Contents

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†Professor R. M. Walker (2004)

†Professor Hermann Bondi, FRS (2005)

†Professor V. Radhakrishnan (2011)

† *deceased*

Chapter 1

The Year In Review

I am glad to report once again that the institute continues to maintain excellence in research, in developing advance research facilities, in producing world-class human resources and in reaching out to the wider community during the period of 2014-2015. Several programmes undertaken in the previous years continue to make excellent progress. It gives me great pleasure to present the highlights of the institute's activities and achievements on many fronts.

The scope of research in this institute ranges from the Sun and the solar system to the galaxies beyond our own Milky Way and to the farthest objects of the Universe known as quasars. Some of the more important discoveries and developments during the last one year are highlighted here.

In the field of solar physics, a statistical analysis of about 63000 soft X-ray flares (class > = C) observed by the geostationary operational environmental satellite (GOES) during the period 1976-2008 was carried out. The dynamics of a Coronal Bright Point seen in the coronal hole was studied using EUV images from the Atmospheric Imaging Assembly and magnetic field information from Helioseismic and Magnetic Imager instruments on board the Solar Dynamics Observatory satellite. A detailed investigation has been performed on the evolution of observed net vertical current using a time series of vector magnetograms of the active region (AR) NOAA 11158 obtained from Helioseismic Magnetic Imager.

In the research field of stellar and galactic astrophysics, the 2014 outburst of the recurrent nova V745 Sco was observed with the 2.34m Vainu Bappu Telescope and the 1.3m J. C. Bhattacharyya Telescope at Kavalur and also the Giant Meterwave Radio Telescope near Pune. Twelve new variables in the globular cluster M5 (NGC 5904) are detected, one SX Phe and eleven semi-regular variables (SR). A detailed abundance analysis of four unexplored candidate post- Asymptotic Giant Branch(AGB) stars IRAS 13110 - 6629, IRAS 17579 - 3121, IRAS 18321 - 1401 and IRAS 18489 - 0629 has been done using high resolution spectra. Analysis of new V and I CCD time-series photometry of the distant globular cluster NGC 6229 has been done. 25 new variables: 10 RRab, 5 RRc, 6

SR, 1 CW, 1 SX Phe, and two unclassified are found.

In the area of Extra-galactic Astronomy and Cosmology, a systematic study using observations from radio, optical, X-ray and gamma-ray bands has been carried out in order to understand the nature of the new class of gamma-ray emitting Narrow Line Seyfert 1 (NLSy1) galaxies. Broad-band spectral and temporal studies showed that these sources exhibit properties similar to the well-known gamma-ray emitting blazer class of AGNs. Using data from the Sloan Digital Sky Survey (SDSS), the nuclear black hole (BH) masses of 24 active galaxies from their broad Hα parameters were derived. The non-linear clustering of matter in the Late Forming Dark Matter (LFDM) scenario was studied in which dark matter results from the transition of non-minimally coupled scalar field from radiation to collision-less matter.

In theoretical physics, the influence of the halide anions on the effective electric field was studied, and HgBr and HgI were identified as attractive candidates for future electric dipole moment search experiments. The relativistic equation-of-motion coupled-cluster (EOMCC) method was employed to compute the principal ionization potentials (IPs) of closed-shell rare-gas atoms, He-like ions, Be-like ions, along with Na+, Al+, K+, Be, and Mg. Four-component Dirac spinors were used in the calculations, and the one- and two-electron integrals were evaluated using the Dirac-Coulomb Hamiltonian.

An important activity of the Institute is the graduate studies programme. Like, the previous years, a large number of bright students have joined the Ph.D. and integrated M.Tech-Ph.D. programmes of the institute through various selection processes during this period. I am glad to report that seven students were awarded the doctoral degree, five students have submitted their thesis for the award of Ph.D. and nine students have completed M.Tech during the period April 2014-March 2015. Thirty-five students from various Universities and colleges attended the School of Physics and Astrophysics coordinated by the Board of Graduate Studies at Kodaikanal Observatory. Out of these thirty-five students, thirteen students continued to do summer projects under IIA faculties. Seventy-three students worked for astronomy related projects under the internship programme of the Institute.

A few important instruments for various observatories were designed and developed during this academic year. The UVIT payload successfully underwent thermo-vacuum tests. The payload was handed over to ISRO for satellite integration and further testing. The satellite is expected to be launched in late 2015. The DST-funded High-Resolution Echelle Spectrograph (HESP) for HCT in Hanle was developed in collaboration with Industrial Research Laboratory, New Zealand. All preparatory work for the installation of the instrument is completed. The instrument is expected to be installed and commissioned during the later half of 2015. A photomultiplier-based polarimeter developed within the Institute is put into trial observation mode at the 1 m telescope at Kavalur after extensive laboratory tests, adding a new capability to study polarisation of point sources. A 20 cm refractor, designed and fabricated by the NIAOT (Nanjing Institute of Astronomical Optics & Technology) of CAS (of the Chinese Academy of Sciences), was installed at Kodaikanal Observatory during October, 2014 and is being operated for solar imaging at the H_{alpha} (6562.81Å) wavelength. Installation of the White light Active Region Monitor (WARM) telescope is completed and the field trials were performed.

The 1.3m telescope at Kavalur was named as the *J. C. Bhattacharyya Telescope* on 19th

Left: Professor B. V. Sreekantan delivering the Founder's day lecture entitled "Symbiotic Developments in Physics and Astronomy in the 20th Century: Where are they leading us in our search for Reality?" on the 14th of August, 2014. Right: Dr P. Sreekumar seen with Professor Ramesh Narayan of Harvard University, USA, who delivered the Vainu Bappu Memorial Lecture entitled "Black Hole Spin and Relativistic Jets" on the 5th of March, 2015.

of April 2014. Prof. B. V. Sreekantan (former Chair, IIA Governing Council) unveiled the plaque dedicating the telescope as the *J. C. Bhattacharyya Telescope* in the presence of Members of the IIA Governing Council, other distinguished invitees and staff of the Institute. Dr. T. Ramaswami (Secretary, DST) felicitated the consultants and agencies contracted to deliver the telescope facility.

In the academic year 2014–2015, the TMT project reached several key milestones. India formally joined the TMT project as a full member. At a function in New Delhi on December 2, 2014, in the presence of the Union Minister for Science and Technology and Earth Sciences, Dr. Harsh Vardhan, the Secretary of Department of Science and Technology, Prof. K. Vijay Raghavan, signed the necessary documents to change India's formal relationship from Associate to full Member of the TMT International Observatory (TIO). The groundbreaking and Hawaiian blessing ceremony for the construction of TMT at the summit of Mauna Kea happened on October 7, 2014. India was represented by Honourable Ambassador Taranjit Singh Sandhu, India Deputy Chief of Mission at Washington, Dr. Srinivasa, San Francisco Consular General, Indian Consulate San Francisco and Prof. Eswar Reddy, Programme Director, ITCC.

At the instance of DST, the IIA Governing Council had constituted a committee to examine the implications of Hanle as the site for NLST instead of Merak and submit its recommendations. The NLST team prepared a preliminary report on the possible changes in the telescope design taking into consideration the potential to carry out observations at infrared (IR) wavelengths in Hanle, and submitted the same during the first meeting of the committee.

Following the tradition of the institute, the Founder's day was celebrated at the institute on the 8th August, 2014. The Founder's day lecture entitled "Symbiotic Developments in Physics and Astronomy in the 20th Century: Where are they leading us in our search for Reality ?" was delivered by Professor B. V. Sreekantan on the 14th of August, 2014. The Vainu Bappu Memorial Lecture entitled "Black Hole Spin and Relativistic Jets" was presented by Professor Ramesh Narayan of Harvard University, USA, on the 5th of

March, 2015.

The public outreach activities of the institute were spread across all field stations. Science day was celebrated and sky watch for general public were organized at Bangalore as well as at other campuses. The implementation of the official language and the activities towards the welfare of SC/ST and physically challenged staffs are also reported here. The list of scientific publications in peer reviewed journals, conference proceedings as well as in monographs, books and popular periodicals are provided in this report. In closing, the new academic year promises IIA staff with access to long-awaited high-quality data from the UVIT instrument on ASTROSAT, closure of pre-construction activities under the TMT program, initiation of a new optics fabrication facility at CREST, Hosakote for the development of optical segments for TMT, exciting new science from the commissioning of the HESP spectrograph at HCT, and significant progress in our ongoing developments in many projects. I believe that the institute will continue to upgrade its scientific productivity and will excel in the field of Astrophysics during the coming years.

P. Sreekumar
Director

Chapter 2

RESEARCH

2.1 The Sun and the Solar System

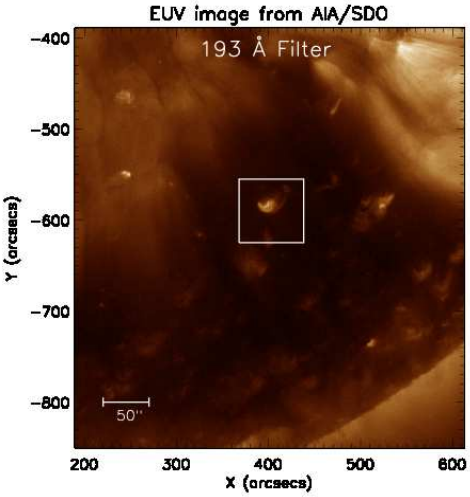


Image shows a portion of the Sun. It was taken by 193 A filter of the AIA instrument on board SDO satellite. This filter primarily captures the hot emission of temperature around 1.5 MK from the solar atmosphere. The white box covers a bright point.

The dynamics of a Coronal Bright Point seen in the coronal hole is studied using the EUV images from Atmospheric Imaging Assembly and magnetic field information from Helioseismic and Magnetic Imager instruments on board the Solar Dynamics Observatory satellite. Spectroscopic data from the newly launched Interface Region Imaging Spectrograph (IRIS) is also used to study the BP evolution. It is inferred that small-scale magnetic reconnections produces local heating. During the total solar eclipse of July 11, 2010, a team from IIA, Bengaluru have performed Multi-slit spectroscopic observations of the solar corona at Easter Island, Chile. High-resolution spectroscopy and sufficiently high cadence have enabled to detect damping of high-frequency oscillations with periods of the order of 10 s and it is inferred that if the observed damped oscillations are due to magnetohydrodynamic (MHD) waves then they can contribute significantly in the heating of the corona.

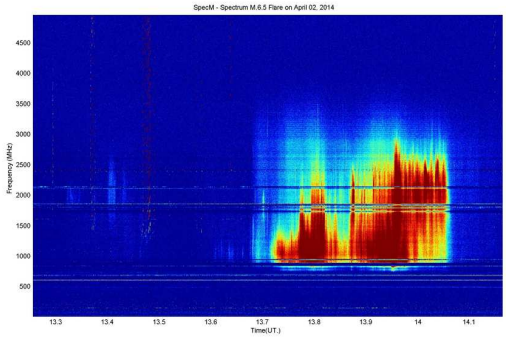
Using sophisticated techniques and methodology, the helicity and energy flux injections from emerging active regions of the Sun is calculated employing vector magnetic field observations by Helioseismic Magnetic Imager at the photosphere. The investigation reveals that the magnetic fluxes evolve to pump net positive, negative and mixed signed helicity flux into the corona, the coronal helicity flux is dominantly coming from the shear term that is related to flux motions whereas energy flux is dominantly contributed from emergence term and the shear helicity flux is having a phase delay of 5-14 hours with respect to absolute magnetic flux.

