INDIAN INSTITUTE OF ASTROPHYSICS

ACADEMIC REPORT 2009-2010

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Cover: Green (top) and Red (bottom) emission line spectra taken during the total solar eclipse of 22nd July 2009 from Anji, China.

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†*deceased*

The Year in Review

It gives me great pleasure to summarize the highlights of the Institute's activities during the current year. IIA has been through another very active and productive year of research and development, astrophysics capacity building and public outreach, besides organizing and hosting a wide range of activities.

The Institute continues to be productive in all its core areas of research. An exciting event for the solar physicists was the total solar eclipse of 22 July, 2009, for which I led a team of researchers to a site in Anji, China, carefully selected for the best predicted weather, to conduct for the first time simultaneous photometric and spectroscopic experiments during the 341 seconds of totality with high temporal resolution. The long duration of the eclipse allowed us to reliably study oscillations with periods of around 30 s in the corona. The difference in temperature between the polar and equatorial regions in the solar corona was measured.

The IIA team at the Solar Eclipse camp in Anji, China.

The efficacy of the Last Scattering Approximation to fit solar polarisation spectra and the bi-conjugate gradient iterative method to handle spherical radiative transfer with high resolution has been demonstrated. High-cadence X-ray images from the Hinode and SOHO (Solar and Heliospheric Observatory) have revealed oscillations with periods below the acoustic cut-off for the solar corona. A signature of accelerating Alfvén waves has been observed from a region just over a solar radius. SOHO spectrometric data in the extreme ultraviolet show that the interior distribution of the cell of the solar atmosphere is different in the quiet Sun and the coronal hole even at the lower transition region. The coronal green lines appear to have blue asymmetry, with the centroids showing increasing blue shifts with radial distance but the line-widths showing no variation. Possible signatures of an extended increased wave speed region in sunspots have been found, as well as a helioseismic signature of acoustic wave absorption. The theoretically predicted rate of decay of the area of sunspots has been found to match observations. It was found that the tilt angle of bipolar spots varies with life span. A latitude-time dependency was inferred for the periodicities of the mean meridional motion of sunspot groups in the northern hemisphere. The umbral to penumbral area ratio shows a clear dependence on the magnetic type of the spot. From spectropolarimetry of an iron and Balmer line in an active region, it was found that the velocity and magnetic field gradients are larger in the umbral region compared to the penumbral region. The magnetic fields in the mid-solar corona have been measured using radio polarimetry, and the coronal mass ejections with comparatively larger acceleration in the low corona are associated with soft X-ray flares. From spectroscopic gamma-ray measurements of the Almahata Sitta meteorite and orbital information of the corresponding asteroid it was found that the prolonged solar minimum during 2001-2008 did not result in any unusually large cosmic ray flux in the near-earth space sampled by this meteorite.

Research in star formation, stellar structure, composition and evolution continue to be pursued vigorously as in the past year. Empirical evidence has been found for the Radiation Driven Implosion model for triggered star formation from a multi-wavelength investigation of the young stellar population of a massive bright-rimmed globule in a Galactic HII region. A semi-analytic treatment of the stability of thin dense shells driven by powerful winds and/or blast waves suggests that fragmentation of

such shells is a propitious mode of forming massive clumps that could possibly spawn star-clusters.

A systematic shift in the radial velocity curve towards shorter orbital phases was found for the binary star V711 Tau, using data spanning over three decades. Spectroscopic evidence for dust-gas separation has been found in several post-AGB stars. The neon abundances of extreme helium stars indicated departure from LTE in their atmospheres. A handle on the fraction of CH stars in star samples at high Galactic latitudes was obtained using $^{12}C/^{13}C$ isotopic ratios, effective temperature estimates and infrared colour-colour diagrams. A rigorous multiple-scattering analysis of cloudless T-dwarfs using the full radiative transfer equations showed that the polarisation decreases with iincrease in effective temperature and that disc-integrated polarisation will be negligible, implying that polarization of cloudless T-dwarfs by atomic and molecular scattering may not be detectable. An investigation of the effects of Compton broadening due to electron-photon scattering in hot stellar atmospheres showed that both redshift and asymmetry in the line can be produced, and both effects increase with the optical depth.

Using observations from the 2.3 m Vainu Bappu Telescope, a Galactic globular cluster was found to have a very large halo not accounted for by current globular cluster evolution models. Constraining the dust-gas separation mechanisms in carbon-rich metal-poor planetary nebulae has been attempted using the Fe abundance and the photospheric depletion. In the nova RS Ophiuchi, a two-component model, consisting of a decelerating shell seen in mixed thermal and non-thermal emission plus faster bipolar ejecta generating the non-thermal emission, is found to account for the multi-frequency radio images. The polarisation of the coherent curvature radiation from neutron stars is estimated by solving the dynamics of the relativistic plasma moving along the magnetic field lines in the pulsar magnetosphere. The absolute emission altitude of both the core and the conal components has been estimated relative to the neutron star centre. A comparison of the quiescent luminosities of low mass X-ray binaries with their binary period has been used to identify the nature of the primary object. The Li abundance in F-type stars is found to be equal to their presumed initial abundance, confirming previous suggestions that pre-main sequence depletion is ineffective for these stars. The radial velocity survey MARVELS found an example of a brown dwarf orbiting its main-sequence companion star at a distance comparable to those of "Hot Jupiters". Microlensing is shown to offer a promising method to search for intermediate-mass black holes in the centres of globular clusters.

In the area of extragalactic physics, RR Lyrae stars in the inner LMC are found to mimic the bar and inclination of the disk, suggesting that a large fraction of these stars is formed in the disk of the LMC. Two blue compact dwarf galaxies that were investigated photometrically and spectroscopically were found not to be young systems but those with episodic star formation superposed on an older component. The few globular clusters that have been found to harbour a black hole in their centre, appear to fit the well-established but intriguing relationship between the mass of central black holes in galaxies and the velocity dispersion of their stars. A spectroscopic investigation of low surface brightness galaxies has yielded central black hole masses and stellar velocity dispersions which deviate from the corresponding relationship obtained for massive galaxies in that they have smaller black hole masses compared to their bulge velocity dispersion. Detailed statistical analysis of a blazar light curve has shown periodicities which place interesting limits on the mass of the central super-massive black hole. Using the relation between gravitational binding energy of the host structure and the central black hole energy, it has been possible to argue why globular clusters are unlikely to harbour large black holes and why dwarf galaxies, if they must host black holes, should have observed mass to light ratios of ~ 100.

In the area of atomic physics, relativistic coupled-cluster theory was used to calculate the polarisabilities of several closed shell atoms including helium and ytterbium. The signatures of superfluid to Mott insulator transition have also been analyzed. In the area of optical sciences, the primary focus has been on the computational approach to investigating various aspects of adaptive optics implementation, including wave-front sensing and reconstruction as well as noise reduction.

The Institute had its annual in-house science meeting on 17 April 2009, at which the newly instituted awards for outstanding research papers by young IIA scientists were given to Gajendra Pandey, Eswar Reddy and Devendra Sahu.

The many different initiatives that IIA has recently undertaken in order to enter into new avenues of astrophysics research are proceeding with vigour. Testing of the detectors and fabrication of mirrors for the Ultraviolet Imaging Telescope (UVIT) which will fly on the ASTROSAT space mission is complete. The site characterization programme for the National Large Solar Telescope project has been

augmented with the commencement of observations at the Devasthal site in Uttarakhand, in addition to continuing observations at the Merak and Hanle sites. A Differential Image Motion Monitor dedicated to monitor the site seeing has been installed at the Vainu Bappu Observatory, and the trial assembly of the 1.3 m telescope for VBO was successfully done at DFM engineering in the USA. A detailed technical report on the multi-institution collaboration for developing a space-based indigenous visible emission-line solar coronagraph was submitted to ISRO. The Industrial Research Laboratory of New Zealand was identified for the fabrication of an echelle spectrograph for the Hanle 2 m Hanle Chandra telescope. IIA has been leading a national effort deliberating on India's participation in a Giant Segmented Mirror Telescope project, the focus has been on maximizing benefit to the development of indigenous technology and human resources, in addition to research goals of the community. A national consensus was reached in favour of the Thirty-Meter Telescope (TMT) project led by a U.S.-based consortium with international partners. A detailed project report was submitted to the Department of Science and Technology (DST).

Left to right are Swapan Saha (IIA), J. A. K Tareen (Vice-Chancellor, Pondicherry University), S. S.Hasan (Director, IIA) and K. Porsezian (Head of Department of Physics, Pondicherry.)

In order to enhance IIA's Ph.D. programme, IIA and Pondicherry Central University entered into a collaboration by launching a joint Ph.D. programme in April, 2009. The two new teaching programmes launched in 2008, *viz.,* the Integrated M.Sc./Ph.D. programme with IGNOU (Indira Gandhi National Open University), New Delhi and the Integrated M.Tech./Ph.D. programme with Calcutta University continue to grow well and have recruited the second batch of students. As a result of these initiatives, the student strength has gone up to 50. As in previous years, IIA once again played host to the International Research Experience for Students (IRES) programme, sponsored by the National Science Foundation of U.S.A, in which two graduate students from U.S.A. visited IIA to carry out research projects with Institute faculty.

IIA continued its intense level of public outreach activities for the International Year of Astronomy through 2009. A total of about 140 popular astronomy lectures were delivered country-wide by IIA scientists as part of the 100-LECTURE SERIES effort in the international year. Under IIA's "*Astronomy for All*" programme, a low-cost 10 cm Newtonian telescope designed by the photonics division of the Institute was mass-produced and distributed to over 200 schools, clubs and individuals. The total solar eclipse of 22 July 2009 and the annual solar eclipse of 15 January 2010 provided rich opportunities for public viewing of the phenomenon as well as spreading scientific temper, which IIA utilised to the full at multiple venues in the totality path and in Bangalore. A new sky-watch programme was initiated with the installation of a small observatory equipped with a 14-in telescope on the roof top of the main campus. Many more programmes are outlined in this report. IIA formally brought its IYA09 celebrations to an end at a closing ceremony in January, which had a thought-provoking lecture by the play-wright Alan Brody, whose play on Isaac Newton was performed in Bangalore. The heightened level of activities undertaken during IYA09 have put in place a network of educational institutions, public associations and individuals that are interested in astronomy at various levels. This has created a strong platform from which IIA can effectively attract students to astrophysics as well as share the excitement of knowledge generation with the public at large.

William D. Phillips, Nobel Laureate, delivering the third Vainu Bappu Memorial lecture.

IIA hosted the Annual Lecture Event of the Alexander von Humboldt Association of Bangalore on August 25, 2009 in which P. Balaram, IISc, Bangalore and J. Schmitt, Hamburg Observatory, Hamburg spoke respectively on "*Reinventing the Research University in India*" and "*High Resolution Stellar Spectrograph for the NLST*". Madhav Gadgil, India's renowned ecologist, delivered the 19th Bicentennial Commemorative public lecture on April 3, 2009 with the title "*Major Transitions in Evolution*". On August 11, 2009, the eminent astrophysicist Govind Swarup gave the Founder's Day lecture - "*Experimental Astronomy in India: Some Lessons*". The third Vainu Bappu Memorial lecture was delivered by William D. Phillips, Nobel Laureate, on January 25, 2010. He spoke on "*Time, Einstein and the Coolest Stuff in the Universe*". All these public lectures attracted a packed auditorium of academics and the public alike, and efforts have begun to make them available to a larger audience via the internet.

Govind Swarup garlanding Vainu Bappu's bust.

IIA organised several meetings that included international ones such as the second workshop on "The Physics and Astrophysics of Dust" at the Kavalur campus, the Kodai Winter School on High Energy Astrophysics at the Kodaikanal campus and the discussion meeting on "Gender Issues in the Science Workplace" at Bangalore. Preparations also commenced for holding an international conference to commemorate the birth centenary of the celebrated astrophysicist S. Chandrasekhar. Many distinguished scientists such as Eric Cornell, Nobel Laureate, from the University of Colorado, U.S.A., William Phillips, Nobel Laureate from the National Institute of Standards, U.S.A. and Peter Biermann from the Max Planck Institute for Radioastronomy, Germany visited IIA and delivered lectures.

The Science Advisory Committee, constituted by the IIA Governing Council, held its deliberations in several sessions at IIA during March 15-19, 2010. It met groups associated with various research programmes, observational facilities and projects and interacted with staff and students. The SAC also visited laboratories at the main campus, CREST, Hosakote and the Vainu Bappu Observatory, Kavalur.

Members of the Science Advisory Committee along with Director, IIA: Left to right are S. Ananthakrishnan, N. Kumar, N. Weiss, S.S. Hasan, M. Dopita and G. Joseph.

IIA continued its efforts in the implementation of the official language. The IIA Newsletter has begun carrying articles in Hindi. The Institute continues to play a constructive and important role in building an equitable work environment by safeguarding the interests of SCs and STs as well as women.

My heartiest congratulations to my colleagues who have received awards and honours for their scientific work. These recognitions include membership of prestigious national and international bodies. It is a pleasure to welcome M. Sampoorna to IIA as the second Chandra Postdoctoral Fellow. She also received the Meera Memorial award of the Indian Institute of Science for the best PhD thesis in physics.

S. S. Hasan
Director

Chapter 1

Research

1.1 Solar Physics

Total Solar Eclipse of July 22 2009

Figure 1.1: The two 40-cm telescopes at the Indian Camp at Anji, China which imaged the solar corona in the green and red emission lines during the total solar eclipse of July 22, 2009.

Total solar eclipses continue to be important, not withstanding the invention of the coronagraph in 1930 and a number of space instruments launched in space to make the observations of the solar corona in EUV, soft X-ray and low resolution broadband images. During a total solar eclipse, the scattered light is about 1000 times lower than that in the coronagraphs. Also observations can be made with high spectral, spatial and temporal resolution compared to those of space-based instruments because size and weight are not stringent constraints in ground-based observations. Imaging of the solar corona provides information over the two-dimensional region of the solar corona but the data may have small uncertainties due to variations in sky transparency. On the other hand spectroscopy provides data only of a small portion of the solar corona, but it is possible to account for the variations in the sky transparency.

Figure 1.2: The spectrograph at the Indian Camp at Anji, China which was used to take spectra of the solar corona in the green and red emission lines during the total solar eclipse of July 22, 2009.

Line profiles can also yield information about the temperature and non-thermal structure of the solar corona. Spectroscopy and imaging of the solar corona were therefore conducted in the green and red emission lines to search for waves in the solar corona and investigate their nature if they exist.

Location of observations: The total solar eclipse of July 22 2009 was visible from a number of places in India but the weather in India was expected to be poor, with frequent rains at the time of eclipse and the altitude of the sun at the time of the eclipse was low around 10 degrees. The best places to observe the eclipse was predicted to be in China. The Indian team, therefore, set up the camp at Anji (latitude 30d 28.1m N; Longitude 119d 35.4m E; Elevation 890 m), China near a big reservoir and performed high-resolution imaging and spectroscopy of the solar corona in two emission lines, namely the green line at 530.3 nm due to Fe xiv and the red line at 637.4 nm due to Fe x simultaneously. There were some passing clouds during the eclipse. All the three

experiments were conducted successfully.

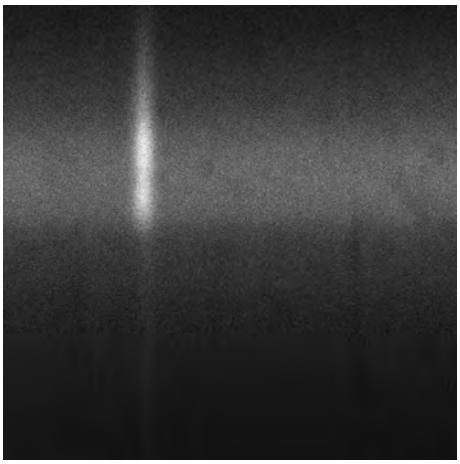

Figure 1.3: The Green spectrum: Spectra obtained around the green emission line during the total solar eclipse of July 22 2009 from Indian Camp at Anji, China.

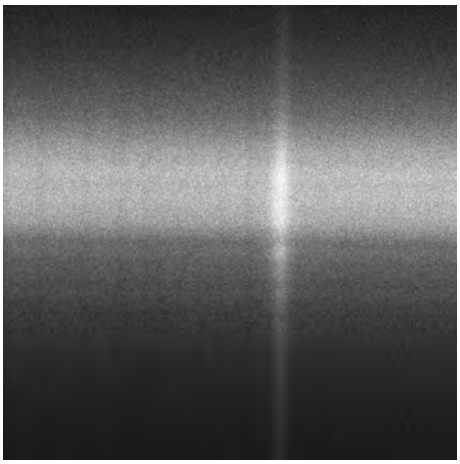

Figure 1.4: The Red spectrum: Spectra obtained around the red emission line during the total solar eclipse of July 22 2009 from Indian Camp at Anji, China.

Spectroscopy of the solar corona: A 30-cm two mirror system (Coelostat) was used to direct the sun & coronal light to a 10 cm objective to form an image of the corona on the slit of the Littrow-type spectrograph. A 14-cm objective collimated the beam and imaged the spectrum on the two CCD cameras. An infrared cut-off filter with a transmission between 500 to 650 nm kept in-front of the slits helped to separate the different orders. A grating with 600 lines/mm blazed at 2 microns provided a reasonable dispersion 2.3 Å mm−1 in the fourth order green and 3.3 Å mm^{-1} in the third order red wavelengths to determine the emission line profiles. Two CCD cameras of 1K×1K format with pixel size of 13.0×13.0 microns were used to take the images. The CCD chip with back illumination provided high efficiency around 85 percent and camera operated in frame transfer mode to obtain data with high frequency. The images were obtained with read out at 14-bit format at 10 MHz (Figure 1.2).

Figure 1.5: Image of the solar corona in the green emission line obtained during the total solar eclipse of July 22 2009 from Indian Camp at Anji, China.

Photometry of the solar corona: Two 40-cm DFM telescopes with an effective focal length of 200 cm each were used to image the solar corona (Figure 1.1). A 5 cm narrow-band (3 A) filter centered around 637.4 nm kept near the focal plane in one of the telescopes permits to take images of the solar corona in the red emission line. The second telescope fitted with 530.3 nm narrow band filter permits to take the images in the green coronal line. The CCD cameras of 2K×2K format with 13.5×13.5 micron pixel size enabled to take images of the solar corona up to 1.5 solar radii where most of the emission occurs. The 16-bit read out at 5 MHz rate, provided high dynamic range and fast kinetic series. The back illuminated chip yielded more than 90 percent efficiency at the wavelengths of interest. The coronal images are of good quality in spite of passing clouds during the totality phase of the eclipse.

Observations and results: The duration of totality was 341 seconds but spectra for 270 seconds could be obtained, after a trial exposure with at an interval of 5 second. The images of the solar corona in the red and green emission lines were obtained with an exposure time of 400 ms. The intensity ratios

of green to red emission lines indicate the temperature of solar corona to be 1.65 million degrees in the equatorial region and 1.40 millions in the polar region relatively higher than the expected temperature in the polar region. The width of the emission lines in different coronal structure show different physical conditions in different structures. (See Figs 1.3–1.5).

(J. Singh, S.S. Hasan, G.R. Gupta, K. Nagaraju & D. Banerjee)

Modeling scattering polarization of the Ca I 4227 Å line

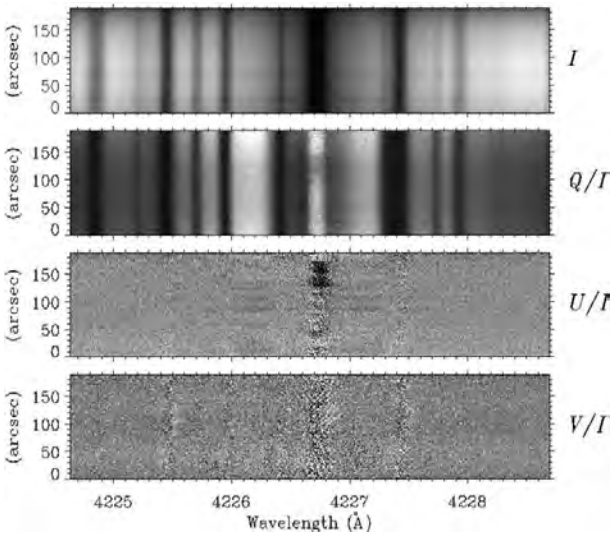

Figure 1.6: The CCD image of the Stokes parameters in a spectral window around the Ca I 4227 Å line. The observations were made with the spectrograph slit placed parallel to the north limb (about 6″ inside). The observations were taken with ZIMPOL-II polarimeter at IRSOL, Locarno, Switzerland. The y-axis shows the spatial extent along the slit, on the quiet solar atmosphere.

To model the polarisation of the Ca I 4227 Å line, radiative transfer effects with partial frequency redistribution must be taken into account. The numerical solution of the relevant polarized radiative transfer (RT) equations is computationally very demanding. The "last scattering approximation" (LSA) is a concept allowing faster methods to be devised, based on single scattering of the radiation field being sufficient for creating most of the polarization. Its key ingredient is the anisotropy of the radiation field. If the anisotropy is extracted from the observed centre-to-limb variation of the intensity profile, only the wings of the Q/I spectrum can be modeled (Sampoorna et al. 2009, ApJ, 699, 1650). It was shown that the core region may be modeled as well if one takes into account the depth variation of the anisotropy which is obtained from an unpolarized multi-level RT code.

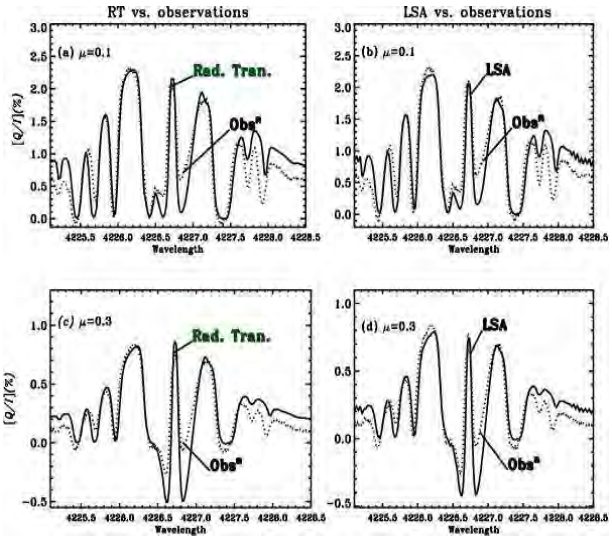

Figure 1.7: Comparison between the theoretical Q/I spectra computed with the RT and LSA approaches and the observations obtained in January 2010. The FALX model atmosphere has been used.

The LSA and RT approaches were applied to model recent observations of the Ca I 4227 Å line polarization taken on the quiet Sun (see Figure 1.6). In Figure 1.7 the observed Q/I profiles were compared with the theoretical profiles computed using the RT and the LSA modeling approaches. Apart from a global scaling factor, both approaches give a very good fit to the Q/I spectrum for all the wavelengths. As the LSA is eight times faster than the RT approach, we can recommend it as an efficient method to analyze other strong resonance lines in the second solar spectrum.The results are published recently in ApJ 2010, 718, 988.

(L. S. Anusha, K. N. Nagendra, J. O. Stenflo, M. Bianda*, M. Sampoorna, H. Frisch*, R. Holzreuter*, R. Ramelli*)*

Pre-conditioned bi-conjugate gradient method for radiative transfer in spherical media

Spherical transfer still remains a fundamental problem in astrophysical radiative transfer theory. The characteristic inverse square variation and peaking nature of the radiation field makes it a difficult problem. Handling these difficulties requires high spatial

*Collaborators from other institutions

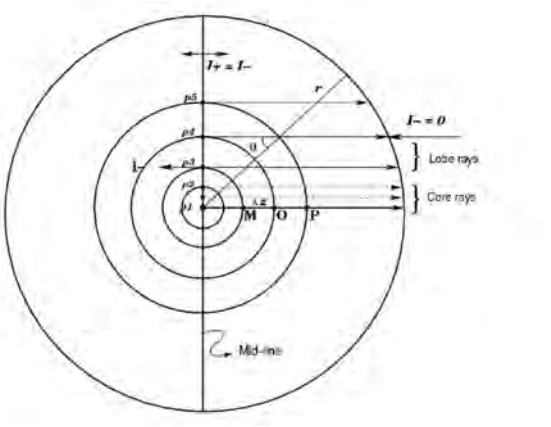

Figure 1.8: Geometry of the problem showing computation of the radiation field in a spherically symmetric system. The set of core rays and tangent rays are marked. The core is defined as a sphere with radius $r = 1$ in units of the core radius $R_{\rm core}$. The surface is a sphere of radius $r = R$ in units of $R_{\rm core}$. The rays that intersect the core are called 'core rays', and the rest are called 'lobe rays'. No radiation is incident on the outer surface of the sphere (outer boundary condition).

and angular resolution. The existing numerical iterative methods slow down with such increased resolution. In order to develop a high speed numerical technique to solve such problems, a robust numerical method called the Preconditioned Bi-Conjugate Gradient (Pre-BiCG) method was formulated for the solution of radiative transfer equation in spherical geometry. A variant of this method called Stabilized Preconditioned Bi-Conjugate Gradient (Pre-BiCG-STAB) was also formulated. These are basically iterative methods based on the construction of bi-orthogonal vectors using projections onto Krylov subspaces of the n-dimensional real space.

Figure (1.8) shows the geometry of the problem and the approach taken. The Pre-BiCG and Pre-BiCG-STAB methods are validated in terms of their efficiency and accuracy, by comparing with the contemporary iterative methods like Jacobi, Gauss-Seidel (GS) and Successive over relaxation (SOR). From Figure (1.9), it is clear that this new method has the advantage of being extremely fast so that high resolutions can still be used in practical computations. Furthermore, the application of Pre-BiCG method in some benchmark tests shows that the method is versatile, and can handle hard problems that arise in astrophysical radiative transfer theory. These results are published in ApJ, 2009, 704, 661.

(*L. S. Anusha, K. N. Nagendra, F. Paletou*, L. Léger**)

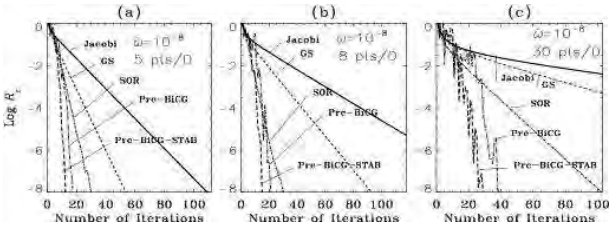

Figure 1.9: Dependence of the Maximum Relative Change $R_{\rm c}$ on the iterative progress for different methods. Panels (a), (b), and (c) represent models with low, medium and high spatial resolution respectively. The figures show clearly that the Jacobi method has the smallest convergence rate, which progressively increases for GS and SOR methods. Pre-BiCG and Pre-BiCG-STAB methods generally have the largest convergence rates compared to the other three.

Dynamics of coronal X-ray bright points in relation to the magnetic field

A co-temporal analysis of coronal X-ray intensity images from Hinode/XRT and photospheric magnetic field measurements using high cadence (1-min) magnetograms from the Michelson Doppler Imager (MDI) on board SOHO was done. A wavelet analysis approach was first used which revealed transient long period oscillations with periods ranging between 18 and 30 minutes. Such periods are still below the acoustic cutoff for the solar corona. Particular examples also support exponential damping of these long-period oscillations with time decay timescales near 90-minutes. Time-averaged MDI magnetograms of reduced noise support a correlation between bipolar magnetic footpoints and XBP evolution, but they do not, as of yet, reveal a driving mechanism for the oscillatory behavior of XBPs. No examples for oscillations in absence of field evolution have been found. This work is in collaboration with T. A. Schad, IRES student from NSO/University of Arizona.(See Fig. 1.10).

(R. Kariyappa & T. A. Schad)*

Flare productivity due to high sunspot rotation rates

Solar flares occur at varying rates over time. That is, the number of flares over a given period as also the flux emitted varies widely. The present work looks at the issue of numerical flare productivity. In a study carried involving 1131 events of solar Hα flare events, it was found that the number of flares that occur in a span of a day associated with a given

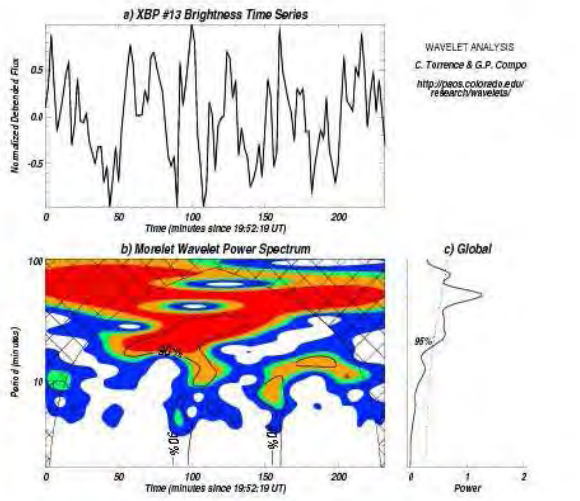

Figure 1.10: Wavelet analysis of the light curve of an X-ray Bright Point (XBP). Top panel: the normalized detrended light curve (solid) along with an exponentially decaying sinusoidal curve (dash-dotted) of a period of 22 minutes. Bottom left panel: wavelet power spectrum for the morelet wavelet transform analysis of the above time series. The cross-hatched region shows the cone-of-influence. Overplotted are contours of 90 % significance. Bottom right panel: global wavelet power spectrum with the dotted line showing the 95 % confidence level.

sunspot group decreases rather rapidly and reaches a near constant frequency of variation. It was found that the occurrence frequency of 5 flares or more, is nearly a constant (Fig. 1.11). The is defined as the flare productivity of a given active region. This is essentially a numerical flare productivity. In contrast, the flare productivity is defined elsewhere in terms of the strength of the flux emitted which is expressed in terms of the flare index. The difference between the two approaches is that the latter conveys the overwhelming weight of the strong flares such as X and M class flares while the former accounts for flares of all classes. The causes of such a phenomenon were then explored. It is well known that flares occur in association with sunspots and in particular, in association with various changes in the sunspots. Of particular interest are the sunspot motions. It is possible to view the rapid motions of sunspots as higher abnormal rotation rates. Therefore, rotation rates of sunspots were computed and it was found that sunspots with an abnormal rotation rate of about 4 – 10 deg/day (0.4 - 0.9 km/sec) trigger high flare productivity.(See Fig. 1.11).

(G. S. Suryanarayana)

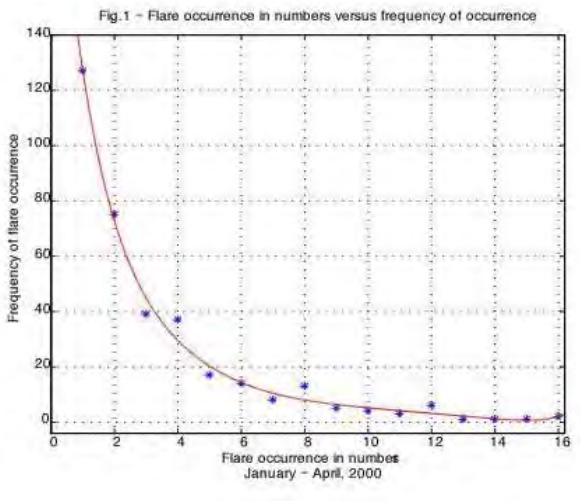

Figure 1.11: Number of flares occurred versus the frequency of occurrence.

Accelerating waves in polar coronal holes

Coronal holes are regions of cool and low density plasma which appears dark at coronal temperatures. Coronal hole regions contains a predominantly unipolar magnetic field which is believed to be responsible for the fast solar wind. MHD waves are important for heating of the solar corona and in acceleration of the fast solar wind. Extreme-ultraviolet images of polar coronal holes reveal the presence of diffuse, spike-like or sheet-like structures which are called as plumes whereas regions between these structures are termed as inter-plumes. Some of the studies have concluded that plumes have lower outflow speeds than inter-plume regions and, hence, may not contribute significantly to the fast solar wind, whereas some other theoretical and observational studies find higher outflow speeds in plumes than in inter-plume regions for at least some altitudes above the photosphere. These contradictory reports have led to a debate on whether plumes or inter-plumes are the preferred source regions for the acceleration of the fast solar wind.

Simultaneous time series data on 13 Nov. 2007 with the EIS/Hinode and SUMER/SoHO spectrometer in the north polar coronal hole region was obtained. From distance-time radiance maps, the presence of propagating waves in the inter-plume region with a period of 15 min to 20 min where propagation speed increases from (130 $\pm$ 14) km s^{-1} just above the limb, to (330 $\pm$ 140) km s^{-1} around 160$''$ above the limb (see Fig. 1.12) was detected. These waves

can be traced to originate from a bright region of the on-disk part of the coronal hole where the propagation speed is in the range of (25 $\pm$ 1.3) km s^{-1} to (38 $\pm$ 4.5) km s^{-1}, with the same periodicity (see Fig. 1.13). The adjacent plume region also shows the presence of propagating disturbance with the same range of periodicity but with propagation speeds in the range of (135 $\pm$ 18) km s^{-1} to (165 $\pm$ 43) km s^{-1} only. A comparison between the distance-time radiance map of both regions (see Fig. 1.12), indicate that the waves within the plumes are not observable (may be getting dissipated) far off-limb whereas this is not the case in the inter-plume region.

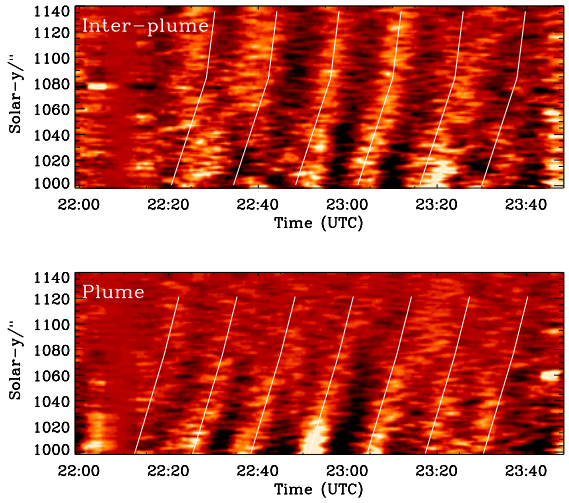

Figure 1.12: Enhanced x-t map of radiance variation along solar-Y with time as seen by EIS/Hinode for the regions as labelled.

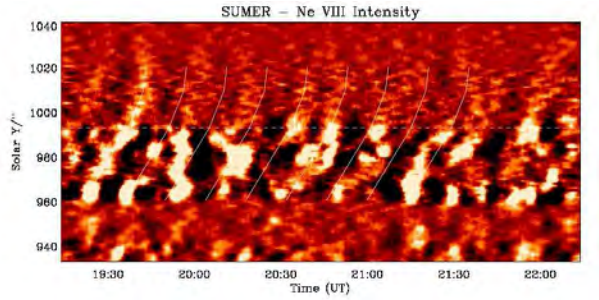

Figure 1.13: Enhanced x-t map of radiance variation along solar-Y with time, for on disk region as seen by SUMER/SoHO.

The propagation speed becomes supersonic ($\geq C_s \approx 150$ km s^{-1} for 1 MK corona) far off-limb in the inter-plume region. Moreover, near the limb region, these propagating disturbances are temperature independent. This, together with the presence of oscillations in Doppler width and shift, may suggest that these waves are Alfvénic in nature. Conversely, the measured propagation speeds are also consistent with the fast magnetoacoustic mode of propagation within the error bars of the propagation speeds and explains the observed radiance oscillations due to its compressible nature. Hence, interpretation of these propagating disturbances in terms of fast magnetoacoustic waves also appears reasonable. This may be the first time that a signature of accelerating Alfvénic waves or fast magnetoacoustic waves originating in an on-disk bright region has been observed within 1.2 R/R$_\odot$. These results also support the view that the inter-plume regions are the preferred channel for acceleration of the fast solar wind.

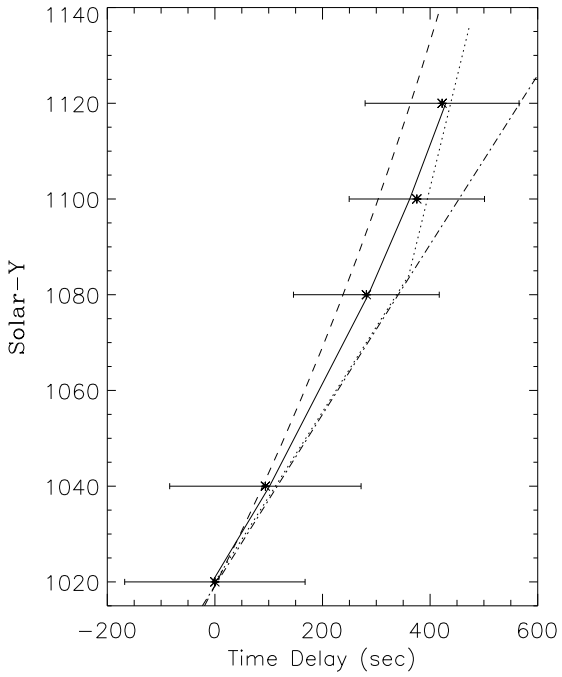

Figure 1.14: Variation of travel time with height in the inter-plume region. The asterisks represent the measured time delays while the continuous line corresponds to a second order polynomial fit applied to the data points. The dotted line corresponds to the fit to the slanted radiance ridges in the x-t maps (white lines of top panel of Fig. 1.12). The dashed and the dot-dashed lines are the theoretically predicted elfvénic time delays obtained assuming a magnetic field constant with height and expanding according to Kopp & Holzer (1976), respectively.

(D. Banerjee)

The intensity contrast of the EUV network

Intensity distributions of the EUV network and the cell interior in the solar atmosphere have been obtained in fourteen emission lines from Solar and Heliospheric Observatory (SOHO)/Coronal Diagnostic Spectrometer (CDS) observations. The formation temperature of the observed lines is in the range log T (T in Kelvin) = 4.90 - 6.06 and hence they represent increasing heights in the solar atmosphere from the upper chromosphere and the transition region to the low corona. Intensity distributions of the cell interior have been found to be different in the quiet Sun and the coronal hole even at the lower transition region, which is in variance with some earlier results. The intensity contrast of the network with respect to the cell interior has been obtained for each line and differences in the quiet Sun and the coronal hole have been examined. The network contrast, in general, is lower for the coronal hole as compared to the quiet Sun, but becomes equal in the upper transition region. The maximum contrast for both the regions is at about log T = 5.3. Also obtained are the relative contributions of the network and the cell interior to the total intensity. The results have some implications to the models of transition region.

(K. P. Raju)

The coronal green line profiles

The coronal green line profiles were obtained from Fabry-Perot interferometric observations of the solar corona during the total solar eclipse of 21 June 2001 from Lusaka, Zambia. The instrumental resolution is about 0.2 Å. About 100 line profiles were obtained within a radial range of 1.0 –1.5 $R_\odot$ and position angle coverage of about 200 deg. Intensity, line width, Doppler velocity, and centroid of the line profiles have been obtained. Preliminary analysis shows that i) line widths do not show any variation with radial distance, ii) line profiles show a pre-dominant blue asymmetry, and iii) Doppler velocities and centroids show increasing blueshifts with radial distance.

(K. P. Raju, T. Chandrasekhar)*

Seismology of sunspots in deep-focus and doub le-skip wave geometry

Work on disentangling 'surface magnetic effects' from any deeper residing structural changes beneath sunsp ots has been continued with substantial improvements over the author's earlier work and results. This work is based on a completely helioseismic diagnostics, i.e. observational approach, wherein a new set of time-distance helioseismic measurements designed to distinguish surface magnetic contributions from those due to deeper perturbations have been carried out. Using an appropriate surface magnetic field proxy, B_s, derived from magnetograms, the near-surface perturbations were contrasted with deeper ones. Possible signatures of an increased wave speed region extending down to at least about 10 - 11 Mm beneath the spot are shown. It is also shown that dominant influences of near-surface perturbations can either subdue or enhance signals from deeper regions depending on the way surface oscillation signals are used in measurements.

(S. P. Rajaguru)

Sunspot seismology: frequency dependence of travel times

Frequency dependence of mean travel times, i.e. average of travel times in opposite directions along a wave path, over a sunspot region, has been interpreted by previous researchers (e.g. Braun & Birch, 2006, ApJ, 647, L187) as an indication of perturbations largely confined to a region not deeper than a few Mm. Here the frequency variations of perturbations in in- and out-going wave travel times, $\delta\tau_{in}$ and $\delta\tau_{out}$, respectively are studied, over the active region NOAA 9787 (observed during 20 - 28 January, 2002) for a travel distance $\Delta = 50$ Mm (Fig. 1.15). For this Δ, since the diameter of the spot is about 38 Mm, all measurements over the umbral area have the distinction of 'source' (center) and 'receiver' (annuli) locations being inside and outside, respectively, and vice versa, but not both together within the spot.

Two noteworthy features concerning the sunspot - p mode interactions and sub-surface structure of sunspot perturbations have been identified in the frequency variations shown in (Fig. 1.15). (1) There is an asymmetry in the frequency dependence of $\delta\tau_{in}$ and $\delta\tau_{out}$: there is a marked depression in the variation of $\delta\tau_{out}$ in the frequency interval 3.5 - 4.5 mHz. Since a material flow would cause a symmetric and opposite change in in- and out-going times, the asymmetric (as a function of frequency) signals in travel time differences, $\delta\tau_{out}$-$\delta\tau_{in}$, are likely from some other physical causes; this is tentatively identified as a helioseismic signature of well observed p mode absorption of sunspots. (2) In comparison with those seen at smaller Δ, waves traveling larger distances (i.e. waves of smaller wavenumbers), and

hence deeper propagating ones, show smaller variation with frequency. This is consistent with the variation of mode mass with frequency, and hence with the interpretation that structural perturbations are largely confined to the near-surface layers.

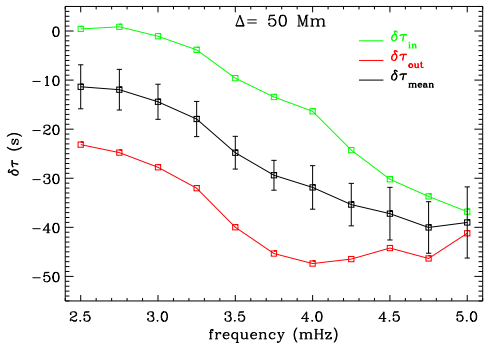

Figure 1.15: Frequency dependence of surface-focus travel times (one way and mean) for $\Delta = 50$ Mm measured over the active region NOAA 9787. The error bars represent standard deviations of travel time perturbations over the umbral pixels (for clarity, error bars are shown only for the mean travel times).

(S. P. Rajaguru)

A new approach to understanding growth and decay of sunspots

From the previous study (Hiremath 2009, arXiv:0909.4420; Hiremath 2010, Sun and Geosphere, Vol. 5, No.1, p.17-22) on genesis of solar cycle and activity phenomena, it is understood that sunspots are formed at different depths by superposition of Alfvén wave perturbations of the strong toroidal field structure in the convective envelope and after attaining a critical strength, due to buoyancy, raise towards the surface along the rotational isocontours that have positive (0.7-0.935 $R_\odot$) and negative (0.935-1.0 $R_\odot$) rotational gradients. Owing to physical conditions in these two rotational gradients, from the equation of magnetic induction, sunspot's area growth and decay problem is solved separately. It is found that the rate of growth of sunspot's area during its evolution at different depths is function of steady and fluctuating parts of Lorentzian force of the ambient medium, fluctuations in meridional flow velocity, radial variation of rotational gradient and $cot(\vartheta)$ (where ϑ is co-latitude). While rate of decay of sunspot's area at different depths during its evolution mainly depends upon magnetic diffusivity, rotational gradient and $sin^2(\vartheta)$. Gist of this study is that growth and decay of area of the sunspot mainly depends upon whether sunspot is originated in the region of either positive or negative rotational gradient.

On the surface, as fluctuating Lorentz forces and meridional flow velocity during sunspots' evolution are considerably negligible compared to steady parts, analytical solution for growth of sunspot area A is $A(t) = A_0 e^{(U_0 cot\vartheta)t/2}$ (where t is a time variable, A_0 is area of the sunspot during its initial appearance and U_0 is steady part of meridional flow velocity on the surface). Similarly analytical solution for decay of sunspot's area follows the relation $A(t) = C_1 e^{-(\frac{\Omega_0^2 R_\odot^2 sin^2\theta}{\eta})t} + C_2$ (where C_1 and C_2 are the integrational constants, $R_\odot$ is radius of the sun, Ω_0 steady part of angular velocity and η is the magnetic diffusivity). For different latitudes and life spans of the sunspots on the surface during their evolutionary history, both the analytically derived theoretical area growth and decay curves match reasonably well with the observed area growth and decay curves.

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

Dynamic and magnetic evolution of sunspots from the Hinode data

Hinode SOT/SP images are used for the measurements of evolutionary strengths of magnetic and dynamic structures (with their angle of inclination) of umbra, penumbra and the whole spot. Details of these results, especially comparison of observed evolution of average Evershed flow velocity field structure of sunspots with the modeled (Gokhale & Hiremath, 1986, Advance Space Res., 6, 47) Evershed flow velocity field structure are compared. Although measured spatial Evershed flow structure is same as the measured spatial structure in the previous studies, signs of the velocity flow in eastern and western parts of penumbra reverse during it's life span. It is found that on average umbra and penumbra regions experience nearly equal and opposite dynamic forces during the life span of a spot as predicted by Gokhale and Hiremath's Evershed flow model. This study is in progress.

