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INDIAN INSTITUTE OF ASTROPHYSICS

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Edited by: Maheswar. G & G. C. Anupama

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Front Cover: Center: The twin telescopes of the Ulta-Violet Imaging Telescope (UVIT).
Images obtained with the UVIT, Clockwise from the top: The Jellyfish Galaxy, JO201; The Barred Spiral Galaxy, NGC 2336; The Spiral Galaxy, NGC 300 (Caldwell 70); The Great Barred Spiral Galaxy, NGC 1365; The Globular Cluster, NGC 5466; The Dwarf Spiral Galaxy, IC 2574.
(The UVIT project is led by the Indian Institute of Astrophysics, Bengaluru, in collaboration with the Inter University Center for Astronomy and Astrophysics, Pune, the Tata Institute of Fundamental Research, Mumbai, several centers of ISRO and the Canadian Space Agency. Image Credit: UVIT team and the Payload operations centre at IIA).

Back Cover: The 1.0 m class Thermo-Vac facility at Prof. M. G. K. Menon Laboratory for Space Sciences, CREST Campus (IIA), Hosakote. *Image credit: VELC Team.*

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IIA Campus at Bengaluru

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Year-In-Review

As the Director of the Institute from October 2019, it gives me great pleasure to summarise the highlights of the Institute during 2019-20. The institute with its facilities spread across the country and sky, is engaged in scientific research and developments in astronomy, astrophysics and related fields, astronomical instrumentation, student training, engaging with the public at large and participation in mega-projects.

Research: In **Solar Physics**, studies of the Solar magnetic field were carried out in active regions on the Sun. The spectropolarimeter at the Tunnel Telescope of the Kodaikanal Solar Observatory was used to study the structure and height variations of sunspots. Using the Multi-Application Solar Telescope at the Udaipur Solar Observatory and employing the Fizeau Mark Interferometry of Solar Features, high-resolution observations of the Sun were performed. On the theoretical front, an iterative technique was developed to solve the problem of polarized line formation in a magnetized isothermal atmosphere.

In **stellar and Galactic astrophysics**, ejection of protostars from their site of formation, interaction of ejecta of Supernova with the surrounding medium, modelling spectra of novae, parameterisation of supernova progenitors, study of kilonova candidates, ejecta properties of planetary nebulae, detection of white dwarf companions to stars in open and globular clusters, abundance of lithium, carbon and slow neutron capture elements in stars in relation to their evolution are some of the highlights.

In **extragalactic astronomy and cosmology,** generating a catalog containing the largest collection of spectroscopically confirmed quasars, quenching of star formation in bars of galaxies, dynamical mass estimation of face-on galaxies, young radio galaxies, star formation in dwarf galaxies are some of the highlights. The researchers obtained data from the ground based telescopes of the Institute, as well as ASTROSAT, the first Indian space observatory, supplemented with multi-wavelength data from other national and international facilities. Interesting results were obtained with the GROWTH-India telescope as the facility successfully followed up a few gravitational wave alerts from LIGO-VIRGO collaboration. Theoretical modelling of the observations using state of the art models/codes were also carried out.

The **theoretical group** carried out research in black hole astrophysics, quantum chemistry, exo-planets, MHD theory of solar flux tubes and pulsar emission mechanisms. New grid of transmission spectra for hot Jupiters, a model to explain the evolution of black holes, the diverse polarization properties of radio pulsars in terms of their viewing

Figure 1.1: *Prof. V. K. Gaur delivering the Founder's Day lecture.*

geometry etc. are the highlights.

Student training: The IIA-Pondicherry University PhD program has achieved a 10 year completion and continues with the renewed MoU. The unique and successful MTech-PhD program on Astronomical Instrumentation with Calcutta University has completed more than a decade and continues with a renewed MoU. The current student strength stands at 75. A total of 14 students were awarded the PhD degree, the highest over the past five years and ten more submitted their theses.

17 students participated in the yearly 2-week long summer school in Kodaikanal Observatory, followed by a 6-week long project at various IIA campuses. 47 students participated in our visiting students programme. 15 students performed Summer Research Fellowship Programme of the Indian Academies and carried out projects under the guidance of IIA faculty, apart from a number of short term projects by undergraduate students.

Astronomical Instrumentation: Members of the System Engineering Group (SEG) are involved in infrastructure creation, scientific projects related to ground based and space based instrumentation, maintenance of our established facilities, participation in TMT mega-project and human resource development.

Figure 1.2: *Indian delegation led by Prof. Annapurni Subramaniam and Prof. G. C. Anupama meeting Her Royal Highness Princess Maha Chakri Sirindhorn at the inauguration ceremony of a new headquarter of NARIT in Chiang Mai, Thailand on the 27th of January*

A new online proposal management system was developed in-house for the Institute operated observing facilities. The upgrade of the telescope control system and the drive of the secondary mirror of the HCT is progressing well. To carry out tests of the space payloads, a new environmental testing facility is being added to the Prof. MGK Menon Laboratory for space Sciences, located in the CREST Campus.

A new thermo-electrically cooled CCD was procured, tested and calibrated for its use with the OMR spectrograph. A near-infrared photometer was designed and fabricated to use with the 40-inch telescope at VBO. A solar spectrograph designed and developed by the Institute for the graduate and undergraduate level students was installed at the Indian Institute of Space Science and Technology, Thiruvananthapuram.

Figure 1.3: *Prof. Annapurni Subramaniam felicitating Dr. V. S. Ramamurthy (former DST secretary) who was the chief guest for the conference organized to celebrate 150 years of the Periodic Table at IIA.*

Ongoing Projects: Many activities were carried out as part of the TMT mega-project. The Optics Fabrication Facility (ITOFF), which will carry out polishing of M1 segments, is nearing its completion in the CREST campus. A set of 18 glass blanks were received from National Astronomical Observatory of Japan and are currently stored at ITOFF. The Common Software which forms the backbone skeletal communication system of the whole observatory software architecture has been successfully delivered. The work packages led by India in telescope hardware components such as segment support assembly, actuators, edge sensors and development of science instruments are also progressing well.

The optics for the Visible Emission Line Coronagraph (VELC), the most important payload onboard India's solar space mission Aditya-L1, are getting tested at the Prof. MGK Menon Laboratory for Space Sciences. Realization of optical bench of VELC has also been successfully completed here. Several of the optics have been integrated into their respective opto-mechanical systems and have undergone environmental tests. A web-based VELC observation proposal submission platform has also been developed.

Upcoming projects: A seed funding was awarded by ISRO for a proposed 1-metre class UV-Optical Indian Spectroscopic and Imaging Space Telescope (INSIST) for a joint mission with Canada. The project completed a conceptual design as well as a preliminary design and has reached maturity to start the final design phase.

The official procedure to lease the land in Merek, Ladakh for the National Large Solar Telescope project is in progress. The final approval of the project is expected soon.

A request for an initial budget for the preparation of a detailed project report for the National Large Optical-Near Infrared Telescope (NLOT), was submitted to the Department of Science and Technology in June 2019.

The Institute conducted several **conferences and schools**. A conference to celebrate the 150 years of the Periodic table titled, "Chemical Elements in the Universe: Origin and Evolution", saw good participation of scientists from various fields. This was inaugurated by Dr. V. S. Ramamurthy (former DST secretary). A conference of engineers in astronomy, titled, "Modern Engineering Trends in Astronomy" was organised by the Institute, jointly with NCRA and RRI. Prof. Vinod K. Gaur presented a talk on "Plate Tectonics and the Making of Himalaya: An ongoing Process", on the occasion of the Founder's day.

The Institute has a number of **Memoranda of Understanding (MoU)** with various national institutions such as BARC, TIFR, 4th Paradigm Institute, etc. This year an MoU with ISRO was signed on space situational awareness. The MoU with the Instituto de Astrofísica de Canarias (IAC) and the GRANTECAN, (GTC), Spain is being pursued. Effort are on to strengthen

the ongoing collaborations with Thailand astronomical community through the National Astronomical Research Institute of Thailand (NARIT).

Outreach activities: This year, the public outreach team of IIA organized several programmes for students and the general public in and around Bengaluru and elsewhere in the country to promote science and astronomy. Several events were organized at Leh under the IIA-Cambridge Academics joint outreach programme and IIA-SALT outreach programme.

An IIA-IAU training programme was organised for school teachers in rural Bengaluru. During the annular eclipse on 26 December 2019, a few hundred people participated in viewing the event at Bengaluru and Kodaikanal campuses. The National Science day activities were conducted in all field stations, with programme and competitions for students of schools in the nearby areas. There was high public participation in the Vigyan Samagam events during May 2019 - March 2020, showcasing the Indian participation in mega-projects.

Other notable points: The IIA archives organized a two days programme as a part of International Archives Week. Several experts delivered a series of lectures on aspects of scientific work and the history of science in India with a focus on the Institute's archives.

The Institute initiated various steps for implementation of the official language and continued efforts to make equitable work environment by safeguarding the interests of SCs, STs, the differently-abled and women.

I would like to end with a few **awards and recognition**. Prof. Dipankar Banerjee was elected as a fellow of the Indian Academy of sciences. He took charge as Director of the Aryabhatta Research Institute of Observational Sciences (ARIES) in December 2019. I was awarded the Sir. C.V. Raman Young scientist award of the Karnataka state for the year 2018, in field of physical sciences.

The Institute has seen continued growth and excellent performance in the last decade. I extend my best wishes to the Institute to produce outstanding scientific research and technological development in the next decade with the generous support and guidance of the Department of Science and Technology and the Government of India.

Annapurni Subramaniam
Director

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Research

Scientists at IIA together with research scholars and post doctoral fellows are engaged in research in the fields related to Astronomy and Astrophysics. Highlights of some of the results obtained during the period from April 2019 to March 2020 in the topics such as the Sun & the solar system, stellar & galactic astrophysics, cosmology and extragalactic astronomy, theoretical physics & astrophysics and experimental astrophysics & instrumentation are briefed below.

2.1 The Sun and the Solar System

Studies of the Sun and its magnetism received most of the attention of the Sun and Solar System group members. The importance of evolving electric currents due to magnetic shear in solar active regions (AR's) has been studied in detail to bring out differences in their roles in flaring-AR's and Coronal Mass Ejection (CME)-producing AR's. This work has utilised vector magnetic field observations by the Helioseismic and Magnetic Imager (HMI) onboard NASA's Solar Dynamics Observatory (SDO). An augmented spectropolarimeter at the Tunnel Telescope of the Kodaikanal Solar Observatory has been used for measuring the vector magnetic field in the photospheric and chromospheric layers associated with sunspots using the Fe I (656.9 nm) and Hα (656.3 nm) spectral lines, respectively. The structure and height variation of sunspot magnetic fields have been studied, with an estimate of vertical field gradient of ≈ -1 Gkm^{-1} that is consistent with many published results. In a related study, chromospheric spectropolarimetry of small-scale energetic events (SSEE) has been carried out using simultaneous observations in the Hα and Ca II 854.2 nm lines. In a study that has implications for the solar irradiance, magnetic flux transfer and solar atmospheric dynamics, the extreme-UV (EUV) properties of solar chromospheric and transition region network have been explored using spectroscopic data taken every day with the Coronal Diagnostic Spectrometer (CDS) on board the Solar and Heliospheric Observatory (SOHO).

In solar instrumentation, efforts have been made to demonstrate high-resolution observations of the solar atmosphere using spatial interferometry - this particular technique uses the Fizeau Mark Interferometry of Solar Features. This demonstration used the Multi-Application Solar Telescope (MAST) at the Udaipur Solar Observatory.

In the theoretical and numerical computation front, an iterative technique to solve the problem of polarized line formation in a magnetized isothermal atmosphere taking into account scattering in a two-level atom with hyperfine structure splitting (HFS) together

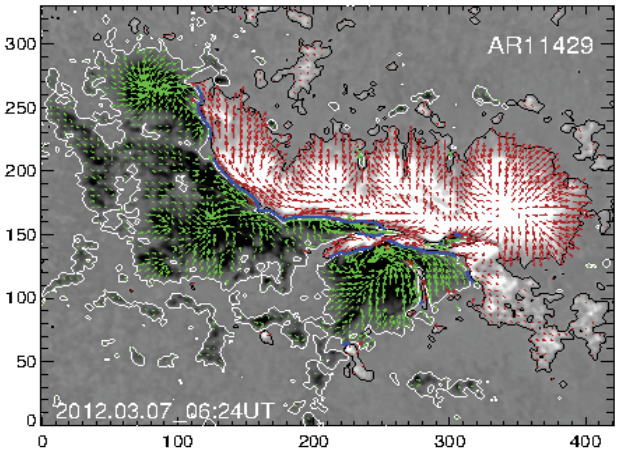

Figure 2.1: *Vector magnetic field observations of solar active region NOAA 11429. The observations are taken by Helioseismic Magnetic Imager on board Solar Dynamics Observatory. Transverse field vectors are shown with the red (green) arrows in north (south) polarity regions. Background is the vertical field image with contours at ±150 G. Blue curve represents sheared polarity inversion line. Axis units are in pixels of 0.5″ size. Courtesy: Vemareddy, P MNRAS, 2019.*

with PRD has been developed. This technique provides a way to model polarized line formation in the incomplete Paschen-Back effect regime and has been tested for a model representing the D_2 line of Na I.

2.2 Stellar and Galactic Astrophysics

In stellar and Galactic astrophysics, the topics on which studies were conducted include Population III stars, interstellar line profiles, molecular clouds, novae, supernovae, globular clusters, open clusters, infrared properties of planetary nebulae, post-AGB stars, chemical abundance studies of stars at different evolutionary stages, extreme helium stars, Li-rich giants, and dwarf galaxies.

A novel semi-analytical model was developed to study the mass accretion by the protostars with the aim to explore whether some of the protostars can remain sufficiently low-mass and long-lived to survive to the present day. The calculations show, Population III protostars that initially form within a certain range of mass, and are ejected with velocity larger than the escape velocity may survive to the present day on the main sequence.

The profile variations of interstellar Ca II H & K and Na I D lines were studied based on high-resolution optical spectra of 15 stars in the direction of the Vela supernova remnant. The spectra were obtained during 2017-2019 with the Southern African Large Telescope. A comparison of the line profiles with those obtained during 1993-1996 by Cha & Sembach shows that the changes in the line profiles are more obvious in the Ca II K line than in the Na D line. These changes are attributed to gas disturbed by interactions between the supernova ejecta and the surrounding interstellar medium.

As a part of "TRAO FUNS" project to survey the Gould Belt's clouds in molecular lines, the central region of the California molecular cloud L1478 was studied in detail. Using the Taeduk Radio Astronomy Observatory 14 m single-dish telescope equipped with a 16 multi-beam, low-density clouds as well as the dense cores were observed. Basic physical properties of filaments such as mass, length, width, velocity field, and velocity dispersion were derived and the formation mechanism of dense cores and filaments are studied. Prestellar cores L1544, L1552, L1689B, L694-2, and L1197 were mapped using two molecular lines, $C^{34}S$ (J=2-1) and N_2H^+ (J=1-0) with the NRO 45 m telescope. In most of the targets, the distribution of $C^{34}S$ emission shows significant depletion of CS molecules towards the centre of the cores.

Sub-parsec-scale mapping of magnetic fields in the vicinity of a very-low-luminosity object L1521F-IRS was conducted. The core-scale magnetic fields in the near vicinity of the VeLLO L1521F-IRS were obtained using sub-millimetre polarization measurements at 850 μm using JCMT POL-2. The magnetic fields are found to be ordered and very well connected to the parsec-scale field geometry seen in optical polarization observations and the large-scale structure seen in the Planck dust polarization. The magnetic energies are found to be 1 to 2 orders of magnitude higher than the nonthermal kinetic energies in the envelope and the core.

Photoionization modelling of quiescence-phase optical spectra of novae T Coronae Borealis, GK Persei, RS Ophiuchi, V3890 Sagittarii and V745 Scorpii, and the symbiotic star BX Monocerotis was performed. The spectra exhibit prominent low-ionization emission features of hydrogen, helium, iron and oxygen and TiO absorption features resulting from the cool secondary component. T Coronae Borealis and GK Persei show higher ionization lines. Using the photoionization code *CLOUDY* the spectra were modelled and contribution from the accretion disc was estimated.

Following the detection of the first binary neutron star merger, a dedicated follow-up campaign was undertaken with the Zwicky Transient Facility (ZTF) and Palomar Gattini-IR telescopes to identify an optical or infrared counterpart to a binary neutron star merger. The initial skymap of the single-detector gravitational wave (GW) trigger spanned most of the sky observable from the Palomar Observatory. Two candidates, ZTF19aarykkb and ZTF19aarzaod, were found particularly compelling given that their location, distance and age were consistent with the GW event, and their early optical light curves were photometrically consistent with that of a kilonovae. Spectra of these two candidates, however, revealed them to be young core-collapse supernovae.

High-cadence ultraviolet, optical, and near-infrared photometric and low-resolution spectroscopic observations of the peculiar Type II supernova (SN) 2018hna were used to study the properties of the object in detail. The early-phase multi-band light curves (LCs) exhibited an adiabatic cooling envelope emission following the shock breakout up to 14 days from the explosion. Hydrodynamical modeling of the cooling phase suggested a progenitor with a radius $\sim$ 50 $R_\odot$, a mass of $\sim$14-20 $M_\odot$, and an explosion energy of $\sim 1.7 - 2.9 \times 10^{51}$ erg. The smaller inferred radius of the progenitor than a standard red supergiant is indicative of a blue supergiant progenitor of SN 2018hna. A subsolar metallicity ($\sim$0.3 $Z_\odot$) was inferred for the host galaxy UGC 07534, concurrent with the low-metallicity environments of 1987A-like events.

Observational signatures of circumstellar interaction and ^{56}Ni-mixing in the Type II supernova SN 2016gfy were studied using the optical and ultraviolet broadband photometric and spectroscopic observations of the Type II SN 2016gfy. Using strong-line diagnostics, a subsolar oxygen abundance was estimated for the supernova H II region ($12 + \log(O/H) = 8.50 \pm 0.11$ Å). A star formation rate of $\sim$ 8.5 $M_\odot$ yr^{-1} is estimated for NGC 2276 using the archival GALEX FUV data.

The observational behaviour of the highly polarized Type IIn supernova SN 2017hcc were studied based on photometric (*Swift* UVOT), broadband polarimetric (V and R-band) and optical spectroscopic observations. The study indicates a substantial variation in the degree of asymmetry in either the ejecta and/or the surrounding medium of

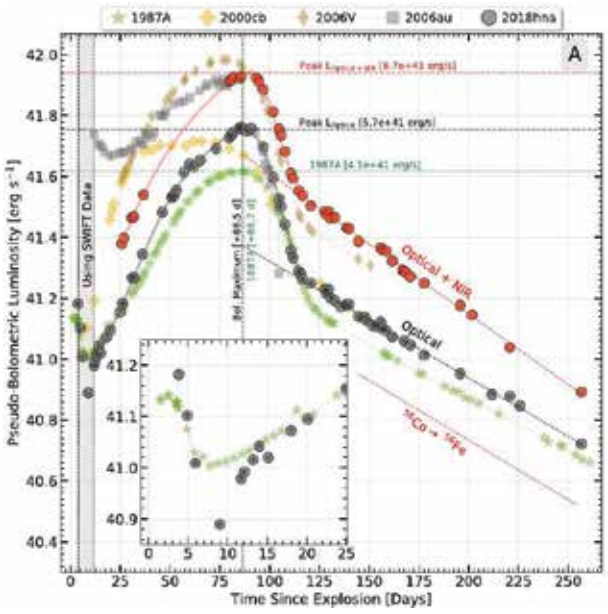

Figure 2.2: *Pseudo-bolometric light curve of SN 2018hna in comparison with 1987A-like events. Inset shows the adiabatic cooling emission following shock breakout. Courtesy: Singh, Avinash et al. ApJ, 2019.*

SN 2017hcc.

Studies on Type Ia supernovae SN 2009ig and SN 2012cg were conducted based on optical and ultraviolet photometry and analysis of a series of optical spectra. Their early spectra show high-velocity features in Si II and Ca II lines. The strong Fe III, Si III, and weak Si II 5972 line during pre-maximum phase are indicative of hot photosphere. The post-maximum velocity evolution shows a plateau like phase with velocities ∼13,000 km/sec for SN 2009ig and ∼10,000 km/sec for SN 2012cg.

Near-, mid- and far-IR photometric data from archives were used to derive the IR properties of planetary nebulae (PNe). IR colour-colour diagrams of PNe were constructed using measurements at 2MASS, IRAS, WISE and Akari bands. A comparison of IR properties indicate that the [WR]PNe have a large near-IR emission from the hot dust component and also show a stronger 12 μm emission as compared to the other two groups *wels*-Pne and the PNe with hydrogen rich central stars. The average dust-to-gas mass ratio is found to be similar for the three groups of PNe. While there is a strong correlation of dust temperature, IR luminosity with the age for the three groups of PNe, their dust mass dust-to-gas mass ratios and IR excess are found to be non-varying as the PNe evolve.

Medium resolution K-band spectra of 12 post-AGB candidates and related stars were studied. The Brγ line in emission was detected in seven objects indicating the onset of photo-ionization in these objects. Four objects show the presence of He I line. H_2 emission line is detected in the spectra of IRAS 06556+1623, IRAS 22023+5249, IRAS 18062 + 2411 and IRAS 20462 + 3416. H_2 emission line ratio 1-0 S(1)/2-1 S(1) indicate that H_2 is radiatively excited in two objects and by shocks in other two objects. The hot post-AGB stars IRAS 22495 + 5134, IRAS 22023 + 5249, IRAS 18062 + 2411 and IRAS 20462 + 3416 seem to be evolving rapidly to young low excitation planetary nebula phase.

The variable star population in the Hercules globular cluster (M13; NGC 6205) and Palomar 13 an evaporating globular cluster were studied based on CCD time-series photometry. Fourier decomposition of the light curves of three cluster member RRab stars led to estimations of [Fe/H] = -1.65, and a distance of 23.67±0.57 kpc for Palomar 13. The Fourier decomposition of the light curves of RRab and RRc stars in M13 gave an average metallicity of [Fe/H]zw = -1.58±0.09 for M13. The distance to this cluster was estimated as 7.1±0.1 kpc from independent methods related to the variable star families RR Lyrae, SX Phe and W Virginis from the luminosity of the theoretical ZAHB and from the orbit solution of a newly discovered contact binary star.

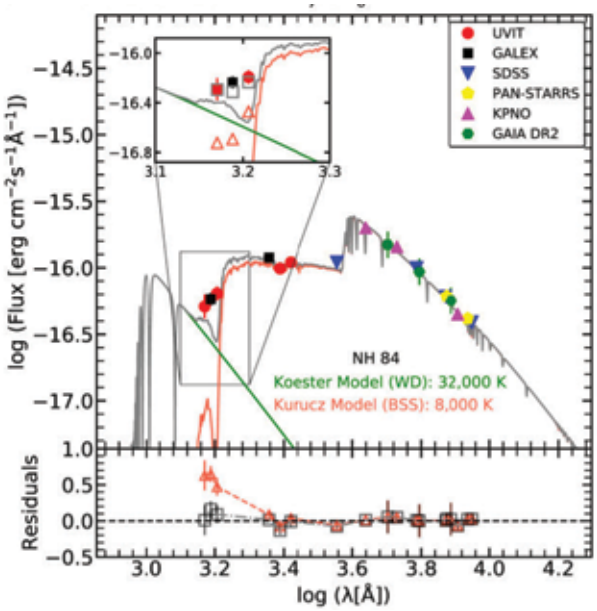

Figure 2.3: *Spectral energy distribution of NH 84 with a composite spectrum (gray color) consisting of the Kurucz model (light-red color) and the Koester WD model (green color). The zoomed-in plot shows the FUV part of the SED fitted with a single and composite spectrum, where the light-red empty triangles indicate the Kurucz synthetic flux and gray empty squares indicate the combined synthetic flux. The residuals obtained with a single and composite spectrum fit are shown as light-red empty triangles and gray empty squares in the lower panel. Courtesy: Sahu, Snehalata et al. ApJ, 2019.*

The formation pathway of blue stragglers, which are stars with acquired mass, is thought to be mainly through stellar mergers. In the case of less dense star clusters and in outer regions of the clusters, there still could be some blue stragglers formed via mass transfer. A search for for such systems in the globular cluster NGC 5466, led to the identification of far-UV bright blue stragglers. A white dwarf companion to a Blue straggler star in the outskirts of NGC 5466 was confirmed using the Ultraviolet Imaging Telescope (UVIT) data. Modelling the spectral energy distribution (SED), the parameters of the blue straggler and the white dwarf (WD) were estimated. This post-mass transfer system was found to be fairly young with a hot (32,000 K) WD. This is a second detection of a mass transfer Blue straggler in a globular cluster and the first one with kinematic membership.

The high energy properties of a relatively young open cluster NGC 2527 were studied using data from ground and space telescopes (XMM-UVOT-Gaia). The accurate fundamental parameters of the cluster including the distance to the cluster, inter-stellar reddening and age were estimated using their member stars. Five stars on the main-sequence are found to have large X-ray flux, likely to be from coronal activity and/or chromospheric activity. FK Comae type active red giants were also detected in this cluster suggesting that such stars can be formed even younger than 1 Gyr. The detection of active binaries suggests that binary stars as young as 630 Myr could produce WUMa type active systems.

The presence of low-mass White Dwarfs were detected in the cluster M67 as companions to Blue straggler stars and main-sequence stars. Parameters estimated using spectral energy distribution were compared with predictions from the models to arrive at the properties of the detected low mass WDs. Some massive WDs were also detected probably formed as a result of evolution of the Blue Stragglers themselves. These findings suggest that the open star cluster M67 houses a relatively large number of systems with such WDs, suggesting (1) a number of systems have undergone mass transfer and (2) mass transfer is one of the pathways for the formation of the Blue stragglers in M67. The stars with WDs as companions are likely to evolve to become binary WDs, which are potential sources of gravitational waves.

A detailed chemical composition studies of a sample of twenty potential CH (CEMP-s) star candidates were conducted. Estimated metallicity [Fe/H] of these stars were found to be in the range −0.48 to −2.45. Carbon is found to be enhanced in all the stars with [C/Fe] in the range -0.43 to 2.19. The objects are found to exhibit the characteristic properties of CEMP-s stars as far as the enhancement of heavy s-process element abundances are concerned.

Barium stars are extrinsic stars, where the observed s-process element abundances are believed to have an origin in the now invisible companions that produced these elements at their Asymptotic Giant Branch (AGB) phase of evolution. To understand the s-process nucleosynthesis as well as the physical properties of the companion stars, a detailed chemical composition study was performed for a sample of 10 barium stars. For these stars, estimates of abundances of several elements, C, N, O, Na, Al, α-elements, Fe-peak elements and neutron-capture elements Rb, Sr, Y, Zr, Ba, La, Ce, Pr, Nd, Sm and Eu were reported. A detailed comparison of observed elemental abundances with the predictions from AGB nucleosynthesis models FRUITY, clearly showed that the former companions responsible for the surface abundance peculiarities of these stars are low-mass AGB stars.

The [Rb/Zr] ratio is an important diagnostic to understand the average neutron density at the s-process site and provide important clues to the mass of the companion AGB stars. Based on the high-resolution spectroscopic analysis of a sample of barium stars the estimates of [Rb/Zr] ratios were derived and characteristic properties including mass of the companion AGB stars were determined. Analysis of the results obtained from a parametric-model based study confirmed the estimated mass of the companion AGB stars derived from [Rb/Zr] ratios.

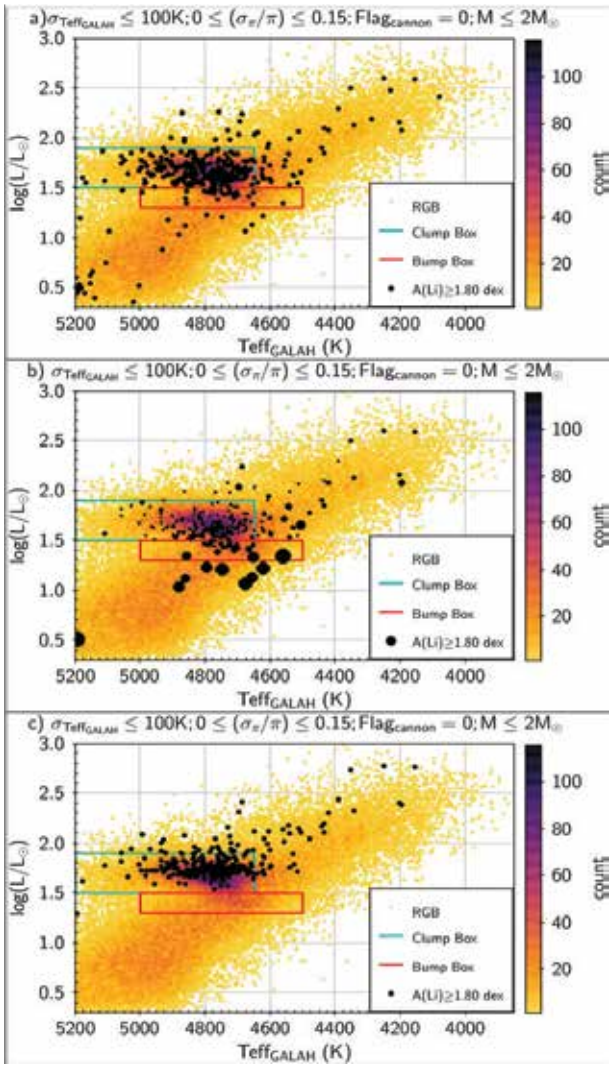

Figure 2.4: *The HR diagram showing Li-rich giants' positions (a) prior to extinction correction, (b) with size of representative point proportional to extinction, and (c) post-extinction correction. Courtesy: Deepak & Reddy, Becham E, MNRAS, 2019.*

Overabundance of fluorine is a characteristic feature of cool Extreme Helium stars (EHes) and R Coronae Borealis stars and further enforces their close connection. Whether such a relationship exists between hot EHes and R Coronae Borealis stars was studied based on their fluorine abundance. Fluorine

abundances were determined using the F II lines in two windows centered at 3505 Å and 3850 Å for 10 stars. These fluorine abundances were compared with the other elemental abundances observed in these stars, which provided an idea about the formation and evolution of these stars.

Abundance analyses of Li-enriched and normal giants in the GALAH survey were conducted and compositions of lithium-enriched and normal giants were compared. Except for Li, the only detectable abundance difference between lithium-enriched and normal giants among the investigated elements from carbon to europium was found to occur for carbon. The Li-enriched and normal giants were found to have similar projected rotational velocity, which suggests that Li enrichment in giants is not linked to scenarios such as mergers and tidal interaction between binary stars.

The Li-rich classification of KIC 9821622, the only bonafide red giant branch (RGB) giant with a He inert core to date was reviewed. Estimated Li abundance was found to be A(Li)LTE = 1.42±0.05 dex and A(Li)NLTE = 1.57±0.05 dex, which is significantly less than the value reported earlier A(Li) = 1.80±0.2 dex. The derived abundance is normal for red giants undergoing dilution during the first dredge-up. Since all known Kepler field Li-rich giants belong to the red clump region, this clarification removes the anomaly and strengthens the evidence that Li enhancement in low-mass giants may be associated only with the He-core burning phase. The origin of Li excess probably lies during the He flash at the RGB tip, a phase immediately preceding the red clump.

A systematic search for Li-rich Giants of a large sample of about 12,500 giants common to the LAMOST spectroscopic and Kepler time-resolved photometric surveys led to the detection of 24 new super Li-rich (A(Li)≥3.2) giants of He-core burning phase at the red clump region. The two key parameters derived from Kepler data are an average period spacing (Δp) between l=1 mixed gravity-dominated g-modes and average large frequency-separation ($\Delta\nu$) l=0 acoustic p-modes, which suggest that all the Li-rich giants are in the He-core burning phase. The results provide strong evidence that the Li enhancement phenomenon is associated with giants in the He-core burning phase post He-flash.

2.3 Cosmology and Extra-galactic Astronomy

The many themes that have been pursued include statistical properties of matter and weak lensing effect on the microwave background in cosmology, extraction of spectral line properties in active galaxies, galaxy morphology, magnetic fields in clusters, and star formation in galaxies.