A detailed investigation has been performed on the evolution of observed net vertical cur-

rent using a time series of vector magnetograms of the active region (AR) NOAA 11158 obtained from Helioseismic Magnetic Imager. The vertical current density is calculated from the magnetic field observations. It is found that the time profile of net current in the sub-region followed the time profile of the rotation rate of the S-polarity sunspot of the same sub-region. The systematic evolution of the observed net current is seen to follow the time evolution of total length of strongly sheared polarity inversion lines in both the sub-regions.

A statistical analysis of about 63000 soft X-ray flare (class $>= $ C) observed by geostationary operational environmental satellite (GOES) during the period 1976-2008 is carried out. The distribution pattern of cycle 21 shows the transit of hemispheric dominance of flare activity from northern to southern hemisphere and remains there during cycle 22 and 23. It is found that the association between the consecutive latitudes appears to be increasing from equator to poleward in northern hemisphere whereas pole to equatorward in southern hemisphere.

Brazilian Decimetric Array (BDA) is a dedicated heliograph which can image the Sun in the frequency range of 1.4-5.6 GHz. The BDA project was initiated as a collaborative project between IIA and INPE(Brazil). It is a "T" shaped array with dimensions of 252 m in the east-west direction and 162 m in the south direction. The array consists of 26 antennae elements (dish antennae of diameter ∼4m), 17 in the east-west arm and 9 in the South arm. The baselines vary from 9m to 216 m in the east-west direction and 9m to 162 m in the south direction. The system can image the Sun with a spatial resolution of $\sim 3 \times 5$ arcmin at 1.4 GHz with a sensitivity of $\sim$ 1 Jy for a bandwidth of 5 MHz with 1 sec integration time. Presently this instrument is being used for regular solar observations.



Dynamic spectrum of solar type III and IV bursts observed using Brazil SpeCM solar radio spectrograph after M6.5 class Solar flare observed on 2014 April 02 from 13:30 -14:00 UT. The vertical features are the Type III group radio emission followed by intense Type IV. The horizontal lines between 1500 - 2200 MHz are due to local 2G & 3G mobile operators.

2.2 Stellar and Galactic Astrophysics

The effect of macroscopic vertical velocity fields on the linear polarization profiles formed due to resonance scattering in an isothermal atmosphere has been studied by taking into account the effects of PRD as well as a weak magnetic field (Hanle effect). It is shown that the presence of vertical velocity gradients in the medium enhances the linear polarization, produces Doppler shifted line profiles that are asymmetric about the line center.

The 2014 outburst of the recurrent nova V745 Sco was observed with the VBT, 1.3m JCBT and also the GMRT. The spectroscopic observations indicated the outburst to be similar to the previous outbursts. Intranight photometric observations in the BVRI around 7-10 days post-maximum bands do not show any short term variations that are indicative of accretion disk re-formation. V745 Sco was detected in the low frequency radio region as a non-thermal source. The two

main results of the study are: (1) The radio emission at a given frequency is visible sooner in successive outbursts in the recurrent novae V745 Sco and RS Ophiuchi. The earlier detection of radio emission is interpreted to be caused by decreasing foreground densities. (2) The clumpy material is located close to the white dwarf which we interpret as being due to the material from the hot accretion disk.

Twelve new variables in the globular cluster M5 (NGC 5904) are detected; one SX Phe and eleven semi-regular variables (SR).

A detailed abundance analysis of four unexplored candidate post- Asymptotic Giant Branch(AGB) stars IRAS 13110 - 6629, IRAS 17579 - 3121, IRAS 18321 - 1401 and IRAS 18489 - 0629 has been done using high resolution spectra. Spectral Energy Distributions (SED) model for these objects is constructed using the existing photometric data combined with infrared (IR) fluxes. For all sample stars, the SEDs exhibit double peaked energy distribution with well separated IR peaks showing the presence of dusty circumstellar material. The CNO abundances indicate the production of N via CN cycling, but observed [C/Fe] indicates the mixing of carbon produced by He burning by third dredge up although C/O ratio remains less that 1.

Analysis of new V and I CCD time-series photometry of the distant globular cluster NGC 6229 has been done. 25 new variables: 10 RRab, 5 RRc, 6 SR, 1 CW, 1 SX Phe, and two unclassified are found. Secular period changes were detected and measured in some favourable cases. The Fourier decomposition of RRab and RRc light curves was used to independently estimate the mean cluster value of [Fe/H] and distance.

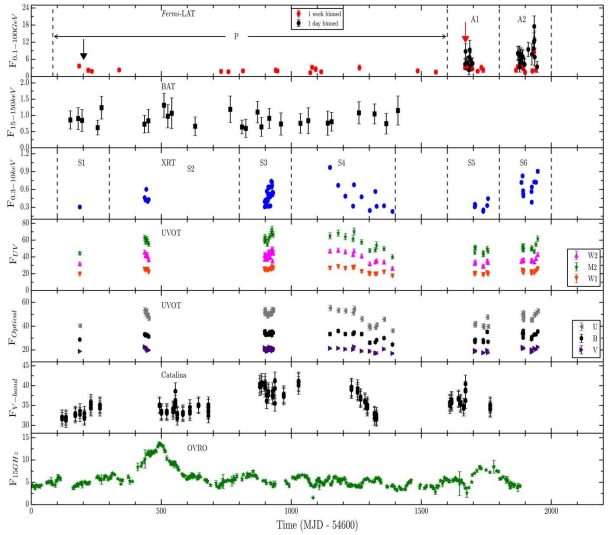
High-resolution (R = 30 000, 45 000 and 75 000) echelle and medium-resolution (R = 22 000 and 10 000) spectroscopic observations of the long-period, eclipsing binary ϵ Aurigae during the 2009 - 2011 eclipse is reported. Low-excitation shell lines, viz, the K I line at 7699 Å(with 346 data points), Cr I lines at 5345.807Åand 5348.326 Åand Fe I line at 5110.435 Åwhich originated from the disk shaped secondary, H alpha and the shell components of the Na D1 and D2 lines show significant variation in their shapes and radial velocities during the eclipse.

High resolution spectroscopic analysis have been carried out for a large sample of potential CH (CEMP-s) star candidates which are metal-deficient high velocity carbon stars in the Galactic halo. The sample is divided into three groups, Group I (known binaries), Group II (objects with limited radial velocity information) and Group III (objects that have no information either on radial velocity or binarity). Majority of the objects belonging to Group I and II are found to exhibit enhancement of heavy elements. The abundance ratios show a large scatter with respect to metallicity suggesting that the enrichment may not be a function of only metallicity.

The properties of 45 poor star clusters in the LMC are studied, using the Washington photometry. The data is deep enough to sample the main-sequence population of the poor clusters. 33 clusters are found to be real clusters and 12 were found to be possible clusters. Majority of the clusters were found to be young and located in the inner LMC. The mass, age and radius of these clusters suggest that these are counter parts of the open clusters in the Milky Way.

2.3 Extragalactic Astronomy and Cosmology

To understand the nature of a few gamma-ray emitting Narrow Line Seyfert 1 (NLSy1) galaxies, a systematic study using observations from radio, optical, X-ray and gamma-



Multi-band lightcurves of the source 1H 0323+342 in gamma-rays, X-rays, UV, optical and radio bands.

ray bands has been carried out. It is found that some of these sources show significant flux variations in the gamma-ray band. A majority of them also have a curved gamma-ray spectrum. In the X-ray band, during some states, thermal emission from the hot corona is found to dominate, while during other states, non-thermal emission from the jet is found to dominate.

Using data from the Sloan Digital Sky Survey (SDSS), the nuclear black hole (BH) masses of 24 active galaxies from their broad Hα parameters are derived. It is estimated that nuclear BH masses lie in the range 10^5 - 10^7 solar mass, with a median mass of 5.62 $\times$ 10^6 solar mass.

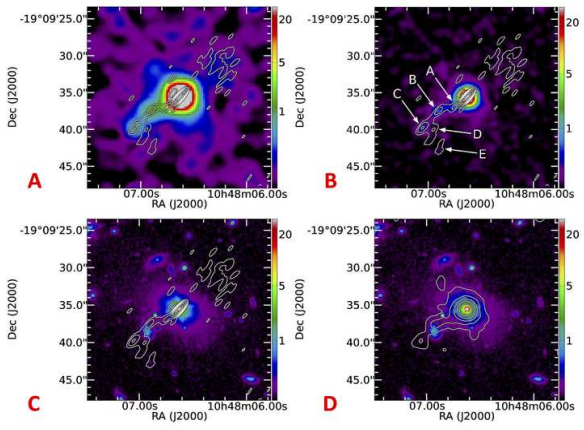
A global semi-analytic axisymmetric model for a turbulent dynamo is presented for a galaxy with a corona. It is shown that the supernovae (SNe) and magneto-rotational instability (MRI) driven turbulence parameters have nearly the same radial dependence and can be treated in a common formalism; however we assume the main contribution from SNe.

The structure and evolution of the disk of the Small Magellanic Cloud (SMC) are traced by studying the Cepheids. The age of the Cepheids and hence the age distribution of the SMC Cepheids are derived. An inclination of 64.4±0.7 degree and a PAlon 155.3±6.3 degree are obtained from the study. The orientation-corrected depth or thickness of the SMC disk is found to be 1.76±0.6 kpc. The scale height is estimated to be 0.82±0.3 kpc. Different scenarios for the origin of the extra-planar Cepheids are also investigated.

Results from Chandra-HST-VLA observations of 13 hybrid sources are presented. A majority of the 13 hybrid sources show that they are "hybrid" in radio morphology but not in total radio power. VLBI observations of ten of the 13 sources show that the X-ray jet is on the same side as the one-sided VLBI jet. X-rays are therefore emitted from relativistically-boosted approaching jets.

Multi-wavelength imaging observations of PKS 1045-188, 8C 1849+670, and PKS 2216-038, three radio-loud active galactic nuclei were carried out from the MOJAVE-Chandra Sample that straddle the Fanaroff-Riley (FR) boundary between low- and high-power jets. It is found that the lack of detected optical emission ruled out the X-ray emission from the same electron population that produces radio emission. All three sources have high total extended radio power, similar to that of FR II sources. Sources PKS 1045-188 and 8C 1849+670 show significant differences in their radio and X-ray termination points, which may result from the deceleration of highly relativistic bulk motion.

