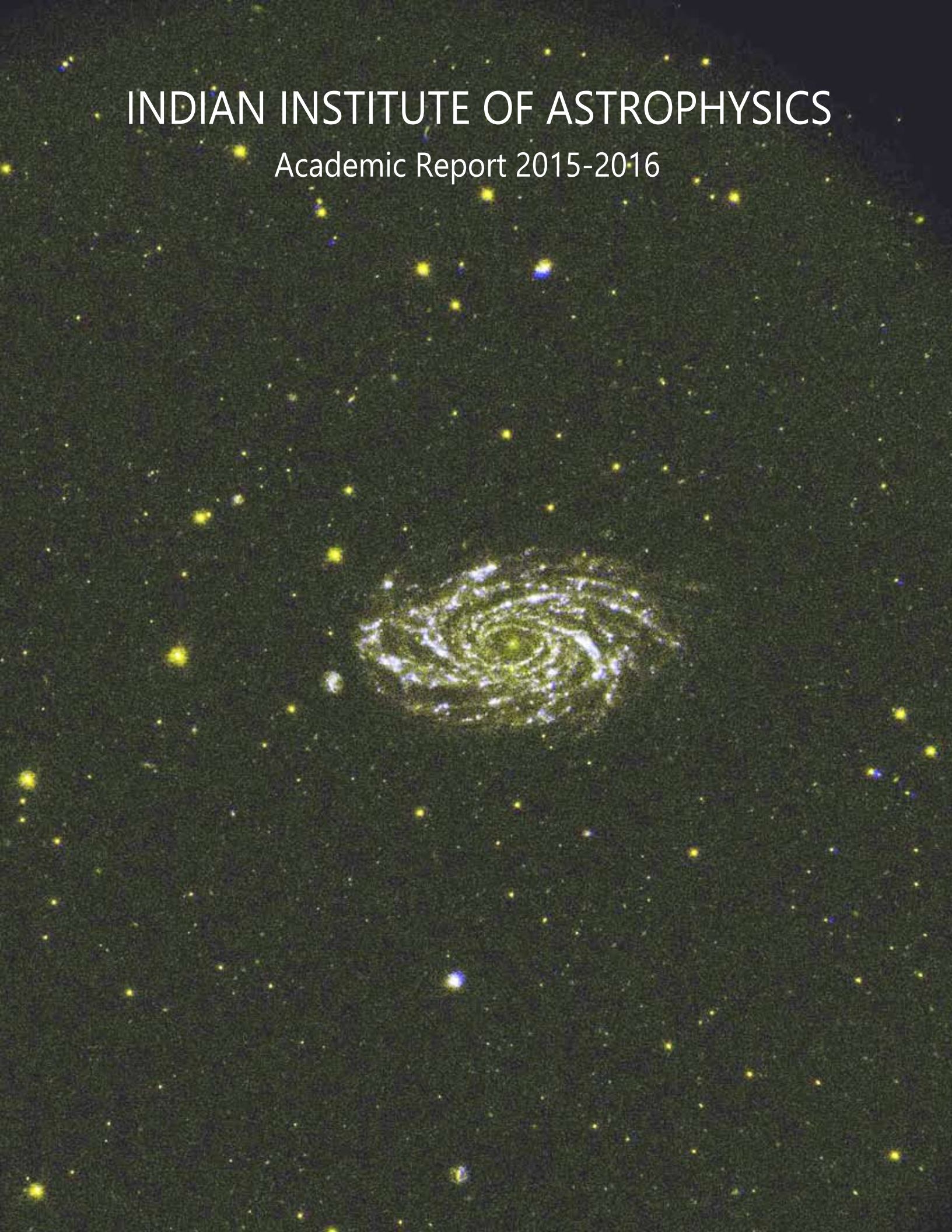
INDIAN INSTITUTE OF ASTROPHYSICS

Academic Report 2015-2016



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ACADEMIC REPORT

2015-2016

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Front Cover figure caption : NGC 2336 imaged by UVIT.

Back Cover figure caption : HESP. The image shows the spectrum of star HD221354 (a radial velocity standard) interlaced by spectra of calibration lamp for a precise estimation of the radial velocity. Spectra is taken with the Hanle Echelle spectrograph, the color composite represents the wavelength of the spectra. Inset shows part of the star spectra and the calibration lamp spectra.

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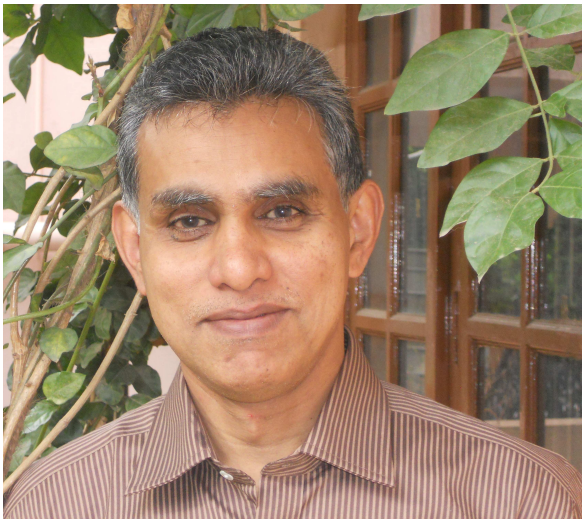
Chapter 1

The Year In Review



The most exciting event at our institute this year was the much awaited launch of the Ultra Violet Imaging Telescope (UVIT) on India's first multi wavelength astronomical observatory, ASTROSAT. UVIT's unique capability in providing some of the highest angular resolution images of the UV sky in multiple filters, is a new global capability in astronomy. IIA, as the lead institution responsible for the integration, testing and calibration of UVIT, proudly announces the better than expected performance of UVIT in orbit. UVIT, developed jointly with IUCAA, TIFR, ISRO, and the Canadian Space Agency, provides a great opportunity to Astronomers around the globe for unique, multi wavelength observations of celestial objects from India's space observatory. The coming year is expected to produce interesting new results from this instrument with the participation of a large user community from India and abroad. A UVIT Payload Operation Center (POC) is established in the main campus of the institute in Bengaluru to support observations, data processing, user needs and training.

The installation of Hanle Echelle Spectrograph (HESP) as a back-end instrument for the Himalayan Chandra Telescope (HCT) is another achievement this year. The thermal enclosure designed and fabricated was integrated with the HESP by the institute engineers. The system is performing very well and the spectrograph has already started yielding interesting scientific results. It will be released to the wider scientific community before the end of this year.

Compilation of the longest data set in the world on Ca II K images of the Sun from Kodaikanal Solar Observatory (KSO) covering a period of nearly hundred years, helioseismology and realistic simulations of solar flares are some of the highlights of the solar research this year. The long term Ca II K data from KSO can be used as a proxy for estimating magnetic activity locations and their strengths at earlier times. The amount of energy that is released during multiple solar flares from a 'delta' sunspot which accounts for nearly 95% of the solar X-ray radiation reaching the Earth was simulated. For the first time, the simulation involved the rotation of the Sun which twists the mag-

Figure 1.1: Most innovative stall award for the IIA-DST pavilion at Indian Science Congress-2016.

netic field lines inside the surface of the Sun. The new simulation is a significant improvement over the existing ones and generates a promising new capability in solar physics research.

Studies on exoplanets, novae, supernovae and chemical abundance analysis of various types of stars were some of the topics in which the stellar astronomy group was engaged in this year. Angular momentum of Sun-like G stars and their exoplanets were estimated. The spin angular momentum of the host stars are found to follow a power law with stellar mass. The probability of detecting Earth-like planets is found to be more likely for host stars that have certain optimum angular momentum. A detailed study was conducted to address the question of how plausible is a discovery of a habitable planet with biota on it among the closest neighbours (within 600 pc) of the Sun. It is shown that at least a third out of confirmed habitable planets are too young to have already developed detectable-biota on them. The type Ia supernova SN 2014J in M82 was monitored in the optical and Near Infra-Red (NIR) using the Himalayan Chandra Telescope (HCT). It was shown that the Hercules stream from the Hipparcos catalogue are dominated by metal-rich stars from the thin disc. For the first time chemical abundance measurements of red giant members in the open clusters (OCs) NGC 1342, NGC 1662, NGC 1912 and NGC 2354 were done. A range of mild enrichment of heavy (Ba-Eu) elements is found in the young OC giants over field stars of the same metallicity. The analysis supports that the youngest stellar generations in cluster might be under represented by the solar neighbourhood field stars.

One of the important cosmological parameters is the Hubble constant at the present epoch (H_0), and therefore its precise determination is very important for many aspects of cosmology. Observations of gravitationally lensed quasar systems were used to estimate H_0.

The many themes that have been pursued by the theoretical astrophysics group include black hole astrophysics, phenomena in active galaxies, magnetic fields in galaxies and inflationary cosmology. A dynamo model of the galaxy was constructed to explain the strength and global 3D structure of the observed magnetic field. A key result is that saturation is achieved within 1 Gyr that has implications for detection and study of its cosmic evolution through upcoming missions such as the Square Kilometer Array. A model of cosmic evolution of black hole energetics was constructed that takes into account the mass and spin accreted by the hole and the angular momentum torque due to an electrodynamical jet. An interesting result is that when the accretion stops, the jet power increases before a gradual decline if the initial

Figure 1.2: Prof. P. C. Agrawal (left) , Dr. P. Sreekumar (centre) and Prof. S. M. Chitre (right) with Prof. M. K. V. Bappu's bust during the Founder's day lecture.

spin is above a certain limit.

The other themes that are pursued by the theoretical group include quantum chemistry and radiative transfer theory. The state-specific multireference perturbation theory (SSMRPT) in conjunction with the improved virtual orbital-complete active space configuration interaction (IVO-CASCI) method has been used to study the potential energy curves of homo nuclear dimers including $Li_2, Na_2, K_2,\ Rb_2, F_2, Cl_2,$ and Br_2. The relativistic SSMRPT has not been explored in the past. For the halogen molecules, a relativistic destabilization of the bond has been found. The results are in good accordance with reference theoretical and experimental data which manifests the computational accuracy and efficiency of this method.

Polarization profiles in the infra-red during the transit phase of the self-luminous gas giant exoplanets with high rotation are calculated to show peak amplitude in the range 0.1 to 0.3 %. The radiative transfer group has proposed a simplified approach called "correction method" to solve the problem of polarized line formation in magnetized media that includes both the effects of Partial Redistribution (PRD) and the lower level polarization (LLP) for a two-level atom.

The radio astronomy group has recently commissioned a broad-band (500 - 50 MHz) Crossed Log Periodic Dipole Antenna (CLPDA) for simultaneous observations of Stokes I (total intensity) and Stokes V (circularly polarized intensity) radio emission associated with the transients in the solar atmosphere. The CLPDA has been designed and fabricated in such a way that the cross-talk between the orthogonal elements in the CLPDA is very small. The radio group has also designed and developed a prototype system for ground based radio observations going up to 10 MHz.

The Institute's PhD programme, in collaboration with the Pondicherry University and the MTech-PhD programme jointly with the Calcutta University continue to progress well. Ten students under the guidance of IIA academic staff were awarded PhD degree for subjects ranging from Solar physics to Astronomical Instrumentation. Six students have submitted PhD theses in topics ranging from Image retrieval in astronomical interferometers to characteristics of gamma-ray emitting AGNs. Five students have submitted MTech theses on various aspects of instrumentation. A Precision Thermal Control unit in a vacuum chamber with 0.01° C thermal stability was realised as a part of a graduate student's project. In addition to the PhD programmes, the Institute also trains students through short term programmes such as the visiting students programme, the summer school and the summer project programmes. Seventy three students underwent internship programme and two schools were conducted.

The System Engineering Group is involved in instrumentation and other engineering activities and provide support

towards development, refurbishment and maintenance of all our facilities. The H-alpha telescope, proposed to be installed at Merak, Ladakh is being tested at the CREST campus for system performance and mock assembly. A 100 KWp Solar power generation plant has been installed on the rooftop of main building at Bengaluru, as a part of the Institute's green initiative programme at all its centres.

For assembly and testing of Visible Emission Line Coronagraph (VELC) payload, the MGK Menon Laboratory facility was upgraded, and a clean room of class 10 area was added. The design, execution and validation of the class 10 area were completed this year. The development of the Near Specular Scatterometer (NSS) for testing VELC was completed and is functional.

A new impetus has been given to the National Large Solar Telescope (NLST) project with approval from the MOD for setting it up at the Merak site. The standing committee of J & K state board for Wildlife has recommended the project which will be forwarded to the National Board for Wildlife for further clearances.

As an important step in Thirty Meter Telescope (TMT) project, the first prototype Segment Support Assembly (SSA) manufactured in India was assembled at a new clean room at IIA, Bengaluru.

The Raman Science Center at IAO, Leh is nearing completion and should be operational from October 2016. The Institute has planned to provide staff accommodation at Hanle with rammed earth wall construction for thermal insulation.

An important development was initiated (jointly with ISRO and RRCAT) at IIA in the area of X-ray optics. Multi-layer X-ray mirrors developed using the facility at RRCAT, were subject to performance tests and showed good promise to meet the needs of the space astronomy community.

An MoU was signed on June 5, 2015 between IIA and CSIR-Institute of 4-Paradigm (earlier known as C-CMMACS), NAL-Belur campus, Bengaluru for establishing a framework of collaborative research in the area of mutual interest. The present MoU is signed in the background of already existing joint programmes on Green House Gas (GHG) studies and GPS Geodesy at IAO, Hanle.

As a part of Outreach activities, National Science day 2016 was celebrated at IIA on 28 February 2016. Altogether 71 students from five schools in Bengaluru participated in various activities organised at IIA. IIA outreach program was conducted at seven different schools during last year benefiting around 700 students. The school outreach program was conducted for the classes 8-10 with PhD student volunteers from IIA and science teachers from the schools. The program for watching the night sky on every Saturday, on all clear nights is still being followed at VBO as part of the outreach program. A total number of about 10,000 persons visited VBO this year. It included groups from 35 schools, 19 colleges, 3 science forum groups, MPBIFR, students from Aryabhatta Foundation, Bhopal etc. IIA has also participated in various exhibitions within the country. I am happy to share with you the news that the IIA stall with the UVIT engineering model and a TMT scale model, bagged the most innovative stall award at the Department of Science and Technology (DST) pavilion in the 103^{rd} Indian Science Congress (ISC) held in Mysuru early this year.

The Founder's day lecture was delivered by Prof. S.M.Chitre on August 14, 2015.

Special consideration as per norms during recruitment and regular assessment are being provided to reserved categories of employees. At the end of the year, members

belonging to the SC, ST and OBC categories constitute 13.55%, 12.71% and 7.62% respectively of the total strength. The Institute celebrated Hindi fortnight during which several competitions were conducted. Special drive to spread Hindi learning at Kavalur, Tamilnadu was taken up.

I am happy to note that there is a significant increase in the number of scientific publications in the current year. While we continue to lose specific expertise in some areas arising from superannuation, we continue to take necessary steps toward recruitment of human resources to strengthen many programs at the institute. Currently, IIA plays a major role in many astronomy programs in the country, including the operation of many national facilities. We hope to improve upon these common facilities and sustain the high quality of research through important publications and student training in the coming year as well.

P. Sreekumar
Director

Chapter 2

RESEARCH

2.1 The Sun and the Solar system

Meridional circulation in the solar convection zone: time-distance helioseismic inferences from four years of HMI/SDO observations

The authors of the present work have obtained results from time-distance helioseismic measurements of meridional circulation in the solar convection zone using 4 years of Doppler velocity observations by the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO). Using an in-built mass conservation constraint in terms of the stream function, the authors invert helioseismic travel times to infer meridional circulation in the solar convection zone. The authors find that the return flow that closes the meridional circulation is possibly beneath the depth of $0.77R_{\odot}$. The significance of this result in relation to other helioseismic inferences published recently and possible reasons for the differences in the results are discussed. Obtained results show clearly the pitfalls involved in the measurements of material flows in the deep solar interior given the current limits on signal-to-noise and limited understanding of systematics in the data. The implications of the present results for the dynamics of solar interior and popular solar dynamo models are also discussed.

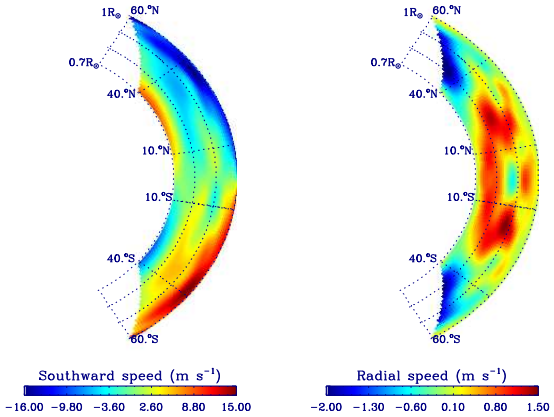


Figure 2.1: Deep structure of solar meridional circulation that results from seismic inversion of travel time differences of interior propagating acoutic waves in the north-south direction. The two panels show the 2D (r,θ) profiles of u_θ and u_r.

(The Astrophysical Journal 2015, 813, 114)

(S. P. Rajaguru and H.M. Antia)*

A Full Study on the Sun-Earth Connection of an Earth-directed CME Magnetic Flux Rope

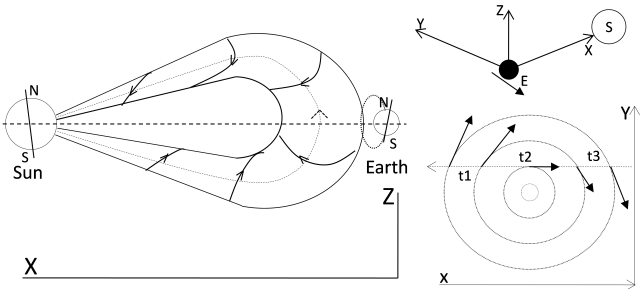


Figure 2.2: Schematic of the MFR orientation in par with in situ magnetic field observations. Rotation of the observed B_y component is demonstrated by the azimuthal field and its handedness in the magnetic cloud, which is shown by a cross section of the MFR in the XY -plane of the GSE coordinate system. Note that axial field contributes to the positive B_z component (northward-directed), consistent with in situ observations.

Coronal Mass Ejections (CMEs) are magnetically driven gigantic events whose disturbance in the outer corona influences the space-weather to a wide range. When propagating from the Sun, they appear to have three-part like while light structure with leading edge, core and cavity. Although not quite clear in the observations, the cavity is supposed to have its connections in the source regions on the Sun and is approximated by coherent, large scale magnetic magnetic flux rope (MFR), manifested by twisted magnetic field lines. Many studies from space and ground based observations suggested that this MFR structure in the outer corona is an evolved form of filaments seen in Hα or sigmodal structure in soft X-rays in active regions (AR) on the Sun. The present investigation, utilizing observations from SDO, STEREO, SOHO, of an eruption event of coronal mass ejection demonstrates Sun-Earth connections of MFR from source AR NOAA 11719 on 11 April 2013 (Figure 2.2). The source AR consists of pre-existing sigmoidal structure stacked over a filament channel. The EUV observations of low corona suggest a further development of this MFR system by added axial flux through tether-cutting reconnection of loops at the middle of sigmoid. The authors infer that the MFR system in the AR is initiated to upward motion by kink-instability and further driven by torus-instability. The CME morphology in the outer corona and its in situ observations of arrival time, are consistent with MFR based model to CME connection of Sun and Earth and further the space-weather in general.
(The Astrophysical Journal, Volume 814, Issue 1, article id. 59, 18 pp. (2015).)

(P. Vemareddy and W. Mishra)*

Two-phase Filament eruption in Association with Flux Cancellations and Contraction of Coronal Loop Dynamics as Observed by AIA/SDO

Using multi-wavelength solar atmospheric data, the authors investigated filament eruptions associated with the plage region NOAA 11444 occurred on March 27, 2012. The filament was inverse J shaped and located above the polarity inversion line. The whole filament was erupted in two different phases. The important morphological changes in and around the filament prior to the eruption and the possible triggering mechanism of the first and second part of the filament are presented in this study.
(Dynamic Sun: MHD waves and confined transients in the magnetized atmosphere, 22-26 Feb 2016, Varanasi INDIA.)

(S.K. Dhara, B. Ravindra, R.K. Banyal)

Variation of the Width of Transition Region Network Boundaries

The transition region network seen in the Solar EUV lines is the extension of the chromospheric network. The network appears as an irregular web-like pattern over the solar surface outside active regions. The average width of transition region network boundaries is obtained from the two-dimensional autocorrelation function of SOlar and Heliospheric Observatory (SOHO)/Coronal Diagnostic Spectrometer (CDS) Synoptic images of the Sun in two emission lines, He I 586 Å and O V 630 Å during 1996–2012. Width of the network boundaries is found to be roughly correlated with the solar cycle variation with some lag. A comparison of the widths in the two emission lines shows that it is larger for the He line. The SOHO/CDS data also show large asymmetry in boundary widths in the horizontal and vertical directions which is shown to be caused by image distortions due to instrumental effects. Since the network cell widths are related to the magnetic flux concentration, the results are expected to have implications in the flux transport on the solar surface and solar cycle.

(K.P. Raju)

Relationships between fluid vorticity, kinetic helicity and magnetic field at the small-scale (quiet-network) on the Sun

The authors derive horizontal fluid motions on the solar surface over large areas covering the quiet-Sun magnetic network from local correlation tracking of convective granules imaged in continuum intensity and Doppler velocity by the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO). Horizontal divergence, vertical component of vorticity, and kinetic helicity of fluid motions are calculated from the obtained results. The authors study the correlations between fluid divergence and vorticity, and that between vorticity (kinetic helicity) and magnetic field.

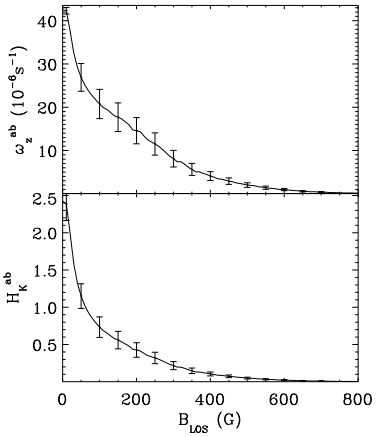


Figure 2.3: Spatial averages of absolute amplitudes of fluid vertical vorticity ω_z^{ab} and kinetic helicity H_k^{ab} against the magnitude of magnetic field strength (LOS), B. As a function of B, as observed by HMI, the magnitudes of absolute vorticities decrease almost exponentially, showing the magnetic suppression of flows due to Lorentz forces. In particular, it is found that the magnetic fields largely suppress the amplitudes of vortical motions when magnetic flux densities exceed about 300 G (from HMI). This magnetic suppression of vorticities or helicities is identified as that arising from the α-quenching action of the magnetic field.

It is found that the vorticity (kinetic helicity) around small-scale fields exhibits a hemispherical pattern (in sign) similar to that followed by the magnetic helicity of large-scale active regions (containing sunspots). The authors identify this pattern to be a result

of the Coriolis force acting on supergranular-scale flows (both the outflows and inflows), and is consistent with earlier studies using local helioseismology. Further, it is shown that the magnetic fields cause transfer of vorticity from supergranular inflow regions to outflow regions, and that they tend to suppress the vortical motions around them when magnetic flux densities exceed about 300 G (HMI). It is also shown that such action of magnetic fields leads to marked changes in the correlations between fluid divergence and vorticity. These results are speculated to be of importance to local dynamo action if present, and to the dynamical evolution of magnetic helicity at the small-scale.
(The Astrophysical Journal 2016, 824, 120)

(C.R. Sangeetha and S. P. Rajaguru)

Modelling repeatedly flaring delta sunspots

There is a certain kind of sunspot, called 'delta' sunspot, that accounts for almost 95 per cent of all X-ray radiation reaching the Earth's surface. In the delta sunspots, the magnetic poles, north and south, lie very close to each other, because of which the magnetic forces are exceedingly stressed. These sunspots continue to release energy through multiple solar flares.

None of the existing computer simulations has come close to reproducing the amount of energy released during a typical solar flare. The present simulation developed by the authors is a significant improvement over the existing ones and generates a very promising picture of a solar flare. The physical equations introduced take into account the effect caused by the rotation of the Sun, something that the existing simulations never did. This rotation twists the magnetic fields inside the Sun's surface, leading to further magnetic stress. The next step is to test the model with actual solar observations from the past, to test whether it can recreate solar flares that have already occurred.

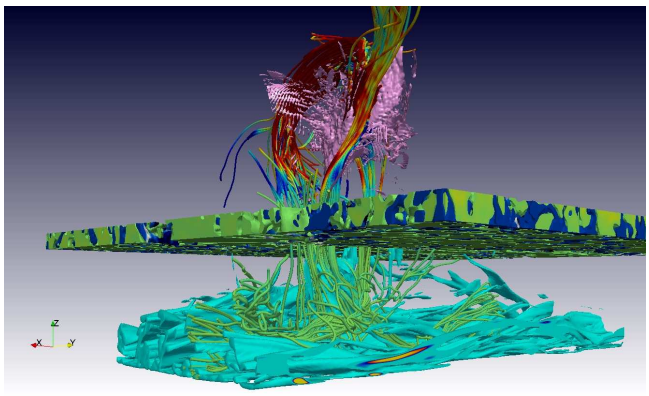


Figure 2.4: Simulating a solar flare. Chatterjee et al.'s simulations begin with a flat sheet of magnetized plasma (shown in light blue). This sheet of magnetic flux breaks into tubes of flux, which rise to the surface (dark blue /green slab), releasing energy at specific points (the flare). Each flare is associated with a high-speed jet of charged particles that squirts outward between reconnecting field lines followed by a moderate decline in magnetic energy. The color of a flux tube indicates the velocity of plasma within the tube: red plasma moves upwards, blue plasma moves downwards, and green plasma has a velocity close to zero.

(Phys. Rev. Lett. 116, 101101)

(Piyali Chatterjee, Viggo Hansteen, Mats Carlsson*)*

3D Simulations of realistic power halos in magneto-hydrostatic sunspot

atmospheres: linking theory and observation

The well observed acoustic halo is an enhancement in time averaged doppler velocity and intensity power with respect to quiet sun values which is prominent for weak and highly inclined field around the penumbra of sunspots and active regions. A 3D linear wave modelling is performed with realistic distributed acoustic sources in a MHS sunspot atmosphere and compared the resultant simulation enhancements with multi-height SDO observations of the phenomenon. Simulated halos are in good qualitative agreement with observations. The authors also provide further proof that the underlying process responsible for the halo is the refraction and return of fast magnetic waves which have undergone mode conversion at the critical a = c atmospheric layer. Additionally, strong evidence is found that fast-Alfvn mode conversion plays a large part in the structure of the halo, essentially taking energy out of the system at favoured distances from the umbra, and may explain the observed dual-ring halo structure at higher (> 8 mHz) frequency.
(The Astrophysical Journal 2016, 817, 45)

(Carlos Rijs, S. P. Rajaguru, Damien Przybylski*, Hamed Moradi*, Paul S Cally*, Sergiy Shelyag*)*

Latitude character and evolution of Sun's Gnevyshev gap

Solar activity maximum is one of a dangerous phase, for space environment, which is observed as a valley, within the double peak, solar cycle structure. The time interval, between two highest peaks, during which activity energy is substantially absorbed, is called Gnevyshev gap (GG). This study focuses on mysterious evolution of the Gnevyshev gap by analyzing and comparing the integrated (over the whole sun) characteristics of magnetic field strength of sunspot groups, soft x-ray flare, filaments or prominences and polar faculae. The time latitude distribution of these solar activities from photosphere to coronal height, for the low (50^o) latitudes, shows the way Gnevyshev gap is evolved. The presence of double peak structure is noticed in high latitude ($> 50^o$) activity. During activity maximum the depression (or valley) in different activity processes probably due to (in this time interval) shifting, spreading, and transfer of energy from higher to lower latitudes and then continuous reversal of process from lower to higher latitudes with progress of cycle. The morphology of successive lower latitude zones, considering it as a wave pulse, appears to be modified /scattered, by certain degree due to shifting of magnetic energy to empower higher or lower latitudes.
(Submitted to Astrophysics and space science)

(K. M. Hiremath, K. K. Pandey, and G. Yellaiah*)*

Polarized light scattering on levels exhibiting combined hyperfine and fine structure interactions

The authors of the present work studied the interference between magnetic substates of the hyperfine structure states belonging to different fine structure states of the same atomic term. It influences the polarization for some of the diagnostically important lines of the solar spectrum, like the sodium and lithium doublets. The polariza-

tion signatures of this combined interference contain information on the properties of solar magnetic fields. With this motivation, using the Kramers–Heisenberg scattering matrix approach, the authors derived the redistribution matrix for this process by including the Paschen–Back (PB) effect and partial frequency redistribution effects. The authors explored the rich polarization structures that arise from various level crossings in the PB regime, in a single scattering case, using the D_1 and D_2 lines of the two stable isotopes of lithium (^{6}Li and ^{7}Li) as a concrete example that has relevance for the Sun.

