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Front Cover figure caption : NGC 2336 - figure captions: NGC 2336 (not 2663) 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. In the inset, shows part of the star spectra and the calibration lamp spectra

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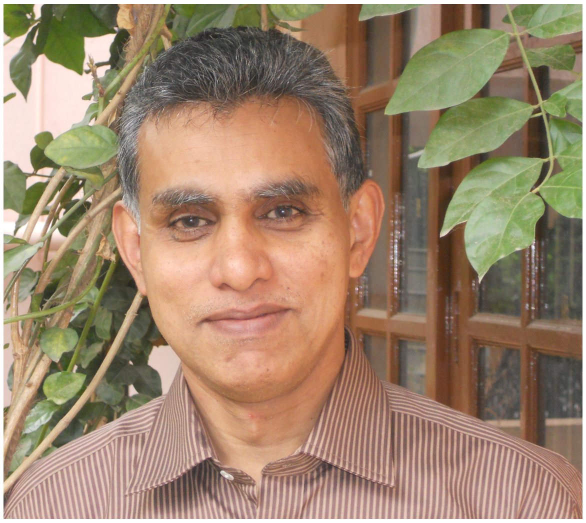
† *deceased*

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 electro-dynamical 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 Ph.D. programme, in collaboration with the Pondicherry University and the M.Tech.-Ph.D. programme jointly with the Calcutta University continue to progress well. Ten students under the guidance of IIA academic staff were awarded Ph.D. degree for subjects ranging from Solar physics to Astronomical Instrumentation. Six students have submitted Ph.D. theses in topics ranging from Image retrieval in astronomical interferometers to characteristics of gamma-ray emitting AGNs. Five students have submitted M.Tech 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 Ph.D. 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 Ph.D. 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 103rd 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

Compilation of the longest data set in the world on Ca II K images of the Sun from Kodaikanal observatory covering a period of nearly hundred years, Helioseismology and a more realistic simulation of a solar flare are some of the highlights of the solar research from IIA this year.

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) were carried out. They indicate that the return flow that closes the meridional circulation is possibly beneath the depth of 0.77 solar radii. The results have implications for the dynamics of the solar interior and the solar dynamo models (see Figure 2.1). 3D linear wave modelling with realistic distributed acoustic sources in a sunspot atmosphere was compared with multi-height SDO observations. The results indicate that the underlying process responsible for the acoustic halos, i.e. the enhancement in time averaged Doppler velocity and intensity power with respect to quiet sun values, is the refraction and return of fast magnetic waves which have undergone mode conversion at the critical atmospheric layer. In addition it was found that the fast-Alfven mode conversion plays a large part in the structure of the halo. Horizontal fluid motions on the solar surface over large areas covering the quiet-Sun magnetic network was derived from local correlation tracking of convective granules imaged in continuum intensity and Doppler velocity by the HMI-SDO.

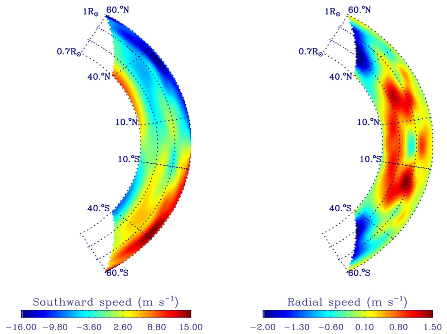


Figure 2.1: Deep structure of solar meridional circulation that results from seismic inversion of travel time differences of interior propagating acoustic waves in the north-south direction. The left and right panels show the 2D profiles of the speed as a function of the angle and radial distance.

The correlations between fluid divergence and vorticity, and that between vorticity (kinetic helicity) and magnetic field was studied. It was found that the vorticity (kinetic helicity) around small-scale magnetic fields on the solar surface exhibit a hemispherical pattern (in sign) similar to that followed by

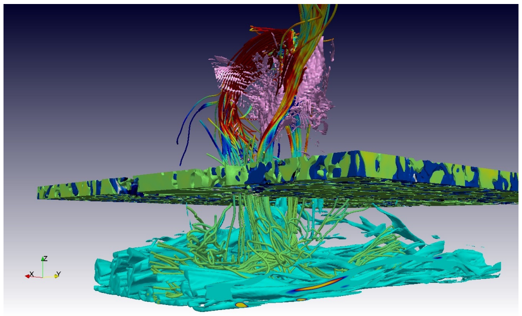


Figure 2.2: Simulating a solar flare. The simulations begin with a flat sheet of magnetized plasma (shown in light blue). This sheet of magnetic flux breaks into tubes of flux, which rise to the surface (dark blue/green slab), releasing energy at specific points (the flare). Each flare is associated 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.

the magnetic helicity of large-scale active regions (containing sunspots). 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. Such action of magnetic fields leads to marked changes in the correlations between fluid divergence and vorticity.

The evolution of Gnevyshev gap between the double peak in the maximum phase of the solar activity cycle (which is very important for the space environment) was compared with the whole Sun integrated characteristics of magnetic field strength of sunspot groups, soft x-ray flares, filaments or prominences, and polar faculae. The time latitude distribution of these solar activities from photosphere to coronal height, for the low latitudes (0 to 50°), shows the way Gnevyshev gap is evolved. The presence of double peak structure is noticed in the high latitude ($> 50°$) activity. The results are expected to be useful to understand the transfer of energy from high to low latitudes and then the reversal of process from low to high latitudes with the progress of solar cycle.

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 magnetic field lines inside the surface of the Sun. The rotation adds further to the magnetic stress which is already large in the delta sunspots due to the spatial closeness of the north and south magnetic poles. The new simulation is a significant improvement over the existing ones and generates a very promising picture of a solar flare (see Figure 2.2).

The width of the transition region network boundaries in He I 586 Å and O V 630 Å lines during the period 1996 - 2012 indicates that the width is correlated with the solar cycle variation with a lag. A comparison of the widths in the two emission lines shows that it is larger for He I 586 Å . The results are expected to have implications in the flux transport on the solar surface and solar cycle.

Coronal Mass Ejections (CMEs) are magnetically driven gigantic eruptions which influence the space weather to a wide range. Investigations of the solar source region of an Earthward directed CME reveal that the magnetic flux ropes (MFR) system in the associated sunspot region are initiated to upward motion by kink-instability and further driven by torus instability. Observations suggest that the MFR structure in the outer corona is an evolved form of filaments seen in Hα images or their sigmodal structure in soft

X-ray images of the Sun. The EUV observations of the low corona suggest a further development of this MFR system by added axial flux through tether-cutting re-connection of the associated magnetic loops in the middle of the sigmoid structure. The CME morphology in the outer corona and its arrival time are consistent with MFR based model. The morphological changes in and around a Hα filament prior to its eruption was investigated. The possible trigger mechanism for two stage eruption was studied.

2.2 Stellar and Galactic Astrophysics

Studies on exoplanets, novae, supernovae and chemical abundance analysis of various types of stars were some of the topics in which IIA astronomers engaged this year.

Angular momentum of Sun like G stars and their exoplanets are estimated. The spin angular momentum (J_*) of the host stars are found to follow a power law ($\alpha \, \frac{M_*}{M_\odot}^{(4.187\pm0.247)}$) 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 ($\alpha \, \frac{m_p}{m_J}^{(1.237\pm0.033)}$) with planetary mass ($\frac{m_p}{m_J}$), yielding terrestrial planets to have very low orbital angular momentum compared to those of exoplanets. The total (spin and orbital) angular momentum L_{tot} of the stellar system is computed and a power law of the form $L_{tot}(\alpha \, \frac{m_p}{m_J}^{(0.637\pm0.032)})$ is obtained. The probability of detecting Earth like planets is found to be more likely for host stars that have total angular momentum $\sim 10^{42}$ kg m^2/sec.

Considering the physical and orbital characteristics of G type stars and their exoplanets, the association between stellar mass and its metallicity is examined. In case of multiplanetary systems, planetary mass is found to be linearly dependent on the stellar absolute metallicity and in case of single planetary systems, planetary mass is found to be independent of stellar metallicity. 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.

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 already have developed detectable biota on them. The old Population II stars with ages up to 13 Gyr are suggested as candidate stars that can host habitable planets with the already existing life on them.

A metric, Cobb-Douglas Habitability Score (CDHS), based on Cobb-Douglas habitability production function (CD-HPF), is proposed that computes the habitability score by using measured and calculated planetary input parameters. 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. 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.