(K. M. Hiremath, Lites, B. W & R. Mandal*)*

Tilt angle of the bipolar spots during their initial appearance

Evolutionary physical properties of the sunspots on the surface are supposed to be indicators of sub-

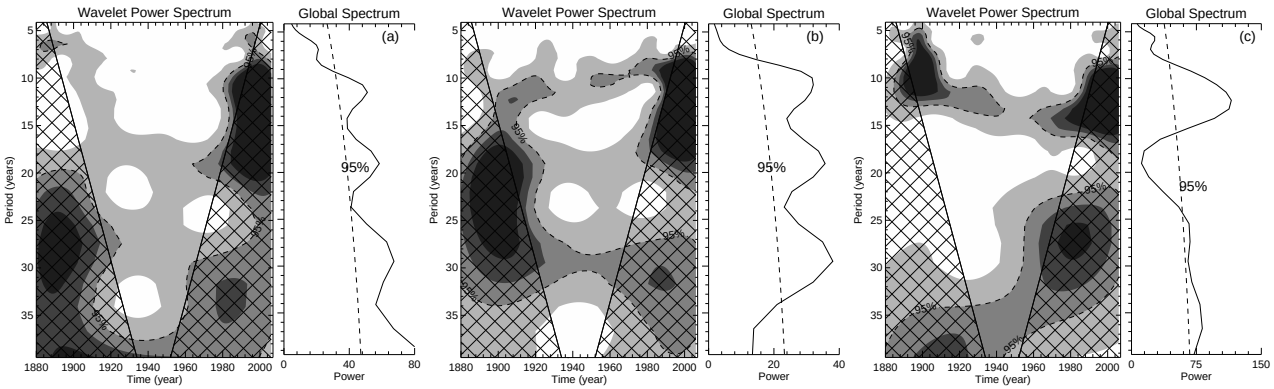

Figure 1.16: Morlet wavelet power spectra and the global spectra of the mean meridional motion of the sunspot groups in the different 10° latitude intervals (a) 0° – 10°, (b) 10° – 20°, and (c) 20° – 30°, of the Sun's northern hemisphere, determined from the 4-year MTIs time series. The wavelet spectra are normalized by the variances of the corresponding time series. The shadings are at the normalized variances of 1.0, 3.0, 4.5, and 6.0. The dashed curves represent the 95% confidence levels, deduced by assuming a white noise process. The cross-hatched regions indicate the "cone of influence", where edge effects become significant.

surface dynamics, thermal and magnetic field structures of the solar convective envelope. For example, from the analysis of more than hundred years of sunspot data from the Greenwich photoheliographic results, Hiremath (A& A, 386, 674, 2002 and references therein) concluded that, for different life spans (that anchor at different depths), variation of rotation rates of the sunspot groups during their initial appearance on the surface is almost similar to the radial variation of angular velocity of the convective envelope. Using SOHO/MDI magnetograms and continuum images, it is possible to estimate strengths of magnetic structure of the sunspots (Hiremath & Lovely ApJ, 667, 58, 2007; Lovely, Ph.D. thesis, 2010) at different anchoring depths and to infer preliminary information on the thermal stratification (Hiremath & Akshatha 2010, in Proc. *Magnetic Coupling between the Interior and Atmosphere of the Sun*, Eds S.S. Hasan & R.J.Rutten, Springer-Verlag, p.421) of the convective envelope. In the present study, by using three years of SOHO/MDI magnetograms, tilt angle, magnetic fluxes of the leader and the follower and their separation distance of the bipolar sunspots during their initial appearance on the surface are measured. Irrespective of their latitude and area, preliminary results show that, tilt angle of the bipolar spots varies with different life spans giving a clue to radial variation of angular velocity and strength of magnetic field structure of the convective envelope.

(K. M. Hiremath, S. B. Gudennavar, S. Sultana*, & D. Paul*)*

Periodicities in the solar meridional flow

The motions of many magnetic tracers, particularly sunspots, have been used for a long time as a proxy of the fluid motions to study the solar rotational and the meridional flows. The Greenwich sunspot group data (1874 – 1976) were compiled from the majority of the white light photographs, which were secured at the Royal Greenwich Observatory and at the Royal Observatory, Cape of Good Hope. The gaps in their observations were filled with photographs from other observatories, including the Kodaikanal Observatory, India. The Solar Optical Observation Network (SOON) sunspot group data (1977 to present) included measurements made by the United States Air Force (USAF) from the sunspot drawings of a network of the observatories that includes telescopes in Boulder, Colorado, Hawaii, etc. David Hathaway scrutinized the Greenwich and SOON data and produced a reliable continuous data series from 1874 up to now (See `http://solarscience.msfc.nasa.gov/greenwch.shtml`). Earlier, based on a preliminary analysis of this data (1979 – 2008), it was found that the mean meridional motion of the spot groups varies considerably on a timescale of about 5 – 20 years. An extended and detailed analysis of these data was done. The variations in the mean meridional motion of the sunspot groups in the Sun's whole northern and southern hemispheres and also in different 10° latitude intervals were determined. The variations are determined from the yearly data and for the sake of better statistics by binning the data into 3 – 4 year moving time intervals (MTIs) successively shifted by

one year.The periodicities in the mean meridional motion are determined from the fast Fourier transform (FFT) power spectrum analysis. The values of the periodicities are determined from the maximum entropy method (MEM) and the temporal dependencies of the periodicities are determined from the Morlet-wavelet analyses. It was found that: there exist ≈ 3.2- and ≈ 4.3-year periodicities in the mean meridional motion of the spot groups in the southern hemisphere, a 13 – 16 year periodicity in the mean meridional motion of the northern hemisphere, and approximate 12- and 22-year periodicities in the north-south difference (north-south asymmetry) of the mean motion. It was also found that there is a considerable latitude-time dependence in the periodicities of the mean meridional motion of the spot groups. That is, it was found that in the 10° – 20° latitude-interval of the northern hemisphere, a periodicity slowly evolved from ≈ 16 year to ≈ 10 year, over the period 1880 – 2007, and it evolved in the opposite way, ≈ 10 year to ≈ 16 year, in 20° – 30° latitude interval as seen (See Fig. 1.16). Such a latitude-time dependency does not exist in the mean merdional motion of the spot groups in the southern hemisphere. These results were published in A&A, 2010, 509, A30.

(J. Javaraiah)

Long-term variations in the growth and decay rates of sunspot groups

Magnetic flux may emerge from near the base of convection zone (where the dynamo process is believed to be taking place) to the surface and forms sunspots and other active phenomena.The area of a spot (or spot group) is closely connected with the magnetic flux of the spot (or spot group) (130 mh area ≈ 10^{22} Mx magnetic flux). The studies of growth and decay of sunspots or sunspot groups are important for understanding geometry and topology of the magnetic structure on the solar surface, and to find the underlying mechanism of solar activity and its variability. The combined Greenwich and SOON sunspot group data during the period 1879 – 2009 were analysed and it was found that: Both the average values (over the period 1874 – 2009) of the growth rate (area increase per day) and the maximum amplitude of its variation are about 70% more than that of corresponding parameters of the decay rate (area decrease per day). (Note: the data correspond to the days during the life times of the spot groups in which the area increased and decreased are treated separately.) The growth rate varies by about

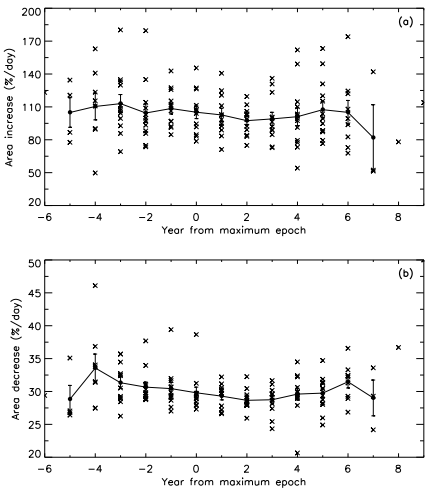

Figure 1.17: Plots of the yearly mean values of the mean growth rate (upper panel) and the decay rate (lower panel) verses the year of the solar cycles. The filled-circle-continuous curve represents the mean solar cycle variation determined from the yearly mean values. The error bar represents the standard error. There is only one data point at years -6 (beginning of cycle 14), 8 (end of cycle 23) and 9 (may be beginning of cycle 24).

35% on a 60-year timescale, whereas the decay rate varies by about 13% on a similar timescale. Near the end of the current cycle (near minimum 2007 – 2008) the growth rate is lowest in the past about 100 years, whereas near the beginning of cycle 24 the decay rate is largest. The strength of the known approximate 33 – 44 year modulation in the solar activity is related to the strength of the north-south asymmetry in the growth rate during the 11-year solar cycles that comprised by the 33 – 44 year cycle in activity. During an average duration solar cycle (11 years duration with 4 – 5 years rise time and 6 – 7 years decline time), the decay rate varies as: slowly decreases from the beginning of the cycle, reaches minimum at 1 – 2 years after the maximum epoch, and then increases up to near the end of the cycle (see lower panel of Fig. 1.17). The solar cycle pattern of the growth rate is not well defined as that of the decay rate.

(J. Javaraiah)

Dynamic responses of sunspots to ambient magnetic field configuration

It emerged earlier from our detailed study in a revisit to the classic Wilson Effect that single isolated sunspots which are present in active regions, and are predominantly of unipolar magnetic field configura-

tion, display the Wilson Effect. The effect manifests itself in the width of the penumbra on the disk-centre side decreasing more rapidly than the width on the limb-ward side, as the spot approaches the limb. It was also found that sunspots present in active regions of strong bipolarity appeared to display no Wilson Effect while those in regions of highly mixed bipolarity, especially those associated with emerging flux regions displayed an inverse effect.

Further, a large number of sunspots of various magnetic configuration types were examined during their disk-passages, using the high resolution digitized photoheliogram data of the Kodaikanal Observatory. It was found that the physical properties of sunspots, especially the morphological parameters such as the ratio of the area of penumbra to that of the umbra, show a clear dependence on the magnetic type of the spot. Details of this and other related properties of penumbrae are being studied.

(S. P. Bagare)

Spectroscopic investigations of molecular lines in sunspot umbrae

Work continued on the investigation of high resolution Fourier Transform Spectra of sunspot umbrae, in order to identify and confirm the presence of many diatoms and to estimate the related effective temperatures in the umbral atmosphere. Our earlier work had shown that effective temperatures lower than known before are observed, under 2000 K through studies of select molecular bands such as AlF, results for which were reported by the authors earlier. Similar results are found for molecules BF & BS, for several band systems were studied recently. The sunspot atmosphere thus shows a wide range of effective temperatures with a minimum cited above and a maximum of around 4800 K for TiO. While the atomic lines and the molecules yielding high effective temperatures are identified in the FT Spectra of the so called 'hot' umbrae, the species appearing at low effective temperatures dominate the spectra of so called 'cold' umbrae.

Identification of spectral features, and therefore the confirmation of presence of related species was carried out for molecules CrH, CrD, and BH, in addition to those discussed above. The effective temperatures were also estimated using observations of several lines in the band spectra for these molecules.

(S. P. Bagare, P. Sriramachandran, N. Rajamanic kam*)*

Spectropolarimetry of an active region at the photosphere and chromosphere

Initial results on the simultaneous spectropolarimetric observations of an active region at the photosphere and chromosphere were obtained. For this purpose, the Fe I line at λ 6569 and the H I at λ 6563 (H α) were used. Stratification of the line-of-sight (LOS) velocity and magnetic fields above an active region were discussed. The LOS magnetic field strengths were derived using the center-of-gravity (COG) method and the LOS velocity gradients were derived using the bisector technique. From this analysis it was found that both the velocity and magnetic gradients are larger in the umbral region above the sunspot compared to the penumbral region. And the magnetic field strength decreases much faster with height in the umbral region compared to the penumbral region. Upflows with larger LOS velocity gradients are located in the regions where stronger photospheric fields are observed.

(K. Nagaraju, K. Sankarasubramanian & K. E. Rangarajan)*

Estimation of magnetic field in the solar corona streamers through low frequency radio observations

Magnetic fields play an important role in the dynamics as well as the formation of the structures in the solar corona. The existing direct estimates using optical/infrared and radio emissions are limited to the inner corona (radial distance, r $<$ 1.2 solar radii). In the outer corona beyond r $>$ 3 solar radii, Faraday rotation observations are used to derive the magnetic field. But due to lack of observational techniques, measurements in the range 1.2 – 3 solar radii (middle corona) are not available until now. As the photosphere, chromosphere, and corona are coupled by the solar magnetic field, the magnetic field strength at these distances is generally obtained by mathematical extrapolation of the observed line-of-sight component of the photospheric magnetic field assuming a potential or force-free model. In this work, we have extended the radio methods of coronal magnetic field measurements in the inner corona at microwave frequencies ($\sim$ GHz) through Bremsstrahlung emission to r = 1.7 and 1.5 solar radii in the middle solar corona. The above distances correspond to the plasma levels of enhanced emission in the coronal streamers at 77 and 109 MHz. The data for the present work were obtained on 30 January 2007 and

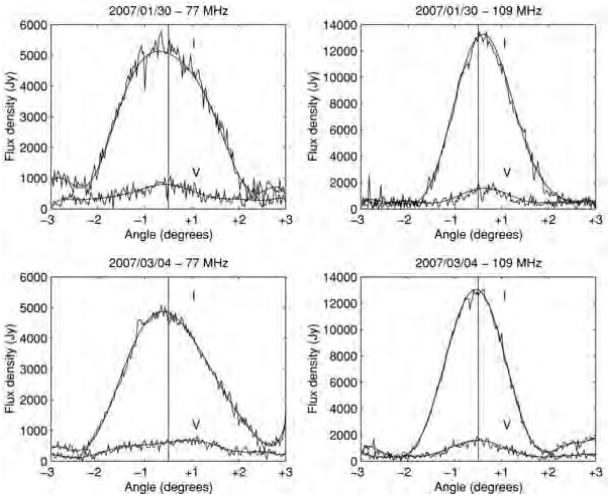

Figure 1.18: One-dimensional observations of Stokes I and V emission from the Sun (around its transit over the local meridian at Gauribidanur) on 2007 January 30 and March 4 at 77 and 109 MHz. The integration time is 0.5 sec. The solid lines plotted on top of the observed data in each panel represent the best fit to the corresponding profiles. The vertical line represents the transit of the Sun over the local meridian at Gauribidanur. The asymmetry in the observed pattern w.r.t. the transit is due to the phase errors between the antennas in the polarimeter array.

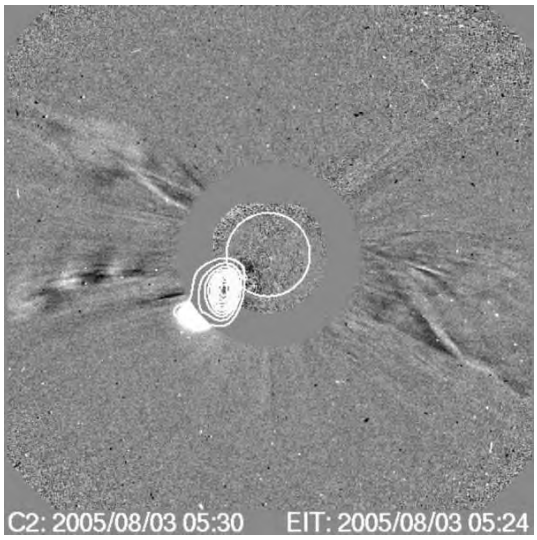

Figure 1.19: Composite of the radioheliogram of the type II burst observed on 3 August 2005 with the Gauribidanur radioheliograph at 109 MHz, and the associated SoHO-LASCO C2 + SoHO-EIT 195 difference image. The dimming close to the southeast limb in the EIT image is the flare location. The intense discrete radio source located between the CME in white light, and the solar limb corresponds to a type II burst. It was observed at r = 1.3 solar radii around 05:08 UT, about 22 minutes before the first appearance of the white light CME at r = 2.71 solar radii in the LASCO field of view.

4 March 2007 with the radio polarimeter at the Gauribidanur observatory. The estimated values of the field at r = 1.7 and 1.5 solar radii are 5 ± 1 G and 6 ± 2 G, respectively.

(R. Ramesh, C. Kathiravan & Ch. V. Sastry)*

Radioheliograph observations of metric type II bursts and the kinematics of coronal mass ejections

Solar type II radio bursts are the signatures of magnetohydrodynamic (MHD) shocks propagating outward through the solar atmosphere. They occur frequently as two relatively slow drifting emission bands (fundamental (F) and harmonic (H)) with a frequency ratio of approximately 1:2. Their drift (typically 0.5 MHz/s), from high to low frequencies, results from the decrease of plasma density with distance in the solar atmosphere. Coronal mass ejections (CMEs), flares, expanding soft X-ray features, coronal waves, small-scale ejecta like sprays, soft X-ray jets, and plasmoids, erupting loops have all been proposed as likely candidates for the driver of MHD shocks leading to metric type II bursts. The metric type II bursts typically occur in the radial distance range 1–2 solar radii. It is difficult to observe CMEs in white light and estimate their speed/acceleration in this distance range due to observational constraints. Since metric type II bursts are considered to be one of the earliest signatures of shocks in the solar corona, the kinematics of the CMEs in the above distance range was investigated with the Gauribidanur radioheliograph data. The estimated acceleration values from the CME source region up to the position of the type II burst are in the range 600-1240 m/s^2 it was also found that: (1) CMEs with comparatively larger acceleration in the low corona are associated with soft X-ray flares of higher energy; the typical acceleration of a CME associated with X1.0 class soft X-ray flare being 1020 m/s^2, and (2) CMEs with comparatively higher speed in the low corona slow down quickly at large distances from the Sun–the deceleration of a CME with a typical speed of 1000 km/s being about -15 m/s^2 in the distance range of 3 – 32 solar radii.

(R. Ramesh, C. Kathiravan, S. S. Kartha & N. Gopalswamy)*

Probing the solar cycle using the Almahata Sitta meteorite

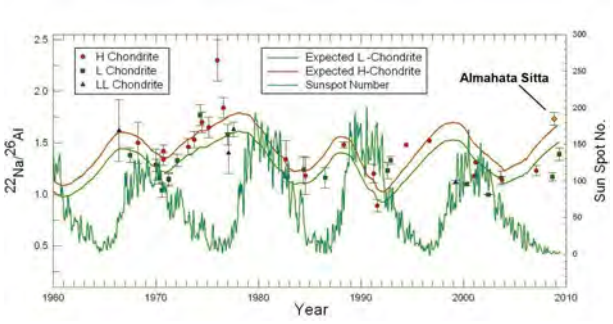

Figure 1.20: ^{22}Na/^{26}Al activity ratio in Almahata Sitta together with those measured in meteorites which fell during the last four solar cycles. For comparison, the sunspot number series is also shown, which indicates a phase difference of one to two years between sunspot cycle and ^{22}Na production.

Asteroid 2008 TC3 fell in Sudan on 7 October 2008. Two months later, 15 meteorites were recovered, 11 of which were classified as polymict ureilites. Only three were larger than 40 grams. Of the three largest samples, 75 gram sample no. 15 was the only ureilite. Based on photometry of the asteroid and the albedo of the recovered meteorites known as Almahata Sitta (AS), the radial size of the asteroid was estimated to be about 1.5 - 2 m. Six gamma emitting radionuclides in sample no. 15 (^{46}Sc, ^{57}Co, ^{54}Mn, ^{22}Na, ^{26}Al, and ^{60}Co) were measured by non-destructive whole rock counting using a sensitive gamma-ray spectrometer at Mounte dei Cappuccinin at Torino, Italy. Cosmic rays (CR) produce a large number of radioactive and stable isotopes in meteoroids while they are exposed in the interplanetary space before they fall on the Earth when the CR irradiation ceases. Study of cosmogenic radionuclides can be used to infer the cosmic ray flux in the orbital space of the meteoroid as well as the depth of the measured fragment within the meteoroid. Considering that the orbit of the meteoroid is known to have low inclination (i = 2.54^o) and apogee in the inner asteroidal belt (a = 1.308 AU) it monitored the cosmic rays in the near-earth space. Since it should be useful to get some information about the cosmic ray flux at the time of the unusual prolonged solar minimum before the 24th sunspot cycle, it was decided to measure the radioactivity due to some gamma emitting radionuclides. Telescopic observations of the meteoroid orbit indicate that the meteoroid crossed the earth orbit as it was approaching its perihelion, 45 days before it would have been at perigee (0.899 AU) on 20 November 2008. The entry in the Earth's atmosphere was at a grazing angle of 20^o) with velocity of 12.4 km/s. The activities of ^{60}Co, produced mainly by neutron capture in cobalt, and of ^{26}Al indicate that fragment no. 15 was located at a depth within 35 and 50 cm inside the 1.5 – 2 m radius asteroid 2008 TC3. The activity of other radionuclides, too, point to a location close to the surface of the asteroid. The ^{22}Na/^{26}Al activity ratio is higher than expected for the average cosmic ray flux, probably due to the unusually prolonged solar minimum before the fall. High ^{2}2Na activity as well as the activity ratio ^{22}Na/^{26}Al of 1.7 is consistent with unusually long sunspot minimum before the fall of Almahata Sitta as shown in (Fig. 1.20). The prolonged solar minimum during 2001-2008 however did not result in any unusually large cosmic ray flux in the near-earth space sampled by the AS ureilite.

(N. Sinha, C. Taricco, N. Bhandari* & P. Colombetti*)*

1.2 Stellar and Galactic Astrophysics

Triggered star formation in bright-rimmed clouds

The young stellar population in and around SFO 38, one of the massive bright-rimmed globules located in the northern part of the Galactic H II region IC 1396, has been studied using the Spitzer IRAC and MIPS observations (3.6–24 μm), and followed up with ground-based optical photometric and spectroscopic observations. Based on the IRAC and MIPS colours and Hα emission, 45 young stellar objects (Classes 0/I/II) and 13 probable pre-mainsequence candidates were identified. Spectral types (mostly K- and M-type stars), effective temperatures, and individual extinction values for the relatively bright and optically visible Class II objects were derived. Most of the Class II objects show variable Hα emission as well as optical and near-infrared photometric variability, which confirm their "youth". Based on optical photometry and theoretical isochrones, the spread in stellar ages is estimated to be between one and eight Myr with a median age of three Myr and a mass distribution of 0.3 – 2.2 $M_\odot$ with a median value around 0.5 $M_\odot$. An enhanced concentration of YSOs closer to the southern rim of SFO 38 and an evolutionary sequence of YSOs from the rim to the dense core of the cloud, with most of the Class II objects located at the bright rim, is found. The YSOs appear to be aligned along two different directions toward the O6.5V type star HD 206267 and the B0V type star HD 206773. This is consistent with the Radiation Driven Implosion (RDI) model for triggered star formation.

(H. C. Bhatt, R. Choudhury & B. Mookerjea)*

Theory of star formation

Two of the outstanding problems before the theory of star-formation viz. (i) understanding the formation of prestellar cores, and (ii) the relationship between stellar initial mass function (IMF) and the dense core mass function (CMF) have been investigated over the said period. Besides, exploratory work is underway on the following: (a) the preferential formation of massive clumps via fragmentation of dense shells, driven by ionising winds from early type massive stars and/or blast waves due to supernovae, and (b) generation molecular outflows from young stellar objects (YSOs) is currently underway.

The formation of prestellar cores: While the evolution of prestellar cores has received unabridged attention from the star-formation community, a study of the formation of prestellar cores has been somewhat restricted. Star forming clouds, as revealed in various infrared bands, often appear filamentary, and stellar wombs seem to be embedded in these filaments. Such wombs, also called prestellar cores, could spawn massive star clusters.

The problem of core formation is therefore bifold: (a) the formation of dense filaments, and (b) the formation of putative star forming cores within these filaments, thus, demands explanation. Using the smoothed particle hydrodynamics (SPH), the hypothesis of structure formation via fragmentation of pressure confined gas slabs was examined. Such slabs could possibly form out of a collision between molecular clouds, or massive streams of gas in the interstellar medium (ISM), scenarios supported by the turbulent nature of the ISM. The proposition that an interplay between various dynamical instabilities within the post-collision slab could possibly fragment it, and that mechanism is a rather propitious mode for clump, and filament formation, was numerically tested. A distinct advantage of this model is its relative independence of an external seed of turbulence. Perturbations within the slab layers arise out of random gas motion in it, and the timescale of fragmentation is of the order of the sound-crossing time for the confined slab. An extension of the same problem is an investigation of the stability of the bow-shock, a curved shock-front. It was shown that the qualitative behaviour of a bow-shock is similar to that of the pressure-confined planar slab, the length of the fastest growing unstable mode has been calculated using a simple perturbative analysis of the equation of motion for the bow-shock.

In another related work, the dynamical response of a molecular cloud to the impact of a weak interstellar shock was studied. Such a shock could originate from a supernova going off in the vicinity of the cloud or due to a strong ionising radiation originating from a nearby star cluster or a massive young star. The impact of the shock-induced turbulent motion within the cloud generates substructure in its interior. This is evident from the occurrence of filamentary structure within the cloud, as shown in the rendered density plot in Fig. 1.21. The volume filling factor of the density structure, i.e. the fraction of total gas within the cloud that ends up in contiguous structure, has been estimated to about 10%, consistent with that reported via detailed observations of clouds in the ISM. This work re-emphasises the importance of in-

terstellar shocks in the formation of dense regions that could possibly spawn stars.

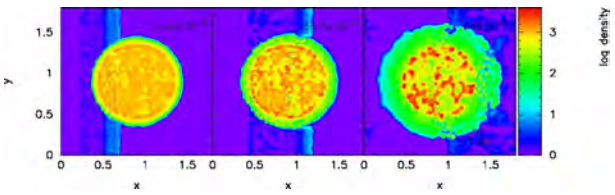

Figure 1.21: Montage showing rendered density plots of a shocked molecular cloud. The resulting filamentary structure can be easily seen.

(S. Anathpindika)

IMF and high mass star formation

There has been considerable interest in the contemporary star-formation community to explore the relationship between the distribution of core masses and the stellar masses, respectively the core mass function (CMF) and the stellar initial mass function (IMF). The similarity in the forms of the two distributions has seen growing support in favour of the proposition that, the CMF could possibly be the progenitor of the stellar IMF. Using a Monte-Carlo simulation, supported by semi-analytic arguments, it was shown that it is indeed plausible to arrive at the canonical IMF starting from a field CMF. With a randomly picked sample of 14,000 cores having masses ranging from 0.1 $M_{\odot}$ to 10 $M_{\odot}$, distributed according to a predefined CMF, a sample of $\sim$105,000 stars was obtained, whose masses were derived for different choices of core temperatures varying between 7K to 20 K. An interesting feature of this result lies in the prediction of Brown dwarfs, as small as $\sim$ 0.02 $M_{\odot}$, despite the relatively naive treatment.(See Figs 1.22, Figs 1.23).

(S. Anathpindika)

Fragmentation of shells and formation of massive clumps

A semi-analytic treatment of the stability of thin, dense shells driven by powerful winds and/or blast waves suggests that the resulting fragments are likely to be massive, of the order of a several hundred $M_{\odot}$. This is consistent with, for instance, the mass of a dense clump located in the HII shell N49. This work suggests that fragmentation of such shells is a propitious mode of forming massive clumps that could

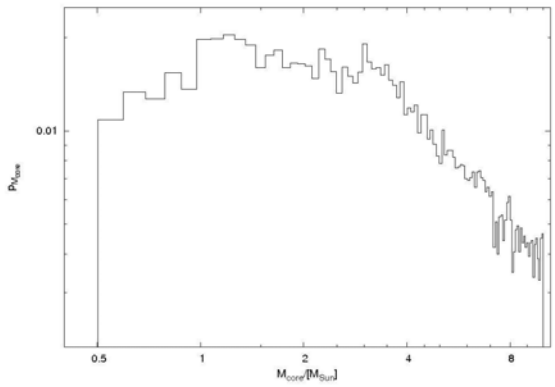

Figure 1.22: The histogram plotted on a logarithmic scale shows the initial distribution of prestellar cores, the one for cores in the Orion nebula, used as a specimen in our work.

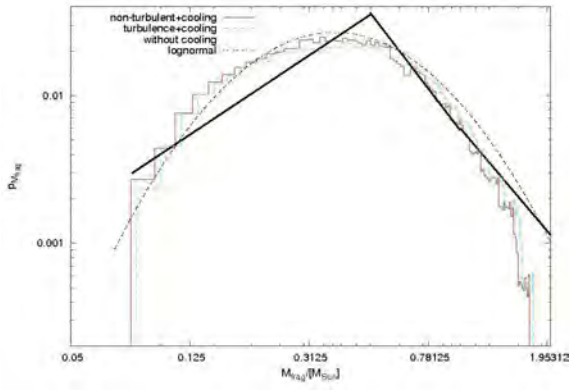

Figure 1.23: Starting with an initial population of cores shown in Fig. (1.22) above, the derived mass distribution for fragments has been plotted for three realisations. The universal IMF, and a lognormal fit to the derived distribution has also been plotted for comparison purposes.

possibly spawn star-clusters. (See Fig 1.24)

(S. Anathpindika)

The V711 Tau binary system

V711 Tau (HR 1099) is one of the bright members of the RS Canum Venaticorum binaries, and it has been the object of several photometric and spectroscopic studies since the discovery of its light variability in 1975. It is a non-eclipsing, double-lined spectroscopic binary with a K0–K1 subgiant as primary and a G5 dwarf as secondary in an almost circular orbit. This object has been in the photometric programme almost continuously since 1979, but for a break during 1995–2000. In the top panel of

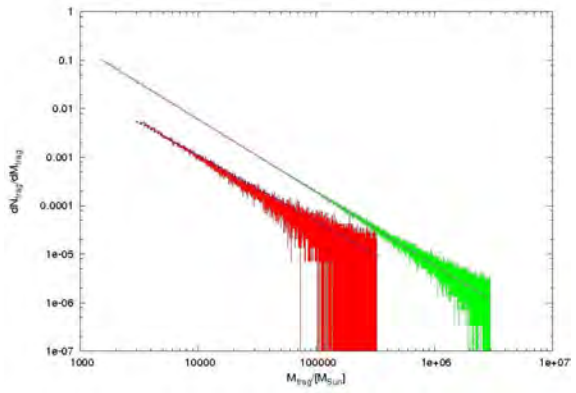

Figure 1.24: The clump mass spectrum generated using a semi-analytic scheme. The green spectrum for a typical O5 star peaks at $\sim 10^3$ $M_\odot$; the peak shifts a little rightward, closer to $\sim 10^4 M_\odot$ for an O9 star that is much cooler (red histogram). Formation of massive clumps $\gtrsim 10^6$ $M_\odot$ is possible, though only sparingly. A power-law fit of the type $\frac{dN}{dM_{clump}} \propto M_{clump}^{-\beta}$ agrees reasonably well with the derived spectrum.

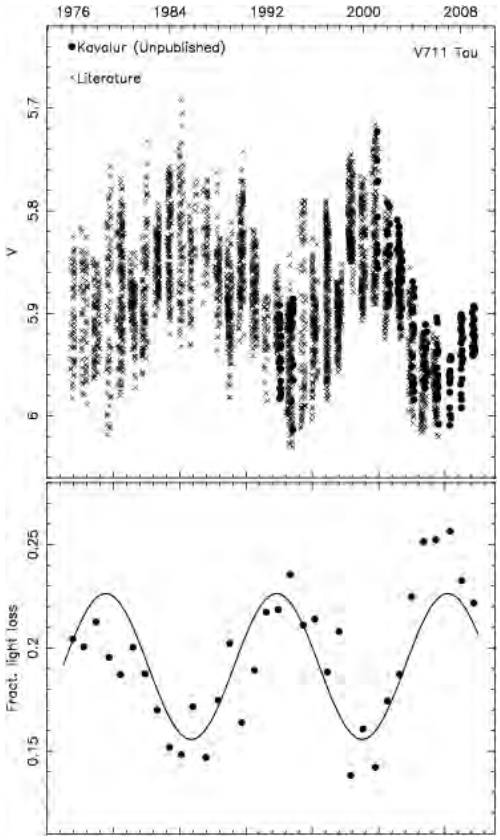

Figure 1.25: *Top panel*: Plot of the V mag of V711 Tau against the corresponding Julian day of observation. The contribution by the faint visual companion was removed from the observed brightness. Literature values include the V band data obtained at Kavalur before 1993. *Bottom panel*: Plot of fractional loss of light over a photometric cycle against the corresponding mean epoch of observations. The continuous line represents a least square sinusoidal fit to the data; the time of maximum and period are JD 2448925 and 5155-d, respectively.

Fig. 1.25 are plotted all the differential V magnitudes of V711 Tau available from 1975 – 2009. The contribution of the visual companion was removed from the differential magnitudes using $V = 8.83$ mag for it before plotting in the figure. Photometry obtained during recent observing seasons at Kavalur shows that the mean brightness of V711 Tau is in a recovery phase from a deep minimum, indicating a continuous reduction in its spot activity observed during the previous seasons. The figure clearly shows that the mean brightness of V711 Tau has a long-term modulation, indicating a corresponding long-term modulation in the spot activity. The fractional light-loss over a photometric cycle was derived during each observing season from the corresponding light curve and the results are plotted in the bottom panel of Fig. 1.25 ; all the available observations during a particular season were used in the computation of the light-loss over a photometric cycle during that season. The $V = 5.65$ mag of V711 Tau observed in 1985 is the brightest so far observed, which is assumed to correspond to its unspotted brightness. The variation in fractional light-loss, and hence, in spot area over the surface of the star, seems to be more of cyclic than of strictly periodic in nature. The available data base-line is not large enough in comparison with the timescales involved in the variation to make any conclusive remarks. So far only two minima and three maxima of the spot activity cycle have been observed. The fractional light-losses observed at the two minima are not very much different, while those at the maxima suggest the possibility of the presence of a long-term modulation. It may be noted that even at the minimum spot activity a substantial fraction of the stellar surface is covered by spots. An average period of 14.1±0.3 yr satisfies the observed variation in light-loss.

The orbital period of V711 Tau is known to vary, but the exact nature of the variation is not established. The last set of radial velocity observations available in the literature is that obtained around the epoch 2001.99. V711 Tau was included in the spectroscopic programme at VBT in 2008 to systematically monitor the variations in its orbital period. The star has earlier spectroscopic observations at several epochs since 2004. The radial velocities of the G-type secondary component of the V711 Tau binary

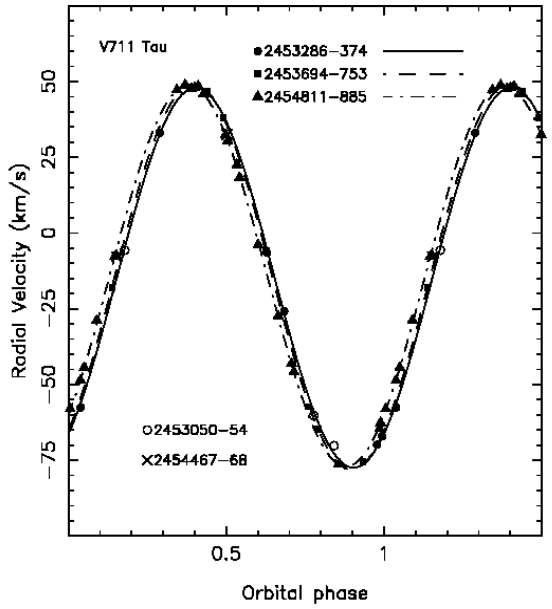

Figure 1.26: Radial velocity curves of the G-type component in V711 Tau binary. The orbital phases were computed using the ephemeris JD = 2442763.952 + 2^{d}.83774 E. The dIfferent symbols correspond to observations obtained at different epochs.

system measured from 42 high resolution spectra obtained at VBT are plotted in Fig. 1.26 after converting the Julian dates of observation to orbital phases. There is a clear systematic shift in the velocity curve towards shorter orbital phases with time, indicating that the above assumed period is slightly longer than the actual orbital period.

(S. Muneer, K. Jayakumar, M. J. Rosario, A. V. Raveendran & M. V. Mekkaden)

Spectroscopic exploration of A-F type post-AGB candidates

Abundance analysis has been done for a sample of nine post-asymptotic giant branch (AGB) candidate stars, eight of which have not been explored before. Four very promising objects were found, *viz*., . HD105262, HD53300 and CpD-62^{o} 5428. Strong evidence of dust-gas separation through selective depletion of refractive elements was found in HD105262, HD53300, CpD-62^{o} 5428 and HD114855 although abundance peculiarities are relatively smaller for the last two stars. Strong enrichment of nitrogen for HD725, HD842, HD1457, HD9233 and HD61227 was found but no further evidence was found to support their post-AGB nature. The observed [N/C] ratios of these stars were compared with the predictions of evolutionary models which include the rotation-induced mixing.

(S. Giridhar, R. Molina, A. A. Ferro* & G. Selva kumar*)*

CCD photometry of variable stars in Globular cluster NGC 5053

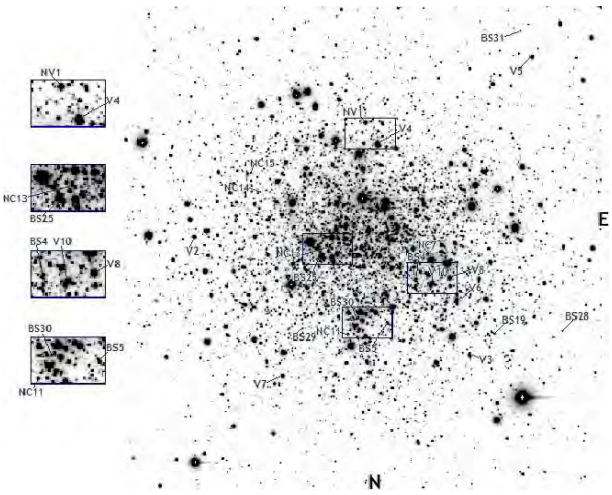

Figure 1.27: V image of NGC 5053 obtained from the 2m HCT, IAO, Hanle, India. All RR Lyrae stars are identified with prefix V, Blue Stragglers with prefix BS or NC. Blown up stamps are included for easy identification (source: A. A. Ferro et al. 2010, MNRAS 402, 226.)

The results of CCD V, r and I time-series photometry of the globular cluster NGC 5053 are reported. (See Fig. 1.27). New times of maximum light are given for eight known RR Lyrae stars in the field of the images, and their periods are revised. Their V light curves were Fourier decomposed to estimate their physical parameters. A discussion on the accuracy of the Fourier-based iron abundances, temperatures, masses and radii is given. New periods are found for the five known SX Phe stars, and a critical discussion of their secular period changes is offered. The mean iron abundance for the RR Lyrae stars is found to be [Fe/H] $\sim$ -1.97 $\pm$ 0.16 and lower values are not supported by the present analysis. The absolute magnitude calibrations of the RR Lyrae stars yield an average true distance modulus of 16.12 $\pm$ 0.04 or a distance of 16.7 $\pm$ 0.3 kpc. Comparison of the observational colour magnitude diagram (CMD) with theoretical isochrones indicates an age of 12.5 $\pm$ 2.0 Gyr for the cluster. A careful identification of all reported blue stragglers (BS) and their V, I magni-

tudes leads to the conclusion that BS12, BS22, BS23 and BS24 are not BS. On the other hand, three new BS are reported. Variability was found in seven BS, very likely of the SX Phe type in five of them, and in one red giant star. The new SX Phe stars follow established period-luminosity relationships and indicate a distance in agreement with the distance from the RR Lyrae stars.

(A. A. Ferro, S. Giridhar & D. M. Bramich*)*

Extreme helium stars: Non-LTE abundance analyses

The hydrogen deficient sub-class, the extreme helium (EHe) stars, overlap the hotter R Coronae Borealis (RCB) stars in effective temperature. Based on the luminosity and the effective temperature, an evolutionary link is suggested between EHes and RCBs. Photospheric abundances of these two sub-classes were compared to test this link. It emerged that the knowledge of neon abundances in these stars may provide clues.

The LTE neon abundances of RCBs were estimated and compared with that of EHes to test this evolutionary link. However, the neon abundances suggest departures from LTE. Hence, non-LTE and LTE stellar model atmospheres were computed. These model atmospheres were combined with the radiative transfer code to derive the elemental abundances from the measured equivalent widths of the observed spectrum. This work includes observations from VBT India, McD USA, and CTIO Chile.

(G. Pandey & D. L. Lambert)*

R Coronae Borealis stars: $^{12}C/^{13}C$ ratios

$^{12}C/^{13}C$ ratios in RCB stars hold the clues to their origin. RCB stars are thought to be the products of a merger of a He white dwarf with a C-O white dwarf. In this scenario no ^{13}C is expected. To test the merger scenario we have estimated the $^{12}C/^{13}C$ ratios in RCB stars using C_2 molecular bands.

(B. P. Hema & G. Pandey)

The CH fraction of carbon stars at high Galactic latitudes

CH stars form a distinct class of objects with characteristic properties like iron deficiency, enrichment of carbon and over abundance in heavy elements. These properties can provide strong observational constraints for theoretical computation of nucleosynthesis at low-metallicity. An important question is the relative surface density of CH stars which can provide valuable inputs to our understanding on the role of low to intermediate-mass stars in the early Galactic chemical evolution. Spectroscopic characterization provides an effective way of identifying CH stars. The present analysis is aimed at a quantitative assessment of the fraction of CH stars in a sample of stars using a set of spectral classification criteria. The sample consists of ninety two objects selected from a collection of candidate Faint High Latitude Carbon stars from the Hamburg/ESO survey. Medium resolution ($\lambda/\delta\lambda$) $\sim$ 1300) spectra for these objects were obtained using OMR at VBO, Kavalur and HFOSC at HCT, IAO, Hanle, during 2007 – 2009 spanning a wavelength range 3800 – 6800 ÅṠpectral analysis shows 36 of the 92 objects to be potential CH stars; combined with our earlier studies (Goswami 2005, MNRAS, 359, 531; Goswami et al. 2007, BASI, 35, 339) this implies $\sim$ 37% (of 243) objects as the CH fraction. Spectral descriptions of the newly identified CH star candidates are obtained. Estimated effective temperatures, $^{12}C/^{13}C$ isotopic ratios and their locations on the two colour J-H vs H-K plot are used to support their identification. The results are published in MNRAS 402, 1111 (2010).

(A. Goswami, D. Karinkuzhi & N. S. Shantikumar)*

Abundances of neutron-capture elements

High resolution spectra obtained from the Subaru Telescope High Dispersion Spectrograph have been used to update the stellar atmospheric parameters and metallicity of the star HD 209621. A metallicity of [Fe/H] = $--1.93$ was derived for this star, and a large enhancement of carbon and of heavy elements, with respect to iron was found. Updates on the elemental abundances of four s-process elements (Y, Ce, Pr, Nd) along with the first estimates of abundances for a number of other heavy elements (Sr, Zr, Ba, La, Sm, Eu, Er, Pb) are reported. The stellar atmospheric parameters, the effective temperature, T_{eff}, and the surface gravity, $\log g$ (4500 K, 2.0), are determined from LTE analysis using model atmospheres. Estimated [Ba/Eu] = +0.35, places the star in the group of CEMP-(r+s) stars; however, the s-elements abundance pattern seen in HD 209621 is characteristic of CH stars; notably, the 2nd-peak s-process elements are more enhanced than the first peak s-

process elements. HD 209621 is also found to show a large enhancement of the 3rd-peak s-process element lead (Pb) with [Pb/Fe] = +1.88. The relative contributions of the two neutron-capture processes, r- and s- to the observed abundances are examined using a parametric model based analysis, that hints that the neutron-capture elements in HD 209621 primarily originate in s-process.The results are published in MNRAS 404, 253 (2010).

(A. Goswami & W. Aoki)*

Elemental abundances in CEMP stars: r- and s- process elements

A number of Carbon-Enhanced Metal-poor (CEMP) stars are known to exhibit enhancement of both $r-$ and $s-$process elements. An understanding of their relative contributions would provide insight into the production mechanisms and nucleosynthetic sites and origins of the heavy elements observed in the stars. Ways to delineate the observed abundances into their respective r- and s-process contributions was investigated. Results obtained using appropriate model functions in the framework of a parametric model are published in "Recent Advances in Spectroscopy: Astrophysical, Theoretical and Experimental Perspectives" Eds R. K. Chaudhuri et al. 2010, pp 211–216, Springer-Verlag.

(A. Goswami, A. P. Subramania, & K. Drisya*)*

Brown dwarfs

While there have been multiple observational programmes aimed at detecting linear polarization of optical radiation emitted by ultracool dwarfs, rigorous theoretical analyses of the problem have been relatively few. The general expectation has been that the atmospheres of those substellar-mass objects with condensate clouds would give rise to linear polarization due to scattering. Because of rotation-induced non-sphericity, there is expected to be incomplete cancellation of disk-integrated net polarization and thus a finite polarization. For cloudless objects, however, only molecular Rayleigh scattering will contribute to any net polarization and this limit has not been well studied. Hence a detailed multiple scattering analysis of the polarization expected from those T-dwarfs whose spectra show absence of condensates is presented. For this, the full radiative transfer equations for linearly polarized radiation have been developed and solved. Only atomic and molecular Rayleigh scattering are considered to be the sources of polarization. The local polarization was computed at different angular directions in a plane-parallel atmosphere calculated for the range of effective temperatures of T dwarfs and then averaged over the whole surface of the object. The effects of gravity and limb darkening as well as rotation induced non-sphericity were included. It was found that the amount of polarization decreases with the increase in effective temperature. It was also found that significant polarization at any local point in the atmosphere arises only in the optical (B band). However, the disk integrated polarization even in the B band is negligible. Hence it is concluded that, unlike the case for cloudy L dwarfs, polarization of cloudless T dwarfs by atomic and molecular scattering may not be detectable. In future this work will be extended to cloudy L and T dwarf atmospheres.

Recent studies have detected linear polarization in L dwarfs in the optical I band. Theoretical models have been developed to explain this polarization. These models predict higher polarization at shorter wavelengths. As predicted by theoretical models, a higher degree of polarization in R band is observed compared to polarization in I band for 2/4 of these brown dwarfs which suggests that dust scattering asymmetry is caused by oblateness. One case for variability of linear polarization was found which suggests the presence of randomly distributed dust clouds and in another case the presence of circumstellar disk is suggested.

(S. Sengupta & M. S. Marley)*

Evolutionary history of a WD binary

Theoretical spectra are constructed for a pair of white dwarf stars in a short period AM CVn system to explore the observational signature probing the thermal state of the mass transferring component and the evolutionary history of the binary system. Spectra were calculated for irradiated and non-irradiated cool, low-mass white dwarfs based on the TLUSTY stellar atmosphere code suitably modified. The spectra in the optical- to near-infrared wavelength band for the white dwarf pair are applied to the first confirmed eclipsing AM CVn system SDSS J0926+3624. For a model in which the emission from a nearly edge-on accretion disk is negligible in comparison to the combined photospheric emission from the two white dwarf stars, it is shown that the thermal state of the donor star can be probed at wavelengths greater than about 1.2 μm, independent of irradiation effects. In such a model, the distance of

J0926+3624 is estimated to be about 290 pc.

(S. Sengupta & R. Taam)*

Intermediate mass black holes in globular clusters

Over the last decade, many theoretical and observational evidences suggest that galactic globular clusters, similar to galaxies, may host IMBHs in their centres. It is also thought, that GCs follow the well-established correlations between the supermassive black holes and their host galaxies in extrapolation. Most of the attempts in search of the central black holes are not direct and present enormous observational difficulties due to the crowding of stars in the globular cluster cores. A new method of detection of the central black hole in globular clusters via microlensing of the cluster stars by the central black hole has recently been proposed. As the core of globular clusters are unresolved, it has been demonstrated that the technique of differential imaging can be applied to identify microlensing events.