In the Figure 2.5, the plots of net circular polarization (NCP) defined as $\int V d\lambda$ as a function of the magnetic field strength B (panels (a) and (b)) are presented. PB effect causes a non-linear splitting of the magnetic components with respect to the line center because of which the Stokes V profiles become asymmetric. As a result of this asymmetry, the integration of the Stokes V over full line profile yields a non-zero value. This non-zero NCP could serve as a tool for the magnetic field strength diagnostics. See Sowmya et al. (2015) for more details.

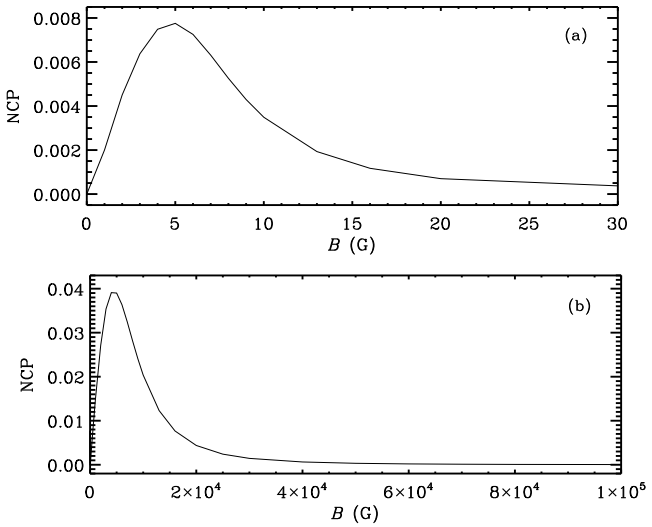


Figure 2.5: Net circular polarization as a function of the magnetic field strength B. A single 90° scattering is considered. The magnetic field is along the line-of-sight.

(ApJ, 2015, 814, 127)

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

Polarized line formation with lower-level polarization and partial frequency redistribution

In the well-established theories of polarized line formation with partial frequency redistribution (PRD) for a two-level atom, it is generally assumed that the lower level of the scattering transition is unpolarized. However the existence of unexplained spectral features in some lines of the Second Solar Spectrum points toward a need to relax this assumption. There exists a density matrix theory that accounts for the polarization of all the atomic levels, but it is based on the complete frequency redistribution approximation. In Supriya et al. (2016), a numerical algorithm to solve the problem of polarized line formation in magnetized media that includes both the effects of PRD and the lower level polarization (LLP) for a two-level atom was proposed. In the present study, the authors derive a collisionless redistribution matrix that includes the combined effects of the PRD and the LLP and then solved the relevant transfer equation using a two stage approach. For the purpose of illustration the authors considerd two case studies in the non-magnetic regime, namely, $1 \rightarrow 0 \rightarrow 1$ and $1 \rightarrow 1 \rightarrow 1$ transitions. Figure 2.6 shows the emergent (I, Q/I) at $\mu = 0.11$ for the $1 \rightarrow 1 \rightarrow 1$ transition. Figure clearly shows that the LLP effects in Q/I

are significant mainly in the core and in the wings the effects of PRD are dominant. This conclusion allowed the authors to propose an alternative approach called "correction method" to solve the problem at hand. This is a simplified numerical approach to solve the concerned radiative transfer problem.

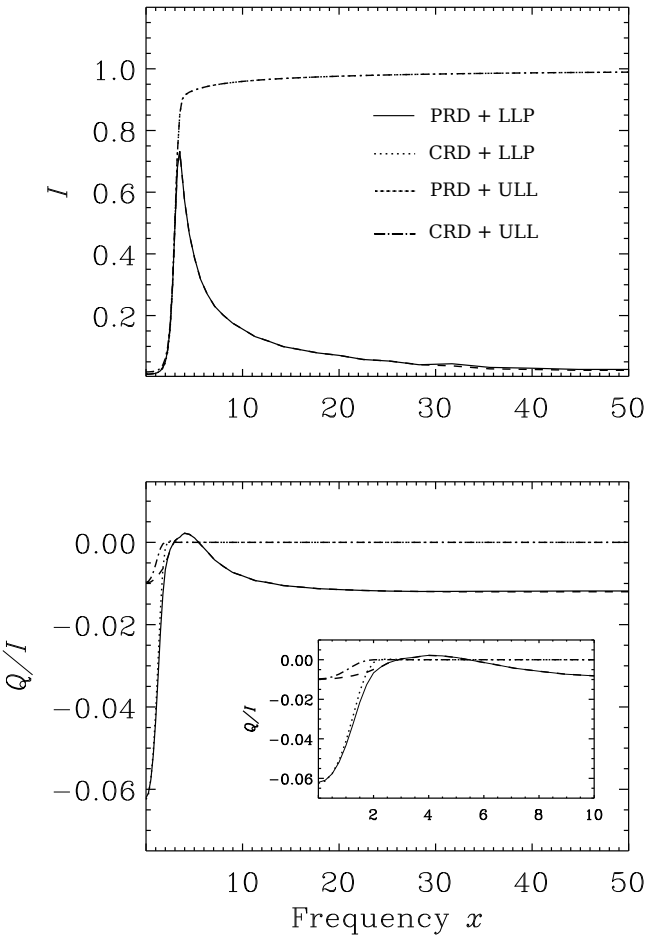


Figure 2.6: Emergent intensity and polarization profiles for a line-of-sight of $\mu = 0.11$ computed using the two stage approach for $J = 1 \rightarrow 1 \rightarrow 1$ case. The different line types show the influence of PRD and LLP. The abbreviation ULL stands for unpolarized lower level. The inset in Q/I panel shows the Q/I profiles for a shorter frequency bandwidth for the sake of clarity.

(ApJ, 2016, accepted for publication.)

(H. D. Supriya, M. Sampoorna, K. N. Nagendra, J. O. Stenflo, & B. Ravindra)*

Model of a flux tube with twisted magnetic field

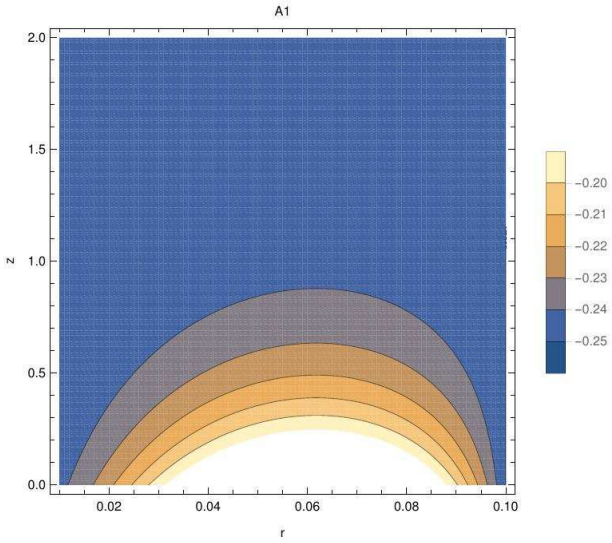


Figure 2.7: Contour plot of the magnetic flux function which represents the magnetic field lines confined inside the fluxtube. The r and z axes are in the units of 10^7 cm. The colour bar represents the magnitude of the flux fuction in the units of 10^{17} G-cm^2.

In this project, the authors assume a single open magnetic flux tube spanning the solar photosphere and the lower corona in magnetohydrostatic equilibrium within a realistic stratified atmosphere subject to solar gravity. The sunspot model with twisted magnetic fields is explored. From the Grad-Shafranov equation, the authors derive the magnetic flux function, $A(r, z)$ which is a complicated mathematical expression whose radial part

is a hypergeometric function and varies exponentially with the vertical height, assuming a specific algebraic form for the pressure, $p(A) = \frac{1}{8\pi^2\mu_0}aA^2 + \frac{1}{4\pi^2\mu_0}bA$ and poloidal current profile $F^2(A) = \frac{1}{\mu_0^2}\alpha A^2 + \frac{2}{\mu_0^2}\beta A + F_0^2$, where a, b, α, β are the four parameters. Using standard flux tube boundary conditions, with reasonable values of the flux tube radius, magnetic scale height, and realistic external pressure and density variations; a family of solutions that are dependent on the eigenvalue of the radial mode and a scale parameter b are found. The authors apply the condition of positivity of gas pressure to constrain the critical value of the scale parameter b which is 2.3×10^{-14} G-cm^{-2}. Using this the magnetic field structure, pressure and density inside the fluxtube are obtained. (Posters presented at Dynamic Sun-I conference, 22-25 February, 2016, Benaras Hindu University, Varanasi, and at at ASI, 10-13 May, 2016, University of Kashmir, Srinagar.)

(S. Sen and A. Mangalam)

Modelling of braided magnetic fields in the solar corona using analytic NLFFF solutions.

In the present work the authors apply their axisymmetric nonlinear force-free field (NLFFF) solutions to reconstruct three-dimensional magnetic field configurations for the solar corona from two dimensional photospheric vector magnetograms. Using the reconstructed configurations, the free energy and relative helicity for active regions AR 10930 and AR 11283 are calculated. The authors calculate the topological quantities like crossing numbers (using two different formulations) for the braided magnetic fields and study their statistical distribution. The crossing number distribution is used to estimate the free energy content and relative helicity for the active regions, which are found to be in good agreement with those obtained from the direct NLFFF calculations. The authors test a model of self-organized criticality (SOC) for the distribution of coherent braid sequences by comparing the resulting distribution of peak-flare energies with those obtained from NLFFF extrapolation. The fact that they are in good agreement imply that a significant component of the energy budget for coronal heating can potentially be supplied by nano- flares during reconnection of magnetic braids in the case of the active Sun.

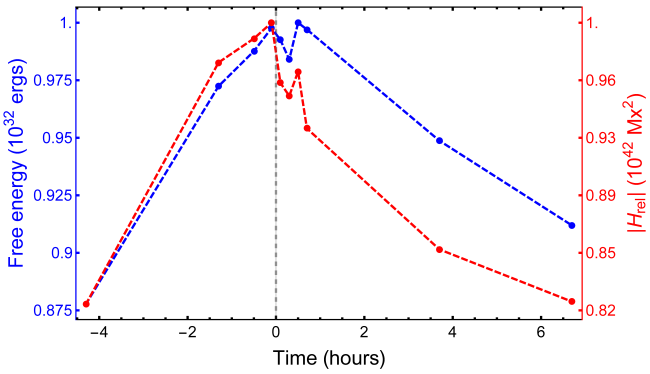


Figure 2.8: Evolution of free-energy (blue) and relative helicity (red) with time for AR 11283 on 06/09/2011. The origin in time axis corresponds to 22.20 hours when a X 2.1 class flare took place.

(Talk presented at Dynamic Sun I, IIT BHU, Varanasi, India.)

(A. Prasad & A. Mangalam)

2.2 Stellar and Galactic Astrophysics

Comprehensive abundance analysis of red giants in the open clusters NGC 1342, 1662, 1912, 2354 and 2447

The authors have observed high-dispersion echelle spectra of red giant members in the five open clusters (OCs) NGC 1342, NGC 1662, NGC 1912, NGC 2354 and NGC 2447 and determined their radial velocities and chemical compositions. These are the first chemical abundance measurements for all but NGC 2447. The authors combined the clusters from this study and their previous papers with a sample drawn from the literature for which the chemical abundances is remeasured to establish a common abundance scale. With this homogeneous sample of OCs, the authors study the relative elemental abundances of stars in OCs in comparison with field stars as a function of age and metallicity. The study finds a range of mild enrichment of heavy (Ba-Eu) elements in young OC giants over field stars of the same metallicity. The present analysis supports that the youngest stellar generations in cluster might be underrepresented by the solar neighbourhood field stars.
(MNRAS, 2015, 450, 4301)

(Arumalla B. S. Reddy, Sunetra Giridhar, David L. Lambert)

Chemical analysis of CH stars - II: Atmospheric parameters and elemental abundances

Authors present detailed chemical analyses for a sample of twelve stars selected from the CH star catalogue of Bartkevicius (1996). The sample includes two confirmed binaries, four objects that are known to show radial velocity variations and the rest with no information on the binary status. A primary objective is to examine if all these objects exhibit chemical abundances characteristics of CH stars, based on detailed chemical composition study using high resolution spectra. High resolution (R $\sim$ 42000) spectra from the ELODIE archive have been used for the analyses. These spectra cover 3900 Å to 6800 Å in the wavelength range. The authors have estimated the stellar atmospheric parameters, the effective temperature T_{eff}, the surface gravity log g, and metallicity [Fe/H] from LTE analysis using model atmospheres. The authors report updates on elemental abundances for several heavy elements, Sr, Y, Zr, Ba, La, Ce, Pr, Nd, Sm, Eu and Dy. For the object HD 89668, this happened to be the first abundance analyses results. Enhancement of heavy elements relative to Fe, a characteristic property of CH stars is evident from the analyses in case of four objects, HD 92545, HD 104979, HD 107574 and HD 204613. A parametric model based study is performed to understand the relative contributions from the s- and r-process to the abundances of the heavy elements.
(MNRAS, 446, 2348, (2015))

(Drisya Karinkuzhi and Aruna Goswami)

SUBARU/HDS study of CH stars: elemental abundances for stellar neutron-capture process studies

A comprehensive abundance analysis providing rare insight into the chemical history of lead stars is still lacking. The authors present results from high resolution ($R \sim$ 50 000), spectral analyses of three CH stars,

HD 26, HD 198269, HD 224959, and, a carbon star with a dusty envelope, HD 100764. Previous studies on these objects are limited by both resolution and wavelength regions and the results differ significantly from each other. The authors have undertaken to reanalyse the chemical composition of these objects based on high resolution Subaru spectra covering the wavelength regions 4020 to 6775 Å . Considering local thermodynamic equilibrium and using model atmospheres, the authors have derived the stellar parameters, the effective temperatures T_{eff}, surface gravities log g, and metallicities [Fe/H] for these objects. The stars are found to exhibit large enhancements of heavy elements relative to iron in conformity to previous studies. Large enhancement of Pb with respect to iron is also confirmed. Updates on the elemental abundances for several s-process elements (Y, Zr, La, Ce, Nd, Sm, Pb) along with the first-time estimates of abundances for a number of other heavy elements (Sr, Ba, Pr, Eu, Er, W) are reported. The present analysis suggests that neutron-capture elements in HD 26 primarily originate in s-process while the major contributions to the abundances of neutron-capture elements in the more metal-poor objects HD 224959 and HD 198269 are from r-process, possibly formed from materials that are pre-enriched with products of r-process. (MNRAS, 455, 402 (2016))

(Aruna Goswami, Aoki Wako, Drisya Karinkuzhi)*

Chemical compositions and kinematics of the Hercules stream

An abundance analysis is reported of 58-K giants identified as highly probable members of the Hercules stream selected from stars north of the celestial equator in the Hipparcos catalogue. The giants have compositions spanning the interval [Fe/H] from −0.17 to +0.42 with a mean value of +0.15 and relative elemental abundances [El/Fe] representative of the Galactic thin disc. Selection effects may have biased the selection from the Hipparcos catalogue against the selection of metal-poor stars. The authors′ reconsideration of the recent extensive survey by Bensby et al. of FG dwarfs, including metal-poor stars, provides a [Fe/H] distribution for the Hercules stream, which is similar to that from the 58 giants. It appears that the stream is dominated by metal-rich stars from the thin disc. The authors discuss suggestions in the literature that the stream includes metal-poor stars from the thick disc. (MNRAS, 2016, 460, 1356)

(P. Ramya, B.E. Reddy, D.L. Lambert, M.M. Musthafa)*

3-D Monte-Carlo Radiative Transfer Study of H-poor PN IRAS 18333–2357 located in M22

The author analyses the characteristics of dust and its distribution in the planetary nebula IRAS 18333–2357 located in M22 using a 3-D radiative transfer code Hochunk3D. SED was constructed using UV, optical and IR archival data. *Spitzer* 8 μm and $WISE$ 22 μm images are also used for the study. Taking the dust shell is carbon-rich, models are presented for amorphous carbon and graphite grains. The SED and the thermal images are fit well by the amorphous carbon model than the graphite model. The stellar photospheric temperature is (50000±3000)K. IRAS 18333–2357 has a 40^o inclined equatorial disk and a thin spherical shell around it, similar to

the inner geometry of the born-again PN A30. Incorporating the very small grain population, the excess emission in the 3- to 12 μm region is explained. The stellar bolometric luminosity is (2300±750)$L_\odot$ and the luminosity reprocessed by the very small grain and the classical grain populations are (22±5)$L_\odot$ and (570±150)$L_\odot$ respectively. Their respective masses are $(9.4\pm0.75)\times10^{-4}$ $M_\odot$ and $(3.1\pm0.24)\times10^{-3}$ $M_\odot$, leading to a total dust mass of $(2.86\pm0.22)\times10^{-2}$ $M_\odot$. The derived gas-to-dust mass ratio is 7.0. It is proposed that the hydrogen-deficient nebula resulted from a very late thermal pulse. *WISE* 22 μm image shows a faint outer shell, which may have H-rich matter ejected before the born-again event.
(MNRAS 2016 (in press))

(C. Muthumariappan)

RR Lyrae stars and the horizontal branch of NGC 5904 (M5)

In this study, the authors report the distance and [Fe/H] value for the globular cluster NGC 5904 (M5) derived from the Fourier decomposition of the light curves of selected RRab and RRc stars. Their aim in doing this was to bring these parameters into the homogeneous scales established by their previous work on numerous other globular clusters, allowing a direct comparison of the horizontal branch luminosity in clusters with a wide range of metallicities. Authors′ CCD photometry of the large variable star population of this cluster is used to discuss light curve peculiarities, like Blazhko modulations, on an individual basis. New Blazhko variables are reported.
(Ap&SS, 2016, 361, 175A)

(A. Arellano Ferro, A. Luna*, D. M. Bramich*, Sunetra Giridhar, J. A. Ahumada*, S. Muneer)*

Exploring the Onset of the Contribution of the First AGB Stars to the Galactic Chemical Enrichment using Isotopic Ratios

There is uncertainty over the time at which the first intermediate and low-mass stars reach the AGB phase and begin to influence their environments with the products of nucleosynthesis. While some studies have indicated that enrichment from AGB stars sets in at a time corresponding to $-2.4 <$ [Fe/H] < -2.1, others suggest a time as early as [Fe/H] ≈ -2.75. These suggestions come from observations of s-process heavy elements in old metal-poor stars. Measurements of stellar isotopic ratios, such as the Mg isotope ratios, can also be a useful probe to explore the contribution of AGB stars to the Galactic chemical inventory. However, measurements of isotopic ratios require spectra with high resolution ($R > 90000$) and high S/N ratios (> 200) which require very long exposure times with the existing observing facilities. Upcoming large telescopes of 25 to 42-m size equipped with high resolution spectrographs will provide the resolution and sensitivity required for measurements of isotopic ratios that are fundamental indicators of nucleosynthesis.
(ASPC, Vol 497, 523-528 (2015))

(Aruna Goswami)

Revisiting the variable star population in NGC 6229 and the structure of the horizontal branch

The authors report an analysis of new V and I CCD time series photometry of the distant globular cluster NGC 6229. They found 25 new variables: 10 RRab, 5 RRc, 6 SR, 1 CW, 1 SX Phe, and 2 were unable to be classified. Secular period changes were detected and measured in some favourable cases. The classifications of some of the known variables were rectified. The Fourier decomposition of RRab and RRc light curves was used to independently estimate the mean cluster value of [Fe/H] and distance. The authors found from the RRab stars, [Fe/H]UVES = -1.31 $\pm$ 0.01(statistical) $\pm$ 0.12(systematic) and a distance of 30.0 $\pm$ 1.5kpc; and from the RRc stars, [Fe/H]UVES = -1.29 $\pm$ 0.12 and a distance of 30.7 $\pm$ 1.1 kpc, respectively. Absolute magnitudes, radii and masses are also reported for individual RR Lyrae stars. The distribution of RR Lyrae stars in the horizontal branch shows a clear empirical border between stable fundamental and first overtone pulsators which has been noted in several other clusters; the authors interpret it as the red edge of the first overtone instability strip.
(MNRAS, 2015, 452, 727)

(A. Arellano Ferro, P. E. Mancera Piña*, D. M. Bramich*, Sunetra Giridhar, J. A. Ahumada*, N. Kains*, K. Kuppuswamy)*

Far-infrared study of K giants in the solar neighborhood: Connection between Li enrichment and mass-loss

The authors searched for a correlation between the two anomalous properties of K giants: Li enhancement and IR excess from an unbiased survey of a large sample of RGB stars. A sample of 2000 low-mass K giants with accurate astrometry from the Hipparcos catalog was chosen for which Li abundances have been determined from low-resolution spectra. Far-IR data were collected from the WISE and IRAS catalogs. To probe the correlation between the two anomalies, 15 Li-rich K giants discovered from this sample with 25 known Li-rich K giants from other studies were supplemented. Dust shell evolutionary models and spectral energy distributions were constructed using the code DUSTY to estimate different dust shell properties, such as dust evolutionary time scales, dust temperatures, and mass-loss rates. Results show that K giants with IR excess are very rare, similar to K giants with Li enhancement. This may be due to the rapid differential evolution of dust shell and Li depletion compared to RGB evolutionary time scales. The authors also infer from the results that during the bump evolution, giants probably undergo some internal changes, which are perhaps the cause of mass-loss and Li-enhancement events. However, the available observational results do not ascertain that these properties are correlated. That a few Li-rich giants have IR excess seems to be pure coincidence.
(A&A, 2015, 577, 10))

(Y. B. Kumar, B. E.Reddy, C.Muthumariappan, G. Zhao)*

Target Selection for the SDSS-III MARVELS Survey

The authors present the target selection process for the Multi-object APO Radial Velocity Exoplanets Large-area Survey (MARVELS), which is part of the Sloan Digital Sky Survey (SDSS) III. MARVELS is a medium-resolution (R $\sim$ 11,000) multi-fiber spectrograph capable of obtaining radial velocities

for 60 objects at a time in order to find brown dwarfs and giant planets. The survey was configured to target dwarf stars with effective temperatures approximately between 4500 and 6250 K. For the first 2 years MARVELS relied on low-resolution spectroscopic pre-observations to estimate the effective temperature and log (g) for candidate stars and then selected suitable dwarf stars from this pool. Ultimately, the pre-observation spectra proved ineffective at filtering out giant stars; many giants were incorrectly classified as dwarfs, resulting in a giant contamination rate of 30% for the first phase of the MARVELS survey. Thereafter, the survey instead applied a reduced proper motion cut to eliminate giants and used the Infrared Flux Method to estimate effective temperatures, using only extant photmetric and proper-motion catalog information. The target selection method introduced here may be useful for other surveys that need to rely on extant catalog data for selection of specific stellar populations.
(2015AJ....149..186)

(Martin Paegert, Keivan G. Stassun*, Nathan De Lee*, Joshua Pepper*, Scott W. Fleming*, Thirupathi Sivarani, Suvrath Mahadevan*, Claude E. Mack III*, Saurav Dhital*, Leslie Hebb*, Jian Ge*)*

Metal poor stars from MARVELS presurvey

Most of the large spectroscopic survey like SDSS and DESI are aimed to survey the high redshift universe and followup of these surveys can be possible only with 8-m class telescopes. The spectroscopic pre-survey of MARVELS has targeted stars between 8-13mag, which are accessible to smaller telescopes. APO-echelle and HESP spectrograph are used by the authors to study metal poor stars. Some of the MARVELS fields also overlap with Kepler and offers a way to compare high resolution spectroscopy with asteroseimology. The authors studied the elemental-abundance analysis of an extremely metal-poor (EMP; [Fe/H] < -3.0) star, SDSS J134338.67+484426.6, identified during the course of MARVELS pre-survey of some 20000 stars to identify suitable candidates for exoplanet searches. This star, with an apparent magnitude V = 12.14, is the lowest metallicity star found in the pre-survey, and is one of the only 20 known EMP stars that are this bright or brighter. The present high-resolution spectroscopic analysis shows that this star is a subgiant with [Fe/H] $= -3.42$, having 'normal' carbon and no enhancement of neutron-capture abundances. Strontium is underabundant, [Sr/Fe] $= -0.47$, but the derived lower limit on [Sr/Ba] indicates that Sr is likely enhanced relative to Ba. This star belongs to the sparsely populated class of α-poor EMP stars. The observed variations in radial velocity from several epochs of (low- and high-resolution) spectroscopic follow-up indicate that SDSSJ134338.67+484426.6 is a possible long-period binary.
(MNRAS, 458, 2648-2656, 2016)

(Susmitha Rani, A., T. Sivarani, T. C. Beers, S. Fleming*, S. Mahadevan*, J. Ge*)*

Study of Frequency ratio of QPOs in XRBs

One of the most interesting findings of X-ray timing analysis of the light curves of X-ray binaries (XRBs) in the past two decades has been the discovery of Quasi periodic os-

cillations (QPOs). Phenomenological explanation for detection of QPOs and 3:2 QPO ratio in XRBs have been given by different models like beat frequency model, relativistic precession model, tidal disruption model, and non-linear resonance model. The authors of this analysis have used expressions of orbital and radial frequencies as function of eccentricity and distance in Schwarzschild geometry to derive the range of eccentricity and radius from the black hole from where the frequency ratio of 1.5 ± 0.2 can arise. Results show that for $r > 18M$, the range of eccentricity to give required ratio becomes very narrow near $e \sim 0.7$ for all models. For circular orbits - Tidal disruption model and Non-linear resonance model give ratio between 1 to 2 for wide range of radii. Relativistic Precession model give required ratio for radii less than $10M$.

The authors considered the stationarity constraint in Kerr geometry for circular orbits with spin of the black hole and distance from central object as parameters for both retrograde and prograde motion. Results show that for high value of spin, smaller radii can emit to give required ratio and vice versa for prograde motion. For retrograde motion, required ratio comes from larger radii for high value of spin and vice versa for retrograde motion.

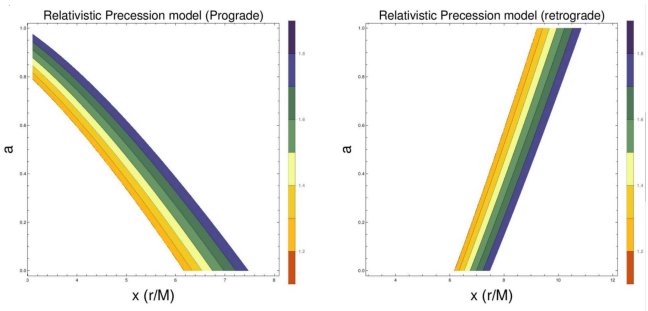


Figure 2.9: Frequency ratio contours of relativistic precession model as function of radius and spin in Kerr geometry.

(Talk presented in Jet Triggering Mechanisms in Black Hole Sources, TIFR Mumbai conference on 21 Januray, 2016.)

