation. This image power spectrum is also needed both for removing some features caused by the possible repetitive noise induced on the camera signal and to eliminate a typical cross-shaped disturbance occurring when the speckle image of the object is not entirely contained in the camera's field of view. The power spectrum is then inverted via Fast Fourier Transform (FFT), and the autocorrelation function (ACF) of the brightness distribution of the astronomical target is obtained. In the case of binary stars, the autocorrelation function shows the characteristic behaviour of a central peak with two opposite and symmetric secondary peaks. The distance between the central peak and one of the secondary ones is the separation between the two components while the position angle is given by the orientation of the secondary peak with uncertainty. The separation of the binary system, HD44112, is found to be $0.3''$. The position angle and separations of the binary components are consistent with the values published in the fourth interferometry catalogues.

(S. K. Saha & S. C. Vella Durai)*

2.10 Star cluster

Basic parameters of unstudied open clusters

The authors present the first BVI CCD photometry of NGC 6846, Tombaugh 4 and $UBVI$ CCD photometry of Be 9 to estimate their fundamental parameters. All the clusters have large reddening towards them (E(B$-$V) = 1.3 – 1.5 mag). NGC 6846 is found

to be 100 Myr old and located at a distance of 7.8 ± 0.8 kpc, in the first quadrant. This is the second farthest cluster known in this quadrant. Tombaugh 4 is found to be 400 Myr old and located at a distance of 3.6±0.4 kpc, in the second Galactic quadrant. This cluster is part of the outward stretch found in the Perseus arm. Be 9 is a very young cluster about 10 Myr old and located at a distance of 3.0 ± 0.3 kpc, in the second Galactic quadrant. Some pre-MS stars are identified based on NIR excess and the cluster has been forming stars for at least 5 Myr.

(Annapurni Subramaniam, Giovanni Carraro, & Kenneth Janes*)*

NGC 6834: Four emission line stars in a 80 Myr old open cluster

NGC 6834 is a poorly studied cluster and known to be 80 Myr old. The authors detect four early type stars with Hα in emission, which is a surprising result as these type of stars are not expected in a cluster of this age. They present a complete analysis of the cluster NGC 6834 based on UBV CCD data, spectra of 4 stars with Hα in emission (both obtained using the HCT), NIR spectrum of two stars using the UKIRT. The CMD analysis indicates that the cluster is likely to be younger than 40 Myr. The detailed analysis of the optical and NIR spectra are in progress.

(A. Subramaniam, Blesson Mathew, B.C. Bhatt, W Varricatt, N.M. Ashok* & D.P.K. Banerjee*)*

Survey of emission-line stars in young open clusters

The authors made a survey in search of emission-line stars in 202 open star clusters, younger than 100 Myr, using slitless spectroscopy. Using this technique they are able to detect stars which show emission in Balmer lines (like Classical Be stars and Herbig Ae/Be stars) among a large number of stars present in open clusters. The observations were carried out using HFOSC mounted on the Himalayan Chandra Telescope (HCT), Hanle. A total of 152 emission stars has been found in 41 clusters. Out of the total number of clusters surveyed $\sim$ 20 % has been found to have emission stars. The authors also found 49 new emission-line stars in 23 open clusters, out of which 18 clusters contain new detections. Clusters like NGC 7419, NGC 663 h & χ Persei and NGC 2345 are rich in emission line stars while others contain a few stars. They have combined the optical and NIR 2MASS photometric information to classify emission stars. The cohabitation of Herbig Be stars with Classical Be stars in certain young clusters has been found, which leads to an episodic star formation scenario. By extending the cluster parameters to the emission stars, it is planned to estimate the properties of the emission stars as a function of age, mass and location in the Galaxy.

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

Characteristics of emission line stars in open clusters

The authors have taken the slit spectra of the emission stars, detected from the above mentioned survey, in the spectral range 3700 - 9000 Å. The observations were carried out using HFOSC in HCT and OMR spectrograph in VBT, Kavalur. The emission stars like Classical Be (CBe) stars and Herbig Ae/Be (HAeBe) stars are found to show emission in spectral lines like Hα, Hβ, OI(8446Å) and Calcium triplet (8498Å, 8542Å, 8662Å) over the photospheric spectrum. This emission is found to arise from the circumstellar disk, whose formation mechanism is different in CBe stars and HAeBe stars. They have found that most of the emission stars in their survey belong to Classical Be category. The results from the survey is expected to give us a better understanding of the Be phenomenon.

(Blesson Mathew & Annapurni Subramaniam)

2.11 ISM

Variability of Na I spectral lines in the ISM (clouds) towards Vela supernovae remnant

The Na I D line profiles in the line of sight to few stars in the direction of Vela supernovae remnant have been obtained including the HD 72127A, which is known to show such variations. Further changes in the profiles of HD 72127A have been seen. A program to monitor more stars in the direction of Vela has been initiated. The time scale for variability etc. would be discussed.

(N. Kameswara Rao, S. Muneer, S. Sriram & Gajendra Pandey)

Planetary nebulae

An 'end-to-end model' of the bipolar planetary nebula *Hubble 5* has been computed using new *Infrared*

Space Observatory observations along with all other available data and the results published. This new kind of model combined a photoionization zone, a neutral zone and a photodissociation zone, all bundled together in a single structure for the first time. Molecules and dust grains have been introduced self-consistently. Cosmic ray and background radiation sources have been considered in the model. It was found that the H2 molecules and dust grains (silicates) could have a synergy leading to strong emission in H2 lines.

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

2.12 Dwarf stars and exo-solar planets

Observational and theoretical evidence of variation in the atmosphere of L-dwarfs

The results of R and I band quasi-simultaneous continuous monitoring of six L dwarfs with time resolution of about 5 min in I band and 10 min in R band are presented. A careful analysis of the data shows that the object 2MASS 0036+1821 is variable in I and R-band. But interestingly when the object was variable in I-filter, remains non-variable in R-band and vice-versa. Combining the literature data of other variability search programs, it was found that the upper limits of amplitude variation is within the range of 0.01 - 0.08 mag in I band and 0.02-0.03 in R band. In order to interpret the upper limits of variability model spectra of Allard et al. (2001, ApJ, 556, 357) has been used. The plausible sources of variability are considered as dust clouds and magnetically induced cool spots. Both the models were able to interpret the upper limits of amplitudes mostly within the surface filling factor of 0.5% -10.5%. Though literature data does not support the existence of magnetically induced cool spots on the atmosphere of L-dwarfs, but it cannot be ruled out through variability results. Spectroscopic fits of model spectrum and the optical polarization observation has confirmed the presence of dust at the optical depth where R and I band photon originates. So this small amplitude variation may be due to low-level dust activity. As scattering is one of the dominant source of opacity in UV to optical regime (Allard et al. 2001, ApJ, 556, 357), so to reproduce the variability results of L-dwarfs dust parameters and dust physics may need more modification.

(Malay Maiti)

Polarisation of starlight by unresolved and oblate exo-solar planet in elliptical orbit

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 particulates 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. The authors employ a chemical equilibrium model to estimate the number density of water and silicate condensates and calculate the degree of linear polarization at R band of starlight as a function of (i) mean size of condensates, (ii) planetary oblateness, (iii) inclination angle, (iv) phase angle, (v) orbital eccentricity e and (vi) the epoch of periastron passage. It is shown that the polarization profile alters significantly at all inclination angles when elliptical orbit is considered and the degree of polarization peaks at the epoch of periastron passage. They 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)

2.13 Galactic disk

Elemental abundance survey of the galactic metal-weak thick disk

Accurate parallaxes, thanks to the Hipparcos mission, together with radial velocities, measured from spectra, enabled to compute kinematic motions of individual stars. Based on the kinematic properties of stars, the galactic disk was resolved into different components: thin disk, thick disk, and a few smaller groups of stars (the so called streams). Recent abundance surveys revealed distinct difference in chemical make-up of thin and thick disks. Thick disk stars found to be old ($\approx$ 10 Gyr), metal-poor ([Fe/H] ≈ -0.70), and enriched in α-process elements relative to their counter parts in thin disk. Though, now it is clear that the thick disk exists and which is different from the dominant thin disk, both in kinematics and chemistry, the nature of the thick disk is still not very clear. Importantly, the extent of metallicity distribution of thick disk stars: lower and upper bounds to the [Fe/H] do not have consensus. The authors have focused on metal-poor end of the

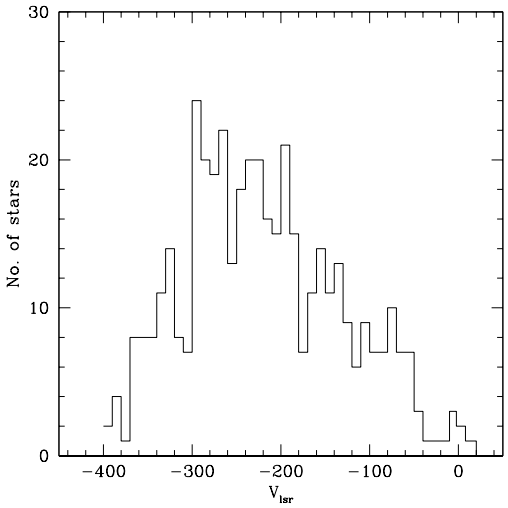


Figure 11: Number of stars as a function of V_{lsr} for stars with [Fe/H] ≤ -1.0. Sample stars are drawn from literature. Below [Fe/H] $= -1.0$, it is expected only halo stars exists, and their distribution with V_{lsr} peaks at around -220 km s^{-1}. Data suggests a weak asymmetry towards lower V_{lsr} and which are found to have disk kinematics.

thick disk, the so called metal weak thick disk (or MWTD). A sample of stars with [Fe/H] ≤ -1.0 and having kinematic properties very similar to thick disk stars were selected. By virtue of metallicity criteria, MWTD stars fall in the halo's metallicity regime (see Figure 11). To understand the chemical differences, if any, between halo and thick disk stars, a sample of halo stars were selected for the study. Sample stars were subjected to high resolution spectroscopy. Abundance were obtained for a set of elements comprising α-process, Mg-like, Fe-like, s-process, and r-process. Results suggest MWTD may extend in metallicity to as low as [Fe/H] $= -1.6$. Abundance ratios of halo and MWTD are indistinguishable suggesting halo and thick disk stars formed, out of SN II enriched material, within a short span of 1-2 Gyr. Detailed analysis are in progress.

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

2.14 Exploding stars

Novae: 2006 outburst of the recurrent nova RS Ophiuchi

The recurrent nova RS Oph was discovered to be in outburst on 2006 Feb 12.9. Monitoring the outburst in the optical was initiated immediately using the VBT as well as the HCT. Monitoring the radio emission from the source was initiated using the GMRT.

Radio observations

RS Ophiuchi was detected, for the first time, at radio frequencies < 1.4 GHz. Radio emission was detected at 0.61 GHz on day 20 with a flux density of ~ 48 mJy and at 0.325 GHz on day 38 with a flux density of ~ 44 mJy. This is in contrast with the 1985 outburst when it was not detected at 0.327 GHz even on day 66. The emission at low radio frequencies is clearly non-thermal and is well-explained by a synchrotron spectrum of index $\alpha \sim -0.8$ ($S \propto \nu^{\alpha}$) suffering foreground absorption due to the pre-existing, ionized, warm red giant wind. The absence of low frequency radio emission in 1985 and the earlier turn-on of the radio flux in the current outburst are interpreted as being due to higher foreground absorption in 1985 compared to that in 2006, suggesting that the overlying wind densities in 2006 are only 30% of those in 1985.

(N.G. Kantharia, G.C. Anupama, T.P. Prabhu, S. Ramya, M.F. Bode*, S.P.S. Eyres*, T.J. O'Brien*)*

Optical observations

The 2006 outburst was monitored for over a year, beginning one day after the outburst discovery. The evolution of the optical spectrum is found to be very similar to the previous outbursts. The evolution of the spectrum and the emission line velocities indicate an interaction of the nova ejecta with the pre-outburst circumstellar material, as seen in the previous outbursts. The velocity evolution indicates that the nova shell was in the adiabatic phase for a very brief period, and quickly moved over to the radiative cooling phase by day +5. This is consistent with the evolution in the X-ray and infrared. The widths of the nebular lines indicate they arise in the unshocked nova shell closer to the white dwarf, while recombination lines arise in the decelerating material. Line profiles also indicate multiple components, consistent with the high resolution radio and optical HST images.

(G.C. Anupama, U.S. Kamath, G. Pandey, D.K. Sahu, S. Muneer, B.C. Bhatt, P.S. Parihar & G. Selvakumar)

Supernovae: SN 2005hk

The photometric and spectroscopic evolution of the type Ia supernova SN 2005hk was monitored during the pre-maximum to nebular phase using the 2 m HCT (see Figure 12). Observations in the nebular

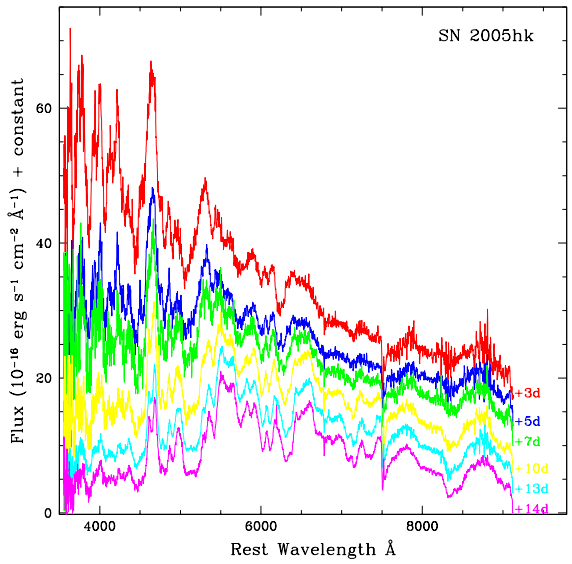


Figure 12: Early post-maximum spectral evolution of the peculiar type Ia supernova SN 2005hk, based on spectra obtained using the HCT.

phase were also made using the 8m Subaru Telescope. The photometric and spectroscopic evolution indicate SN 2005hk to be peculiar, very different from normal type Ia SNe. SN 2005hk is found to be very similar to the peculiar Ia SN 2002cx. The bolometric light curve of SN 2005hk is characterized by its faintness at the maximum ($M_{bol} = -17.7$). This certainly indicates that only a small amount of ^{56}Ni ($\leq 0.2 M_{\odot}$) is synthesized during the explosion. The slow decline rate of the light curve of SN 2005hk compared to normal SNe Ia indicates an explosion with lower kinetic energy. Also, the brightness at late phases indicates a more efficient trapping of the γ-rays from decaying ^{56}Co in SN 2005hk compared to normal SNe Ia such as SN 1992A. The pre-maximum spectra show a blue continuum, dominated by Fe III lines with weak Si II and Ca II H&K absorption, very similar to the over-luminous Ia SN 1991T. However, the photospheric velocities, measured based on the the absorption minimum corresponding to the Ca II H& K, Fe II, Fe III and Si II lines, indicate that SN 2005hk has much lower expansion velocities that decrease from $\sim$ 6900 km s^{-1} on day -6 to $\sim$ 6200 km s^{-1} on day -4. This is consistent with the low kinetic energy estimates based on the light curve. The spectrum of SN 2005hk remained peculiar throughout. The nebular phase spectrum shows no signature of strong forbidden iron and cobalt lines that are seen in normal SNe Ia. On the contrary, SN 2005hk spectrum is dominated by Fe II lines and forbidden lines due to [Ca II] 7291, 7234 Å and lines due to [Fe II] at 7155 Å and 7453 Å. The presence of these lines is quite similar to what is observed in the late time spectra of SNe IIP.

(D.K. Sahu, M. Tanaka, G.C. Anupama, K.S. Kawabata*, N. Tominaga*, & K. Nomoto*)*

SN 2004A

The optical light curve and spectral evolution of the normal type IIp supernova SN 2004A, discovered in the galaxy NGC 6027 on 2004 January 9.84 UT was studied. Early observations indicated the supernova was discovered at about two weeks since explosion. Using the standard candle method, the distance to the supernova is estimated as 20.35 ± 4.5 Mpc. The nickel mass ejected during the explosion is estimated 0.035 ± 0.02 M$_{\odot}$. The plateau luminosity, its duration ($\sim$ 70 days) and the expansion velocity of the supernova ejecta at the middle of the plateau indicate an explosion energy of $4.7 \pm 2.7 \times 10^{50}$ ergs and an ejected envelope mass of 7.2 ± 2.2 M$_{\odot}$. The ejected envelope mass implies a main sequence mass of 10 ± 2.5 M$_{\odot}$ for the progenitor.

(U.K. Gurugubelli, D.K. Sahu, G.C. Anupama, & N.K. Chakradhari)

2.15 Small Magellanic Cloud

RR Lyrae stars in the Small Magellanic Cloud: smaller halo

The Small Magellanic Cloud is the smallest of the the interacting galaxy-LMC-SMC system. Using the RR Lyrae stars detected by the OGLE survey, the author studied the distribution and depth of the old halo of the SMC. RR Lyrae stars are denser near the SMC centre and the bar. The density decreases towards the outer regions. The depth is also found to be more near the central regions (up to 5kpc) and much less outward. Thus the SMC halo is flatter than the LMC halo, which in turn is less extended than the galaxy. This might indicate a gradation in the extent of the halo with the mass of the galaxy.

(Annapurni Subramaniam)

2.16 Activity in galaxies

Study of star formation in NGC 1084

$UBVRI$ broad band, Hα narrow band photometry

and medium resolution spectroscopy of the star forming complexes have been carried out in the infrared bright galaxy NGC 1084. The metallicity of the galaxy are found to be close to the solar value. The shocked regions within the galaxy have been identified using the diagnostic diagram. Star formation rate for a few of the complexes are found to be as high as 0.5 $M_\odot$ yr^{-1}. The star forming complexes are found to lie in the age range 3 Myr to 6.5 Myr. The ages of the underlying stellar populations present in the star forming complexes are estimated using the $U-B$ vs $V-I$ colour-colour mixed population model created using the Starburst99 evolutionary model tracks. The interaction of a gas rich dwarf galaxy whose remnant is seen at a projected distance of 19 kpc from the centre of the galaxy is the likely trigger for enhanced star formation in the galaxy NGC 1084.

(S. Ramya, D. K. Sahu & T. P. Prabhu)

AGN and gas disk in the low surface brightness galaxy PGC 045080

Radio observations and optical spectroscopy of giant low surface brightness (LSB) galaxy PGC045080 have been presented. Highly inclined optical disk and massive HI gas content are found to be present in this moderately distant galaxy. 320 MHz, 610 MHz and 1.4 GHz radio continuum observations are obtained for the galaxy. Continuum emission has been detected and mapped. The emission is extended over the inner disk at all the three frequencies. Two distinct lobes are noticed at 1.4 GHz and 610 MHz. Optical Spectroscopy of the galaxy nucleus has been carried out and no strong emission lines associated with AGN activity have been identified in the spectrum but the presence of a weak AGN cannot be ruled out. Hα flux and radio continuum at 1.4 GHz are compared and it is found that a significant fraction of the nuclear emission is non-thermal in nature. Hence it is concluded that a weak or hidden AGN may be present in PGC 045080. The extended radio emissions are found to represent lobes/jets from the AGN. Although LSB galaxies have been characterised as metal poor systems with very little star formation, their centers are found to host significant AGN activity. HI gas disk in PGC 045080 is found to extend well beyond the optical disk and found to be warped. The disk of the galaxy has revealed lopsidedness in the HI intensity maps. On the lopsided side of the disk the velocity fields are found to be disturbed. HI rotation curve is derived using the velocity field. The rotation curve has a flat rotation speed of $\sim$ 190 kms^{-1}.

(M. Das, N. Kantharia*, S. Ramya, T. P. Prabhu, S. S. McGaugh*, & S. N. Vogel*)*

Lineless quasars in 2dF and SDSS

Traditionally, BL Lacs are discovered either from radio or X-ray surveys. It is currently not known if there exists radio-quiet BL Lac objects, when it is quite natural to expect them by analogy to radio-quiet quasars. Recently, the SDSS and 2dF have come up with the first optically selected sample of BL Lac candidates. Majority of the objects in this sample have weak (absent) emission lines in their spectra, resembling classical BL Lacs. However, they do not have other characteristics of classical BL Lacs (they are not detected in existing X-ray and radio observations). Intranight optical variability (INOV) observations were carried out on 12 objects over 23 nights using the 2-m HCT and 1.2 m OHP, France. Polarimetric observations were also done on 19 objects using the ESO 3.6m. These observations hint that these objects have $< 3\%$ optical polarization and show INOV similar to radio-quiet quasars and hence they could not be radio-quiet BL Lacs.

(C. S. Stalin, D. K. Sahu, R. Srianand, P. Petitjean*, & A. Aghaee*)*

QSOs in CFHT Legacy survey

The Canada-France Hawaii Telescope Legacy survey (CFHTLS) is an imaging program currently underway at the CFHT using MEGACAM, a 36 CCD mosaic camera. CFHTLS consists of a deep survey on four fields (D1, D2, D3 and D4) each covering about 1x1 deg^2 and a shallower survey on four fields (W1, W2, W3 and W4) each covering 7x7 deg^2 in u, g, r, i and z filters, reaching final limiting magnitudes in the deep fields of 28.3, 28.5, 28.3, 28.3 and 27.0 in the five bands respectively. Selection of quasars were done on the D1-W1 and D4 fields (as the fields are also observed by XMM, SWIRE and GALEX) down to $g < 22.5$ mag. ($\sim$3 magnitudes fainter than the SDSS quasar survey). A successful spectroscopic observing run was carried out in September 2006 using AAOmega at the AAT, where 858 QSOs were identified out of the 1977 candidates selected based on 2-D colour colour diagrams, coupled with the photometric redshift code *hyperz*.

(C. S. Stalin, R. Srianand P. Petitjean*, A. Smette* and D. Elbaz*)*

X-ray emission from Seyfert galaxies and the unification scheme

Seyfert Galaxies emit a substantial fraction of their bolometric luminosity in the X-ray regime and show both soft and hard nuclear emission components. The continuum can be fitted with simple photoelectric absorbed power-law. The X-ray spectral properties are being studied for a rigorously selected sample of Seyfert galaxies, matched in orientation independent parameters, in the framework of the unification scheme, which hypothesizes that Seyfert 1s and 2s constitute the same parent population and appear different solely due to their differing orientations. The authors find that for their sample, X-ray luminosity of Seyfert 1s is systematically higher than Seyfert 2s in both soft (0.2-2.4 keV) and hard (2.0-10 keV) energy bands, which is broadly consistent with the unification scheme which predicts that the X-ray photons are absorbed by the torus in Seyfert 2s, leading to the reduction in X-ray luminosity, however, absorption effect is weaker at hard X-ray band. The hard band (2.0-10 keV) photon index distributions are similar for both Seyfert subclasses, while, in the soft band, Seyfert 2s show systematically higher photon indices than Seyfert 1s, opposite to that predicted by the unification scheme. It could be that non-nuclear extended soft X-ray emission contributes significantly to the measured X-ray flux in this energy band in the Seyfert 2s, causing steepening of their spectra. These results are broadly consistent with the predictions of the orientation based unification scheme of Seyfert galaxies. A weak trend of hard (2.0-10 keV) X-ray luminosity increasing with [O III] luminosity has been noticed, however, a linear correlation is expected between hard X-ray and [O III] luminosities, if both are the measures of AGN intrinsic power.