(M. Safonova & C. S. Stalin)

Spectroscopic study of a few Herbig Ae/Be stars in young open clusters

A spectroscopic study of 5 Herbig Ae/Be stars in young open clusters is presented. These are identified from a survey of emission-line stars in young open clusters. The Herbig Ae/Be stars are found to show a linear correlation in H_α equivalent width versus reddening corrected $(H-K_s)$ colour plot, with a clear offset from the distribution of Classical Be stars. The candidates are found to show near infrared excess which was revealed through de-reddened (J−H) versus $(H-K_s)$ colour-colour diagram and Spectral Energy Distribution. From optical/near-IR photometry and spectroscopy, it is suggested that Bochum 6-1, IC 1590-1 and NGC 6823-1 are Herbig Be while IC 1590-2 and NGC 7380-4 are Herbig Ae candidates. Bochum 6-1 is an interesting Herbig B[e] star with a high H_α equivalent width of −206 Å which is the highest among the surveyed stars. The optical and near-IR photometry was combined to estimate the duration of star formation in the clusters Bochum 6, IC 1590, NGC 6823 and NGC 7380. On-going star formation was found in all these clusters, with an appreciable number of pre-main sequence stars. The age of these Herbig Ae/Be stars, estimated using pre-main sequence isochrones, were found to range between 0.25−3 Myr. IC 1590 is found to be an interesting young cluster (∼ 4 Myr) with 3 emission stars, each belonging to Herbig Ae, Herbig Be and Classical Be respectively. All the four clusters studied here were found to be forming stars for the last 10 Myr.

(B. Mathew, A. Subramaniam & B. Bhavya)

A 500 parsec halo surrounding the Galactic globular NGC 1851

Using imaging that shows 4 mag of main-sequence stars, it has been discovered that the Galactic globular cluster NGC 1851 is surrounded by a halo that is visible from the tidal radius of 700 arcsec (41 pc) to more than 4500 arcsec (> 250 pc). This halo is symmetric and falls in density as a power law of $r^{-1.24}$. It contains approximately 0.1% of the dynamical mass of NGC 1851. There is no evidence for tidal tails. Current models of globular cluster evolution do not explain this feature, although simulations of tidal influences on dwarf spheroidal galaxies qualitatively mimic these results. Given the state of published models, it is not possible to decide between creation of this halo from either isolated cluster evaporation or from tidal or disk shocking, or from destruction of a dwarf galaxy in which this object may have once been embedded.

(E. W. Olszewski, A. Saha*, P. Knezek*, A. Subramaniam, T. de Boer* & P. Seitzer*)*

Optical photometry and basic parameters of 10 unstudied open clusters

BVI CCD photometry of 10 northern open clusters, Berkeley 43, Berkeley 45, Berkeley 47, NGC 6846, Berkeley 49, Berkeley 51, Berkeley 89, Berkeley 91, Tombaugh 4 and Berkeley 9 are presented and their fundamental parameters are estimated. Eight of the clusters are located in the first galactic quadrant and 2 are in the second. This is the first optical photometry for 8 clusters. All of them are embedded in rich galactic fields and have large reddening towards them (E(B−V) = 1.0 – 2.3 mag). There is a possibility that some of these difficult-to-study clusters may be asterisms rather than physical systems, but assuming they are physical clusters, it is found that 8 of them are located beyond 2 kpc, and 6 clusters (60% of the sample) are located well above or below the Galactic plane. Seven clusters have ages 500 Myr or less and the other three are 1 Gyr or more in age. This sample of clusters has increased the opti-

cal photometry of clusters in the second half of the first galactic quadrant, beyond 2 kpc, from 10 to 15. NGC 6846 is found to be one of the most distant clusters in this region of the Galaxy.

(A. Subramaniam, G. Carraro & K. A. Janes*)*

Optical and IR studies of 21 micron sources

21 micron sources are carbon rich metal poor protoplanetary nebulae which show very large infrared excess and their photospheres are heavily enriched with s-process abundances. Fe depletion often seen in these sources can be partly due to the dust-gas separation occurring during the ejection of the envelopes. The infrared feature at 21micron is believed to be occurring from FeO grains and by looking at a detailed energy balance in the circumstellar envelope and estimating the energy radiated out from Fe O grains, the Fe abundance in the dust grain can be constrained. Together with the observed photospheric depletion, this in turn will constrain the mechanism of dust-gas separation. This is investigated with a sample of fiber 21 micron sources.

(C. Muthumariappan & B. E. Reddy)

Recurrent Nova RS Ophiuchi

A detailed analysis of the multifrequency radio observations of the 2006 outburst of the recurrent nova RS Ophiuchi was done. The observations were made with the Multi-Element Radio-Linked Interferometer Network (MERLIN), Very Large Array (VLA), One-Centimetre Radio Array (OCRA), Very Long Baseline Array (VLBA), Effelsberg and the Giant Metrewave Radio Telescope (GMRT), beginning 4.5 days after the discovery of RS Ophiuchi undergoing its 2006 recurrent nova outburst.

Observations over the first 9 weeks enabled following the spectral development throughout the three phases of the remnant development. A dramatic brightening is seen on days 4 to 7 at 6 GHz and an accompanying increase in other bands, particularly 1.46 GHz, consistent with transition from the initial free expansion phase to the adiabatic expansion phase. This is complete by day 13 when the flux density at 5 GHz is apparently declining from an unexpectedly early maximum (compared with expectations from observations of the 1985 outburst). The flux density recovered to a second peak by approximately day 40, consistent with behaviour observed in 1985. At all times the spectral index is consistent with mixed non-thermal and thermal emission. The spectral indices are consistent with a non-thermal component at lower frequencies on all dates, and the spectral index changes show that the two components are clearly variable. The estimated extent of the emission at 22 GHz on day 59 is consistent with the extended east and west features seen at 1.7 GHz with the VLBA on day 63 being entirely non-thermal.

A two-component model, consisting of a decelerating shell seen in mixed thermal and non-thermal emission plus faster bipolar ejecta generating the non-thermal emission, as seen in contemporaneous VLBA observations is suggested. Our estimated ejecta mass of $4 \pm 2 \times 10^{-7}$ $M_{\odot}$ is consistent with a white dwarf (WD) mass of 1.4 $M_{\odot}$. It may be that this ejecta mass estimate is a lower limit, in which case a lower WD mass would be consistent with the data.

(S. P. S. Eyres, T. J. O'Brien*, R. Beswick*, T. W. B. Muxlow*, G. C. Anupama, N. G. Kantharia*, M. F. Bode*, M. P. Gawronski*, R. Feiler*, A. Evans*, M. T. Rushton*, R. J. Davis*, T. P. Prabhu, R. Porcas* & B. J. M. Hassall*)*

Recurrent Nova U Scorpii

The recurrent novae U Scorpii was discovered in outburst on 29 January 2010. This tenth outburst was predicted by B. Schaefer based on a detailed study of its light curve over several decades. The outburst was extensively monitored spectroscopically using the HCT, at almost daily intervals during the early phases. Spectroscopic and polarimetric observations were also made with the IGO 2m telescope. Low frequency radio observations were also obtained with the GMRT.

Preliminary analysis of the spectra indicate ejection of matter at extremely high velocities ($\sim$ 10000km s^{-1}). The spectral evolution is very fast and similar to previous outbursts. The nova was not detected in the radio, implying (a) low ejection mass and (b) low density circumstellar medium. Observations of this object are continuing.

(G. C. Anupama, U. S. Kamath, N. G. Kantharia, A. N. Ramaprakash*, V. Mohan*, M. Hegde, M. F. Bode*, S. P. S. Eyres*, A. Evans*, T. J. O'Brien*)*

Recurrent Novae at Quiescence

Spectroscopic monitoring of the recurrent novae T

CrB, RS Oph, CI Aql and U Sco at quiescence were continued.

(G. C. Anupama)

Supernova SN 2009jf

The type Ib supernova SN 2009jf was monitored extensively using the 2m HCT. This supernova was found to be peculiar in showing He I lines very early in the pre-maximum phase at high velocities ∼16000 km/s. The UBVRI light curves indicate a slow evolution, with decline rates much slower than seen in other type Ib supernovae. The slow evolution of the supernova is indicative of a massive ejecta. Observations of this object in the nebular phase are being continued.

(D. K. Sahu, U. K. Gurugubelli, G. C. Anupama & K. Nomoto)*

Monitoring Supernovae

The type Ia supernovae SN 2009an, SN 2009dc, SN 2009ig and PTF10bjs were monitored extensively, both photometrically and spectroscopically using the 2m HCT. Monitoring during the nebular phase is under progress.

(G. C. Anupama, D. K. Sahu, U. K. Gurugubelli, S. Arora & P. Anto*)*

Serendipitous discovery of a Supernova

During an investigation of the blue-compact dwarf galaxy I Zw 97, excess emission at 610 MHz was serendipitously discovered, which is likely due to the Type II supernova SN 2008bx.

(S. Ramya, U. K. Gurgubelli, N. G. Kantharia, G. C. Anupama & T. P. Prabhu)*

A possible alternate scenario for short duration GRB's

A new class of objects made up entirely of dark matter particles is considered. These objects are considered as possible candidates for short duration gamma-ray bursts eliminating the baryon load problem. These could also provide a possible scenario for the formation of sub-stellar black holes, distinct from the usual Hawking black hole.

(C. Sivaram & A. Kenath)*

Circular polarization in pulsars due to curvature radiation

It is attempted to solve the dynamics of relativistic plasma moving along the dipolar magnetic field lines in the pulsar magnetosphere, and thereby estimate the polarization of the coherent curvature radiation.

The beamed radio emission from relativistic plasma (particles or bunches), constrained to move along the curved trajectories, occurs in the direction of velocity. The coherent curvature radiation model has been generalized to include the detailed geometry of the emission region in pulsar magnetosphere, and deduced the polarization state in terms of Stokes parameters. By considering both the uniform and modulated emissions, the a few typical pulse profiles are simulated.

The antisymmetric type of circular polarization survives only when there is modulation or discrete distribution in the emitting sources. This model predicts a correlation between the polarization angle swing and sign reversal of circular polarization as a geometric property of the emission process. Further details can be obtained from ApJ, 2010, 710, 29.

(R. T. Gangadhara)

Absolute emission altitude of pulsars: PSR B1839+09, B1916+14 and B2111+46

The mean profiles of the multi-component pulsars PSRs B1839+09, B1916+14 and B2111+46 are studied, and the absolute emission altitudes corresponding to the core and conal components are estimated.

By fitting Gaussians to the emission components, the phase location of the component peaks is determined. The findings indicate that the emission beams of these pulsars have the nested core–cone structures. Based on the phase location of the component peaks, the aberration-retardation (A/R) phase shifts in the profiles is estimated. Due to the A/R phase shift, the peak of the core component in the intensity profile and the inflection point of the polarization angle swing are found to be symmetrically shifted in the opposite directions with respect to the meridional plane in such a way that the core shifts towards the leading side and the polarization

angle inflection points towards the trailing side of the profile.

It has been possible to locate the phase location of the meridional plane and estimate the absolute emission altitude of both the core and the conal components relative to the neutron star center, using the exact expression for the A/R phase shift given by Gangadhara (2005, ApJ, 628, 923). It is found to be located at zero phase in Fig. 1.28. Details are published in A&A 2010, Vol. 515, A86.

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

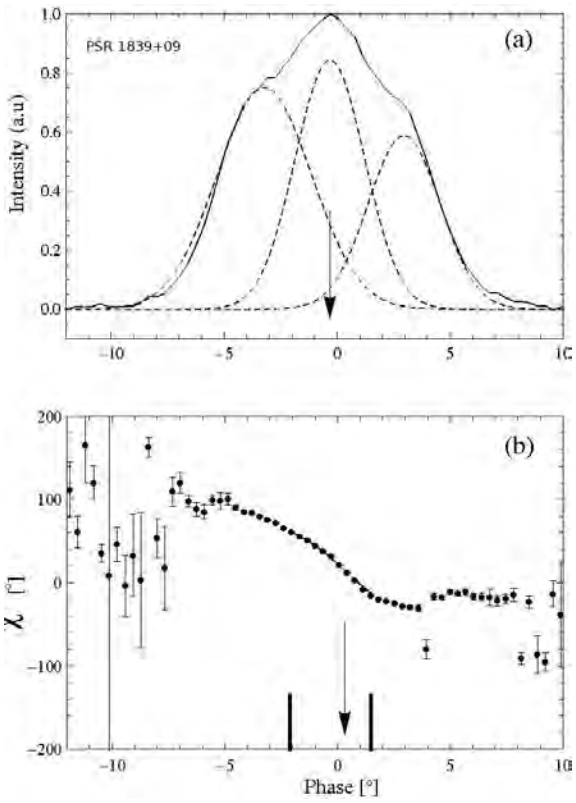

Figure 1.28: Profile of PSR B1839+09 at 1418 MHz, is fitted with the Gaussians to the sub-pulse components. Panel (a) for mean intensity profile and panel (b) corresponding polarization angle. Arrows point to the phase of PA inflection point and core peak.

Understanding the effects of geometry and rotation on pulsars intensity profiles

It is aimed to explore the role of the geometric and the pulsar spin (rotation) effects on the pulsar intensity profiles. A method was developed to compute the possible distribution of radio emission regions in a typical pulsar magnetosphere, taking into account the viewing geometry and rotational effects of the neutron star. This method can estimate the emission altitude and the radius of curvature of particle trajectory as a function of rotation phase for a given inclination angle, impact angle, spin-period, Lorentz factor, field line constant and the observation frequency. Further, using curvature radiation as the basic emission mechanism, the radio intensity profiles that would be observed from a given distribution of emission regions are simulated, for different values of radio frequency and Lorentz factor.

It is clearly shown that rotation effects can introduce significant asymmetries into the observed radio profiles. The dependency of profile features on various pulsar parameters is investigated. It is found that the radiation from a given ring of field lines can be seen over a large range of pulse longitudes, originating at different altitudes, with varying spectral intensity. Preferred heights of emission along discrete sets of field lines are required to reproduce realistic pulsar profiles, and this is illustrated for a known pulsar. Finally, it is shown how the model provides feasible explanations for the origin of core emission, and also for one-sided cones which have been observed in some pulsars. For details the article in MNRAS (2010, Vol. 736T) can be referred to.

(R. M. C Thomas, Y. Gupta*, & R. T. Gangadhara)*

Study of magnetar properties

Magnetars are a rare ($\sim$ 21 objects known) and a special class of neutron star with surface magnetic fields in the excess of 10^{14} G, which emit radiation via decay of the magnetic field. Archival X-ray and gamma-ray data are used to study high energy characteristics and timing properties of these objects, in order to constrain theoretical emission models and to identify a unique evolutionary scenario which would explain their rarity.

(F. Sutaria)

X-ray studies of quiescent LMXBs

Soft X-ray transients (SXTs) are low mass X-ray binaries (LMXBs) consisting of a neutron star (NS) or a black hole (BH) primary, undergoing accretion from a Roche-lobe filling, low-mass, secondary. While bright in outbursts, they are most often detected in quiescence, when they are extremely faint, and their X-ray spectra are statistically sparse. This study attempts to identify the nature of the primary

object by comparing their quiescent luminosites with their binary period.

(F. Sutaria)

A method to determine distances to molecular clouds using near-IR photometry

A method has been developed to determine distances to molecular clouds using JHK near-infrared photometry. It is based on a technique that aids spectral classification of stars lying towards the fields containing the clouds into main sequence and giants. In this technique, the observed $(J-H)$ and $(H-K_s)$ colours are dereddened simultaneously using trial values of A_V and a normal interstellar extinction law. The best fit of the dereddened colours to the intrinsic colours giving a minimum value of χ^2 then yields the corresponding spectral type and A_V for the star. The main sequence stars, thus classified, are then utilized in an A_V versus distance plot to bracket the cloud distances. This method was applied to four clouds, L1517, Chamaeleon I, Lupus 3 and NGC 7023 and their distances were estimated as 167±30, 151±28, 157±29 and 408±76 pc respectively, which are in good agreement with the previous distance estimations available in the literature.

(G. Maheswar, C. W. Lee*, H. C. Bhatt, Mallik, S. V. & S. Dib*)*

Lithium abundances in the α Persei cluster

As a sequel to the Li observations by Balachandran, Lambert and Stauffer (1988,ApJ, 333, 267; 1996, ApJ, 470, 1243) in 35 stars of the 50 Myr old cluster α Persei, high resolution spectra have been obtained and analyzed of another 51 stars. Following a reconsideration of the cluster membership of the stars, the Li abundances are discussed for 70 stars. With our larger sample, the scatter in Li abundance at a given T_{eff} seen in young clusters has been reexamined. The Li abundance in the F-type stars is equal to its presumed initial abundance confirming previous suggestions that pre-main sequence depletion is ineffective for these stars. Intrinsic star-to-star scatter in Li abundance among these stars is comparable to the measurement uncertainties. The large scatter observed at cooler temperatures is far larger than could be explained by the standard sources of uncertainty. Several studies in the past, report a strong correlation between the Li scatter and stellar activity. In the absence of contemporaneous indicators of stellar activity for pairs of stars with maximum and minimum Li abundance but similar observed properties such as colour and rotation period, the debate continues on whether the star-to-star spread is due to real differences in Li abundances or arises due to atmospheric effects.

(S. V. Mallik, S. C. Balachandran & D. L. Lambert*)*

Target selection for SDSS-III MARVELS survey

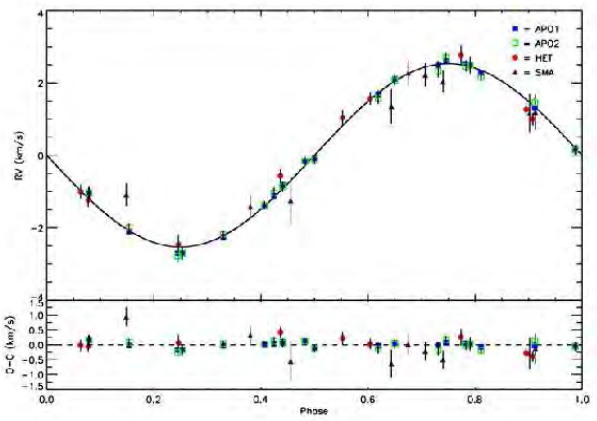

Figure 1.29: Phase-folded Keplerian orbital solution and RV residuals for TYC 1240-00945-1. Blue squares and green squares are MARVELS discovery data, red circles are HET data, and purple triangles are SMARTS data.The bottom panel shows the residuals between the data points and the orbital solution.

The multi-object APO (Apache Point Observatory) Radial Velocity Exoplanet Large-area Survey (MARVELS) completed its first year of operation. The survey will have the radial velocities for 11,000 bright stars, with the precision and cadence needed to detect gas giant planets that have orbital periods ranging from several hours to two years. With well-characterized sensitivity and a broad range of target star properties, MARVELS will provide a critical dataset for testing theoretical models of the formation, migration, and dynamical evolution of giant planet systems. It will have unique sensitivity to rare systems such as extreme eccentricity planets or objects in the "brown dwarf desert". The target selection for the survey is done using R = 2000 SDSS spectroscopic pre-survey. An automated method is been developed, to select stars with $T_eff < 6500$ K and $\log g > 3.5$. The first paper (S. Fleming et al., 2010, ApJ, in press) from the survey reports the discovery of a low-mass companion orbiting the metal-rich, main sequence F star TYC 2949-00557-1. The

companion has an orbital period of 5.69449± 0.00023 days and straddles the hydrogen burning limit with a minimum mass of 64 M_J, and may be an example of a rare class of brown dwarfs orbiting at distances comparable to those of "Hot Jupiters". The survey also has identified many more candidates and the follow up work in chartering and confirming is underway. Discovery of a short-period brown dwarf desert candidate TYC 1240-945-1B (see Fig. 1.29): from the SDSS-III-MARVELS planet search, by Lee et al. is submitted to Ap J.

(T. Sivarani, J. Ge & SDSS-III MARVELS team)*

Carbon in the early Galaxy

Carbon is one of the abundant and key elements, which originates from supernovae, rapidly rotating massive stars, or intermediate-mass AGB stars in the early Universe. Many metal poor stars ([Fe/H] < -2.0) of the Galaxy, which are polluted by these stars are expected to retain their initial composition and provide constraints on the nature of the first stars. Trace amounts of CNO might also play a key role in the transition from the presumed top-heavy IMF of the first stars to the formation of low-mass stars. Recent observations of metal poor stars suggest, copious amount of C and N in the early epochs. Many of the Carbon Enhanced Metal Poor (CEMP) stars which are polluted by AGB companions also provide an unique tool to probe the unseen intermediate mass IMF of the early Galaxy. Carbon abundances were derived for 300,000 stars from SDSS DR7(Sloan Digital Sky Survey, data release 7), which is the large sample ever analysed. The results confirm that there is an increase in carbon abundance at low metallicities and also finds tentative evidence for spatial variations in the frequency CEMP stars. This indicate, that there might be an influence on the CMB temperature variations in modifying the IMF in the early Galaxy. A detailed kinematics of the sample is underway.

(T. Sivarani, T. C. Beers, D. Carollo*, Y. S. Lee* & the SEGUE team)*

Declining lithium abundances in the extreme metal poor stars [Fe/H] ∼ -3.0

Primordial or stellar evolution? Bonifacio et al. 2007,(A&A 462 851) first noticed an increased scatter or a decreasing trend, in the observed Li abundance in metal poor stars below [Fe/H] < -3.0. In the present work, which is a part of ESO-VLT Large programme (First stars, P. I. R. Cayrel), Li abundance for 10 more stars below [Fe/H] < -3.0, were derived using 1D and 3D stellar atmospheric models with NLTE spectral analysis and various methods for stellar effective temperatures. A strong slope of about 0.30 dex in A(Li) per dex in [Fe/H], significant to 2-3 sigma was obtained for all the four T_eff estimators. The scatter in A(Li) increases by a factor of 2 towards lower metallicities, while the plateau appears very thin above [Fe/H] = -2.8. The meltdown of the Spite plateau below [Fe/H] < -3 is established (Sbordone et al. 2010, A&A, in press(arXiv:1003.4510.), but its cause is still unclear. If the primordial A (Li) is the one derived from WMAP, it appears difficult to envision a single depletion phenomenon producing a thin, metallicity independent plateau above [Fe/H] = -2.8, and a highly scattered, metallicity dependent distribution below. The fact that no star below [Fe/H] = -3 lies above the plateau suggests that they formed at plateau level and underwent subsequent depletion.

(L. Sbordone, P. Bonifacio*, P. Molaro*, T. Sivarani & the "First Stars team")*

Study of Compton broadening due to electron-photon scattering

The effects of Compton broadening due to electron-photon scattering in hot stellar atmospheres were investigated. A purely electron-photon scattering media is assumed to have plane parallel geometry with an input radiation field localized on one-side of the slab. The method is based on the discrete space theory of radiative transfer for the intensity of emitted radiation. The solution is developed and solved to study the importance of scattering of radiation by free electrons in high temperature stellar atmospheres which produces a broadening and shift in spectral lines because of the Compton effect and the Doppler effect arising from mass and thermal motions of scattering of electrons.

It is noticed that the Comptonized spectrum depends on three parameters, the optical depth of the medium, the temperature of the thermal electrons and the viewing angle. It was also shown that the Compton effect produces redshift and asymmetry in the line. These two effects increase as the optical depth increases. It is also noticed that the emergent specific intensities become completely asymmetric for higher optical depths.

(M. S. Rao)

Effects of Compton broadening due to electron scattering on spectral lines

The above work is extended for an expanding spherical stellar atmosphere by considering electron scattering atmosphere and solved the equation of transfer for obtaining spectral lines. The effect on spectral line formation is studied due to optical depths and different velocity laws.

It is noticed that the expansion of the gases in the atmosphere produces P-Cygni type profiles and at higher optical depths the line profiles change from emission to absorption with their line centers shifting to blue side in the expanding atmospheres.

(A. Peraiah & M. S. Rao)*

Simultaneous solution of Kompaneets equation and Radiative Transfer equation in the photon energy range 1 – 125 KeV

Calculation of theoretical spectrum in the region of 1 – 125 KeV photon energy using radiative transfer equation in plane-parallel geometry and Kompaneets equation is considered. Diffuse radiation field is calculated using time-independent transfer equation in plane-parallel geometry using discrete space theory of radiative transfer equation in a homogeneous medium with total optical depth 1 and 5. It was assumed that free-free emis- sion and absorption and emission due to electron gas operate in the medium. The terms in Kompaneets equation and those due to free-free emission are utilized to calculate the change in the photon phase density in a hot electron gas. Two types of incident radiation are considered: (1) isotropic radiation with the modified black body radiation and (2) anisotropic radiation which is angle dependent. It was noticed that, the initial spectrum is angle dependent, the Kompaneets equation gives a spectrum which is angle independent after several Compton scattering times.

(A. Peraiah, M. S. Rao & B. A. Varghese)*

Transient UV events

UV transient events from specific sources such as possible collisions in extrasolar planetary systems, M dwarf flares, etc. and the probability of their detection by space UV observatories, in particular by Tauvex has been investigated. It is estimated that in one year of Tauvex observations we can expect about 90-350 short scale transient events.

(C. Sivaram, M. Safanova & J. Murthy)

1.3 Extragalactic Astrophysics and Cosmology

RR Lyrae stars in the inner LMC: Where did they form?

RR Lyrae stars (RRLS) belong to population II and are generally used as a tracer of the host galaxy halo. The surface as well as vertical distribution of RRLS in the inner Large Magellanic Cloud (LMC) are studied to understand whether these stars are actually formed in the halo. RRLS identified by the OGLE III survey are used to estimate their number density distribution. The scale-height of their distribution is estimated using extinction corrected average magnitudes of ab type stars. The density distribution mimics the bar, confirming results in the literature. Position angle (PA) of the elongation is estimated to be $125.^o5 \pm 17.^o3$. This value of PA is found to be same as the PA_{maj} of the bar, within the errors, estimated using red clump stars and giants. The distribution of their scale height indicates that there may be two populations, one with smaller scale-height, very similar to the red clump stars and the other, much larger. The distribution of the reddening-corrected magnitude along the minor axis shows variation, suggesting an inclination. The inclination is estimated to be $i = 31.3 \pm 3^o.5$ degrees, very similar to the inclination of the disk. Thus, the RRLS in the inner LMC mimic the bar and inclination of the disk, suggesting that a major fraction of RRLS is formed in the disk of the LMC.

(A. Subramaniam & S. Subramanian)

The mysterious bar of the Large Magellanic Cloud: What is it?

The bar of the Large Magellanic Cloud (LMC) is a prominent but controversial feature. In order to study the relative location of the bar with respect to the disk, The high resolution map of the structure across the LMC was investigated. Reddening corrected mean magnitudes (I_0) of red clump (RC) stars from the OGLE III catalogue were used to map the relative variation in distance (vertical structure) or variation in RC population across the LMC. The bar does not appear as an identifiable vertical feature in the map, as there is no difference in I_0 values between the bar and the disk regions. It is concluded that the LMC bar is very much part of the disk, located in the plane of the disk and it is not a separate component within 0.02 mag. Warps or variation were identified in RC population with increase in radial distance.

(A. Subramaniam & S. Subramanian)

An estimate of the structure of the Large Magellanic Cloud using red clump stars

Estimate of the structure of the Large Magellanic Cloud (LMC) is presented. The red clump stars from the *VI* photometric data of the Optical Gravitational Lensing Experiment (OGLE III) survey and from the Magellanic Cloud Photometric Survey (MCPS) were used to estimate the structural parameters of the LMC disk, such as the inclination, i and the position angle of the line of nodes (PA_{lon}), ϕ. The observed disk region is divided into sub-regions. The dereddened peak I magnitude of the red clump stars in each sub-region is used to obtain the relative distances and hence the z coordinate. The RA and Dec of each sub-region is converted into x and y Cartesian coordinates. A weighted least-square plane-fitting method is applied to these x,y,z data to estimate the structural parameters of the LMC disk. An inclination of $i = 23^o.0 \pm 0^o.8$ and PA_{lon}, $\phi = 163^o.7 \pm 1^o.5$ was found for the LMC disk using the OGLE III data and an inclination of $i = 37^o.4 \pm 2^o.3$ and PA_{lon} $\phi = 141^o.2 \pm 3^o.7$ for the LMC disk using the MCPS data. Extra-planar features, which are in front as well as behind the fitted plane, are seen in both the data sets. The estimates of the inclination and position angle of the line of nodes are comparable with some of the previous estimates. The effect of choice of center, reddening, and area covered on the estimated parameters are discussed. Regions in the northwest, southwest and southeast of the LMC disk are warped with respect to the fitted plane. A symmetric but off-centered warp in the inner LMC is also identified. The structure of the LMC disk inside the 3 degree radius is found to be different from the outside disk in a way that the inner LMC has relatively less inclination and relatively large PA_{lon}. The 3D plot of the LMC disk suggests an off-centered increase in the inclination for the northeastern regions, which might be due to tidal effects. It is suggested that the variation in the planar parameters estimated by various authors as well as in this study is caused by the difference in coverage and the complicated inner structure of the LMC disk. In the inner LMC, the stellar and the HI disk are found to have similar properties.

(S. Subramanian & A. Subramaniam)

Variability in QSOs: Radio-intermediate quasars

The results of intensive intranight optical monitoring of eight optically bright 'radio-intermediate quasars' (RIQs) having flat or inverted radio spectra were reported. The monitoring was carried out in R band on 25 nights during 2005 – 2009 using the ARIES 1m telescope and the 2m HCT. On each night only one RIQ was monitored for a minimum duration of $\sim$ 4h (the average being 5.2h per night). Using the CCD as an N-star photometer, an intranight optical variability (INOV) detection threshold of $\sim$1-2 per cent was achieved for the densely sampled differential light curves derived from our data. These observations amount to a large increase over those reported hitherto for this rare and sparsely studied class of quasars which can, however, play an important role in understanding the link between the dominant varieties of powerful active galactic nucleus, namely the radio-quiet quasars (RQQs), radio-loud quasars (RLQs) and blazars. Despite the probable presence of relativistically boosted nuclear jets, inferred from their flat/inverted radio spectra, clear evidence for INOV in our extensive observations was detected only on one night. Furthermore, flux variation between two consecutive nights was clearly seen for one of the RIQs. These results demonstrate that as a class, RIQs are much less extreme in nuclear activity compared to blazars. The availability in the literature of INOV data for another two RIQs conforming to our selection criteria allowed us to enlarge the sample to 10 RIQs (monitored on a total of 42 nights for a minimum duration of $\sim$ 4h per night). The absence of large amplitude INOV ($\Psi >= 3$ per cent) persists in this enlarged sample. These extensive data base have enabled us to arrive at the first estimate for the INOV duty cycle (DC) of RIQs. The DC is found to be small ($\sim$ 9 per cent), increasing to $\sim$ 14 per cent if the two cases of 'probable' INOV are included. The corresponding value is known to be 60 per cent for BLLacs and $\sim$ 15 per cent for both RLQs and RQQs, if they too are monitored for $\gtrsim$ 4-6 h in each session. Our observations also provide information about the long-term optical variability of RIQs, which is found to be fairly common and reaches typical amplitudes of $\sim$ 0.1mag. The light curves of these RIQs were discussed in the context of a theoretical framework proposed earlier for linking this rare kind of quasars to the much better studied dominant classes of quasars.

(A. Goyal, Gopal-Krishna*, S. Joshi*, R. Sagar*, P. J. Wiita*, G. C. Anupama & D. K. Sahu)*

BL Lac PKS 0735+178

The results of an extensive intranight optical monitoring of the well-known low-energy peaked BL Lac (LBL) object PKS 0735 + 178 were reported. The long-term follow-up consists of R-band monitoring for a minimum duration of $\sim$4 hours, on 17 nights spanning 11 years (1998-2008) using the ARIES 1m telescope and the 2m HCT. Using the CCD as an N-star photometer, a detection limit of around 1 per cent was attained for the intranight optical variability (INOV). Remarkably, an INOV amplitude of $>=$ 3 per cent on hour-like time-scale was not observed on any of the 17 nights, even though the likelihood of a typical LBL showing such INOV levels in a single session of $\gtrsim$ 4 hours duration is known to be high ($\sim$50 per cent). Our observations have thus established a peculiar long-term INOV quiescence of this radio-selected BL Lac object. Moreover, the access to unpublished optical monitoring data of similarly high sensitivity, acquired in another programme, has allowed us to confirm the same anomalous INOV quiescence of this LBL all the way back to 1989, the epoch of its historically largest radio outburst. Observational evidence revealing the very unusual INOV behaviour of this classical BL Lac object were presented and discussed in the context of its other known exceptional properties.

(A. Goyal, Gopal-Krishna*, G. C. Anupama, D. K. Sahu, R. Sagar*, S. Britzen*, M. Karouzos*, M. F. Aller* & H. D. Aller*)*

Blue compact dwarf galaxies

Two blue compact dwarf galaxies, Mkn 104 and I Zw 97, are studied photometrically and spectroscopically. Mkn 104 is found to contain three distinct bright star-forming regions, whereas I Zw 97 is found to contain three bright and two faint star-forming regions. Medium-resolution spectra of three bright HII regions in the two galaxies were obtained. Oxygen abundance in these regions was found to be 2.7 times lower than the solar value. The highest star-formation rate for I Zw 97 is found to be 0.04 solar masses per year, and for Mkn 104 it is 0.02 solar masses per year. I Zw 97 is realized to be a cometary blue compact dwarf galaxy undergoing a strong burst of star formation. A (U - B) versus (V - I) colour-colour mixed population model is created using the Starburst99 evolutionary model curves. Both the galaxies show a 4 Gyr and a 500Myr old population with current star formation of 5 – 13 Myr age.

The surface-brightness profiles of both the galaxies can be represented well by a two-component Sérsic profile consisting of a near-exponential distribution and a Gaussian nuclear starburst. To conclude, neither of these galaxies is a young system; instead they are undergoing episodic star formation superposed on a faint older component. I Zw 97 is a cometary blue compact dwarf galaxy where the underlying low-surface-brightness (LSB) galaxy is a dwarf irregular observed during a major stochastic enhancement of its otherwise moderate star-formation activity, a phenomenon widely accepted as self-propagating stochastic star formation.

The multifrequency radio continuum and 21 cm H I data on five blue compact dwarf galaxies, Mrk 104, Mrk 108, Mrk 1039, Mrk 1069 and I Zw 97 were obtained using the Giant Meterwave Radio Telescope. Detailed study of the data revealed the following:

Radio continuum emission at 610 MHz is detected from all the observed galaxies whereas only a few are detected at 325 MHz and 240 MHz. In our sample, three galaxies (Mrk 104, Mrk 108 and Mrk 1039) are members of poor groups and two galaxies (Mrk 1069 and I Zw 97) are isolated galaxies. The radio emission from Mrk 104 and Mrk 108 is seen to encompass the entire optical galaxy whereas the radio emission from Mrk 1039, Mrk 1069, I Zw 97 is confined to massive HII regions. It is suggested that the environment in which the galaxy is evolving plays a role in this.

The integrated radio spectra of four galaxies are modelled over the frequency range where data is available. It is found that one of the galaxies Mrk 1069, shows a turnover at low frequencies which is well fitted by free-free absorption whereas three galaxies show a power law spectrum to the lowest observed frequencies. Mrk 1039 is not detected at 240 MHz and the limit suggests a low frequency turnover. This, it is suggested, is also indicative of the environment in which the galaxies reside.

The H I observations of four galaxies Mrk 104, Mrk 108, Mrk 1039 and Mrk 1069 show extended disks as large as $\sim 1.5 - 6$ times the optical size. All the four observed BCDs show rotating disk with a half power width of $\sim 50 - 122$ km/s. Solid body rotation is common in our sample.

From our data we note that the tidal dwarf (TD) origin for the BCDs cannot be ruled out. Timescales for BCDs to move away from their nearest, most probable, progenitor galaxy are estimated to be few Gyr (2 – 9 Gyr), assuming the difference in their systemic velocities as the receding velocity. This implies that a strong tidal interaction with another galaxy could have created (few Gyr ago) these BCDs in the tidal tails which then moved away. This would then indicate that the observed old stellar population in BCDs were derived from the parent galaxy.

(S. Ramya, N. G. Kantharia, D. K. Sahu & T. P. Prabhu)*

Low surface brightness galaxies

Low Surface Brightness (LSB) galaxies have been spectroscopically studied in order to disentangle the AGN component in the galaxies present, if any. Medium resolution spectroscopy of 9 LSB galaxies was obtained with the HCT. In order to search for the presence of AGN, stellar light has been decomposed from the spectra along with some nebular contribution using the Starburst99 high resolution spectra of solar metallicity. The underlying stellar population is aged between 1–4 Gyr. To detect an AGN, the H-alpha line was decomposed into narrow and broad components. The velocities of broad components were calculated, which are as large as 900-1600 km/s. Galaxy UGC 6614 is a definite AGN. Other galaxies with positive AGN detection are UGC 1922, UGC 6968 and LSBC f568-6. Stellar velocity dispersions are calculated using the Calcium Triplet and masses of the AGNs are estimated. The calculated masses and stellar velocity dispersions are seen to deviate from the relationship obtained for massive galaxies in that the LSB AGN have smaller black hole masses compared to their bulge velocity dispersion. The implications of this result are being studied.

(S. Ramya, T. P. Prabhu & M. Das)*

Dynamics of the brightest members of galaxy clusters

Based on a list of member redshifts in Abell clusters compiled by Andernach, it was found that a significant number of cD and Brightest Cluster Members (BCMs) have a large peculiar velocity relative to their parent cluster. A programme is underway to obtain the largest possible sample of rich (Abell) clusters of galaxies with one to three dominant galaxies in them, and with measured redshifts for at least the 10 brightest galaxies. Spectra were so far obtained for about 120 galaxies in 60 clusters with the HCT. Targets are brighter than 17 mag (which is within reach of HCT because of its high altitude location and good image quality), and lack redshifts

according to NED/Simbad and our compilation of cluster members for the full Abell cluster catalogue. Most clusters selected for the study have no or very poor redshifts, but very few have a high number of redshifts, EXCEPT for the brightest one(s). For the former we need a reliable redshift to improve our super-cluster catalogue out to z 0.14, while for the latter we wish to obtain the peculiar velocity in the cluster. The collaboration is collecting data from other telescopes around the world as well.

(H. Andernach, T. P. Prabhu, C. Caretta*, & S. Jeyakumar*)*

Galaxies in groups and clusters - Evolution and morphology

In order to disentangle the cosmic evolution of clusters from cluster-to-cluster variations in a quantitative fashion, a sample of nearby small clusters and groups is being investigated, using deep CCD imaging, an observational programme is being carried out with facilities at IIA. The sample is selected from several catalogues; the Abell catalogue and several catalogues of groups, including those found from the SDSS data (e.g. Lee et al. 2004, AJ, 127,1811; Tago et al. 2007, A & A). Deep imaging through broad band and Ha filters is being done for this sample of about 30 groups/clusters. U band imaging will be particularly desirable for objects with more blue members and will provide a wavelength continuity for future observations with the UVIT. In a later phase it is proposed to image through filters sampling lines sensitive to AGN and starburst activity.

This programme has been proposed as one of the guaranteed time programmes with UVIT telescope on the ASTROSAT mission. The ultraviolet region is well suited to the detection of hot young stars (hence incidence of star formation) and the existence of a large component of post-starburst populations in galaxies. Thus the UV colours obtainable with UVIT will contribute significantly in discriminating between "red" (early type morphology) and "blue" (late-type morphology) types of the Hubble sequence down to faint levels in the luminosity function in groups/clusters. The UVIT will also be sensitive to detection of diffuse enveloping emission in group environments where interaction between galaxies trigger largescale star formation or starbursts. The current ground-based programme will facilitate sample creation for use in the proposed UVIT programme.

(A. K. Pati)

Self-consistent model of the evolution of black hole mass and spin

A self-consistent relativistic model of the evolution of black hole spin and mass is being developed. It takes into account the mass and spin accreted by the hole and angular momentum torque due to an electrodynamical jet. The spin-down time scale for the case of no accretion is about $\tau_{spin} = 0.5/(B_4^2 M_9)$ Gyr. The evolution of the jet power indicates an increase before a gradual decline if the initial spin, $j > \sqrt{3}/2$, as a result of the hole's increasing size. This naturally has implications for the evolution of the jet. Specific analytic forms have been calculated for the case of Bondi accretion and thin disk.

An important issue is the maximum spin j that can be achieved in disk accretion process. Preliminary results indicate that the black hole achieves the maximum value when there is no jet. It is planned to compare this with fully relativistic, axisymmetric simulations of a non-radiative, magnetized plasma onto a Kerr-Schild black hole within the MHD approximation.

(A. Mangalam)

Analysis and modelling of quasi-periodic behaviour in light curves from AGN

Analyses of light curves from active galactic nuclei have been considered, comparing a wide variety of techniques that have been used in the literature. Useful properties have been derived from light curves by implementation of the following time series techniques: wavelets, periodograms, Lomb-Scargle periodograms, structure functions and multi-harmonic analysis of variance. Different noise models are used in these analyses.

The applications of all these techniques to optical light curves have yielded consistent and strong periods of 1323 & 1386 s for 2 nights out of 20 densely sampled archival light curves of the blazar S5 0716+714; however, although such variations are more likely to arise from a relativistic jet in blazars, the only model that can be cleanly analysed assumes these variations arise from orbital signatures from a region located at some location between a few and 100 gravitational radii around the central black hole; adopting such a model places a lower limit on the mass to be $\gtrsim 0.9 \times 10^6 M_\odot$.

A similar analysis for an XMM-Newton X-ray light curve of the Narrow Line Seyfert 1 galaxy RE J1034+396 confirms an earlier claim of a quasi-

periodic oscillation around 4000 s and indicates a lower mass limit of $\sim 4 \times 10^6 M_\odot$.

(P. Mohan, A. Mangalam, A. Gupta & P. J. Wiita*)*

Constraints on astrophysical magnetic fields from magnetic helicity

Helicity conservation imposes constraints on dynamo action. A calculation was done of the the minimal field strength of the large scale magnetic field that could result given the constraints using a quasi linear model. The calculation of helicity is technically complicated because of open boundaries and the usual form for the MHD invariant is modified to take this into account. Further, the helicity fluxes at the boundaries are accounted for approximately.

An application of the quasi linear model to the solar and galactic dynamos is being worked out.

(A. Prasad & A. Mangalam)

Optical identification of XMM sources in Canada-France-Hawaii telescope legacy survey

Optical identification of X-ray sources detected by XMM-Newton in about 3 square degrees was carried out on the Canada-France Hawaii Telescope Legacy Survey (CFHTLS) fields. For that, optical spectroscopic observations were carried out with the AAO mega muti-object spectrograph at the 4 m AAT telescope in Australia. In a flux-limited sample of 829 point-like sources in the CFHTLS, with g $<$ 22 mag and the 0.5 –2 keV flux $> 1 \times 10^{-15}$ erg cm^{-2} s^{-1}, 693 objects were observed of which reliable spectroscopic identifications were possible for 487 sources. This amounts to about 59 per cent of the overall sample.

Galactic stellar sources comprise about 15 per cent of this sample (74/487). About 54 per cent (265/487) of the sources were found to be active galactic nuclei (AGN) with broad emission lines having redshifts between 0.15 and 3.87 with a median value of 1.68.

The optical-to-X-ray spectral index of the broad-line AGN was found to be 1.47 $\pm$ 0.03. This value is typical of optically selected type I quasars. The optical-to-X-ray spectral index was found to correlate with the rest-frame X-ray and optical monochromatic luminosities at 2 keV and 2500 Å, respectively. In addition, 32 and 116 X-ray sources were found to be respectively, absorption and emission-line galaxies at z$<$0.76. From a line ratio diagnostic diagram, it was found that in about 50 per cent of these emission-line galaxies, the emission lines are powered significantly by AGN.

(C. S. Stalin, P. Petitjean, R. Srianand*, A. J. Fox*, F. Coppalani* & A. Schwope*)*

Black hole entropy

It was shown in earlier work that holography implies a phase space associated with the interior volume which just happens to be a quantum of phase space irrespective of the black hole mass and number of dimensions. This was in the frame of an external observer. The phase space and entropy associated with an observer falling into the event horizon, i.e. the comoving observer, has been analysed. In this case the entropy and phase space are conserved and have the values prior to entering the event horizon. Similar ideas are now associated to cosmological models, e.g. collapsing models which rebound etc. These approaches with very similar results to the black hole case, lead to new insights into quantizing gravity by generalized Einstein field equations to include curved phase space and quantizing the same rather than just space-time.

(C. Sivaram & A. Kenath)*

X-ray emission from Seyfert galaxies and unification schemes

Seyfert galaxies are nearby low-luminosity "radio-quiet" active galaxies powered by accretion onto supermassive black holes (SMBH) residing at their cores. Several results in the literature make a compelling argument for the ubiquitous presence of gas and dust surrounding the central accretion disc in a roughly toroidal geometry, thereby obscuring visible and soft X-ray photons from the central regions in edge-on lines of sight and accounting for the wide range of observed properties by merely the inclination of the accretion disc (the 'Unification Scheme' in the literature). X-ray spectra primarily from the XMM-Newton telescope were used to test this idea. A sample of purportedly pole-on and edge-on Seyferts, with matched intrinsic (orientation-independent) parameters is used which makes for rigorous tests of the predictions of unification.

The X-ray spectra are typically fitted with a combination of an absorbed power law, a reflection component, an excess at soft X-ray energies modelled as a blend of emission lines and a Fe Kα emission line at 6.4 keV. It was found that the purportedly

edge-on Seyferts (whose nuclei are predicted to be obscured), show systematically lower soft X-ray luminosities, but not significantly different hard X-ray luminosities. Further, they show larger X-ray absorbing columns, and higher equivalent widths of the Fe Kα line at 6.4 keV, all of which are consistent with the predictions of unification.

(V. Singh, P. Shastri & G. Risaliti)*

The Compton-thick Seyfert galaxy NGC 5135

Archival *Suzaku* broad-band X-ray data were used to investigate the Compton-thick Seyfert galaxy, NGC 5135, to unveil the nature of obscuring material around the AGN. The 0.5–10 keV spectrum of NGC 5135 is characterized by the standard components for a Compton-thick source: a reflection continuum, a prominent iron emission line (equivalent width $\sim$ 2.2 keV) and a soft excess. At energies higher than 10 keV the intrinsic AGN continuum is apparent, implying an absorbing column density of the order of $\sim$ 10^{24} cm^2. Our X-ray spectral analysis provides the first accurate estimates of the absorbing column density, the strength of the reflection component and the viewing angle of the torus for this source, which are key ingredients in understanding the nature of Compton-thick obscuring material around AGN.

(V. Singh, G. Risaliti, P. Shastri & V. Braito*)*

The low-frequency radio structure of Seyfert galaxies

Seyfert galaxies are categorised as radio-quiet (ratio of the radio flux at 5.0 GHz to the optical flux in B-band is less than 10). Their bipolar synchrotron jets, imaged at radio frequencies, typically 1 GHz and above, are confined well within the bounds of their stellar distributions. Their lower frequency morphology, expected to be more diffuse and from an older electron population, was investigated by imaging a sample of Seyferts at 610 MHz with the Gian Metre Wave Radio Telescope. The sample contained roughly equal numbers of pole-on and edge-on Seyferts matched in their intrinsic properties. These data were combined with archival 1.4 GHz images from the Very Large Array.

While the investigation is under progress, the 610 MHz emission appears to primarily arise from the AGN, and the flux densities and two-point radio spectral indices show no significant differences for the two Seyfert sub-types, consistent with the predictions of unification for Seyfert galaxies.