(Prerna Rana, A. Mangalam)

Angular momentum of Sun like G stars and their exoplanets

In the solar system, most of the angular momentum is distributed in planetary bodies rather in the Sun, and remains a mystery in understanding genesis of the solar system formation. In order to find the clues, the authors estimate the spin angular momentum (J_*) of the host stars, that follows a power law ($\alpha \frac{M_*}{M_\odot}^{(4.187 \pm 0.247)}$) with stellar mass ($\frac{M_*}{M_\odot}$). The orbital angular momenta (L_p) of exoplanets are estimated and a best fit yields a power law ($\alpha \frac{m_p}{m_J}^{(1.2370.033)}$) with planetary mass ($\frac{m_p}{m_J}$), yielding terrestrial planets have very low orbital angular momentum compared to those of exoplanets. In order to match with the average orbital angular momentum of the exoplanets, present mass of all the solar terrestrial planets has to be increased substantially ($\sim$ 150 times), suggesting that there is missing mass in the vicinity of Sun. Further, the total (spin and orbital) angular momentum L_{tot} of the stellar system is computed and a power law of the form $L_{tot}(\alpha \frac{m_p}{m_J}^{(0.637 \pm 0.032)}$ is obtained. This study also suggests that Jupiter and Saturn migrated outward during the early history of solar system formation. The authors find that the probability of detecting Earth like planets is more likely for host stars that have total angular momentum $\sim 10^{42}\ kgm^2/sec$. From the relation between masses of the exoplanets and their orbital distances, clues for

missing mass in the vicinity of Sun are obtained.
(Submitted to MNRAS)

(K. M. Hiremath, R. Shashanka, and V. Ramasubramanian*)*

Metallicity of Sunlike G stars that have exoplanets

By considering the physical and orbital characteristics of G type stars and their exoplanets, the authors examine the association between stellar mass and its metallicity that follows a power law. Similar relationship is also obtained in case of single and multiplanetary stellar systems suggesting that, Sun's present mass is about 1% higher than the estimated value for its metallicity. Further, for all the stellar systems with exoplanets, association between planetary mass and the stellar metallicity is investigated, that suggests planetary mass is independent of their stellar metallicity. Interestingly, in case of multiplanetary systems, planetary mass is linearly dependent on the stellar absolute metallicity. That means, metal rich stars produce massive ($\geq$ 1 Jupiter mass) planets compared to metal poor stars. This study also suggests that there is a solar system planetary missing mass of $\sim$ 0.8 Jupiter mass. It is argued that probably 80% of missing mass is accreted onto the Sun and about 20% of missing mass might have been blown off to the outer solar system, beyond the present Kuiper belt, during early history of solar system formation. The 20% of planetary missing mass beyond Kuiper belt of solar system is estimated to be $\sim$ 60 Earth mass. In the case of single planetary systems, the authors have found that planetary mass is independent of stellar metallicity. Interestingly, the present study also suggests that planets of single planetary systems are not originated and formed in the host stars protoplanetary disk, instead they might have been captured from the space. Final investigation of dependency of semi major axis of the planets with respect to host star metallicity reveals that inward migration of planets is dominant in case of single planetary systems supporting the result that most of the planets in single planetary systems are captured from the space.
(Submitted to JAA)

(K. M. Hiremath, R. Shashanka, and V. Ramasubramanian*)*

Very Low-Mass Stellar and Substellar Companions to Solar-like Stars From MARVELS VI: A Giant Planet and A Brown Dwarf Candidate in a Close Binary System HD 87646

The authors report the detections of a giant planet (MARVELS-7b) and a brown dwarf candidate (MARVELS-7c) around the primary star in the close binary system, HD 87646. The work is submitted to AJ. The detection of this giant planet was accomplished using the first multi-object Doppler instrument (KeckET) at the Sloan Digital Sky Survey (SDSS) telescope. Subsequent radial velocity observations using ET at Kitt Peak National Observatory, HRS at HET, the spectrograph at Fairborn observatory and MARVELS from SDSS-III confirmed this giant planet discovery and revealed existence of a long-period brown dwarf in this binary. HD 87646 is a close binary with a separation of $\sim$22 AU between the two stars, estimated using Hipparcos catalogue and the newly acquired Palomar AO image. The primary star in the binary,

HD 87646A, has T_{eff} = 5770±80K, log g =4.1±0.1 and [Fe/H] = −0.17±0.08. The derived minimal masses of the two substellar companions of HD 87646A are 12.39±0.60 M_{Jup} and 55.6±2.7 M_{Jup}. The periods are 13.4815±0.0001 days and 674.4±1.9 days and the measured eccentricities are 0.049±0.012 and 0.499±0.003 respectively. The authors conclude by using their dynamical simulations that the system is stable if the binary has a large semi-major axis and a low eccentricity, which could be verified with future astrometry observations.
(Submitted to AJ March 2016)

(Ma et al. and 31 authors including T. Sivarani as 19th author in alphabetical listing after the first 4th authors)

Low Frequency Radio Observations of Recurrent Novae

The 2014 outburst of the recurrent nova V745 Sco was monitored in the 610 and 235 MHz using the Giant Metrewave Radio Telescope (GMRT). The 610 MHz light curve was fitted by a model of synchrotron emission from an expanding shell being modified by radiative transfer effects due to local absorbing gas consisting of a uniformly distributed and a clumpy component. Using the model parameters, the emission at 235 MHz was modelled to peak around day 35, which was consistent with the observations. The low frequency light curve evolution of V745 Sco was compared with the evolution of the 2006 outburst light curve of RS Ophiuchi at the same frequencies. The two main results of the study are (1) The radio emission at a given frequency is visible sooner after the outburst in successive outbursts of both V745 Scorpii and RS Ophiuchi. The earlier detection of radio emission is interpreted to be caused by decreasing foreground densities. (2) The clumpy material, if exists, is close to the white dwarf and can be interpreted as being due to the material from the hot accretion disc. The uniform density gas is widespread and attributed to the winds blown by the white dwarf. The implications of these results on the evolution of both novae were studied. Such studies, along with theoretical understanding have the potential of resolving several outstanding issues such as why all recurrent novae are not detectable in synchrotron radio and whether recurrent novae are progenitor systems of Type 1a supernova.
(MNRAS, 2016, 456, L49)

(N.G. Kantharia, P. Dutta*, N. Roy*, G.C. Anupama, C.H. Ishwara-Chandra*, A. Chitale*, T.P. Prabhu, D.P.K. Banerjee*, N.M. Ashok*)*

The type Ia supernova SN 2014J

The type Ia supernova SN 2014J in M82 was monitored in detail in the optical and NIR using the HCT. The observed light curves were found to be similar to normal SNe Ia, with a decline rate parameter $\Delta m_{15}(B) = 1.08 \pm 0.03$. The optical spectra showed a red continuum with deep interstellar Na I absorption, but otherwise resembled those of normal SNe Ia. The Si II 6355 Å feature indicated a velocity of $\sim$ 12000 km s^{-1} at B-band maximum, which placed SN 2014J at the border of the Normal Velocity and High Velocity group of SNe Ia. The velocity evolution of SN 2014J placed it in the Low Velocity Gradient subclass, whereas the equivalent widths of Si II features near B-band maximum placed it at the border of the Core Normal and Broad Line subclasses

of SNe Ia. An analytic model fit to the bolometric light curve indicated that a total of $\sim 1.3 M_{\odot}$ was ejected in the explosion, and the ejected ^{56}Ni mass was $\sim 0.6 M_{\odot}$. The presence of clumpiness in the ejecta was inferrred based on the low [Fe III] 4701 Å to [Fe II] 5200 Å ratio in the nebular spectra. Optical broadband, linear polarimetric observations of SN 2014J obtained on four epochs indicated an almost constant polarization ($P_R \sim 2.7$ % ; $\theta \sim 37^0$), which suggested an interstellar origin.
(MNRAS, 2016, 457, 1000)

(S. Srivastav, J.P. Ninan, B. Kumar, G.C. Anupama, D.K. Sahu, D.K. Ojha*, T.P. Prabhu)*

Age Aspects of Habitability

The concept of the habitability implies a water-containing rocky Earth-like planet orbiting a Solar-type star at a distance of around 1 AU. However, this requirement only characterizes a potential of a planetary system to sustain life. When a possibility of the existence of life is questioned, the age of a planetary system becomes of a primary importance. The authors discuss here how plausible is a discovery of a habitable planet with biota on it among the closest (within 600 pc) neighbours of the Sun. The authors argue that even for known habitable planets possible variations in their albedo, diameters, orbits and other critical parameters, the onset of photosynthesis and a formation of oxygen atmosphere may take much longer time than the planetary age. They show that at least a third out of confirmed habitable planets are too young to already have developed detectable biota on them. The authors argue that old Population II stars with ages up to 13 Gyr can host habitable planets with the already existing life on them, and discuss the prospects of detecting it.
(International Journal of Astrobiology, 15, 93, 2016)

(M. Safonova, J. Murthy and Yu. A. Shchekinov)*

CD-HPF: New Habitability Score Via Data Analytic Modeling

Search for life on planets outside the Solar System can be broadly classified into the following: looking for planets similar to Earth (Earth similarity), and looking for the possibility of life in a form known or unknown to us (habitability). Two frequently used indices, Earth Similarity Index and Planetary Habitability Index, describe heuristic methods to score similarity /habitability in the efforts to categorize different exoplanets. ESI considers Earth as the reference frame and is a quick screening tool to categorize and measure physical similarity of any planetary body with the Earth. The PHI assesses the probability that life in some form may exist on any given world. The authors of the present work propose a different metric, a Cobb-Douglas Habitability Score (CDHS), based on Cobb-Douglas habitability production function (CD-HPF), which computes the habitability score by using measured and calculated planetary input parameters. As an initial set, they used radius, density, escape velocity and surface temperature of a planet normalized to the Earth Units. The proposed metric, with exponents accounting for metric elasticity, is endowed with verifiable analytical properties that ensure global optima, and is scalable to accommodate finitely many input parameters. The model is elastic,

does not suffer from curvature violations and the standard PHI turned as a special case of CDHS. Computed CDHS scores are fed to K-NN classification algorithm that facilitates the assignment of exoplanets to appropriate classes via supervised feature learning, producing granular clusters of habitability. Proposed work describes a decision-theoretical model using the power of convex optimization and algorithmic machine learning.

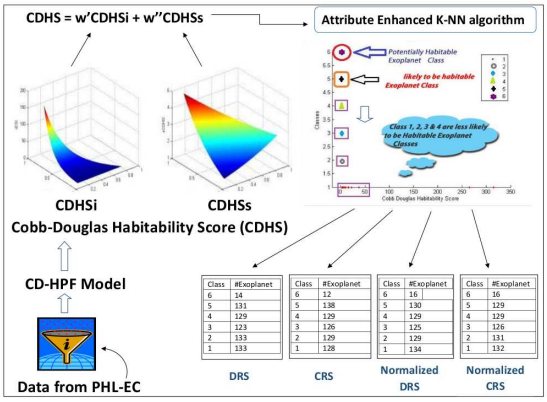


Figure 2.10: Graphical abstract illustrating the article

(Astron. and Comp., 2016, Submitted.)

(Kakoli Bora, Snehanshu Saha*, Surbhi Agrawal*, Margarita Safonova, Swati Routh*, Anand Narasimhamurthy*)*

2.3 Cosmology and extra galactic astronomy

Near-Infrared Imaging of Barred Halo Dominated Low Surface Brightness Galaxies

The authors present a near-infrared (NIR) imaging study of barred low surface brightness (LSB) galaxies using the TIFR near-infrared Spectrometer and Imager (TIRSPEC). LSB galaxies are dark matter dominated, late type spirals that have low luminosity stellar disks but large neutral hydrogen (HI) gas disks. Using SDSS images of a very large sample of LSB galaxies derived from the literature, it is found that the barred fraction is only 8.3%. Twenty five barred LSB galaxies in the J,H,K_S wave-bands and twenty nine in the K_S band are imaged. Most of the bars are much brighter than their stellar disks, which appear to be very diffuse. The image analysis gives deprojected mean bar sizes of Rb/R25 = 0.40 and ellipticities e $\approx$ 0.45, which are similar to bars in high surface brightness galaxies. Thus, although bars are rare in LSB galaxies, they appear to be just as strong as bars found in normal galaxies. There is no correlation of Rb/R25 or e with the relative HI or stellar masses of the galaxies. In the (J-K_S) color images most of the bars have no significant color gradient which indicates that their stellar population is uniformly distributed and confirms that they have low dust content.
(MNRAS, 2016, in press.)

(M. Honey, M. Das, J.P. Ninan, M. Purvankara*)*

GMRT HI 21 cm study of giant low surface brightness galaxies

The authors present HI observations of four giant low surface brightness (GLSB) galaxies UGC 1378, UGC 1922, UGC 4422 and UM 163 using the Giant Meterwave Radio Telescope (GMRT). They include HI results on UGC 2936, UGC 6614 and Malin 2 from literature. HI is detected from all the galaxies and the extent is roughly twice the optical size; in UM163, HI is detected along a broken disk encircling the optical galaxy. The present results are combined with those in literature to further understand these systems. The main results are the following: (1) The peak HI surface densities in GLSB galaxies are several times 10^{21} cm^{-2}. The HI mass is between $0.3 - 4{\times}10^{10}$ M$_{\odot}$, dynamical mass ranges from a few times 10^{11} M$_{\odot}$ to a few times 10^{12} M$_{\odot}$. (2) The rotation curves of GLSB galaxies are flat to the outermost measured point with rotation velocities of the seven GLSB galaxies between 225 and 435 km/s. (3) Recent star formation traced by near-ultraviolet emission in five GLSB galaxies in the present sample appears to be located in rings around the galaxy centre. It is suggested that this could be due to a stochastic burst of star formation at one location in the galaxy being propagated along a ring over a rotation period. (4) The HI is correlated with recent star formation in five of the seven GLSB galaxies. Little correlation is found for one (UM 163) of the GLSB galaxy. (MNRAS, 2016, under revision.)

(Alka Mishra, N. G. Kantharia*, M. Das, A. Omar* and D. C. Srivastava*)*

Doppler-beamed AGN Jets, their Parsec-scale Environments and the Blazar Divide

Most if not all accreting supermassive black holes appear to produce bipolar outflows of hot gas and bipolar synchrotron-emitting plasma jets. While these jets typically appear quenched well within their host galaxies, in a small minority, they are launched at relativistic speeds, and their large kinetic power takes them to scales of several hundred kiloparsecs. At small inclinations to the line of sight, these jets are Doppler beamed, and called Blazars. The authors investigate a sample of these Blazars at multiple frequencies, including gamma-rays (data from the Fermi telescope) and radio frequencies (imaging data from the MOJAVE project). The hypothesis that the Blazar divide constitutes a dichotomy is tested. For samples dominated by highly Doppler-beamed active galactic nuclei, there are limitations to using the standard radio core-dominance parameter as a statistical measure of orientation. The ratio of nuclear optical emission to host galaxy emission is an alternate measure to probe the Doppler factor in the context of the Blazar divide. The systematics of the gamma-ray emission are consistent with the Blazar divide being a dichotomy.
(APS Meeting 2015, 2015APS..APRX14005S; 2015IAUGA..2257341S)

(P. Shastri, M. Gupta, B. Rani*, E. Jimenez-Gomez*, G. Madejski*)*

A GMRT study of Seyfert galaxies NGC 4235 and NGC 4594: evidence of episodic activity?

Low-frequency observations at 325 and 610 MHz have been carried out for two 'radio-loud' Seyfert galaxies, NGC 4235 and NGC 4594 (Sombrero galaxy), using the Giant Meterwave Radio Telescope (GMRT). The 610 MHz total intensity and 325-610

MHz spectral index images of NGC 4235 tentatively suggest the presence of a 'relic' radio lobe, most likely from a previous episode of active galactic nucleus (AGN) activity. This makes NGC 4235 only the second known Seyfert galaxy after Mrk 6 to show signatures of episodic activity. Spitzer and Herschel infrared spectral energy distribution (SED) modelling using the CLUMPYDREAM code predicts star formation rates (SFRs) that are an order of magnitude lower than those required to power the radio lobes in these Seyferts ($\sim$ 0.13 – 0.23 $M_\odot$ yr^{-1} compared to the required SFR of $\sim$ 2.0 – 2.7 $M_\odot$ yr^{-1} in NGC 4594 and NGC 4235, respectively). This finding along with the detection of parsec and sub-kpc radio jets in both Seyfert galaxies, that are roughly along the same position angles as the radio lobes, strongly support the suggestion that Seyfert lobes are AGN powered. SED modelling supports the 'true' type 2 classification of NGC 4594: this galaxy lacks significant dust obscuration as well as a prominent broad-line region. Between the two Seyfert galaxies, there is an inverse relation between their radio-loudness and Eddington ratio and a direct relation between their Eddington-scaled jet power and bolometric power.

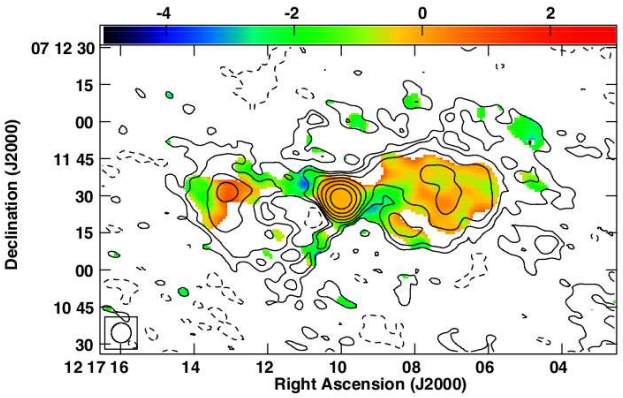


Figure 2.11: 325-610 MHz spectral index images in colour overlaid with 610 MHz radio contours for NGC 4235. The average spectral index is $\sim$ –0.6 in the lobes.

(MNRAS, 2016, 459, 1310)

(P. Kharb, S. Srivastava, V. Singh*, J. F. Gallimore*, C. H. Ishwara-Chandra*, Ananda Hota*)*

Gamma-ray emitting NLSy1 galaxies

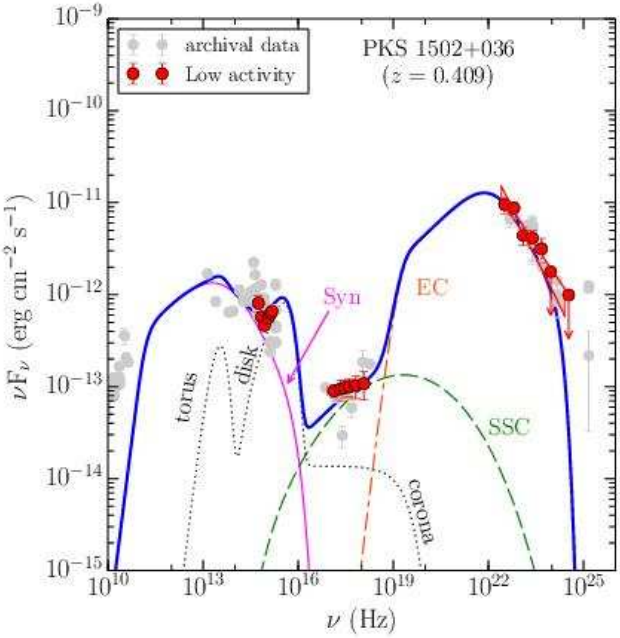


Figure 2.12: Broad band spectral energy distribution of PKS 1510-089 during the low activity state. Here red points are the quasi-simultaneous observations, whereas grey points are the archival data.

Narrow line Seyfert 1 (NLSy1) galaxies are a sub class of AGN with properties different from the conventional broad line Seyfert 1 galaxies. They in general host low mass (10^6 - 10^8 $M_\odot$) black holes accreting close to the Eddington limit. They are hosted by spiral

galaxies and about 7% of NLSy1 galaxies are found to be radio-loud contrary to the 15% we know for quasars. The Large Area Telescope (LAT) instrument on board the Fermi Gamma-ray Space Telescope has as of now detected gamma-ray emission in about half a dozen NLSy1 galaxies, which confirms the presence of relativistic jets in them. Several episodes of gamma-ray flaring activity have been observed in some of the gamma-ray emitting NLSy1 galaxies, however, their jets are less luminous compared to flat spectrum radio quasars. One among the gamma-ray emitting NLSy1 galaxies, PKS 1510−089 exhibited its first gamma-ray outburst in 20 December 2015 (Vaidehi S. Paliya & C. S. Stalin, 2016, ApJ, 820, 52). In this source, the optical-UV part of the broad band spectral energy distribution is explained by a combination of synchrotron and accretion disk emission, whereas the high energy X-ray and gamma-ray emission is well fit by inverse Compton scattering of torus photons. Intra-night optical variability (INOV) observations from the Himalayan Chandra Telescope (HCT) on another gamma-ray emitting NLSy1 galaxy SBS 0846+513 show the source to show large amplitude INOV on all the 6 nights of observations similar to what is known for blazars.
(ApJ, 2016, 820, 52.)

(Vaidehi S. Paliya, C. S. Stalin)

Frequency dependent core shifts and parameter estimation for the blazar 3C 454.3

The author studies the core shift effect in the parsec scale jet of the blazar 3C 454.3. The study is conducted using the 4.8 GHz - 36.8 GHz radio light curves obtained from three decades of continuous monitoring of this bright, strongly variable source. From a piece wise Gaussian fit to each flare, time lags Δt between the observation frequencies ν and spectral indices α based on the flare amplitudes A were determined. An equipartition between the magnetic field energy density and the particle energy density based on $k_r \sim 1$ is inferred from the fit $\Delta t \propto \nu^{1/k_r}$. From the fit $A \propto \nu^{\alpha}$, α is in the range -0.70 and 1.52. A magnetic field strength at 1 pc, $B_1 = 0.51 - 0.62$ G and an average of $B_{\rm core} = (0.07 - 0.08)$ G for the emitting core are obtained, consistent with that obtained in previous studies of this source. The core position offset $\Omega_{r\nu} = 6.38 - 8.57$ pcGHz when averaged over all frequency pairs. A Fourier periodogram analysis yields power law slopes in the range -1.9 to -3.5 to represent the shape of the underlying power spectral density at lower temporal frequencies. This result and the positive and negative values of α indicate that the flared emission originates due to multiple shocks. Important objectives met in the present study include the demonstration of the computational efficiency and statistical basis of the piece-wise Gaussian fit; its applicability to a wide range of light curves; the check for consistency with previously reported results; the evidence it provides for the core shift dependence on the observation frequency and its usefulness in the determination of jet diagnostics in the region close to the resolving limit of very large baseline interferometric observations.

(Arun Mangalam)

Cosmic evolution of AGN using self-consistent black hole energetics

In the present study, the author considers a model that takes into account the mass and

spin accreted by the hole and the angular momentum torque due to an electro-dynamical jet. The spin evolution is calculated with and without accretion; if the accretion stops 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 also been calculated for the case of Bondi accretion, thin disk and an MHD disk. The results indicate that the black hole achieves the maximum spin value when there is no jet. It is planned to compare this with fully relativistic MHD simulations.

(Arun Mangalam)

A Global Galactic Dynamo with a Corona Constrained by Relative Helicity

The authors present a model for a global axisymmetric turbulent dynamo operating in a galaxy with a corona that treats the parameters of turbulence driven by supernovae and by magneto-rotational instability under a common formalism. The nonlinear quenching of the dynamo is alleviated by the inclusion of small-scale advective and diffusive magnetic helicity fluxes, which allow the gauge-invariant magnetic helicity to be transferred outside the disk and consequently to build up a corona during the course of dynamo action. The time-dependent dynamo equations are expressed in a separable form and solved through an eigenvector expansion constructed using the steady-state solutions of the dynamo equation. The parametric evolution of the dynamo solution allows to estimate the final structure of the global magnetic field and the saturated value of the turbulence parameter α_m, even before solving the dynamical equations for evolution of magnetic fields in the disk and the corona, along with α-quenching. The authors then solve these equations simultaneously to study the saturation of the large-scale magnetic field, its dependence on the small-scale magnetic helicity fluxes, and the corresponding evolution of the force-free field in the corona. The quadrupolar large-scale magnetic field in the disk is found to reach equipartition strength within a timescale of 1 Gyr. The large-scale magnetic field in the corona obtained is much weaker than the field inside the disk and has only a weak impact on the dynamo operation.

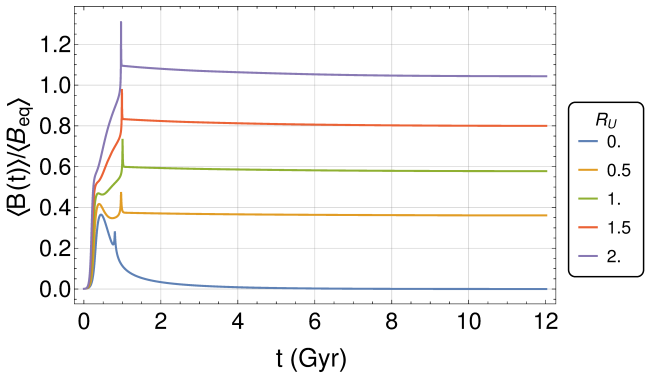


Figure 2.13: The evolution of the mean magnetic field (in units of equipartition field strength) for the galactic disc with time for different values of advection parameter R_U. The mean magnetic field in the disk is found to reach equipartition strength within a timescale of 1 Gyr.

(ApJ, 2016, 817, 12)

(A. Prasad & A. Mangalam)

The Interplay between AGN Outflows and their Host Galaxies

It is well-known that accreting supermassive black holes must impact star-formation in their host galaxies. Understanding this mechanism perhaps holds the key to explaining the well-established but not so well-understood scaling relationships of supermassive black holes. In this context the authors have undertaken a spectroscopic imaging survey of a sample of ∼140 nearby active galaxies with an integral field unit mounted on the Siding Spring 2.3-m telescope, in order to investigate connections between their nuclear properties and extended emission-line regions, star-formation regions and radio structures. Follow-up radio imaging with the GMRT and ATCA is also being done. Integrated spectra for over half the sample are included in the first data release. The radio-IR scatterplot for the sample shows excess radio emission over that predicted by star formation in most cases, which is clearly due to the AGN. Nearly all the observed Seyfert galaxies have an extended emission-line region, often within a star formation ring of a few kpc across, which may be interpreted as the Inner Lindblad Resonance. With sufficient spatial resolution, the narrow-line regions showing elongated and sometimes biconical morphology, aligned with the radio jet are seen. The narrow-line regions are dynamically active over kpc-scales and emission-line diagnostics indicate that they are radiation-pressure dominated at least initially and sometimes throughout. Thus accreting central supermassive black holes can indeed regulate star formation in their hosts well beyond their sphere of influence in active galaxies.
(ApJS 217, 12; AIPC 1697, 110002.)

(P. Shastri, M. Dopita, L. Kewley*, R. Davies*, J. Scharwaechter*, R. Sutherland*, P. Kharb, J. Maithil*, A.M. N. Sundar*, AP. Muralimohan* and the S7 team)*

$M_\bullet - \sigma$ Relation and Galactic Structure

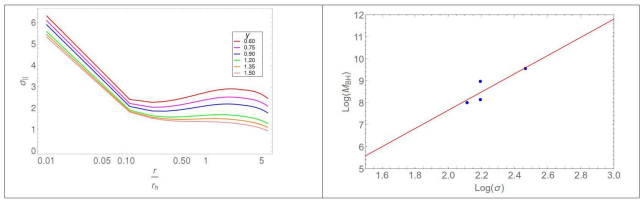


Figure 2.14: Plot of velocity dispersion (in units of $\frac{GM_\bullet}{r_h}$) against projected radius for single power law galaxies (left), log σ vs log $M_\bullet$ plot for four galaxies (NGC 3115, NGC 4486, NGC 3379, NGC 4551) along with the fitted straight line with slope 4.15, σ^2 is in unit of potential and $M_\bullet$ is in units of solar mass (right).

The authors consider elliptical galaxy cusps that follow a single power law profile given by $\rho(r) = \rho_0(r/r_0)^{-\gamma}$ and calculate the stellar potential. They then derive the distribution function of the stars in presence of the supermassive black hole (SMBH) at the center from the total potential and compute the line of sight (LOS) velocity dispersion assuming the system to have a spherical symmetry. For a range of values for masses of SMBH, $M_\bullet \propto \sigma^p$ for different power law profiles are derived, where p = 3.5 – 4.5. Taking typical values of $\sigma_{||}$ and approximate range of values of r_0, a range for ρ_0 is derived. For galaxies whose intensity profiles are described by the Nuker profile, mass density is calculated using the Abel inversion formula and obtain the stellar potential assuming spherical symmetry. From the total potential using the Eddington's formula the distribution function of stars is obtained and the resulting velocity dispersion along the LOS. Assuming that

a proportionality relation holds between M_{Bulge} and $M_\bullet$ and applying that to several galaxies to find $M_\bullet \propto \sigma^{4.15}$. For both power and Nuker profiles it is concluded that the model is in agreement with observational values.
(Poster presented at ASI, 10 - 13 May, 2016, University of Kashmir, Srinagar.)

(Dipanweeta Bhattacharyya & Arun Mangalam)

Stellar and Gas Dynamical Model for Tidal Disruption Events in a Quiescent Galaxy

A detailed model of the tidal disruption events (TDEs) has been constructed using stellar dynamical and gas dynamical inputs that include black hole (BH) mass $M_\bullet$, specific orbital energy E and angular momentum J, star mass $M_\star$ and radius $R_\star$, and the pericenter of the star orbit $r_p(E, J, M_\bullet)$. The authors solved the steady state Fokker–Planck equation using the standard loss cone theory for the galactic density profile $\rho(r) \propto r^{-\gamma}$ and stellar mass function $\xi(m)$ where $m = M_\star/M_\odot$ and obtained the feeding rate of stars to the BH integrated over the phase space as $\dot{N}_t \propto M_\bullet^\beta$, where $\beta = -0.3 \pm 0.01$ for $M_\bullet > 10^7 M_\odot$ and $\sim 6.8 \times 10^{-5}$ Yr^{-1} for $\gamma = 0.7$. The values are used to model the in-fall rate of the disrupted debris, $\dot{M}(E, J, m, t)$, and discuss the conditions for the disk formation, finding that the accretion disk is almost always formed for the fiduciary range of the physical parameters. The light curve profiles are simulated in the relevant optical g band and soft X-rays for both super and sub-Eddington accretion disks as a function of $\dot{M}(E, J, t)$. Using this, standard cosmological parameters, and mission instrument details, the authors predict the detectable TDE rates for $\gamma = 0.7$ in optical g band for LSST to be $\sim$ 5003 yr^{-1}, PanSTARRS in 3π survey to be $\sim$ 6337 yr^{-1} and in deep imaging survey to be $\sim$ 12.3 yr^{-1} and for eROSITA in the soft X-ray band is about $\sim$ 679.5 yr^{-1}.

