SPACE RESEARCH IN INDIA

HIGHLIGHTS OF 2022–2023

FOR THE FORTY-FIFTH COSPAR SCIENTIFIC ASSEMBLY

SPACE RESEARCH
IN INDIA

Highlights of
2022-2023

A Report of the
Indian National Committee for Space Research (INCOSPAR)
Indian National Science Academy (INSA)
Indian Space Research Organisation (ISRO)

For the 45th COSPAR Scientific Assembly
Busan, South Korea ; 13 to 21 July 2024

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FOREWORD

The Indian Space Programme, since its genesis, has nucleated around scientific exploration and societal applications. During the process of evolution, the Indian Space Research Organisation (ISRO) has witnessed several transformative phases in the realms of space transportation systems, scientific exploration capabilities, as well as space applications like Earth Observation, Communication, as well as Satellite Navigation. The endeavour of Human Spaceflight Programme in India will add yet another dimension, facilitating human-in-loop scientific experiments from space. This course of development has received a significant boost with the Hon'ble Prime Minister of India showing the countrymen the big vision of an Indian Space Station for space exploration, as well as Indian astronauts landing on the Moon with Indian space transportation systems.

This ambitious trajectory of development necessitates the synergy between the academia, institutes and industries in the country. The space sector reforms in India, which happened in the year 2020, has been a major step towards achieving this goal. This has been corroborated by the Indian Space Policy, which was released in year 2023. Meanwhile, the National Education Policy (NEP), rolled out in year 2020, addresses this requirement from the fundamental level of human capability development, focusing on strengthening the educators, as well as by restructuring the regulatory framework of education.

Equipped with these, India is progressing with multi-pronged approach. On one hand, the country is engaging in complex space missions, on the other hand, it is investing in enabling the academia, institutes and industries to contribute to this journey in a more resourceful way.

The last couple of years have been quite significant in India's space exploratory journey. India has significantly contributed to the scientific exploration of the solar system and astronomical X-Ray sources with the success of the Chandrayaan-3, Aditya-L1 and XPoSat missions. In the domain of exploration, India is playing a resourceful role in International Cooperation, and has been collaborating with several space agencies. The recent event of signing the Artemis Accord by India opens up even broader opportunity to contribute to the ongoing and future global endeavours in the realm of space exploration.

India has also announced the names of the *Gaganyatri* designates for the Human Space Flight programme Gaganyaan. Several important technology demonstrations have been completed, which mark the major milestones towards the materialization of the Gaganyaan mission.

Recently, The Government of India has accorded its approval for India's participation in the international mega science project, Square Kilometer Array (SKA), which will revolutionize radio astronomy, while driving the growth of many important new state-of-the-art technologies.

The Department of Space, Government of India, along with NSIL and INSPACE, is actively facilitating the industries and start-ups to enhance the space ecosystem of the country. As a result, the country has already witnessed two rocket flights from private players. Several technology demonstrations by the start-ups are also being facilitated. The science, technology and innovation of India is an outcome of the concerted effort of the national academia, institutes and industries.

Thus, India looks forward to contributing more to the global efforts of space exploration and innovation, and promote peaceful and sustainable use of the outer space. At this juncture, I am happy to present the INCOSPAR report to the 45th COSPAR scientific assembly, to be held at Busan, Korea, during July 13-21, 2024. I hope that the information on space science activities in India, as provided in this report, will be an important reference to the global scientific community.

I wish the 45th COSPAR Scientific Assembly every success.

सोमनाथ

Date: July 01, 2024

(सोमनाथ. एस / Somanath. S)

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Distinguished Professor and Director, Physical Research Laboratory
Chairman, Indian National Committee for COSPAR

5 July 2024

PREFACE

With immense pleasure, I introduce the report on Space Research in India, prepared for the 45th COSPAR Scientific Assembly, 13–21 July 2024, Busan, Korea, by the Indian National Committee for Space Research (INCOSPAR), Indian National Science Academy (INSA), and Indian Space Research Organisation (ISRO). The report gives an overview of the important accomplishments, achievements and research activities conducted in India in several areas of near-Earth space, Sun, Planetary science, and Astrophysics for the duration of Jan 2022–Dec 2023. This report also provides glimpses of capacity building activities in space science research, academic courses offered on space science and technology, national and international collaborations in space science and technology, laboratories and facilities established at various institutes and centres contributing to space science exploration and research in India, to name a few.

The Indian space science community has been active in the domains related to Astronomy and Astrophysics, Solar Physics, Space Weather and Sun-Earth connection, Space and Atmospheric Sciences, Planetary Science, Geomagnetism and Geosciences. This report describes highlights of the research from the studies on oceanography, atmospheric structure and dynamics, clouds and convective systems, aerosols, radiation and trace gases, weather and climate change, middle atmosphere, ionosphere, magnetosphere, solar wind and space weather, lunar and planetary studies, Sun and the solar system bodies, stars, galaxies, galactic and extragalactic astronomy and cosmology.

In the area of planetary science, the soft-landing of Chandrayaan-3 in the lunar southern high latitudes at Shiv-Shakti point on 23 August 2023, made India the fourth country to master soft landing on the Moon, but the first to do so in the south polar region. Chandrayaan-3 collected data for one lunar day on elemental composition, thermo-physical properties, plasma environment and seismicity in the vicinity of the landing site. Hopping from the lunar surface, de-orbiting from the lunar orbit to Earth orbit were successfully demonstrated, which would pave way for future sample return. Chandrayaan-2 orbiter is completing five years and is providing newer insights to the lunar science.

AstroSat, India's first multi-wavelength space-based astronomical observatory, has successfully completed eight years of operation on 28 September 2023. The observatory operating on proposal-basis is open to astronomy community since October 2016. Currently, AstroSat has around 2700 user from 50 countries. In the first eight-years, AstroSat observations have produced more than 440 refereed publications, and >1500 conference proceedings, GCN circulars, Astronomer's telegrams and other non-refereed publications. Some of the major science results that came out of AstroSat data during the period include discovery of extended emission in distant dwarf galaxies using UVIT, Spectral transition in the changing-look active galaxy NGC 1566 during the declining phase of the 2018 outburst, and multi-wavelength observations of spectral states of OJ 287 blazer.

Aditya-L1, launched on 2 September 2023, is the first space-based Indian mission to study the Sun from the Sun-Earth system Lagrangian point 1 (L1). This mission, with seven payloads onboard to observe the photosphere, chromosphere and corona, provide a greater advantage of observing the solar activities and their effect on space weather. Aditya-L1 captured the solar events (flares & CMEs) during May 2024. India's X-ray polarimetry mission XPoSat launched on 1 January 2024, has commenced its scientific observations, which include the generation of the pulse profile of the Crab pulsar by the POLIX, a polarimeter instrument in X-rays onboard XPoSat.

I thank the scientists who have provided inputs on the space research activities being carried out in their respective Institutes and departments for the preparation of this report. I acknowledge the hard work of Science Programme Office, ISRO HQ, Bangalore, for compiling and editing the report on behalf of INCOSPAR.

Prof. (Dr.) Anil Bhardwaj
Chairman, Indian National Committee for COSPAR

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Message

In the last couple of years, India has made significant progress in space-based exploration in planetary science, solar physics, as well as astronomy. In planetary exploration, India has moved forward with its systematic lunar exploration programme by the successful soft-landing of Chandrayaan-3. In solar physics, India has sent its first dedicated solar observatory Aditya-L1 at the first Sun-Earth Lagrange point. In the realm of astronomy, India has sent X-Ray astronomy spacecraft XPoSat with the capability of studying the polarisation of the X-Rays from bright X-Ray sources.

India's lunar exploration program is motivated by the spirit of comparative planetology. After the encouraging science results from the two orbiter-based missions Chandrayaan 1 and 2, India emphasized on Chandrayaan-3 as a lander-rover mission to study the Moon at its surface. Chandrayaan-3 soft-landed on the Moon on August 23, 2023, at the Southern higher latitude (69.3 degree South, 32.3 degree East) of the Moon. The landing site of Chandrayaan-3 has been named as Statio Shiv Shakti. The scientific results are being analysed, which indicate scientifically interesting observations on the lunar surface, as well as the near-surface plasma environment.

The beginning of the year 2024 was celebrated by India through two major scientific events; first, the launch of the X-Ray polarimetry mission XPoSat on January 01, and then the successful insertion of the Indian Solar observatory Aditya-L1 to the halo orbit around the Sun-Earth L1 point on January 06. The XPoSat spacecraft is placed at Low Earth Orbit (non-sun synchronous orbit of ~650 km altitude, low inclination of ~6 degree), carrying two scientific payloads. The XPoSat mission is capable of simultaneous studies of temporal, spectral, and polarization features of the bright X-Ray sources. India’s maiden Solar observatory Aditya-L1is aimed at the measurement of the radiation, particles and magnetic field emanated by the Sun. The Aditya-L1 spacecraft is conducting solar observation from the halo orbit around the first Sun-Earth Lagrange point. The spacecraft is equipped with a Visible Emission Line Coronagraph, an UV Imaging Telescope to measure UV photons, instruments to study the solar wind particles (ions and electrons) and the associated interplanetary magnetic field from the Sun.

While all these events represent ISRO’s endeavour for space-based exploration, there are significant number of ground stations and observatories to study several important parameters related to the ionosphere, upper atmosphere, geomagnetism, cosmic ray physics, muon physics, solar observations, Radio Astronomy, to name a few. These ground-based observations complement, as well as supplement the space-borne observations. Many of these facilities belong to several government departments.

India is also a global contributor to scientific research through mega-projects. Recently, the Government of India has approved the LIGO-India for Gravitational-Wave research. Government of India has also accorded approval for India’s participation in the Square Kilometer Array (SKA) project. Indian academia, institutes are coming together to contribute to the scientific exploration programme.

This report presents an overview of the space science activities carried out by the laboratories under ISRO/Department of Space, Government of India, as well as some of the major academia and institutes who are engaged in space science research. I believe, this report will serve as a quick reference to the space science activities in India, and the major updates in the last couple of years.

At this juncture, I wish the 45th COSPAR Scientific Assembly every success.

(Tirtha Pratim Das)

Director,
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ISRO Headquarters
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Date: July 01, 2024

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INDIA'S SPACE SCIENCE ECOSYSTEM

INTRODUCTION TO THE INDIAN SPACE SCIENCE PROGRAMME

The Indian Space Programme nucleated around scientific exploration and societal applications. Today, the space science research activities of India are distributed among several institutes and academia of the country, and Indian Space Research Organisation (ISRO) is the space agency, under the Department of Space, Government of India. During the process of evolution, ISRO has witnessed several transformative phases in the realms of space transportation systems, scientific exploration capabilities, as well as space applications like Earth Observation, Communication, as well as Satellite Navigation.

When it comes to space science and exploration, Indian scientists from several institutes and academia work in all the domains of modelling, simulation and observation. As far as the observation is concerned, India has a pool of ground-based observatories for astronomy and solar science, along with several space-based observation platforms.

Apart from the fact that early astronomers from India made significant discoveries in terms of the understanding of the astronomical bodies, in modern times, India's ground-based observations date back to 1786, with the foundation of the Madras observatory; to 1826 with the foundation of the Bombay observatory (which later came to be known as the Colaba observatory); to 1899 with the foundation of the Kodaikanal Solar observatory. The domains of observation were the planets, the Moon, stars, the Sun, as well as the Earth's magnetic field. The invention of the electromagnetic field transmission and reception technologies opened the door for probing of the celestial subjects of interest remotely.

The first set of systematic observations of the Earth's ionosphere was conducted by Prof. Sisir Kumar Mitra, a renowned Indian physicist, a disciple of Acharya Jagadish Chandra Bose, through his radio sounding experiments in the first half of the twentieth century. That was the first time in India, were radio waves were used for the remote sensing observations of the Earth's ionosphere. His work on the ionosphere, the ionized layer of Earth's atmosphere, proved instrumental in understanding its properties and paving the way for future space exploration endeavors. He founded the Ionosphere Field Station at

Haringhata, near Kolkata, in 1953, in order to conduct radio-sounding experiments of the Earth's ionosphere. While Mitra's primary tool for exploration was the humble radiosonde, which was used as remote sensing tool, in-situ studies of the Earth's ionosphere and upper atmosphere were later initiated with sounding rockets from Thumba, a village near the Southern-most tip of India.

In the 1940s, Dr. Homi Bhabha and Dr. Vikram Sarabhai established two significant institutions, Tata Institute of Fundamental Research (TIFR) and Physical Research Laboratory (PRL), respectively. During this period, pioneering cosmic ray experiments were conducted using scientific balloons from the National Balloon Facility, TIFR. Both TIFR and PRL played crucial roles in laying the foundation for India's ambitious space exploration journey.

In addition to cosmic ray studies, the exploration of the upper atmosphere and ionosphere near the geomagnetic equator became a focal point for Indian scientists. The Thumba Equatorial Rocket Launching Station (TERLS) was established in Thumba, Kerala, in 1962, recognizing the importance of this unique region. Situated near the geomagnetic equator, TERLS served as an optimal launch site for rockets, becoming a central hub for experiments and sounding rocket launches that gathered valuable data about these regions. TERLS was dedicated to the United Nations on 2nd February 1968. Throughout the 1960s and 70s, Thumba witnessed numerous scientific experiments using sounding rocket platforms, with the first sounding rocket launched on 21 November 1963.

Meanwhile, the Indian National Committee for Space Research (INCOSPAR), established in 1962, laid the groundwork for the founding of the Indian Space Research Organisation (ISRO) in 1969. The subsequent formation of the Space Commission and the Department of Space (DoS) in 1972 aimed to guide the development of space science and technology in India, with ISRO coming under the purview of DoS. Since its inception, ISRO has undertaken a multitude of space science missions, contributing significantly to our understanding of the universe and showcasing India's advancements in space technology.

Building scientific instruments for sounding rockets laid the foundation for developing space borne tools for exploratory science. Through several learning experiences, Indian scientists and engineers mastered the art of crafting robust instruments that withstand the harsh space environment. This culminated in the launch of Aryabhatta in 1975, India's first satellite carrying experiments in X-ray astronomy, aeronomy, and solar physics. Subsequent ventures like SROSS C2 (1994) and IXAE (1996) continued the emphasis on astronomy and solar physics, often piggybacking on operational missions to gain experience.

The early 21st century saw India embark on dedicated scientific missions to explore the solar system. Chandrayaan-1 (2008) placed the nation on the global map as the fourth lunar explorer, mapping the lunar surface and discovering water molecules. Mangalyaan, the Mars Orbiter Mission (2013), achieved remarkable success on its maiden attempt, earning global acclaim and providing valuable insights into the Martian atmosphere.

ISRO's space science portfolio expanded with AstroSat (2015), India's first dedicated multi-wavelength observatory, contributing significantly to astronomy through diverse celestial observations and astrophysical studies. Building on these achievements, Chandrayaan-2 (2019) attempted a lunar landing, showcasing India's prowess in complex missions even though the lander encountered challenges during the final descent.

On July 14, 2023, Chandrayaan-3 successfully soft-landed on the lunar surface at the "Statio Shiv Shakti" (69.3°S, 32.3°E), leading to the declaration of August 23rd as "National Space Day" in India. This feat demonstrates continued progress in lunar exploration.

Meanwhile, the Aditya-L1 mission was launched on September 2, 2023. It was successfully inserted to the designated halo orbit around the Sun-Earth L1 point on January 6, 2024. Since then, the mission is studying the Sun from the halo orbit, offering unique insights into our star's influence.

With several ambitious missions planned, including the X-ray polarimetry satellite XPoSat, launched on January 1, 2024, ISRO remains committed to expanding its scientific objectives and space exploration endeavors. The journey from early cosmic ray experiments to lunar landings exemplifies India's steady progress in space science and technology.

Figure 1 shows the distribution of the ISRO / Department of Space centres throughout the country.

Fig.1: ISRO/DOS centres in India

ORGANISATION STRUCTURE OF THE DEPARTMENT OF SPACE (DOS)

DOS is responsible for carrying out space research and related activities in the country through ISRO's constituent units and major autonomous institutions. The Organisation chart for Department of Space, ISRO and its major establishments are shown in Fig.2

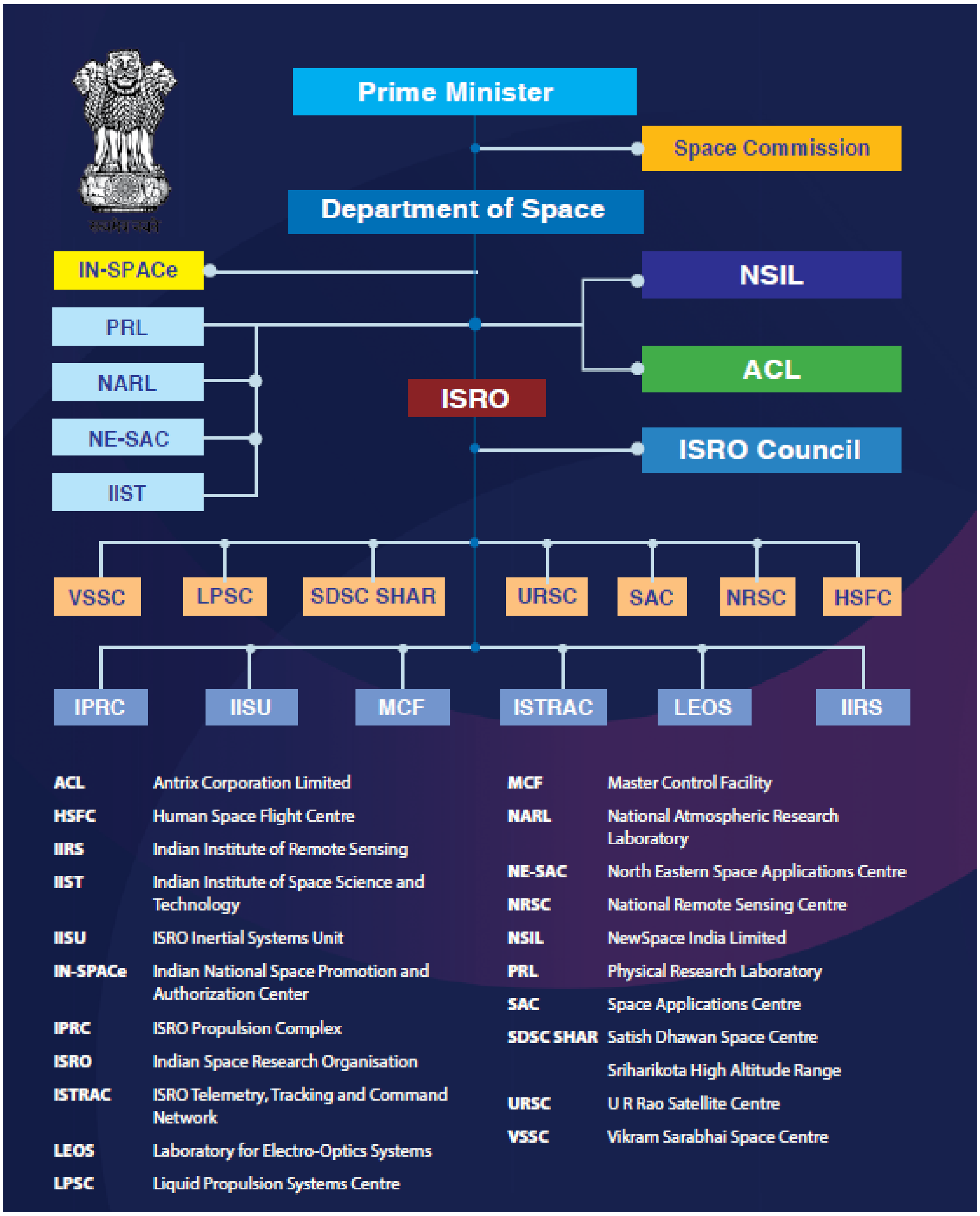


Fig 2: Organisation chart of DOS/ISRO

INDIAN NATIONAL COMMITTEE FOR SPACE RESEARCH (INCOSPAR)

The Indian National Committee for Space Research (INCOSPAR) operates as one of the committees under the umbrella of the Indian National Science Academy (INSA). INSA serves as the national adhering organization to the International Council of Scientific Unions (ICSU) and holds membership in the ICSU Council. Currently, Dr. Anil Bhardwaj serves as the Chairman of INCOSPAR, and Dr. K Rajeev represents the nation at the COSPAR Council.

INCOSPAR is tasked with the following terms of reference:

(i) To recommend and promote national activities as well as international cooperation in space exploration and space research.

(ii) To facilitate essential liaison with COSPAR of ICSU, fostering participation in international initiatives that contribute to the peaceful utilization of outer space.

SPACE SCIENCE PROMOTION SCHEMES AND PROGRAMMES

RESPOND Programme

Since its inception, ISRO's RESPOND (Sponsored Research) programme has served as a vital bridge between the Indian space agency and the nation's academic institutions. This unique initiative plays a critical role in not only bolstering space science research but also cultivating a robust talent pool to fuel India's ambitious space exploration endeavors.

RESPOND operates on a fundamental principle: fostering collaboration between academia and ISRO to unlock the immense research potential within universities and research institutions. This translates into financial support for cutting-edge projects aligned with ISRO's priorities. Imagine a bustling research environment where academic minds, brimming with fresh ideas, receive the necessary funding and technical guidance from ISRO's experienced scientists. This synergy not only ensures research aligns with practical space applications but also empowers academics to push the boundaries of knowledge.

RESPOND's impact extends far beyond individual projects. It acts as a breeding ground for the future generation of space scientists and engineers. By actively engaging students and researchers in real-world challenges, RESPOND ignites a passion for space exploration and provides invaluable exposure to the inner workings of ISRO. This early interaction nurtures future leaders, equipping them with the skills and knowledge needed to propel India's space program to even greater heights. Faculty members too benefit from RESPOND's knowledge-sharing platform, honing their expertise and guiding students towards impactful research. The program fosters a vibrant research ecosystem where cross-pollination of ideas between academia and industry becomes the norm, leading to innovative solutions and advancements in critical space technologies.

From developing advanced materials for spacecraft to exploring novel propulsion technologies, the program has played a pivotal role in addressing crucial research gaps and ensuring India remains competitive in the global space arena. The success stories are numerous – miniaturized instruments gracing space missions, deeper understanding of space weather phenomena safeguarding satellites, and the list goes on.

Space Technology Cells (STC)

ISRO has established several Space Technology Cells (STCs) across premier academic institutions. These dedicated units serve as catalysts within the Indian space science ecosystem, fostering a seamless collaboration between academia and industry.

STCs operate on a three-pronged approach. Firstly, they offer financial support and technical guidance to researchers pursuing projects aligned with ISRO's mission-critical needs. This empowers academics to translate their innovative ideas into tangible technologies, bridging the gap between theoretical research and practical application. Secondly, STCs create vibrant research hubs where interdisciplinary collaboration flourishes. Students and researchers from diverse backgrounds come together, sharing knowledge and tackling complex challenges with fresh perspectives. This collaborative environment accelerates the development of cutting-edge technologies. Finally, STCs play a crucial role in nurturing the next generation of space scientists and engineers. Enthusiastic students gain early exposure to real-world projects, participate in workshops, and interact with renowned ISRO scientists, igniting their passion for space exploration and attracting them to pursue careers in this exciting field.

Regional Academic Centre for Space (RAC-S)

Also, under the Capacity Building Programme Initiatives, ISRO has set up six Regional Academic Centre for Space (RAC-S) at six geographic regions of the country. These centres are located at MNIT, Jaipur (Western region), Gauhati University, Guwahati (North-Eastern Region), NIT Kurukshetra (Northern Region), NITK Surathkal (Southern Region), IIT (BHU) Varanasi (Central Region) and NIT Patna (Eastern Region). RAC-S aims to pursue advanced research in the areas of relevance to the future technological and programmatic needs of the Indian Space Programme and act as a facilitator for the promotion of space technology activities among students in the region. This will also inculcate scientific temper in the student community and will give them an opportunity to work in the advanced field of research. RAC-S will also facilitate and engage other institutes of excellence in the region to take part in the capacity building, awareness creation and research & development activities.

Space Technology Incubation Centres (S-TIC)

In addition, in order to attract and nurture the young academia with innovative ideas / research aptitude for carrying out research and developing the Academia–Industry ecosystem for Space Technology, ISRO has set up of Six Space Technology Incubation Centre (S-TIC) in 6 regions of our Country at NIT Bhopal (Central), East, NIT Jalandhar (North), NIT Agartala (North-East), NIT Trichy (South) and NIT Nagpur (West). This will enable the young academia to realize their innovative ideas / research aptitude into space grade components/elements which can be utilized for space applications, and guide them towards setting-up the future start-ups.

Space Science and Technology Awareness Training (START) program

Launched in July-August 2023, ISRO's Space Science and Technology Awareness Training (START) program aimed to ignite passion for space science and technology among undergraduate and postgraduate students. START typically offers twenty-five hours of lecture module, followed by an online examination. This online programme provides an introductory-level exposure to diverse domains, including astronomy, astrophysics, and planetary science. Renowned scientists and experts engaged participants through lectures, interactive sessions, and discussions. With a 2-3 hour daily commitment for 2-3 weeks, the program balances knowledge sharing with accessibility. The Indian Institute of Remote Sensing (IIRS) plays a crucial role in hosting and organizing this initiative.

Centres and Laboratories within the Department of Space (DOS), Government of India

INDIAN INSTITUTE OF REMOTE SENSING, DEHRADUN, INDIA

https://www.iirs.gov.in

ABOUT IIRS, DEHRADUN

Indian Institute of Remote Sensing (IIRS) is a premier institute with a primary aim to build capacity in Remote Sensing and Geoinformatics and their applications through education and training programmes at postgraduate level. It is a constituent Unit of Indian Space Research Organisation (ISRO), Department of Space, Government of India. Formerly known as Indian Photo-Interpretation Institute (IPI), founded in 1966, the Institute is first of its kind in entire South-East Asia. While nurturing its primary endeavor to build capacity among the user community by training mid-career professionals since its founding in 1966, the Institute has enhanced its capability and evolved many training and education programmes that are tuned to meet the requirements of various stake-holders, ranging from fresh graduates to policy makers including academia, industry and NGOs.

The capacity building activities of the Institute are primarily grouped into the following three domains – (1) Training & Education (2) Research and (3) Outreach. The Institute also hosts and provides support to the Centre for Space Science and Technology Education in Asia and The Pacific (CSSTEAP), affiliated to the United Nations, to conduct the remote sensing and GIS training & education programmes at postgraduate level.

Vision: *"Achieve excellence and remain in the forefront for capacity building in Remote Sensing & Geoinformatics and their applications."*

MAJOR RESEARCH DOMAINS

IIRS faculty have actively contributed the research in the areas of photogrammetry, SAR/ InSAR/ PolSAR remote sensing, LiDAR remote sensing, image processing techniques, etc. thereby contributing to the space program of the country for societal benefits, etc.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

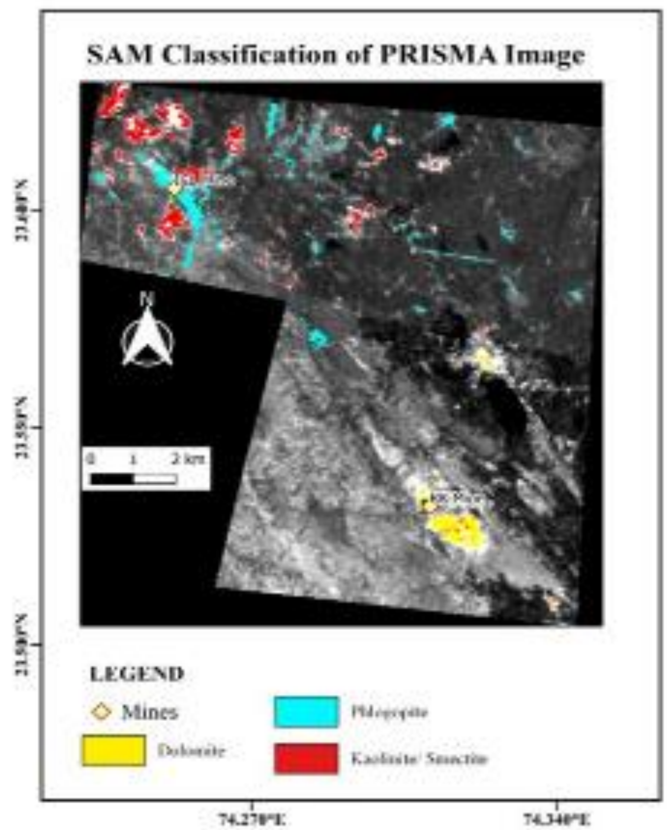
- **Evidences of Climate Change from the Higher Himalaya, Lahaul, Himachal Pradesh:** The mounting evidences from the high-mountain areas via accelerated glacier melting, permafrost thaw and expansion of glacier lakes are becoming a major concern for high-mountain communities, environmentalists and policy makers. The accelerated expansion of glacial lakes in the higher Himalaya is not just the expression of glacial melting to climate warming, but poses a serious threat in terms of glacial lake outburst floods (GLOFs). The present investigation focuses on a moraine-dammed pro-glacial lake (MDPGL) in the Kadu Nala valley (Lahaul, western Himalaya, India) that has evolved in less than a decade and has been expanding at an alarming rate since 2014. The data show that the actual development of the lake started in 2010 and has expanded to ~0.18 km2 in 2021. It was noteworthy to observe that between 2014 and 2021, the lake's area has increased by 134% in just seven years. The glacier associated with the lake was discovered to be retreating and lost 4% of its area between 2008 and 2021, exemplifying Himalayan glaciers' response to warming through melting ice, resulting in lake formation and exacerbating further glacier ice loss. Any breach in the moraine dam would immediately drain the entire lake, carry the loose sediments available in this glaciated valley and transform into a catastrophic hyper concentrated debris flow/flood. As seen recently in the Chamoli (Uttarakhand) event and throughout the world, such hyper-concentrated flows are capable of causing substantial damage to life and property.

- **Landslide Susceptibility in parts of Rishi Ganga Valley, Upper Alaknanda Basin, Uttarakhand:** Several devastating landslides have hit Uttarakhand in recent years, causing casualties, damaging infrastructure and disrupting transport networks. Rishi Ganga valley region is particularly prone, in this context, to landslides and debris flows mainly due to high slopes in mountainous terrain, heavy annual rainfall, complex geology and active tectonic activity. Pertinently, Landslide Hazard Zonation mapping is an important tool for mitigating such risks of landslides. Accurate and reliable Landslide Hazard Zone maps can be produced using high-resolution satellite data with the help of Remote Sensing and GIS technology and other ancillary information. To assess the susceptibility of landslide hazard, in this study, conditioning or causative factors viz. slope, aspect, lineament density, drainage density, lithology, geomorphology, curvature, TWI, NDWI, NDVI and SPI were analyzed in AHP based on assigned weights owing to their

Landslide susceptibility map in parts of Rishi Ganga Valley area region using AHP relative importance in influencing landslide factors in multi-criteria decision making. The validation was done considering both ground truthing and satellite based inventory maps of active and old/stabilized landslides. The vulnerable areas were, subsequently, spatially categorized into very low, low, moderate, high, and very high classes. The results showed that approximately 20% - 30% of the study area is classified as very high or high hazard zones, which is quite alarming. These areas are particularly vulnerable to landslide occurrences/ recurrences and should, thus, cautiously be used for development. These maps hold promise to be used in land-use planning, infrastructure development and provide aid in disaster preparedness and help save lives and property.