The target selection process for the Multi-object APO Radial Velocity Exoplanets Large-area Survey (MARVELS) is determined; this procedure may also be useful for other surveys that need to rely on extant catalog data for selection of specific stellar populations. The detection of a giant planet (MARVELS-7b) and a brown dwarf candidate (MARVELS-7c) around the primary star (HD 87646A) in the close binary system, HD 87646 is reported. The derived minimal masses of the two sub stellar companions of HD 87646A are 12.39 ± 0.60 $M_{Jupiter}$ and 55.6 ± 2.7 $M_{Jupiter}$. 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 2014 outburst of the recurrent nova V745 Sco was monitored in the 610 and 235 MHz using the Giant Metrewave Radio Telescope (GMRT). The two main results obtained from the analysis of these data 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 type Ia supernova SN 2014J in M82 was monitored in the optical and Near Infra Red (NIR) using the Himalayan Chandra Telescope (HCT). The observed light curves were found to be similar to normal SNe Ia. The optical spectra showed a red continuum with deep interstellar $Na\ I$ absorption. The velocity estimate from Si II 6355 Å feature places SN 2014J at the border of the Normal Velocity and High Velocity group of SNe Ia. From an analytical model fit to the bolometric light curve the mass ejected in the explosion is calculated. Optical broadband, linear polarimetric observations of SN 2014J obtained on four epochs indicated an almost constant polarization which suggest an interstellar origin.

A detailed abundance analysis was performed for sixteen candidate CH stars based on high resolution ELODIE spectra for twelve objects and Subaru/HDS spectra for four objects. The stellar atmospheric parameters, the effective temperature T_{eff}, the surface gravity log g, and metallicity [Fe/H] are estimated from LTE analysis using model atmospheres. Updates on elemental abundances for several heavy elements, Sr, Y, Zr, Ba, La, Ce, Pr, Nd, Sm, Eu and Dy are reported. Large enhancement of Pb with respect to iron is confirmed in HD 26, HD 198269 and HD 224959. Analysis suggests that neutron-capture elements in HD 26 primarily originated 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.

An abundance analysis of fifty eight K giants identified as highly probable members of the Hercules stream selected from stars north of the celestial equator in the Hipparcos catalogue is performed. The giants are found to 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. It appears that the stream is dominated by metal-rich stars from the thin disc.

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 are analysed. Radial velocities and chemical compositions are determined for these objects. These are the first chemical abundance measurements for all but NGC 2447. A range of mild enrichment of heavy (Ba-Eu) elements is found in 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.

An analysis of new V and I CCD time series photometry of the distant globular cluster NGC 6229 revealed 25 new variables: 10 RRab, 5 RRc, 6 SR, 1 CW, 1 SX Phe, and 2 that we were unable to classify. Secular period changes were detected and measured in some favourable cases. The classifications of some of the known variables were rectified. 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 is interpreted as the red edge of the first overtone instability strip.

The distance and metallicity ([Fe/H]) value for the globular cluster NGC 5904 (M5) are derived from the Fourier decomposition of the light curves of selected RRab and RRc stars. The 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.

An abundance analysis of an extremely metal-poor star, SDSS J134338.67+484426.6, shows the object to be a subgiant with [Fe/H] = −3.42, having 'normal' carbon and no enhancement of neutron-capture abundances. Strontium is under abundant but likely enhanced relative to Ba. The star exhibits low ratios of [Mg/Fe], [Si/Fe], and [Ca/Fe] compared to typical halo stars at similar metallicity. The observed variations in radial velocity indicate that the object is a possible long-period binary.

2.3 Cosmology and Extragalactic Astronomy

The many themes that have been pursued 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 magnetic field that is observed. The dynamo is driven by supernovae turbulence and using constraints such as helicity and its flux into the corona where it is dissipated, the steady modes are calculated. A time dependent solution is obtained using eigen vector expansions of the steady mode that allows the estimate of the final saturated field structure and the strength; the key result is that the saturation is achieved with a 1 Gyr (see Figure 2.3) that has implications for detection and study of its cosmic evolution through upcoming missions such as the Square Kilometer Array.

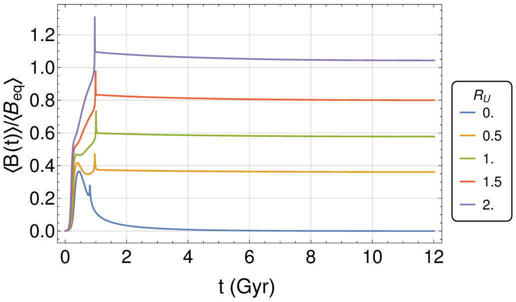


Figure 2.3: The evolution of the mean magnetic field (in units of equipartition field strength) for the galactic disc with time for different values of advection parameter R_U. The mean magnetic field in the disk is found to reach equipartition strength within a timescale of 1 Gyr.

The core shift effect in the parsec scale emission of the blazar 3C 454.3 was studied using 4.8 GHz - 36.8 GHz radio light curves obtained from three decades of continuous monitoring of this bright, strongly variable source. The evidence provides the core shift dependence on the observation frequency and is used to determine jet diagnostics in the region such as the spin and magnetic field close to the resolving limit of very large baseline interferometric observations.

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 electro-dynamical jet. The spin evolution is calculated with and without accretion; when the accretion stops, the jet power increases before a gradual decline if the initial spin is above a certain limit, 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.

A near-infrared (NIR) imaging study of barred low surface brightness (LSB) galaxies was carried out using the TIFR near-infrared Spectrometer and Imager (TIRSPEC) on the HCT. Using SDSS images of a very large sample of LSB galaxies derived from the literature, it was found that the barred fraction is only 8.3%. From images of twenty five barred LSB galaxies in the J,H, KS wavebands and twenty nine in the KS band, it was seen that most of the bars are much brighter than their stellar disks, which appear to be very diffuse. Although bars are rare in LSB galaxies, they appear to be just as strong as bars found in normal galaxies.

In order to understand the well-established but not so well-understood scaling relationships of supermassive black holes, a spectroscopic imaging survey of a sample of ~ 140 nearby active galaxies with an integral field unit mounted on the Siding Spring 2.3m 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 is done with the GMRT and ATCA, and the radio-IR scatter plot for the sample shows excess radio emission over that predicted by star formation in most cases, which is clearly due to the AGN. Thus, accreting central supermassive black holes can indeed regulate star formation in their hosts well beyond their sphere of influence in active galaxies.

Low frequency observations at 325 MHz and 610 MHz have been carried out for two "radio-loud" Seyfert galaxies, NGC 4235 and NGC 4594 (Sombrero galaxy), using the 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 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 predicts star formation rates (SFR) that are an order of magnitude lower than those required to power the radio lobes in these Seyferts. This finding along with the detection of parsec and sub-kpc radio jets in both Seyfert galaxies, support the suggestion that Seyfert lobes are AGN-powered.

A model of elliptical galaxy cusps that follow a single power law and the Nuker profile was used to derive the distribution function of the stars in presence of the supermassive black hole (SMBH) at the center and compute the line of sight (LOS) velocity dispersion (σ) assuming the system to have a spherical symmetry. For a range of values for masses of SMBH, we derive $M_\bullet \propto \sigma^p$ for different power law profiles where $p =$ 3.5 - 4.5. Taking typical values of $\sigma_{||}$, we derive a range for the central density. Assuming that a proportionality relation holds between M_{Bulge} and $M_\bullet$ and applying that to several Nuker profile galaxies it was found that $M_\bullet \propto \sigma^{4.15}$. For both power and Nuker profiles, it was concluded that the model is in agreement with observational values.

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 $r_p(E,\ J,\ M_\bullet)$. We solved the steady state Fokker–Planck equation using the standard loss cone theory for typical galactic density profile and stellar mass function 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 $\gamma = 0.7$. We use this to model the in-fall rate of the disrupted debris, 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. We have simulated the light curve profiles 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, we 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}.

A self consistent calculation of the time evolution of non-relativistic time dependent accretion disk was carried out for both cases of sub-Eddington and super Eddington accretion with outflowing wind. For a sub-Eddington disk, the disk is considered to be gas pressure dominated whereas for the super-Eddington disk is considered as an extended disk with radiation pressure. With an analytic solution of surface density, the luminosity profile in various spectral bands are calculated. Then the model is fit to the observations in optical and X-ray bands to derive 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 (See Figure 2.4).

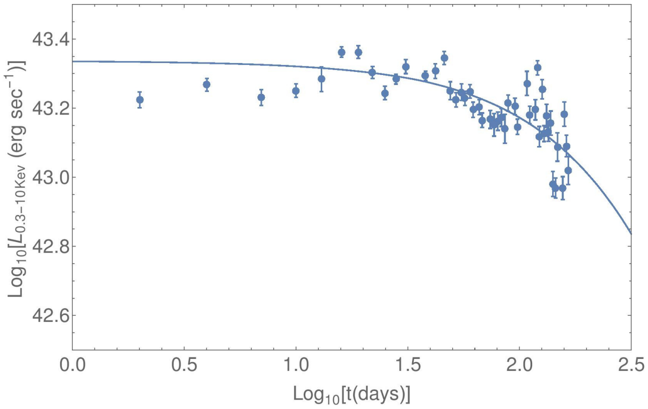


Figure 2.4: Our sub Eddington model fit to the X-ray observation ASASSN-14li by ASAS-SN survey. The fit parameters are $\bar{e} = 10^{-3}$, $\ell = 0.32$, $M_6 = 2.2$ and $M_\star = 1.2 M_\odot$ (Holoien et al. 2016) where $\bar{e} = E/(GM_\bullet/r_t)$, $\ell = J/J_{lc}$, $M_\bullet = 10^6 M_\odot M_6$ and r_t is the tidal radius.