The final Sloan Digital Sky Survey IV (SDSS-IV) quasar catalog from Data Release 16 of the extended Baryon Oscillation Spectroscopic Survey (eBOSS) comprises the largest selection of spectroscopically confirmed quasars to date. The full catalog includes two sub-catalogs: a superset of all SDSS-IV/eBOSS objects targeted as quasars containing 1,440,627 observations and a quasar-only catalog containing 750,426 quasars, including 225,082 new quasars appearing in an SDSS data release for the first time, as well as known quasars from SDSS-I/II/III. An automated identification and redshift information for these quasars alongside data from visual inspections for 320,164 spectra was carried out. Automated and visual inspection redshifts are supple-

mented by redshifts derived via principal component analysis and emission lines, including those of Hα, Hβ, Mg II, C III, C IV, and Lyα. Identification and key characteristics generated by automated algorithms are presented for 99,856 Broad Absorption Line quasars and 35,686 Damped Lyman Alpha quasars. In addition to SDSS photometric data, multi-wavelength data for quasars from GALEX, UKIDSS, WISE, FIRST, ROSAT/2RXS, XMM-Newton, and Gaia were presented. Calibrated digital optical spectra for these quasars can be obtained from the SDSS Science Archive Server.

In the recent past, there have been many attempts to solve the tension between direct measurements of H_0 and from the respective low redshift observables and indirect measurements of these quantities from the cosmic microwave background (CMB). A model independent approach was taken that boils down to different classes of cosmological models under suitable parameter choices. This parameterization is tested against the latest Planck CMB data combined with recent BAO, SNeIa datasets and the R16 direct H_0 measurements, and compare among different cosmological models. The analysis reveals that a strong positive correlation between H_0 and σ_8 is more or less generic, irrespective of the choice of cosmological models. However, new cosmological models that attempt to resolve one tension often worsen the other. A decaying dark matter (DDM) model was investigated as a solution to both tensions simultaneously.

The suppression of star formation in the inner kilo-parsec (kpc) regions of barred disk galaxies due to the action of bars is known as bar-quenching. The significance of bar-quenching in the global quenching of star formation in the barred galaxies and transforming them into passive galaxies were studied. To do this, the offset of quenched barred galaxies from star forming main sequence galaxies was compared with the length of the bar, which is considered as a proxy of bar-quenching (see Fig.2.5). An analysis of the star formation rate-stellar mass plane of 2885 local Universe face-on strong barred disk galaxies ($z < 0.06$) identified by Galaxy Zoo shows that the offset of the quenched barred galaxies from the main sequence relation is not dependent on the length of the stellar bar. This implies that the bar quenching may not be contributing significantly to the global quenching of star formation in barred galaxies.

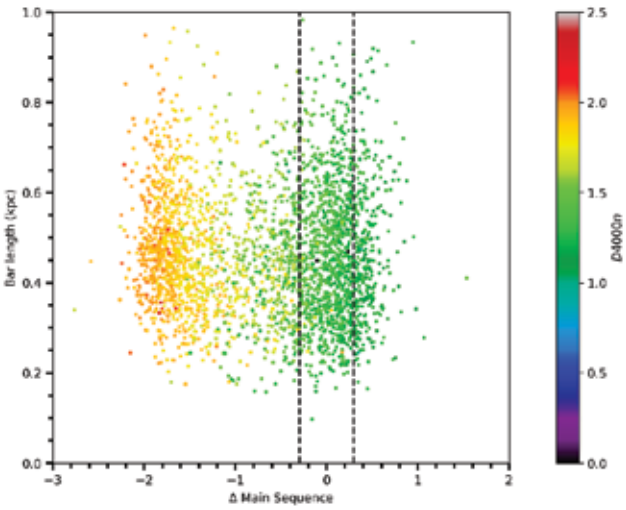

Figure 2.5: *The offset of galaxies from the SFR-M⋆ relation is plotted against the scaled length of the bar. The D4000n index strength of galaxies is shown with a color scale. Courtesy: George, K et al. A& A, 2019.*

The decay of turbulence and magnetic fields generated by fluctuation dynamo action was explored in the context of galaxy clusters, where such a decaying phase can occur in the aftermath of a major merger event. Using idealized numerical simulations that start from a kinetically dominated regime, the decay of the steady state rms velocity and the magnetic field was studied for a

wide range of conditions that include varying the compressibility of the flow, the forcing wavenumber, and the magnetic Prandtl number. Irrespective of the compressibility of the flow, both the rms velocity and the rms magnetic field decay as a power law in time. In the subsonic case, the exponent of the power law is consistent with the $-3/5$ scaling reported in previous studies. However, in the transonic regime both the rms velocity and the magnetic field initially undergo rapid decay with an $\sim t^{-1.1}$ scaling with time. This is followed by a phase of slow decay where the decay of the rms velocity exhibits an $-3/5$ scaling in time, while the rms magnetic field scales as $-5/7$. Furthermore, analysis of the Faraday rotation measure (RM) reveals that the Faraday RM also decays as a power law in time $\sim t^{-5/7}$, steeper than the $t^{-2/5}$ scaling obtained in previous simulations of magnetic field decay in subsonic turbulence. Apart from galaxy clusters, this work can have potential implications for the study of magnetic fields in elliptical galaxies.

Weak gravitational lensing causes shearing and magnification of the hotspots and cold spots of the CMB fields. By understanding the resulting distortion patterns, one may then, in principle, infer the integrated effect of the interaction between the CMB and the intervening matter distribution along each line of sight. The morphological information encoded in the Minkowski tensors makes them well suited to probe the size and shape distortions of the structures of the CMB. The structures in the lensed field are more anisotropic compared to the structures in unlensed field. Using unlensed and lensed maps simulated using the publicly available code LENSPIX, the effect of varying cosmology was studied, as well as a toy model of temperature field having hemispherical anisotropy, on morphological properties of the structures. Each of these cases has effects that are distinct from that of lensing and hence can be easily distinguished. The Minkowski tensors of anisotropic fields were evaluated that is applied to quantifying the effects of redshift space distortions in observations of the matter distribution in the Universe.

One way to study the ionization history of the EoR is to study the morphology of ionized regions created by the radiation from the luminous sources. At the beginning stages of reionization, many such ionized bubbles appear and grow in size until they start merging. As reionization progresses, the shape and size of these ionized regions change. This is qualitatively analyzed through the redshift evolution of the morphology of these fields that is traced by the brightness temperature field and its CMT and Betti numbers.

A method was devised to calculate the dynamical mass of face-on galaxy disks using their HI velocity dispersion, and the dynamical disk mass of 7 nearby, gas rich galaxies, including 4 large disk galaxies and 3 dark matter dominated dwarf galaxies to determine the stellar disk mass distributions. It was found that in most low luminosity parts of galaxies, there is dark matter associated with the disk, and it helps to gravitationally bind the HI gas layer. This is possible if the halo is oblate rather than spherical or if the disk contains dark matter accumulated from the accretion of smaller galaxies that leave behind their dark matter in the disk, as they are swallowed up by the major galaxy.

Radio observations of ultraluminous infrared galaxies (ULIRGs) using the GMRT were combined with archival multi-frequency observations to examine whether ULIRGs are the progenitors of the powerful radio loud galaxies in the local Universe. ULIRGs are generally thought to be the merger remnants of gas rich galaxy mergers. They are characterized by large infrared luminosities (LIR

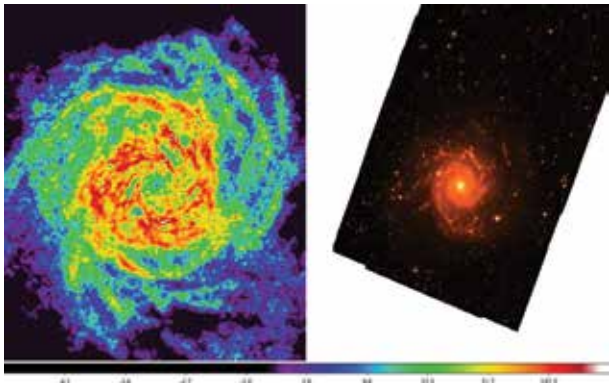

Figure 2.6: *The HI and stellar disk of the nearby galaxy NGC 628.* **Left:** *the extended HI disk. The data is from the THINGS survey (Walter et al. 2008) and the image was observed with the VLA.* **Right:** *3.6 microns image of the stellar disk of the same galaxy at the same scale obtained from the Spitzer NASA data archive. Courtesy: Das, Mousumi et al. ApJ, 2020.*

$>$ 1012 $L_{\odot}$), large dust masses (10 $\sim$ 8$M_{\odot}$) and vigorous star formation (star formation rates $10 - 100 M_{\odot}$ yr^{-1}). Their luminosity can be due to both starburst activity and active galactic nuclei (AGN). Using a sample of 13 ULIRGs that have optically identified AGN characteristics with 1.28 GHz GMRT observations, it was attempted to resolve any core-jet structures or nuclear extensions and hence examine whether the ULIRGs are evolving into radio loud ellipticals; the observations show marginal extension for only one source. Although most ULIRGs do not show kpc scale extended radio emission associated with a nuclear activity, their radio spectral energy distributions do show signatures of young radio galaxies.

The flat spectrum radio quasar, 3C 279 was monitored in the optical B, V, R, and I passbands from 2018 February to 2018 July for 24 nights, with a total of 716 frames, to study flux, color, and spectral variability on diverse time-scales. 3C 279 was observed using seven different telescopes: two in India, two in Argentina, two in Bulgaria, and one in Turkey to understand the nature of the source in the optical regime. A close inspection of variability patterns during the observation cycle revealed simultaneity among optical emissions from all passbands. During the complete monitoring period, a progressive increase in the amplitude of variability with frequency was detected.

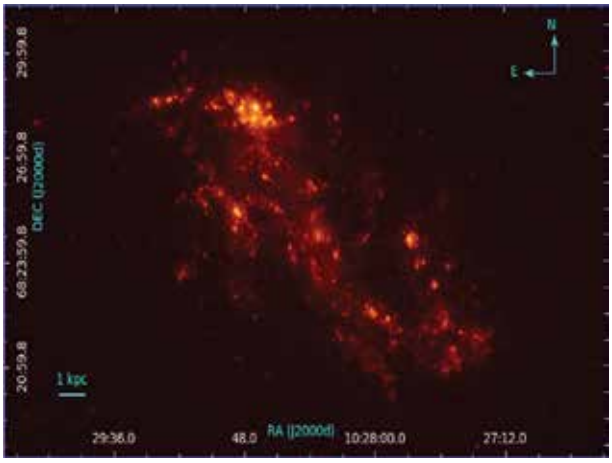

Figure 2.7: *The FUV image of the galaxy IC 2574 observed with the UVIT F148W filter. Courtesy: Mondal, Chayan et al. AJ, 2019.*

Dwarf galaxy IC 2574 was studied using the UVIT far-UV images to understand the star formation characteristics. Many Far-UV bright regions were found to be located in the HI-shells, possibly created by supernovae explosions or heavy winds from OB stars. The study found that many regions in the inner parts of the galaxy are found to be associated with the shells, whereas a large number of regions in the outer galaxy are not. Star formation in the galaxy has been partly triggered due to the expanding H I holes, whereas in the majority of the sites, it is driven by other mechanisms. Irrespective of the location, larger star-forming complexes were found to have multiple substructures, an indication of turbulence. Two resolved components for the

remnant cluster of the supergiant shell were reported and their masses were estimated.

2.4 Theoretical Physics and Astrophysics

The themes pursued include black hole astrophysics, quantum chemistry, exoplanets, MHD theory applied to solar flux tubes and pulsar emission mechanisms.

New grids of transmission spectra was presented for hot Jupiters by solving the multiple-scattering radiative transfer equations with non-zero scattering albedo instead of using the Beer-Bouguer-Lambert law for the change in the transmitted stellar intensity. The scattering plays a double role in determining the optical transmission spectra: increasing the total optical depth of the medium and adding the diffused radiation due to scattering to the transmitted stellar radiation. For a cloudless planetary atmosphere, Rayleigh scattering albedo alters the transmission depth up to about 0.6 μm, but the change in the transmission depth due to forward scattering by cloud or haze is significant throughout the optical and near-infrared regions. The model is compared with observational data for a few hot Jupiters, which may help with constructing better retrieval models in the future.

The Auger and Coster-Kronig transitions (related to double ionization potentials) of noble gas elements have been analyzed using the relativistic coupled cluster method. The resulting Auger and Coster-Kronig lines are found to be in accord with the experimental data and with other reference theoretical estimates. Interestingly, the coupled cluster and the multi - configuration Dirac- Fock calculations exhibit an inversion in the triple P energy levels of the Xenon atom where the triplet state energies appear in the order $J = \{1, 0, 2\}$, a feature which can be verified experimentally.

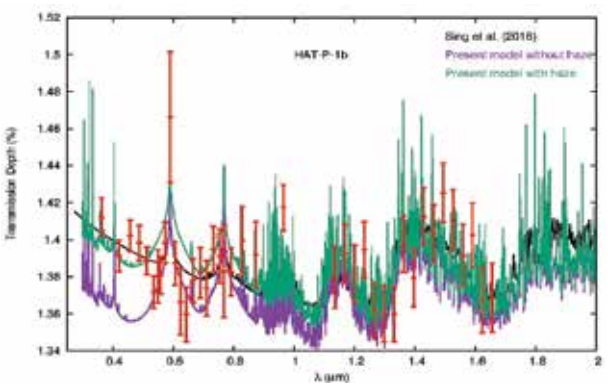

Figure 2.8: *Comparison of model transmission spectra with and without the effect of haze and with the observed data (red) for HAT-P-1b. Courtesy: Sengupta, Sujan et al., ApJ, 2020.*

Adaptation of improved virtual orbital complete active space configuration interaction functions in state-specific multi reference perturbation theory motivated by the Brillouin-Wigner perturbation scheme is examined. This approach yields size-extensive energy and avoid intruder-state problems in a natural manner. It allows relaxation of the reference space wave function in the presence of the perturbation, which produces an important differential effect on the energy and cannot be neglected for quasi-degenerate electronic states.

A mechanism for pulsar radio emission was developed which takes into account of the detailed viewing geometry of pulsars and dipolar magnetic field configuration. The model can explain the enhanced radiation and most of the diverse polarization properties of radio pulsars. The estimated brightness temperature of $\sim 10^{25}$ K seems to agree with the observations. The polarization angle predicted by the model is in good agreement with the rotating vector model.

An evolution model of the central black hole was built that depends on the processes of gas accretion, the capture of stars, mergers, and electromagnetic torque (see Figure 2.9). In the case of gas accretion in the presence of cooling sources, the flow is momentum-driven, after which the black hole reaches a saturated mass; subsequently, it grows only by stellar capture and mergers. The evolution of the mass and spin with the initial seed mass and spin in ΛCDM cosmology is modeled. For stellar capture, a power-law density profile for the stellar cusp was assumed in a framework of relativistic loss cone theory that includes the effects of black hole spin, Carter's constant, loss cone angular momentum, and capture radius. Based on this, the predicted capture rates of 10^{-5} to 10^{-6} yr^{-1} are closer to the observed range. Merger activity is effective for $z \lesssim 4$, and the Blandford–Znajek torque was included. Before saturation, accretion dominates the black hole growth ($\sim 95\%$ of the final mass), and subsequently, stellar capture and mergers take over with roughly equal contributions. The simulations of the evolution of the $M_\bullet$–σ relation using these effects are consistent with available observations. The model is evolved backward in time to retrodict the parameters at formation; this theory will provide useful inputs for building demographics of the black holes and in formation scenarios involving stellar capture.

The Relativistic Precession (RP) model is expanded to include non-equatorial and eccentric trajectories and apply it to Quasi-periodic oscillations (QPOs) in black hole X-ray binaries (BHXRB) and associate their frequencies with the fundamental frequencies of the general case of non-equatorial (with Carter's constant, $Q \neq 0$) and eccentric ($e \neq 0$) particle trajectories, around a Kerr black hole. The cases of BHXRB with either two or three simultaneous QPOs in their Fourier power spectrum are studied, e.g. GROJ 1655-40, M82 X-1, XTEJ 1550-564, 4U 1630-47, and GRS 1915+105, to extract the parameters $\{e,\ r_p,\ a,\ Q\}$, where r_p is the periastron distance of the orbit, and a is the spin of the black hole (see Figure 2.10). The results compare well with the model of fluid flow in the general relativistic thin accretion disk in the edge region, which is suggested as responsible for the launch of the QPOs.

The conditions for a non-equatorial eccentric bound orbit to exist around a Kerr black hole in two-parameter spaces, are derived in terms of the energy, angular momentum of the test particle, spin of the black hole, and Carter's constant space (E, L, a, Q), and eccentricity, inverse-latus rectum space (e, μ, a, Q). These conditions distribute various kinds of bound orbits in different regions of the (E, L) and (e, μ) planes, depending on which pair of roots of the effective potential forms a bound orbit. These are useful inputs to study bound trajectory evolution in various astrophysical applications like simulations of gravitational wave emission from the extreme-mass ratio in spirals, relativistic precession around black holes, and the study of gyroscope precession as a test of general relativity.

A magnetohydrostatic (MHS) equilibrium model was constructed of a vertical axisymmetric flux tube with a twisted magnetic field that expands as it spans from the photosphere to the transition region in a stratified solar atmosphere subject to solar gravity. Using a self-similar formulation and a quadratic form of the flux function for the gas pressure and poloidal current, expressed as a second order polynomial of the flux function for the magnetic shape function, the Grad-Shafranov equation (GSE) was solved analytically. Incorporating the appropriate boundary conditions, a closed field configuration of the flux tube was built. Using the input parameter space, which is consistent with

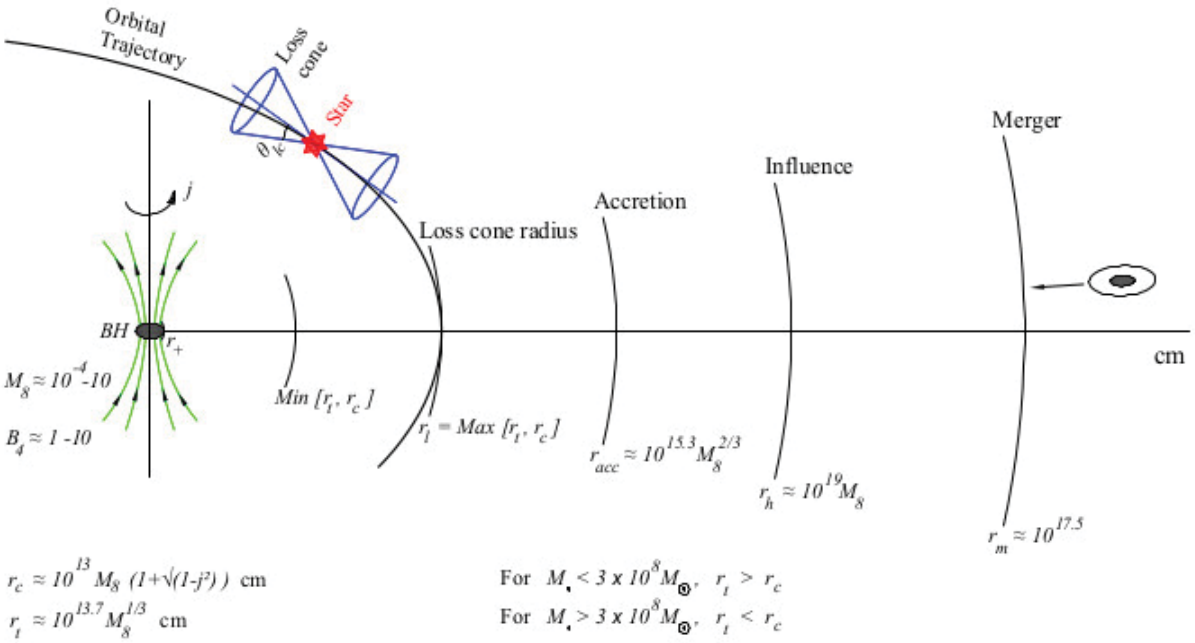

Figure 2.9: *Important radii corresponding to all the processes contributing to the growth of the black hole are shown for $M_\bullet = 10^4 - 10^6 M_\odot$ Courtesy: Bhattacharyya & Mangalam, ApJ, 2020.*

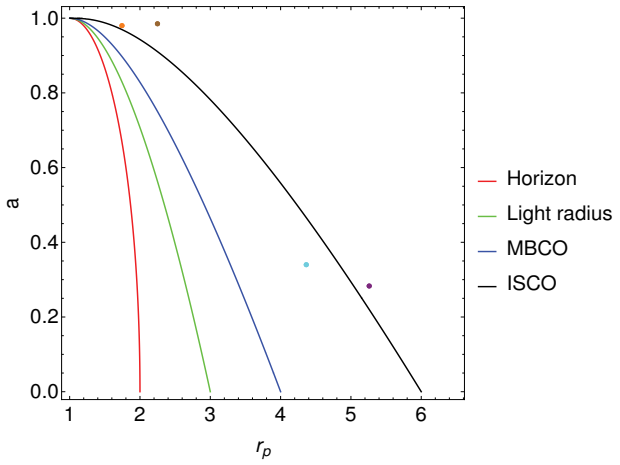

Figure 2.10: *The equatorial eccentric orbit solutions for QPOs observed in BHXRB GROJ 1655-40 (purple), XTEJ 1550-564 (cyan), 4U 1630-47 (brown), and GRS 1915+105 (orange) for $Q = 0$.*

the observations, the magnetic and thermodynamic structure of the flux tube was calculated, which is found to be in reasonable agreement with the observations for magnetic bright points (MBPs). The obtained closed field model can be used to construct a realistic structure like a magnetic canopy. The 3D configuration of the magnetic field lines are shown in Figure 2.11.

Tidal disruption events (TDEs) can be used to build the black hole mass function (BHMF) using the inferred TDE rates from various surveys. A steady accretion models with time-varying accretion rate is used to obtain the peak bolometric luminosity L_p at time t_p. Assuming a trend for subsequent luminosity to be $L = L_p(t/t_p)^{-5/3}$, steady loss cone model for the theoretical capture rate of stars $\dot{N}_t$, the Schechter luminosity function $\Phi(L) = \Phi_\star(L/L_\star)^{-\alpha_1} \exp(-L/L_\star)$, the Faber-Jackson law and the $M_\bullet - \sigma$ relation, the TDE detection rates for ASAS-SN, PTF, iPTF, PS-MDS and GALEX are estimated. Based on a statistical survey of TDE host properties and black hole mass and redshift

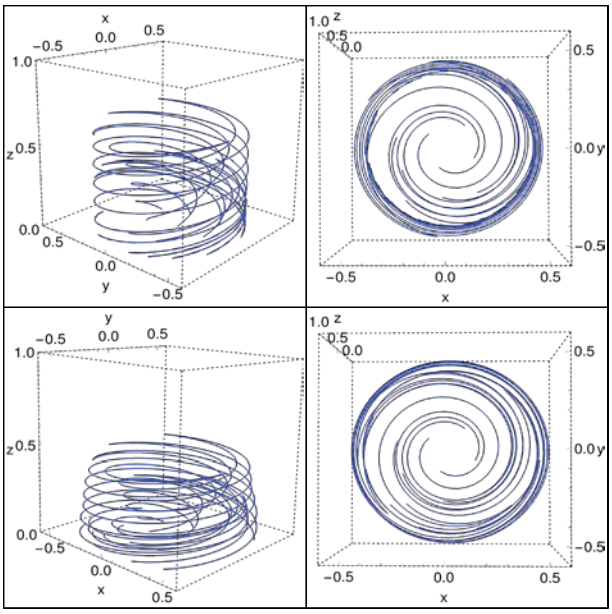

Figure 2.11: *The 3D geometry of* 10 *different magnetic field lines for self-similar closed field flux tube model. The left and right columns show the side and top view of the configuration. The domain of the simulation box is* $-0.5 \leq x \leq 0.5$, $-0.5 \leq y \leq 0.5$, *where the* x *and* y *axes are scaled in units of* 500 *km. The vertical domain is* $0 \leq z \leq 1$ *where the* z *axis is scaled in units of* 2 *Mm. Courtesy; Sen, Samrat & Mangalam, A, ApJ, 2019.*

distributions and considering four priors resulting from the combinations of two variants for the form of $M_\bullet = k\sigma^n$, where k and n are constants, and two variants for the form of the duty cycle and comparing with the observed rates, the Schechter parameters are found to be $\{\phi_\star(\mathrm{Mpc}^{-3}),\ \alpha_1,\ L_\star(\mathrm{erg\ s}^{-1})\} = \{3.01 \times 10^{-4},\ 0.718,\ 2.49 \times 10^{46}\}$ for $n = 4.86$ and $\{1.12 \times 10^{-4},\ 0.859,\ 5.35 \times 10^{46}\}$ for $n = 4.38$. The useful by-products of this method designed to build the black hole mass functions are intermediate formulae which are survey (in)dependent and can be applied for larger data sets that will be soon available in the future. It is shown that the rate tension between the observations ($\sim 10^{-5}$ yr^{-1}) and theory ($\sim 10^{-4}$ yr^{-1}) can be explained by a statistical average of $\dot{N}_t$ over BHMF.

2.5 Experimental Astrophysics and Instrumentation

A Near-Infrared photometer for the 40-inch telescope: A near-infrared (0.9-1.85 microns) photometer for studying bright variable stars has been designed, developed and tested on the 40-inch Carl Zeiss telescope. This instrument is optimized for its use at a low altitude site like Kavalur and will cater to observations of bright sources which saturate conventional infrared detectors. The instrument uses an InGaAs PIN photoodiode (Hamamatsu-G12181-203K) detector, IRWG filters from Omega Opticals, and optomechanical components from Edmund Optics. InGaAs sensors provide low dark currents even without thermoelectric cooling, making the photometer simple, light-weight and easy to operate.

The optical design of the collimator-camera type re-imaging system was done using Zeemax. An uncooled electrometer-amplifier was designed and fabricated to amplify the signal coming from the photodiode. A stepper motor controller for the filter slider mechanism and data aquisition system were also developed. A CAD model of the complete instrument was constructed before fabrication. The entire optomechanical system was assembled in-house. Some components such as the mounting flange and the side walls were machined to the desired specification in the VBO workshop.

Various sub-systems of the instrument were tested and fine-tuned in our laboratory at Bengaluru. The instrument was then taken to

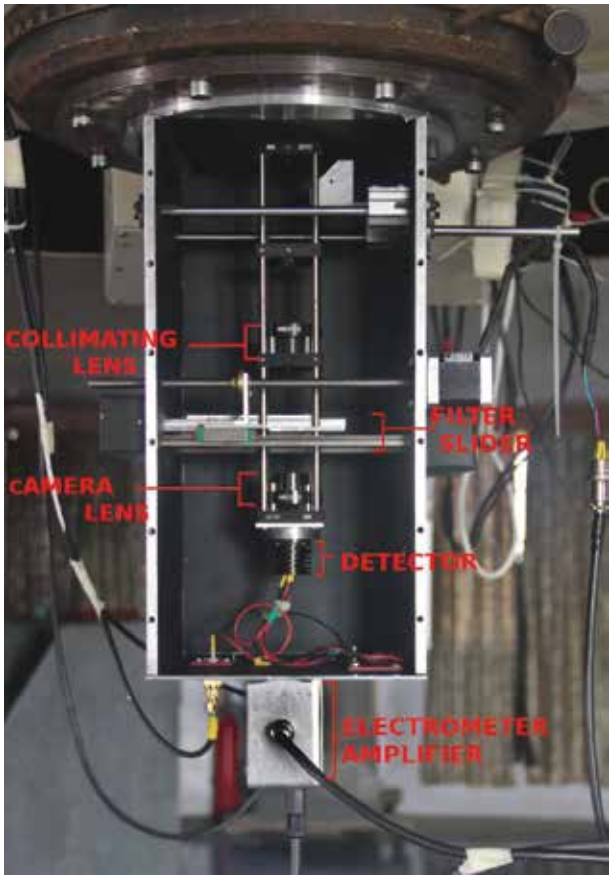

Figure 2.12: *A cross-sectional view of the photometer mounted on the 40-inch telescope showing various components.*

Kavalur and mounted on the 40-inch (1.02m) telescope on February 12th, 2020 for on-site tests. The photometer had its first light observations on the star Sirius on February 25th. Currently, standard stars are being observed for better characterization of the instrument capabilities. The photometer should be ready for use by observers during the upcoming winter season. This instrumentation project is the Ph.D thesis work of Anwesh Kumar Mishra.

3

Student Programmes and Training Activities

Student programmes at the institute are carried out by the Board of Graduate Studies. The Ph.D. programme in collaboration with Pondicherry University, Puducherry and M.Tech.-PhD. programme in collaboration with the University of Calcutta, Kolkata are the major academic pillars of IIA.

The MoU with Pondicherry University (PU) for collaboration in areas of Astronomy and Astrophysics was first signed in 2009, and was renewed for another 10 years in 2019. Student intake happens twice every year – in January and August. Student selection is done on the basis of academic record, performance in national screening tests, and interview. The competition being high, only around 4-5 students join in each session (three and two students have joined in August 2019 and January 2020, respectively). Our student attrition rate is low, so a similar number submit and successfully defend their thesis. Students joining the programme carry out their pre-Ph.D coursework at IIA. Then they join their thesis supervisor, who is a faculty at IIA. The research work is carried out at IIA and the degree is awarded by PU. Under the MoU, IIA faculty undertake some teaching and training of students of the M.Sc Astrophysics specialisation of PU.

The MoU with University of Calcutta (CU) was first signed in 2008, and has been renewed twice – in 2014 and 2020. This collaboration was done to combine the strength of the Department of Applied Optics and Photonics of CU with the astronomy expertise of IIA in order to progress in the area of Astronomical Instrumentation. The student intake happens once a year, in July. The process and results are similar to that given above (four students have joined in July 2019). The M.Tech courses are taught at IIA and CU. For practical experience, students have to carry out internships at various field stations of IIA and undertake a project. Only those students scoring above a certain grade are eligible to study further for their Ph.D. The research work for Ph.D is carried out under the supervision of a faculty member of IIA and the degree is awarded by CU.

Some students of the Joint Astronomy Programme carry out their research under the guidance of our faculty. We also train students through short term programmes such as the Visiting Students Programme, Summer School and Summer Project.

3.1 PhD Degree Awarded

Joice Mathew successfully defended (on April 17, 2019) his thesis titled “Ultra Violet

Space Instrumentation and Studies of Astronomical Objects" submitted to the University of Calcutta. He carried out this work under the supervision of Jayant Murthy.

Ambily S successfully defended (on June 18, 2019) his thesis titled "Development of Detectors for Space Missions and Balloon Flights" submitted to the University of Calcutta. She carried out this work under the supervision of Jayant Murthy.

Avinash Surendran successfully defended (on July 12, 2019) his thesis titled "Development of a scalable generic platform for adaptive optics real time control" submitted to the University of Calcutta. He carried out this work under the supervision of Padmakar Singh Parihar & A. N. Ramprakash, IUCAA, Pune.

Nancy Narang successfully defended (on August 22, 2019) her thesis titled "Study of Small-Scale Features observed in Solar Atmosphere" submitted to Pondicherry University. She carried out this work under the supervision of Dipankar Banerjee.

Sindhu N successfully defended (on August 28, 2019) her thesis titled "Multiwavelength study of old open clusters: NGC188 and M67" submitted to the Vellore Institute of Technology (VIT), Vellore. She carried out this work under the supervision of Annapurni Subramaniam & Anuradha C, VIT, Vellore.

Joby P.K. successfully defended (on September 18, 2019) his thesis titled "Confronting physics of the early Universe with cosmological observations" submitted to the University of Calicut. He carried out this work under the supervision of Pravabati Chingangbam.

V. Mugundhan successfully defended (on November 20, 2019) his thesis titled "Design of Digital Receivers for low Frequency Radio Astronomy" submitted to the University of Calcutta. He carried out this work under the supervision of R. Ramesh.

Sandeep K Kataria successfully defended (on December 2, 2019) his thesis titled "The formation and Evolution of Bars, and its Impact on Glalaxy Dynamcs" submitted to the Indian Institute of Sciences, Bangalore. He carried out this work under the supervision of Mousumi Das and Tarun Deep Saini, I.I.Sc. under the Joint Astronomy Programme (JAP), IISc., Bangalore.