- **Spectral Characterization of minerals in parts of the Bhukia Area, Banswara District, Rajasthan using Hyperspectral Data**

Hyperspectral Remote Sensing has been a key technology in mineral exploration and mapping for some time now. In this study, PRecursore IperSpettrale della Missione Applicativa (PRISMA) data is utilized to identification of minerals in Bhukia region of Banswara district, Rajasthan. The rock spectra obtained from the surface reflectance hyperspectral datasets after applying the processing techniques were compared against USGS spectral library and the field/ laboratory spectra to identify the diagnostic spectral features. For this study, 200 out of 234 bands in PRISMA were used for processing and a total of 14 bands were selected out of 200 input bands based on eigenvalues. Spectral Angle Mapper (SAM) algorithm was applied to the dataset and PRISMA identified kaosmectite, phlogopite and dolomite minerals. The score of the minerals matched with the USGS spectral library and classified mineral map of



SAM Classification of PRISMA Image

PRISMA is shown in the figure and table given here. Furthermore, absorption band parameters were estimated and interpreted to corroborate the chemistry of the rock which resulted in differentiation of limestone based upon Al^{3+}/ Mg^{2+} content.

Table: Score of mineral match between USGS Library standard vis-à-vis filed rock/mineral types

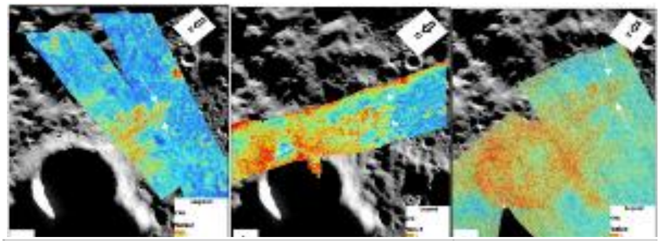
Rock Name	Mineral Name	Score
Dolomite	Dolomite	0.536
Phyllite	Kaosmectite Phlogopite	0.577 0.535

- **Application of CORS data in the study of subsidence crisis at Joshimath, NWH**

The sinking crisis in the Joshimath region has flustered the local people's daily routine with a peek of curiosity and concern among the researchers. Data from the CORS station JOSH (located in Joshimath, installed by Survey of India, Dehradun) have been analyzed. Along with JOSH, four other CORS stations namely, PURO, CHAM, BHEL, MAND (installed by IIRS, ISRO, Dehradun) and 20 IGS stations data (located on Indian and other neighboring plates) have been analyzed in GAMIT/GLOBK software in three components (North, East & Vertical) with respect to ITRF2014. The data analyzed have been recorded at 1 sec sampling interval and 24 hrs. observation during January 01, 2022 to March 30, 2023. The time series (October 01, 2022 to February 07, 2023) showing changes in displacement at these three components explains the reason for this alarming natural disaster. From this perspective, it can be stated that GNSS data measurements can be executed in the study of subsidence at the Joshimath and other parts of the Himalayan region.

- **Morphological, CPR and Ejecta Facies Analysis using Radar and Optical data at selected sites across the Lunar surface**

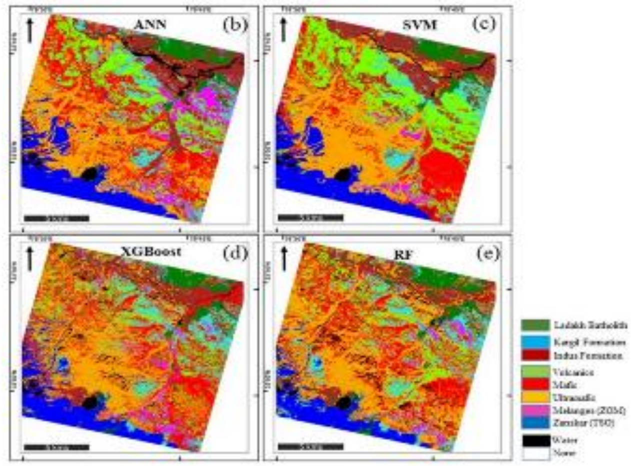
SAR data from MiniSAR, DFSAR and Mini-RF instruments onboard Chandrayaan 1, Chandrayaan 2 and NASA's Lunar Reconaissance Orbiter (LRO) were utilized in this study. LROC-NAC and LROC-WAC optical data were also used. The sites selected were craters Aristarchus, Thales on the Nearside; Giordano Bruno, Stearns, Das, Tharp on the Farside; Whipple near the Lunar North Pole; parts of the South Polar Nearside Region and craters Kocher and Idel'son. The derived information about the lunar surface/subsurface at these sites was integrated with that from optical datasets for a comprehensive and detailed analysis of a diverse set of impact craters across the lunar surface. Comprehensive and detailed morphological maps showing various features such as hummocky floor unit, impact melt flows, boulder/block units, channeled flow walls, melt veneers melt ponds, etc. for non-permanently shadowed craters were generated. The extent of proximal (continuous) ejecta blanket was mapped, the different types of ejecta facies based on their radar and optical signature were distinguished and extensive melt flows that were only sensitive to radar wavelengths were also observed. Observations were made regarding the impactor and the possible pre-impact topography. A statistical CPR analysis was conducted and variations were plotted across the test sites. Higher values for the DFSAR L-band dataset than both the S band counterparts in spite of the lower incidence angles were observed, possibly due to greater penetration capability.



Dataset	CPR Values	Standard Deviation
Melt flow (DFSAR L Band)	0.60	± 0.25
Melt flow (DFSAR S Band)	0.51	+ 0.21
Melt flow (Mini-RF S Band)	0.56	+ 0.51

Multi frequency CPR investigation of Whipple melt flow feature in a) DFSAR L band full pol., b) DFSAR S band full pol., c) Mini-RF S band Hybrid pol. images. The white arrows denote the extent of the melt flow. The table shows the mean CPR values and standard deviation for feature (All datasets are present for this region with S-band data of both Mini-RF & DFSAR along with DFSAR L band data)

Machine learning-based approach on PRISMA data for Mapping Nidar ophiolites, Ladakh and their study as Martian analogues



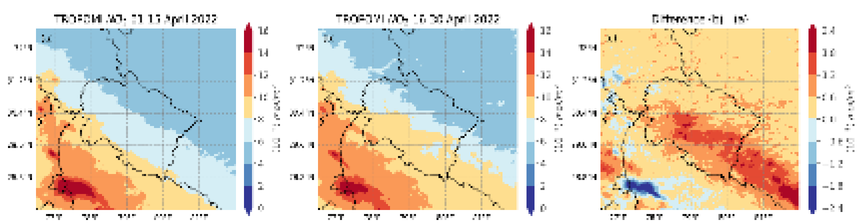
Outputs from ML-based classification algorithms using PRISMA data for Nidar ophiolite applying methods (b) Artificial Neural Network, (c) Support Vector Machine, (d) XGBoost (e) Random Forest

This study classifies the major litho-units present in the Nidar ophiolite complex exposed towards South East of Ladakh (32^{o}45’-33^{o}35’N & 78^o-79^{o}E) to observe mineral diversity and associated alteration products. Given the complex mineralogy of the target rock assemblages in the given study area and present status of limited work that exists on exploration of ophiolites using high-resolution hyperspectral remote sensing, the study has attempted to apply machine learning (ML) based classification techniques on data obtained from recently launched (March, 2019) PRISMA mission to assess their accuracy in the lithological mapping of Ophiolites. ML algorithms, namely Artificial Neural Network (ANN), Extreme Gradient Boosting (XGBoost), Random Forest (RF) and Support Vector Machine (SVM) have been used in the present classification based on mineral composition. They have been applied to one of the hyperspectral data image tiles of the PRISMA sensor available for the study regions. The downloaded level 2 reflectance product (L2D) of PRISMA data tile was georeferenced and layer stacked in ENVI®. After processing for noise removal and extraction of pure endmember spectra, training data was prepared based on the dominant lithological units/classes of the region. The results were analysed based on per-pixel-based classification approach followed by performance and accuracy assessment.

❖ **Spectral Calibration of Chandrayaan-2 Imaging Infrared Spectrometer (IIRS) data and analysis of South Pole region of the Moon**

The Chandrayaan-2 Imaging Infrared Spectrometer (IIRS) sensor is providing high-resolution data with a wider wavelength range (0.8-5 mm). The scientific goals of IIRS sensor are to identify and map minerals and completely characterize the surface hydration feature of the Moon. After thermal corrections, it further demands for photometric correction and calibration of Ch-2 IIRS data with the wavelength range 0.8-3.3 □mm to generate photometrically corrected reflectance product. Spectral calibration of Chandrayaan-2 IIRS reflectance data for ground truth correction using a standard reference were applied to rectify the issues related with absolute reflectance. Ch-2 IIRS calibrated spectra acquired from different locations of the South Pole region of the Moon was analysed. The reflectance spectral curve and its continuum-removed spectra for different locations of the Moon (i.e., highland, mare and polar regions) from the available strips acquired by Ch-2 IIRS were analyzed. All the analyzed regions selected to capture variability both in terms of underlying lithology as well as topography. The results were compared with their corresponding Chandrayaan-1 Moon Mineralogy Mapper (M^3) strips for the same locations with the assumption that the surface should have received the same signal under similar conditions to reveal the correction accuracy of IIRS level 2 data.

- **Effects of heatwave-induced forest fire event on the distribution of air pollutants over Uttarakhand during April 2022**



Spatial distribution of TROPOMI observed total column density of NO_2 averaged from (a) 01 to April 15 2022, (b) 16 to 30 April 2022, and (c) Difference of both period

Prevailing dry conditions and rainfall deficit during the spring season in North India led to heatwave conditions which resulted in widespread and intense forest fire events over Uttarakhand during April 16-30, 2022. A total of 7589 active fires were detected by VIIRS during the second half of April 2022 compared to 1558 during the first half. The TROPOMI observed total column values of CO and NO2 increased by 4.4% and 11.7% respectively during April 16-30, 2022 with respect to April 1-15, 2022. A noticeable increase in surface level concentration of trace gases was also observed at Dehradun. In-situ measurements of CO, NO_x, and O3 compared to previous year observations during April 16-30, 2022 show an increase of 133%, 35%, and 6%, respectively. Weather Research and Forecasting model with chemistry (WRF-Chem) is utilized to quantitatively estimate the contribution of this event on the distribution of air pollutants over this state. The model results were evaluated against ERA5 reanalysis, upper air soundings, and TROPOMI retrieved Total Column

Density (TCD) of CO, NO_2, and O_3. Two simulations with (Fire) and without (NoFire) biomass burning emissions were performed to quantify the contribution of forest fires to the concentration of trace gases. The CO, NO_2, and O_3 emitted/produced from forest fire over Uttarakhand during April 2022 contributed approximately 39.95%, 35.73%, and, 9.97%, respectively to the surface concentration of respective gas. The vertical profile analysis of pollutants revealed that such events can perturb the distribution of air pollutants from the surface up to 450 hPa.

- **JULES Compatible High resolution LULC tiles- a Collaborative Research work with NCMRWF**

Land use land cover (LULC) data plays a vital role in land surface models (LSMs) by providing information about the spatial distribution and features of various land cover types. Joint UK Land Environment Simulator (JULES) is one such LSM that is used to simulate the flow of energy, water, and carbon dioxide between the land surface and atmosphere. It provides a gridded data product referred to as JULES tiles, used in LSM. The nine land surface types used in JULES model includes five Plant Functional Types (broad leaf, needle leaf, C3 grass, C4 grass, and shrubs) and four non-vegetation types (urban, water body, bare soil, and ice). The European Space Agency (ESA) provides the global LULC data through the Climate Change Initiative (CCI), but there are discrepancies in data due to lack of ground validation. A need has been felt to replace CCI LULC with a higher resolution LULC, which is compatible with JULES LSM such that it can provide improved weather prediction over Indian subcontinent. On the request of National Centre for Medium Range Weather Forecasting (NCMRWF), Jules Compatible High resolution LULC tiles (five plant functional types and four non- plant functional types) were prepared and shared with NCMRWF by collating multi–source remote sensing derived data products. Resourcesat-2 Advanced Wide Field Sensor (AWiFS) LULC 250k (18 classes), LULC 50k, and Wasteland map 50k from National Remote Sensing Centre (NRSC), crop type from

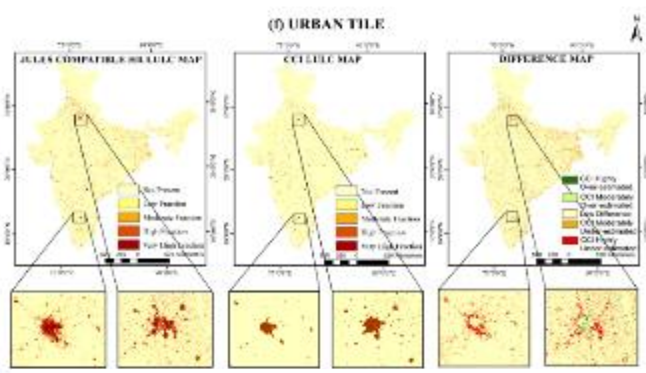


Fig: JULES compatible HR LULC, CCI LULC and Difference image of both the LULC for urban tiles

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and vegetation type from Indian Space Research Organization (ISRO), were integrated to create JULES compatible high resolution LULC. Figure presents the delineation of urban areas in JULES compatible high resolution LULC and CCI LULC and the difference image.

❖ **Analysing the diurnal changes and trends in land surface temperature and surface urban heat island intensity for Lucknow, India**

Understanding the patterns and possible causes of urban heat islands (UHI) effect due to urbanisation-induced anthropogenic activities is an important area in urban climatic research. The present study investigates the day/night seasonal and annual changes and trends in land surface temperature (LST) and surface urban heat island intensity (SUHII) during the last two decades for Lucknow city. Moderate Resolution Imaging Spectroradiometer (MODIS) LST data products acquired during daytime and nighttime from 2001 to 2018 are processed and analysed for this purpose. MODIS-based aerosol optical depth (AOD) and normalised difference vegetation index (NDVI) products are used to understand the plausible reasons of change in LST and SUHII patterns. The urban (contiguous built-up) and non-urban (surrounding rural) areas are delineated by applying city clustering algorithm on MODIS Land Cover datasets of 500 m spatial resolution. Mann-Kendall and Seasonal-Kendall tests along with Theil-Sen estimator are used for trend analysis. The findings show that the diurnal temperature range (DTR) has decreased from 2001 to 2018 due to higher increase in nighttime LST as compared to daytime. Positive trends in mean annual daytime (0.003 to 0.029 ℃/year) and nighttime (0.069 to 0.078 ℃/year) LST are observed in Lucknow. Seasonal analysis indicates high warming rates during monsoon and summer seasons, particularly during nighttime (0.069 to 0.1 ℃/year). Nighttime SUHII is positive for Lucknow with mean annual SUHII ranging from 1.09 to 2.55 ℃. Decreasing trend in SUHII (-0.023 and -0.009 ℃/year during daytime and nighttime, respectively) is observed over Lucknow due to higher rate of increase in LST in non-urban area as compared to urban area.

ACADEMIC INTERFACE

❖ **Deep Learning for Earth Observation Data Processing: Towards Crop Management in the Cauvery Delta Region**

The project addresses four major application problems in crop management with remote sensing data processing using deep learning. One of the applications is crop classification. Solutions are provided for crop classification and mapping using convolutional neural networks and transformers. Another application of remote sensing in agriculture is monitoring crop growth. In order to monitor the crop growth throughout the year, a methodology is proposed to obtain NDVI from SAR images using generative adversarial networks. The other application of remote sensing is the crop damage assessment during natural disasters. A hybrid machine learning model is designed to assess the damage of a particular crop (coconut trees) by cyclone. Agricultural field boundaries extraction is yet another application which is an essential process in precision agriculture. The automation of field boundaries extraction can save time and costs, making precision agriculture more accessible to farmers. Deep learning techniques are proposed for automatic extraction of field boundaries.

- **Modelling Spatio-Temporal Forest Growth Dynamics using Dendrochronological and Remote Sensing Observations in North-East India**

Ecological information on changing forest growth during past couple of decades in relation to climate is highly limited because of our poor understanding on forest growth and climate data. Tree ring analysis provides us with accurate information on changing periodical increment in wood and infers about changing climatic patterns during the period. Further, the Normalised Difference Vegetation Index (NDVI) is affected by important climatic factors, particularly temperature, precipitation, and moisture availability. Increased temperatures and enough precipitation promote plant development, resulting in higher NDVI values, but excessive temperatures and drought cause stress that will lead to lower NDVI, a measure of photosynthetic activity. The correlation between NDVI and climatic factors is contingent upon the type of ecosystems, the plant species, and their geographical locations, which are further modified by land cover, vegetation density, and human activities. However, the NDVI data is not reliable sometimes due to prevailing weather conditions in tropical moist forests, and hence in such cases tree rings can be used as a corrective measure to reconstruct climate variables. Tree ring analysis is used to identify the main climatic elements that affect tree development. This helps to improve the accuracy of NDVI measurements, particularly in areas where satellite evaluations are hindered by atmospheric constraints. The integration of tree ring data improves understanding of ecosystem dynamics, confirming and improving the accuracy of NDVI information. This methodology enhances climate evaluations by providing valuable insights into the connections between climate and vegetation, resulting in more precise environmental monitoring and more efficient conservation efforts in tropical forests.

- **National Facility for Tree-ring Research:**

  Department of Forestry at Mizoram University has established a National Facility for Tree Ring Research, equipped with a specialized stereo-zoom microscope, WinDendroTM Tree-ring measuring system, Tree-ring corer, GPS unit, and a belt sander through this project. This facility enables meticulous examination, cross-dating, and analysis of tree rings, which are together supporting the development of trained manpower in tree ring research in the northeastern region of India. This facility will promote high quality research on understanding past climatic events and their relations with forest growth dynamics in northeastern India, which will further enhance our ability to more accurately predict/model forest growth under changing climate.

- **Urban Seismic Risk Assessment**

  Seismic risk assessment of Coimbatore city in Tamil Nadu is carried out by Probabilistic Seismic Hazard Analysis (PSHA) considering faults, lineaments within the radius of 500 km and past earthquake catalogue. Contour maps of Peak Ground Acceleration (PGA) for Coimbatore city were evaluated in terms of 10% and 2% probability of exceedance for the return period of 475 and 2475 years. The PGA value ranges from 0.146 g to 0.155 g for 2475 years return period. Seismic site characterization of Coimbatore city was carried out by conducting Multi-channel Analysis of Surface Wave (MASW) test at 35 locations. Contours of shear wave velocity profile and Standard Penetration Test (SPT) N-values were developed. Rapid Visual Screening (RVS) of 100 buildings in Saibaba colony and RSpuram areas were carried out. Seismic vulnerability maps were prepared and submitted to Coimbatore Corporation for earthquake risk planning.

Capacity Building in Space Science Research

The Institute has so far trained 14,440 professionals (till December, 2023), wherein special tailor-made/on-demand courses are conducted at the request of the User Departments from national as well as international level.

In addition to aforesaid activities, IIRS also supports activities of UN-CSSTEAP wherein 67 PG Courses (26 in RS&GIS, 13 in SATCOM, 12 in each SATMET and SAS and 04 in GNSS) and 85 short courses and workshops including online short courses, have been conducted in last 28 years. These programmes have benefited 3495 participants (PG-1093, Short courses-1366 and online short courses-857) from 37 countries in the Asia-Pacific region including 70 participants from 25 countries, outside Asia Pacific region. Till date, 195 PG students (85 in RS&GIS; 54 in SATCOM; 22 in SATMET; 27 in SAS & 07 in GNSS) from 17 different countries have been awarded M. Tech. degree.

Courses offered on Space Science and Technology

Table: Training programmes being conducted by IIRS

S. No.	Programme	Duration	Seats
1.	POST-GRADUATE DIPLOMA IN REMOTE SENSING and GIS 9 Specialisations –Agriculture and Soils; Forest Resources & Ecosystem Analysis; Geosciences; Urban & Regional Studies; Marine & Atmospheric Sciences; Water Resources; Natural Hazards & Disaster Risk Mgmt and Satellite Image Analysis & Photogrammetry and Spatial data science	01 year	30
2.	POST-GRADUATE DIPLOMA IN GEO-INFORMATION SCIENCE and EARTH OBSERVATION (with ITC, University of Twente, The Netherlands) 2 Specialisations– Geoinformatics; Natural Hazards and Disaster Risk Management	01 Year	10
3.	CERTIFICATE COURSE IN REMOTE SENSING *Remote Sensing and Image Analysis (for Indian User participants)*	8 weeks	20
4.	INTERNATIONAL PROGRAMME – CERTIFICATE COURSE IN REMOTE SENSING, GEOINFORMATICS (Sponsored by ITEC, Ministry of External Affairs, Govt. of India) Remote Sensing (with emphasis on Digital Image Processing); Geoinformatics	8 weeks	2*20 = 40
5.	NNRMS, ISRO-SPONSORED CERTIFICATE COURSE IN REMOTE SENSING and GIS FOR UNIVERSITY FACULTY *10 Specialisations - Satellite Image Analysis & Photogrammetry; GIS Technology and Advances; Agriculture and Soils; Forestry Resources and Ecosystem Analysis; Geosciences; Coastal and Ocean Sciences; Urban and Regional Planning; Water Resources; Natural Hazards and Disaster Risk Management and Geocomputation and Visualization in Web Platforms*	8 weeks	64

6.	AWARENESS PROGRAMME Remote Sensing – An Overview for Decision Makers	1 week	10
7.	Tailor-made On-Demand Courses	1 to 8 weeks	Variable
8.	Online Courses / Workshops	Variable	Variable

Table: M.Tech./M.Sc. courses being conducted by IIRS

S. No.	Title and standard of course (PG Courses)	Specializations Topics	Duration	Intake Capacity
1.	M.Tech. in Remote Sensing and GIS (with Andhra University) *09 Specialisations-*	*Agriculture and Soils; Forest Resources and Ecosystem Analysis; Geosciences; Urban & Regional Studies; Marine and Atmospheric Sciences; Water Resources; Natural Hazards & Disaster Risk Management and Satellite Image Analysis & Photogrammetry and Geoinformatics*	2 years	60
2.	M.Sc. (with ITC, University of Twente, The Netherlands)	in Geo-information Science and Earth Observation with *Specialisations in-* Geoinformatics(GI);	2 years	10

Laboratories and Facilities Available for Space Instrumentation

- A trace gas laboratory consists of ozone, CO and NO_x analysers. Ozone and CO analysers.
- Multi-wavelength solar radiometer is used for measuring Aerosol Optical Depth to understand the Aerosol loading over Dehradun region.

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY, THIRUVANANTHAPURAM, INDIA

www.iist.ac.in

ABOUT IIST

Indian Institute of Space Science and Technology (IIST), situated at Thiruvananthapuram, Kerala, is the academic wing of the Department of Space. It is a Deemed-to-be University under Section 3 of the UGC Act, 1956. IIST, established in 2007, functions as an autonomous institution, under the Department of Space (DoS), Government of India. IIST was conceived to nurture human resource for the Indian Space Research Organization (ISRO), one of the world's leading scientific organizations engaged in space research and space applications. The vision of IIST is "To be a world class educational and research institution contributing significantly to the Space endeavors". Its missions are to: a) Create a unique learning environment enriched by the challenges of the Space Programme, b) Nurture the spirit of innovation and creativity, c) Establish Centers of Excellence in niche areas, d) Provide ethical and value based education, e) Promote activities to address societal needs, f) Network with national and international institutions of repute. The institution has garnered a commendable reputation among educational establishments, owing to its distinguished lineage of Chancellors. Dr. A.P.J. Abdul Kalam, former President of India, and Prof U.R. Rao, former Chairman of ISRO. Currently, Dr. B.N. Suresh, the Founding Director of IIST, holds the position of Chancellor, overseeing the institution's affairs. Additionally, the esteemed Shri S. Somanath, Secretary of the Department of Space and Chairman of ISRO, serves as the President of the Governing Body at IIST. Dr. Unnikrishnan Nair S, the Director of IIST, leads the institute, propelling it towards its goal of becoming one of the premier educational institutes in the country. IIST comprises seven departments and offers a comprehensive range of academic programs, including three undergraduate, fifteen post-graduate programs, as well as Ph.D. and PDF opportunities. Admission to undergraduate programs is based on JEE advanced scores, while post-graduate admissions rely on GATE scores or interviews. Doctoral candidates are admitted through written exams or interviews. Notably, IIST operates as a fully residential campus, providing accommodation for all its students, thereby fostering a conducive learning environment.

MAJOR RESEARCH DOMAINS

Aerodynamics and flight mechanics	Thermal Fluid flow and propulsion	Structures Design and Robotics	Materials science and Engineering	Manufacturing and Management
Control systems	RF and Microwave Engineering	Electronics and Navigation system	Signal processing and communication	Semi-conductors and IC design
Power Electronics	Nano Technology, Nano electronics, and MEMS	Computer vision and virtual reality	High Temperature and Energy Storage Materials	Bio-Materials and Nano-composites
Synthetic Organic Chemistry	Nano Science, Nano materials, and Sensors	Astronomy and Astrophysics	Atmospheric science and climate studies	Planetary Geosciences and Solid Earth
Remote Sensing and Geospatial technologies	Atomic and Molecular Physics	Condensed Matter Physics	Applied and Adaptive Optics	Quantum Information and Computing
Machine learning and Data mining	Industrial mathematics and soft computing	Artificial intelligence and Data Analytics	Nonlinear Dynamics and Chaos	Stochastic modelling and Analysis
Queuing theory and Network Models	Differential Geometry and Applications	Mathematical Elasticity, and Homogenization	Commutative Algebra and applications	Applied Numerical Analysis
Space Economics and Policy	Literature and communications	Supply Chain Management	Optical and laser based combustion diagnostics	Composites and structural health monitoring
Design and analysis of Additive manufacturing	5G and IoT applications	Networking and cyber-physical systems	Thermoregulation for biomedical and space	Payloads and satellite development
Sensors for space-applications & crew models	Space biology and microgravity applications	Electric propulsion and Diagnostics	Tracking satellites using own ground station	Rovers and robots for space applications

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Research contribution by IIST Students

Specialized research applicable to both the space and other technological fields happen across all the departments at IIST. In the last two years, IIST has graduated a total of 539 candidates in UG/PG/Ph.D. programmes, An unique feature at IIST to promote research in the UG level, the final semester of all B.Tech programmes is completely devoted to a research project. Mostly, each UG student will do an independent project mentored by faculties. Hence, a vibrant research ambience exists due to the involvement of a team of UG/PG/Ph.D. candidates. In the last two years, 53 Ph.D. students have (inclusive of part-time candidates from ISRO/ other industries) completed their dissertation. The details of their thesis are available on IIST's annual report available on https://www.iist.ac.in/library/annual

Research contribution by various departments

IIST has seven departments, and contemporary research is promoted across all the departments. Each of the department has various Government/ Department of Space/ industrial funded projects. MoU with other academia/ industries is a common practice across all the departments to promote collaborative research. IIST has received a lot of INAE student awards in UG/PG/Ph.D., best post-graduate thesis awards from external organizations, best paper/ poster awards at various international/ national conferences. All departments had published several articles in reputed journals. All the details are available on sections 2,4, & 5 of IIST's annual report (https://www.iist.ac.in/library/annual). The following sections brief the core competence of each department.

Department of Aerospace Engineering

The core research focus of this department is on (a) Aerodynamics and flight design, (b) Thermal and propulsion, (c) structures and design, (d) Materials, manufacturing, and Industrial engineering. There are 22 faculties with additional technical staff. Close to 70 research scholars including part-timers are contributing to the research. The research spans across 10+ research labs. The department is building up a hybrid rocket for space system propulsions. It also involves in the design and fabrications of small satellites and payloads.

Department of Avionics

The core research focus of this department is on (a) Computer vision, (b) Intelligent Robotics and machine learning, (c) control systems, (d) Digital signal processing and Communication system, (e) Microwave and RF, (f) Power Electronics, (g) VLSI and microsystems. There are 23 faculties with 12 technical staff. Around 86 research scholars including part-timers are contributing to the research. The research spans across 16 research labs. The department has recently added anechoic chamber to excel in the microwave and RF field. Their SSPACE lab is the nodal point in IIST for various student satellite projects. Their IEEE student chapter is quite vibrant.

Department of Chemistry

The research of this department focusses on a) composite materials, (b) Chemical/ Electrochemical sensors, (c) Electrochemical energy storage, (d) Organic functional materials, (e) high-temperature materials, (f) Biology payload for human space program. They have nine faculties. Forty Ph.D. candidates are performing research in this department. They had designed and developed novel materials to cater to the ongoing human space program.

Department of Earth and Space Sciences

The core research focus of this department is on (a) Astronomy and Astrophysics, (b) Atmospheric and Ocean Sciences, (c) Remote Sensing, (d) Planetary Geosciences. There are 14 faculties and 3 technical staffs. Around 49 research scholars including part-timers are contributing to the research. The research spans across 8 research labs. They are studying on extracting meaningful information from the data obtained using Aerial LiDAR survey.

Department of Humanities

The core research focus of this department is (a) Space Economics, (b) Technology diffusion and economic development, (c) Supply Chain management, (d) space technology and society. There are five faculties and one technical staff. Twenty-three Ph.D. candidates are contributing to the research in their research lab as well as on the field. They do interesting work on space economy, impact of telemedicine, English language, etc.

Department of Mathematics

The core research focus of this department is (a) Commutative Algebra, (b) Control Theory, (c) Differential geometry, (d) Machine Learning, (e) Numerical Analysis, (f) Partial differential equations, (g) Queuing Theory, and (h) Stochastic Modelling and Analysis and society. There are eleven faculties and three technical staffs. Twenty-three research scholars are doing research. Virtual element method, fitted-mesh methods, mathematical elasticity, are some of the recent research in progress.