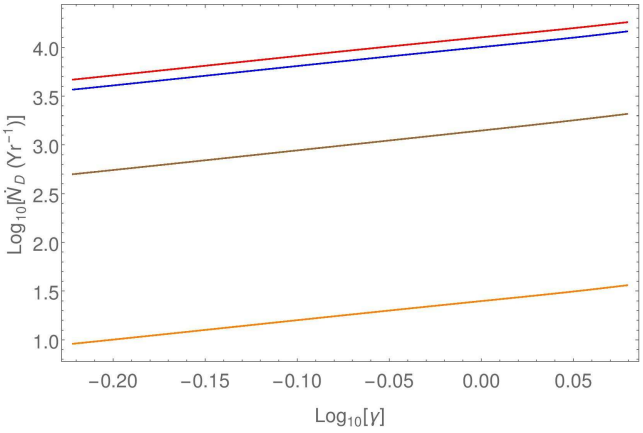


Figure 2.15: The detectable rate, $\dot{N}_D$, as a function of γ for LSST (blue), Pan-STARRS 3π (red), Pan-STARRS MDS (orange), and eROSITA (brown).

(ApJ, 2015, 814, 141)

(T. Mageshwaran & A. Mangalam)

Accretion and wind dynamics of tidal disruption events

A supermassive black hole influences the orbital and spatial distribution of stars in the inner parsec region of its host galaxy which together determine the ingestion rate of stars; this results in tidal disruption events (TDEs) where the stars are disrupted by the strong tidal gravity of the hole and subsequently the shredded debris forms an accretion disk around the black hole. The

authors have self consistently calculated the time evolution of non-relativistic time dependent accretion disk for both sub-Eddington and super Eddington disk with outflowing wind. The viscous stress is taken to be $\Pi_{r\phi} \propto \Sigma_d^b r^c$ where Σ_d is the surface density of the disk, r is the radius and b and c are constants. For a sub-Eddington disk, the disk is considered to be gas pressure dominated with $b = 5/3$ and $c = -1/2$ whereas for the super-Eddington disk, an extended disk is considered with pressure $P \propto \rho^\gamma$ which results in $b = \gamma$ and $c = 1 - \gamma$. A power law solution of surface density Σ_d is obtained and then calculated the luminosity profile in various spectral bands. The model is fitted to the observations in optical and X-ray bands and deduced the parameters such as black hole mass $M_\bullet$, star mass $M_\star$ and radius $R_\star$ and initial orbital energy E and angular momentum J of the star.

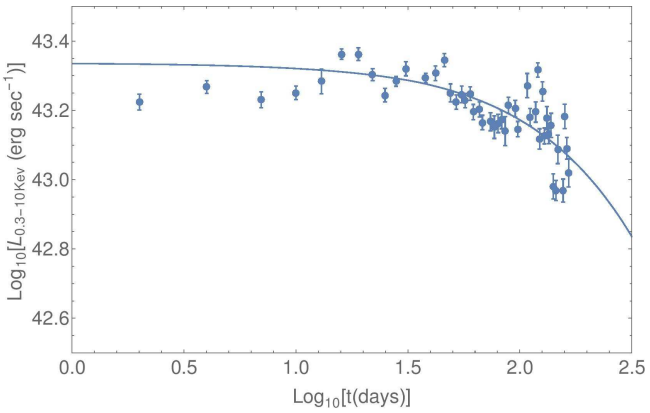


Figure 2.16: The sub Eddington model fit to the X-ray observation ASASSN-14li by ASAS-SN survey. The fit parameters are $\bar{e} = 10^{-3}$, $\ell = 0.32$, $M_6 = 2.2$ and $M_\star = 1.2 M_\odot$ (Holoien et al. 2016) where $\bar{e} = E/(GM_\bullet/r_t)$, $\ell = J/J_{lc}$, $M_\bullet = 10^6 M_\odot M_6$ and r_t is the tidal radius.

(Poster presented at ASI 2016, University of Kashmir, Srinagar)

(T. Mageshwaran & A. Mangalam)

Flux and colour variation in quasars

Flux variations over the accessible electromagnetic spectrum, from low energy radio waves to high energy gamma-rays is one of the defining characteristics of active galactic nuclei (AGN). Such observed variations that are commonly aperiodic in nature are known to occur on a wide range of time scales from days to years. The observed variations in flux are also generally associated with changes in the spectra of the sources. Different claims of the nature of colour variations in quasars (a category of AGN) relative to their continuum flux changes are available in nature. However, such studies do not taken into account the correlation between the errors in the colours and the magnitudes. This problem was investigated using a sample of 59 quasars from the Massive Compact Halo Object (MACHO) project. These sources have observations in V and R-band that spans for about 7.5 years. Using the Markov Chain Monte Carlo approach and properly taking into account the correlation between the errors in colour and magnitude, it is found that majority of the quasars show a bluer when brighter trend. This study also demonstrates that the ordinary linear least squares technique normally used to study colour variations in quasars is not the correct approach to use. In this sample it is found that in a majority of sources, the excess variance is more in the V-band compared to the R-band (see Fig.).

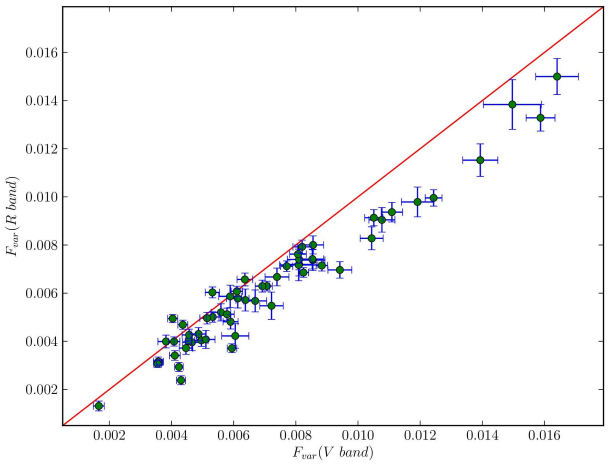


Figure 2.17: Flux variations between V and R bands.

(RAA, 2016, 16, 7)

(N. Sukanya, C. S. Stalin, S. Jeyakumar*, D. Praveen*, A. Dhani*, R. Damle*)*

Hubbble constant from time delay measurements of lensed quasars

One of the important cosmological parameters is the Hubble constant at the present epoch (H_0), and therefore its precise determination is very important for many aspects of cosmology. Values of H_0 available in literature range between 60 and 74 km sec^{-1} Mpc^{-1} with a wide range of uncertainties from 2 to 10%. Most of the determinations of H_0 available in literature suffer from systematic uncertainties. The phenomenon of strong gravitational lensing provides a way to measure H_0. This is based on the measurement of time delays between light curves of lensed quasars. However, this method of measuring time delays and consequently measuring H_0 is extremely challenging as it needs good quality photometric monitoring observations over a long period of time. As of now time delays are known for about two dozen gravitationally lensed quasars. Varied techniques are used to infer the time delays in these systems. A homogeneous analysis has been carried out to find new time delays from the light curves of these systems using a newly developed time delay estimation technique called the difference smoothing method (Rathna Kumar et al.2013, A&A, 557, A44). From mass modelling of 10 good systems form the sample of 24 using PixeLens code a value of H_0 of 68.1 +/- 5.9 km sec^{-1} Mpc^{-1} is estimated for a spatially flat universe having $\Omega_m = 0.3$ and $\omega_\lambda = 0.7$.

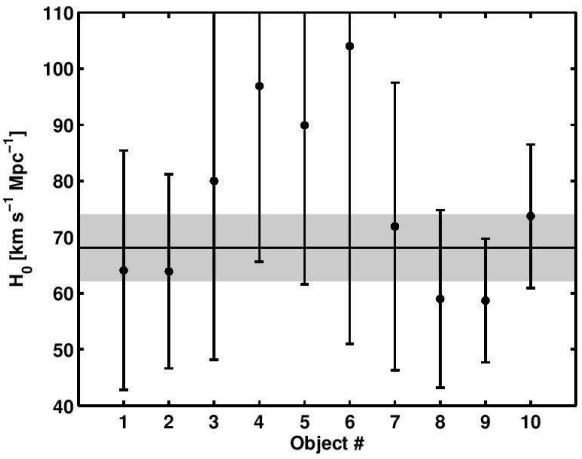


Figure 2.18: Estimates of Hubble constant and 1 sigma uncertainties for 10 gravitationally lensed systems.

(A&A, 2015, 580, 38.)

(S. Rathna Kumar, C. S. Stalin, T. P. Prabhu)

2.4 Theoretical Physics & Astrophysics

Relativistic state-specific multireference perturbation theory incorporating improved virtual orbitals: Application to the ground state single-bond dissociation

Relativistic second-order state-specific multireference perturbation theory (SSMRPT) in conjunction with the improved virtual orbital-complete active space configuration interaction (IVO-CASCI) method has been used to study the potential energy curves of homonuclear dimers including Li_2, Na_2, K_2, Rb_2, F_2, Cl_2, and Br_2. As SSMRPT curbs intruder effects, the results preseneted here are numerically stable. The relativistic SSMRPT has seldom explored in the past. Selective spectroscopic constants that are closely related to the correct shape and accuracy of the energy surfaces have been extracted from the computed PECs. For the halogen molecules, a relativistic destabilization of the bond has been found. Relativistic and electron correlation effects need to be incorporated to get reliable estimates. The present results are in good accordance with reference theoretical and experimental data which manifests the computational accuracy and efficiency of this method. The method opens for an improved description of multi-reference systems containing heavy elements. The inexpensiveness of this approach makes IVO-based SSMRPT method promising for studies on large systems of heavy elements. (J. Comp. Chem. DOI: 10.1002/jcc.24037)

(Anirban Ghosh, Sudip Chattopadhyay*, Rajat K Chaudhuri and Uttam Sinha Mahapatra*)*

State-specific multireference perturbation theory: Development and present status

The state-specific multireference perturbation theory (SSMRPT), which provides one state at a time may now gradually become a new useful ab initio tool for studying electronic states with strong configurational quasidegeneracy owing primarily to its suitability toward numerical implementation in the presence of intruders and also to a great extent for its firm theoretical construct and the scope of a systematic and hierarchical improvement. The method works with a complete active space, and treats each of the model space functions on the same footing by exploiting Jeziorski-Monkhorst parametrization of the wavefunction. The SSMRPT is size-extensive and size-consistent (with the orbitals localized). The real challenge remains in developing MRPT methods capable of maintaining explicit size-extensivity and avoiding intruders over a vast range of molecular geometries. Recently developed relativistic SSMRPT for the four-component spinors is very promising to describe the near-degenerate states of molecules containing heavy atoms. The analysis of the formal aspects and practical utility of the SSMRPT method vis-a-vis the other MRPT formalisms that bear kinship with the SSMRPT formulation is also presented. Illustrative results show high accuracy of the SSMRPT method in describing quasidegenerate situations such as those appearing when one or more covalent bonds in the molecule become stretched or broken. While actively pursuing SSMRPT method, it became apparent that this method encounters two major limitations: (1) the scaling of the computational cost with respect to the number of active orbitals and (2) the lack of invariance of the

energy with respect to a unitary transformation of the active orbitals. The future will tell whether the SSMRPT method will be able to acquire the same faith as other widely used single-root MRPT methods.
(Wiley Interdisciplinary Reviews (WIRES) DOI: 10.1002/wcms.1248.)

(Rajat K. Chaudhuri, Uttam Sinha Mahapatra, Anirban Ghosh* and Suvonil Sinha Ray*)*

Detecting Exomoons Around Self-luminous Giant Exoplanets Through Polarization

Many of the directly imaged self-luminous gas giant exoplanets have been found to have cloudy atmospheres. Scattering of the emergent thermal radiation from these planets by the dust grains in their atmospheres should locally give rise to significant linear polarization of the emitted radiation. However, the observable disk averaged polarization should be zero if the planet is spherically symmetric. Rotation-induced oblateness may yield a net non-zero disk averaged polarization if the planets have sufficiently high spin rotation velocity. On the other hand, when a large natural satellite or exomoon transits a planet with cloudy atmosphere along the line of sight, the asymmetry induced during the transit should give rise to a net non-zero, time resolved linear polarization signal. The peak amplitude of such time dependent polarization may be detectable even for slowly rotating exoplanets. Therefore, it is suggested that large exomoons around directly imaged self-luminous exoplanets may be detectable through time resolved imaging polarimetry. Adopting detailed atmospheric models for several values of effective temperature and surface gravity which are appropriate for self-luminous exoplanets, the authors present the polarization profiles of these objects in the infrared during transit phase and estimate the peak amplitude of polarization that occurs during the the inner contacts of the transit ingress/egress phase. The peak polarization is predicted to range between 0.1 and 0.3 percent in the infrared.

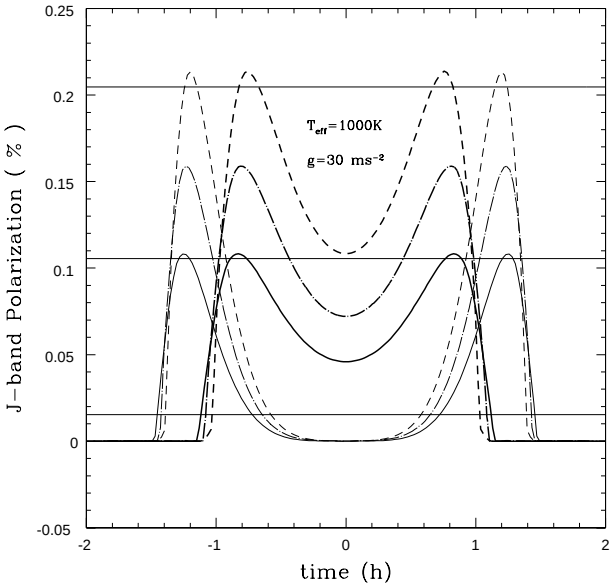


Figure 2.19: J-band disk integrated polarization of self-luminous, spherical exoplanets partially eclipsed by an exomoon. Thin and thick lines represent the percentage polarization for an exomoon transit with an orbital inclination angle of $i = 90^o$ and 88^o respectively. Solid lines, dashed-dot lines and dashed lines represents eclipse polarization profile with R_m/R_P=0.046, 0.07 and 0.1 repectively. The orbital period of the exomoon is set to 7 days for all cases. From top to bottom, the horizontal lines represent linear polarization integrated over the disk of a rotation-induced oblate exoplanet (with no eclipse) with spin period 6.1, 6.6, and 15 hours respectively.

(The Astrophysical Journal, 2016, 824, 76)

(Sujan Sengupta and Mark S. Marley)*

Galaxy outflows without supernovae

High surface density, rapidly star-forming galaxies are observed to have $\approx 50 - 100$ km/s line of sight velocity dispersions, which are much higher than expected from supernova driving alone, but may arise from large-scale gravitational instabilities. Using three-dimensional simulations of local regions of the interstellar medium, the authors explore the impact of high velocity dispersions that arise from these disk instabilities. Parametrizing disks by their surface densities and epicyclic frequencies, a series of simulations are conducted that probe a broad range of conditions. Turbulence is driven purely horizontally and on large scales, neglecting any energy input from supernovae. It is found that such motions lead to strong global outflows in the highly compact disks that were common at high redshifts, but weak or negligible mass loss in the more diffuse disks that are prevalent today. Substantial outflows are generated if the one-dimensional horizontal velocity dispersion exceeds 35 km/s, as occurs in the dense disks that have star-formation rate (SFR) densities above 0.1 solar mass per yr per kiloparsec squared. These outflows are triggered by a thermal runaway, arising from the inefficient cooling of hot material coupled with successive heating from turbulent driving. Thus, even in the absence of stellar feedback, a critical value of the SFR density for outflow generation can arise due to a turbulent heating instability. This suggests that in strongly self-gravitating disks, outflows may be enhanced by, but need not caused by, energy input from supernovae.

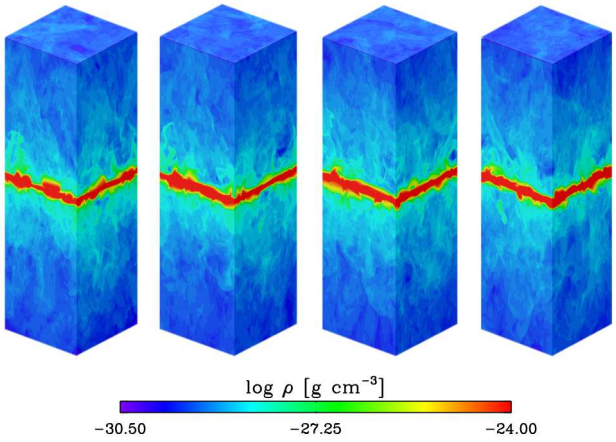


Figure 2.20: Three dimensional rendering of the logarithm of the density in a run with gas surface density of 250 solar masses per parsec squared, showing the gradual evolution of an outflow at four different times. Plumes of gas move away from the disk mid plane and leave the simulation domain through the vertical boundaries.

(ApJ, Vol. 818, 2016)

(Sharanya Sur, Evan Scannapieco and Eve C. Ostriker*)*

How CMB and large-scale structure constrain chameleon interacting dark energy

The authors of the present work explore a chameleon type of interacting dark matter-dark energy scenario in which a scalar field adiabatically traces the minimum of an effective potential sourced by the dark matter density. Extensive discussions are given on the effect of this coupling on cosmological observables, especially the parameter degeneracies expected to arise between the model pa-

rameters and other cosmological parameters, and then test the model against observations of the cosmic microwave background (CMB) anisotropies and other cosmological probes. It is found that the chameleon parameters α and β, which determine respectively the slope of the scalar field potential and the dark matter-dark energy coupling strength, can be constrained to α.
(JCAP 1507 (2015) no.07, 033)

(Daniel Boriero, Subinoy Das, Yvonne Y. Y. Wong*)*

Comoving frame method for polarized line transfer with velocity fields

The atmospheres of hot stars with fast stellar winds (like those in O stars or Wolf–Rayet stars), expanding nebulae, novae, supernovae, quasars, and rapidly changing solar prominences are some of the examples for which fluid motions cannot be neglected when calculating the polarized radiation field emerging from them. Thus it becomes necessary to solve the radiative transfer equation for polarized lines in moving atmospheres. Solutions based on the "observer's frame method" are computationally expensive to obtain, especially when partial frequency redistribution (PRD) in line scattering and large-amplitude velocity fields are taken into account. The authors recently presented an efficient alternative method of solution, namely, the comoving frame technique, to solve the polarized PRD line formation problems in the presence of velocity fields. One-dimensional planar isothermal atmospheres are considered with vertical velocity fields. The effect of velocity fields on the emergent linear polarization profiles formed in optically thick moving atmospheres is illustrated in Fig. 2.21. It is shown that the comoving frame method is far superior when compared to the observer's frame method in terms of the computational speed as well as memory requirements.

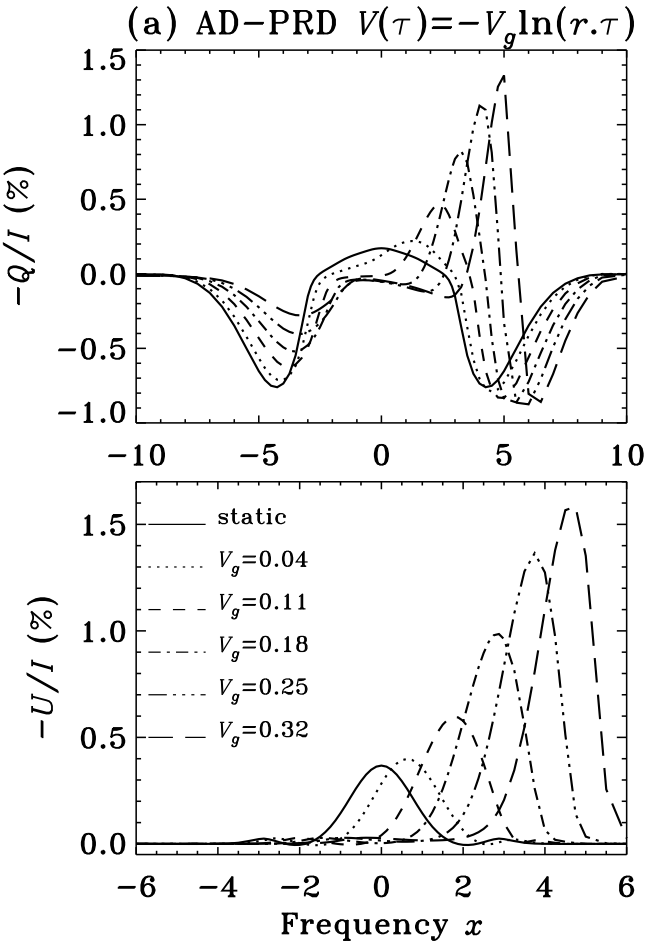


Figure 2.21: Emergent linear polarization profiles for a nearly vertical ray (cosine of the heliocentric angle = 0.7). Isothermal planar atmosphere with a weak magnetic field, a linear velocity field, and angle-dependent PRD is considered. Notice the Doppler-shifted asymmetric line profiles and the enhanced polarization amplitudes as the velocity gradient V_g increases.

(ApJ, 2015, 812, 28 (18 pages).)

(M. Sampoorna, & K. N.Nagendra)

The effects of the small-scale DM power on the cosmological neutral hydrogen (HI) distribution at high redshifts

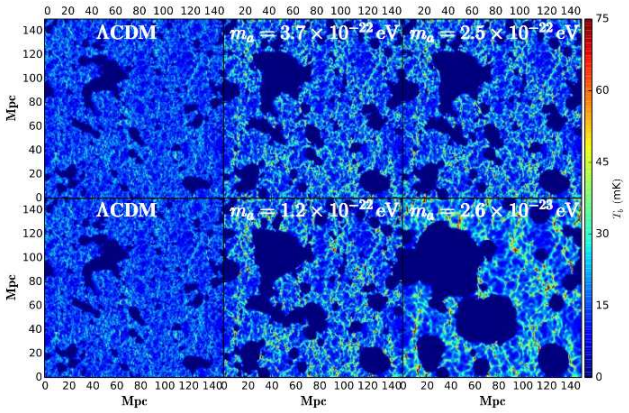


Figure 2.22: Two dimensional sections through the simulated brightness temperature maps of the four different axion DM models with axion masses m_a = 3.7×10^{-22} eV, 2.5×10^{-22} eV, 1.2×10^{-22} eV and 2.6×10^{-22} eV for $\bar{x}$HI fraction = 0.5. The ΛCDM (left) map has been shown twice. The direction of redshift space distortion is with respect to a distant observer located along the vertical axis.

The particle nature of dark matter remains a mystery. In this work, the authors consider two dark matter models: Late Forming Dark Matter (LFDM) and Ultra-Light Axion (ULA) models where the matter power spectra show novel effects on small scales. The high redshift universe offers a powerful probe of their parameters. In particular, two cosmological observables are studied: the neutral hydrogen (HI) redshifted 21-cm signal from the epoch of reionization, and the evolution of the collapsed fraction of HI in the redshift range $2 < z < 5$ (for LFDM) and the axion mass $m_a > 2.6 \times 10^{23}$ eV (for ULA). The comparison of the collapsed mass fraction inferred from damped Lyman-α observations to the theoretical predictions of the present models lead to the weaker bounds: $z_f > 2 \times 10^5$ and $m_a > 10^{23}$ eV. These bounds are consistent with other constraints in the literature using different observables; it is also shown that how these bounds compare with possible constraints from the observation of luminosity function of galaxies at high redshifts. In the case of ULAs, these constraints are also consistent with a solution to the cusp-core problem of CDM.
(arXiv:1512.03325)

(Abir Sarkar, Rajesh Mondal*, Subinoy Das, Shiv.K.Sethi*, Somnath Bharadwaj*, David J. E. Marsh*)*

2.5 Instrumentation

Fabry-Perot based narrow band imager for solar filament observations

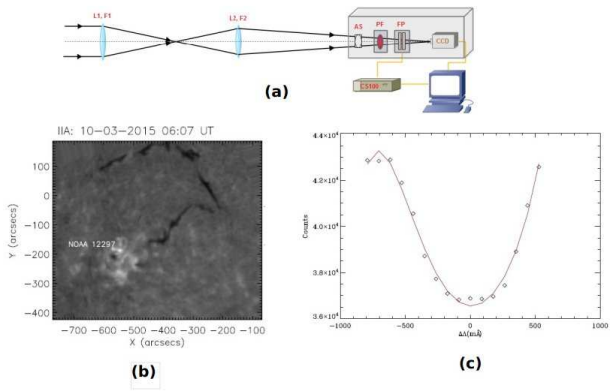


Figure 2.23: (a) A schematic diagram representing the optical and control layout of the NBI. L1- 15 cm objective lens with focal length F1=225 cm, L2-10 cm re-imaging lens with focal length F2=100 cm, AS circular aperture stop, PF-pre-filter inside a temperature controlled oven, FP-Fabry-Perot interferometer and CCD-camera. (b) Observed active region and filament using NBI at the H-alpha line core positions. (c) Constructed line profile at 656.3-nm wavelength from the observations. The line profile is scanned at 18 wavelength positions from –0.0792nm to 0.0616nm with a step of 0.0088nm.

The authors have recently developed a narrow band imager (NBI; Dhara, Ravindra and Banyal, 2016) using an air-gap based Fabry-Perot (FP) interferometer at IIA. Figure 2.23(a) shows the schematic layout of the instrument. NBI is made by using an FP working in combination with an order sorting pre-filter. The instrument is being used to observe the Sun at chromospheric height and is capable to scan the H-alpha spectral line profile at different wavelength positions. The observed data from the instrument was used in producing the dopplergrams at the chromospheric height. The FP has a clear aperture of 50 mm with a bandpass of 0.0247-nm, a free spectral range of 0.53-nm at 656.3-nm. The GUI was developed in LabVIEW using the IEEE - 488 as well as the analog interface using PCIe -DAQ to operate the CS100 controller with a PC. An H-alpha filter centered at a wavelength of 656.28-nm was used as an order sorting filter placed in front of the FP. A temperature stabilized box was also developed which can keep the filter within 0.1-deg Celcius of the set temperature. A series of images were obtained by tuning the plate separation of FP across different wavelength positions on the spectral line. Figure 2.23(b) shows the image of active region NOAA 12297 on March 10 2015 at H-alpha line core position using the NBI. The H-alpha spectral line was constructed from the set of observations and is shown in Figure 2.23(c). (RAA, 2016, 16a, 10D)

(Sajal Kumar Dhara, B. Ravindra, Ravinder Kumar Banyal)

High-resolution, high-sensitivity, ground-based solar spectropolarimetry with a new fast imaging polarimeter: I. Prototype characterization

The present work is about the instrument called the Fast Solar Polarimeter in depth, including the fast pnCCD camera employed, the achromatic modulator package, the main calibration steps, the effects of the modulation frequency on the levels of seeing-induced spurious signals, and the effect of the camera properties on the image restoration quality. Sample sunspot observation is shown in the attached image to demonstrate the effects of the polarimeter cadence and duty cycle

when restoring 1.92-s of narrow band data by means of an Multi-Object Multi-Frame Blind Deconvolution (MOMFBD) post facto image reconstruction technique. The first column in this picture corresponds to a simple average of the 192 measurement cycles, including one modulated intensity (a), Stokes I (d), and normalized Stokes V (g). The second column illustrates the results of the MOMFBD restoration performed using all the 4×192 available intensity measurements. Both a single modulated intensity (b) and two of the resulting Stokes parameters (e) and (h) are shown. The third column gives the outcome of the same MOMFBD algorithm, run on the data set that has a reduced frame rate (44.4 fps) and duty cycle (11.1%), including a single modulated intensity (c) and two of the restored Stokes parameters (f) and (i). The data with 44.4 fps frame rate was obtained by eliminating intermediate intensity measurements from the original FSP data set (acquired at 400 fps and a duty cycle of 98.6%) before demodulation.

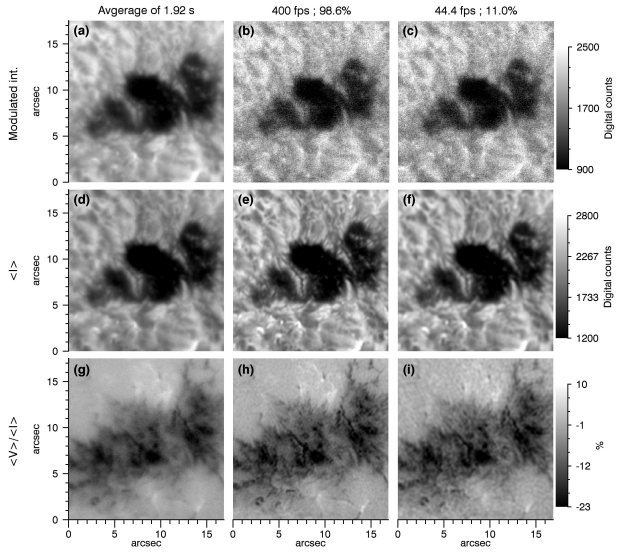


Figure 2.24: Sample images of a sunspot demonstrating the effect of modulation frequency and duty cycle on the spatial resolution.