(V. Singh, P. Shastri & R. Athreya)*

Dark energy, inertia and Mach's principle

Mach's principle says that a particle's inertia is due to some interaction of that particle with all the other masses in the universe. Here, the possibility of the gravitational interaction energy of the background quantum vacuum energy playing the role of a global Higg's field (described by a varying cosmological constant) is explored, entirely contributing to the local inertial masses of particles in the spirit of Machs principle.

(C. Sivaram & A. Kenath)*

Possible constraints on neutron electric dipole moment from pulsar radiation

Even if only a small fraction of neutron dipole moments are aligned in a neutron star, observed pulsar radiation loses provide a stringent limit on the neutron electric dipole moment of $< 10^{-29}$ ecm, more stringent than best current experimental limits.

(C. Sivaram)

Some aspects of rotational and magnetic energies for a hierarchy of celestial objects

Celestial objects, from earth like planets to clusters of galaxies, possess angular momentum and magnetic fields. The rotational and magnetic energies of a whole range of these celestial objects are compared, together with their gravitational self energies and find a number of interesting relationships. The celestial objects, due to their magnetic fields, also possess magnetic moments. The ratio of magnetic moments of these objects with the nuclear magnetic moments also exhibits interesting trends. Their gyromagnetic ratio which appears to fall in a very narrow range for the entire hierarchy of objects is also compared. It is attempted to understand the physical aspects implied by these observations and the origin of these properties in such a wide range of celestial objects, spanning some twenty orders in mass, magnetic field and other parameters.

(C. Sivaram & A. Kenath)*

Charged black holes and constraints on Baryon asymmetry

The no-hair theorem, which postulates that all black holes can be completely characterized by only three externally observable parameters: mass, electric charge, and angular momentum, sets constraints on both the maximal angular momentum and maximal electric charge. In this work the consequence of these for the formation of primordial black holes in the early universe and also the formation of black holes due to collapse of dark matter configurations is explored, and also how this could be used to probe the conditions in the very early universe and constrain the epoch when baryon asymmetry was established.

(C. Sivaram & A. Kenath)*

Bounds on photon charge from evaporation of massive black holes

Photon charge has been of interest as a phenomenological testing ground for basic assumptions in fundamental physics. There have been several constraints on the photon charge based on very different considerations. Here further limits are put based on the well known properties of charged black holes and their subsequent evaporation by Hawking radiation and the assumption of charge conservation over this long physical process.

(C. Sivaram & A. Kenath)*

Thermal gravitational waves from primordial black holes

Thermal gravitational waves can be generated in various sources such as, in the cores of stars, white dwarfs and neutron stars due to the fermion collisions in the dense degenerate Fermi gas. Such high frequency thermal gravitational waves can also be produced during the collisions in a gamma-ray burst or during the final stages of the evaporation of primordial black holes. The thermal gravitational waves from primordial black holes and the integrated energy of the gravitational wave emission over the entire volume of the universe and over Hubble time are estimated. The gravitational wave flux from gamma-ray bursts and jets is also estimated.

(C. Sivaram & A. Kenath)*

Big Bang nucleosynthesis and primordial black holes

There are ongoing efforts in detecting Hawking radiation from primordial black holes (PBH) formed during the early universe. An upper limit on the PBH number density that could have been formed prior to the Big Bang nucleosynthesis era is derived, based on the constraint that the PBH evaporation energy consisting of high energy radiation not affect the observed abundances of elements, by disintegrating the nuclei. This puts a limit of $\Omega_{PBH} \leq 10^{-15}$.

(C. Sivaram & A. Kenath)*

Is the binding energy of galaxies related to their core black hole mass?

Most of the large galaxies host a supermassive black hole, but their origin is still not well understood. A possible connection between the gravitational binding energies of large galaxies and the masses of their central black holes is investigated. Using this relation (between gravitational binding energy of the host structure and the black hole energy) it is argued as to why globular clusters are unlikely to harbour large black holes and why dwarf galaxies, if they have to host black holes, should have observed mass to light ratios of 100.

(C. Sivaram & A. Kenath)*

Gammaless Gamma Ray Bursts

The compactness problem in GRB's has been resolved by invoking the Lorentz factors associated with the relativistic bulk motion. This scenario applies to GRB's where sufficient energy is converted to accelerate the ejected matter to relativistic speeds. In some situations this may not be a possible mechanism. Hence the gamma rays are trapped in the region. Here these possible scenarios are considered, where the neutrino pair production process dominates, and the neutrinos are able to escape freely. This could give a scenario where release of neutrinos precedes the gamma-ray emission, which is much attenuated, possibly explaining why fewer GRB's are observed than what is expected.

(C. Sivaram & A. Kenath)*

Intermediate black holes in globular clusters and the $M_{BH} - \sigma$ relationship

A few globular clusters have been found to harbour a black hole in their centres, and the suggested masses of these black holes are "intermediate", i.e., a few hundred to thousand solar masses, which is in between stellar-mass black holes and super-massive black holes that drive active galactic nuclei. The super-massive black holes (both in active and non-active galaxies) show a well-established but intriguing relationship between the mass of the supermassive black holes and the mass and stellar velocity dispersion of the galaxies that house them.

Using updated measurements of the central black hole masses in globular clusters, the question how these masses behave w.r.t. the velocity dispersion of their stars was investigated. It was found that they are consistent with the $M_{BH} - \sigma$ relationship for galaxies. The different types of stellar systems occupy distinct regions in the plot, suggesting that black hole masses of about 10,000 solar masses represent the *lowest* limit for the central supermassive black holes of galaxies. Masses of the central black holes that are below this limit correspond to the globular cluster domain. It is recalled that globular clusters G1 and ω Centauri are believed to be tidally stripped dwarf galaxies and not "genuine" globular clusters. The consistency of globular clusters with the $M_{BH} - \sigma$ relationship implies consistency with the theoretical predictions such as that of Begelman & Nath (2005), but not with those that predict a steepening of the relationship at the low-mass end from heirarchical black hole growth models (e.g., Granato et al. 2004).

The extended $M_{BH} - \sigma$ relationship was used to estimate the black hole masses in the globular clusters in which candidate central black holes have been predicted (e.g., Drukier & Bailyn 2003). These estimated masses were used to extend the $M_{blackhole}$-luminosity plot to lower black hole masses. Here again, the measured and estimated central black hole masses of globular clusters taken together are consistent with the extrapolation of the plot for galaxies. The consistency of black hole masses in globular clusters with the extrapolated $M_{BH} - \sigma$ and $M_{blackhole}$-luminosity relationships reinforces the idea that globular clusters harbour intermediate-mass black holes in their centres. Furthermore, if this consistency persists even with increased sample size and reduced measurement uncertainties, it would imply that common mechanisms underlie the parallel growth of black holes and their hosts in both galaxies and globular clusters.

(M. Safonova & P. Shastri)

1.4 Atomic Physics

Atomic astrophysics

A knowledge of atomic polarizabilities is necessary for several situations in astrophysics. However, it is challenging to perform accurate calculations of these quantities, particularly for heavy atoms where the interplay between relativistic and correlation effects are important. The relativistic coupled-cluster theory was used to calculate the polarizabilities of a number of closed shell atoms ranging from helium to ytterbium. The polarizability and the van der Waals coefficients for lithium were also calculated using a novel approach.

(B. P. Das & B. K. Sahoo)*

Ultracold atoms

The superfluid to Mott insulator transition in a Bose ladder consisting of two coupled chains has been successfully studied, leading to some important conclusions. In particular, it has been found that this transition occurs at a larger value of the onsite interaction than in the case of a one dimensional chain.

The various signatures for the superfluid to Mott insulator transition in a one dimensional optical lattice in the presence of a trap have also been analysed.

(T. Mishra, B. P. Das, M. Sethi, R. V. Pai*, S. Ramanan*)*

Non-accelerator particle physics

Investigation of the relativistic many-body theory of the electric dipole moments (EDMs) of atoms continues.

Work on the EDM of the diamagnetic atom Hg at the coupled cluster one hole-one particle, two hole-two particle and partial three hole- three particle level, has been completed. By combining the results with the available experimental data, upper limits have been extracted for a CP violating nuclear moment and also a CP violating tensor-pseudotensor electron-nucleus interaction. These limits provide new avenues for probing physics beyond the Standard Model and also shed light on hadronic and semi-leptonic CP violations.

A new project on the EDM of the heaviest alkali atom Francium has been recently started, in collaboration with Yasuhiro Sakemi's group at Tohoku University, Japan. Francium is indeed a promising candidate from the point of view of observing an EDM as its enhancement factor (ratio of atomic EDM to electron EDM) is about 1000.

(K. V. P. Latha, H. S. Nataraj, B. P. Das, B. K. Sahoo*, D. Mukherjee* & D. Angom*)*

1.5 Optical Sciences

Adaptive optics

The Shack Hartmann wavefront sensor has been investigated, with two components to the research. In the first part, different centroiding algorithms for a point source were studied. It was found that the Iterative Weighted Centre of Gravity (IWCoG) method is more efficient and fast for the Shack-Hartmann sensor. The second part focuses upon developing a fast phase retrieval algorithm which reduces the noise and improves the sensitivity. From the centroid the wavefront is reconstructed through modal approach, which has been done taking care of the amount of time consumed. At first the slope is measured from the centroid data. From the slope measurements, the wavefront has been reconstructed through Zernike polynomials, which are orthogonal over a unit circle. The programme has been written in MatLab 7. This work was part of an M.Tech. project.

Work on the real time wavefront sensing using two crossed Babinet Compensators (BC) is being continued. A value of 100 ms for evaluating the intensity data has been reached. Efforts are on to bring it to less than 20 ms.

(Photonics Division)

Dither based sensor for improved consistency of adaptive optics system

Atmospheric turbulence that stands between the telescope and the science target severely limits the resolution of the image obtained from the telescope. Adaptive optics has proved to be a feasible and best technological solution to improve the imaging of astronomical objects with large ground based telescopes. It is a tool which continuously and in real time compensates the turbulence effects using a wavefront corrector, generally a deformable mirror. A wavefront sensor is used to read the shape of the wavefront and a digital controller acts as a bridge between the sensor and corrector. For continuous and uninterrupted observation of transient events and phenomena, it is important to have an adaptive optics system that maintains consistency in the degree of correction.

By applying Monte Carlo simulations on vector matrix multiply methods and Fourier reconstructor it can be shown that the wavefront reconstruction accuracy is not a constant but fluctuates about a mean value irrespective of the sensing geometry at place. The inconsistency in the wavefront reconstruction accuracy will have a serious effect on the stability of imaging and maintenance of a good Strehl ratio. A small dither signal which acts like a translating operator on the wavefront sensor with respect to the phase screen can be used to improve the wavefront reconstruction accuracy. This dither signal is applied on the wavefront sensor so that it is displaced to a new location such that the wavefront reconstruction accuracy is maximized. This idea is evaluated through numerical simulations. Considering the case of a telescope with an effective diameter of 1m at a site with r_0 ∼10cm and a Shack Hartmann sensor with 100 subapertures Monte Carlo simulations were performed. The wavefront reconstruction accuracy depends on the way in which the wavefront distortion points match with the centers of subapertures. The centre of the lenslet array was displaced to different discrete locations with respect to the centre of the incoming wavefront within the distance of a single subaperture. The point of best wavefront reconstruction is the point to which the centre of the lenslet array has to be moved to. It was observed that the application of dither signal not only increases the accuracy of reconstruction but also significantly improves the consistency in the case of Fourier and VMM reconstruction procedures. An improvement in wavefront reconstruction accuracy is shown in Fig 1.30 for the case of VMM method.

Probabilistically the point of best wavefront reconstruction occurs close to the centre of the wavefront. Hence it is enough to apply a dither close to the centre of the wavefront. The choice of the spatial range over which the dither signal may be applied varies with the number of Shack Hartmann subapertures, the Fried parameter and the degree of freedom in the lenslet array. The dither should be applied at a frequency three times the frequency of adaptive optics wavefront correction. This gives enough time to check the Strehl ratio and make suitable corrections to the dither applied. It was also observed that by applying dither within shorter intervals of time gives smaller variance in the wavefront reconstruction accuracy and hence is more consistent. This dither based sensor can be realized using a Liquid Crystal based Spatial Light Modulator (LC-SLM) by projecting a digital diffractive optical lenslet array on it. The application of the dither signal is much simpler here since the physical movement of the sensor is not needed. The speed and physical dimensions of the SLM limits its application to this method in different situations.

(A. Vyas, M. B. Roopashree & B. R. Prasad)

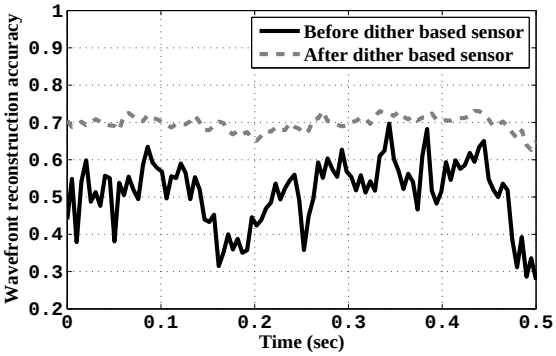

Figure 1.30: Improvement in the accuracy of wavefront reconstruction case of the VMM method.

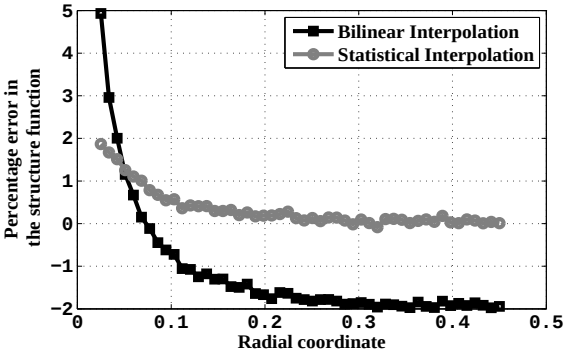

Figure 1.31: A comparison of the percentage error in the structure function in the case of bilinear and statistical interpolators: The case of mixing 5 atmospheric layers of turbulence (100×100 square pixels) with L_o = 100m, r_o = 10cm, v_w = 4.7, 9.4, 12.4, 26.9, 19.4m/s. Monte Carlo simulations run on 10,000 samples.

Multi-layered temporally evolving phase screens based on statistical interpolation

To simulate temporally evolving wavefronts, frozen in turbulence approximation is applied on individual layers. A very large wavefront with turbulence strength defined for a single layer is simulated as a first step. A small portion of this very large wavefront is selected as the initial phase screen in the temporal evolution of this particular layer. The subsequent phase screens at later times are formed by translating the initially selected portion on the very large wavefront in a definite direction and well defined velocity read from the wind velocity profile. The number of such phase screens generated is limited by the number of pixels on the large wavefront. The phase screens representing the evolution of atmospheric turbulence are finally obtained by superposing different evolving layers. The simulation of temporally evolving phase screens described above has a serious problem when a finite number of pixels are used for their representation and also in case of laser guide star adaptive optics. To properly simulate the atmospheric sampling by the reference source, statistical interpolation of the wavefronts at different layers is a requirement. This also helps in studying multiple laser guide star based adaptive optics system which corrects insufficient sampling and focal anisoplanatic effects which arise due to single reference star. The turbulence characteristics are not only functions of altitude but also time. The temporal variability of turbulence layer statistics makes it even more difficult to simulate them in real time. Statistical interpolation was applied in the simulation of multilayered temporally evolving phase screens and an improvement is shown in the statistics when compared to the simple bilinear interpolation technique Fig 1.31.

The performance of the random mid-point displacement method and the statistical method was evaluated in comparison with the bilinear interpolation technique. Kolmogorov phase screens of size 200×200 square pixels were simulated using the FFT method. A smaller portion of this larger phase screen (of size 100×100 square pixels) was selected and moved along to simulate evolving turbulence. Three layered temporally evolving phase screens were simulated by superposing three independent layers with appropriate wind velocities. The superposition of the phase screens was also done using the bilinear interpolation technique. This was repeated in the case of five layered atmospheric wind model too. The structure function was calculated for the original phase screens and resultant phase screens obtained after interpolation. The radial distance on the phase screens was normalized between 0 and 1. The percentage error in the structure function was then calculated in the case of different interpolation techniques and was compared. The evolving turbulence phase screens can also be simulated by keeping the value of r_0 fixed for all the layers. This kind of assumption makes the simulation of temporally evolving phase screens with known r_0 value simpler. In such a case, mixing phase screens of same r_0 value does not result in exactly the same r_0 value, but a slightly higher one. Hence it is appropriate to start with a slightly lower value of r_0 than required while simulating evolving turbulence phase screens based on the statistical interpolation technique.

(M. B. Roopashree, A. Vyas & B. R. Prasad)

Noise reduction in the centroiding of laser guide star spot pattern using thresholded Zernike reconstructor

The need for the use of a laser guide star for wavefront sensing is well known and the problems involved in centroiding are under study. A single subaperture spot pattern is simulated and was used in our analysis. A simple method of noise removal based on thresholded Zernike reconstructor is suggested here. The individual spots are reconstructed using complex Zernike polynomials to evaluate complex Zernike moments and then thresholded. A threshold of nearly within the range 50 and 90% was preferred. The Zernike reconstructed and thresholded spots are now subjected to weighted centroiding. The weighting function used is a standard reference of the spot pattern without noise by taking the most probabilistic simple sodium layer profile. A significant improvement was observed in the centroid estimation accuracy when thresholded Zernike reconstructor is applied in conjugation with the weighted centroiding technique. It was observed that TZR algorithm performs equally in comparison with other algorithms at signal to noise ratio between 1 and 2. At a signal to noise ratio less than 1, IWCoG performs better than TZR as shown in the Fig 1.32 When TZR is combined with WCoG instead of CoG, it performs better than any other algorithm at low signal to noise ratio. The elongation of the LGS spot pattern is assumed to be equal to the elongation of the equivalent closest ellipse. The elongation of the LGS spot has little effect on the centroiding estimation error after application of TZR. When compared against smaller spots or streaks, the performance of the algorithm is better in the case of larger ones. The centroid estimate is best when the spots are oriented along the direction of the pixels (at 0 orientation angle). The performance of the algorithm can be improved by using a polar coordinate detector where the major axis of each rectangular pixel is aligned with the axis of elongation. It was observed that the fluctuations in the sodium profile nearly double the centroid estimation error. It is hence important to continuously monitor the fluctuations and make corrections to the weighting function used in the centroiding of the spots. By doing so it was observed numerically that the centroiding estimation error reduces by little above 10%, but does not reach the value which is obtained with zero fluctuations. Using a very few Zernike moments for reconstruction weakens the spot of its details and having too many of them includes the higher order effects which can be identified with noise. As the image size increases, it becomes important to include more and more Zernike terms to closely reconstruct the features of the spot. Centroid estimation error dropped with reducing thresholding percentage upto 60%. Reducing the thresholding percentage further is risky and would retain noise features which may lead to large errors in the case of a spot of size 30×30 pixels with 29 Zernike modes. The number of pixels used for a single subaperture can also influence centroiding estimation while using TZR. This is because image reconstruction in the case of smaller images becomes easier with fewer Zernike moments. At a low signal to noise ratio, reconstructing a 24×24 spot pattern using n = 29 leads to inefficient representation of all the required spot features, whereas representation of a 12×12 spot with the same number of Zernike modes is more efficient. Hence in this case (n = 29 and 60% thresholding) at low signal to noise ratio, smaller spots must be preferred. On the other hand, at a high signal to noise ratio, fewer Zernike modes are sufficient to represent all the features of the spot. The centroiding accuracy is good for larger spot pattern at high signal to noise ratio.

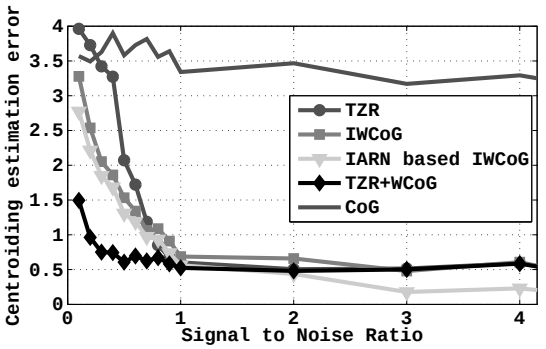

Figure 1.32: A comparison of different centroiding algorithms with the TZR method in conjugation with WCoG. At low SNR, TZR+WCoG performs better than any other technique.

(A. Vyas, M. B. Roopashree & B. R. Prasad)

Hidden periodicities on a rough a surface

The problem of finding periodic structures on a surface, hidden behind surface imperfections is beset with difficulties, when conventional methods of analysis are used. It is known that the light scattering intensity data fail to show up the periodic structures if $\Lambda \leq 0.33 r_0$ where Λ is the wavelength of the periodic structure and r_0 is the coherence length of the photon, as introduced by the randomness of the surface. A new method of analysis, based on matched

filtering has been shown to be capable of detection of the hidden periodic part for $\Lambda \leq 0.11 r_0$, i.e. allowing detection for much larger randomness than what would be possible with conventional methods of inversion. The role of the amplitude of the periodic part in rendering the detection possible was investigated and suitable statistical tests were employed to judge the efficacy of these methods.

(S. Chatterjee & V.C. Vani⋆)

Speckle techniques with hypertelescope

Interferometric imaging through aperture synthesis with many baselines to reconstruct images, has been highly successful at radio wavelengths and also demonstrated at optical wavelengths. Recently, it was realized that many-aperture optical arrays can provide snapshot images, with arbitrarily diluted apertures. This 'hypertelescope' approach to imaging may be viewed as a simple modification of the classical Fizeau interferometer by employing pupil densification. It has a vast potential, particularly since large arrays of relatively small apertures are easy to implement. A prototype instrument has already been developed and a largescale version like CARLINA 2 is under development.

A major challenge for the hypertelescope system is the development of adaptive phasing system. Modified wave sensing techniques such as dispersed speckle analysis are planned to be used with these systems. But development and installation of such advanced methods are not available at present. In such a scenario, speckle mode observations with hypertelescope becomes a viable alternative. Even in table top versions of hypertelescope, speckle images have been observed due to phase variations in the sub-apertures. A study of speckle techniques with such systems is thus of great interest.

The aim is to study imaging with such a diluted aperture interferometer in speckle mode with techniques like speckle interferometry and speckle masking. For imaging with hypertelescope the incomplete output pupil filling provides a serious limitation. It is shown with the help of numerical simulations that even with smaller pupil filling rate in output pupil, high resolution imaging can be done with this interferometer by utilizing aperture rotation throughout the night. Techniques for using aperture rotation with speckle techniques for better reconstruction are also explored.

(A. Surya⋆ & S. K. Saha)

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Chapter 2

Facilities

2.1 Photonics Laboratory

Vacuum coating

The 2.34m primary of the Vainu Bappu Telescope was aluminized during this period. Periodic maintenance work was carried out at the 1.5m and 2.8m vacuum coating plants at VBO Kavalur.

The trial runs were carried out at the newly upgraded 1.5m coating plant. Few minor modifications need to be carried out in the course of time.

Thin film research

The BC 300 coating plant, the Scanning Electron Microscope (SEM) and Energy Dispersion Spectrometer (EDS) facilities have been in use for various training programmes of the institute.

The BC 300 coating plant has been in continuous use for providing various multi-layer coatings like aluminium, silicon, silicon-dioxide, chromium, magnesium fluoride on glass substrates through electron beam (EB) gun facility.

As part of the training programme of the institute, different thin films on glass substrate and silicon wafers were analyzed using SEM and the Energy Dispersive Spectroscopy to assess qualitative and quantitative information of the prepared samples. Design work has been initiated to produce Lyman α band pass filter which has great astronomical applications.

10.5 micron detector development

The design of the 10.5 micron detector has been completed and reported earlier. The design consists of multilayer coatings, which has to be carried out by molecular beam epitaxy (MBE) method. Such a facility does not exist in the institute.

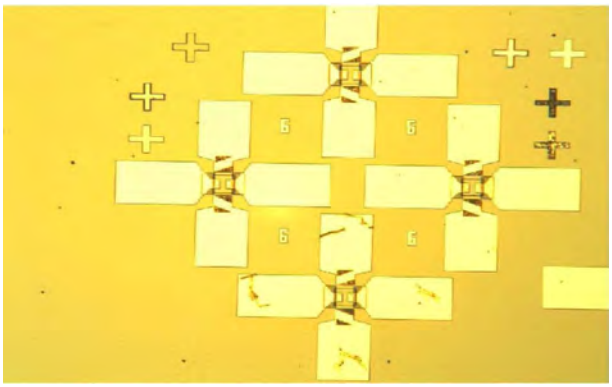


Figure 2.1: Fabricated 10.5 micron QWIP device for V-I characterization. The mask set consisted of 40x40, 50x50 and 60x60 square micron area, each 4 in number. The V-I characterization was done for all three sample device areas.

The device was grown at the Cavendish laboratory, UK by molecular beam epitaxy (MBE) method. Considering the machine constraints of the MBE system the performance of the device grown was found to be within the expected limits. The wafer grown was cut into 5mm x10mm chip and was etched chemically to the desired device area dimensions: 40μm$\times 40\mu$m, 50μm$\times 50\mu$m and 60μm$\times 60\mu$m. Au–Ge -Ni contact layer (1500Å)was done by sputtering. Bottom and top Ohmic layers made of Ti-Au (200Å/1000Å) were deposited by low tension vaporization method. The top and bottom layers were separated by a layer of polymide by spinning. The activation energy was found for the sample and from that the aluminium content was found to be 0.371 (true value 0.365) which was within the limits. The QWIP device grown at Cavendish Laboratory and its spectrum is shown in the (See Fig. 2.1) and (Fig. 2.2). The direct current characterization (See Fig. 2.3) was done and the current density and the dark current were measured at the cryogenic set up at liquid Helium temperature. The measured dark current value

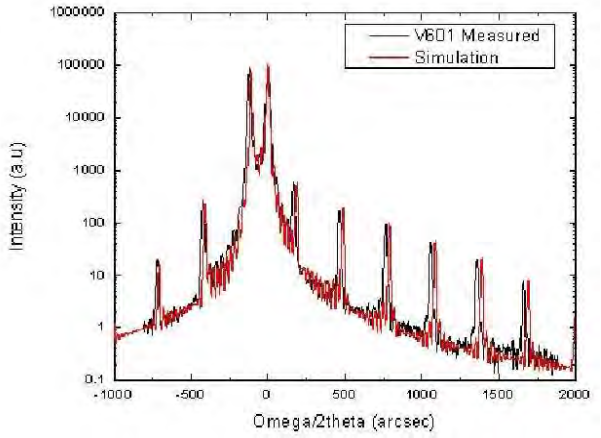


Figure 2.2: The DCXRD spectrum of the QWIP wafer sample grown at Cavendish. The double crystal x-ray diffraction shows that there is a highly precise growth process. The various satellite peaks reveal that there are no major relaxation interstructures except for minimum compressive and tensile strain.

coincides with the theoretical value (See Fig. 2.4). The Cambridge University has reported that the device is found to be successful one. This forms the part of the doctoral thesis work of Ms.Celine Joseph, an FIP student from Jyothi Nivas College.

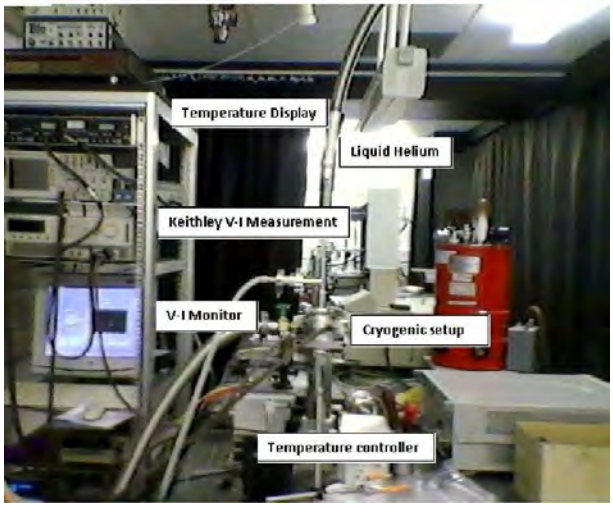


Figure 2.3: DC characterization at the Cavendish laboratory.

Galileoscope for IYA09

As part of IIA's International Year of Astronomy 2009 programmes, a simple low-cost 4-inch aperture Newtonian telescope was designed at IIA. These were

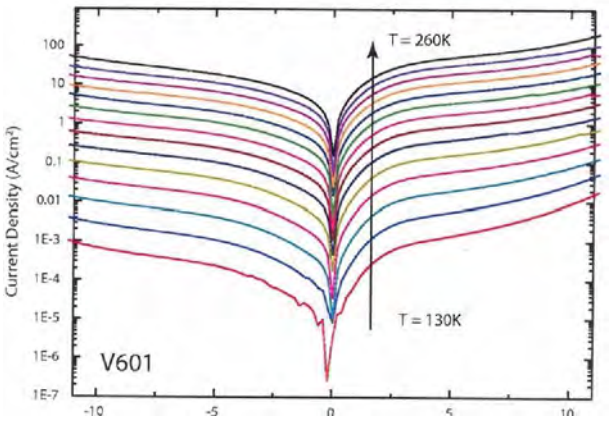


Figure 2.4: Current density versus voltage at different temperatures.

mass-produced and a record number have been distributed to many schools, groups and individuals across the country.

12 inch telescope optics

The fabrication work on a 12 inch Cassegrain telescope optics system having a prime f-ratio of f/3 and system f-ratio of F/10 is in the final stages of figuring.

(Photonics Division)

2.2 MGK Menon Laboratory for Space Sciences

IIA has embarked on new challenging projects to build both ground-based and space-based observation platforms and instruments to be in the forefront of research and technology. Most of these efforts are towards developing multi-wavelength capabilities both in solar and stellar astronomy.

IIA is a major participant in the ASTROSAT Mission of ISRO. It is building the UV Imaging Telescope (UVIT) which is the most important part of this mission. IIA will also be building the Visible Line Space Solar Coronagraph for ISRO's Adithya-I Mission. All these space payloads require ultra-clean and state-of-the-art laboratory facility to build, test and calibrate. Thus, IIA planned a major effort to build and operate a state-of-the-art space instrumentation facility. The primary purpose of this facility is for integration, characterization and calibration of space-based UV instruments, coronagraphs and telescopes.

An Optical Sciences Laboratory with a clean-room environment has been established to carry out research in adaptive optics and non-linear optics. This facility has a BeamLokTM 2085 argon-ion laser from Spectra Physics (USA), a high power (15W) cw laser with Z Lok and J-Lok options. A solid-state diode-pumped Nd:YVO4) cw laser MillenniaTM V from Spectra Physics is used for pumping titanium-doped sapphire (Ti: Sapphire). A tunable laser action over a broad range at near infrared (750-950 nm) makes it an excellent substitute for the dye lasers. The facilities include vibration isolation tables, wavelength meter, diode lasers, a multi-channel power meter, electronic balance, interferometer, CCDs, spatial light modulator, high quality optics and optomechanics, precision actuators and state-of-the-art motion controllers, LabView etc. This laboratory also acts as a training centre in optics for graduate students.

The MGK Menon Laboratory is designed and built as per the requirements of the International Organization for Standardization which has evolved standards and common definitions for different classes of clean-rooms. ISO has evolved two standards viz the first ISO 14644-1 devoted to the new ISO Classification System for Clean-rooms and the second ISO 14644-2 devoted to Specification for Testing Clean-rooms to prove continued compliance with ISO 14644-1.

2.3 Electronics Laboratory

Temperature control of CCD dewars using PT100 and AD590 sensors

CCD detectors in astronomical cameras need to be operated at stable cryogenic temperatures. Temperature sensors such as the PT100 AD590 can be used for these purposes.

The principle of operation of the PT100 is to measure the resistance of a platinum element. The most common type (PT100) has a resistance of 100 ohms at 0^o C and 138.4 ohms at 100^oC. The relationship between temperature and resistance is approximately linear over a small temperature range.

The PT100 sensor setup consists of a simple bridge circuit to measure the difference in the voltage across the bridge which is developed on a result of temperature difference. One of the arms of the bridge is to be connected to the CCD sensor which has the PT100 temperature sensor attached to it.The other arm is to be connected to an identical sensor that at any reference temperature the difference is potential across the bridge is almost to zero. This difference is taken from a sensor for AD624 amplifier. Gain is altered to get the measurable analog voltage. Once the difference in potential is set to zero, the PT100 sensor is replaced with a fixed resistance of approximately 100 Ohm so that the difference in voltage across the bridge is indication of temperature difference from 0^oC. The amplified output voltage of AD624 is then reduced to 51.28% using a potentiometer for the calibration of 0.1^oC to 1mv in DPM, to display the temperature in ^{o}C.

The AD590 is a two terminal integrated circuit temperature transducer that produces an output current proportional to absolute temperature. For supply voltages between +4V and +30V the device acts as high impedance, constant current regulator passing 1μA/K.

In the temperature controller circuit, the temperature sensor AD590. provides a current output which produces 1mv/^{o}K when terminated with a 1KΩ resistor. This signal is compared with the set temperature by a gain comparator. The comparator controls a Darlington transistor to regulate the current in a heater resistor and thereby temperature in the camera mount. When the dewar is filled with LN_2 the CCD mount is heated to the set temperature and stabilizes at the set point with an accuracy of 1^o.

(A. V. Ananth & K. Anupama)

2.4 Kodaikanal Observatory

Micro-stepping drive for high precision tracking of solar image with coelostat system

Figure 2.5: KML 063 being used in the Coelostat

The high precision micro-stepping drive system consists of micro-step module MD 808, stepper motor KML 063 and a five channel digital counter/timer (Measurement computing based on USB 4301 – 9513). (See Fig. 2.5) The Slo-Syn (Superior electric) MD 808 is a bipolar, speed adjustable, two phase PWM drive which uses power MOSFET devices set to operate the stepper motor in eight step resolutions from full-step movement to 1/100 micro-step with a maximum running speed of 3,000 rpm or 20,000 pulses per revolution. To reduce the possibility of electrical noise problems, the control signals are optically isolated from the drive circuit. The drive has under voltage and transient over-voltage protection and thermal protection.

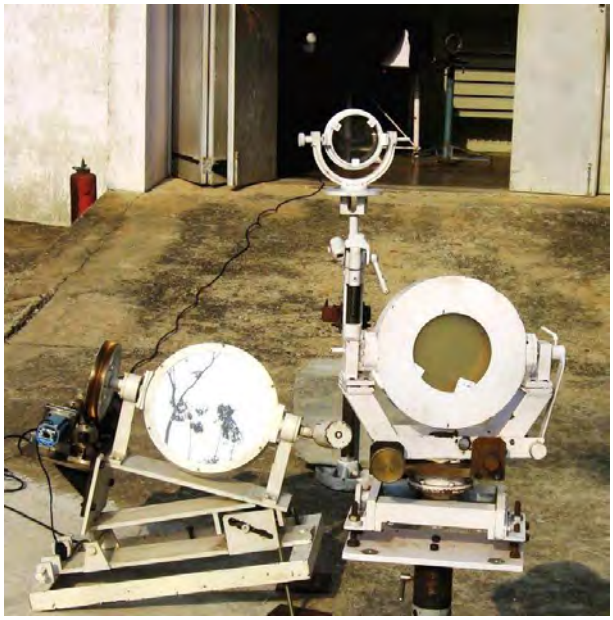


Figure 2.6: Optical light path arrangement and tracking of the solar image to the spectrograph during the total solar eclipse experiment.

The smooth tracking movement of the coelostat, produces a very sharp solar image without causing any vibrations or jerk. Hence it has been decided to go for the micro-stepping drive system with stepper-motor for the coelostat tracking in place of the earlier full-step system replacing the gears with high precision system for achieving higher resolution and tracking. In order to avoid the instabilities which cause a loss of torque at stepping rates outside the range of natural resonance frequencies, the base speed is selected to be above the motor's resonant frequencies. The acceleration and deceleration are adjusted so that the motor moves through the unstable regions quickly.

Testing and trial runs of the coelostat system, the gear's alignment, balancing, tuning, tracking, pointing accuracy and positioning of the system were carried out at VBO, Kavalur. The tracking accuracy, image quality tests and performance of the system was also monitored before despatching it to China for the total solar eclipse expedition programme. The system was successfully used for tracking the solar images with the coelostat during the total solar eclipse expedition of IIA in Anji, China during July 2009.(See Fig. 2.6)

(N. Sivaraj & J. Singh)

Micro-step positioning of grating system at 24 inch Solar Tower Tunnel Telescope, Kodaikanal

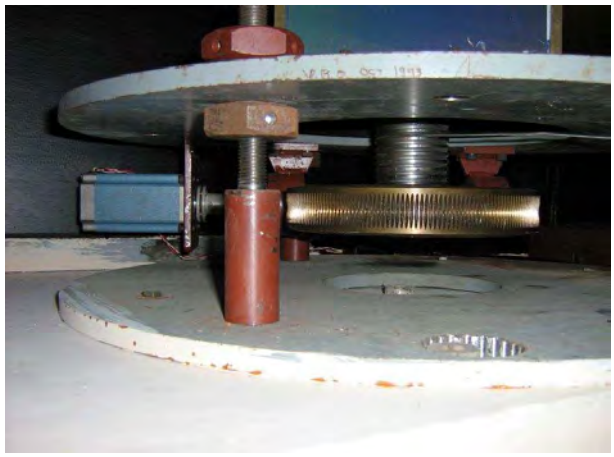


Figure 2.7: Stepper motor KML 063 being used for positioning the grating

The high precision micro-stepping drive has been introduced into the grating drive of the tunnel telescope at Kodaikanal, thus it reduces the shaft speed for a given input pulse rate and runs smoothly. (See Fig. 2.7). The drive provides a stable vibration free movement even at lower speeds, when compared with the stepper motors that involve full-step movement. The successful installation of the micro-stepping drive for the grating of the tunnel telescope has meant that, now the grating could be moved line by line quite comfortably with micro-step resolution, greatly enhancing the efficiency and ease of spectroscopic observations.

The USB-4301 is designed to use a programmable 9513 counter/timer chip for event counting, pulse and frequency measurement, alarm comparisons and

Figure 2.9: Control system testing.

other output functions. The chip has five independent 16 bit counters, each with an input source, internal counter register, load register, hold register, output, and gate. It is a 5 channel, 16 bit counter/timer with event counting, PWM, frequency measurement/ division and duty cycle generation. Visual Basic, .net framework and visual C C++ were used for programming the system which runs on the Microsoft Windows platform.

(N. Sivaraj)

WARM telescope control system

The WARM (White-light Active Region Monitor) coelostat is a two mirror coelostat system installed at Kodaikanal. It is a control system based on brushless AC servo motors, brushless AC servo drives (Microflex model) and next move PC 1 four axis motion controller card from Baldor. The control system has four bins housed in a rack. (See Fig. 2.8 and Fig. 2.9).

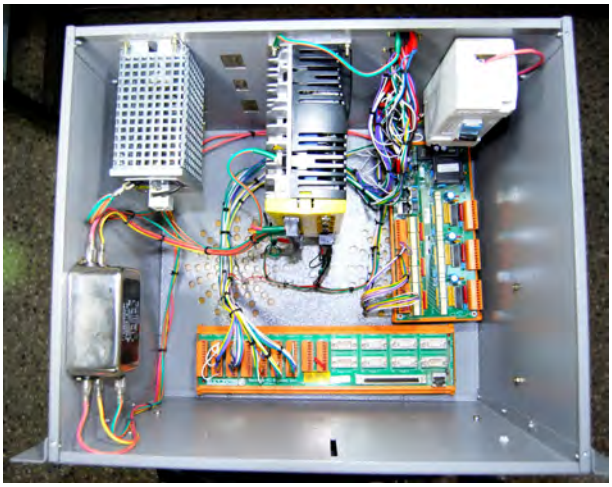


Figure 2.8: Drive mounting.

The top most bin is the track control bin for the primary mirror. The second and third bins are RA and DEC control bins for secondary mirror image guiding of RA and DEC. The fourth bin is the DC power supply bin. Complete wiring and Assembling of the above four bins in a rack was carried out in the IIA electronics lab.

(K. C. Thulasidharen & C. V. Sri Harsha)

Sky conditions: Kodaikanal Observatory

		No. of observations			**Seeing conditions***				
Year	Month	Ca K(TT)	WL(TT)	PHGM	5	4	3	2	1
2009	April	10	10	18	-	6	9	2	-
	May	17	17	18	-	7	10	1	-
	June	15	15	15	-	6	8	1	-
	July	9	10	11	-	1	6	4	-
	Aug	12	13	14	-	7	4	0	-
	Sep	12	12	10	-	7	2	1	-
	Oct	8	9	18	-	7	8	2	-
	Nov	7	7	7	-	4	3	-	-
	Dec	16	16	14	-	10	4	-	-
2010	Jan	28	28	29	-	25	3	1	-
	Feb	27	27	25	-	12	13	0	-
	Mar	30	30	31	-	8	17	4	-

CaK: CaK filtergrams taken by twin telescope.
WL: Whitelight filtergrams taken by twin telescope.
PHGM: Photoheliograms
*Seeing conditions (1-very poor, 2-poor, 3-fair, 4-good, 5-excellent)

2.5 Vainu Bappu Observatory

A dedicated 40-cm telescope for seeing and extinction measurements

A dedicated telescope of 40-cm with a Differential Image Motion Monitor (DIMM) was installed at VBO. The telescope and instrument were procured from M/s DFM Engineering. The instrument parameters were specified to suit the range of "astronomical seeing" at VBO. The instrument is also specified for carrying out measurements of extinction on command from any other facility at VBO. It is expected that this facility would save considerable time from the larger telescopes for such routine measurements. The telescope and instrument controls and software interface will allow unattended operation over a network.

Figure 2.10: The 40cm DIMM telescope mounted atop the tower at VBO. The DIMM instrument is mounted at the cassegrain focus which is within the telescope tube. Only the CCD camera and some controls are seen outside. Mark Kelley of DFM is seen in the picture.

The most popular method for measuring the Earths atmospheric turbulence (called "seeing") uses a mask over the entrance pupil of the telescope, allowing star light from two sub-apertures located as far apart as the telescope aperture allows to enter the telescope. Normally the telescope optics would bring these two "beams" of rays to the focal plane where they would fall on top of each other (and actually be in phase). A small angle prism introduced into one of the beams will separate the two images by a distance preferably much larger than the image diameter.

Each of the sub-apertures forms an image which under all but the worst seeing conditions is diffraction limited. Because of the relatively small aperture of each beam, the diffraction limited image is fairly large and the focal length of the telescope and the pixel size of the camera are chosen so each image covers an area on the CCD detector that is at least 4 pixels by 4 pixels. About 200 measurements of the relative positions of the centroids of the two images are used to gather sufficient statistical information to calculate the seeing. The relative or Differential Image Motion (DIM Monitor or DIMM) is used to separate the star image motions from any telescope or instrument vibrations. Because the Earth's atmospheric refraction causes image motion and the scale of the refraction effects are in the range of a few cm to 40 cm, the images move relative to each other.

Figure 2.11: Erection of the DIMM tower at VBO. The separate steel cylinder (pier) and outer pipe structure are seen.

Relatively short exposures are needed to "freeze" the star position. The combination of a small aperture and a short exposure means there is less light and a highly sensitive detector and a bright star are needed. The DIMM system actually measures the differential image motion, the statistics of which allows the derivation of the Fried's parameter (R_o) and further the 'seeing' at any wavelength.

The system at VBO uses a 40 cm (16 inch) F/9 telescope with a plate scale of 56 arcsecmm^{-1}. The DIMM optical system has a field stop located at the cassegrain focal plane, followed by a collimating lens and filter wheel and aperture wheel in the collimated beam. A second lens re-images onto the CCD camera. The collimated beam diameter is 20 mm, corresponding to the full telescope aperture. The aperture wheel has a metal diaphragm with two apertures, each being equivalent to a 66 mm diameter aperture at the entrance pupil of the telescope and a spacing (between the two) equivalent to 330 mm. A small angle prism (wedge) is behind one of the apertures to separate the two beams on the CCD.

The centroids of the two images are measured using the 'centre of gravity' method on dark subtracted, flat-fielded images. The diffraction limited image for a 66 mm aperture at a wavelength of 500 nanometers gives a diameter of at least 3.8 arcsec, corresponding to about 70 microns at the plate scale of the telescope. The CCD camera has a Kodak CCD chip with pixels 7.4 × 7.4 microns. If the CCD is binned 2 × 2 then the image is covered by 4.7 × 4.7 pixels. This allows centroiding accuracy to a fraction of a pixel. The camera can be read out at 30 frames per second and, a small region of interest at up to 70 sub-frames per second giving an exposure time of 14 milliseconds. The readout rate can be adjusted to best match the site measurement requirements. During installation tests, it appeared that a rate of 50 – 60 sub-frames per second (exposure 20 to 17 milliseconds) would be adequate to measure seeing with the specified precision.

The system is capable of measuring seeing with an accuracy of 10 % in the range of 0.3 – 3 arcsec. In good seeing conditions, the accuracy is limited by scintillation. Since seeing and scintillation are not necessarily correlated, when the seeing is better than 1 arcsec, the accuracy may be degraded by adverse scintillation.

Though the instrument is specifically designed for automated seeing and extinction (photometry) measurements, the CCD temperature control is only relative to the ambient. Hence frequent dark frames are required to get sufficient accuracy in photometry. The automated extinction measurements use a windowed readout centered around the star. It is possible to carry out direct imaging using the full CCD. Some preliminary tests of imaging were done during installation. Though this was not among the specified objectives of the instrument, efforts are underway to ensure that the software finally produces standard format images in this mode. The field of view of the DIMM instrument for imaging will be 507 × 378 arcsec.

The DIMM telescope is installed atop a tower of somewhat radical design about 14 metres high. This height is necessary to clear the turbulence generated by the trees around the location. The design of the tower incorporates a novel steel cylinder constituting the 'pier' of the telescope and a spiral staircase within this allows access to the top. An outer structure made from steel pipes and having a top ring serves as the enclosure which supports a 'clamshell' dome that can be fully opened to the sky.

Fig. 2.11 shows the tower during the erection process and Fig. 2.12 shows a view of the dome being installed atop the tower. An air venting system has also been designed and installed, which will allow quick venting of the inner cylinder (pier) during a hot summer's day. The design, fabrication and installation of the tower have been done to in-house specifications and supervision. The clamshell dome has been procured from a vendor.

Figure 2.12: Lifting the clamshell dome to the top of the tower for installation.

Regular, unattended operation of the facility will commence after installation of ancillary facilities such as UPS power and network extension. Extensive testing of the instrument in different seasons can be carried out after these are available.

The DIMM tower design and fabrication experience gives important inputs for the 1.3 m telescope enclosure and indeed provides validation of a design where natural ventilation can ease many of the "seeing" problems with traditional telescope buildings.

(A. K. Pati & DIMM project team)

1.3 m telescope project

The 1.3 m telescope fabrication progressed satisfac-

torily over the year. The design of the mount of the telescope has been done by the vendor to specially suit the low latitude of the Vainu Bappu Observatory. Since this design is being made for the first time by the vendor, it has been necessary to evolve the correct procedure for assembly and alignment at the vendor's facility. This procedure was completed satisfactorily and a trial assembly of the full telescope was done by October 2009. Figs 2.13 and 2.14 show the fully assembled telescope structure. During this process some fine tuning of the hydrostatic bearing system (flow control system) was also carried out, along with modifications to some elements of the system. The structure was disassembled after these trials; painting of the various parts of the structure will be carried out at a different vendor location.