Subhamoy Chatterjee successfully defended (on December 24, 2019) his thesis titled "Characterizing Image Quality of Solar Ultraviolet Imaging Telescope On Board Aditya L1-Mission and Long-term Study of The Sun" submitted to the University of Calcutta. He carried out this work under the supervision of Dipankar Banerjee.

Ramya M Anche successfully defended (on January 13, 2020) her thesis titled "Determination of Polarimetric Capabilities of Astronomical Telescopes" submitted to the University of Calcutta. She carried out this work under the supervision of G. C. Anupama.

Priyanka Rani successfully defended (on January 21, 2020) her thesis titled "Temporal and Spectral Characteristics of Active Galactic Nuclei in X – rays using NuSTAR" submitted to Pondicherry University. She carried out this work under the supervision of C.S.Stalin.

Rubinur Khatun successfully defended (on February 12, 2020) her thesis titled "A Radio and Ultraviolet Study of Dual Nuclei in Galaxies" submitted to Pondicherry University. She carried out this work under the supervision of Mousumi Das.

Singam Srikanth Panini successfully de-

Table 3.1: *Number of PhD degrees awarded over the past five years.*

Year	No.
April 2015 - March 2016	10
April 2016 - March 2017	5
April 2017 - March 2018	7
April 2018 - March 2019	9
April 2019 - March 2020	14
Total	**45**

fended (on February 20, 2020) his thesis titled "Design and development of multilayer X-ray optics" submitted to the University of Calcutta. He carried out this work under the supervision of P. Sreekumar.

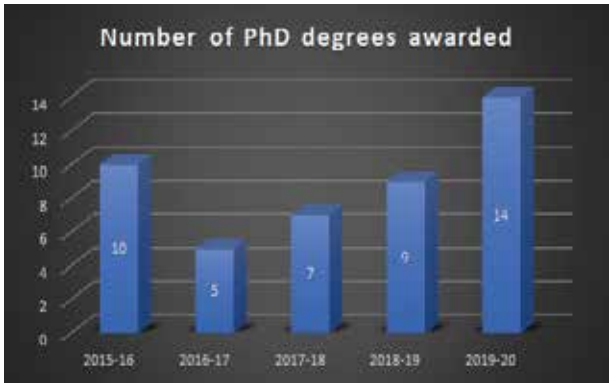

Figure 3.1: *Number of PhD degrees awarded over the past five years.*

3.2 PhD Theses Submitted

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

Avrajit Bandyopadhyay submitted his thesis titled "Study of Milky Way Halo stars and connection to globular clusters" to Pondicherry University on April 25, 2019. The research was done under the supervision of T.Sivarani.

Hemanth Pruthvi submitted his thesis titled "Design and Development of Chromospheric Vector Magnetograph for Sunspot Studies" to the University of Calcutta on May 14, 2019. The research was done under the supervision of B.Ravindra and K.Nagaraju.

Sireesha Chamarathi submitted her thesis titled "High Precision Radial Velocity Studies on VBT Echelle Spectrograph" to the University of Calcutta on August 21, 2019. The research was done under the supervision of Ravinder K Banyal and Gajendra Pandey.

Sreekanth Reddy V submitted his thesis titled "Development of High Resolution System for Stellar Imaging" to the University of Calcutta on August 21, 2019. The research was done under the supervision of Ravinder K Banyal and B. Ravindra.

Snehalata Sahu submitted her thesis titled "UV stellar populations in Globular Clusters: Horizontal Branch Morphology and Blue Straggler Stars" to the Pondicherry University on September 27, 2019. The research was done under the supervision of Annapurni Subramaniam.

Chayan Mondal submitted his thesis titled "Multi-wavelength Study of star Formation in Nearby Galaxies" to the Pondicherry University on September 27, 2019. The research was done under the supervision of Annapurni Subramaniam.

Anshu Kumari submitted her thesis titled "Radio Polarimetric Imaging of the Solar Corona at Low Frequencies" to the University of Calcutta on December 19, 2019. The research was done under the supervision of C. Kathiravan.

Avinash Singh submitted his thesis titled "Observational study of a Core-Collapse

Supernovae" to the Indian Institute of Sciences, Bangalore on January 10, 2020. The research was done under the supervision of G.C.Anupama and Prateek Sharma, I.I.Sc. under the Joint Astronomy Programme (JAP), IISc., Bangalore.

Samrat Sen submitted his thesis titled "Twisted Magnetic Fluxtubes in the Sun" to Pondicherry University on Jaunary 13, 2020. The research was done under the supervision of Arun Mangalam.

Dipanweeta Bhattacharyya submitted her thesis titled "Cosmic evolution of black holes and the M.- sigma relation" to Pondicherry University on January 13, 2020. The research was done under the supervision of Arun Mangalam.

3.3 Completion of MTech programme

All seven students from the 11th batch of the IIA-CU integrated M.Tech-Ph.D programme have completed their M.Tech. Course in July 2019.

Bharat Chandra P, under the guidance of Jayant Murthy, submitted his thesis titled "Development of 6U Spectrograph Payload for NUV Studies".

Bane Kshitij Suhas Trupti, under the guidance of R Ramesh, submitted his thesis titled "Development of radio antenna array and receiver system for observations of Pulsars at Low Radio Frequencies".

Harsh Mathur, under the guidance of K Nagaraju, submitted his thesis titled "Single Shot Solar Spectroscopic Design Aspects".

Soumya Bandyopadhyay, under the guidance of S Sriram, submitted his thesis titled "Study on the Effects of Mount Induced Errors, Tmeperature Induced Errors and Baisc Alignment Errors of TMT Primary Mirror Segments on the Image Quality Using PSSN Metric".

Sarthak Choudhary, under the guidance of B Ravindra, submitted his thesis titled "Study and Design of a Soft X-ray Imager and Spectrometer for Observation of Non-Flaring Sun".

Surayadevara Pruthvi, under the guidance of B Raghavendra Prasad, submitted his thesis titled "Calibration of Subsystems of Visible Emission Line Coronagraph".

Vishnu M, under the guidance of Dipankar Banerjee, submitted his thesis titled "Calibration of spectral channels for VELC onboard ADITYA-L1 and preparing datapipeline".

3.4 School in Physics and Astrophysics

The Summer School held at Kodaikanal Solar Observatory is a yearly activity coordinated by the Board of Graduate Studies, IIA. The main aim of the school is to introduce students of M.Sc, B.E./B.Tech. degree courses to the field of Astronomy and Astrophysics, and to motivate them to take up a career in Astronomy and Astrophysics. M.Sc students of Pondicherry University who have opted for the Astrophysics specialisation also participate in this activity. The school consists of a series of lectures covering various topics in Astronomy and Astrophysics, tutorials, visits to labs and science facilities in the observatory and other academic interactions. This year the school was held during May 20 to June 2, 2019 and had thirty five participants

from all over India.

A subset of the participants are selected to carry out month-long projects at Bangalore or other field stations. This year seventeen students did their summer projects during June 2019.

[1] **Summer Projects carried out at IIA, Bangalore**

Shikhar Asthana - "Automatic sigmoid detection from Carrington maps" under the guidance of Dipankar Banerjee.

Himanshu Grover - "Why galaxies stop forming stars?" under the guidance of Sudhanshu Barway.

Mrinalini Singh - "Mining and analysis of GALEX and SDSS photometric data" under the guidance of Jayant Murthy.

Antareep Gogoi - "Ultra-violet View of Globular Clusters" under the guidance of Gajendra Pandey.

Eshita Banerjee - "Accretion properties of Pre-main sequence stars of Orion cluster with future UV mission" under the guidance of Maheswar Gopinathan.

Sowmya Bhowmick - "Chemical abundances in nova ejecta" under the guidance of U. S. Kamath.

Mayukh Chowdhury - "Automated Technique for the Detection of Sigmoidal filaments from Carrington Maps" under the guidance of Dipankar Banerjee.

Shifana Koya - "Cross-correlation tracking vs Centroid tracking for image stabilization systems" under the guidance of R. Sridharan.

Arabinda Sahoo - "Search for massive compact relic galaxies in local universe" under the guidance of Smitha Subramanian.

Sachin P - "Evaluation of Planetary Boundary Layer (PBL) height using multi-reanalysis data against the CALIOP observations over Hanle and Merak sites" under the guidance of N. S. Shantikumar.

[2] **Summer Projects carried out at Kodaikanal Solar Observatory**

Aiswarya Ramachandran - "Determining the sunspot group number for the solar cycle 19 to 24 using Kodikanal Observatory White-Light Images" under the guidance of B. Ravindra & P. Kumaravel.

Richita Ghosh - "Solar filaments and its Cycle" under the guidance of B. Ravindra & P. Kumaravel.

Susrisangita Patra – "Fourier filtering technique to remove fringes from Ca II K spectral data recorded using the Kodaikanal Tower Tunnel telescope (KTT)" under the guidance of K. Nagaraju.

Valliamai R. M – "Variation of photospheric and chromospheric magnetic field v/s sunspot radius" under the guidance of K.Nagaraju.

Archana Aravindan – "Helicity storage as a flux rope formation and its eruption from solar active regions" under the guidance of Vemareddy Panditi.

[3] **Summer Projects carried out at VBO, Kavalur**

Abhay Hareendran – "Estimation of radial velocity of a star using High Resolution Echelle Spectrograph" under the guidance of G. Selvakumar.

Teja Vardhan Reddy – "High Resolution Spectroscopic data analysis techniques" under the guidance of G. Selvakumar.

3.5 Visiting Students Programme

This is conducted with an aim to promote scientific research interest in college and university students. Selected students work on specific projects that form a part of ongoing research at IIA, either at the main campus in Bangalore or our field stations. Students carrying out their Ph.D. in Universities, and willing to visit IIA for collaborative research are also encouraged to apply for this programme. During 2019 – 2020, forty seven (47) students did their projects under the guidance of the various academic staff members.

Fifteen students selected under the Summer Research Fellowship Programme of the Indian Academy of Sciences did their projects under the guidance of IIA faculty at various times during May to July 2019.

3.6 Student participation in National Meetings / Workshops / Conferences

[1] **Following students participated in the 38th meeting of the Astronomical Society of India held at IISER Tirupati, Tirupati during 1 February 2020:**

Jyoti presented a poster "UVIT study of star forming regions in spiral galaxies."

Bhoomika presented a poster "Characterization of the correlation between optical and gamma-ray flux variations in bright flat spectrum radio quasars."

Vikrant Jadhav gave a talk on "UVIT catalog of open clusters with machine learning based membership probability"

Partha Pratim Goswami gave a talk on "Metal-poor stars and neutron-capture nucleosynthesis".

Ritesh Patel gave a talk on "CMEs identification in Inner Solar Corona"

Saraswathi Kalyani presented a poster "Correlation interferometer set-up for observing the Sun in Ku band".

Deepak presented a poster "Evolution of lithium in the Milky Way"

Indrani Pal presented a poster titled 'Coronal temperature variation in Active Galactic Nuclei'

Anirban Dutta gave a talk 'Observational'Studies of Type Ia Supernovae SN2017hpa"

Chayan Mondal presented a poster titled 'Tracing young star forming clumps in the earby flocculent spiral galaxy NGC 7793 with UVIT'

Kshitij Bane Suhas presented a poster "Instrumentation for observations of Pulsars at Low Radio Frequencies."

Sioree Ansar presented a poster "Modeling Observations of Galaxy Halos with Simulations"

Shejeelammal J gave a talk "Chemical and kinematic analysis of metal-deficient barium stars".

Piyali Saha gave a talk "A census of young stellar population associated with the Herbig Be star HD 200775"

[2] **Following students participated in the Young Astronomers Meet held at Kodaikanal during 23-27 September 2019:**

Ankit Kumar gave a talk “Effect of Flyby Interactions on the Bulges of the Galaxies”

Sandeep K Kataria gave a talk "The effect of bulges on bar formation and bar pattern speed in disk galaxies "

Sandeep K Kataria presented on "Can bars erode cuspy halos?"

Partha Pratim Goswami gave a talk on " CEMP-r/s stars and intermediate neutron-capture process".

Kshitij Bane Suhas gave a talk “Development od radio antenna array and receiver system for observations of Pulsars at Low Radio“

Sioree Ansar gave a talk “Enhanced 21-cm Power Spectrum due to inhomogeneous CMB heating of gas during Dark Ages”

Deepthi S Prabhu presented a poster “Exploring the Enigmatic Hot Stellar Population in Globular Cluster NGC 2808 using UVIT". She won the second prize.

Fazlu Rahman P.P gave a talk “Gaussianity and Statistical Isotropy of Haslam 408 MHz Map”

[3] **Following students participated in the conference ’REcent Trends in the study of Compact Objects - IV’ during 17 - 20 April 2019, at IUCAA, Pune, India:**

Prerna Rana gave a talk ‘A dynamical model for QPO frequencies in BHXRB”

Dipanweeta Bhattacharyya gave a talk "Spin and mass evolution of the black hole"

Indrani Pal presented a poster titled ’Coronal temperature variation in AGN’

[4] **Following students participated in the IRIS -10 meeting held during November 4-10, 2019 in Bengaluru:**

Harsh Mathur presented a poster "Morphologic dynamics of an evolving pore observed by GREGOR"

Manoj Varma S.V gave a talk on "Testing the flare localization algorithm for Solar Ultraviolet Imaging Telescope (SUIT), using AIA and IRIS images"

Sahel Dey gave a talk “Modeling the Solar Spicule Forest”

[5] **Following students participated in the meeting “MODEST-20” at TIFR, Mumbai during 4-Feb-2020:**

Vikrant Jadhav gave a talk "Evidence of post-mass transfer binaries containing extremely low mass white dwarfs in the open cluster M67"

Deepthi S Prabhu gave a talk "The first extensive exploration of UV bright stars in the globular cluster NGC 2808"

[6] **Following students participated in the international conference ‘150 years of the periodic table: Chemical elements in the Universe: origin and evolution’ held from December16 to 19, 2019 at Indian Institute of Astrophysics:**

Partha Pratim Goswami gave a talk "i-process nucleosynthesis: observational evidences from CEMP stars”

Anirban Bhowmick gave a talk titled 'Fluorine in Extreme Helium Stars'

Shejeelammal J, gave a talk "[Rb/Zr] ratio in Ba stars as a diagnostics of the companion AGB star nucleosynthesis"

Sharmila Rani, gave a talk "Exploring the formation mechanism of extreme horizontal branch stars"

[7] **Following students delivered talks at various institutions within the country:**

Vikrant Jadhav gave a talk " Study of Star clusters in the Magellanic Bridge" at the Magellanic Clouds meeting, IIA 19 December 2019.

Fazlu Rahman P.P gave a talk on "Gaussianity and Statistical Isotropy of Galactic Synchrotron at 408 MHz" at the Workshop on Geometric and Topological Methods for Cosmological Data Analysis, 20-23 July 2019, NISER Bhubaneswar, Odisha

Partha Pratim Goswami gave a talk "Nucleosynthesis in Carbon Enhanced Metal Poor Stars " at the One day Indo-Thai Workshop on "Investigating the Stellar Variability and Star Formation" held on March 02, 2020 at ARIES, Nainital.

Anirban Dutta presented a poster 'Photometric and Spectroscopic Observations of type Ia Supernovae' at the conference "Applications of Data Science in Astrophysics and Gravitational Wave research" held at IIIT, Allahabad on 1 Nov 2019.

Samriddhi Sankar Maity attended the COSPAR Capacity Building Workshop "Coronal and Interplanetary Shocks: Analysis of Data from Space and Ground based Instruments" held at Kodaikanal Solar Observatory during January 6, 2020 to 17 January 2020.

Chayan Mondal attended the workshop 'WStars' at MG University, Kerala, between 10 - 12 January 2020.

Dipanweeta Bhattacharyya and *Prerna Rana* attended the discussion meeting on 'Astrophysics of Supermassive Black Holes' during 17 December 2019, at ICTS, Bangalore, India.

Indrani Pal participated in a conference on Transient Astronomy during 11-12 November 2019, organised by Space Astronomy Group, U R Rao Satellite Centre, Bengaluru.

[8] **Student participation in International Meetings/ Conferences / Workshops and collaborative visits**

Fazlu Rahman P.P presented a poster "Statistical Isotropy and Gaussianity of Haslam 408 MHz Map" in the 'B-mode from Space' Conference, Max Planck Institute for Astrophysics, Garching, Munich.

Megha A gave a talk at the Solar Polarization Workshop-9, at Max Planck Institute for Solar System Research, Germany, from from 26-30 August, 2019.

Megha A participated in an international school on Solar Spectropolarimetry from September 9 to 14, 2019, Lugano, Switzerland.

Harsh Mathur participated in Solarnet School: Solar spectropolarimetry: From virtual to real observations from Sept. 9-14, 2019 at Lugano, Switzerland.

M. Pavana gave an oral presentation on "Geometry of nova ejecta" at the

IAU 357 symposium on White Dwarfs as probes of fundamental physics and tracers of planetary, stellar and galactic evolution at Hilo, Hawaii, USA from 21-25 October 2019.

Ankit Kumar presented a poster "The Evolution of Galaxy Bulges in Minor Interactions" at IAUS 353: Galactic Dynamics in the Era of Large Surveys held during June 28 - July 07, 2019 at Shanghai, China.

Ritesh Patel presented a poster "Onboard automated CME detection algorithm for Visible Emission Line Coronagraph in Aditya-L1" at the conference "Towards Future Research on Space Weather Drivers" held at San Juan, Argentina, 2-7 July 2019.

Sandeep K Kataria presented a poster "Can bars erode cuspy halos?" at "Galactic Dynamics in the Era of Large Survey" conference organised by SHAO and SJTU from June 30th to July 5th, 2019 at Shanghai, China.

Deepak gave a talk on " Lithium enrichment in the Galaxy: A study using the GALAH and Gaia surveys" at the meeting 'Lithium in the Universe: to Be or Not to Be' at Observatory of Rome, Monte Porzio Catone, Italy from 18th to 22nd November 2019.

Deepak presented a poster titled, "Lithium enrichment in the Galaxy: A study of RGB stars using the GALAH and Gaia survey" at the International Astronomical Union Symposium 353: Galactic Dynamics in the Era of Large Surveys, Shanghai, China.

Sahel Dey presented a poster titled, "Dynamics of chromospheric jets in the realistic solar atmospheric simulation" at XXXI Canary Islands Winter School of Astrophysics, Universe in a Box, La Laguna, Tenerife, Spain 9th-19th November, 2019.

3.7 Awards and Recognition

Fazlu Rahman P.P won the best poster award for his poster "Statistical Isotropy and Gaussianity of Haslam 408 MHz Map" at the Tonale Winter School on Cosmology, 9-13 December 2019, Passo de Tonale, Italy.

Ritesh Patel selected for the SCOSTEP Visiting Scholar program which is a capacity building activity of SCOSTEP, NASA Goddard Space Flight Center, USA, Duration: October-December 2019.

Satabdwa Majumdar received the "Best Poster Award from the Indian Academy of Sciences for the discipline Sun and the Solar System" on the 38th meeting of the Astronomical Society of India, 2020 held at IISER Tirupati. The poster titled: "Connecting 3D Kinematics of slow and fast CMEs to their source regions: A preparatory study for the ADITYA L1 mission".

Deepthi S. Prabhu received the 2nd Prize in the poster presentation competition at YAM-2019 held at Kodaikanal during 23-27 September 2019. The poster titled: "Exploring the Enigmatic Hot Stellar Population in Globular Cluster NGC 2808 Using UVIT".

4

Instruments and Facilities

4.1 System Engineering Group

The System Engineering Group (SEG) is supporting major activities of the Institute like infrastructure creation, involvement in scientific projects related to ground based and space based instrumentation and their maintenance activities. The SEG consists of engineers and technical staff belonging to Electronics & Instrumentation, Mechanical, Electrical, Civil and Optics Divisions who provide support in the design, development, operation and maintenance of telescopes, their instruments and peripherals.

Highlights of major activities carried out by the SEG during the year 2019 -2020 are:

- The optics division was involved in the design of a Multi-Object Slit Spectrograph for proposed future UV mission, Indian Spectroscopic and Imaging Space Telescope (INSIST) and the design of the primary mirror for the National Large Optical Telescope and Maunakea Spectroscopic Explorer (MSE).
- The Electronics and Instrumentation Division team participated in the realization of the detector system hardware for the Visible Emission Line Coronograph (VELC) payload on Aditya satellite, at Indian Space Research Organization (ISRO), and development of a detector system and digital mirror device (DMD) controller for the INSIST project.
- The Electrical Engineering and Services Section was involved in the installation of new LT metering panel and up-gradation of old energy meters into digital meters at the staff quarters at Banasawadi road, Bengaluru and work on office rooms which were refurbished at IIA, Koramangala, in addition to the regular maintenance work ensuring electrical power supply round the clock.

Figure 4.1: *The installation of new LT metering panel at the staff quarters at Banasawadi raod, Bengaluru.*

- Civil Engineering Section carried out the renovation of the 2nd floor of the UPS Building for India Thirty Meter Telescope (I-TMT) project office and renovation of two guest rooms for the Aditya and the TMT projects at IIA, Koramangala.
- The barbed wire fencing around the Centre for Research & Education in Science & Technology (CREST) campus at Hosakote, is getting replaced with a stone compound wall to enhance safety. Half of the perimeter has been completed and the rest will be taken up shortly.
- Campus survey work of the Vainu Bappu Observatory (VBO) at Kavalur was taken up and completed.
- Concrete road work inside Kodaikanal Solar Observatory (KSO) campus of IIA, Kodaikanal was also done.
- The mechanical engineering division was involved in the design and analysis of the mechanical configuration of the INSIST, development of M1 system of the MSE which includes the analysis of subsystems such as the segment support assembly, and design and fabrication of a new filter wheel system for the 0.7m GIT.
- In order to improve the quality of human resources, members of the division were provided training in technical and management subjects. The management training programme titled: "Emotional Intelligence at Workplace for Scientists/Technologists" was conducted at the Centre for Organization Development (COD), Hyderabad in February 2020. The technical training programme on FPGA was arranged at the centre for electronics engineering and research Institute (CEERI), Pilani. Members from the Electronics and Instrumentation division and Electrical Engineering and Services Section participated in this programme.

4.2 Observatories

4.2.1 Indian Astronomical Observatory (IAO)

Himalayan Chandra Telescope

The 2-m Himalayan Chandra Telescope (HCT) at Indian Astronomical Observatory (IAO) Mt. Saraswati, Digpa-ratsa Ri, Hanle is located at an altitude of 4500 m (15000 ft) above mean sea level. It is remotely operated using a dedicated satellite communication link from the CREST campus, Hosakote, which is located about 35 km northeast of Bengaluru. With a low atmospheric water vapour content, Hanle is one of the best sites in the world for observations in infrared wavelengths. Currently three instruments are available for the scientific community - the Hanle Faint Object Spectrograph Camera (HFOSC), the NIR Imaging Spectrograph (TIRSPEC), and the Hanle Echelle Spectrograph (HESP).

The HCT has been a very productive telescope in the country. Because of its capabilities of medium and high resolution optical spectroscopy, imaging and low resolution spectroscopy in near infrared band, a large number of astronomers submit proposals for telescope time to make observations with the instruments. During May 2019 – April 2020, on an average, the telescope time was over subscribed by a factor of 2.5, while the dark moon period was over subscribed by a factor of 3. For 2019-Cycle2 (2019 May–August) 55 proposals, 2019-Cycle3

(2019 September–December) 52 proposals and 2020-Cycle1 (2020 January–April) 45 proposals were received.

Annual maintenance of the 2m HCT, the vacuum coating plant and other auxiliary systems at IAO was carried out during August 2019.

The process for upgrade of the telescope control system and the drive of the secondary mirror of the HCT is progressing. In response to the call for expression of interest to carry out the feasibility study of the telescope refurbishment, a good number of proposals were received. One vendor was identified to conduct the feasibility study. The feasibility study was carried out and a detailed report received. The evaluation of feasibility study report and defining the final strategy for the upgrade is in progress.

An online proposal management system (IPS) was developed in-house for IIA's observing facilities (VBO and IAO). The proposal management system was deployed and it is being used since 2019-Cycle3 (2019 September–December). This system has streamlined the proposal submission and evaluation process.

GROWTH India Telescope

Located at the IAO, the Global Relay of Observatories Watching Transients Happen (GROWTH) India Telescope (GIT) is India's first fully robotic optical telescope and is part of an international collaboration. The telescope was installed and commissioned in the summer of 2018. The project is funded by DST-SERB and administered by Indo-U.S. Science and Technology Forum (IUSSTF) under the Partnerships for International Research & Education (PIRE) programme. The GIT is a 70 cm CDK-700 Alt-Az telescope with focal ratio f/6.5, developed by Planewave Instruments. It has two Nasmyth ports, Andor iKon-XL-230, thermoelectrically cooled CCD is installed at one of the ports along with a filter-wheel of wide field imaging capabilities in u′, g′, r′, i′, z′ filters. GIT can be operated in either robotic or manual mode. The default mode is the robotic mode with queue-based observations. The data acquired is stored at IAO and is downloaded in real-time at the processing unit situated at IIT Bombay via the satellite link to the CREST Campus of IIA. As soon as the data is downloaded, the automated processing is done in real-time. Apart from the usual queue-based mode, GIT also has a Target of Opportunity (ToO) mode of observation.

The last one year has been very fruitful for GIT in terms of scientific results. With the automated observation and data reduction capacities, GIT has successfully followed up a few gravitational wave alerts from Laser Interferometer Gravitational-Wave Observatory (LIGO-VIRGO) collaboration, gamma ray bursts (GRBs) afterglow search in optical bands and young supernovae.

4.2.2 Merak site at Ladakh

The location of Merak, a place near the Pangong Tso lake in the Ladakh which is situated at an elevation of 4,225 m (13,862 ft), is identified as the site for the National Large Solar Telescope. A number of instruments mainly for the site characterization are installed here. Instruments such as an automatic weather station, an all-sky camera, a Solar Differential Image Motion Monitor (SDIMM), and a Shadow Band Ranger (SHABAR) Scintillometers are in operational and continue to obtain data. The SDIMM and SHABAR instruments have made the observations for 654 hours spanning over the 10 months (from June 2019 – April 2020).

An Hα telescope, identical to the Ko-

daikanal Hα telescope, is also operational here. The Hα telescope made observations of the chromosphere of the Sun from April 2019 till December 2020 spanning over 112 days.

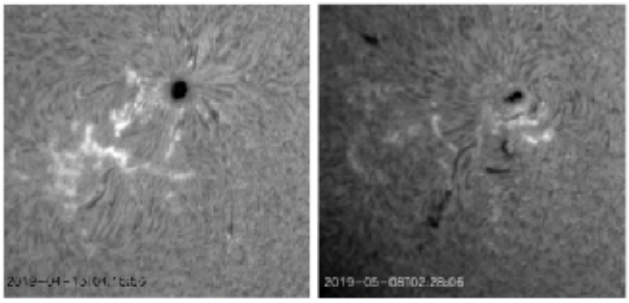

Figure 4.2: *Hα images of a small region on the Sun taken from the Merak site.*

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

The observations with the HCT located at Hanle is carried out from the CREST using the point-to-point satellite link between the CREST and the IAO. The observers who have been allotted time at HCT visit the CREST Campus for making observations. However, since mid of March 2020, due to the COVID-19 pandemic situation, it was decided to continue the observations in "service mode". The observers were requested to send the details of their plan, observations were carried out by the observing staff at the CREST and the data was sent to the proposers.

The grid power at CREST campus is being augmented to meet the demands of the ITOFF in the future. In order to improve the internet connectivity of the CREST Campus, the NPLS internet link was replaced with a BSNL fiber broad-band, with a data rate of 10 Mbps. The Local Area Network (LAN) at the CREST campus is also being upgraded to fiber network. For the security of the Campus, CCTV cameras were installed during previous years, in a stand alone mode. The optical fiber network within the campus is being used to integrate these CCTV cameras. To strengthen the security of the Campus, construction of an 'L' shaped (two wings) boundary wall around the Campus is completed. The construction of the remaining two wings of the boundary wall is planned during the next year.

Figure 4.3: *Stone wall construction around the CREST campus at Hosakote.*

A Green House Gas (GHG) measurement facility is now operational at the CREST Campus under an MoU signed between CSIR–4th-Paradigm (4PI), Bengaluru and IIA. This facility, established under the 12th Five Year Plan project of the CSIR consists of a gas calibration unit and an Automated Weather Station installed on a 32 m tall tower. This station is also used as a reference station for calibration of the secondary cylinders and other GHG instruments set up in the country. The facility continues to produce important data for research on green house gases.

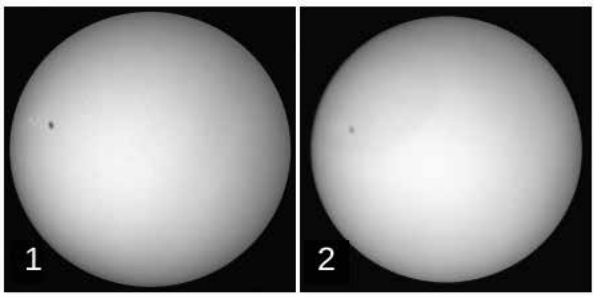

Figure 4.4: *Images taken with the WARM telescope.* **(1)** *In G-band (430.5 nm),* **(2)** *In Ca-II K (393.3 nm). Solar north is straight up and east is to the left. The dark 'black' feature on the solar disk close to the east limb is the sunspot region NOAA 12738.*

4.2.4 Kodaikanal Observatory

Synoptic observations of the Sun are carried out on daily basis using the Hα and the White-light Active Region Monitor (WARM) telescopes in the Kodaikanal Observatory. The observations are in full-disk mode at 1-minute cadence. In the academic year 2019 - 2020 only three filament/prominence eruptions and two small flare observations were carried out as there were not many active regions on the Sun. The total number of days observations were made with the WARM telescope in this academic year is 216 and 62,539 images were obtained in total. In addition to the above, daily observations of the Sun in white light were carried out with the legacy 6-inch telescope using photographic plates. Latitudinal scan of Ca II K (393.3 nm) spectrum of the Sun, a synoptic observational programme with the Kodaikanal Tower Tunnel Telescope (KTT) to study the long term variation of the magnetic activity on the Sun, were continued.

The observatory witnessed an annular solar eclipse on 26th of December 2019. The KTT was used to measure the stray light within the instrument during the eclipse period. Spectra centered around the Hα spectral line (656.28 nm) line were recorded at different phases of the eclipse. Ideally, the spectra from the region of the Sun covered by the shadow of the Moon should be devoid of any features. If any features are present, they are most likely due to stray light. The observations are expected to be useful to characterize the off-limb observations of the Sun with the KTT.

4.2.5 Vainu Bappu Observatory

The VBO is located in the Javadi hills of Tamilnadu, at an elevation of about 750 m above the mean sea level. Established in the 1970s, VBO hosts the 1 m Carl Zeiss Telescope, the 1.3 m J.C. Bhattacharya Telescope (JCBT) and the 2.3 m Vainu Bappu Telescope (VBT). At the prime focus of the VBT, CCD cameras are used for imaging in various optical wavelength bands. A high resolution Echelle spectrometer is in operation where the light is fed through an optical fibre from the prime focus directly to the spectrograph slit. A spectral resolution of 70,000 has been achieved with the spectrograph in the visible wavelength range. At the Cassegrain focus, an Optomechanics Research (OMR) spectrograph is used for low-to medium resolution spectroscopy. The field of view of the JCBT is 30 minutes of arc and the plate scale is 20 arc sec/mm. It has three instrument ports where instruments can be mounted for observations. The 1m telescope is attached with an optical polarimeter and a medium resolution Universal Astronomical Grating Spectrograph (UAGS).

Observing proposals are invited from the observers and based on the merit, observing nights are scheduled. All the three telescopes were operated as per the allocated schedule during the year 2019-2020. A severe light-

Figure 4.5: *Wiring of the VBT console and replacement of the damaged components of the OMR spectrograph.*

ning struck on 5th May 2019 causing damages to some of the components of the VBT. The telescope was made fully functional after rectifying the issues with some of the console switches, control units of the telescope and the instrument and auxiliary systems. The Fiber-fed Echelle Spectrograph setup with the telescope was restored for observations within ten days. The OMR Spectrograph, which was mounted during the lightning strike, suffered major damage to its electronic units. Grating encoder, DC-DC converter for source power supply, filter switch and other components also got damaged. The restoration of the operation of OMR was done by October 2019.