The energy scale of non-commutativity of spacetime is investigated by using cosmic microwave background data from PLANCK. It is found that PLANCK data put the lower bound on the non-commutativity energy scale to about 20 TeV, which is about a factor of 2 larger than a previous constraint



(A) Chandra X-ray image of Hybrid Blazar PKS 1045-188 in colour superimposed by VLA 4.8 GHz radio contours with contrast adjusted to show possible counter jet emission. (B) Jet knots identified. The colour scales correspond to image counts. The lowest contour level is 3 times the rms and each higher contour is 4 times the previous one. (C) VLA 4.8 GHz radio and (D) Chandra X-ray contours superimposed on the colour Hubble Space Telescope/F160W image of PKS 1045-188.

that was obtained using data from WMAP, ACBAR and CBI. We further show that inclusion of data of E mode of cosmic microwave background polarisation will not significantly change the constraint.

The non-linear clustering of matter in the Late Forming Dark Matter (LFDM) scenario is studied in which dark matter results from the transition of non-minimally coupled scalar field from radiation to collisionless matter.

2.4 Theoretical Physics

The influence of the halide anions on the effective electric field is studied, and HgBr and HgI are identified as attractive candidates for future electric dipole moment search experiments. The importance of electron correlation effects in the hyperfine structure constants of many low-lying states in Fr210 and Fr212 is demonstrated. This is achieved by calculating the magnetic dipole and electric quadrupole hyperfine structure constants using the Dirac-Fock approximation, second-order many-body perturbation theory, and the coupled-cluster method in the singles and doubles approximation in the relativistic framework. By combining the results of theoretical investigation with the corresponding experimental values, improved nuclear magnetic dipole and electric quadrupole moments of the above isotopes are determined. The permanent electric dipole moment of the X2Σ+ electronic ground state of the strontium monofluoride molecule is calculated using a relativistic coupled-cluster method. The result obtained suggests that the relativistic coupled-cluster method used in the present work is capable of yielding accurate results for the permanent electric dipole moments of molecules for which relativistic effects cannot be ignored.

The complete quantum phase diagram of bosons on a two-leg ladder in the presence of attractive onsite and repulsive interchain nearest-neighbor interactions by imposing the onsite three-body constraint is obtained. Three distinct phases are found; namely, the atomic superfluid (ASF), dimer superfluid (DSF), and the dimer rung insulator (DRI). By evaluating different order parameters, the complete phase diagram and the properties of the phase transitions is obtained by using the self-consistent cluster mean-field theory. The relativistic equation-of-motion coupled-cluster (EOMCC) method is employed to compute the principal ionization potentials (IPs) of closed-shell rare-gas atoms, He-like ions, Be-like ions, along with Na+, Al+, K+, Be, and Mg. Four-component Dirac spinors are used in the calculations, and the one- and two-electron integrals are evaluated using the Dirac-Coulomb Hamiltonian.

The relative stabilities of cis- and trans-

isomers of 1,2-difluoroethylene and 1,2-difluoro diazene have been studied via the state-specific multi-reference coupled cluster (SS-MRCC) method and its perturbative counterpart through the computation of the optimised structures and corresponding energies.

Chapter 3

STUDENTS' PROGRAMS AND TRAINING ACTIVITIES

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

3.1 Ph.D. Degree Awarded

S. Krishna Prasad was awarded (on April 2014) the Ph.D. degree for his thesis titled "Spectroscopic Studies of Coronal Structures using Ground and Space Based Data" submitted to the Mangalore University. He carried out the above work under the supervision of Jagdev Singh and Dipankar Banerjee.

K. Chandrasekhar was awarded (on May 2014) the Ph.D. degree for his thesis titled "Small scale transient events in the Solar Corona" submitted to the Pondicherry University. He carried out the above work under the supervision of Dipankar Banerjee.

M. B. Roopashree was awarded (on February 2015) the Ph.D. degree for her thesis titled "Investigation of Hartmann Shack and curvature sensors in quantifying lower order aberrations" submitted to the University of Calicut. She carried out the above work under the supervision of B. Raghavendra Prasad.

B. P. Hema was awarded (on March 2015) the Ph.D. degree for her thesis titled "Observational Studies of Hydrogen Deficient Stars for Investigating their Evolutionary Connections" submitted to the Pondicherry University. She carried out the above work under the supervision of Gajendra Pandey.

S. Rathna Kumar was awarded (on March 2015) the Ph.D. degree for his thesis titled "Determination of H through monitoring of gravitationally lensed quasars" submitted to the Pondicherry University. He carried out the above work under the supervision of C. S. Stalin.

H. N. Smitha was awarded (on March 2015) the Ph.D. degree for her thesis titled "Application of polarised line formation theory to the Solar Spectrum" submitted to the Pondicherry University. She carried out the above work under the supervision of K. N. Nagendra.

Lakshmi Pradeep Chitta was awarded (on March 2015) the Ph.D. degree for his thesis titled "Fine-Scale Magnetic Features in the Solar Atmosphere" submitted to the Pondicherry University. He carried out the above work under the supervision of R. Kariyappa.

3.2 Ph.D. Thesis Submitted

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

Dinesh Kumar submitted his thesis titled "Geometry of Emission Region in Pulsars and the Stokes Parameters" to the Pondicherry University on 07.04.2014. The research was done under the supervision of R. T.Gangadhara.

A. Bala Sudhakara Reddy submitted his thesis titled "Abundance Patterns of Old Open Clusters as Tracers of Galactic Chemical Evolution" to the Pondicherry Univ. on 30.06.2014. The research was done under the supervision of Sunetra Giridhar.

K. Sasikumar Raja submitted his thesis titled "Radio Polarization Studies of The Solar Corona At Low Frequencies" to the University of Calcutta on 15.10.2014. The research was done under the supervision of R. Ramesh.

P. Subramnia Athiray submitted his thesis titled "Study of Lunar surface chemistry using Swept Charges Devices" to the University of Calicut on 30.10.2014. The research was done under the supervision of P. Sreekumar.

Drisya, K. submitted her thesis titled "Studies on Carbon-Enhanced Metal-Poor (CEMP) stars" to the Bengaluru University on 17.03.2015. The research was done under the supervision of Aruna Goswami.

3.3 Completion of M.Tech. program

The following students from the 5th batch of the above program have completed their M.Tech. Degree under the IIA-CU integrated M.Tech-Ph.D program.

Subhamoy Chatterjee under the guidance of Dipankar Banerjee submitted his M.Tech. thesis titled "Solar Imaging and Image processing: Tolerance Analysis of SUIT Optics and Implementation of Different Image Processing Approaches" to the University of Calcutta on August 2014.

Ambily, S under the guidance of Jayant Murthy submitted her M.Tech. thesis titled "Development of an FPGA based photon counting detector" to the University of Calcutta on August 2014.

Hemanth Pruthvi under the guidance of K. B. Ramesh submitted his M.Tech. thesis titled "Developing a Two-Channel Imaging System & Preliminary Experimentation to Deduce the Requirements of a Full Disk Longitudinal Magnetograph for the Warm Telescope" to the University of Calcutta on August 2014.

Sreekanth Reddy, V under the guidance of Padmakar Singh Parihar submitted his M.Tech. thesis titled "Capacitive Edge Sensor and Sensor Electronics for Segmented Mirror Telescopes" to the University of Calcutta on August 2014.

K. Nirmal under the guidance of Jayant Murthy

submitted his M.Tech. thesis titled "Inertial Stabilization Platform and Pointing System for Balloon Borne Telescope" to the University of Calcutta on August 2014.

Ramya M. Anche under the guidance of G. C. Anupama submitted her M.Tech. thesis titled "Analytical Modelling of Thirty Meter Telescope Polarization" to the University of Calcutta on August 2014.

Annu Jacob under the guidance of Padmakar Singh Parihar submitted her M.Tech. thesis titled "A Co-Phasing Technique for Segmented Mirror Telescopes" to the University of Calcutta on August 2014.

Mugundhan, V. under the guidance of R. Ramesh submitted his M.Tech. thesis titled "Beam-former For Single Beam, Total Power mode observations with Gauribidanur Radioheliograph" to the University of Calcutta on August 2014.

Phanindra, D. V. S under the guidance of K. E. Rangarajan submitted his M.Tech. thesis titled "Development of SHABAR for Estimating Atmospheric Scintillation" to the University of Calcutta on August 2014.

3.4 Visiting internship program

The visiting student's internship program 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 program 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.

3.5 School in Physics and Astrophysics

The school in Physics and Astrophysics, coordinated by the Board of Graduate Studies, is an yearly activity of the IIA. The main aim of the school is firstly to introduce students of B.Sc, M.Sc, B.E./B.Tech. degree courses to the field of Astronomy and Astrophysics and secondly to motivate them to take up a career in Astronomy and Astrophysics. For the year 2014, the school was held at the Kodaikanal Observatory, during 12 – 23 May 2014.

Thirty five students participated in the school, of which thirteen students each did a short-term summer project for a duration of six weeks during June–July 2014, under the guidance of an IIA faculty in Bengaluru. They also had to make presentations on the results of their project work. The program consisted of a series of lectures including Physics and Astrophysics mostly by the faculties of IIA.

Chapter 4

INSTRUMENTS AND FACILITIES

4.1 System Engineering Group (SEG)

The UVIT payload sub-systems have successfully undergone thermo-vacuum tests. The payload has been handed over to ISRO for satellite integration and further testing. The UVIT team has been coordinating with ISRO on the final tests. The satellite is expected to be launched this year.

The DST funded project, HESP for HCT, Hanle has been developed in collaboration with Industrial Research Laboratory, New Zealand. The instrument is being transported after functional tests in the laboratory. Site preparations are being done at HCT for installation. As a part of site preparation, an enclosure to the instrument with environment controls has been designed and tests are conducted at the site.

Electronics Engineering Division:

A 2K*4K CCD camera system based on SDSU controller is under development for 30 inch telescope. The liquid nitrogen Dewar for housing the CCD sensor has been reported earlier. The camera has been undergoing tests in the lab. The performance of the system is as shown below:

The test is conducted at 400KHz readout clock.

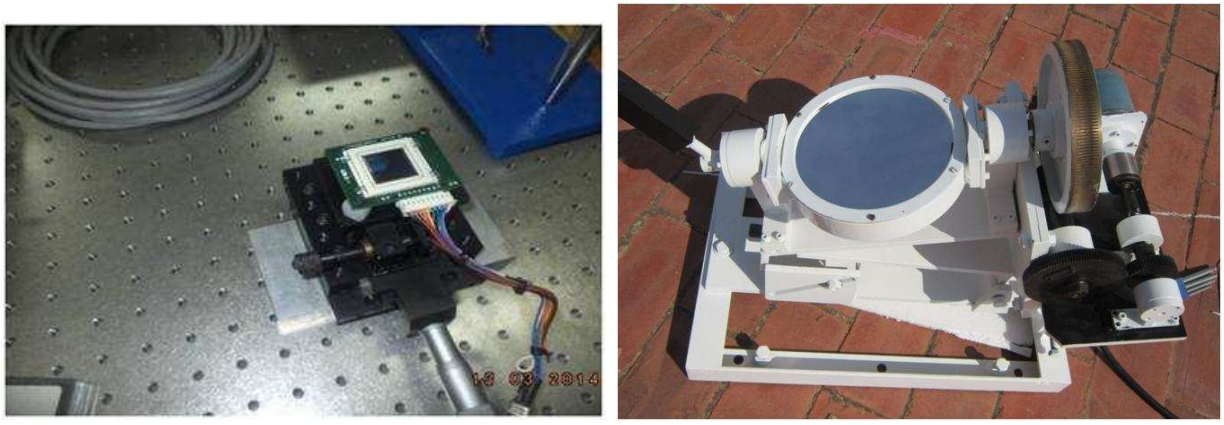
The readout time of 2K* 4K CCD : 22.6sec
Bias mean value :1380 ADU
Std. deviation :1.09 ADU
Further tests are to be conducted before field trials.