The particle nature of dark matter remains a mystery. In this context two dark matter models, namely Late Forming Dark Matter (LFDM) and Ultra-Light Axion (ULA) models were considered where the matter power spectra show ineresting effects on small scales. The high redshift universe offers a powerful probe of their parameters. Assuming a fiducial model where a neutral hydrogen fraction $x_{HI} = 0.5$

must be achieved by $z = 8$, the reionization process puts approximate bounds on the redshift of dark matter formation $z_f > 4 \times 10^5$ (for LFDM) and the axion mass $m_a > 2.6 \times 10^{-23} eV$ (for ULA).

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. From mass modelling of 10 gravitationally lensed quasar systems using a 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 $\omega_\lambda = 0.7$.

2.4 Theoretical Physics & Astrophysics

The themes that have been pursued include relativistic astrophysics, magnetic fields, quantum chemistry, galactic gas dynamics and radiative transfer theory.

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 oscillations (QPOs). Phenomenological explanation for detection of QPOs and 3:2 QPO ratio in XRBs have been given by different phenomenological models that are dependent on radial and orbital frequencies. Expressing frequencies as function of eccentricity and distance in Schwarzschild geometry, an analysis was done to derive the ranges in these parameters from where the frequency ratio of 1.5 ± 0.2 can arise. Results show that for $r > 18M$ (M is the black hole mass, velocity of light and gravitational constant are taken as 1) the range of eccentricity to give required ratio becomes very narrow near $e \sim 0.7$ for all models. For circular orbits the models give a ratio between 1 to 2 for wide range of radii. A model with relativistic precession gives required ratio for radii less than $10M$. Stationarity constraints in Kerr geometry for circular orbits imply 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.

A previously derived axisymmetric nonlinear force-free field (NLFFF) solutions are applied 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 (see Figure 2.5). Topological quantities like crossing numbers (using two different formulations) are obtained for the braided magnetic fields and their statistical distributions. 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. We 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.

The sunspot is modelled using 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 with twisted magnetic fields. From the Grad-Shafranov equation, we derive the magnetic flux function, $A(r, z)$ whose radial part is a hypergeometric function and varies exponen-

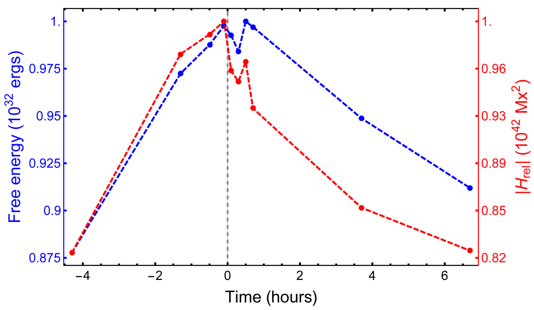


Figure 2.5: Evolution of free-energy (blue) and relative helicity (red) with time for AR 11283 on 06/09/2011. The origin in time axis corresponds to 22.20 hours when a X 2.1 class flare took place.

tially with the vertical height, assuming a specific algebraic form for the pressure and poloidal current profile. 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 was derived; by applying positivity constraints for the gas pressure, the magnetic field structure, pressure and density inside the sunspot was constructed.

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.

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. 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.

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. Rotation-induced oblateness may yield a net non-zero disk averaged polarization if the planets have sufficiently high spin rotation velocity. Adopting detailed atmospheric models for several values of effective temperature and surface gravity which are appropriate for self-luminous exoplanets, the polarization profiles of these objects in the infrared during transit phase are calculated and the peak amplitude of polarization is predicted to range between 0.1 and 0.3 percent. High surface density, rapidly star-forming galaxies are observed to have 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 impact of high velocity dispersions that arise from these disk instabilities are explored. The results suggests that in strongly self-gravitating disks, outflows may be enhanced by, but need not be caused by, energy input from supernovae.

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 to a need to relax this assumption. A numerical algorithm has been proposed 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. We show 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 us to propose a simplified approach called "correction method" to solve the problem at hand.

The interference between magnetic substates of the hyperfine structure states belonging to different fine structure states of the same atomic term has been studied. It influences the polarization for some of the diagnostically important lines of the solar spectrum, like the sodium and lithium doublets. The polarization signatures of this combined interference contain information on the properties of solar magnetic fields. With this motivation, using the Kramers–Heisenberg scattering matrix approach, we derived the redistribution matrix for this process by including the Paschen–Back (PB) and partial frequency redistribution effects. We 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.

Chapter 3

STUDENT PROGRAMMES AND TRAINING ACTIVITIES

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

3.1 Ph.D Degree Awarded

P. Subramania Athiray was awarded (on 08 July 2015) the Ph.D. 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 Ph.D. 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 Ph.D. 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 August 2015) the Ph.D. 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 October 2015) the Ph.D. 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 October 2015) the Ph.D. 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 January 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 January 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 February 2016) for her thesis titled "Studies on Carbon-Enhanced Metal-Poor (CEMP) stars" 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 February 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.

3.2 Ph.D Thesis Submitted

The following students have submitted their Ph.D. thesis:

Arun Surya submitted his thesis titled "Image Retrieval in Astronomical Interferometers Affected by Atmospheric Turbulence" to the University of Calcutta on 24 June 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 August 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 August 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 February 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 March 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 March 2016. The research was done under the supervision of B. Ravindra and K. N. Nagendra.

3.3 Completion of M.Tech. Programme

The following students from the 7th batch of the above programme have completed the IIA-CU integrated M.Tech-Ph.D course:

Anwesh K Mishra under the guidance of U.S. Kamath submitted his M.Tech. thesis titled "Mid-infrared imager for the 2m 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 M.Tech. 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 M.Tech. 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 M.Tech. 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 M.Tech. thesis titled "Edge Sensor for Segmented Mirror Telescopes" to the University of Calcutta on August 2015.

3.4 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 Ph.D. 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.

3.5 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 B.Sc, M.Sc, B.E./B.Tech. 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 18–29 May 2015. It consisted of a series of lectures in Physics and Astrophysics mostly by the faculties of IIA. The areas on which lectures were given include Solar Physics (K. Sundara Raman, S. P. K. 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. Satya Narayanan) and recent trends in astronomy (P. Sreekumar). 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 arrangements of the school were made by the staff of the Kodaikanal Observatory under the guidance of R. Selvendran, and the entire summer programme was coordinated by C. S. Stalin, Firoza K. Sutaria and Mousumi Das.

3.6 External Students

The Institute's faculty also supervise the Ph.D. thesis of students in universities, external to IIA's Ph.D. programmes, as guide / co-guide. Faculty from universities and colleges working towards their Ph.D. 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 Ph.D. thesis submitted, and two students have been awarded Ph.D. degree.

Chapter 4

INSTRUMENTS AND FACILITIES

4.1 Systems Engineering Group

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.


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Figure 4.1: Class 10 up gradation 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 M Tech-PhD students were completed. Experiment using these stages at Kodaikanal observatory is in progress.

Design and fabrication of 4K × 4K CCD Dewar for 1.3m JCBT has been completed. Trial assembly and preliminary checks are under progress. The performance tuning of 75cm telescope has been completed. The STARS (ISRO) building at VBO, Kavalur has been renovated by changing the asbestos

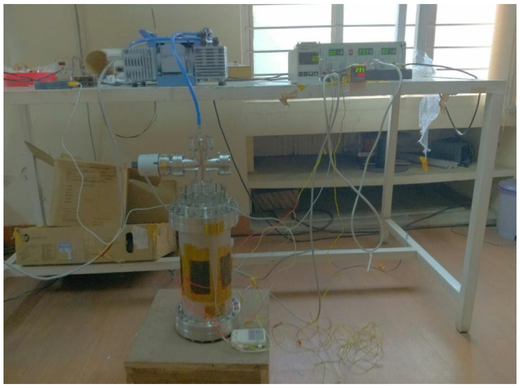

Figure 4.4: Precision thermal control vacuum chamber (0.01° C thermal stability)

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 2nd & 3rd 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 $20\mathring{A}$ 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 X-ray instrumentation

Multilayer mirrors provide high reflectivity for X-rays at non-grazing incidence angles. They are used in large numerical aperture X-ray 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. 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's law. Figure 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.