Department of Physics

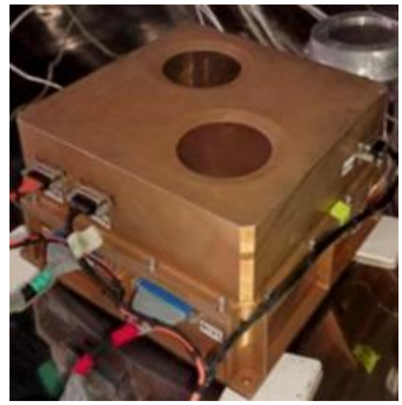
The core research focus of this department is (a) Applied and Adaptive Optics, (b) Quantum Optics and Technologies, (c) Atomic and Molecular Physics, (d) Solid State Physics, (e) Theoretical Condensed Matter Physics, (f) Statistical Physics, and (g) Non-linear dynamics. There are thirteen faculties and nine technical staffs. Forty-four research scholars are doing research spread across fourteen different research labs. This department actively contributes to the design and development of sensors, payloads for the student satellite projects.

Advanced Space Research Group (ASRG)

ASRG is the unique liaison unit to facilitate the seamless integration of ideas, expertise and know-how between IIST and all the ISRO centres and thereby leveraging collective wisdom to forge the puzzle pieces for futuristic space programs.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

ARIS 201F (Advanced Retarding Potential Analyser for Ionospheric Studies) payload launched on 22 Apr 2023 through PSLV C55



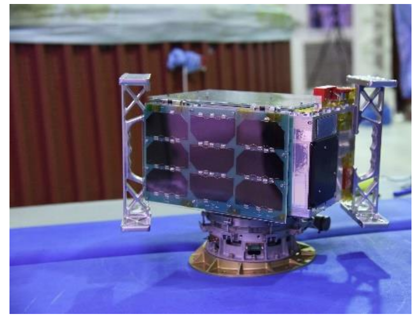
An Inter-Disciplinary team from Physics, Avionics, and Aerospace built this payload. It is a plasma and electrostatic instrument to study the structural and composition of the ionosphere. Small and difficult-to-detect geomagnetic variations can easily be sensed in the ionosphere, to predict the imminent earthquakes by a few hours. Similarly, solar activity which is the main driver of the ionosphere can be studied in real-time by performing ion and electron density measurements in the ionosphere. Such measurements provide us with the warning of hazardous radiation effects on space assets, possible radiation exposure to aircraft crew and possible power grid disruptions.

Pslv-In-orbital Obc and Thermals (PILOT) payload launched on 22 Apr 2023 through PSLV C55

Pslv-In-orbital Obc and Thermals (PILOT) is a student payload to validate a thermal simulation model at real flight conditions. IIST designed it and 3D printed by L&T Pvt. Ltd. The obtained flight data is used to validate the thermal simulation model. To evaluate the performance of the indigenously designed On-Board Computer (OBC), flight software, and RS485 telemetry communication.

INSPIRESat-1 International Satellite Program in Research and Education launched on 14 Feb 22 through PSLV-C52

INSPIRESat-1 is a 9U CubeSat conceptualized, designed and launched by the students of CU/LASP, IIST, and NCU (National Central University), Taoyuan City, Taiwan. Its payloads are (1) DAXSS (Dual Aperture X-ray Solar Spectrometer) instrument to build knowledge on Sun's Coronal Heating process, and (2) Compact Ionosphere Probe to understand Ionosphere dynamics. All students gained valuable knowledge by contributing creative ideas to overcome the highly complex technological challenge.



Development of Surface Discharge Sparkplugs (SDS)

Surface discharge sparkplug is an innovative product frequently used in aircrafts and racing cars due to its high plasma throughput at a lower power, and also independent of its operating pressure. Physics department, IIST developed and characterized it for space-based applications

Development of Laser Ignition Systems (LIS)

An alternative to the conventional sparkplug that operates at a high voltage is to employ laser-based ignition in space missions. IIST signed another MoU with LPSC on developing Laser Ignition Systems (LIS) for future missions. The feasibility of a portable LIS for space applications has been demonstrated by our team at IIST and LPSC.

HyPER- Hybrid Propulsion Experimental Rocket

The IIST student-faculty team has commenced a new research endeavor on hybrid rockets, building upon the achievements of previous launches of the IIST student rocket 'VyOM'. The activity is initiated with the support of ISRO centres, especially VSSC, LPSC, IISU and CMSE. The team aims to accomplish the following objectives in their research. Hybrid Rocket Propulsion Characterization: (a) Recovery of the vehicle with deep throttling of the thrust, (b) Rocket structures using composites and 3D printed components. (c) Restartability & Recovery with Landing Legs, (d) Retro-Propulsion

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

IIST supplies the critical human resources to various ISRO centres. B.Tech. and Dual Degree graduates who secure a CGPA of 7.5 and above are absorbed directly into the different centres of ISRO/ DOS. A total of ~1300 graduates from the institute have joined

ISRO so far. These students were trained in many unique labs at IIST such as Small spacecraft/payload labs, Satellite Ground station, Electric propulsion diagnostics, and centre of excellences. Most of the UG/PG/Ph.D. candidates work across this lab to learn the cutting edge technology involved in the Space Science Research. Fifty-three Ph.D. candidates completed their thesis, and some of them pertinent to space applications are listed below.

1. 6.7 GHz methanol masers and the early phases of massive star formation
2. Design and Realization of Single and Multi-band Monopulse Feed using Horn and Dielectric Rod for LEO Satellite Tracking Application.
3. Dynamic Analysis of a Two-spool Aero-engine Model Undergoing Multi-disk Rub-impact using a Semi-analytical Method
4. Study of Liquid Jets at Transcritical to Super critical Conditions in Single and Multicomponent Systems
5. A Study on Spatial and Temporal Variabilities in the Martian Thermosphere
6. Graphene and Molybdenum Disulphide Based Nano-Structures for Toxic Metal ion Removal from Water and Electrochemical Sensing Applications.
7. MEMS Nanomechanical Membrane-Flexure Sensors with Integrated Electromechanical Transduction: Design, Fabrication, and Application.
8. Studies on Mechanical Performance and Electromagnetic Shielding Effectiveness of Electrospun Fiber /Epoxy Composites.
9. Lyapunov Based Stable and Robust Adaptive Control Design for a Class of Space Transportation Systems
10. 3D Lidar Point Cloud Processing using Statistical and Machine Learning Methods for Precision Agriculture
11. Graphene Quantum Dot and Metal Nanocluster-based Nano Functional Materials for Electrochemical Sensing Applications
12. Design, Development and Fabrication of Gallium Nitride (GaN) High Electron Mobility Transistor (HEMT) based terahertz devices for Space Applications

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Title of the course	Level of the course	Intake capacity	subjects of specialization in Space Science and technology
Aerospace	B. Tech	75	Spaceflight Mechanics, Space Mission Design and Optimization, Rocket Propulsion, Aerospace Vehicle Design, Flight Mechanics and Propulsion Lab, High Temperature Gas Dynamics, Introduction to Space Laws, Fundamentals of Combustion, Turbomachines

Electronics and Communication Engineering	B. Tech	75	Satellite and Optical Communication
Astronomy & Astrophysics	M.S./ Ph.D.	7	Astronomical Techniques, Radiation Processes in Astrophysics, Planetary Sciences, Computational Astrophysics, Structure and Evolution of Stars, Galaxies (Structure, Dynamics and Evolution), Cosmology, Physics of Interstellar and Intergalactic Medium
Aerodynamics and Flight Mechanics	M. Tech/ Ph.D.	18	Spaceflight Mechanics, Hypersonic Aerothermodynamics, Navigation Guidance and Control, Space Mission Design, High Temperature Gas Dynamics
Thermal and Propulsion	M. Tech/ Ph.D.	18	Aerospace Propulsion, Design and Modeling of Rocket Propulsion Systems, Optical & Laser Based Combustion Diagnostics

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

Small-spacecraft Systems and PAyload CEntre (SSPACE)

It is an interdisciplinary centre to design, develop, and qualify small spacecraft systems & payloads with the maximum participation of students mentored by IIST faculties, and ISRO scientists. It has indigenously developed hardware/ software modules for small satellites/payloads, such as On-board Computer (OBC), Electrical Power System (EPS), Integrated Diagnostics Module (IDM), etc. Contact - Priyadarshnam, Professor (Avionics), priyadarshnam@iist.ac.in

Satellite Ground Station

IIST has a fully functional satellite ground station. Its objectives are to carry out tracking, telemetry and commanding (TT&C) operations of student satellite missions, and stratospheric balloon borne payloads. In the recent PSLV C-58 XPoSat mission launched on the new year day, IIST is playing a pivotal role in extending telemetry and tele-command support to the space start-up Dhruva Space. Contact - Priyadarshnam, Professor (Avionics), priyadarshnam@iist.ac.in

Electric Propulsion and Diagnostics Lab

This lab offers the design, development, testing and implementation of the diagnostic tools essential for the characterization of the ISRO's Stationary Plasma Thruster (SPT).

The researchers in this lab generate plasma source to mimic lower earth ionospheric conditions, hence making the facility as **India's only ionospheric plasma simulator.** Contact - Umesh R. Kadhane, Professor (Physics), umeshk@iist.ac.in

Gas and Bio Sensors Lab

This lab involves in the design, development, characterization of various indigenous gas and bio-sensors for space/ domestic applications. It has a good calibration facility to test the sensors. This lab is developing sensors for ISRO's Human Space Flight program. Recently, it ventured to develop biosensor for the early detection of cancers. Contact – PalashkumarBasu, Associate Professor (Avionics), palashkumarbasu@iist.ac.in

IIST- Ponmudi Climate Observatory

It is situated on the hilltop of the Western Ghats (PCO, 8.76°N, 77.12°E, 1 km, AMSL). It has state-of-the-art field instrumentation for aerosol-cloud interactions, solar radiation instruments for energy budget studies. Contact – P.R. Sinha, Assistant Professor (ESS), prs@iist.ac.in

Advanced Propulsion and Laser Diagnostics Lab (Aravind V, Professor (AE), aravind7@iist.ac.in)

This centre has Rocket Injector Spray characterization rig, Single Element Coaxial Combustion Facility, Supersonic Free Jet Facility, and laser diagnostic measurements.

Centre of Advance Research in Nanoscience and Technology (Sandya, K.Y., Professor (chemistry), hod-chem@iist.ac.in)

This centre focusses on the research in the area of nanoscience and energy storage materials

Computer Vision and Virtual Reality Lab (Deepak Mishra, Professor (Avionics), deepak.mishra@iist.ac.in)

This lab is established to provide excellence in the area of virtual reality and intelligent computer vision for cutting edge space science, societal and technological applications.

NEMS and Opto–Nanoelectronics (NEMO) (Seena V, Professor (Avionics), seena.v@iist.ac.in)

This centre establishes an R&D ecosystem in the area of VLSI, Micro Electro Mechanical Systems (MEMS)/ Micro/Nano electronics/optoelectronics and sensors.

IoT and 5G Lab (Manoj, B.S. Professor (Avionics), bsmanoj@iist.ac.in)

This centre has designed and built an IoT system with the architecture and edge computing algorithms for high-altitude platforms. They proposed a sliding window block-chain (SWBC) architecture to suit IoT applications. They developed a prototype 5G system over the WiFi radios and three architectural concepts for 5G-satellite integration. Recently, honorable Prime Minister of India awarded a dedicated 5G lab to IIST to further excel in this field.

NATIONAL ATMOSPHERIC RESEARCH LABORATORY, GADANKI, INDIA

www.narl.gov.in

ABOUT NARL

National Atmospheric Research Laboratory, a premiere institute under Department of Space, is engaged in carrying out frontline research on atmospheric, ionospheric & space weather, and planetary ionospheric sciences through observations, innovative technique/technology, instrument development, and simulations/modelling. Currently more than 45 observational facilities are in regular operation at NARL, including MST radar, Rayleigh/Mie lidar, Rayleigh Doppler lidar, Lower Atmospheric Wind profiler (LAWP), Digisonde, Gadanki ionospheric Radar interferometer (GIRI), X-band Polarimetric radar, Airglow imager, GPS-sonde, Instrumented towers, networks of GNSS receivers, and radiation, aerosol and trace gases measuring instruments along with a High Power Computing (HPC) system. Recently, NARL initiated two camp observatories at Hyderabad and Kolkata to understand impacts of urbanization on boundary layer, clouds and precipitation and origin and impacts of elevated aerosol layers, respectively.

MAJOR RESEARCH DOMAINS

- **Ionosphere, Space Weather and Planetary Atmosphere:** Investigate plasma processes of the Earth's ionosphere, ionospheric variability and plasma irregularities including those associated with space weather and ionosphere of other planets.

- **Atmospheric Structure, Dynamics and Coupling:** Investigate dynamical coupling among different regions of Earth and planetary atmospheres through wave motion and its role in determining thermal structure, mean circulation and distribution of chemical constituents, model simulations and analysis.

- **Cloud and Convective Systems:** Study the microphysics and dynamics of clouds, precipitation, and other high impact weather systems, boundary layer processes, monsoon dynamics, urban ramifications and GNSS meteorology.

- **Aerosol, Radiation and Trace gases:** Study the role of aerosols and trace gases in the regional and global climate, aerosol-cloud interactions and elevated aerosol layers. Generate climate quality data generation using sophisticated instruments.

- **Weather and climate research**: Develop high resolution model and parameterization schemes. Understanding various atmospheric processes as core research activities for developing futuristic model, Real-time weather prediction for potential applications and rocket launching support.

- **Atmospheric/Ionospheric Radar development:** Develop new radar systems indigenously for atmospheric and planetary studies, operate and maintain MST radar, LAWP, GIRI, and beacon receiver. Responsible for making MST radar wind measurements for all rocket launches from SDSC SHAR.

- **Atmospheric lidar development:** Responsible for the indigenous development of new lidar systems for atmospheric research, operation and day-to-day maintenance of various high power lidars.

- **Space-borne instrument development:** Development of new atmospheric sensing techniques with state-of-the-art technologies. Development of flight instrumentation and observation.

- **Computer and data analytics:** Maintain the data center, archival and dissemination of data and maintenance of internet facility. Managing NARL Bi-lingual web portal and wind portal for SHAR launch program, and developing portals for the workshops/conferences conducted by NARL.

MAJOR SCIENTIFIC APPLICATIONS

The global dust storms of Martian Years 25, 28, and 34 lead to significant enhancements in the gravity wave activity in Mars. The Auger and photoelectrons show significant correlation and a linear relationship with the solar fluxes, while the thermal electrons do not correlate due to their dependence on electron temperature and ionization and the neutral heating efficiencies. Using radar observations of daytime 150-km echoes from Gadanki, India and Kototabang, Indonesia, ionospheric vertical plasma drifts have been estimated and they differ remarkably on many days even though they are longitudinally separated only by 20^{o}. A comprehensive multi-instrument study of the geomagnetic storm of August 2018 confinement of ionospheric structures in specific longitude (local time) zones during 26-27 August 2018 as specifically traced from the auroral oval expansion at different local times. Sudden degradation of kinematic precise point positioning (KPPP) in the range of 10-30 meters in east-north-up coordinate system & 3-D positioning error up to ~100 meter under the Equatorial Plasma Bubbles (EPBs) effect has been observed and it is a serious cause of concern for satellite-based navigation applications. The GPS-TEC observations during Hudhud cyclone reveal that the prominent perturbations from tropospheric sources are possibly located near the center of the cyclone.

During the stratospheric QBO disruption period December 2019-January 2020, the ICON-MIGHTI thermospheric meridional winds are unusually equatorward over northern geomagnetic low latitudes and zonal winds exhibit delayed eastward transition, while the plasma drift exhibits semi-diurnal variation with upward drift over the dip equator during midnight hours. Analysis of the meteor radar wind observations in the upper mesosphere and lower thermosphere (UMLT) region (82–98 km) reveals that the monthly mean zonal winds show large westward winds during November-December of some years, when there are more ozone loss and large eastward winds in the stratosphere. It is due to the low planetary wave activity maintains the low polar stratospheric temperature which will lead to the increase of the meridional temperature gradient and hence eastward wind speeds. NARL airglow (630 nm) imager observation over Srinagar on the night of July 29, 2019 show simultaneous presence of ionospheric plasma blobs (enhancements) medium scale travelling ionospheric disturbances (MSTIDs) and plasma depletion structures. It is found that the plasma blobs followed by the occurrence of MSTIDs interacts with plasma depletion structures and suddenly disappears, resulting in reduction of bubble intensity.

DROP-X measurements during the passage of very severe cyclone – Nivar have provided new insights on microphysical processes, which are first of their kind, during the life cycle of convective cells. A systematic assessment of MRR-derived DSD’s against those obtained by disdrometer at the surface and LAWP and MST radar aloft clearly reveals that MRR severely underestimates DSD’s by a factor of 2 mainly due to attenuation and unaccounting of vertical wind correction. Results from the recently installed instruments of flux towers, net radiometers, and soil temperature and moisture probes show large differences in average radiative fluxes in rural and urban locations, though they are separated only by less than 20 km. A larger storage term in the urban canopy than in the rural canopy indicates the influence of air pollution and trace gases in trapping heat energy.

Aerosol-cloud interaction (ACI) in water clouds is estimated using long-term ground-based, in-situ, and satellite-based observations over an Indian continental region. The role of background meteorological, dynamical influences, including turbulence on the ACI, is delineated. Long-term trends in Aerosol Optical Depth (AOD) from 2001 to 2020 are obtained across the globe using multi-satellite measurements. Using measurements from the Kolkata Camp Observatory of NARL, a mutual response hypothesis between surface temperature and aerosol (BC and non-BC) mass concentration is reported in an urban environment. Measurements of Volatile Organic Compounds at a rural site in India, including their variability and sources during the seasonal transition, are reported. Influence of background dynamics on the vertical distribution of trace gases (CO/WV/O3) in the UTLS region during COVID-19 lockdown over India is noticed. Using 92 BATAL campaign observations, the exact upper boundary of the Asian Tropopause Aerosol Layer (ATAL) using static stability is defined. The role of deep convection in the spatial asymmetry of the UTLS aerosols in the Asian summer monsoon anticyclone region is perceived. Using simultaneous lidar and radiosonde measurements, it is shown that the strong thermal inversions control the vertical extent of aerosols but not the atmospheric boundary layer altitude most of the time.

The modeling of the helical organization of tropical cyclones revealed that the TC emerges from self-sustaining primary and secondary overturning circulations starts intensifying mutually and local maxima in intensities of TCs commensurate with the TC intensification stages. The investigation of the different parameters controlling the life cycles of tropical cyclones revealed that the maximum intensification of tropical cyclones controlled by Ocean Mean Temperature (OMT) and Tropical Cyclone heat potential (TCHP) than sea-surface temperature (SST). The validation of the prediction of tracks, intensities, and rainfall of tropical cyclones in North Indian Oceans showed that satellite data assimilation improves the pattern, displacement, and volume errors associated with their predictions. The modeling studies of the heavy rainfall episodes over Kerala from 7-10 August 2019 indicated that the presence of an offshore trough, intense low-level jet, and moisture advection caused heavy rainfall. Orography plays an important in determining the rainfall over Kerala by stacking the low-level clouds and increasing convergence over the windward side of the mountains.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

- Programmable HF Sounder system is developed, which operates in the frequency band of 1-25 MHz for sounding the ionosphere. The reflected echoes are used to derive the electron density profiles.
- A lightning E-Field measurement system has been developed, which records lightning transient E-Fields using two capacitive antennas having a time constant of 0.5 ms and 2 s, termed fast and slow antenna, respectively. It records not only the return strokes but also the leader processes and continuing currents that might occur between return strokes. In addition, time derivative of E-fields (dE/dt) and VHF emissions in the 68-74 MHz band are also measured to study leader breakdown processes.
- Differential Absorption lidar is developed for ozone concentration measurements in the troposphere and stratosphere.
- A hybrid Monte-Carlo Gear solution solver is developed for profiling of minor trace gases.
- NARL developed a multi-pollutant high-resolution spatiotemporal hourly gridded on-road traffic emission inventory for Delhi to understand the pollution dispersion.
- A neural network-based vertical plasma drift model is developed to overcome the serious limitation of studying/forecasting many equatorial/low latitude ionospheric processes. This model reproduces the daytime vertical plasma drift with a maximum error of ~2.7 ms^{-1} and they agree well with C/NOFS measurements and Scherliess-Fejer model.
- A machine learning technique has been developed to predict integrated water vapor from GNSS receiver measurements, which are later used to nowcast storms.
- Developed a method to retrieve atmospheric temperatures using the penalized maximum likelihood method after denoising the backscattered signal using the dictionary learning technique,
- Using long-term measurements of the sky radiometer, a fuzzy clustering technique has been developed to precisely classify aerosols and is tested.
- An optical-fiber-coupled lidar system with its transmitter injection seeded was developed and has been operated during the daytime at Gadanki (13.6˚N, 79.2˚ E). The signal-to-noise ratio of the return signal is used as the performance indicator, to evaluate the improvements. Signal-to-noise ratios with and without the Fabry-Perot interferometer are measured with near identical test set-ups. The signal-to-noise ratio enhancement factor is ca. 4, in agreement with the theoretical value.

- A new radio probing technique is developed for studying meteors in passive radar mode. This technique uses FM radio broadcast signals which get scattered from the meteor trails and come back to ground.
- An optimized GNSS receiver network for two-dimensional imaging of the ionosphere with a spatial resolution of 50 km and temporal resolution of 5 minute has been designed using unsupervised machine learning framework.

INSTRUMENTATION/FACILITIES

Advanced Indian MST Radar: This high-power radar operating at 53 MHz has 360° beam agility, modularity, multi-receiver capability and built-in scalability, which makes it the most powerful active array radar in the world, catering to the present and future scientific requirements of the atmospheric research community.
Rayleigh/Mie Lidar: A pulsed monostatic lidar system was setup at NARL for studying atmospheric aerosols, cirrus clouds and thermal structure of stratosphere and mesosphere. It uses second harmonic of Nd:YAG laser at 532 nm with an energy of 600 mJ to obtain photon counts in the height region of 8-80 km.

1.68 petascale High Performance Computing System: NARL has established a petascale HPC for high-resolution modelling of weather phenomena and improving parameterization schemes. The system has 196 nodes and a total computing power of 1.69 petaFLOPS. The system has 2 PB storage capacity with a throughput of 27 Gbps and an additional 250 TB storage with a throughput of 100 Gbps.

For further details on the inputs as provided in the document, please contact:
Dr. Amit Kumar Patra, **Director E-mail: director@narl.gov.in**

NATIONAL REMOTE SENSING CENTRE, HYDERABAD, INDIA

www.nrsc.gov.in

ABOUT NRSC

National Remote Sensing Centre (NRSC) is one of the primary centres of Indian Space Research Organisation (ISRO), Department of Space (DOS). NRSC has the mandate for establishment of ground stations for receiving satellite data, generation of data products, dissemination to the users, development of techniques for remote sensing applications including disaster management support, geospatial services for good governance and capacity building for professionals, faculty and students.

NRSC operates through multiple campuses to meet national and regional remote sensing data and applications needs of the country.

MAJOR RESEARCH DOMAINS

- Satellite Data Acquisition.
- Data Processing & Dissemination
- Aerial Services & Data Management
- Remote Sensing Applications
- Earth and Climate Studies.
- Disaster Management Support
- Geo Spatial Services
- Regional Specific Services

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

1. Seasonal and annual variations of CO_2 and CH_4 at Shadnagar, a semi-urban site;http://dx.doi.org/10.1016/j.scitotenv.2022.153114 and doi:10.1016/j.scitotenv.2022.153114
2. Unravelling the Interannual Changes in the Decade Observations of GHGs as Climate Indicators, https://doi.org/10.1007/s12524-023-01718-9.

3. Implications of Emission Sources and Biosphere Exchange on Temporal Variations of CO_2 and δ13C Using Continuous Atmospheric Measurements at Shadnagar, India, https://doi.org/10.1029/2022JD036472
4. Ground based Remote Sensing of Total Columnar CO_2, CH_4, and CO Using EM27/SUN FTIR Spectrometer at a Suburban Location (Shadnagar) in India and Validation of Sentinel-5P/TROPOMI, doi: 10.1109/LGRS.2022.3171216.
5. Wind power potential over India using the ERA5 reanalysis, https://doi.org/10.1016/j.seta.2023.103038
6. Atmospheric rivers fuelling the intensification of fog and haze over Indo-Gangetic Plains, https://doi.org/10.1038/s41598-022-09206-9
7. Estimation of soil moisture and soil temperature over India using the Noah multi-parameterisation land surface model, https://doi.org/10.1007/s40808-022-01603-3
8. High-resolution GEOS-Chem model for Indian Monsoon Region: Seasonal Cycle and Budget of Tropospheric CO_2,https://doi.org/10.1016/j.atmosenv.2023.119913
9. Consistency of seasonal variability in regional CO_2 fluxes from GOSAT-IM, NASA-GEOS, and NOAA-CT, https://doi.org/10.1007/s12040-022-01934-w
10. Long-term changes in rainfall epochs and intensity patterns of Indian summer monsoon in changing climate, https://doi.org/10.1016/j.atmosres.2023.106997
11. Contrasting changes of snowfall in response to Temperature and Rainfall over two distinct geographic ranges of the Himalayas: A study using long-term observations, https://doi.org/10.1007/s12040-023-02090-5
12. Deciphering the Signatures of Oceanic Convective Rain Cells Using C-band Synthetic Aperture Radar on-board EOS-04 satellite, https://doi.org/10.1029/2022GL102317
13. Variability of the aerosol and trace gases over polar latitudes, doi:10.1016/j.polar.2023.101012, 2023; and doi:10.1016/j.polar.2023.101011, 2023
14. Studies on the aerosol and green-house gases and Identification of global ventilation corridors for pollutants with space-borne sensors and reanalysis data. doi:10.1016/j.atmosenv.2021.118933; https://www.nature.com/articles/s41598-023-51140-x; and https://doi.org/10.21203/rs.3.rs-2888054/v1.

15. Generation of lightning essential climate variable for Atmospheric and Space Science Studies, doi: 10.1007/s11069-021-05042-8, 2022; doi:10.1007/s11069-023-05839-9, 2023; and doi: 10.1080/2150704X.2023.2258458, 2023.
16. Open Source Geospatial Technology for Urban Frame Surveying: https://www.ijceronline.com/papers/Vol13_issue2/D13022732.pdf
17. Extraction of Built-Up Areas Using Landsat Satellite Images and Deep Learning Algorithms: https://www.ijceronline.com/papers/Vol13_issue6/F13063642.pdf
18. Advancing GIS map maintenance: change detection and update using ResU-Net https://www.currentscience.ac.in/data/forthcoming/787.pdf
19. Region-Growing-Based Automatic Localized Adaptive Thresholding Algorithm for Water Extraction Using Sentinel-2 MSI Imagery | IEEE Journals & Magazine | IEEE Xplore https://ieeexplore.ieee.org/document/10049083
20. Response of crop water indices to soil wetness and vegetation water content. Advances in Space Research, 73(2), 1316–1330. : https://doi.org/10.1016/j.asr.2022.11.019
21. Net ecosystem CO2 exchange from jute crop (Corchorus olitorius L.) and its environmental drivers in tropical Indo-Gangetic plain using open-path eddy covariance technique https://doi.org/10.1007/s10661-022-09872-2
22. Rainfed cotton crop in central India is a strong net CO2 sink: An eddy covariance-based analysis of ecosystem fluxes https://doi.org/10.1016/j.fcr.2022.108595
23. Generating pre-harvest crop maps by applying convolutional neural network on multi-temporal Sentinel-1 data https://doi.org/10.1080/01431161.2022.2030072
24. Spatio-temporal trend of crop phenology, SPEI, and their interactions over different agro-ecological regions of India. DOI: 10.1007/s00704-023-04557-3
25. Monitoring early-season agricultural drought using temporal Sentinel-1 SAR-based combined drought index. DOI: 10.1007/s10661-023-11524-y
26. Satellite-based assessment of hailstorm damages in potato crop https://doi.org/10.1007/s11069-022-05412-w.
27. Paddy crop insurance using satellite-based composite index of crop performance https://doi.org/10.1080/19475705.2021.2025155

28. Remote sensing based crop insurance for jute (Corchorus olitorius) crop in India https://doi.org/10.1016/j.rsase.2022.100717

29. Vegetation health conditions assessment and mapping using AVIRIS-NG hyperspectral and field spectroscopy data for -environmental impact assessment in coal mining sites. https://doi.org/10.1016/j.ecoenv.2022.113650

30. Estimation of natural vegetation phenology metrics using time series EVI over Jharkhand state, India. https://doi.org/10.1080/14498596.2023.2281926

31. Machine learning-based meta-classifier for Kharif Bajra (pearl millet) discrimination in the mixed cropping environment using multi-temporal SAR data https://doi.org/10.1080/10106049.2022.2113452

32. Evaluation of different gridded precipitation products for drought monitoring: a case study of Central India. https://doi.org/10.1007/s00704-022-04304-0

33. Geospatial technologies for resources planning and management Edited Book (Springer publishers)https://doi.org/10.1007/978-3-030-98981-1; ISBN978-3-030-98980-4; ISBN978-3-030-98983-5

34. Geospatial Technologies for Land and Water Resources Management Edited Boo (Springer publishers) ISBN 978-3-030-90479-1 (eBook) https://doi.org/10.1007/978-3-030-90479-1

35. Combined use of band shape algorithm, linear spectral un-mixing on Clementine & Moon Mineralogy Mapper data for identifying the imprints of magmatic differentiation–A study around Aristarchus Plateau. Advances in Space Research, 69(8), pp.3164-3181 https://doi.org/10.1016/j.asr.2022.01.028.

36. Characterization of Ejecta Halo on the Lunar Surface around Chandrayaan-3 Vikram Lander Using OHRC Imagery. Journal of the Indian Society of Remote Sensing, 51(10), pp.1919-1922 (https://doi:10.1007/s12524-023-01774-1).