A photo-polarimeter developed in the division is put into trial observations at 40" telescope after extensive tests done in the lab. From the observations of standard polarization stars, the results through the instrument is highly agreeing with standards. The 30 inch telescope controls developed in house has been put into trial. The tuning of the servo system is going on. The auto dome control of the telescope is being linked to the observatory server of the telescope, where from the dome control software fetches the telescope coordinates for dome rotation.

An 8 inch coelostat with stepper motor drive unit was developed and installed at Kodaikanal observatory museum for public outreach activities.

Mechanical Engineering Division:

The group was involved in general maintenance of the telescopes, peripherals and infrastructure supporting at VBO, Kavalur. A detailed proposal for aluminizing of the HCT primary mirror has been prepared. Handling procedure for the complete sequence of operations from disassembly of mirror cell from



(left) WARM telescope auto-guider Lab setup. (right) Coelostat for Koaikanal outreach program.

the telescope to transferring the mirror up to the coating plant and vice versa has been prepared and presented in various review committee meetings. This includes the finite element analysis of the mirror and the handling system. In connection mechanical engineering team carried out testing and preparatory works at Hanle. A special lifting tackle has been designed and detail engineering of the same is completed. Detail engineering design, manufacture and installation of radial support for 30 inch telescope primary mirror has been completed. A detailed engineering design off-set guider unit for the CCD imager has been completed. The VBTs 38 pole circumferential bus-bar system meant for telescope dome power has been refurbished after 30 years. The 21m diameter bus-bar system made with 15 segments and 76 current collectors and housed inside the duct at ring-beam level of the dome.

Photonics Division

The Photonics division has been involved in establishing the M1 mirror segment polishing facility at CREST, Hosakote campus. Currently involved in preparing the technical document for the requirements and segment polishing process flow. The secondary mirror of VBT was re-aluminized and mounted on the cell. The Wynne corrector which had developed problems was brought down and the chipped pieces of glass which were inside the 1st and 2nd elements were removed. The chipped portion of the optical element was blackened to avoid scattering. The Wynne corrector was remounted at prime focus and aligned. Sample images of the star fields have been taken. Then secondary was mounted on the telescope and alignment procedures carried out. Periodic maintenance work at the 1.6M, 2.5M and 2.8M vacuum coating plants were carried out. Aluminization process of 20 mirrors for HAGAR telescopes has started. The coating process is likely to be completed in April 2015. During the maintenance activity of 2.5m coating plant at Hanle, the defective gauges and other components were replaced and the coating plant was tested for its performance. Trial coating was taken on sample plates and the performance was found to be satisfactory. As per the MoU, polishing of the sunshield panels for the MET payload for the INSAT 3DR2 has been completed. The process to undertake the polishing of INSAT-3D satellite panels during the current year has already been started.

Civil engineering activities:

The construction of the Raman science centre building at Leh is in progress. Most of the structural work is complete and interior works to be started. Refurbishing old building for electronics laboratories at Kavalur has been taken up.

Electrical Engineering:

A new MV panel with higher capacity has been put into service in place of old and lower rating panel. 500KVA capacity transformer, voltage stabilizer and high voltage switching panel has been erected. The high voltage cable connection from BESCOM pole structure is to be completed. Electrical fencing works in Kodiakanal observatory is being supervised. Bus-bar repairing work in the 90 inch telescope dome has been supervised and completed. Electrical works of RAMAN science centre building at LEH bas been supervised. The power house for this building has been planned and being executed by the electrical section.

4.2 OBSERVATORIES

4.2.1 Indian Astronomical Observatory

2m Himalayan Chandra Telescope

The Himalayan Chandra Telescope (HCT) completed 12 years of utilization through competitive time allocation, with a steady increase in its user base. 34 proposals were received for 2014-Cycle2 (2014 May-August), 36 proposals for 2014-Cycle3 (2014 September - December) and 32 proposals were received for 2015-Cycle1 (2015 January - April). The telescope was over subscribed by a factor 2 on an average, while the dark moon period was over subscribed by a factor 3. HCT proposals cover a wide range of scientific problems, from the observations of nearby solar system objects to the distant quasars. The TIRSPEC instrument was released for regular use after commissioning and science verification.

The telescope is being used by the observers remotely from IIA's CREST campus through a dedicated satellite-based communication link having a bandwidth of 2MHz. An additional bandwidth of 3 MHz + 1.5 MHz that has been allotted for satellite communication, which is awaiting clearances from the concerned authorities.

All preparatory work for the installation of the High Resolution Echelle Spectrometer (HESP) has been completed. The instrument is expected to be installed and commissioned during the later half of 2015.

The difficulties in remotely operating the telescope installed at high altitude and the complexity of the modern astronomical instrumentation requires the team of engineers and scientists to closely collaborate and undertake periodic monthly preventive maintenance and rigorous annual maintenance for successfully operating such facilities.

The preventive maintenance activities of HCT were carried out on monthly basis, around full moon period, when the demand for telescope time is low. Various calibrations and checks were periodically undertaken to keep the performance of the telescope at its optimum level and minimize the downtime of the telescope/instruments during the time allotted for science observations. During monthly preventive maintenance various components of the telescope, dome and instruments were inspected carefully, cleaned and serviced. The instrument dewars were evacuated at an interval of once in a few months during the preventive maintenance

period.

The annual maintenance of the HCT was carried out during September 01 - 15, 2014, 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 Gamma Ray Facility

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 of 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.

Major Atmospheric Cerenkov Experiment

Bhabha Atomic Research Centre (BARC), Mumbai is installing a 21-m imaging Atmospheric Cerenkov telescope Major Atmospheric Cerenkov Experiment (MACE) near HAGAR. Various components of the telescope were transported to Hanle, and the installation activity began in October 2014. The installation of the telescope structure is underway and four azimuth drive wheels have been installed successfully.

Site Characterization for National Large Optical Telescope (NLOT)

Site characterization activities for NLOT has continued at Hanle and surrounding regions. In this regard, weather data has been collected by three automated weather stations installed at IAO, Raindong and Kalak-taltar. The NLOT-DIMM and lunar scintillometer, developed in-house at IIA and installed at IAO, Hanle, regularly document the site seeing and its seasonal variation. An automed extinction monitor has been installed at IAO, Hanle for monitoring extinction coefficient in the optical region.

Earth Sciences

Under the Aerosol Radiative Forcing over India (ARFI) project of ISRO-GBP, a high altitude aerosol observatory was set up in 2009, at IAO, Hanle, by Space Physics Laboratories (SPL), Vikram Sarabhai Space Centre (VSSC), Trivandrum in collaboration with IIA. This observatory, consisting of four instruments has been in continuous operation for measuring the Solar radiation; black carbon; nanometer size particles, including identification of new particle formation, their dynamics and other relevant parameters.

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 4th Paradigm (formerly called Centre for Mathematical Modeling and Computer Simulation), Bengaluru. This analyzer monitors carbon dioxide concentration of the ambient air in addition to molecular concentration of Methane and Water Vapour in the ambient air.

Vacuum coating plant

Annual maintenance, test operations and servicing of the 2.5m vacuum coating plant was carried out from September 19 - 24, 2014

by Team of IAO, IIA and Hind HiVac engineers. The various modules of the coating plant were checked for smooth operation and wherever necessary, corrective measures were taken. The plant was operated for thermal evaporation mode for 3000 A deposition and few sample mirrors were coated for evaluating the quality of coating.

4.2.2 Kodaikanal Observatory

H-alpha Telescope

A 20 cm refractor, designed and fabricated by the NIAOT (Nanjing Institute of Astronomical Optics & Technology) of CAS (of the Chinese Academy of Sciences), was installed during October, 2014 and is being operated in the Halpha (6562.81Å) wavelength. It is equipped with a H-alpha Lyot filter with 0.01Åstep tuning over the entire h-alpha wavelength range(6558.81Å 6566.81Å). The telescope can be operated in two modes, 1. Full disc mode with spatial resolution of 1.24"/pixel and 2. Partial disc or high resolution mode with 0.49"/pixel. An Andor DW346N CCD camera with pixel size of 13.5 μm is used for imaging.

WARM telescope

Installation of the White light Active Region Monitor telescope has been completed and the field trials have been performed. Dual channel imaging system has been enabled and put on routine observations since December 2014. Specifications of the reimaging achromats have been worked out using ZEEMAX and subsequently procured and installed for obtaining high quality images in the G-band and red-continuum spectral regions. Regular mode of observations is at 15 minute intervals while the cadence can be set to less than a minute.

Solar Tunnel Tower telescope

Observations for select programs continued during the year. Teething problems with the rotation stage of the grating have been attempted and solved to a large extent. It has been identified that the selection of suitable controller parameters is essential to bring the select spectral line in to the field of view. Since no such standard parameters were defined new software was developed using Python and proper parameters have been identified for each mode of grating controller by trial and error method. These new set of controller parameters have been incorporated and tested for the repeatability in positioning the required spectral line. The new parameters and identification of correct home position has ensured that all the regularly observed spectral lines fall within the scope of the CCD window.

a) An observational program to study the H-alpha spectra of solar prominences using the Kodaikanal Tunnel Telescope and spectrograph has been started recently. Studies of prominence spectra can provide useful information on CME initiation. Some preliminary observations are made and further studies are underway. b) The Ca K line spectra from different solar latitudes were obtained from Kodaikanal Tunnel Telescope on a routine basis from 1986 until 2011. This program is now revived after installing a new CCD. Regular observations have been initiated. c) Imaging the Sun in spectral line 8542 A is an advantage for the studies of chromospheric dynamics. Preliminary observations using Tunnel telescope and the Littrow spectrograph have been performed to check the possibility of observations at Kodaikanal using 8542 A line. Data indicated that the seeing limited full disk imaging using WARM telescope should be possible. Specifications of the filter have been worked.

(left)H alpha Telescope at Kodaikanal. (right) An image obtained from H alpha telescope.