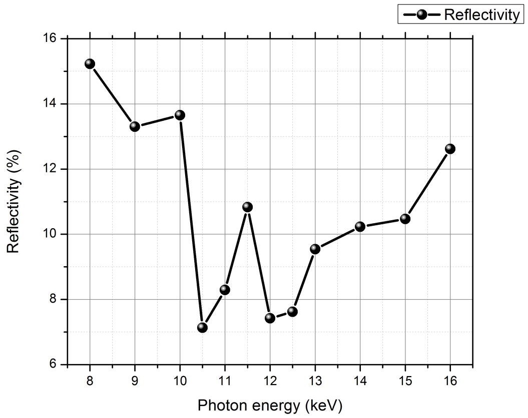

Figure 4.5: Peak reflectivity at first Bragg peak of the mirror as a function of incident photon energy

4.4 Integration of Mathematica using PBSPro as Cluster Management Technology

Mathematica is a powerful computational tool using symbolic, procedural and functional programming aspects. Mathematica is designed to make use of local multicore or multi-CPU hardware, as well as supports distributed computing across systems. It integrates with a large number of third party cluster management technologies including the Altair PBSPro. The behaviour of Mathematica with the different queues configured in PBSPro scheduler on HPC cluster for submission of parallel and serial jobs have been studied. With 24 simultaneous WolframKernels (Mathematica Kernels) launched on 24 cores across the cluster using PBSPro scheduler, we were able to achieve a speedup of 18 times (approx), compared to a single WolframKernel on a single core as benchmark result.

4.5 OBSERVATORIES

4.5.1 Indian Astronomical Observatory

Himalayan Chandra Telescope

The 2m 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 2nd 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 28th August to 5th 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.

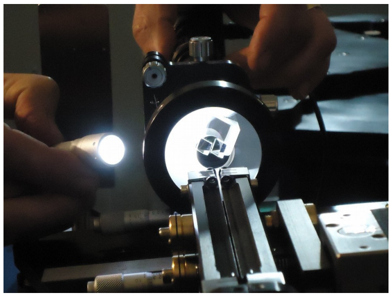

Figure 4.6: Assembly of the HESP input optics.

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 0.02pixels 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}

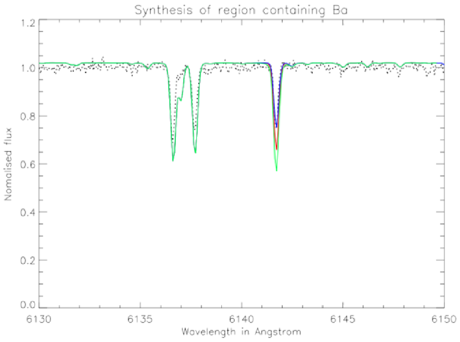

Figure 4.7: Newly discovered Carbon enhanced metal poor star (CEMP) from SDSS survey, observed with HESP, show depleted neutron capture (Barium) elements indicting that the CEMP star is formed from ISM polluted by metal poor faint supernovae that are similar to those observed at high redshifts.

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/ development 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 setting up a 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 2nd 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 10m and 30m 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.

4.5.2 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 allocation 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 32m high tower at CREST Campus of IIA, Hoskote. The tower has been erected and the lab space has been identified at CREST campus.

4.5.3 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.

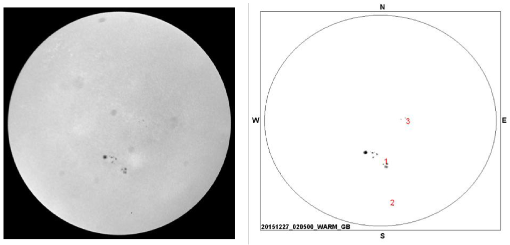

Figure 4.8: A typical example of the results of sunspot detection scheme.

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, and was 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 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.

4.5.4 Vainu Bappu Observatory

Four major telescopes were used for regular observations. VBT, JCBT and the 1m Carl

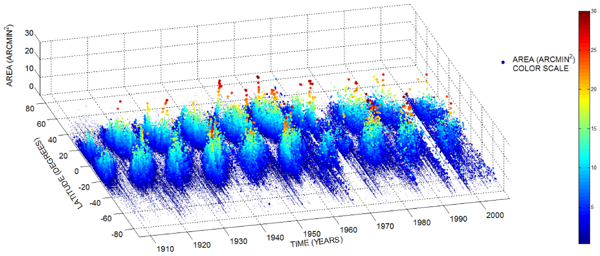

Figure 4.9: 3 dimensional visualisation of Ca II K butterfly diagram with area of individual plages as the z-axis. These observations include information on the sizes and positions of plages as well as their numbers. These data show that plages do not appear at random over the surface of the sun but 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.

Zeiss telescopes had scheduled observations, while trial observations were done at 30 inch telescope.

Medium resolution spectroscopy of IRAS sources with far-IR colors similar to Post-AGB stars and planetary nebulae, T Tauri stars, novae, supernovae, hydrogen-deficient stars, contact binaries were the observing programs carried out using OMR spectrograph at VBT.

Differential photometry of blazars and novae using UKATC 2K × 4K CCD system and Jovian satellites occultation and eclipse events, cataclysmic variables and exoplanets using ProEM 1024B CCD system were the observing programs carried out at JCBT.

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 and medium resolution spectroscopy of Be stars using UAGS were the observing programs carried out at 1 metre telescope.

30 inch telescope performance

Tracking tests were carried out in May, 2015 using LUCA EMCCD camera (13.5 MHz), similar to the 1.3M 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.

4.5.5 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 between + 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.

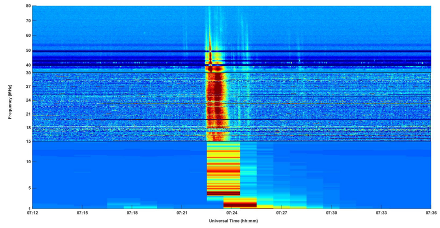

Figure 4.10: Composite of the spectrum of a solar radio transient observed with existing radio spectrograph in the Gauribidanur observatory in the frequency range 85-35 MHz, the new very low frequency observing facility there in the frequency range 30-14 MHz (see the text), and observations of the same 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.

4.6 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: noindent 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 prototype 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 3rd 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 103rd 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

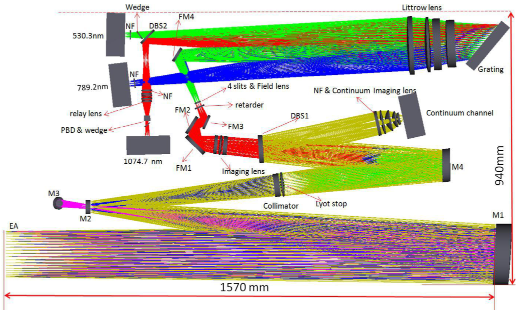

Figure 5.2: Optical layout of VELC

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.

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-

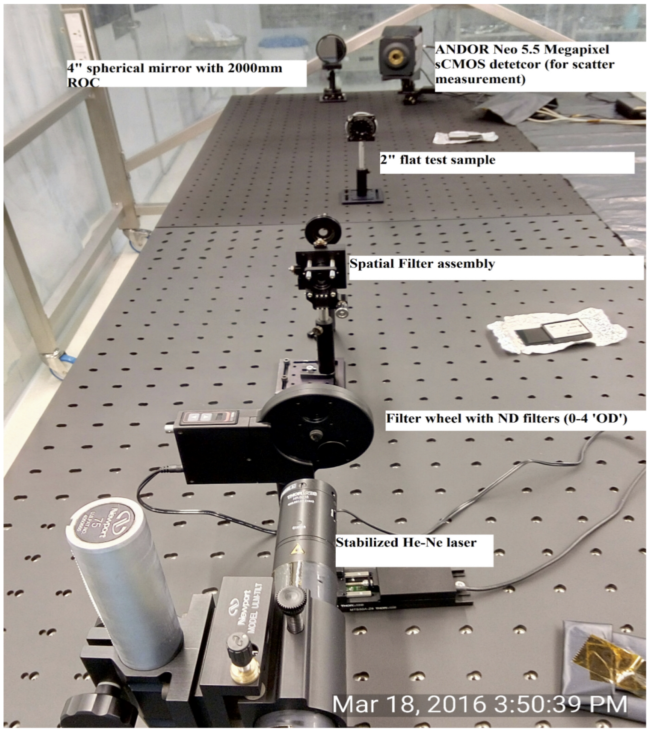

Figure 5.3: NSS experiments in class-10 clean room

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.

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

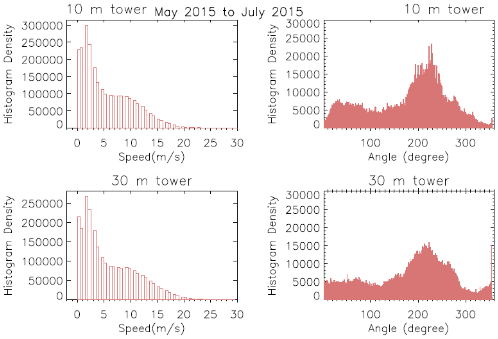

Figure 5.4: Wind speed frequency histograms at two heights at Hanle, observed simultaneously.