37. Discrimination of pearl millet in the rainfed agroecosystem using multitemporal sentinel-1 SAR data (URL: https://doi.org/10.1007/s43538-023-00218-1)

38. Characterization of forest fire frequency using fire scar mapping of temporal satellite data for forest fire management (URL: https://doi.org/ 10.31357/ jtfe.v11i02.5597)

39. Analysis of Support Vector Machine and Maximum Likelihood Classifiers in land cover classification using Sentinel 2 images (https://doi.org/10.1007/ s43538-022-00078-1)
40. Management of Citrus Orchards in Central India using Geospatial Technology (URL: https://doi.org/10.1007/978-3-030-98981-1_13)
41. Potential zones for hydrocarbon exploration have been identified in North Cambay and Jaisalmer Basins under a collaborative project with ONGC (https://doi.org/10.1016/j.asr.2023.09.011).
42. Space-based Information Support for Decentralised Planning - Update (URL: https://bhuvanpanchayat.nrsc.gov.in):

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

- Tri-band (S,X,Ka) Antenna system for LEO data reception.
- Tri-axis Antenna Control Servo System.
- 2.7M ADE reflector antenna for INS-2B Data Reception.
- Data Reception Subsystems:

  - Programmable IF Matrix
  - Down Converters (X & Ka Bands)
  - Next GEN Satellite Data Processing Acquisition Reconfigurable Card (NextGen SPARC).
  - 32 x 32 High speed Differential Data Switch Matrix
  - Antenna Pointing Error Model (APEM)
  - Centralized SPS-PB Data Archival System software
  - Satellite Data Reception Station (SDRS) Dashboard applications
  - Portable Data Serializer

- PCB Fault detection System.
- Bathymetry System.
- Unmanned Aerial Vehicle (UAV) for atmospheric studies.
- NavIC PPK Software.
- Remote sensing enabled Online Chemical Emergency Response System - ROCERS - (URL: https://rocers.fabkerala.gov.in):
- Online Nuclear Emergency Response System :

(URL: http://dx.doi.org/10.1016/j.pnucene.2022.104141)

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

National Workshops/Conferences:

- National Workshop on Space Technology in Disaster Risk Management at Delhi.
- 3 Day workshop on Space Technology for DRM for IORA member countries during Sep 2023 (online)
- National Meet on Disaster Risk Management – Trends and Technologies at Hyderabad.
- Workshop on Modeling In Hydrologic Unit Model for India (HUMID) at IIT Madras and RRSC Nagpur (2-Day).
- Remote Sensing & GIS Technologies (1-Week).
- RS & GIS Technologies for Sustainable Watershed Management (2-Week).
- Use of GIS for Ground Water Studies (2-Week).
- RISAT-1A (EOS-04) Satellite Data & Its Applications (2-Week).
- RISAT-1A Satellite Data Applications (3-Day).
- Water Use Quantification and Efficiency Estimation in Irrigated Command Areas using Satellite Data (2-Week).
- ISRO DMS Training Programmes and NDEM Training Programmes
- Yuvika 2022 & 2023
- Customized training on 'Auditing through Remote Sensing and GIS' for officials of Indian Audit and Accounts Department by RRSC-East.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

S.No	Title of the Course	Level of the Course	Intake capacity	Subjects of specialization in Space Science and technology
1.	CSSTEAP Short Course on Remote Sensing Data Acquisition	Graduate and above	20 International, 5 National (3 from INSPACe and 2 from Academia)	RF feed, Antennas, Electronics relating to ground segment data acquisition.

2.	CSSTEAP Short Course on Remote Sensing Data Processing	Graduate and above	20 International, 5 National (3 from INSPACe and 2 from Academia)	Digital Image Processing, AI/ML
3.	CSSTEAP Short Course on Satellite Remote Sensing for Ocean Applications	Graduate and above	20 International, 5 National (3 from INSPACe and 2 from Academia)	Satellite technologies (Active and Passive Sensing), Ocean Physical process measurements, Ocean Remote Sensing Applications.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

- **Anechoic Chamber Test Facility**
- **RF & Baseband Systems Lab**.
- **Aircraft Platform for Aerial Surveys/Payload evaluation**.
- **Gravel target extension for moderate resolution sensors characterization**.
- **Calibration site for NISAR L and S band imaging and quality analysis**.
- **Corner reflector sites (Challakere, Moulali) for NISAR mission**.
- **Multi-band Active Radar Calibrator** (ARC) at IMGEOS Microwave Cal-Val Site (Application / End use): captured responses in X, C and S-band sensors.
- **Goniometer for BRDF measurements**.
- **Thermal instrumentation for Microsat sensors characterization**. Temperature Range: -50 to 650 Deg C Accuracy: +/- 0.2 DegC
- **Sensor Characterization studies with USGS team** (Application / End use): Standard target for spatial characterization of imaging sensors. Validated the results with USGS team.
- **Climate Research Laboratory for Atmosphere**.
- A **nationwide lightning detection sensor network** for validation of space-borne measurements.
- **Network of 8 Micro Rain Radar instruments over India** to study profiles of precipitation parameters like rain rate, drop size distribution, fall velocity etc.

- **An analytical laboratory is established at RRSC-East** for analysing the coastal water samples for their biogeochemical characteristics and supporting the Cal-Val activities of EOS-6 / OCM-3.

For further details on the inputs as provided in the document, please contact:

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NORTH EASTERN SPACE APPLICATIONS CENTRE, SHILLONG, INDIA

https://nesac.gov.in

ABOUT NESAC

North Eastern Space Applications Centre (NESAC) was established in the year 2000 as an autonomous organization under Department of Space, Government of India with an objective to facilitate extensive use of space technology inputs for the development of the north eastern region (NER) of India. The major objectives of the centre are (i) to provide an operational remote sensing (RS) and geographic information system (GIS) aided natural resource information base to support activities on development and management of natural resources, infrastructure planning, and governance in the region, (ii) to provide operational satellite communication applications services in education, health care, disaster management support, and developmental communication, (iii) to take up research in space and atmospheric science area and establish an regional instrumentation facility and networking with various academic institutions, (v) to enable single window delivery of all possible space based support for disaster management, and (vi) to set up a regional level infrastructure for capacity building in the field of geospatial technology. The centre has successfully completed more than 250 projects covering different thematic areas during last 23 years of its existence. It has emerged as a major centre catering to the needs of space technology interventions towards holistic development of NER of India.

MAJOR RESEARCH DOMAINS

The major research domains at NESAC are as follows

- Satellite Remote Sensing: NESAC utilizes different types of satellite data to develop innovative methods for natural resource management, sustainable infrastructure planning support, site suitability analysis, etc.
- Application of Artificial intelligence, Machine Learning, and deep learning for different applications like auto detection of features, nowcasting of weathers, etc.
- Disaster risk reduction: NESAC has developed innovative methods for early warning and management strategy for disasters like Floods, Lightning, vector borne diseases, landslides, forest fires, etc.

- Development of innovative applications using unmanned aerial vehicles based remote sensing data for on-demand and high resolution mapping and monitoring services, emergency services, etc.
- Research to improve short and medium range weather forecast, severe weather forecasting, characterization of aerosol and atmospheric boundary layers, aerosol-cloud interaction studies, climate analysis and impact assessment, etc.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

The major scientific applications / results from the centre is listed below

(i) **Space-based support for the integrated development of horticulture in NER:** Space technology along with ground level information has been very effectively used for identification of sites where different forms of horticulture activities can be expanded, which has direct implication on the livelihood of population in NER, particularly for those living in the remote hilly regions. The study is being done for the 55 districts of NER for major horticulture crops like pineapple, kiwi, apple, orange, ginger, lemon, etc.

(ii) **Applications of Space Techniques for Agricultural Assessment in NER:** Space technology is used for overall assessment of agricultural practices in NER, that includes acreage estimation of winter and summer rice, which is challenging over the hilly regions and is very important for planning purpose. The acreage of summer rice is estimated for the state of Assam, Tripura, and Meghalaya. Cropping intensity analysis is also done for selected areas in NER. Additionally, the suitability analysis for the expansion of priority crops have is done based on requirement.

(iii) **Identification of forest gap area in the reserved forests of NER:** The degraded forest land mapping has been done within the reserved forests for the states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura based on the Reserve Forest (RF) boundary received from the respective State Forest Departments. The forest gaps identified using space technology can be afforested to increase the green cover in our country.

(iv) **Flood Early Warning System (FLEWS) for NER:** Flood early warning is done under the FLEWS project for Assam and other priority flood prone regions of NER. The forecast leverages the strength of numerical model based rainfall forecasting as well as near real time space based weather monitoring, both integrated in a hydrological framework supported by ground level information collected using satellite imagery. The operational phase of FLEWS project in Assam has success score exceeding 80% with maximum lead time of 48 hours.

(v) **Mineral Mining Database and geospatial database updation of mineral deposits:** The Identification and demarcation of the coal-bearing areas in Meghalaya is done and efforts are being made to identify the same for other important minerals. A rationalized spatial distribution analysis was carried out based on mineral category and morphotectonic units in the region. This introspection of the mineral resources database will serve as anchorage knowledge for strategic resource planning and will help gauge the success of future mineral prospecting in the region.

(vi) **Remote sensing & GIS based input for Hazard, Vulnerability and Risk Assessment (HRVA):** Multi disaster (flood, lightning and storm, landslide, and forest fire) assessment of hazard zones, vulnerability and risk of selected urban centres and districts in Meghalaya and Tripura is being done. The HRVA assessment helps in better planning for disaster management and resilience.

(vii) Setting up new greenfield township and model villages in NER: Remote sensing and GIS tolls are effectively used for planning the sustainable model villages and greenfield towns in NER. With the objective of creating a framework for a model township for the Zeme community in Manipur, a strategic plan/model is being designed. A reconnaissance survey is conducted before preparation of any plan. NESAC developed plan for three model village, one greenfield towns, Shillong city plan, etc.

(viii) **Election e-Atlas:** The election e-Atlas consists of a dashboard and mobile Apps to support in planning and execution of elections using the strengths of geospatial technology. The election e-Atlas application was effectively utilized by in the states of Manipur, Tripura and Mizoram during the state Assembly elections held on 2022 and 2023 respectively. The tracking applications were successfully used to track all sector officers, flying squads and other important senior police officers during the poll day for smooth functioning of electoral process.

(ix) **Tele-education in NER:** The tele-education network in NER has been set up with Seven HUB (teaching end) installed in NE states and 330 Satellite Interactive Terminal (SIT). The network benefitted thousands of students, particularly from the remote areas to provide them with quality education.

(x) **UAV Technology & Applications:** Different types of UAVs have been used for survey and mapping across NER and other parts of India. More than 25,000 ha of land has been mapped using the UAVs covering very critical applications like, embankment mapping in Tripura, mapping of hydroelectric power sites, fire assessment, flood extent mapping, landslide mapping and assessment, etc.

(xi) **Development of location-based lightning now-casting system for NE region of India:** The lightning nowcasting with lead time up to nine hours is done over the NER utilizing the lightning data from the national network operated by IITM, Pune and assimilating the same to the WRF (Weather Research and Forecasting) - Elec model. The same data has also been used to develop a near real time severe weather tracking system to nowcast location-based lightning with lead time up to 45 minutes. The probability of detection (PoD) was found to be more than 0.7 and success ratio more than 0.6 for lead time up to 4 hours.

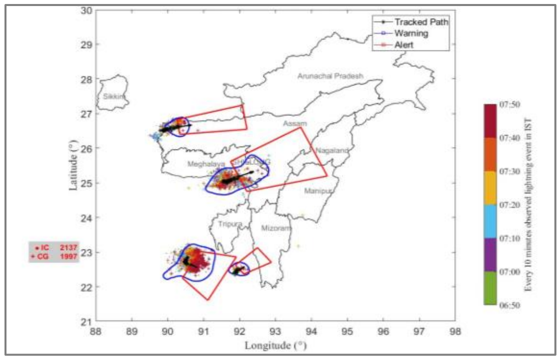


Fig: Lightning early warning using the severe weather tracking system over the NER

(xii) **Aerosol Radiative Forcing over India – NER Scenario:** Three aerosol observatories are operated in NER including two at high altitude sites to collect data on aerosol physical and optical properties using multiple instruments. Three campaigns have been conducted along the Brahmaputra and Barak River valley to complete the multi-seasonal data collection process to study the aerosol-cloud-precipitation interaction over the NER. The analysis suggests that the aerosol over the NER is more hygroscopic in general and within NER, the aerosol over the eastern part is relatively more hygroscopic even though the concentration of aerosol is less over the region compared to other sampling places.

(xiii) **Network of Boundary Layer Experiments (NOBLE) – NER component:** Spatial and seasonal variation of atmospheric boundary layer (ABL) height and dynamics over the Brahmaputra valley of Assam has been evaluated using the Dr Pisharoty Radio sonde data collected during two land campaigns. Mutli-decadal analysis of ABL height indicates decreasing trend towards the western region of NER during the pre-monsoon and winter season. The ABL estimates by different global reanalysis models have also been evaluated for the NE region.

(xiv) **The behavior of cloud base height over a hilly remote station of NER:** The study has been done using ground-based remote sensing technique (LIDAR Ceilometer) over Umiam, Meghalaya, India (altitude 1040m). Cloud occurrences showed distinct seasonality with maxima in wet months and minima in dry months.

Multilayer cloud structures are found mostly in the monsoon season, although single-layer clouds dominated throughout the year.

(xv) **Study on drop size distribution (DSD) of orographic rain:** The rain conditions in which collisional drop breakup is prominent and is capable of modifying the shape of DSD in orographic rain over north-eastern India was studied using five laser precipitation monitor. The DSDs in stratiform and convective rain types were studied separately and observed that even though drop breakup in intense to moderate rain seemed to be in notable percentage (0.2% - 11.2%), the low intensity rain also showed a considerable break-up signature (2.5% - 9%), depending upon the locations. The study helped in improving the rainfall estimate using radar data over the hilly regions.

(xvi) **Assimilation of satellite-based soil moisture in a land data assimilation system for investigating the spatio-temporal behavior of land-atmosphere interaction over India:** Inter-comparison of land surface models and implementation of land data assimilation system have been completed to develop an improved product for the soil moisture estimation over the Indian region.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PRODUCTS / SENSORS / DETECTORS

NESAC develops several products for consumption by users. The major among them are listed below:

(i) A portable and miniature pollution monitoring devise has been developed in collaboration with NIT Agartala under the Space Technology Incubation Centre (STIC) initiative of ISRO. The device is capable of providing real time data on PM10, PM2.5, Temperature, Humidity, SOx, NOx, and CO_2 and transmit the same using GSM/GPRS channel. The data can be monitored using a mobile app.

(ii) Daily weather forecast over NER (rainfall, temperature, humidity)

(iii) Precipitation estimate from Doppler Weather Radar (DWR), Sohra

(iv) Max Z (reflectivity), Max V (velocity), Vertical wind product from DWR, Sohra

(v) Flood warning and Flood inundation maps (during summer monsoon season)

(vi) Value added product for forest fire location and management.

(vii) Lightning warning products

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Training and outreach programs have been one of the major activities at NESAC. These activities are being expanded to address the growing demand from the user departments, industries, academia, and students' communities, particularly from the NER of India.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

NESAC offers the following short term courses (2 weeks)

- Basic Training course on Remote Sensing & GIS Technology and Applications
- RS & GIS applications in IT and Web services
- RS & GIS applications in Agriculture and Soil
- Advanced training course on UAV Remote Sensing technological advances & applications
- RS & GIS applications in water resources
- RS & GIS applications in Forestry & Ecology
- RS & GIS applications in Urban and regional planning
- RS & GIS applications in Geosciences
- Satellite Meteorology and its Applications in Numerical Weather Prediction
- Satellite communication technology for emergency applications
- 2 Weeks basic training course on RS and GIS for the BIMSTEC countries.

In addition to the above, NESAC also provides tailor made courses for project specific requirements

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

- Laboratory with all relevant GIS and Remote Sensing (RS) tools such as high end systems and software for performing RS information retrieval and data analysis, large scale mapping, etc. Latest map plotters, printers, GPS systems and cameras including GAGAN, NAVIC & DGPS for professional grade surveys
- Laboratory for development of Mobile Apps, Dashboard applications, Geo-web services, disaster management support services.
- High performance computing system including GPU servers for atmospheric modeling, hydrological modeling, Machine learning applications.
- Unmanned Aerial Vehicles for remote sensing, quick mapping support, disaster management support including drone testing, fabrication using 3D printers, drone pilot training, etc. Electronics laboratory including PCB printing facility.
- Satellite communication facilities including satellite phones, to support various developmental programs and emergency communication support.
- S Band Doppler Weather Radar for Atmospheric science studies.
- UHF Wind profiler for 3D measurement of wind up to a height of 6-8 km.
- Facility to launch tethered balloons and atmospheric sondes using hydrogen gas filled meteorological balloons for vertical profiling of atmosphere.

For further details on the inputs as provided in the document, please contact Director, NESAC (director@nesac.gov.in, +91 364 2308702)

PHYSICAL RESEARCH LABORATORY, AHMEDABAD, INDIA

www.prl.res.in

ABOUT PRL

Physical Research Laboratory is mandated to conduct fundamental and cutting-edge research in niche areas of sciences. Its research is organized in seven major science areas, namely, Astronomy & Astrophysics, Solar Physics, Space and Atmospheric Sciences, Planetary Sciences, Geosciences, Atomic, Molecular and Optical Physics, and

Theoretical Physics. PRL, formed in 1947, is also considered as the ‘cradle’ of space research in India as it is from PRL, conceived by Prof. Vikram Sarabhai, that the basic and applications research in space was initiated in India. PRL currently has four campuses at Navrangpura and Thaltej in Ahmedabad, Udaipur (for solar research) and Mt. Abu (for astronomy).

MAJOR RESEARCH DOMAINS

The domains of research relevant to Space Sciences in PRL include investigations of the sun and its variability, atmospheres of the earth and other planets, space weather effects on the atmospheres, the sun and the interplanetary medium, the study of the interiors, surfaces, and atmospheres of solar system objects and the processes governing their dynamics. This is accomplished through theoretical models (computer simulations), laboratory experiments, remote sensing, in-situ observations and experiments, development pf payloads and ground- and space-based instruments.

Astoronomy and Astrophysics: The Research in the Astronomy and Astrophysics Division involves investigations in the optical, infrared, X-ray and the radio wavelength bands to understand some of the outstanding problems related to galactic and extragalactic cosmic phenomena, such as star formation, stellar evolution, interstellar medium, binary stars, pulsars, active galactic nuclei and giant radio galaxies.

Solar Physics: The science goals of solar physics research are to understand the physics of solar oscillations, evolution of sunspots, sunspot fine structure, MHD processes in the solar atmosphere, coronal heating, solar eruptions and space weather prediction.

Planetary Sciences: The study focusses on planetary atmospheres, plasma physics and astrochemistry, origin/ evolution of the solar system, planetary geology, solar system objects, their surfaces and interiors, and governing processes. Research is also aimed at conceptualization, science, instrument design, implementation, experiments, data analysis, of space missions, such as Chandrayaan-3, -4, and for the upcoming missions to Venus and Mars.

Space and Atmospheric Sciences: The current research foci include Sun-Earth interactions, space weather and its effect on societal applications, coupling, energetics and dynamics of atmospheric regions, investigations of solar disturbances/geomagnetic storms, and global-scale atmospheric circulation. Research is also aimed at conceptualization, science, instrument design, implementation, ground- and space-borne experiments, data analysis, of Indian missions for space weather, such as, Aditya L1, and the proposed Aeronomy satellite.

Astrochemistry: The cold dust (10 K) in the ISM and icy surfaces (30 K – 200 K) of solar system objects are recreated in the laboratory to understand the physico-chemical nature of the molecules and the complex chemical reaction network initiated by the energetic particles. The hypervelocity impact induced shock and the ISM shocks are recreated in the laboratory to understand the physico-chemical nature of a mixture of elements, molecules, nano and micro dust subjected to instantaneous and simultaneous high pressure (~ kPa) and temperature (~ 16000 K).

MAJOR SCIENTIFIC APPLICATIONS

Over 450 peer reviewed publications have been obtained by PRL in the years 2022-23. The complete list is available at: https://www.prl.res.in/prl-eng/prl/data/recent_publication. A flavor of results obtained are given below.

Scientists Discover an extreme Massive Giant and Most Dense Exoplanet

A new Jupiter size exoplanet with highest density of ~14 g/cm3 known till this date, and mass 13 times that of Jupiter has been discovered by an international team of scientists led by Prof. Abhijit Chakraborty at the Exoplanet Research Group of the Physical Research Laboratory (PRL), Ahmedabad. The team includes scientists from India, Germany, Switzerland and the USA. The discovery of this massive exoplanet was made using the indigenously made PRL Advanced Radial-velocity Abu-sky Search spectrograph (PARAS) at the 1.2 m telescope of PRL at its Gurushikhar Observatory in Mt. Abu by measuring the mass of the planet precisely. The newly discovered exoplanet is found around the star called TOI4603 or HD 245134. It is located 731 light years away. It orbits a sub-giant F-type star TOI4603 every 7.24 days. The newly discovered exoplanet TOI 4603b is one of the most massive and densest giant planets that orbits very close to its host star at a distance less than 1/10th the distance between our Sun and Earth. The exoplanet with a surface temperature of 1670 K is likely undergoing high-eccentricity tidal migration with an eccentricity value of approximately 0.3. https://doi.org/10.1051/0004-6361/202245608

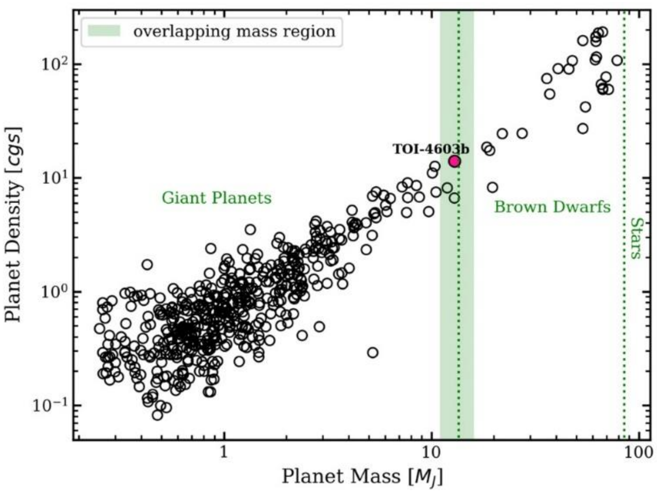


Fig. Planetary density as a function of planetary mass for transiting giant planets and BDs (0.25–85MJ). The shaded area represents the overlapping mass region of massive giant planets and BDs based on the deuterium burning limit, and the dotted lines are at MP = 13MJ and MP = 85MJ. The position of TOI-4603 b is denoted by the magenta dot.

Probing the global dust properties and cluster formation potential of the giant molecular cloud G148.24+00.41

Clouds more massive than about 105 M⊙ are potential sites of massive cluster formation. Studying the properties of such clouds in the early stages of their evolution offers an opportunity to test various cluster formation processes. We make use of CO, Herschel, and UKIDSS observations to study one such cloud, G148.24+00.41. Our results show the cloud to be of high mass (M⊙), low dust temperature (∼ 14.5 K), nearly circular (projected radius ∼ 26 pc), and gravitationally bound with a dense gas fraction of ∼18 per cent and a density profile with a power-law index of −1.5. We compare our results with models of star cluster formation, and conclude that the cloud has the potential to form a cluster in the mass range of around 2000–3000 M☉ through dynamical hierarchical collapse and assembly of both gas and stars. https://doi.org/10.1093/mnras/stad639

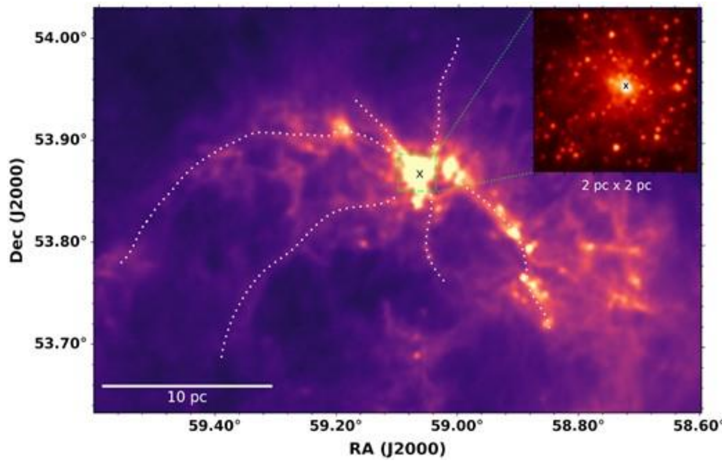


Fig.Herschel 250 mm image of G148.24+00.41, revealing the filamentary structures in its central area. The inset image shows the zoomed-in view of the central region in Spitzer 3.6 mm, which is taken from GLIMPSE360 survey (Whitney & GLIMPSE360 2009). It shows the presence of an embedded cluster in the hub. The cross sign shows the position of the massive YSO.

Genesis of three-dimensional magnetic null

Three-dimensional (3D) magnetic nulls are preferential sites for triggering solar flares. Such 3D nulls are abundant in the solar atmosphere but mechanism of their origin or the reason beyond their abundance is yet a puzzle. Towards solving this puzzle, PRL scientists have performed numerical simulation of the dynamics of an isolated 3D null. Astoundingly, it is found that the evolution leads to spontaneous generation of 3D nulls, which are distributed throughout the computational domain. Reconnection of magnetic field lines was identified as the underlying mechanism toward genesis of these spontaneous nulls. Further, it can be hypothesized that these spontaneously generated 3D nulls can contributed to coronal heating. DOI: https://doi.org/10.1063/5.0107601.

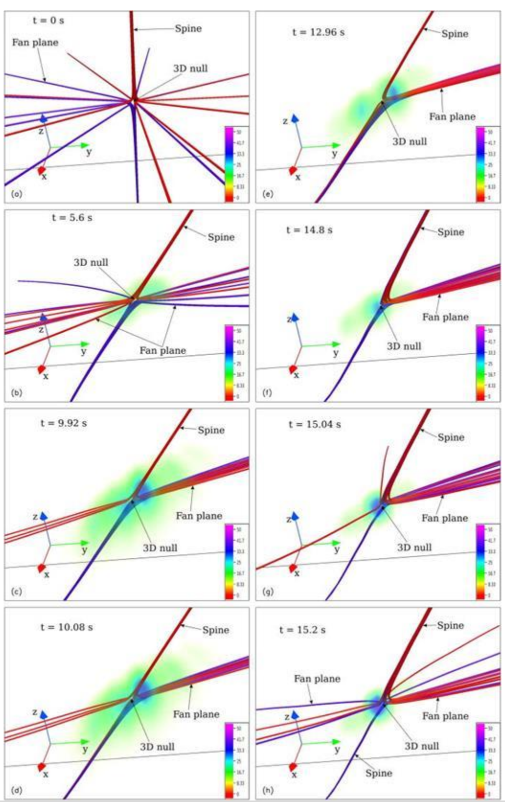


Fig.The snapshots of field lines spanning the t∈{0,15.2} s illustrate the evolution of central null marked by 3D null in the figure (the initial current free radial null located at the center of the box). The spine and fan field lines of the initial null are plotted in red and blue [panel (a)] with red field lines constituting the upper spine while field lines in blue belong to the lower spine. With the evolution, the current sheet (CS) near the central null develops, which facilitates the magnetic reconnection in the current sheet. Panel (b) shows an intermediate field line structure in which current sheet has been started to *develop (identified with DVR of large |J|/|B|). The color scale of the DVR (right bottom corner) represents the magnitude of the current intensity. The blue and red field lines slip over the fan plane and an intermediate structure is shown in panel (c) before the reconnection in the CS near the central null. The red and blue field lines are changing its connectivity [evident by panels (d)–(h)] and become the part of lower and upper spine, earlier at t = 0 s [panel (a)], and the red and blue field lines were only part of the upper and lower spine, respectively.*

An effective generalized mechanism responsible for the production of broad CMEs resulting from compact solar eruptive flares

Coronal mass ejections (CMEs) exhibit a range of shapes and sizes. CMEs are designated as homologous when they originate from the same location of an active region with similar morphological resemblances in coronagraphic observations. PRL scientists have analyzed the formation mechanism of three homologous broad CMEs resulting from a series of solar blowout-eruption flares with successively increasing intensities (M2.0, M2.6, and X1.0), which originated from NOAA Active Region (AR) 12017 during 2014 March 2829 within an interval of 24 hr. Coronal magnetic field modeling based on nonlinear force-free field extrapolation helps to identify low-lying closed bipolar loops within the flaring region enclosing magnetic flux ropes. Double flux rope system were obtained under closed bipolar fields for all the events. The sequential eruption of the flux ropes led to homologous flares, each followed by a CME. Each of the three CMEs formed from the eruptions gradually attained a large angular width, after expanding from the compact eruption-source site. These eruptions and CMEs are found to be consistent with the magnetic-arch-blowout (MAB) scenario. https://doi.org/10.3847/1538-4357/ac5cc1

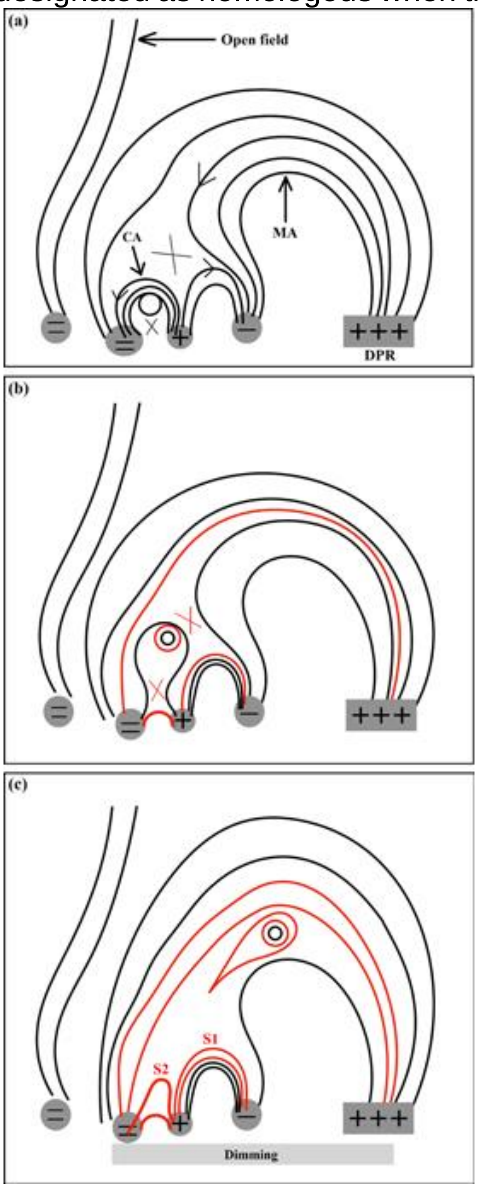
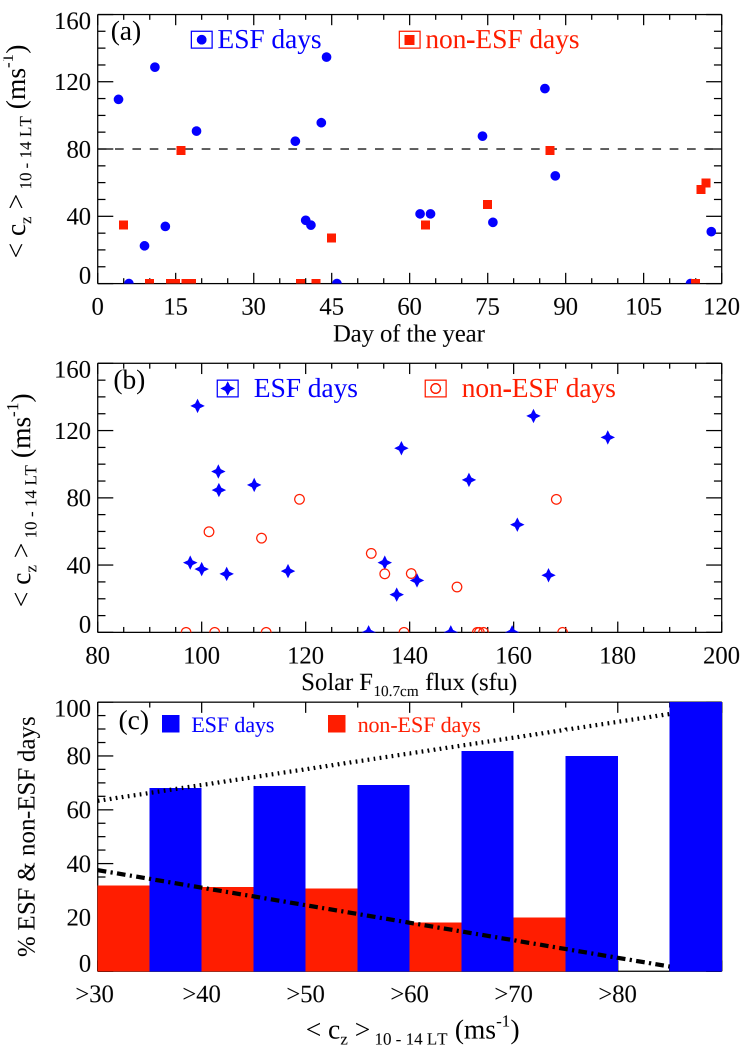


Fig.Schematic representation of the MAB scenario for the production of broad CMEs resulting from homologous compact major blowout eruptions, viewed from solar west. Panel (a): the large MA connects the DPR and the negative flux region of the AR. The large negative sunspot of the Active Region (double negative signs), from where the open field lines also originate. On the right of the large sunspot, compact bipolar region hosting the compact arcade (CA) is shown, *enveloping the flux rope. The plausible reconnection sites are marked by cross signs. Panel (b): the reconnection between CA and MA, weakens the MA field lines and creates a pathway for the eruption of the flux rope. Panel (c): the external reconnection between CA and MA produces the set of field lines labeled S1, and the internal reconnection between the legs of the field lines stretched by the erupting flux rope creates the set of field lines labeled S2. The brightening in the outer footpoints of the S1 field lines is observationally confirmed by the wide circular ribbon structure, whereas, the S2 field lines exhibit themselves as compact postflare loop arcades. The extent of the dimming resulting from the blowout eruption of MA is also indicated in panel (c).*

Daytime vertical propagation speeds of gravity waves as precursors to equatorial plasma irregularities

The vertical propagation characteristics of gravity waves in daytime thermosphere have been obtained by using a digital ionosonde at a magnetic equatorial latitude location, Trivandrum, and it has been shown to be a crucial parameter for the generation of ESF during post-sunset hours. The results indicate that vertical propagation activity of gravity waves exists on 85% of the ESF days, whereas it is only 50% for the days without the occurrence of ESF during post-sunset hours. Further, vertical propagation speeds, Cz, of these gravity waves are higher on the ESF days than on the non-ESF days. Also, ESF has been found to occur on 100% of the occasions, whenever the vertical speeds of these gravity waves are greater than 80 ms⁻¹. On such days, the peak altitude of the F-region also showed the same period as that of the gravity waves indicating that the high-speed gravity waves are capable of perturbing the ionosphere more efficiently on the ESF days compared to the non-ESF days.