(Veeresh Singh & P. Shastri)

Emission line ratios of the Seyfert galaxy NGC 4151

Theoretical modeling of the extended narrow line region (ENLR) of NGC 4151 at a position angle 51° is under progress. Hydrogen atmosphere of Seyfert galaxy NGC 4151 is considered to calculate the emission line ratios $H\alpha/H\beta$, $H\gamma/H\beta$, $H\delta/H\beta$, etc., and compare them with the observations. To calculate above line ratios the authors consider non-LTE radiative transfer equation in spherical symmetry with multilevel model which is solved with Monte Carlo technique.

(M. Srinivasa Rao & Mika Juvela)*

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

Continuing the OGLE II data analysis work of eclipsing binary systems, the photometric data presented in the catalog of eclipsing binary stars were collected with secondary minimum phase, in the range 0.49 - 0.51 in LMC and SMC. This data reduction is to derive the physical parameters (like mass, density, temperature, luminosity and the orbital parameters) of an eclipsing binary system. This work is in progress.

(M. Srinivasa Rao, B. N. Ashoka, D. Kjurkchieva*, & Valentin*)*

Dynamics of the narrow-line region in the Seyfert 2 galaxy NGC 1068

With the launch of HST and its high angular resolution ($\sim 0''.1$), the narrow line regions (NLRs) of Seyfert galaxies have received considerable attention. With the limited long-slit capability of the faint object camera (FOC), and later the expanded capability of Space Telescope Imaging Spectrograph (STIS), detailed constraints on the kinematics of the NLRs in Seyferts and other galaxies became possible. In turn, these kinematic studies provided good diagnostics upon which dynamical analyses can be based.

The authors present dynamical models based on a study of high-resolution long-slit spectra of the NLR in NGC 1068 obtained with the STIS aboard The Hubble Space Telescope (HST). The dynamical models consider the radiative force due to the active galactic nucleus (AGN), gravitational forces from the supermassive black hole (SMBH), nuclear stellar cluster, and galactic bulge, and a drag force due to the NLR clouds interacting with a hot ambient medium. The derived velocity profile of the NLR gas is compared to that obtained from previous kinematic models of the NLR using a simple biconical geometry for the outflowing NLR clouds. The results show that the acceleration profile due to radiative line driving is too steep to fit the data and that gravitational forces along cannot slow the clouds down, but with drag forces included, the clouds can slow down to the systemic velocity over the range 100–400 pc, as observed. However, they are not able to match the gradual acceleration of the NLR clouds

from $\sim 0-\sim 100pc$, indicating the need for additional dynamical studies.

(V. Das, D.M. Crenshaw, & S.B. Kraemer*)*

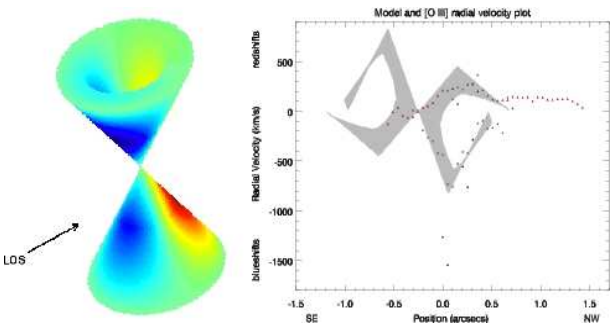


Figure 13: Left: Model of the NLR of NGC 7674 based on a fitted slit shown on the right. The Line-of-sight is pointed by the arrow. Right: The model in shaded gray fits the data points in color. Points after 0.5 arcseconds are in the host galaxy.

Kinematics of the narrow-line region in the Seyfert 2 galaxy NGC 7674

The authors used data taken by HST Telescope Imaging Spectrograph (STIS) and obtained from the Multimission Archive (MAST) to study the kinematics of the narrow-line region (NLR) of NGC 7674. They present a kinematical model that closely matches the geometry and velocity field in the NLR, similar to previous studies done on NGC 4151, NGC 1068, and Mrk 3. These Seyferts all show a common accelerated and decelerated outflow pattern that indicates a common driving mechanism for the NLR gas. A high resolution MERLIN radio map was used to test radio jet/NLR cloud interactions in NGC 7674, and have shown that the jet is not the principal driving mechanism of the NLR gas, but that the gas is pushed aside laterally, similar to the interactions in previous studies mentioned above.

The authors present a simple modeling scheme which is consistent with the unification theory of Seyferts, which closely matches the NLR of Seyfert galaxies regardless of type, and apply it to the Seyfert 2 galaxy, NGC 7674. The model easily matches both types of galaxies, and are consistent with the orientation of type 1s and 2s, in which the Seyfert unification scheme demand large inclinations for the type 1s and smaller inclinations for the type 2s to account for the obscuration. A model is shown in Figure 13.

The authors would like to concentrate on the pure qualitative nature of the common outflow pattern seen in the NLR gas in a rising number of Seyfert galaxies, and how these common flows can be fitted by a simple biconical geometry with a simple velocity field. More importantly, they present these results expressing the need for a more theoretical study to explain such flow pattern, since it seems that all Seyfert galaxies may show similar flows. This is of particular importance since the physical mechanism that dominate the flow pattern may not only operate in Seyferts, but also in other AGN as well. They also stress the importance in explaining this simple yet strange phenomenon.

(V. Das, D. M. Crenshaw, S. B. Kraemer* & P. Shastri)*

Understanding the flow patterns in the narrow-line region of Seyfert galaxies: A dynamical approach

Recent studies focusing on the kinematics of the NLR of Seyfert galaxies, unraveled a common flow pattern in the gas. It was seen that the NLR gas in several of the brighter Seyfert galaxies (NGC 4151, NGC 1068, Mrk 3, Mrk 78, and NGC 7674) flows in a simple yet currently unexplained manner. The velocity of the gas assumed a 'Hubble-flow' law, where v(r) $\sim$ r, where r is measured from or approximately near the supper massive black hole (SMBH).

Previous work attempted to the match the flow velocity of NGC 1068, using gravity, radiation pressure, and a drag force emanating from a hot ambient medium to test whether the clouds can assume the velocity seen in the data. The fit to the data, while promising, was not well constrained. A calculation including the effects of rotation and MHD is being carried out; the angular momentum constraints yield the correct asymptotics in the velocity profile that is expected to match the observed flow patterns.

(V. Das, A. Mangalam, D. M. Crenshaw & S. B. Kraemer*)*

3 Theoretical Astrophysics and Physics

3.1 Scattering of light

Detection of periodicities hidden behind randomness, by the matched filtering method

A new method to extract weak periodicities, hidden behind a highly rough surface, to study the propagation of a wave in a random medium, has been developed, using for the first time, a matched filter method. Conventional methods suggest that detection is impossible, unless the coherence length of the radiation field, as restricted by the randomness (r_0) and the wavelength of the periodic part (Λ) have a relation $(r_0/\Lambda) \geq 0.33$. This method, succeeds in finding hidden periodicities, even for $(r_0/\Lambda) = 0.11$, which is thus an advance over the limits known.

The method begins with the hypothesis that, in the presence of a hidden periodic part, the given intensity distribution consists of a train of identical peaks (matched ones, hence the name matched filtering) and tries to identify the location, amplitude and width of these identical hidden peaks by successively eliminating the more intense, lower order ones. It is found that it is possible to identify by this method, the underlying periodic part, up to $(r_0/\Lambda) = 0.11$, even for $(a/\lambda) = 0.05$, where a is the amplitude of the randomness and λ the wavelength of light. Several statistical tests have vindicated the correctness of the method in the limit mentioned above. The efficiency of the method for multiply periodic structures is being investigated.

The possibility of using this method is being investigated to detect structures, when viewed through dusty atmospheres, a situation of great astrophysical importance. This method shows great promise in enhancing the performance of gratings, including those of highly sensitive echelle type gratings.

(S. Chatterjee)

3.2 MHD

Exact nonlinear solution for the Hall-Alfvén wave in partially ionized plasmas

It is shown that the exact nonlinear solutions for Hall - Alfvén waves can be obtained in a uniformly rotating weakly ionized plasma such as those which exist in various types of accretion disks. In addition, this piece of work demonstrates a method of eliminating the inaccuracies embedded in the literature on the subject.

(V. Krishan, M. Furukawa & S. Mahajan)

Irregular singularity of the magneto-rotational instability in a Keplerian disk

The center of a Keplerian disk is an irregular singularity for the eigenfunctions of magneto-rotational instabilities. The singularity yields continuous eigenvalues (growth rates in the unstable regime and frequencies in the stable regime) - their physical implications are rather complex, reflecting the 'non - Hermitian' nature of the rotating plasma system. Invoking the Laplace transform, as well as numerical simulations, interesting long -term behaviour of the instability has been found.

(M. Furukawa, Z. Yoshida*, M. Hirota* & Vinod Krishan)*

MHD stability in flowing plasmas: Connection between fusion plasma and astrophysics research

Magneto-rotational instability (MRI) is studied by comparison with interchange instability (Intl) in a rotating cylindrical plasma. MRI is driven by the shear of plasma rotation, whereas the Intl by the density gradient. The eigenmode equation for the MRI has the same form as that for the Intl. The local stability criterion is also summarized in a similar form as *Spatial gradient of centrifugal force greater than the square of Alfvén frequency causes instability.* However, the MRI is essentially different from the Intl because of the 'non-Hermitian' property. Keplerian rotation generates the irregular singularity at the center of the disk, which yields the continuum of eigenvalues with non-orthogonal and square-integrable eigenfunctions.

(M. Furukawa, Z. Yoshida*, M. Hirota* & Vinod Krishan)*

Astrophysical magnetic fields: aspects of 2D MHD flows its applications

A general treatment of axisymmetric MHD flows was considered using a new approach. A by product of the analysis are solutions for inviscid conducting rotating fluids. A set of unique constraints on magnetic stream functions have been found. They could be applied to superconducting and superfluid flows

with possible applications to terrestrial plasma experiments or to neutron stars interiors.

A MHD wind passing through 3 critical surfaces has been formulated that are *self consistent* The issues are simplified by calculating the solutions in the asymptotic fast magnetosonic linear regime in addition to making assumptions of self-similarity (which implies that the Alfvén surface is a cone). The author provides a class of self-similar solutions with a power law form for the stream function, ψ in the asymptotic regime. The condition for collimation in their formulation requires that the poloidal field scale as $B_p \sim r^{\mathrm{x}}$, where $\mathrm{x} < -1$. The solutions numerically to match to equatorial dynamo generated flux can be extended. The dynamo flux eigen functions have been reported in earlier work. Such solutions will be used to produce non-self similar flow geometries.

There are subtle but essential differences in the wind geometries for active galaxies, X-ray binaries, and young stellar objects. The estimates for the jet luminosities and terminal velocities are reasonable. The correct calculation of the Alfvén radius is crucial in determining the terminal velocity. An electrodynamical jet model emerging from a disk dynamo is being worked out.

(A. Mangalam)

Hybrid viscosity and the magnetorotational instability

The effects of the 'hybrid' viscosity mechanism on the development of the magnetorotational instability in hot, two-temperature accretion disks around black holes have been investigated. This mechanism, which is due to hot, collisionless protons scattering off perturbations in the magnetic field lines, is the only one relevant to this situation. It is shown that it will effectively mediate the instability and significantly augment its growth rate during the initial, high-beta stages of its development.

(P. Subramanian, P. Becker & Menas Kafatos*)*

3.3 Pulsars

Emission Height of Core in PSR B2111+46

The mean profile of core dominated PSR B2111+46 is studied at multiple frequencies. To identify the phase location of component peaks, fitted Gaussians and identified it's five emission components. It is proposed that the emission beam of PSR B2111+46 has a nested cone structure consisting of two cones centered on core. Using the phase location of component peaks, 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. By recognizing this fact, located the phase of meridional plane and estimated the absolute altitude of emission of core (see Figure 14) and conal components relative to the neutron star center, using the more exact expression for phase shift given recently by Gangadhara (2005, ApJ, 628, 923).

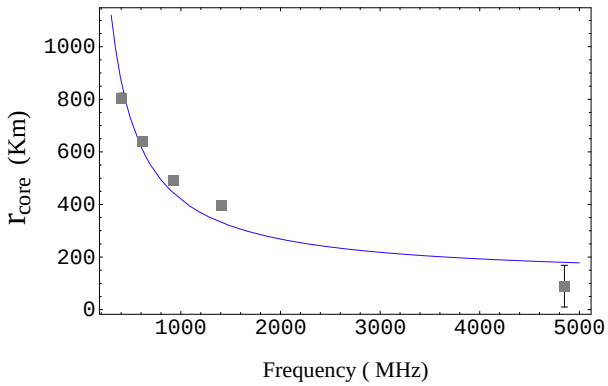


Figure 14: The core emission height r_{core} is plotted as a function of frequency ν. The points are fitted with a curve of the form $r = (C/\nu) + d$, where the fit parameters are C=3×10^5 and $d = 115$..

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

Geometry of emission region in pulsars and the Stokes parameters

The beamed emission from relativistic sources (plasma particles or bunches) constrained to move along the curved trajectories, occur in the direction of their velocity. To receive it, observer's line-of-sight must align with the velocity within the beaming angle $1/\gamma$, where γ is the Lorentz factor. Hence by solving the viewing geometry in an inclined and rotating dipole magnetic field, one can expect that at any given pulse phase a distant observer tends to receive the radiation only from the specific heights or regions. To understand the pulsar emission, one must model for all the Stokes parameters (I, Q, U & V —a set of parameters used to specify the phase and polarization of radiation) of the pulsar emission, and compare with the observations. They have been found to offer a very convenient method for establishing the as-

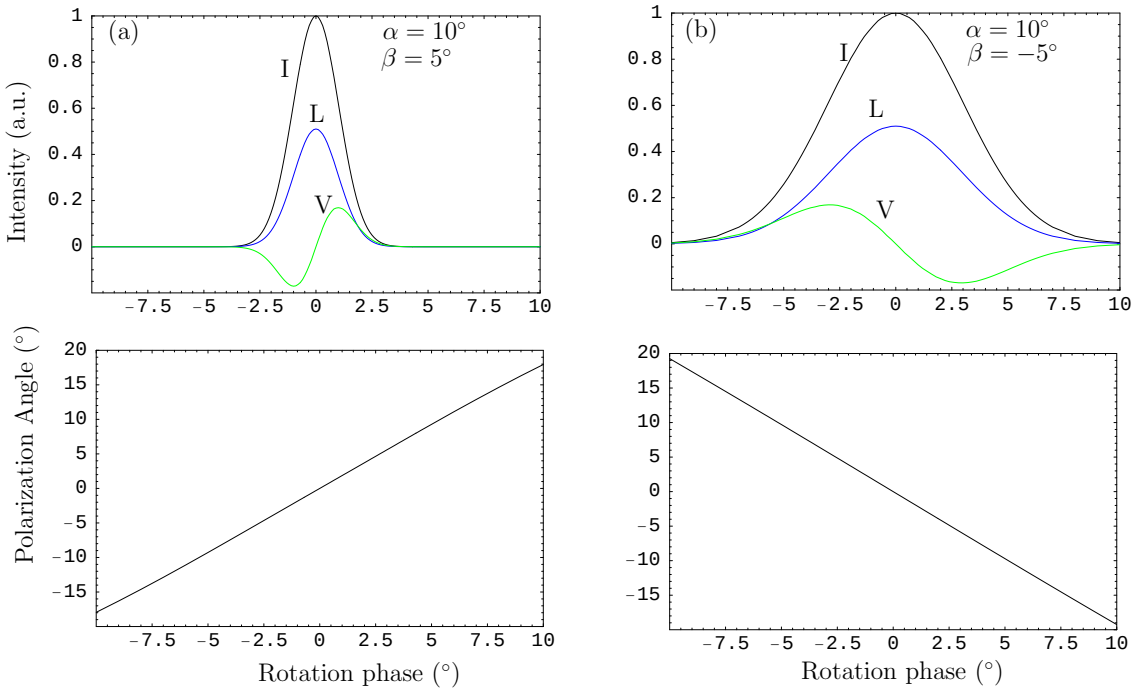


Figure 15: Simulated pulsar profiles. In panels (a) and (b) I is intensity, L linear polarization and V circular polarization. In both cases, lower panels represent the polarization angle. The angle α is the magnetic axis inclination angle, and β is the sight line impact angle. Chosen pulsar period $P = 1$ s, and Lorentz factor $\gamma = 400$ for the relativistic bunches.

sociation between the polarization state of observed radiation and the geometry of emitting region. By carefully modeling the polarization Stokes parameters, it is possible to construct the geometry of emission region at multifrequencies. The parameter I defines the total intensity, Q and U jointly define the linear polarization L and polarization angle, and V describes the circular polarization. The model shows that the polarization features such as polarization angle swing, antisymmetric circular polarization and their correlation can be explained within the purview of the model (see Figure 15).

(R. T. Gangadhara)

Gravitational dipole moment

Astrophysical implications for a gravitational dipole moment were considered. The slow down rate, of the 2.4 hour binary pulsar and of millisecond pulsars can put tight constraints on a gravitational dipole moment. Limits are put on the coupling of such a dipole interaction as less than a trillionth of the Newtonian gravitational constant. Implications for the early universe are being studied.

(C.Sivaram)

3.4 Radiative transfer

Hanle-Zeeman redistribution matrix: classical scattering theory expressions in the laboratory frame

To model the distribution of solar surface magnetic fields, the light scattering theories that are valid in arbitrarily strong fields are required. The authors undertake derivation of a scattering theory applicable in arbitrary field strengths, based on the work by Stenflo (1994, Solar magnetic fields, Kluwer Acad. Publ.). Polarized light scattering in spectral lines is governed by a (4×4) matrix that describes how the Stokes vector is scattered and redistributed in frequency and direction. They have developed a classical theory for this redistribution matrix in the presence of magnetic fields of arbitrary strength and direction. This general case of scattering in the magnetic fields is called the Hanle-Zeeman regime, as it covers both of the partially overlapping (weak) and well separated Zeeman components (strong-field) regimes in which the Hanle and Zeeman effects respectively dominate the scattering polarization. In this general regime the angle-frequency correlations between incoming and outgoing photons that describe the so-called partial frequency redistri-

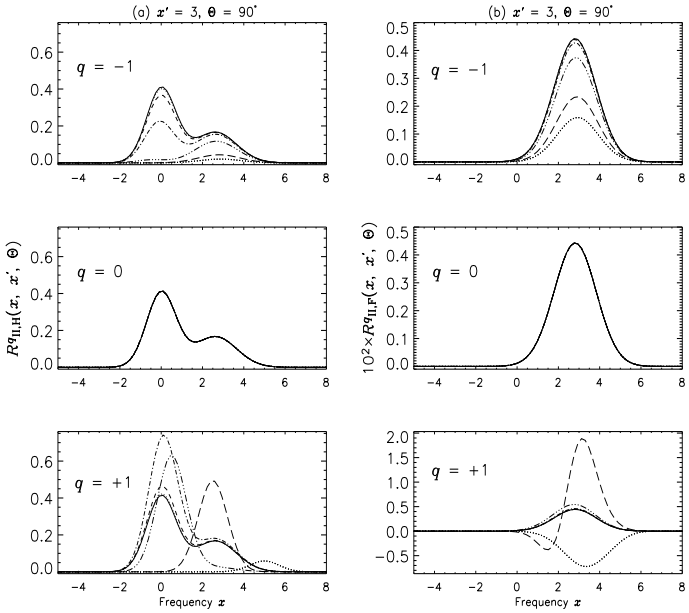


Figure 16: Effect of magnetic field strength on the Hanle-Zeeman scattering. The magnetic redistribution function (RF) of Hummer's type II is shown.

bution (PRD) are intimately coupled to the atomic polarization properties.

The authors have developed the theory for the PRD redistribution matrix in this general case and explored its detailed mathematical properties and symmetry properties for the case of a $J = 0 \rightarrow 1 \rightarrow 0$ scattering transition, which can be treated in terms of time-dependent classical oscillator theory. It is shown how the redistribution matrix can be expressed as a linear superposition of coherent (collisionless) and non-coherent (collision controlled) parts, each of which contain the magnetic redistribution basis functions that resemble the well known Hummer's type functions. They also show how the classical theory can be extended to treat atomic and molecular scattering transitions for any combinations of upper and lower level quantum numbers.

The left panels (Figure **??**a) show $R^q_{\rm II,\,H}(x,\, x',\, \Theta)$, while the right panels (Fig. **??**b) show $R^q_{\rm II,\,F}(x,\, x',\, \Theta)$, for different values of the field strength, parameterized through $v_{\rm H}$. All the curves for $q = -1, 0$ of $R^q_{\rm II,\,H}$ (Figure **??**a) are multiplied by a factor of 10^5. For $q = +1$, the solid to the dash-dotted lines (four of the curves) are multiplied by 10^5, the dash-triple dotted line by 10^4, the long-dashed line by 20, and the thick dotted line by 10^2, to be able to have them displayed in the same scale, and to show their frequency dependence.

The authors have encountered magnetic redistribution basis functions of Hummer's type II and III. Figure **??** shows the Hummer's type II magnetic redistribution functions for incoming frequency ($x = 3$ in dimensionless units); damping parameter 10^{-3}; and scattering angle 90°, for different values of magnetic field strength (parametrized as $v_{\rm H}$). The field strength parameter $v_{\rm H}$ is varied as follows: $v_{\rm H} = 0.0008$ (solid line), 0.004 (dotted line), 0.02 (dashed line), 0.1 (dash-dotted line), 0.5 (dash-triple-dotted line), 2.5 (long-dashed line), and 5 (thick dotted line). One can clearly see the two competing effects, – namely the well known frequency-coherent behaviour of type II functions, and the magnetic-coherent behavior arising due to the non-zero magnetic field.