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 10m 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 vapour 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 clearance for the Merak site came from the Ministry of Defence. 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.

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. 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

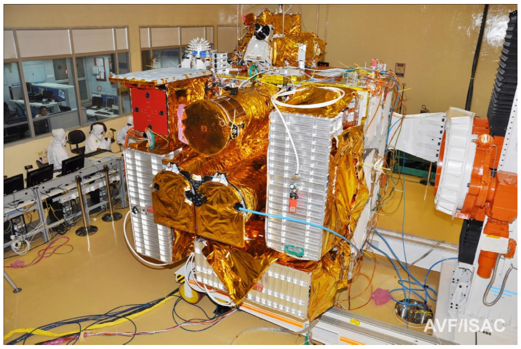

Figure 5.5: ASTROSAT is shown before the launch. The golden looking foils all over are for thermal control. Doors of the two telescopes of UVIT are seen in the front.

ISITE campus of ISAC, ISRO. 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.

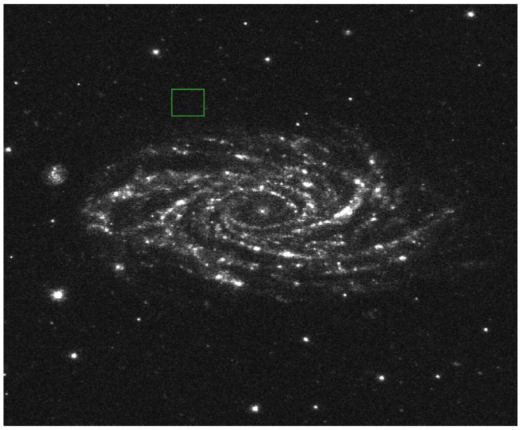

Figure 5.6: Image of galaxy NGC2336, in Near Ultraviolet, is shown at top.

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 varia-

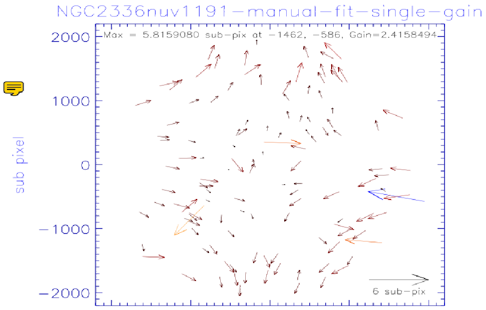

Figure 5.7: Astrometric accuracy is illustrated for the field of galaxy NGC2336. The arrows show error-vectors for positions of the stars as found by comparision with an image taken with a ground based telescope. Scale of the image is 0.4”/pixel and scale of the error vectors is illustrated by the arrow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

tions in coordination with the X-ray telescopes on ASTROSAT.

Chapter 6

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 Ph.D. 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. IIA had set up a stall under DST Pavilion in

Figure 6.1: A group photo taken during one of school outreach event at Bharathi Education Society, Bengaluru.

the 35th 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.

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 103rd Indian Science Congress (ISC) held at Mysuru. The IIA-DST pavilion won the most innovative stall award at ISC 2016.

Founder's Day The Birth anniversary of Prof.M.K.Vainu Bappu was celebrated on 10th 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.

Figure 6.2: UVIT at 103rd Indian Science Congress 2016 held at Mysuru

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 10th 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.

6.1 Staff Activities

6.1.1 Welfare of SC/ST Staff & Physically challenged

A senior officer of the Institute has been functioning as the liaison officer to support the welfare of the SCST staff members. Special consideration as per norms during recruitment and regular assessment has been provided to these categories of employees. As of the end of the year, members belonging to the SC, ST and OBC categories constitute 13.55%, 12.71% & 7.62% respectively of the total strength. In addition, reservations continue to be extended to OBCs and physically disabled persons. Proactive efforts are continuously made towards their welfare. Facilities and mechanisms have been provided for special administrative as well as technical training of staff from the historically disadvantaged categories.

6.1.2 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 member's 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 1st 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 7

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Chapter 8

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, i 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. Sankar Subramanian

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 Valsalan

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

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, M. Rajalingam, S. Ramamoorthy, 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

Chapter 9

AUDITED STATEMENT OF ACCOUNTS, 2015 - 16

CONTENTS

V.K. NIRANJAN & CO. ★ Chartered Accountants ★
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Ref. No.: I-5351/20239/2016-17

Date : 19/09/2016

INDEPENDENT AUDITORS' REPORT
TO THE MEMBERS OF INDIAN INSTITUTE OF ASTROPHYSICS,

Report on the Financial Statements;

We have audited the accompanying financial statements of INDIAN INSTITUTE OF ASTROPHYSICS which comprise the Balance Sheet as at 31 March 2016, the Statement of income and expenditure for the year then ended, and a summary of significant accounting policies and other explanatory information.

Management's Responsibility for the Financial Statements;

The management is responsible for preparation of financial statements that give a true and fair view of the financial position and financial performance of the Institute in accordance with the accounting principles generally accepted in India. This responsibility also includes the maintenance of adequate accounting records for safeguarding of the assets of the Institute and for preventing and detecting frauds and other irregularities; selection and application of appropriate accounting policies; making judgments and estimates that are reasonable and prudent; and design, implementation and maintenance of adequate internal financial controls, that were operating effectively for ensuring the accuracy and completeness of the accounting records, relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility;

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit of the financial statements in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal financial control relevant to the Institute's preparation of the financial statements that give a true and fair view in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by the Institute's Management as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion on the financial statements.

Basis for Qualified Opinion

<u>Accounting Standard 15 in relation to Employee Benefits:</u> The Institute has not created provision for post-employment benefits such as gratuity, pension and leave encashment as per accrual basis and the actuarial valuation to be made every year. This is contrary to Accounting Standard - 15 - Employee Benefits. The impact of above deviation from the accounting standard is not ascertainable.

Opinion

In our opinion and to the best of our information and according to the explanations given to us, except for the effects of the matter described in the 'Basis for Qualified Opinion' paragraph above, the aforesaid financial statements, give the information required and give a true and fair view in conformity with the accounting principles generally accepted in India;

a) In case of the Balance Sheet, of the state of affairs of the Institute as at March 31, 2016;

b) In case of the Statement of Income and Expenditure Account, of the excess of expenditure over income for the year ended on that date;

Report on other Legal and Regulatory Requirements

We further report that:

a) We have sought and obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit.

b) In our opinion proper books of account as required by law have been kept by the Institute so far as appears from our examination of those books and proper returns adequate for the purposes of our audit.

c) The Balance Sheet, the Statement of Income and Expenditure account dealt with by this Report are in agreement with the books of account.

d) In our opinion, the aforesaid financial statements comply with the Accounting Standards.

Place: BENGALURU
Dated: 19/09/2016

For V K NIRANJAN & CO
Chartered Accountants
Firm's Reg. No. 002468S

CA NIRANJAN V K
PARTNER
M No. 021432

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INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU -560034

BALANCE SHEET AS AT 31ST MARCH, 2016

(Amount in Rs.)

	SCH	AS at 31.03.2016	AS at 31.03.2015
I. SOURCES OF FUNDS			
CAPITAL FUND	1	67,98,11,510	60,70,15,493
GENERAL FUND	2	5,000	5,000
CURRENT LIABILITIES & PROVISIONS	3	45,05,70,127	25,38,73,936
TOTAL		**1,13,03,86,637**	**86,08,94,429**
II. APPLICATION OF FUNDS			
FIXED ASSETS	4	64,36,08,985	44,12,58,177
CURRENT ASSETS: ADVANCES AND DEPOSITS	5	2,46,48,295	22,07,23,030
CASH AND BANK BALANCES:	6		
IIA Account		2,06,63,733	42,39,916
External Projects Account		44,14,65,623	19,46,73,306
TOTAL		**1,13,03,86,637**	**86,08,94,429**
Notes on Accounts:	15		

Note:- The Schedules and Notes on accounts referred to above form an integral part of the Balance Sheet & Income & Expenditure Account.

S.B.RAMESH
Accounts Officer

P.KUMARESAN
Administrative Officer

P.SREEKUMAR
Director

As per our report of even date,
for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

NIRANJAN V.K.
Partner
M.No: 021432

Place: BENGALURU
Date: 19.09.2016

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BANGALORE
560 009

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU - 560034

INCOME AND EXPENDITURE ACCOUNT UNDER PLAN
FOR THE YEAR ENDED 31ST MARCH, 2016

(Amount in Rs.)