[https://doi.org/10.1029/2022JA030401]

Fig. (a) Daily average values of Cz during 10–14 LT. (b) The value of Cz showing larger values even on the days with low-solar F10.7 cm flux indicating its importance. (c) The percentage of the number of the ESF and non-ESF days are categorized based on the values of vertical phase speeds of gravity waves in the daytime thermosphere. The leftmost red-colored bar indicates that 30% of the days are of the non-ESF category when Cz are greater than 30 ms^{-1}, whereas, for the ESF category, it is 65% (leftmost blue-colored bar). Similarly, the rightmost bar suggests that all the days are found to be of the ESF category if Cz is greater than 80 ms^{-1}. The dotted and dash-dotted lines show the trends for the ESF days and non-ESF days.

Relative roles of IMF Bz and By in generating global asymmetry in ΔX variations during a geomagnetic storm

This investigation is directed to understand the asymmetry in ΔX variations caused due to the relative roles played by Interplanetary Magnetic Field (IMF) Bz and IMF By during the main phase of a strong geomagnetic storm event of 06 April 2000 (Ap = 236). Two pairs of antipodal stations, being part of the SuperMAG network, are considered here. Observations show increases in the difference in ΔX variations between nearly antipodal stations from the Japanese-European/African sector with respect to the same between the nearly antipodal stations from the Pacific/American-Indian sector. This asymmetry is observed during the period when the absolute magnitude of IMF By is larger than that of IMF Bz resulting in a significant and conspicuous enhancement in IMF |By/Bz|. It is suggested that the distortions in DP2 cells and associated rotation of electrodynamic day-night divider, bring one pair of stations under the same DP2 cell and one station of the other pair under a different DP2 cell and throat flow region leading to the asymmetry in ΔX variations between the antipodal stations. Therefore, the work highlights the importance of the interplay between IMF Bz and IMF By in determining the ionospheric impact over low latitudes during strong geomagnetic conditions. https://doi.org/10.1029/2022JA031047

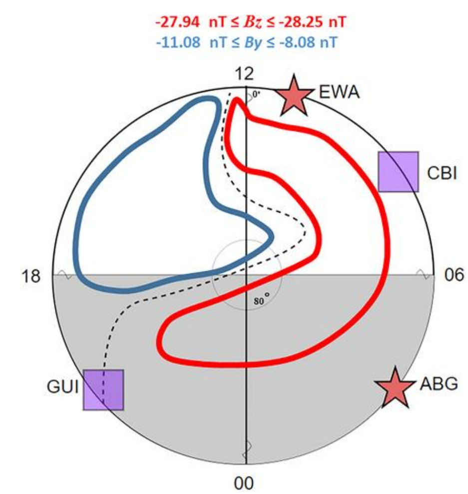


Fig.A schematic of the DP2 equipotential contour under southward IMF Bz and negative IMF By condition during the region of interest. The shaded (gray) hemisphere represents the nightside. The solid black line represents the midnight-noon meridian while the dashed black line represents the electrodynamical divider between the dawn (red) and dusk (blue) cells. The nearly antipodal station pairs are marked in violet squares for CBI and GUI and red stars for EWA and ABG.

Morphological changes currently occurring in sand-filled gully channels on Mars: Implications for the role of substrates inside channels.

The evidence for present-day changes in sand-filled gully channels consistent with ripples is presented. These channels are ubiquitous in the mid-latitudes and found in gullies formed over a variety of substrates on crater walls. Over 1483 gullied craters were investigated that were present in at least two High Resolution Imaging Science Experiment (HiRISE) images. Investigation of the sequence of events revealed CO_2 frost inside the sand-filled gully channels in the image acquired during winter and prior to the image in which recent changes have been observed. This suggests a connection with the sublimating frost inside the channels and a seasonal control that subsequently produces extensive changes in the sand-filled gully channels during defrosting seasons in approximately a Mars year. Comparison of changes on both sand-filled gully channels and dune gully channels substantiates that the currently active processes have similar effects on the loose, unconsolidated substrate in both the gully types. The results signify that the sand-filled gully channels represent a significant component of present-day modification of gully channels on Mars. https://doi.org/10.1016/j.icarus.2022.115334

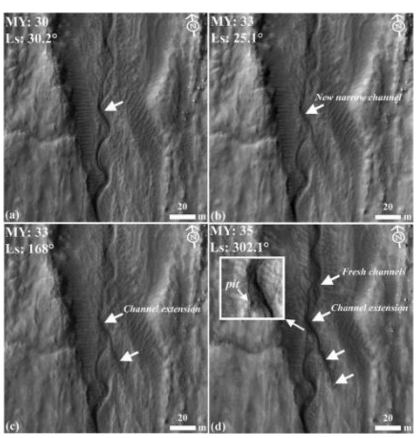


Fig.(a-d) Active flows in the upslope led to the incision of a new narrow channel (arrow in b) and subsequent extension of the channel (arrows in c and d) on the floor of a broad sand-filled channel in Gebog crater. Active flow in the upslope has led to the incision of fresh channels (upper arrow) in (d). Potential evidence of pit at the terminus of a channel (zoomed image in Figure d) possibly indicates downslope transport of CO2 ice block inside the channel. Sublimation of CO2 ice block on reaching the terminus of the channel will likely remove sand from beneath and form a circular pit. The dark area associated with circular pit observed here could be also due to boulder shadow, etc. since these features are at the instrument's resolution limit. (a) ESP_016046_1425, (b) ESP_042353_1425, (c) ESP_046309_1425, and (d) ESP_066775_1425.

The recent meteorite fall in Kopargaon, Maharashtra

On January 24, 2023, a meteorite fell piercing through the roof of a house, resident of Bhojade Chauki in the Kopargaon taluka in Ahmednagar district, Maharastra at around 6:50 am IST. Preliminary examination suggests that the meteorite appears to be a variety of stony meteorite covered with thin fusion crust. Further studies suggested that the specimen resembles an amalgamation of several fragments and clasts. Based on quantitative analyses of mineral phases, the meteorite is classified as LL (petrologic type 5) fragmental breccia. The Kopargaon LL chondrite is likely to be the fragmental pieces of the S type asteroid (in the Main Asteroid belt), ar to that probed by the Asteroid sample return mission of the Hayabusa-1. This work was also published on the cover page of the journal Current Science, Volume 124, Number 10, May 25 2023.

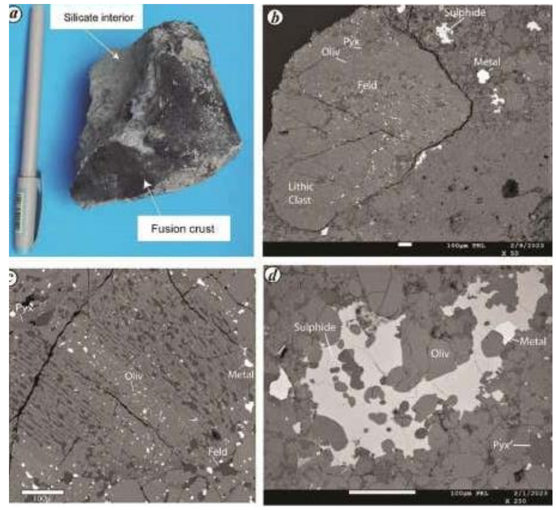
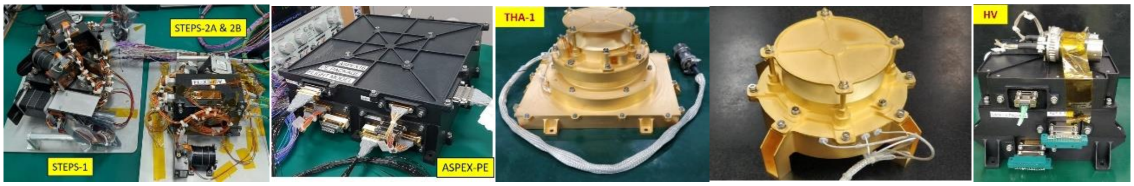


Fig.Left: a, Hand specimen of Kopargaon meteorite. Black fusion crust and grey silicate interior are shown. Length of the pen is 14 cm. b, c, Back-scattered electron (BSE) images of Kopargaon fragmental breccia. Lithic clasts and chondrule clasts are shown. Oliv, Olivine; Feld, Feldspar; Pyx, Pyroxene. d, BSE image of sulphide (troilte) and metal (Fe–Ni alloy) in Kopargaon chondrite.

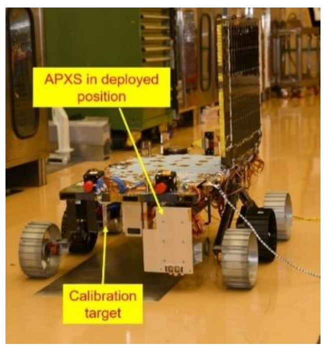
INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

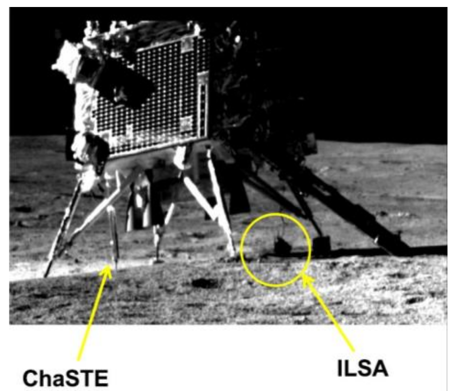
1. Aditya Solar Wind Particle Spectrometer (ASPEX): Solar Wind Ion Spectrometer (SWIS), a low energy ion spectrometer, and high energy spectrometer, Supra-Thermal Energetic Particle Spectrometer (STEPS) has been developed for the Aditya-1 mission which was launched in Sept 2023. It will continuously monitor the flux of solar wind particles at the L1 point of Sun-Earth system. The data from

this instrument will help understand the anisotropy and acceleration processes in the interplanetary medium. The payload has been made operational in Nov 2023.



2. An Alpha particle X-ray spectrometer (APXS) was flown on Chandrayaan-3. It was placed in the Pragyaan rover for the investigations of mineralogical composition of the lunar surface.





3. Chandra's Surface Thermophysical Experiment (ChaSTE) has been flown on the Chandrayaan-3 mission. It was a payload on the Vikram Lander and is aimed to measure the thermal conductivity and temperature of the lunar regolith in the top 10cm.

2.5m Telescope at Mt. Abu Observatory fully commissioned

The PRL 2.5m telescope project is a state of the art technological development taken up at Physical Research Laboratory (PRL) in collaboration with Advanced Mechanical and Optical Systems (AMOS), Belgium. The tracking accuracy of the telescope is 0.2-0.5 arcsec RMS in close loop with Auto guider unit. The telescope is commissioned and has been operationalized. The second generation PARAS-2 (PRL Advanced Radial velocity

All Sky Search-2) has also been commissioned with the new 2.5 m telescope. The PARAS-1 attached to the 1.2 m telescope enabled discoveries of all the three exoplanets made from India. It is anticipated that the present upgraded PARAS-2 attached to a much higher resolution 2.5 m telescope will enable many more new and exciting discoveries.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

A few capacity-building events, workshops, and conferences, hosted by PRL are listed below:

1. Space Weather: Applications and Opportunities, 17 – 18 October 2023.
2. 1st and 2nd Indian Space Weather Conferences, 12-13 January 2022 and 19-20 October 2023, respectively.
3. Indian Planetary Science Conferences 15-17 February 2022 and 22-24 March 2023, respectively.
4. 12th Post graduate course on Space and Atmospheric Sciences, August 2020 – April 2021
5. High-end workshop "Karyashala" on "Astrochemistry and cratering in the solar system" , 04-10 July 2022.
6. 10th July 2022 was celebrated as Asteroid day in PRL.
7. Venus Science Conferences, 29-30 September 2022 and 21-22 September 2023.
8. VRITIKA: student training program , 25 July to 21 August 2023.
9. National Symposium on Shock Waves – NSSW- 2023, 15-17 Feb 2023.
10. Online Short course on Planetary Science in May 15-19, 2023.
11. ISRO-STP on "Sun-Planet interactions: A space weather perspective) during 25-29 September, 2023.
12. 13th Post graduate course on Space and Atmospheric Sciences, August 2023-April 2024.

13. PRL and IIT-Mandi jointly organized the DST funded high-end workshop “Karyashala” on “Astrobiology and analogue sites for the Indian space programme”, 30 Oct – 4 Nov 2023.
14. 13th CSSTEAP PG Course during October to December 2023.
15. Project training offered to UG and PG students of Science and Engineering during FY 2021-22 (58) and during FY 2022-23 (38).

Ph. D. theses in the space sciences domain Awarded

1. “Multi-wavelength studies of Active Galactic Nuclei”, Degree awarded by the IIT, Gandhinagar, 21-11-2022.
2. “Geological and Geochemical Study of Martian Volcanic Provinces: Implications for Igneous Evolution of Mars”, Degree awarded by the IIT, Gandhinagar, 10-01-2023.
3. “Evolution of remnant radio galaxies”, Degree awarded by the IIT, Gandhinagar, 18-01-2023.
4. On the role of Hall magnetohydrodynamics in magnetic reconnection: Astrophysical Plasmas”, Degree awarded by the IIT, Gandhinagar, 23-01-2023.
5. “Investigations on Low Latitude Ionosphere under Varying Space Weather Conditions”, Degree awarded by the IIT, Gandhinagar, 17-02-2023.
6. “Investigating the coronal X-ray characteristics - From Sun as a star to imaging spectroscopy”, Degree awarded by the IIT, Gandhinagar, 20-02-2023.
7. “Investigations of Low- and Equatorial-Latitude Upper Atmospheric Processes using Optical and Radio Techniques”, Degree awarded by the IIT, Gandhinagar, 21-02-2023.
8. “Eruption of Solar Magnetic Flux Ropes and Associated Flaring Activity: Observational Perspectives”, Degree awarded by the IIT, Gandhinagar, 22-02-2023.
9. “Study of the Evolution of Velocity and Magnetic Fields in the Solar Atmosphere”, Degree awarded by the IIT, Gandhinagar, 13-03-2023.
10. “Aspects of Spectroscopic and Polarimetric Instrumentation for Ground Based Optical Telescopes with related Observations”, Degree awarded by the IIT, Gandhinagar, 28-03-2023.
11. “Daytime thermospheric neutral wave dynamics over lowand equatorial-latitudes”, Degree awarded by the IIT Gandhinagar, 01-06-2021,[Supervisor: Duggirala Pallamraju].
12. “Infrared Astronomical Instrumentation and Polarisation Studies”, Indian Institute of Technology IIT, Gandhinagar, 29-08-2021.
13. “Insights into the Geological History of Mars through Impact Craters”, IIT Gandhinagar, 20-09-2021, [Supervisor: S.Vijayan].

14. "Various manifestations of accretion onto stellar-mass black holes", IIT, Gandhinagar, 21-10-2021, [Supervisor: Santosh Vadawale].
15. "Magnetic field and Electric current in the Solar atmosphere", IIT Gandhinagar, Gandhinagar, 22-09-2021, [Supervisor: Ramit Bhattacharyya].

Laboratories and Facilities Available for Space Instrumentation

1. A Class 10000 with Class 100 laminar flow bench cleanroom facility is available for the development of interplanetary dust detector.
2. **X-ray Florescence Spectrometer (XRF):** For quantitative elemental analyses (major oxides and some minor/trace elements) of bulk Earth and Planetary materials.
3. **X-ray Diffractogram (XRD):** For identification and quantification of minerals.
4. **Field Emission Electron Probe Micro Analyser (FE-EPMA):** For in situ, elemental quantification and X-ray mapping of the Earth and Planetary materials.
5. **Lunar environment simulation chamber**
6. **Payload operation center (POC):** A POC for data exchange, storage and analysis of the data from ASPEX payload onboard Aditya-L1 mission has been established at Thaltej.
7. **Test facility for space borne ion spectrometers:** As part of calibration and test set-up for Solar Wind Ion Spectrometer (SWIS) instrument, a test facility containing ion source with energies up to 5keV has been established at Thaltej. In-line ion beam diagnostic and mass filter has also been incorporated in the existing set-up. The developed set-up was extensively used for final calibrations of SWIS flight model (FM) packages.

For further details on the inputs as provided in the document, please contact:

Dr. Anil Bhardwaj, Distinguished Professor and Director, Physical Research Laboratory, Navrangpura, Ahmedabad Email:director@prl.res.in

SATISH DHAWAN SPACE CENTRE SHAR (SDSC SHAR), SRIHARIKOTA, INDIA

https://www.shar.gov.in

ABOUT SDSC SHAR

Satish Dhawan Space Centre SHAR (SDSC SHAR), the Spaceport of India, is located at Sriharikota, the spindle shaped island in Tirupati district of Andhra Pradesh about 80 km North of Chennai. The space centre, which was popularly known as SHAR (Sriharikota Range) was renamed as Satish Dhawan Space Centre SHAR on September 5, 2002, in fond memory of Prof. Satish Dhawan, former Chairman of ISRO.

Sriharikota covers an area of about 43,360 acres (175 sq.km) with a coastline of 50 km. SDSC SHAR has a unique combination of facilities such as a Solid Rocket Motor Production Plants, Solid Rocket Motor static test facilities, Launch complexes for a variety of rockets, Telemetry, Tele-command, Tracking, Data Acquisition and processing facilities & other support services. SDSC SHAR became operational on October 9, 1971 with the flight of 'Rohini-125', a small sounding rocket. Since then the facilities at SDSC SHAR are being expanded/upgraded to meet the growing needs of ISRO.

MAJOR RESEARCH DOMAINS

- Propellants, Polymers & Chemicals,
- Liquid/Cryo Propellant Storage and Service
- Solid Motor Performance, Flight Components, Hardware & Environmental Testing
- Launch Vehicle Integration
- Launch Vehicle Tracking System, Range Operation and Safety Engineering

MAJOR SCIENTIFIC APPLICATIONS/RESULTS/PUBLICATIONS

S. No	Title of the Paper	Corresponding Authors	Conference/ Journal	Publication Details (Year, Vol. and pp)	Publication Website Link
1	Qualification of New Real Time Mission Network (Full Paper)	Virendra Singh et.al.,	National Conference on Aerospace Quality & Reliability (NCAQR 2022)	*Journal of Aerospace Quality & Reliability (6th May 2022, Vol.-8 ISSN 0973-4422 page no (41 to 45)*	https://www.saqrindia.com
2	Detection Techniques for Air-	S Karunakaran et.al	The Royal Society of	*Published on 26th September 2022*	https://pubs.rsc.org/en/co

	borne Isocyanates based on Fluorescent Derivatizing Agents (Full Paper)		Chemistry 2022		ntent/articlehtml/2022/ea/d2ea00098a
3	Real-time Forward Moving Target Tracking in Multi-Stage Launch Vehicle (Full Paper)	Venkataraman a P et.al.,	3rd IEEE International Conference on Range Technology (ICORT-2023)	*Date Added to IEEE Xplore: 19 September 2023 DOI: 10.1109/ICORT56052.2023.10249091*	ieeeeplore.ieee.org
4	Probabilistic Data Association Performance During Launch Vehicle Tracking (Full Paper)	Challa Ravindra et.al.,	3rd IEEE International Conference on Range Technology (ICORT-2023)	*Date Added to IEEE Xplore: 19 September 2023 DOI: 10.1109/ICORT56052.2023.10249148*	ieeeeplore.ieee.org
5	Determination of burn rate affecting elements in solid composite propellant and its ingredients by microwave-induced plasma optical emission spectrometry. (Full Paper)	S. Selvakumar et.al.,	Analytical Science, International journal	*Anal.sci., 2023, 39, 1501–1514* *DOI: https://doi.org/10.1007/s44211-023-00372-y*	https://link.springer.com/article/10.1007/s44211-023-00372-y
6	Development of Mid-Way Testing Contingencies for Solid Rocket Motor Processing (Full Paper)	S. Selvakumar et.al.,	Propellants, Explosives, Pyrotechnics, International Peer reviewed journal	*Prop. Exp. Pyro., 2022, Vol 48, No 3, e202200316 DOI : https://doi.org/10.1002/prep.202200316*	https://onlinelibrary.wiley.com/doi/abs/10.1002/prep.202200316

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS /DETECTORS

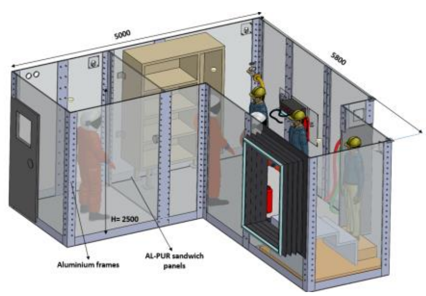
Development of PRecision Instrumentation AMPlifier (PRIAMP) prototype

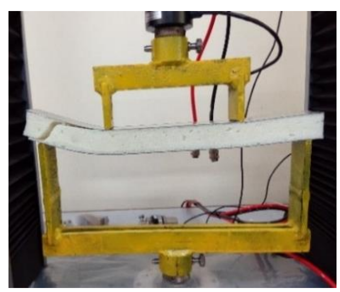
- High accuracy Instrumentation Amplifiers are being used for measurement of critical parameters like thrust, pressure, displacement, firing current among others, during static testing of solid rocket motors at Solid Motor Preparation & Environmental Test Facilities (SMP&ETF).
- The Instrumentation Amplifiers being used at present are imported and have become obsolete. This necessitated an initiative for indigenous development of a PRecision Instrumentation AMPlifier (PRIAMP).

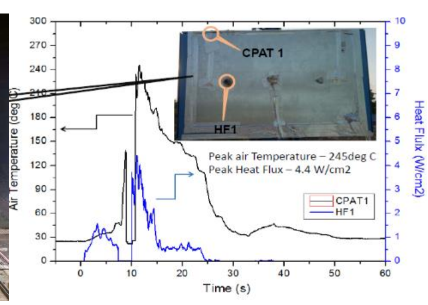
- The development is taken up in phased manner with PRIAMP prototype development in Phase – 1. The design and development of PRIAMP prototype was initiated as a joint effort of SDSC SHAR with CDAC, Thiruvananthapuram, on a No Cost - No Commitment (NC - NC) basis.
- The prototype is jointly developed by SDSC SHAR and C-DAC based on the specifications provided by SDSC SHAR.

Development of White room sandwich panel and qualification

- Al-PUR Composite panel (with Aluminium facing on either side & Polyurethane foam as core) assembled with Aluminium frames was developed as wall material for White room at launch pad for Gaganyaan mission.
- Mechanical tests are performed to obtain its flatwise tensile, compressive, core shear and flexural properties and also tested in thermal humidity testing chamber at elevated temperatures.
- Whereas the effects of dynamic parameters like acoustics, vibration, heat flux, over pressure, air and face temperatures which usually controls the structural integrity during Launch environment are investigated during PSLV launch and solid motor static test. Post-test, panel was Ultrasonic tested to verify its integrity and was qualified.



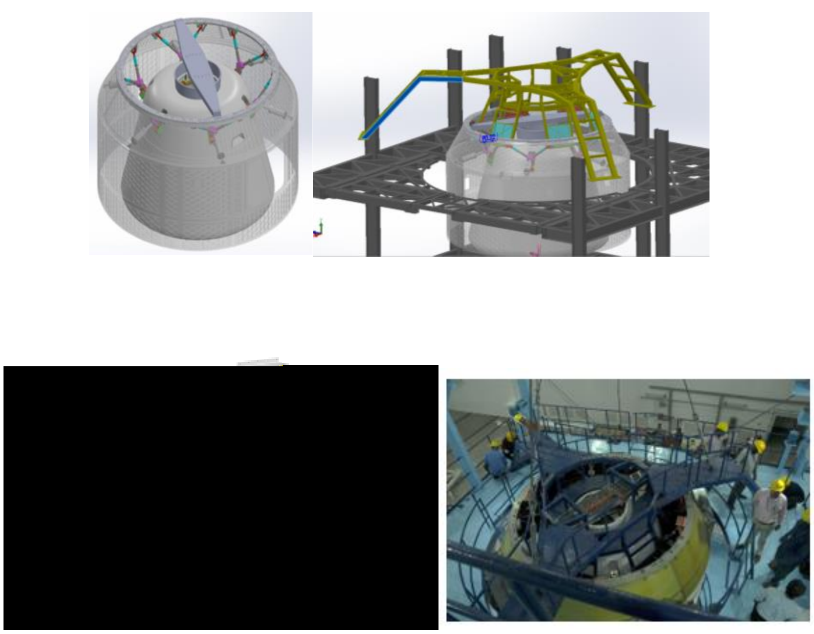




White room configuration, qualification tests and results

Design of CM-CES links Assembly Fixture

- In Human Spaceflight Programme at ISRO, during any exigency from launch to solid booster's separation, Crew Escape System (CES) takes Crew Module (CM) through the 6 CM-CES separation links interface only.
- A fixture is required for assembly of these 6-separation links and electrical harnessing. Since CM is tapered conical structure and CMF is partly conical & partly cylindrical structure with auxiliary bridge overhead, the approach to this assembly inside the annular gap between CM & CMF (which is only around 400mm between two flight components) is extremely complex. Also, the positioning of this system during final phase of integration activity is very crucial, deflection to be contained and the same to be considered critically for arriving the configuration of this fixture.
- Accordingly, a fixture was configured with minimum self-weight maintaining minimum clearances with respect to flight hardware, provide platforms for assembly activities & ensure concentricity through guidance. It is analysed for different load cases establishing load transfer path through ground system.
- The deformation and stress results are found benign during the analysis and load test as well. The fixture is realized and used for flight integration activities which turned out to be the most sophisticated fixture to ease the assembly requirements of CES inside the confined area between CM & CMF.



CM-CES links, Fixture compatibility studies, Analysis and Utilization

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

I. High Altitude Test Facility

Upper stage rocket motors experience vacuum conditions during its's flight regime. The ballistic performance of these articles is evaluated at a vacuum level of 2-5 mbar in this facility. The facility consists of vacuum chamber, vacuum pumps, test fixtures and valve actuation system. The vacuum level is achieved and maintained using a set of vacuum pumps which are operated remotely from a control console. The articles are being tested in two modes, one is Simulated high altitude test and the other one is Vacuum ignition test. In simulated high-altitude test, supersonic diffusers are coupled to the vacuum chamber to maintain the vacuum pressures during the test.

II. Sea Level Static Test Facility

Thrust performance of solid rocket motors at sea-level condition is evaluated in single component or six-component mode. The test stands are designed interfacing the test article based on its geometry and as per the measurement requirements. The most common type of test stand under this category is six components test stand. Three forces along three mutually perpendicular axes and three moments in mutually perpendicular planes are measured during static firing. From these measurements, the magnitude and orientation of the resultant thrust vector is computed. The thrust measurement can be done both in horizontal mode and vertical mode. Several other parameters like chamber pressure, strain, temperature, vibration, displacement, and acoustics are also measured during the static test.

III. Agni Motor Test Facility

Agni motor test facility is realized to cater the extra demand of static testing of Agni motors at SDSC SHAR. The facility consists of Block house, Test bay, Earthen Merlon, Camera pill boxes, Igniter storage and inspection rooms, Store room & Electrical panel room. The facility is also equipped with Safety systems like hazard indication light, siren and fire hydrants. This facility is capable of testing more than 1000 nos. of Agni motors per year. RS1, RS2, Ullage or similar kind of motors can also be tested in this facility.