(A&A, vol. 590, p89, 2016)

(F. A. Iglesias, A. Feller*, K. Nagaraju, and S. K. Solanki*)*

Two-channel imaging system for the White light Active Region Monitor (WARM) telescope at Kodaikanal observatory: design

One of the three planned back-end systems for the proposed National Large Solar Telescope (NLST) is the Solar Dynamics Imaging System (SDIS) which is intended to obtain near simultaneous images in multiple wavelengths. As a first step, a prototype system with two channel imaging has been developed and installed at the back-end of the White light Active Region Monitor (WARM) telescope at Kodaikanal Observatory. A two-mirror Coelostat serves as a light feeding system to a refracting objective while an optical breadboard serves as a platform for the back-end instruments. A re-imaging system is used before the prime focus to get two light channels for the observations in two wavelengths. The re-imaging system is designed using ZEMAX and the alignment of the system is done using a laser. Full disk images are obtained using a red filter (674.2nm/10nm) and a G-band filter (430.5nm/0.84nm). Design aspects of the re-imaging system, preliminary observations and image reduction methods are described.
(In the Proc. SPIE, International Conference on Optics and Photonics, 2015)

(Hemanth Pruthvi and K. B. Ramesh)

Rotation correction for full disk images acquired using Coelostat tracking

In any solar image processing, one of the integral steps is to determine the heliospheric coordinates. Any feature detection must be done with respect to this coordinate system. In case of synoptic full disk images, Coelostats are often used to track the Sun. Unlike its predecessors Heliostat or Siderostat, the Coelostat doesn't cause continuous field rotation throughout the day. However, comparing with the equitorial mounting systems, it causes a constant field rotation that depends upon the free parameters of the Coelostat. This constant rotation is derived as a function of declination and the ratio of the free parameters. The correction is applied to the full disk images obtained at White light Active Region Monitor (WARM) telescope at Kodaikanal observatory and the images are presented.
(Presented in the National Space Science Symposium held at SPL, VSSC, Trivandrum during February 2016)

(Hemanth Pruthvi, K. B. Ramesh)

Solar Dynamics Imaging System - A back-end instrument for the proposed National Large Solar Telescope

The Solar Dynamics Imaging System (SDIS) will be one of the focal plane instruments operated at the National Large Solar Telescope (NLST). The prime objective of the instrument is to obtain high spatial and temporal resolution images of the region of interest on the Sun in the wavelength range from 390 nm to 900 nm. The SDIS provides filtergrams using broad-band filters while preserving the Strehl ratio provided by the telescope. Furthermore, the SDIS is expected to provide observations that allow image reconstruction to extract wave front information and achieve a homogenous image quality over the entire FOV.
(Submitted to Experimental Astronomy)

(K. B. Ramesh, N. Vasantharaju, P. Hemanth, K. Reardon*)*

Precision Controller for Segmented Mirror Telescope Actuator: Control and Tuning

The authors describe their effort to develop a precision actuator controller at India TMT Coordination Centre (ITCC) laboratory, Indian Institute of Astrophysics, Bangalore. The actuator controller is implemented around a single board computer called SBC6845. They have also designed and developed a customized actuator drive board which comprises power electronics to handle the voice coil motor (VCM), off-loader as well as snubber stepper motors. In addition to this, drive board also contains a decoder, current sensor and related circuitry to get the position and other feedbacks. The closed loop proportional-integralderivative controller (PID controller) is implemented for position loop using the feedback from linear optical encoder. Another closed loop is introduced around off-loader with the feedback from current sensor. The tuning of position loop is done by two different methods based on Relay Auto tuning and System Identification. By making use of above controller and the optimum gain, several experiments have been conducted to test the performance of prototype soft actuator. The Actuator along with its best tuned controller gives the steady state position error around 2.44-nm RMS. At the

tracking rate of 300nm/s, RMS position error of 4.04-nm could be achieved, which is better than what is required. These results and other details of controller and its tuning are presented.
(IEEE Indian Control Conference (ICC) 2016, Indian Institute of Technology Hyderabad.)

(Prasanna Deshmukh, Padmakar Parihar)

HPC Integration of Mathematica using PBSPro as Cluster Management Technology

Mathematica is a powerful computational tool using symbolic, procedural and functional programming aspects. Scientists, Mathematicians and Engineering professionals around the world use Mathematica as it utilizes optimally, all aspects of programming to execute computations efficiently and powerfully. Mathematica is designed to make use of local multicore or multi-CPU hardware, as well as supports distributed computing across systems. This design feature helps Mathematica to run in both cluster as well as grid environment and reap the benefits of parallel computing. Mathematica uses the Cluster Integration connection method to run parallel workers on different computers from the master Wolfram Language. It integrates with a large number of third party cluster management technologies including the Altair PBSPro. The authors studied the behavior of Mathematica with the different queues configured in PBSPro scheduler on their HPC cluster for submission of parallel and serial jobs. With 24 simultaneous WolframKernels (Mathematica Kernels) launched on 24 cores across the cluster using PBSPro scheduler, they were able to achieve a speedup of 18 times (approx), compared to a single WolframKernel on a single core as benchmark result.

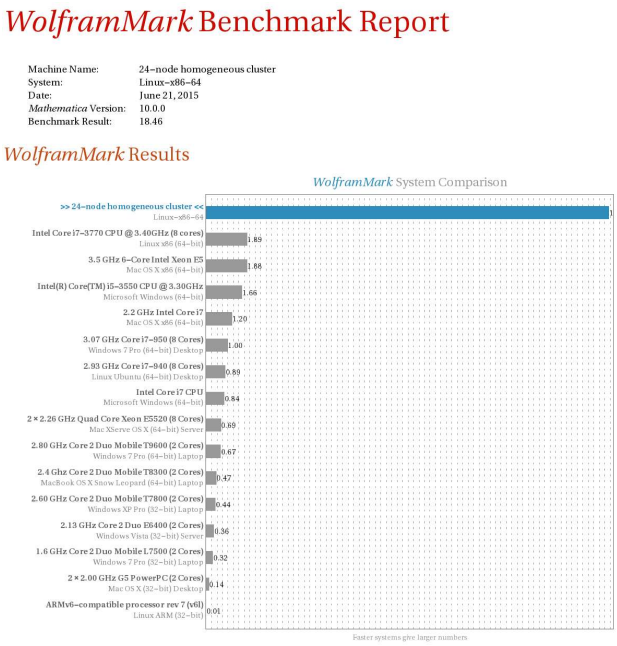


Figure 2.25: Benchmark result for Mathematica when 24 WolframKernels were run on 24 cores on HPC Cluster using PBSPro as Cluster Management Technology.

(2015 India Altair Technology Conference, Bengaluru, Page 167.)

(Anish Parwage, Avijeet Prasad, Arun Mangalam)

Collection of Stratospheric Samples Using Balloon-Borne Payload System

Earth's atmosphere at stratospheric altitudes contains dust particles lifted by weather, volcanic dust, man-made aerosols, traces of IDP (Interplanetary Dust Particles): remnants of comets and asteroids, and

even interstellar dust. However, very little is known about microbial life in the upper atmosphere. Despite the importance of this topic to the astrobiology, stratospheric microbial diversity/survival remains largely unexplored, probably due to significant difficulties in the access and in ensuring the absence of contaminations. The authors are developing the balloon-borne payload system SAMPLE (Stratospheric Altitude Microbiology Probe for Life Existence) to collect dust samples from stratosphere and return them back in a hygienic and uncontaminated manner, to further study the possible biological isolates.

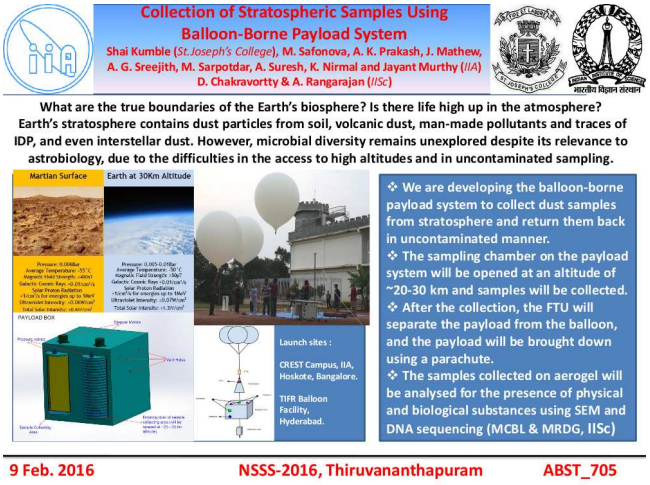


Figure 2.26: One slide poster presentation on NSSS-2016, Thiruvananthapuram.

(NSSS-2016, Feb. 2016, Thiruvananthapuram, abst_705)

(Shai Kumble, M. Safonova, A. K. Prakash*, J. Mathew, A. G. Sreejith, M. Sarpotdar, A. Suresh*, K. Nirmal, Jayant Murthy, D. Chakravortty*, A. Rangarajan*)*

Smear correction of highly variable, frame-transfer CCD images with application to polarimetry

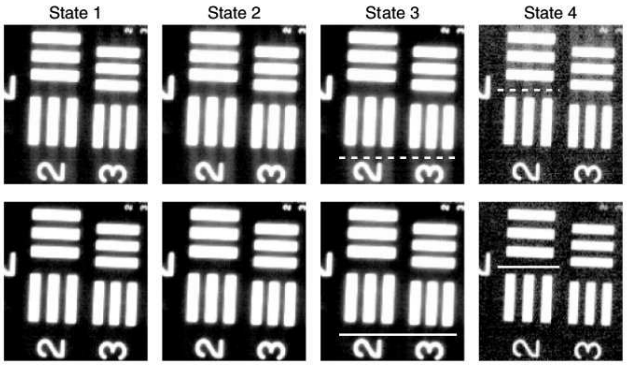


Figure 2.27: Smeared (upper row) and corrected (lower row) images, displayed using logarithmic scales to enhance the smearing. The mean values of the bright areas in the upper-row images are 1950, 2828, 2825, and 297 arbitrary counts for States 1 to 4, respectively.

Image smear, produced by the shutterless operation of frame-transfer 2D detectors, can be detrimental for many imaging applications especially when the charge transfer time is significant compared to the exposure time. There are numerical algorithms exist which minimise the smearing effects. However, they assume constant intensity between the successive exposures. Hence the existing algorithms have limited application in the case of polarimetric observations of the strongly polarised sources (or regions) such as sunspots. This work is a modified algorithm to take into account a specific variations of the sensor illumination. The corresponding desmearing expression and its noise properties are presented and demonstrated in the context of fast imaging polarimetry. Application of this method to the case of Fast Solar Polarimeter is demonstrated in the image shown below. The top row shows the uncorrected four modulated intensity images

and the bottom row shows the corresponding smearing corrected images.
(Appl. Optics, vol 19, p5970, 2015)

(F. A. Iglesias, A. Feller*, and K. Nagaraju)*

X-ray mirror development : Multi-wavelength reflectivity analysis of a Multilayer mirror

Multilayer mirrors provide high reflectivity for X-rays at non-grazing incidence angles. This provides efficient mirrors for large numerical aperture X-ray telescopes and normal incidence Extreme Ultra Violet telescopes. A multilayer mirror consists of thin layers of alternative materials with high and low refractive indices. A typical multilayer mirror is made up of many bi-layer coatings wherein each bi-layer, is made up of a high Z- material (reflector) and a low Z-material(spacer). The input wave is divided into reflecting and transmitting components at every layer interface. Since the reflectivity of the material is small, an optimised bi-layer can ensure that subsequent interactions of the transmitting component, builds up the total reflected signal *coherently*.

As part of the ongoing developmental activity on X-ray mirror development (jointly with ISRO and RRCAT), a multilayer mirror of Tungsten (W) and Boron-Carbide (B_4C) as spacer and reflector respectively is coated at RRCAT, Indore with 170 repetitions of bi-layers each of thickness 1.92 nm. The thickness of the Tungsten layer to the bi-layer thickness is maintained as 0.4 for all layers. Multilayer mirrors are tested with X-ray reflectivity (XRR) tests for both structural characterization on the mirror as well as for measuring the reflectivity of the mirror. XRR test is a measure of reflectivity of the mirror as a function of incident angle at a given wavelength. To understand the behaviour of the fabricated multilayer mirror at various X-ray wavelengths, multi-wavelength XRR tests are conducted at Indus-2, beam line 16, RRCAT. XRR measurements are conducted from 8 keV to 16 keV X-rays and results are presented in Figure 2.28(a). It is observed that as, the energy of the incident photon increases, the position of the first reflectivity peak moves to lower angles. This follows Bragg law. Figure 2.28(b) shows the peak reflectivity of the first Bragg's peak of the mirror at different energy of the incident photons. The sudden dip in the peak reflectivity of the first Bragg peak at around 10 keV is mainly due to the absorption edge of Tungsten.

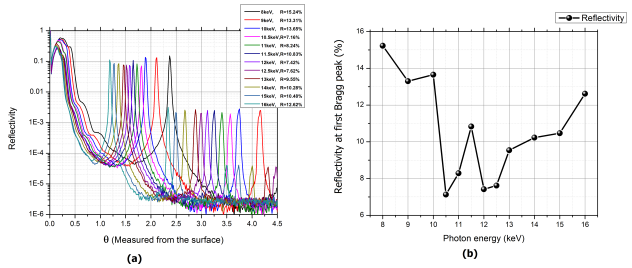


Figure 2.28: Figure:(a) XRR plots of $W - B_4C$ multilayer mirror at different energies. (b) Peak reflectivity at first Bragg peak of the mirror as a function of incident photon energy.

(S.S. Panini, P. Sreekumar, K.C. Shyama Narendranath, M. Nayak*, P.S. Athiray*)*

Chapter 3

PUBLICATIONS

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* *Collaborators from other Institutions*

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Table 3.1: Publication List

Year	Published in Journals	Published in Proceedings	Total
April 2011 – March 2012	132	40	172
April 2012 – March 2013	94	16	110
April 2013 – March 2014	103	16	119
April 2014 – March 2015	128	29	157
April 2015 – March 2016	120	31	151
Total	577	132	709

Chapter 4

INSTRUMENTS AND FACILITIES

4.1 System Engineering Group (SEG)

The Systems Engineering Group (SEG) provides engineering support to all activities in the Institute such as instrument development, maintenance of the observatories and laboratories, and augmentation of the facilities. A brief summary of the various activities are provided in this Section.

Satellite Payload instrumentation
Electrical and Performance Testing on UVIT Payload was carried out after Integration with ASTROSAT Spacecraft (S/C) at several stages till its launch on 28 September 2015. After ASTROSAT Launch, UVIT-ASTROSAT post launch operation which includes its health monitoring and its proper operations were done at ISTRAC-MOX till mid December 2015. To carry out these operations, a focused planning along with mission team was started in the month of June 2015 itself.

MGKM Laboratory for Space Sciences, CREST, Hosakote
This is a world class facility for assembly, integration and testing of space payloads for Astronomy. The laboratory was kept operational round the clock with regular maintenance. Many visitors from various Scientific Institutions around the world visit this laboratory. Till recently, the lab had class 3 lakh, class 1 lakh, class 1000 and class 100 facilities. For assembly and testing of VELC (Visible Emission Line Coronagraph) payload, the facility was upgraded and a class 10 area was added. The design, execution and validation of the class 10 area were completed this year.

Figure 4.1: Class 10 upgradation at the MGKM Lab for VELC integration

HESP project
The HESP instrument control software was designed and programmed in IIA. The software was tested in IIA on spare actuators and later at KSO-CI (Kiwi Star optics - Callaghan Innovation), Wellington during pre-shipment test. The electrical instrument control system for the HESP instrument was supplied after testing and validation at KSO-CI, Wellington NZ in the

month of May 2015. Installation of HESP instrument and the control system (electrical and software) was done at IAO-Hanle during the months of August and September 2015. Many accessories related to control cabinets were also procured and sent to Hanle to finish the installation without any hurdles. Installation of cassegrain cabinet below the yoke base was quite challenging. A brief training for IAO staff was also conducted on the operation of instrument. For observers to operate instrument from IIA-CREST campus, consoles were installed and operation manual was provided.

HESP instrument requires precision thermal control. Thermal control equipments were designed, assembled and installed at site and the thermal stability obtained is much better than the requirement (0.05 °C against the requirement of 0.5 °C).

Solar Photo Voltaic Power Generating System

Figure 4.2: Solar panel structure on the main building at Bengaluru

Government of India (GoI) is laying great emphasis on reducing the country's carbon footprint. In tune with the idea of GoI, Indian Institute of Astrophysics accords high priority to harnessing solar energy. The energy generated by grid integrated solar photovoltaic system will be utilized to feed IIA's electrical loads during daytime. As a result, during daytime, the purchase of electricity from the electricity authority will get reduced. The surplus generated will be supplied to grid through net metering facility.

H-Alpha Telescope Project

Figure 4.3: H-alpha Telescope housed inside the sliding enclosure at CREST, Hosakote.

IIA has procured two telescopes for chromospheric observations of the Sun. One is installed at IIA, Kodaikanal and other one will be installed at Merak in Ladakh region. Prior to the installation at Merak, it was planned to test the telescope at CREST, Hosakote. A temporary concrete pier and a sliding roof enclosure were installed at CREST campus for housing the telescope. Testing the telescope is under progress.

SEG work for observatories

The design, detail engineering and realization of a rotary stage for a polarizer involving MTech-PhD students were completed. Experiment using these stages at Kodaikanal observatory is in progress.

Design and fabrication of 4K×4K CCD Dewar for 1.3-m JCBT has been completed. Trial assembly and preliminary checks are under progress. The performance tuning of

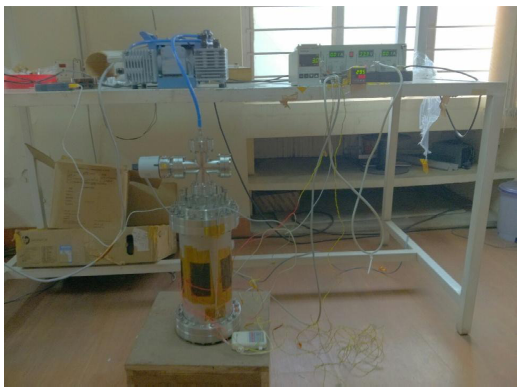

Figure 4.4: Precision thermal control vacuum chamber (0.01 °C thermal stability)

75-cm telescope has been completed. The STARS (ISRO) building at VBO, Kavalur has been renovated by changing the asbestos roofing to puff insulated sheet roof. The entire building has been provided with waterproofing. Three rooms have been upgraded with ESD flooring and epoxy wall painting for setting up clean room facility.

Upgradation of the mirror coating plants at IAO, Hanle and at VBO have been planned.

The structure of the Raman Science Center building at IAO, Leh is completed. Finishing work is in progress. The building consists of Basement + Ground floor + 3 upper floors. The ground and first floors have been planned for office, Science museum and medical room whereas the 2^{nd} & 3^{rd} floors for accommodation for the guests comprising of 4 VIP suites and 8 double bedded rooms. It is planned to set up an observatory at terrace floor for public outreach programmes. The building is planned for passive heating techniques with solarium, walls with soil cement stabilized blocks with necessary insulation. The construction is expected to be completed by October 2016.

The Institute has planned to provide staff accommodation at IAO, Hanle, with rammed earth wall construction for thermal insulation. The floor, walls and the roof are insulated. The construction has commenced and will be completed in the current working season ending September 2016.

Installation of surveillance cameras in all campuses have been undertaken.

Development of a Fabry Perot Cavity Stabilization System at IIA
This is a part of the project of a graduate student of IIA which requires a Precision Thermal Control. The required precision thermal control in a vacuum chamber (0.01 °C thermal stability) has been realised.

4.2 Optics Division

Vacuum Coating
Optics Division undertakes Vacuum coating of all the optics of various telescopes and instruments. One meter meniscus slump mirrors (20 Nos.) of HAGAR telescope was aluminized at the coating plant at VBO, and sent to Hanle for installation. Efforts are on to improve the performance of the 2.8 meter vacuum coating plant at VBO, Kavalur. The Optics Division also has taken the initiative to procure a new 2.5 meter vacuum coating plant with horizontal mounting and aluminium deposition using sputtering technique.

ISRO Project
As per the MoU signed between ISRO and IIA, the Optics Division was engaged in polishing the sunshield panels for various satellites of ISRO. The last project was for INSAT 3DR2. The micro roughness of each panel was measured to be less than 20 Å which meets the space quality.

16 inch f/4 paraboloid mirror The zerodur 16 inch blank having a thickness of 75 mm was fabricated as part of training experience for the opticians and optical engineers.

The final surface was tested with Focault's wire test and found to be better than l/8 PV. The complete fabrication process has been documented for academic purpose.

Torroidal mirror polishing
A requirement has come for X-ray experimentation work from outside the institute. A blank was sliced to the required dimension and later on fixed with resin and polished to 250 mm radius of curvature. The efforts are on to generate the torroidal surface of 230 mm radius of curvature.

4.3 Observatories

4.3.1 Indian Astronomical Observatory

Himalayan Chandra Telescope
The 2-m Himalayan Chandra Telescope completed 15 years of its operation and 13 years of utilization through competitive time allocation. The HCT achieved a major milestone with the installation of the 2^{nd} Generation instrument, the Hanle Echelle SPectrometer (HESP), a fibre-fed, high resolution (R = 30,000 and 60,000) spectrograph. The instrument covers the entire optical wavelength in a single instrument setup, without any gap in the wavelength cover, utilizing a 4K×4K CCD. The Cassegrain interface is mounted on one of the side ports of the instrument cube, while the main spectrograph is located in the ground floor of the dome in a temperature controlled enclosure. The spectrograph was built by Callaghan innovation, New Zealand and the instrument control interface was developed by IIA. The project was funded by the Department of Science and Technology, (DST), India. With the installation of HESP, HCT is now equipped to obtain optical and NIR images and low-medium resolution spectra, and high resolution optical spectra. The pre-shipment acceptance test of the spectrograph was successfully completed in New Zealand during May 2015 and was shipped to Bengaluru in June 2015. HESP was installed at the telescope during 28^{th} August to 5^{th} of September. The on-sky commissioning was performed during 5-7 September at IAO Hanle. During September 28-30, the remote observations of HESP were tested from CREST. The thermal enclosure was installed in the base area by the IAO team for thermally insulating the HESP. Temperature control system was installed in Nov 2015 and it gives thermal stability of ±0.1° C over 24 hours. The spectrograph is being maintained at the temperature of +16.0° C for normal operation, but its functionality at temperatures +10° C and +20° C has been tested for compliance with specifications.

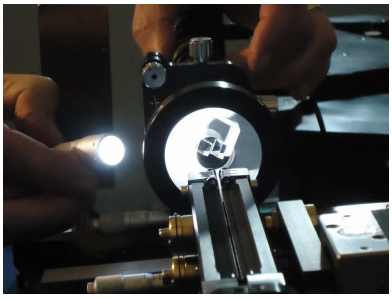

Figure 4.5: Assembly of the HESP input optics.

System specifications tests related to precision radial velocity measurements and mechanical stability have also been carried out and was reviewed by an expert committee. The instrument was found to meet all the technical specifications and the committee recommended the acceptance of the instrument. The on sky tests, performance tests and science verification observations are being performed since October 2015, without much impact to the other observing programs of the telescope. We show here some

tests and early science results to demonstrate the capability of the instrument. System stability tests show shifts of 0.02 pixels non-referencing and 0.002 pixels for referencing mode, which corresponds to 50 ms^{-1} and 5 ms^{-1} respectively, which is better than the required stability of 200 ms^{-1} and 20 ms^{-1}.

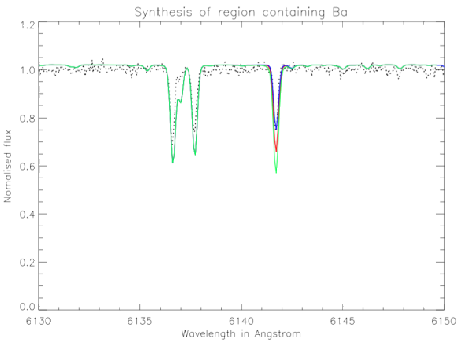

Figure 4.6: Newly discovered Carbon enhanced metal poor star (CEMP) from SDSS survey, observed with HESP, show depleted neutron capture (Barium) elements indicting that the CEMP star is formed from ISM polluted by metal poor faint supernovae that are similar to observed at high redshifts.

The annual maintenance of the HCT was carried out in September 2015, during which a thorough inspection and performance evaluation of various optical, mechanical, electrical and electronics components were carried out. The engineers at IAO and HCT astronomers participated in the annual maintenance activities.

High Altitude Aerosol observatory ARFI

As part of Aerosol Radiative Forcing over India (ARFI) project under the Indian Space Research Organization-Geosphere Biosphere Program (ISRO-GBP), Space Physics Laboratory (SPL), is operating a high altitude aerosol observatory at Hanle since August 2009 in collaboration with IIA. This is the highest aerosol observatory in the country and has been successfully running ever since its installation with the local technical and logistics support from IAO, Hanle. Presently this observatory has been carrying out the measurements of aerosol black carbon mass concentration, spectral aerosol optical depth and net solar radiation at the surface using a set of instruments. Apart from these aerosol measurements, the ARFI hut at Hanle also hosts a GPS receiver system since 2015 which provides the information about total electron content in the upper atmosphere, which is used in the ionospheric studies under SPL's research activities.

CARIBOU

Hanle, being a pristine site has attracted international community also for atmospheric studies. A continuous carbon dioxide analyzer is operated jointly by IIA, Laboratorie des Sciences du Climat et de l'Environment (LSCE), France, and Centre for Mathematical Modeling and Computer Simulation (CMMACS), Bengaluru. This analyzer monitors carbon dioxide concentration of the ambient air in addition to molecular concentration of the Methane and Water Vapour in the ambient air.

Gamma-Ray facilities at IAO

HAGAR

The High Altitude Gamma Ray (HAGAR) observatory, operated jointly by IIA and Tata Institute of Fundamental Research (TIFR) Mumbai, has been in regular use since 2007. The telescope array has been used for monitoring supernovae remnants, active galactic nuclei and gamma-ray emitting binary stars. Apart from the science observations, maintenance/ developement activities were also carried out regularly, which includes improving the performance of telescope e.g. pointing and alignment of

the primary mirrors.

MACE
Bhabha Atomic Research Center (BARC), Mumbai is collaborating with IIA in the development of next generation gamma ray facility, a 21 meter imaging Atmospheric Cerenkov telescope, the Major Atmospheric Cerenkov Experiment (MACE), at IAO Hanle. The basket assembly is in progress. Installation of 2^{nd} layer alidade pipe joints, Elevation platform assembly and shelter with electrical cabinets has been completed.

Site Characterization for National Large Optical Telescope (NLOT)
Site characterization activities for NLOT are being continued at Hanle and surrounding regions. In this regard weather data is collected by three automated weather stations installed at IAO, Raindong and Kalak-taltar. The Lunar Scintillometer and Cloud Monitor developed in-house at IIA and installed at IAO, Hanle in December 2015 are being used regularly for documenting ground layer seeing characteristic and its seasonal variation, and the cloud coverage over IAO. An automated extinction monitor installed at IAO, Hanle, is in use for monitoring extinction coefficient in the optical region. The MASS-DIMM is a site survey device which gives atmospheric turbulence profile starting from 500 m to 16 km. Design and manufacture of the MASS-DIMM telescope have been completed. The assembly and testing of the telescope are under progress.

Site Characterisation for NLST
As a part of NLST project, Sky radiometer (Prede, POM-01, Japan) was installed at IAO-Hanle during 2007. It was later shifted to Merak for NLST site characterization and brought back to Hanle in May 2015. The instrument measures direct and diffuse solar irradiance at several wavelengths from near UV to NIR region. The observed direct and diffuse irradiance are used to estimate aerosol optical depth, size distribution, single scattering albedo, asymmetry parameters at various wavelengths. The instrument is equipped with scanning radiometer, automatic sun tracker and rain sensor. The instrument operates in a robotic mode and has in-situ calibration facilities. If the sky is cloudy (i.e., below the threshold value of signals), then the observation stops immediately and parked the instrument in a safer position automatically. As of now, the Sky radiometer (model: POM series) is operating more than few hundred units across the globe and the raw data are processed under same protocol of SKYNET (http://aeronet.gsfc.nasa.gov). Recently, the Hanle Sky radiometer has linked with the SKYNET. The Automated Weather station (AWS) at Merak was shifted to IAO Hanle and the same was calibrated along with the present NLST AWS at Hanle for 2-3 days. Necessary permission was taken from BSNL Leh to install the Wind Vane and Anemometer at the BSNL BTS tower at 10-m and 30-m height respectively to characterize the Wind profile at 30-m height, Both the instruments were installed at the tower in the first week of May. Data is being sent to IIA, Bengaluru daily through mail.