	SCH	2015-16	2014-15
A. INCOME			
Grants-in-aid	7	50,29,10,750	44,39,99,021
Other Income	8	45,35,435	35,25,763
TOTAL - A		**50,74,46,185**	**44,75,24,784**
B. EXPENDITURE			
Salaries and Allowances	9	27,00,03,969	40,27,11,949
Office Expenditure	10	1,54,58,015	1,60,12,937
Working Expenses	11	14,07,18,231	10,36,08,099
Stores & Consumables	12	29,94,223	34,01,874
Depreciation	4	6,05,84,662	4,97,00,244
TOTAL - B		**48,97,59,099**	**57,54,35,102**
C. SURPLUS / (DEFICIT) FOR THE YEAR (A - B)		1,76,87,086	(12,79,10,318)
Notes on Accounts:	15		

S.B.RAMESH	**P. KUMARESAN**	**P.SREEKUMAR**
Accounts Officer	Administrative Officer	Director

As per our report of even date,
for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

NIRANJAN V.K.
Partner
M.No: 021432

Place: BENGALURU
Date: 19.09.2016

V.K. NIRANJAN & CO.
☎ 22267769
22285005
BANGALORE
560 009
Chartered Accountants

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU - 560034
INCOME AND EXPENDITURE ACCOUNT UNDER NON-PLAN
FOR THE YEAR ENDED 31ST MARCH, 2016

(Amount in Rs.)

	SCH	2015-16	2014-15
A. INCOME			
Grants-in-aid	13	50,00,000	76,50,000
TOTAL - A		**50,00,000**	**76,50,000**
B. EXPENDITURE			
Salaries and Allowances	14	50,00,000	76,50,000
TOTAL - B		**50,00,000**	**76,50,000**
Notes on Accounts:	15		

S.B.RAMESH	**P. KUMARESAN**	**P.SREEKUMAR**
Accounts Officer	Administrative Officer	Director

As per our report of even date,
for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

NIRANJAN V.K.
Partner
M.No: 021432

Place: BENGALURU
Date: 19.09.2016

RECEIPTS AND PAYMENTS ACCOUNT UNDER PLAN
FOR THE YEAR ENDED 31ST MARCH, 2016

(Amount in Rs.)

		SCH	2015-16	2014-15
RECEIPTS				
Opening Balance				
IIA Account			42,34,916	1,18,79,974
External Projects Account			19,46,73,306	4,96,25,575
Grants-in-aid	55,39,00,000			
Add:Interest from Bank and Staff Advances	41,19,681	A	55,80,19,681	50,68,44,837
Other Receipts		B	45,35,435	35,25,763
Advance Recoveries / Credits/Adjustments		C	56,76,45,717	22,13,22,263
TOTAL			1,32,91,09,055	79,31,98,412
PAYMENTS				
Recurring Expenditure		D	48,02,45,438	47,46,61,489
Non-Recurring Expenditure		E	5,81,08,931	4,60,18,608
Deposits and other payments		F	32,86,30,330	7,36,10,093
Closing Balance				
IIA Account		6	2,06,58,733	42,34,916
External Projects Account		6	44,14,65,623	19,46,73,306
TOTAL			1,32,91,09,055	79,31,98,412

S.B.RAMESH
Accounts Officer

P.KUMARESAN
Administrative Officer

P.SREEKUMAR
Director

As per our report of even date,
for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

NIRANJAN V.K.
Partner
M.No: 021432

Place: BENGALURU
Date: 19.09.2016

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INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU - 560034

RECEIPTS AND PAYMENTS ACCOUNT UNDER NON-PLAN FOR THE YEAR ENDED 31ST MARCH, 2016

(Amount in Rs.)

	SCH	2015-16	2014-15
RECEIPTS			
Opening balance		5,000	5,000
Grant-in-aid	G	50,00,000	76,50,000
TOTAL		**50,05,000**	**76,55,000**
PAYMENTS			
Recurring Expenditure	H	50,00,000	76,50,000
Closing Balance	6	5,000	5,000
TOTAL		**50,05,000**	**76,55,000**

S.B.RAMESH	**P.KUMARESAN**	**P.SREEKUMAR**
Accounts Officer	Administrative Officer	Director

As per our report of even date,
for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

NIRANJAN V.K.
Partner
M.No: 021432

Place: BENGALURU
Date: 19.09.2016

ACCOUNT FOR THE YEAR ENDED 31-03-2015

PARTICULARS	As at 31.03.2016	As at 31.03.2015
	Rs.	Rs.
SCHEDULE -1		
CAPITAL FUND		
As per Previous Balance Sheet	60,70,15,493	67,20,79,995
Add: Grants received during the year		
(Non-Recurring Expenditure)	5,51,08,931	6,28,45,816
	66,21,24,424	**73,49,25,811**
Add/(Less): Surplus/(Deficit) for the year (Plan)	1,76,87,086	(12,79,10,318)
TOTAL	**67,98,11,510**	**60,70,15,493**
SCHEDULE -2		
GENERAL FUND		
As per Previous Balance Sheet	5,000	5,000
TOTAL	**5,000**	**5,000**
SCHEDULE -3		
CURRENT LIABILITIES & PROVISIONS		
Audit Fee Payable	86,640	86,640
Earnest Money Deposit	43,64,325	32,04,825
Security Deposit - Contractors	37,49,232	30,32,285
Caution Deposit	9,02,380	8,05,880
GLSI Payable	1,927	-
External Projects Fund Balances	44,14,65,623	19,46,73,306
Advance Recovery from Contract Payments	-	10,00,000
Provision for Terminal Benefits	-	5,10,71,000
TOTAL	**45,05,70,127**	**25,38,73,936**

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU - 560034
SCHEDULE-4
FIXED ASSETS AS AT 31.03.2016

		Gross Block				Depreciation Block					Net Block	
Sl. No.	Description	As on 01.04.2015	Additions During the year	Transfer/ Adjustment	As on 31.03.2016	Rate %	As on 01.04.2015	For the Year	Transfer/ Adjustment	As on 31.03.2016	As on 31.03.2016	As on 31.03.2015
		Rs.	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Land	2,48,98,870	-	-	2,48,98,870	-	-	-	-	-	2,48,98,870	2,48,98,870
2	Buildings	33,45,75,572	77,00,640	-	34,22,76,212	5%	9,25,46,383	1,24,86,491	-	10,50,32,875	23,72,43,337	24,20,29,190
3	MGK Menon Lab (UVIT)	12,13,47,901	6,65,270	-	12,20,13,171	5%	-	61,00,659	-	61,00,659	11,59,12,512	-
4	Vainu Bappu Telescope	5,30,85,009	-	-	5,30,85,009	15%	5,30,59,371	3,846	-	5,30,63,217	21,792	25,638
5	2m Telescope	45,30,13,898	-	-	45,30,13,898	15%	45,28,00,585	31,997	-	45,28,32,582	1,81,316	2,13,313
6	HAGAR	5,12,54,355	-	-	5,12,54,355	15%	3,35,16,590	26,60,665	-	3,61,77,255	1,50,77,100	1,77,37,765
7	Capital Equipments	95,75,98,742	1,95,81,517	-	97,71,80,259	15%	84,92,06,093	1,91,96,125	-	86,84,02,218	10,87,78,041	10,83,92,649
8	Furniture	2,54,48,899	5,70,536	-	2,60,19,435	10%	2,47,38,633	1,28,080	-	2,48,66,714	11,52,721	7,10,266
9	Vehicles	1,50,59,268	-	-	1,50,59,268	15%	1,35,70,981	2,23,243	-	1,37,94,224	12,65,044	14,88,287
10	Computers	13,54,59,612	54,35,417	-	14,08,95,029	60%	12,92,61,835	69,79,916	-	13,62,41,751	46,53,278	61,97,777
11	Books and Journals	14,38,45,638	65,47,024	-	15,03,92,662	60%	14,04,96,860	59,37,481	-	14,64,34,341	39,58,321	33,48,778
12	Typewriter	2,55,369	-	-	2,55,369	15%	2,55,368	-	-	2,55,368	1	1
13	HESP-IIA	3,94,18,858	61,55,534	-	4,55,74,392	15%	-	68,36,159	-	68,36,159	3,87,38,233	-
	WORK-IN-PROGRESS											
1	Building at Leh	3,62,15,645	64,22,394	-	4,26,38,039	-	-	-	-	-	4,26,38,039	3,62,15,645
2	N.L.S.T.	4,59,53,870	16,61,790	-	4,76,15,660	-	-	-	-	-	4,76,15,660	-
3	N.L.O.T	11,05,909	3,68,809	-	14,74,718	-	-	-	-	-	14,74,718	-
	Total Rs.	**2,43,85,37,415**	**5,51,08,931**	-	**2,49,36,46,346**		**1,78,94,52,701**	**6,05,84,662**	-	**1,85,00,37,362**	**64,36,08,985**	**44,12,58,177**

V.K. NIRANJAN & CO.