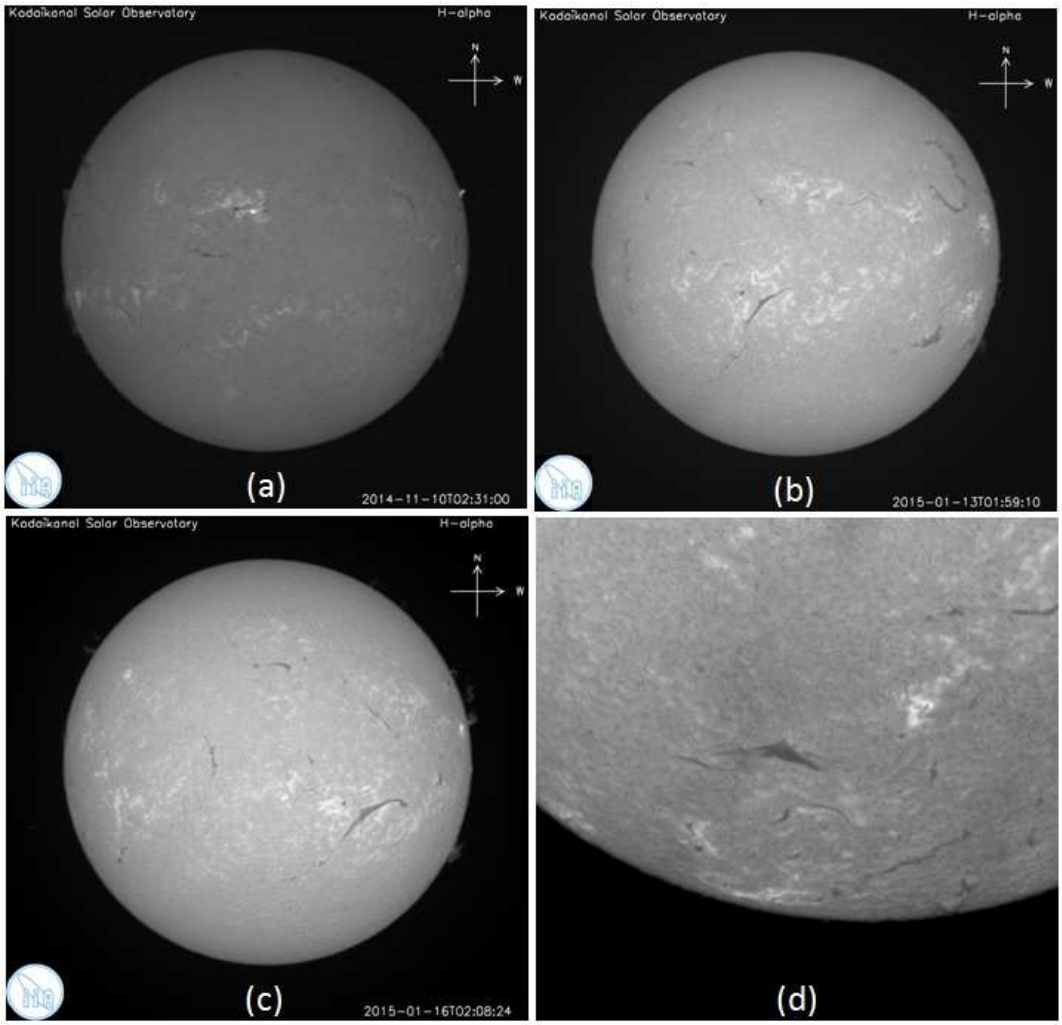
Digitization of photographic archival data

Digitization of over hundred years of solar observational data obtained on photographic plates and films and archived at the Kodaikanal observatory continued. During the year of this report, digitization of 1248 H-alpha plates for the years 1999-2000 is completed. Calibration of H-alpha plates for the years 1912 to 2007 (95 years) is completed. Digitization of 14437 prominence plates for the years 1904 to 1933 has been carried out. The Kodaikanal digitized images are now archived in the IIA data centre and hosted through the portal http://kso.iiap.res.in/data. A sample calibrated H-alpha image is shown here.

H-Alpha telescope Installation at the Kodaikanal Solar Observatory

The solar group at the Indian Institute of Astrophysics (IIA) has procured two telescopes along with two repaired Lyot filters from the Nanjing Institute of astronomical Optic & Technology, China in 2011. One of the telescopes was installed at the Kodaikanal observatory with the help of Chinese Engineers in the month of October, 2014. The core H-alpha team communicated with the Chinese Engineering team and fixed the date for their arrival at Bengaluru and Kodaikanal.

Telescope Shelter & Pier: The telescope pier was erected in the year 2008. The pier height was kept 1.3 m above the ground level.



(a), (b) & (c) H-alpha full-disk images taken on different days (shown at bottom right corner of the figure) of observation. (d) Partial disk of the sun obtained using the Barlow lens and H-alpha Lyot filter (taken on 08-October-2014).

The telescope shelter is made out of thin iron sheets and attached to steel triangular structures. Next to the telescope shelter a small room was built for keeping the telescope control system as well as data acquisition system. The telescope shelter is movable on the rail in the N-S direction. The overall shelter and room dimensions are about 4-m height, 14-m long and 4.3 m width. During the solar observations the dome can be moved out completely from the telescope pointing direction.

Telescope Installation: The Chinese team consisting of 10 members arrived at Bengaluru on 28th September night, 2014. The telescope installation work started on 30th September at Kodaikanal observatory.

On October 1, 2014, the telescope base and yoke unit was positioned on the pedestal using crane and chain pulley arrangement. Next day the encoders were fixed on the RA and DEC axes of the telescope. They were aligned with the help of micrometer screw attached on the telescope and then aligned the telescope. Later, the soft and hard limit switches were fixed on the tele-

scope and examined for their functions properly. The X-Y stage for the guide tube was fixed on the guider tube and alignment of the main tube was carried out with respect to the guider tube. Mechanical adopter for the CCD mount was tested and fixed on the end of the main tube. Gear boxes were fixed and tested for their proper function. On October 2, 2014, in the evening around 5:43 pm the main telescope with its optics in position, aligned the telescope and pointed towards the sun.

On October 5, the H-alpha filter unit was installed on the telescope. A Barlow lens was also installed on the telescope. With this setup the telescope can make the solar image in H-alpha wavelength in full-disk mode as well as partial disk mode. Once the telescope system and the filter unit started working the team had tested the filter unit for its tuning capability using the software developed for controlling the stepper motor. The whole spectral line was scanned to ensure that we are observing the different features at different positions on the line profile. Once the filter testing was completed, the team tested the Barlow lens by acquiring the images of the partial solar disk. With the Barlow lens we get 4 times magnified image of the sun.

The guider telescope is an essential part of many modern ground based solar telescope. The guider unit attached to the H-alpha telescope has a quad lens which produces 4 overlapping images of the sun. A dark portion between the overlapped image is exposed on the detector camera. Any movement of the dark image on the detector will be sensed and the feed back signal is given to the drive unit to bring back the sun image in the main telescope to the original position. An image formed by the guider unit is shown in Figure.

Telescope Specifications:

The main telescope has a 20-cm objective lens, collimating lens and reimaging lens. All are of high quality manufactured in Nanjing Institute for Astronomical Optics Technology (NIAOT), China. The pixel resolution of the image is 1.21 arcsec in the full-disk mode and 0.48 arcsec in partial disk mode. Daily solar observations in H-alpha wavelength are made since October 2014. The images are stored at every one minute cadence.

4.2.3 Vainu Bappu Observatory

1.3 metre J. C. Bhattacharyya Telescope

The 1.3m telescope was named as the *J. C. Bhattacharyya Telescope* on 19th April 2014 at the Vainu Bappu Observatory. Members of the Governing Council, other distinguished invitees and staff of the institute participated in the event. Prof B. V. Sreekantan (past Chairman, Governing Council), Dr. K. Kasturirangan (past Chairman, Governing Council and Member, Planning Commission), Dr T. Ramaswami (Secretary, DST), Prof P.C. Agrawal (Chairman, Governing Council), Dr P. Sreekumar (Director) and Prof T. P. Prabhu addressed the participants at the lecture hall in VBO. They recalled the contributions of Prof Bhattacharyya to the formation and development of the observatory. Prof A.K. Pati talked about the development of the telescope project and the contributions from staff of the institute as well as consultants and contractors who contributed to the design and construction of the facility. Mrs. Anuradha Mitra (daughter of late Prof Bhattacharyya) was also present at the meeting and recalled her association with the institute and VBO and thanked the Council and staff of the institute for naming the facility after her father. Dr. Ramaswami felicitated the consultants and agencies contracted to deliver the telescope facility. Prof Sreekantan unveiled the plaque dedicating

(left) Releasing the brochure on late Prof J. C. Bhattacharyya. (l to r) Mrs Anuradha Mitra, Dr. P. Sreekumar, Dr. T. Ramaswami, Prof B.V. Sreekantan, Dr. K. Kasturirangan, Prof P. C. Agrawal. (right)Unveiling the plaque naming the 1.3 metre telescope after late Prof J.C. Bhattacharyya. (l to r) Prof B. P. Das, Prof A. K. Pati, Prof B. V. Sreekantan, Mrs Anuradha Mitra.

the telescope as the *J. C. Bhattacharyya Telescope*.

Mosaic CCD system for the JCBT

Mosaic CCD system for imaging at JCBT using two e2v 44-82 [2048 × 4096] CCDs is under development. The CCD cryostat has been developed in-house. The ARC controller will be used to control the devices. Preliminary wiring and DSP coding to interface the controller with existing 2kx4k CCD was completed and tested.

The design of the can for holding 2.4 lts of LN2 inside the cryostat is retained but the Camera Head has been modified to accommodate two devices, two FANOUT boards and connectors for feeding signals. The CAD design is finished and the mechanical fabrication of the Camera Head is under process. The initial vacuum and LN2 holding time tests give positive results. To further improve the LN2 holding capacity, Mylar radiation shield will be introduced between LN2 can and outer body.

The thermal analysis of the CCD Cryostat is under progress and initial values for conduction and radiation losses were obtained for the design. The rate of cooling / heating of the CCD & Mount will be adjusted by adding copper strips in the conduction path to obtain the recommended flow rate. The fabricated and assembled CCD Cryostat is expected to be available for integration and testing by the end of 2015.

Multi-spectral band photo-polarimeter at the 1 metre telescope

The new astronomical photo-polarimeter, which was designed and built in the Institute, was mounted on the 1-m Carl Zeiss telescope during 14 April-30 May 2014 and observations were made to determine its suitability for efficient observations. The polarimeter can measure linear polarization of point sources simultaneously in three spectral bands. An analysis of the observational data indicated a very high degree of mechanical stability for the instrument, and a low value ($< 0.05\%$) for the instrumental polarization. However, the polarization efficiency of the instrument was found to be 94.72%, against a normally expected value of 98-99%.

In order to determine the polarization efficiency, a total of 160 observations of several unpolarized stars were made with the Glan-Taylor prism in the light path. The polarization efficiency is found to have a slight wavelength dependency, with lower values in the V-R spectral region. The polarization efficiency, which is halfway between the maximum and the minimum, is 99.211%. The total amplitude of variation of polarization efficiency in the U-I spectral region is only 0.271%.

Vainu Bappu Telescope

The scondary mirror of the VBT being removed for aluminisation.

The mirrors of the telescope were aluminised for increasing the observing efficiency. The secondary mirror has not been aluminsed ever since cracks in the back of the mirror were noticed over two decades ago. This mirror was carefully removed from the secondary mirror assembly and alumisation was carried out at the 1.2 metre aluminising chamber at the observatory.