Hanle had 1732 photometric and 2312 spectroscopic hours of observation out of 206 and 263 nights respectively.

4.3.2 Centre for Research and Education in Science and Technology (CREST)

The CREST Campus facilitates the remote observations of 2-m HCT, IAO-Hanle for the visiting observers who have been allotted time on HCT from a national time alloca-

tion committee (HTAC). A small group of astronomers at CREST help visiting observers for their observations remotely and later with data transfer.

An MoU was signed on June 5, 2015 between India Institute of Astrophysics and CSIR-Institute of 4-Paradigm (earlier known as C-CMMACS), NAL-Belur campus, Bengaluru for establishing a framework of collaborative research in the area of mutual interest. The present MoU is signed in the background of already running joint programs on Green House Gas (GHG) studies and GPS Geodesy at IAO, Hanle. The new objective will be to setup a new GHG station and a calibration unit to the scale of WMO standard along with an AWS on a 32-m high tower at CREST Campus of IIA, Hoskote. The tower has been erected and the lab space has been identified at CREST campus.

Sky Conditions, Indian Astronomical Observatory, Hanle, Ladakh

A. Night hours

Year	Month	Photometric (night hrs)	Spectroscopic (night hrs)	Total (night hrs)
2015	April	102	162	240
	May	93	128	217
	June	61	82	210
	July	18	71	217
	August	90	112	248
	September	212	216	270
	October	203	272	310
	November	201	271	330
	December	189	274	341
2016	January	231	290	341
	February	188	235	290
	March	144	199	279
	Total	1732(53%)	2312(70%)	3293

B. No. of Nights

Year	Month	Photometric nights (night)	Spectroscopic nights (night)	Total (night)
2015	April	14	22	30
	May	19	19	31
	June	10	12	30
	July	3	12	31
	August	14	16	31
	September	21	24	30
	October	22	29	31
	November	21	26	30
	December	19	28	31
2016	January	23	27	31
	February	20	25	29
	March	20	23	31
	Total	206(56%)	263(72%)	366

4.3.3 Kodaikanal Observatory

Solar Tunnel Tower Telescope

The Two beam spectropolarimeter, being used to measure the vector fields of solar active regions, has been upgraded with the computer controlled rotating stages to rotate the polarimetric components quickly and position them in place with the best possible accuracies. The automated rotation stage has been developed to accommodate optical components having a maximum outer diameter of 2 inches. The resolution of these rotation stages is 0.06 degrees. The rotation speed can be controlled from the computer via RS232 interface. The control software on the PC side was developed in Python using wxWidgets while the controller was developed using Microchip's dsPIC33 microcontroller. The firmware was developed in Embedded-C. The rotation stage was tested at Bangalore for performance and later installed in the tunnel telescope. An indigenously developed motorized rotation stage is also coupled to the system which serves as the calibration unit for the spectropolarimeter. The spectropolarimetric observations are being carried out routinely during clear sky conditions and at times of strong field region present on the Sun. Regular observations of latitude scans in Ca II K line and prominence spectra have been carried out.

WARM telescope

The WARM (White Light Active Region Monitoring) facility at Kodaikanal Observatory is a dual-channel full solar disk imaging system; Regular observations with G-Band filter at 4305.4 Å (passband: 8.4 Å) in one channel and at 6724 Å (passband : 100 Å) in the other, are in progress. The images are acquired at 15 minute intervals using PCO camera in G-Band and using ANDOR camera in the red Continuum. 1. The PCO CCD camera has stain marks on the entrance optical window formed due to intense condensation. These marks should ideally be removed by flat fielding during post processing. Several flat fielding procedures were implemented before the correct procedure for our setup was finalized. The current scheme uses a diffuser (a semi-opaque plastic sheet) that is kept on the primary mirror of the coelostat while it tracks the sun and gives uniform illumination across the CCD. This ensures a high intensity count on the CCD for low exposure times. This method has been adopted for daily observations since March 2016.

Sunspot Detection: To extract the main features of a digitized image, method of morphological operators that allows region segmentation and distinguishes meaningful shapes from the background, has been implemented. The morphological operation used for our application is called the Top Hat transformation which consists of subtracting the original image with a closed image. The closed image consists of the image with the darker areas (sunspots) erased. This is analogous to an image obtained after filtering and in our case, is obtained by translating the image with the structuring element. This transformation leaves an image with only the sunspots which is illustrated in the figure. A graphic user interface on the MATLAB platform has been developed and installed in a desktop at WARM laboratory.

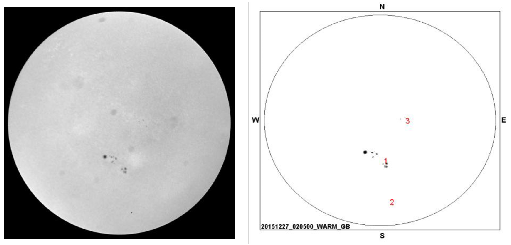

Figure 4.7: A typical example of the results of sunspot detection scheme.

H-alpha telescope

The H-alpha telescope is operational at

Kodaikanal since October 2014. Chromospheric observations are made in H-alpha line center on a regular basis. Occasionally, near simultaneous images of the chromosphere and photosphere are obtained by tuning the Lyot filter. Every day the dark and flat images are taken for the calibration purposes. All the calibrated data is stored in the data center. A webpage is being developed to host the data for the public use.

Verdure in the Kodaikanal campus

In order to keep the campus green and clean regular maintenance program was carried out. Several saplings were planted in the campus and the existing trees were numbered to maintain the tree population.

A Winter School was conducted at Kodaikanal during 14–18 Dec. 2015 attended by 37 students.

Kodaikanal had 47 days of good seeing conditions this year.

Digitization program

The Kodaikanal observatory has been obtaining solar images since 1904 in broad band white light, narrow band Ca II K 393.37 nm and H_α 656.3 nm wavelengths. Many of these observations are still continuing. The historical data which were on photographic plates has been digitized. The first level calibration of the Ca II K, white light and H_α images have been completed and the data is now available through https://kso.iiap.res.in/data. The digitized data are now open to the scientific community. A data catalog is available through this portal and a search engine allows to view the quick look data. Data requests can be sent through this web portal. The results from the Ca K images have been recently published in the article ApJ: http://iopscience.iop.org/article/10.3847/0004-637X/827/1/87/pdf. The century-long (1907-2007) Ca II K spectroheliograms from Kodaikanal Solar Observatory (KSO) are calibrated, processed and analysed in the present study to follow the evolution of bright on disc structures called plages, the possible representatives of magnetic activity on the Sun. This has been the longest dataset studied in Ca II K till date covering about 9.5 cycles of 11 year periods. The long term Ca II K data from KSO can be used as a proxy for estimating magnetic activity locations and their strengths at earlier times.

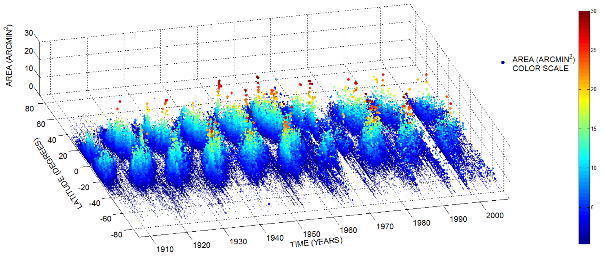

Figure 4.8: 3 dimensional visualisation of Ca II K butterfly diagram with area of individual plages as the z-axis. These observations include information on the sizes and positions of plages as well as their numbers. These data show that plages do not appear at random over the surface of the sun but are concentrated in two latitude bands on either side of the equator. Minimum to maximum plage area range is defined by dark blue to dark red through green, yellow and orange as indicated by the color scale.

Sky conditions: Kodaikanal

Year	Month	Number of Observations					Seeing conditions *				
		6″ Refractor	WARM Telescope		H-Alpha	Twin Telescope	5	4	3	2	1
		PHGM	G-band	Red cont.	Line center						
2015	April	28	22	22	26	-	-	1	2	18	7
	May	21	19	19	16	-	-	-	1	14	6
	June	20	16	16	16	-	-	-	-	3	17
	July	19	20	20	17	-	-	1	-	7	11
	August	22	16	16	25	-	-	5	-	11	6
	September	21	21	-	24	-	-	2	1	6	12
	October	21	26	-	26	-	-	3	-	4	14
	November	8	12	12	11	-	-	4	1	3	-
	December	14	18	17	17	-	-	7	1	-	6
2016	January	31	30	30	30	11	-	6	14	11	-
	February	26	25	25	25	21	-	8	9	7	2
	March	31	14	14	14	21	-	10	2	14	5
	Total	262	239	191	247	53	-	47	31	98	86

PHGM: Photoheliograms observed through 6-inch telescope.

*Seeing conditions (1-very poor, 2-poor, 3-fair, 4-good, 5-excellent)

4.3.4 Vainu Bappu Observatory

30-inch telescope performance

Tracking tests were carried out in May, 2015 using LUCA EMCCD camera (13.5 MHz), similar to the 1.3-m JCBT testing. The telescope was successfully handed over for trial observations in January 2016. PC based servo monitoring system was used to display as a strip chart and store the positional error of RA and Dec axes, which helped tremendously in understanding the problems and evaluating the status of any improvements after any tuning/ modification. Fine tuning of the handset control in the PMAC software was first done. The auto-guiding methodology had to be modified for successful operation. Every cycle has a fixed relay ON time of 100 milliseconds, which is sensed by the PMAC to move the telescope for a fixed time followed by a delay of 50 milliseconds, irrespective of the drift. The response at extreme south and south east had improved and the performance has become very good.

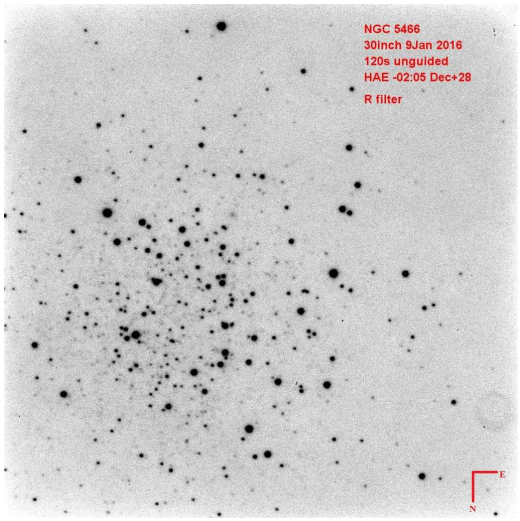

Figure 4.9: Image of NGC 5466 in R-filter using the 30-inch telescope on January 9, 2016.

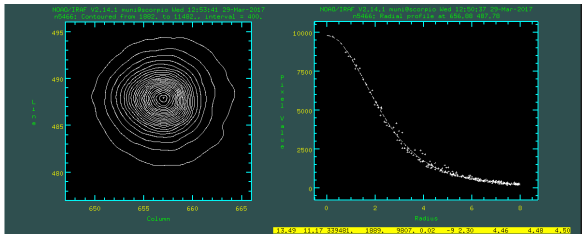

Figure 4.10: The intensity contours and radial distribution of intensities of star image shown in figure 4.9.

(P. Anbazhagan, A. Ramachandran & Mechanical Team)

Remote Testing of JCBT

A trial initiative was taken to operate 1.3 meter JCBT from a remote location and was completed successfully. The DFM control has provision for server in the software to accept commands through TCP/IP sockets for telescope movements and to provide telescope coordinates etc. Instead of connecting straight to DFM control machine for security reasons, a buffer machine at VBO was used to communicate between the DFM control machine and a remote client. A simple Python code acted as the server program on this machine while the remote client with a GUI was coded using Delphi. The client displays the current telescope coordinates RA, DEC, Hour angle with UT and ST. It also has graphical inputs for target position with all safety limits incorporated in the software. The application worked reliably and satisfactorily without any delay even through the slender bandwidth.

The task of displaying the acquired data at a remote location was also tried. The data acquired from ProEM 1K×1K CCD system using Princeton Lightfield software was used. A server program written in JAVA communicates with the Lightfield add-in to know the absolute pathname of the recently acquired file. The remote client sensing the completion of the data acquisition would display the

frame with X, Y and Intensity values. The transfer time depends on the connectivity.

(P. Anbazhagan & K. Ravi)

OMR Spectrograph Control software upgradation

The old DOS based OMR control software was successfully ported to windows platform coded in Borland Delphi. The old ISA interface card was replaced by A PCI Multifunction card retaining all other OMR hardware. The Zero it function is built into the software and additional features for grating movement has been provided. The instrument status is also made available for CCD header information. The whole system has been installed and is in operation.

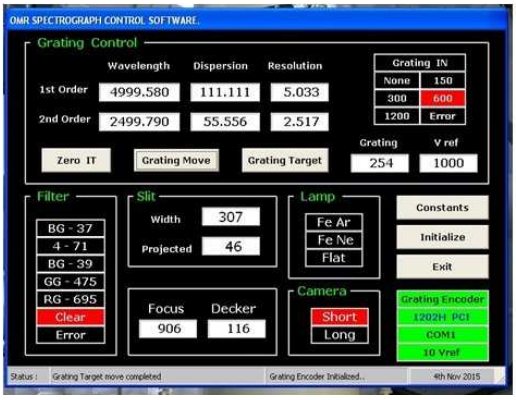

Figure 4.11: OMR Spectrograph Control software GUI.

(K. Ravi)

Labs at STARS building, VBO

(a) **1000 class Clean room**
A clean room cubicle of 1000 class is setup in the STARS building. The validation of the clean room is to be taken up after finishing minor touch up works for the ESD floor and the PU painting of the wall. The facility is to be used for the assembly and servicing of cryostats, both indigenously developed and other CCD systems.

(b) **CCD Calibration Lab**
A CCD calibration lab is planned to be setup adjacent to the clean room. All CCD characterization tests like Gain and quantum efficiency determination could be carried out. There are 7 CCD systems used for data acquisitions at different telescopes (apart from the guide camera systems). There are 3 more liquid nitrogen cooled CCD systems which are not in regular use. Periodical calibration and testing of these systems could be done in this lab.

(c) **Optics Lab**
An optics table, lamp sources, monochromator, integrating sphere and associated optical elements were procured to setup an optics lab at VBO. This lab will be used for calibration of optical filters and testing of various back-end instruments available at VBO. This lab would provide support to testing of the upcoming instruments such as Imaging Polairmeter and Adaptive optics.

(VBO Electronics group)

VBT Cassegrain Position Angle Device

The VBT Cassegrain focus has a Rotating Position Angle Device (PAD), which is driven by a stepper motor through a 1:256 gear box. A micro-controller based system is built to control the device and communicate with a host computer through RS232/RS422 interface. The motor drive is implemented using SS2000MD4 and the control logic is implemented in PIC16F877A. The PAD is operated either by remote commands or by operating switches in the front panel. The position information is given by a 256 turn 20

bit encoder, which is converted into degrees: minutes: seconds format displayed both locally and at the host computer. The software written in Delphi5 uses COM port for controlling the PAD. The program also provides PAD angle information over TCP/IP socket.

(K. Ravi)

1.3-m Mosaic CCD System

Mosaic CCD system for imaging at JCBT using two e2v 44-82 [2048×4096], 15 micron pixel, CCDs is under development. Indigenous CCD cryostat is used to house the CCDs. ARC controller is used to control the devices. Preliminary wiring and DSP coding to interface the IIA existing 2K×4K CCD was completed and frames were taken.

The 2.4 ltr capacity LN_2 Can part is retained and the Camera Head is to be modified to accommodate two devices, two FANOUT boards and connectors for feeding signals. The cryostat has been fabricated and is undergoing vacuum tests.

The thermal analysis of the CCD Cryostat is under progress and initial values for conduction and radiation losses are obtained for the given design. The rate of cooling / heating of the CCD & Mount will be adjusted by adding copper strips in the conduction path to obtain the recommended flow rate.

After succeeding with the vacuum tests, internal wiring and further system integration needs to be done. The expected time period would be about five months and the plan is to put the system for testing with the telescope by October, 2016.

(K. Ravi, P. Anbazhagan, K. Sagayanathan, P.U. Kamath & A.K. Pati)

Scientific programs carried out at the VBO

Four major telescopes of VBO were used for regular observations. VBT, JCBT and one metre Carl Zeiss telescopes had scheduled observations, while trial observations were done at 30-inch telescope.

High resolution spectroscopy of novae, contact eclipsing binaries with iodine cell, stars with high IR fluxes, early F-dwarfs and characterization of exoplanets hosts were carried out using the Echelle spectrograph. Further, monitoring of the rapidly mass losing post-AGB with large UV excess were carried out to understand the shaping mechanism of planetary nebulae using Echelle Spectrograph at a lower resolution. Observations of hydrogen-deficient stars to determine their $^{12}C/^{13}C$ ratio or presence of fluorine in their spectra were performed to constrain their origin. Medium resolution spectroscopy of IRAS sources with far-IR colours similar to Post-AGB stars and planetary nebulae were carried out to identify their evolutionary nature. Medium resolution spectroscopy of T Tauri stars, novae, supernovae, and contact binaries were also carried out using OMR Spectrograph at VBT.

Differential photometry of blazars and novae using UKATC 2K×4K CCD system were carried out at JCBT. Observations of mutual events of Galilean satellites were done at JCBT using the ProEM CCD detector. About 23 mutual events of the Jovian satellites were obtained. Differential photometry of cataclysmic variables and exoplanets using ProEM 1024B CCD system were the observing programmes carried out at JCBT during this period.

Stellar polarimetry of Post-AGB stars, symbiotic stars, novae, BL Lac objects, Be stars, RV Tauri stars and polarization of standard stars using 3 Channel Photopolarimeter were carried out at 1-m telescope. Medium resolution spectroscopy of Be stars were carried out using the UAGS spectro-

graph with a pixis-400 peltier cooled CCD detector at 1 metre telescope.

Differential photometry of blazars and BL Lac objects using TEK 1K CCD system was the observing programs carried out at 30-inch telescope from the month of January. About 120 hours of exposures mainly covering two objects, OJ287 and MRK421 were done.

Sky conditions at VBO

The table gives the summary of night sky conditions for the months April 2015 to March 2016. The columns list the number of nights having 2 or more continuous hours and 4 or more continuous hours of nights classified as fit for spectroscopic or photometric studies. It is to be noted that for nights classified as "photometric" the sky has to be fully clear for the stated number of hours.

(VBO Team)

Sky Conditions at VBO

Year	Month	Spectroscopic Hours		Photometric Hours	
		2 hrs or more	4 hrs or more	2 hrs or more	4 hrs or more
2015	April	20	17	1	1
	May	7	3	0	0
	June	7	2	0	0
	July	8	4	0	0
	August	2	1	0	0
	September	8	4	0	0
	October	14	8	0	0
	November	3	3	0	0
	December	20	18	2	1
2016	January	24	23	3	3
	February	29	26	5	3
	March	29	27	7	3
Total (nights)		171	136	18	11

4.3.5 Gauribidanur Radio Observatory

Crossed Log-Periodic Dipole Antenna (CLPDA)

The radio astronomy group has recently commissioned a broad-band (500 - 50 MHz) CLPDA set-up for simultaneous observations of Stokes I (total intensity) and Stokes V (circularly polarized intensity) radio emission associated with the transients in the solar atmosphere. The CLPDA (a special antenna for this purpose) has been designed and fabricated in the observatory workshop using appropriately chosen aluminum materials in such a way that the cross-talk between the orthogonal elements in the CLPDA is very small (−30 dB). This is about factor of two lower than that provided by similar commercially available antennas. The motive is to estimate the solar coronal magnetic field (B) with the above antenna in the heliocentric distance range 1.1 - 2.0 solar radii over which radio emission in the above frequency range typically originates. The magnetic field dominates most of the solar corona, playing a crucial role in the formation and evolution of the structures there. In this regard, exploration of the above distance range is very important since some of the transient activities that lead to solar-terrestrial disturbances have their origin there. As on date only the radio techniques can simultaneously observe the Stokes I and Stokes V emission in the above distance range. The added advantages with radio observations are that it can simultaneously observe both the corona above the solar disk ('disk' corona) and the corona off the solar limb ('limb' corona), with comparatively higher temporal resolution. Presently a conventional analog spectrum analyzer is used to record the radio emission. Work is in progress to use a fast analog-to-digital converter (ADC, with 1 GHz speed) and FPGA based digital data acquisition system. These will facilitate data acquisition over the entire spectral band at the same time, and with temporal resolution better than 100 msec.

Radio spectral observations with ground and space - based facilities

Ground based radio observations are limited to typically 30 MHz on the low frequency side due to radio frequency interference (RFI), and the cut-off ('critical') frequency for radio wave propagation in the Earth's ionosphere. The existing NASA space mission (Wind-Waves) for solar radio observations operates in the frequency range 14 MHz - 30 KHz. In view of this, there is a gap in the spectral coverage of the Sun at low frequencies. Bridging the above gap (30 - 14 MHz) will provide a seamless frequency coverage, and hence facilitate investigation of several scientific problems (related to Sun-induced disturbances in our terrestrial environment) which are predominant at low frequencies. Lower the frequency, the larger the heliocentric distance from where the radio radiation originates. So the propagation of the magnetohydrodynamic shock waves due to transient disturbances like the coronal mass ejections (CMEs) can be continuously tracked (via the associated radio emission) as they propagate outward through the solar atmosphere, if there are radio observations over a continuous range frequencies. Some of these shocks are responsible for the aforementioned Sun-induced disturbances.

The RFI in Gauribidanur is comparatively lower. Further the ionopsheric cut-off frequency there is typically 15 MHz. This is expected to decrease in the coming years due to the prolonged minimum in the ongoing solar cycle 24 and the predictions of a weak solar cycle 25. The local latitude in Gauribidanur is 14 deg North. Sun moves be-

tween +23 deg North and −23 deg South in declination every year. The above implies that Sun will be close to the zenith (in declination) in Gauribidanur for a major part of the year, and hence zenith angle dependent propagation errors will be minimal. Taking advantage of the above, the radio astronomy group has designed and developed a prototype system for ground based radio observations down till 10 MHz. The system comprises of two identical antennas in the front end, and FPGA based digital receiver in the back end that extracts all possible in-phase and quadrature correlations with 16-bit amplitude resolution. The novelty in the present set-up is that it operates in the spectro-correlator mode as compared to the conventional spectral observations at low frequencies with a single antenna/receiver system in the spectral mode alone. This has provided a factor of five improvement in the dynamic range. The experience gained is expected to be useful for possible space-based low frequency solar radio observations in the future with the help of ISRO.

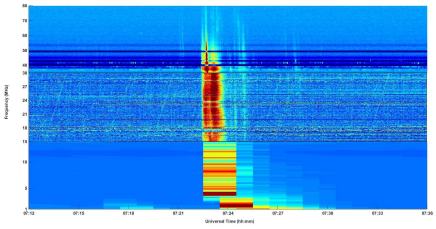

Figure 4.12: Composite of the spectrum of a solar radio transient observed with existing radio spectrograph in the Gauribidanur observatory in the frequency range 85-35 MHz, the new very low frequency observing facility there in the frequency range 30-14 MHz (see the text), and observations of the same transient with the Wind-Waves space mission in the frequency range 14-1 MHz.

The temporal and spectral resolutions in the Wind-Waves data are lower compared to the Gauribidanur observations. Hence the patchy nature of the spectrum over the frequency range 14-1 MHz. It is clear that but for the Gauribidanur observations in the frequency range 30-15 MHz range, the continuity of the ground based and space based observations would have been ambiguous.

4.4 Library

The library plays an important role with the research community of IIA to achieve the organization goal. A total number of 185 books and 965 bound volumes of journals have been added to the existing collection of the library. The current journals subscription is 79 and 7 databases, out of which 71 titles can be accessed full text online in all the campuses of IIA and all the field stations. IIA library continued to get e-journal access to various publishers as a IIA library is a member of NKRC consortium.

Document Delivery Services:
85 Inter-library loan requests from IIA faculty and students were fulfilled as they are not there in the IIA collection. More than 120 requests from other libraries and individuals were catered to from our collections as part of the document delivery service.

Open Access Repository (OAR):
The OAR software has been upgraded to the new version and has a new look and feel with new features. The new collection called Books has been created to highlight the details of books published by IIA faculties and staff members. Currently IIAs open access repository is ranked 727 in the list of top 1200 institutional repositories covered worldwide as of January 2016 and contains 6736 records.

Archives:
The contents in the archives have grown more

from the Institutes administrative file which has evidence of earlier scientific work done in the Institute. All the historical content in the archives has been used for research purpose by people from IIA, nationally and internationally.

Bibliometric Analysis:
IIA library has given substantial input to the Annual Report and DST Reports by submitting scientometric analysis of IIA research publications.

Library Training and Internship Programme:
Library continues to offer two year library trainee programme, and the trainees are trained in all the sections of the library especially in the digitization procedure.

Chapter 5

UPCOMING FACILITIES

5.1 Thirty Meter Telescope

India TMT Activities

The Year 2015-16 was a mixed bag for the Thirty Meter Telescope project. While pursuing the re-permit process at Hawaii, the project is also considering alternate sites for placing the Thirty Meter Telescope. One of the alternate sites in the Northern Hemisphere includes Hanle, Ladakh. In spite of the issues related to the site, the project has made impressive progress on technical aspects such as the design of telescope structure, mirror polishing, production of mirror blanks and other telescope control systems across the partner countries.

Figure 5.1: The first SSA manufactured in India after assembly at class 1 lakh facility at IIA, Bengaluru.

During this period, India TMT made significant progress by signing a two year contract to manufacture 3 SSAs each by Godrej and Boyce and Avasarala Technologies Limited in March 2016. The ITCC SSA team made an in-depth root cause analysis of every component that deviated from the design specifications, which has led to improved design of some key components and elimination of possible risks during the production phase. A few key components of SSA were given to R&D units such as NCAIR, IIT, Mumbai and CTTC, Bhubaneswar for process development. The Software team made progress in identifying industry partners to work on TMT telescope control systems. India TMT instrument group completed the Wide Field Optical Spectrograph (WFOS) optical configuration analysis, which included derivation of sensitivity and distortion maps, and optimization techniques to derive corrective motions for the flexure compensation. The team continues to play a key role in the design analysis of WFOS. Another critical work package is the polishing of 90 TMT segments. The work package includes building a mirror polishing plant at CREST, Hoskote, training of IIA/ India TMT engineers at Coherent, the company selected for technology transfer and build of polishing equipment, and hex cutting of segments. This work is stalled due to issues related to TMT site. In the meantime, the optics team has made

important studies on stress mirror polishing (SMP) techniques and simulations on optimizing mirror warping forces.

To promote the project among students and younger scientists, India TMT held its 3^{rd} Science & Instrumentation Workshop in December 2015 at Tezpur University, Tezpur, Assam. Around 70 engineering and science students from the region participated. Also, India TMT set-up a stall at the 103^{rd} Indian Science Congress held in January 2016 at Mysore University, where a scaled model of the TMT, and working of a functional actuator were displayed. India TMT members gave lectures on TMT and its science capabilities at different universities and other places.

5.2 Visible Emission Line Coronagraph on ADITYA(L1)

Aditya-I is India's first dedicated scientific mission to study the Sun. A Satellite placed in the halo orbit around the Lagrangian point 1 (L1) of the Sun-Earth system has the major advantage of continuously viewing the Sun without any occultation/ eclipses. Therefore, the Aditya-1 mission has now been revised to Aditya-L1 mission and will be inserted in a halo orbit around the L1, which is 1.5 million km from the Earth. The satellite carries additional six payloads with enhanced science scope and objectives. The project is approved and the satellite will be launched during 2019 – 2020 timeframe by PSLV-XL from Sriharikota. These studies will enhance our current understanding of the Solar Corona and also provide vital data for space weather studies.

Visible Emission Line Coronagraph (VELC) payload onboard Aditya(L1) is an internally occulted solar coronagraph with simultaneous imaging, spectroscopy and spectro-polarimetry channels close to the solar limb. The primary science goals of this mission are (1) Diagnostics of the coronal and coronal loops plasma (Temperature, Velocity, & Density), (2) Heating of the corona, (3) Development, dynamics and origin of Coronal Mass Ejections (CMEs), (4) Studies on the drivers for space weather and (5) Measurement of coronal magnetic fields in the corona (not planned by any mission so far). The imaging of the solar corona provides information about the intensity and its variation with space and time only. Whereas the spectroscopy gives information about velocity, line-width and its variation with space and time which are essential for the complete understanding of the physical and dynamics characteristics of solar corona and its heating mechanism. Addition of the spectroscopic and polarimetric capability will address the space weather driving mechanisms at the corona which in turn potentially can lead to prediction. The proposed payload will provide the first comprehensive measurements of the strength and topology of the magnetic field in the upper solar atmosphere (VELC-Science Working Group). IIA is building the Visible Emission line Coronagraph (VELC), which will image the solar corona and perform the spectroscopic observations. Spectroscopy and Spectro-polarimetric capabilities are key features of this payload. VELC is designed to image solar corona from $1.05R_{\odot}$to $3R_{\odot}$($R_{\odot}$: solar radius) with a plate scale of $2.5''$/pixel. It has multi-slit spectroscopic channels at three emission lines namely 530.3 nm, 789.2 nm and 1074.7 nm with spectral resolution of 65 mÅ , 95 mÅ and 150 mÅ respectively. It has dual-beam spectro-polarimetry at 1074.7 nm for magnetic field measurements. FOV for spectroscopy and spectro-polarimetry is from $1.05R_{\odot}$to $1.5R_{\odot}$. This project was

approved by ADCOS, ISRO on 11-10-2013. Formal approval of the project was received in February 2016. An amendment was signed on 25-04-2016 for the existing MoU between ISAC and IIA for the enhanced mission. Aditya Working Group has been constituted by ISRO to monitor the overall progress of the mission and also to evolve comprehensive science plans including all the pay-loads.