The JCBT used 2K×4K CCD system at the main port and ProEM CCD with the tip-tilt instrument mounted at the west port for seeing measurements. The 4K×4K CCD203 Red, used for the VBT Echelle observations, was serviced recently in a clean room facility available at the VBO by the VBO engineering team. They also serviced the 2K×4K dewar used at the JCBT recently to rectify ground noise patterns seen on the images taken with it. A new dome drive was installed at the VBT and the older unit was replenished to avoid break down. The guide camera at 30-inch telescope developed technical issues during the lightning strike which was replaced with an another intensified CCD camera. The problems with UPS, TEK1K CCD controller and Baldor Right Ascension drive amplifier were also rectified and the observations started in January, 2020.

The Andor LUCA guide camera which was used with the VBT Echelle spectrograph also malfunctioned in mid-January which was then replaced with the HAWK 216 EMCCD which is having an analog video output. The auto-guider setup was replaced with an indigenously developed Picolo card based system along with a new software. Optics team adjusted the guider alignment and fixed the reference point for the guiding operations. The fibers used for the Echelle spectrograph setup were also relaid.

Fabrication of a mounting flange, outer cover and machining of the filter holder, 45 degree mirror holder and mounting assembly for a new near-infrared photometer was car-

Figure 4.6: *A new thermoelectrically cooled CCD Andor Newton DU920P attached with the OMR spectrograph.*

ried out which was then mounted on to the 1 m telescope for carrying out test observations.

A new thermoelectrically cooled CCD Andor Newton DU920P was procured for the OMR spectrograph. Calibration was performed to estimate gain, read out noise and dark noise for different settings of the CCD in the VBO lab. After fixing the optimized values for operation, the CCD was mounted on the OMR and test observations were performed. The VBT console is now installed with two new split A/C units.

Two servers are planned for remote operation of the JCBT, one to handle the data acquisition and another to handle the data transfer. The data acquisition has been tested for a remote client request. The data transfer is required at first hand to display the image as early as possible and hence a test to get binned data at the client end from the data server was successfully done. The ProEM CCD is the detector that will be used for the first phase and a server is the add-in to communicate with client with a separate data server application.

The VBT Mirror Coating Plant sequential operation has been modified and tested. Corrections were made to improve the reading from Penning and Inficon vacuum gauges.

Following the lighting strike at VBO in May 2019, technical team undertook several protective and maintenance activities to protect the facilities from such future events. The telescope buildings at VBO had employed early streamer emission air terminal (ESE) rods for protection from lightning. This was done in 2014 when the ESE rods were recommended by the designer of the building and dome for the JCBT. As per the 2016 revision of NEC/IS/IEC standards, the use of ESE rod for protection of structures from lightning is not recommended. Accordingly, the ESE rods at the buildings of the VBT, the JCBT and the the 1 m Zeiss telescope were replaced with conventional Franklin rods. Reconditioning of old earth pits and addition of new earth pits were carried out. Removal of roller assembly in the lightning down conductor path in the VBT building and connection made through dome rail. Installation of equipotential bonding of metallic structures in all telescopes is being planned. Installation of Surge protection devices at all the telescope buildings as per standard IEC 62305 has been initiated. Maintenance and watering of earth pits and measurement of earth resistance periodically following earthing standards and earthing networks as per standard IS 3043. Earth pits around VBT were renovated with new electrodes, GI pipes with copper plate and flats.

4.2.6 Gauribidanur Radio Observatory

Gauribidanur RAdioheliograPH (GRAPH) augmentation

Measuring the magnetic field strength (B) in the solar corona and localizing it there is important since it plays a major role in the formation and evolution of coronal structures. Presently, the determination of B in the near-Sun corona is generally obtained by mathematical extrapolation of the observed line-of-sight component of the photospheric magnetic field. Since the circularly polarized radio emission associated with different types of non-thermal energy releases can be used to estimate B, a dedicated instrument to obtain two-dimensional images of the solar corona via its polarized radio emission would be very useful. To realize this, the existing GRAPH is currently being augmented with additional antennas having perpendicular (90 degrees) orientation with respect to the existing antennas. In this connection, 128 Log Periodic Dipole (LPD) antennas that work in the 30–120 MHz frequency range were recently fabricated in house.

All of these were tested and mounted on to RCC poles in the North-South 'arm' of the GRAPH. The orientations of the arms of the new LPDs are perpendicular to those in the existing GRAPH array as mentioned earlier. Since the LPDs belong to the linearly polarized broadband antenna category, the new antennas shall receive the radio waves whose plane of vibration is in perpendicular direction to those received by the antennas in the old array. This arrangement is essential to measure the flux density of the polarized radio emission that are generated in the aftermath of transient flares, Coronal Mass Ejections, etc. in the solar atmosphere. The reception characteristics of the new antennas were studied and were found to work satisfactorily. The other RF modules such as the analog front-end receivers, RF filters, Declination control modules, etc. were also fabricated in house, and are being tested. The development of FPGA based digital back end system is also being carried out.

Figure 4.7: *GRAPH augmentation project: Close-up view of the LPD antennas in mutually orthogonal orientation and the front end modules.*

Low frequency array for pulsar observations

The present understanding of Pulsars, the highly magnetized and rapidly rotating Neutron stars, are primarily due to observations at high radio frequencies. Due to various con-

straints, observations of pulsars at low frequencies are limited. In view of the above, it was decided to explore the possibility to observe pulsars at radio frequencies < 100 MHz with the LPD antenna array in the Gauribidanur observatory. A new receiver setup was designed for this purpose. The signal received by the antennas are first high-pass filtered and then amplified using low-noise amplifiers. The amplified signals are then combined using a beam-former module and latter transmitted to the receiver room via low-loss coaxial cables. In the receiver room, a digital back end system having a 4-channel broadband ADC and a FPGA with maximum 100 MHz bandwidth processing capability are used to process the signal further. Also, since pulsar observations require very high spectral and temporal resolution, the receiver system is being designed to give a spectral resolution of 10 kHz and temporal resolution of 0.5 nsec. The estimated mean sensitivity of the system for 30 MHz bandwidth (centered at ∼60 MHz) and one hour integration is about 2 Jy (1 Jy = 10^{-26} W/m^2/Hz). Testing and characterization of the new observing system is being carried out to realize the goal. Also new software pipelines to process and analyze the pulsar data are being developed. Once the full-fledged system is completed, trial observations with known Pulsars whose flux density are above the sensitivity limit will be carried out with the new system.

4.3 Ultra-Violet Imaging Telescope

The ultra-violet imaging telescope (UVIT) is one of the five payloads on-board India's first multi-wavelength astronomical satellite, AstroSat launched by the ISRO in the year 2015. Observations are routinely been carried out with the UVIT, currently in the far ultraviolet (FUV: 1300-1800 Å) and the visual (VIS: 3200-5500 Å) bands. Observations done in the VIS channel are used for aspect correction. During the period 01 April 2019 - 31 March 2020, a total of 273 sets of observations (OBSIDs) were carried out with the UVIT. Of these 273 sets, level 1 (L1) data were received at the payload operations center (POC, IIA) for a total of 95 OBSIDs. Of the 95 OBSIDS, POC has processed 73 OBSIDS and sent their science ready level 2 (L2) images to the Indian Space Science Data Center for archiving and dissemination. Initial calibration of UVIT was based on the data acquired at the ground. After the launch, new calibration data was acquired through in-orbit observations. This was used to obtain (i) new photometric calibration (that includes, (a) zero-points, (b) flat fields, and (c) saturation) (ii) variations in sensitivity and (iii) spectral calibration of the near ultraviolet (NUV; 2000 - 3000 Å) and FUV gratings. Using the data acquired over the last three years, it was found that the UVIT is performing well with no reduction in the sensitivity in both the UV channels (Tandon et al. 2020, AJ). During the last one year period, a total of 14 papers were published that uses the data from the UVIT, which includes 6 papers in the refereed international journals and 8 papers in the conference proceedings.

4.4 Computational Facilities

IIA data center houses several important servers, for e.g mail server, anti-spam server, web server, ERP server, computational servers etc. which are kept up-to-date by up-

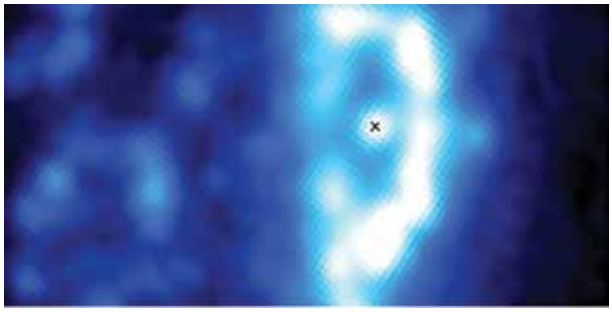

Figure 4.8: *The near-ultraviolet image of the Jellyfish Galaxy JO201. Appeared as the AstroSat Picture of the Month for May 2019. Picture credit: George, K and team.*

grading the system and application software to its latest version and updating the system with latest security patches to mitigate vulnerabilities in the system that can be exploited by prevalent security threats. The firmware of all network devices viz. firewall, switches etc. are kept up-to-date on regular basis to mitigate any possible security threat.

The hardware infrastructure hosting the critical services are kept up-to-date by replacing the old and outdated ones with newer technology(ies) when they are nearing their end of life. As the number of users and devices in the network have increased many folds in the recent years, the system was recently migrated to a newer firewall device with more load handling capacity and new features in terms of policy, debugging, log and management.

Eduroam service which is a world-wide roaming access service developed for the international research and education community has been configured at IIA recently. Eduroam allows students, researchers and staff from participating institutions to obtain Internet connectivity across campus and when visiting other participating institutions by simply opening their laptop. Further, in continuation to our efforts in improving the existing network infrastructure at IIA, we have upgraded the connectivity between computer center and data center from 10G fiber to 40G. The network rack at computer center has also been populated with a few newly procured, high-end, managed switches and compatible cabling technology as shown in Figure 4.9, replacing the old switches and cables which had reached their end-of-life.

IIA has an ongoing computer trainee programme under the computer division which imparts IT training to young engineers for providing system and application support to a wide range of users at IIA and skill them to be industry ready as a part of IIA's contribution to the socio-economic cause.

Figure 4.9: *Network Rack at IIA Computer center.*

Computational Activities

The High Performance Computing (HPC) cluster at IIA has been upgraded from 8 nodes to 26 Nodes with a performance improvement of 295% over the previous one. The HPC cluster, now has a total of 720 cores and 3.5 TB of memory at users' disposal. The cluster is used by a large number of researchers and scientific community at IIA for their computational requirements which require high performance and precision, to help them pursue with their research interest. A large number of research papers have also been published based on the computational work achieved on the HPC cluster. The cluster is kept up-to-date with latest system and application packages as applicable.

WEB related Activities

IIA web services with latest content management system (CMS) has been optimized for better performance with improved user interface design. The server has been implemented with better security features and centralized authentication for accessing the Intranet. As per the directive of Ministry of Finance IIA is publishing its tender enquiries, corrigenda thereon and details of bid awards on the Central Public Procurement Portal.

Enterprise Resource Planning

Enterprise Resource Planning (ERP) software custom made for IIA, Bangalore and its various field stations are being widely used. This consists of modules such as Human Resources, Accounting, Finance, and Purchase etc. The software has evolved over a period of time to include new reports as required for each module including indents, purchase and inventory to facilitate auditory processing.

4.5 Library

IIA library is the main learning centre of the institute that constitutes of a well-balanced and extensive collection of both print and electronic resources in the major subject areas of research such as Astronomy & Astrophysics. This rich and valuable collection built over 200 years has some of the rare reference materials and back volumes of several important journals. The resources collection was updated with recent literature relevant to the Institute periodically. Apart from its print resources, the Library has access to a large collection of eJournals, eBooks, and databases. The library renewed its subscription to 65 journals and discontinued 25 print journals which already has online access.

The library is continued to be the partner of the National Knowledge Resource Consortium (NKRC), access to eJournals and databases through this consortium remained available through this year for IIA users. The total number of full-text eJournals from NKRC reached to over 4500+ journals published by 15 publishers. The library continues to get access to eBooks and databases, Annual Reviews of Astronomy & Astrophysics, Astronomical Society of the Pacific (ASP) conference series, Proceedings of IAU Symposium, SPIE Digital Library, SPIE e-books collection, and JSTOR general science collection. A comprehensive stock verification was completed for all field stations libraries and was cross-checked with previous stock verification reports, old accession register, no dues files, previous audit reports, etc. A detailed stock verification report and recommendations for untraceable library books was prepared for further action.

Document Delivery Services

The Library continues to provide need-based information services, book recommendation requests, book purchase requests for projects, new additions of books and journals, other services like reminders, reservations, overdue intimation, and email-based reference services. The library participates in inter-library networking activities with various other similar subject-oriented institutions and served 53 inter-library loan requests from our faculties and students. Library receives continuous requests from IISc, IUCAA, RRI, and other DST and CSIR libraries for inter-library loan requirements for technical literature. During this period, a total of 88 articles requests were received and 65 articles were delivered to them.

Bibliometric Analysis

The library assisted in the compilation of bibliometric and scientometric analysis of IIA publications required for making policy decisions from time to time, and as input to the DST report. Also, the library has given substantial input for the yearly publications statistics, quarterly publications statistics, the cumulative impact factor for the journal articles published, and publication data of faculty for the last 5 years collectively and individually. Few of the reports are automated using the Excel application and this saved around 70% of manual labour related to data capture and calculations.

IIA Archives

During the International Archives Week 2019, the IIA archives organized a two days programme on the 3rd and 4th of June 2019 at the Institute. During the event, selected experts delivered a series of lectures on aspects of scientific work, the history of science in India with a focus on our collections.

The oral sessions had several speakers from our Archives Committee. Dr. Indira Chowdhury spoke about the importance of orality in archives in the post-colonial world. Several talks were capturing the rich history of IIA's astronomical contributions including an overview by A. Mangalam, on the establishment of the IIA archives by Christina Birdie, on archives as a crucible and as commons by Venkat Srinivasan, on the works of Ragoonatha Chary by Shylaja B. S, on preservation by Mrinalini Mani, on the work of Comets at the Madras Observatory by R.C. Kapoor, on the history of Pogson by N.K. Rao, and on the discovery of Helium by Biman Nath. The poster presentations also had many interesting presentations including on the life and work of C.V. Raman and S. Chandrasekhar. All in all, it was a very lively and interesting event that also included film shows and a guided tour of our archives. The main objective of this exhibition was to create awareness among scientists, historians of science, and librarians in the country, of the rich archival material available at IIA.

The old photographs were collected from various sections of IIA, and the process of captioning, storing, and digitizing them is initiated. The library team facilitated the digitisation of solar chart pilot projects through the movement of archives materials from Kodaikanal to Bangalore main campus.

Field Station Libraries

The branch libraries at the field stations like Kodaikanal, Kavalur, Hosakote, Gauribidanur, and Leh-Hanle are monitored and maintained by the Bangalore library. Most of the new acquisitions of books & journals in all the field stations are made available electronically for seamless access. The Kodaikanal library is now refurnished

Figure 4.10: **Top-Left***: Glimpses of the lecture session on Archives day,* **Top-right***: Lecture by A. Mangalam seen with J. Murthy during the inauguration,* **Bottom-Left***: Drs. R. C. Kapoor, B. S. Shylaja and Christina Birdie in discussion and* **Top-Left***: Students during the tour to the Archives.*

and upgraded with more shelves and display racks.

Library Training programme

The library continues to offer a two-year library trainee programme; two new trainees joined the library and is training to carry out all the library activities.

IIA Digital Repository

The IIA digital repository collects, selects, stores, and disseminates in digital format the research output created by the IIA research community. During the year, research articles, technical reports, archival materials, and PhD theses were uploaded to the repository. As on date, the total number of publications in the repository is about 7462. As a content partner, it is continued to contribute to the public by sharing the metadata to the National Digital Library of India (NDLI), which will also provide publicity to IIA publications.

4.6 Facilities Developed for Other Organisations

Fabry-Perot Interferometer

The optics division is developing a Sky Scanning Fabry-Perot Interferometer de-

signed to measure thermosphere winds and temperatures as well as mesospheric winds through airglow emissions at wavelengths of 630 nm in collaboration with the Indian Institute of Geomagnetism, Navi Mumbai.

Solar Spectrograph for graduate and undergraduate level students of IIST, Thiruvananthapuram

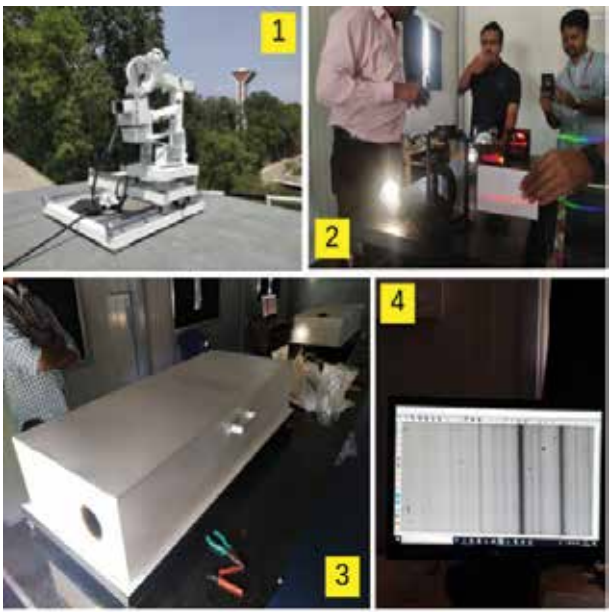

Figure 4.11: **[1]** *Coelostat assembly;* **[2]** *IIA team reassembling and testing the set-up;* **[3]** *The instrument kept inside the laboratory;* **[4]** *The sodium D1 and D2 spectral line obtained with the solar spectrograph and displayed it on the desktop screen.*

Several institutions, both universities and colleges, have a course on Astronomy and Astrophysics. Most of these courses are oriented towards teaching in class rooms rather than through laboratory experiments. With an aim to provide user-friendly instrumental kit to teachers and students for getting hands-on experience in data collection, reduction and analysis, IIA has designed, developed and tested a telescope and a spectrograph unit for solar observations. The experimental kit is designed to not only facilitate in collecting the data but it also provides software tools to extract some of the interesting details about the Sun. The first set of experiments are at a preliminary level or first level and the next set of experiments are at a little advanced level. These experiments are designed in a manner that people with no exposure to the astronomy instruments can perform them.

On March 01, 2020 a team from IIA installed the instruments on the roof top of the Science Block, D2 building of the Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram. The instrument is capable of capturing image and recording photospheric and chromospheric spectra of the Sun. With this setup the college students can carryout experiments such as identifying the Fraunhoffer lines, finding their wavelength, line depth, width, etc,. The instrument kit includes the telescope control system and a camera with all the required computer software. After the installation, the team provided training to the Scientists at IIST, Thiruvananthapuram, in the operation of the telescope, obtaining the data through the camera and demonstrated how to carry out calibration of the data.

5

Future Facilities

5.1 The Thirty Meter Telescope

Thirty Meter Telescope (TMT) project is a collaboration between institutes in the US, Japan, Canada, China and India. India became a full member of the TMT International Observatory in the year 2014 and since then the ITCC has been contributing substantially to the design and development efforts of the TMT. India's in-kind contributions include Primary mirror Segment Support Assembly (SSA), Actuators, Edge Sensors, Primary mirror Segment Polishing, Observatory Software (OSW) and Telescope Control Software (TCS), M1/M2/M3 segment coating and Science Instruments. During the year April 2019 to March 2020, the ITCC has contributed well to the efforts of the TMT efficiently which have been briefed below.

Mauna Kea, Hawaii, continues to be the most preferred site for construction. In the year 2019, legal hurdles were over with Mauna Kea site. Government of Hawaii had issued a notice of "proceed with construction" of the TMT on the summit and its assurance of all possible assistance for safe construction of the project. The board of the TMT decided to start the construction process starting mid July, 2019. The native Hawaiian protesters in much larger number occupied the roads lading to the summit preventing construction material from reaching the summit. Stalemate continues since then. After that several Members (Financial Authorities: In India's case the DST secretary) meetings held to define the course of action. Members agreed to give a chance for negotiations with native Hawaiian elders. New schedule for commencing construction will not be earlier than 2021 with around 10 yrs of construction. Project is looking at NSF for additional funding.

La Palma, Canary Islands: As regards to La Palma site, permits are in hand and project can go ahead with the construction if the project decides so.

Optics

M1 Segment Polishing: India is entrusted with the polishing of 90 out of 492 plus spares of TMT segments which are each of 1.44 metre diameter. As there are no industries having capabilities of meeting the requirement of large optics needs in the country, IIA has taken up the challenge. In order to fulfill India's obligations, a large Optics Fabrication Facility is established in CREST, Hosakote, Bengaluru. The method used is called as the Stress-mirror polishing that will provide a surface figure of 1 micron Peak-to-Valley. The final accuracy of the polished mirror segment to be achieved after ion-beam figuring (IBF) pro-

Figure 5.1: *The ITOFF facility coming up at the CREST campus, Hosakote.*

cedure is 2 nm. Several activities have been completed in the year 2019-2020. Associated equipment like PMM, CMM, Thermal Chamber, Reference Sphere, D.G.Sets, electrical equipment, Crane, Scissor jack, elevators, etc. have been procured. Installation and testing of these equipment have been carried out successfully. a total of 18 clear Ceram-Z glass blanks made by Ohara have been received from National Astronomical Observatory of Japan (NOAJ), Japan. These are stored in ITOFF.

The ITCC, in partnership with M/s Coherent (USA), is developing Segment Polishing Machine and its associated equipment. Procurement process has been completed and cleared by the DST.

Hardware

Segment Support Assembly (SSA): India is supplying all the required number of SSAs to the TMT. Nearly 600 SSA will be manufactured. The ITCC is partnering with M/s. L&T for manufacturing 10 Primary Mirror Assembly (PMA) kits and 4 sub cells under Production cum qualification stage and, on qualifying in the PQP Stage, will manufacture 90 additional PMA Kits and 90 sub cells for the TMT. The ITCC is planning to manufacture the remaining SSA's through mid scale vendors to accommodate them within the available fund. Many vendors are identified by the ITCC and the qualification is in progress by placing orders for critical components.

Manufacturing prototype of Central Diaphragm, which is integral and critical part of the SSA has been successfully achieved in Indian industries. The ITCC will be procuring SSA acceptance test tool for final testing of the critical SSA components.

Actuators: Actuators form another important part of the mirror segment. Three ac-

Figure 5.2: **(a)** *displays the image of CMM installed in April 2019,* **(b)** *displays the image of Thermal Chamber installed in May 2019;* **(c)** *shows the Hexagonal Buyoff station received in December 2019;* **(d)** *shows the Etching station received in February 2020. Final image in the bottom displays 18 blocks of Ohara Ceram glass roundels arrived at ITOFF from Japan.*

Figure 5.3: *18 blocks of Ohara Ceram glass roundels arrived at ITOFF from Japan*

tuators are required per mirror segment and all ∼1500 Actuators will be manufactured by ITCC/IIA. The manufacturing of 20 prototype Actuators (see Figure 5.2) - 5 Nos. each by four vendors was completed during 2019 and were sent to project office for testing and qualification. These successfully passed the test and found to be meeting the specifications. Another round of manufacturing qualification of 20 Nos. as per the Project requirement has been initiated.

Edge Sensors: The activities in manufacturing Edge sensors include Coupon machining, Gold Coating, Laser etching, Inspection and Accelerated life cycle test to see effect of laser etching on gold coating. All these activities are partly for qualifying the laser etching process. Six pairs of Edge sensors are required for each segment. All edge sensors will be fabri-

cated at India.

ITCC is working with M/s Optica, Bengaluru for fabrication of sensor coupons for the laser etching trials. This work is currently in progress and delivery time is 6 weeks. The possibility of gold coating by Optica is also being explored. Optica also performs plastic moldings, and their services can be used for dust boot fabrication. Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad and Raja Ramanna Centre for Advanced Technology (RRCAT), Indore were identified for laser etching and some coupons have been given to them.

Software

Observatory Software:

Common Software: Common Software (CSW) which forms the main backbone skeletal communication system of the whole TMT software architecture has been successfully developed. The industry partner is M/s Thoughtworks, Pune, India. CSW 0.1 version was released on 30th August 2019 within the TMT community. CSW has completed the Acceptance Review and Pre-Shipment Review and the CSW software has successfully passed all the reviews. Currently, CSW maintenance is ongoing and will continue for 2 years. CSW v2.0.1 was released on 20th Mar 2020.

Executive Software: The Executive Software (ESW) system of TMT provides support to all the operation modes of TMT including: PI-Directed observing, Pre-planned Service Queue, and conditions-based queue scheduled observing. The ESW enables operation of all the TMT subsystems using user interfaces or other programs. The ESW Phase 1 development has started by the ThoughtWorks. The development work is going on well. ESW v0.1 was released on 19th March 2020. The ITCC is also producing the Infrared Guide Star Catalogue (IRGSCAT) for the TMT and the work is in progress.

Figure 5.4: *ThoughtWorks, ITCC/IIA, TMT Project Office meet during the Pre-shipment review of CSW.*

Telescope Control Software (TCS): This work package is being handled by IUCAA. The Contract awarded for PDP to Honeywell, India has been cancelled due to their underperformance and not able to cope up with the design development. Two separate contracts will be made for Final Design phase, one with OSL and another Indian vendor to be finalized shortly. Final Design phase lasts for 18 months;

Science Instruments

Wide field Optical spectrograph (WFOS): The ITCC is involved in the core development of one of the first light science instruments for TMT, WFOS. The WFOS is the first generation optical spectrograph on the TMT. It is one of the major workhorse instrument. A few key areas of research probed by the WFOS will be galaxy formation and evolution,

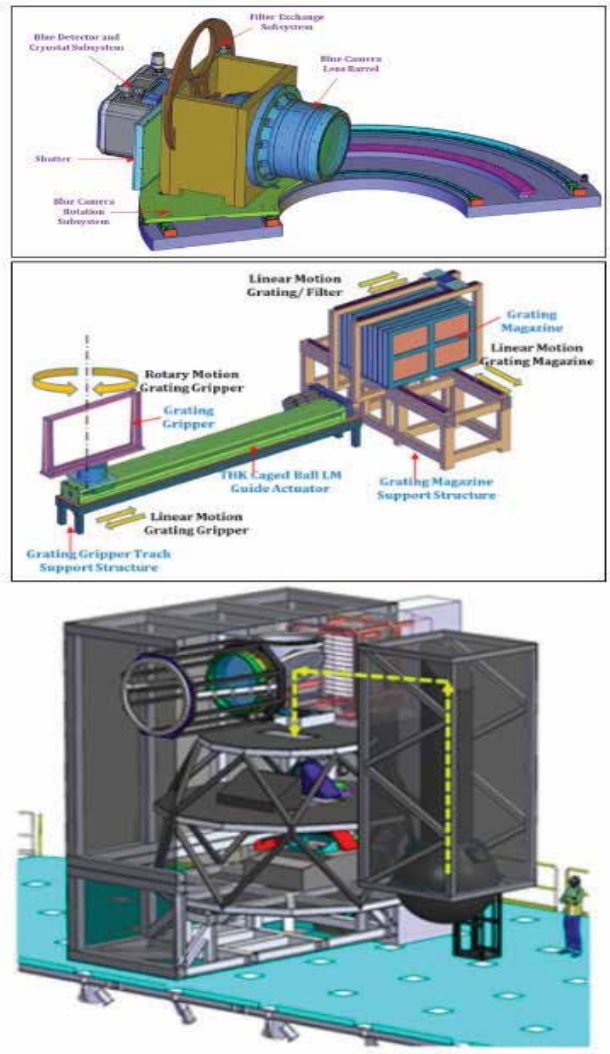

Figure 5.5: *Camera rotation system (top), Grating rotation and exchange system (middle) and calibration system (bottom, yellow dashed line) developed by ITCC for the WFOS spectrograph.*

intergalactic medium (IGM) tomography, near-field cosmology and transient objects. The spectrograph is designed to consist of slit-mask capable of obtaining spectra about 60 objects simultaneously. It consists of two channels -blue and red covering the near UV-optical-near IR wavelength range from 310-1000 nm providing three different spectral resolutions R∼1500, 3500 and 5000.

Figure 5.5 shows some of the key areas of Indian contribution. The main areas are Camera Rotation System (CRS), Grating Rotation and Exchange system (GRX). Apart from this India leads the development of the entire instrument control software (SWE) and the calibration system (CAL) for the instrument. All the milestones towards the conceptual design phase-II (CoDP-II) was successfully met and delivered to the project office, this includes design description document (DDD), CAD models, ZEMAX models and the software design description document (SDDD). Next phase will commence from June 2020.

High Resolution Optical Spectrograph (HROS): HROS will be the first second-generation instrument for the TMT. India leads the development of the instrument and forms the collaboration with the other TMT partners. This is the first TMT instrument that will be led outside the US institutions. It is a big challenge and a great opportunity. The HROS is going to be one of the biggest instruments on the TMT Nasmyth platform sized 10 m×10 m×4 m. India-TMT has completed a detailed optical design of the spectrograph channels.

High resolution optical spectrographs in general serve as a work horse instruments for most observatories. It can take advantage of poor seeing condition, when other instruments can not be used. Some of the key science drivers of the high resolution optical spectroscopy with the TMT are the study of Galactic archaeology, Inter- and circumgalactic medium and transit spectroscopy of exoplanets. The HROS will be used to study the sites of the first metals that were produced in the early Universe by the Pop-III stars and can trace its evolution all the way to the present day exoplanet atmospheres. High stability and precision calibration of HROS will

facilitate studies of characterising the Earth like planets around nearby stars and possible variation of fundamental constants at different red shift.

The instrument has two main observing configurations, a "single object" mode that will access a narrow central field of 10″ diameter and a "multi-object" mode that can cover the full TMT field view of 20′ diameter. The "single object" mode provides several spectral resolutions (R∼1,00,000, 50,000, 40,000) using fibers as well as with slits. The highest resolution R∼1,00,000 mode, will have an additional precision radial velocity (PRV) mode. The multi-object mode will have a fixed spectral resolution of R∼40000 using fibers of larger diameter. Complete wavelength coverage for up to 6 objects is possible in the multi-object mode and objects can be chosen over anywhere in the 20′ diameter field of view. More number of objects can be observed with limited wavelength coverage, by blocking the echelle orders with order-sorting filters and etalons.

The design consists of two spectrographs for the complete wavelength coverage from 310 nm to 1100 nm. Blue spectrograph covers a wavelength range from 310 nm to 450 nm with single channel and the red spectrograph covers a wavelength range from 450 nm to 1100 nm having four channels.

Outreach Activities

Vigyan Samagam - a multi-venue mega-science exhibition organized to bring the world's major Mega Science projects together. This was India's first-ever, global Mega-Science exhibition. This was an year long exhibition which started from May 2019 and continued till March 2020. The event was organized in four cities - Mumbai, Bengaluru, Kolkata and Delhi and attracted people from all walk of life. The TMT was also a part of this and India-TMT had put up a booth with posters, working models, interactive portal, videos etc. in all the venues to involve students, academia and industry as major benefiters of the project. Vigyan Samagam event was a big success gathering nearly 3 lakh - 6 lakh visitors in every venue. Scientists and Engineers working with TMT/IIA participated in the outreach week and delivered interesting talks and presentations at every venue. Glimpses of the India TMT's efforts are shown in Figure 5.6.