Refurbishment of the VBT dome bus-bar system

VBT building has a circular bus bar system 21 metres in diameter, to provide power to the dome and shutter motors. The system is in 13 segments of 38 bus bars separated by hylam insulators. It was installed in 1982 and due to aging and usage, problems like damage in copper bus bars, in the Hylam insulation, brittleness of hylam reinforcement tubes etc had become frequent. The work was completed in 110 days, during which period it was not possible to schedule the telescope for observations. The work included reduction of bus bars from 38 to 31, replacement of broken hylam insulation strips and replacing 180 hylam tubes with nylon tube assembly, replacement of damaged copper busbars, providing varnish coating to the insulation, strengthening the joints between segments (17×31 joints), painting the bus bar duct and checker plate covers etc. The current collectors in the moving trolley assembly were replaced. New rubber flaps for shielding the bus bars were installed.

75 cm telescope and 40 cm DIMM telescope

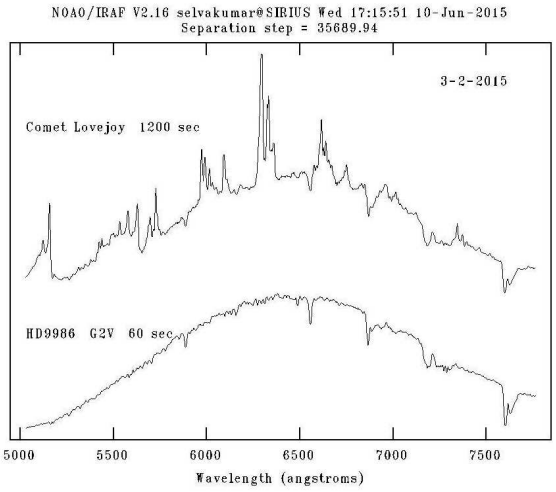
During tests of the 75 cm telescope, it was found that there was a shift in the mirror (within the mirror cell). The radial supports were redesigned and made afresh and installed in the cell. An offset unit to facilitate viewing of the field as well as guiding was also designed, built and installed. The 14 metre high steel tower housing the 40 cm DIMM telescope had to be repainted since the original paint was scraping off due to weathering. It was repainted using a special polyurethane metal coat paint selected for better thermal characteristics and longevity.

Image of the Crab nebula using the VBT at the prime focus.

Electronics & Instrumentation at telescopes

An upgraded control hardware & software interface was taken up for the OMR Spectrograph used at the cassegrain focus of the VBT. The system was designed and laboratory simulation has been completed. The work of encoding the grating position is going on, after which the system will be implemented. The system using selsyns for position display in the 1 metre telescope over the past four decades has become obsolete and gives frequent problems. An upgradation using 17 bit absolute encoders in place of selsyns was taken up. The encoder data is to be directly displayed on a PC. Initially, a mechanical interface to mount a single encoder on-axis with the selsyn used to encode the 'hours' position was installed. It was found that the gear backlash error did not permit an encoding accuracy better than 2.5 minutes of arc with a single encoder. A revised design involving the use of two encoders on the 'hours' and 'minutes' axes has been taken up.

The gain calibration of the fast CCD (Pro EM 1024B) at the JCBT telescope was earlier done only for the 5 Mhz readout speed and high gain mode and not for all combinations of speed and gain settings (high, medium and low). Certain programs of observation (eg. the occultation of Jovian satellites) required the determination of suitable gain and hence calibration data had to be taken for all possible combinations of gain



Spectrum of Comet Lovejoy obtained with the cassegrain spectrograph at the VBT. The spectrum of a solar type star is also shown for comparison. Most of the features in the cometary spectrum are due to molecular emission.

and speed covering the full dynamic range. The corresponding gain calibration were determined using photon transfer histogram method and made available for the observations. A formal report of the gain calibration is being prepared. Out of the three gain settings only 'High' and 'Medium' were found suitable, since the 'low' setting reached full well capacity before saturation of the analog to digital convertors. The Jovian occultation program also entailed rapid recording of images in a data cube. The camera software records timing data only at the start of the sequence of images. Software to split large SPE format files (native format of the detector) into individual FITS files for each frame with time stamping was developed.

4.2.4 Gauribidanur Radio Observatory

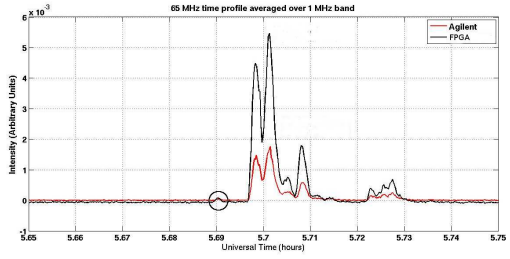
Gauribidanur RAdioheliograPH (GRAPH):

As mentioned in the recent annual reports, the GRAPH in being augmented in a phased manner by the radio astronomy group. Recently the Phase-I of the augmentation programme which includes calibration of the 384 antennas, 64 analog receiver systems (the 384 antennas have been configured as 64 groups), and the 4096-channel digital backend receiver system to correlate the signal received from the 64 antenna groups (in addition to the in-house design, development and fabrication of various hardware items mentioned earlier), was successfully completed. Observations are presently carried out at two frequencies (55 MHz and 80 MHz) everyday, and the calibrated daily radioheliograms are made available to the community via the institute website. The total length of the array and the number of antennas in GRAPH Phase-I are twice of that in the earlier configuration. This has resulted in a factor of two improvement in the angular resolution and the sensitivity of the array (see Figures). We are able to achieve a rms noise level of $\sim$10 Jy (with a bandwidth of $\sim$1.5 MHz and temporal resolution of $\sim$5 s) in the case of point source observations against 'weak' background. Work related to the Phase-II of the augmentation programme is currently underway.

Gauribidanur LOw-frequency Solar Spectrograph (GLOSS)ii

Recently the radio astronomy group has developed a FPGA based digital radio spectrometer to carry out observations of the solar radio transients with better sensitivity as

compared to a conventional spectrum analyzer. The temporal and the spectral resolutions are also significantly higher, $\sim$ 20 millisec and $\sim$ 25 KHz, respectively. The latter provides the flexibility to average the observations in both time and frequency domains which in turn enhances the capability to observe weak transients. Fourier transformation and related operations are carried out off-line at present. Work is going on to carry out the same 'on-board'. The daily spectrograms are made available to the community via the institute's website.



Time profile of a solar radio transient (type III solar radio burst) observed with a conventional spectrum analyzer (manufactured by M/s. Agilent Technologies) and a FPGA based digital spectrometer. The improvement in the signal-to-noise ratio, and the observations of weak features (see the circled region in the image) with the FPGA system are clearly evident.

4.2.5 Computer Center Activites

The Computer Center of IIA continues its endeavour to work towards providing IIA users with better network infrastructure to support the modern technologies while implementing best security measures to mitigate the modern day attacks and vulnerabilities. For that reason, network infrastructure augmentation was undertaken by the IIA computer team replacing the old and unmanaged switches with new managed switches which provide better management and availability features and support for 1 Gbps network. New Generation Wireless Access points were installed at various locations with in IIA, Bengaluru campus to increase bandwidth and coverage area. Web based authentication was also implemented to ensure proper security in terms of WiFi access. A new UTM(Unified Threat Management) firewall with improved security features and better network activity logging facilities was purchased, installed and configured to make IIA network more secure and perform more stringent monitoring of network activity on a routine basis. All critical servers in the Data Center are kept up-to-date by upgrading the software to its latest version or updating with latest security patches, to minimize the exposure to vulnerabilities. A few software upgrades activities which were taken up: Anti-spam software on mail server, Library software Dspace etc. Mathematica, Grid Mathematica and IDL campus licenses were upgraded to their latest versions.

HPC Activities

Computational servers in Data Center supporting infiniband architecture were installed with the latest infiniband drivers and connected to the high-speed network for faster data access with other servers in that network. A professional scheduler on the HPC cluster is installed to test integration of Mathematica in HPC environment. A monitoring tool called "Ganglia" was configured to log the activities of the HPC cluster and provide monitoring for all the nodes in the cluster. Several parallel applications were ported on the HPC cluster for use by the different users e.g. CosmoMC-2013, UTCHEM, DIRAC, SYNOW, ESYNOW etc.

ERP :

IIA is in the final stages of full implementation of custom made ENTERPRISE RESOURCE PLANNING (ERP) software within IIA and its various field stations. Generally, this type of system consists of modules such as Human Resources, Accounting, Finance, Purchase etc. Once implemented, an ERP system will enable employees to manage resources in all areas, to simulate different scenarios and to obtain real-time consolidated information.

4.3 Library

IIA library facilitates need-based information services towards the growth of the academic research of the Institute. The library added 137 books and 145 bound volumes of journals to its collection. The library reviewed the existing journals collection and the current journals subscription is 88 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 continues to be a member of the NKRC consortium and has e-journals access with 12 major publishers.

Document Delivery Services: Forty four Interlibrary loan requests from IIA Faculty and students were fulfilled as they were not there in the IIA collections. More than 65 requests from other libraries and individuals were catered to from our collections as part of the document delivery service.

Open Access Repository: IIA library is maintaining its open access repository by adding new and old research publications of IIA dynamically.

Archives: IIA library maintains its archives and the archival material has been used for research purpose by researchers both nationally and internationally.

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

Non-Chemical Treatment of Books & Journals: The non-chemical treatment was carried out for books and Journals and archival materials in the month of August 2014. The process includes Gas Hermetic Treatment, Wood borer treatment and Pro Guard service. Unpolished wood is sprayed directly, polished surfaces have been treated by injecting chemicals into the shot holes.

Library Training & Internship program: Library continues to offer training for two years, and the trainees are trained in all the sections of the library especially in the digitization procedure.

Internship: IIA Library has provided internship training to two MLIS students from Bishop Heber College, Department of Library and Information Science, Tiruchirapalli as a part of their curriculum.

Chapter 5

UPCOMING FACILITIES

5.1 Thirty Meter Telescope

India TMT: Milestones and highlights

In the academic year 2014–2015, the TMT project reached several key milestones. India formally joined the TMT project as a full member. At a function in New Delhi on December 2, 2014, in the presence of the Union Minister for Science and Technology and Earth Sciences, Dr. Harsh Vardhan, the Secretary of Department of Science and Technology, Prof. K. Vijay Raghavan, signed the necessary documents to change India's formal relationship from Associate to Member of the TMT International Observatory (TIO).

The groundbreaking and Hawaiian blessing ceremony for the construction of TMT at the summit of Maunakea happened on October 7, 2014. India was represented by Honble Ambassador Taranjit Singh Sandhu, India Deputy Chief of Mission at Washington, Dr. Srinivasa, San Francisco Consular General, Indian Consulate San Francisco and Prof. Eswar Reddy, Project Director, ITCC.

As part of ongoing activities by India-TMT, it is proposed to host periodic meetings at various geographical locations in India. The first meeting was held at ARIES, Nainital, during 05–06 November 2014, to update the present status of the project and discuss the scientific challenges and capabilities of TMT. The primary aim of this meeting was to make the project familiar to Indian scientists and solicit their participation in this mega project. Around 40 scientists and engineers from various Universities and Institutes attended this meeting and showed interest in contributing to the TMT project. Resource persons were drawn mainly from IIA, IUCAA and ARIES.