Optical design: The optical design consists of multiple sub-assembles. The Standing review Committee (Optics) constituted by ISRO reviewed the optical design on 25-09-2014 and gave clearance for the realisation of all the optical subsystems. All the reflective optics, some of the refractive optics and opto-mechanics are being developed at LEOS, Bengaluru. IIA has already completed design of optics such as narrow band filters, dichroic beam-splitters, retarder and the polarisation beam displacer. IIA payload team is in the process of procuring narrowband filters, Dichroic beam splitters and diffraction gratings of VELC instrument. VELC payload alignment and performance evaluation schemes are being worked out. Experiments are being designed for calibrations of various narrow band filters, dichroic beam splitters and diffraction gratings etc. Presently the pay-load team is developing the test facilities for various component level and system level calibrations in Prof. MGK Menon Space Science Laboratory.

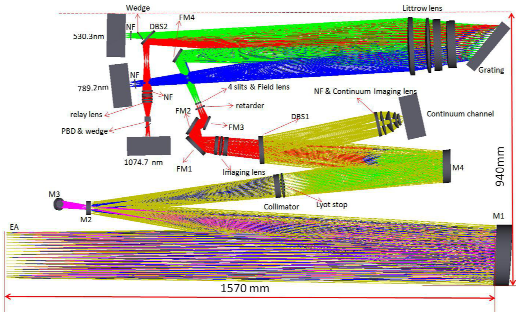

Figure 5.2: Optical layout of VELC

Mechanical structures: VELC optical bench has to accommodate 18 sub assemblies consisting of optical systems, detector systems, mechanisms etc. Opto-mechanical systems have been designed and fabrication drawings are being reviewed. The first global resonating frequency of VELC is close to 100 Hz and the thermal distortions are within the acceptable limits. The dynamic parameters of the VELC system are established and found acceptable by mission. The base design of the system is completed and reviewed and cleared by ISRO committees. The Standing Review Committee (Mechanical Structures) constituted by ISRO reviewed the structural design on 23-09-2014 and have given the clearance for the realization of EM and FM. All the fabrication drawings are finalised and are being issues to M/s BATL for fabrication. Thermal and thermo-structural design and analysis is being carried out by Thermal Group, ISAC. Laboratory model of structural systems is expected to be completed by December-2016. The multi-operational mechanisms are being developed by ISAC and IISU.

Detectors Systems: VELC consists of three sCMOS (visible channels) and one InGaAs (IR channel) detector systems. Each of the detector has four packages consisting of Detector Head Assembly (DHA), Control and Data Processing Electronics (CDPE), Power Supply Electronics and (PSE) and Interface to BMU (CERT). Detector, Detector Proximity electronics (DPE) and Interface with Payload Thermal control system constitute DHA. Considerable effort and time was given towards selection of detector, configuring electronics interface, mechanical interface, thermal interface, optimizing camera electronics, on-board data processing schemes etc. Space Appli-

cations Center, Ahmedabad is developing all the Detector Systems and the Ground Check-out Systems for VELC. VELC is capable of continuous observation of sun with minimal non-observation period. The estimated data volume from all the four channels and in particular, the continuum channel is about couple of TBs. However, keeping in view of challenges of L1 orbit in data down-links and the large SSR requirements, development of on-board intelligence is essential. The essential logic and protocols to build on-board intelligence and detector data processing is finalised. This is to select the required data especially for the standard mode operation of the detector (which is the CME mode operation). Since this channel is utilized to capture CMEs from Sun as the standard mode of operation, and CMEs generally do not occur always and hence selection of data which has CME would help in reducing the data volume considerably. VELC will primarily have two modes of operation i.e. synoptic mode (default mode for CME observations) and proposal based mode. VELC Data volume per day is around 120Gbits, with all the possible reduction in cadence and observation time. The requirements of ob-board calibration of VELC is very critical and methodologies for realizing the same are being finalized.

VELC Integration and Calibration: VELC has 18 sub assemblies and all of them have to be integrated, tested and calibrated to achieve the designed performance. Sub-system level tests and calibrations are being developed. Stringent contamination control protocols have been evolved and implemented. The system level integration protocols are being evolved and the required facilities are being implemented. A large vacuum tank is being designed for the final performance test of VELC under vacuum conditions. It is very critical to control the instrument background to achieve the proposed Science Goals of VELC. The disk light scattered from the surface micro-roughness of primary mirror is the major contributor for instrument scatter. Primary mirror is the main sub-system which needs to provide low scattered light in the coronagraph since it collects the full disk light along with coronal light. Pay-load team adopted following methodologies for estimation of scattered light from the primary mirror:

[1] Theoretical estimation of scatter light using existing theoretical models.

[2] Development of Near Specular Scatterometer (NSS).

[3] Development of Coronagraph Scatter Measurement Facility (CSMF).

[4] Design of baffles and

[5] Contamination control protocols.

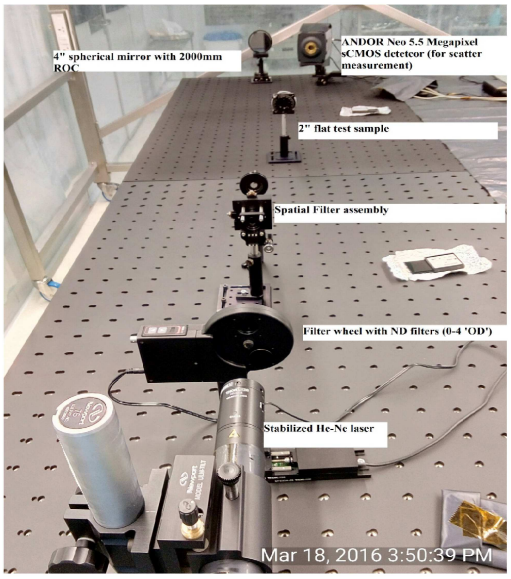

Figure 5.3: NSS experiments in class-10 clean room

Development of the NSS is completed and is functional. Scatter measurements on different super-polished mirrors are in progress. The design of CSMF is completed and the realization process is in progress.

5.3 National Large Solar Telescope

The Governing Council of IIA on behalf of DST, had constituted a committee to examine the implications of Hanle as the site for NLST and submit its recommendations. The NLST team has made a detailed analysis of the wind data at 10-m and 30-m heights, reanalysed the Solar Differential Image Motion Monitor (SDIMM) and Shadow Band Ranging (SHABAR) and radiometer data to look in to the wind speed, direction, and seeing values etc. at different times of the epoch. The analysis showed that though the wind speed was high during the afternoon hours of most of the days, the mild wind speed with good seeing up to mid-day was good for small scale magnetic field studies. The low temperature, low precipitable water vapor content, good median seeing value of 5.7 cm at 20 m height above the ground, with good number of annual sunshine hours makes the Hanle as a good site for infrared observations. The committee has several queries regarding the changes need to be made to the telescope, dome, science cases etc. keeping Hanle as a site. A detailed augmented report containing the study conducted so far was submitted to the committee. The committee approved the report and forwarded it to the governing council.

During the same time a letter of approval for the Merak site came from ministry of Defense. Following this we have submitted all the required documents for the environmental clearance from the Wildlife board of Jammu and Kashmir. The standing committee of state board for Wildlife recommended the proposal and forwarded the application to the National Board for Wildlife.

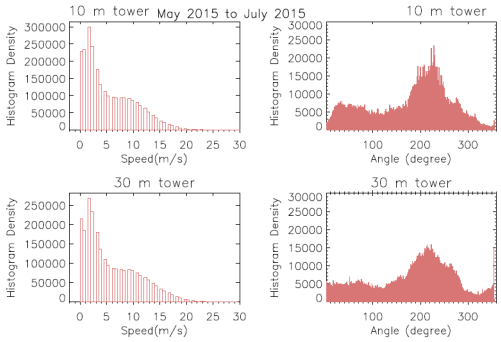

Figure 5.4: Wind speed frequency histograms at two heights simultaneously observed.

5.4 Ultra-Violet Imaging Telescope (UVIT)

Ultra Violet Imaging Telescope (UVIT) is one of the 5 instruments on ASTROSAT satellite, which was launched on September 28, 2015. UVIT was designed to make images with a resolution of $< 1.8''$, simultaneously in three channels: Far Ultraviolet (130 - 180 nm), Near Ultraviolet (200 - 300 nm), and Visible (320 - 550 nm); the total field of view is $28'$. It was developed through a collaboration between several Indian institutions: IIA, ISRO, IUCAA, and TIFR, and Canadian Space Agency. The other 4 payloads are X-ray telescopes covering energy range from 0.3 keV to 100 keV. A picture of ASTROSAT before the launch is shown in Figure 5.5.

After full mechanical, electrical, and optical testing of UVIT at MGKM Laboratory, CREST, IIA and at ISAC, ISRO, it was integrated with ASTROSAT at ISAC. After the integration, electrical and optical tests

were carried out. Final qualifications of the integrated satellite involved vibration tests, acoustic tests, and thermo-vacuum tests at ISITE campus of ISAC, ISRO.

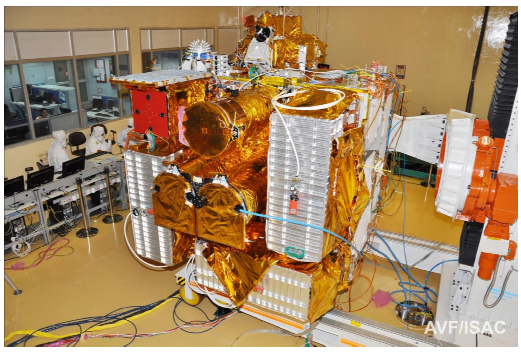

Figure 5.5: ASTROSAT is shown before the launch. The golden looking foils all over are for thermal control. Doors of the two telescopes of UVIT are seen in the front.

After the satellite was shifted to SHAR, ISRO for launch, further electrical tests were conducted on the payload. During all the tests at ISAC and SHAR extreme care was taken by the UVIT team to avoid any contamination by strict monitoring of all the locations of work and the processes used for the tests. Generation and testing of the command sequences for operation of the payload in the orbit demands great care and it was done successfully in collaboration with the teams from ISRO. Two weeks after the launch electrical tests of the payload were started and were finished successfully. However, no observations were made for two months as the doors were kept closed to avoid any cross contamination from the satellite. Observations were made for four months for calibrations of the payload. Results of the calibrations show that the performance has met expectations of UVIT team. Some key indicators of the performance are : a) sensitivity in 130-180 nm is nearly 85% of what was predicted, i.e. instrumental zero-point is AB-mag. 18.08 (this gives one detected photon per second), b) the point spread function gives Full Width at Half maximum of $< 1.6''$, c) the background in 130-180 nm for dark fields is nearly AB mag. 26 for 10 square arcsecond solid angle, and d) mean relative astrometric accuracy within the field for the Near Ultraviolet detector is found to be 0.7 (rms). (The spatial resolution is illustrated by image of a galaxy in Figure 5.6, and the astromeric accuracy is illustrated in Figure 5.7) This performance promises bright prospects for deep imaging and imaging of crowded fields, in which source confusion and background should be minimised. UVIT is performing well in the orbit, and is expected to produce a large volume of excellent astronomical results over its life of 5 years.

A payload operations centre (POC) has been established in the main campus of the Institute to support observations with UVIT through all the stages, i.e. planning of the observations for the intended science, receiving of the raw data from ISRO, analysis of the raw data to generate standard images, and depositing of the analysed data at ISRO for archiving and dissemination to astronomy community. Science observations have just started with UVIT and there are bright prospects for exciting results on a large variety of objects, from individual stars to clusters of galaxies in sizes, including multi-wavelength observations of temporal variations in coordination with the X-ray telescopes on ASTROSAT.

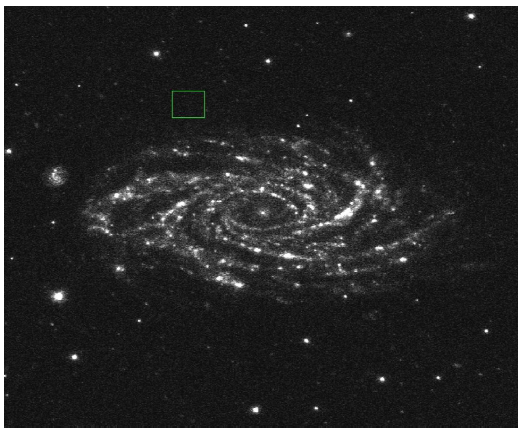

Figure 5.6: Image of galaxy NGC2336, in Near Ultraviolet.

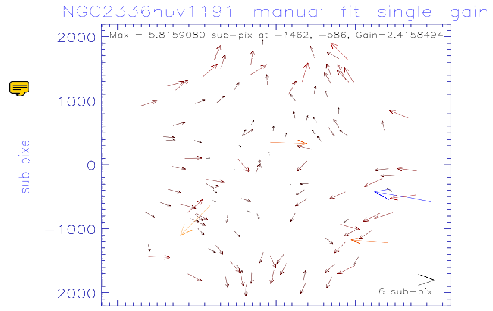

Figure 5.7: Astrometric accuracy is illustrated for the field of galaxy-NGC2336. The arrows show error-vectors for positions of the stars as found by comparision with an image taken with a ground based telescope. Scale of the image is $0.4''$/pixel and scale of the error vectors is illustrated by the arrow in bottom-right. (An elliptical distortion is clearly visible and an empirical fit to that reduces the errors to $< 0.5''$.)

Chapter 6

STUDENT PROGRAMS AND TRAINING ACTIVITIES

Student programs at the institute are carried out by the Board of Graduate Studies (BGS). The Institute conducts a PhD program, in collaboration with the Pondicherry University and an MTech - PhD program jointly with the Calcutta University. Apart from these, the Institute also trains students through short term programs such as the visiting students program, the summer school and the summer project program. The highlights of these programs are summarized below.

6.1 PhD Degree Awarded

P. Subramania Athiray was awarded (on 08 July 2015) the PhD degree for his thesis titled "Study of Lunar surface chemistry using Swept Charges Devices" submitted to the University of Calicut. He carried out the above work under the supervision of P. Sreekumar.

A. Bala Sudhakara Reddy was awarded (on 14 July 2015) the PhD degree for his thesis titled "Abundance Patterns of Old Open Clusters as Tracers of Galactic Chemical Evolution" submitted to the Pondicherry University. He carried out the above work under the supervision of Sunetra Giridhar.

G. Indu was awarded (on 17 July 2015) the PhD degree for her thesis titled "The Structure, Kinematics and Evolution of the Magellanic Clouds" submitted to the Pondicherry University. She carried out the above work under the supervision of Annapurni Subramaniam.

K. Sasikumar Raja was awarded (on 13 Aug. 2015) the PhD degree for his thesis titled "Radio Polarization Studies of The Solar Corona at Low Frequencies" submitted to the University of Calcutta. He carried out the above work under the supervision of R. Ramesh.

K. Drisya was awarded (on 08.10.2015) the PhD degree for her thesis titled "Studies on Carbon-Enhanced Metal-Poor (CEMP) stars" submitted to the Bangalore University. She carried out the above work under the supervision of Aruna Goswami.

Dinesh Kumar was awarded (on 26.10.2015) the PhD degree for his thesis titled "Geometry of Emission Region in Pulsars and the Stokes Parameters" submitted to the Pondicherry University. He carried out the above work under the supervision of R.T.Gangadhara.

Manpreet Singh was awarded (on 07 Jan. 2016) for his thesis titled "Theoretical studies of ultracold atoms in optical lattics and superlattices" to the SOITS, IGNOU,

New Delhi. He carried out the above work under the supervision of B.P. Das.

Samyaday Choudhury was awarded (on 12.01.2016) for his thesis titled "Study of evolved stellar populations in the Magellanic Clouds" to the Indian Institute of Science under the Joint Astronomy Programme (JAP). He carried out the above work under the supervision of Annapurni Subramaniam and Tarun Deep Saini.

G. Sindhuja was awarded (on 02.02.2016) for her thesis titled "Study of solar chromosphere: Variation of Calcium K line profiles with solar cycle." to the Mangalore University on 16.07.2015. She carried out the above work under the supervision of Jagdev Singh.

Avijeet Prasad was awarded (on 15.02.2016) for his thesis titled "Magnetic helicity and force-free properties of astrophysical magnetic fields" to the SOITS, IGNOU, New Delhi. He carried out the above work under the supervision of Arun Mangalam.

Table 6.1: **Number of PhDs awarded over the past five years**

Year	No.
April 2011 – March 2012	5
April 2012 – March 2013	2
April 2013 – March 2014	5
April 2014 – March 2015	7
April 2015 – March 2016	10
Total	29

6.2 PhD Thesis Submitted

The following students have submitted their PhD thesis:

Arun Surya submitted his thesis titled "Image Retrieval in Astronomical Interferometers Affected by Atmospheric Turbulence" to the University of Calcutta on 24.06.2015. The research was done under the supervision of S.K. Saha and R. Ramesh.

Sajal K. Dhara submitted his thesis titled "Radio Polarization Studies of The Solar Corona At Low Frequencies" to the University of Calcutta on 14.08.2015. The research was done under the supervision of B. Ravindra.

Anantha Chanumolu submitted her thesis titled "High Resoultion Fibre Fed Echelle Spectrograph: Calibration and Characterisation for Precise Radial Velocities And Chemical Abundances" to the University of Calcutta on 25.08.2015. The research was done under the supervision of T. Sivarani.

Vaidehi Sharan Paliya submitted his thesis titled "General Physical Characteristics of - gamma ray Emitting Beamed AGNs in Fermi Era." to the University of Calicut on 25.02.2016. The research was done under the supervision of C. S. Stalin.

K. Sowmya submitted her thesis titled "Scattering Polarization with Pashen Back Effect As A Tool To Diagnose The Magnetic Structuring of The Solar Atmosphere" to the Pondicherry University on 18.03.2016. The research was done under the supervision of K. N. Nagendra.

H. D. Supriya submitted her thesis titled "Exploration of The Second Solar Spectrum Through Polarimetric Studies" to the Pondicherry University on 18.03.2016. The research was done under the supervision of B. Ravindra and K. N. Nagendra.

6.3 Completion of MTech Program

The following students from the 7^{th} batch of the above program have completed the IIA-

CU integrated MTech-PhD course:

Anwesh K Mishra under the guidance of U.S. Kamath submitted his MTech thesis titled "Mid-infrared imager for the 2-m Himalayan Chandra Telescope: Feasibility, conceptual design and roadmap for implementation" to the University of Calcutta on August 2015.

Anshu Kumari under the guidance of C. Kathiravan submitted her MTech thesis titled "Development of Cross-Polarized Log-Periodic Dipole Antenna for Low Frequency Radio Spectral Observations" to the University of Calcutta on August 2015.

Srikanth Singam Panini under the guidance of P. Sreekumar submitted his MTech thesis titled "Design and development of soft X-ray optics for planetary observations" to the University of Calcutta on August 2015.

Sireesha Chamarathi under the guidance of Ravinder K. Banyal submitted her MTech thesis titled "Towards Radial Velocity Measurements with Iodine Absorption Cell on VBT Echelle Spectrograph" to the University of Calcutta on August 2015.

Varun Kumar under the guidance of Padmakar Singh Parihar submitted his MTech thesis titled "Edge Sensor for Segmented Mirror Telescopes" to the University of Calcutta on August 2015.

6.4 Visiting internship program

The visiting student internship programme is conducted by the Indian Institute of Astrophysics (IIA) with the aim to promote scientific research interest in college and university students. Students selected for this programme work on specific projects that form a part of the ongoing research at IIA. Based on the nature of the project, the students are asked to work at either the main campus of IIA in Bengaluru or its field stations. Students carrying out their PhD in Universities, and willing to visit IIA for collaborative research are also encouraged to apply for this programme. During 2015–2016, seventy three students did their projects under the guidance of various academic staff members. (with stipend: 29 + without stipend: 44, Total = 73)

6.5 School in Physics and Astrophysics

The school in Physics and Astrophysics, coordinated by the BGS, is an yearly activity of the Institute. The main aim of the school is to introduce students of BSc, MSc, BE/BTech degree courses to the field of Astronomy and Astrophysics and also to motivate them to take up a career in Astronomy and Astrophysics. In the year 2015, the school was held at the Kodaikanal Observatory, during 12–23 May 2015.

Twenty one students participated in the school, of which eight students did a short-term project for a duration of six weeks during June–July 2015, under the guidance of IIA faculty in Bengaluru and Kodaikanal. During the second week of July they made presentations on the results of their project work. The program during the period 18–29 May 2015, in Kodaikanal consisted of series of lectures including Physics and Astrophysics mostly by the faculties of IIA. The areas on which lectures were given include Solar Physics (K. Sundara Raman, S. P. Rajaguru, B. Ravindra and R. Selvendran), Stellar Physics (G. Pandey, S. G. Bhargavi, M. Safonova and Firoza K. Sutaria), Galactic astronomy (Mousumi Das and Koshy Geroge), Radiative Process (K. E. Rangarajan), Extragalactic astronomy

(C. S. Stalin), Observational Cosmology (P. Chingangbam and Subinoy Das), Astrophysical Techniques (U. S. Kamath), Black holes (Arun Mangalam), Magnetic fields (A. Satyanarayanan) and recent trends in astronomy (P. Sreekumar). Local arrangements of the school were made by the staff of the Kodaikanal Observatory under the guidance of R. Selvendran and the summer programme was coordinated by C. S. Stalin, Firoza K. Sutaria and Mousumi Das.

The Institute organized a winter school on 'The Sun and the space weather' during December 14-18, 2015 at Kodaikanal. The programme was meant for MSc (Physics) final year students. A team of resource persons have actively interacted with the students. Students were provided hands on experience in both observations and image reduction methods. Assignment sessions were also arranged to enhance their problem solving capabilities. The school was supported by the following team: K. E. Rangarajan, K. P. Raju, K B. Ramesh, B. Ravindra, H. N. Ranganath Rao, Piyali Chatterjee, K. Nagaraju, P. Vemareddy, and P. Hemanth. Observing and laboratory facility visits were assisted by R. Selvendran, P. Kumaravel, and P. Devendran. The program was coordinated by K.B. Ramesh.

6.6 External Students

The Institute's faculty also supervise the PhD thesis of students in universities, external to IIA's PhD programmes, as guide / coguide. Faculty from universities and colleges working towards their PhD under the Faculty Improvement Programme (FIP) are also guided by IIA's faculty. At present, there are 12 external students and one FIP being guided by IIA's faculty, registered at their home institutions. In addition, one FIP and two students have PhD thesis submitted, and two students have been awarded PhD degree.

Chapter 7

PUBLIC OUTREACH

Celebration of Science Day

National Science day 2016 was celebrated at IIA on 28 February 2016. Altogether 71 students from five schools in Bangalore participated in various activities organised at IIA. The programmes started with drawing and essay writing competitions. After the competitions, the students were taken around the campus by student volunteers of IIA to the locations where various experiments and displays were set-up. They were 1. Observing the sun through telescope and celostat, 2. A demo of Balloon Experiment, 3. Visit to the Optics Laboratory 4. Demonstration of astronomical kits, 5. An exhibition of posters and models. Later the students assembled at the auditorium for a popular talk given by Prof. Jayant Murthy IIA on "Neil Armstrong: A Perspective and Retrospective". Thereafter a quiz competition was conducted in which the students participated enthusiastically. Lastly there was the prize distribution by the chairman of the Board of Graduate Studies IIA, Prof. Gangadhara to the winners of all competitions. Evening events started with a popular talk delivered by Dr. P. Ajith on recent discovery of gravitational waves, titled "Undreamt by Einstein: The discovery of gravitational waves". The science day celebrations concluded with sky watch programme arranged at the terrace observatory of IIA in which a large number of public participated. Students and staff of IIA volunteered and made the programme a grand success.

Outreach for School Children

IIA outreach program was conducted at seven different schools during last year benefiting around 700 students. This school outreach program was conducted for the classes 8-10 with PhD student volunteers from IIA and the science teachers of the schools. The duration for the program was 3 to 4 hours for each school. Kannada and English were the preferred medium of instruction. The event was divided into 3 sections, a talk, demonstration and activities and a final session followed by astronomy role-play, discussion and interaction with the students. The talk and the demo were held in parallel sessions. Students attended the talk and video tour of the solar system, a half an hour presentation of Stellarium and demonstration of adjoining kits and activities. The demonstration also included a basic description of an astronomical telescope and how one can make use of it in the night for viewing heavenly bodies like Moon, planets and few deep sky objects.

Visitors from Schools and Colleges

In addition to school programmes, as a part of outreach activities, all through the year, IIA receives large number of students from various schools and colleges. Special lectures are arranged followed by visit to the facilities like library, IIA archives and optics labs.

Figure 7.1: A group photo taken during one of school outreach events at Bharathi Education Society, Bengaluru.

IIA had set up a stall under DST Pavilion in the 35^{th} India International Trade Fair 2015 at Pragati Maidan, New Delhi from November 14 to 27, 2015. Posters introducing astronomy and related work done at IIA were put up in the designated area of the exhibition with audio-visual display of astronomical events.

Outreach at VBO

The program for watching the night sky on every Saturday, on all clear nights is still being followed at VBO as part of the outreach facility. A total number of 9,851 persons visited VBO. This included groups from 35 schools, 19 colleges, 3 science forum groups, MPBIFR, students from Aryabhatta Foundation, Bhopal etc. The observatory was open for visitors on National Science Day.

Prof. Ram Sagar gave few lectures on Telescope and Instrumentation for the first and second year PhD students of institute on 6^{th} June. Dr.R. Srinivasan gave a talk on BLDC motors on 25^{th} June.

Founder's Day

The Birth anniversary of Prof. M.K. Vainu Bappu was celebrated on 10^{th} August. Selected students from five colleges were invited to attend the function. The program started with a talk about Prof. Bappu in the morning session. In the afternoon, a quiz program was conducted; later the students visited the telescope facilities.

Outreach activity at CREST

HCT remote operation is a point of attraction at CREST for aspiring scientists, students, amateur astronomers, educationists and other interest people. The students range from 10^{th} standard to post-graduate level from different organizations all over India under different banners as Amit Smriti- Project Aryabhatta Bhopal, Jagdish Bose Science Talent Search Programe - BASE/REAP - Amateur Astronomy Session associated with Jawaharlal Nehru Planetarium, Bengaluru to name a few.

IIA pavillion in Indian Science Congress

The Engineering Model of the UVIT was kept for display at the pavilion of the Department of Science and Technology (DST), Government of India, at the 103^{rd} Indian Science Congress (ISC) held at Mysuru. The IIA-DST pavilion won the most innovative stall award at ISC 2016.

Figure 7.2: UVIT at 103^{rd} Indian Science Congress 2016 held at Mysuru

Chapter 8

MISCELLANEOUS ACTIVITIES BY IIA STAFF

8.1 Talks given in national/ international meetings outside IIA

Invited:

G. C. Anupama

- *A study of novae,* June 15-19, 2015, Indo-US Workshop on "Advances in variable star research", Texas A&M University.
- *Observational properties of nova systems,* December 2-6, 2015, Workshop "Novae and accreting binaries: A multi-wavelength study", Centre for Excellence in Basic Sciences, Mumbai University.
- *Recurrent nova systems – a multiwavelength perspective,* December 2-6, 2015, Workshop "Novae and accreting binaries: A multi-wavelength study", Centre for Excellence in Basic Sciences, Mumbai University.

R. Banyal

- *Development of an Actively Stabilized Fabry-Perot Wavelength Calibrator for Precision Doppler Spectroscopy,* 9 July, 2015, Gitam University, Bangalore, Karnataka.

P. Chatterjee

- *Mystery of repeatedly flaring delta sunspot,* 13/06/2016, IBUKS 2016, KU Leuven, Belgium.
- *A new twist to simulating solar flares,* 08/07/2016, Athens, Greece.

P. Chingangbam

- *Primordial non-Gaussianity and a bit of noncommutativity,* 04/11/2015, Discussion meeting on cosmology, Institute of Physics, Bhubaneshwar.
- *Imprint of the early Universe on cosmological observations,* 29/03/2016, Frontiers of Physics, Hyderabad Central University.