SCHEDULE - 5

CURRENT ASSETS

PARTICULARS	As at 31.03.2016 Rs.	As at 31.03.2015 Rs.
A) INVENTORY		
Stock on hand - Stores & Consumables	7,91,457	2,44,728
(As Certified by the Management)		
B) ADVANCES TO SERVICE PROVIDERS		
Deposit for Residential Accommodation	6,31,491	6,31,491
Deposit with Hamsa Service Station	6,000	6,000
Deposit with KEB	3,94,364	3,33,124
Deposit with St.Philomena Hospital	10,000	10,000
Deposit with Telephone Dept.	3,95,158	3,95,158
Deposit with TNEB	2,41,225	2,35,604
Deposit with CPWD for Civil Works	5,75,062	5,75,062
C) LOANS & ADVANCES TO STAFF		
Contingent Advance	24,000	13,000
Festival Advance	36,294	81,669
House Building Advance	33,69,377	44,78,607
LTC Advance	2,59,160	2,42,750
Motor Car Advance	17,38,202	18,90,247
Motor Cycle Advance	15,91,903	18,32,480
Computer Advance	4,86,436	7,63,122
Travelling Advance	2,65,205	2,16,550
D) Amt Receivable		
Amt receivable from CSIR (Avijeet Prasad)	11,91,900	8,71,900
Amt receivable from CSIR (Nancy Narang)	3,21,786	
Tax Deducted at Source	3,75,000	75,000
Margin Letter of Credit	17,80,000	-
Amt receivable from Aditya Project	1,01,64,275	-
TOTAL	**2,38,56,838**	**1,26,51,764**
TOTAL (A+B)	**2,46,48,295**	**1,28,96,492**

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V.K. NIRANJAN & CO.

PARTICULARS	As at 31.3.2016	As at 31.3.2015
	Rs.	Rs.

SCHEDULE - 6

CASH AND BANK BALANCES

Cash on Hand		
Bangalore	31,122	38,359
Kodaikanal	11,036	734
Kavalur	3,584	10,833
Leh	25,105	14,310
Hoskote	6,433	5,295
Cash at Banks		
Bank of Baroda, Bangalore (2/74)	5,79,747	14,15,875
Bank of Baroda, Bangalore (SB A/c 1/1565)	7,06,79,345	18,21,87,740
Bank of Baroda, Bangalore (TMT SB A/c 1/1575)	38,71,63,708	1,12,15,682
State Bank of India, Kodaikanal	-	22,313
State Bank of India, Kodaikanal (SB A/c)	1,77,805	2,65,796
Indian Overseas Bank, Kavalur (SB A/c)	7,10,463	3,43,582
State Bank of India, Leh	6,60,510	4,19,729
State Bank of Mysore, Bangalore	3,59,071	1,65,894
State Bank of Mysore, Hoskote	9,268	9,268
State Bank of Mysore, Hoskote (SB A/c)	8,37,575	10,19,932
Union Bank of India, Bangalore	2,49,187	1,78,580
Union Bank of India, Bangalore (SB A/c)	1,99,836	10,47,811
Canara Bank, Gauribidanur	4,03,016	5,28,944
HDFC Bank, Bangalore	22,544	22,544
TOTAL	**46,21,29,356**	**19,89,13,222**
Plan	**2,06,58,733**	**42,34,916**
Non-Plan	**5,000**	**5,000**
Project Fund	44,14,65,623	**19,46,73,306**

PARTICULARS		2015-2016 Rs.	2014-2015 Rs.

SCHEDULE - 7

Grants-in-aid - PLAN		55,39,00,000	49,96,48,000
(Ministry of Science & Technology, Dept of Science & Technology)			
Add: Bank Interest	24,28,981		
Interest on Advances to Staff	16,90,700	41,19,681	71,96,837
Less : Amount transferred to Capital Fund			
(Non Recurring Expenditure during the year)			
Fixed Assets		5,51,08,931	6,28,45,816
TOTAL		**50,29,10,750**	**44,39,99,021**

SCHEDULE- 8
OTHER INCOME

Licence Fees	3,94,936	4,97,144
Others / Misc Income	41,40,499	30,28,619
TOTAL	**45,35,435**	**35,25,763**

SCHEDULE-9
SALARIES AND ALLOWANCES

Pay & Allowances	18,87,58,796	22,26,89,110
Uniform and Washing Allowance	8,730	1,80,146
Leave Travel Concession	23,76,400	57,83,457
Medical Expenses	2,76,21,466	2,29,11,864
Honorarium	6,96,846	4,86,589
CPF Institute Contribution	97,779	85,667
NPS Institute Contribution	37,24,835	28,70,921
Ad-Hoc Bonus	3,43,673	4,68,221
OtherTerminal Benefits:		
- Gratuity	5,40,456	2,00,95,802
- EL Encashment	-	1,90,37,953
- Commutation of Pension	-	1,85,97,462
Children Education Allowance	18,80,090	21,39,880
Overtime Allowance	1,02,862	1,22,564
Pension Contribution	4,38,52,036	3,61,71,313
Provision for Retirement Benefits	-	5,10,71,000
	27,00,03,969	**40,27,11,949**

SCHEDULE - 10
OFFICE EXPENDITURE

Postage & Courier	2,28,946	3,10,352
Conveyance	2,04,306	1,28,961
Printing and Stationery	7,49,374	9,90,557
Entertainment Expenses	6,674	4,660
Vehicle Maintenance	22,71,011	25,57,406
Advertisement Expenses	3,36,159	8,56,330
Audit fee	84,360	86,640
Legal Fee	7,80,800	6,33,840
Guest House Expenses	38,63,976	34,20,593
Travel - International	12,89,477	11,31,875
Travel - Domestic	56,42,932	58,91,723
TOTAL	**1,54,58,015**	**1,60,12,937**

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PARTICULARS	2015-2016	2014-2015
		Rs.
SCHEDULE-11		
WORKING EXPENSES - PLAN		
Property Tax	15,33,841	11,22,411
Electricity & Water Charges	1,45,68,188	1,61,10,992
Telephone charges	23,22,093	24,51,452
Travel Expenses	38,29,709	47,87,737
Repairs, mainteance for Computers, Electrical, Electronics, Mech & Optical Equipments & Manpower Outsource Charges	7,14,05,722	7,16,58,861
Other Expenses, Training, Public Outreach	56,71,010	43,01,292
Conference/Meetings/Workshops/Schools	29,12,713	3,72,279
Rent for Hiring Accommodation	5,51,640	6,08,856
Canteen Expenses	26,79,653	21,15,007
Lease rent for Observatories (VBO,Kavalur & Gauribidanur)	8,51,180	79,212
Research Scholarship/Visiting Fellowship	3,36,58,906	-
HAGAR Expenses	7,33,577	-
TOTAL	**14,07,18,231**	**10,36,08,099**
SCHEDULE - 12		
STORES & CONSUMABLES		
Opening Balance	2,44,728	5,02,995
Add: Purchases during the year	35,40,952	31,43,607
	37,85,680	36,46,602
Less: Closing Stock	7,91,457	2,44,728
Consumption during the year	**29,94,223**	**34,01,874**
SCHEDULE - 13		
GRANTS-IN-AID (NON - PLAN)		
Grant-in-aid	50,00,000	76,50,000
Ministry of Science & Technology		
(Dept.of Science & Technology)		
SCHEDULE 14		
SALARIES & ALLOWANCES - NON PLAN		
Pay and Allowances	50,00,000	76,50,000
TOTAL	**50,00,000**	**76,50,000**

PARTICULARS		2015-2016	2014-2015
			Rs.

SCHEDULE - A

GRANTS - IN - AID (PLAN)

Grants-in-aid - Plan		55,39,00,000	49,96,48,000
(Ministry of Science & Technology, Dept of Science & Technology)			
Add: Bank Interest	24,28,981		
Interest on Advances to Staff	16,90,700	41,19,681	71,96,837
TOTAL		**55,80,19,681**	**50,68,44,837**

SCHEDULE - B

OTHER RECIEPTS

Licence Fee	3,94,936	4,97,144
Other Receipts	41,40,499	30,28,619
TOTAL	**45,35,435**	**35,25,763**

SCHEDULE - C

ADVANCE RECOVERIES, CREDITS / ADJUSTMENTS

Advances (Travelling & LTC)	4,59,300	10,69,110
Contingent Advance	33,64,142	34,73,476
Caution deposit from Research scholars	1,65,000	1,75,000
Earnest Money Deposit	29,92,000	8,45,075
House Building advance	14,84,230	11,76,403
Computer Advance	5,82,753	7,45,718
Festival Advance	1,65,375	1,93,500
Motor Car Advance	5,39,645	5,45,247
Motor Cycle Advance	3,18,577	2,39,731
Security deposit from Contractors	8,01,478	6,65,901
Margin Letter of Credit	46,50,000	2,18,77,000
GLSI	1,927	
TDS (Tax Credits)	75,000	-
Exp reimbursed from Aditya Project	38,76,788	-
External Projects	54,59,24,774	18,83,24,558
Pre-Paid Exp	-	4,86,267
Advance from Suppliers	20,00,000	10,00,000
Telephone Deposit	-	2,280
Consumable Stores	2,44,728	5,02,996
TOTAL	**56,76,45,717**	**22,13,22,263**