Figure 2.13: Assembled structure of the 1.3m telescope viewed from the N-W side. The RA axis drive assembly is seen on the face of the horseshoe. The north side horseshoe is on two hydrostatic bearing pads. The top ring of the telescope truss assembly and the 5-axis positioner for the secondary mirror are also seen.

The design of the enclosure and dome for the telescope at VBO, initiated in-house, reached an advanced stage of detailed engineering during this year. The concrete pier of the telescope, of height about 14 meters, is specified to have a natural frequency above 10 Hz. The FE modeling of the pier and the design required to achieve this was completed. The design and drawings of the civil works for the foundation of the enclosure were also completed. The specifications for the dome and enclosure design were finalised and detailed engineering reached an advanced stage. The non-availability of the desired type of elevator (for the Kavalur location) has led to some setbacks in the schedule, since the design of the enclosure needs to be modified to accommodate the type of lift for

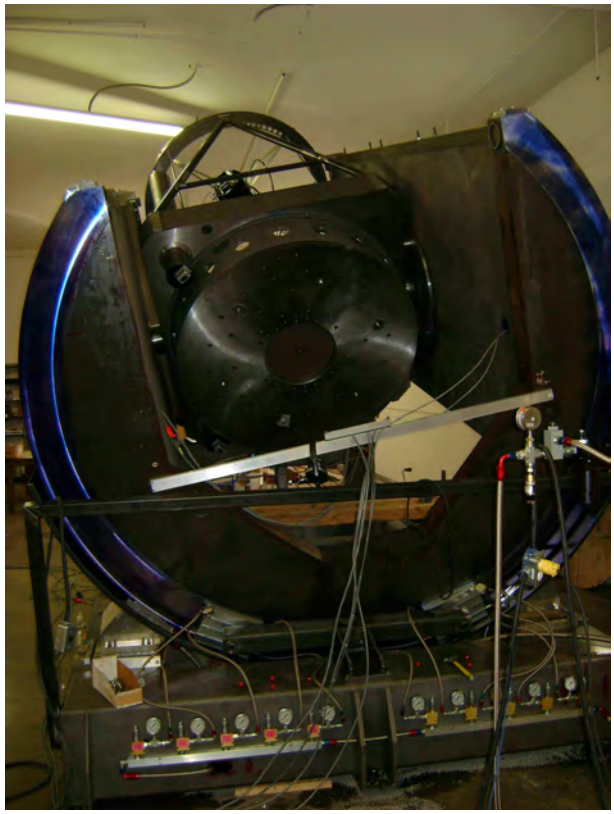


Figure 2.14: View of the assembled structure of the 1.3m telescope from the south side. The polished bearing surface for two of the hydrostatic bearings can be seen on the face of the south horseshoe. The numerous other fixtures, valves and dials are part of the hydrostatic bearing testing system. The centre section and mirror cell of the telescope are also seen.

which bids were received. It is anticipated that civil tenders will be awarded by mid-2010 and tenders for steel enclosure and dome would be placed soon thereafter. Barring unforeseen problems the installation of the telescope would probably take place in early 2011.

The project implementation is being done with part time involvement of the existing mechanical and civil sections of the institute. Other sections will be involved as work progresses.

(A. K. Pati & 1.3 m project team)

Control scheme and software for the 30 inch optical telescope

The control system including the software has been tested for the newly refurbished 30 inch telescope at VBO, Kavalur. The software has been devel-

Figure 2.15: The newly refurbished 30 inch optical telescope at Vainu Bappu Observatory, Kavalur.

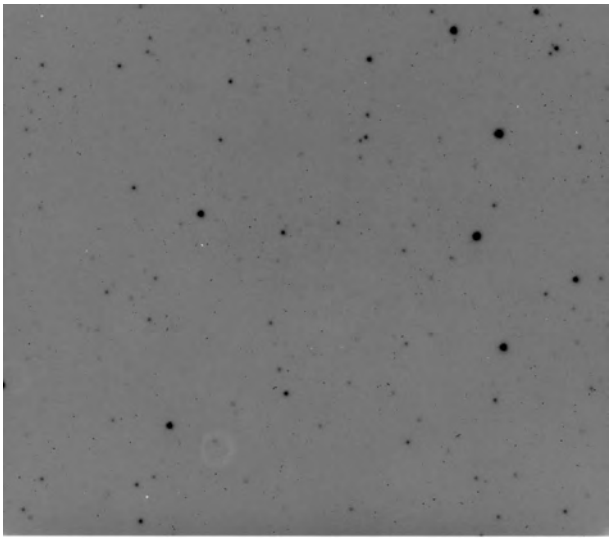


Figure 2.16: The image of NGC 2169 taken with the R filter, and an exposure of 2400 sec on 05 March 2010, with the 30 inch telescope using a 1K×1K Photometrics CCD and autoguider.

oped in two phases. (1) An autonomous mode where the telescope and other associated sub-systems work independently. (2) A networked mode where the telescopes and other sub-systems communicate through a common communication server based on client/server technology, which would also enable back-ends to be clients and communicate with other sub-systems.

The first phase of the software has been developed and tested at the site in Kavalur. The control scheme based on a turbo-PMAC II hardware handles the movement in two axes and can move the focus motor. Incremental optical encoders act as position feedback elements and provide 3.6 million counts per revolution with a basic resolution of 0.36 arcseconds in both axes.

The D.C. servo motors are connected through a large gearing of 1:5000 which provide necessary speed reduction at required torques. The hardware mechnical limit switches are placed such that the telescope can operate from +4.5 hrs to -4.5 hours in east-west axis and -70 to +70 degrees in north-south axis.

The Telescope is of equatorial mount type and hence the telescope needs to be tracked only in one axis namely, RA axis and at a constant rate of 15 arcsec/sec.The telescope has five speed settings viz: 1.Slew 2.Set 3.Track 4.Guide 5.Fine-guide The servo motor operates from approximately 800 R.P.M. at slew speed to 3 R.P.M at track and 1 R.P.M and 1/5 R.P.M for guide/fine guide speeds. There is a also a handset control for set/guide/fine-guide speeds achieved through an accessory for turbo-PMAC II boards. The control scheme for both RA and DEC axis primarily consists of a position loop with a built-in velocity loop.

The control software has been developed under WINDOWS-NT using Pcomm-32 library provided for Visual C++ by delta tau. The programme uses: (a) PLCs (programmable logic control feature) for input/output interaction. (b) Motion programmes for actual movement of axes.

The telescope control programme allows the telescope to move from one object position to another and also track the object at sidereal rates.This is a multi-threaded application which uses Microsoft Foundation Classes (MFC's) for graphical user interface development.

The user interface allows to set the position (RA and DEC) through the GUI and allows the object so acquired to be tracked. There is also a provision for offset movement, so that the telescope can be offset by small increments if required. There is also a provision for controlling the telescope through a handset interface which allows objects to be positioned, tracked and guided.The GUI has a provision for displaying Universal Time (UT), local sidereal time (LST), present RA, DEC and HA. There is also a provision for enabling focus movements. A graphical display in real-time of the telescope position is also part of GUI.

Focus drive: The secondary focus movement is driven by a HS50 stepper motor. The stepper motor drive circuit is built using IM483 driver module. Handset control and remote control are also enabled. The secondary focus movement is read through a

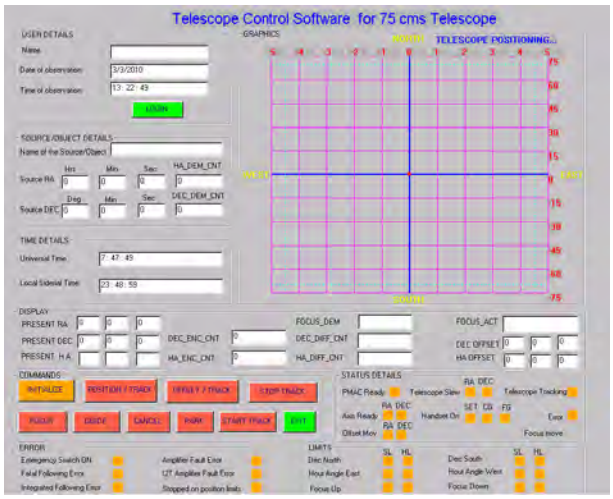


Figure 2.17: GUI for the telescope control programme.

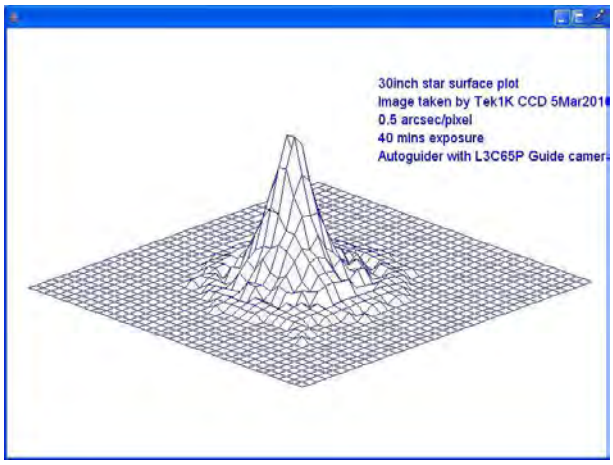


Figure 2.18: Surface plot of a star image taken with an exposure of 40 mins using the 30 inch telescope with a Tek 1K CCD on 05 Mar 2010.

25 mm traverse digital dial gauge. The dial gauge has a display interface unit from which the dial gauge reading can be read by a PC or terminal via an RS232 port.

Auto-guider: A provision for an autoguider also exists. The autoguider camera is an uncooled L3 CCD camera and the offset movements are effected through PMAC I/O. The autoguider accuracy is ± 0.9 arcsec for 90 % of the time (tested for integration time of 40 minutes).

(A. V. Ananth, P. Anbhazhagan, V. Arumugam, A. Ramachandran, K. Ravi & S. V. Rao)

Dome control hardware and software for 30-inch telescope

The dome control software developed using VC++ under NT environment for 30 inch telescope, is installed and under testing, some more trial runs are required for fine tuning all the parameters. The software has two modes of operation: automatic local and automatic remote mode. A interface unit based Atmel 89c51 microcontroller to read 16 bit absolute serial encoder data and convert to parallel data is developed in lab.

(F. Saleem)

Sky Conditions:

Month	Spectroscopic Hours	Photometric Hours
April 2009	175	26
May	89	01
June	63	01
July	32	00
August	10	00
September	32	05
October	126	16
November	33	00
December	28	00
January 2010	160	53
February	190	68
March	219	44
Total	1157	214

VBT Time allocation during April09-March10:

No. of spectroscopic proposals:	7
No. of nights allotted for spectroscopic proposals:	125

No proposals for imaging were received.
The telescope was under maintenance (painting and refurbishment of electrical parts) during Sept 2009–April 2010.

2.6 Indian Astronomical Observatory

Himalayan Chandra Telescope

The HCT has been continuously in use by the national and international astronomers since May 2003. The HCT engineers, staff astronomers and two engineers from EOS Tuscon participated in the annual maintenance of the telescope during November 2009. HCT continued to be a productive telescope, and the total number of papers in referred journals using data from HCT has crossed 80.

Work on the second generation instruments continued during the year. A 4K×4K CCD (CCD 203-Blue) was procured from UKATC and was tested by HCT and VBO engineers at Kavaur. The CCD has reached Hanle and will be mounted at the telescope once the interface unit is ready. This will replace the existing 1K×1K photometric CCD. Negotiations were undertaken with Industrial Research Laboratory, Government of New Zealand for construction of a high-resolution fiber-fed spectrometer and a funding proposal is made. IIA is collaborating with TIFR, Mumbai towards development of a near-infrared imager-spectrograph (TIRCAM). The Preliminary and Critical Design Reviews were conducted during the year and fabrication initiated.

The solar power stations of HCT are working satisfactorily for the last twelve years due to excellent on-site maintenance. Initiatives to replace the batteries of the power stations and upgrade the satellite link between Hanle and Hosakote used for operating the telescope are underway.

HAGAR Telescope

High Altitude GAmma Ray (HAGAR) experiment is an array of seven telescopes located at Hanle base camp, at an altitude of about 4300 m. This telescope array, based on atmospheric Cherenkov technique, is designed to achieve lower energy threshold in the neighbourhood of 100 GeV. HAGAR array constitutes the first phase of the experiments from HiGRO collaboration comprising of members from TIFR, BARC, IIA and SINP. Second phase will consist of 21 m diameter telescope called MACE, which will be installed in another year or two, near HAGAR.

The HAGAR array has seven telescopes arranged in the form of a hexagon with spacing of 50 m and one telescope at the center. Each telescope has seven para-axially mounted front coated mirrors of diameter 0.9 m with a UV sensitive photo-tube at the focus of each mirror. These telescope has alt-azimuth mount. Each telescope is provided with a finder telescope. In order to ensure correct pointing of these telescopes, pointing model is worked out for each telescope by sighting about 25 stars distributed over the accessible sky. Co-alignment of mirrors is checked by conducting RA-DEC scans around some bright stars and studying count rate profiles from various photo-tubes. With few iterations of RA-DEC scans and mirror adjustments, co-alignment of mirrors is improved and overall pointing accuracy of 0.2 +/- 0.12 deg is achieved (Fig 2.19)

The Data Acquisition (DAQ) system consists of two parts: CAMAC based conventional DAQ system developed in-house and commercial ACQIRIS make digitizer to digitize and record fast pulses for each event. During this year, new trigger logic was implemented in DAQ. In addition to several other desirable features, this module offers the flexibility in terms of possibility of selecting combinations of triggering telescopes. In combination with the programmable delay generator module, which is in the advanced stage of development, new trigger logic will offer the possibility of reducing energy threshold of the experiment by reducing the coincidence width. At present HAGAR energy threshold for near vertical showers, as obtained from simulations, is about 185 GeV. With ongoing to modifications in DAQ, we hope to reduce energy threshold of HAGAR to about 100 GeV.

During this year, observations with HAGAR were conducted on dark nights throughout, except for the month of January. Sources observed include blazar class AGN like Mkn 421, Mkn 501, 1ES2344+514, 3c454.3 as well as galactic sources like Crab nebula, Geminga pulsar, LSI +61 303, CTA 1. In addition to this, several runs were carried out for estimation of delays in various channels as well as for estimation of systematic errors. These observations can be conducted only on clear moonless lights. Total observation duration for this year was about 480 hours. The authors had longest coverage of about 50 hours ON-source and 56 hours OFF-source for Mkn 421 this year. This source showed a flare in X-ray and gamma-ray bands during February 2010. Preliminary analysis of Mkn 421 data from HAGAR indicate flaring activity. Fig 2.20 shows the light curve during this flare in three energy bands: X-ray (1.5-20 keV) from ASM onboard RXTE, gamma-rays (100 MeV - 300 GeV) from LAT on board Fermi and very high energy gamma-rays (> 200 GeV) from HAGAR.

Further work on HAGAR data is in progress.

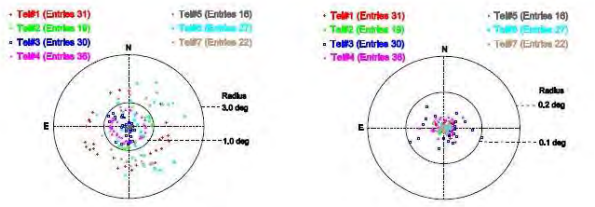


Figure 2.19: Positions of stars' images relative to corresponding finder telescope axis (a) before and (b)after application of pointing model. The centre of the circles represents the pointing direction of finder telescope and the distribution of the star positions for a given telescope of HAGAR array is represented by a set of dots with a colour specific to a telescope.

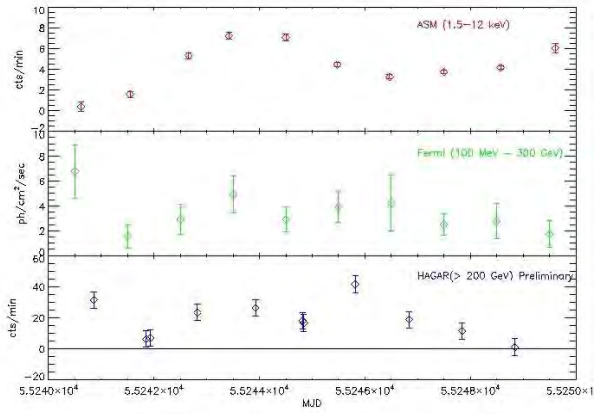


Figure 2.20: Light curves of Mkn 421 during the flaring episode in February 2010. Top panel shows count rates in X-ray band (1.5-12 keV) from ASM onboard RXTE satellite. Middle panel shows the gamma-ray flux in units of $10^{-7} ph/cm^2/s$ in the energy range of 100 MeV - 300 GeV as obtained from LAT onboard Fermi. Bottom panel shows preliminary estimates of very high gamma-ray count rate at energies above 200 GeV as obtained from HAGAR

Simulations play very important role in experiments like HAGAR. In absence of direct calibration with sources of known energies, performance of these experiments can be understood only through detailed simulations. Simulations for HAGAR consist of two parts: simulations of extensive air showers generated by gamma rays and cosmic rays incident at the top of the atmosphere and simulations of response of HAGAR. First part is done by using a package called CORSIKA developed by Karlsruhe group and second part is done by using package developed in-house. During this year these packages were successfully installed on pleiades cluster in the institute and simulations of large samples of showers initiated by gamma rays and various species of cosmic rays were started. Also comparison of simulations with HAGAR data was initiated.

(HAGAR team)

Atmospheric studies

Atmospheric water vapour and aerosol optical depth are being monitored at IAO, Hanle, using a hand held sun photometer and also 220-GHz radiometry. Recently, IIA and Space Physics Laboratory, VSSC/ISRO Thiruvananthapuram collaboratively established an aerosol observatory at Hanle under the Aerosol Radiative Forcing over India (ARFI) project of ISRO Geosphere Biosphere Programme (IGBP). Data from this location benefits the project by providing insight into the background aerosol conditions, far removed from human habitats. The altitude is also of importance being in the location where the altis and stratus clouds form, which improves our understanding of aerosol-cloud interactions. This observatory will thus play a pivotal role in understanding the role of the regional warming due to elevated aerosol layers close to the Tibetan Plateau on the weather and climate of Indian subcontinent, which has been indicated by simulations. The instruments deployed at present include (i) a Multi-Wavelength Radiometer for aerosol and water vapour monitoring, (ii) a specially configured Aethelometer for measuring the amount of absorbing Black Carbon aerosol particles which heat the atmosphere, (iii) a Scanning Mobility Particle Sizer + Counter for aerosol number size distribution measurements in the nanometer size range, which are important in aerosol-cloud interaction at this altitude, and (iv) a radiation instrument to characterize the incoming short-wave and long wave radiations. Initial observations from Hanle show that the columnar AOD has a mean value of 0.1 ± 0.05 and the mean black carbon mass concentration is 60 ng m^{-3} during August– December 2009.

(K. Krishna Moorthy, T. P. Prabhu, S. P. Bagare, D. Angchuk, S. Suresh Babu*, V. Sreekanth*, M. Gogoi*, K. Sobhan Kumar*, J. P.Chaubey*, D. P. Vajja* P. P. Pramod*, P. S. Ajeesh Kumar*)*

Sky Conditions, Indian Astronomical Observatory, Hanle, Ladakh.

A. Night hours

Year	Month	Photometric (night hrs)	Spectroscopic (night hrs)	Total (night hrs)
2009	April	114	140	240
	May	126	143	217
	June	152	158	210
	July	66	83	217
	August	76	131	248
	September	203	213	270
	October	216	246	310
	November	171	256	330
	December	216	285	341
2010	January	150	207	321
	February	93	149	280
	March	154	193	341
	Total	1817	2204	3283

Sky Conditions, Indian Astronomical Observatory, Hanle, Ladakh.

B. No. of Nights

Year	Month	Photometric nights	Spectroscopic nights	Total
2009	April	16	21	30
	May	19	22	31
	June	20	25	30
	July	7	17	31
	August	13	20	31
	September	24	24	30
	October	24	26	31
	November	17	26	30
	December	24	28	31
2010	January	15	22	31
	February	12	19	28
	March	20	24	31
	Total	211	274	365

2.7 Gauribidanur Radio Observatory

Gauribidanur radioheliograph (GRH) expansion

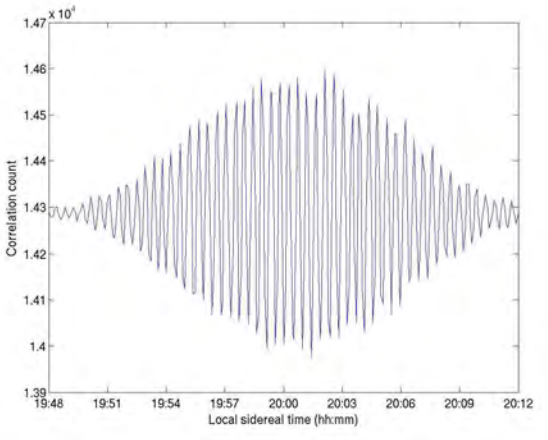


Figure 2.21: Observations of 3C405 on 10 June 2010

The first light with the Phase I of the expansion was obtained on the night of 10 June 2010 by correlating the signal from the extreme two antenna groups (interferometer mode) in the East-West arm of the expanded array. The baseline separation between the two antenna groups is about 3 km. The observations were on 3C405 (a calibrator source for the GRH) in the meridian transit mode. The observing frequency was 80 MHz. The integration time used was 256 ms. The observations were carried out with a prototype single channel receiver. The development of a 64 channel analog receiver (corresponding to the 64 antenna groups in the expanded array), and a 4096 channel digital correlator receiver required to make two-dimensional images with the Phase I of the expanded GRH are underway. The Phase-I of the GRH will provide an angular resolution of about 2 arc min at 150 MHz. For comparison, the upcoming Murchinson Widefield Array (MWA) in Australia will have a resolution of about 4 arcmin at the same frequency. While the MWA is expected to observe over the band 80-300 MHz, the GRH observations are in the frequency range 30–150 MHz. And no other radio telescopes for dedicated observations of the solar corona are in operation in this low frequency range close to the limit of radio observations from the ground.

(Radio Astronomy Group)

2.8 The Library

The Library collection

The Library enhanced its collection by adding 453 books and 140 bound volumes of journals, which includes the books and journals bought for libraries at the Bangalore campus and field stations. Several text book titles have been added in multiple copies to cater to the students of various Ph.D. programmes initiated recently.

E-resources

As a member of National Knowledge Resource Consortium (CSIR-DST Libraries) IIA library at Bangalore and other field stations are able to access 2419 additional titles of journals of 16 publishers in electronic form. Many journal titles which were subscribed in both print and electronic form have been converted to online-only access from 2009. The Inter-Library loan service for books and journal articles has been facilitated through the consortium gateway to accelerate access. 135 inter-library loan requests from scientific and technical staff were fulfilled during the period April 2009 – March 2010. The library continues to offer scientometric & bibliometric analysis of IIA publications. It also offers photocopying and scanning services to the members. The libraries at the centre at Hosakote and field stations at Kodaikanal, Kavalur and Leh/Hanle are maintained with additional copies of books. It is proposed to subscribe to electronic books from the field stations to supplement the collections in those libraries. The library continues to run a trainee programme to train the library school graduates in all the sections of the library.

The Open Access Repository

The library continues to maintain the open access repository that includes the research publications by IIA staff, both current and historical documents from IIA's collection. Recently, 382 items from the archival collection were added to the repository, which is heavily accessed by the community. The library participated in the Open Accesss Week celebrated world-wide during October 19-23, 2009, by reaching a target of 5000 scholarly records in its open access repository. Currently IIA's open access repository is ranked 206 in the list of top 400 institutional repositories covered worldwide as of January 2010.

The Archives Display

New items continue to be added to IIA's archives display. There were 15 visitors and dignitaries who visited the archives during the year. The archives website was re-furbished to include the access policy, and the catalogue of items contained in it. 220 photographic observational plates were added to the collection.

6th International Conference of Library & Information Services in Astronomy (LISA VI)

IIA library staff played a major role in organizing the LISA VI conference hosted at IUCAA, Pune during 14 – 17 February 2010. The theme of the conference was "21st Century Astronomy Librarianship: From New ideas to Action". As a member of LOC C. Birdie took an active part in organizing and executing all the events related to LISA VI.

(Librarian)

2.9 Computational Facilities

The new 8 Mbps internet link to the main IIA campus, the 5 Mbps link to the CREST campus and the 2 Mbps link to the Kavalur and the Kodaikanal campuses respectively are fully operational. Further upgradation of these links to 15 Mbps is underway. Included is VPN connectivity to the field stations. The central disk server has also been upgraded. In addition to the over 300 individual computers in the institute, several dedicated clusters including special purpose clusters are fully operational.

(Computer Division)

2.10 Upcoming Facilities

2.10.1 Ultra-Violet Imaging Telescope (UVIT)

UVIT is one of the five science payloads that will fly on ASTROSAT. The telescope is designed to simultaneously image a field of view of $\sim$ 29 arcmin with an angular resolution of $\sim$ 1.8 arcsec in the far-UV, near-UV and visible bands (1300-1800 Å, 2000–3000 Å, and 3500–5500 Å). In addition to a selection of filters for each of the three channels, low resolution ($\sim$ 100) slitless spectroscopy is planned for the far-UV and near-UV channels. ASTROSAT aims to observe simultaneously in X-rays, UV and the visible. The science goals of UVIT include the study of star-forming galaxies, interacting galaxies, the interstellar medium, globular clusters and hot/evolved stars, in addition to variable objects in coordination with the X-ray telescopes on ASTROSAT.

Present Status

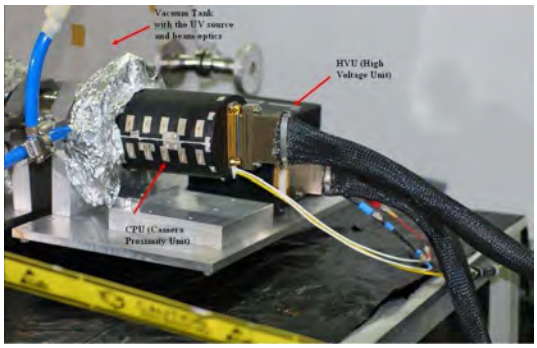


Figure 2.22: Quantum efficiency test setup of the flight-model detector in a class 10,000 area at CREST; in order to minimize any contamination of the detector-window a Class 100 air-blower is used on the Camera Proximity Unit (front end of the detector system).

The Flight Model detector systems have been completed and calibrated, and delivered to IIA by the Canadian Space Agency – who are a collaborator in UVIT project. After the functional and performance tests, the quantum efficiency tests were satisfactorily done on the Far-UV and Near-UV detectors at the MGKM Laboratory, CREST. The experimental set-up for these measurements is shown in Fig 2.22, and the results are shown in Figs 2.23 and 2.24. The EMI/EMC test on the Engineering Model UVIT Detector System were completed at ISRO Satellite Centre (ISAC).

Fabrication of the flight model mirrors has been completed by LEOS (ISRO). Tests on combinations of the primary and secondary mirrors are being done. All indications are that the specifications shall be met for the two telescopes. It is expected that the mirrors, with reflective coatings, would be delivered to IIA in a few months.

Structure of the engineering model is being assembled. The engineering model will be tested for vibrations etc and the flight model of the payload will be ready for tests by the end of this year.

(UVIT team)

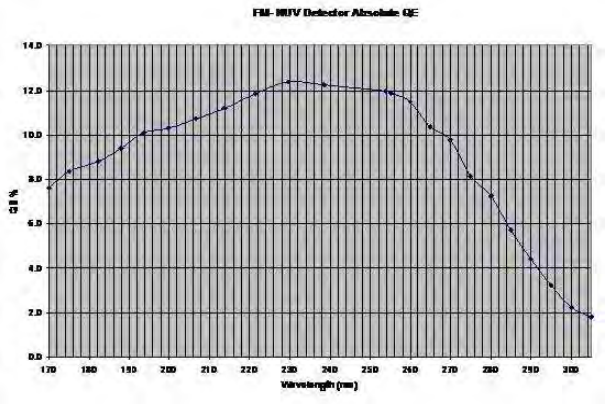


Figure 2.23: QE (%) test result of FM detector (NUV Channel).

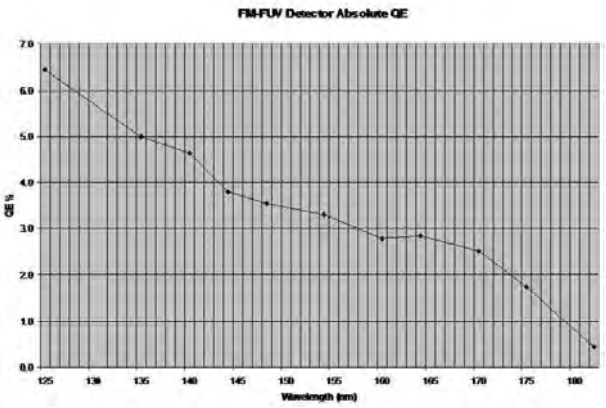


Figure 2.24: QE (%) test result of FM detector (FUV Channel).

2.10.2 TAUVEX

When, by mid-2009, the launch date of the Indo-Israeli collaborative project TAUVEX (Tel Aviv University UV Explorer) was fixed by ISRO for December 2009, the TAUVEX core group at IIA, responsible for the scientific planning of the mission, development of the pipeline and science tools, was fully ready for the launch with the completion of the detailed, minute-to-minute mission plan for the first months of the flight Performance Verification (PV) phase, of the detailed plan for the subsequent months dedicated to space calibration of the instrument including the full list of calibration targets and of the detailed science plan for the first year of observations.

The combined observing plan for investigation of interstellar dust was discussed at the Workshop on Dust at Kavalur in September 2009.

After the removal of the TAUVEX instrument from GSAT-4 in January 2010, with an understanding from ISRO to shift the payload to a PSLV, the TAUVEX core Group at IIA has prepared a new plan identifying unique science objectives for the payload in its new orbit. and the plan has been submitted to ISRO. Further communication from ISRO is awaited in order to start preparations for launch.

(TAUVEX group)

2.11 New Initiatives

2.11.1 National Large Solar Telescope (NLST)

Site characterization programme for NLST

The programme continued vigorously during the year. While observations at Hanle and Merak continued, installation of instruments and starting of observations at the station Devasthal was carried out. Reasonably definitive conclusions can now be drawn for Hanle and Merak with over two years of observations in both the sites. The Devasthal site conditions are under study and more data need to come in before an understanding of the site conditions can emerge. The daily monitoring of observations at the sites, the data down loading, handling and analysis is being carried out at the NLST laboratory at Bangalore. Details in a site-wise manner and at the lab are given below.

Hanle: Seeing measurements with the Solar Differential Image Motion Monitor (SDIMM) and Shadow Band Ranger (SHABAR) of the National Solar Observatory (NSO) were obtained for 18 months before moving them to Merak during the latter part of the previous year. The IIA-SDIMM was used for observations for about 8 months but with the constant exposure to heavy winds at Hanle, the telescope developed mechanical problems and was moved to Bangalore for repairs. Since sufficient data needed for characterization of the site had already been procured, the SDIMM observations were discontinued at Hanle.

High cadence observations with the automatic weather station (AWS) continued at the site. The meteorological data procurement is thus complete for over four years now. It is proposed to continue observations with the AWS since it is an all-weather and a stand alone instrument.

The Prede all-sky camera which completed two years of observations at Hanle was moved to the Devasthal site during the year. Observations of the irradiance and aerosol measurement parameters with the automatic sky radiometer continued during the

year. The measurements and data reduction using inversion techniques show that Hanle has very low aerosol optical depth with an annual average of 0.05, typical of the Tibetan plateau, and excellent for day time observations. However, higher values of AOD are observed during windy conditions, as expected. The winds seem to bring in the loading of dust from the Saharan desert. The post-noon heavily windy periods at Hanle therefore appear to be unsuitable for day-time observations.

The micro-thermal tower was used for observations of the thermal conditions close to ground, up to a height of 15 m, throughout the year. The near-ground inversion seems to occur at heights of 10 to 12 m depending upon prevailing met parameters. Details of the behaviour are under study. The five sets of differential temperature probes, which were replaced with those of improved design in March 2009, functioned well during the year.

Merak: The NSO SDIMM and SHABAR instrument, installed atop a 4 m tower, started functioning at the beginning of the year. However, its hard disc crashed and attempts are on at the NLST lab to replace the old technology NT based system and to retrieve the programmes. The seeing observations however continued with two of the IIA-SDIMMs, *viz*., a Meade 12 inch telescope based and installed on the 4 m tower, and a Celestron 14 inch telescope.

Observations of the met parameters continued with both the old AWS and the new high cadence AWS at the site. The Prede all-sky camera functioned well throughout the year. Observations with the MTT also continued satisfactorily though with occasional trouble shooting since the thermal probes are sensitive to wind gusts and precipitation. The results clearly show the typical lake site behaviour of the thermal stabilization above ground at the site (see Fig.2.25).

Since the Merak site is in the midst of the Pangong Lake, and since the land incursion is just over a meter above the water body at the selected location, the embankments had to be reinforced and maintained from being washed away at close proximity to the instrument bases. General maintenance of all the instruments both at Hanle and at Merak were carried out in May 2009 and January 2010.

Devasthal: Observations at the site started during the year. A high cadence AWS was installed in October 2009 and observations with this continued throughout the year. An all-sky camera was also installed and observations of the sky conditions for estimation of the clear sky periods were begun (see Fig.2.26).

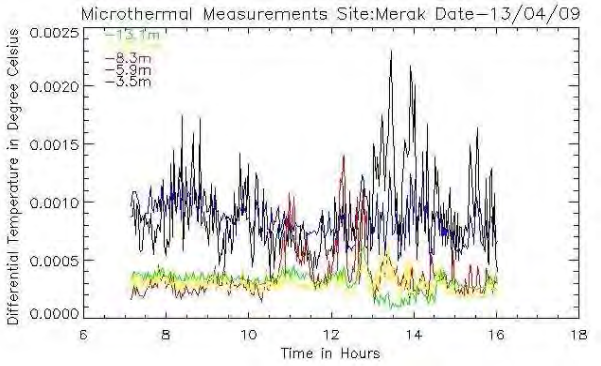


Figure 2.25: Differential temperature measured by five sets of probes on MTT at Merak. The impact of ground heating is seen up to about 6 m above ground, beyond which it stabilizes in a manner typical for lake sites

.

Figure 2.26: A sample all-sky frame at Devasthal obtained on 29 January 2010. The tree line and the 15 m micro thermal tower are seen in the frame. The dark strip blocks the sun to provide a fish-eye view of the sky.

A micro-thermal tower, designed and fabricated at IIA was also installed in November 2009 jointly by the IIA and ARIES teams. A 6 m high tower with slide-off roof and an FRP hut for housing the observing instrumentation, power supply and computers was in place by the end of 2009. An IIA-SDIMM using a 14 inch Celestron telescope was installed and it started functioning in January 2010. Observations are being carried out regularly by the NLST team at IIA, with the support of ARIES personnel. A collage of the instruments installed is shown in the Fig.2.27.

A preliminary analysis of the data procured so far indicate that good spells of seeing occur especially during the early morning and evening hours when mild winds are favourable. The met data show that

Figure 2.27: A collage of views of the instruments installed at the Devasthal site between October 2009 and January 2010.

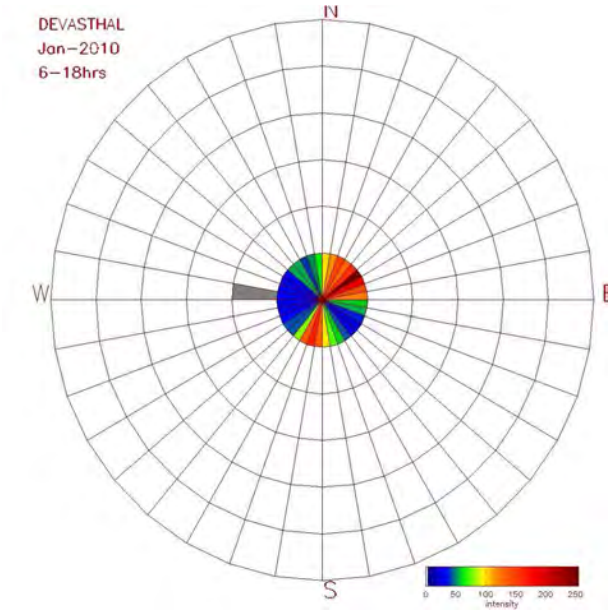


Figure 2.28: Polar plot of wind conditions at Devasthal in January 2010. The concentric circles are in steps of 5 mps. The winds are within a few mps for most of the time.

prevailing winds are very mild for most of the time (see Fig. 2.28)). Wind direction is very important at this site which is an end point of a prominent ridge in the mountain range. It is favourable when the wind blows over the deep valleys. Winds from over land are not likely to be very suitable for day-time seeing conditions. A detailed evaluation of the seeing conditions is being carried out.

NLST lab at IIA, Bangalore: Planning and monitoring of the programme was carried out from the lab. Procurement of data, either online or through storage devices, was continued from all the three sites. Improvements and adaptation of inversion techniques and software development were carried out on a regular basis. In particular, software was developed for evaluation of sunshine hours from the AWS and all sky camera data. Improvements were made to the handling of data for inversion technique of the SHABAR data.

The indigenous development of the SHABAR unit was taken up by the electronics group at IIA, Bangalore. The NLST team participated and coordinated the task. Procurement of components, especially for the repair of SDIMM units and the data loggers for the pyro-heliometers were initiated. The activity of training new trainees and staff and conducting of scientific and technical seminars also continued during the year.

The highlight of the studies so far is that the Merak site turns out to be an excellent site for solar observations. The seeing conditions compare well with those of the well known world-class site of the Big Bear Solar Observatory, typical of a good lake site. Significant spells which are suitable for implementing adaptive optics corrections occur at the site. Following an evaluation of the Devasthal site, a detailed report of the site characterization programme is expected to emerge by the end of the next academic year, 2010 – 2011.

(S. P. Bagare, S. S. Hasan, A. K. Saxena, T. P. Prabhu, K. E. Rangarajan, A. Dorje, R. B. Singh, N. Dorjey, S. K. Padhy, N. Vasantharaju, N. Verma, Md. Ismail, Wahab Uddin, D. Tsewang, K. Dhanajnay, N. S. Shantikumar, J. Sonam, M. Tashithsering, R. Norbo, S. Tundup, D. Tseten, J. Ismail, & N. Sivaraj)*

Aerosol content in the terrestrial atmosphere over Hanle in Western Himalayas

The extent of scattering of solar radiation by aerosols is referred to as turbidity of the terrestrial atmosphere and it is a function of both the size distribution and the number density of aerosols. Detailed analysis of aerosol content provides one of the inputs necessary for the selection of a good astronomical site as the modulated solar radiation reaching the atmosphere limits the performance of the ground-based telescope. Therefore, as a part of the site characterization programme for the proposed National Large Solar Telescope (NLST), a Skyradiometer (PM01L, of M/s Prede) was installed at Hanle in Ladakh, in

October 2007. Aerosol optical properties such as aerosol optical depth (AOD), single scattering albedo (SSA), volume size distribution, and refractive indices were retrieved using measurements of direct and diffuse solar irradiation through inversion computations.

The skyradiometer at Hanle consists of an automatic sun-tracking system, a spectral scanning radiometer, rain detector and a sun sensor with an inbuilt calibration capability, an automatic disk scanner for calibration of solid view angle, and a single detector design. It has 7 filters with central wavelength at 315, 400, 500, 675, 870, 940 and 1020 nm with band widths ranging from 2 to 10 nm. Aerosol optical properties are derived from the measured sun/sky irradiance data at 5 wavelengths using Skyrad.Pack (version 4.2) radiative transfer model.(See Fig. 2.29)

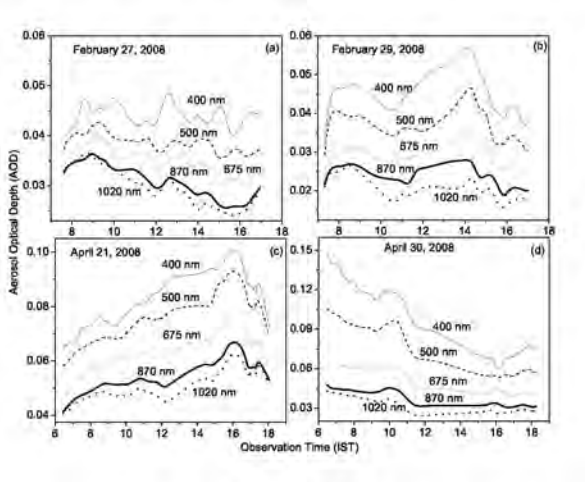


Figure 2.29: Diurnal variation of AOD on typical summer and winter clear days for five channels at Hanle.

Polar plot of wind conditions at Devasthal in January 2010. The concentric circles are in steps of 5 mps. The winds are within a few mps for most of the time.

The daily AOD values obtained at Hanle are below the general background level in the terrestrial atmosphere, with a yearly average being around 0.05 at 500 nm. Fig. 2.29)shows the diurnal variations of AOD on typical summer and winter clear days for five channels. On some occasions, however, higher AOD values of above 0.1 are observed, but such cases are rather rare. It is suspected that long range transport of dust aerosols contribute to the higher AOD values at the station. Back trajectories derived from the HYSPLIT model computations indicate the presence of parcel of air mass coming from the neighboring Saharan desert.

The inferred average values of SSA during winter and summer seasons are 0.96 ± 0.002 and 0.97± 0.002 at 500 nm respectively. The higher values of SSA indicate strong absence of absorbing aerosols such as those of anthropogenic origin. The volume size distribution shows a general bimodal behavior with two peaks at around 7 to 10 m and 0.1 to 0.2 m with an occasional tri-modal behaviour, usually in the summer months. This may occur due to the inflow of desert dust at the site.

The observed aerosol optical properties are comparable to those reported at other high altitude sites such as Nam Co, in central Tibetan Plateau and Dome C in Antarctica. The periods of clear skies with moderate winds have low content of aerosols and hence high level of sky transparency at Hanle.

(S. P. Bagare, N. Verma, N. S. Shantikumar & B. S. Rajendra)

2.11.2 Giant Segmented Mirror Telescope Project

The astronomy community in the country continued their deliberations on joining one of the three proposed international mega-optical and infrared ground-based facilities (GSMTs): the 42-m European Extremely Large Telescope (EELT), the Thirty Meter Telescope (TMT) and the 25-m Giant Magellan Telescope (GMT). A full report on the requirement of such an international collaboration, the best option among the three projects, for India's participation and strategies for the human resources growth to meet the challenges was prepared and submitted to the Department of Science and Technology (DST) in early 2010.

(B. E. Reddy – for TMT-India group)

Chapter 3

Student Programmes & Teaching Activities

3.1 Ph.D. Programmes

In addition to the participation in the Joint Astronomy Programme of IISc, IIA has been conducting its own Ph.D. programme, and students have received their Ph.D. degrees from different universities in the country. The institute has now entered into an a collaboration with Pondicherry Central University to conduct a joint Ph.D. programme.

3.2 A Joint Programme with Pondicherry University

Harish Bhatt, Dean (Academic), IIA speaking at the signing ceremony

IIA and Pondicherry Central University entered into a collaboration by launching a joint Ph.D. programme on the 28 April 2009. S. S.Hasan (Director, and Harish Bhatt (Dean-Academic) from IIA, and S. Loganathan (Registrar) and S. Balakrishnan, (Dean, School of Physical, Chemical & Applied Sciences) from Pondicherry University, were signatories to the Memorandum of Understanding signed on the Pondicherry University Campus, under which, the Ph.D. Programme will be jointly administered by the two institutions. The MoU will be a platform for a variety of academic collaborations, student and faculty exchanges, and joint conferences and workshops.

IIA admits students with a Masters degree in the physical sciences (and also students with BTech/BE with a strong background in physics) after selection through a nation-wide admission test. The students then undergo one year of course work to be followed by research leading to a Ph.D. thesis. The course work under the Joint Astronomy Programme (JAP, of which IIA is a major participating institute), coordinated by the Indian Institute of Science, Bangalore, forms a part of the one-year course work of the IIA' Ph.D. Programme.

Students desirous of pursuing research in astrophysics, thus have the opportunity of being exposed to a wide range of topics in astrophysics, first during the course work and later through the on-going seminars and colloquia, apart from day-to-day interactions with a large number of practising astrophysicists and physicists. They have the benefit of selecting their research topics from a wide range of subjects. For their M.Sc. projects, they are able to work on cutting-edge research topics that are meant to give them a headstart in their research careers.

3.3 Integrated M.Sc.-Ph.D. Programme

IIA runs an Integrated MSc-Ph.D. programme in collaboration with the Indira Gandhi National Open University, that recruits students with Bachelor's Degrees. The normal duration of the programme is six years, including two year's of a Masters Degree.

The laboratory courses of the Integrated MSc-Ph.D. Programme in Physics are an important component of the programme. The goal is to expose students to a variety of fundamental concepts and measurement techniques through a set of instructive experiments. The lecture courses are designed to expose the students to a wide spectrum of disciplines in physical sciences, to cover the topics indispensable to research in astronomy and astrophysics and also essential to understand the interplay between the generalities and specificities.

3.4 Experimental Physics Lab

Experimental setup for verification of Coulomb's law of electrostatics force.

The laboratory course included a set of ten general physics experiments for the first semester students and several optics experiments for the third semester students. The experiments dealt with laboratory measurements of various physical constants such as the speed of light, Gravitational constant measurements, Planck's constant, e/m ratio, Millikan's oil drop experiment etc. As a part of 2nd year laboratory optics course, 3rd semester students did about five optics experiments which included wavelength and refractive index determination, with different interferometers (Michelson, Fabry-Perot, Mach-Zander etc), single slit and multi-slit diffraction experiments, verification of Malus's law and inverse square intensity law for point source.

Students are expected to understand error analysis and include errors estimations of each experiment in their laboratory report. However, without prior exposure, students sometimes find it difficult to compute experimental errors in different cases. Before starting the experiment, a few lectures on error analysis were given to the students, covering different types of experimental errors, laws of error propagation, regression and model fitting, scientific ways to represent laboratory results (in the form of numerical values, tables, graphs, images etc) and finally how to report errors in the data.

(R. K. Banyal & B. Ravindra)

3.5 Integrated MTech-PhD(Tech) Programme

An Integrated MTech-PhD(Tech) programme, geared towards research in instrumentation, was launched under a memorandum of understanding with Calcutta University. The M.Tech. component of two years duration consists of two semesters of course work at Calcutta University, and two semesters of internship and project work at IIA. The students would then go on to do a Ph.D., which is expected to be completed in four years. In order to reach a wider pool of candidates for selection into the programme, written admission tests were conducted in large number of centres across the country.