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

Hanle-Zeeman redistribution matrix: comparison of classical and quantum electrodynamic approaches

The Hanle-Zeeman redistribution matrix accounts for the intricately coupled correlations in frequency, angle, and polarization between the incoming and outgoing radiation and embodies the physics of the scattering process. The authors show explicitly for a $J = 0 \rightarrow 1 \rightarrow 0$ scattering transition, the equivalence between the Hanle-Zeeman redistribution matrix that is derived through quantum electrodynamics, and the one derived through classical time-dependent oscillator theory. This equivalence

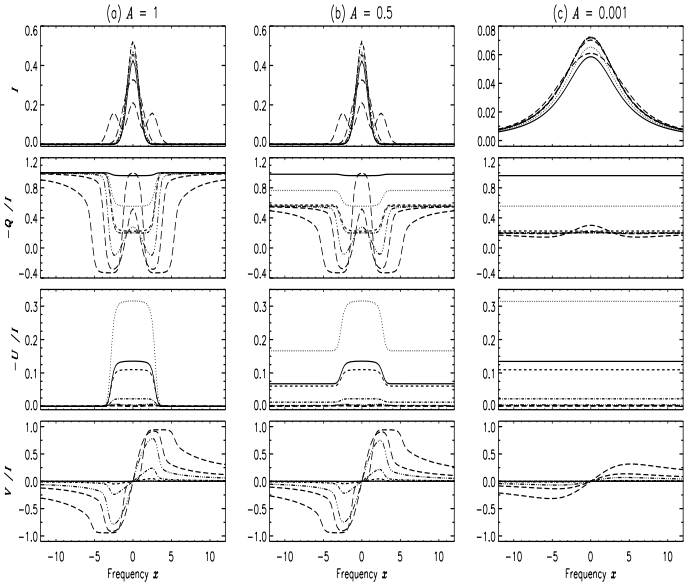


Figure 17: Stokes profile I and the fractional polarization profiles Q/I, U/I, and V/I after integration over the incoming frequencies (x').

holds for all strengths and directions of the magnetic field. Several aspects of the Hanle-Zeeman redistribution matrix are illustrated, and explicit algebraic expressions are given, which are of practical use for the polarized line transfer computations. While the efficiency of the Hanle effect is usually confined to the line core, they show how elastic collisions can produce a 'wing Hanle effect' as well, under favorable conditions in the solar atmosphere (namely the collisional spreading of coherence into the line wings). It is shown how the correlated 'Zeeman scattering' in the strong-field regime differs from the absorption process (described by the Zeeman absorption matrix) and the emission process (described by an emission vector) that is uncorrelated with the absorption.

Panels (a) and (b) Figure **??** in correspond to $\Gamma_E/\Gamma_R = 0, 1$ (pure $\hat{\mathbf{R}}^{\rm II}$ and mixed $\hat{\mathbf{R}}^{\rm II}$ and $\hat{\mathbf{R}}^{\rm III}$ respectively), while panel (c) corresponds to $\Gamma_E/\Gamma_R = 999$ — the case of almost pure $\hat{\mathbf{R}}^{\rm III}$ type scattering (collision dominated scattering becoming responsible for the wing Hanle effect). Figure **??** shows the single scattered Stokes intensity component I and the fractional polarizations $(Q/I, U/I, V/I)$ for a 90° scattering event in a chromospheric canopy like field geometry. Different curves correspond to different values of magnetic field strength. The incident spectrum is flat, so that the integration over the incoming frequencies in the scattering integral can be performed. Different panels correspond to the different values of the elastic collision rate Γ_E/Γ_R. For the case of $\Gamma_E/\Gamma_R = 1$ it is evident from the figure, that the wing Hanle effect predicted by their theory, becomes significant (namely the scattering does not approach Rayleigh limit of zero linear polarization in the line wings).

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

3.5 Astrophysical spectropolarimetry

Scattering polarization in the presence of uniform magnetic and electric quadrupole fields

The polarization of radiation by scattering on an atom embedded in combined external quadrupole electric and uniform magnetic fields is studied theoretically. Limiting cases of scattering under Zeeman effect and Hanle effect in weak magnetic fields are discussed. The theory is general enough to handle scattering in intermediate magnetic fields (Hanle-Zeeman effect) and for arbitrary orientation of magnetic field. The quadrupolar electric field produces asymmetric line shifts and causes interesting level-crossing phenomena either in the absence of an ambient magnetic field or in its presence. It is shown that the quadrupolar electric field produces an additional depolarization in the Q/I profiles and rotation of the plane of polarization in the U/I profile over and above that arising from magnetic field itself. This characteristic may have a diagnostic potential to detect steady state and time varying electric fields that surround radiating atoms in Solar atmospheric

layers.

(Yee Yee Oo, M. Sampoorna, K.N. Nagendra, S. Ananthamurthy* & G. Ramachandran)*

Scattering phase matrices for polarized radiation in the presence of external magnetic fields: expressions for higher multipoles of scattering

The scattering phase matrices for forbidden lines in the presence of an external magnetic fields are derived. The particular cases of E2 (electric quadrupole) and the M2 (magnetic quadrupole) forbidden line transitions are considered. The quantum electrodynamical approach employed in the calculations is discussed. As an example, compact analytical expressions for the case of a multiplet (J = 0 → 2 → 0 scattering transition) are presented. The Rayleigh scattering phase matrix for some forbidden lines in the non-magnetic case is also given. The Stokes profiles produced in a single scattering of forbidden line radiation for an unpolarized beam of incident radiation, are shown in the week-field limit (Hanle scattering), upto the strong field limit (Zeeman scattering), covering also the intermediate field strength regime of Hanle-Zeeman scattering.

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

Scattering of polarized radiation on polarized atoms

To explain some of the enigmatic features in Astrophysical Spectropolarimetry, lower level polarization has been considered by several authors in atomic scattering of polarized radiation. Therefore, a precise quantum electrodynamical theory for discussing the scattering processes of polarized radiation on polarized atoms has been developed. To take care of the anisotropic illumination of the atom, plane wave radiation with polarization μ_i, is considered to be incident along an arbitrary direction, specified by polar angles (θ_i, ϕ_i) and getting scattered by the atom into a direction along (θ_f, ϕ_f) with polarization μ_f. The atom is considered, in general, to be initially in a state of total angular momentum j_i and making a transition to a final state with total angular momentum j_f. In the particular case of a two level problem $j_i = j_f \neq 0$, in order that the atom is polarized initially. The state of initial polarization of the atom is assumed to be the most general one and characterized by an arbitrary set of Fano statistical tensors $t^{k_i}_{q_i}$ of rank k_i, going upto the maximum $2j_i$. The scattering amplitude is expressed as a linear combination of irreducible tensor amplitudes, $\mathcal{F}^{\lambda}_{m_\lambda}(\mu_f, \mu_i)$ of rank $\lambda = |j_i - j_f|...(j_i + j_f)$. The phase matrix $\mathcal{R}$ for scattering is then obtained in the elegant form of a weighted sum of phase matrices $\mathcal{R}(k_i q_i)$, whose coefficients are the complex conjugates of the Fano statistical tensors $t^{k_i}_{q_i}$, with the summation extended over all the k_i and q_i. Explicit formulae for the $\mathcal{R}(k_i, q_i)$ are derived in terms of the quasilinear combinations of rank k_i constructed out of the irreducible tensor amplitudes $\mathcal{F}^{\lambda}(\mu_f, \mu_i)$. Further detailed studies are in progress.

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

Effects of electric field (uniform and quadrupolar) together with a uniform magnetic field on the Stokes profiles of Na I D2 lines

The simultaneous action of uniform electric and magnetic fields on Hydrogen lines has attracted considerable attention during the last two decades. Theoretical work on the effects of electric quadrupole fields on line spectra of atoms was initiated for the first time from this Institute. Following this earlier work of Oo et al in the last few years, a preliminary investigation of the effect of electric quadrupole field on the Stokes profiles of NaI D2 line was reported by Nagaraju et al. (2005, Indo-Chinese Workshop on Recent Advances in Solar Physics), as the upper level with total angular momentum $J = 3/2$ is quite sensitive to the presence of an external electric quadrupole field. It is also known that even in the presence of a uniform electric field, the two D lines are split into three through the quadratic Stark effect. Therefore, a comprehensive theoretical formalism is being developed to study the effects of combined quadrupole and uniform electric fields together with an external uniform magnetic field on the line spectra and to study scattering of radiation on atoms in such an environment.

(K. Nagaraju, Yee Yee Oo, M. Sampoorna, K. N. Nagendra & G. Ramachandran)*

3.6 Interacting galaxies

Dynamics

Galaxies interact in a multitude of ways with their environment. Such interaction can alter the morphological type of galaxies, trigger star formation and

even produce active galactic nuclei. The most important parameter in a galaxy collision is the impact parameter. Numerical simulations have been performed to study the effect of changing the impact parameter in a galactic collision. Both merging and non-merging collisions of galaxies represented by a polytrope of index n = 4, have been studied to see the development of the density structure in merger remnants. It has been observed that the density profiles follow the $r^{1/4}$ law in the inner regions up to R = $4R_h$ and show deviations beyond this part.

(P.M.S. Namboodiri)

Effect of intergalactic medium on the motion of Quasars in the variable mass hypothesis in Hoyle-Narlikar theory

Further investigations were carried out on the effect of intergalactic medium [IGM] on the motion of a variable mass quasar ejected from the nucleus of the parent galaxy in the Variable Mass Hypothesis [VMH] scenario of Hoyle-Narlikar theory of gravitation. The following two scenarios were considered:

1. It was assumed that the QSO,born as a massless object in the galactic nucleus,is held captive there till its redshift decreases from the initial infinite value to one of the values in the Karlsson geometric series of redshifts $(1 + z)$ and then ejected outwards. The observations require that the speed of the quasar should be around 10,000 km/s when it is observed. The imposition of this boundary condition can be used to determine the initial speed of ejection. Numerical calculations were done for a few selected cases from Narlikar, Das et al. (2002, Int. J. Mod. Phys. D, 11, 245). Further work is in progress.

2. In the original Narlikar-Das model the ejected QSO slows down due to the increase of its mass from zero. In the present scenario the resistance from the IGM will give rise to an additional decelerating force. Assuming Stoke's law for this force (force proportional to $r \times v$), since the radius of the object is inversely proportional to its mass in VMH, one obtains a force $-kv/m$ where k is a constant. Introducing this additional term in the original Narlikar-Das equation of motion for the quasar numerical computations were done with the boundary condition of final velocities v 10^4 km/s to adjust the values of the parameter k, for a few cases from Narlikar, Das et al. (2002, Int. J. Phys. D, 11, 245). Additional work is required to obtain more accurate results and compare with the observational data.

(P.K. Das)

3.7 High energy astrophysics

Constraint on extra dimensions from gamma ray bursts

The phase space constraints on neutrino luminosities from compact objects were extended to include extra spatial dimensions using the generalized uncertainty principle (GUP). It was shown that peak TeV neutrino fluxes from such objects (and from gamma ray bursts) and the highest energy particle fluxes could constrain extra dimensions and this could supplement forthcoming LHC limits.

(C.Sivaram)

3.8 Non-accelerator particle physics

Electric dipole moments of atoms and molecules

The focus has been on the electric dipole moments of atoms and molecules that arise from violations of parity and time-reversal symmetries. Significant progress has been made on the relativistic many-body theory of the electric dipole moment of atomic mercury. A linearized version of the relativistic coupled-cluster theory of electric dipole moments of atoms has been formulated and have applied it to mercury to gain insights into CP violation in the nuclear sector arising from the Schiff moment and the tensor-pseudotensor electron-nuclear sector.This work has the potential to shed light on new physics beyond the Standard Model in general and supersymmetery in particular.

The authors have also performed accurate calculations of atomic rubidium and caesium electric dipole moments. Experiments to observe the electric dipole moments of these two atoms are under way at Pennsylvania State University and the University of Texas, Austin. The results of these experiments when they come to fruition in combination with the results of their theory could provide important insights into new physics beyond the Standard Model and the origin of leptonic CP violation.

The authors' theoretical work on the electric dipole moment of ytterbium fluoride originating from the

electron-nucleus scalar-pseudoscalar interaction has led to a new limit for the coupling constant of this interaction. This work was based on the relativistic configuration interaction method.

(K. V. P. Latha, H. S. Nataraj, M. K. Nayak, R. K. Chaudhuri, B. P. Das, B. K. Sahoo & D. Mukherjee*)*

Many-body theory of ultracold atoms

Quantum phase transitions have important applications in many areas of physics. The authors have used the density matrix renormalization group method to study quantum phase transitions in a mixture containing two species of ultracold bosonic atoms. The focus of this work was phase separation and they have obtained both phase separated superfluids and phase separated Mott insulators corresponding to different densities of the two species.

(Tapan Mishra, B. P. Das, R. V. Pai)*

Atomic astrophysics

Accurate calculations of the oscillator strengths of several low-lying transitions in boron-like magnesium, silicon and sulphur using the relativistic coupled-cluster theory have been successfully carried out. These ions are of astrophysical importance, particularly in the atmospheres of the solar corona.

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

3.9 Atomic and molecular physics

Computational chemistry

Molecular geometries and vibrational frequencies are essential ingredients in finding the reaction paths and in identifying the end products of a chemical reaction. Numerical geometry optimization based on 'improved virtual complete active space' configuration interaction (IVO-CASCI) approach has been introduced in GAMESS software package (General Atomic and Molecular Electronic Structure System) maintained by Prof. Mark Gordon and his group (AMESS Lab, Iowa State University). This code will be soon freely available.

(Rajat K Chaudhuri)

Atomic spectroscopy

The effects of higher body excitations in the relativistic CC calculations for atoms and ions with one valence electron using Fock-space CCSD, CCSD(T) and its unitary variants has been studied. The present work demonstrates that CCSD(T) estimates the ionization potentials (IPs) and the valence electron removal energies quite accurately for alkali atoms and singly ionized alkaline earth ions, but yields unphysical energy levels for atoms and/or ions with partially filled sub-shell like C II. It also demonstrates that the higher body excitation effects can be incorporated more effectively through the unitary coupled cluster theory (UCC) compared to the CCSD(T) method.

(Chiranjib Sur and Rajat K Chaudhuri)*

Molecular spectroscopy

Ab initio calculations are used to characterize the ground and low lying excited electronic states of selected dicayanocarbene (C_3N_2 or $C(CN)_2$) isomers. The calculated ground state geometries and the corresponding vibrational frequencies agree well with available experimental and theoretical data, thereby providing the reliability of the predicted quantities. The present calculations are used to identify the possible emitting species for some unidentified emission bands observed in certain low temperature matrices. It is found that the $1^3A' \rightarrow X^1A'$ transition of 3-cyano-2H-azirenylidene, i.e., cyclic C_2N-CN satisfactorily explains all the observed spectral features of these bands.

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

3.10 Nuclear astrophysics

Isoscalar M1 contribution to $d + \gamma \rightarrow n + p$

A model independent theoretical approach to $d(\vec{\gamma}, n)p$ was developed taking ab initio all the relevant amplitudes simultaneously at the amplitude level itself, viz., the isoscalar and isovector magnetic dipole amplitudes $M1_v$ and $M1_s$ and all the three electric dipole amplitudes $E1_v^{j=0,1,2}$, individually, where j denotes the total angular momentum, which is conserved in the process. The resulting analysis showed that both the differential cross section with linearly polarized photons as well as the unpolarized differential cross section contain an additional term pro-

portional to $\cos\theta$, where θ denotes the c.m. angle for neutron emission. Based on this precise theoretical result, appropriate laboratory measurements have been suggested to determine empirically the $M1_s$ contribution at astrophysical energies.

(G. Ramachandran & S. P. Shilpashree)

Neutron polarization in $d(\gamma, n)p$

The model independent theoretical formalism is being extended to study neutron polarization in photodisintegration of deuterons, as this is a spin observable which is measurable experimentally. The present investigation aims to focus attention on the sensitivity of this observable to the presence of isoscalar $M1_s$ amplitude at astrophysical energies relevant to the Big Bang Nucleosynthesis (BBN).

(G. Ramachandran & S. P. Shilpashree)

Front-Back polar angle asymmetry in $d(\vec{\gamma}, n)p$

Experimental measurements at University of Virginia on $d(\vec{\gamma}, n)p$ at lab photon energies between 3.5 and 10 MeV have revealed a front-back polar angle asymmetry in c.m. photo neutron yield, which increases as the photon energy falls towards the threshold. This asymmetry is explained by the theoretical formalism of the authors and indicates (i) the inequality of the three isovector electric dipole amplitudes with total angular momentum $j = 0, 1, 2$ and (ii) a non-zero value for the isoscalar magnetic dipole amplitude for the reaction, as the energy moves towards the region relevant to Big Bang Nucleosynthesis (BBN).

(G. Ramachandran & S. P. Shilpashree)

3.11 High energy nuclear physics

Meson production in NN collisions

Following the authors' earlier theoretical work on pion and omega production, they have shown that it is advantageous to measure experimentally the polarization of ω in *pp* collisions, which could be in addition to the proposed experiment to study the differential cross section for omega production employing a polarized beam on a polarized target. The existing measurements on unpolarized differential cross section has also been analysed using their formalism and a scheme was evolved to determine empirically the threshold partial wave amplitudes for ω production in pp collisions.

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

Irreducible tensor approach to spin observables in photo production

A theoretical formalism leading to elegant derivation of formulae for all spin observables is outlined for photo production of mesons with arbitrary spin parity s^π. The salient features of this formalism based on irreducible tensor techniques are (i) the number of independent irreducible tensor amplitudes is $4(2s + 1)$, (ii) a single compact formula is sufficient to express these amplitudes in terms of allowed electric and magnetic multipole amplitudes and (iii) all the spin observables including beam analyzing powers as well as the differential cross section are expressible in terms of bilinear irreducible tensors of rank 0 to $2(s + 1)$. The relationship between the irreducible tensor amplitudes and the helicity amplitudes is elucidated in general and explicit expressions for the helicity amplitudes are given in terms of the irreducible tensor amplitudes in the particular cases of pseudoscalar and vector meson photo production. The connection between the irreducible tensor amplitudes introduced here and the well known CGLN amplitudes for photo production of pseudoscalar mesons is also established.

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

Tensor polarization of ω produced at threshold in $p - p$ collisions

It is shown that the dominant decay mode of $\vec{\omega} \to \pi^+\pi^-\pi^0$ can be employed to determine the Fano statistical tensor parameter, t_0^2 of $\vec{\omega}$ with respect to the quantization axis normal to the decay plane. In $pp \to pp\vec{\omega}$ one can choose decay planes with different orientations with respect to a given direction of the momentum $\mathbf{q}$ of the ω meson produced. By choosing three different experimentally convenient orientations of the decay planes for the same $\mathbf{q}$, one may determine empirically the t_0^2 and $t_{\pm 2}^2$ characterising the tensor polarization of ω in the transverse frame for $pp \to pp\vec{\omega}$.

(G. Ramachandran, J. Balasubramanyam, S. P. Shilpashree & G. Padmanabha*)*

Photo and electro production of mesons with arbitrary spin-parity

A new unified approach has been developed to identify the independent amplitudes for photo and electro production of mesons with arbitrary spin parity. A comprehensive general formula has been derived to express the independent amplitudes in terms of partial wave electric and magnetic multipole amplitudes. The structure of these independent amplitudes is such that it facilitates direct identification of different resonance contributions.

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

4 Experimental Astronomy

4.1 High resolution astronomy

Diffraction-limited imaging with large and moderate telescopes

This book begins with a treatment of the fundamentals of wave optics, polarization, interference, diffraction, imaging, the origin, properties, optical effects of turbulence in the Earth's atmosphere. Techniques developed during the last few decades to overcome atmospheric image degradation (including passive methods that are applied on a single telescope such as speckle interferometry and active methods such as adaptive optics), are highlighted. Other related concerns, such as the relationship between image-plane techniques and pupil-plane interferometry, differential speckle interferometry, speckle spectroscopy and polarimetry, phase diversity, wavefront shearing interferometry, phase-closure methods, and dark speckle imaging. Also discussed are high resolution sensors, image processing, and the astronomy fundamentals. The book concludes with a discussion of the aims, scientific results obtained with these techniques.

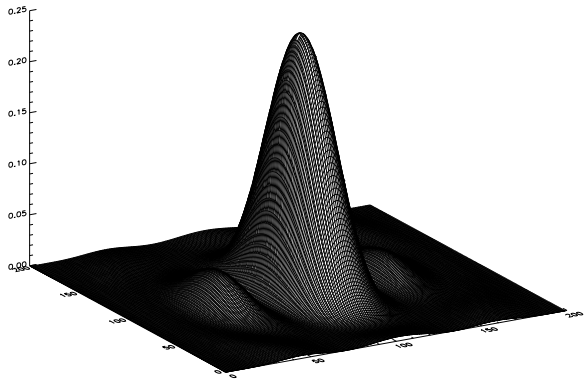


Figure 18: Diffraction-limited image of a two meter class telescope.

(S. K. Saha)

Aperture synthesis in optical astronomy: current status

A milestone in observational astronomy was achieved when the interferometric fringes of α Lyrae (Vega) in the visible band were obtained in July 1974, by A. Labeyrie from an interferometer, called Interférомètre à deux télescope (I2T), with a pair of independent telescopes on a North-South baseline configuration at Nice Observatory. These were the first fringes that are obtained by using the concept of merging speckles from both the telescopes. Such a success in synthesizing images impelled astronomers to venture towards ground-based very large arrays. Potentials for progress in the direction of developing large interferometric arrays of telescopes are expected to provide images, spectra of quasar host galaxies, exo-planets that may be associated with stars outside the solar system. Several interferometers using large telescopes (8-10 meters) have been successfully producing results since the dawn of this century and several new such instruments will be in operation soon both at ground, as well as in space. In view of the present scenario the current trend and the path to future progress in optical interferometry using diluted apertures are discussed.

(S. K. Saha)

New approach to stellar image correction for atmospherically degraded images

This research work is an effort to understand the degradations due to the atmospheric turbulence, build appropriate wave front sensor to measure the errors in the wave front and correct the wave front in real time keeping the cost as one of the main factors. To estimate such a degradation on astronomical images, Fried's parameter, r_0 was measured with a new experimental method using speckle interferometer at the Vainu Bappu Telescope at Kavalur, India. Based on this measurement, essential parameters for real time correction were arrived. The costs involved in a real time correction experiments are very high and hence, alternate low cost methods were developed. New imaging cameras based on CMOS imagers have architecture that is more suitable for high frame rate video acquisition. Experiments were conducted to characterize their performance for high-speed image acquisition. Various methods of wave front sensing were studied. A wave front sensor using Shack-Hartmann (SH) lenslet array and the CMOS imager was developed indigenously for this purpose. New algorithms were developed for the CMOS imager based wave SH wave front sensor and were successful in getting desired results. Charge Coupled Device (CCD) being an efficient detector at low light levels, investigations were carried out with Andor L3CCD based SH wave front sensor. Adaptive mirror fabricated with the newly emerging technology of MEMS was

used as a wave front compensator. There are 37 actuators to control the mirror shape. The mechanical properties of the mirror were theoretically investigated using Finite Element Analysis. For the first time, the author has developed a non-contact type testing method to find out the shape of the mirror for different actuator voltage configuration, using the in-house developed Long Trace Profilometer (LTP). It is found that the LTP based measurements were more accurate and realistic than the finite element analysis. The wave front sensor data acquisition, processing and computation of voltages required for adaptive mirror control are computationally intensive jobs. A low cost PC was used as a computational and control element. PCI based interface card having 40 channels of digital to analog converter were developed. Based on the wave front sensor outputs correction of the wave front was achieved by controlling 37 actuators of the adaptive mirror and 3 actuators of the tip-tilt mirror for low order aberrations.