IV. Multi-Object Tracking Radar (MOTR)

MOTR is an active phased array radar with 4608 radiating elements. It achieves multiple object tracking by electronically steering an agile beam on time sharing basis covering a span of -60 deg to +60 deg in azimuth and -45 deg to +45 deg in elevation. A maximum of 10 objects can be tracked simultaneously. Operating in L-band at 1.35 GHz, this skin - mode radar is capable of long - range tracking with a peak radiating power of 830 kW

V. Vibration Test Facility

In vibration test facility, an electrodynamic shaker is normally used for vibration testing of rocket motor and their subsystems. For simulating longitudinal vibration, the motor is mounted on the vertically positioned shaker and is vibrated to the specified test vibration level, frequency and duration. For simulating lateral vibration, the motor is kept on a slip table which is a magnesium plate floating on a thin film of oil. The shaker is rotated by 90º from its vertical position and connected to the slip table. In this configuration by operating the shaker, the motor can be tested for the required lateral vibration level. If the capacity of one shaker is inadequate, then 2 or 4 shakers combination is used for vibration testing.

VI. Thermal Soak & Humidity Test Facility

This facility is used for simulating low temperature, high temperature, temperature cycling and different humidity conditions on the rocket motors and their subsystems. The motor is kept on a trolley which in turn is pushed inside an insulated steel test chamber. Air inside the chamber is drawn out, conditioned by passing it over heater or refrigerant coils depending on the temperature required and then this air is circulated back to the test chamber.

VII. Constant Acceleration Test Facility

Constant acceleration test facility is used for simulating acceleration loads on the rocket motor. The test article is mounted on one end of the centrifuge horizontal arm and on the other end of the same arm balancing counter weights are assembled. The arm is then rotated about a vertical axis passing through the middle of this arm. Either an electric drive or a hydraulic drive is normally used.

SPACE APPLICATIONS CENTRE, ISRO, AHMEDABAD, INDIA

https://sac.gov.in

ABOUT SPACE APPLICATIONS CENTRE (SAC)

Situated in the city of Ahmedabad, the Space Applications Centre (SAC) is one of the lead ISRO centres for the development of the payloads for various planetary missions, development of pipelines for data products generation and effective data dissemination. It also plays a major role in the scientific analysis of the data products provided by these payloads for advanced research activities and publication of newer findings, in order to cater to the larger global community. SAC has contributed immensely towards the development of important payloads of Chandrayaan-1, 2 and 3 missions and MOM mission. These instruments have provided immense amount of data, which has led to large number of scientific publications and increased our understanding about the planetary bodies. The important scientific contributions credited to the SAC are the discovery of magmatic water on the Moon associated with silicic lithologies; detection of OOS suite of rocks; etc. SAC is also involved in developing instruments for future planetary missions, SAC has contributed immensely towards the development of important payloads of various earth observations, planetary and space science missions such as LuPEx, Chandrayaan-4, Shukrayaan and MOM-2 / MLM. Recently, state-of-the-art submm/Terahertz ground-based telescope has been designed for astronomical observations and science. Recently, SAC has taken up an initiative by forming a new division namely Space Science Division (SSD) to carry out various research activities in the field of space science and astronomy with special emphasis on ISRO's ongoing (such as Aditya-L1) and upcoming/planned missions (DISHA).

Major Research Domains

Morphology and morphometry of Planetary Bodies

Optical data and Digital Elevation Model (DEM) are utilized to identify and map the geological features as well as make measurements to understand their morphometry.

Mineralogical and Composition studies of planetary surfaces

Hyper-spectral data over Planetary bodies helps in identifying and mapping various minerals as well as quantification of the same. This helps in understanding the crustal composition and stratigraphy and thus, provides important clues related to crustal evolutionary processes.

Study of physical properties of planetary surfaces/sub-surfaces

Microwave frequencies have the ability to penetrate the surface and, thus microwave sounder and SAR instruments are used over planetary bodies to understand the surface and sub-surface features along with their physical properties such as surface roughness, variation in dielectric properties, etc. This helps in identifying the buried lava flows, melt pools, ejecta deposits and potential water-ice bearing horizons.

Planetary interior studies using Gravity data

Gravity datasets (such as available from GRAIL instrument over Lunar surface) help in identifying gravity anomalies over the planetary surface, which when modelled can reveal information regarding the planetary interiors and thus, helps in understanding mega-structures, dykes, etc. beneath the crustal layers.

Reflectance and emission studies of planetary surfaces

Planetary surfaces when imaged at variety of viewing geometries are used to model the photometric functions. The retrieved photometric parameters can provide insight into the physical properties of the surface such as compactness, grain sizes, etc.

Technique development and simulation studies for on-going and future missions

Various simulation studies are carried out and models are developed in-house to tackle the complex datasets received from various scientific payloads, and also for providing suitable instrument specifications for future planetary missions.

Planetary Analogue Studies

Samples collected from planetary analogues regions are analyzed in-situ and in lab to understand the geological settings and the processes responsible for their formation, which helps in constraining the similar process happening on extra-terrestrial bodies.

Exoplanet studies

Exoplanet research includes developing methods to find new worlds, looking for signs of certain molecules in their atmospheres, & studying newborn planets around young stars.

Studies of Soft X-ray emission from solar flares

Solar flares are violent release of stored magnetic energy from the sun during magnetic rearrangement, which have huge implications on satellite's health and communications, power grids, etc. Understanding the formation and evolution of flares is therefore of great importance. Various theoretical and observational aspects of solar physics along with detailed modeling studies are taken up at SAC under this theme.

Understanding ISM with TeraHertz

The use of terahertz signals is key to the understanding of the cold matter in the interstellar medium & universe. And filament structures are often kernel to the problem of understanding the formation of high mass star and the stellar initial mass function. Many theoretical and modeling aspects of Terahertz science studies are taken up at SAC.

Ionosphere Studies

Detailed studies of Earth's ionosphere are being carried out at SAC using theoretical modeling and satellite data

Study of Massive Star formation using Multi-wavelength Astronomy

Massive stars are one the most important factors in the process of evolution of the interstellar medium. The area of formation of massive stars is still not very well understood and require multi-wavelength astronomy to find several unanswered questions.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Analysis of the permanently shadowed region of Cabeus crater in lunar South Pole using orbiter high-resolution camera imagery

Two images of the Permanently Shadowed Region (PSR) and adjacent area of Cabeus crater acquired by OHRC were analyzed. Numerous small features, such as meter scale boulders, craters, and slope-normal lobes were identified in these images. Boulders and craters as small as 1.5 m and 1.8 m, respectively, were identified in PSR making this size limit two times better than the currently reported values (>3 m for boulders and > 4 m for craters). Slope-normal lobes (potentially related to the presence of ice) were present in PSR as well as in Non-PSR areas. The impact generated debris (potentially) of Lunar Crater Observation and Sensing Satellite (LCROSS) impactors were also identified inside the Cabeus crater. **Link:** https://doi.org/10.1016/j.icarus.2023.115762.

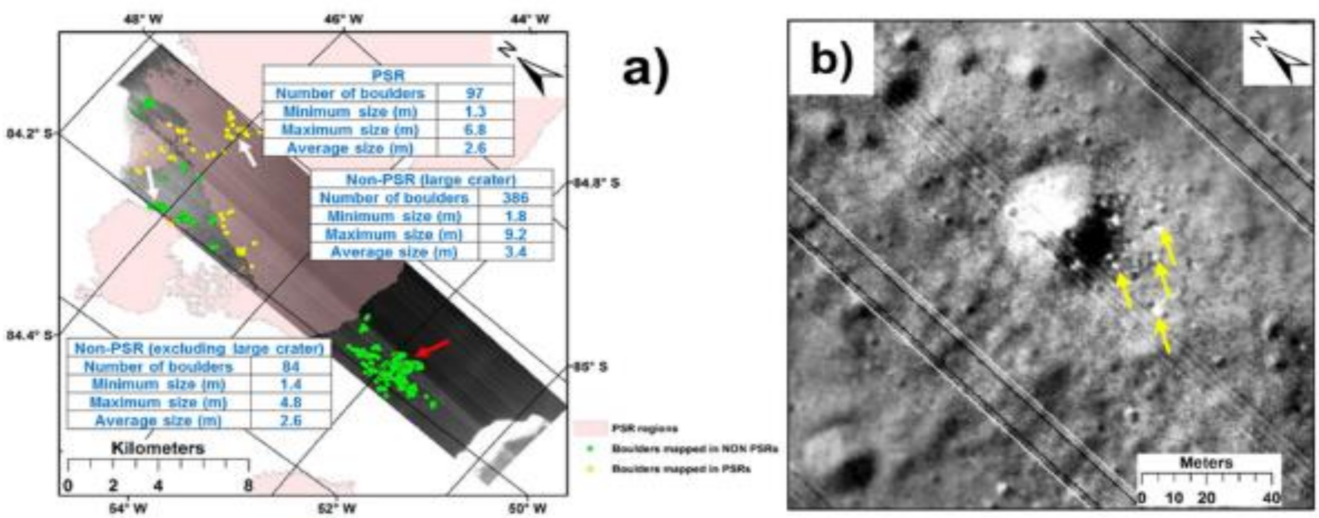


Figure 1: *(a) Yellow and green dots show the location of all the boulders in PSR and Non-PSR, respectively. (b) shows a small crater in the centre with surrounding boulders.*

Comparative analysis of photometric parameters over Apollo landing sites from Terrain Mapping Camera (Chandrayaan-1/2) and lab-measured data

This study presents the comparative analysis of photometric properties in visible domain from TMC and lab measured data over Apollo 11, 12, 14, 16 and 17 landing sites. Retrieved photometric parameters from TMC datasets were analyzed, compared and validated with the parameters retrieved from the available lab measurements over Apollo Landing sites soil samples using the same model over the same phase angle ranges. Differences in retrieved parameters from TMC with respect to lab-measured data were observed, for example, retrieved albedo from TMC datasets were found to be less by 30–33% and 45–50% with respect to lab measurements at 550 nm and 750 nm respectively for both mare and highland regions (Apollo 11, 12 and 16 landing sites). These differences may be due to the changes in lunar soil properties such as compaction, disturbances in particle arrangement or soil structure, etc. caused during sample preparation Link:https://doi.org/10.1016/j.pss.2023.105635.

Spectroscopic Studies on the Puga Hot Spring Deposits, Ladakh, an Astrobiological Martian Analog Site in India: In this study, we have characterized the complete mineralogical assemblage of the Puga hot spring deposit, Ladakh, India, using detailed spectroscopic and X-ray diffraction studies. The identified mineral phases include Na-borates, such as borax and tincalconite, and hydrous sulfates such as jarosite, alunite, copiapite, tamarugite, and gypsum, in conjunction with native sulfur, halite, and opaline silica. We have compared mineral assemblages found in Puga with other hot spring/hydrothermal deposits on Earth identified as Martian analog sites, and also with mineral assemblages identified in situ on Mars. The spectral characterization of hydrated borates in natural association with hydrous sulfates can be used for identification of fossil/paleo hydrothermal settings on Mars that are prospective in the search for extinct/extant extra-terrestrial life. **Link:** https://doi.org/10.1029/2022JE007299.

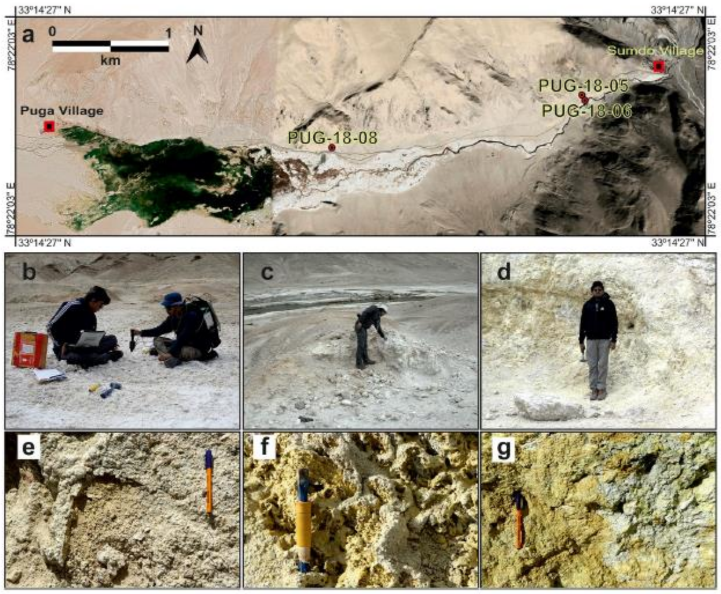


Figure 2: (a) Field locations between Puga and Sumdo Village (Google Earth images), (b) in-situ VNIR spectroscopy of valley fill material, (c and d) are field photographs, (e–g) are the images of the representative samples.

Identification of smectites by IR and LIBS instruments of SuperCam Suite onboard Mars 2020 Perseverance rover: comments on the Non-retrieval of First Drill Core

Preliminary investigations on the Infrared Spectrometer onboard Mars 2020 Perseverance rover show the presence of Fe-/Mg-smectite minerals near the first drilling site, Roubion. LIBS data show characteristic emission peaks for O, H and the major constituent elements of smectites, viz. Si, Fe, Mg, etc. These minerals suggest aqueous alteration of the basaltic floor of the Jezero crater. The mechanically weak nature of this basalt weathering layer holds clues to the non-retrieval of the first drill core. Water confinement capacity and high porosity–permeability make the smectite-rich rock units a good host for preserving macro- and microscopic biosignatures. **Link:** https://doi.org/10.18520/cs/v123/i1/93-96.

Lunar impact craters: New perspectives from full-polarimetric analysis of Chandrayaan-2 Dual-Frequencey SAR data

Polarimetric behavior of a total of 115 impact craters was studied using Chandrayaan-2 DFSAR data within a specific size range (~1–25 km diameter) belonging to different categories viz. fresh, degraded, polar and non-polar anomalous craters. Results confirm that both kinds of non-polar and polar anomalous craters overall hold centimeterdecimeter scale surface roughness similar to the exterior of the fresh craters, which mainly leads to the anomalous nature of the craters. Analysis indicates possible control of the crater degradation process on the change in the radar scattering behavior of the studied lunar craters. Also, water ice is not in the form of dominant scatterers that can influence the radar signature. However, the occurrence of relatively higher CPR values in smooth low dielectric crater interiors supports the possibility of the presence of water ice in some of the studied polar anomalous craters. **Link:** https://doi.org/10.1029/e2023JE007745.

Spectral unmixing analysis for the lunar surface mineralogy using Chandrayaan-2 IIRS imagery

A sensitivity study of hyperspectral observations of the IIRS sensor was carried out for the detection and mapping of various lunar minerals using spectral unmixing analysis. An L1-norm based denoising algorithm is used for mixed noise removal from both the IIRS and M3 reflectance datasets. Endmember extraction and fractional abundance estimation are carried out using the N-Findr algorithm and the fully-constrained least square method, respectively. Our results reveal different minerals such as high-calcium pyroxene (Clinopyroxene), low-calcium pyroxene (Orthopyroxene), and regolith surface (matured and younger). The results obtained from the IIRS and M3 observations are in strong agreement. **Link:** https://doi.org/10.1016/j.pss.2022.105537.

Site Characterization for THz facility

SAC-ISRO has designed and planned to set up a THz/sub-mm observational facility in the Hanle, Ladakh. Characterization of the site is extremely important due to strong attenuation of incoming signal by atmospheric water vapor, Results of the study of the variation of atmospheric transmittance for different columnar WV is shown in Fig 3. The transmittance drops sharply with increase in WV concentration significantly affecting observations at longer wavelengths (>350 micron). Based on long-term analysis of ERA5 reanalysis dataset & MODIS satellite WV product, a significant increase is observed in columnar WV during the monsoon season.

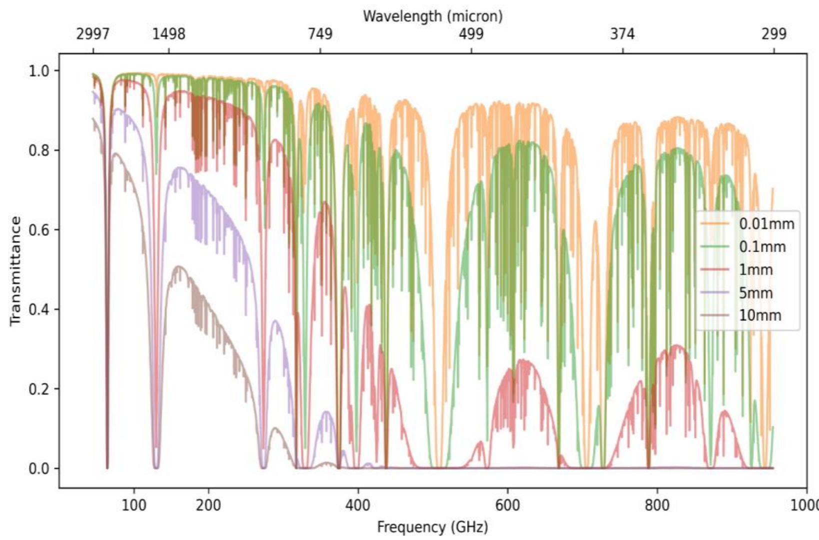


Figure3: Atmospheric transmittance at Hanle, Ladakh simulated using Line-By-Line Radiative transfer model

Studies of Soft X-ray emission from solar flares

The soft X-rays (0.1 - 10 nm) are uniquely placed to probe the thin hot plasma (~10 MK) formed during solar flare. SAC has been conducting studies using Dual-zone Aperture X-ray Solar Spectrometer (DAXSS) onboard INSPIRESat-1 (International Satellite Program in Research and Education Satellite) and its predecessors MinXSS 1 and 2 to probe hot plasma (~10 MK) formed during solar flare and the evolution of elemental abundances during the flare. The results (figure 4) showed a decrease in the abundances of low FIP (first ionization potential) elements during the impulsive phase, broadly agreeing with chromospheric evaporation predicted by standard flare model. Based on our initial experience gained through INSPIRESAT-1, we have extensive plans to carry out detailed studies with Aditya-L1 observations.

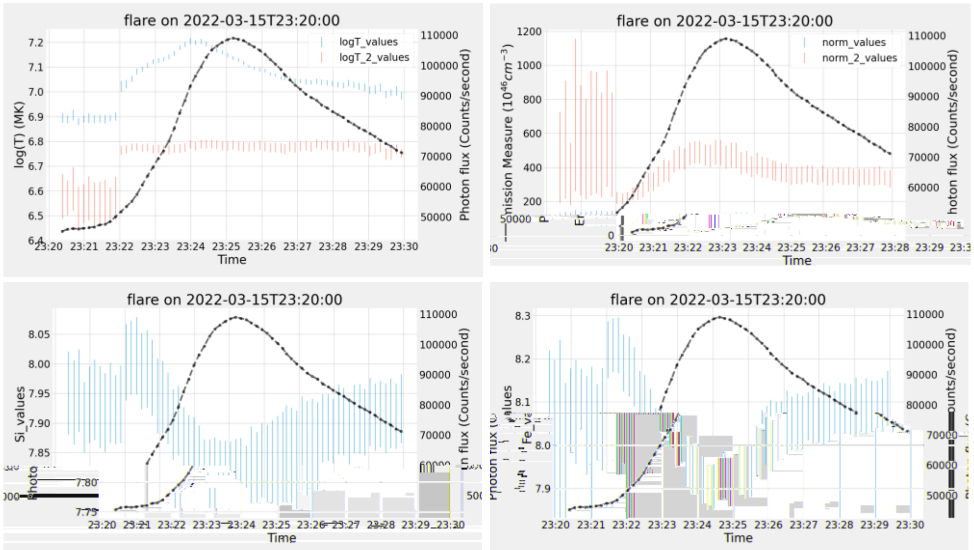


Figure 4. Top panel shows evolution of temperatures and emission measures of two components. Bottom panel show evolution of Abundances of Si and Fe during the flare. The black line shows the flux from the flare in photons/cm2.

Understanding ISM with TeraHertz: The cold matter in interstellar reveals a complex filamentary structure. These filaments are key to und erstanding questions like formation of high mass star & stellar initial mass function. With AI/ML based methods we identify, characterize and catalogue the filament-hub systems over a wide range of submm/THz survey. One example of identified filaments in the Vela-C molecular cloud complex analyzed in Herschel's data is shown in Fig. 5.

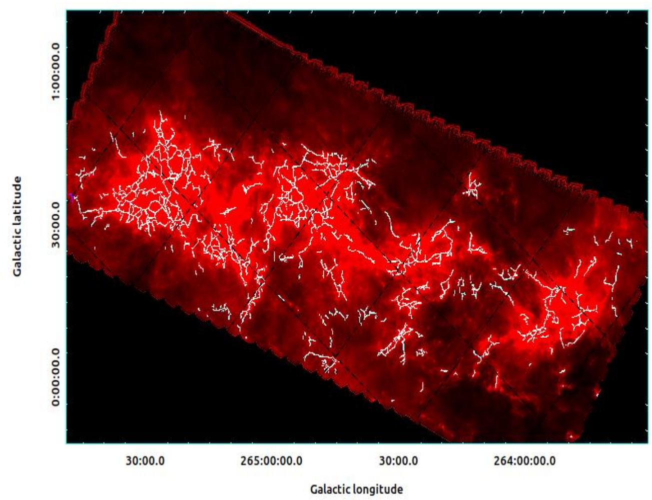


Figure 5: Filaments identified using trained ML model overlaid on Vela-C molecular cloud complex observed in Herschel SPIRE-PACS parallel observation. (Kumaran et al. in preparation)

Exoplanet transit modelling studies: SAC has designed a numerical transit simulator using Monte-Carlo technique, which can generate lightcurves produced by transiting objects with any arbitrary, complex geometry. This can be utilized to study a wide range of effects that cause deviations from a standard exoplanet model. Three such examples are shown in the figure 6. The tidally distorted exoplanet WASP 103b, eccentric eclipsing binary systems causing heartbeat tides and exocomets (KIC 3542116). The simulated lightcurve matches closely the data, as well as with existing model **ellc**. Simulator reveals complex phenomena occurring in star-planet systems from transit lightcurves.

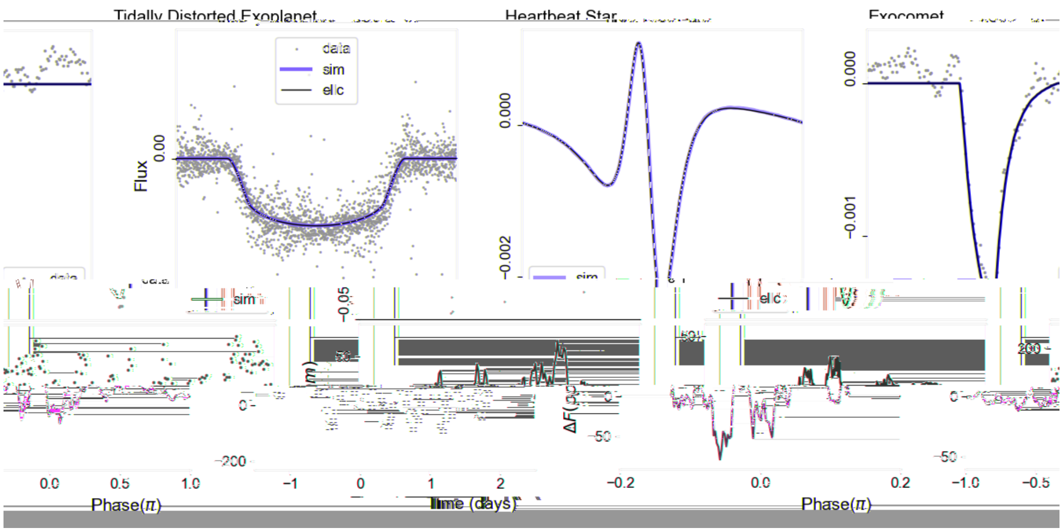


Figure6. Simulations of tidally distorted exoplanet WASP-103b along with observations from CHEOPS (1st panel), eccentric heartbeat star (2nd panel) and exocomet observation in KIC 3542116 (last panel).

Ionosphere Studies: Background state of ionosphere through various ionospheric parameters is simulated using an empirical model, IRI-2020. Implementation of global distributions of these parameters in the altitude range of 80–1500 km at step of 20 km with an interval of 2 hours are implemented & available on SAC, VEDAS portal (vedas.sac.gov.in/vstatic_1/ionosphere/). These parameters include Total electron content, Peak Density, Electron density, Ion composition etc.

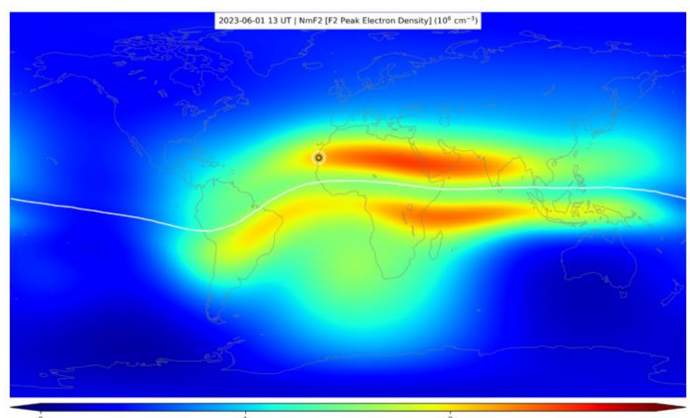


Figure7: Distribution of peak electron density in the ionosphere as simulated from an empirical model IRI20.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

SAC hosts students for PhD research, M Tech. Dissertations, M Sc. and B Tech. Projects and summer internships in planetary sciences activities. Scientists in SAC provide guidance to these students in identifying suitable problems and help in carrying out their respective research works. Scientists at SAC also collaborate with academia and other outside researchers on various projects related to planetary data processing, analysis and interpretations, and in planetary analogue studies.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

Planetary Science Laboratory (PSL) at SAC hosts variety of instruments such as a) lab based Vertex-80V instrument to carry out spectroscopic measurements in spectral range extending from 0.4-25 µm with in-built vacuum chamber along-with integrated imaging microscope (Hyperion), b) ASD portable spectrometer (0.4-2.5 µm) for in-situ and laboratory VNIR spectroscopy measurements, c) portable FTIR spectrometer with spectral range 2-16 µm for in-situ and lab emission spectroscopic measurements and d) thermal imager instrument (FLIR E75) for in-situ land surface temperature anomaly detection. The lab also has computer systems for lab-measured and remote–sensing data processing and analysis.

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SPACE PHYSICS LABORATORY, VSSC, THIRUVANANTHAPURAM, INDIA

Website: https://www.vssc.gov.in/spl.html

ABOUT SPACE PHYSICS LABORATORY (SPL)

Space Physics Laboratory (SPL) is a premier laboratory of Vikram Sarabhai Space Centre (VSSC), Indian Space Research Organisation (ISRO), with its activities aiming at the scientific understanding of the energetics, dynamics and chemistry of the terrestrial and planetary environments and space weather impacts. The genesis of the SPL is closely entwined with the evolution of space research in India and dates back to more than five decades. From the humble beginning in as an ionospheric observatory at the magnetic dip equator and Space Physics Division in 1968 to study equatorial upper atmosphere, the institution has been elevated to SPL in 1984, with the mandate to carry out advanced research in all domains of atmospheric, space and planetary sciences. Since then, SPL has expanded its horizon and attained the status of a vibrant research institution having front ranking research areas covering the whole gamut of atmospheric, space and planetary sciences, having scientific importance and social relevance.

SPL also conceives cutting edge scientific instruments and satellite payloads and develop them in collaboration with other entities of VSSC. SPL has flown science payloads onboard Chandrayaan-1, -2, and -3, Mars Orbirer Mission and the Aditya-L1 solar mission. First-of-its-kind results have emerged from various ground-, rocket- and space-borne studies. SPL is also leading two national projects (ARFI & NOBLE) under the ISRO-Geosphere-Biosphere Programme (IGBP). The INSWIM project of SPL makes systematic ionospheric observations. Network of observatories operated in collaboration with universities/institutions spread across India form a vital component of the above projects. SPL has a research fellowship program to support capacity building, through which 102 researchers obtained Ph.D so far. This is in addition to the Ph.Ds produced through the collaborative programs under national projects led by SPL. SPL collaborates closely with the academia and research institutions in India and a few institutions/universities abroad for scientific pursuits. SPL has ambitious programs for the years to come, as per ISRO's vision.

Keywords

Microwave and Boundary Layer Physics; Aerosols, Trace gases and Radiative Forcing; Numerical Atmosphere Modelling; Atmospheric Dynamics; Ionosphere Thermosphere Magnetosphere Physics; Planetary Science; Atmosphere Technology.

MAJOR RESEARCH DOMAINS

The major research activities at SPL cover the whole gamut of atmospheric, space and planetary sciences from the surface of Earth to the ionosphere-magnetosphere and the solar system bodies. The groups are identified for focusing on specific themes, but are interlinked and have direct linkage to planetary research.

- **Microwave and Boundary Layer Physics** branch focuses on the surface characteristics, structure and dynamics of the atmospheric boundary layer and its coupling with free-troposphere, clouds, convection, precipitation, and microwave remote sensing of the Earth and other planetary bodies.
- **Aerosols Trace gases and Radiative Forcing** division primarily aims at investigating the physical/chemical properties of atmospheric aerosols and trace gases, involving processes that control their three-dimensional distribution and interaction with clouds, cryosphere and radiation with impact on hydrological cycle and climate, based on ground-, balloon- and satellite-based measurements and modeling.
- **Numerical Atmosphere Modelling** branch focuses on the prediction and analysis of the weather and climate system through a range of atmospheric models including the general circulation models, regional numerical weather prediction and climate models, atmospheric transport models, and large eddy simulations. It also supports the short-range weather predictions for ISRO's launch vehicle missions.
- **Atmospheric Dynamics Branch** investigates the dynamical processes responsible for vertical coupling of the atmosphere, from troposphere to lower thermosphere. It aims at quantifying the atmospheric motion spectra from gravity waves to solar cycle using ground and space based observations and to explore planetary atmospheric dynamics.
- **Ionosphere Thermosphere Magnetosphere Physics** branch aims at investigating the energetics and dynamics of terrestrial and planetary upper atmospheres, and

space weather impacts using a variety of ground-, rocket- and satellite-based instruments. It is also developing thermosphere-ionosphere models in-house and makes use of the research outcomes to provide better input for technological applications.

- **Planetary Science Branch** carries out experimental and modeling investigations of the Sun, planets, moons and comets, mainly focusing on: (a) solar wind and its interaction with planetary bodies, (b) Interaction of solar radiation with planetary atmospheres and the processes initiated through space weather, and (c) dynamics and composition of planetary atmospheres.
- **Atmosphere Technology Division** develops the experimental systems for atmospheric and space research, which includes the design, development and testing of balloon-, rocket-, and space-borne payloads from the proof-of-concept and development of ground-based systems for in-situ probing and remote sensing of the atmosphere.
- Other entities of VSSC also significantly contribute in the development of satellite payloads, conceived by SPL.