V.K. NIRANJAN & CO.
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Chartered Accountants

PARTICULARS	2015-2016	2014-2015
	Rs.	Rs.
SCHEDULE - D		
RECURRING EXPENDITURE - PLAN		
A) Salary and Allowances		
Pay and Allowances	18,87,58,796	20,23,75,845
Research Scholars/Em.Professor	-	2,03,13,265
Honorarium	6,96,846	4,86,589
Pension Contribution	4,38,52,036	3,61,71,313
Medical Expenses	2,76,21,466	2,29,11,864
CPF Institute Contribution	97,779	85,667
NPS Institute Contribution	37,24,835	28,70,921
Gratuity/Leave Encashment/Retirement Benefits	5,16,11,456	5,77,31,217
Uniform,Washing and Over Time Allowance	1,11,592	3,02,710
Ad-Hoc Bonus	3,43,673	4,68,221
Children Education Allowance	18,80,090	21,39,880
Leave Travel Concession	23,76,400	57,83,457
	32,10,74,969	**35,16,40,949**
B) Administrative Expenditure		
Postage & Courier	2,28,946	3,10,352
Conveyance	2,04,306	1,28,961
Printing and Stationery	7,49,374	9,90,557
Entertainment Expenses	6,674	4,660
Vehicle Maintenance	22,71,011	25,57,406
Advertisement Expenses	3,36,159	8,56,330
Audit fee	84,360	84,270
Legal / Professional Fee	7,80,800	6,33,840
Guest House & Mess Expenses	38,63,976	34,20,593
	85,25,606	**89,86,969**
C) Travelling Allowances		
Travel - Domestic	56,42,932	58,91,723
Travel - International	12,89,477	11,31,875
	69,32,409	**70,23,598**
D) Working Expenses		
Property tax	15,33,841	11,22,411
Electricity & Water charges	1,45,68,188	1,61,10,992
Telephone charges	23,22,093	24,51,452
Lease rent for Observatories (VBO,Kavalur & Gauribidanur)	8,51,180	79,212
Rent for Hiring Accommodation	5,51,640	6,08,856
Repairs & Maintenance	1,81,75,388	1,85,72,975
Manpower Outsource Exp	3,72,11,959	3,31,85,152
Communication Charges	1,60,18,375	1,99,00,734
Consumables forLabs (computer, electronics, mechanical..)	29,94,223	34,01,874
Other Expenses, Public Outreach, Bank Charges etc.	56,71,010	43,01,292
Travel expenses	38,29,709	47,87,737
Meeting/Workshop/Schools/Conferences etc.	29,12,713	3,72,279
Canteen expenses	26,79,653	21,15,007
Research Scholarship/Visiting Fellowship	3,36,58,906	-
HAGAR Expenses	7,33,577	-
TOTAL	**14,37,12,454**	**10,70,09,973**
TOTAL(A+B+C+D)	**48,02,45,438**	**47,46,61,489**

PARTICULARS	2015-2016	2014-2015
	Rs.	Rs.

SCHEDULE - E

NON-RECURRING EXPENDITURE - PLAN - NET

Computers	54,35,417	51,43,618
Capital equipment	1,95,81,517	1,91,91,729
Civil Works	1,71,23,034	1,62,87,155
Furniture	5,70,536	1,58,423
Books & Journals	65,47,024	49,86,317
Vehicles	-	(60,300)
HAGAR	-	2,23,559
2 M Telesope	-	57,946
VBT	-	30,161
UVIT	6,65,270	3,48,320
NLST	16,61,790	15,41,238
HESP-IIA	61,55,534	1,38,31,741
NLOT	3,68,809	11,05,909
TOTAL	**5,81,08,931**	**6,28,45,816**

SCHEDULE -F

DEPOSITS & OTHER PAYMENTS (Current Assets)

Contingent Advance	33,75,142	31,64,626
House Building Advance	3,75,000	10,00,090
Margin for LC	64,30,000	44,62,000
Computer Advance	3,06,067	1,44,000
Motor Car Advance	3,87,600	3,60,000
Festival advance	1,20,000	1,61,250
Motor cycle advance	78,000	3,00,000
External Projects	29,91,32,458	4,32,76,827
Deposit with KEB	61,240	19,950
Earnest Money Deposit	18,32,500	7,65,998
Advances (TA, LTC)	5,24,365	4,59,300
Deposit with TNEB	5,621	-
Deposit with Telephone Dept	-	20,000
Security Deposit Returned to Contractors	84,531	14,14,384
Caution Deposit	68,500	10,000
Professional Tax	-	32,832
CSIR Students Scholarship and TDS	10,16,786	9,46,900
Aditya Project Expenditure	1,40,41,063	-
Consumable Stores	7,91,457	2,44,728
TOTAL	**32,86,30,330**	**5,67,82,885**

PARTICULARS	2015-2016 Rs.	2014-2015 Rs.

SCHEDULE-G
GRANT-IN-AID (NON-PLAN)

Grants-in-aid Ministry of Science & Technology (Dept.of Science & Technology)	50,00,000	76,50,000

SCHEDULE - H
RECURRING EXPENDITURE - NON-PLAN

Salary and Allowances Pay and Allowances	50,00,000	76,50,000

S.B.RAMESH
Accounts Officer

P.KUMARESAN
Administrative Officer

P.SREEKUMAR
Director

As per our report of even date,
for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

NIRANJAN V.K.
Partner
M.No: 021432

Place: BENGALURU
Date: 19.09.2016

SCHEDULE: - 15

SIGNIFICANT ACCOUNTING POLICIES AND NOTES ON ACCOUNTS FOR THE YEAR ENDED 31.03.2016

A. SIGNIFICANT ACCOUNTING POLICIES:

1. ACCOUNTING CONVENTION:

The Financial Statements are prepared on the basis of Historical cost convention and on the accrual method of accounting, except Bank Interest, which is accounted on 'Cash Basis', as in previous years. The guidelines given by the Government of India for drawing Financial Statements for central autonomous bodies have been adopted, to the extent that they are directly applicable.

2. FIXED ASSETS:

Fixed assets are stated at cost of acquisition less depreciation. The same was verified physically on periodical basis by the Management.

3. DEPRECIATION:

Method of Depreciation is charged on WDV at rates as stated in the Fixed Assets Schedule. The amount of depreciation has been debited to the Income & Expenditure Account as per the guidance of C&AG Audit. The rate of depreciation has been charged as per the Income Tax Act, 1961 and guidance of C&AG Audit.

4. INVENTORY:

Stocks on hand such as spares, materials, consumables are valued at cost.

5. GOVERNMENT GRANTS:

Government grants received from DST are accounted on receipt basis and the same have been separately shown under Plan and Non-Plan in the Annual accounts of the Institute. Out of the total Plan grant amount received, an amount equal to the amount of non recurring expenditure incurred during the year is directly credited to the Capital Fund A/c, the balance of Plan grants is reckoned as Income and shown in Income & Expenditure Account as Grants-in-Aid. The interest earned on Government Grants such as bank interest and interest on staff advances has been credited to Grants-in-aid account.

6. FOREIGN CURRENCY TRANSACTIONS:

Transactions denominated in foreign currency are accounted at the exchange rates prevailing as on the dates of the transaction.

7. RETIREMENT BENEFITS:

- Institute's Contribution to Provident Fund and Pension Fund are charged to Income and Expenditure Account of the Institute. Apart from this, any deficit in the Provident Fund and Pension Fund amount is borne and provided for in the accounts of the Institute on payment basis.

- Estimated liability for Gratuity on the date of Balance Sheet has not been quantified. The same is accounted for on actual cash basis payment.

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8. Non-Plan grants have been fully utilized only for payment of non-plan salaries and allowances and a separate Receipts & Payments Account, and Income & Expenditure Account have been prepared.

B. NOTES ON ACCOUNTS:

1. In the opinion of the Management, the Current Assets, Advances and Deposits have been recorded at the actual value of transactions in the ordinary course of activities. The aggregate amount is shown in the Balance Sheet.
2. The expenses towards payment of Research Scholarship and Visiting Fellowship have been re-grouped from Salaries & Allowance to Working Expenses.
3. Capital Expenditures of UVIT, HESP, NLST and NLOT have been transferred to Fixed Asset Schedule-4 and, previous year figures have been re-grouped wherever necessary.
4. Figures have been rounded off to the nearest rupee.

S.B.RAMESH **Accounts Officer**	**P.KUMARESAN** **Administrative Officer**	**P.SREEKUMAR** **Director**

for V.K.NIRANJAN & Co.,
Chartered Accountants
F.R.NO: 002468S

Place: BENGALURU
Date : 19.09.2016

NIRANJAN V.K., FCA
Partner
M No.021432