(V. Chinnappan)

4.2 Space astronomy

UVIT

UVIT is one of the five science payloads on ASTROSAT: there are four X-ray telescopes, which observe in soft/hard X-rays, and UVIT observes in ultraviolet and visible bands. Three of the X-ray telescopes and UVIT can observe an object simultaneously. UVIT observes simultaneously in far UV (1300-1800 A), near UV (1800-3000 Å), and VIS (3500-5500 Å). In addition to wide-field-high-angular-resolution imaging in UV, ASTROSAT aims to observe simultaneously in X-rays, UV and visible. In particular, a study of phase relationships between variations in hard X-rays, in soft X-rays, and in UV is of great interest to understand the physical processes underlying the origin of these radiations in active galactic nuclei. UVIT would be used to study X-ray objects in coordination with the X-ray telescopes, and would observe on its own objects like interacting galaxies, star forming galaxies, globular clusters, hot/evolved stars etc.

The UVIT is designed to achieve a sensitivity of magnitude 20 in FUV in 1000 s observation, and a time resolution < 1 s. It is also desirable that UVIT images are synchronized to X-ray observations with an accuracy $\sim$1 ms. The field of UVIT is $\sim$29 arcmin circle, and images are made in far UV and near UV with a resolution better than $1.8''$; resolution of the

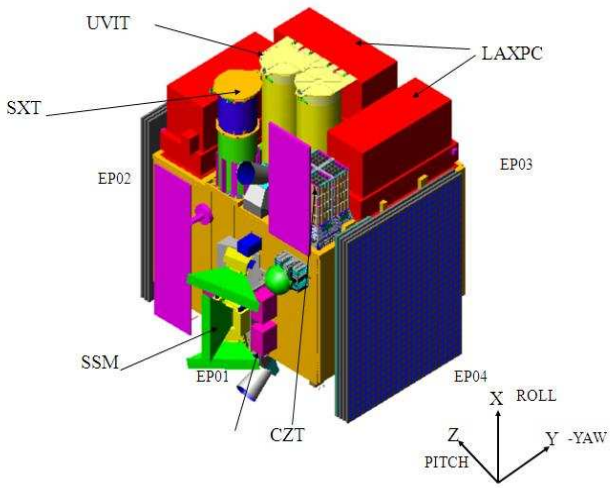


Figure 19: Configuration of the payloads on Astrosat.

images in VIS is $2.2''$; for all the three channels intensified CMOS imagers are used which support photon counting mode (See Figure 19).

The payload is configured as a twin telescope: one of these makes images in far UV and the other makes images in near UV and VIS; the radiation is divided between the two channels by a dichroic filter. Each of the two telescopes is a RC-Cassegrain configuration, with an aperture of 375 mm and a focal length of 4750 mm. For selection of a band within each of the three channels a set of filters is mounted on a wheel; in addition a grating is mounted on the wheel in each of far UV and near UV channels for low resolution slitless-spectroscopy. The status report is given below:

1. The Preliminary Design Review of the payload was conducted in March 2006. Detailed design of all subsystems is in an advanced stage, and engineering models of several subsystems are expected to be ready in the next year.

2. Detector modules with a very small gap between photo-cathode and MCPs, to minimize lateral drift of photo-electron, have been developed to give a $< 1''$ contribution to image spread. This development is key to get the overall image spread of $< 1.8''$.

3. All the mirrors have been figured by LEOS (ISRO) and they are optimizing the coating process to get a $> 70\%$ reflectivity in FUV.

4. The MGK Menon Space Science Laboratory at CREST is nearing completion, and would be

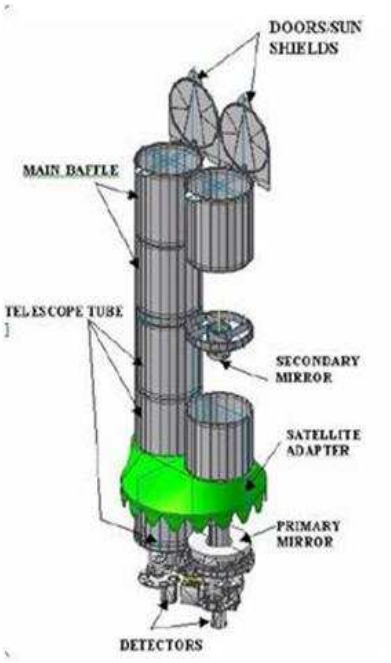


Figure 20: Schematic of UVIT assembly.

ready soon for assembly of UVIT (see Figure 20).

5. An engineering model of one (of two) telescope is expected to be ready for tests in the next year. The full payload is expected to be ready in the beginning of year 2009.

(UVIT group)

TAUVEX

The TAUVEX payload is a set of three UV telescopes to be launched by ISRO as part of the GSAT-4 satellite in mid-2008. The mission is a collaborative effort between the Indian Institute of Astrophysics and Tel Aviv University, under which the instrument is provided by the Israeli group while the software and mission planning is being done at IIA. The data will be shared equally between scientists from the two countries.

The instrument has been built and is now being calibrated in Israel and will be delivered to ISRO for integration with the satellite near the end of this year. The pipeline software, which is designed to convert the raw spacecraft data into a format usable by scientists, has been completely written and is undergoing tests. There are several constraints such as the position of the Sun and the scanning nature of the spacecraft and these have to be considered to maximize the science yield from the mission.

(TAUVEX group)

4.3 Laboratory physics

FPGA based fast readout and processing system for photon counting ICCD

Photon Counting Intensified Charge Coupled Devices (ICCD) is the viable choice for imaging detectors for the soft X-ray to UV spectral band. ICCD operation principle consists of converting incoming photons into a luminous spot captured by a CCD camera, preserving event spatial information. The processing system should directly interface with the readout system and identify the valid photon events against the bad or spurious ones, by morphological analysis of event profiles. The system consists of the following four units: Serial Acquisition Unit (SAU), Event Identification Unit (EIU), Centroiding Unit (CU) and an Output Control Unit (OCU) that calculates the pixel coordinates and handles the data transmission to the host PC interface. OCU generates a frame-tag at the end of every CCD frame, which is stored in series with the photon event coordinates. And the resulting pixel image is stored. The digitized output readout (8-bit CCD camera) is taken and is processed through the above four units of the processing system. The resulting output data is simulated using the Xilinx FPGAs and the corresponding output digital waveform is produced using the Model ∼6.0 d of Xilinx. The hardware code is developed using the hardware description language VHDL. The simulation of the processing system is done.

(Priya Perumal and B. Raghavendra Prasad)*

Wavefront correction using optical phase conjugation

Optical phase conjugation (OPC) incorporates nonlinear optical effects to precisely reverse both the direction of propagation and the overall phase factor for each plane wave in an arbitrary beam of light. One of the most promising applications of OPC is the aberration correction and imaging through turbulent media such as atmosphere. An efficient method of realizing optical phase conjugation is to use Four Wave Mixing (FWM) in photorefractive (PR) or any other nonlinear media and the most compact scheme is self

pumped phase conjugation (SPPC) in PR crystals. Experiments were carried out in a photorefractive Rhodium doped Barium Titanate (Rh: BaTiO3). The authors investigated the generation of phase conjugate signal using degenerate four-wave mixing (DFWM) and SPPC configurations. Phase conjugate efficiency is studied as a function of input beam intensity, angle of incidence etc. From the results obtained, they believe that the SPPC mechanism is FWM-SPB (Stimulated photorefractive backscattering).

(Misha Hari, B. R. S. Babu* & B. Raghavendra Prasad)*

Photorefractive crystals for non-volatile optical memories

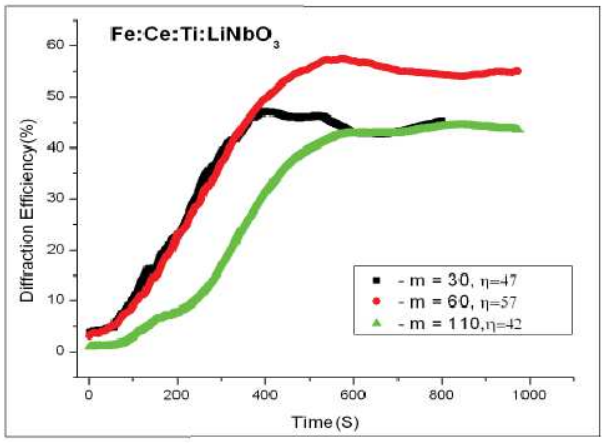


Figure 21: Diffraction efficiency as a function of pump-probe ratio.

Holographic memories are of intense interest and have advantages compared with conventional memories in that they offer a data storage density up to a few hundred of gigabytes per cubic centimeter through multiplexing. In this work the authors report studies on Fe: LiNbO3 and Fe:Ce:Ti:LiNbO3 using 488 nm. Phase grating formation and erasure studies were carried out by two-beam coupling technique. Time evolution of phase grating for both the crystals is studied. It is observed that the time taken for the complete growth of grating depends on the intensity ratio of the pump and probe beams (m) and the writing time increases with the increasing intensity ratio m (see Figure 21). Efficiency increased up to a certain value of m_0 and then began to decrease. They obtained diffraction efficiencies of 51.7% and 58% for Fe:LiNbO3 and Fe:Ce:Ti:LiNbO3 respectively. Grating decay is relatively slower even in the presence of strong pump illumination. This is an extremely useful feature for realizing nearly non-volatile holographic memories.

(Praseetha, B. R. S. Babu* and B. Raghavendra Prasad)*

Design and performance of a sub-nanoradian resolution autocollimating optical lever

Precision geometry using optics has the advantage that it does not impose much stress on the object of investigation and, as such, is adopted extensively in gravitational wave detection, in torsion balances investigating fundamental forces, in specialized studies of biological samples and it has potential applications in condensed matter physics. In this work, the authors present the considerations that go into designing optical levers and discuss the performance of the instrument they have constructed. They motivate the design by considering an idealized set-up and the limitations to the angular resolution induced by statistical fluctuations of the photon count rate and diffraction at the apertures. The effects of digitization of the count rate and of the spatial location of the photons on the image plane are discussed next motivating the actual design.

Based on these considerations the authors have developed an autocollimating optical lever which has a very high resolution and dynamic range. An array of 110 slits, of 90 micron width and a pitch of 182 microns, is located in the focal plane of a field lens, of focal length 1000 mm, and is illuminated by a CCFL-tube. This array is imaged back on to the focal plane after retro-reflection from a mirror placed just beyond the lens.

The image is recorded on a linear CCD array at the rate of 1000 images per second and is processed through a special algorithm to obtain the centroid. The instrument has a centroid stability of $\sim 3 \cdot 10^{-10}\mathrm{rad} \cdot \mathrm{Hz}^{-1/2}$ and a dynamic range of $\sim 10^7$.

(R. Cowsik, R. Srinivasan, S. Kasturirengan, A. Senthil Kumar*, K. Wagoner*)*

5 Telescopes and Observatories

5.1 Kodaikanal Observatory

Infrastructure development

For the Kodai School program, Internet and Local Area Network (LAN) were planned and implemented at the Observatory. Internet throughput is 2 Mbps. A hybrid LAN consisting of fiber optic cable and wireless network was laid. Firewall was installed to ensure the security of communication. It was a campus wide network connecting all the office buildings, laboratories and the guest houses within the observatory.

For the 2006 Solar physics winter school, a computer lab was established consisting of 8 pcs and two printers with scientific computing software like IDL and Fortran. The auditorium at Kodaikanal was modernised with video-conferencing facility, motorized screen, multimedia projectors and a heavy duty photocopier. All the systems were installed and tested.

(K. E. Rangarajan & Dipankar Banerjee)

Efficient modulation scheme for dual beam polarimetry

An eight stage balanced modulation scheme for dual beam polarimetry is presented. The four Stokes parameters are weighted equally in all the eight stages of modulation resulting in total polarimetric efficiency of unity. The gain table error inherent in dual beam system is reduced by using the well known beam swapping technique. The wavelength dependent polarimetric efficiencies of Stokes parameters due to the chromatic nature of the wave plates are presented. The proposed modulation scheme produces better Stokes Q and V efficiencies for wavelengths larger than the design wavelength whereas Stokes U has better efficiency in the shorter wavelength region. Calibration of the polarimeter installed as a backend instrument of the Kodaikanal Tower Telescope is presented. It is found through computer simulation that a 14% sky transparency variation during calibration of the polarimeter can introduce $\approx 1.8\%$ uncertainty in the determination of its response matrix.

(K. E. Rangarajan, K. Nagaraju, K.B. Ramesh & K. Sankara Subramanian)*

Digitization of ionogram and magnetograms of Kodaikanal Observatory

Round-the-clock recording of geomagnetic field on photographic paper and quarter- hourly sounding of the ionosphere and recording of the ionograms on 35 mm film, started at Kodaikanal Observatory in 1949 and 1955, respectively. This database is unique for its continuity, quality and keeping in view the location of Kodaikanal close to the magnetic equator, it is veritable resource for carrying out a host of studies of Space Weather and Space Climatology of the dip equatorial upper atmosphere and the various coupling processes underlying them. It is imperative to preserve these meticulously acquired observations for posterity by transferring them from the analog form to the modern digital form, which will also facilitate speedy analysis. Ground work for undertaking this task has been initiated

(J. H. Sastri & J. V. S. V. Rao)

5.2 Vainu Bappu Observatory, Kavalur

1.3 metre telescope project

A new 1.3 metre aperture telescope is being acquired for installation at the Vainu Bappu Observatory, which remains the only site with accessibility to the southern sky down to declinations of the Magellanic clouds. The telescope will provide a wide field imaging capability optimised for use with contemporary CCD arrays. The principal characteristics of the telescope will be as below:

1. 130 cm aperture Ritchey-Chretien configuration.

2. Fused silica field corrector providing a corrected flat field of 30 arcmin.

3. White light images with $> 75\%$ ensquared energy in 15 micron (0.3 arcsec) pixel, and 90% of the energy within a square 30 microns on a side (0.65 arcsec) for the entire 30 arcmin field.

4. R-C focus without corrector has $> 55\%$ ensquared energy in 0.6 arcsec pixel over the 30 arcmin field primary mirror is F/2.5. Final RC focal ratio F/8 and plate scale 20.63 arcsec/mm.

The design iterations for mechanical mounting of the telescope to suit the latitude of Kavalur and

for the optical system to cater to the scientific programs envisaged for the telescope have been completed. The telescope will be ready for shipment and installation by December 2008. The design and fabrication of the enclosure will be done by the institute; initial concepts for this take into account the need for minimal thermal inertia to retain the intrinsic 'seeing' of the site.

A mosaic CCD imager of 4K by 4K pixels is being developed within the institute as the 'first light' instrument. Efforts are underway to design an instrument mounting cube incorporating an autoguider as well as filter positioners for the various ports. Initial planning for a multi-object fibre-fed spectrograph has also commenced.

(A. K. Pati)

5.3 Indian Astronomical Observatory, Hanle

Himalayan Chandra Telescope (HCT)

The telescope tests and preventive maintenance was continued by the HCT team of astronomers and engineers at monthly intervals near the full moon. This included image quality tests, determination of optimal focus/tip/tilt, checks on the wavefront quality, updating the pointing model, calibration and updating of secondary drive lead screws, checks of the mechanical system and balancing, and azimuth drive alignment. Special problems encountered during the current year were:

1. The exposure to rain on one occasion of remote operation. The primary mirror was cleaned with distilled water following the incident. The first optical element of HFOSC was also cleaned.

2. Wearing out of some of the micrometers of the secondary drive unit. Spares were procured, but were no longer available to the exact dimensions of the original. One unit was modified to suit the requirement with help from the Mechanical Design Section and workshops in Bangalore as well as Hanle. Some of the ruby limit switches in the drive unit were also replaced. M/s EOST provided quick attention to the secondary drive problem initially through e-mails, and then during their visit to the site.

3. Frequent problems with the Telescope Control Computer. The problems were attended by frequent cleaning of disk, virus checks, defragmentation, occasional replacement with spare disk, etc.

The HFOSC continued to be the workhorse with HCT and worked well except for some problem with the temperature controller card. A spare card was shipped immediately by the Copenhagen University Observatory. The NIR camera control computer crashed towards the end of the year, and a new computer is being configured. The high-resolution CCD camera was brought to Bangalore for further development, and the spare 1kx1k CCD continues to be available. The maintenance activities at the site included generation of liquid nitrogen for the instruments, topping up the dewar twice daily, and evacuation of dewars once in several months.

(HCT team)

HAGAR telescope array

High Altitude Gamma Ray (HAGAR) astronomy experiment at Hanle, is a joint effort of Indian Institute of Astrophysics, and Tata Institute of Fundamental Research. Hanle, at an altitude of 4300 m offers an advantage in lowering the threshold of energy of gamma ray observation. All the telescopes were transported and installed on the piers, together with cable wraps for most of the telescopes. These telescopes have been extensively checked in the factory for smooth operation, before acceptance. Subsequently the telescopes have been transported to Hanle and installed over their respective piers. The new Motion Control Interface Unit has also been tested extensively with the telescopes and the servo performance meets the stringent specification with an rms error of 10 arcsec (one count in Absolute Encoder) for tracking. A slew speed of 2/3 deg/sec could also be obtained for the fast motion of these telescopes. The new Shutter Controller units have also been commissioned.

In this year, three telescopes have been fully commissioned and checked for the complete drive system performance. Though three more telescopes have been brought up to a testing level, some mechanical alignment of the encoders and subsequent servo-tests are needed. The central telescope is yet to be commissioned and the work would commence from June 2007. A mobile crane was procured for the installation. The commissioning activities included computer control through the locally developed microcontroller and control software, alignment of individual telescopes and determination of pointing model. The activities were not complete before the onset of

Figure 22: The institute staff members with the honourable members of Parliamentary committee for Science & Technology, Environment & Forest, Government of India.

deep winter, and will continue through early summer of 2007.

(HAGAR group)

Visit of Parliamentary Committee for Science & Technology, Environment & Forests

The Parliamentary Committee for Science & Technology, Environment and Forests, Government of India, visited IAO, Leh, as a part of visits to the science facilities in Jammu & Kashmir, between 10-14 June 2006. The Committee was received by Professor Vinod Krishan, Dean (Academic), who briefed the Committee on the existing facilities at IAO, their utilization, and future plans, in the general background of the activities of IIA in astronomy and related sciences.

National large solar telescope

Efforts have begun this year to locate promising sites for the national large solar telescope (NLST) and to characterize them in a time bound manner. Changthang Ladakh is a strong candidate for the proposed National Large Solar Telescope, due to high-altitude, cold, and dry conditions. Apart from Hanle, the lake sites were also considered due to the stabilizing effect of large water body on the atmosphere, especially during the day time. After several reconnaissance trips and a study of the overall topography of the Ladakh region, as well as bearing in mind the requirements of weather conditions for a good solar site, it was decided to closely examine and characterize the Hanle and Pangong Lake regions. Hanle represents a mountain site in the region while Pangong Lake provides high mountain with lake incursions along its 30 km stretch within India. Pangong Tso region was found more promising due to its almost East-West elongation, wind ducting from East and West, large flat land at the southern shore with several incursions into the lake, and availability of some human resources. The presence of moderate laminar winds flowing over the water body is expected to be extremely favourable. Such a site is expected to provide stable thermal conditions which are generally good for day time seeing. These characteristics need to be examined in detail. A weather station from Hanle, and a site characterization hut with solar power earlier stationed at Polagongka La were shifted to Merak village at the centre of Indian

Figure 23: Weather station at the possible site, Pangong lake.

part of Pangong Tso in November 2006 and trips to the site were organized at monthly intervals. Early results from the weather station are encouraging, and more intense site characterization will be initiated during the summer of 2007.

Efforts were made during the year 2006, to put together the instrumentation required to evaluate the prospective sites. Solar Differential Image Motion Monitor (SDIMM) and Shadow Band Ranging (SHABAR) devices were procured on a loan basis from the National Solar Observatory, Tucson. The SDIMM and SHABAR equipment was received during later part of 2006 and was installed at Bangalore for familiarization, checking, and for initial observations with the instruments. Some of the adaptation requirements such as balancing of the Meade telescope, procurement of video equipment, and purchase of spares for operations in remote areas, etc. were carried out. Efforts were also initiated for the duplication and adaptation of the SDIMM and SHABAR set up in the electronics and optics laboratories at Bangalore.

Development of improved device for micro-thermal measurements was taken up. Procurement of equipment such as solar trackers, sun photometer, pyrheliometers, weather stations, and all sky cameras were initiated. Design work for towers to mount these devices was also started off. Observations using an array of these devices will provide inputs required to reliably evaluate the prospective sites.

The weather station data and the visual observation records of sky conditions which have been obtained regularly at Hanle were examined for the period 1998 to 2006. The pyranometer data was used to infer the clear sky periods. This was combined with visual data to arrive at an estimate of the general day time sky conditions at Hanle. The wind and humidity data are also being examined to ascertain the useful periods for solar observations. The weather station data from Merak is being studied to infer the clear sky periods and the wind conditions at the site.

(S. P. Bagare, S. S. Hasan, T. G. Aditya, J. P. A. Samson, T. P. Prabhu, Angchuk Dorje, M. P. Singh, Jagdev Singh, K. P. Raju, A. K. Saxena, R. Srinivasan, G. Srinivasulu, P. U. Kamat, K. E. Rangarajan, Thubstang Dorje)

5.4 CREST, Hosakote

Scientific research

The astronomers using the 2-m HCT at Hanle gather their data remotely from the Centre for Research & Education in Science & Technology (CREST), using the dedicated satellite communication link. A group of astronomers of IIA who are prime users of this telescope, work regularly from this campus. This team of astronomers also ensures that the telescope and communication link are in excellent state of health, with the help of engineers at CREST and IAO.

Research activities at the Laser Laboratory at CREST and also the CRABEX experiment in the area of solar-terrestrial relationship continued during the current year. Apart from this, some activities are continuing in the laser laboratory. TAUVEX software development team moved to this campus during the current year. Development of MGK Menon Space Sciences Laboratory continued and is scheduled to be validated during the next year.

Technology development

The site characterization towards the large telescope is undertaken with the existing instruments at Hanle and further development work was undertaken in the development of an automated Differential Image Motion Monitor instrument. The HCT data archive is another area where significant developments took place, and the archive is scheduled to be operation during the next year. Software development was also undertaken for ease of remote operation of HCT. The all-sky camera, which was hitherto controlled from Michigan is currently controlled locally from IAO and the images are available through the CREST homepage.

Education in science & technology

The education is undertaken at CREST through a variety of programs, demonstration of remote operation of the telescope in particular. CREST has significantly contributed to the area of research and training programs at HCT. The engineer trainee is continuing with the developments of data archive and site characterization instrumentation. Several students of M.Sc. and B.E. undertake their course work project at CREST with supervision from scientists at IIA or CREST.

CREST organizes the demonstration of remote operation of HCT and viewing the telescope through video-conferencing equipment. A brief history of the development of IAO, and the importance of site characterization in astronomy is also explained during such events. Several groups visited CREST for this demonstration during the current year. Apart from these activities, a group of amateur astronomers spent a night at CREST to view the sky with their own equipment.