MAJOR SCIENTIFIC APPLICATIONS/ RESULTS

ATMOSPHERIC SCIENCE

Satellite retrieval and surface observations of Aerosol Black Carbon over India

Light-absorbing black carbon (BC) aerosols strongly affect Earth's radiation budget and climate. Satellite retrieval of BC over India has been derived from the spectral radiance measured by the Cloud and Aerosol Imager-2 (CAI-2) on-board GOSAT-2 satellite. This has been validated using the near-surface BC mass concentrations measured at the Aerosol Radiative Forcing over India NETwork (IGBP-ARFINET) observatories located a different regions in India (Fig.1). The validated BC values were used to elucidate the global BC distribution of BC concentration. This study highlights the effectiveness of satellite-derived BC for the regular monitoring of BC loading attributable to vehicular, industrial, or biomass burning activities.

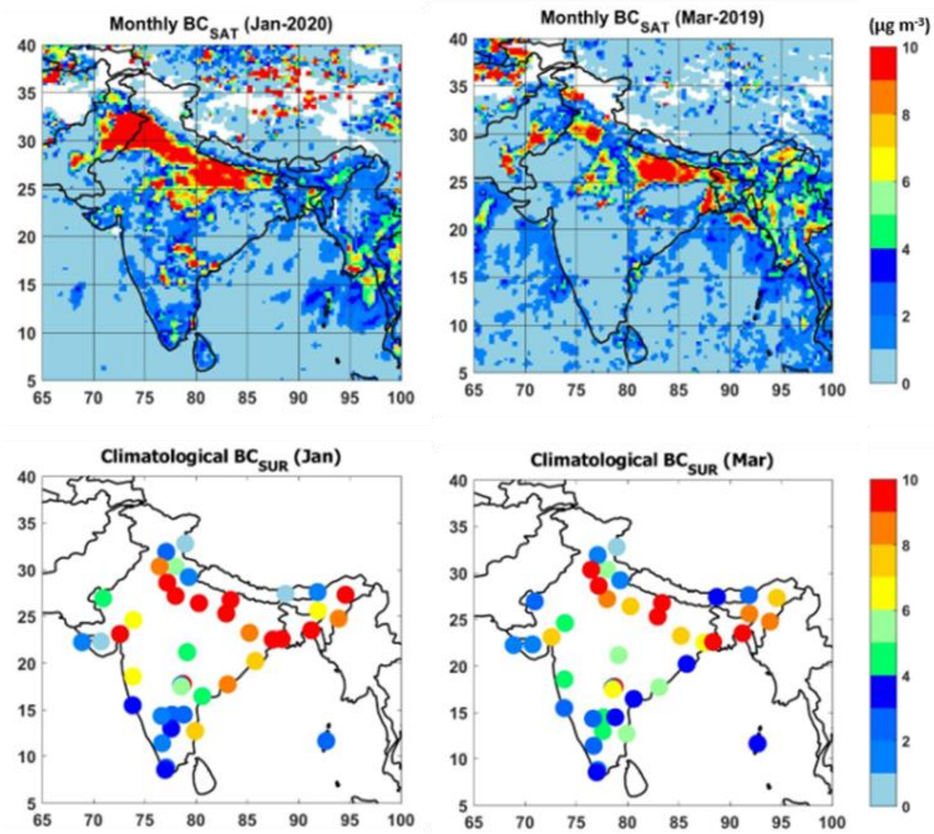

Figure 1. Regional distribution of monthly average BC over the Indian region from satellite (top panel) and surface measurements (bottom panel) in January and March [Gogoi et al., Atmos. Chem. Phys, 2023].

Aerosol-Induced Snow Albedo Feedback on Dust Emission over Tibetan Plateau

The aerosol-induced snow albedo effect (SAE) and its feedback on the dust emission over the Himalayan-Tibetan Plateau (HTP) were investigated using the regional climate model (RegCM4.6) coupled with aerosols. Significant surface warming (1 to 4 K) and a decrease in snow cover fraction were observed over the HTP due to SAE, which is further strengthened by the positive feedback mechanism between the change in temperature and snow cover fraction (Fig. 2). This resulted in an early and more exposure of non-vegetated land that increased the dust events by 10%–20% and the dust emission flux by 60% over central Tibet.. The increased dust emission due to SAE results in a surface cooling of − 4 Wm^{-2}, which further strengthens the direct radiative effects of dust aerosols and partly compensates the SAE.

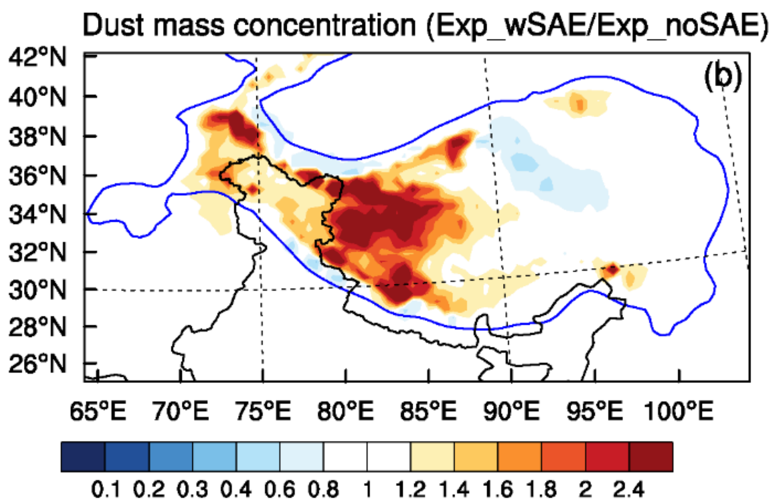

Figure 2: Ratio of dust loading for aerosol simulation with SAE (wSAE) and without SAE (no_SAE) during May-June period [Usha et al., J. Geophys. Res.-Atmos.,2022].

Characterization of ITCZ using Megha Tropiques - SAPHIR Observations

Global ITCZ characteristics were derived by mapping the deep convective cloud cores using Megha-Tropiques (MT)-SAPHIR observations. This method is free from the inherent issues of conventional methods related to cirrus anvils observed in IR remote sensing. It performs better over (a) anvils and cirrus dominated areas where conventional methods face difficulties, and (b) coastal and continental areas where satellite scatterometer data are unavailable to estimate surface convergence. Using this method, the annual migration and inter-annual variability of the ITCZ across the globe have been estimated (Fig. 3).

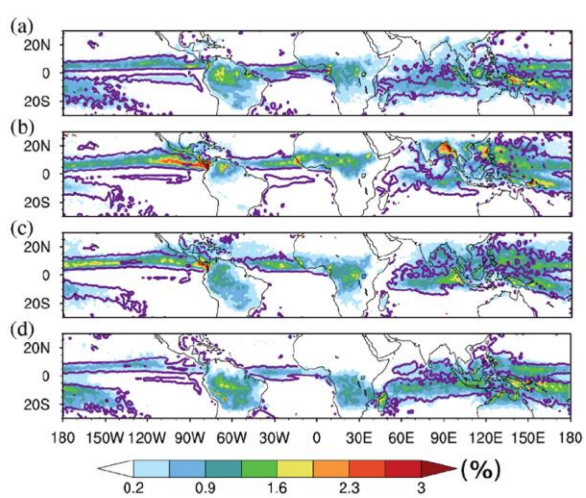

Figure 3: Seasonal mean distribution of occurrence frequency of DCCCs (%) showing the width of ITCZ The contours overlaid show the boundary of surface wind convergence threshold of

−0.1×10−5 s^{-1} obtained from ASCAT measurements over the global oceans [Samuel et al., Clim. Dyn., 2022].

Balloon Borne Experiment for Quasi-Lagrangian Frame of Reference Measurements of Intrinsic Frequency Spectrum of Stratospheric Gravity Waves

An experiment has been carried out to measure intrinsic frequency spectrum of atmospheric gravity waves (GWs) using balloon-borne quasi-Lagrangian frame of reference observations in the mid-stratosphere using the high altitude balloon facility at Hyderabad (17.4°N, 78.2°E). A zero-pressure polyethylene balloon with GPS-sonde payload was drifted at ~31 km altitude for a horizontal distance of ~100 km for measuring pressure, wind and temperature at 1 sec temporal resolution. These observations reported the intrinsic frequency spectrum of GWs in the mid-stratosphere over this region (Fig.4). The experiment has opened up a new avenue for studying not only the stratospheric GW dynamics.

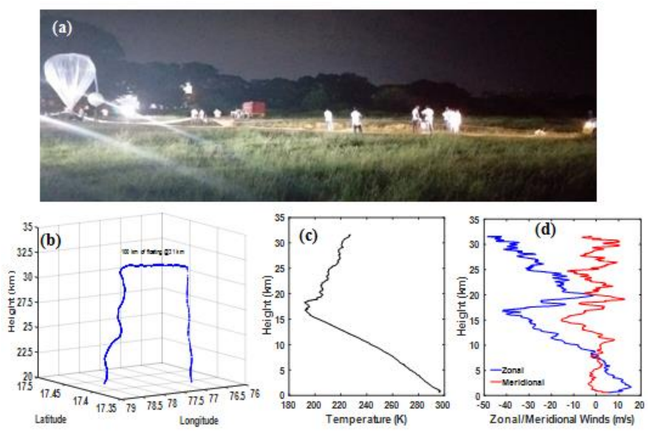

Figure 4:(a) A photograph of the preparation for the Balloon Experiment at TIFR Balloon Facility, Hyderabad, (b) Path of the balloon (c) Vertical profile of temperature and (d) Vertical profiles of zonal and meridional winds on 13 September, 2019 [Kumar et al., Current Science, 2022].

Model atmosphere from the surface to 110 km over the Indian tropical region developed from in-situ and space-based measurements

Atmospheric models of the altitude variations of temperature, pressure and density are crucial for designing launch vehicles as well as for scientific research. Empirical models of the above parameters and their variabilities in the altitude range of 0 to 110 km for the south peninsular Indian region were developed using long-term data of radiosonde (44 years), M-100 rocket (21 years) and SABER satellite (17 years) over the Indian region (*Uma et al., Earth and Space Science, 2023*).

Net Ecosystem Exchange over India using Vegetation Photosynthesis and Respiration Model simulations.

The terrestrial biosphere has a crucial role in controlling the rate of CO_2 accumulation in the atmosphere. The quantification of Net Ecosystem Exchange (NEE) is critical to determine whether the regional terrestrial ecosystem is a net sink or source of CO_2. The Vegetation Photosynthesis and Respiration Model (VPRM), which incorporates satellite derived land use-land cover (LULC) and surface reflectance data, is used to compute the biospheric CO_2 fluxes over India during 2011-2020. The VPRM model captures the spatial pattern and seasonal features of NEE over the country (Fig.5). The VPRM model simulated NEE is in agreement with the NEE observations from the eddy covariance estimates, which are accepted as the ground truth. The fusion of high-resolution LULC and surface reflectance data in the VPRM suggests that the Indian region is a net biospheric sink (-0.16 ± 0.02 PgC yr^{-1}) during 2011-2020.

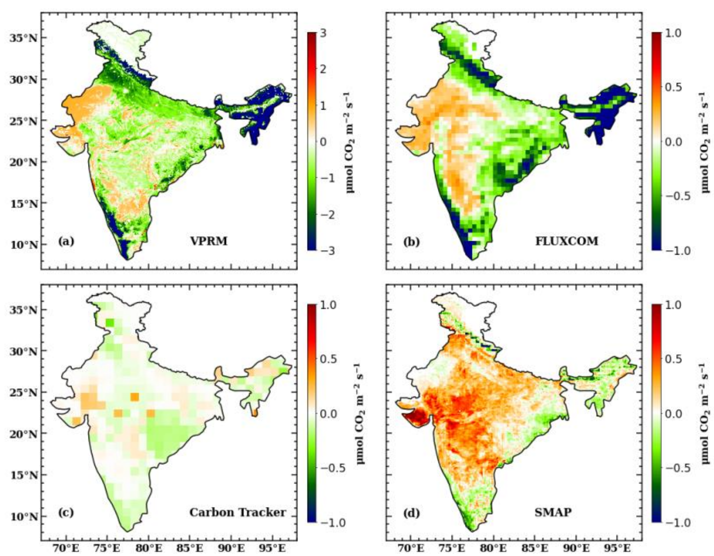

Figure 5: Spatial distribution of the mean NEE from (a) VPRM model, (b) FLUXCOM, (c) Carbon Tracker and (d) Soil Moisture Active Passive Level-4 (SMAP) during the period 2016–2018 (Unit: µmol CO_2 m^{-2} s^{-1}).

SPACE SCIENCE

Midnight temperature maximum in thermospheric oxygen airglow emissions: Results from the first ship-borne aeronomy experiments over the Indian Ocean

Airglow measurements were carried out using the in-house developed multiwavelength photometer onboard ORV Sagar Kanya cruise on both sides of the geomagnetic equator over the Indian Ocean. The experiment revealed that the thermospheric nightglows, especially the OI 630.0 nm emission near to the geographic equator exhibits 'midnight brightness' on different days of observations (Fig.6). Simulation studies using the in-house developed quasi 2-dimensional ionospheric model revealed that such an enhancement could be due to the F-region collapse associated with the Midnight Temperature Maximum phenomenon around the geographic equator. This has implications on the large-scale processes prevailing over the equatorial ionosphere.

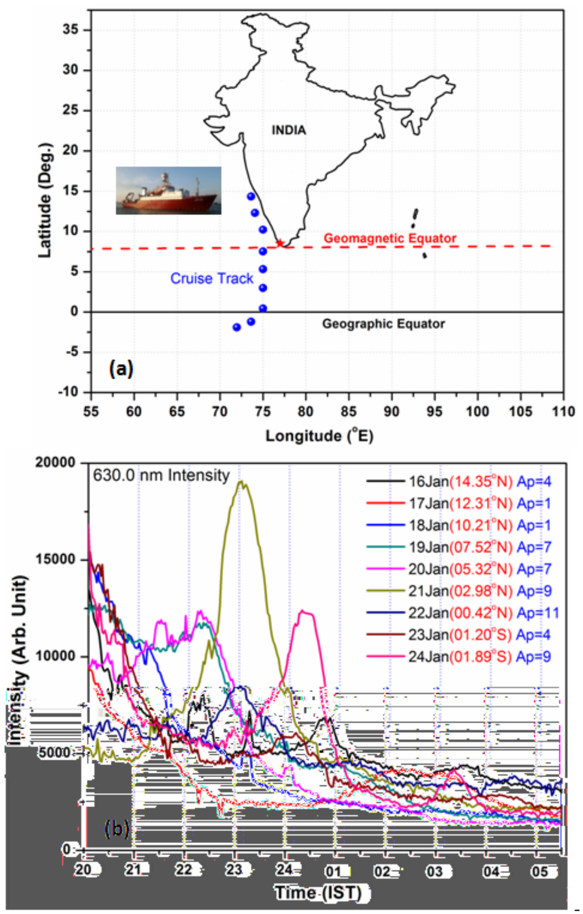

Figure 6 (a) Position of the ship during the period 16 January to 24 January 2018. The location of the magnetic and geographic equators are shown in the figure as red dashed line and black solid lines respectively. (b) Time-latitude plot of the nocturnal OI 630.0 nm intensity during this period [Vineeth et al., Adv. Space Res., 2022].

Electron density and stratified layers at the Geomagnetic Equator inferred through Sounding Rocket Experiment (SOUREX)

As part of the SOUREX, in-situ measurements of electron density and neutral wind at the dip equatorial *E* region were carried out using Electron Density and Neutral Wind (ENWi) and Langmuir Probe (LP) payloads onboard an RH300 sounding rocket on 6 April 2018. The ENWi profiles observed during this experiment were found to be remarkably structured (Fig.7a). The electron density fluctuations and hodograph analysis of the neutral wind components reveal the gravity wave origin of the observed fluctuations (Fig.7b). The gravity wave induced convergence rate assessed based on the in situ measurements is considerably greater than the calculated requisite convergence rate for the formation of electron density stratifications.

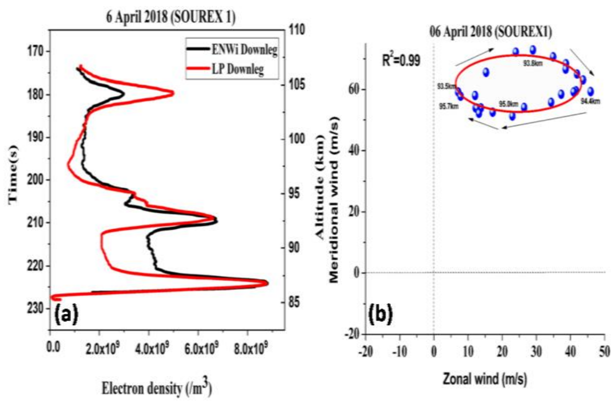

Figure 7: Panel a displays two Electron density profiles i.e. one derived from ENWi and the second LP data. Panel b shows the hodograph exhibiting the rotation of wind with altitude [Manju et al., J. Geophys. Res., 2023].

PLANETARY SCIENCES:

On the origin and characteristic features of the V1 layer in Venus ionosphere using Akatsuki radio science experiment and 1-D photochemical model

Radio Occultation (RO) measurements carried out by tracking Akatsuki satellite signal at the Indian Deep Space Network and the in-house developed 1-D photochemical model (1D-PCM) revealed characteristic features of the V1 layer in Venus ionosphere, which peaks ~125 km (Fig.8). The model simulations also show that major ions below 135 km are O_2^+ and NO^+ with O_2^+ increasing linearly up to ~135 km, while NO^+ peaks at around 127 km.

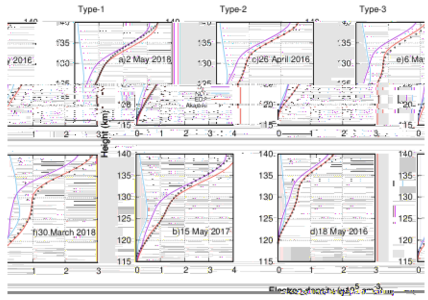

Figure 8 (a,b)Comparison of NO^+ and O_2^+ *density with modeled and observed electron density during Type 1 on 2 May 2018 and 15 May 2017), (c,d) Type 2 on 26 April 2016 and 18 may 2016 and (e,f) Type 3 on 6 May 2016 and 30 march 2018 [Ambili* et al.*, MNRAS, 2023].*

On the characteristic features of the lunar ionosphere using dual frequency radio science (DFRS) experiment onboard Chandrayaan-2 orbiter: The first of its kind measurements using radio occultation (RO) experiments with the DFRS payload onboard Chandrayaan-2 orbiter revealed enhanced integrated electron density at the lunar wake and trans-terminator regions. The DFRS uses one-way coherent signals at X and S bands of radio frequencies for RO measurements. The electron content is found to be large (~1.5 TECU, with 1 TECU = 10^{16} m^{-2}) in the lunar wake region compared to the dayside (Fig. 9). Large electron content is also seen near lunar polar region during solar transition periods. These observations are unique as they show post-sunset enhancements in the electron densities compared to dayside, as reported by earlier missions.

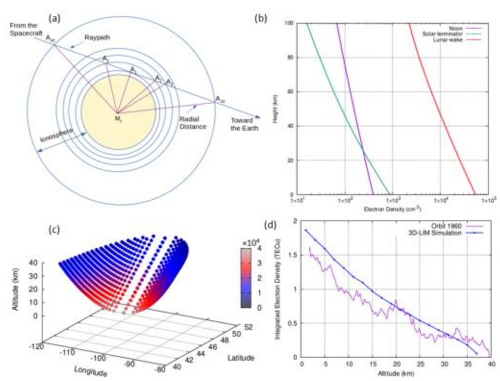

Figure 9: (a) Ray-tracing of radio signals in the lunar ionosphere. A1 is the impact factor point.(b) Electron density profiles simulated using the 3D-LIM model for three different conditions. (c) The altitude/latitude/longitude cross-section of the radio signal grazing through the closest near-surface occultation point. The color bar represents the electron density along the radio path. (d) Comparison of simulated iEDP with observed ones for the orbit no. 1960 for the occultation at a location inside the lunar wake [Tripathi et al.,MNRAS 2022].

Studies on solar coronal dynamics during the post-maxima phase of solar cycle 24 using S -band radio signals from the Indian Mars Orbiter Mission

Radio signals from the Mars Orbiter Mission (MOM) were used to study turbulence in the solar plasma during the post-maximum phase of solar cycle 24. The S-band (2.29 GHz) radio carrier downlink signals from MOM were received at the Indian Deep Space Network, Bangalore, and the frequency residuals were spectrally analyzed to obtain coronal turbulence spectra at heliocentric distances ranging between 4 and 20 R_s, corresponding to coronal regions where the solar wind is primarily accelerated. The turbulence power spectrum at smaller heliocentric distances (< 10 R_s) reveals flattening in lower-frequency regions, with a spectral index $\alpha_f \sim 0.3 - 0.5$, which corresponds to the solar wind acceleration region. For larger heliocentric distances (>10 R_s), the curve steepens with a spectral index $\alpha_f \sim 0.7 - 0.8$, a value close to 2/3 and indicative of a developed Kolmogorov-type turbulence spectrum (Fig. 10). Plausible mechanisms to support the theory of coronal heating by magnetohydrodynamic waves and the acceleration of the solar wind were proposed.

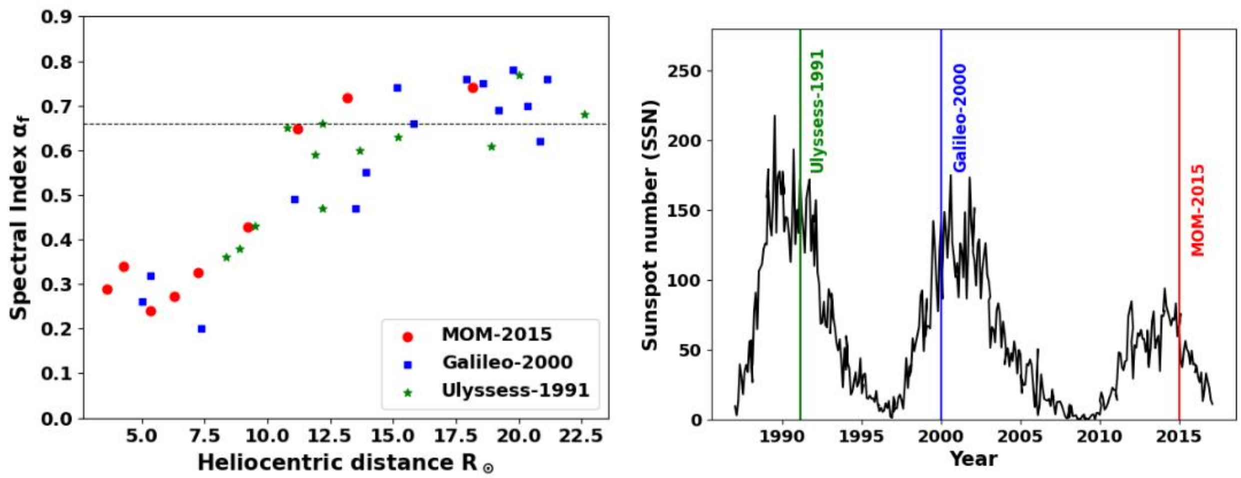

Figure 10: (Left panel) Spectral index (α_f) of the frequency fluctuation spectrum obtained from spacecraft radio signals at various heliocentric distances R# during the coronal radio sounding experiments of (a) Ulysses , (b) Galileo, and (c) Indian Mars Orbiter Mission. (Right panel) Average sunspot numbers over the years 1987–2016, spanning three solar cycles. Vertical lines mark the period when radio-sounding experiments were conducted by the three spacecrafts [Jain et al., MNRAS, 2022].

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

ChaSTE onboard Chandrayaan-3 Lander

Jointly developed by the Space Physics Laboratory (SPL), VSSC, Thiruvananthapuram, and the Physical Research Laboratory (PRL), Ahmedabad, the Chandra's Surface Thermophysical Experiment (ChaSTE) payload was used to investigate the thermophysical properties of lunar regolith at the landing site of Chandrayaan-3 in the near-polar region. Several entities of VSSC (MVIT, AVN, PCM, STR, SR, MME, AERO, SPRE and CMSE) and Physical Research Laboratory, Ahmedabad made significant contributions to the development and operation of this payload. The ChaSTE probe was released from its stowed position, deployed, and slowly inserted into the lunar regolith till its tip reached 140 mm deep. The temperature profile of the regolith up to 96 mm depth and its variations at 1 second intervals during the lunar day were observed using ten PT1000 temperature sensors (Fig.11). Heating experiments were conducted at two different depths to determine thermal conductivity of the regolith. The observations revealed large vertical temperature gradients and poor soil thermal conductivity, which have several scientific and practical implications.

(a)

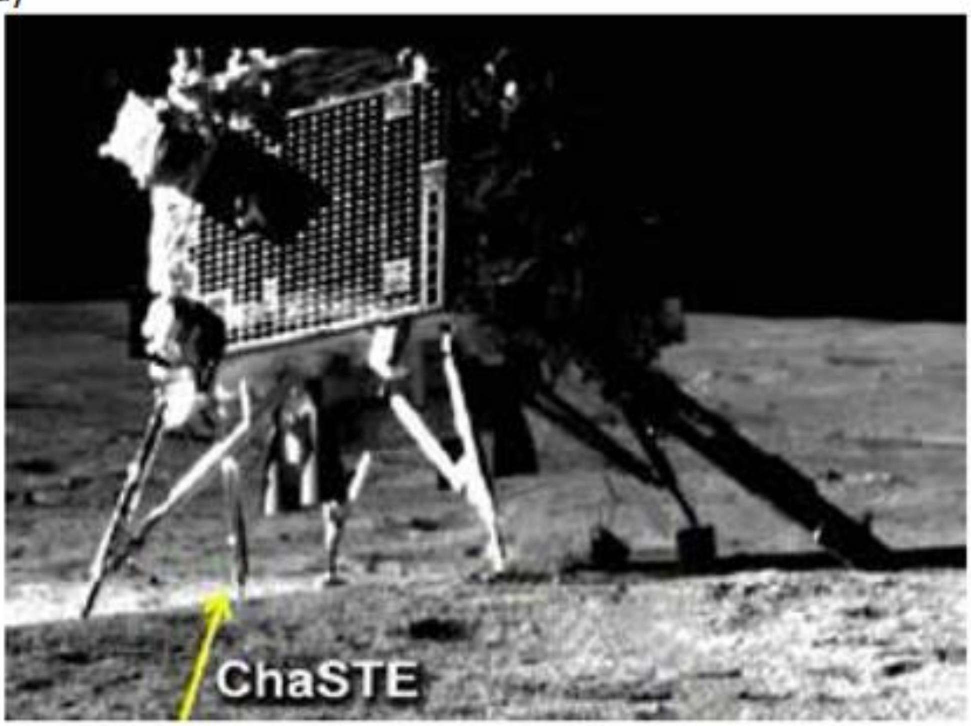

Figure 11: (a) The photo of Chandrayaan-3 lander taken by rover camera. ChaSTE is seen in the inserted configuration, (b) The variation of temperature of lunar surface with depth during the ChaSTE penetration operation.

RAMBHA-LP onboard Chandrayaan-3:

The Radio Anatomy of Moon Bound Hypersensitive Atmosphere and ionosphere-Langmuir Probe (RAMBHA-LP) onboard Chandrayaan-3 lander measured the near surface plasma density and electron temperatures. The RAMBHA-LP was deployed (Fig. 12) and operated from 24 August to 02 September 2023, and made the first in-situ measurements of plasma content near the lunar surface. The observations were made when moon was within and outside the geomagnetic tail. The estimated electron density was typically a few hundred million electrons per cubic meter, and is comparable to the daytime electron densities derived from DFRS/Chandrayaan-2 observations at the lowest possible altitude (~2 km) and that calculated using the lunar photochemical model near the surface.

Figure 12: (a) Photograph of RAMBHA-LP system during Spacecraft level Deployment & Functional Test. (b) The photograph the Chandrayaan-3 lander, showing the shadow of the deployed LP.

PAPA onboard ADITYA-L1: The Plasma Analyser Package for Aditya (PAPA) is designed to study the composition of solar wind and measure its energy distribution for electrons and ions in the low energy range. It has two sensors: the Solar Wind Electron Energy Probe (SWEEP, measuring electrons in the energy range of 10 eV to 3 keV) and the Solar Wind Ion Composition Analyser (SWICAR, measuring ions in the energy range of 10 eV to 25 keV and mass range of 1-60 amu). These sensors are also equipped to measure the direction of arrival of solar wind particles. The PAPA payload for Aditya L1 mission has been developed jointly by SPL and AVN/VSSC in collaboration with other entities of VSSC. The PAPA payload was switched on 12 December 2023 and has been making in-situ measurements on the composition of solar wind and energy distribution of the ions and electrons at L1 point since then (Fig.13).

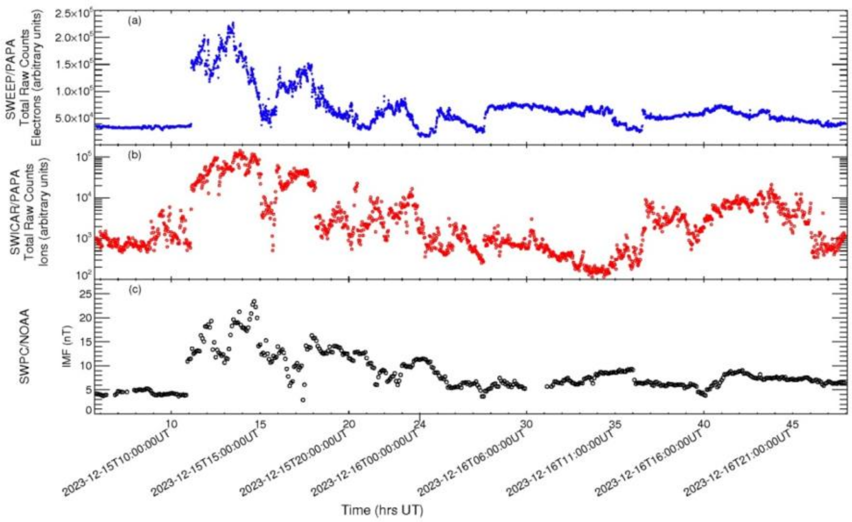

Figure 13: Time series of the integrated raw counts for: (a) solar wind electrons measured by PAPA-SWEEP sensor, and ***(b)*** *solar wind ions measured by PAPA-SWICAR sensor, from 05:45:00 UT on 15 December to 23:55:00 UT on 16 December 2023. (c) The corresponding time series of the total magnetic field measured at L1 point by DSCOVR and ACE (obtained from SWPC).*

Rocketsonde for Middle Atmospheric Temperature Measurement: SPL has designed and developed a rocketsonde payload for profiling the atmospheric temperature from 30 to 60 km above Earth's surface using RH200 rocket. The thermal sensors are designed and mounted so as to minimizes the impact of solar and terrestrial radiations and the effect of thermal conduction. It will be ejected from the rocket after reaching its apogee and decelerated to ground by using a parachute for making the measurements. The rocketsonde (Fig. 14) consists of a special type temperature sensor, a thin film based mount for the sensor, sensor electronics, a GPS/NavIC receiver and battery power supply. The in-house developed rocketsonde has been successfully tested on balloon platform.