5.2 Visible Emission Line Coronagraph on Aditya-L1

Visible Emission Line Coronagraph (VELC) is the most critical payload onboard India's first space solar mission Aditya-L1. It is an internally occulted solar coronagraph capable of simultaneous imaging, spectroscopy and spectro-polarimetry close to the solar limb. The uniqueness of the VELC is simultaneous observations in multiple wavelength bands closer to the limb from 1.05 $R_\odot$ ($R_\odot$ is solar radius) with high pixel resolution (≈2.5 arcsec & 1.5 arcsec). This payload is designed to study the coronal plasma and heating of the solar corona. Investigation of the development, the dynamics and the origin of Coronal Mass Ejection (CME) and the measurement of coronal magnetic fields over active regions are other important science goals. The VELC is designed to image solar corona at 500 nm with an angular resolution of 5 arcsec over an FOV of 1.05 $R_\odot$ to 3 $R_\odot$. It also facilitates simultaneous multi-slit spectroscopy at three emission lines viz Fe XIV (530.3 nm), Fe XI (789.2 nm) and Fe XIII (1074.7 nm)

Figure 5.6: *Various public outreach programmes organized by the TMT team during the Vigyan Samagam conducted during May 2019 - March 2020.*

with a spectral resolution of 28 mÅ/pixel, 31 mÅ/pixel and 202 mÅ/pixel respectively, over an FOV of 1.05 $R_\odot$ to 1.5 $R_\odot$. The payload has a dual-beam spectro-polarimetry channel for magnetic field measurements at 1074.7 nm. It is a multi-institutional project with IIA as the lead institution. Several ISRO centers such as the Space Applications Centre (SAC), the Laboratory for Electro-Optics Systems (LEOS), the Vikram Sarabhai Space Centre (VSSC), and the U. R. Rao Satellite Centre (URSC) etc., are developing various subsystems for this payload.

The VELC consists of 18 optical subassemblies, 4 detectors, 4 baffles and 4 mechanisms. All these are very critical in terms of requirements, specifications and finally performance to determine the ability of the payload to meet the proposed science goals.

Optics

Several of the custom designed and fabri-

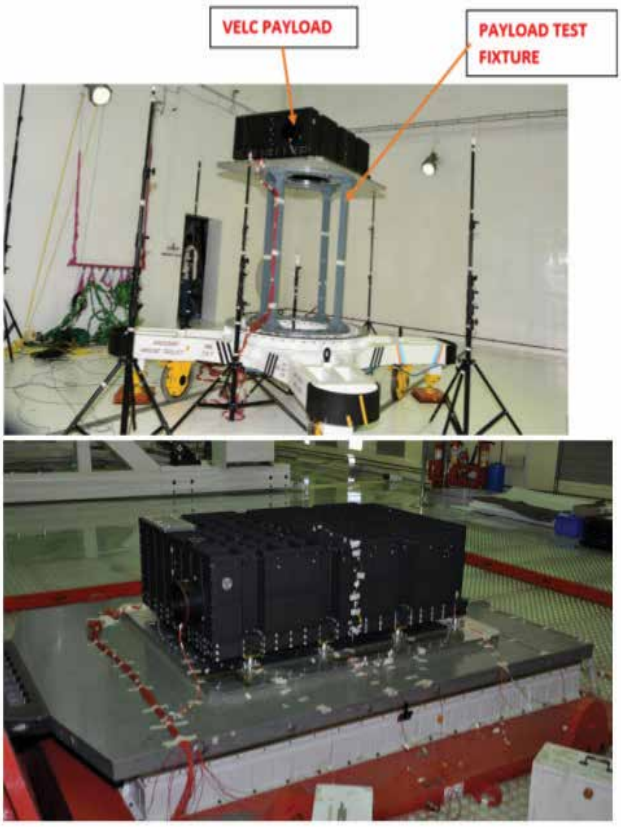

Figure 5.7: **Top:** *The VELC Lab Model at the ISRO Satellite Integration and Testing Establishment (ISITE) Acoustic Vibration Chamber;* **Bottom:** *The VELC Mass Model (Mass & Inertia simulation) on 29 Ton Shaker.*

cated optics are supplied by the LEOS. All these are tested and characterised for their performance at Prof. MGK Menon (MGKM) Laboratory for Space Sciences, IIA. These include primary mirror, secondary mirror, lens assemblies etc. Team-VELC procured several made-to-design optics such as narrow-band filters, gratings, retarders, polarisation beam displacers etc. Many of them are of non-space qualified grade optics and had to be qualified for space applications. Team-VELC set up state-of-the-art test and calibration facilities for the test and the qualification of these optics for their use in the VELC payload.

Mechanical systems and opto-mechanics

All the mechanical sub systems such as optical bench, opto-mechanical mounts for optics etc are designed and reviewed. Realization of Optical Bench of the VELC has been successfully completed and the bench is taken inside the MGKM laboratory after carrying out surface coating and thermal implementation to begin the payload integration. The optical bench is the primary element of the mechanical structure of the payload and demands very high levels of dimensional and geometrical tolerances. In order to control the residual stress due to material removal process, the part is subjected to heat treatment procedure at various stages. The optical bench is made of Titanium alloy material to achieve high level of stiffness with optimal mass and desired thermal co-efficient of expansion.

Team-VELC took the responsibility of fabrication of most of the important opto-mechanical mounts and delivered them to LEOS-ISRO for integration of optics satisfactorily. Several of the optics have been integrated into their respective opto-mechanical systems and have undergone environmental tests. All these systems have been tested for their required optical performance both pre and post environmental tests. Critical parts like the entrance aperture unit, primary and secondary baffles have been fabricated and made ready for integration.

Team-VELC and facilities teams at ISRO Satellite Integration and Testing Establishment (ISITE) carried out the environmental tests on the VELC-Mass model. These tests included the vibration tests in random and sine and the acoustic tests. Mass model of the VELC is tested for acoustic, random and sine vibrations. This helped in ascertaining

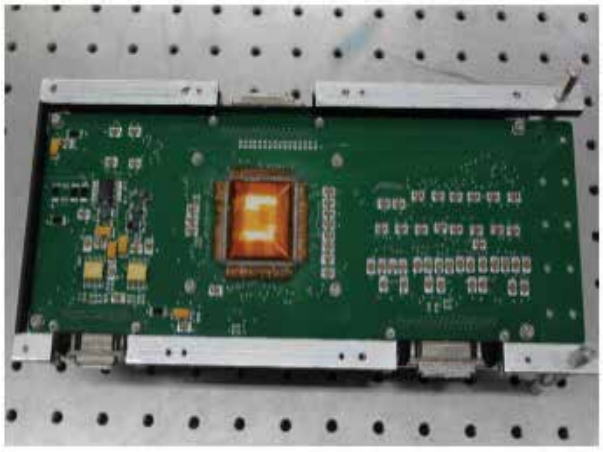

Figure 5.9: *Detector Head Assembly.*

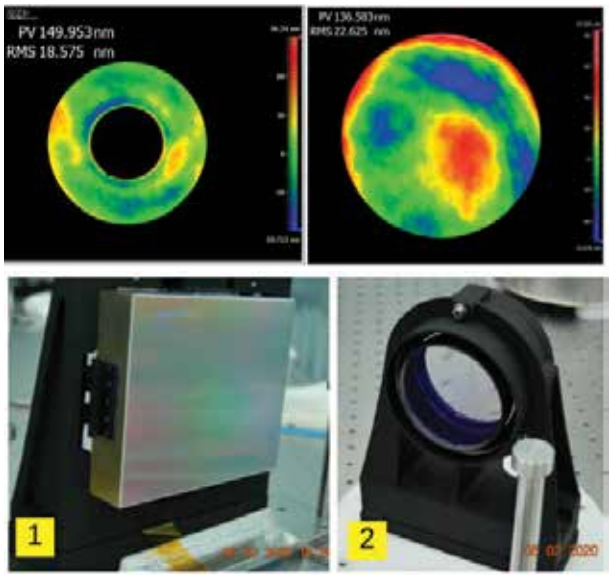

Figure 5.8: **Top:** *Cumulative wavefront error of collimating lens assembly, Quaternary mirror and Dichroic beam splitter-1.* **Bottom:** *(1) VELC Grating Assembly; (2) VELC Collimator Assembly.*

the appropriate levels and specifications for critical optical subsystems and detectors on the payload for implementation on the flight model.

Team-VELC is working with the ISRO thermal group in thermal implementation plans and fabrication and supply of some of the important hardware items. Fine tuning of the VELC thermal systems design is completed and all the required hardware are being fabricated. The VELC thermal systems implementation plans are also worked out jointly with URSC/TSG team and approved plans and procedures are in place.

Detector systems and data pipe-line

The VELC detector systems hardware is being realized at SAC. Detailed Detector Systems Calibration and Environment Test Procedures have been developed and are being implemented. Team-VELC participated in test and evaluation activities at the SAC as and when required. Based on the test and evaluation data, Detector Systems performance analysis is carried out and the results are being analysed. Continuum channel of the VELC payload has an automatic Coronal Mass Ejection (CME) detection logic on-board. The implementation of this logic on detector hardware is tested for its performance. All the electrical interfaces of the VELC payload with ADITYA-L1 spacecraft are finalized.

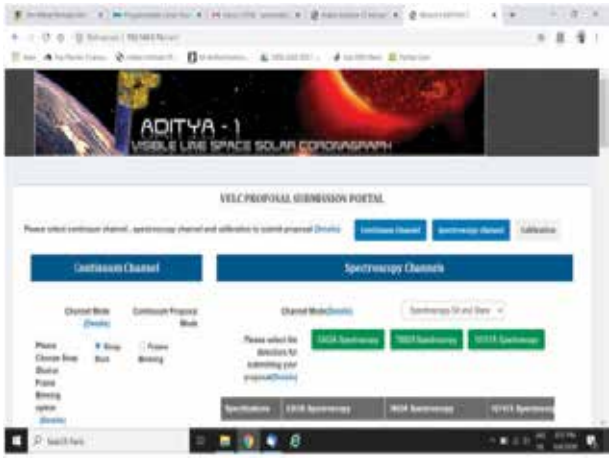

Figure 5.10: *VELC Observation Proposal submission form portal.*

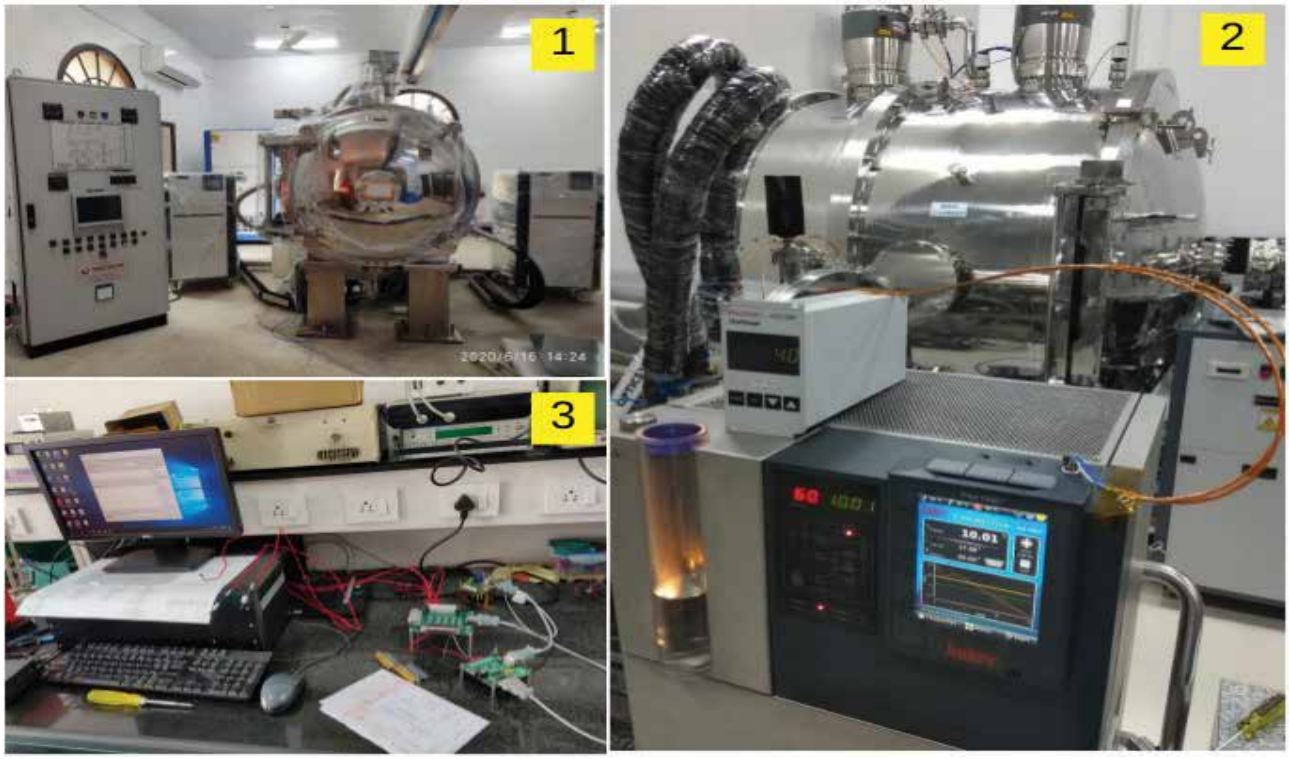

Figure 5.11: **(1)** *1m-class Thermo-Vac Facility;* **(2)** *0.5m class Thermo-Vac Facility;* **(3)** *VELC Temperature Monitor Setup (Microcontroller Based).*

Team-VELC has developed a web-based VELC observation proposal submission platform for the science community. This portal is self-explanatory and helps the science community to understand the payload capabilities. This enables them to structure the observation proposals accordingly to meet their science goals. This portal is reviewed by various committees constituted by the ISRO and has been approved. Team-VELC is working on the VELC data pipeline development and required software tools for analysis the observation data.

New facilities

The VELC and its subsystems have to go through several optical and environmental test and calibration protocols. These demand setting up of scatter measurement facilities, vacuum calibration facilities etc. Fume extractor for maintaining local cleanliness, Airborne particle counters, class 10 air set up for 18 m long scatter tube, GN2 purity measurement set up, ultra clean desiccators, etc., are the latest addition of facilities at the MGKM Laboratory for Space Sciences for the VELC.

The VELC sub systems have to go through thermal cycles and their required performances have to be verified at operational temperatures. To enable these measurements, two different capacity thermos-vac chambers were designed and developed by Team-VELC for testing of the VELC subsystems. The larger facility (Figure 5.11) is of one meter diameter and can accommodate payload (DUT) size of ϕ850 mm$\times$2000 mm (L) and the testing range varies between -70 deg C to + 150 deg C with 10^{-6} mbar vacuum. The smaller facility (Figure 5.11)

is of 600 mm diameter is developed for calibrating the smaller components including detector systems. For TVAC test of Payload, microcontroller based temperature control and monitoring setup is developed and tested at IIA.

VELC Integration

A Class-10 clean facility was developed for integration and calibration of the VELC due to the stringent contamination, both molecular and particulate, control requirements. All the required contamination control and measurement process are detailed out and have been implemented successfully. In order to meet the desired performance requirements, the subsystems should be aligned within the given tolerance limits. Several tests, both optical and mechanical, have to be carried out at different stages of the integration process. Many of the optical and mechanical sub-assemblies are ready for integration. A detailed process plan for optical & mechanical integration and alignment checks was prepared and the same was presented before an ISRO appointed Test Plan committee for approval. The Test Plan Committee had several rounds of reviews with team-VELC and cleared the document for integration and calibration of the payload. Payload integration activities are being carried out by the Team-VELC.

5.3 Seed Funded Project: Indian Spectroscopic and Imaging Space Telescope

In response to the call for future astronomy mission by the ISRO, a proposal for a 1 m class UV-Optical imaging and spectroscopic space telescope, named as "Indian Spectroscopic and Imaging Space Telescope (INSIST)" was submitted in April 2018. After a review of all proposals, INSIST was awarded seed funding of 30 Lakh, for a year of pre-project phase, in March 2019. Combining a large focal area with an efficient optical design, INSIST is expected to produce HST-quality imaging and moderate resolution multi-object spectra of astronomical sources. The main science drivers for this mission span a wide range of topics, starting from evolution of galaxies in groups and clusters, chemodynamics and demographics of the nearby universe, stellar systems with accretions, to stars with planetary systems, to cosmology near and far.

Major achievements during pre-project phase:

[1] Indian partner share capabilities and possibilities identified.

[2] Joint meeting with the international partner (CSA- CASTOR mission) held in September 2019. INSIST and CASTOR teams agree to have a joint mission. The top-level joint optical design finalized. The down-select of on-axis versus off-axis optical design completed using trade studies based on scientific requirements and technical aspects.

[3] The UV multi-object spectroscopic capability demonstration is being carried out. The UV multi-object spectrograph (UV-MOS) based on Digital Micro mirror device under fabrication in IIA.

[4] The optical design incorporated to have a slit-less spectroscopy mode as a valuable additional capability for UV-MOS.

[5] Initial discussions with mission team to optimize the design with respect to mass and volume budget.

Currently, the INSIST project has com-

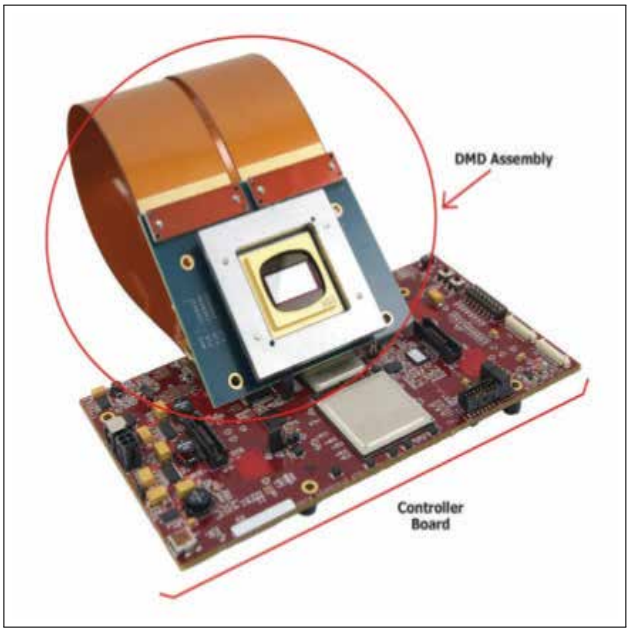

Figure 5.12: *Commercial DMD Controller currently being tested at IIA for the INSIST project.*

pleted a conceptual design as well as a preliminary design and has reached the maturity to start the final design phase. The CASTOR-INSIST teams agree to work for a joint mission. The next phase requires close coordination with the mission team to finalise various parameters such as the mass, volume, thermal, power, data rates, orbit details etc.

Figure 5.13: **Left:** *Six glass blanks trepanned from parent glass blank using core drilling machine.* **Right:** *Curve generated parent glass blank with six mirror segments.*

Meanwhile the INSIST team is engaged in the development of a lab model of a spectrograph to test the working of the DMD which includes the working of its control system. There is a plan to test this spectrograph on a 1 m class telescope to make observations on a bright star to perform photometry and spectroscopy by giving appropriate tilts to the DMD mirrorlets. Recently, a multi-mirror fabrication was made by the optics group for using them in the construction of the spectrograph. Six glass blanks of required size are trepanned from a parent glass substrate by core drilling tool as shown in Figure 5.13. The parent blank was ground to generate the required Radius of Curvature (ROC) and polished to the specification as a single glass blank as shown in Figure 5.13.

5.4 National Large Solar Telescope

National Large Solar Telescope (NLST) is a proposed ground based 2-m class optical and near infra-red (IR) observational facility to be set up at the Merak site at Ladakh. It is designed to address key scientific issues related to origin and dynamics of solar magnetic fields at a spatial resolution of 0.1-0.3 arc-second. Apart from having an array of instruments, the telescope will also be equipped with a high-order adaptive optics (AO) package to produce close to diffraction limited performance.

In March 2019 DST gave the first installment of the budget approved for the NLST project to procure land. Subsequently, a payment was made to the forest department of the earlier Jammu and Kashmir (J & K) Government. IIA has received a no objection certificate from the earlier J & K Government to proceed with the procurement of

the land for the project. Necessary paperwork to lease the land is in progress with the Ladakh administration. In June 2019, the Standing Finance Committee (SFC) document was circulated to the Department of Expenditure (DoE), Department of Space (DoS), Niti Aayog, Ministry of Human Resource Department (MHRD) and principal scientific adviser to the Indian Government. The responses with some queries were received to which in November replies were sent to all the above mentioned departments. The final approval of the project is expected sometime in the middle of 2020.

In the mean time, at the site, embankment work was taken up. More works are planned at the site to protect it from erosion and water seepage into the incursion site.

5.5 National Large Optical - Near Infrared Telescope

As a part of 2019 Astronomical Society of India annual meeting held at the Christ (Deemed to be) University, Bengaluru, a one-day workshop was organized by IIA to garner a wider national level participation in our effort to build a 10 m class telescope in India. A brief report of the decisions taken during the meeting was reported in the 2018-19 Annual Report. Of the several action items, one of the action items was to submit a detailed project report that briefly describes the background, scientific motivation, efforts that are being carried out at IIA for the National Large Optical-Near Infrared Telescope (NLOT) and finally request for an initial budget for the preparation of a DPR. It was decided in the meeting that IIA will lead this action item and submit this report to the DST, its funding agency, for further action.

Accordingly, IIA submitted a report to the DST in June 2019. In addition to other details, a concept design was also given in the report submitted to the DST. The primary mirror will be segmented, about 10-12 meter in diameter, with an F-ratio between 1.5 and 1.8. The NLOT primary mirror will consists of 60 mirror segments. Each segment will be of size 1.44 meter and thickness 45 mm and will be made of zerodur glass due to its high thermal stability. Each segment will be mounted on 27 point whiffletree segment support assembly. A study was conducted at IIA to understand the segment surface deformation due to thermal effect on the SSA. The thermal distortion arises because of the coefficient of thermal expansion (CTE) mismatch between the SSA and the glass. The study was carried out for 10°C change in temperature. The primary error induced on the mirror surface was power (∼3 nm) as expected. The higher order distortion observed on the mirror surface after subtracting the power from deformed surface (see Figure 5.14).

5.6 Prototype segmented mirror telescope

In order to understand the complexities of the segmented mirror technology which will provide us with sufficient expertise in the design of NLOT, a 1.5 meter size prototype segmented mirror telescope (PSMT) is proposed. The PSMT will have subsystems similar to those one can expect in any large segmented mirror telescope. The proposed prototype telescope will use seven hexagonal mirrors, which will be supported by simple mirror support assembly and driven by indigenously developed voice coil based actuators. We also plan to make use of in-house devel-

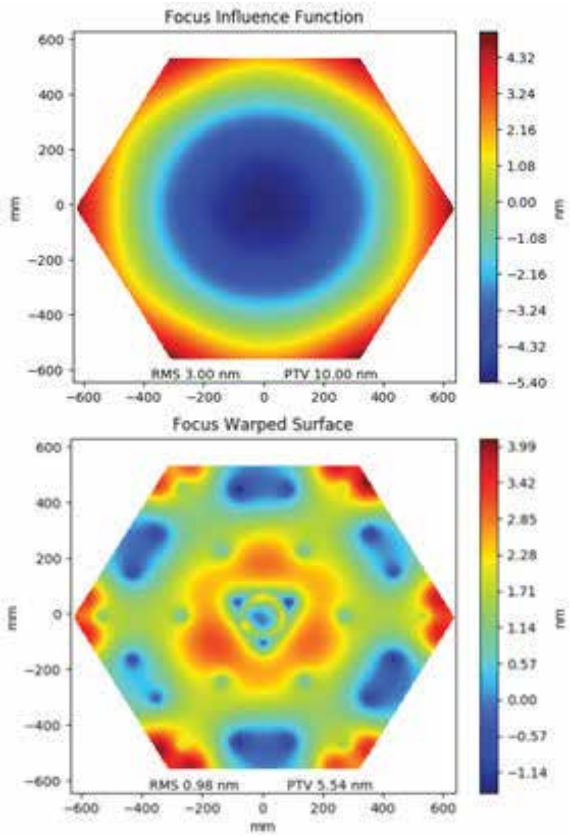

Figure 5.14: **Top:** *Thermal distortion on segment due to the temperature change of 10° C. The primary error is power ∼2.6 nm.* **Bottom:** *Power alone (∼3 nm) seen on segment due to the temperature change of 10° C.*

oped inexpensive inductive edge sensor. The entire development activities is divided into two phases. In the first phase, a seven segments laboratory test bed will be developed, and in the second phase the full-fledged telescope will be realized.

The phase-I labratory setup consisting of 7 mirror segments is under development. Each segment will be placed on indigenously designed segment support and driven by three actuators. The sides of these segments will be populated with inductive edge sensors. To understand the effect of the variable gravity on the mirror control, the primary mirror will be mounted on motorised mount which will allow PM to swing in elevation direction. A Shack-Hartman (SH) based alignment and phasing device will be mounted at the prime focus. The performance of the primary mirror control (M1CS) will be judged based on the optical feed back coming from the SH. At present, the design and analysis of the mechanical aspects of the PSMT phase I has been completed and many subsystems linked with the test bed are at various stages of realization.

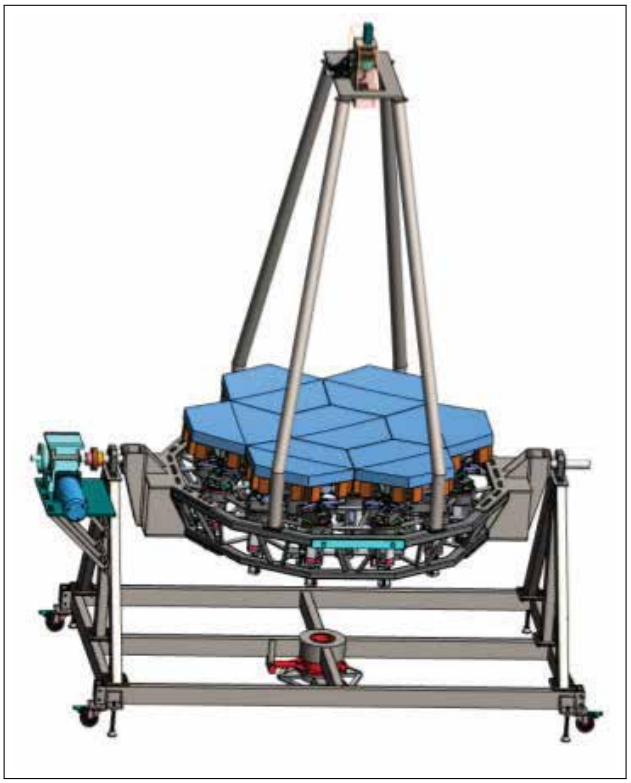

Figure 5.15: *Mechanical model of the PSMT phase-I, which is a seven segment laboratory setup to test control of the segmented primary mirror.*

The most complex subsystem of the test bed is the segment support, which is indigenously designed. The first prototype is undergoing assembly and testing phase at IIA workshop. The design of the segment support actuator has been improved and the second prototype (P2) which is quite compact in the

Figure 5.16: **(1)** *Partially assembled segment support;* **(2)** *Part of the mirror cell;* **(3)** *The P2 actuator.*

form is going through the performance test in the laboratory. The PSMT phase-I requires a customized Shack Hartman, and effort is being carried out to design its optics as well as electro-mechanical components.

5.7 Maunakea Spectroscopic Explorer

Maunakea Spectroscopic Explorer (MSE) is a planned 11.25 m aperture segmented telescope dedicated to carry out multi-object spectroscopic facility, with an ability to simultaneously measure thousands of objects with three spectral resolution modes respectively low resolution of R≈3,000, moderate resolution of R≈6,000 and high resolution of R≈40,000.

In collaboration with the MSE, IIA is involved in (a) the development of an SSA for the primary mirror segments and (b) the estimation of error budget in the image quality. The primary mirror of the MSE telescope has 60 segments in total with each of them measuring 1.45 m in diameter. Together, they give the monolithic shape to the primary mirror.

The scope of the development of the primary mirror system for MSE includes design & optimization of the SSA to support the MSE primary mirror segments, finite element modelling & simulation for the MSE mirror segments, optimisation of the mirror figure for static, dynamic and thermal loads for both zenith and horizon pointing scenarios and development of the primary mirror segments support cells. In this regard, the mirror level/print thru finite element modelling and simulation was completed. Structural analysis was carried out for the zenith pointing of the primary system and the thermal analysis for a change of 10 deg in temperature was conducted.

The M1 mirror systems in TMT, MSE and our proposed 10 m class NLOT are all of similar dimensions. Hence, the experience gained from the TMT and MSE will be highly beneficial for the realization of the NLOT. The planned activities for the MSE include a dynamic analysis for the SSA to be carried out for various angle of orientations, effect of wind loading on the structural analysis of mirror segment supported with the SSA and a final optimization and finer adjustments of actuator.

6

Public Outreach

As one of the premier institutes engaged in carrying out research and development in the fields of Astronomy & Astrophysics, IIA is committed to engage with the public to share exciting results and disseminate our research findings in a simpler and more effective manner. The Public Outreach Committee (POC) of IIA is responsible for this activity. The outreach activities carried out during 2019-2020 are detailed below.

6.1 Annular Solar Eclipse on 26 December 2019

The rare phenomenon of the annular solar eclipse occurred on 26th of December 2019. The annularity was visible from many countries including southern India. IIA outreach team made elaborate arrangements at the IIA main campus in Bengaluru and at its campuses at Kodaikanal, Kavalur and Hanle to not only show the eclipse to the public but also to impart awareness of how to view it safely. A number of other events like talks and live presentations were also organized along with the live streaming of the event. The event was widely publicized through a flyer designed for the purpose. Around 300 people visited the IIA Bengaluru campus to witness the event. The Outreach team had arranged two projection screens. One was to show the coelostat set up for the viewing of the eclipse and another was to project the solar eclipse live streaming from the Kodaikanal campus, where the annularity was 96.3% . A live commentary was also given as the event progressed. The eclipse started at around 8.09 am, peaked at around 9.26 am and ended at around 11.11 am. There were three talks delivered by Dr. Chrisphin Karthick, Dr. Ravinder Banyal on the solar eclipse and Mr. P. K. Mahesh on instrumentation and techniques used in Astronomy & Astrophysics research. The team also gave a practical explanation and demonstration of the coelostat instrument.

6.2 National Science Day Celebrations

National Science Day event is celebrated every year on 28 February to commemorate the discovery of the phenomenon of scattering of photons which was later known as *Raman Effect* by renowned Indian scientist Sir Chandrasekhara Venkata Raman in 1928. Every year we conduct several programmes at our main campus at Bengaluru and at our other campuses. The main purpose of the celebrations are:

- to widely spread a message about the significance of scientific applications in the daily life of the people,

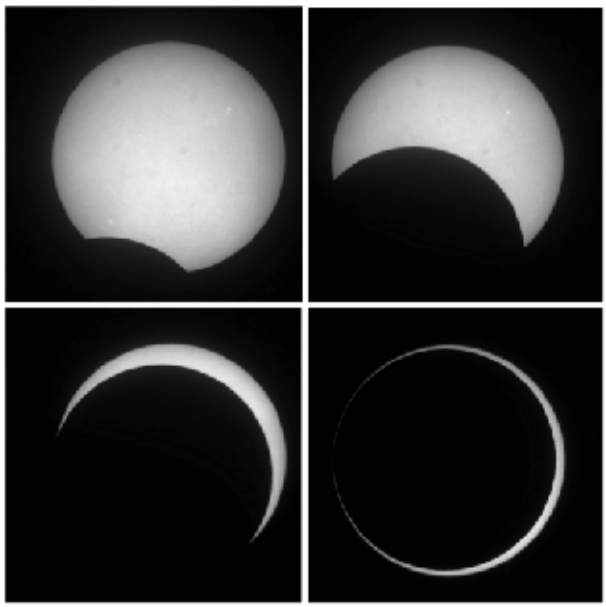

Figure 6.1: *Annular solar eclipse, occurred on 2019 December 26 at ∼04:00 UT (∼09:30 IST), imaged with the Hα telescope at Kodaikanal.*

- to display all the activities, efforts and achievements in the field of science for the welfare of human beings,
- to discuss all the issues and implement new technologies for the development of the science,
- to give an opportunity to the scientific minded citizens in the country to explore the progress happening in the field of Astronomy & Astrophysics,
- to encourage the people, especially the younger minds, as well as popularize the Science & Technology.