5.5 Radio Telescope, Gauribidanur

Upgradation of Gauribidanur Radio Heliograph (GRH)

Efforts are being made to enhance the sensitivity and angular resolution of the GRH array. The size will be increased in East, West and South directions to about 1500 m from the present 640 m, by installing 200 additional LPD's. The antennas will be grouped into 64 subgroups. To process the signals from these subgroups, a 5000-channel digital backend system is required. Conceptual design is being made to construct the receiver system. It has been planned to have a larger BW of 6 MHz for the upgraded system, instead of the present BW of 2 MHz, to achieve better sensitivity. A prototype unit to work with 12 MHz sampling clock has been designed. The same will be installed at Gauribidanur shortly.

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

Brazilian Decimetric Array (BDA) - 2nd phase

In the first phase, 6-antenna receiver system was installed at BDA observatory. The second phase of BDA will consist of 38 parabolic antennas. To process the signals from these antennas, a 1500 channel digital correlator system is required. Conceptual design of the correlator is in progress.

(M. S. Sundara Rajan, K. R. Subramanian & R. Ramesh)

Gauribidanur Radio Array Solar Spectrograph (GRASS)

The Gauribidanur Radio Array Solar Spectrograph (GRASS) system consists of an array of 8 log periodic dipoles, a spectrum analyzer and a data acquisition system. The spectrograph normally operates in the frequency range of 30 - 150 MHz with a frequency resolution of 250 KHz and a time resolution

of 43 msec. The Gauribidanur radio array solar spectrograph operates approximately from 04:00 UT to 10:00 UT each day. This instrument has been used to study the radio signatures of flare activities and Coronal Mass Ejections.

Figure 24: Gauribidanur Radio Array Solar Spectrograph (GRASS). The Agilent spectrum analyzer along with control and data acquisition PC are shown.

(E. Ebenezer, R. Ramesh, M. S. Sundara Rajan & K. R. Subramanian)

6 Activities at the Bangalore Campus

6.1 Electronics laboratory

New EEV 44-82 Echelle CCD camera system

The Echelle spectrograph in VBT was working with a grade-4 EEV chip. A new camera has been built with a grade-0 CCD chip. The sensor is based on a EEV 44-82 matrix of 2048 lines and 4096 columns, with 15 × 15 micron pixels. The grade '0' sensor has been installed in a 150 K liquid nitrogen cryostat. A dedicated DSP processor works in conjunction with a host PC, providing the GUI interface. The PC carries out data acquisition, data processing, image storage and image processing features. The camera system is being fine-tuned, for the optimization of noise performance. The system will be commissioned at VBT Echelle Spectrograph during mid 2007.

CCD image acquisition software under QNX

A new real-time operating system called QNX has been available for software development of real-time applications. Important features of QNX include POSIX compliance, micro kernel architecture, process manager, message passing paradigm, SMP, HAS (High Availability System), critical process monitoring and is particularly suited for embedded real-time application development. A resource manager is a user-level server program that accepts messages from other programs and, communicates with the hardware. It is a process that registers a pathname prefix in the pathname space (e.g /dev/ser1) and other processes can communicate to it. Resource manager is akin to a Device Driver in Linux, but the major difference is that the device driver is a kernel module in Linux, whereas in QNX a resource manager is a user-level program. The CCD camera software under QNX was developed as a client-server program. Server program is a resource manager that communicates with the hardware and does the intended tasks. Processes can be added in/out with the kernel on the fly. A GUI (Graphical User Interface) using photon (micro GUI developer) was developed, for user interaction, which connects to a client. The client sends the user request to the resource manager to perform the intended tasks (viz. initialization of DSP, setting voltages and operations like bias, dark, expose etc.). The image data acquired is written into a file in FITS format and stored in the hard disk. At present, this version of image acquisition software acquires the image data but needs to be analyzed on a Linux system.

CCD image acquisition software under Linux

An image acquisition software was developed under Linux using C++ with Gtkmm earlier. This software based on client/server model, has CCD image acquisition software running the server, while the client provides the graphical user interface for display. This was developed for 2K × 4K CCD sensor from Marconi as well as 2K × 2K Tek sensor. The acquisition software had a timing of approximately 4 min 23 seconds. In order to reduce the acquisition time, the hardware was modified for dual read out facility, available on the 2K × 4K sensor. The acquisition software was also appropriately modified.

Micro thermal data acquisition system for prospective NLST sites

A project has been taken up to determine the telescope seeing, at selected sites, through the measurement of differential temperatures for a given separation, at chosen heights. The principle is to obtain the temperature function from the measurement of differential temperature between two points, separated by a known distance, at a height 'h'. These measurements are carried out at different heights simultaneously in order to obtain the integrated effect through the layers. From these sets of temperature data, Fried's parameter can be obtained through the well-established equations. The telescope seeing is related to the derived 'Fried's parameter'. In this implementation, temperature probes are made from commercially available film type platinum temperature detectors, housed in $50mm \times 50mm \times 50mm$ cubical made up of ebonite. A short length of constantan wire is added on both the ends of the probe to isolate the thermal loading from the subsequent stages of the circuit. Any change in the temperature of the probe reflects a corresponding change in the wire resistance. These probes form the lower arms of the wheat-stone bridge. Therefore, any thermal difference between the probes causes an imbalance at the output of the bridge due to difference in resistances of the probes. This imbalance in voltage is measured digitally after passing through the signal conditioning electronics. For a good performance, the fixed metal-film resistors of upper arms of the wheat-stone bridge and the pre-amplifier are placed

close to the probes and the remaining electronics are kept away from the probes. Measurements are carried out at five different heights simultaneously.

Software for Fabry-Perot instrument

Software for the control of a Fabry Perot instrument using IEEE-488 interface has been developed under Windows environment. This instrument is under testing and would be installed at the Solar Tower tunnel telescope by December 2007.

Improvements to the drive system for the Kodaikanal Solar Tunnel Telescope

The existing set and guide speeds of the Kodaikanal Solar Tunnel Telescope have been inadequate for carrying out sunspot studies. Hence, it was decided to go for a stepper motor attachment for implementing fine speed movements in RA and DEC. With this hardware, the image positioning accuracy in RA and DEC has improved and sunspot scanning with finer steps has been facilitated.

(Electronics group)

6.2 Photonics laboratory

1 m telescope

A new secondary mirror of Zerodur material is being fabricated to replace the existing secondary for the 1 m telescope, at VBO Kavalur. A concave secondary with matching eccentricity has already been fabricated and tested with the existing secondary. The figuring work on the Zerodur convex secondary is in progress. An elliptical flat mirror is being prepared to be used in the Hindles sphere test set up for testing the convex secondary.

Thin film box coater BC300 coating plant

As a part of the R & D facility for thin film technology a multipurpose thin film box coater BC 300 coating plant has been set up. Nano thin films for various astronomical applications, including filters and detectors are the areas of interest. The current research work aims at developing thin films for NIR filters and detectors. The box coater BC 300 coating plant has the provision for physical vapor deposition methods, using thermal evaporation, electron beam gun evaporation and magnetron sputtering are available with this coating plant. Augmentation of the facility with Scanning Electron Microscope (SEM) and Energy Dispersion Spectrometer (EDS) is in progress. These facilities will enable us to characterize the thin films at nano level.

Vacuum coating

The 1.2 M vacuum plant has been serviced and the aluminium coating of about 47 numbers 0.9M diameter HAGAR mirrors were done. Major repairs of the coating plant are planned to be taken up later. Necessary preparatory work is progress at the 2M vacuum coating plant at Hanle, in order to take up the coating of the HCT primary mirror.

VHRR sun shield panels for INSAT 3D satellites

The polishing of the sunshield panels for INSAT 3D imager and sounder coolers six sets of panels (10 Nos. each) along with the samples (300 Nos.) has been completed. The remaining sets will be completed in six months time.

Long Trace Profilometer: funded by BRNS, DAE

The Long Trace Profilometer (LTP), Version II (improved version) was completed as per the schedule and will be shipped to RRCAT, Indore. Since the housing for this instrument is still not ready, a more exhaustive calibration of the instrument is being carried out and the documentation is being prepared.

(Photonics team)

Adaptive optics

After successful design, fabrication and testing of a laboratory model, efforts are being made to fabricate a trial adaptive optics system for 2.34 m VBT. Shack Hartmann images were recorded at VBT using cooled ANDOR CCD camera at 10 to 20 millisecond integration time. It is found that a standard star of 8.3 magnitude gave 1500 counts with a gain of 1000. Further experiments are planned in the coming months to measure the wavefront errors at VBT focus with the aim of final atmospheric correction.

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

6.3 Mechanical engineering division

Re-engineering of 30 inch telescope

Design, analysis and detail engineering of the mechanical mount of the 30 inch telescope, VBO, Kavalur has been completed. Order for the realization of the project has been placed and the progress of the work is satisfactory. The telescope is expected to be ready for shop testing by July/August 2007.

7 inch Coelostat system

The conceptual design for white light active region monitor has been completed. The shop survey for the design, manufacture and supply has been carried out as well. The order for fabricating the same will be placed soon.

(Mechanical design section)

6.4 Civil engineering division

Hostel building 'Bhaskara' equipped with a library, conference facilities and rooms for accommodating students and visitors is under construction. The building consists of 24 single occupancy rooms, 18 double occupancy rooms, and 3 guest rooms, kitchen and dining hall. The work is expected to be completed by September 2007.

(Civil engineering section)

6.5 Computer centre

The paradigm of the computer centre at IIA has changed over the years. From a central facility with a single powerful (for the time) computer, it has become a distributed network overseeing more than 200 desktops used by individuals for most of their computing needs. Part of the computer centre's duties includes providing hardware and software support to individuals through a centralized error reporting and logging system.

Internet access in the main campus has been increased to 5 Mbps but is already nearing peak utilization rates of close to that resulting in network congestion. It is planned to host a data centre at CREST with data from IAO and TAUVEX and are steadily improving the computer infrastructure to allow this. The other three campuses are planned to have 2 Mbps links but only Kodaikanal has been implemented to date. Attempts are being made at Kavalur and Gauribidanur but rural connectivity is difficult and these are taking longer to get in place than expected.

A data centre with about 8 TB of disk space has been set up. This disk space will be used for mirroring international data sets used by IIA scientists, such as the SDO archive, and for storing data. The next major initiative for the Computer Centre is to implement high performance computing. Implementation of a fast cluster will allow a quantum leap in the type and importance of the problems addressed.

(Computer division)

6.6 Library

In 2006, IIA library continued to make progress in collection and support the research activities of the Institute more effectively. The library acquired 316 new books, and subscribed to 6 new journals in 2006-2007, ensuring that the requirements of all the academic and technical staff in Bangalore and other field stations are met. Online access to five more journals was activated thus increasing the total number of online journals to 139.

From October 2006, the access to back files of eleven journals published by Elsevier is procured through Science Direct. This access is enabled in all the campuses of IIA. IIA library continues to be a member of FORSA consortium and from this year the University of Chicago Press journals (Astronomical Journal, Astrophysical Journal and Astrophysical Journal Supplement Series) are accessible as a consortium deal.

Overall loans and renewals of books increased in the library. Promotion of new books through displays and e-mail communication has enhanced the visibility of dynamic collection development. Efforts to improve re-shelving and weeding of collections have been undertaken from this year to maximize the space.

Printing and photocopying research papers from journals has decreased due to the increasing online availability of most of the journals.

Library endeavors to develop expertise in areas relevant to research including scholarly communication, open access, electronic document delivery, new electronic services and databases. It also helps locating research resources held outside IIA library, through stronger links with the other astronomy libraries within and outside the country.

Technically, IIA library is responsible for the delivery of the libraries electronic and web based ser-

Figure 25: Painting of the Kodaikanal Observatory drawn in 1908 by an unknown artist.

vices. This includes coordinating and supporting work on the library's web pages, managing the electronic journals library and maintaining the library databases electronically.

The collection at Hosakote and other field stations libraries has been enhanced. Additional copies of important titles and new titles have been procured for Kodaikanal library during the Summer School Programme at Kodaikanal in June 2006. The electronic access to many journals has been enabled in the campuses at Hosakote, Kavalur and Kodaikanal. The library trainee program continues and the trainees are well trained in all the sections of the library.

Preserving the old collection through appropriate storage and treatment

Nearly 20,000 pages of old manuscripts and books were cleaned and laminated during the year. 109 historical documents were scanned and uploaded onto the open access repository. Efforts are made to convert the printed holdings lists for manuscript collections into searchable web guides to increase the use of these materials substantially. From this year, funds are allocated on an annual basis for new priorities such as preservation of digital materials and improving the infrastructure for archives.

New material for the archives was received from Mrs. Cherry Armstrong the great-great granddaughter of N. R. Pogson. She donated 33 photographs, 2 publications, a bunch of finding charts, 6 newspaper clippings and a few personal letters.

Jeffrey Crelinsten, The Impact Group, Toronto from Canada visited the institute in February 2007 and gave a talk on Einstein. He spent a day at the archives and used material on John Evershed. Richard Walding, Research Fellow, Griffiths University, Australia visited Kodaikanal library in February and looked at the records of magnetic observations.

BBC representatives visited the institute and made an audio program on the Institute's profile. They interviewed A. Vagiswari and C. Birdie regarding the IIA archives with special focus on Pogson's collection, to be relayed as part of the program.

(Library staff)

7 Board of Graduate Studies

The Board of Graduate Studies opened the Ph D admissions throughout the year so that the applications can be submitted anytime of the year. The selection process was carried out at regular intervals. The first such admission test was done on 7 January 2007 and four students joined the Ph D program from the winter session. One student joined IIA in August 2006. The students were selected through JEST written test followed by interviews. The students who qualified for JRF through UGC, CSIR exams were also called for interviews.

K.V.P. Latha submitted her thesis titled *Many-body theory of electric dipole moments and it's implications for the standard model of particle physics* to Mangalore University, under the guidance of B. P. Das. Under the guidance of R.T. Gangadhara, R. M. Thomas submitted his thesis titled *Emission of radiation in Pulsar magnetosphere owing to charged particles acceleration* to the Mangalore University. M. Nayak submitted his thesis titled *Theoretical Investigations of Relativistic effects in Heavy Atoms and Polar Molecules* to IISc under the guidance of Rajat Chaudhuri.

The Summer school program was carried out during May 16-July 14, 2006. Applications were received from all over India and 12 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 supervisions of their guides. At the end of the project, they submitted written reports and gave an oral presentation of the project.

Mike Dopita delivered a lecture course on *Astrophysics of the Diffuse Universe*, comprising of 10 lectures between 20 September - 18 October 2006. The topics covered in the lectures included *Line emission Processes, Collisional Excitation, Line Transfer Effects, Collisional Ionization (Coronal) Equilibrium, Cooling Plasmas, Interstellar Shocks, Theory of Photoionized Plasmas, and Interstellar Dust.* The lectures were well attended by students and faculty of IIA, ISAC(ISRO), IISc and RRI.

As part of the graduate outreach program, A. Subramaniam visited the Govt. Victoria College, Palakkad, Kerala and gave a presentation on the various student program and projects at IIA and interacted with the students. A visit of the graduate students from the same college to IIA and CREST campus was also organised. Dipankar Banerjee visited the Presidency College, Calcutta and gave presentation and interacted with the students.

(H. C. Bhatt)

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 March 31, 2007 was 354. As per orders of the Government, 52 posts of scientific and technical categories were exempted from the reservations. Out of 302 positions 48 members belongs to SC and 30 members belong to ST, forming 15.85% and 9.93% respectively. Apart from this, reservations have been extended to OBC's and physically handicapped persons

9 Official Language Implementation

All round efforts have been made to ensure successful implementation of the official language. Section 3/3 of the official language act have been complied with, and Administrative and other reports have been prepared bilingually. These include the Institute's 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 6561/-. 28 Bilingual rubber stamps have been prepared for the Institute and for the Hanle project. Hindi software has been bought for CREST (Hosakote).

10 Publications

10.1 In Journals

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10.2 In Books

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10.3 In Proceedings

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Off-limb coronal loop dynamics as seen from CDS, EIT and TRACE

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Exploiting large surveys for galactic astronomy

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A report on Commission 45: Spectral classification

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Relativistic many-body theory of the electric dipole moment of atomic ytterbium

*Frisch, H., Sampoorna, M., Nagendra, K. N., 2006b, in ASP Conf. Ser. 358, *Solar polarization*, Eds R. Casini, & B. W. Lites, 126
Polarized spectral line formation in turbulent magnetic fields: The Zeeman and Hanle effects

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Automated classification and stellar parameterization

Hiremath, K. M., 2006, Proc. *ILWS workshop*, Goa, 178
Influence of solar activity on the rainfall over India

Reddy, B. E., 2007, Proc. IAU Sym. on *Stellar populations as building blocks of galaxies*, Santa Cruz De Lapalma, Spain (in press)
Decomposition of galactic disk: abundances and kinematics

Reddy, B. E., *Lambert, D. L., *Allende Preto, C. 2007, in Proc. Conf. on *Metal rich universe*, Canary Islands, Spain (in press)
Abundance survey of the galactic thick disk

Sastri, J. H., 2006, in *ILWS workshop on solar influence on the heliosphere and Earth's environment: recent progress and prospects*, 361
Effect of magnetic storms and substorms on the low latitude-equatorial ionosphere

Sur, C., *Latha, K. V. P., Chaudhuri, R. K., Das, B. P., *Mukherjee D., 2007, in *Current topics in atomic, molecular and optical physics*, World Scientific, Eds. C. Sinha and S. Bhattacharyya, 199
Optical frequency standard with Sr+:A theoretical many-body approach

10.4 Books

Saha, S. K., 2007, World Scientific, New Jersey
Diffraction-limited imaging with large and moderate telescopes

10.5 Books edited

Hasan S. S., Banerjee D., 2007, AIP Conf. Proc. 919, American Institute of Physics, New York
Kodai School on Solar Physics

*Sandra Ricketts, Birdie C., *Eva Isaksson, 2007, ASP Conf. Proc. 377, Astronomical Society of the Pacific, San Francisco
Library & Information Services in Astronomy V: Common Challenges, Uncommon Solutions

10.6 Paper presentations in meetings

Birdie C., Vagiswari, A., 2007, Intl Conf. on Semantic web & digital libraries, DRTC, Bangalore
Copyright ownership to historical contents in the Open access repository (OAR): Case study of Indian Institute of Astrophysics (IIA) repository

Gangadhara, R. T., 2007, XXV ASI meeting, Feb.7-9, Hyderabad
Influence of rotation on pulsar radio emission

Gajendra Pandey, Kameswara Rao, N., 2006, *UV and Multiwavelength Astronomy with ASTROSAT*, 27-29 September 2006
Studies of hot hydrogen deficient stars with UVIT

Giridhar, S., 2007, In-house workshop, IIA, Bangalore, April 13-14,2007
Automated parameterization of OMR spectra using ANN

Goswami Aruna, 2006, In-house meetings, IIA, Bangalore, April 12-13, 2006
Abundance distribution of neutron-capture elements in carbon-enhanced metal-poor stars

Goswami Aruna, 2006, In-house meetings, IIA, Bangalore, April 17-18, 2006
CEMP stars and early galactic chemical evolution

*Misra, K., *Bhattacharya, D., Sahu, D. K., *Sagar, R., Anupama, G. C., *Castro-Tirado, A. J., *Guziy, S. S., Bhatt, B. C., 2007, *XXVth ASI meeting*, February 7-9, 2007, Hyderabad
Optical observations of GRB 060124 afterglow: a case for an injection break

Ramachandran, G., 2006, DAE-BRNS Symposium on Nuclear Physics, Vadodara during 11-15 Dec. 2006. :with *S. P. Shilpashree*on $d(\vec{\gamma}, n)p$ *analyzing power at astrophysical energies*; with *M. S. Vidya** *and J. Balasubramanyam** on *Meson polarization in photoproduction*; with *J. Balasubramanyam**, *S. P. Shilpashree and G. Padmanabha** on *Decay of polarized ω into three pions.*

Saxena, A.K., 2006, 3rd Intl Workshop *Metrology for X-ray Optics,* Daegu, Korea, May 2006
A new polarization shearing interferometer based long trace profilometer (Version II)
Subramanian A., Bhatt, B. C., 2006, In-House meeting, IIA, Bangalore, April 17-18, 2006
Photometric study of distant open clusters in the second quadrant: NGC 7245, King9, King13 and IC 166

10.7 Abstracts/Poster presentations in meetings

Aruna Goswami, 2007, XXVth ASI Meet-2007, Feb 7-9, 2007 Osmania University, Hyderabad
Neutron-capture elements in Carbon-enhanced metal-poor stars
Carbon-enhanced Metal-Poor stars at high Galactic Latitudes

Hiremath K. M., 2006, *Long Term Variations of the Solar Cycle: Forecast of the Future Cycles*; *Magnetic flux in the solar convective envelope inferred from the sunspots' initial appearances* (with M. R. Lovely) at the IHY-2007, Bangalore.

Gajendra Pandey, 2007, XXVth meeting, Feb 7 - 9,

2007, Osmania University, Hyderabad
A search for neutral fluorine lines in late B- and A-type supergiants

Gajendra Pandey, Kameswara Rao, N., *David Lambert, 2007, XXVth ASI meeting, Feb 7 - 9, 2007, Osmania University, Hyderabad
Emission lines in high resolution spectra of EHe stars
Fluorine abundances in R CrB and EHe stars

Kameswara Rao N., Gajendra Pandey, 2007, XXVth ASI meeting, Feb 7 - 9, 2007, Osmania University, Hyderabad
The hydrogen deficient binary stars KS Per and Upsilon SGR - spectroscopic monitoring

Kameswara Rao N., Gajendra Pandey, Eswar Reddy, B., S. Sriram, K. Jayakumar, 2007, XXVth ASI meeting, Feb 7 - 9, 2007, Osmania University, Hyderabad
Precision radial velocities with VBT Echelle - A global network of 2 m-class telescopes

Kameswara Rao N., Goswami, A., Eswar Reddy B., Gajendra Pandey, 2007, XXVth ASI meeting, Feb 7 - 9, 2007, Osmania University, Hyderabad
The Hα width and absolute magnitude relation in late type stars

Kameswara Rao N., S. Muneer, S. Sriram, Gajendra Pandey, 2007, XXVth meeting, Feb 7 - 9, 2007, Osmania University, Hyderabad
Variablity of Na I spectral lines in the ISM (clouds) towards Vela Supernovae remnant

Nataraj, H. S., Das, B. P., *Sahoo, B. K., Chaudhuri, R. K., *Mukherjee, D., 2006, December 4-7, VII Asian international seminar on *Atomic and molecular physics*, IIT, Chennai, India
The electric dipole moment of electron: Test of P & T violation

Saxena, A.K., Chinnappan, V., Lancelot, J. P., 2007, XXVth meeting, Feb 7 - 9, 2007, Osmania University, Hyderabad
Proposed adaptive optics system for Vainu Bappu Telescope

Sivaraman, K. R., Gupta, S. S., Ananth, A. V., 2006, IHY-2007, Bangalore.
Measurement of solar diameter

10.8 GCN Circulars, IAUC, CBET, Newsletters

Aruna Goswami, IIA Newsletter, 2007, 12, 9
CEMP stars at high galactic latitudes

*Castro-Tirado, A. J., Anupama, G. C., Srividya, S., Ramya, S., *de Ugarte Postigo, A., *Sanchez, S., *Montoya, L., *Castillo, A., *Munoz-Mateos, J. F., *Jelinek, M., *Gorosabel, J., 2006, GCN 5384
GRB 060801: Optical observations at Hanle and Calar alto

*Gurugubelli, U. K., Anupama, G. C., Sahu, D. K., CBET 789 & 790
Supernova 2006td

Sahu, D. K., Anupama, G. C., 2006, CBET, 665
Supernova 2006it in NGC 6956

10.9 Popular articles

C. Sivaram published the following popular articles :
A burst of brightness SN 1006, May 23, 2006, DH
A celestial tale of two entities, Aug. 29, 2006, DH
Remembering Giottos rendezvous, June 2006, DH
PLUTO: No nine pizzas, August 26, 2006 - Centre page article, DH
Alternative biochemistries for life on earth, Oct. 3, 2006, DH
Report on Plutos status, Times of India, Aug. 26, 2006.
All in the name, Sept.12, 2006, DH
How Long is a second?, Oct. 24, 2006, DH
Gamma ray effect on life, Jan.9, 2007, DH
Spacecraft to smash comet, June 27, 2006, DH
Magnetic showers in space, Dec. 19, 2006, DH
Fifty years of neutrinos and antimatter, Jan. 23, 2007, DH
Starry-eyed surprise, SN 1987-A (20 yr), March 27, 2007, DH
Tryst with devils number, June 6, 2006. DH
Astronomical realities, Feb. 21, DH
Discovery of Vesta by Olbers, March 2007, DH

11 Miscellaneous activities

11.1 Teaching and guidance

Aruna Goswami supervised a student for her degree project on *Low resolution spectroscopy of carbon stars: A search for CH stars* during April-May 2006. She is also guiding a student on a project on *Spectral characteristics of carbon stars* under IIA's SPSP program, 2007.