Integrated MTech-PhD(Tech) students.

The first batch of six students of the Integrated M.Tech.-Ph.D.(Tech.) programme in Astronomical Instrumentation (a joint programme with the University of Calcutta) had arrived in March to attend part of their second semester courses in the Bangalore campus of IIA. The material for the semester was a combination of theoretical concepts and topics related to instrumentation.

The background of the students was very diverse, ranging from engineering to physics. The material was tuned to suit their basic background on the one hand and the challenges of modern astronomical instrumentation on the other. They were exposed to the fundamental issues of astronomical optics and the degrading effects that require to be corrected. The students also obtained hands-on expe-

rience when they were trained to handle amateur level telescopes, and they participated in the public sky watch programme at the Lalbagh on 04 – 05 April 2009 as part of the 100 HOURS OF ASTRONOMY event.

3.6 Completion of Ph.D.

The following students completed their Ph.D. research and submitted their theses.

H. S. Nataraj
Thesis title: ELECTRIC DIPOLE MOMENT OF THE ELECTRON AND ITS IMPLICATIONS FOR MATTER-ANTIMATTER ASYMMETRY IN THE UNIVERSE
Thesis supervisor: *B. P. Das*
Submitted: Mangalore University
Date: 24 September 2009

T. Mishra
Thesis title: QUANTUM PHASE TRANSITIONS IN MIXTURES OF ULTRACOLD ATOMS
Thesis supervisor: *B. P. Das*
Submitted: Mangalore University
Date: December 2009

M. R. Lovely
Thesis title: STUDY OF DYNAMICS AND MAGNETIC FIELD STRUCTURE OF THE SOLAR CONVECTIVE ENVELOPE USING SUNSPOT ACTIVITY
Thesis supervisor: *K. M. Hiremath*
Submitted: Calicut University
Date: 20 December 2009

G. Vigeesh
Thesis title: STRUCTURE, DYNAMICS AND HEATING IN MAGNETIZED REGIONS OF THE SOLAR ATMOSPHERE
Thesis supervisor: *S. S. Hasan*
Submitted: Mangalore University Date: 10 Jan 2010

B. Mathew
Title: STUDY OF EMISSION LINE STARS IN YOUNG OPEN CLUSTERS
Thesis supervisor: *A. Subramaniam*
Submitted: Calicut University
Date: January 20 2010

3.7 International Research Experience for Students (IRES)

IRES students T. A. Schad (left) and S. E. Williams (right) with K. Jain, the co-ordinator of the IRES programme (centre).

S. E. Williams from Iowa State University, USA and T. A. Schad from the University of Arizona and National Solar Observatory, Tucson, USA, were visiting research students at IIA during June – August 2009, under the International Research Experience for Students (IRES) programme sponsored by the National Science Foundation, USA.

The IRES programme, which is for graduate students of the United States to study astrophysics in India, is administered by the National Solar Observatory, Tucson, USA, and is currently co-ordinated by K. Jain from NSO, herself an alumnus of IIA. The programme aims to expose potential researchers to an international setting at an early stage in their careers. 2009 is the third year of the programme at IIA. The students associate with a faculty members at IIA for a research project, and also undertake visits to IIA's observatories and field stations. Cultural and social events are interleaved too. The programme covers the students travel and stay and allows them to extend their return date in order to be a tourist in India at the end of the the research period.

S. E. Williams did a project with A. Subramaniam on *Spectroscopic study of Herbig Ae/Be stars*, and T. A. Schad did a project with R. Kariyappa on *The Dynamics of Coronal X-ray Bright Points in Relation to the Magnetic Field*.

The Summer School at VBO.

3.8 Summer and Winter Schools

3.8.1 The Kodai Summer School in Astrophysics

IIA conducts a summer school on a special topic in astrophysics or physics each year at the Kodaikanal Observatory campus. Lecturers are drawn both from IIA and other institutions in the country. This year's Kodai summer school was held in the observatory campus during 8–20th June 2009 on the theme of *Theoretical Astrophysics*. The topics covered were: Classical mechanics, Pulsars, Relativity and Plasma astrophysics. The participants were about 25 students in their final year B.Sc. or first year M.Sc. from all over the country. The lectures were given by scientists from IIA, RRI and NCRA. K. E. Ranjarajan was the convenor and R. Gangadhara was the coordinator of the school.

(R. Gangadhara)

3.8.2 Summer School in Astronomy and Astrophysics

The IIA summer school in introductory astrophysics was organised at the Vainu Bappu Observatory, during 15–22 May, 2009.

Twenty three students of physics or engineering from different parts of the country participated in the school amidst the picturesque surroundings of the observatory campus. The students heard lectures by IIA scientists that covered Solar, Galactic and extra-Galactic astrophysics and astronomical instrumentation. A special feature of the school was the presence of S. Balakrishnan, Professor of Pondicherry University. He spoke to the students on the connection between astronomy and geology. Tutorials on photometric and spectroscopic data reduction techiniques were conducted by IIA Ph.D. students B. K. Yerra, S. Ramya and P. Ramya. S. Pukalenthi organised a night sky-watch with the 6 inch refractor. M. J. Rosario organised a photometric observation session with the 15 inch telescope. The school gave the participants an opportunity to get a flavour of observational research in astronomy, and to have a dialogue on the possibilities of pursuing astronomy and instrumentation research as a career. Eleven of the participants went on to do projects at IIA's Bangalore campus.

(C. Muthumariappan)

3.8.3 Winter School on High Energy Astrophysics

A winter school on "High Energy Astrophysics" was held in Kodaikanal between 1 – 11 December 2010. The school was organised jointly by IIA and the Institute of Mathematical Sciences (IMSC), Chennai. The coordination was done by D. Indumathi (IMSc),

Participants of the *Winter School on High Energy Astrophysics.*

Varsha Chitnis (IIA) and P. R. Vishwanath (IIA) with excellent help from K. Sundara Raman and the other members of the Kodaikanal observatory. The emphasis was on neutrino astrophysics in the first week and gamma-ray astronomy in the second week. 33 students from all over the country attended the meeting. About half of them were Ph.D. students and the rest from Master's programmes. After the inauguration by Professor S. S. Hasan, Professor G. Rajasekaran started the academic programme with a series of lectures on the fundamentals of particle physics with a detailed exposition of the Standard Model. F. Sutaria, G. C. Anupama and S. Gopalakrishna introduced the students to topics in Stellar Evolution, Supernovae and Dark Matter respectively. M. V. N. Murthy, Kamalesh Kar, D. Indumathi, and Pijush Bhattacharjee lectured the students on different aspects of neutrino astrophysics like Atmospheric Neutrinos, Supernovae Neutrinos, Solar neutrinos and Ultra High Energy Neutrinos respectively. There were talks on Cosmic Rays by Kalyani Baruah and general electronics by S. Upadhya. Talks on Low-Energy Gamma-Ray Astronomy, Gamma Ray production and Gamma Ray processes were given by P. R. Vishwanath, R. C. Rannot and A. K.Tickoo respectively. Razmik Mirzoyan gave a series of talks on gamma-ray astronomy using the Atmospheric Cerenkov Technique with emphasis on the MAGIC telescope. The students were given an in-depth look into the instrumentation and physics of new Indian initiatives in gamma-ray astronomy like HAGAR (V. Chitnis), MACE (Rannot and Tickoo) and in neutrino astrophysics like the INO (B. Satyanarayana). Evening lectures on LHC, X-Ray Astronomy and Indian Cosmic Ray Research were given by Rahul Basu, Biswajit Paul and B. S. Acharya. The feedback from the students showed that the pedagogical lectures and the interaction sessions were appreciated very much.

(P. R. Vishwanath)

A lecture in progress at the Kodai Winter School.

3.9 Individual Teaching Activities

3.9.1 Research Guidance

S. P. Bagare co-guided the Ph.D. research of P. Sriramachandran of the Physics Research Centre of Virudhunagar, and he was awarded Ph.D. by the Madurai Kamaraj University for his thesis titled *Spectroscopic studies of molecules of astrophysical and allied interest* in February 2009.

D. Banerjee is supervising the following Ph.D. students: G. Gupta from the JAP programme; S. Chandrashekhar from the IIA programme; Co-guide to an IIA student S. Krishnaprasad; supervising A. Datta under FIP programme.

S. Chatterjee served as co-guide for Rezvan Ravanfar Haghighi, PhD Student of the Medical Physics Unit, All Indian Institute of Medical Sciences, New Delhi.

B. P. Das is guiding A. Dhar on his Ph.D. thesis titled *Novel Quantum Phases in Ultra-cold Atoms in Optical Superlattices.*

R. T. Gangadhara is guiding the Ph.D. research of Dinesh Kumar (IIA) on radio pulsars. He co-guided Ph.D. student Pengfei Wang of the National Astronomical Observatories, Beijing, on *Relativistic radio emission from pulsar plasmas* during 19 February – 5 March 5 2010.

A. Goswami guided two JRFs S. S. Kartha & D. Kurinkuzhi working on a DST-sponsored project titled *Determination and modelling of chemical compositions of metal-poor stars and observational constraints for Galactic chemical evolution*; and C. Shaji, SPSP programme student, (M.Sc. student, Physics dept., Pondicherry University) on a project titled *CH stars as tracers of AGB nucleosynthesis* during the period 15 May–15 July, 2010.

K. M. Hiremath guided Rajni, M.Sc. student from the National Institute of Technology, Rourkela, on a project titled *Dynamic and Magnetic Evolution of Sunspots from the Hinode Data*, and two M.Sc. (by Research) students, D. Paul and S. Sabrina from Christ University, Bangalore, on a project titled *Tilt angle of the bipolar spots during their initial appearance.*

U. S. Kamath guided S. Smera (Calicut University) who worked under the "Degree Project Students Programme" on the topic *Analysis of spectra of the star SS Lep* from April – May 2009. He also guided H. D. Supriya (Bangalore university) for the project *Estimates of extinction, distance and absolute magnitudes of some novae* under the Summer Project Students Programme 2009.

R. Kariyappa guided an IRES student T. A. Schad of the University of Arizona/National Solar Observatory, USA, for his project work on *Dynamics of coronal X-ray bright points in relation to the magnetic field* during June – August 2009; guided T. G. Aditya (Ph.D. student, IIA) for his observational project on *Study of coronal bright points* during January – July 2009; co-guided S. T. Kumara, Department of Physics, Bangalore University, for his Ph.D. thesis on *Understanding the solar variability from spatially resolved images*; guiding L. P. Chitta (IIA) for his short-term project on *G-band and CaII H bright points from Hinode spacecraft.*

J. P. Lancelot gave lectures on *Optical telescopes* at the BIFR, Bangalore for the Astronomy and Astrophysics courses.

P. K. Mahesh guided the following undergraduate students: (i) A. V. Menon and P.Sandeep P. from the B.T.L. Institute of Technology, Bangalore, on a final-year dissertation project titled *Re-Engineering of the 75 cm Optical Astronomical telescope*; (ii) N. Sandeep from the Oxford College of Engineering, Bangalore, on a project titled, *A study of solar telescopes (siderostats, heliostats, uranostats and coelostats)*; (iii) S. P. Thomas from M. S. Ramaiah

Institute of Technology, Bangalore, on a project titled *A study of Astronomical telescopes*.

A. Mangalam is supervising the Ph.D. thesis of P. Mohan on the topic of *Spin and mass of black hole and their observational signatures* since August 2009, and A. Prasad on the topic of *Dynamo constraints from magnetic helicity* towards Master's thesis project under IIA-IGNOU I-Ph.D. programme. He gave a short course on *Relativistic Astrophysics*, 12 – 25 May 2009, 8 lectures at ARIES, Nainital.

K. N. Nagendra supervising the Ph.D. research of L. S. Anusha, on *Advanced numerical methods for polarized Radiative Transfer: Astrophysical applications*; He guided H.N. Smitha on the course-work project '*Analysis of the polarimetric data of Ca* I *4227 Å line*', and D. Shrilatha on a summer project titled *Interaction of radiation with matter*.

T. P. Prabhu is supervising the Ph.D. thesis of S. Ramya on *Blue compact galaxies*. He lectured in the 100-hour course on Astronomy, MPBIFR, Bangalore in November and December 2009 on *Observational Facilities in India*.

T. P. Prabhu & G. C. Anupama are supervising the Ph.D. thesis of A. Shukla on *Multiwavelength studies of blazars*.

K. P. Raju guided the summer project of V. K. Sharma, B.Tech student, Dept. of Electronics & Communication Engineering, National Institute of Technology, Hamirpur, HP on a project titled *Multiwavelength study of coronal holes*.

B. E. Reddy is guiding the Ph.D. research of B. K. Yerra on *Study of Li-rich K giants* and P. Ramya on *Galactic streams*.

S. Sengupta is supervising the Ph.D. research of S. Choudhury, JAP student on the topic *Polarization of Sub-stellar Mass Objects - Brown Dwarfs and Extrasolar Planets*.

S. K. Saha is guiding an IIA-CU Integrated M.Tech-Ph.D. student A. Surya on a thesis titled *Image Processing*.

P. Shastri supervised the PhD research of Veeresh Singh on *A Multiwavelength Study of Active Galaxies*.

C. S. Stalin supervised the Ph.D. research of S. Rathna Kumar on *Lensed quasar monitoring*; T. Shibina, Calicut University during April – May 2009 on an M.Sc. project on *The Study of the Seyfert Galaxy SDSS J 1032+650*, and V. S. Narra for his M.Tech. thesis on *UVIT detector ground calibration*.

K. Sundara Raman guided 2 M.Phil students of Mother Teresa Women's University, Kodaikanal in their dissertation work as a summer internship programme of IIA at Kodaikanal during June – July 2009, and eight B.Sc. (Physics) students of Mother Teresa Women's University on topics in Solar Physics.

3.9.2 IIA/JAP programme courses and other lecture series

S. Anathpindika taught "Classical electrodynamics" (second-half of Spring 2009) for Integrated PhD students.

S. P. Bagare & K. E. Rangarajan taught a course on Physical Astronomy to the final year students of the integrated M.Sc. programme of the University of Mysore.

D. Banerjee taught the course on fluids and Plasmas for the JAP programme.

R. K. Banyal conducted "General physics experiments" and an "Optics laboratory" course for IIA integrated Ph.D. students from August 2009 – December 2009.

S. Chatterjee taught "Statistical Physics" in IIA integrated Ph.D. course, March 2009 – May 2009; "Observational techniques" in IIA M.Tech.-Ph.D. course, March–May, 2009; "Quantum Mechanics" in IIA integrated Ph.D. course, October–December, 2009; "Solid State Physics" in IIA integrated Ph.D. course, Jan–June, 2010.

V. R. Chitnis gave lectures on *High Altitude GAmma Ray Experiment (HAGAR)* in "International School on High Energy Astrophysics" organised by IIA and The Institute of Mathematical Science, Chennai at Kodaikanal during December 2009.

R. T. Gangadhara taught the "Electrodynamics" course during the second semester of Integrated Ph.D. programme 2009.

A. Goswami taught the following courses: Stellar and high energy physics during January – May 2010 to JAP and IIA Ph.D. students (shared with C. Sivaram); Nuclear and Particle Physics during February – June 2010 (Integrated Ph.D. students) (shared with P. Vishwanath).

U. S. Kamath taught the following courses in *Spherical Astronomy and related topics* for the Integrated Ph.D. students and M.Tech-Ph.D. students (July 2009). He also taught *Astrophysical Techniques* for the M.Tech-Ph.D., JAP and IIA Ph.D. students (August – September 2009).

J. P. Lancelot taught *Optical Instrumentation Techniques* to the students of the M.Tech. - Ph.D. programme during the month of March 2010.

A. Mangalam taught the following I.Ph.D. - Ph.D. courses *Astrophysical concepts*, *Classical mechanics*, *Statistical physics*, *General Relativity & Cosmology Numerical & Statistical techniques*. He also taught a short course on *Relativistic Astrophysics*, (eight lectures and 5 tutorials) in the Kodai School in Physics.

G. Pandey with B. E. Reddy taught a course to MSc/Ph.D. students on *Astronomical Techniques; Optical Astronomyi*.

S. P. Rajaguru and *A. Satya Narayanan* taught *Mathematical Methods I* to the 1st semester Integrated Ph.D. students.

S. Sengupta taught *Introduction to Fluid Mechanics* as part of the first semester of IIA-JAP programme.

C. Sivaram gave the JAP course on High Energy Astrophysics and a Course on Nuclear and Particle Physics to Integrated Ph.D. students.

F. Sutaria taught the Integrated Ph.D. course titled *Stellar Structure and Evolution* from August – December 2009; and gave a series of lectures on *Stellar Evolution* in the "International School on High Energy Astrophysics" organised by IIA and The Institute of Mathematical Science, Chennai at Kodaikanal during December 2009.

P. R. Vishwanath taught "Particle Astrophysics" as part of the *Nuclear and Particle Physics* course to Integrated Ph.D. students during February –June 2010. He gave two talks on *Low Energy Gamma Ray Astronomy* in the "International School on High Energy Astrophysics" organised by IIA and The Institute of Mathematical Science, Chennai at Kodaikanal during December 2009.

3.9.3 Lectures & courses outside IIA

S. Chatterjee taught an advanced course on *Spectroscopy and radiative transfer* for M.Sc. students at the Mohan Lal Sukhadia University, Udaipur, during January, 2010.

K. M. Hiremath taught a course on Solar Physics to M.Sc (Physics) students as a guest faculty at the Centre for Post Graduate Studies of Sri Bhagawan Mahaveer Jain College, Jayanagar, Bangalore.

A. Mangalam taught a semester long week-end course on *Electrodynamics* as part of the Research Education Advancement Programme (REAP) run by the Bangalore Association for Science Education (BASE), Nehru Planetarium for advanced graduate and undergraduate students during December 2009 – March 2010.

T. P. Prabhu lectured on *The World of Galaxies*, at the Bangalore Association for Science Education Summer School, JN Planetarium, Bangalore, 23 May 2009.

C. Sivaram taught the following courses: (i) *General Relativity and Cosmology* given to Post Graduate students, Bangalore University, February – May 2010 (20 lectures); (ii) *Advanced course in Astrobiology and Astrochemistry* (to graduate students), BIFR, February-March 2010 (iii) *Space and Rocket Dynamics*, Intercollegiate course, St. Joseph's College and ISRO (20 lectures) (iv) Several pedagogical lectures (about 25) given in the past one year on various topics in physics and astrophysics at various refresher courses, certificate courses at different colleges and institutes.

K. Sundara Raman as Adjunct Faculty of Mother Teresa University, Kodaikanal, taught various courses in the M.Phil. programme in Astrophysics during July – August 2009; He functioned as the external examiner and conducted the viva voce and practical examinations of II M.Sc. Physics students of the university.

K. Sundara Raman also conducted a national level

programme for college teachers (Physics faculty) and delivered a series of four lectures on *Space Science and Astrophysics* in the refresher course on *Recent Trends in Physics* at the UGC-Academic Staff College, Madurai Kamaraj University.

Chapter 4

Scientific Conferences, Workshops & Lectures at IIA

4.1 In-house Scientific Meeting

The scientists and students of IIA gathered once again on the 17th April, 2009 at an In-House Scientific Meeting to discuss their research. In a programme that was spread over the whole day, several recent scientific results were presented in the areas of solar, stellar, Galactic and extragalactic astrophysics, fundamental physics and instrumentation.

The Outstanding Research Paper Awardees (left to right) G. Pandey, D. K. Sahu and B. E. Reddy with the Director, S. S. Hasan (3rd from left).

There were two special features of the in-house meeting this year. The first was the announcement of the winners of the newly instituted 'Outstanding Research Paper Awards' for the year 2008. These awards went to papers by G. Pandey, B. E. Reddy and D. K. Sahu.

The second special feature was an evening lecture by C. Sivaram. The Director, S. S. Hasan, described his outstanding contributions to science communication, especially in teaching and in communicating with the public. C Sivaram then spoke on *Decades of Communicating Science at All Levels*. He regaled the audience with an exciting talk, which included fascinating insights and anecdotes that were seasoned with humour all through, which was a fitting conclusion to the meeting in the International Year of Astronomy.

4.2 Founder's Day

IIA celebrated the Founder's day on the 10 August 2009 with a public lecture to a packed auditorium by the internationally renowned astrophysicist and pioneer instrument builder Govind Swarup.

In his rivetting lecture that was delivered in his characteristically candid and pragmatic style, Govind Swarup recalled the history of empirical astrophysics research in India and its impact on research productivity as well as capacity building. With personal anecdotes, he emphasised the extremely productive partnership between Indian industry and astrophysicists in building the many indigenous observing facilities that have made world-class contributions to research. He expressed his grave concern for the fact that the Indian research community is currently unable to attract sufficient number of younger people to keep up with the requirements of the newer and ambitious research facilities that the community plans to build and operate in the future. He also expressed his concern that research institutions remained disconnected from universities. He advocated the doctrine that indigenous instrumentation development was key to nation-wide capacity building in the different dimensions of research.

4.3 National Meeting on New Solar Observatories

Participants at the *National Meeting on New Indian Solar Observatories*.

A one-day national meeting to discuss current and future observational opportunities for research in solar physics was organised by IIA on the 22nd of August, 2009. About 35 solar physicists from all over the country got together at IIA to review the recent accomplishments with the existing facilities, and also the newly emerging tools and techniques the field. A substantial part of the deliberations focused the proposed new observatories, viz., the National Large Solar Telescope (NLST), the Multiple Application Solar Telescope (MAST) and the Visible Emission Line space Coronagraph (VELC).

The meeting was co-ordinated by D. Banerjee and S. S.Hasan.

(D. Banerjee)

4.4 Physics and Astrophysics of Dust II

Twenty-five participants from multi-disciplinary backgrounds gathered in the first week of September, to bring their diverse insights to deliberations on the *Physics and Astrophysics of Dust* in an international workshop held in the picturesque surroundings of the Vainu Bappu Observatory. The workshop which was the second in the series, was held during the 02 – 05 September 2009.

The aim of the workshop was to discuss the new results related to cosmic dust and to attempt to reach a comprehensive understanding of the phenomena associated with dust. The workshop attracted about 25 researchers from both India and abroad, who are engaged in multiple disciplines that included observations, theoretical modelling, computation and laboratory astrophysics. About twelve participants were from IIA.

In addition to the scientific sessions, there were also tutorial sessions, and the workshop schedule was designed to facilitate extensive discussions and foster new collaborations. The atmosphere was most conducive for mutual interactions among participants both within and outside of the sessions. In the final session of the workshop, a summary of the scientific presentations was given by Ashoke Sen, Assam University, Silchar. This was followed by a lively debate lead by U.J.Sofia, American University, USA. Washington. Outstanding problems on cosmic dust were intensely debated upon.

S. Chatterjee and C. Muthumariappan were the co-ordinators of the workshop.

4.5 National Meeting on Giant Telescopes

About forty scientists from all over the country met at IIA on 10 October, 2009 to discuss India's possible partnership in a giant segmented-mirror telescope consortium, and recomended that India should participate in the Thirty-Meter Telescope Project to be built on Mauna Kea in Hawaii by an international collaboration of several institutions from North America and Japan. The other participating institutes apart from IIA at the meeting included ISRO, Bangalore University, IUCAA, ARIES, TIFR, Utkal University, Assam University, Calcutta University, Delhi University, Mahatma Gandhi University, IIIT-Allahabad among others.

Several international consortia are planning to build telescopes with mirrors that are over twenty metres in size, in order to make the next leap in searching the depths of the cosmos. These telescopes will achieve their ultra-large sizes using mirror segments put together rather than a single giant mirror. Located in the best astronomical sites they will operate in the visible and infra-red region of the electromagnetic spectrum, and will be used to investigate a range of intriguing questions from Kuiper-belt objects to dark energy.

The Indian astronomical community has been debating the idea of participating in one of these consortia as a partner, and IIA hosted a meet-

Participants of the workshop on *Physics and Astrophysics of Dust*.

ing in September last year to deliberate on this topic. Subsequently scientists from several institutes got together to investigate the scientific benefits to the community from India's partnership in such a project, the feasibility of Indian participation, and the evaluation criteria for selection of an observatory from among the several international consortia. National working groups were formed to report on various aspects of the idea, including human resources development and possible participation of Indian industries. The October meeting at IIA, deliberated on the Detailed Project Report that emerged from these efforts, which is planned to be submitted to the Department of Science and Technology for consideration. Several presentations were made on the scientific, technical, industrial and human aspects. The Thirty-Meter Telescope project was seen as the most advantageous, considering the synergy with the astrophysics facilities in India, the potential technical contributions that the Indian community could make to the project and the impact on India's future in astrophysics research. The Thirty Meter Telescope which is well into the early construction phase, is expected to be commissioned around 2018. The participation in what will be be one of the world's most advanced astronomical observatories, is expected to bridge the gap in access to state-of-the-art international facilities for the Indian astrophysics community.

(B. Eswar Reddy)

M. Gadgil gives an intellectually stimulating discourse on transitions in evolution when he delivered the 19th Bicentennial Commemorative Lecture, 3rd April, 2009.

4.6 Lectures at IIA

19th Bicentennial Commemorative Lecture

The 19th Bicentennial Commemorative Lecture was delivered by India's foremost ecologist, Madhav Gadgil of the Agharkar Research Institute, Pune, on the topic *Major Transitions in Evolution*, on the 3rd April, 2009. In his lecture, Madhav Gadgil described the saga of life on earth as a continuous expansion and diversification, occupying a greater range of habitats and utilizing newer forms of resources. Most impor-

tantly, there has been an overall trend from simple to increasingly complex life forms and their interactions. He outlined a set of nine major transitions in evolution. The first eight are strictly biological: from individual replicating molecules becoming populations of replicating molecules in protocells, from independent replicators to chromosomes, from RNA to DNA genes and protein enzymes, from bacterial cells to cells with nuclei and organelles, from asexual clones to sexual populations, from single-celled organisms to multicellular ones, the emergence of animals with nervous systems, and the emergence of animal colonies with non-reproductive castes. This evolutionary process gave rise to two other forms of replicating entities besides genes, namely, memes (behaviour patterns) and artifacts. The development of memes has led to the ninth major transition, that from primate societies to human societies with symbolic languages. The evolutionary culmination of artifacts into the present day information and communication technology has brought us to the threshold of a tenth major revolution, from language-based human societies to a human society with global access to the entire stock of human knowledge.

Vainu Bappu Memorial Lecture

The third Vainu Bappu Memorial Lecture was delivered by William D. Phillips, Nobel Laureate from the National Institute of Standards, USA, on the 25th of January, 2010, on *Time, Einstein, and the Coolest Stuff in the Universe*.

The Vainu Bappu Memorial Lecture by Professor Phillips: Seen is one of the several live demonstrations of basic physics behind low temperature phenomena, with a liberal use of liquid nitrogen.

Professor Phillips gave a historic account of the human endeavour of timekeeping and how it acquired a new meaning and perception through the ideas of Albert Einstein at the beginning of the 20th century. He explained how the scientific and technological developments since then have driven timekeeping as an endeavour with ever-improving precision, ultimately resulting in atomic clocks, the best timekeepers ever made. Such super-accurate clocks are essential to industry, commerce, and science; they are the heart of the satellite navigation system that guides cars, airplanes, and hikers to their destinations. Professor Phillips then explained how Einstein's predictions, that used some new ideas from the Indian physicist Satyendra Nath Bose on a new state of matter - a new kind of gas called a "Bose-Einstein Condensate (BEC)", are being exploited to improve the accuracy of atomic clocks. BEC's occur when the atomic gas is so cold that a large fraction of the atoms essentially stops moving. Professor Phillips then used the long table on the speaker's podium as a mini laboratory to unfold a series of live demonstrations of the basic physics behind atomic and molecular motions, concepts of temperature, heat and cooling, and magnetic levitation, involving liquid nitrogen, air balloons and levitrons. These were basic physical processes, whose mastery and refinements led to the revolutionary advances in the cooling of neutral atoms to temperatures close to absolute Zero by means of laser light, known as "laser cooling", by Professor Phillips in the early 1980's. The packed auditorium remained spellbound during Professor Phillips's inspiring and exciting presentation, for which he is renowned. The great enthusiasm and innate curiosity of the speaker left a clear impact on everyone present, and the end of the lecture saw the audience, especially the young students from schools and colleges, flocking the podium to interact with the Nobel Laureate.

Eric Cornell, Nobel Laureate, Boulder, USA gives a popular lecture at IIA on *Stone Cold Science*, 8 March 2010.

Founder's Day Lecture

10 August 2009
Govind Swarup
NCRA, TIFR, Pune
Experimental Astronomy in India: Some Lessons

Popular Lectures

19 March 2010
Mike Dopita
Mount Stromlo and Siding Spring Observatories, Australia
Hubbles New Window to the Universe

08 March 2010
E. Cornell
University of Colorado & National Institute of Standards and Technology, Boulder, USA
Stone Cold Science: Bose-Einstein Condensation and the Weird World of Physics a Millionth of a Degree Above Absolute Zero

15 February 2010
C.V. Vishveshwara
Formerly IIA & J N Planetarium, Bangalore
Galileos Gift

25 January 2010
W. D. Phillips
National Institute of Standards and Technology, Gaithersburg, USA
Time, Einstein and the Coolest Stuff in the Universe

6 January 2010
Alan Brody
MIT, Cambridge, USA
Enriching Science Education: The Role of Science Theatre

22 October 2009
T. Jayaraman
TIFR, Mumbai & Institute of Mathematical Sciences, Chennai
From Static Worlds to Evolving Systems: Philosophical Implications of Changes in the Natural World

29 May 2009
S. Chatterjee
IIA, Bangalore
Meghnad Saha: The Scientist and the Crusader

30 April 2009
Balachandra Rao
Gandhi Centre of Science & Human Values, Bharatiya Vidya Bhavan, Bangalore
Classical Indian Astronomy - Some Landmarks

03 April 2009
Madhav Gadgil
Agharkar Research Institute, Pune
Major Transitions in Evolution

Colloquia

30 March 2010
M. Safonova
IIA, Bangalore
The Quest for Intermediate-Mass Black Holes in Globular Clusters

02 March 2010
G. Shaw
Centre for Excellence in Basic Sciences, University of Mumbai
Spectroscopic Signatures of Star Formation at High Redshift

23 February 2010
M. Purvankara
Univ. Rochester, Rochester, USA
The Structure and Evolution of Protoplanetary Disks

16 February 2010
D. J. Thompson
NASA GSFC, Greenbelt, USA
Highlights from the Fermi Gamma-ray Telescope

05 January 2010
D. Mitra
Queen Mary's College, Univ. London, UK
Understanding Solar Dynamo: Some Recent Results

22 December 2009
M. Das
BITS, Pilani, Hyderabad
The Dark Side of Galaxy Evolution: Extreme Late Type Galaxies

24 November 2009
R. Bhattacharyya
NCAR, Boulder, USA
Spontaneous Current Sheet Formation: Untwisted Magnetic Field Lines

17 November 2009
Y. Schekinov
Southern Federal Univ., Russia
Gas in Gamma-Ray Burst Hosts

10 November 2009
P. L. Biermann
MPI fr Radioastronomie & Univ. Bonn, Germany
Understanding Supermassive Black Holes

03 November 2009
S. Kwok
Univ. Hongkong, China
The Synthesis of Organic Compounds in the Late Stages of Stellar Evolution

27 October 2009
B. S. Shylaja
BASE, Bangalore
The Madras Observatory and Contemporary Indian Astronomy

13 October 2009
V. Sahni
IUCAA, Pune
Puzzling over Einsteins 'Blunder: Why does the Universe Accelerate?

29 September 2009
K. Elankumaran
RKM Vivekananda College, Chennai
Non-linear Effects in Waves: Experimental Studies with Ultrasonics

08 September 2009
P. Majumdar
Deutsches Elektronen Synchrotron (DESY), Zeuthen, Germany
Recent Highlights from the MAGIC Experiment

11 August 2009
P. N. Bhat
Univ. of Alabama, Huntsville, USA
Gamma-ray Burst Astronomy in the FERMI Era

28 July 2009
M. Sampoorna
Instituto de Astrofisica de Canarias, Tenerife, Spain
The Enigma of the Scattering Polarization in the Wings of the Solar Ca I 4227 Å Line

14 July 2009
R. Garcia
Service dAstrophysique, CEA, Saclay, France
Solar-Like Stars: From the Core of the Sun to the Stars

30 June 2009
N. Brosch
Tel-Aviv University, Tel-Aviv, Israel
Discovery of a Nearby Dark Matter Filament

02 June 2009
D. Alloin
Service d'Astrophysique, CEA, Saclay, France
On Formation of Extremely Massive Star Clusters

Seminars

24 March 2010
H. Dass
IISc, Bangalore
CPU and GPU Computing

25 February 2010
A. Deep
Leiden University, Leiden, The Netherlands
Use of AO PSF Models to Study Resolved Stellar Populations

18 January 2010
V. Soni
Jamia Millia Islamia University, New Delhi
Magnetars Incognito

17 December 2009
D. Tripathi
University of Cambridge, UK
Source Region Magnetic Configuration in CMEs and their Initiation

17 December 2009
N. Gopalswamy
NASA GSFC, Greenbelt, USA
Some Recent Findings on Interplanetary Shocks Driven by Coronal Mass Ejections

10 December 2009
J. Vivekanandan
National Center for Atmospheric Research, USA
Remote Sensing of Cloud Microphysics, Aerosols, and Water Vapor Using Microwave Radiometers and Lidars

05 November 2009
C. H. Ishwara-Chandra
NCRA, TIFR, & IUCAA, Pune
A Deep Search for High-redshift Radio Galaxies

29 October 2009
A. Borch
IIA, Bangalore
Direct NBODY Simulation

16 September 2009
C. Joseph
Jyoti Nivas College
Bangalore
On Development of 10.5 micron Quantum-well Infrared Photodetector for Astronomical Applications

24 August 2009
J. Schmitt
Hamburger Sternwarte
Hamburg, Germany
A High-resolution Stellar Spectrograph for the NLST

13 August 2009
R. Britto
TIFR, Mumbai
Observation of the Crab Nebula with the HAGAR Telescope System in the Himalayas

31 July 2009
A. Vagiri
IIIT, Allahabad
Accessing FITS Files over the Internet

23 July 2009
R. Mohan
IIA, Bangalore
An Introduction to High-performance Computing using Graphics Processors

02 July 2009
N. Brosch
Tel-Aviv University, Tel-Aviv, Israel
Grey extinction in the Milky Way

11 June 2009
D. Alloin
Service d'Astrophysique
CEA, Saclay, France
Differential Gravitational Lensing to Unveil Molecular Structures around High Redshift AGN

14 May 2009
A. Pathak
School of Chemistry, Univ. Nottingham, UK
Polycyclic Hydrocarbons in Space

Lecture Courses

10 June 2009
D. Alloin
Service d'Astrophysique, CEA, Saclay, France
Galaxies II

04 June 2009
D. Alloin
Service d'Astrophysique, CEA, Saclay, France
Galaxies I

Special Lectures

18 February 2010
V. Connaughton
NSSTC, Huntsville, USA *Fermi Gamma-Ray Space Telescope Observations of Gamma-Ray Bursts*

04 November 2009
S. M. R. Ansari
IUPS, Aligarh
Modern Astronomy in Persian sources

27 August 2009
D. Lambert
University of Texas, Austin, USA
A Half-century of Spectroscopic Astrophysics: Personal Recollections

25 August 2009
J. Schmitt
Hamburger Sternwarte, Hamburg, Germany
Magnetic Activity of the Sun and the Stars: Insights and Problems

25 August 2009
P. Balaram
IISc., Bangalore
Reinventing the Research University in India
A High Resolution Stellar Spectrograph for the NLST

19 June 2009
V. Soni
NPL, New Delhi
River Flood plains: An Invaluable Natural Storage for Water

Chapter 5

Outreach Activities

IIA's public outreach programme intensified significantly during the International Year of Astronomy. All the new programmes that were initiated on the occasion, as well as participation in the world-wide activities, gathered considerable momentum through the year, right up to the concluding event and beyond.

5.1 International Year of Astronomy

IIA vigorously participated in several of the IAU-IYA09 global cornerstone projects, *viz*., 100-HOURS OF ASTRONOMY, SHE IS AN ASTRONOMER, designing and distributing a 'GALILEOSCOPE' and the GALILEAN NIGHTS. IIA's 100-LECTURE SERIES of country-wide public talks far surpassed its target by reaching a total of over 140 lectures in the International Year. IIA's telescope participated in the AROUND THE WORLD IN 80 TELESCOPES webcast. People in their hundreds participated in the special public sky-watching events during the 100-HOURS OF ASTRONOMY and GALILEAN NIGHTS programmes. A 10 cm aperture telescope designed by IIA for amateur use was mass-produced and over 250 pieces were widely distributed countrywide. IIA built partnerships with amateur astronomers of the Bangalore Astronomical Society, and science popularisers of the All-India Peoples' Science Network, thereby maximising the reach of its activities. In addition, several interdisciplinary events were organised including those that built collaborations with the Bangalore Little Theatre and the Srishti School of Art, Design and Technology, Bangalore. IIA's IYA09 activities were co-ordinated by S. Chatterjee, P. Shastri, R. Banyal, C. Muthumariappan, P. Anbazhagan, K. Sundara Raman, S.P. Rajaguru, D. Angchuk and S. Muneer.

5.1.1 100 hours of astronomy at Lalbagh

About 500 people from all walks of life participated in the celebration titled 100 HOURS OF ASTRONOMY, by viewing the beauty of the Moon and Saturn through telescopes at the Lalbagh gardens in Bangalore, during the first week of April. IIA set up a sky-watching programme and interaction with the public.

The 100 HOURS OF ASTRONOMY programme (2–5 April 2009) was an occasion for observatories and astronomers world-wide, professional as well as amateur, to organise astronomy-related activities for the public. IIA stationed its six-inch and fourteen-inch telescopes at the foot of the rocky hillock in Lalbagh gardens after dusk on Saturday and Sunday, the 4th and 5th April. Both Lalbagh regulars and those that specifically came for the star-party thronged and queued up in large numbers for a telescopic view of the sky. Curiosity and enthusiasm drove some people to visit on both the days. While Bangalore's skies preclude viewing of most of the interesting astronomical objects because of the high-levels of light pollution, the public were still able to view the Moon and its craters, and Saturn, which had its beautiful rings oriented virtually edge-on.

5.1.2 Around the World in 80 Telescopes

The Himalayan Chandra Telescope of IIA at Hanle, participated in the AROUND THE WORLD IN 80 TELESCOPES, a live 24-hour webcast during and as part of 100 HOURS OF ASTRONOMY. The webcast followed some of the most advanced observatories around the planet, both on ground and in space. The programme gave viewers worldwide the opportunity to "visit" some of the most advanced observatories on earth and in space, highlighting the diversity of astronomical community and the international na-

Sky-watching at Lalbagh gardens during 100 HOURS OF ASTRONOMY.

S.S. Hasan speaking at the science festival of the Bangalore Science Forum

ture of astronomy. The 15-minutes devoted to HCT included live webcast and interaction from the telescope floor at IAO, Hanle and remote control room at CREST, Hosakote. HCT was chosen because of being the world's highest telescope that is fully operated remotely from Bangalore. The webcast was co-ordinated by Tushar Prabhu.

5.1.3 Evenings with Stars

Several of the IYA09 public lectures at IIA were followed by night sky-watching events for the public on the roof of the IIA main building, organised in partnership with the Bangalore Astronomical Society, an amateur astronomy group committed to bringing the excitement of discovering the universe to the public. Both veterans and freshers to astronomy, including adults and children gathered at these events to watch the Moon, Venus, Saturn and Jupiter and occasionally the Orion nebula through the telescopes. On those evenings when it was clear that the skies would not clear, the scheduled "Evening with Stars" converted itself into an animated discussion on stars, planets the scientific method and astrology. During these discussions IIA astrophysicists as well as Naveen Nanjudappa and others of the BAS led the public through the basics of how to make simple beginnings with astronomy as a hobby and yet experience the excitement of scientific exploration.

5.1.4 Astronomy at the BSF Science Festival

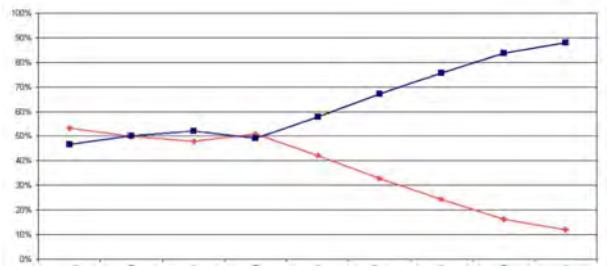
S. S. Hasan inaugurated the 32nd annual science festival of the Bangalore Science Forum on 1 July, 2009, at the H. Narasimaiah hall of National College. This science festival is an annual Bangalore celebration for and by science buffs. It was first proposed by the late H. Narasimaiah, founder of the Bangalore Science Forum and an outstanding science populariser, who strove to spread scientific temper among the public. In keeping with 2009 being the International Year of Astronomy, the science festival this year was kicked off with an astronomy lecture by S. S. Hasan, who spoke on *New windows to the mysteries of the Sun.*

5.1.5 She is an Astronomer

As part of IIA's activities under the SHE IS AN ASTRONOMER corner-stone project in IYA09, an international discussion meeting was held at the Bangalore campus of IIA on the 17 June 2009, where astrophysicists, physicists and social scientists came together to debate on the theme *Countering Gender Prejudice in the Science Workplace.* Over 80 people that included scientists from IIA, ISAC, IISc, JNCAR and NIAS, as well as college students and members of the public, participated in the meeting.

The meeting was inaugurated by the Director, Siraj Hasan, and chaired by the eminent economist Gita Sen of the Indian Instiute of Management, Bangalore, who initiated the discussion with her introductory remarks. Prajval Shastri (IIA) gave an overview of the issue. Danielle Alloin, renowned astrophysicist from Service d'Astrophysique, Saclay (France) followed with her presentaion on the experience and statistics from the European Union. Mousumi Das, astrophysicist from BITS Hyderabad, discussed the gender situation in astronomy in Indian research institutions.

SHE IS AN ASTRONOMER discussion meeting at IIA on *Countering Gender Prejudice in the Science Workplace.* left to right: Gita Sen (IIM, Bangalore, who chaired the meeting), Mousumi Das (BITS-Pilani, Hyderabad), Danielle Alloin (Service d'Astrophysique, CEA Saclay, France), Prema Rajagopalan (IIT Madras), Andrea Borsch (IIA) & Prajval Shastri (IIA).



The 'Scissor Diagram': Statistics for German Academia from 2007, showing fraction of males and females (blue & red points respectively) as a function of level increasing to the right (high school, university, Ph.D., post-doctoral, through to professorship).

Andrea Borch, astrophysicist and post-doctoral fellow at IIA, presented the now-famous *Scissor diagram*, and discussed the the recent paradigm shift in the underlying theoretical framework adopted in the European Union, from "gender-equalisation" to "gender-mainstreaming". Prema Rajagopalan, sociologist from IIT-Madras, presented a very large number of extremely insightful observations from her extensive sociological investigations. These presentations were followed by remarks by a set of respondents that included Jayant Murthy, A. Vyas and Rekhesh Mohan from IIA, Suchitra Balachandran (Univ. of Maryland) and Shobhana Narasimhan (JNCAR), wherein several new points were brought out. A lively discussion followed, after which the Chair, Gita Sen delivered a fascinating set of concluding remarks. The participation of significant proportions of both genders in the meeting was testimony to the recognition that the gender issue was not merely one of "justice for women" but also of general institutional concern from the point of view of scientific productivity. The meeting was organised by P. Shastri, S. Chatterjee, R. K. Banyal and S. P. Rajaguru.

5.1.6 Workshops at Chennai & Trichy

Inauguration of the workshop.

IIA along with the Tamilnadu Science & Technology Centre organised two-day workshops for college students and teachers at the Periyar Science & Technology Centre, Chennai (26 & 27 June), and the Anna Science & Technology Centre, Tiruchirapalli (29 & 30 June), on the theme 'Understanding the Universe from Earth to the Galaxy: An Astrophysical Journey'. With the extensive help of M. Iyamperumal, Executive Director, Tamil Nadu Sci-

ence and Technology Centre, and co-ordination by S.Soundararajaperumal, IIA alumnus who is now at the Tamilnadu Science & Technology Centre, nearly a hundred students and teachers from several colleges in the area were able to participate in each workshop.

The topics were selected to cover several aspects of astrophysics, including solar, stellar and galactic physics, sun-earth interactions, and instrumentation. The students were also introduced to the time, mass and distance scales involved in astronomy and were shown how basic physical laws govern the birth, evolution and death of stars, and the thickness of our galaxy. At the Chennai workshop, P. R. Vishwanath explained the importance of the International Year of Astronomy, and narrated how the work of Galileo set in motion the advance of scientific reason that ushered in the era of enlightenment. Sundara Raman explained the observational facilities at the Kodaikanal Observatory, which recently celebrated its centenary.

The Chennai workshop ended with a lively panel discussion on the theme of spreading the message of astronomy and scientific rationality. After the Trichy workshop, Dr. Azhagiriswamy, Project Director and other members of Science Centre arranged night-sky watching and a planetarium show for the participants.

K. Sundara Raman, T. P. Prabhu, P. R. Vishwanath, S. Chatterjee, K. B. Ramesh,F. Sutaria and R. K. Banyal were the IIA team members at Chennai, and K. Sundara Raman, S. Chatterjee, K. B. Ramesh, F. Sutaria, R. K. Banyal, S. Ramya and S. P. Rajaguru were the IIA team members at Trichy.

5.1.7 Sky-watching and Learning in a non-School Environment

An IIA outreach team together with the Bangalore Astronomical Society conducted a sky-watching event at the final day of an astronomy summer camp for children run by the Drishya Kalike Kendra in Bayyappanhalli on 03 July 2009.

The Drishya Kalike Kendras (learning centres), of which there are three in Bangalore, attempt to respond to the needs of underprivileged children living in urban slums, by developing innovative curricula within non-school environments of learning. The summer camp sought to bring exposure of astronomy, space sciences and technology to these children in participatory ways, involving hands-on activities, the medium of stories, dance and theatre, and field-visits to ISRO facilities. On the final day of the camp, the children made a presentation, followed by sky-watching with IIA's 14 inch telescope, and the children viewed the moon's landscape through the telescope.

Resource persons A. Sharma (BAS), J. P. A Samson and P. Shastri at the sky-watch at Drishya Kalike Kendra.

5.1.8 IIA-IGNOU Extension Programme

S. Chatterjee (IIA) and C. K. Ghosh (IGNOU) are first and second from the right, at the IIA-IGNOU outreach programme, Patna.