India TMT work packages

1. Segment Support Assembly: The work on Segment Support Assembly (SSA) was carried out at M/s. Godrej and Boyce Mfg. Co. Ltd., Mumbai and also at Avasarala Tech Ltd., Bengaluru. The schedule of the work got delayed as the manufacturing process for quite a few components, like the central diaphragm made of invar, had to be tried and proved to obtain the specified tolerances. Some of the critical components like casting, extrusion and the strain gauged leaf spring were manufactured and supplied to the vendors by ITCC. A 1 lakh class clean room for assembling the SSA at ITCC, IIA, Bengaluru was set up. P. K. Mahesh leads the hardware efforts.

2. Actuators and Edge Sensors: Discussion with prospective vendors for actuators were carried out to identify additional vendors for the production phase. The test on the coupons of various surface roughness

(left)Prof. K. Vijay Raghavan, Secretary, DST signing the documents in the presence of Dr. Harsh Vardhan Minister of Science and Technology and Earth Sciences, Govt. of India. Prof. P Sreekumar, Director IIA, Prof. Ajit Kembhavi, Director IUCAA and Prof. Eswar Reddy, Project Director, ITCC were also present. (right) Indian representatives at the TMT ground breaking ceremony.

was conducted at JPL, USA and a surface roughness of 0.2micron as against the earlier 5 Angstrom was selected. The process coating and litography process on this new surface finish is being made by the vendor.

3. M1 coating chamber: Discussions were held with a prospective vendor for developing the design for the vacuum coating chamber for coating the M1 mirror segments.

4. M1 Segments Polishing: (a) Efforts are on to set up an optics polishing facility at IIA's CREST campus for polishing India's share of the M1 segments. Architecture consultants, M/s EPICONS, Mumbai have been selected for the design of the building based on the requirements provided by ITCC's Segments Polishing Group. (b) A python code was developed by Vineeth Valsan to estimate the stress to be applied for warping the mirrors in Stressed Mirror Polishing (SMP) technique. In the SMP technique, forces are applied to the mirror blank in order to elastically deform the desired surface into an asphere, which is then polished to spherical profile. These forces have been theoretically modeled using thin plate theory. The program deals with the calculation of these forces for any segment in general. In-house development of this code is vital as India-TMT will be polishing ∼15% of the total primary mirror segments for TMT using the SMP technique.

5. Generation of near infrared guide star catalog (IRGSC): The generation of a near infrared guide star catalog for TMT observations is a critical resource for TMT operations, enabling efficient planning and observing. Such a catalog fulfills a role similar to that of the Guide Star Catalogs I and II, which were created to enable acquisition and control of the Hubble Space Telescope. No catalog currently exists with objects faint in the IR over a large enough area of the sky to be useful as a guide star catalog. It is highly essential to develop this catalog by computing the expected NIR magnitudes of stellar sources using their observed optical magnitudes. We developed a methodology to compute the expected NIR magnitudes of stellar sources from there optical magnitudes using stellar atmospheric models. The methodology was applied in three test fields

and found to be satisfactory. From the initial analysis, it is found that the reference optical data from PAN STARRS is promising and the final all sky PAN STARRS data is expected to be used for the final production of the TMT IRGSC. The report of this work package is provided in the TMT document TMT.SFT.TEC.14.024.REL03.pdf. Smitha Subramanian lead the efforts in realizing this work package.

6. Mini studies on the first light instrument – MOBIE: MOBIE, the Multi-Object Broadband Imaging Echellette, is a seeing-limited, wide-field imaging multi-object echellette spectrograph. MOBIE can directly image or create low (R = ∼1000) to medium-resolution (R = ∼8,000) spectra in two color channels simultaneously, spanning 310-550nm and 500-1100nm passbands respectively. MOBIE views a rectangular field of approximately 3.0 arcmin × 8.3 arcmin resulting in a field area of 24.9 square arcminutes, and a total slit length of 500 arcsec. Starting in October 2013, the TMT partnership has been engaged in an effort to form a full MOBIE team through an international work share development process. In April 2014, during the MOBIE stakeholder meeting, a number of mini-studies were initiated among the partner countries. The mini-studies are a key element of the TMT instrumentation work share development process, and their goals reach beyond technical work.

7. Estimation of the instrument polarization due to TMT telescope optics: India-TMT lead the efforts to estimate the polarimetric properties and the instrumental polarization due to the telescope optics in an effort to assess the suitability of polarimetric observations with the telescope. An analytical model approach as well as Zemax modelling of the telescope optics were used to estimate the instrumental polarization (IP). IP was estimated at the primary focus, secondary focus and the Nasmyth focus, as well as for the AO optics and the first generation NIR instrument - IRIS. Mean IP and variance were estimated for all the instrument ports at various field angles and zenith distances.

5.2 Visible Emission Line Coronagraph on ADITYA(L1)

Visible Emission Line Coronagraph (VELC) payload onboard Aditya(L1) is an internally occulted solar coronagraph with simultaneous imaging, spectroscopy and spectro-polari metry 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 & origin of CME's, (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). VELC is designed to image solar corona from ±1.05Ro to ±3Ro (Ro: solar radius) with a plate scale of 2.5"/pixel. It has multi-slit spectroscopic channels at three emission lines namely 530.3nm, 789.2nm and 1074.7nm with spectral resolution of 65mÅ, 95mÅand 150mÅrespectively. It has dual-beam spectro-polarimetry at 1074.7nm for magnetic field measurements. FOV for spectroscopy and spectro-polarimetry is from ± 1.05Ro to ±1.5Ro. This project was approved by ADCOS, ISRO on 11-10-2013. A detailed BDR of the pay-load was held on 05-05-2014 and the committee appreciated the progress made by the pay-load team.

5.3 National Large Solar Telescope

At the instance of DST, the IIA governing council had constituted a committee to examine the implications of Hanle as the site for NLST instead of Merak and submit its recommendations. The NLST team prepared a preliminary report on the possible changes in the telescope design taking into consideration the potential to carry out observations at infrared (IR) wavelengths in Hanle, and submitted the same in the first meeting of the committee. Based on the presentations, the latter asked the NLST team to prepare an updated site survey report, study the clearances needed, validate the earlier technical bid, financial impact on the project due to the IR instrumentation, functioning of the Adaptive Optics (AO) at the longer wavelengths, etc. and submit the information to them. Presently the wind measurements at 10 m and 30 m heights are being carried out at Hanle to understand the variation of the wind speed with height. Note that the wind measurements obtained during the earlier site characterization were at a height of 2-m. Additionally work is also going on to obtain statistics on the characteristics of the turbulence as a function of height, isoplanatic patch size, size of the dust particles, etc. Science goals are also being refined in the light of the IR capabilities offered by the Hanle site.

5.4 Ultra-Violet Imaging Telescope (UVIT)

UVIT is one of the five science payloads on ASTROSAT, the first Indian satellite devoted fully to astronomy, which is to be launched in the year 2014. ASTROSAT has four X-ray telescopes, which observe in soft/hard X-rays, and UVIT observes in ultraviolet and visible bands. Three of the X-ray telescopes and UVIT can observe an object simultaneously. The instrument is configured as two similar Cassegrain telescopes of $\sim$ 375 mm diameter. One of the two telescopes observes in FarUV (1300–1800 Å), while the other observes in NearUV(2000-3000 A) and VIS (3200–5500 Å). Images are made simultaneously in all the three channels with an angular resolution of $\sim$ 1.8 arcseconds in a field of $\sim$ 28 arcmin. In addition to a selection of filters for each of the three channels, low resolution (100) slitless spectroscopy is available for FarUV and NearUV channels. ASTROSAT aims to observe simultaneously in X-rays, UV and visible. UVIT would be used to study time variability of X-ray objects, on time scales ranging from seconds to days, in coordination with the X-ray telescopes, and would observe on its own objects like interacting galaxies, star forming galaxies, globular clusters, hot/evolved stars.

Assembly and optical testing of the payload was completed in year 2013. However during the vibration tests at ISRO, the detector for visible channel had failed. A new detector was assembled by CSA, Canada (collaborator in the project), the failed detector was replaced by this in November 2014. After all the optical tests with the new detector, the payload went through thermal-vacuum tests at ISAC, ISRO. Fully qualified payload was delivered to ISAC in November 2014. The payload was integrated with the spacecraft in January 12015. All the tests on the integrated satellite are expected to be completed at ISAC by June 2015, and the launch is expected by September 2015. Planning and preparations of the tools for calibrations and performance verification of the payload is being done. It is expected that all the payloads on ASTROSAT would be fully

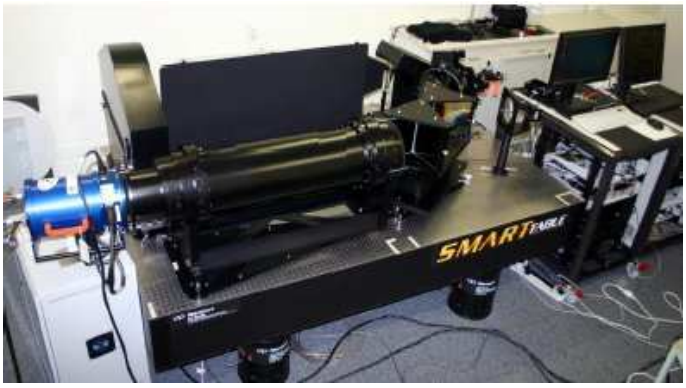
ready with calibrations, and open for observations, by April 2016.

5.5 Hanle Echelle Spectrograph

Hanle echelle spectrograph (HESP) is a fibre-fed, high resolution (R = 30,000 and 60,000), spectrograph developed for the 2m Himalayan Chandra Telescope (HCT), Hanle. The instrument is developed in collaboration with Callaghan Innovation Research Limited (CIRL, formerly known as Industrial Research limited), New Zealand. The project is largely supported by Department of Science and Technology grant under fast track scheme IRHPA.

HESP is unique compared to many other spectrographs, due to its complete wavelength coverage in optical. It provides accurate stellar abundances for almost all the key chemical elements in a single exposure, which is an efficient way to use the telescope time. The spectrograph has very low scattered light ($< 1\%$), hence the shape of the broad line profiles will be accurate and can be used to derive accurate stellar parameters from the line wings. The instrument also provides precise radial velocity $\sim$ 20m/s using simultaneous ThAr calibration exposures.

Following the design review in June 2012, the opto-mechanical fabrication was completed during June 2014. The subsystem and interfaces were tested during December 2014. The optical test results showed that the fabrication quality was much superior to the required specifications. The full system was integrated and tests were performed during January–March 2015. The full assembled spectrograph was tested for endurance over a range of ambient temperatures ($-30\ to + 30C$). The Cassegrain unit



The Hanle Echelle Spectrograph with all its assemblies.

that interfaces the telescope and the spectrograph was tested for performance over the entire expected range of ambient conditions ($-30\ to + 30C$) at the observing site.