D. Banerjee is supervising a Ph D student from JAP program (Mr. Girjesh Gupta). He has also taught a course on *Fluids and plasmas* for the JAP programme. He delivered a series of introductory lectures on the *Sun*, for the summer project students at Bangalore. He also supervised a summer project student in the year 2006.

S. P. Bagare continued to serve as external examiner for the PG exam in Physics, Bangalore University. One of the co-guided students, Mr. K. Balachandra Kumar, was awarded Ph D during early 2007 by the Madurai Kamaraj University.

V. Chinnappan has submitted his Ph D thesis on *A new approach to stellar image correction for atmospherically degraded images* under the guidance of A. K. Saxena.

Gajendra Pandey guided a summer project student T. Abhijit on *Spectral classification of stars.*

K. M. Hiremath is guiding M. R. Lovely, an FIP candidate for her Ph D thesis. He is also co-guiding Mr. Ivan Molnar's for his Ph D thesis (Konkoly Observatory, Hungary). Hiremath taught a course in Solar Physics for M.Sc (Physics) students at the Center for Post Graduate Studies of Sri Bhagawan Mahaveer Jain College, Bangalore.

S. M. Vijayan under the guidance of V. K. Gaur, S. S. Gupta et al. has been awarded the Ph D degree during November 2006, by the Gandhigram Rural Institute, Tamil Nadu, on his thesis *Estimation of tropospheric precipitable water vapour and crustal deformation using GPS.*

S. S. Gupta guided two M. Phil. physics students of The Mother Teresa Womens University, Kodaikanal, on *Solar physics.* S. S. Gupta was appointed as external examiner to conduct practical examination for the M. Sc., 2nd semester of the Mother Teresa Womens University, Kodaikanal.

R. Kariyappa taught a course in *Solar physics* for M.Sc. Astrophysics students at the physics dept., Bangalore University for 3 months during August - October, 2006. He was appointed as a member of the Board of Examiners for M.Sc. (Physics: Astrophysics) of the same University and served as an external examiner as well. He also served as an examiner at the Department of Physics, Christ College (Autonomous).

A. Mangalam taught a JAP course in high energy Astrophysics during January-April 2007. He also guided Mr. Sanat Pandit, M Sc. (IIT Delhi) on a project on *Virial configurations of relativistic fluids.*

K. N. Nagendra is guiding M. Sampoorna a Ph D student of IIA, since 2004.

P.M.S Namboodiri guided T. Ilavenil, an M. Phil student of theoretical physics department, University of Madras, who completed an M Phil. project under him. The project titled *The density structure and shape of interacting galaxies* was submitted and approved by the University. He has also been an external examiner for the M.Sc. (Astronomy) examination of Osmania University, Hyderabad.

T.P. Prabhu is supervising the Ph.D. project of Ramya, S.

Akash Raman and *Anchit Malhotra* from BITS were guided by *K. E. Rangarajan* and **Sankara Subramanian* on the project titled *Solar magnetism and Zeeman effect* from May 16-July 16.

B. E. Reddy is guiding a student *Bharath Kumar* towards his Ph D on *Study of lithium rich K giants.* He has also guided two students Smitha and Rupa Shree from IIA for their three months project on *Identifying stellar populations using kinematic motion* and *Measuring Li isotopes from the spectrum of a star hosting planets.*

S. K. Saha delivered 14 lectures on *Astronomical techniques* to the JAP and IIA graduate students during July-September, 2006. He supervised a summer school student on *Aperture synthesis* during May-June, 2006. He guided a student, S. C. Vella durai, American College, Madurai, for his M. Phil degree on *Speckle imaging.*

A. Satya Narayanan delivered 12 lectures on *Introduction to the Sun* to the graduate students during August - October 2006.

C. Sivaram taught a semester course on *General relativity and cosmology* (25 lectures), to final year M.Sc student, Bangalore University (Jan-April 2007); One-semester JAP course *High energy astrophysics* to Ph D Students (Jan.-April 2007). He has also guided a summer project student on *Accretion discs around rotating black holes.*

K. R. Sivaraman delivered three lectures on the topic Observational Techniques (Optical) at the Solar physics winter school, held at Kodaikanal in December 2006.

A. Subramaniam has guided three students towards their short-term projects under the degree project program. She is also guiding *Blesson Mathew* for his Ph D thesis and co-guiding *B. Bhavya*, Research Scholar, Cochin University of Science and Technology.

K. R. Subramanian has been guiding *Ebenezer* for his Ph D thesis on *Radio signatures of shocks in the corona.*

K. Sundara Raman has guided three M.Sc. (Physics) students of Mother Teresa Womens University, Kodaikanal, two students of St. Josephs' College, Trichy in their dissertation work for the Master's program. He functioned as the external examiner of II M.Sc. (Physics) students of the said University, Kodaikanal. He had functioned as the Course Director, Kodai summer school in physics, during 6-25 June, 2006.

11.2 Invited talks/lectures in meetings

S. P. Bagare gave an invited talk on *Importance of spectroscopic techniques in astrophysical studies*, during the golden jubilee symposium on *Applications of Spectroscopy* held in March 2007 at the VHNSN post graduate college, Virudhunagar.

D. Banerjee gave two invited oral presentations at the *36th COSPAR scientific assembly*, Beijing, China, 16-23 July 2006; *MHD waves and oscillations in solar magnetic structures*, Palma de Mallorca, Spain, 29 May - 1 June 2006.

R. K. Chaudhuri gave following invited talk titled *Recent trends in many-body methods for electronic structure and properties of atoms and molecules* at Toshali, Puri; *Physics and Astrophysics of dust: Formation, probes and astrophysical implications*, Kavalur.

H.C. Bhatt gave a talk on *Dust-gas separation: Dynamical aspects* Workshop on *Physics and Astrophysics of dust* at VBO Kavalur; 24-27 Feb. 2007.

B.P. Das gave the following invited talks: International Conference on atomic physics, 2006, 21 July, Innsbruck, Austria, *Theory of parity nonconservation in trapped ions*; 7th Asian international seminar on atomic and molecular physics, 2006, 5 December, Chennai *Parity nonconservation in atomic ions*; National theoretical chemistry conference, 2006, 22 December, Tiruchirapalli *Relativistic coupled-cluster theory: Application to hyperfine interactions in the D states of alkaline earth ions*; XVI National conference on atomic and molecular physics, 2007, 7 January, Mumbai, *Quantum phase transitions in ultracold bosonic atoms*; Recent trends in many-body theory of atoms and molecules, 2007, 10 January, Bhubaneswar, Puri, *Relativistic coupled-cluster Theory of parity nonconservation in atoms.* Das gave the following colloquia's and seminars: at the IISc, 16 November, 2006 *CP Violating Scalar-Pseudoscalar Interactions*; at the University of California, Berkeley,USA,17 April, 2007 *Quantum Phase Transitions in Ultracold Atoms*; at the University of California, Merced,USA,25 April, 2007 *Atomic Parity Nonconservation:A Non-Accelerator Probe of the Unification of Fundamental Forces*; at the Pennsylvaina State University, USA,4 May, 2007 *Atomic Electric Dipole Moments: A Table-Top Search for the Higgs Particle*; at the Institute for Theoretical Atomic and Molecular Physics, Harvard University, 6 May, 2007 *Electric Dipole Moment of the Electron*; at the Yale University, 8 May, 2007 *A New Limit for a T-Violating Electron-Nucleus Interaction*

S. Giridhar delivered an invited review paper at JD 13 on *Exploiting Large surveys for galactic astronomy.*

S. S. Hasan delivered following invited reviews: *Chromospheric dynamics*, in the meeting on *Scientific and technological requirements for future high resolution solar space missions*, July 17-18, 2006 during the 36th COSPAR Scientific Assembly, Beijing,

China, and in IAU General Assembly, Prague, Czech Republic during August 15-26, 2006; *Dynamics of the magnetized solar chromosphere* , at the *2nd UN/NASA Workshop on the IHY & Basic Space Science*, November 27 - December 1, 2006 at IIA, Bangalore. He delivered Keynote address on 'Solar Physics in India', National Workshop on Solar Physics, Meerut, November 7-10, 2006. Hasan presented a statement on Indian programmes related to the *International Heliophysical Year 2007* at the 44th Session of the Scientific and technical Subcommittee on the *Peaceful uses of outer space*, February 19-20, 2007, Vienna, Austria.

K. M. Hiremath gave an invited talk entitled *Forecast of future solar cycles and Indian monsoon rainfall* at the National Workshop on *Dynamical Long-Range Forecasting of Indian Monsoon : Status, User Needs and Grand Challenges*, 12-13 Feb 2007, organized by C-MMACS at NAL, Bangalore.

R. Kariyappa gave contributory following talks: *Contribution of solar chromospheric fine scale features to UV irradiance variability* at *IHY-2006*, *Spatially resolved images and solar irradiance variability* at held at PRL, Ahmedabad during January 22-25, 2007.

V. Krishan gave the following invited talks: *The Hot and cold of the Sun*, Kodai School on Solar Physics, December 10-22, 2006; *Partially ionised solar atmosphere*, Frontiers of plasma physics, at Kathmandu,January 23-27, 2007; *Hall and Effect and Ambipolar Diffusion in the Solar atmosphere*, ICCSC-24, Ahmedabad , January 21-26, 2007; *Solar atmosphere*, Solar Physics Workshop, Meerut; *Magnetic spectrum in the solar wind*, IHY Workshop, Bangalore, IIA, November 27- December 1, 2006; *Density spectrum in the solar wind*, IHY Workshop, ARIES, Nainital, May7-10, 2007; *Solar atmosphere*, Meerut *Magnetic spectrum in the solar wind*, IHY, Bangalore; *Density spectrum in the solar wind*, IHY, Nainital.

T. P. Prabhu gave an invited talk titled *Star Formation in Galaxies* at the Indo-French Workshop on *Observational Astronomy*, IUCAA, Pune, March, 2007.

G. Ramachandran gave an invited talk titled *Baryometer* at the Academic meeting, 'Parthafest' on 13 March 2007 in honour of R. Parthasarathy at the IMS, Chennai.

B. E. Reddy gave a talk in absentia titled *Abundance survey of the galactic thick disk* at the international conference held during 12-16 June, 2006 on *The metal rich universe* at Los Cancajos, Canary Island and on *Decomposition of galactic disk: abundances and kinematics,* IAU Symp. 241, *Stellar populations as building blocks of galaxies,* Santacruz De Lapalma, Spain, 12 December 2006.

S. K. Saha gave the following invited talks : *Optical metrology in astronomy* at the DST-SERC School on *Optical metrology and diffraction optics*, University of Calcutta, Kolkata, December, 2006; *Optical interferometry in astronomy* at the Centre for Space Physics, Kolkata, on 23rd December, 2006; *Adaptive optics and its applications* at the *Symposium of Optical Society of India*, on 3rd March, 2007, Baroda MS University, Baroda; *Optical interferometry* at the CSIO, Chandigarh, on 23rd March, 2007; *Aperture synthesis in optical astronomy*, organised by *Optical Society of America and Physics Society*, IIT-D, at the Indian Institute of Technology, Delhi, on 30th March, 2007.

J. H. Sastri gave following invited talks: *Physical processes underlying the equatorial effects of solar wind dynamic pressure (Pd) variations* in the *2nd UN/NASA Workshop on IHY & Basic Space Science* held in IIA, Bangalore during November 27-December 1, 2006; *Evolution of studies in India of high latitude- low latitude upper atmosphere coupling*, at the Golden Jubilee Symposium on *Radio Science (INCURSI-2007)* held in NPL, New Delhi, during 21 - 24 February, 2007.

M. Sampoorna gave a talk on *Effect of a turbulent magnetic field on Spectral lines polarization*, at *10th Young Astronomers' Meet* held at IIA, Bangalore, India, during January 3 - 5 2007.

J. Singh delivered following talks: *Magnetic nature of coronal loops* at the *2nd UN/NASA Workshop on IHY & Basic Space Science*, Nov.29-Dec.1, 2006 held at IIA, Bangalore; *Proposed National large Solar Telescope*; at the Golden Jublee celebration meeting of PRL, Ahmedabad, December 2006 *Proposed emission line Space Coronagraph* at Indo-US meeting held at Udaipur December 2006 and ADCOS meeting held at ISRO, *Variation of Coronal Emission line profiles with height above the limb* ASGI meeting, March 4, 2007, Armagh, UK.

K. R. Subramanian gave an invited talk titled *Global solar radio flux variations during October - Novem-*

ber 2003 at the 2nd UN/NASA Workshop on IHY & Basic Space Science, meeting held at IIA, during November 27 - Decemeber 1, 2006.

P. Subramanian gave the following invited talks: *Electron acceleration in solar noise storms*, at *IHY 2006*, IIA Bangalore, Nov 27 - Dec 01, 2006; *The Sun: our nearest particle accelerator*, Winter school on astroparticle physics, Ooty, Dec 20-28 2006; *Radio and coronographic studies of CMEs*, ASI meeting, Hyderabad, Feb 04-07 2007.

R. Vasundhara gave an invited talk at the *Asia Oceania Geosciences Society 3rd Annual meeting (AOGS 2006)*, at Singapore, 10-14 July, 2006. She gave an oral presentation at the meeting, *Mutual events of the Uranian satellites and further observations in network*, Paris, November 15-18, 2006.

11.3 Attendance in meetings

Abhay Karnataki attended the first Heidelberg Summer School hosted by the IMPRS for Astronomy and Cosmic Physics at the University of Heidelberg, Germany, during in September 25-29, 2006; Workshop on *Study of Emission from Hot Diffuse Gas with ASTROSAT* December 27, 2006 to January 3, 2007 at Christ College, Bangalore; Workshop on Physics and Astrophysics of Dust: Formation, Probes and Astrophysical Implications held in Kavalur, during VBO, Kavalur during 24 Feb 2007 to 27 Feb 2007.

A. V. Ananth, S. S. Gupta, S. S Hasan, K. M. Hiremath, R. Kariyappa, V. Krishan, M. Sampoorna, J. H. Sastri, A. Satya Narayanan, J. Singh, K. R. Sivaraman participated in the second UN/NASA Workshop on *International Heliophysical Year and Basic Space Science*, Bangalore, India, Nov. 27-Dec. 1, 2006

G.C. Anupama, V. Das, V. Krishan, A. Subramaniam, R.T. Gangadhara, A. Goswami, A. Singh attended the XXV ASI meeting held at Hyderabad during 2007 February 7-9.

B.C. Bhatt attended the Academy's discussion meetings on *Inverse problems with special reference to atmospheric transport* at Coorg, Karnataka during November 23-26, 2006 organized by C-CMMACS and India Academy of Sciences, Bangalore.

C. Birdie participated in the LISA V conference held at Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, in June 2006. She participated in the panel discussion on *Role of libraries to access knowledge* in April, 2006, at the Yale law School.

V. Das attended the Workshop on *Physics and Astrophysics of Dust: Formation, Probes and Astrophysical Implications* 24th–27th February 2007, at Vainu Bappu Observatory, Kavalur.

S. Giridhar attended XXVI IAU General Assembly, at Prague Czech Republic, during Aug 14-25, 2006.

R. Kariyappa attended an *International conference on Challenges for solar cycle-24*, held at PRL, Ahmedabad during January 22-25, 2007.

V. Krishan attended the following meetings *Frontiers of Plasma Physics*, at Kathmandu, January 23-27, 2007; ICCSC -24, Ahmedabad, January 21-26, 2007; *Kodai School on Solar Physics*, December 10-22, 2006; *Solar Physics Workshop*, Meerut; *IHY Workshop at ARIES*, Nainital, May 7-10, 2007.

M. Sampoorna participated in the Kodai Winter School on 'Solar Physics' held at Kodaikanal Solar Observatory, Indian Institute of Astrophysics, during December 10 – 22 2006.

S. K. Saha chaired a session of the Symposium of Optical Society of India', during 2-3rd March, 2007, Baroda MS University, Baroda.

J. H. Sastri participated in the Golden Jubilee Symposium on Radio Science (INCURSI-2007) held in National Physical laboratory, New Delhi, during 21-24 February 2007.

A. K. Saxena attended the 3rd International Workshop on *Metrology for X-ray Optics*, Daegu, Korea, held during May 2006. He also attended the third International Workshop on *Metrology for X-ray Optics*, Daegu, Korea, May 2006.

J. Singh attended the *Winter school* meeting at Kodaikanl on December 2006; Golden Jublee celebration meeting of PRL meeting held at PRL, Ahmedabad in December 2006; Indo-US meeting held at Udaipur December 2006.

M. P. Singh attended the Rajbasha Seminar on *Widening dimensions of modern science in Ladakh*

at the Field Research Laboratory, DRDO, Leh on National science Day on 28th February 2007. He delivered a talk on *Indian Astronomical Observatory - a multidisciplinary Observatory in Ladakh.*

K.R.Subramanian participated in the IHY 2007 meeting held at IIAP during November 27 to December 1, 2006.

11.4 Visits

Abhay Karnataki visited Max Planck Institute for Astrophysics, Heidelberg, Germany, for a mini-project with Dullemond, *Study of proto-planetary discs around young solar objects*, 2-14 October 2006.

G. C. Anupama visited the University of Tokyo, Hiroshima University and Kyoto University during 2006 November 4-26.

D. Banerjee visited Armagh Observatory, U.K. for three weeks during September 2006, under the Royal Society British Council joint project grant.

B. C. Bhatt visited Vellore Institute of Technology (VIT), Vellore, Tamilnadu on October 13, 2006 during its SED-VIT week and presented a seminar on *Site Testing in Astronomy-Himalayan site and IAO*, Ladakh at their Physics department.

H.C. Bhatt visited St Philomena's College, Mysore on January 23 2007.

B.P. Das visited the University of California, Berkeley, USA 18 March-3 May 2007; Institute for Theoretical Atomic and Molecular Physics, Centre for Astrophysics, Harvard University, 5-15 May 2007.

R.T. Gangadhara visited the National Centre for Radio Astrophysics (TIFR), Pune during 6-14 April 2007; ARIES, Nainital during April 25-26, 2007 and gave an informal talk on *Spectroscopic methods and automated parametrization using ANN.*

S. S. Hasan visited (i) Harvard Smithsonian Center for Astrophysics, Cambridge, U.S.A. during April-June, 2006, (ii) Kiepenheuer Institute, Freiburg, Germany, in November, 2006, and (iii) Anglo Australan Observatory, Sydney; Siding Springs & Mt. Stromlo, Canberra, Australia in December, 2006

C.S. Stalin visited the Anglo-Australian observatory during September 24-28, 2006.

R. Vasundhara visited the Queen's University, Belfast during August-September, 2006 for two weeks to work with Alan Fitzsimmons and Stephen Lowry on the *Deep impact data.*

11.5 Involvement with scientific community

G. C. Anupama is 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. She is a member of the review committee for the project *Virtual Observatory India - The Next Generation*, funded by the Ministry of Communications and Information Technology.

C. Birdie has been invited to serve as the standing committee member of S/T section of IFLA for the year 2005-2009. She is a member of the editorial team of *Proc. LISA V conference* to be published as a volume of ASP conference series, as well as of *J. Sci. & Techn. Libraries* published by the Haworth Press, New York for the term 2006-2008.

S. Giridhar has been elected as president of IAU Commission 45 on *Stellar Classification* for 2006-2009. She served as co-chair of SOC which conducted the Joint Discussion (JD) titled *Exploiting Large Surveys for Galactic Astronomy* for the IAU General Assembly. The Journal Mem. Soc. Italiana published full proceedings of this JD as a special issue. Giridhar is co-editor along with C. Corbally and Coryn Bailer-Jones. She also gave a keynote address at WAM lunch on Aug 21, 2006 during GA 26 on *Women Astronomers in India.* Giridhar continues to serve as BGS member for Pt. Ravinshankar Univ. Raipur, since 2005.

S. S. Hasan is an Associate of the Harvard College Observatory, Cambridge, U.S.A., since 1991. He is the principal investigator of a DST-DAAD International Programme with the Kiepenheuer Institute, Freiburg, Germany on *Dynamics and Heating of the Magnetized Chromosphere.* Hasan has been elected as a member of the editorial board of Solar Physics, as well as a member of the IHY International Steering Committee, which has the responsibility of overseeing the operations within IHY. He is also a member of the editorial board of Journal of Astrophysics and Astronomy.

R. Kariyappa continues to be a council member for Karnataka State Council for Science & Technology, Karnataka Government, IISc, Bangalore, for a period of 3-years (2004 - 2007). He continues to serve as a co-investigator for SOLARNET space mission project under CNRS, France. He continues to be as a 'Mail-in-Reviewer for NASA' to review three research proposals which have been submitted to NASA for funding.

V. Krishan was honored by the Mother Teresa University, on National Science Day, February 28, 2007 as *Woman of the Year* for IHY. She is a visiting Professor at the RRI. for two years. She is also on the Editorial Board of The African Physical Review. She is an Associate Member of NIAS.