This year, a total of eight schools participated in the event at IIA's Koramangala campus. 126 students and nine teachers attended the events. In addition to them, individuals affiliated to various schools also participated the events taking the total to around 150. We conducted drawing and essay competitions for the students. About 30 students participated in the drawing competition and 35 students participated in the essay competition. The rest were taken to various institute facilities, displayed how observations of the Sun are made using the coelostat, and gave demonstrations of several science experiments by our research scholars and post doctoral fellows. A special lecture by Dr. Sharanya Sur, on the topic:*The Magnetic Universe – Deciphering the invisible* was also arranged for the students. A quiz competition was conducted which had participation from four schools. Prizes (Books and Certificates) were distributed to the winners of the various competitions along with some consolation prizes for their participation in the events.

A Public Lecture titled, *The Moon and Beyond -A Neil Armstrong Retrospective and Perspective* was delivered by Prof. Jayant Murthy in the evening. This was attended by around 200 people from all walks of life. The public lecture was followed by a night sky-watching programme, organized for all the visitors.

National Science Day celebration at the CREST Campus in Hoskote and Indian Astronomical Observatory

National Science Day celebration was organized at the CREST Campus in Hoskote. An open house was conducted with more than 150 students and teachers participating from different schools. The students participated in drawing, quiz and essay writing competitions, and also interacted with the scientists. Highlights of Institute's activities were explained to the students through posters and working models. Remote operation of 2-m HCT, IAO, Hanle was also demonstrated with Video-conferencing. CCTV footage of MGK Menon lab was shown to the students. The event was convened by Prof. B. C. Bhatt with support from other scientific, technical and administrative staff.

Figure 6.2: *National Science Day celebrations at IIA campus Bengaluru. [1] Students participating in drawing competition; [2] Drawings made by the students; [3] Students viewing the displayed drawings; [4] & [5] The special lecture delivered by Dr. Sharanya Sur; [6] Popular level talk delivered by Prof. Jayant Murthy; [7] Students viewing through telescope; [8] Students after the sky-watching programme.*

A lecture on basic astronomy was delivered by Mr. Namgyal Dorgey at the Kendriya Vidyalaya, Leh.

National Science Day celebrations at VBO

The National Science Day celebrations at VBO, Kavalur was attended by the 6th and 9th standard students from eight Government schools. The celebrations were held on the 28th of February. A trip to various facilities of the observatory was arranged for the students. Presentations were made highlighting the importance of the observatory location, about different types of telescopes that are available at VBO and about the kind of research that is happening using the data obtained with the telescopes. The students were also told about various colors of the stars in which they appear in the sky and the reason for the same. The students also visited the Visitors' Gallery.

National Science Day celebrations at Kodaikanal Observatory

The National Science Day was celebrated

on 28th of February at the Kodaikanal Observatory. The event was participated by students from Kodaikanal region and took part in various competitions. Prizes and medals were distributed to the winners of various competitions.

Figure 6.3: *Students of Mt. Zion High School at Kodaikanal Observatory.*

6.3 Joint Outreach Programmes

IIA - Cambridge Academics Joint Outreach Programme

IIA and University of Cambridge jointly conducted a 6 day outreach programme in the Ladakh region during 12th-17th April 2019. The team consisted of Dr. Jack Williams and two other members from the University of Cambridge, and four PhD students from IIA. Around 3000 students from six schools participated in the event.

Presentations and lectures on topics like astronomy tools to observe the night sky, basics on telescope designing, concept of electric charge, functioning of electric motor, total internal reflection, pitch of sound waves, cryptography, solar astronomy, journey through the universe, entropy, theory of curvature and number theory and general theory of relativity were delivered. Students from the following schools participated in the programme:

a) Govt. boys higher secondary school, Leh
b) Govt. girls higher secondary school, Leh
c) Druk Padma Karpo school, Shey
d) Lamdon model senior secondary school, Leh
e) Moravian mission school, Leh
f) Hanle school, Hanle
g) Nomadic residential school, Puga Changthang

IIA - Southern African Large Telescope joint outreach Programme

On 7th November 2019, IIA along with the Southern African Large Telescope (SALT) conducted a joint outreach program at the Lamdon Model Senior Secondary School, Leh. Prof. David Buckley from SALT and Prof. Padmakar Parihar from IIA gave presentations to around 600 students who participated in the event.

Figure 6.4: *Prof. David Buckley of the Southern African Large Telescope making a presentation at the Lamdon Model Senior Secondary School, Leh.*

6.4 Teacher Training programme

The IIA outreach representatives have received a grant from the International Astronomical Union (IAU) to organize a training programme for school teachers. The main objective of the programme is to provide training to teachers on how the basic science / Astronomy experiments can be explained to their school students in a simple and elegant manner. These teachers are expected to promote Astronomy among school children. The Government school at Devanahalli was identified as the location for the event this year. About 40 teachers from various schools and 100 students from Government school, Devanahalli attended this programme. Basic science experiments covering the topics such as optics, acoustics, electromagnetism, classical mechanics, etc. were demonstrated. The IAU grant was used to procure instruments, science kits, etc., and were donated to the teachers who took part in the programme. IIA's former faculty member Prof. P. R. Viswanath delivered the keynote address.

6.5 Visits of school students and general public to IIA campuses

A group of 40 students from the City Montessori School, Lucknow visited IIA during May, 2019. The participants visited the Optics division. A poster session was arranged to introduce the observing facilities and explain the ongoing research programmes of IIA. One of our faculty members delivered a scientific talk to the school children.

Every year students selected through the Jagadish Bose National Science Talent Search (JBNSTS) programme visit IIA. Last year, the team visited IIA in July 2019. Initiated by Pandit Jawaharlal Nehru, JBNSTS is an autonomous Society that identifies, nurtures young talented minds of science and engineering by providing scholarships to them. The students visited both IIA main campus and the CREST campus at Hosakote. Scientific talks were also delivered during the event.

Figure 6.5: *National Science Day celebrations at VBO.*

School Students' visit to VBO

Night sky watching programme is organized at VBO on every Saturday. Using a 6-inch telescope, installed for this purpose, visitors are allowed to view interesting astronomical sources available in the sky. The visitors are also allowed to take a tour of Vis-

itors' Centre where posters and videos illustrating the history of the VBO and an introduction to the Astronomy and Astrophysics are displayed. Since 15 February 2020, the programme is on a hold because of the Covid-19 pandemic. Prior to this, a total of 13,427 visitors which include 2,364 school students and 1,173 college students visited the observatory. Apart from the general visitors' programme on Saturdays, the school and college students are permitted, in restricted numbers, to view the 2.34 metre VBT. The research activities carried out with the telescope were explained to them.

Visits of school students and general public to IAO

Every year a sizable number of people visit the observatory. In 2019, around 1,500 people visited the IAO Hanle. Of these, students from five schools belonging to the Ladakh region also visited the observatory. The District Magistrate, Senior Superintendent of Ladakh Police and Sub Divisional Magistrate of Nyoma division were also among the visitors this year.

Visits of school students and general public and other events at Kodaikanal Observatory

As a part of the International museum day which is celebrated worldwide on 18th May, events were organized at Kodaikanal Observatory. The main aim of the celebration was to raise awareness among people about the museums as an important means of cultural exchange, dissemination of ideas and information, develop scientific temper among people. The observatory museum displays posters and models to explain wide topics like Solar System, Big Bang theory, Galaxies to the extend of observable Universe. It also provides explanations on various celestial objects. Models of the ASTROSAT, upcoming NLST, ionospheric recorder, transit instrument is also available. A glimpse of the HCT was provided to the visitors through a video presentation.

Figure 6.6: *School students who visited Kodaikanal Observatory.*

The outreach center in the campus works from Monday to Saturday from 10:00 am to 12:00 pm and 2:00 pm to 4:00 pm except Sundays. Last year, a total of 35,749 people from various regions of India visited the observatory. Among those, 5,096 were from various colleges and 2,733 were from various schools which includes teachers as well.

7

Other scientific activities

7.1 Talks given in National/International Meetings outside IIA

Invited:

Annapurni Subramaniam

- *Stellar Population Studies: Insights from UVIT,* 12 April 2019, Physics Department, IISc, Bengaluru.
- *Observatory Software of the Thirty Meter Telescop,* 17 October 2019, I-TMT science and instruments workshop, ARIES, Nainital.
- *Proposed new UV mission: INSIST,* 17 February 2020, ASI meeting, IISER, Tirupati.
- *Stellar Population Studies: Insights from UVIT,* 5 September 2019, Seminar at IAP, Potsdam.

Arun Mangalam

- *On the rate of Stellar consumption by black holes,* 17 April, 2019, 4th RETCO meeting, IUCAA, Pune.
- *Black Hole Science with TMT,* 17 October 2019, I-TMT science and instruments workshop, ARIES, Nainital.
- *Formation, evolution, and distribution of SMBH mergers,* 16 December 2019, Supermasive black holes, ICTS, Bangalore.
- *Stellar Dynamics around black holes,* 19 December 2019, Supermasive black holes, ICTS, Bangalore.

Aruna Goswami

- *Stellar Structure and Evolution : Evolution of low-mass stars,* 31 May, 2019, IIA Summer School , Kodaikanal Solar Observatory.
- *Stellar Structure and Evolution : Evolution of massive stars,* 31 May, 2019, IIA Summer School , Kodaikanal Solar Observatory.
- *Metal-poor stars and Galactic chemical evolution,* 01 June, 2019, IIA Summer School , Kodaikanal Solar Observatory.
- *Stellar Archaeology with metal-poor stars,* 2 March, 2020, Workshop on Investigating the Stellar Variability and Star Formation.

Bacham Eswar Reddy

- *Unravelling Story of Lithium in Red Giants,* 17th September, 2019, NAOC, Beijing

- *Stellar Structure and Evolution : Evolution of low-mass stars,* 15 October, 2019, Beijing Normal University, Beijing.
- *Lithium in Red giants: Current Status,* 18 November, 2019, IIA Summer School , Kavali Institute, Peking University, Beijing.

Brajesh Kumar

- *Polarimetry: A tool to understand the geometry of Supernovae,* 14-18 October 2019, Time-domain astronomy workshop, Tohoku University, Sendai, Japan.

Chrisphin Karthick

- *A brief History of Astronomical Research,* 27 September 2019, National conference on Advances in Mathematical and Applied Sciences, Dr. MGR- Janaki College of Arts and Science for Women, Chennai.

C. S. Stalin

- *Narrow Line Seyfert 1 galaxies,* 17-20 April 2020, 4th National Conference on RETCO, IUCAA, Pune.
- *Narrow Line Seyfert 1 galaxies: the current scenario,* 13-17 February 2020, ASI meeting, IISER, Tirupati.
- *High Energy Astronomy,* 27-29 November 2019, National Seminar on Astrophysics, Calicut University.
- *Transient Blazar Flares: Discovery and Multi-wavelength Follow-up,* 11-12 November 2019, National Conference on Transient Astronomy, URSC, ISRO, Bangalore
- *Observational Astronomy,* 25 February 2020, Workshop on Space Science, K.S. Rangasamy College of Arts & Science, Tiruchengode, Tamil Nadu.

E. Ebenezer Chellasamy

- *Solar Radio Astronomy,* 6-17 January 2020, COSPAR Capacity Building Workshop on Coronal and interplanetary shocks: Analysis of data from Space and Ground based Instruments.

G. C. Anupama

- *Transients with IIA's optical observatories,* 4 December, 2019, Indo-Chile Astronomy Dialogue, IUCAA, Pune.
- *Time Domain Astronomy - A Case Study for Indian Astronomy, Present and Future,* 17 February, 2020, BASI-2020 Meeting, IISER, Tirupati.
- *Recurrent novae: single degenerate progenitors of Type Ia supernovae,* 18 December, 2019, 150 years of Periodic Table, IIA Bengaluru.

Maheswar Gopinathan

- *Distance to Molecular Clouds using M-dwarfs from Pan-STARRS photometry and Gaia DR2 parallaxes,* 10 May, 2019, Korea Astronomy and Space Sciences, S. Korea.

Mousumi Das

- *Star Formation in the Outer Disks of Galaxies,* 19 December 2020, Indo-Japan Subaru Collaboration Meeting, TIFR, Mumbai.

- *Tracing the Evolution of Gas Rich Disk Galaxies into Radio Loud Ellipticals using Millimeter Observations,* 11 January 2020, First meeting on Submillimeter-wave/Terahertz astronomy from India, RRI, Bangalore.
- *The Dynamical Mass Distribution in Galaxy Disks and its Implications for Outer Disk Star Formation,* 14 February 2020, Astronomy Society of India (ASI 2020), IISER Tirupati.

Pravabati Chingangbam

- *Introduction to scalar and tensorial Minkowski functionals,* 20 July, 2019, Geometrical and topological methods for cosmological data analysis, NISER, Bhubaneshwar.
- *Symmetry in randomness in the Universe,* 20 September 2019, Pressing for Progress, University of Hyderabad.
- *Cosmology using sub-millimetre observations,* 11 January, 2020, Indian Sub-millimetre Astronomy Meeting, RRI, Bangalore.

R. T. Gangadhara

- *Mini-workshop on Understanding pulsar Radio Emission,* 29 September, 2019, YunNan Univ. , Kunming, China.
- *FPS-Special meeting: Magnetospheric Dynamics: Collective Radio Emission due to Relativistic Plasma,* 11-13 October 2019, Fragrant Hill Hotel, Beijing, China.
- *Mini-workshop on Pulsar Radio Emission Mechanism and polarisation,* 24 October, 2019, NTSC-CAS, Xi'an, China.

Sharanya Sur

- *Decaying turbulence and magnetic fields in galaxy clusters,* 23-24 January 2020, National Conference on Plasma Simulations, Institute for Plasma Research (IPR), Gandhinagar.

Smitha Subramanian

- *VMC galaxy structures,* 12 September 2019, ESO 2019 Workshop: A synoptic view of the Magellanic Clouds: VMC, Gaia and beyond.

Sridharan Rengaswamy

- *Adaptive Optics,* 12 November 2019, International Conference on Optomechatronic Technologies, (ISOT2019), Goa.

Sujan Sengupta

- *Mathematical Modelling of Exo-Planetary Atmospheres,* 10 January 2020, National Seminar on Mathematical Sciences - 2020, Department of Mathematics, University of Burdwan.

Vivek. M

- *Outflowing winds in active galaxies,* International Conference on Theoretical and Experimental Physics (ICTEP2020), Department of Physics, Farook College, Kozhikode, Kerala, India.

Contributed:

B. P. Hema

- *Investigating the Helium-enhancement in the Super Lithium Rich K-giant HD 77361,* 17 December 2019, 150 years of the Periodic Table: Chemical Elements in the Universe, IIA, Bengaluru.

C. Muthumariappan

- *Infrared properties of PNe with WR type central star. Oral presentation,* 22-26 October 2019, International Conference on Infrared Astronomy and Astrophysical Dust, IUCAA, Pune.

K. Nagaraju

- *Diagnosing chromospheric magnetic field through simultaneous spectropolarimetry in Hα and Ca II 854.2 nm,* 30 June - 6 July, 2019, IAU Symposium No. 354, Copiapo, Chile.
- *Sunspot magnetometry in Hα and Ca II 854.2 nm spectral lines,* 13-17 February 2020, IISER, Tirupati.
- *Proposed Back-End Instruments for the National Large Solar Telescope,* 13-17 February 2020, IISER, Tirupati.

Mousumi Das

- *Dual Active Galactic Nuclei and their Importance for Galaxy Evolution : discussion,* 18 December 2019, SMBH Discssion Meeting, ICTS, Bengaluru.
- *Studying Star Formation in the Outer Disks of Galaxies using the UVIT,* 27 June 2019, European week of astronomy and astrophysics SS5: Extragalactic UV Astronomy, Lyon, France.

P. Vemareddy

- *Time Evolution of Helicity flux from Eruptive and Non-Eruptive Active Regions,* 02 February, 2020, APSPM, IUCAA, Pune.

Smitha Subramanian

- *Galaxy Scaling Relations,* 13 February 2020, ASI meeting workshop.

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

Invited:

Annapurni Subramaniam

- *Observatory Software of the Thirty Meter Telescope,* 16 September 2019, META conference, IIA.

C. Muthumariappan

- *Introduction to IR Astronomy (3 lecture 3 tutorials),* 16-30 May 2019, Kodaikanal Solar Observatory, Indian Institute of Astrophysics Kodaikanal.

E. Ebenezer Chellasamy

- *Introduction to Kodaikanal Solar Observatory,* 23-27 September 2019, Young Astronomers meet at Auditorium, Kodaikanal Solar Observatory.
- *Solar Radio Astronomy,* 6-17 January 2020, COSPAR Capacity Building Workshop on Coronal and interplanetary shocks: Analysis of data from Space and Ground based Instruments.

G. C. Anupama

- *Recurrent novae: single degenerate progenitors of Type Ia supernova,* 18 December 2019, 150 years of Periodic Table, IIA Bengaluru.

Gajendra Pandey

- *Stellar Spectroscopy I, II, III,* 23-25 May 2019, Kodai Summer School 2019, Kodaikanal

Mousumi Das

- *Dark Matter Distribution in Galaxies and its Importance for Disk Equilibrium in Low Luminosity Galaxies,* 24 September 2019, Young Astronomers Meeting 2019, Kodaikanal Solar Observatory.
- *Summer school lectures,* May, 2019, Kodaikanal Solar Observatory.

Contributed:

Brajesh Kumar

- *Polarimetric investigation of supernovae,* 11 September 2019, IIA Seminar, Bengaluru.
- *Observational signature of circumstellar interaction and 56Ni-mixing in the Type II Supernova 2016gfy,* 23 January 2020, In-house meeting 'Stars and Galaxies', IIA, Bengaluru.

Smitha Subramanian

- *Structure and Evolution of the Magellanic System,* 19 February, 2020, Meeting on Magellanic Clouds, IIA, Bengaluru.

Sridharan Rengaswamy

- *Astronomical Instrumentation,* May 31 -June 1, 2019, Summer School at Kodaikanal.
- *Speckle Imaging and Adaptive Optics for Solar High Resolution Imaging (in Ground-based instrumentation for solar astronomy,* 13 February 2020, IISER Tirupati.

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

Annapurni Subramaniam

- *Foundation Day talk,* 19 December 2019, IUAC, New Delhi.
- *Science day lecture,* 28 February 2020, NAL, Bengaluru.

Arun Mangalam

- *Astrophysically useful solutions to trajectories around a Kerr black hole,* 18 June 2019, DAA, TIFR, Mumbai.
- *Relativistic Dynamics in black hole systems,* 21 June 2019, Physics Department, IIT Mumbai.
- *Stellar Dynamics around black holes,* 22 June 2019, Physics Department, IIT Mumbai.

C. S. Stalin

- *Astronomy from Ground and Space,* 13 November 2019, Scott Christian College, Nagercoil.
- *Optical Astronomy,* 13 April 2019, Christ College, Malur.

E. Ebenezer Chellasamy

- *Annular Solar Eclipse,* 12 December 2019, Nandha Arts and Science College, Erode, Tamil nadu.

G. C. Anupama

- *Time Domain Astronomy,* 5 September 2019, RRI, Bengaluru.

Gajendra Pandey

- *Stellar Spectroscopy,* 13 July 2019, MPB-IFR, Bengaluru.
- *The exotic stars: Extreme Helium and R CrBs,* 31 October 2019, REVA University, Bengaluru.

Mousumi Das

- *Star Formation in the Extended Disks of Nearby Galaxies,* 30 January 2020, Department of Astronomy, University of Maryland, USA.
- *CHERA summer school lectures,* 4 July, 2019, Gauribidnur radio observatory, Raman research institute, Gauribidnur.
- *Dual Nuclei Galaxies in Merger Remnants and their Importance for Galaxy Evolution,* Pressing for Progress meeting, All India Physics association, Hyderabad Central University.

Pravabati Chingangbam

- *Morphology of lensed CMB fields,* 2 May, 2019, KIAS, Seoul, S. Korea.
- *Minkowski tensors as probes for cosmological fields,* 3 July, 2019, Ecole Normale Superieure, Lyon, France.

R. T. Gangadhara

- *Given colloquium talk on "Mechanism of Pulsar Radio Emission" ,* 19 June, 2019, NAOC, Beijing, China.

Sharanya Sur

- *The Magnetic Universe - deciphering the Invisible,* 13 September, 2019, Vigyan Samagam, SKA Week, VITM, Bengaluru.
- *The Magnetic Universe - deciphering the Invisible,* 28 February, 2020, IIA, National Science Day, 2020.

Smitha Subramanian

- *Evolution of the Small Magellanic Cloud,* 5 December, 2019, UWA seminar talk at ICRAR, University of Western Australia.
- *Evolution of the Small Magellanic Cloud,* 10 December, 2020, Special seminar talk at Macquarie University, Sydney.

Subinoy Das

- *Dark matter from light sterile neutrino nuggets,* April 2019, Stanford University, KIPAC, USA.
- *Dark matter from light sterile neutrino nuggets,* April 2019, Johns Hopkins University, USA.
- *Dark Matter decay and cosmological Hubble measurement anomaly,* August 2019, IITB, Mumbai.

Sujan Sengupta

- *Exoplanets: Search for Unintelligent Life,* 15 November, 2019, Institute of Mathematical Sciences, Chennai.
- *Exploring the Exoplanets,* 31 January, 2020, Dept. of Physics, Indian Institute of Science, Bengaluru.

7.2 Awards, Recognition, Professional Membership, Editorship etc.

Annapurni Subramaniam

- Sir C. V. Raman young scientist award for Physics and Mathematical Sciences from the Government of Karnataka, for the year 2018. The award was presented by the Honorable CM of Karnataka on 22nd October 2019.
- Chief Editor, Journal of Astrophysics and Astronomy, jointly published by the Indian Academy of Sciences and the Astronomical Society of India (2019-2021)

Bacham Eswar Reddy

- Chinese Academy of Sciences fellowship award for visiting NAOC, Beijing for 3 months starting from 1st Sept. 2019.

Dipankar Banerjee

- Elected as a fellow of the Indian Academy of Sciences, Bengaluru.

G.C. Anupama

- President, Astronomical Society of India (2019-2021)

R. T. Gangadhara

- Chinese Academy of Sciences President's International Fellowship Initiative for research contributions during 1 June 2019-31 May 2020 on radio pulsars at National Astronomical Observatories, Beijing, China.

7.3 Externally Funded Projects

Annapurni Subramaniam

- Indian PI of the project -*Signatures of recent interaction in the Magellanic clouds through panchromatic study.* [INT/FRG/DAAD/P-08/2018, DST-DAAD-2017 exchange programme (On-going)]

Arun Mangalam

- PI of the project - *Relativistic, Magnetic and Dynamical Astrophysics* (SERB core research grant No: CRG/2018/003415).

Aruna Goswami

- PI of the project - *Galactic Evolution of Neutron-capture elements: Insight from chemical analysis of carbon enhanced metal-poor stars* (SERB No: EMR/2016/005283 (On-going)).
- Indian PI - *Indo-Thai collaboration for Studying Pulsating Variables at Different Evolutionary Stages*. Indo-Thai joint project DST/INT/thai/P-16/2019, DST International Bilateral Cooperation Division, (On-going).

C. S. Stalin

- *Alexander von Humboldt-Linkage Programme, 2018 - 2021*.

D. K. Sahu

- PI of the project - *Multi-Wavelength and Multi-Messenger Studies of the Transient Universe (MuMeSTU),* funded by DST-BRICS (2018-2021).

- PI of the project - *Theoretical studies in explosion physics of nearby supernovae based on high-quality optical and near-infrared observational data,* funded by DST-JSPS (2018-2020).

G. C. Anupama

- *Indian PI of the project: Global Relay of Observatories Watching Transients Happen.* International PIRE project funded by SERB and administered by IUSSTF.

P. Vemareddy

- DST INSPIRE Fellowship - *Formation and Eruption of magnetic flux ropes.*

Rajat Kumar Chaudhuri

- PI of the project - *Profiling the electronic structure properties of relativistic and non-relativistic systems using computationally cost effective ab initio methods.* DST-SERB : No. EMR/2015/000124.
- Co-PI of the project - *Time dependent linear and nonlinear response properties of atomic systems : Effect of classical and quantum plasma environment and spatial confinement.* DST-SERB: No. EMR/2017/000737.
- Co-PI of the project - *Development and application of cost effective ab-initio methods for strongly correlated electrons: A challenge for electronic structure theory.* CSIR No: 01/(2973)/19/EMR-II.

Smitha Subramanian

- *Ramanujan Fellowship by SERB, DST.*

Subinoy Das

- PI of the project - *Shedding light on dark matter interactions through CMB, supernovae and global 21 cm (EDGES) experiments data.* SERB CRG grant: CRG/2019/006147.

7.4 Memorandum of Understanding (MOU)

[1] IIA signed an MoU with ISRO in January 2020 for collaboration in the areas of Space Situational Awareness and Astronomy & Astrophysics. A 1-m class telescope will be set up at IAO, Hanle for tracking geosatellites, space debris and near-Earth objects. Also, a 3-m antenna for observations in the 220 GHz and 350 GHz will be set up at IAO for survey of the Galaxy in CO emission, and studies of star formation.

[2] A delegation from IIA comprising of Prof. Annapurni Subramaniam (Director) and Prof. G.C. Anupama (Dean & President, Astronomical Society of India) participated in the Inaugural Ceremony of the Center Headquarter of National Astronomical Research Institute of Thailand (NARIT) on 27 January 2020 at Chiang Mai, Thailand. During the visit, they held discussions on enhancing the collaboration between IIA and NARIT.

[3] IIA is pursuing an MoU with The Instituto de Astrofísica de Canarias (IAC) and the the GRANTECAN, S.A. (GTC), Spain to establish the baseline of joint work between the participants addressing common interests, which may include the development of segmented telescope technologies as well as the development of robotic telescopes and other future potential specific collaborations.

7.5 Workshops, Conferences and Schools

[1] **COSPAR Capacity Building Workshop (6-17 January 2020, Kodaikanal Observatory)**
A workshop was organized to provide introductory lectures and hands-on experience to young researchers from India and other developing nations like Africa, Sri Lanka, etc. on topics related to "Coronal and interplanetary shocks driven by solar coronal transients". The introductory lectures covered the basic structure of the Sun, its various observable features, different types of solar activity, etc. During the hands-on sessions, the participants were trained to use and combine solar data obtained with ground and space based observatories from India and elsewhere.

[2] **Chemical Elements in the Universe: Origin and Evolution (16-19 December 2019, IIA Bangalore)**
An international conference to celebrate the 150 years of the periodic table was organized at IIA. The meeting was attended by students and researchers (about 120 participants) in the area of physics and astrophysics.

[3] **IRIS-10 conference (4-8 November 2019)**
The 10th IRIS meeting was held from 4-8 November 2019 in Bangalore India, jointly hosted by Indian Institute of Astrophysics and CHRIST (Deemed to be University).

[4] **Young Astronomers' Meet 2019 (23-27 September 2019, Kodaikanal Observatory)**
Young Astronomers' Meet is organized every year to bring young researchers together to enrich the nation wide collaboration among students from different fields of Astronomy and Astrophysics. YAM-2019 which was organized by the students of IIA was held at Kodaikanal Observatory.

[5] **Modern Engineering Trends in Astronomy - 2019 (META-2019) 15-17 September 2019**
META-2019, jointly organized by National Centre for Radio Astrophysics of TIFR, Raman Research Institute and Indian Institute of Astrophysics, was held during 15-17 September 2019 at Indian Institute of Astrophysics, Bangalore.

[6] **Solar Physics Summer School (10-16 June 2019, Raman Science Center, Leh)**
The summer school was focused on the Physics of the Sun and Sun-Earth connection. The one week long International School introduced and trained PhD students in the state-of-the-art theoretical and data analysis techniques. The techniques taught in the school are expected to enhance the scientific outcome from various space as well as ground based observatories. The school was highly relevant and topical as India is gearing up to launch Aditya-L1, the Indian space mission to study the Sun.

8

Publications

8.1 In Journals

[1] Agarwal, Aditi., et. al. (including Anupama, G. C.; Raj, Ashish), 2019, Monthly Notices of the Royal Astronomical Society, Vol. 488, No. 3, 4093. Multiband optical variability of 3C 279 on diverse time-scales.

[2] *Akshaya, M. S; Murthy, J; *Ravichandran, S; *Henry, R. C; *Overduin, J., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 489, No. 1, 1120. Components of the diffuse ultraviolet radiation at high latitudes

[3] *Andrews, Jennifer E., et. al. (including Sahu, D. K.; Singh, Avinash; Anupama, G. C.), 2019, The Astrophysical Journal, Vol. 885, No. 1, 43. SN 2017gmr: An Energetic Type II-P Supernova with Asymmetries

[4] Anshu Kumari; Ramesh, R.; Kathiravan, C.; *Wang, T. J.; *Gopalswamy, N., 2019, The Astrophysical Journal, Vol. 881, No. 1, 24. Direct Estimates of the Solar Coronal Magnetic Field Using Contemporaneous Extreme-ultraviolet, Radio, and White-light Observations

[5] *Appleby, Stephen; Joby P. K.; Chingangbam, Pravabati; *Park, Changbom., 2019, The Astrophysical Journal, Vol. 887, No. 2, 128. Ensemble Average of Three-dimensional Minkowski Tensors of a Gaussian Random Field in Redshift Space

[6] *Bait, Omkar; *Wadadekar, Yogesh; Barway, Sudhanshu., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 485, No. 1, pp. 428-439, Outlying Hα emitters in SDSS IV MaNGA

[7] *Bait, Omkar., et. al. (including Barway, Sudhanshu), 2020, Monthly Notices of the Royal Astronomical Society, Vol. 492, No. 1, 1 Discovery of a large H I ring around the quiescent galaxy AGC 203001

[8] *Basak, S., et. al. (including Safonova, M), 2020, Astronomy and Computing, Vol. 30, 100335 CEESA meets machine learning: A Constant Elasticity Earth Similarity Approach to habitability and classification of exoplanets

[9] Bellhouse, Callum., (including George, K)., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 485, No. 1, pp. 1157-1170 GASP. XV. A MUSE view of extreme ram-pressure stripping along the line of sight: physical properties of the jellyfish galaxy JO201

[10] *Baug, T., (including Bhatt, B. C)., 2019, The Astrophysical Journal, Vol. 885, No. 1, 68 Influence of Wolf-Rayet

Stars on Surrounding Star-forming Molecular Clouds

[11] *Bell, Cameron P. M., et. al. (including Subramanian, Smitha), 2019, Monthly Notices of the Royal Astronomical Society, Vol. 489, No. 3, 3200 The intrinsic reddening of the Magellanic Clouds as traced by background galaxies - I. The bar and outskirts of the Small Magellanic Cloud

[12] *Bhattacharyya, Archita; *Alam, Ujjaini; Lal Pandey, Kanhaiya; Das, Subinoy; *Pal, Supratik., 2019, The Astrophysical Journal, Vol. 876, No. 2, 143, Are H_0 and σ8 Tensions Generic to Present Cosmological Data?