M. Das

- *Bars in Halo Dominated Low Surface Brightness Galaxies,* 15-17 December 2015, International Conference on celestial Mechanics and Dynamical Astronomy, Maulana Azad national Urdu University, Hyderabad.

R. T. Gangadhara

- *Pulsar radio emission and viewing geometry,* April 17, 2015, In group meeting at NAOC, Beijing.

A. Goswami

- *Exploring the Milky Way and Nearby Galaxies with TMT,* June 11-13, 2015, TMT Science Meeting at IIST, Thiruvananthapuram.
- *ISDTS activities and TMT-DSC,* December 1-3, 2015, TMT-India Science and Instrumentation Workshop, Tezpur Central University.

K. M. Hiremath

- *Forecast and Backcast of the Solar Cycles,* 1-3 March, 2016, Variability of the Sun and Its Terrestrial Impacts, Bern, Switzerland.

U. S. Kamath

- *The late-stage decline and quiescence of novae,* 2-6 Dec 2015, Novae and accreting binaries : a multiwavelength study, Centre for Excellence in Basic Sciences, Mumbai.

P. Kharb

- *Probing the Low-Frequency Radio Domain of AGN Physics with the GMRT,* June 15-17, 2016, Workshop on Science with the uGMRT.
- *Triggering kiloparsec-scale Outflows in Seyfert Galaxies,* January 20-23, 2016, Conference on 'Jet Triggering Mechanisms in Black Hole Sources' at TIFR, Mumbai.
- *The Search for Binary Black Holes in Seyferts with Double-peaked Emission Lines,* May 6-8, 2015, Conference on "Recent Trends in the Study of Compact Objects – Theory & Observation (RETCO-II)" at ARIES, Nainital.

A. Mangalam

- *Supermassive Black Holes & Jet Formation: Theory, Observations & Simulations,* 13 October 2015, Extragalactic Relativistic Jets: Cause and Effect, at ICTS, Bangalore.
- *Plasma acceleration in a relativistic magnetized jet,* 6-8 May 2015, Recent Trends in the study of Compact Objects: Theory and Observation, ARIES, Nainital.
- *HPC with Mathematica: applications to astrophysics,* 18^{th} January 2016, Wolfram Technology Conference in Bangalore.
- *ED and MHD relativistic jets,* January 20-23, 2016, Jet Triggering Mechanisms in Black Hole Sources, TIFR Mumbai.

P. Parihar

- *Prototyping a Segmented Mirror Telescope,* June 11-13, 2015, IIST Trivandrum.
- *A Step Toward Realization of a Large Optical-NIR Telescope in India,* May 20, 2016, ARIES, Nainital.

A. Prasad

- *A global galactic dynamo with a corona constrained by helicity,* 28^{th} March, 2016, Neighbourhood Astronomy Meeting, ICTS, Bangalore, India.

S. P. Rajaguru

- *Meridional flows on the Sun: review of helioseismic measurements and implications for interior dynamics,* December 7-11, 2015, International conference on "Advances in the Seismology of the Sun and Stars", TIFR, Mumbai.

B. Ravindra

- *Reconstruction of Velocities in Solar Active Regions,* 3-6 November, 2015, 3^{rd} Asia-Pacific Solar Physics Meeting (APSPM 2015).

B. E. Reddy

- *The Thirty Meter Telescope Project: A New window to the Universe,* 15 March 2016, DST sponsored University Workshop, Davanagire University, Davanagire, Karnataka.

- *The Thirty Meter Telescope Project: A New window to the Universe,* 01 December, 2015, TMT science and Instrumentation workshop, Tezpur University, Tezpur, Assam.

- *The Thirty Meter Telescope Project: A New window to the Universe,* 30 March, 2016, Visitor Programme, Delhi University, Delhi.

M. Safonova

- *Search for planets in globular cluster M4 by microlensing: reasons, methodology and first results,* 15-17 Dec. 2015, Int. Conf. on Celestial Mechanics & Dynamical Astronomy, Maulana Azad National Urdu University (MANUU), Hyderabad.

P. Shastri

- *The Fanaroff-Riley Dichotomy in AGN Jets and their Emission-line Regions,* 12-20 October 2015, Extragalactic Relativistic Jets: Cause and Effect, ICTS-TIFR, Bengaluru.

T. Sivarani

- *On the role of next generation ground and space based facilities in characterising exoplanet atmospheres,* 10/02/2016, NSSS 2016, Thiruvananthapuram.

P. Sreekumar

- *Remote Sensing the Universe,* 12 August, 2015, ISRO HQ, Bangalore, Karnataka.

C. S. Stalin

- *UVIT observations of AGN in ASTROSAT PV phase,* July 27, 2015, Workshop on AGN science with ASTROSAT, TIFR, Mumbai.

- *Variability of blazars: Optical and GeV,* January 20-23, 2016, Jet tirggering mechanisms in black hole sources, TIFR, Mumbai.

- *Gamma-ray emitting narrow line Seyfert 1 galaxies,* October 12-20, 2015, Extragalactic Relativistic Jets: Cause and Effects, ICTS, Bangalore.

- *Recent Advancements in observational astronomy,* 26 February 2016, National seminar on recent developments in observational astronomy and big data, S. Vellaichamy Nadar College, Madurai.

V. Valsan

- *400 years of optical telescopes: From Galilean to TMT,* 14^{th} -16^{th} December 2015, National Seminar on Experimental Techniques In Astronomy & Space Science (NSETAS-2015), Department of Physics, NSS Hindu College, Changanacherry, Kerala.

Contributed:

M. Das

- *The HI distribution and dark Matter Content of the nearby LSB galaxy NGC4701,* June 2015, 'Cosmology with the HI 21-cm line', Raman Research Institute.

- *Molecular Gas and Star Formation in Void Galaxies,* February 1-12, 2016, Large Scale Structure: from Galaxies to the Cosmic Web, IUCAA.

S. Das

- *Astrophysical small scale signatures of non-WIMP dark matter,* 11/02/2016, IUCAA.

P. Deshmukh

- *Precision Controller for Segmented Mirror Telescope Actuator: Control and Tuning,* 4- January - 2016, IEEE Indian Control Conference (ICC) 2016, Indian Institute of Technology, Hyderabad.

B. Kumar

- *Study of core-collapse supernovae with the ILMT facility and implications,* 2015-05-08, Recent Trends in the study of Compact Objects: Theory and Observation, ARIES, Nainital.

- *Polarimetric study of type IIP supernovae,* 2015-10-10, 3^{rd} Neighbourhood Astronomy Meeting, IISc, Bangalore.

T. Mageshwaran

- *Transient jet activity induced by TDEs around Supermassive Black Holes,* 21 January 2016, Jet Triggering Mechanisms in Black Hole Sources, TIFR Mumbai, India.

A. Mangalam

- *Plasma acceleration in a relativistic magnetized jet,* 16 October 2015, Extragalactic Relativistic Jets: Cause and Effect, ICTS-TIFR, Bengaluru.

A. Parwage

- *HPC Integration of Mathematica using PBSPro as Cluster Management Technology,* 14 July 2015, India Altair Technology Conference, Ritz-Carlton, Bengaluru.

A. Prasad

- *Modelling of braided magnetic fields in the solar corona using analytic NLFFF solutions,* 24^{th} February, 2016, Dynamic Sun I, IIT BHU, Varanasi, India.

S. P. Rajaguru

- *Deep structure of solar meridional circulation: helioseismic inferences from four years of HMI/SDO observations,* August 31 – September 4, 2015, International Solarnet III/HELAS VII/SpaceInn Conference.

P. Rana

- *Parameter study of QPO models,* 20-24 January 2016, Jet Triggering Mechanisms in Black Hole Sources, TIFR Mumbai.

M. Safonova

- *MBHs in Globular Clusters,* 20-24 April 2015, XXXII annual conference on Modern Problems in Extragalactic Astronomy, Pushchino Radio Astronomy Observatory, Pushchino, Moscow region, Russia.

P. Shastri

- *The Systematics of Relativistically Beamed Jets from Active Galaxies and the Blazar Divide,* 11-14 April 2015, American Physical Society Meeting, Baltimore, USA.
- *Relativistically Beamed Jets and the Blazar Divide,* 12-20 October 2015, Extragalactic Relativistic Jets: Cause and Effect, ICTS-TIFR, Bengaluru.

C. S. Stalin

- *Narrow line Seyfert 1 galaxies: A new class of gamma-ray emitting AGN,* 20-24 April 2015, Relativistic jets: creation, dynamics and internal physics, Krakow, Poland.

Lectures given in any national, international, in-house meeting, conference, workshop, school organized at IIA

Invited:

M. Das

- *Extragalactic Astronomy,* May 2015, Summer School at Kodaikanal.

R. T. Gangadhara

- *Influence of Perturbations on Pulsar Radio Emission,* May 6, 2015, Lunch talk at NAOC, Beijing.

S. Giridhar

- *Hanle Echelle SPectrograph; system description and science programs,* 26/11/2015, Indo-French Astronomy school for optical spectroscopy.
- *Elemental abundances from high resolution spectra,* 27/11/2015, Indo-French Astronomy school for optical spectroscopy.

P. Kharb

- *Lectures on,* May 27-28, 2016, IIA Kodaikanal Summer School.

A. Mangalam

- *Lectures on Black Hole Physics,* May 27-30, 2015, Kodai Summer School in Astrophysics, Kodaikanal.

V. Panditi

- *Introduction to Magnetohydrodynamics,* 17-12-2015, Winter School, Kodaikanal.

K. P. Raju

- *Introduction to the solar atmosphere,* 14/12/2015, Physics of the Sun and the space weather, Kodaikanal.

K. B. Ramesh

- *The Solar interior,* 14 December 2015, Winter school on 'The Physics of the Sun and the space weather' - Kodaikanal.
- *Long-term Solar activity and Climate,* 16 December 2015, Winter school on 'The Physics of the Sun and the space weather' - Kodaikanal.
- *The solar wind and the Earth's magnetic field,* 18 December 2015, Winter school on 'The Physics of the Sun and the space weather' - Kodaikanal.

B. Ravindra

- *Solar Eruptive Events,* May 2015, Summer school at Kodaikanal Observatory.
- *Solar Eruptive Events,* December 2015, Winter school at Kodaikanal observatory.

P. Shastri

- *Footprints of Black Hole Growth Feedback at z∼ 0,* 28 March 2016, 4^{th} Neighbourhood Astronomy Meeting, ICTS-TIFR, Bengaluru.

T. Sivarani

- *Hanle Echelle Spectrograph - update on pre-shipment test results,* 20/06/2015, IIA Faculty meeting, Bangalore.

S. Sur

- *Simulating Galaxy Outflows without Supernovae,* 12/11/2015, IIA Theoretical Astrophysics Group Meeting.

V. Valsan

- *Development of Stressed Mirror Polishing Technology,* April 22, 2016, Indian Institute of Astrophysics.

Contributed:

P. Kharb

- *Introduction to Galactic and Extragalactic Astronomy,* 2015, Ph.D. students at IIA.

M. Safonova

- *Demonstration of UV instruments operating on high-altitude balloons,* 28 March, 2016, The Neighborhood Astronomy Meeting (NAM), ICTS, Bangalore.

M. Sampoorna

- *A brief summary of contributions by Prof. K. N. Nagendra to Polarized Line Formation Theory,* July 31, 2015, A scientific meeting held in honor of Prof. K. N. Nagendra on the occasion of his superannuation at IIA Auditorium.

Invited lectures (not popular lecture) given in any academic institution other than IIA which is not a part of any meeting/ conference

G. C. Anupama

- *Thirty Meter Telescope: An India Perspective,* 7 August 2015, LEOS, Bengaluru.

P. Chatterjee

- *How the sun produces cannibalistic CMEs,* 05/07/2016, RCAAM, Athens, Greece.

P. Chingangbam

- *Constraining noncommutative spacetime,* 12/05/2016, Jamia Millia Islamia, New Delhi.

- *How well can CMB data constrain noncommutative spacetime?,* 07/09/2016, Korea Institute for Advanced Study, Seoul, South Korea.

M. Das

- *The Evolution of ULIRGs into Radio Loud galaxies,* 16-23 august, 2015, LERMA, Paris.

- *Low Surface Brightness Galaxies : the slowest evolving systems in our Universe,* August 21, 2015, GEPI, Observatoire de Paris, Meudon.

S. Das

- *Invited colloqium: CDM or WDM? A particle as well as astrophysical view,* September 2015, NCRA.

R. T. Gangadhara

- *Aberration-Retardation effects on Pulsar Profiles,* May 11, 2015, Peking University, Beijing.

P. Kharb

- *Radio Astronomy and Space Astronomy,* February 2016, M.Sc. Astrophysics at Christ University.

B. Kumar

- *Stellar Evolution,* 2015-12-08, M. P. Government PG college, Hardoi (UP, India).

A. Mangalam

- *Tidal Disruption Events around SMBH,* February 16, 2016, Delhi University.

V. Panditi

- *Helicity and Energy Flux Transport in Emerging Solar Active Regions,* 26-10-2015, BAO, NAOC, Beijing, China.
- *Sun-Earth connection of a CME magnetic flux rope,* 15-10-2015, Astronomy department, Najing University, Nanjing, China.
- *Sun-Earth connection of a CME magnetic flux rope,* 16-10-2015, Department of Geophysics and Planetary Sciences, University of Science and Technology of China, Hefei-230026, China.

P. Shastri

- *Multi-wavelength Properties of AGN with Relativistically Beamed Jets,* 16 Apr 2015, Max-Planck Institute for Radioastronomy, Bonn.

Award, recognition, professional membership, editorship etc. obtained during 2015-2016

G. C. Anupama

- Elected as Fellow, Indian Academy of Sciences, Bengaluru.
- Member, Time Allocation Committee, IUCAA Ghirawali Observatory, IUCAA.
- Co-Chair, ASI-SOC.

P. Chatterjee

- ASI lifetime membership.

M. Das

- SKA-India Continuum Surveys Science Working Group Member.

A. Goswami

- Editor of the Chapter 'Exploring the Milky Way and Nearby Galaxies' of the TMT Detailed Science case - 2015 (arXiv:1505.01195), Skidmore et al. RAA, 15, 1945 (2015).

K. M. Hiremath

- Invited by the "The French National Research Agency".

P. Kharb

- Member of the IAU.
- Member of the TMT ISTD on Supermassive Black Holes.
- Co-ordinator of the SKA-India Working Group on.

K. N. Nagendra

- Main editor for the proceedings of IAU Symposium 305.
- Member of the SOC constituted for organizing the international conference on "Solar Polarization Workshop 8" held at Florence, Italy, during September 12–16, 2016.

T. P. Prabhu

- Member, Finance Committee, International Astronomical Union.
- Member, Project Management Committee and Chair, Time Allocation Committee, Devasthal Optical Telescope, ARIES, Nainital.

A. Prasad

- PhD degree awarded under the Integrated MSc-PhD programme on 31^{st} March, 2016 for Thesis entitled "Magnetic Helicity and Force-Free Properties of Astrophysical Magnetic Fields".

S. P. Rajaguru

- Team member, NASA's Robert H. Goddard Exceptional Achievement for Science to Solar Dynamics Observatory Team.

M. Sampoorna

- Member of Division E (Sun and Heliosphere), Division G (Stars and Stellar Physics), Commission E1 (Solar Radiation and Structure), Commission E2 (Solar Activity), and Commission G5 (Stellar and Planetary Atmospheres) of the International Astronomical Union (IAU) since September 2015.

S. Sengupta

- Kavli Frontiers of Science Alumni by National Academy of Sciences, U.S.A.
- Signatory, Breakthrough Initiative Programme.
- Editor, Academic and Annual Report, Indian Institute of Astrophysics.

P. Shastri

- Professional membership: IAU Commission B3, Astrostatistics and Astroinformatics, Vice-President.

Externally funded projects

G. C. Anupama

- PI of the DST-JSPS project, *A study of supernovae in the nearby Universe – Building blocks of high redshift Universe*.
- PI of *"GROWTH: Global Relay of Observatories Watching Transients Happen"*, funded by SERB under the IUSSTF-PIRE Program.

R. Banyal

- *Development of a stabilized Fabry-Perot wavelength calibrator for precision Doppler spectroscopy*, funded by SERB, DST.

R. K. Chaudhuri

- *Profiling the electronic structure properties of relativistic and non-relativistic systems using computationally cost effective ab initio methods*: EMR/2015/000124.

S. Giridhar

- *Development and Fabrication of Hanle Echelle Spectrometer for enhancement of the capability of the Himalayan Chandra Telescope*, Funded by DST/SERB under IRHPA scheme.

A. Goswami

- *Estimation of surface chemical composition of CEMP stars and AGB nucleosynthesis*, Funding agency: under DST, SERB scheme (2014- 2017).

J. Murthy

- *Space Payloads and ballooning*, funded by DST.

P. Parihar

- *Exploring Design Options for New Optical Telescopes in South Africa and India*, Indo-South African Bilateral Joint Project funded by the Department of Science & Technology, Govt. of India and National Research foundation, Republic of South Africa.

S. Sur

- *Simulating hydromagnetic turbulence from galaxies to the Sun* - Project was granted supercomputing time at NPSF Yuva supercomputer at CDAC, Pune. I am the PI of the project - No money is involved in granting this project.

Workshop, conference, school etc. organized at IIA or outside IIA

G. C. Anupama

- *TMT Science Forum*, Washington, D.C. on June 23-25, 2015. Organised the ISDT session on "Time Domain Astronomy".

D. Bhattacharyya

- *Astronomical Society of India Annual Meeting*, 10 - 13 May, 2016, University of Kashmir, Srinagar.

P. Chingangbam

- 3^{rd} *Neighbourhood Astronomy Meeting*, 10/10/2015.

- 4^{th} *Neighbourhood Astronomy Meeting*, 28/03/2016.

K. George

- Attended *IAU Symposium 321.*

P. Kharb

- ICTS-IIA International Conference on *Extragalactic Relativistic Jets: Cause and Effect*, 12-20 October 2015.

- Co-organized a one-day meeting on "Continuum Survey Science with SKA: The Indian Perspective", at NCRA-TIFR, Pune on 25 January 2016.

S. Sen

- *Dynamic Sun-I conference*, 22-25 February, 2016, Benaras Hindu University, Varanasi.

- *Astronomical Society of india*, 10-13 May, 2016, University of Kashmir, Srinagar.

P. Shastri

- *Extragalactic Relativistic Jets: Cause and Effect*, ICTS-TIFR, Bengaluru, 12-20 October 2015.

V. Valsan

- *Thirty Meter Telescope (TMT)-India Science and Instrumentation Workshop*: 1-3 December, 2015, Tezpur University, Assam, India.

8.1.1 Popular lectures

G. C. Anupama

- *Thirty Meter Telescope*, 9 August 2015, Nehru Planetarium, Bengaluru.

R. Banyal

- *Why light matters?*, August 1-2, 2015, International Year of Light, Gadak Karnataka.

P. Deshmukh

- *Astronomical Telescopes - Past Present Future*, 05 March 2016, Fullinfaws College, Akshayanagara, Bangalore.

R. T. Gangadhara

- *Lorentz factor of radio emitting sources in pulsars*, May 13, 2015, Collaborative discussion talk at NAOC, Beijing.

K. George

- *Introduction to Optical Astronomy*, 9-11 July, 2015, Workshop on 'Time Domain Astronomy & Cosmology', C.M.S college, Kottayam, Kerala.

P. Kharb

- Delivered a lecture on STARS, GALAXIES AND EVOLUTION OF THE UNIVERSE on February 12, 2016 at the SDM MMK College, Mysore.

B. Kumar

- *Observational Astronomy*, 2015-12-09, Bareilly College, Bareilly (UP, India).
- *Evolution of massive stars*, 2015-05-29, Motivational summer workshop on observational astronomy, ARIES, Nainital.

P. Parihar

- *Present and Future of Astronomical Observing Facilities in India*, February 12, 2016, State level seminar at MMK & SDM Mahila Mahavidyalaya Mysore.

M. Safonova

- *Lecture and demonstration of high-altitude ballooning experiments*, April 3-5, 2015, The Annual Science festival, IISER, Bhopal.

P. Shastri

- *Mane Baagilinda Mugilige (From Our Doorstep to the Sky, in Kannada)*, 21 Sep 2015, Karnataka Vijnana Vidya Jagriti programme, St Xaviers Pre-University College, Siranuru, Kalburgi.

V. Valsan

- *Ground based Future Optical Telescopes: Motivations and Solutions*, December–2015, 'International Year of Light', St. Thomas College, Thrissur, India.

Public Communication

G. C. Anupama

- Addressed about 15,000 school children participating in a winter camp near Rajkot on 29 December 2015.

B. C. Bhatt

- Participated in the 35^{th} India International Trade Fair 2015 at Pragati Maidan, New Delhi from November 14-27, 2015 by setting up IIA stall under DST Pavilion. Posters introducing astronomy and related work done at IIA were put up in the designated area of the exhibition with audio-visual display of astronomical events.

- Attended annual general meeting of 102^{nd} Indian Science Congress held at Manas Gangotri Campus, Mysore University, Mysore January 3-7, 2016.

M. Das

- Science Day organization : was part of the organising committee for Science Day.

- Judge in Physics Society-Bangalore lecture competition, June 2015.

C. Muthumariappan

- Organised Founder's Day celebration at VBO on 10^{th} August 2015. A total of 70 selected PG physics students from five colleges participated the event. An Inter-college quiz program on Science and Astronomy was conducted and coordinated their visit to the observing facilities.

M. Safonova

- Demonstration of high-altitude ballooning experiments. March 5, 2016, IISc Open Day.

8.2 Staff Activities

8.2.1 Official Language Implementation (OLI)

OLI Committee Meeting
Four meetings were conducted in the Institute on 15 April, 2015, 25 June, 2015, 27 November, 2015 & 10 March, 2016 and the reports were sent to the Dept. of Science & Technology, New Delhi.

Hindi Workshop
In order to expedite the implementation of Official Language in the Institute and to improve the staff members capacity for doing official work in Hindi, two Hindi Workshops were conducted for the employees working in Administration on 26 June, 2015 and 28 March, 2016. The reports were sent to the Dept. of Science & Technology, New Delhi.

Hindi Day Fortnight Celebration
The Institute celebrated Hindi Fortnight from 1^{st} September, 2015 to 14 September, 2015. During the occasion seven competitions were conducted in the Institute viz. "Hindi-English Noting" competition on 01 September, 2015, "Hindi Speech" competition on 03 September, 2015, "Hindi Easy Writing" competition on 04 September, 2015, "Hindi Song" competition on 07 September, 2015, "Hindi Dictation" competition on 08 September, 2015, "Hindi Visual-Quiz" competition on 10 September, 2015 and "Hindi Antakshari" competition on 11 September, 2015. Hindi Pakwada closing ceremony was observed on 08 October, 2015 in the institute. Dr. P. Sreekumar, Director presided over the function. Prof. T.P. Prabhu, Dean gave the welcome speech. Chairman addressed the audience and congratulated all the employees for their efforts taken towards official language implementation in their official work. He also encouraged them to keep up this pace as it is the moral responsibility of all staff members to accomplish official work in Hindi. Dr. Gajendra Pandey, Associate Professor read out the message received from the Home Minister, Govt. of India. Chairman distributed the cash prizes to the winners. The function was concluded with a vote of thanks by Dr. S. Rajanatesan, Section Officer (Hindi).

Two Hindi competitions were conducted viz. "Hindi-English Noting" competition and "Hindi Visual-Quiz" competition on 15 September, 2015 respectively at VBO, IIA,

Kavalur. Cash awards were given to the winners to encourage them and to motivate other staff members to participate in the activities in the forthcoming years.

Chapter 9

STAFF LIST 2015 – 2016

Director: P. Sreekumar

Distinguished Professor: Bhanu Pratap Das (up to 24.06.2015)

Senior Professor: Jayant Murthy, K. N. Nagendra (up to 31.07.2015), A. K. Pati (up to 31.01.2016), Sunetra Giridhar

Professor: G. C. Anupama, Annapurni Subramaniam, Arun Mangalam, R. K. Chaudhuri, Dipankar Banerjee, B. Eswar Reddy, R. T. Gangadhara, R. Kariyappa, Prajval Shastri, B. Raghavendra Prasad, R. Ramesh, K. E. Rangarajan (up to 30.11.2015)

Associate Professor: Aruna Goswami, B. C. Bhatt, Gajendra Pandey, K. M. Hiremath, U. S. Kamath, Muthumariappan, S. Muneer, P. S. Parihar, S. Paul Kaspar Rajguru, K. P. Raju, K. B. Ramesh, D. K. Sahu, A. Satya Narayanan, S. K. Sengupta, Sivarani Thirupathi, C. S. Stalin

Scientist E: B. A. Varghese

Reader: Firoza Sutaria, C. Kathiravan, Mousumi Das, Nagaraju. K, Piyali Chatterjee, Pravabati Chingangbam, Preeti Kharb, B. Ravindra, M. Sampoorna, Sharanya Sur, Subinoy Das, Ravinder Kumar Banyal

Scientist D: Rekesh Mohan, N. Shantikumar Singh, R. Sridharan

Scientist C: E. Ebenezer Chellasamy, B. S. Nagabhushana (up to 30.04.2015), G. S. Suryanarayana

Scientist B: Namgyal Dorjey, G. Selvakumar

Research Associate B: M. Appakutty

Adjunct Scientist: Durgesh Tripati (up to 14.11.2015), K. Sankarasubramanian

Adjunct Professor: A. N. Ramaprakash

Visiting Professor: K. N. Nagendra, G. Srinivasan, S. N. Tandon

Visiting Scientist: S. G. Bhargavi (Up to 31.05.2015), Brajesh Kumar, Margarita Safonova, Suresh Doravari (up to 09.10.2015), Wasim Iqbal, Yuvraj Harsha Sreedhar (up to 30.01.2016)

Honorary Professor: S. S. Hasan, K. E. Rangarajan, P. Venkatakrishnan

Consultant: C. H. Basavaraju, Lt. Col Kuldip Chandar, Y. K. Raja Iyengar

Post Doctoral Fellow: Arun Surya, K. Drisya, Hema. B. P, Koshy George, Smitha Subramanian (up to 04.07.2015), Suvendu Rakshit, Vineeth Valsan

Technical staff

Engineer F: G. Srinivasulu

Engineer E: V. Arumugam, S. S. Chandramouli (up to 30.11.2015), Faseehana Saleem, P. M. M. Kemkar, P. K. Mahesh, S. Nagabushana, R. Ramachandra Reddy, M. V. Ramaswamy, B. Ravikumar Reddy, S. Sriram, J. P. L. C. Thangadurai

Engineer D: Amit Kumar, P. Anabazhagan, Dorje Angchuk, S. Kathiravan, Sanjiv Gorka, K. C. Thulasidharen, Tsewang Dorjai, P. Umesh Kamath

Principal Scientific Officer: R. Selvendran

Principal Document Officer: Sandra Rajiva (up to 29.02.2016)

Engineer C: K. Anupama, Anish Parwage, K. Dhananjay, K. Ravi, A. Ramachandran, Sonam Jorphail, Tashi Thsering Mahay, Vellai Selvi, Venkata Suresh Narra

Technical Officer B: Narasimhappa, N. Sivaraj (up to 31.08.2015)

Engineer B: I. V. Barve, V. S. Gireesh Gantyada, V. K. Gond, Mallappa, Madhur Juneja, V. Natarajan, M. Rajalingam, S. Ramamoorthy, N. Raj Kumar, Tsewang Gyalson

Technical Officer: A. V. Velayuthan Kutty (up to 30.11.2015), C. V. Sri Harsha, M. R. Somashekar

Tech. Associate B: D. Babu, P. Kumaravel, J. Manoharan, S. Pukalenthi (up to 30.09.2015), S. Venkateshwara Rao

Draughtsman E: V. K. Subramanian (up to 30.4.2015)

Sr. Tech. Asst. C: R. Ismail Jabillullah, T. K. Muralidas, A. Muniyandi

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

Sr. Tech. Asst. B: K. Sagayanathan

Sr. Research Asst. B: V. Moorthy

Technical Asst. C: D. Premkumar, V. Robert

Administrative staff

Administrative Officer: P. Kumaresan

Principal Staff Officer: K. Thiyagarajan

Accounts Officer: S. B. Ramesh

Stores & Purchase Officer: Y. K. Raja Iyengar (up to 30.04.2015)

Assistant Personnel Officer: Narasimhamurthy

Sr. Section Officer: K. Padmavathy, Pramila Mohan, S. Rajendran (up to 31.05.2015)

Section Officer (SG): Maliny Rajan, N. K. Pramila, N. Sathya Bama, Uma Maileveloo

Section Officer: Diskit Dolker, Ramaswamy, N. Valsalan

Section Officer (Hindi): S. Rajanatesan

Sr. Office Superintendant: S. Savithri (up to 31.10.2015), A. Veronica


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