IIA and the Indira Gandhi National Open University partnered in launching a country-wide series of astronomy outreach programmes, aimed at developing a scientific temper and sharing the spirit of science and with the public at large. This series was launched with two workshops. The first workshop was at Lucknow on the 20 July 2009, in the Education Department of the Lucknow University, and was inaugurated by the University's Vice- Chancellor Dr. U. N. Dwivedi. The second one was at Patna at the Indian Institute of Business Management on the 21 July 2009. At both the events, C. K. Ghosh of IGNOU and S. Chatterjee of IIA were the main

speakers. Dr. Ghosh emphasised that the IYA09 was meant not to commemorate a certain person or a certain discovery but to set forth a chain reaction, leading to wide emergence scientific rationality. Recalling that Galileo was thought of as the father of modern science, S. Chatterjee described how Galileo put primacy on experiments, but also brought in a synthesis of theory and experiments and was the father of "Galilean relativity", on which Newton's works rest. He discussed how the flood gates that Galileo opened up paved the way for Horrocks and Crabtree to measure the earth-sun distance, using the transit of Venus on December 4, 1639.

Each of the meetings were attended by eminent academics of the two cities and by over hundred students and teachers. The talks were followed by lively discussions on astronomy, its advances, the impact on human thought and world views. The Patna workshop had a special significance since it was on the day before the total solar eclipse there. Both the speakers debunked astrology and the superstitions surrounding eclipses, and urged the audience to view the forthcoming total solar eclipse, due on 22 July 2009.

5.1.9 Outreach activities at the Total Solar Eclipse

The total solar eclipse of 22 July, 2009, was an excellent opportunity to mobilise the public into safely viewing the eclipse, and provided an occasion for intense public interaction with scientists. At Patna, (which was in the path of totality) during the two days before the eclipse, the All-India Peoples' Science Network conducted *Suryotsav*, a Solar Eclipse Science Festival for children and the public. S. Chatterjee and P. Shastri gave several lectures in the festival in both English and Hindi, to school, college and public audiences. Although the weather clouded out during the moments of totality, over fifteen-thousand people assembled at Gandhi Maidan to watch the eclipse, and viewed the crescent sun through safe glasses. S.Chatterjee, P.Shastri, Andrea Borch and Firoza Sutaria from IIA participated in the in the public interaction during the eclipse.

At Benares, an IIA team led by R. C. Kapoor performed white-light photography during totality.

At Bangalore, IIA in partnership with Bharat Gyan Vigyan Samithi organised an eclipse-viewing event at the Lalbagh Gardens, equipped with telescopes to project the sun's image, as well as spectacles for safe solar viewing. The eclipse was of course partial, and not only was it very close to the horizon, but the sky was also cloudy, and thus not conducive to viewing. Nevertheless, a very enthusiastic crowd of over 500 Lalbagh regulars, other members of the public and the media gathered at the event, and partook both in the refreshments that were served as well as in the discussions on telescopes, the physics of eclipses and prevailing beliefs around them, safety of sun viewing, solar filters and astronomy in general. The media persons who were present to cover the event live on TV also participated in the conversations. The IIA team had Ravinder Banyal, Edwin Ebenezer, P.K. Mahesh, and the visiting American students Sarah Willis and Thomas A. Schad.

5.1.10 IYA09 at the IAU General Assembly

S. S. Hasan participated in the special session on the International Year of Astronomy at the XXVII General Assembly of the International Astronomical Union. This special session was held during 3–5 August 2009 at the venue of the General Assembly at Rio de Janeiro, Brazil. The session, occurring eight months after the kick-off of the International Year, was an opportunity to showcase in one spot, the activities from around the planet that attempted to take astronomy and the excitement of science to the public. S. S. Hasan presented two posters from IIA *viz*., *Universalising the Universe: The IYA09 activities and approaches of IIA* authored by P. Shastri, S. Chatterjee, R. K. Banyal and S. P. Rajaguru, and *Gender Inequity in Astrophysics: Cultural Change through Structural Change* authored by P. Shastri. Many of the activities and concepts had both a strong regional flavour and the potential to be adapted elsewhere. The session thus provided a forum for rich exchange of ideas to take the international year celebrations forward.

5.1.11 Coastal Region Lecture Series

The Association of Physics Teachers of Mangalore University organised a week-long series of public lectures on astronomy in different colleges all across the Karnataka coastal districts of Udupi and Dakshina Kannada, in September, on the occasion of the International Year of Astronomy, in which amateur astronomer associations of the districts also partnered. The inaugural session of this series was in the Poornaprajna College, Udupi, where Chandrashekhar Shetty, physicist and the former Registrar of Mangalore University, delivered the key-note address on the significance of Galileo's work, the sci-

entific method and the impact on astronomy and science in general. This was followed by a lecture on *Landmarks in Astronomy* by S. Chatterjee and another on *Shining Black Holes and Growing Galaxies* by P. Shastri. Following the inaugural event, S. Chatterjee and P. Shastri gave lectures at colleges in Kalyanpur, Bantwal, Udupi, Mulki and Mangalore.

5.1.12 Dance of Stars: Nataraja and the Cosmos

IIA hosted a unique interactive, internet-streamed, cross-continental dance performance at its Hosakote campus on 17 October, 2009, with Bharatanatyam dancer and scientist Sharada Srinivasan performing in IIA, and contemporary dancer Anusha Emrith performing in Cit De L'Espace in Toulouse, France.

This event, titled *Dance of Stars: Nataraja and the Cosmos (Danse e-Toile: Nataraja et le Cosmos)*, featured in the first Toulouse knowledge festival Festival La Novela, which attempted a view of science from an artistic, enjoyable perspective. The event was streamed live from both venues for remote audiences. Distant streaming and e-interaction was explored as a means of conveying the metaphors of the cosmos and cosmic order and flux. The streaming was made visible to the two dancers as well, so that each could respond to the other in real time. The webcast used technology to combine images of the two performances so that sometimes the dancers were seen separate, and sometimes merging. It was a synthesis of art, science and advanced technology, produced in collaboration with the French *K.danse Company* led by Jean-Marc Matos and Anne Holst, among whose specialties are internet-streamed dance performances. The entire event was webcast live from both venues through the website of Thtre Villette, Paris.

The internet-streamed event was preceded by a photo-montage exhibition by Sharada Srinivasan at both the Indian and French venues, elucidating the art-science-dance connections and the archaeometallurgical and archaeoastronomical aspects of the *Chola Nataraja* bronze imagery. The exhibition also integrated aspects of the Cit De L'Espace, Toulouse, a innovative and educative science museum with test models of satellites, and the IIA's Hanle telescope. Geetha Navale's veena performance was streamed live as a prelude to the dance recital. David Fieffe arranged the combination of Bharata Natyam music interwoven with electronic background music to convey a sense of 'space' and with mridangam inputs from Gurumurthy and veena by Geetha. Rekhesh Mohan and Sanjiv Gorkha were technical co-ordinators of the event from IIA, together with Digvijay Mallah and Rakesh Mannar working on the videographic aspects.

The performance was followed by an on-line discussion between French and Indian scholars and artists. Sharada Srinivasan, science writer and science-historian Balachandra Rao, artist Sultana Hasan from Bangalore, and astronomer Karine Gadre, and digital choreographer Jean-Marc Matos from Toulouse, among others, discussed the art-science interface, the interplay between Bharata Natyam and contemporary dance, the links between astronomy, pre-modern art, architecture and religious beliefs, and the unique artistic idiom that emerges when performances images are streamed.

Sharada Srinivasan performing at the Danse e-Toile. The projection of the internet-streamed "e-duet" with the merged images of Srinivasan from France and Emrith from Toulouse is seen in the background.

5.1.13 Landmarks in Astronomy

A series of public lectures titled Landmarks in Astronomy was initiated in the International Year. These lectures were held at IIA through the International Year, and described the work of eminent scientists who not only made outstanding contributions to the advancement of astrophysics but also have had a special impact on human society. The lectures were followed by lively debates, usually centred around the social processes in which the practice of science is embedded. The public who attended the lectures stayed on for night sky-watching on the terrace of the IIA building, conducted in collaboration with the Bangalore Astronomical Society.

The following LANDMARK LECTURES were held during April – December, 2009:

S. Balachandra Rao: *Classical Indian Astronomy - Some Landmarks,* (30 April)

S. Chatterjee: *Meghnad Saha: The Scientist and the Crusader,* (29 May)

T. Jayaraman: *From Static World to Evolving Space-Times: Lessons from Modern Cosmology,* (22 October)

5.1.14 Galilean Nights

Spurred by the phenomenal success of the 100 HOURS OF ASTRONOMY programme that spawned public sky-watching events throughout the world, the IAU declared a second world-wide programme of public sky-watching during 22 – 24 October 2009, called GALILEAN NIGHTS. The dates were chosen when the moon as well as jupiter and its planets would be visible fairly high in the sky.

On the first Galilean night IIA organised a sky-watching session on the terrace of the IIA building. Many members of the public who had come to the *Landmark Lecture* by T. Jayaraman stayed on for the session and were joined by others as well. Venus, Jupiter and the moon were popular targets through both the 14 inch and 6 inch telescope. The use of IIA's GALILEOSCOPE was also demonstrated. The sky-watching was conducted in partnership with the Bangalore Astronomical Society (BAS).

On the 2nd and 3rd Galilean night, IIA again partnered with the BAS to celebrate the beauty of the night sky at the rocky outcrop of Lalbagh gardens. The IIA telescopes were joined by several telescopes belonging to the members of the BAS. Over 700 people queued up to watch Jupiter, its moons and our moon. The occasion, as always, resulted in dialogue between the scientists, the amateur astronomers and the public on a wide variety of topics. The event exemplified in more ways than one, spirit of the slogan of IYA 2009, *viz.*, THE UNIVERSE, YOURS TO DISCOVER.

5.1.15 IIA's Galileoscope

IIA's GALILEOSCOPE that was designed as part of the International Year of Astronomy activities has now become available, with over 250 telescopes shipped to destinations country-wide.

P. Parihar (IIA) showing Jupiter and its moons to the public through the 14 inch Meade telescope on the first GALILEAN NIGHT sky-watching programme at IIA.

The IIA and BAS teams that participated in the public sky-watching programme at Lalbagh gardens during the GALILEAN NIGHTS.

Given IIA's expertise in telescope-making, designing a sturdy, easy-to-handle and low-cost telescope was seen as an important goal of IIA's IYA09 *Astronomy for All* programme, whose aim is to spread the excitement of viewing objects the night sky as widely as possible. The design efforts of the Photonics division resulted in a prototype Newtonian reflecting telescope with a 100 mm-diameter aluminium-coated mirror as the aperture, and a standard 10x eye-piece. The telescope was designed to have a sturdy circular base, and an alt-azimuth mount, with dual-axis manual fine movement. The light-weight tube was designed to house the Newtonian optics, and have a simple gun-sight arrangement for ease of pointing. The telescope was mass-produced by Lensel Optics Pvt. Ltd., Pune. It is intended for basic night-sky viewing and was made available for purchase by both institutions and individuals at cost from IIA, using a web-based interface.

One Galileoscope was presented by IIA to the Government High School, Madivaala, with which IIA initiated an extension programme in February, 2008.

The use of IIA's Galileoscope was demonstrated at the *Galilean Nights* programme, which was an IYA event consisting of public sky-watching programmes world-wide, during 22 – 24 October 2009. The public viewed the Moon and Jupiter through the telescope. The Galileoscope has been provided to a variety of interested parties that includes schools, colleges, science associations, amateur astronomers, students and other individuals.

A school boy trying out IIA's Galileoscope at the Galilean Night public sky-watching programme at Bangalore's Lalbagh gardens. Viswa Keerthy from Bangalore Astronomical Society looks on.

5.1.16 Programmes for Students at IIA

Through the year, IIA had several school and college student groups from both Bangalore city and outside, visit for a day's or half-a-day's programme. Typically 100-150 students participated in each programme, during which the students listened to a lecture or two by IIA scientists on a choice of astronomy topics, followed by extended discussion between the students and the scientists. The topics covered this year included the Sun, the death of stars and supernovae, telescopes, contributions of Galileo, galaxies and black holes. The programmes included a visit to the photonics lab. If the weather and time permitted, demonstrations of sun-watching experiments were also conducted. The groups that visited included students from the Nehru Cultural Children's Association, Chennai, thirty Jagadish Bose

An educational event by IIA for school children from Bangalore (Rotary Club youth wing).

National Science Talent Scholars (who also visited the CREST campus), students from the Mallya Aditi School, Bangalore, and those from the Rotary Club programme for six Bangalore schools.

5.1.17 Extension Programme in the Neighbourhood School

IIA continued its extension programe with the Government High School, Madivaala, which was begun in the run-up to IYA09. A special programme was organised at the IIA campus for the children on Science Day, and also during the annular solar eclipse.

A highlight of the year was the participation of over 50 children of the school in an event for school children organised by the Consulate of Switzerland on the 13th August09 at the Cambridge School, Bangalore, wherein they children heard presentations by Claude Nicollier, Swiss astronaut and Hubble repair mission specialist, and Muriel Noca, Project Manager of the satellite SWISSCUBE (launched by ISRO). Following the presentations, the children took part in extensive discussions with the two Swiss experts.

Another highlight of the extension programme was the presentation of an IIA Galileoscope to the school for sky-watching activities. On the occasion of Mahatma Gandhi's Birthday, H. C. Bhatt (Dean-Academic), A. K. Saxena (Dean-Engineering and head of Photonics Division), and S. Chatterjee (Chair, IYA09 committee) from IIA participated in a ceremony to hand over the Galileoscope to the school. At the gathering of the students and teach-

At the extreme left is A. K. Saxena (Dean, Engineering, IIA) handing over the IIA Galileoscope to T. N. Dheeresh Kumar (extreme right), Principal, Madivaala Government High School. Also seen are (left to right) H. C. Bhatt (Dean Academic, IIA), J. S. Gayatri and B. J. Begum (science teacher and Deputy Principal respectively, of Government High School, Madivaala).

ers of the school, H. C. Bhatt and S. Chatterjee explained the significance of Galileo Galilei's work 400 years ago, and emphasised the importance of experiments in science. A. K. Saxena handed over the Galileoscope to the school, which was received by the Principal, Shri T. N. Dheeresh Kumar.

5.1.18 Documentary Films on Astronomy

IIA facilitated the filming of *Four Hundred Years of the Telescope*, a Vigyan Prasar documentary, which was shot at the Bangalore, CREST, Kodaikanal, Kavalur, Gauribidanur and Hanle campuses of IIA during May-June 2009. Several IIA scientists were interviewed for the film.

Doordarshan, Chennai, filmed a documentary in Tamil, *Vinnaithandi Paarpoma* (*Looking Beyond the Sky* in Tamil) at the VBO, in July and Sept. 2009. C. Muthumariappan, co-ordinated the filming, and Sivarani Thirupathi was interviewed for the 50 minute film, which was broadcast several times by Doordarshan.

5.1.19 The 100-Lecture Series

The IYA09 team of IIA had planned a countrywide 100-LECTURE SERIES during 2009, i.e., a series of popular lectures at schools, colleges, science clubs and other public fora, over 40 of which were listed in last year's report. At the end of the International Year, this effort resulted in over 140 lectures, in Bangalore as well as other parts of the country. A few of these lectures were given in the vernacular language.

The list of lectures K. Sundara Raman: *The Sun and an Overview of Stars*, Institute of Road Transport Technology, Erode. (9 April)

S. Chatterjee: *Universalizing the Universe,* Andhra Pradesh Jana Vignana Vedike, Hyderabad. (12 April)

S. Chatterjee: *Landmarks in Astronomy (in Hindi),* All India Peoples' Science Network regional workshop, Bhopal. (14 April)

S. Chatterjee: *How thick is our galaxy?,* Physics Department, Barkatulla Khan University, Bhopal. (15 April)

D. Banerjee: *The Sun,* Bose Institute, Kolkata. (15 April)

S. Chatterjee: *How thick is our galaxy?,* Jamia Milia University, Delhi. (17 April)

D. Banerjee: *The Sun,* Al Ameen School, Midnapoore, West Bengal. (17 April)

C. Muthumariappan: *Multi-wavelength Astronomy,* VBO Kavalur. (21 April)

K. Sundara Raman: *Solar Physics*, Tejaa Shakthi Institute of Technology For Women, Coimbatore. (25 May)

P. R. Vishwanath: *Galileo and the night sky,* Tibet School, Leh. (2 June)

P. R. Vishwanath: *The Many Faces of Light,* Tamilnadu Science and Technology Centre, Chennai. (Jun 2009)

P. R. Vishwanath: *Galileo and the night sky,* Government College, Leh. (2 June)

P. R. Vishwanath: *Galileo and the rise of science,* Inter-University Accelerator Centre, New Delhi. (3 June)

P. Shastri: *AntharArAshtrIya KhagOLa vijnAna varsha, Galileo mattu khagOLa shAstrada tiLuvaLike* (*IYA, Galileo and Concepts from Astronomy* in Kannada), Government of Karnataka Education Officers' Workshop, Bangalore. (5 June)

N.S. Shantikumar: *An Introduction to Astronomy & Astrophysics*, Cambridge Higher Secondary School, Imphal, Manipur. (4 June)

N.S. Shantikumar: *Science with the Himalayan Chandra Telescope*, Department of Physics, Manipur University, Imphal, Manipur. (4 June)

C. Muthumariappan: *Astronomy & Modern Civilization,* Tamilnadu Science and Technology Centre. (10 June)

P. R. Vishwanath: *Galileo and the rise of science,* National College, Jayanagar, Bangalore. (13 June)

T. Prabhu: *Astronomy from High Altitudes*, MP-COST, Ujjain, Madhya Pradesh. (21 June)

P. R. Vishwanath: *Life and work of Galileo,* Tamilnadu Science and Technology Centre, Chennai. (26 June)

K. B. Ramesh: *Sun-Earth interaction,* Tamilnadu Science and Technology Centre, Chennai. (26 June)

T. Prabhu: *Galaxies and the question of vastness revisited,* Tamilnadu Science and Technology Centre, Chennai. (26 June)

S. Chatterjee: *How thick is our galaxy? A Text book approach,* Tamilnadu Science and Technology Centre, Chennai. (27 June)

P. R. Vishwanath: *Spectroscopy, the science of colours,* Tamilnadu Science and Technology Centre, Chennai. (27 June)

F. Sutaria: *Stars, from birth to death,* Tamilnadu Science and Technology Centre, Chennai. (27 June)

F. Sutaria: *Stars, from life after death,* Tamilnadu Science and Technology Centre, Chennai. (27 June)

R. K. Banyal: *Telescopes through the ages,* Tamilnadu Science & Technology Centre, Chennai. (27 June)

K. Sundara Raman: *Basics of Solar Physics*, Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

K. Sundara Raman: *Solar observations at Kodaikanal observatory,* Tamilnadu Science and Technology Centre, Chennai. (27 June)

S. Chatterjee: *Journey in Physics,* Anna Science Centre Planetarium, Tiruchirappalli. (29 June)

K. Sundara Raman: *Basis of solar physics,* Anna Science Centre Planetarium, Tiruchirappalli. (29 June)

K. B. Ramesh: *Sun-Earth interaction,* Anna Science Centre Planetarium, Tiruchirappalli. (29 June)

S. Ramya: *Galaxies, the question of vastness revisited,* Anna Science Centre Planetarium, Tiruchirappalli. (29 June)

S. Chatterjee: *How thick is our galaxy?* A Text book approach, Anna Science Centre Planetarium, Tiruchirappalli. (29 June)

K.E. Rangarajan: *Physics of Solar Atmospheres,* Gurunanak Dev University, Amritsar, Punjab (29 June)

S. P. Rajaguru: *What goes on inside a typical star like the Sun?,* Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

F. Sutaria: *Stars, from birth to death,* Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

F. Sutaria: *Stars, from life after death,* Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

R. K. Banyal: *Telescopes: A window to our universe,* Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

K. Sundara Raman: *Basics of Solar Physics*, Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

K. Sundara Raman: *Solar observations at Kodaikanal observatory,* Anna Science Centre Planetarium, Tiruchirappalli. (30 June)

P. Shastri: *The Fascinating Cosmos,* CNR Rao Hall of Science and Education Technology, JNCAR, Bangalore. (30 June)

K.E. Rangarajan: *The Sun,* Kuvempu University, Shankaraghatta, Karnataka. (7 December)

S. S. Hasan: *New Windows to the Mysteries of the Sun,* Bangalore Science Forum, National College Bangalore. (1 July)

K.E. Rangarajan: *Solar Eclipse,* Kendriya Vidyalaya, Gwalior Air Force station, Madhya Pradesh. (22 July)

S. P. Rajaguru: *Solar Eclipses, Visvesvaraya Industrial and Technological Museum,* Bangalore. (16 July)

B. Ravindra: *Total Solar Eclipse -Jul 22nd 2009,* Jayashree English Medium High School, Anekal, Bangalore. (16 July)

P. Shastri: *namma vishva mattu antharar Ashtr Iya KhagOLa vijnAna varsha* (*Our Universe and the International Year of Astronomy* in Kannada), IYA09 State-Level Teachers' Workshop, Karnataka Rajya Vijnana Parishat, Bangalore. (16 July)

S. Chatterjee: *Eclipses and transits: measurement of earth-sun distance,* Joint workshop of the IIA and IGNOU, Lucknow University. (20 July)

P. Shastri: *The Sun, the Cosmos and I*, Solar Eclipse Science Festival, All-India People's Science Network, Patna. (21 July)

S. Chatterjee: *Landmarks in Astronomy*, Solar Eclipse Science Festival, All-India People's Science Network, Patna. (21 July)

P. Shastri: *Surya, Vishva aur Main* (*The Sun, the Cosmos and I* in Hindi), Solar Eclipse Science Festival, All-India People's Science Network, Patna. (21 July)

S. Chatterjee: *Eclipses and transits: measurement of earth-sun distance,* Joint workshop of the IIA and IGNOU, Patna. (21 July)

F. Sutaria: *The Solar Corona, Jadavpur University,* Kolkata. (24 July)

A. Vyas: *Astronomy and Optics,* Department of Physics, National Institute of Technology, Tiruchirapalli. (6 August)

P. R. Vishwanath: *Galileo and the Rise of Science,* Jawaharlal Nehru University (JNU), New Delhi. (6 August)

F. Sutaria: *The life and death of stars,* Aditi Mallya school, Bangalore. (8 August)

R. K. Banyal: *400 years of the telescope,* Physics Department, Sri Sathya Sai Institute of Higher Learning, Prasanthi Niliyam. (8 August)

K. Nagaraju: *Vishvadalli namma sthAna Enu?* (*What is Our Place in the Universe?* in Kannada), Vishwa Bharathi Junior College, Mallasandra, Bangalore. (14 August)

S. Chatterjee: *Landmarks in Astronomy,* Kannur Science Centre, Kannur. (18 August)

S. Chatterjee: *Astronomy and scientific rationality,* KSSP meet to commemorate M. K. Vainu Bappu and Janaki Ammal: Tellicherry. (19 August)

S. Chatterjee: *Meghnad Saha: the scientist and crusader,* Raman Research Institute, Bangalore. (20 August)

E. Ebenezer: *Sun: The nearest Star*, Embassy School, Bangalore. (20 August)

P. Shastri: *Munching Black Holes & Growing Galaxies,* children's programme, IIA, Bangalore. (26 August)

P. K. Mahesh: *Some Aspects of Design of Astronomical Telescopes,* Er. Perumal Manimekalai Polytechnic College Students, VBO, Kavalur. (28 August)

R. K. Banyal: *400 years of Astronomy, Sona College of Technology,* Salem. (29 August)

R. K. Banyal: *400 years of the Telescope (translated to Tamil by Ajith P.),* Salem Astronomical Society, CSI polytechnic Institute, Salem. (29 August)

P. Shastri: *Our Enchanting Universe, University Womens' Association,* Bangalore. (29 August)

P. Shastri: *Shining Black Holes and Growing Galaxies, Poornaprajna College,* Udupi, Karnataka. (9 September)

S. Chatterjee: *Landmarks in Astronomy,* Poornaprajna College, Udupi, Karnataka. (10 September)

P. Shastri: *kappu kuLigaLu mattu gAlaksigaLu* (*Black Holes and Galaxies* in Kannada), SVS College, Bantwal, Karnataka. (10 September)

S. Chatterjee: *How thick is our galaxy?,* Milagres College, Kallianpur, Karnataka. (10 September)

S. Chatterjee: *Landmarks in Astronomy,* Government Women's First Grade College, Udupi, Karnataka. (10 September)

P. Shastri: *Our Enchanting Universe,* St Agnes College & Mangalore Amateur Astronomers Association. (11 September)

S. Chatterjee: *Landmarks in Astronomy,* Vijaya College, Mulki, Karnataka. (11 September)

S. Chatterjee: *Landmarks in Astronomy,* Mahatma Gandhi Memorial College, Udupi, Karnataka. (11 September)

R. K. Banyal: *Antriksh Ki Gehraiyon mai (in Hindi),* AIPSN All India Training Workshop on Astronomy, Hyderabad. (18 September)

S. Chatterjee: *Landmarks in Astronomy,* AIPSN All India Training Workshop on Astronomy, Hyderabad. (18 September)

R. K. Banyal: *Our Solar System, AIPSN All India Training Workshop on Astronomy,* Hyderabad. (20 September)

K. Sundara Raman: *The Sun - Our Star*, Seethalakshmi Ramaswamy College, Tiruchirappalli, (24 September)

P. Shastri: *AntharArAshtrIya KhagOLa vijnAna varsha* (*The International Year of Astronomy* in Kannada), radio talk, All India Radio, Mangalore. (6 October)

H. C. Bhatt: *Our Place in the Universe, Visvesvaraya Industrial and Technological Museum,* Bangalore. (9 October)

Dipankar Banerjee: *Our Nearest Star: The Sun,* BEL, Bangalore. (21 October)

H. C. Bhatt: *Our Place in the Universe,* Parikrama Foundation, Jayanagar, Bangalore. (12 November)

P. R. Vishwanath: *KhagoLada kutUhalagaLu* (*The Curiosities of the Cosmos* in Kannada), Karnataka Rajya Vijnana Parishat School Students' Programme, Mysore. (13 November)

R. K. Banyal: *Khagol Vigyan aur Jyotish Vidya* (*Astronomy and Astrology* in Hindi), Himachal Gyan Vigyan Samiti, Kullu. (13 November)

S. Chatterjee: *Landmarks in Astronomy,* Karnataka Rajya Vijnana Parishat Students' Programme, Ramnagara, Karnataka. (15 November)

S. Chatterjee: *Landmarks in Astronomy,* Karnataka Rajya Vijnana Parishat Students' Programme, Mandya, Karnataka. (15 November)

R. K. Banyal: *The Telescope: A window to our universe,* National Institute of Technology (NIT), Hamirpur. (16 November)

P. R. Vishwanath: *The Curiosities of the Cosmos*, KRVP School Students' Programme, Bangalore. (19 November)

S. Chatterjee: *Galileo, Kepler and the IYA 2009,* Asiatic Society of Bengal, Kolkata. (20 November)

S. P. Rajaguru: *The Sun,* School students' programme at IIA, Bangalore. (27 November)

R. K. Banyal: *Telescope: Past, Present and Future,* Educational tour for high school children by Rotary club, IIA, Bangalore. (27 November)

P. Shastri: *kappu kuLigaLu mattu gAlaksigaLu* (*Black*

Holes and Galaxies in Kannada), Karnataka Rajya Vijnana Parishat School Students' Programme, Kolar District, Karnataka. (8 December)

S. Chatterjee: *Astronomy, the universal science of the universe,* Bharatiya Vidya Bhavan. (8 November)

R. K. Banyal: *Light: A Cosmic Messenger,* Parikrama Foundation, Koramangala, Bangalore. (17 December)

K. B. Ramesh: *Living with our active star - the Sun (in Kannada),* KRVP School Students' Programme, Yadgiri, Karnataka. (18 December)

P. Shastri: *Munching Black Holes & Growing Galaxies,* Bharatiya Vidya Bhavan, Bangalore. (18 December)

C. Muthumariappan: *Observing Facilities and Research Activities at IIA,* Educational tour for Christ college students, Kavalur. (19 December)

Dipankar Banerjee: *The Sun as an astrophysical laboratory.* Mercara. (22 December)

5.1.20 IYA09 Concluding Event

IIA brought its International Year of Astronomy cel-

Alan Brody (right), professor of theatre arts at the Massachusetts Institute of Technology, seen with Vijay Padaki of Bangalore Little Theatre, at the closing event of the International Year of Astronomy at IIA.

ebrations to an end on the 6th January 2010, with a closing ceremony whose highlight was a thought-provoking public lecture by Alan Brody, Professor of theatre arts at the Massachusetts Institute of Technology, USA. S. Chatterjee summarised these activities at the closing ceremony.

Alan Brody enthralled the audience with his insights on the interplay between the practice of science and the perspective from theatre. He lectured on the topic *Enriching Science Education: The Role of Science Theatre.* As a professor at MIT, he is part of MIT's efforts towards incorporating a strong multi-disciplinary approach to learning. He is a well-known playwright and novelist, and penned the play *Small Infinities*, which explores the life and paradox of Isaac Newton, the scientific genius and father of modern science. Alan Brody was visiting Bangalore on the occasion of the performances of *Small Infinities.* The play was produced by Bangalore Little Theatre as part of its *History of Ideas* project, in which IIA is also a partner. Alan Brody's lecture was followed by a lively discussion moderated by Vijay Padaki, behavioural scientist, theatre educator and life member of Bangalore Little Theatre.

S. Chatterjee concluded the proceedings by announcing that the International Year of Astronomy was mainly an occasion to make a strong beginning towards "universalising the universe".

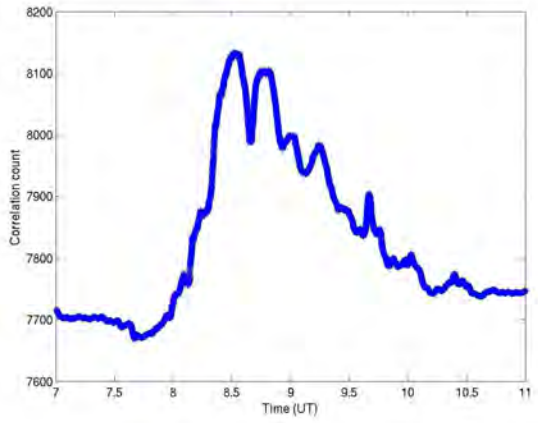
(P. Shastri & S. Chatterjee)

5.2 Radio Interferometer Kit

Students of IISER, Pune fabricating the antennas of the two-element interferometer at the Gauribidanur observatory workshop.

Fourteen students from IISER, Pune visited Gauribidanur observatory during December 2009 in connection with the two-element radio interferometer kit

Students of Pune University measuring the radiation pattern of the antenna they fabricated at the Gauribidanur observatory.



Observations of the radio counterpart of the long duration soft X-ray solar flare on 1 August 2010 with the two-element radio interferometer by the Pune University students. The integration time used was 1 sec.

which the institute offers as a part of its public outreach programme.

Following the above, two students from the Physics Department, Pune University visited the observatory during July 2010 for the same antenna kit.

The students from both the aforementioned institutions were trained by the members of the radio astronomy group on how to fabricate the antenna system, receiver system, install and use the equipment. They learnt the basics of radio interferometry in the process. They also carried out observations on the Sun with the kit which they fabricated during their stay at Gauribidanur.

(Radio Astronomy Group)

5.3 The Annular Solar Eclipse of 15 January 2010

Kanyakumari

An eight member team of scientists and students led by S. S. Hasan, Director, IIA, camped at Kanyakumari on the southern tip of the Indian subcontinent, to record the annular solar eclipse of 15 January, 2010, using digital cameras. Kanyakumari lay about thirty km away from the central line of the annular path. There were passing clouds during the event but it was possible to record the event.

The IIA eclipse team at Kanyakumari.

IIA also participated in a national observation camp for school children organised by Vigyan Prasar in collaboration with the Tamilnadu Science and Technology Centre. P. Shastri from IIA was a resource person at the event. Over 800 children from all across the country, accompanied by their teachers, gathered at the three-day camp, which had lectures, demonstrations, talks on safe viewing of the eclipse and interactions with scientists. On the day of the eclipse, the children, teachers and resource persons gathered at the helipad on the sea front of the cape to watch the eclipse. They were joined by several hundred members of the public which included local citizens, tourists as well as eclipse chasers from afar. The long duration of annularity allowed photography as well as observation of the different eclipse-related phenomena, and the children of the observa-

A montage by the IIA team of Kanyakumari, showing the progress of the annular eclipse.

tion camp conducted several experiments, including, finding the angular size of the sun and moon, the percentage of the eclipse, effects on flora and fauna, etc.

Bangalore

Vivek Erkadithaya and Gautam of the Bangalore Astronomical Society projecting an image of the partial solar eclipse onto a screen using their 8 inch telescope at the Malleswaram grounds.

At its Koramangala campus, IIA set up a coelostat system with a 6-inch objective, which projected a foot long image of the sun on a large white screen to track the progress of the eclipse. Eclipse viewing spectacles were distributed to the public for safe viewing of the phenomenon directly. Over 400 children and adults alike thronged the campus to view the partial eclipse.

IIA in collaboration with Bharat Gyan Vigyan Samiti and the Bangalore Astronomical Society, organised another sun-viewing event in the Malleswaram grounds, where over a 1000 members of the public gathered. There were telescopes that projected the sun's image onto screens, in addition to the protective screens and glasses to view the eclipse directly. The weather was excellent, providing a clear view of the progress of the partial annular eclipse. Everyone assembled at the grounds also partook in the refreshments that were distributed on the occasion, which was a symbolic rebuttal of the common superstitious taboo against eating and drinking during an eclipse, which appears to be practiced even among the educated public. Many rationalists and science activists used the occasion to interact with public to promote a scientific temper and dispel the superstitious beliefs about the eclipse. R. K. Banyal and P. K. Mahesh co-ordinated IIA's participation and were also engaged in many lively discussions with the students, the public and the media.

The partial eclipse being watched by the public of Bangalore at the Malleswaram grounds.

(R. C. Kapoor, B. Ravindra, R. K. Banyal & P. Shastri)

On National Science Day, enthusiastic members of the public watch the night sky from IIA's terrace. One of them takes a peek through IIA's 4 inch Galileoscope (seen in the foreground), while others queue up to have a look through the 14 inch telescope.

5.4 National Science Day

National Science Day celebrations at IIA this year were spread over three days, starting on the 26 February 2010. A highlight of the celebrations was the inauguration of IIA's skywatch observatory, by S. S. Hasan, Director, IIA. Located on the 5th floor terrace of the main building in the Bangalore campus, this 14 inch reflecting telescope, with electronic tracking, is housed in a protective dome that was fabricated at IIA. It is easy to use, and is meant to facilitate regular sky-viewing opportunities for the public.

On the following day, the 27th February, about 200 school children from the Government High School, Madivaala (with whom IIA has had an extension programme for about two years) and Chinmaya Vidyalaya, Koramangala, listened to lectures by IIA scientists. They heard S. P. Rajaguru speak on the *Sun*, R. K. Banyal on *Light: A Cosmic Messenger*, and M. Safonova on *Space astronomy.* P .K. Mahesh conducted a sun-viewing programme for the children.

The first public sky-watch with the newly inaugurated facility occurred on Science Day, the 28th February 2010. The event, conducted mainly by the students of IIA in collaboration with the Bangalore Astronomical Society, drew a large participation from the enthusiastic public. About hundred and fifty people visited the IIA for this event and were introduced to the night sky. The occasion was also used to demonstrate the use of IIA's 4 inch Galileoscope, a low-cost telescope that IIA designed on the occasion of the International Year of Astronomy, 2009, and which has been distributed to over 400 interested groups and individuals.

(R. K. Banyal & S. Chatterjee)

5.5 Founder's day at VBO

The highlight of the Founder's day celebrations at the Vainu Bappu Observatory was a special outreach programme for college students. Sixty physics students and eight lecturers from four different colleges of the district heard an enthralling lecture titled *New*

Bangaloreans partake in refreshments during the partial annular solar eclipse.

The new Skywatch Observatory on the terrace of IIA's main building, which houses a 14 inch telescope. Amar Sharma from the Bangalore Astronomical Society is seen explaining a point to interested viewers.

R. K. Banyal (IIA) and E. Basavaraju (BGVS) fielding questions at Malleswaram grounds

C. Sivaram delivering a popular lecture to college students and lecturers on Founder's Day at VBO.

Frontiers in Astronomy from C. Sivaram. They also participated in a Physics and Astronomy quiz. The Auxilum college, Vellore and Maruthar Kesari Jain College for Women, Vaniambadi were the winners of the first and second prizes respectively. The visitors also had a tour of the telescopes, and watched the movie *Cosmic Collisions*. The students spent their lunch and tea breaks discussing various aspects of astronomy, and were clearly enthused by the experience.

(C. Muthumariappan)

5.6 Other Popular Lectures,* Radio Talks & Interviews

G. C. Anupama gave the following talks: *Supernovae* at (a) Govt. Science College, Palakkad,(b) Christ College, Bangalore and (c) AIR, Bangalore.

R. C. Kapoor gave the following interviews *Brahmand ki Utpatti ka Mahavisphot Siddhanta,* BBC (Hindi Service) interview, 21 June 2009; *Why is the sky dark at night? and What is dark matter,* BBC (Hindi Service) interview, 21 September 2009; He gave a talk on *total solar expeditions of the Indian Institute of Astrophysics* , Department of Applied

*Popular lectures under the IYA09 100-Lecture Series are listed in section 5.1.19

Physics, Institute of Technology, Banaras Hindu University, Varanasi, 21 July 2009; and a TV talk titled *Chandrayaan-1 discovery of water on the Moon*, on 25 September, 2009.

R. Kariyappa participated in a live panel discussion on *Annular Solar Eclipse* in January 2010 in *the Suvarna News TV Channel*, in Kannada.

B.E. Reddy gave a public lecture on *Astronomical telescopes: Past, present and future*, at Mangalore University, Mangalore, on December 5, 2009.

M. Safonova gave a popular talk titled *Space astronomy – from stargazers to starships*, at the National Science Day celebrations, IIA, February 2010.

P. Shastri spoke and gave interviews at the the Press Meet on the Annular Solar Eclipse on 8 January, 2010, Press Club, Bangalore; gave a radio talk titled *kappu kuLigaLu* (*Black Holes* in Kannada), in the *gaganayAna*, programme, AIR, Bangalore, February 2010, and gave a lecture on *Galaxies and Their Growing Black Holes*, at Surana College, Bangalore, March 2010.

C. Sivaram gave the following lectures: *New frontiers in Astronomy and Astrophysics*, 22 July 2009, Bangalore Science Forum, National College, Bangalore; *Frontiers in Astronomy and Astrophysics, Founder's Day lecture, 10 August 2009 at VBO, Kavalur*; *Gravitational waves and searches for their detection*, 22 August 2009, St. Joseph College, Bangalore; Modern Developments in Astronomy and Space Science, On occasion of Science Day, 28 February 2010, Institute of Engineers (Indian), Karnataka State Centre, Bangalore; *The LHC and Big Bang Cosmology*, 13 March 2010, Dr. Ambedkar Institute of Technology, Bangalore; *Big Bang Cosmology and the LHC*, 30 March 2010, JSS College, Mysore; *Re-entry of meteorites and rockets in planetary atmospheres*, 6 April 2010, Symposium on Space and Planetary Physics, Seshadripuram College, Bangalore; *Frontiers in Astronomy*, 30 April 2010, Vemana Institute of Technology; *Introduction to current Areas in Astronomy*, 4 May 2010, Department of Physics, MGR College, Hosur; *New frontiers in Astronomy and Astrophysics*, 6 May 2010, CNR Rao Hall, JNCASR, Bangalore; *Physical Limits on Computation*, 9 October 2010, Jyothi Nivas College, Bangalore.

K. Sundara Raman gave lectures on *Solar Physics* at the Muthayammal Engineering College, Rasipuram on 15 February 2010; on *Application of Engineering in Astrophysics* and *Space Weather: Sun-Earth Relationship*, at the Rangasamy college of Techonology, Tamilnadu, 16 February 2010; on *Stellar Evolution* at the Tamil Nadu Science and Technology Centre, Chennai in a *Meet The Scientist* programme, 1 March 2010; on *Astrophysics - Universe, Stars & Galaxies*, at Holy Cross College, Tiruchirappalli, Tamilnadu, 5 March, 2010; on *Solar Physics*, at National College, Trichy on 17 March 2010, at Muthayammal College of Arts and Science, Rasipuram on 19 March 2010, at Paavai Engineering College, Namakkal on 20 March 2010, at The Standard Fireworks Rajaratnam College for Women, Sivakasi on 29 March 2010, and at Arulmigu Palaniandavar College of Arts and Science, Palani, on 30 March 2010. He delivered a special lecture on 26 August 2009, on *Importance of Education* at St. Teresa High School, Pamparpuram, Kodaikanal on the occasion of Parents-Teachers Function. As chief guest, he gave a lecture on *Astrophysics* to the students of Bhavan's Gandhi Vidhyasram on the occasion of "Gandhi Jayanthi" on October 2 2009, and to the students of Sri Sankara Vidyalaya Higher Secondary School, Kodaikanal at their Annual Day celebration.

F. Sutaria gave a talk titled *Chandra and his contribution to Astrophysics,* Bangalore Science Forum, National College, Bangalore 20 January 2010.

Sivarani Thirupathi participated in the VBO documentary for the Tamil TV channel.

P. R. Vishwanath gave a talk titled *Gallileo mattu AkAsha* (*Galileo and the night sky* in Kannada) at the Karnataka Rajya Vijnana Parishat School Students' Programme, Chitradurga District (Feb 2010) and a talk titled *The Many Faces of Light,* at SJVO college, National Level Seminar, Harihara, March 2010.

5.7 Popular Books & Articles

P. R. Vishwanath, 2009, *KhagOLa VijnAnada Kathe*, (*The Story of Astronomy* English original by U. Patil translated into Kannada by P. R. Vishwanath.), Navakarnataka Publications, Bangalore.

R.K. Banyal, 2009, *In defence of scientific temper* Current Science 79,7.

S. Chatterjee, 2010, *Freeing Software,* Deccan Herald, 23rd March.

S. Chatterjee, 2009, *Climate change: the politics of science*, The GNLU Journal of law, Development and Politics 1, 107.

R.C. Kapoor published the following articles in The Hawk: *21veen sadi ka dirghatam poornata ka Surya grahana,* Jun 11, 2009; *Chandrayaan 1 finds watering holes on the dry Moon,* 25 September, 2009; *Uranus in Opposition this Month,* 18 September, 2009 *Yeh Shukravaar hai Shani ka Vaar,* 4 September, 2009.

S. P. Rajaguru, 2009, *The Evershed effect as we understand it today,* Resonance, 14, 1040.

C. Sivaram published the following articles in the Science and Technology section of Deccan Herald (Spectrum): *Exploring Moons other than Earths*, 25 August 2009; *Lakhs of Asteroids and still counting*, July 14 2009; *To the moon and back*, September 22 2009; *Upper limit on power production*, November 3 2009; *To catch a dying star*, December 22 2009 *Exciting Habitats*, 23 March 2010; *In search of neutrinos*, 13 April 2010; *Intense beam of light- Fifty years of LASER*, May 11 2010; *Changing Lives*, 15 June 2010; *When the sunlight sky goes dark*, (with *Kenath, A.) July 21 2010.

Chapter 6

Miscellaneous Activities by IIA Staff

6.1 Invited & Contributed Talks*

G. C. Anupama gave an invited lecture at the "First IUCAA Reunion Meet" held at IUCAA, Pune in August 2009. She gave a talk at the "National Seminar on India's participation in one of the GSMT projects", held at IIA Bangalore in September 2009, and a lecture at the Kodai School on "High Energy Astrophysics" held in December 2009.

L. S. Anusha presented the following contributed talks: *Modeling linear polarization of the Solar Ca* I *4227 Å line* at the In-house scientific meeting held at IIA, on 09 April 2010. She presented a student seminar entitled *Modeling the Second Solar Spectrum: The last scattering approximation and its validation* on 23.03.2010 at IIA; *Linear Polarization of the Solar Ca* I *4227 Å line: Modeling based on radiative transfer and last scattering approximations*, at the international conference on "Solar Polarization Workshop 6", held in Maui, Hawaii, USA, during 30 May – 04 June 2010.

D. Banerjee delivered the following invited lectures: Colloquium titled *The Sun as an astrophysical Laboratory* at IISER Kolkata, 22 January 2010; Plenary lecture titled *Solar Physics from small satellites* at National Space Science Symposium at Rajkot, 24 February 2010; lecture titled *Sun and its effects on Earth's Atmosphere* at 2 days workshop on Space Physics and Atmospheric Science, Seshadripuram College, Bangalore 5 April 2010; lecture titled *Propagating Waves in the Polar Regions of the Sun as seen by SOHO and HINODE* in CAS-IAU Joint Solar Eclipse meeting at Suzhou, China, 23 July 2009; lecture titled *Propagating waves in the polar regions of the Sun as seen by SOHO and HINODE* at AOGS-9 at Singapore, 11 August 2009; lecture titled *Alfvén waves in polar coronal holes* in IAGA-2 workshop at Cairo, Egypt, 4 December 2009; Colloquium titled *Propagating waves in the polar regions of the Sun* at Armagh Observatory, UK 14 December 2009.

B. C. Bhatt gave a presentation on *GPS Stations in Ladakh and Kodaikanal - IIA's participation in national network* at the workshop-cum-meeting on GPS Network in India organised by the Ministry of Earth Sciences, Govt. of India at the Institute of Seismological Research, Raisan, Gandhinagar, Gujarat, on 03 August 2009. He gave a seminar on *High Altitude Site for Research in Atmospheric Green House gases*, at the National Institute of Ocean Technology, Chennai on the 15th June, 2009.

S. Chatterjee gave an invited lecture *Scattering of light by a rough surface with hidden periodicity: Problems of detection* at the Physics Department, Assam University, Silchar on 11 February, 2010.

B. P. Das gave the following invited talks: *Many-Body Theory of Ultracold Atoms in Optical Lattices* at Eotvos Lorand University, Budapest, Hungary, May 2009; *Quantum Phase Transitions in Mixtures of Ultracold Bosonic Atoms* at Ecole Normale Superieure, Paris, May 2009; *Probing Time-Reversal/CP Violation with Atomic Electric Dipole Moments* Indian Institute of Science, Bangalore, October 2009.

S. S. Hasan presented invited talks on *NLST: Large Solar Telescope for India*, IAU Symposium 264 on "Solar and Stellar Variability: Impact on Earth and Planets", August 3 – 7, 2009, Rio de Janeiro, Brazil; *The Indian National Large Solar Telescope*, First EAST-ATST Workshop in Solar Physics on "Science with Large Solar Telescope", Freiburg, Germany, October 14-17, 2010; *New Vistas in Solar Astronomy*

*Pedagogical lectures are listed in Chapter 3 and popular talks in Chapter 5.

at the "2nd National Conclave of Nobel Laureates", IIIT, Allahabad, December 7 – 14, 2009; 2nd V V Narlikar Memorial Lecture on *Understanding our nearest star: The Sun*, Jamia Millia Islamia, New Delhi, October 28, 2009.

K. M. Hiremath gave the following invited talks: *Physics of the mighty Sun* in the "State Level Seminar on Astronomy", Physics Department, Kuvempu University, Shimoga, Karnataka; *Physics and Chemistry of the Sun* at the "National Level Seminar in Physics and Chemistry", Science College, Harihara, Karnataka.