[13] Bhowmick, Anirban; Pandey, Gajendra; *Lambert, David L., 2020, The Astrophysical Journal, Vol. 891, No. 1, 40 Detection of Fluorine in Hot Extreme Helium Stars

[14] Chakrabarty, Aritra; Sengupta, Sujan., 2019, The Astronomical Journal, Vo. 158, No. 1, 39 Precise Photometric Transit Follow-up Observations of Five Close-in Exoplanets: Update on Their Physical Properties

[15] Chakradhari, N. K.; Sahu, D. K.; Anupama, G. C., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 487, No. 2, pp. 1886-1904 Optical and UV studies of type Ia supernovae SN 2009ig and SN 2012cg

[16] Chamarthi, Sireesha; Banyal, Ravinder K.; Sriram, S., 2019, Journal of Astronomical Telescopes, Instruments, and Systems, Vol. 5, 028004 Toward precision radial velocity measurements using Echelle spectrograph at Vainu Bappu Telescope

[17] Chamarthi, Sireesha; Banyal, Ravinder K.; Sriram, S., 2019, Journal of Astronomical Telescopes, Instruments, and Systems, Vol. 5, 038003 Estimation and correction of the instrumental perturbations of Vainu Bappu Telescope Echelle spectrograph using a model-based approach

[18] Chatterjee, Piyali., 2020, Geophysical & Astrophysical Fluid Dynamics, Vol. 114, No. 1-2, pp. 213-234 Testing Alfvén wave propagation in a "realistic" set-up of the solar atmosphere

[19] Chatterjee, S.; *Vani, V. C.; *Haghighi, Rezvan R.; Banyal, Ravinder K., 2019, Applied Optics, Vol. 58, No. 31, 8638 Diffraction by ruled gratings with variable spacing: fundamental method of intensity calculation

[20] Chatterjee, Subhamoy; Hegde, Manjunath; Banerjee, Dipankar; Ravindra, B.; *McIntosh, Scott W., 2020, Earth and Space Science, Vol. 7, No. 3, e00666 Time-Latitude Distribution of Prominences for 10 Solar Cycles: A Study Using Kodaikanal, Meudon, and Kanzelhohe Data

[21] *Chatzistergos, T., et. al. (including Banerjee, Dipankar; Jha, Bibhuti K.; Chatterjee, Subhamoy), 2019, Solar Physics, Vol. 294, No. 10, 145. Delving into the Historical Ca ii K Archive from the Kodaikanal Observatory: The Potential of the Most Recent Digitized Series

[22] Chaudhuri, R. K.; *Chattopadhyay, Sudip., 2019, The Journal of Chemical Physics, Vol. 151, No. 7, 074114 Fock-space multireference coupled cluster

calculations of Auger energies of noble gas elements using relativistic spinors

[23] *Chung, Eun Jung., et. al. (including Maheswar, G)., 2019, The Astrophysical Journal, Vol. 877, No. 2, 114 TRAO Survey of Nearby Filamentary Molecular Clouds, the Universal Nursery of Stars (TRAO FUNS). I. Dynamics and Chemistry of L1478 in the California Molecular Cloud

[24] *Coughlin, Michael W., et. al. (including Anupama, G. C), 2019, The Astrophysical Journal Letters, Vol. 885, No. 1, L19 GROWTH on S190425z: Searching Thousands of Square Degrees to Identify an Optical or Infrared Counterpart to a Binary Neutron Star Merger with the Zwicky Transient Facility and Palomar Gattini-IR

[25] Das, Mousumi; *McGaugh, Stacy S.; *Ianjamasimanana, Roger; *Schombert, James; *Dwarakanath, K. S., 2020, The Astrophysical Journal, Vol. 889, No. 1, 10 Tracing the Dynamical Mass in Galaxy Disks Using H i Velocity Dispersion and Its Implications for the Dark Matter Distribution in Galaxies

[26] *Dastidar, Raya; *Misra, Kuntal; Singh, *Mridweeka; Sahu, D. K.; *Pastorello, A.; *Gangopadhyay, Anjasha; *Tomasella, L.; *Benetti, S.; *Terreran, G.; *Sanwal, Pankaj; Kumar, *Brijesh; Singh, Avinash; Kumar, Brajesh; Anupama, G. C.; *Pandey, S. B., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 486, No. 2, pp. 2850-2872 SN 2016B a.k.a. ASASSN-16ab: a transitional Type II supernova

[27] Deepak; Reddy, Bacham E., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 484, No. 2, pp. 2000-2008 Study of Lithium-rich giants with the GALAH spectroscopic survey

[28] *Deras, D.; *Arellano Ferro, A.; *Lázaro, C.; *Bustos Fierro, I. H.; *Calderón, J. H.; Muneer, S.; Giridhar, Sunetra., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 486, No. 2, pp. 2791-2808 A new study of the variable star population in the Hercules globular cluster (M13; NGC 6205)

[29] *Dey, Arjun., et. al. (including George, K)., 2019, The Astronomical Journal, Vol. 157, No. 5, 168 Overview of the DESI Legacy Imaging Surveys

[30] *Dhakal, Suman; Vemareddy, P; *Karna, *Nishu; Zhang, Jie., 2019, Bulletin of the American Astronomical Society, Vol. 51, No. 4, 106 Homologous Coronal Mass Ejections and Their Precursor Phase

[31] *El Youssoufi, Dalal., et. al. (including Subramanian, Smitha), 2019, Monthly Notices of the Royal Astronomical Society, Vol. 490, No. 1, 1076 The VMC survey - XXXIV. Morphology of stellar populations in the Magellanic Clouds

[32] Eswaraiah, Chakali; *Lai, Shih-Ping; *Ma, Yuehui; *Pandey, Anil K.; Jose, Jessy; *Chen, Zhiwei; *Samal, Manash R.; *Wang, Jia-Wei; *Sharma, Saurabh; *Ojha, D. K., 2019, The Astrophysical Journal, Vol. 875, No. 1, 64 Polarimetric and Photometric Investigation of the Dark Globule LDN 1225: Distance, Extinction Law, and Magnetic Fields

[33] *Gangopadhyay, Anjasha., et. al. (Anupama, G. C.; Kumar, Brajesh; Sahu, D. K.; Singh, Avinash), 2020, The Astrophysical Journal, Vol. 889, No. 2, 170

Flash Ionization Signatures in the Type Ibn Supernova SN 2019uo

[34] *Gaur, H.; *Gu, M.; Ramya, S.; *Guo, H., 2019, Astronomy & Astrophysics, Vol. 631, A46 Properties of radio-loud quasars in the Sloan Digital Sky Survey

[35] George, K.; *Poggianti, B. M.; *Bellhouse, C.; *Radovich, M.; *Fritz, J.; *Paladino, R.; *Bettoni, D.; *Jaffé, Y.; *Moretti, A.; *Gullieuszik, M.; *Vulcani, B.; *Fasano, G.; Stalin, C. S.; Subramaniam, A.; Tandon, S. N., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 487, No. 3, pp. 3102-3111 GASP XVIII: star formation quenching due to AGN feedback in the central region of a jellyfish galaxy

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[14] Kataria, Sandeep Kumar; Das, Mousumi; *Mcgaugh, Stacy., 2019, Galactic Dynamics in the Era of Large Surveys. Proceedings of the IAU Symposium, Vol. 353, pp. 184-185 Can bars erode cuspy halos?

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[16] *Kumar, Ranjan; *Pradhan, Ananta C.; Parthasarathy, M.; *Ojha, Devendra K.; *Mohapatra, Abhisek; Murthy, Jayant., 2020, Star Clusters: From the Milky Way to the Early Universe. Proceedings of the IAU Symposium, Vol. 351, pp. 464-467 UVIT observations of UV-Bright stars in four Galactic Globular Clusters

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[19] Mallik, D. C. V., 2019, Under One Sky: The IAU Centenary Symposium. Proceedings of the IAU Symposium, Vol. 349, pp. 214-221 India's participation in IAU over the years

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[30] Sampoorna, M.; Nagendra, K. N.; *Sowmya, K.; *Stenflo, J. O.; *Anusha, L. S., 2019, Radiative Signatures from the Cosmos, ASP Conference Series, Vol. 519, p. 113 Polarized Line Formation with Incomplete Paschen-Back Effect and Partial Frequency Redistribution

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[32] Shastri, Prajval., et. al. 2019, WOMEN IN PHYSICS: 6th IUPAP International Conference on Women in Physics, AIP Conference Proceedings, Vol. 2109, No. 1, 090003 The environments of accreting supermassive black holes in the nearby Universe: A brief overview of the Southern Seyfert spectroscopic snapshot survey (S7)

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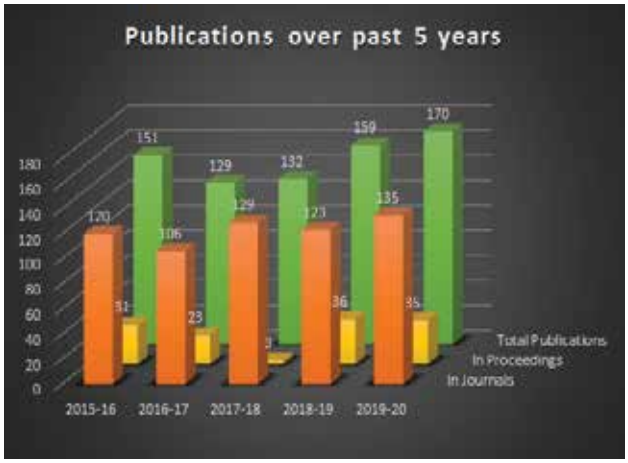

Figure 8.1: *Number of publications over the past five years.*

Table 8.1: *Number of publications over the past five years.*

Year	Published in Journals	Published in Proceedings	Total
2015-16	120	31	151
2016-17	106	23	129
2017-18	129	3	132
2018-19	123	36	159
2019-20	135	35	170
Total	**613**	**128**	**741**

2020, Star Clusters: From the Milky Way to the Early Universe. Proceedings of the IAU Symposium, Vol. 351, pp. 482-485 Detection of White Dwarf companions to Blue Straggler Stars from UVIT observations of M67

[34] Subramanian, Smitha., 2019, A Synoptic View of the Magellanic Clouds: VMC, Gaia and Beyond, Proceedings of the conference held 9-13 September, 2019 in Garching, Germany, mcs2019, id. 49 VMC galaxy structures

[35] Sutaria, Firoza; *Singh, K. P.; Murthy, J; Rao, N. K.; *Ray, A., 2019, Supernova Remnants: An Odyssey in Space after Stellar Death II, held 3-8 June 2019 in Chania, 38 A deep, UV, imaging study of the Cygnus Supernova Remnant

8.3 Technical Reports, Monographs, Circulars, ATel

[1] Dutta, Anirban; Kumar, Brajesh; Anupama, G. C.; Sahu, D. K.; *Sujith, D. S.; Singh, Avinash., 2020, The Astronomer's Telegram, No. 13404 Optical spectrum of SN 2020oi (ZTF20aaelulu)

[2] Dutta, A.; Kumar, B.; *Kumar, H.; Shejeelammal, J.; *Anaswar, C. G.; *Bhalerao, V.; Anupama, G. C.; *Perley, D.; Growth Collaboration., 2019, GCN, Circular Service, No. 26490 LIGO/Virgo S191213g: HCT spectroscopy of PS19hgw / AT2019wxt

[3] *Kasliwal, Mansi M., et. al. (including Anupama, G. C.; Barway, Sudhanshu), 2019, GCN, Circular Service, No. 25199 L IGO/Virgo S190728q: Optical Candidate from the Zwicky Transient Facility ZTF19abjethn

[4] *Khandagale, M., et. al. (including Anupama, G. C), 2019, GCN, Circular Service, No. 24748 GRB190604B: GROWTH-India telescope followup - no optical counterpart found

[5] *Kool, Erik., et. al. (including Anupama, G. C), 2019, GCN, Circular Service, No. 25616 LIGO/Virgo S190901ap: Candidates from the Zwicky Transient Facility

[6] Kumar, Brajesh; Sahu, D. K.; Anupama, G. C.; *Bhalerao, V.; Growth Collaboration., 2019, GCN, Circular Service, No. 25917 LIGO/Virgo S190930t: HCT observations of ZTF19acbpsuf

[7] *Kumar, H., et. al. (including Anupama, G. C), 2019, GCN, Circular Service, No. 24954 GRB190701A: No candidates/counterpart in optical follow-up from GROWTH-India Telescope

[8] *Kumar, H.; *Bhalerao, V.; *Stanzin, Jigmat; Anupama, G. C.; Barwe, S.; Growth-India Collaboration, 2019, GCN, Circular Service, No. 25560

[9] *Kumar, Harsh., et. al. (including Dutta, Anirban; Singh, Avinash; Anupama, G. C), 2019, GCN, Circular Service, No. 25632 LIGO/Virgo S190901ap: GROWTH-India follow-up of ZTF19abvionh

[10] *Nandi, D., et. al. (including Anupama, G. C), 2019, GCN, Circular Service, No. 24745 GRB190530A: Photometric follow-up with GROWTH-India telescope

[11] Pavana, M.; Anupama, G. C.; Kumar, S. Pramod., 2019, The Astronomer's Telegram, No. 13060 Optical spectroscopy of the recurrent nova V3890 Sagittarii

[12] Pavana, M.; *Roy, Nirupam; Anupama, G. C.; *Singh, K. P.; *Girish, V.., 2019, The Astronomer's Telegram, No. 13092 GMRT observations of the recurrent nova V3890 Sagittarii

[13] Pavana, M.; Anupama, G. C.; Kumar, S. Pramod., 2019, The Astronomer's Telegram, No. 13245 Optical spectroscopy of the Galactic nova AT 2019tpb/ASASSN-19aad *Singh, K. P.; *Girish, V.; Anupama, G. C.; Pavana, M., 2019, The Astronomer's Telegram, No. 13102 AstroSat SXT observations of V3890Sgr

[14] *Singh, K. P.; *Girish, V.; Anupama, G. C.; Pavana, M., 2019, The Astronomer's Telegram, No. 13145 A long look at V3890 Sgr during its SSS phase with the AstroSat SXT

[15] *Stein, Robert., et. al. (including Anupama, G. C), 2019, GCN, Circular Service, No. 25634 LIGO/Virgo S190901ap: Additional observations from the Zwicky Transient Facility

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[17] *Stein, Robert., et. al. (including Anupama, G. C), 2019, GCN, Circular Service, No. 25899 LIGO/Virgo S190930t: Candidates from the Zwicky Transient Facility

[18] *Wyrzykowski, L., et. al. (including Anupama, G. C), 2019, 2019yCat..36330098W VizieR Online Data Catalog: Gaia16aye microlensing event photometry (Wyrzykowski+, 2020)

8.4 HCT Publications by non-IIA Users

[1] Borwankar, Chinmay; Sharma, Mradul; Bhatt, Nilay; Bhattacharyya, Subir; Rannot, R. C.; Tickoo, A. K., 2020, Nuclear Inst. and Methods in Physics Research, A, Vol. 953, 163182 Estimation of expected performance for the MACE γ-ray telescope in low zenith angle range

[2] Chandra, Poonam; Nayana, A. J.; Björnsson, C. -I.; Taddia, Francesco; Lundqvist, Peter; Ray, Alak K.; Shappee, Benjamin J., 2019, The Astrophysical Journal, Vol. 877, No. 2, 79 Type Ib Supernova Master OT J120451.50+265946.6: Radio-emitting Shock with Inhomogeneities Crossing through a Dense Shell

[3] Dutta, Somnath; Mondal, Soumen; Joshi, Santosh; Das, Ramkrishna., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 487, No. 2, pp. 1765-1776 Optical photometric variable stars towards Cygnus OB7

[4] Eswaraiah, Chakali; Lai, Shih-Ping; Ma, Yuehui; Pandey, Anil K.; Jose, Jessy; Chen, Zhiwei; Samal, Manash R.; Wang, Jia-Wei; Sharma, Saurabh; Ojha, D. K., 2019, The Astrophysical Journal, Vol. 875, No. 1, 64 Polarimetric and Photometric Investigation of the Dark Globule LDN 1225: Distance, Extinction Law, and Magnetic Fields

[5] Ghosh, Supriyo; Mondal, Soumen; Das, Ramkrishna; Khata, Dhrimadri., 2019, Monthly Notices of the Royal Astronomical Society, Vol. 484, No. 4, pp. 4619-4634 Spectral calibration of K-M giants from medium-resolution near-infrared HK-band spectra

[6] Gonzales, Eileen C.; Faherty, Jacqueline K.; Gagné, Jonathan; Teske, Johanna; McWilliam, Andrew; Cruz, Kelle., 2019, The Astrophysical Journal, Vol. 886, No. 2, 131 A Reanalysis of the Fundamental Parameters and Age of TRAPPIST-1

[7] Joshi, Yogesh C.; Sharma, Kaushal; Gangopadhyay, Anjasha; Gokhale, Rishikesh; Misra, Kuntal., 2019, The Astronomical Journal, Vol. 158, No. 5, 175 A Long-term Photometric Variability and Spectroscopic Study of Luminous Blue Variable AF And in M31

[8] Lata, Sneh; Pandey, Anil K.; Kesh Yadav, Ram; Richichi, Andrea; Irawati, Puji; Panwar, Neelam; Dhillon, V. S.; Marsh, T. R., 2019, The Astronomical Journal, Vol. 158, No. 2, 68 Short-period Variable Stars in Young Open Cluster Stock 8

[9] Mishra, Sapna; Gopal-Krishna; Chand, Hum; Chand, Krishan; Ojha, Vineet., 2019, Monthly Notices of the Royal Astronomical Society: Letters, Vol. 489, No. 1, pp. L42-L46 Are there broad absorption-line blazars?

[10] Pandey, Rakesh; Sharma, Saurabh; Panwar, Neelam; Dewangan, Lokesh K.; Ojha, Devendra K.; Bisen, D. P.; Sinha, Tirthendu; Ghosh, Arpan; Pandey, Anil K., 2020, The Astrophysical Journal, Vol. 891, No. 1, 81 Stellar Cores in the Sh 2-305 H II Region

9

Colloquia/Seminars Given By Visitors

9.1 Colloquia

18 June 2019
Hard X-ray Observations as Diagnostics of Particle Acceleration in Solar Flares
Säm Krucker
Space Sciences Laboratory, UC Berkeley & University of Applied Sciences Northwestern Switzerland

27 August 2019
Testing Cosmic Ray Acceleration in the Laboratory
Subir Sarkar
Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford, UK

9.2 Seminars

23 April 2019
Exploring the Universe at High Energies
Lab Saha
Universidad Complutense de Madrid, Spain

23 April 2019
Algebraic topology and its application to cosmological data sets
Pratyush Pranav
University of Lyon, Lyon, France

07 May 2019
Galaxy Transformation in the local Universe
Luca Cortese
International Centre for Radio Astronomy Research, The University of Western Australia

16 May 2019
Small Astronomy - How small satellites and new technologies are pushing the limits of astrophysics in the ultraviolet
Brian Fleming
University of Colorado, Boulder

12 June 2019
Recent targeted pulsar and transient searches: Results and updates
Yogesh Maan
ASTRON, the Netherlands

13 June 2019
Five Degrees of Variation at Nalanda: a stellar hypothesis
M. Rajani
NIAS, Bangalore

19 June 2019
Advanced solar physics data analysis techniques: Local Correlation Tracking and

Spectro-Polarimetric Inversions
Jose Ivan Campos
Karl-Franzens University of Graz, Institute of Physics/IGAM

19 June 2019
Long-time study of MBPs in regards to the solar cycle
Dominik Utz
GAM, Institute of Physics, Karl-Franzens University Graz, Austria

26 June 2019
Theoretical Modeling: an essential tool for confronting Neutron Star observations
Debarati Chatterjee
CNRS, France

23 July 2019
Properties of Inverse Evershed Flow around Sunspot
Debi Prasad Choudhary
California State University Northridge

23 July 2019
Dynamic Loading Assembly for Testing Actuators of Segmented Mirror Telescope
Prasanna Deshmukh
Indian Institute of Astrophysics, Bangalore

25 July 2019
Rocky Exomoon Signatures Hidden in the Transmission Spectra of Close-in Gas Giant Exoplanets
Apurva V. Oza
Physikalisches Institut, University of Bern, CH-3012 Bern, Switzerland

02 August 2019
Nearly Polar Orbit of the sub-Neptune HD3167 c: Constraints on a multi-planet system dynamical history
Shweta Dalal
IAP, Paris

13 August 2019
What heats the corona of a sun-like star?
Pradeep L. Chitta
Max Planck Institute for Solar System Research, Göttingen, Germany

13 August 2019
NoiseChisel: non-parametric detection and analysis of astronomical targets
Mohammad Akhlaghi
Instituto de Astrofísica de Canarias, Tenerife (Canary Islands), Spain

14 August 2019
Template for reproducible scientific datasets/papers
Mohammad Akhlaghi
Instituto de Astrofísica de Canarias, Tenerife (Canary Islands), Spain

22 August 2019
Density Turbulence in the Solar Wind using Low-frequency Angular-broadening Observations
Kantepalli Sasikumar Raja
LESIA, Observatoire de Paris, Meudon, France

23 August 2019
Small-scale Magnetic Flux Cancelation - lower atmosphere characteristics
Anjali J. Kaithakkal
Kiepenheuer Institute for Solar Physics, Freiburg, Germany

29 August 2019
Galactic Evolution and Chemical Tagging with Open Clusters
A. B. Sudhakara Reddy
Indian Institute of Astrophysics, Bangalore

12 September 2019
Polarimetric investigation of Supernovae
Brajesh Kumar
Indian Institute of Astrophysics, Bangalore

23 September 2019
The Next Generation Virgo Cluster Survey
Patrick Cote
NRC, Herzberg Astronomy & Astrophysics Research Centre, Victoria, BC, Canada

30 September 2019
Space Weather Impacts of Solar Wind High-Speed Streams: A comparative study for the Earth and comet
Rajkumar Hajra
National Atmospheric Research Laboratory (NARL), Gadanki

23 October 2019
Experimental visualization of interfacial stresses in an aqueous foam
Chirag Kalelkar
Dept. of Mechanical Engg. IIT, Kharagpur

28 October 2019
Dissecting star-forming galaxies at Cosmic Noon
Wiphu Rujopakarn
National Astronomical Research Institute of Thailand; Chulalongkorn University

31 October 2019
Spectroscopy of low lying transitions of noble gas atom confined in a fullerene cage : A theoretical study
Supriya K Chaudhuri
Indian Institute of Astrophysics, Bangalore

05 November 2019
AR Scorpii: A White Dwarf Pulsar
David Buckley
SAAO, Capetown South Africa

06 November 2019
The survey of Planetary Nebulae in Andromeda (M31): Discrete tracers in the disc and inner halo
Souradeep Bhattacharya
ESO, Germany

08 November 2019
The International Liquid Mirror Telescope (ILMT): present status and future scientific participation
J. Surdej
Liege University, Liege, Belgium

13 November 2019
Observation of supra-arcade downflows and vortex shedding in post-flare regions
Tanmoy Samanta
Peking University

18 November 2019
Towards and improved, self-consistent local distance framework
Richard de Grijs
Macquarie University

19 November 2019
SALT status update, research highlights and future plans
Encarni Romero Colmenero
South African Large Telescope (SALT), SAAO, Cape Town, South Africa

27 November 2019
Star Formation in the Magellanic Clouds
Venu Kalari
Gemini Observatory and University of Chile

27 November 2019
Probing stellar evolution with S stars and Gaia
Shreeya Shetye

Universite Libre de Bruxelles, Belgium

12 December 2019
Plasmon excitation in Large molecules including PAH and fullerenes
Lokesh Tribedi
Tata Institute of Fundamental Research, Mumbai

12 December 2019
CHACE to Moon
S.M. Ahmed
Central Instruments Laboratory, University of Hyderabad

13 December 2019
MOSEL survey: Tracking the Growth of Massive Galaxies at z∼2
Anshu Gupta
School of Physics, UNSW, Sydney

19 December 2019
The dawn of wide-field near-infrared time domain astronomy with Palomar Gattini-IR
Kishalay De
California Institute of Technology

30 December 2019
Energy Contribution of Vortex Flows in the Solar Atmosphere
Nitin Yadav
Max Plnack Institute for Solar System Research, Goettingen, Germany

06 January 2020
Spectropolarimetry of two B-class flares in the Ca II 8542 Å line
Jayant Joshi
Institute of Theoretical Astrophysics, University of Oslo, Norway

09 January 2020
Wavefront sensing using extended stars - Ingot wavefront sensor
Kalyan Radhakrishnan
INAF-Observatory of Padova, Italy

10 January 2020
Magnetic reconnection: plasmoid instability in an experimentally accessible regime
Pallavi Bhat
University of Leeds, UK

16 January 2020
Neutron star model atmospheres
Klaus Werner
University of Tübingen, , Germany

17 January 2020
Chandra study of Restarting Radio Galaxies
Karthik A Balasubramaniam
Ph.D. scholar Department of High Energy Astrophysics Astronomical Observatory of the Jagiellonian University ,Krakow Poland:30-244

20 January 2020
Development of detector systems at ESO for next generation VLT and ELT instruments
B. Nagaraja Naidu
European Southern Observatory, Germany

21 January 2020
Characterization of spicules in high resolution observations and simulations
Souvik Bose
Institute of Theoretical Astrophysics, University of Oslo, Norway

22 January 2020
Detection of Extreme and Exceptional Langmuir Wave packets in Solar Type III Radio Bursts
G. Thejappa
University of Maryland, College Park, MD 20742 USA

30 January 2020
Study of UV bright stars in Galactic Globular Clusters
Gaurav Singh
Aryabhatta Research Institute of Observational Sciences, Nainital

05 February 2020
The Origin of Large-Scale Magnetic Fields in Low-Mass Galaxies
Prasanta Bera
University of Southampton, UK

10 February 2020
Extraordinary Activity of Magnetized Plasmas in the Sun, Stars, and Galaxies
Kazunari Shibata
Kyoto University, Kyoto, Japan

10 February 2020
Heliospheric Evolution of Coronal Mass Ejections and their Arrival Time at the Earth
Wageesh Mishra
Max Plnack Institute for Solar System Research, Goettingen, Germany

11 February 2020
Black Holes in Low Mass Galaxies
Anil C. Seth
University of Utah, USA

24 February 2020
Eclipsing binaries with pulsating mass-accreting components
David Mkrtichian
National Astronomical Research Institute of Thailand

25 February 2020
Photophysics of PAHs and Fullerenes and in situ Emission Spectroscopy of Shock Induced Interstellar Dust Analogues
Shubhadip Chakraborty
Institut de Physique de Rennes, UMR CNRS 6251, Université de Rennes 1, Campus de Beaulieu, 35042 Rennes Cedex, France

9.3 Special Lectures

28 June 2019
The Standard Model of the Universe ... open questions
Bharat Ratra
Kansas State University, Kansas, USA

30 July 2019
Astrobiology – The Hunt for Alien Life
Lewis Dartnell
Department of Life Sciences, University of Westminster, London, UK

05 August 2019
First Stars in the Universe
Tirthankar Roy Choudhury
National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Pune

09 August 2019
Plate Tectonics and the Making of Himalaya: An ongoing Process
Vinod K. Gaur
CSIR Fourth Paradigm Institute, Bangalore

31 January 2020
Science communication as a mirror to science
Aashima Dogra
Life of Science

20 February 2020
Tracing the physical and chemical evolution during low-mass star formation
Neal J. Evans
The University of Texas at Austin

10

Miscellaneous

10.1 Official Language Implementation (OLI)

OLIC Meeting

Four meetings were conducted in the Institute on 28.06.2019, 24.09.2019, 31.12.2019 & 09.03.2020 and the reports were sent to the Dept. of Science & Technology, New Delhi and the Member Secretary, TOLIC, Bengaluru.

Hindi Workshop

In order to implement Official Language in the Institute and to improve the official work in Hindi by the staff members, four Hindi Workshops were conducted on19.06.2019, 23.09.2019, 29.11.2019 and 13.03.2020for the employees working in Administration section of the Institute.

Hindi Day/Fortnight Celebration

The institute celebrated the Hindi Fortnight from 14 September 2019 to 30 September 2019. During the occasion seven competitions were conducted in the institute viz. "Hindi Gaan" competition on 18 September 2019, "Hindi Sulekh" competition on 19 September 2019, "Hindi Shrutlekh" competition on 23 September 2019, "Hindi Antakshari" competition on 24 September 2019, "Hindi SamacharVachan" competition on 27 September 2019, "SmaranShakthi" competition on 30 September 2019 and "Online Hindi Prashnothari" competition on 30 September 2019. Hindi Pakwada closing ceremony was observed on 29 November 2019 in the institute. Prof. Annapurni Subramaniam, Director chaired the function in the presence of Administrative Officer. Dr. Sudhanshu Barway, Scientist-D gave a special lecture in Hindi on the topic "Hanny and the mystery of the voorwerp". Director addressed the audience and appreciated all the employees for their efforts taken towards the implementation of the official language in their respective official work and congratulated the winners of Hindi competition & distributed the prizes. The function was concluded with a vote of thanks presented by the Section Officer (Hindi).

Figure 10.1: *Participants of the Hindi Pakwada closing ceremony organized at IIA.*

Incentives

Under this scheme four IIA employees were awarded incentives for implementing Official Language in their day-to-day official work.

10.2 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 (31.03.2020), members belonging to the **SC, ST, OBC & Physically Challenged** categories constitute **10%, 13%, 15% & 1.4%** respectively of the total strength. In addition, reservations continue to be extended to OBCs and physically disabled persons. Proactive efforts are continuously made towards their welfare. Facilities and mechanisms have been provided for special administrative as well as technical training of staff from the historically disadvantaged categories.

10.3 Committee against Sexual Harassment

A Gender Amity Cell, constituted to provide a platform to discuss and address gender related issues, is functional in the Institute. The Gender Amity Cell works towards sensitization and impart awareness amongst all members on the gender inequality and sexual harassment. An internal committee is constituted to provide an institutional framework for the creation of a safe, equitable and inclusive institute environment. The Committee's chief mandate includes considering complaints or grievances in relation to sexual harassment offences committed by students, faculty, staff and visitors on IIA's campuses, and awareness-raising.

A special Anna Mani Lecture was organized at IIA on 31 January 2020. The talk was delivered by Ashima Dogra on "Science communication as a mirror to science". This talk was organized jointly by the Working Group of Gender Equality (WGGE)-ASI and the Gender Amity Cell of IIA.

A Handbook on 'Sexual Harassment of Women at Workplace' is available at the Institute's website https://www.iiap.res.in/files/.pdf. An internet web page is having matters related to the Gender Issues is available at https://www.iiap.res.in/intranet/gender.

11

People

Director: Annapurni Subramaniam (from 15.10.2019)
Director (Acting): Jayant Murthy (up to 14.10.2019)

Academic & Scientific members

Senior Professor: G. C. Anupama, Jayant Murthy, B. Raghavendra Prasad, Rajat Kumar Chaudhuri

Professor: Arun Mangalam, Aruna Goswami, Dipankar Banerjee (up to 11.12.2019), D. K. Sahu, B. Eswar Reddy, R. T. Gangadhara, Gajendra Pandey, P. S. Parihar, K.P. Raju, R. Ramesh, Sujan K. Sengupta, S. Paul Kaspar Rajaguru

Associate Professor: B. C. Bhatt, Firoza Sutaria, C. Kathiravan, Maheswar Gopinathan, Mousumi Das, Muthumariappan, S. Muneer, Pravabati Chingangbam, B. Ravindra, Ravinder Kumar Banyal, M. Sampoorna, Sivarani Thirupathi, C. S. Stalin, Subinoy Das, Umanath S. Kamath

Reader: E. Ebenezer Chellasamy, Nagaraju.K, Piyali Chatterjee, Sharanya Sur

Assistant Professor: Smitha Subramanian, P. Vemareddy, Sudhanshu Barway

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

Scientist C: M. Chrisphin Karthick, G. Selvakumar, G. S. Suryanarayana

Scientist B: Namgyal Dorjey

Adjunct Scientist: K. Shankar Subramanian

Visiting Professor: K.V. Govinda

Visiting Scientist: Aditi Agarwal, Brajesh Kumar, Margarita Safonova

Honorary Professor: P. Sreekumar, S.N. Tandon

Consultant: C.H.Basavaraju, Lt. Col Kuldip Chandar, Jagdev Singh, P. Umesh Kamath, Viswanatha Narasimhaiah

Post Doctoral Fellow: Ashish Raj, Bala Sudhakara Reddy. A, Binu Kumar, Dipen Sahu, Labani Mallick, Rahna.T, Sumana Nandi, Supriya Kumar Chaudhuri, Richa Rai

N-PDF: Aditi Agarwal (up to 07.06.2019), Brajesh Kumar (up to 26.06.2019)

Ramanujan Fellow: M. Vivek

Technical staff

Engineer F: P.K. Mahesh

Engineer E: P. Anbazhagan, Amit Kumar,

V.Arumugam, Dorje Angchuk, S. Kathiravan, P.M.M. Kemkar, S. Nagabhushana, M.V. Ramaswamy, B.Ravikumar Reddy, S. Sriram

Engineer D: Anish Parwage, K. Anupama, Sanjiv Gorka, Sonam Jorphail, Tashi Thsering Mahay, K.C. Thulasidharen, Tsewang Dorjai, R. Vellai Selvi,

Principal Scientific Officer: R. Selvendran

Engineer C: Indrajit V. Barve, D.V.S. Phanindra, M. Rajalingam, A. Ramachandran, S. Ramamoorthy, V.S. Gireesh Gantyada

Engineer B: Chinchu Mohanan. K, Mallappa, Manoj Kumar Gubbala, Srinivasa K.V, Totan Chand, Tsewang Gyalson, Vinay Kumar Gond

Technical Officer: R. Ismail Jabillullah, J. Manoharan, C.V. Sriharsha (up to 30.06.2019), M.R. Somashekar, S. Venkateshwara Rao

Tech. Associate B: P. Kumaravel, K. Sagayanathan

Librarian: Arumugam Pitchai

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

Research Associate B: V. Moorthy

Research Associate: C. Velu

Technical Assistant C: P. Janakiram (up to 30.04.2019), Premkumar. D (up to 31.10.2019)

Technical Associate: P.R. Sreeramulu Nayaka

Sr. Mechanical Assistant B: N. Thimmaiah

Sr. Technical Assistant B: Phuntsok Dorjay

Administrative staff

Administrative Officer: Shripathi. K

Accounts Officer: S.B. Ramesh (up to 01.06.2019), Vasumathi. S (In-Charge from 01.07.2019)

Principal Staff Officer: S. B. Ramesh (from 01.07.2019)

Deputy Administrative Officer: Vasumathi. S

Stores & Purchase Officer: K.P. Vishnu Vardhan

Section Officer (SG): Diskit Dolker, Maliny Rajan, Ramaswamy, N.Sathya Bama, Uma Maileveloo (up to 31.01.2020), A. Veronica (up to 30.09.2019)

Section Officer: S. Dhananjaya, K. Sankaranarayanan, P. Selvakumar, Srinivasa Rao. V, V. Vijayaraj (up to 13.06.2019)

Hindi Officer: S. Rajanatesan

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Auditors' Report & Statement Of Accounts

Gireesha Vijayan & Associates
CHARTERED ACCOUNTANTS

Cell : 9880004161
Tel : 080-4144 0645

No. 2012, Ground Floor, High point 2,
Next to Hotel Chalukya, Bangalore - 560 001.
E-mail : cagvassociates@gmail.com / gireeshatl@yahoo.com

Ref.IIA/Audit/001/19-20

Date..31.07.2020.....