The instrument control software along with the telescope interface is developed at IIA. The electrical interface developed at IIA has been integrated with the spectrograph in New Zealand. The electrical cabinet for Cassegrain unit control would be mounted under the telescope base and has been provided with thermal insulation using Styrofoam material. The electrical controls for calibration box (to select the calibration source of interest) and spectrograph components would be housed in the spectrometer room at the ground floor of the HCT dome.

The system control software is being developed by IIA towards different operational steps. It would control the individual actuators of the instrument to desired location during the observation. The software has been developed on QT platform using CPP programming language.

Chapter 6

PUBLIC OUTREACH

Celebration of National Science Day: IIA Bengaluru campus: National Science Day 2015 was celebrated at IIA on 28 February 2014. Altogether 134 students from six schools in Bengaluru participated in various activities organised in the Koramangala campus of IIA. The schools which participated were, Reddyjana Sangha School, Christ School, M. S. Ramaiah Vidyaniketan, Chinmaya Vidyalaya, Our lady of Fatima School and Government High School, Madivala. The program started with a drawing competition in the morning for the students. After the competition, the students were taken around the campus by student volunteers of IIA to locations where various experiments and displays were set-up. They were 1. Observing the sun through telescope and coelostat. 2. A demo of Balloon Experiment. 3. Visit to the Photonics Laboratory 4. Demonstration of astronomical kits 5. An exhibition of posters and models. After visiting the above, the students assembled at the auditorium and a quiz competition was conducted in which the students participated enthusiastically. Following the quiz competition, there was the prize distribution by the dean of IIA, Prof. Rangarajan to the winners of drawing and quiz competitions. The science day celebrations concluded with sky watch program arranged at the terrace observatory of IIA in which a large number of public participated. Students and staff of IIA volunteered and made the program a grand success.

Outreach for School Children: IIA outreach program was conducted at different schools during last year benefiting around 600 students of four schools. This school outreach program is conducted for the high school classes, a total of around 100 students in each school with the help of Ph.D. student volunteers from IIA and the science teachers of the school. The duration for the program was 3 to 4 hours in each school. Kannada and English was the preferred medium of instruction. The event was divided into 3 sections, a talk which lasted for an hour, another one hour for demonstration and activities and a final session was for astronomy role-play, discussion and interaction with the students. The talk and the demo were held in parallel sessions with the group of about 50 students in each batch respectively. Students attended the one hour talk and video tour of the solar system, an half an hour presentation of stellarium and demonstration of adjoining kits and activities, and the demonstration on how to use the telescope, including a demonstration on how terrestrial objects were magnified by the telescope.

Science Day celebrations at IIA.

Govt. High School, Madhugiri & Rural Residential High School, Madhugiri.

Other Activities at IIA, Bengaluru:

Workshop on 900 years of Bhaskaracharya-II:
To celebrate the 900th birth anniversary of the great Indian mathematician and the astronomer Bhaskaracharya-II, a one day workshop was organised at IIA on December 17, 2014. This workshop was a joint effort of IIA, Jawaharlal Nehru Planetarium, Bangalore and Astronomical Society of India. The Workshop was divided into two sessions and seven scholars presented the works and life of Bhaskaracharya-II. Noted historian of science, Prof. B. V. Subbarayappa inaugurated the workshop and gave an overview of ancient Indian science in the context of Bhaskaracharya-II. There were about 80 participants, with a large number of young participants keen to learn about Bhaskar's contribution to astronomy and mathematics.

Visitors from schools and colleges:
In addition to school programme, as a part of outreach activities, all through year, we received a large number of students from various schools and colleges. Special lectures were arranged for them and then after they visited to our facilities, like library, IIA archives, and few labs.

National Science Day at CREST campus: On February 28, 2015 the National Science Day was celebrated at the CREST campus. More than 120 students from various schools (New Horizon Public School, Narayana e-Techno School, Narayana Olympiad School, Bharathmatha School etc.) visited the campus with their teachers. One exhibit area with posters in general astronomy and highlighting the institute's facilities and the work done in the field of Astronomy & Astrophysics was showcased. Drawing, Essay writing and Quiz competitions were also held among the students of these schools. Remote operations of 2-m HCT were also demonstrated through video conferencing to IAO, Hanle. MGK Menon Lab

Photographs taken during the workshop.

activities were shown through CCTV network. These events were followed by a lecture - *Optical Telescopes in India* by B. C. Bhatt. One small film - *Journey to Stars* was also shown to the students. The complete program which lasted a day was conceived and organized by B. C. Bhatt with the help of CREST staff members. Local Kannada press also covered the events and news items on our science day celebrations were published in 3 local Kannada newspapers.

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 SC/ST 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 12.87%, 11.36% & 6.43% respectively of the total staff 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

Hindi Workshop: In order to expedite the implementation of Official Language in the Institute and to improve the staff members capacity for doing official work in hindi, one Hindi Workshop was conducted for the employees working in Administration on 26.08.2014. The report was sent to the Dept. of Science & Technology, New Delhi.

Hindi Day/Fortnight Celebration: The institute celebrated Hindi Fortnight from 1st September, 2014 to 22 September, 2014. During the occasion seven competitions were conducted in the institute viz. “Hindi-English Noting” competition on 01 September, 2014, “Hindi Song” competition on 02 September, 2014, “Hindi Speech” competition on 03 September, 2014, “Hindi Essay Writing” competition on 04 September, 2014, “Hindi Easy Writing” competition on 05 September, 2014, “Hindi Visual-Quiz” competition on 11 September, 2014 and “Hindi Antak-

shari" competition on 12 September, 2014. 22 September, 2014 was celebrated as "Hindi Day" 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.

Chapter 7

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Chapter 8

STAFF LIST 2014 – 2015

Director: P. Sreekumar

Distinguished Professor: Bhanu Pratap Das, S. Sirajul Hasan (up to 30.06.2014)

Senior Professor: S. P. Bagare (up to 28.02.2015), H. C. Bhatt (up to 31.12.2014), Jayant Murthy, K. N. Nagendra, A. K. Pati, T. P. Prabhu (up to 31.12.2014), Sunetra Giridhar

Professor: G. C. Anupama, R. K. Chaudhuri, R. Kariyappa, Prajval Shastri, B. Raghavendra Prasad, K. E. Rangarajan

Associate Professor: Annapurni Subramaniam, Aruna Goswami, Arun Mangalam, B. C. Bhatt, Dipankar Banerjee, B. Eswar Reddy, R. T. Gangadhara, Gajendra Pandey, K. M. Hiremath, J. Javaraiah (up to 31.01.2015), U. S. Kamath, Muthumariappan, S. Muneer, P. S. Parihar, S.Paul Kaspar Rajguru, K. P. Raju, K. B. Ramesh, R. Ramesh, D. K. Sahu, A. Satya Narayanan, S. K. Sengupta, Sivarani Thirupathi, M. Srinivasa Rao (up to 31.01.2015), C. S. Stalin, K. Sundararaman (up to 30.11.2014)

Reader: Firoza Sutaria, C. Kathiravan, Mousumi Das, Pravabati Chingangbam, Preeti Kharb, B. Ravindra, M. Sampoorna, Subinoy Das, Ravinder Kumar Banyal

Scientist D: Rekesh Mohan, B. A. Varghese

Scientist C: E. Ebenezer Chellasamy, B. S. Nagabhushana, N. Shantikumar Singh, G. S. Suryanarayana

Scientist B: Muthu Priyal (up to 31.08.2014), Namgyal Dorjey, K. Prabhu, G. Selvakumar

Research Associate B: M. Appakutty

Adjunct Scientist: Durgesh Tripati , Shankar Subramaniam

Visiting Professor: S. N. Tandon

Visiting Scientist: S. G. Bhargavi, Margarita Safonova, Ramya Sethuram

Honorary Professor: V. K. Gaur, S. S. Hasan

Post Doctoral/Visiting Fellow: Jessy Jose, Koshy George, Smitha Subramanian, Vineeth Valsalan

Scientific Officer SD: L. Yeswanth (up to 31.12.2014)

Technical staff

Engineer G: A. V. Ananth (up to 31.03.2015)

Engineer F: M. S. Sundararajan (up to 31.03.2015), G. Srinivasulu

Engineer E: V.Arumugam, S.S.Chandramouli, P. M. M. Kemkar, P. K. Mahesh, S. Nagabushana, R. Ramachandra Reddy, S. Sriram, J. P. L. C. Thangadurai

Librarian: Christina Birdie (up to 31.07.2014)

Engineer D: Amit Kumar, P. Anabazhagan, Dorje Angchuk, Faseehana Saleem, S. Kathiravan, B.Ravikumar Reddy, M. V. Ramaswamy, K. C. Thulasidharen, Tsewang Dorjai

Principal Scientific Officer: K. Jayakumar (up to 31.12.2014), R. Selvendran

Principal Document Officer: Sandra Rajiva

Engineer C: K. Anupama, Anish Parwage, K. Dhananjay, K. Ravi, Sanjiv Gorka, Sonam Jorphail, Tashi Thsering Mahay, P. Umesh Kamath, Vellai Selvi, Venkata Suresh Narra

Technical Officer B: N. Sivaraj, Narasimhappa

Engineer B: I.V. Barve, V. S. G. Gantyada, V. K. Gond, Mallappa, Madhur Juneja, V. Natarajan, M. Rajalingam, A. Ramachandran, S. Ramamoorthy, N. Raj Kumar, S. Suresh (up to 30.09.2014), Tsewang Gyalson

Technical Officer: A. V. Velayuthan Kutty

Tech. Associate B: D. Babu, P. Kumaravel, J. Manoharan, S. Pukalenthi, C.V. Sri Harsha, M.R. Somashekar, S. Venkateshwara Rao

Draughtsman E: V. K. Subramanian

Sr. Tech. Asst. C: R. IsmailJabillullah, T. K. Muralidas

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

Tech. Associate: V. Gopinath (up to 28.02.2015)

Sr. Tech. Asst. B: D. Kanagaraj (up to 31.03.2015), A. Muniyandi, M. Nagaraj (up to 31.10.2014), K. Sagayanathan

Sr. Research Asst. B : V. Moorthy

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

Consultant: Lt. Col Kuldip Chandar

Sr. Consultant: M.Nageswara Rao

Administrative staff

Administrative Officer: P. Kumaresan

Principal Staff Officer: K. Thiyagarajan

Accounts Officer: S. B. Ramesh

Stores & Purchase Officer: Y. K. Raja Iyengar

Sr. Asst. Accounts Officer: G. R. Venugopal (up to 31.07.2014)

Assistant Personnel Officer: Narasimhamurthy

Sr. Section Officer: K. Padmavathy,

Pramila Mohan, S. Rajendran

Section Officer: Diskit Dolker, Ramaswamy, N. Valsalan

Section Officer (Hindi): S. Rajanatesan

Sr. Office Superintendant: Maliny Rajan, N. K. Pramila, N. Sathya Bama, Uma Maileveloo, A. Veronica

Chapter 9

AUDITED STATEMENTS OF ACCOUNTS, 2014 - 15