A. Mangalam gave the following invited talks: *Vorticity and related issues*, 11 May 2009 at ARIES, Nainital; *Black hole spin down and cosmic evolution of AGN*, 12 May 2009 at ARIES, Nainital; *Supermassive black holes"*, 29 December 2009, International Conference on Astronomy, IICFA 2009, Madikeri; *Pulsars and Black Holes*, at Christ University, Bangalore, in "Astrophysics Workshop on Stars", 19 December 2009.

C. Muthumariappan delivered an invited talk at "State level seminar in Astrophysics" organised by the Loyala College, Chennai, on 06 February 2010.

K. N. Nagendra gave an invited review talk entitled *Polarization: proving ground for methods in radiative transfer* at the XXVII IAU General Assembly, Joint discussion 10 (JD10) on "3D views on cool stellar atmospheres: theory meets observations", held at Rio de Janeiro, Brazil, during 03 – 14 August 2009.

G. Pandey gave an invited talk in a workshop "Stellar mergers", which was organized at the Lorentz Center, Leiden, The Netherlands during September – October 2009 on *H-deficient stars - merger products? Clues to their origin from spectroscopy.*

T. P. Prabhu gave the following talks: *Astronomy from High Altitudes*, IIT Madras, 24 June 2009; *Astronomy from High Altitudes*, IMSc Chennai, 25 June 2009; *Optical and Infrared Astronomy* in the "Workshop on Multiwavelength Astronomy", St Joseph's College, Bangalore, 21 August 2009; *Science with IAO, Hanle* at the International Workshop on "Interstellar Matter and Star Formation - A Multi-Wavelength Perspective" TIFR Balloon Facility, Hyderabad, 5–7 October 2009; *Observational Facilities in India*, Astronomy Workshop at the Bangalore University. 26 November 2009; *Observatories in India*. Workshop on Popularization of Astronomy. Association of Friends of Astronomy. National Institute of Oceanography, Dona Paula, Goa. 12 December 2009. *Science Facilities at Hanle*, at EU-India Workshop on Research Infrastructures, INSA, New Delhi, 11 January 2010; *Discovering the Universe*, Silver Jubilee Celebration seminar on "Recent Trends in Astronomy and Astrophysics", IGNOU Convention Centre, 22 March 2010.

S. P. Rajaguru gave the following invited talks: *Local helioseismology and near-surface variability in structure and dynamics* at the AOGS 2009 Meeting held at Singapore, 11 – 15 August 2009; *Line profiles and dopplergrams in active regions* at the Helioseismic and Magnetic Imager (HMI)/SDO Science Team Meeting held at the Stanford University, Stanford CA, USA during 7 – 10 September 2009; *Deep-focus and double-skip time-distance helioseismic measurements over a sunspot region* at the third HELAS Local Helioseismology Workshop, held in Berlin, Germany during 12 – 15 May 2009.

B. Ravindra participated in the conference "Asia Oceania Geosciences Society", held at Singapore during 11–15 August 2009 and presented a talk titled *Evolution of Spinning and Braiding Helicity in the Emerging Active Region.*

B. E. Reddy gave the following invited talks: *The Galactic thick disk: An observational perspective* at the IAU Symp. 265. "Chemical Abundances in the Universe: Connecting first stars to Planets", IAU General Assembly, Rio De Janiero, Brazil, 2 – 10 August 2009; *Chemical tagging of stars in the solar neighbourhood: Clues to the Milky Way formation*, Colloquium at IISc, Bengaluru, 4 September 2009.

M. B. Roopashree gave a talk at the "International Conference on Optics and Photonics", CSIO, Chandigarh, India, 30 October – 1 November 2009, titled *Phase characterisation of reflecting and transmitting type twisted nematic spatial light modulators.*

M. Safonova gave the following talks: *TAUVEX status and interstellar dust studies*, Workshop on Dust, Kavalur, September 2009; *In Search of IMBHs in Globular Clusters*, April 2010, In-House Scientific Meeting, IIA; *The quest for IMBHs in globular clusters*, seminar at Sternberg Astronomical Institute, Moscow State University, Moscow, 09 June 2010.

S. K. Saha gave the following invited talks: *High res-*

olution imaging at the "Summer School on Astronomy and Astrophysics", VBO, Kavalur, during 15 – 22 May 2009; *Detectors for the astronomical applications* at the International Conference on "Emerging Trends in Electronic and Photonic Devices & Systems" (Electro-2009) at Banaras Hindu University, during 22 – 24 December, 2009; *Post-galileo telescopes* at Acharya Prafulla Chandra College, Madhyam Gram, West Bengal, 21 November 2009; *From Galileoscope to hyper-telescope* at a seminar on "Recent Trends in Astronomy and Astrophysics" conducted in connection with the Sliver Jubilee Celebration of IGNOU, on 22 March 2010, New Delhi.

A. K. Saxena gave a lecture on *Technology of extremely large telescopes* at Calcutta University on 19th November, 2009.

S. Sengupta gave a talk on *Planets outside Our Solar System* on 18th December, 2009, at the Christ University, Bangalore.

P. Shastri gave the following invited talks: *Dust in Active Galaxies* in the workshop on *Physics and Astrophysics of Dust II*, VBO, Kavalur, Sep 2009; *Challenges of Modern Empirical Astrophysics & Astrostatistics* at the international conference on *Frontiers of Interface between Statistics and Sciences* held at the C. R. Institute of athematics, Statistics and Computer Science, University of Hyderabad during 30 December – 2 January 2010; *Gender Inequities in the Science Workplace: An Experiential Perspective* at the DST-NIAS workshop on *Transcending Barriers to Performance: the Indian Woman in Science*, 25 March, 2010.

T. Sivarani gave an invited talk at the International meeting on "Cosmological Reionization" at HRI, Allahabad, 16 – 20 February 2010 titled *Probing the first stars through the abundances of metal poor stars*, and a seminar *On Early Galaxy*, at the Physics Dept. Cochin university.

F. Sutaria gave an invited talk on *Dust and Supernovae* at the workshop on *Physics and Astrophysics of Dust II*, VBO, Kavalur, Sep 2009; She also made several presentations on the progress made in the topic *PSF and timing calibrations of the UVIT instrument on board AstroSat* at various meetings on AstroSat calibration held at ISRO-ISAC during 2009 – 2010.

A. Vyas gave the following talks: *Optimization of existing centroiding algorithms for Shack Hartmann sensor*, "National Conference on Innovative Computational Intelligence and Security Systems", Sona College of Technology, Salem, India, 3–4 April 2009; *Denoising Shack Hartmann Sensor spot pattern using Zernike reconstructor*, and *Progressive prediction of turbulence using Wave Front Sensor data in adaptive optics using data mining*, International Conference on "Advanced Computing", Cauvery College for Women, Tiruchirappalli, India, 6 – 8 August 2009; *Performance of centroiding algorithms at low light level conditions in adaptive optics*, International Conference on "Advances in Recent Technologies in Communication and Computing", ACEEE, Kottayam, India, 27 – 28 October 2009; *Effective coherence length estimation of optical wavefronts*, International Conference on "Optics and Photonics", CSIO, Chandigarh, India, 30 Oct – 1 November 2009; *Extrapolating Zernike moments to predict future optical wave-fronts in adaptive optics using real time data mining* at International Conference on "Information Systems and Software Engineering", Meenakshi Sundararajan Engineering College, Chennai, India, 28 – 30 December 2009; *Improved iteratively weighted centroiding for accurate spot detection in laser guide star based Shack Hartmann sensor* at SPIE Photonics WEST 23 – 29 January 2010, San Francisco, CA, US; *Real-time wind speed measurement using wavefront sensor data* at SPIE Photonics WEST 23 – 29 January 2010, San Francisco, CA, US; Presented a talk *Astronomy and Optics*, SPIE student chapter/OSA student chapter, also part of IYA-09 at National Institute of Technology, Tiruchirappalli, August 2009.

6.2 Participation in Meetings

G. C. Anupama attended the "First IUCAA Reunion Meeting - 2009", August 11 - 14, IUCAA, Pune; and the meeting on "High Performance Computing in Observational Astronomy: Requirements and Challenges", 12 – 16 October 2009, IUCAA, Pune.

L. S. Anusha attended the international conference on "Solar Polarization Workshop 6", held in Maui, Hawaii, USA, during 30 May – 04 June 2010.

D. Banerjee attended the international colloquium on "Perspectives in Fundamental Research" at TIFR, Mumbai, 3–6 March, 2010; "National Space Science Symposium" at Rajkot, 24 February 2010; "IAGA-2 workshop at Cairo", Egypt, 4 December, 2009; "AOGS-9 at Singapore", 11 August, 2009; "CAS-

IAU Joint Solar Eclipse meeting" at Suzhou, China, 23 July 2009.

R. K. Banyal attended the "Physics and Astrophysics of Dust II workshop", Vainu Bappu Observatory, Kavalur, 02 – 05 September 2009.

C. Birdie participated in the "2nd DST Librarians meeting on CSIR-DST E-Journals Consortium" on 15 – 16 May 2009, held at ARIES, Naini Tal; the training programme on "Web of Science (Citation Database)" held at Raman Research Institute, Bangalore on 23 June 2009; the training programme on "JCCC (J-Gate Custom Content for Consortia)" held at National Aerospace Laboratory, Bangalore on 30 July 2009; and the international conference LISA-VI on "21 century Astronomy Librarianship: From New Ideas to Action" during February 14 – 17 2010 at IUCAA, Pune.

S. Chatterjee participated in the workshop on *Physics and Astrophysics of Dust II*, VBO, Kavalur, September 2009, and in a two day national seminar organised by The Asiatic Society of Bengal entitled "The International Year of Astronomy: Perspective and Challenges" during the 20 – 21 November 2009 at Kolkata, where he gave a lecture on *Galileo, Kepler and the IYA 2009.*

V. R. Chitnis participated in "International School on High Energy Astrophysics" organised by IIA and Institute of Mathematical Science, Chennai at Kodaikanal during 1 – 11 December 2009, and in the "11th COSPAR Capacity Building Workshop on Data Analysis of the Fermi Gamma-ray Space Telescope" at Raman Research Institute, Bangalore during 08 – 19 February 2010 as an instructor for data analysis projects.

S. S. Hasan attended the CAS-IAU Joint Solar Eclipse meeting "Dynamic Solar Corona", Suzhou, China, July 23-26,2009; Organized a one day session on "Magnetic Structuring of the Solar Atmosphere as Drivers of Variability" at the Fifth Asian Oceania Geosciences Society Meeting, Singapore, August 11-15, 2009; chaired the session "Effects of magnetic activity on planet formation and evolution" on August 6, 2009 of IAU Symposium 264 "Solar and Stellar Variability: Impact on Earth and Planets", Rio de Janeiro, Brazil; organised the National workshop on "New National Facilities for Solar Observations", IIA, Bangalore, 22 August 2009; and chaired the session on *Fundamental Statistical Inference as Applicable to Astrophysical Problems* at the international conference on "Frontiers of Interface between Statistics and Sciences" held at the C.R. Rao Institute of Mathematics, Statistics and computer Science, held on 30 December 2009 – 2 January 2010.

R. Kariyappa attended the International Workshop on "25th NSO Workshop on Chromospheric Structure and Dynamics From Old Wisdom to New Insights" held during 31 August – 4 September, 2009 at NSO/Sac Peak, NM, USA.

S. V. Mallik attended the IAU Symp. 268 on "Light Elements in the Universe" held in Geneva, Switzerland during 09 November – 13 November, 2009.

B. S. Mohan participated in the training programme on "Web of Science (Citation Database)" held at Raman Research Institute, Bangalore on 23 June 2009; the training programme on "JCCC (J-Gate Custom Content for Consortia)" held at National Aerospace Laboratory, Bangalore on 30 July 2009; and the international conference LISA-VI on "21 century Astronomy Librarianship: From New Ideas to Action" during February 14 – 17 2010 at IUCAA, Pune.

K. N. Nagendra participated and presented an invited review talk at the international conference on "3D views on cool stellar atmospheres: theory meets observations", held at Rio de Janeiro, Brazil during 10 –11 August 2009.

A. K. Pati was an invited participant at the "International colloquium on Perspectives in Fundamental Research", TIFR, Mumbai, 3 – 6 March 2010. He also participated in several meetings of the ASTROSAT Science Committee as one of the original proposers of the UVIT payload.

P. Prabahar participated in the training programme on "Web of Science (Citation Database)" held at Raman Research Institute, Bangalore on 23 June 2009; the one day workshop on "Soft Skills for the 21st Century Librarian" held on July 4, 2009 at Bangalore Management Academy, Bangalore; the training programme on "JCCC (J-Gate Custom Content for Consortia)" held at National Aerospace Laboratory, Bangalore on 30 July 2009; the one day "Workshop on Open Source Library Management Software" on 05 December 2009 at Anna University, Chennai; the one day workshop on "Library & Information Science Leadership" on 19 December 2009 at Seshadripuram College, Bengaluru; and the international conference

LISA-VI on "21 century Astronomy Librarianship: From New Ideas to Action" during February 14 – 17 2010 at IUCAA, Pune.

T. P. Prabhu participated in the "Neutrino Workshop", Mahabalipuram, 6 – 7 April 2009; "IUCAA Reunion Meeting", Pune, 11 – 14 August 2009; International Workshop on "Interstellar Matter and Star Formation - A Multi-Wavelength Perspective", TIFR Balloon Facility, Hyderabad, 5 – 7 October 2009; and "EU-India Workshop on Research Infrastructures", INSA, New Delhi, 11 January 2010.

S. P. Rajaguru participated in the following meetings: third "HELAS Local Helioseismology workshop", held in Berlin, Germany during 12 – 15 May 2009; "AOGS 2009 meeting" held at Singapore, 11 – 15 August 2009; "Helioseismic and Magnetic Imager (HMI)/SDO Science Team Meeting" held at the Stanford University, Stanford CA, USA during 7 – 10 September 2009.

B. Ravindra participated in the conference "Asia Oceania Geosciences Society", held at Singapore during 11 – 15 August 2009.

M. B. Roopashree participated in the "International Conference on Optics and Photonics", CSIO, Chandigarh, India, 30 October – 1 November 2009 and the Conference on the "Big Bang and Particle Physics Cosmic Connection", 31 March 2010, JSS College for Women, Chamarajanagar.

S. K. Saha chaired three sessions of the Conference on "Emerging Trends in Electronic and Photonic Devices & Systems" (Electro-2009) at Banaras Hindu University, during 22 – 24 December 2009.

P. Shastri participated in the workshop on *Physics and Astrophysics of Dust II*, VBO, Kavalur, Sep 2009; in the conference *Frontiers of Interface between Statistics and Sciences*, held at the C. R. Rao Institute of Mathematics, Statistics and Computer Science, University of Hyderabad, January 2010; in the DST-DBT meeting with the Minister of Science & Technology on governmental measures to address gender inequity, 1 July, 2009; and lectured at the DST-NIAS workshop on *Transcending Barriers to Performance: the Indian Woman in Science*, 25 March, 2010.

A. Shukla attended the following meetings: "3rd International Summer School on Astroparticle Physics "NIJMEGEN09" at Nijmegen, The Netherlands during 19-28th August, 2009; the "International School on High Energy Astrophysics" organised by IIA and The Institute of Mathematical Science, Chennai at Kodaikanal during 1 - 11 December, 2009; the "11th COSPAR Capacity Building Workshop on "Data Analysis of the Fermi Gamma-ray Space Telescope" at Raman Research Institute, Bangalore during 8 – 19 February 2010.

R. B. Singh attended the "16th National Space Science Symposium" 2010, 24 – 27 February 2010, Dept Physics, Saurashtra University, Rajkot, India

T. Sivarani attended the International meeting on "Cosmological Reionization" at HRI, Allahabad, 16 – 20 February 2010.

F. Sutaria participated in the workshop on *Physics and Astrophysics of Dust II*, VBO, Kavalur, Sep 2009, and was a participant and instructor at the "11th COSPAR Capacity Building Workshop on Data Analysis of the Fermi Gamma-ray Space Telescope" at Raman Research Institute, Bangalore during 08 – 19 February 2010.

P. R. Vishwanath participated in "International School on High Energy Astrophysics" organised by IIA and The Institute of Mathematical Science, Chennai at Kodaikanal during 1 – 11 December 2009 as an organizer.

A. Vyas participated in the following conferences: "SPIE Photonics WEST", San Francisco, USA, 23 – 29 January 2010; International Conference on "Information Systems and Software Engineering", Meenakshi Sundararajan Engineering College, Chennai, India, 28 – 30 December 2009; International Conference on "Optics and Photonics", CSIO, Chandigarh, India, 30 October – 1 November 2009; International Conference on "Advances in Recent Technologies in Communication and Computing", ACEEE, Kottayam, India, 27 – 28 October 2009; International Conference on "Advanced Computing", Cauvery College for Women, Tiruchirappalli, India, 6 – 8, August 2009; National Conference on "Innovative Computational Intelligence and Security Systems", Sona College of Technology, Salem, India, 3 – 4 April, 2009.

6.3 Collaborations across Institutions

Institutional Collaborations

IIA is collaborating with the Tata Institute of Fundamental Research (TIFR), Bhabha Atmomic Research Centre (BARC) and Saha Institute of SINP Nuclear Physics (SINP) on HAGAR experiment.

Individual Collaborations

S. Anathpindika is collaborating with the following groups: Star formation group at Cardiff university, UK, David Hubber (Sheffield university, UK), and James di'Francesco* (Herzberg Research Institute, Canada), a major participant in the Gould belt legacy survey. The C-DAC, Bangalore, is the technical collaborator in all numerical/theoretical projects.

L. S. Anusha is collaborating with (1) H. Frisch, Observatoire de la Cote d'Azur, France. Topic: *Radiative transfer in inhomogeneous media*; (2) J.O. Stenflo, ETH Zentrum, Zurich, Switzerland. Topic: *The theory and application of last scattering approximations*; (3) M. Bianda, IRSOL, Locarno, Switzerland. Topic: *Observations of the scattering polarization with ZIMPOL II*; (4) R. Ramelli, IRSOL, Locarno, Switzerland. Topic: *Observations of the scattering polarization with ZIMPOL II*; (5) Frederic Paletou, University of Toulouse, France. Topic: *Advanced numerical methods in Radiative Transfer.*

B. C. Bhatt is involved in the project *GPS Geodesy* in collaboration with IIA-CMMACS; in the National Network of GPS stations in India which is a project of the Department of Earth Sciences, Govt. of India; in the project on *Atmospheric Chemistry* in collaboration with LSCE/CMMACS. He is co-PI of the project "Aerosol Characterization and Assessment of the Radiative Impacts from the High-Altitude Trans-Himalayan site in Hanle, Ladakh", in collaboration with SPL, Trivandrum.

S. Chatterjee is collaborating with (a) Pratik Kumar & Rezvan Ravanfar Haghighi of the Medical Physics Unit of the All India Institute of Medical Sciences, New Delhi on the tomographic imaging and detection of coronary artery lipid plaques; (b) V.C. Vani of the Indian Institute of Science on modelling the scattering of light.

K. N. Nagendra is collaborating (1) M. Sampoorna, IAC, La Laguna, Tenerife, Spain, Topic: *Astrophysical line formation theory*; (2) H. Frisch, Observatoire de la Cote d'Azur, France. Topic: *Turbulence theory for solar applications*; (3) J. O. Stenflo, ETH Zentrum, Zurich, Switzerland. Topic: Hanle-Zeeman scattering theory; (4) M. Bianda, IRSOL, Locarno, Switzerland. Topic: *Observations of the second solar spectrum with ZIMPOL II*; (5) R. Ramelli, IRSOL, Locarno, Switzerland. Topic: *Observations of the second solar spectrum with ZIMPOL II*; (6) F. Paletou, University of Toulouse, France. Topic: *Advanced numerical methods in Radiative Transfer*; (7) L. Leger, University of Toulouse, France. Topic: *Advanced numerical methods in Radiative Transfer.*

K. E. Rangarajan collaborated with Gwalior IAF station senior pilots to take pictures of Solar Corona during the Total Solar Eclispe of 22 July, 2009, on board a Mirage 2000 aeroplane.

B. Ravindra is collaborating with D. Nandi IISER, Kolkatta for the work on *Determining the Active Region Twist without using the force-free field equation.*

M. Sampoorna is collaborating with (1) K. N. Nagendra, IIA, Bangalore, India. Topic: *Astrophysical Line Formation Theory*; (2) H. Frisch, Observatoire de la Cote d'Azur, France. Topic: *Radiative transfer with angle-dependent partial frequency redistribution*; (3) J. O. Stenflo, ETH Zentrum, Zurich, Switzerland. Topic: *The theory and application of last scattering approximations*; (4) M. Bianda, IRSOL, Locarno, Switzerland. Topic: *Observations of the scattering polarization with ZIMPOL II*; (5) R. Ramelli, IRSOL, Locarno, Switzerland. Topic: *Observations of the scattering polarization with ZIMPOL II*; (6) J. Trujillo Bueno, IAC, Tenerife, Spain. Topic: *On the sensitivity of the linear polarization profiles to atmospheric parameters*; (7) E. Landi Degl'Innocenti, University of Firenze, Italy. Topic: *On the sensitivity of the linear polarization profiles to atmospheric parameters.*

N. Sinha is working with the group at the University of Torino, Italy on the measurement of Cosmogenic radionuclides in meteorites using a high purity germanium detector. She is involved with the study of cosmic ray flux intensity and variation at the interplanetary space through meteorites. The study of long-term solar activity variations requires the use of radioisotopic data planetary reservoirs. At the Laboratory of Monte dei Cappuccini in Torino (IFSITorino,INAF) for many years the group has been

studying radioisotopes in meteorites, because their production, which is related to galactic cosmic ray flux in the heliosphere, is anticorrelated with the heliospheric magnetic field variations. They have developed very sensitive gamma detection techniques, in particular to measure 44Ti activity in meteorites; due to its half-life (t1/2 = 59.2 years), this radioisotope is an ideal index to reveal the imprint of solar activity variations on the centennial scale. Recently they have improved the spectrometer by a new multiparametric acquisition system, which allows to extract efficiently the 44Ti peak from the natural background.*Sinha* is collaborating with G. M. Ballabh of the Osmania University, Hydrabad, India, for the study of orbital movement of the meteorite.

T. Sivarani has the following collaborations: with T. C. Beers at MSU, USA and D.Carollo at ANU, Australia, on the study of *Metal poor stars and kinematics of Milkyway halo substructures using SDSS and SEGUE spectra.* with P. Bonifacio from Observatory Meudon, Paris on the same topic; with B. Nordstrom from Niels Bohr Institute, DK, on the *CNO abundance in early Universe Galaxy project*; with J. Ge and the ET team at university of Florida, studying the *exoplanet host star properties*; She is a CoI of the GTO programme (Available through Copenhagan) VLT-Xshooter 085.D-0041(A) UT2.

C.S. Stalin is collaborating with G. Meylan and F. Courbin of the Observatoire de Sauverny, Ecole Polytechnique Federale de Laussane, Geneva on *Estimating the Hubble constant using Gravitational Lensing.*

6.4 Externally funded projects

B. C. Bhatt is a co-PI for the Atmospheric Science study funded by DST, and the IIA-CMMACS-NIOT-LSCE project on climatic chemistry funded by CSIR, New Delhi.

S. Giridhar is the PI for the Indo-Mexico project *Variability in the atmospheres of the sun and stars.* Under this programme a visit to UNAM, Mexico has been made during Nov 6 to Dec 6, 2009 by her. Giridhar,S. is PI of the project *High resolution Echelle SPectrometer for 2m HCT at Hanle.* The DPR of this project has been submitted to DST in May 2009 for funding.

A. Goswami is the PI for the project titled *Determination and modelling of chemical compositions of metal-poor stars and observational constraints for Galactic chemical evolution* sanctioned by DST, New Delhi.

C. S. Stalin is the PI of an Indo-Swiss collaborative project funded by DST (Govt. of India) and EPFL (Govt. of Switzerland) on *Estimating the Hubble constant using Gravitational Lensing.*

6.5 Involvement with the Scientific Community

G. C. Anupama served as an Editor of the "Bulletin of the Astronomical Society of India" since 2004 March; Member of the review committee for the project "Virtual Observatory India - The Next Generation", (PI: A. K. Kembhavi, IUCAA), funded by the Ministry of Communications and Information Technology; Member of the "Subject Expert Committee on Physical and Mathematical Sciences for technical evaluation of proposals" received under Women Scientist Scheme – (WOS-A); Chair, "Time Allocation Committee, IUCAA," Ghirawali Observatory, IUCAA, Pune (2009-2012).

S. P. Bagare served as an external examiner for Ph.D. evaluation and M.Sc. (Physics) courses of the Madurai Kamaraj University and the University of Mysore respectively.

H. C. Bhatt served as member, Programme Advisory Committee of DST on Plasma, High Energy, Nuclear Physics, Astronomy & Astrophysics and Nonlinear Dynamics.

B. P. Das was the co-organizer of the *International School and Conference on Cold Ions and Atoms* (Sponsored by International Centre for Theoretical Sciences) at Kolkata and Sankarpur, January 2010.

S. Giridhar has been serving as President of IAU commission 45 *Spectral Classification* since 2006 till August 2009. As past president, she continues to serve the SOC of IAU commission 45. Giridhar has been invited to be a member of the Editorial Board of the Journal of Astrophysics and Astronomy.

A. Goswami was a Ph.D. thesis examiner for the Assam university, Silchar.

S. S. Hasan represented India at the IAU General As-

sembly, August 3 – 14, 2009, Rio de Janeiro, Brazil. He is a member of the Organizing Committee of IAU Commission 10, of the International Committee of the Royal Astronomical Society, U.K., and of the Editorial board of Solar Physics; Chair of the Executive Council, VITM, Bangalore; Member of the Governing Councils of ARIES (Nainital), Bose Institute (Kolkata), IUCAA (Pune), National Council of Science Museums, Institute for Plasma Research (Gandhinagar), and of the Board of Management, Centre for Theoretical Physics, Jamia Millia University, New Delhi; He is President of the Oxford and Cambridge Society of Bangalore and of the Alexander von Humboldt Association of Bangalore.

K. M. Hiremath was external examiner for Physics Department, Bangalore University.

R. Kariyappa served as a member of the Board of Examiners for M.Sc. (Physics: Astrophysics) exams of 2009 – 2010 by Tumkur University.

A. Mangalam served as resource person in the preparation of the Indian contingent to the International Earth Science Olympiad during 18 – 21 August 2009 (The team was awarded the bronze medal at the Olympiad held in Taipei, Taiwan during 14 – 22 September 2009). He was a resource person for the Indian team for the International Astronomy Olympiad (IAO) as well as International Olympiad in Astronomy and Astrophysics (IOAA) coordinated by HBCSE, TIFR. He participated in the paper setting, knowledge camp and tutorials for the Indian team during 2 – 4 November 2009 and 2 – 5 May 2010. (In IAO 2009, the Indian team was first with a total tally of 5 golds and one silver.)

K. N. Nagendra served as a member of the SOC of the *Joint Discussion 10* of the XXVII IAU General Assembly, Rio de Janeiro, Brazil, August 2009; and member of the SOC, *Solar Polarization Workshop 6 (SPW6)* held at Maui, Hawaii, USA, during 30 May – 4 June 2010.

A. K. Pati continued as a board member of the 1.3 m telescope project and the Schmidt telescope project of ARIES.

T. Prabhu is a member of the GMRT Time Allocation Committee, TIFR.

B. E. Reddy is an elected member of the ASI executive council for (2010 – 2012).

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

P. Shastri is a member, Organising Committee, Division X (Commission 40), of the International Astronomical Union, member of the GMRT Time Allocation Committee, TIFR, and member, Board of Studies of the Physics Department, St.Agnes College, Mangalore.

6.6 Visits by IIA Scientists

S. Anathpindika visited NCRA, Pune, as a visiting researcher, September – October 2009.

L. S. Anusha visited the Observatory of Nice, Nice, for a month (October – November 2009), to work on *Polarized radiative transfer in inhomogeneous media* in collaboration with K. N. Nagendra and Helene Frisch; Visited the Instituto Ricerche Solari Locarno (IRSOL), Locarno, Switzerland, for two months (August – October 2009), under Indo-Swiss programme, to work on *Modeling the linear polarization of Ca* I *4227 Å line* in collaboration with Drs. K. N. Nagendra, J. O. Stenflo, and M. Bianda.

D. Banerjee visited Armagh Observatory, U.K for one week during December 2009, under the Royal Society-British Council joint project grant.

B. C. Bhatt visited (i) National Institute of Ocean Technology, Chennai on June 15, 2009 to participate in the discussions for collaboration in atmospheric research and possible sites available at Anadaman Island for starting data collection center. (ii) Island Research Centre, NIOT Campus, Port-Blair during 5 – 8 July 2009 for site survey to establish continuous Carbon Dioxide Analyzer similar to CARIBOU-Hanle in Andman Islands. He also established an air sampling unit at one site near Andaman-east coast and trained 2 research students of NIOT at their Island Campus for getting weekly samples of the site air data. (iii) PU Campus, Pondicherry during July 8-9, 2009 to have a on the spot discussions on the data collection/quality of Air Samples collected dur-

ing last 3 years. (iv) Pondicherry University Campus on 24 December 2009 for maintenance of the air sample Unit and Automatic Weather Station.

R. T. Gangadhara visited J. L. Han, National Astronomical Observatories, Beijing during 20 April – 5 May 2009, for collaboration work on *pulsars emission mechanism*. He also visited Mr. Pengfei Wang (National Astronomical Observatories, Beijing) for his Ph.D. thesis work on *Relativistic radio emission from pulsar plasmas* during 19 February – 5 March 2010. Gangadhara visited Picking University, China, on 24 April 2009, and gave a talk on *Aberration – Retardation phase sift in pulsar radio profiles*.

S. Giridhar visited Department of Astronomy, Univ. of Texas at Austin, U.S.A. during 22 October 2009 - 05 November 2009 to work on a collaborative project on *post-AGB candidates among IRAS objects*. Giridhar visitied the Institute of Astronomy, Univ. Nacional Autonoma de Mexico, Mexico during 06 November - 06 December 2009 to work on collaborative projects on *high galactic latitude post-AGB candidates* as well on a project on *CCD photometry of variable stars in Globular cluster NGC 5053*.

S. S. Hasan visited (i) Paris Observatory, Meudon, France, June 1-2, 2009; (ii) the Hamburg Observatory, Hamburg, Germany, June 3-5, 2009 and gave a colloquium on *The Indian National Large Solar Telescope and Research at IIA*; (iii) the Royal Astronomical Society, London, U.K., June 7–8, 2009; (iv) the Led the Indian expedition to Tinhuangping (Shanghai region), China for the Total Solar Eclipse on July 22, 2009; (v) the National Institute for Space Research (INPE), Sao Paolo, Brazil, August 2, 2010 and gave a talk on *Indian Institute of Astrophysics: An Overview*; (vi) Visited Moscow as a member of DST's delegation for the "Year in Russia" meeting, September 12 – 18, 2009. (vii) Organized a Joint Indo-Russia discussion meeting at IZMIRAN, Troitsk on September 16 and gave a talk on "Solar Physics Research in India"; (vii) Delivered a colloquium at ARIES, Nainital, October 25, 2009 on "New solar programmes at IIA"; (viii) Led the IIA expedition to Kanyakumari to observe the Annular Solar Eclipse on January 15, 2010

R. Kariyappa visited Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA for 2-weeks in September 2009 on a collaborative research project related to the *study of X-ray bright points from Hinode/XRT*. This is in collaboration with Drs. DeLuca, van Ballegooijen, Steve Saar, Golub etc. He also visited Service d'Aeronomie du CNRS (LATMOS), France for 2 weeks in Sept - Oct 2009 to work with Professor Luc Dame on UV bright points and network elements from TRACE observations.

K. N. Nagendra visited the Istituto Ricerche Solari Locarno (IRSOL), Locarno, Switzerland, for one month (August – September 2009), under Indo-Swiss programme, to continue the collaboration with J. O. Stenflo, and M. Bianda.

S. P. Rajaguru visited the group of Dr. Laurent Gizon at the Max-Planck Institute of Solar System Research at Katlenburg-Lindau, Germany during 16 – 18 May 2009; He also visited Kiepenheuer Institut fur Sonnenphysiq, Freiburg, Germany during 19 – 22 May, 2009; Solar Observatories Group, Stanford University, Stanford CA, USA during 7 – 22 September, 2009 for collaborative work.

C. S. Stalin visited Observatoire de Sauverny, the astrophysics department of Ecole Polytechnique Federale de Laussane, Geneva for a month's collaborative work during September 2009.

P. R. Vishwanth visited Inter-Universtiy Accelerator Centre, New Delhi in June 2009; Tamilnadu Centre for Science and Technology in June 2009; Jawaharlal Nehru University, New Delhi, July 2009; SJVO College, Harihara in March 2010

6.7 Awards and Recognition

S. S. Hasan received the J. T. M. Gibson Award for Excellence from the Maharaja Gaj Singh of Jodhpur at a ceremony on the 21st February, 2010 in Mayo College, Ajmer. The award was instituted in the memory of Jack Gibson, former principal of the College, and is given to alumni who have made a difference to society. He is an Associate of the Harvard College Observatory, Cambridge, U.S.A. since 1991 and Distinguished Adjunct Professor, Centre for Astroparticle Physics, Kolkata.

M. Sampoorna received the Kumari L. A. Meera Memorial Medal on 03 March 2010 for the year 2008–2009 given by the Council of the Indian Institute of Science (IISc) for the best Ph.D. thesis of the year in the Department of Physics at IISc. The title of the thesis is *Polarized line formation in turbulent and*

S. S. Hasan receiving the JTM Gibson Award for Excellence at Mayo college.

scattering media. She is also recepient of the prestigious Chandrasekhar Fellowship.

Kumari L. A. Meera Memorial Medal received by M. Sampoorna.

H. N. Smitha presently a Juniour Research Fellow at IIA, received seven Gold Medals at the Convocation of the Bangalore University, held on 30 April 2010 for securing the highest marks in the university exams in 2009, including the affiliated post-graduate centers. She also secured First Rank in M.Sc. Physics for this year (2010) from Bangalore University.

K. Sundara Raman has been conferred with the Sir J. C. Bose Memorial Award by "Indian Science Monitor" an NGO at Chennai and Tamil Nadu State Council of Science and Technology in recognition of his contribution to dissemination of Space Science, Astrophysics and Higher Education and was given on National Science Day, 2010.

H. N. Smitha receiving the awards from the Governor of Karnataka, during the convocation.

K. Sundara Raman receiving the citation and the medal.

A. Vyas received the second best paper award for the paper titled *Denoising Shack Hartmann Sensor spot pattern using Zernike Reconstructor*, and the best paper presentation in the session "Data Mining" for the paper titled *Progressive prediction of turbulence using wave-front sensor data in adaptive optics using data mining* in the International Conference on "Advanced Computing", August 2009. Vyas' paper *Improved iteratively weighted centroiding for accurate spot detection in laser guide star based Shack Hartmann sensor* was nominated in the semifinals for the best student paper prize in the LASE symposium of SPIE Photonics WEST-2010, San Francisco, US.

6.8 Welfare of SC/ST Staff

An officer at a senior level of the Institute is functioning as the liaison officer to support the welfare of the SC/ST staff members. 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, 2010 was 328. As per the orders of the Government, 50 positions in scientific and technical categories were exempted from the reservations. Out of 278 positions, 48 members belong to SC and 28 members belong to ST, forming 17.26% and 10.07% respectively. Apart from this, reservations have been extended to OBCs and physically handicapped persons.

6.9 Official Language Implementation

The effective implementation of the official language in the administration of the Institute has been carried out. In the wake of the visit by the Honourable second Sub-Committee of Parliament on the official language on 03 October 2008 for inspection of the Hindi implementation programme by IIA, the cell has been required to take up follow-up action on their recommendations. As an appreciation of the good progress made by the Hindi Cell in the year 2008-2009, the Town Official Language Implementation Committee, Bangalore awarded Fourth Prize to the Institute in July 2009.

Emphasis was given on the implementation of the Section 3 (3) of Official Language Act and all the circulars, tender notices, advertisements, forms, Administrative and other reports have been prepared bilingual, including the Institute's annual and financial audit reports. Letters received in Hindi are replied to in Hindi. Since the last one year, Hindi articles in the Institute's Newsletter are being published every quarter.

Hindi Fortnight was celebrated at the Bangalore campus from 03 – 14 September 2009. Four Hindi workshops were conducted for the Administrative staff which resulted in a great increase in Hindi correspondence. Hindi Books worth Rs. 42,081/- have been purchased for Hindi Cell during the year as per Annual Programme of Official Language issued by the Dept. of Official Language, Govt. of India. Saransh Hindi software has been installed in 30 computers in the Administration to enable staff members to get themselves trained and work in Hindi.

Three incentive schemes for staff to encourage them to work in Hindi were introduced. Official Language Implementation Committee meetings were being conducted regularly under the Chairmanship of the Director, IIA. Quarterly Reports are being sent to the DST, New Delhi regularly.

(R. C. Kapoor, for the Hindi Cell)

Chapter 7

People

7.1 Staff List 2009 – 2010

Director: S. S. Hasan

7.1.1 Academic & Scientific Staff

Senior Professor: B. P. Das, T. P. Prabhu, J. Singh, C. Sivaram

Professor: S. P. Bagare, H. C. Bhatt, S. Giridhar, J. Murthy, K. N. Nagendra, A. K. Pati, A. V. Raveendran

Associate Professor: G. C. Anupama, S. Chatterjee, R. K. Chaudhuri, V. Chitnis, R. T. Gangadhara, R. Kariyappa, S. G. V. Mallik, M. V. Mekkaden, B. R. Prasad, K. E. Rangarajan, K. P. Raju, S. K. Saha, P. Shastri, R. Surendiranath

Reader: D. Banerjee, J. Javaraiah, C. Muthumariappan, G. Pandey, S. P. Rajaguru, R. Ramesh, B. E. Reddy, S. K. Sengupta, A. Subramaniam, F. Sutaria, T. Sivarani

Scientist D: B. C. Bhatt, A. Goswami, K. M. Hiremath, U. S. Kamath, A. Mangalam, S. Muneer, P. S. Parihar, K. B. Ramesh, D. K. Sahu, A. Satya Narayanan, K. Sundara Raman, M. S. Rao, B. A. Varghese

Scientist C: R. K. Banyal, B. S. Nagabhushana, B. Ravindra, N. S. Singh, C. S. Stalin

Scientific Officer SD: R. Mohan, L. Yeshwanth

Scientist B: N. A. Ahmed, P. Bama, E. E. Chellasamy, N. Dorjey, M. Priyal R. B. Singh, G. S. Suryanarayana

Fellow: C. Kathiravan

Research Associate: M. Appakutty, G. Selvakumar

Distinguished Professor: V. K. Gaur

Adjunct Professor: A. R. Choudhuri, S.N. Tandon

Honorary Professor: V. Krishan, R. Srinivasan, K. R. Subramanian

Visiting Professor: N. K. Rao, P. R. Vishwanath

Honorary Consultant: R. C. Kapoor, D. C. V. Mallik

Post Doctoral/Visiting Fellow: S. V. Anathpindika, C. Konar, A. Pathak, M. Safonova, M. Sampoorna, N. Sinha, N. V. Sujatha

Sr. Research Fellow: L. S. Anusha, Chandrashekar, R. Chaudhari, C. G. Gupta, G. U. Kumar, B. Mathew, T. Mishra, A. C. Pradhan, S. Ramya, S. Rao, B. K. Y. Reddy, M. B. Roopashree, A. Shukla, V. Singh, S. Subramaniam, G. Vigeesh, A. Vyas

Jr. Research Fellow: S. Choudhury, L. P. Chitta, M. Das, A. Dhar, Drisya, B. P. Hema, G. Indu, S. S. Kartha, S. Krishnaprasad, D. Kumar, R. Kumar, Prasanth, P. Ramya, B. Reddy, Sindhuja, H. N. Smitha

Integrated Ph. D: S. Chowdhury, R. Kumar, S. Kumar, A. Prasad, M. Sastry, M. Singh, S. Srivastav

IIA-CU M. Tech-Ph. D: C. Anantha, S. Arun, S. K. Dhara, A. Mohanty, S. Pal, J. Paul, K. Pullapally,

K. S. Raja, N. Reddy, T. K. Sharma, N. V. Suresh, V. Vineeth

7.1.2 Technical Staff

Engineer G: A. K. Saxena

Sr. Principal Scientific Officer: A. V. Ananth

Engineer F: M. S. Sundararajan

Engineer E: V. Chinnappan, G. Srinivasulu

Engineer D: V. Arumugam, S. S. Chandramouli, P. M. M. Kemkar, P. K. Mahesh, S. Nagabushana, B. R. Reddy, M. V. Ramaswamy, R. R. Reddy, F. Saleem, S. Sriram

Principal Scientific Officer: J. P. Lancelot, J. S. Nathan

Librarian: C. Birdie

Engineer C: P. Anbazhagan, D. Angchuk, T. Dorjai, S. Gorka, S. Kathiravan, A. Kumar, K. C. Thulasidharan

Sr. Technical Officer: K. Jayakumar, K. Kuppuswamy, K. Rangaswamy, M. J. Rosario, J. P. A. Samson, A. Selvaraj, R. Selvendran

Technical Officer B: J. V. S. V. Rao, N. Sivaraj, K. S. Subramanian

Sr. Documentation Officer: S. Rajiva

Engineer B: K. Anupama, K. Dhananjay, S. Jorphail, P. U. Kamath, T. T. Mahay, M. F. Nawaz, A. Ramachandran, K. Ravi, V. Selvi, S. Suresh

Technical Officer: A. V. V. Kutty

Tech. Associate B: D. Babu, Narasimhappa, S. Pukalenthi, C. V. Sriharsha, M. R. Somashekar

Sr. Mech. Asst. C: A. Mani

Tech. Associate: P. Kumaravel, C. Mallappa, M. G. Mohan, J. Manoharan, S. Ramamoorthy, S. Venkateshwara Rao

Draughtsman E: V. K. Subramanian

Sr. Tech. Asst. B: A. P. Balakrishnan, R. I. Jabillullah, D. Kanakaraj, A. Muniyandi, T. K. Muralidas, M. Nagaraj, V. Ponnurangam

Tech. Asst. C: V. Gopinath, M. G. Mohan

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

Driver Mech. E.: Anandaraman

Consultant: K. Chandar, C. N. Gowda

Consultant Engineer: M. N. Karthikeyan, B. S. Nataraju, M. N. Rao, V. N. Rathnam

Technical consultant: F. Gabriel

7.1.3 Administrative Staff

Administrative Officer: P. Kumaresan

Dy. Administrative Officer: S. Rajasekaran

Personnel Officer: A. Narasimharaju

Staff Officer: K. Thiyagarajan

Accounts Officer: M. P. Parthasarathy

Sr. Asst. Administrative Officer: K. Mohan Kumar

Asst. Administrative Officer: Y. K. R. Iyengar

Asst. Accounts Officer: G. R. Venugopal

Stores Officer: D. Lakshmaiah

Sr. Section Officer: L. Josephine, Meena, A. P. Monnappa, P. Mohan, K. Sutherson

Section Officer: N. Murthy, K. Padmavathy, R. M. Paulraj, S. Rajendran, S. B. Ramesh, N. Valsalan

Sr. Office Superintendent: U. Maileveloo, G. A. Mary, N. K. Pramila, M. G. C. Nair, M. Rajan, N. Sathya Bama, A. Veronica

7.2 Visitors to IIA

12 May 2009 - 15 May 2009
A. Pathak
School of Chemistry
Univ. Nottingham, UK

12 May 2009 - 16 May 2009
H. S. Sawant
INPE
Brazil

01 June 2009 - 17 June 2009
D. Alloin
Service d'Astrophysique, CEA
Saclay, France

06 June 2009 - 12 June 2009
T. K. Jha
PRL, Ahmedabad

19 June 2009
V. Soni
NPL, New Delhi

29 June 2009 - 02 July 2009
N. Brosch
Tel Aviv University
Israel

13 July 2009 - 21 July 2009
R. A. Garcia
Service d'Astrophysique, CEA,
Saclay, France

17 July 2009 - 08 August 2009
M. Sampoorna
Institute de Astrofisica de Canarias
Tenerife, Spain

31 July 2009
A. Vagiri
IIIT, Allahabad

05 August 2009 - 12 August 2009
P. N. Bhatt
Univ. Alabama, Huntsville
USA

06 August 2009 - 14 August 2009
R. Britto
TIFR, Mumbai

09 August 2009 - 28 August 2009
D. Lambert
Univ. of Texas, Austin
USA

10 August 2009
G. Swarup
NCRA, TIFR, Pune

18 August 2009 - 29 August 2009
A. G. Hernandez
Service d'Astrophysique, CEA,
Saclay, France

23 August 2009 - 28 August 2009
J. Schmitt
Hamburger Sternwarte
Hamburg, Germany

25 August 2009
P. Balaram
IISc, Bangalore

06 September 2009 - 09 September 2009
P. Mazumdar
Deutsches Elekronen Synchrotron (DESY)
Zeuthen, Germany

16 September 2009
C. Joseph
Jyoti Nivas College, Bangalore

26 September 2009 - 29 September 2009
K. Elankumaran
RKM College Chennai

06 October 2009 - 07 October2009
D. Bose
Madrid, Spain

12 October 2009 - 14 October 2009
V. Sahni
IUCAA, Pune

29 October 2009 - 03 November 2009
S. Kwok
Univ. of Hongkong, China

04 November 2009
S. M. R. Ansari
IUPS, Aligarh

05 November 2009 - 06 November 2009
Ishwar Chandra
NCRA, TIFR, Pune

10 November 2009
P. L. Biermann
MPI fr Radioastronomie &
Univ. of Bonn, Germany

17 November 2009
Y. Schekinov
Southern Federal University
Russia

22 November 2009 - 27 November 2009
R. Bhattacharyya
NCAR, Boulder, USA

08 December 2009 - 11 December 2009
J. Vivekanandan
NCAR
Boulder, USA

13 December 2009 - 16 December 2009
H. Wilsch
KVC, Netherland

17 December 2009 - 20 December 2009
D. Tripathi
Univ. of Cambridge
UK

22 December 2009
M. Das
BITS, Pilani, Hyderabad

26 December – 14 January 2010
M. Sampoorna
Institute de Astrofisica de Canarias
Tenerife, Spain

05 January 2010
D. Mitra
Queen Mary College, Univ. of London, UK

18 January 2010
V. Soni
Jamia Millia Islamia University, New Delhi

16 February 2010
D. J. Thompson
NASA GSFC, Greenbelt, USA

18 February 2010
V. Connaughton
NSSTC, Huntsville, USA

22 February 2010 - 26 February 2010
P. Manoj
Univ. of Rochester, USA

25 February 2010
A. Deep
Leiden University, Leiden,
The Netherlands

01 March 2010 - 03 March 2010
G. Shaw
Centre for Excellence in Science
University of Mumbai
Mumbai