Independent Auditor's Report

To
The Members of the INDIAN INSTITUTE OF ASTROPHYSICS,

Report on the Financial Statements

Opinion

We have audited the accompanying financial statements of **INDIAN INSTITUTE OF ASTROPHYSICS** which comprises the Balance Sheet as at March 31, 2020, the Statement of Income & Expenditure Account and statement of receipts and Payments Account for the year then ended, and notes to the financial statements, including a summary of significant accounting policies and other explanatory information.

Responsibility of Management for the Standalone Financial Statements

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

Auditor's Responsibility for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with Standards on

Auditing will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

Opinion,

In our opinion, and to the best of Our Information and according to the explanations given to us, the aforesaid financial statements give the information required and give a true and fair view in conformity with the accounting principles generally accepted in India.

a. In case of Balance sheet , of the state of affairs of the Institute as at 31st March 2020;
b. In case of statement of Income & expenditure Account, of Excess of Income Over Expenditure over Income for the year ended on that date;
c. In case of receipts and payments account for the year ended on that date;

We further report that,

a. We have sought and obtained all the information and Explanations which to the best of our Knowledge and belief were necessary for the purpose of our Audit.
b. In our opinion, proper books of account as required by law have been kept by the Company so far as it appears from our examination of those books.
c. The Balance Sheet, the Statement of Income & Expenditure Account and the Receipts and Payments Account dealt with by this Report are in agreement with the books of account

For Gireesha Vijayan & Associates
Chartered Accountants
Firm Regn.No 014117S

Vijayan.G.
Partner
M. No.036348
UDIN:20036348AAAAAB8882

Place: BENGALURU
Date: 31/07/2020

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU
BALANCE SHEET AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Sch	Current Year	Previous Year
CORPUS/CAPITAL FUND AND LIABILITIES			
Corpus/Capital Fund	1	74,91,61,405	78,79,99,083
Reserves & Surplus	2	-	-
Earmarked & Endowment Funds	3	79,57,18,871	30,86,04,381
Secured Loans & Borrowings	4	-	-
Unsecured Loans & Borrowings	5	-	-
Deferred Credit Liabilities	6	-	-
Current Liabilities & Provisions	7	2,57,53,874	2,30,25,529
TOTAL		**1,57,06,34,149**	**1,11,96,28,993**
ASSETS			
Fixed Assets	8	76,26,22,015	76,49,57,426
Investments- from earmarked & endowment funds	9	-	-
Investments-Others	10	-	-
Current Assets, Loans & Advances	11	80,80,12,135	35,46,71,567
TOTAL		**1,57,06,34,149**	**1,11,96,28,993**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

S.B.RAMESH
ACCOUNTS OFFICER

SHRIPATHI.K
ADMINISTRATIVE OFFICER

ANNAPURNI SUBRAMANIAM
DIRECTOR

As per our report of even date
For Gireesha Vijayan & Associates
Chartered Accountants
FRN 014117S

VIJAYAN.G.
Partner
M No.036348

Date: 31.07.2020
Place :BENGALURU

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MARCH 2020

	Sch	Current Year	Previous Year
INCOME			
Income from Sales/Services	12	-	-
Grants/Subsidies	13	60,43,04,000	65,74,77,000
Fee/Subscriptions	14	-	-
Income from Investments (earmarked/endowment funds)	15	-	-
Income from Royalty, Publication etc.	16	-	-
Interest Earned	17	7,97,000	48,64,224
Other Income	18	22,26,219	51,01,464
Increase/Decrease in stock of finished goods	19	-	-
TOTAL (A)		**60,73,27,219**	**66,74,42,688**
EXPENDITURE			
Establishment Expenses	20	48,79,21,312	46,33,41,509
Other Administrative Expenses	21	17,30,95,488	17,77,34,945
Expendtiture on Grants/Subsidies etc.	22	-	-
Interest	23	-	-
Depreciation (Net Total at the year end as per Schedule 8)		7,27,03,097	6,44,72,071
TOTAL (B)		**73,37,19,897**	**70,55,48,525**
Balance being Surplus/(Defecit) Carried to Corpus/Capital Fund		**(12,63,92,678)**	**(3,81,05,837)**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

S.B.RAMESH
ACCOUNTS OFFICER

SHRIPATHI.K
ADMINISTRATIVE OFFICER

ANNAPURNI SUBRAMANIAM
DIRECTOR

As per our report of even date
For Gireesha Vijayan & Associates
Chartered Accountants
FRN 014117S

VIJAYAN. G
Partner
M No.036348

Date: 31.07.2020
Place :BENGALURU

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

RECEIPTS AND PAYMENTS STATEMENT FOR THE YEAR ENDED MARCH 31, 2020

(Amt. in Rupees)

Receipts	Current Year	Previous Year	Payments	Current Year	Previous Year
I) Opening Balances			I) Expenses		
a) Cash in hand	70,876	95,281	a) Establishment Exp (Sch.20)	48,79,21,312	46,33,41,509
b) Bank Balances			b) Admin Expenses (Sch 21)	17,30,95,488	17,77,34,945
i) Current Accounts	5,268	35,52,497			
ii) Deposit Accounts	-	-	II) Payments made against projects	23,58,09,454	56,36,34,148
iii) Savings Accounts	34,44,90,800	60,28,94,175	III) Investments made		
			a) Out of Earmarked/End. Funds	-	-
II) Grants Received			b) Out of own funds	-	-
a) From Govt. of India	-	-			
i) Capital Grants	8,75,55,000	9,66,05,200			
ii) Recurring Grants	60,43,04,000	65,74,77,000			
b) From State Govt.	-	-	IV) Increase in Current Assets	2,65,43,519	4,95,818
c) From other sources	-	-	V) Capital Expenditure		
			a) Purchase of fixed assets	15,01,88,164	1,34,93,778
III) Project Receipts	72,29,23,944	26,85,01,460	b) Expenditure on Work-in-progress	(7,98,20,478)	11,87,20,713
IV) Increase in Current Liabilities	2,56,05,241	35,77,391	VI) Refund of surplus money/Loans		
V) Decrease in Current Assets	2,69,61,893	4,18,10,898	a) To the Govt. of India	-	-
VI) Interest Received			b) To the State Govt.	-	-
a) On Bank deposits	2,31,543	40,21,387	c) To other providers of funds	-	-
b) on Loans, Advances etc.	5,65,457	8,42,837			
			VII) Finance Charges (Interest)		-
VII) Other Income (Specify)	-	-	VIII) Decrease in Current Liabilities	2,28,56,896	24,91,735
VIII) Amount Borrowed	-	-	IX) Closing Balances:		
IX) Any other receipts	22,26,219	51,01,464	a) Cash in hand	1,29,718	70,876
			b) Bank Balances	-	
			i) Current Accounts	6,13,756	5,268
			ii) Savings Accounts	79,76,02,411	34,44,90,800
			c) Deposits Account	-	-
TOTAL	181,49,40,241	168,44,79,590	TOTAL	181,49,40,241	168,44,79,590

S.B.RAMESH
ACCOUNTS OFFICER

SHRIPATHI.K
ADMINISTRATIVE OFFICER

ANNAPURNI SUBRAMANIAM
DIRECTOR

As per our report of even date
For Gireesha Vijayan & Associates
Chartered Accountants
FRN 014117S

VIJAYAN.G
Partner
M No.036348

Date: 31.07.2020
Place :BENGALURU

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Current Year		Previous Year	
Schedule 1- Corpus/Capital Fund				
Balance as at the beginning of the year	78,79,99,083	-	72,94,99,720	
Add: Capital Grants	8,75,55,000	87,55,54,083	9,66,05,200	82,61,04,920
	-	-		
Add/Deduct: Balance of net Income/(Expenditure) transferred from the Income & Expenditure Account	(12,63,92,678)	(12,63,92,678)	(3,81,05,837)	(3,81,05,837)
Balance as at the Year End		74,91,61,405		78,79,99,083

	Current Year		Previous Year	
Schedule 2 - Reserves & Surplus				
1, Capital Reserve:				
As Per last Account	-		-	
Addition during the year	-		-	
Less: Deduction during the year	-	-	-	-
2, Revaluation Reserve:				
As Per last Account	-		-	
Addition during the year	-		-	
Less: Deduction during the year	-	-	-	-
3, Special Reserve:				
As Per last Account	-		-	
Addition during the year	-		-	
Less: Deduction during the year	-	-	-	-
4, General Reserve:				
As Per last Account	-		-	
Addition during the year	-		-	
Less: Deduction during the year	-	-	-	-
Balance as at the Year End		-		-

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2020

Schedule 3- Earmarked/Endowment / Project Funds

(Amt in Rs.)

Sl No	Funding Agency	Project Name	Opening Balance	Received during the year	Utilisation			Total Utilisation	Balance as on 31/03/2020
					Capital Expenditure	Revenue Expenditure	Advances/LC/Security Dep		
		Funded by Government Agencies							
1	DAE	DAE - TMT	1,06,63,739	30,44,30,000	-	-	-	-	31,50,93,739
2	DST	DST - TMT	13,97,84,863	27,00,00,000	9,43,36,000	2,63,49,868	-	12,06,85,868	28,90,98,995
3		DST - GSMT	1,56,09,006	-	-	-	-	-	1,56,09,006
4		DST-Newton-Bhabha (UK/2018/1)-Annapurni S	1,26,000	-	-	68,695	-	68,695	57,305
5		DST Indo-South Africa (P04) - P.Parihar	5,01,594	-	-	3,530	-	3,530	4,98,064
6		DST Indo-Polish (P05) - CS Stalin	3,92,370	-	-	2,700	-	2,700	3,89,670
7		DST Indo-Belgium (P3) - D Banerjee	41,155	-	-	-	-	-	41,155
8		DST INSPIRE(15275) - Vema Reddy	(1,15,893)	18,95,040	-	12,08,873	-	12,08,873	5,70,274
9		DST INSPIRE (1478) - Lalitha Sairam	10,73,522	-	-	-	-	-	10,73,522
10		DST-JSPS (P-281) - DK Sahu	2,13,210	7,211	-	1,97,144	-	1,97,144	23,277
11		DST Indo-UKIERI - D Banerjee	(78,440)	-	-	-	-	-	(78,440)
12		DST - G C Anupama	11,628	-	-	11,628	-	11,628	-
13		DST N-PDF (1563) - Brajesh Kumar	1,58,797	80,000	-	2,87,137	-	2,87,137	(48,340)
14		DST N-PDF (2648) - Aditi Agarwal	2,00,899	-	-	2,83,550	-	2,83,550	(82,651)
15		DST-WOS (83) - Maya Prabhakar	17,112	4,00,000	-	84,764	-	84,764	3,32,348
16		DST-Indo-Russian (265) - Jayant Murthy	3,49,307	8,733	-	-	-	-	3,58,040
17		DST-Ramanunan Fellow-Smitha S	6,66,906	1,00,000		5,35,593	-	5,35,593	2,31,313
18		DST-Indo-German - Lalitha Sairam	4,79,153	-	-	-	-	-	4,79,153
19		DST-Indo Austria (P-05) - D Banerjee	-	4,03,416	-	1,46,993	-	1,46,993	2,56,423
20		DST-JSPS (P-300) D Banerjee	-	2,17,519	-	93,134	-	93,134	1,24,385
21		DST-Indo-Thai Aruna Goswami	-	2,34,313	-	1,07,807	-	1,07,807	1,26,506
22		DST-BRICS(2017-G) - D Banerjee	2,11,546	9,67,672	1,29,690	8,22,132	-	9,51,822	2,27,396
23		BRICS-(MuMeSTU/2017 G)- DK Sahu	3,35,000	16,244	-	-	-	-	3,51,244
24		DST- 150 Years of the Periodic Table	-	1,51,387	-	1,51,387	-	1,51,387	-
25		DST-DAAD - Annapurni Subramaniam	75,262			1,16,750	-	1,16,750	(41,488)
26	ISRO	ISRO-INSIST-Annapurni Subramaniam	30,00,000	53,465		9,36,542	-	9,36,542	21,16,923
27		ISRO Aditya	12,23,22,658	13,61,51,234	8,41,57,546	1,42,39,179	(94,764)	9,83,01,961	16,01,71,931
28		ISRO (ARFI)- G C Anupama	13,50,601	-	-	-	-	-	13,50,601
29		ISRO UVIT	11,50,910	39,223	38,640	3,91,325	-	4,29,965	7,60,168
30	IUSSTF	IUSSTF PIRE GROWTH - G C Anupama	20,85,070	44,362	72,048	6,01,342	-	6,73,390	14,56,042
31		IUSSTF -Solar Coronal - P Sreekumar	(67,944)	67,944	-	-	-	-	-
32		IUSSTF (JC-014) - Mousumi Das	95,601	6,06,707	-	5,53,573	-	5,53,573	1,48,735

33	SERB	SERB (003415) - Arun Mangalam	11,90,500	20,277	4,77,750	5,50,965	-	10,28,715	1,82,062
34		SERB-Aruna Goswami - EMR	3,96,336	6,711	-	2,72,165	-	2,72,165	1,30,882
35		SERB (001535) - Sharanya Sur	6,09,141	1,08,167	3,35,580	91,346	-	4,26,926	2,90,382
36		SERB (1450) - Jayant Murthy	32,70,919	8,55,770	19,12,484	8,65,923	-	27,78,407	13,48,282
37		SERB (941) - Ravindra Banyal	17,12,219	27,331	-	13,05,013	-	13,05,013	4,34,537
38		SERB (124) - Rajat Chaudhury	10,55,143	25,834	-	32,672	-	32,672	10,48,305
39		SERB (2470) - Gajendra Pandey	(3,50,664)	-	-	83,958	-	83,958	(4,34,622)
40		SERB (P39) Kodai Digi - D Banerjee	-	10,00,000	-	12,90,410	-	12,90,410	(2,90,410)
41		SERB - P Shalima	(18,039)	-	-	-	-	-	(18,039)
42		SERB-Vivek-Ramanujan Fellowship		12,25,500		4,34,516	-	4,34,516	7,90,984
43		SERB-(003786)-SPK Rajaguru	-	8,82,034	-	52,356	-	52,356	8,29,678
44		SERB (MATRICS/000896) - Pravabati C	2,00,000	-	-	2,17,911	-	2,17,911	(17,911)
45	CSIR	CSIR [03/890(005)] N Sindhu	(4,42,387)	9,91,387	-	2,65,367	-	2,65,367	2,83,633
46	NASI	NASI - Ram Sagar	2,526	1,63,800	-	1,59,575	-	1,59,575	6,751
47		NASI - RAM SAGAR (New 2020)	-	1,00,000	-	-	-	-	1,00,000
48		NASI - Amit Mondal	63,050	-	-	63,050	-	63,050	-
49	IAU	IAUS 340 - D Banerjee	2,62,005	16,42,663	-	15,65,607	-	15,65,607	3,39,061
TOTAL			**30,86,04,381**	**72,29,23,944**	**18,14,59,738**	**5,44,44,480**	(94,764)	**23,58,09,454**	**79,57,18,871**

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Current Year		Previous Year	
Schedule 4- Secured Loans & Borrowings				
TOTAL		-		-

	Current Year		Previous Year	
Schedule-5- Unsecured Loans & Borrowings				
TOTAL		-		-

	Current Year		Previous Year	
Schedule 6- Deferred Credit Liabilities				
TOTAL		-		-

	Current Year		Previous Year	
Schedule-7- Current Liabilities & Provisions				
A. Current Liabilities				
1. Acceptances	-	-	-	-
2. Sundry Creditors	-			
a) For goods			-	
b) Others (services)	60,27,414	-	66,11,625	-
3) Advances Received	-			
4. EMD, Security Dep.Caution Dep etc	1,94,40,102	-	1,59,08,063	-
5. Statutory Liabilities		-	-	-
a) Overdue	-	-	-	-
b) Others	-	-	-	-
6. Other Current Liabilities	1,79,273	2,56,46,789	4,08,491	2,29,28,179
TOTAL (A)		2,56,46,789		2,29,28,179
B. PROVISIONS				
1. Taxation /Audit Fee Payable	1,07,085		97,350	
2. Gratuity	-		-	
3. Superannuation / Pension	-		-	
4. Accumulated Leave Encashment	-		-	
5. Other (specify)	-	1,07,085	-	97,350
TOTAL (B)		1,07,085		97,350
TOTAL (A+B)		2,57,53,874		2,30,25,529

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2020

(Amt. in Rupees)

Schedule 8- Fixed Assets										
Description	GROSS BLOCK			Rate	DEPRECIATION				NET BLOCK	
	Cost /Valuation as at the beginning of the year	Additions /Deletions During the year	Cost / Valuation at the end of the year		As at the beginning of the year	Additions during the year	Deductions during the year	As at the end of the year	As at the end of current year	As at the end of Previous Year
1. Land - Freehold	2,48,98,870	-	2,48,98,870	-	-	-	-	-	2,48,98,870	2,48,98,870
NLST Land at Merak	5,65,64,200	-	5,65,64,200	-	-	-	-	-	5,65,64,200	5,65,64,200
2. Buildings - On freehold land	35,58,18,042	11,03,42,271	46,61,60,313	5%	13,99,36,917	2,06,42,125	-	16,05,79,042	30,55,81,271	30,25,00,229
3. MGK Menon Laboratory	12,23,60,233	1,58,740	12,25,18,973	5%	2,26,82,181	49,91,840	-	2,76,74,021	9,48,44,952	9,96,78,052
4. Vainu Bappu Telescope	5,34,06,249	1,91,410	5,35,97,659	15%	5,31,68,075	64,438	-	5,32,32,513	3,65,146	2,38,174
5. 2M Telescope	45,30,13,898	-	45,30,13,898	15%	45,29,02,547	16,703	-	45,29,19,250	94,648	1,11,351
6. HAGAR	5,12,70,665	-	5,12,70,665	15%	4,19,97,577	13,90,963	-	4,33,88,540	78,82,125	92,73,088
7. Scientific Equipments	1,14,92,61,456	2,39,72,831	1,17,32,34,287	15%	96,73,77,763	3,08,78,479	-	99,82,56,242	17,49,78,045	18,18,83,693
8. Vehicles	1,67,11,268	-	1,67,11,268	15%	1,47,40,803	2,95,570	-	1,50,36,373	16,74,895	19,70,465
9. Furniture & Fixtures	2,76,55,208	3,08,146	2,79,63,354	10%	2,54,40,617	2,52,274	-	2,56,92,891	22,70,463	22,14,591
10. Computers	17,15,29,155	98,68,010	18,13,97,165	40%	15,63,50,494	1,00,18,668	-	16,63,69,162	1,50,28,003	1,51,78,661
11. Library Books	16,31,16,381	53,46,756	16,84,63,137	40%	15,80,83,040	41,52,039	-	16,22,35,079	62,28,058	50,33,341
TOTAL	**2,64,56,05,625**	**15,01,88,164**	**2,79,57,93,789**		**2,03,26,80,014**	**7,27,03,097**		**2,10,53,83,111**	**69,04,10,678**	**69,95,44,715**
Capital Work in Progress										
Building at Leh	8,66,19,104	(8,66,19,104)								
NLST	5,78,42,028	41,83,383	6,20,25,411		-	-	-	-	6,20,25,411	5,78,42,028
NLOT	75,70,684	26,15,243	1,01,85,927		-	-	-	-	1,01,85,927	75,70,684
TOTAL OF CAPITAL WORK IN PROGRESS	**15,20,31,816**	(7,98,20,478)	**7,22,11,338**		-	-	-	-	**7,22,11,338**	**6,54,12,712**
GRAND TOTAL	**2,79,76,37,441**	**7,03,67,686**	**2,86,80,05,127**		**2,03,26,80,014**	**7,27,03,097**	-	**2,10,53,83,111**	**76,26,22,015**	**76,49,57,426**

INDIAN INSTITUTE OF ASTROPHYSICS,BENGALURU

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Current Year		Previous Year	
Schedule 9- Investments from Earmarked/Endowment Fund				
1. In Government Securities				
2. Other Approved Securities	-		-	-
3. Shares	-		-	-
4. Debentures and Bonds	-		-	-
5. Subsidiaries and Joint Ventures	-		-	-
6. Others	-	-	-	-
TOTAL		-		-

	Current Year		Previous Year	
Schedule-10 Investment (Others)				
1. In Government Securities	-		-	-
2. Other Approved Securities	-		-	-
3. Shares	-		-	-
4. Debentures and Bonds	-		-	-
5. Subsidiaries and Joint Ventures	-		-	
6. Others	-	-	-	-
TOTAL		-		-

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Current Year		Previous Year	
Schedule 11- Current Assets, Loans & Advances				
A. CURRENT ASSETS				
1. Inventories				
a.Stores & Spares	-	6,03,548	-	6,25,317
b.Loose tools	-		-	
c.Stock in trade	-	-	-	-
2. Sundry Debtors				
a.Debts outstanding	-		-	
b.Others	-	-	-	-
3. Cash balances in hand (Including cash imprest)	1,29,718	-	70,876	-
4. Bank Balances				
- On Current Accounts	6,13,756		2,38,128	
- On Savings Accounts	79,76,02,411		34,42,57,940	
- On Deposit Accounts (IIA Margin LC)	10,62,000	79,94,07,886	6,72,000	34,52,38,944
TOTAL (A)		**80,00,11,434**		**34,58,64,261**
B. LOANS/ADVANCES AND OTHER ASSETS				
1. Advances and other amounts recoverable in cash				
On Capital Account	-		-	
Deposits	21,92,409		22,52,229	
TMT - Project	7,66,113		7,66,113	
Advances to Staff Members	35,67,407	65,25,929	46,98,859	77,17,201
2. Income Accrued				
On Investments-Others	-		-	
On Loans & Advances	-	-	-	-
3. Claims Receivable (CSIR JRF)	10,90,105		10,90,105	
Other Claims (Receivable from ASI)	3,84,667	14,74,772	-	10,90,105
TOTAL (B)		**80,00,701**		**88,07,306**
Grand Total (A+B)		**80,80,12,135**		**35,46,71,567**

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF INCOME & EXPENDITURE ACCOUNT AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Current Year		Previous Year	
Schedule 12- Income from Sales/Service				
1, Income From Sale	-	-	-	-
2, Income from Services	-	-	-	-
TOTAL		-		-

	Current Year		Previous Year	
Schedule 13- Grants/Subsidies				
(Irrevocable Grants & Subsidies Received)				
1. Central Government	-	-	-	-
	-		-	-
a. Revenue Grants	60,43,04,000	60,43,04,000	65,74,77,000	65,74,77,000
2. State Government	-	-	-	-
3. Government Agencies	-	-	-	-
4. Institutions/ Welfare Bodies	-	-	-	-
5. International Organisations		-	-	-
6. Others	-	-	-	-
TOTAL		60,43,04,000		65,74,77,000

	Current Year		Previous Year	
Schedule 14- Fees/Subscriptions				
1. Licence fees	-	-	-	-
2. Annual Fees/Subscriptions	-	-	-	-
3. Seminar/Program Fees	-	-	-	-
4. Consultancy Fees	-	-	-	-
5. Others	-	-	-	-
TOTAL		-		-

	Current Year		Previous Year	
Schedule 15- Income from Investments				
(Income on investments from earmarked/endowment funds)				
1. Interest				
a) On govt. securities				
b) Other bonds/debentures	-		-	
2. Dividends	-		-	
a) On Shares				
b) On Mutual Fund Securities				
3. Rents	-		-	
4. Others	-			-
TOTAL		-		-

	Current Year		Previous Year	
Schedule 16- Income from Royalty/Publication				
1. Income from Royalty	-			
2. Income from Publications	-			
3. Others	-	-	-	-
TOTAL		-		-

	Current Year		Previous Year	
Schedule 17- Interest Earned				
1. On term Deposits				
a.With Scheduled Banks	-		-	
b.With Non Scheduled Banks	-		-	
c.With Institutions	-		-	
d.Others	-	-	-	-
2. On Savings Accounts				
a.With Scheduled Banks	2,31,543		40,21,387	
b.With Non Scheduled Banks	-		-	
c. Post office savings Accounts	-		-	
d.Others	-	2,31,543	-	40,21,387
3. On Loans				
a.Employees/Staff	5,65,457		8,42,837	
b.Others	-	5,65,457	-	8,42,837
TOTAL		**7,97,000**		**48,64,224**

	Current Year		Previous Year	
Schedule 18- Other Income				
1) Profit on sale/disposal of assets				
a) Own Assets				
b) Assets acquired out of grants				-
2) Licence Fee	4,48,877	-	4,49,705	
2) Overhead Income, Tender Fee and Other Receipts	17,77,342	22,26,219	46,51,759	51,01,464
TOTAL		**22,26,219**		**51,01,464**

	Current Year		Previous Year	
Schedule 19- Increase/(Decrease) in stock of finished goods				
TOTAL		-		-

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU

SCHEDULES FORMING PART OF INCOME & EXPENDITURE ACCOUNT AS AT 31ST MARCH 2020

(Amt. in Rupees)

	Current Year	Previous Year
Schedule 20- Establishment Expenses		
a) Salary & Wages	28,05,87,556	25,35,81,627
b) Allowances & Bonus	61,69,848	1,05,85,986
c) Contribution to Other Provident Funds NPS etc	86,58,675	64,81,017
d) Staff Welfare Expenses	3,10,49,271	4,03,25,626
e) Employees' Retirement and Terminal Benefits & Pension	16,14,55,962	15,23,67,253
TOTAL	**48,79,21,312**	**46,33,41,509**

	Current Year	Previous Year
Schedule 21- Other Administrative Expenses		
1) Advertisement	7,73,667	6,92,100
2) Audit Fee	1,07,085	97,350
3) AMCs/ Repairs	1,21,98,116	98,91,358
4) Bank Charges	2,21,691	2,46,958
5) Canteen Expenses	41,28,594	30,65,312
6) Conveyance	1,07,856	1,95,182
7) Electricity & Water Charges	1,39,22,138	1,31,22,052
8) Field Trips & Transport Expenses	22,69,543	29,43,346
9) Guest House	17,99,454	19,54,436
10) Leased Rent for Observatories	1,33,654	1,77,313
11) Legal Charges	8,48,825	12,41,200
12) Maintenance of campus / Outsourced Manpower etc.	9,39,53,091	9,08,13,952
13) Other Expenses	43,93,384	38,82,244
14) PhD/M.Tech. PhD Programme	21,04,439	20,77,347
15) Postage & Courier	2,23,869	1,48,523
16) Printing & Stationery	7,11,434	9,59,532
17) Property Tax	29,89,016	11,08,776
18) Public Outreach Expenses	32,386	5,23,951
19) Stores & Consumables	37,90,210	49,81,751
20) Summer Schools/Conference/Workshops	39,97,008	29,62,469
21) Telephone and Communication Charges	1,21,85,127	1,65,58,429
22) Travel Expenses	98,83,908	90,22,307
23) Vehicle Maintenance / Transport	23,20,993	25,40,304
24) Welfare measures for Scheduled Tribes	-	85,28,753
TOTAL	**17,30,95,488**	**17,77,34,945**

	Current Year	Previous Year
Schedule 22- Expenditure on Grants, Subsidies ETC		
a) Grants given to Institutions/Organisations	-	-
b) Subsidies given to Institutions/Organisations	-	-
TOTAL	-	-

	Current Year	Previous Year
Schedule 23- Interest		
a) On Fixed Loans	-	-
b) On Other Loans	-	-
c) Others		
TOTAL	-	-

Schedule-24: SIGNIFICANT ACCOUNTING POLICIES

1. ACCOUNTING CONVENTION:

   The Financial Statements are prepared on the basis of historical cost convention unless otherwise stated and on accrual basis of accounting. The guidelines given by the Government of India for drawing financial statements for Central Autonomous Bodies have been adopted to the extent that they are directly applicable.

2. FIXED ASSETS

   The Fixed Assets are stated at cost of acquisition less depreciation. The same was not verified physically on periodical basis by the Management.

3. DEPRECIATION:

   The Depreciation is charged on WDV at rates as stated in the Fixed Assets Schedule. The amount of depreciation has been debited to the Income & Expenditure Account as per the guidance of CAG Audit. The rate of depreciation has been charged as per the Income Tax Act, 1961 except Buildings which are depreciated at 5%.

4. INVENTORY:

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

5. GOVERNMENT GRANTS:

   Government Grants received are accounted on receipt basis and the same have been separately shown under Capital Grants and Recurring Grants in the Annual Accounts of the Institute. Out of the total Grants, the Capital Grant is directly credited to the Capital Fund Account, the Recurring Grant accounted as Income and shown in Income & Expenditure Account. The interest earned on Government Grants such as Bank Interest and Interest on Staff Advances has been credited to Income & Expenditure Account.

6. FOREIGN CURRENCY TRANSACTIONS:

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

7. RETIREMENT BENEFITS:

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

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

8. The Schedule-3: Earmarked / Endowment Fund is the Unspent Balances of the Projects at the year end.

Schedule-25: CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS

A. Contingent Liabilities :
   1. Claims against the Institute not acknowledged as Debt : Nil
   2. Bank Guarantees given by the Institute : Nil
   3. Disputed Demands in respect of Taxes : Nil

B. NOTES ON ACCOUNTS:

1. In the opinion of the Management, the Current Assets, Advances and Deposits have been recorded at the actual value of transactions in the ordinary course of activities. The aggregate amount is shown in the Balance Sheet.

2. In the Receipts and Payments Accounts, the amount shown in Project Receipts includes Grants received during the year, Interest received from banks and the difference in value of LC and actual payment pertaining to projects during the last year.

3. In the Receipts and Payments Account, the amount shown in Project Payments includes Capital Expenditure, LC Payments and the Revenue Expenditures pertaining to projects during the year.

4. In the Receipts and Payments Account, the amount shown in Closing Balance includes the Project Balances.

5. Previous year figures have been re-grouped wherever necessary.

6. The figures have been rounded off to the nearest rupee.

7. During the year, the capital WIP amounting to Rs.8,66,19,104/- has been capitalized.

S.B.RAMESH
ACCOUNTS OFFICER

SHRIPATHI.K.
ADMINISTRATIVE OFFICER

ANNAPURNI SUBRAMANIAM
DIRECTOR

As per our report of even date
For Gireesha Vijayan & Associates
Chartered Accountants
FRN 014117S

VIJAYAN.G.
Partner
M No.036348

UDIN:20036348AAAAAB8882

Date: 31.07.2020
Place : BENGALURU

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