K.N. Nagendra continues to be a (SOC) Member of IAU Comm. 36, on Stellar Atmospheres, with an elected term of 3 years; He is a consulting specialist for the French CNRS Programme involving Observatoire de Nice, and Observatoire de Paris.

B. Raghavendra Prasad is a member of DST (TSG) Expert Group on *Molecular Electronics, conducting polymers, Non-invasive and other bio-sensors.* He is a member of DST (TSG) project review committee on *Molecular electronics, conducting polymers, Non-invasive and other bio-sensors.*

K.B. Ramesh is a member of the design and development group of the optical solar telescope for school and college students under the public outreach cell of IIA.

S. K. Saha continues to be a member of the Project Appraisal and Review Committee (PARC) of a project on *Design and 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. *S.K. Saha* continued to be a member of the Editorial Board, Asian Journal of Physics.

J. H. Sastri served as a member of the Program Advisory Committee for Atmospheric Sciences (PACAS) of the DST, New Delhi. He served as a member of the Scientific Advisory Committee of Space Physics Laboratory (SPL) of VSSC/ISRO, Trivandrum. He served as a co-chair of the Working Group2 (WG2) for *Space Weather: Science and Applications* of CAWSES-India program funded by DOS/ISRO and also a member of the National Science Steering Committee of CAWSES-India.

C. Sivaram has brought out 4 issues of the 'Astrobiology newsletter' in 2006-07.

A. Subramaniam was elected as a Councillor of the ASI for the triennium 2007-2009. She is a member of the expert committee on Physical and Mathematical Sciences for the Women Scientist Scheme of the DST.

12 Public Outreach

12.1 Popular talks

S. P. Bagare gave lectures on *Contributions of total solar eclipse observations to Physics and Astrophysics,* at the Birla Institute, Bangalore in October 2006. He gave a talk on *New insights into our understanding of the solar system*, at Sri Sri Ravishankar College, Bangalore, in November 2006.

D. Banerjee delivered lectures for the Olympiad students at Kavalur; on open days at IIA Bangalore; as part of graduate outreach program have visited Presidency college, Calcutta and St. Xaviers College Calcutta (October 2006) and gave a series of lectures.

B. C. Bhatt gave a lecture on *Site Testing in Astronomy with demonstration of 2-m HCT remote operation on telescope operation, data acquisition* etc from CREST network, on March 11, 2007, to a group of students who visited CREST under REAP/BASE program.

H. C. Bhatt gave a lecture on *Our Galaxy: The Milky Way* at St Philomena's College, Mysore on Jan 23 2007.

Gajendra Pandey gave a talk on *Life and death of heavyweight and lightweight stars* on National science day, held at IIA.

R. T. Gangadhara gave the following public talks : *Pulsar emission altitude from relativistic phase shift*, NCRA, Pune, 6 April 2006; *Radio Pulsars*, The Bangalore Science Forum, National College, Bangalore, 19 April 2006; *White Dwarfs, Neutron Stars and Pulsars*, B.V. Jagadeesh Science Centre, National College, Bangalore, 28 April 2006.

J. P. Lancelot gave lectures at BIFR for the Astronomy and Astrophysics course.

A. Mangalam gave a talk on *Physics of stars* to college students at the Nehru Planetarium in May 2006. He also gave a talk on *Birth and death of stars* at the National Symposium on Physics in the 21st Century at CMERI, Durgapur, during February, 10 - 11, 2007. A. Mangalam is also a part of the Research Education Advancement Programme (REAP) training and research program run by the Bangalore Association for Science Education (BASE), Nehru Planetarium for advanced graduate and undergraduate students, in which IIA is a participating institute. He taught a semester long course on some topics from mathematical physics.

T. P. Prabhu gave talks entitled *Astronomy from High Altitudes* at the Astronomy Club, John H. Welsh Technology Centre, Bangalore, on 23 February 2007, and at Vemana Institute of Technology, Bangalore, on 21 March 2007.

K. B. Ramesh gave five guest lectures on *Solar Physics* at BIFR, Bangalore and also gave a guest lecture on *The Sun, our star* at Vivekananda college, Madurai.

G. Ramachandran gave a talk at B. V. Jagadish Science Center, The National College, Bangalore - 560076 (25th Aug 2006) on *Nuclear forces*

B. E. Reddy gave a talk titled *Milky Way as seen from the Earth* on 23 January 2006 at the astronomy program *Windows to our Galaxy* at St. Philomena's college, Mysore. He also gave a talk on *Stars and the Milky Way* on 02 Feb 2007 at St. Alosius College, Mangalore

M. Sampoorna presented two public lectures at the Nehru Planetarium on the topic *Second Solar Spectrum - a new window to the Sun* on June 8 2006.

K. R. Subramanian gave a talk titled *Gauribidanur radio heliograph* to students of Dept of Physics and Astronomy of Nimengen University, Netherlands at the Gauribidanur radio observatory on October 9, 2006. He also gave two lectures on Radio astronomy to students of certificate course on *Rocket and space dynamics* conducted by St. Joseph's collage, Bangalore, in collaboration with ISRO on January 13, 2007 and March 11, 2007. He gave a talk on *Radio Sun* to students of IEEE Chapter, UVCE college, Bangalore on March 9, 2007. He gave several lectures on basic radio astronomy to students of certiciate course in astronomy conducted by the BIFR, Bangalore, during May, October 2006.

Prasad Subramanian is participating in an ongoing program with the Jagannath Institute of Technology and Management (JITM) in southern Orissa.

C. Sivaram gave the following lectures : *New status of Pluto as a dwarf planet and new definitions of a Planet* at the Visweraya Industrial Museum and Planetarium, Oct. 2006; *Comet power houses*,

B.V. Jagadeesh Science Centre Aug. 11 and August 25, 2006; *Gravitational waves* Mahaveer Jain College, July 27, 2006; *Calendar and on astrobiobiology* Bharatiya Vidya Bhavan, January 2007; *Perceptions of the universe* Rotary Club, Indiranagar, February 2007; *Cosmic microwave background* and *Nobel Prize Physics 2006* at the National Science Day, Bangalore University, February 28 2007. He was also the Director of the course on *Rocket dynamics, Space science and astrophysics*, which was an intercollegiate undergraduate course for B.Sc/BE students, held at St. Joseph College, from Sept. 2006 April 2007. He was Chief Resource person, for course on *General relativity cosmology and astrophysics*, for Phys. Dept. Christ College, (Sept. 2006, Apr. 2007). Sivaram taught a four week graduate course at BIFR on *Introduction to astrobiology*, Jan - Feb 2007. Also several lectures (about 25) given to students of *Certificate course in astronomy*, at BIFR.

K. Sundara Raman inaugurated the Physics Association at Bishop Heber College, Trichy and delivered 2 lectures on *Basics of Astrophysics and Solar Physics* on July 28 2006. He participated as the chief guest for a function at Anna Science Centre Planetarium, Trichy on 29 January 2007 and delivered a lecture *On the importance of dissertation and project works being undertaken as a part of the curriculum*. He functioned as the chief guest during the Inter Collegiate Meet PHYSI KALAM 2007 conducted at Vivekananda College, Madurai. He gave a lecture on *Astrophysics* to the gathering. He also delivered a keynote address *On the importance of basic sciences*, and gave a lecture on *Sun as a Star*, belonging to various colleges on the occasion of the function PHYSICS QUEST 2007 conducted in connection with the National science day on 28 February 2007 by the Mother Teresa Womens University, Kodaikanal.

12.2 National science day

The National science day was celebrated in the Institute with great enthusiasm on 28 February, 2007. Lectures on astronomy, and a short movie on IIA entitled, 'From Nungambakkam to Hanle', a continuous movie show at the Seminar Room and an exhibition of colourful posters on astronomical objects and models of telescopes were among the several activities during the day, in which more than 200 school children have participated. Celebrations were finally brought to a close by watching the night sky through the Meade telescope.

Figure 26: A group of students are watching solar spectra.

Observation of the Sun and sunspots through an appropriate telescopic arrangement in a tent was set up. A two mirror Coelostat system was set up to demonstrate the presence of sunspots on the solar disk to the school children. A 3 inch objective and a reimaging unit was used to obtain a 10 inch image of the Sun on a big screen. Apart from this demonstration, a quiz on sunspots was set up, just adjascent to the live demonstration of Sun's image, to create inquisitiveness in them towards the solar astronomy. A compact disk based spectroscope was made for the first time in IIA for the students to look at the solar Fraunhofer spectrum. College and school students were explained about the sunspot numbers, how the absorption spectrum is formed in the Sun and other details. Several volunteers took part in explaining the experiments to the students.

(K. B. Ramesh, K. E. Rangarajan, K. Nagaraju, J. P. A. Samson & mechanical staff)

IHY outreach program

Several groups were formed for bringing out a prototype experimental setup to study the Sun by college and school students during the current International Heliophysical year Outreach program. The instruments were (i) two element radio interferometer, (ii) 3 inch optical telescope design and fabrication, (iii) optical arrangement for the Coelostat and spectrograph, (iv) CCD and computer arrangement for data collection and (v) mechanical design and fabrication of Coelostat. Later on, the know-how will be passed on to the industry for mass production of the units and the equipment will be distributed to selected in-

stitutions for the purpose of public education.

(K. E. Rangarajan & R. Ramesh)

IIA stall at outstations

Figure 27: IIA stalls at Govt. engineering college, Trissur on November 1-3, 2006.

A team from IIA participated in the following exhibitions as part of the public outreach programme consisting of students and technical staff. The events are (i) Swasraya Bharath 2006, National Self Reliance Week Celebration, during 11-17 October 2006, Kochi, Kerala, (ii) science exhibition, Trichur Engineering College, during 1-3 November 2006, Trichur, Kerala, (iii) science Expo 2006, Vishwesvaraya Techmology Museum 24-27 November 2006, Bangalore, and (iv) Xplore-2007, A National level Technical Exhibition, Kannur Government Engineering College, 20-22 February 2007, Kannur, Kerala.

The exhibits in the stall included a tabletop model of Vainu Bappu Telescope, a model showing the progress of astronomy, and some optical and X-ray images of celestial objects. A documentry about the life and times of Einstein prepared by IIA students as well as a movie on Hanle Observatory were also screned.

(T. K. Muralidas, Blesson Methew, Vigeesh, Bharat Y., Pukazhenthi)

13 Colloquia/Seminar given by visitors

04 April 2006
The Mystery of the Accelerating Expansion of the Universe
Tarun Deep Saini
JAP, IISc, Bangalore

06 April 2006
Optical observations of GRB afterglows
Shashi Bhushan Pandey
Instituto de Astrofisica de Andalucia, Spain

21 April 2006
The Origin of E+A (post-starburst) Galaxies
Tomotsugu Goto
Department of Infrared Astrophysics, Institute of Space & Astronautical Science (ISAS), Japan

02 May 2006
Metal and Dust Content of the Universe as Determined through QSO Absorption Lines
Pushpa Khare
Physics Dept., Utkal University, Bhubaneshwar.

30 May 2006
Fourier decomposition of RR Lyrae Light Curves and the Oosterhoff Dichotomy
Armando Arellano Ferro
Instituto de Astronomia, Universidad Nacional Autonoma de Mexico, Mexico.

02 June 2006
Bhas Bapat
Photo Triple Ionization of CO2
Laboratory Astrophysics Group, PRL, Ahmedabad

9 June 2006
Relativisitic Numerical Hydrodynamics and Equation of State
Indranil Chattopadhyay
Chungnam National University, South Korea

14 June 2006
Exposure Time Calculator for IFOSC and Sky Background Estimation
Pavan Chakraborty
Assam University, Silchar

15 June 2006
PSR B0329+54 - A Pulsar with Unique Emission Properties
Dipanjan Mitra
National Centre for Radio Astrophysics, TIFR, Pune

20 June 2006
X-raying Stellar Coronae: Structure, Composition, and Energetics
Vinay Kashyap
Harvard-Smithsonian Center for Astrophysics, USA

20 June 2006
Do you need to understand General Relativity to understand Gravitation?
Hari Dass
Institute of Mathematical Sciences, Chennai

27 June 2006
Vertical Structure and Dynamics of Galaxies
Chanda Jog
JAP, IISc, Bangalore

29 June 2006
Unravelling the morphologies of Luminous Compact Galaxies using the HST/ACS GOODS survey
Abhishek Rawat
IUCAA, Pune

03 July 2006
Optical and Near-Infrared Instrumentation at the UK Astronomy Technology Centre
Nagaraja Naidu
UK Astronomy Technology Centre, Edinburgh, UK

06 July 2006
Distant SN Surveys for Cosmological Expansion Measurements using SUBARU
Mamoru Doi
Institute of Astronomy, University of Tokyo, Japan

07 July 2006
Spectropolarimetric and Spectroscopic studies of Circumstellar Environments of Explosive stars, and the Hiroshima 1.5-m Telescope Project
Koji S. Kawabata
Astrophysical Science Center, Hiroshima University, Japan

10 July 2006
Core-Collapse Supernovae and Gamma-Ray Bursts: Type Ib SN2005bf and Type Ic SN2006aj/GRB060218
Nozomu Tominaga
Department of Astronomy, University of Tokyo, Japan

11 July 2006
Cosmic-ray Muons, Atmospheric Neutrinos and Neutrino Oscillations in the Back-drop of the India-based Neutrino Observatory
D. Indumathi
Institute of Mathematical Sciences, Chennai

13 July 2006
GMRT Observations of Galaxy Group Holmberg 124: Signatures of Tidal Interaction and Ram Pressure Stripping
Nimisha Kantharia
NCRA, Pune

25 July 2006
Clues to Early Universe from Fossil Stars
Biman Nath
RRI, Bangalore

28 July 2006
An Explosion of Cosmic Explosions
Shrinivas R. Kulkarni
California Institute of Technology, USA

08 August 2006
Statistical Problems in Astronomy
Jogesh Babu
Center for Astrostatistics, Pennsylvania State University, USA

10 August 2006
Status of the development of the Brazilian Decimetric Array and other activities of the solar physics Group at INPE
Sawant H.S
BDA Team -Brazilian National Space Research Institute - INPE Brazil

22 August 2006
Sliding Down the Double Helix: How do Proteins Find their Binding Sites Inside the Cell Nucleus?
Holger Merlitz
Department of Physics, Xiamen University, China

24 August 2006
Observation of VHE Gamma Ray Sources with the MAGIC Telescope
Pratik Majumdar
Max-Planck-Institute for Physics, Germany

29 August 2006
The Hobby-Eberly Telescope Dark Energy Experiment
David Lambert
Department of Astronomy, University of Texas at Austin, USA

31 August 2006
The Giant Magellan Telescope
David Lambert
Department of Astronomy, University of Texas at Austin, USA

05 September 2006
Occurrence of Radio Halos and Relics in Galaxy Clusters: Hints on their Origin and Properties from a Deep GMRT 610 MHz Cluster Survey
Tiziana Venturi
Istituto di Radioastronomia, Bologna, Italy

12 September 2006
What Thermonuclear X-ray Bursts can tell us about Neutron Stars
Sudip Bhattacharyya
NASA Goddard Space Flight Center, USA

19 September 2006
Magnetars under the Chandra and XMM-Newton Eye
Firoza Sutaria
Pennsylvania State University, USA

26 September 2006
On the Role of MHD Waves in solar wind source region
Abhishek Kumar Srivastava
BHU, Varanasi

03 October 2006
All About HII Regions
Mike Dopita
Mt. Stromlo & Siding Spring Observatories, Institute of Advanced Studies, Australia

31 October 2006
Level-crossing Phenomena in Astrophysics
Palash Baran Pal
SINP, Kolkota

02 November 2006
Chemical Evolution of Molecular Clouds
Satoshi Yamamoto
University of Tokyo, Japan

21 November 2006
Small-scale dymanics in coronal holes

Miruna D. Popescu
Armagh Observatory, Northern Ireland

22 November 2006
Temporal Variations of Solar Rotation during Solar Cycle 23
H. M. Antia
TIFR, Mumbai

07 December 2006
Star-forming galaxies in the Hubble Ultra Deep Field parallels
Yogesh Wadadekar
Princeton University, USA

12 December 2006
Line Formation in Media with Stochastic Velocity Fields
Wilhelm H. Kegel
Zentrum fuer Astronomie & Astrophysik, Technische Universitaet Berlin, Germany

02 January 2007
First star-Hypernova connection: explosive nucleosynthesis & abundance patterns of extremely metal poor stars
K. Nomoto
University of Tokyo, Japan

09 January 2007
SIM, Stellar Aberration, and Special Relativity
Richard Conn Henry
The Johns Hopkins University, Canada

10 January 2007
Diffuse Elliptical galaxies: A Rosette stone to Understand the Evolution of Galaxies in Clusters
Philippe Prugniel
Observatoire de Lyon, France

10 January 2007
Multiple and Multi-centred Scattering in Bounded and Unbounded Media
Dilip Ghosh Roy
University of Utah, USA

11 January 2007
Analysis of Stellar Populations
Mina Koleva
Observatoire de Lyon, France

11 January 2007
Quasar time delays, Ho and Dark Matter
F. Courbin
Ecolé Polytechnique Fédérale de Lausanne, Switzerland

12 January 2007
Ages for Illustrative Field Stars using Gyrochronology
Sydney Barnes
Lowell Observatory, Flagstaff, USA

16 January 2007
The Accretion disk and its Transport Mechanism The Current Status
Banibrata Mukhopadhyay
JAP, IISc

01 February 2007
Halo Coronal Mass Ejections and their Geoeffectiveness
N. Gopalswamy
NASA Goddard Space Flight Center USA

05 February 2007
Recent Low-frequency Studies near the Galactic Centre
Subhashis Roy
ASTRON, The Netherlands

06 February 2007
Einstein's Jury : Trial by Telescope
Jeffrey Crelinsten
The Impact Group, Toronto, Canada

26 February 2007
The Internal Structure of Venus and Mars from Satellite Tracking
Dan McKenzie
Department of Earth Sciences, University of Cambridge, UK

27 February 2007
Gravitational Wave Astronomy
Achamveedu Gopakumar
Friedrich-Schiller-University, Germany

01 March 2007
Inspiral Dynamics of Compact Binaries: its Applications and Implications
Achamveedu Gopakumar
Friedrich-Schiller-University, Jena, Germany

06 March 2007
Warm Absorbers in Active Galactic Nuclei

Ajit Kembhavi
IUCAA, Pune

12 March 2007
HII Regions
Humeshkar Nemala
University of Kentucky, Lexington, USA

13 March 2007
Orion: A Case Study of Star Formation in a Magnetized Medium
Gary Ferland
University of Kentucky, USA

14 Visitors at IIA

30 April - 3 May, 2006
Pushpa Khare
Utkal University, Bhubaneswar

May 1 - 2 June, 2006
A. Arellano Ferro
Instituto De Astronomia
Universidad Nacional Autonoma De Mexico, Mexico

15 - 17 May, 2006
D. Ojha
TIFR, Mumbai

20 May - 1 June & 11 - 14 July, 2006
Sanjoy Mozumdar
IIT, Chennai

June - August, 2006
Kasey Wagoner
Department of Physics, Washing University St, Louis, Missouri, USA

3 June - 2 July, 2006
Albert Tarantola
IPGP, Paris, France

7 - 15 June, 2006
Pavan Chakraborty
Assam University, Silchar

11 - 18 June, 2006
Dipanjan Mitra
IUCAA, Pune

11 - 16 June, 2006, 21 June - 1 July, 2006 & September 20 - 22, 2006
Pijush Bhattacharjee
SINP, Kolkata

12 - 15 June, 2006
Haridass
Institute of Mathematical Science, Chennai

20 June, 2006
Vinay Kashyap
CFA, Harvard, USA

27 June - 3 July, 2006
Abishek Rawat
IUCAA, Pune

4 - 14 July, 2006
M. Doi, K. Kawabata, N. Tominaga, N. Tanakashi
University of Tokyo, Japan

6 - 14 July, 2006
Nimisha Kantharia
TIFR, Mumbai

July - September, 2006
Holger Merlitz
Department of Physics, Xiamen University, China

7 - 14 August, 2006
H. S. Sawant
INPE, Brazil

August, 2006
David L. Lambert
McDonald Observatory, University of Austin,
- for 4 weeks Texas, USA

6 - 12 August, 2006
Jogesh Babu
Pennsylvania State University, USA

22 - 23, August, 2006, & 27 November - 1 December, 2007
Rajmal Jain
PRL, Ahmedabad

30 August - 10 September, 2006
Tiziana Venturi, Simona Giacintucci
Istituto di Radioastronomia, INAF / CNR, Bologna, Italy

10 - 19 September, 2006 & Februray 17 - 19, 2007
Angom Dilip
PRL, Ahmedabad

12 September, 2006
Sudip Bhattacharyya
NASA Goddard Apace Flight Center, USA

13 - 14 September, 2006
Nihita Goel
TIFR, Mumbai

16 September - 3 October, 2006
Firoza Sutaria
S.N.Bose Center for Basic Science, Kolkata

September - November, 2006
Michael Dopita
Mt. Stromlo & Siding Spring Observatories Institute of Advanced Studies, Australia,

11 - 15 September, 2006
Kaushar Sanchawala
Graduate Institute of Astronomy
National Central University, Taiwan

26 - 29 September, 2006
John Hutchings
Herzberg Instt. Astrophysics, Vancouver, Canada

13 - 14 October, 2006 & 26 -27 February, 2007
B. R. S. Babu
Calicut University, Calicut

31 October - 2 November, 2006
Palash B. Pal
SINP, Kolkata

9 November - 4 December, 2006
Miruna Daniela Popescu
Armagh Observatory, UK

12 December, 2006
Wilhelm Kegel
University of Frankfurt, Germany

2 - 22 December, 2006
Oskar Steiner
Kiepenheuer-Institut fr Sonnenphysik Freiburg, Germany

December 2006- February, 2007
Lars Kreiger
Kiepenheuer-Institut fr Sonnenphysik Freiburg, Germany

December 28, 2006 - January 4, 2007
K Nomoto
University of Tokyo, Japan

4 January, 2007
E. N Parker
University of Chicago, Chicago, USA

8 - 14 January, 2007
Philippe Preugniel, Mina Koleva
Observatoire de Lyon, France

9 - 16 January, 2007
Frederic Courbin
Laboratoire d'Astrophysique, EPFL, Switzerland

10 January, 2007
Martin Rees, Bernie Jones, Guru Gujral
The Royal Society, London

27 January - 2 February, 2007
N Gopalswamy
NASA/Goddard Space Flight Center, Greenbelt, USA

10 - 18 February, 2007
Pat Eliason
NSO, USA

10 - 17 February, 2007
Kiran Jain NSO, USA

24 Februray, 2007
P C Agarwal
TIFR, Mumbai

27 February - March 2, 2007
Michel Dennefeld
Institut d'Astrophysique, Paris, France

5 - 6 March, 2007
A Khembavi
IUCAA, Pune

11 - 15 March, 2007
Gary Ferland, Humeshkar Nemala
University of Kentucky, USA

14 - 28 March, 2007
Gopal Krishna
NCRA, Pune

Visitors during 27 November - 1 December, 2006.

Mohamed Alabdoadaim
Sebha University, Libya

Najat Mohammed Rashid
University of Baghdad, Iraq

Zainol Abidin
University of Malaysia, Malaysia

Hamid M.K. Al-naimiy
University of Sharjah, UAE

Luc Damé
Service d'Aronomie du CNRS, France

Baylie Damtie
Department of Physics, Bahir Dar University, Ethopia

Thomas Djamaluddin
National Institute of Aeronautics & Space (LAPAN), Indonesia

Jiulin Du
Tianjin University, China

Guenther Eichhorn
Harvard-Smithsonian CFA, Cambridge, USA

Robert Erdelyi
University of Sheffield, UK

Josè Henrique Fernandez
University of Taubate - UNITAU, Brazil

Trevor Garner
Univ. of Texas, Austin

A. R. W. Hughes
University of KwaZulu-Natal, South Africa.

Umran S. Inan
Stanford University, USA

Jose Kaname Ishitsuka Iba
Instituto Geofisico del Peru, Peru

M. K. H. Ismail
National Space Agency of Malaysia, Malaysia

Jie Jiang
National Astonomical Observatories, China

Endawoke Yizengaw Kassie
Institute of Geophysics & Planetary Physics, UCLA, USA

Abebe Kebede
NC A&T State University, Greensboro

Sergey Krasotkin
Theoretic & App. Space Phy. Dept. Moscow State

University, Russia

Alejandr Lara Sànvhez
Instituto de Geofisica UNAM, Ciudad Universitaria Coyoacan, Mexico

Ayman Mahrous
Helwan University, Egypt

Christian Monstein
ETH Zurich Institute of Astronomy, Switzerland

Yong-Jae Moon
Korea Astronomy & Space Science Institute, South Korea

Jared O. Hera Ndeda
Jomo Kenyatta University of Agriculture & Technology, Kenya

Mikhall Panasyuk
Moscow State University, Russia

Miruna Daniela Popescu
Armagh Observatory, Ireland, UK

Akeem Babatunde Rabiu
Federal University of Technology, Nigeria

Takashi Sakurai
National Astronomical Observatory, Tokyo, Japan

Nassim Seghouani
Chemin de l'Observatoire, Algeria

Jalu Tejo Nugroho
National Institute of Aeronautics & Space (LAPAN), Indonesia

Satoru Ueno
Kyoto University, Japan

Klaus Wilheim
Max-Planck-Institut fur Sonnensystem, Germany

Han Wonyong
Korea Astronomy & Space Science Institute, South Korea

Kiyohumi Yumoto
Kyushu University, Japan

Ashok Ambastha, P. Venkatakrishnan, Nandita Srivastava, Sanjay Gosain
USO, Udaipur

Subramanian
NCRA, TIFR, Pune

Shanmugaraju Annamalai
Arul Anandar College, Tamilnadu

I. A. Ansari
Aligarh Muslim University, Aligarh

Badruddin
Aligarh Muslim University, Aligarh

Lokesh Bharati
Mohanlal Sukhadia University, Udaipur, Rajasthan

Archana Bhattacharyya, Veenadhari B Pantuala, Sobhana Alex, Raman S Thevar, Rajesh Singh, Gurbax Lakhina, Ashwini K Sinha
IIG, Mumbai

Shyamal Chakraborty
Raja Peary Mohan College, Hooghly

S. M. Chitre,
University of Mumbai, Mumbai

Bhola Dwivedi, Ravindra Pratap Patel, Kalpana Patel, Vinay S Pandey Abhishekh K Srivastava, Shubha Singh
BHU, Varanasi

T.E. Girish
Government Engineering College, Trivandrum

Ashok Kumar Gwal
Barkatullah University, Bhopal

Ravindra Jadav
Bahauddin Science College, Junagath,

Ajay Kumar Jadeja, Malini Aggarwal
Saurashtra University, Gujarat.

Santhosh Kumar
Rani Durgawati University, Chattisgarh

Subhash Chandra Kaushik
Department of Physics, Government Autonomous

PG College, Madhya Pradesh

Rajmohan Kombiyil
Tohoku University, Japan

P. K. Manoharan
RAC, Ooty

Arak M. Mathai
Centre for Mathematical Sciences, Kerala

Saumitra Mukherjee
JNU, New Delhi

A. Paranjapye
IUCAA, Pune

Kamlesh Pathak
S.V. NIT, Surat

Felix Pereira
St. Xavier's College, Trivandrum

Girija Rajaram, Radharani Alyana
IIT, Mumbai

P. Balarama Rao
National Remote Sensing Agency, Hyderabad

D. Narayana Rao
National Atmospheric Research Lab., Tirupati

B. Madhava Reddy
National Geophys. Res. Institute, Hyderabad

Ashok K Sharma, Parashram T. Patil, R.V. Bhonsle
Shivaji University, Kolhapur

Ram Pal Sharma
IIT, New Delhi

Ashok K. Singh
Bundelkhand University, Jhansi

K. C. Srivastav
University of Allahabad, Allahabad

R. Sridharan
Vikram Sarabhai Space Centre, Trivandrum

Wahab Uddin
Institute of Observational Sciences, Uttaranchal

Manohar Lal Yadava, S. Guruvain
IIG, Tirunelveli

15 Conferences, Workshops at IIA

15.1 In-house scientific meeting

An In-house scientific meeting was conducted for the first time in the history of IIA on April 17th and 18th. There were 52 presentations of 15 minutes duration each on various subjects like Theoretical Astrophysics, Solar Physics, Stellar physics, Galactic astronomy and Instrumentation by the scientific and technical staff of the Institute. A partial list of the topics of the talks of the two day meeting are given below: The first two sessions were devoted to the topics covering the observations of Sun in various wavelength bands of different regions like chromosphere, corona and photosphere, in-house developed instrumentation for polarization measurements, radio observation and instrumentation for the study of Sun. In the next two sessions, the topics on Stellar physics included accretion disk disks, abundance analysis, star clusters, novae, pulsars and diffuse radiation field. Radiative transfer and theories on atomic physics were discussed in the theoretical astrophysics session. Development on HAGAR telescope and speckle interferometry were covered in the instrumentation session.

15.2 International workshop on UVIT and ASTROSAT

IIA organised an international workshop on 'UV and Multiwavelength Astronomy with ASTROSAT' during 27 to 29 September 2006. It was a well attended meeting. In addition to participants from various national organisations, there were partcipants from Canada, UK, and Australia.

The first part of the programme covered the overview of the various payloads on Astrosat and the science, followed by the status of the satellite ASTROSAT as a whole by the PI and project manager of ASTROSAT respectively. It looks that the programme is progressing as expected and no major hurdles are anticipated. The presentations on the sensitivities, capabilities, constraints and status of six payloads on Astrosat were discussed. The data pipe line of UVIT, ground and onboard calibrations and the preparations to achieve them were also discussed. A presentation on the new addition to UVIT, the gratings was also made. The science plans and programmes to be conducted mainly with UVIT as lead were discussed next. These included topics on binary stars, star clusters, novae and supernovae, hot stars, interstellar extinction, star forming galaxies, H II regions, Planetary nebulae. and Variable stars.

Later multiwavelength based programmes were discussed which included X-ray binaries, QPOs, black hole candidates, AGNs, GRBs, micro-variability of Quasars, pulsars etc. Topics on UV and other backgrounds and groups of galaxies and the science that is being done with the UV mission GALEX were also covered. Deep surveys with UVIT of selected areas and discussion on which areas and for how long was also formed part of the topics covered. In addition a long discussion on the observational strategies to be adopted was also considered along with complimentary ground based studies required and the resources needed.

15.3 Second UN/NASA workshop on IHY and basic space science

The term heliophysical is a broadening of the concept of geophysical, extending the connections from the Earth to the Sun & interplanetary space. The Earth, Sun & Solar system are studied not as separate domains but through the universal processes governing the human realm of space. An workshop on International Heliosphysical year (IHY) has been conducted at the institute during 27 November - 1 December 2006. The objectives of IHY are:

- Global study of the Sun-heliosphere system outward to the heliopause to understand the external, and historic drivers of geophysical change,
- provide benchmark measurements of the response of the magnetosphere, the ionosphere, the lower atmosphere and Earth surface to identify global processes and drivers which affect the terrestrial environment and space,
- foster international scientific cooperation in the study of heliophysical phenomena now and in the future, and
- communicate the unique scientific results of the IHY to the interested scientific community and to the general public.

Researchers and educators from a large number of countries were invited by the United Nations, NASA and IIA to participate in the workshop. There were participants from universities and research institutions, observatories, national space agencies, planetariums and international organizations. More than 150 participants from 30 Member States of the UN

Figure 28: Left to right: S. S. Hasan, M. Guhathakurta, B. V. Sreekantan, K. Kasturirangan, H. Haubold, J. Davilla, N. Gopalswamy

were represented at the workshop. The workshop was inaugurated by Dr. K. Kasturirangan, Director, National Institute of Advanced Studies and Member of Parliament (Rajya Sabha). At the opening of the workshop, statements were made by the Director of IIA, and by representatives of the IHY secretariat, NASA and UNOOSA.

15.4 Young astronomers' meet

The Young astronomers' meet (YAM) was organized in IIA with the aid of Department of Science & Technology during January 3-5, 2007. The YAM is an exclusive forum for the young researchers working in Astronomy & Astrophysics to express and exchange their ideas related to the current developments in the field. YAM also aims at motivating the bright M.Sc. students to choose their career in Astronomy. About 90 participants including 50 research scholars from various research institutes and universities working in the diverse fields of Astronomy and Astrophysics ranging from solar & stellar astrophysics to cosmology attended the Meet. Around 30 M.Sc. students and a few engineering students also participated. The program included the oral and poster presentations by the participants, evening colloquiums by the senior scientists, a visit to ISRO Satellite Center to overview the various ongoing space projects at ISRO and a trip to CREST campus, Hosakote to introduce the remote operational techniques of the Himalayan Chandra Telescope.

15.5 Kodai summer school in physics

A three week summer school in Physics was conducted during 5-24 June 2006 on the subjects (i) special theory of relativity, (ii) general theory of relativity, and (iii) fluid dynamics was conducted at IIA, Kodaikanal. Twenty one students of final year postgraduate and graduate courses from various parts of the country participated. The classes and simultaneous tutorials were conducted by the eminent persons in the field from the premier institutions of the country. Professor Albert Tarantola and Dr. K. Sundara Raman delivered evening special lectures to the students and local public. The students were exposed to the solar observations and night sky viewing.

15.6 Solar physics winter school

An international school on Solar Physics was organised during December 10 – 22, 2006 at Kodaikanal Observatory. The aim of the school was to teach the basics of solar physics and to motivate the students to take up a research career. This is the first time the students were exposed to a course on So-

lar physics. Thirty six students (undergoing M.Sc and Ph.D. programs) from within the country and six foreign students attended the school. Thirteen speakers (seven from abroad and six from within the country) gave 42 lectures and in addition, five evening seminars were arranged. Students took part in observational exercises, solved short problems and familiarised themselves with few computer models. An evening seminar titled 'Radiative equilibrium in solar atmosphere' was given by Rangarajan.

15.7 Workshop on physics and astrophysics of dust

A workshop on Interstellar Dust was organised at the Vainu Bappu Observatory, Kavalur, during February 24-26, 2007. The aim was to discuss the formation, probes and astrophysics of dust. A heterogeneous group of about thirty people, physicists, chemists, astronomers, and mathematicians were brought together with a common purpose in mind- to solve the mysteries of dust5 grains in outer space.

The characteristics of cometary dust were discussed and its difference with interstellar dust was emphasized. Presence of dust in the atmosphere of brown dwarfs and of T Tauri type stars is generally inferred form infra red studies of these objects and through polarization studies. A careful study of the gas phase abundances in diffuse clouds can yield valuable information on the amount of dust forming material available in the ISM. A systematic effort in this direction reveals that the amount of heavy elements available is not enough to produce the observed extinction. Doubts are cast on the once widely accepted Mathis-Rumpl-Nordsieck mixture with power law type distribution. The ubiquitous 218 nm feature may not be due to graphite at all. The first results on a survey of dust through infra red studies in the inner Milky Way were also presented.

Evidence of dust in elliptical and lenticular galaxies was presented through extinction maps of these galaxies which were obtained from extensive photometric data. Evidence of the presence of dust in starburst galaxies and in quasars was also presented. Heavy elements, which the grains are seemed to be composed of seem to have formed rather early in the history of the universe since there appears to be substantial amounts of dust in high redshift quasars. Supernovae are thought to be responsible for producing the heavy elements and dust in these environments.

The workshop dealt with the physics and chemistry of dust and several interesting topics, e.g. heterogeneous chemistry of very small dust particles, crystallization and morphology of grains, dynamical aspects the separation of dust and gas in various interstellar environments, spectroscopic studies in the identification of dust species, and the importance of the study of complex molecules in understanding the chemistry of dust. Possibility of laboratory simulation of dust-gas interaction and observing the dynamics through holographic imaging was also examined.

The workshop also discussed on the spectroscopy and light scattering as probes of interstellar dust. The theoretical modeling of the scattering process was discussed in several talks. The results of the application of the theory of Discrete Dipole Approximation to scattering by grains were discussed. The formal presentation of the talks closed with a description of a new effort on laboratory studies of light scattering by grains. At the end, there was a discussion on the identification of the possible areas of overlap between the various groups in the country.

16 National & International Programmes

16.1 Collaborations with other countries

1. Collaboration between IIA and INPE, Brazil in the development of the digital system for the Brazilian decimetric array continued. A 32 channel digital correlation system was interfaced to the 5 element interferometer system at INPE. 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 and is expected to be launched as part of the next GSLV mission (GSAT-4) in mid-2008.

3. An antipodal transient telescope has been installled at IAO, hanle in collaboration with the McDonnell Center for Space Sciences, Washington University, St Louis. This is one of the two 0.5-m optical telescopes for photometric monitoring of active galactic nuclei, the other one already operating in Arizona, USA.

4. 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 has set up a Gamma Ray Telescope array at IAO, Hanle, in collaboration with TIFR. The telescope design and development (mechanical, civil and control electronics) is implemented by IIA, while the Software for the telescope control and Data Acquisition System are developed by TIFR. The complete array of 7 telescopes is expected to be operational by December 2007 and the preliminary science observations could begin thereafter.

17 Extra-curricular activities

Annual day celebrations

Figure 29: IIA is in festive mood.

After a gap of more than a decade, the Institute celebrated the annual day function on April 15, 2006. On this occasion, the Institute's magazine 'TARA' was brought out. The function was well attended by the staff members and their families.

Raj-rakt

Figure 30: Scene from Raj-rakt performed by Habib Tanvir's Naya Theatre.

The Institute's Hosakote campus hosted a play entitled, 'Raj-rakt' based on Tagore's 'Visarjan' on 11th February this year. It was played by Naya Theatre, a professional touring company, headed by Habib Tanvir. It was well attended.

18 Staff list 2006-2007

Director: S. Sirajul Hasan

18.1 Academic & Scientific members

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

Professor: S. P. Bagare, H. C. Bhatt, S. Surendra Gupta, R. C. Kapoor, Jayant Murthy, A. K. Pati, A. V. Raveendran

Associate Professor: G. C. Anupama, S. Chatterjee, Sunetra Giridhar, Sushma G. V. Mallik, K. N. Nagendra, K. E. Rangarajan, S. K. Saha, K. R. Subramanian, R. Surendiranath

Scientist - E: P. M. S. Namboodiri, B. Raghavendra Prasad

Scientist - D: B. C. Bhatt, R. K. Chaudhuri, R. T. Gangadhara, K. M. Hiremath, R. Kariyappa, Arun Mangalam, M. V. Mekkaden, S. Mohin, K. P. Raju, K. B. Ramesh, Prajval Shastri, Prasad Subramanian, A. Satyanarayanan

Scientist - C: S. Annapurni, D. Banerjee, Aruna Goswami, J. Javaraiah*[2], U. S. Kamath, S. Muneer, Gajendra Pandey, P. S. Parihar, R. Ramesh, M. Srinivasa Rao, B. Eshwar Reddy, D. K. Sahu, S. K. Sengupta, C. S. Stalin, K. Sundara Raman, B. A. Varghese

Scientist- B: P. Bama, E. Ebenezer, B. S. Nagabhushana, Shanthikumar Singh

Research Associate: M. Appakutty

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

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

Visiting Professor: D. C. V. Mallik, M. Parthasarathy, Vasundhara Raju

Post Doctoral/Visiting Fellow: Varendra Das, P. Gopakumar, C. Kathiravan, Rhekesh Mohan, Margarita Safonova

Sr. Research Fellow: Abhay M Karnataki, P. Venkatpani Lata, Malai Maiti, Blesson Mathew, K. Nagaraju, H. S. Nataraj, Ramya, S., Sampoorna, M., Veeresh Singh, Reji Mathew Thomas, G. Udaya Kumar

Jr. Research Fellow: Anusha L, Rumpa Chaudhari, Girijesh Gupta, Tapan Mishra, Anantha Charan Pradhan, Sumangala Rao, Bharat Kumar Era Reddy, Roopashree, Amit Shukla, Smitha Subramanian, Vigeesh G

18.2 Technical staff

Engineer G: A. K. Saxena

Sr. Principal Scientific Officer: A. V. Ananth

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

Engineer D: P. M. M. Kemkar, J. S. Nathan, R. Ramachandra Reddy, N. Selvavinayagam

Principal Scientific Officer: J. P. Lancelot

Librarian: Christina Bridie

Engineer C: Amit Kumar, Dorje Angchuk, V. Arumugam, S. S. Chandramouli, Faseehana, S. Kathiravan, P. K. Mahesh, S. Nagabhushan, B. Ravikumar Reddy, M. P. Singh, S. Sriram

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

Sr. Technical Officer: J. P. A. Samson, A. Selvaraj

Technical Officer B: F. Gabriel, J. V. S. V. Rao, K. S. Subramanian

Sr. Documentation Officer: Sandra Rajiva

Engineer B: P. Anbazhagan, K. Anupama, K. Dhananjay, Tsewang Dorjai, Sanjiv Gorka, Sonam Jorphali, P. U. Kamath, T. T. Mahay, Vellai Selvi, K. C. Thulasidharen

Technical Officer: C. Nanje Gowda, A. V. Ve-

[2]*On leave of absence

layuthan Kutty, S. Muthukrishnan, K. Rangaswamy, R. Selvendran

Tech. Associate B: K. Jayakumar, K. Kuppuswamy, Narasimhappa, M. Joseph Rosario, N. Sivaraj, G. S. Suryanarayana

Sr. Mech. Asst. C: A. Mani

Tech. Associate: D. Babu, P. Kumaravel, Mallappa, S. Pukalenthi, A. Ramachandra, S. Ramamoorthy, S. Venkateshwara Rao, K. Ravi, M. R. Somashekar, C. V. Sriharsha

Draughtsman D: V. K. Subramanian

Sr. Tech. Asst. B: A. P. Balakrishnan, R. Ismail Jabillullah, J. Manoharan, T. K. Muralidas

Asst. Librarian B: B. S. Mohan, P. Prabahar

Project Consultant: A. Vagiswari

Consultant: Kuldip Chandar, B. R. Madhava Rao

Visiting Project Associate: N. Jayavel

18.3 Administrative staff

Administrative Officer: A. J. Ragupathy

Dy. Administrative Officer: S. Rajasekaran

Finance Officer: K. Ramachandran

Accounts Officer: M. P. Parthasarathy

Staff Officer: K. Thiyagarajan

Personnel Officer: A. Narasimharaju

Asst. Administrative Officer: Y. K. Raja Iyengar, K. Mohan Kumar, Ramaiah

Asst. Accounts Officer: G. R. Venugopal

Store Officer: D. Lakshmaiah

Sr. Section Officer: Meena, K. Sutherson

Section Officer: Narasimhamurthy, S. Rajendran

Hindi Officer: Saroj Ishwaralal

Sr. Office Superintendant: L. Josephine, Uma Maileveloo, P. Alphonse Mary, Pramila Mohan, A. P. Monnappa, M. G. Chandrasekaran Nair, R. M. Paulraj, K. Padmavathy

19 Sky conditions

Vainu Bappu Observatory, Kavalur

Year	Month	Spectroscopic Hours	Photometric Hours
2006	April	149	8
	May	103	10
	June	24	0
	July	43	0
	August	13	0
	September	21	7
	October	50	6
	November	53	10
	December	134	29
2007	January	206	63
	February	230	86
	March	72	20
	Total	1026	219

VBT Time Allocation during the period : 1 April 2006 - 31 March 2007

Total No. of proposals received	:	50
Number of spectroscopic proposals	:	45
Number of imaging proposals	:	5
Number of nights allocated for spectroscopy	:	263
Number of nights allocated for imaging	:	26

Sky conditions at Indian Astronomical Observatory, Hanle

Year	Month	Photometric (night hrs)	Spectroscopic (night hrs)	Total (night hrs)
2006	April	99	153	240
	May	85	136	217
	June	85	129	210
	July	79	101	217
	August	12	37	248
	September	125	212	270
	October	179	214	310
	November	223	263	330
	December	197	243	341
2007	January	306	335	341
	February	69	105	280
	March	148	185	279
	Total	1607	2113	3283

Kodaikanal Observatory

Spectro / Photoheliograms and Seeing Conditions at Kodaikanal

Year	Month	No. of observing days			Seeing Condition*				
		Hα	Kfl	PHGM	5	4	3	2	1
2006	April	26	26	28	–	3	17	8	–
	May	13	13	22	–	–	–	21	1
	June	9	8	19	–	–	14	4	1
	July	2	2	21	–	–	12	7	2
	August	2	2	20	–	–	2	16	12
	September	1	1	17	–	–	4	11	2
	October	8	8	–	–	–	–	–	–
	November	3	5	–	–	–	–	–	–
	December	16	21	12	–	–	–	–	–
2007	January	11	13	24	–	2	8	7	9
	February	10	11	24	–	–	2	18	4
	March	16	19	29	–	–	–	28	1
	Total	117	127	216	–	5	59	120	32

Hα = H-alpha spectro-heliograms; Kfl = Ca-K line spectro-heliograms; PHGM = Photo-heliogram (Ca-k line filter-grams taken on 127 days with about 30 minute intervals)
*(1–Very poor, 2–Poor, 3–Fair, 4–Good, 5–Excellent)

Solar Tower Telescope Observations from April 2006 to March 2007

Year	Month	Total Number of days of observations	Seeing (in arcsec) 2 to 3	3 to 4	4 to 5	>5 (poor)
2006	April	11	8	2	1	
	May	8	6	2	–	
	June	6	3	2	1	
	July	4	4	–	–	
	August	5	5	–	–	
	September	7	4	1	2	
	October	7	3	3	1	
	November	12	7	3	2	
	December	21	10	7	4	
2007	January	23	17	4	2	
	February	19	13	5	1	
	March	23	14	7	2	
	Total	146	94	36	16	

Ca+K Latitude Observations - 109 days; Polarimeter Observations - 29 days,
Spectrographic Observations - 11 days