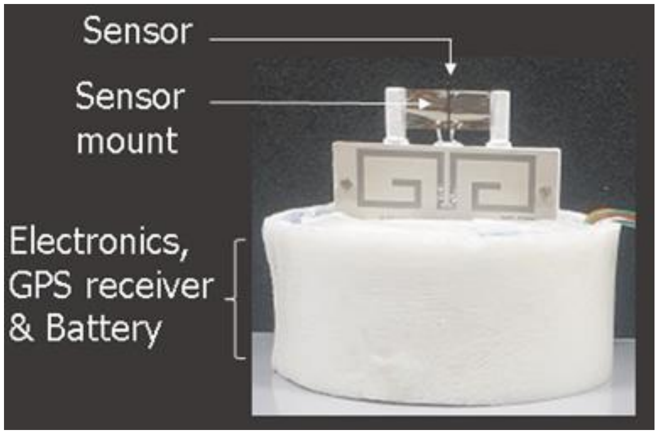

Figure 14: The developed Rocketsonde

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

SPL provides opportunities for doing frontline research in the areas of atmospheric, space and planetary sciences. The ISRO Research Fellowship program at SPL has a total strength of 30 students. So far, 102 researchers obtained Ph.D through SPL. This is in addition to the Ph.Ds produced through various programmes (including IGBP-ARFI & NOBLE) led by SPL. SPL also hosts several post-doctoral programmes, including ISRO Research Associates, INSPIRE Faculty, National PDF, DST Women PDF, and Ramanujan Fellows to pursue their research activities. SPL also has a Visiting Scientist program for senior scientists who have sufficient experience and holding a permanent position elsewhere.

SPL also fulfills its commitment to society by imparting training to young students, which includes: (i) B.Tech and M.Sc. Projects, (ii) M.Tech Dissertation Supervision. So far more than 400 M.Sc. students and 75 M.Tech students have received supervision from SPL Scientists/Engineers. SPL plays an important role in bringing scientific awareness, in the dissemination of expert knowledge to students, teachers and general public. These are archived through various outreach programs that include invited lectures at colleges and schools and public lectures during various science events.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Through the ISRO Research Fellowship programme, 30 students can pursue Ph.D at SPL in atmospheric, space and planetary sciences. The fellowship is for a maximum period of 5 years. On average, the annual intake in this fellowship is 6-8, depending on vacancy. SPL is a Research Centre recognized by the University of Kerala and Cochin University of Science and Technology (CUSAT) for doing Ph.D, including the course work.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

High Vacuum Space Simulation Facility (HVSSF)

With SPL's involvement in the development of space-borne instruments, a state-of-art High Vacuum Space Simulation Facility (HVSSF) has been set up at SPL (Fig.15a). The HVSSF is a 1-m class chamber providing vacuum of the order of 10^{-7} Torr in a few hours. The HVSSF is equipped with ion and electron sources for characterization of detectors, and testing and calibration of plasma analysers and neutral mass spectrometers.

Clean Room Facility

The Clean Room facility at SPL (with class 10000 and class 100000 clean rooms equipped with work benches of class 100 and class 1000 Laminar flow tables) has been utilized for the testing and development activities for scientific payloads of SPL and for the requirements from other entities of VSSC (Fig. 15b).

Figure 15: (a) High Vacuum Space Simulation Facility and (b)Clean room Facility.

Payload Operation Centre at SPL

The payload operation centre of SPL is handling the data from CHACE-2 and DFRS payloads onboard Chandrayaan-2 orbiter and PAPA and Magnetometer onboard Aditya-L1. The POC also handled the data from MENCA onboard Mars Orbiter Mission till recently. Level-0 data sets from normal phase observations of CHACE-2 have been regularly received from ISSDC via NKN-VRF link. These data sets are processed using automated software pipelines at POC; quick look plots are generated to verify the payload functionality. Also, a chain to generate the data products as per planetary data system (PDS) standard for archival and subsequent public release also runs in POC.

For further details on the inputs as provided in the document, please contact

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U R RAO SATELLITE CENTRE, BANGALORE, INDIA

https://www.ursc.gov.in/

ABOUT U R RAO SATELLITE CENTRE (URSC)

The UR Rao Satellite Centre (URSC), previously known as ISRO Satellite Centre (ISAC), is the lead center for satellite design, development and operations in the country. URSC is also involved in the development of science missions and scientific payloads. URSC is actively involved in successfully operating the multi-wavelength astronomy satellite AstroSat launched in 2015 and also Chandrayaan-2, the second mission to the Moon launched in 2019. It plays a major role in planning and operating the AstroSat satellite and Chandrayaan-2 orbiter for the required scientific observations. URSC is also the lead centre for the recently launched missions, Chandryaan-3, Aditya-L1, and the XPoSat.

URSC is also actively involved in optical, X-ray and gamma-ray research with a strong emphasis on design and development of novel instrument concepts for space-based as well ground payloads / facility. Apart from payload development, URSC is also involved in the analysis and interpretation of existing astronomical data from space- and ground-based facilities around the world. Extensive research is being carried out using observational data from ISRO's AstroSat observatory, Chandrayaan-2 and recently launched Chandryaan-3, Aditya-L1, and XPoSat missions. Analysis of the data from the International Space Observatories is also pursued. In addition, Monte Carlo simulation tools are used for optimization of various system performance parameters such as detector sensitivity and response, estimation of expected background and complementing ground calibration activities. URSC carries out strong science collaboration with National Institutes and Universities.

This document contains very briefly, the major science research carried out at this centre during the period January 2022 to December 2023 along with instrument development activities towards achieving the science.

Keywords
Compact Objects, Sun, Space Weather, Magnetars, Moon, Planetary Atmosphere, Exo-planet, X-ray Instrumentation, UV Instrumentation, IR Instrumentation

MAJOR RESEARCH DOMAINS

URSC research on space experiments concentrates on the following major research area especially during the said period:

- Astronomy & Astrophysics and Exoplanet
  - Black Hole Astrophysics – Observations, Modeling, Interpretation and Theoretical aspects of accretion dynamics.
  - LMXB-NS & Magnetars - Observations, Modeling, and Interpretation of emission mechanisms from weakly to strongly magnetized neutron stars.
  - Study of atmospheric constituents through polarimetric measurements and simulations; Concept and design optimization for Exoplanet imaging.
- Solar Physics & Space Weather
  - Measurement and study of coronal magnetic fields to understand the dynamic processes occurring in the Sun.
  - Solar flare studies using X-ray observations of Sun.
  - Study of magnetospheric processes underlying space weather phenomena.
  - Measurement of energetic particles in the Earth's magnetosphere.
- Lunar & Planetary Sciences
  - Elemental mapping of Lunar compositions.
  - Modeling/Simulation of atmospheric composition in planetary atmospheres.
- Instrumentation
  - Development of X-ray spectrometer and polarimeter for space missions
  - Development of UV imager
  - Development of NIR spectrometer

MAJOR SCIENTIFIC APPLICATIONS

(A) Astronomy & Astrophysics & Exoplanet Research

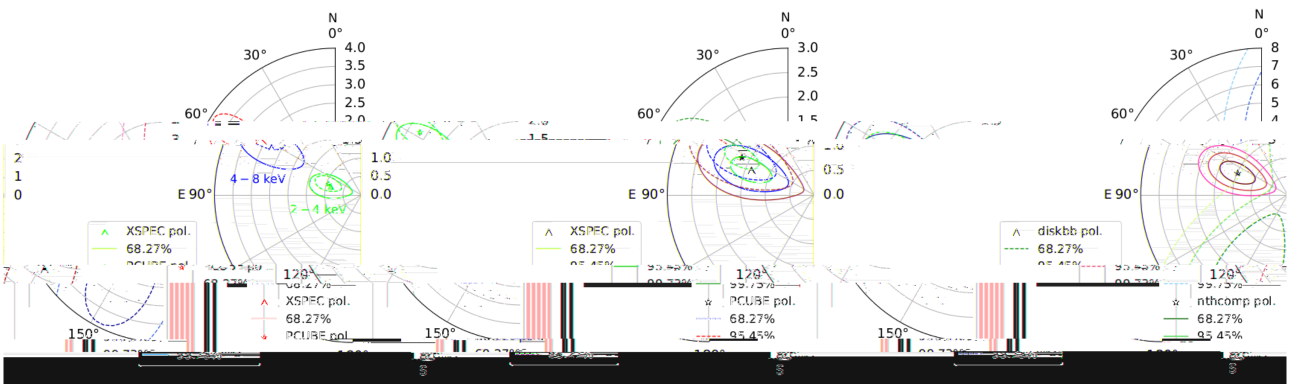
(a) AstroSat View of 'Clocked Burster' GS 1826-238: Broad band Spectroscopy of Persistent and burst emission

GS 1826-238 is a neutron star low-mass X-ray binary that shows frequent thermonuclear bursts. During the AstroSat observation the source showed soft spectral nature and traced a 'Banana' track in color-color diagram. Broad band spectra in the energy band 0.7-25 keV consist of emission from standard accretion disc with inner disc temperature

0.7-1.2 keV and Comptonized component with temperature ~ 2.2 – 4.8 keV. The source exhibited two type-I X-ray bursts during the AstroSat observations. During the peak of the type I X-ray bursts the increase in hard X-rays was observed unlike previous bursts in the source where decrease in the hard X-ray emission was seen.

(b) Spectro-polarimetric View of Bright Atoll Source GX 9+9 using IXPE and AstroSat data:

GX 9+9 is a neutron star low mass X-ray binary (NS-LMXB), classified as an 'atoll' source. NS-LMXBs have complex spectra, which require multiple components to model them. Often, multiple models, having differnt geometries, are able to fit the spectrum of the same source, i.e. the models are degenerate with respect to the geometry, location and nature of the Comptonized corona. This is where polarization measurements serve as a valuable tool to infer the source geometry and emission properties. The Imaging X-ray Polarimetry Explorer (IXPE), launched in December 2021, observed GX 9+9 on 2022 October 9 for ~ 90 ks exposure time. Being a stable atoll source, data from SXT and LAXPC instruments on-board Astrosat were utilized, for understanding the spectral nature of the source. A significant polarization signature of this source (PD = 1.7% in 2-8 keV), with hints of increasing polarization with energy was observed. Moreover, the Comptonized component was found to be strongly polarized with PD ~ 3% and PA roughly perpendicular to that of the thermal disk emission. Comparing these results to simulations by Gnarini et al. (2022), a shell type corona, probably in the form of a spreading layer



above the NS surface was proposed.

Figure: Results of model-independent and model-dependent polarization measurements of GX 9+9.

(c) Detection of Significant X-ray Polarization from Transient Low Mass X-ray Binary XTE J1701-462 with IXPE and its Implications on Coronal Geometry:

XTE J1701−462 is a transient neutron star low-mass X-ray binary discovered with the All Sky Monitor of the Rossi X-ray Timing Explorer in January 2006. The source went into an outburst on 6th September 2022, following which, the Imaging X-ray Polarimetry Explorer (IXPE) observed it twice once on 29th September 2022 (hereafter, Epoch 1) and again on 8th October 2022 (hereafter, Epoch 2). A detailed spectro-polarimetric analysis was performed using IXPE, NICER, and NuSTAR data. Significant energy-dependent polarization was detected during Epoch 1 with polarization degree (PD) of 4.5 ± 0.4 % and polarization angle (PA) of 143º ± 2° in the 2-8 keV energy band. The spectra were modelled using a combination of thermal emission from an accretion disc, Comptonized emission from a corona and a Gaussian line. The PD from disc emission was unconstrained however the Comptonized emission was well constrained at 7.7 ± 2.5%. The results suggest that the Comptonized emission may originate from a spreading layer/boundary layer above the neutron star surface. The source polarization was below the minimum detectable polarization during Epoch 2 probably due to a weaking of the coronal Comptonized emission. More observations of the source are needed to characterize the exact geometry of the corona.

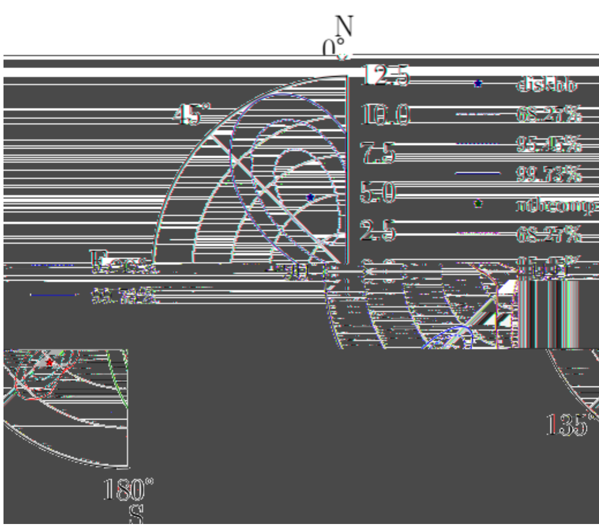


Figure: Polarization contours derived from spectro-polarimeteric fitting using individual constant polarization model (polconst) for diskbb (thermal emission) and nthComp (Comptonized emission), respectively in XSPEC for the 2–8 keV energy range

(d) Spectro-polarimetric properties of blackhole X-ray binary 4U 1630-47

The spectro-polarimetric study results in first detection of X-ray polarization from a recurrent transient BH-XRB 4U 1630−47 by IXPE during its outburst in 2022. The investigation reports a substantial degree of polarization (PD) = 8.33±0.17 % in disc dominated outburst phase of the source in 2 − 8 keV energy range. The energy resolved PD reaches as high as 11.02±0.92 % in 6.5 − 8 keV. These measurements are significantly higher when compared with prediction from theoretical models. This indicates that additional physical processes and effects are in play on top of electron scattering on the surface of accretion disc around black hole along with reflection of return radiation from the near side of the disc which can enhance the degree of polarization.

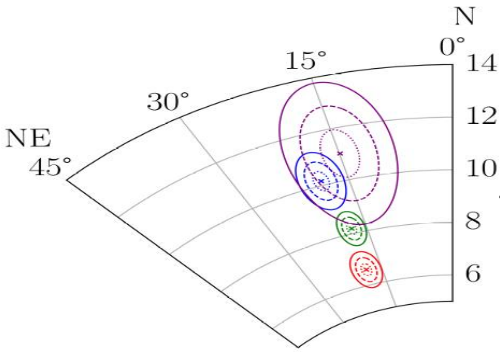


Figure: Polarization contour in different energy bands as measured from IXPE.

<u>(e) Specular Reflections from artificial surfaces as Technosignature</u>

The specular reflection can be several orders of magnitude brighter than the lambertian reflections from the planetary surfaces. Direct imaging of exoplanets will allow for observation of a planet in reflected light. Such a scenario may eventually allow for the possibility to scan a planetary surface for the presence of artificial structures which can cause specular reflection of light in the direction of the observer. Such a scenario will allow us to scan the surface of the exoplanet for the presence of any alien made structure.

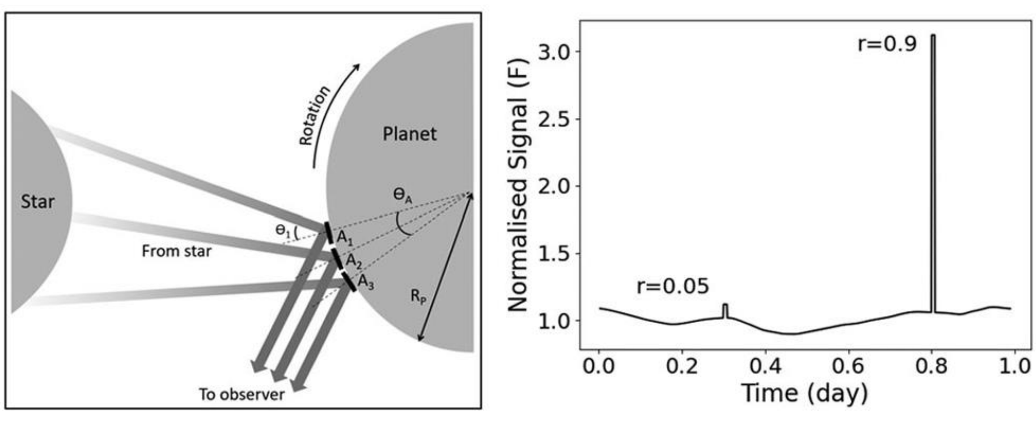


Figure: The specular reflection geometry from a planetary surface is shown on the left. The specularly reflected signal is shown as bright and narrow peaks in the planetary light curve in the right panel.

<u>(f) Scattering Transparency of Clouds in Exoplanet Transits of JWST</u>

The presence of aerosols in an exoplanet atmosphere can cover the underlying gases and can lead to a flat transmission spectrum during primary transit observations. We explore forward scattering effects from super-micron sized cloud particles present in the atmosphere of a transiting exoplanet. We find that the impacts of forward scattering from larger aerosols can significantly impact exoplanet transits and the strength of these effects can lead to positive slopes in the broadband spectrum such as those observed with NASA's James Webb Space Telescope.

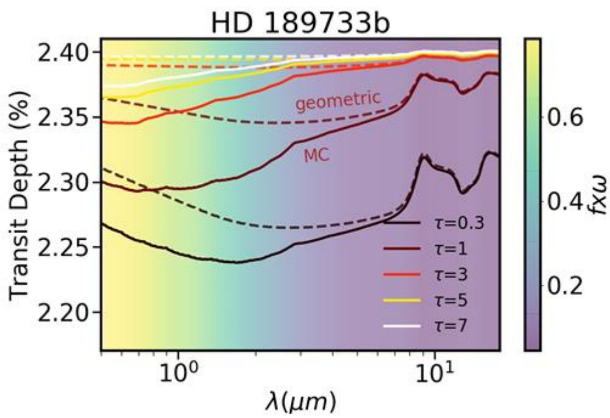
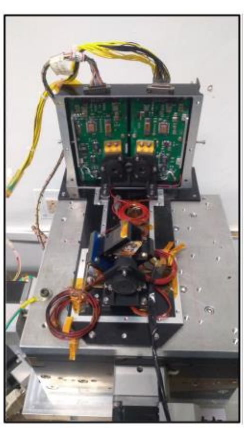
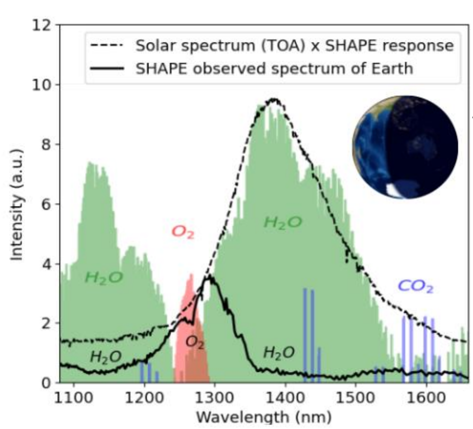


Figure: Positive slope in the spectrum of a cloudy HD189733b planet. The simulations are done for various optical depths; by Monte Carlo (MC) as well as geometric simulation. These broadband spectral slopes could be observable by JWST observations.

(g) SHAPE on Chandrayaan 3 to observe Earth as an exoplanet:

Spectro-polarimetry of HAbitable Planet Earth (SHAPE) on Chnadrayaan 3 propulsion module (orbiter) is an experiment to observe Earth as an exoplanet. It observes the disc integrated spectrum of Earth in the 1000-1700 nm wavelength range. It uses an AOTF as a dispersing and polarising element and uses a set of two InGaAs detectors for detection of light in two channels. The two channels measure the light whose state of polarization is mutually perpendicular to each other. As Moon goes around the Earth, the SHAPE samples Earth at different phase angles mimicking the observations of





exoplanets in reflected light. SHAPE is a first of its kind experiment and has observed Earth for about two months period. The observation campaign lasted for about two months (Aug-Oct 2024) in which a large range of Earth phase angles have been sampled. The absorption bands of O2, H2O and CO2 have been identified in majority of the observation. Further study of the data is underway to study the effect of clouds, ocean and surface albedo on the observed spectrum.

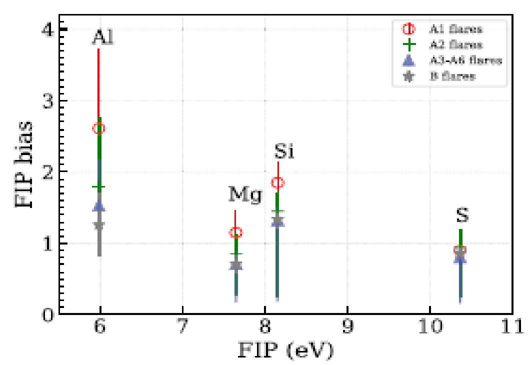
Figure: [Left] SHAPE experiment in open condition on the calibration bench. [Right] The observed SHAPE spectrum (bold lines) is marked with major absorption bands of O2, H2O and CO2 (as colored lines in the background). The solar continuum multiplied with the spectral response of the instrument is marked as dashed lines

(B) Solar Physics & Space Weather

Solar Flares:

X-ray solar monitor (XSM) on-board Chandrayaan-2 (Ch-2) data was used to study the solar flares. Abundance variations during A-class flares were studied and the following conclusions were arrived at:

- We find that the temperature and emission measure scales with the sub-class of flares while the measured abundances show an intermediate FIP bias for the lower A-flares (e.g. A1), while for the higher A-flares, the FIP bias is near unity

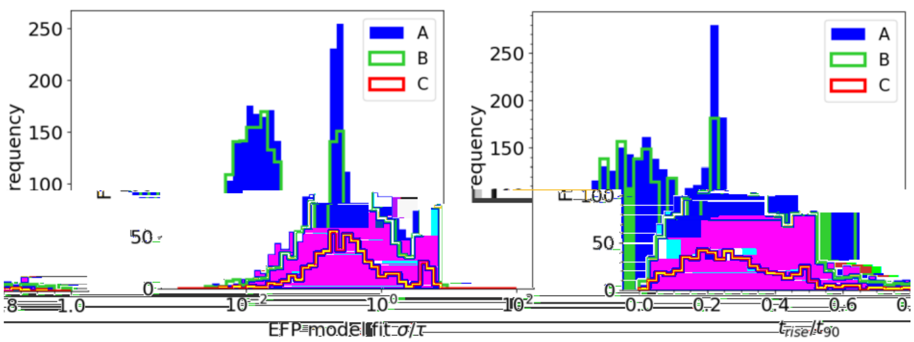


Average FIP bias for different classes of flares

- Time evolution of the flares show that the abundances drop from the coronal values towards their photospheric values in the impulsive phase of the flares and, after the impulsive phase, they quickly return to the usual coronal values. The transition of the abundances from the coronal to photospheric values in the impulsive phase of the flares indicates the injection of fresh unfractionated material from the lower solar atmosphere to the corona due to chromospheric evaporation.
- The quick recovery back to the coronal values is yet to be explained.

Using the XSM data, a flare catalogue for 6266 flares was made. The catalogue represents the first large sample, including both type A, hot thermal flares and type B, impulsive flares, with a sub-A-class sensitive instrument. The algorithm developed for the catalogue also detected 213 sub-A and 1330 A-class flares. Major results from this study are:

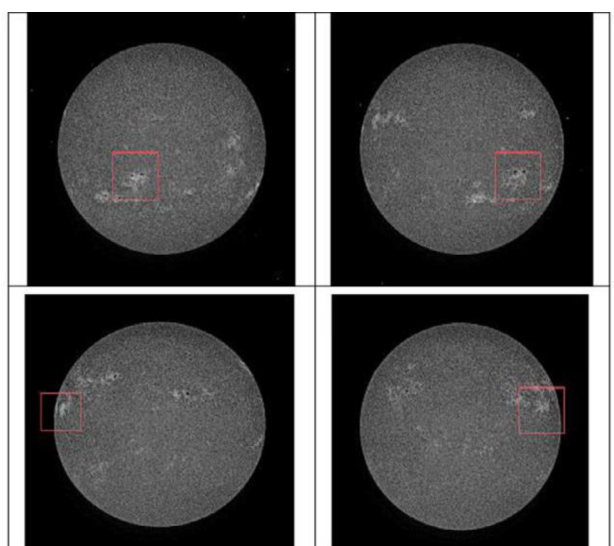
- A clear bimodality in the ratio of the width to decay time between type A and B flares is found.
- A power-law index of αF=1.92 ±0.09 for the background-subtracted peak flux distribution of XSM flares was found, which is consistent with the value ~2 reported in the literature. This work also infers αF=1.90 ±0.09 for type B, and αF=1.94 ±0.08 for type A flares, which has previously not been reported in the literature. These comparable values hint at a similarity in their generative processes.



Clear bi-modality seen in the thermal and impulsive flares

Two of the instrument flown on Aditya-L1 was characterized by the URSC teams. They are Solar Ultra-violet Imaging Telescope (SUIT) and Visible Emission Line Coronagraph (VELC).

SUIT: SUIT will perform It will perform full disc imaging of the Sun in the near-ultraviolet (UV) wavelength range of 200-400 nm and provide near-simultaneous observations of the Sun from the photosphere and chromosphere. The CCD used for SUIT was characterized for the in-house developed readout electronics. The following parameters were measured by making separate test set-up in the laboratory: noise, dark current, gain, linearity, and cross-talk. The results show a satisfactory performance from the CCD as well as the readout electronics and meet the specifications required by the SUIT payload.



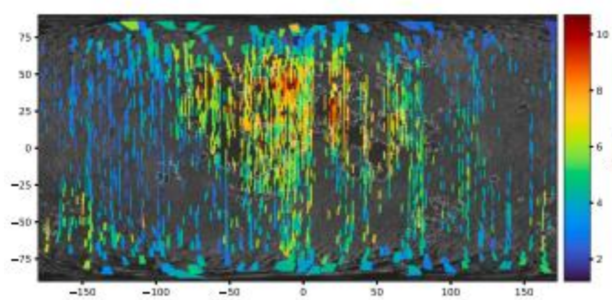
SUIT Region-of-Interest (ROI) tracking module for different times. Red box inside the image is the ROI

VELC: VELC is an internally occulted coronagraph with four channels to image the Sun at 5000 Å in the field of view 1.05 - 3 R⊙, and to pursue spectroscopy at 5303 Å, 7892 Å and 10747 Å channels in the FOV (1.05 - 1.5 R⊙). In addition, spectropolarimetry is planned at 10747 Å channel. VELC has three sCMOS detectors and one InGaAs detector. All the detectors were characterized at the facility in India to derive the specifications in the vacuum. The estimated conversion gain, full-well capacity, and readout noise at different temperatures were established. Based on the numbers, it is thus concluded that it is essential to operate the sCMOS detectors and InGaAs detector at -5° and -17° C, respectively, at the spacecraft level.

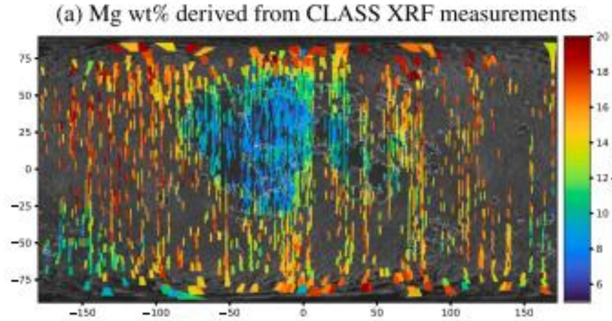
(C) Lunar & Planetary Science

(a) Lunar elemental maps with Chandrayaan-2:

The CLASS instrument onboard Chandrayaan-2 measured lunar X-ray spectra triggered by solar flares. We have determined abundances of the major rock forming elements from the lunar X-ray spectra and generated Mg, Al, Si and Fe maps at the highest spatial resolution yet. Lunar X-ray spectra and elemental maps in PDS4 standard are regularly released through ISRO's data archive. The main conclusions from the new elemental maps are as follows:



(a) Mg wt% derived from CLASS XRF measurements



(b) Al wt% derived from CLASS XRF measurements

Mg and Al abundance maps derived from CLASS data onboard Chandrayaan-2 Orbiter

- Global correlations among the elements agree well with those known in the lunar soil samples, in situ measurements as well as LP-GRS.
- CLASS elemental maps reproduce the well known mare-highland composition differences where the former are rich in Mg and Fe and the latter in Al.
- Finer variations in composition within mare-highland are also uncovered. Notable are regions of high Mg (up to 13 wt%) in certain portions of Mare Imbrium and Oceanus

Procellarum where the Fe and Al abundances are low which could suggest the presence of less evolved, primitive magma.

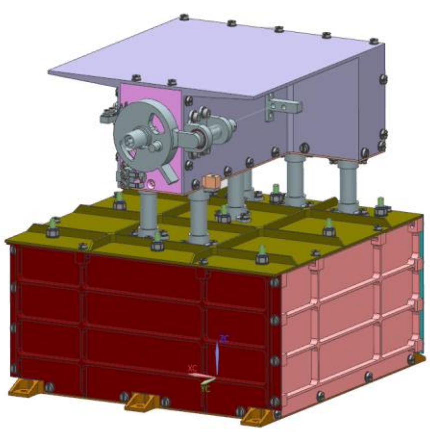
(b) The Chandrayaan-3 landing site average composition was determined prior to landing with high resolution (15 km) elemental maps from CLASS.

(c) Three sites close to the lunar South Pole, Connecting Ridge 1, 2 and Shackleton Ridge were studied in detail with data from LRO, Chandrayaan-1 and 2. A trafficability map was also prepared that would help plan rover traversal. These sites are considered for the LuPEX mission. We found that Connecting Ridge 1 is the most suitable amongst the three for LuPEX.

INSTRUMENTS / PAYLOADS / PRODUCTS DEVELOPED / SENSORS / DETECTORS

SoLEXS: Solar Low Energy X-ray Spectrometer

SoLEXS on Aditya-L1 is a soft X-ray spectrometer (1 keV to 22keV) for studying solar flares. The main science goals of SoLEXS are: (i) Flare and coronal abundance studies as a standalone spectrometer and (ii) Dynamical events studies along with other payloads. In addition to the flare & coronal abundance studies, the heating mechanism of these flares, pre-flare activities indicating the flare initiation mechanisms and the coronal abundances and hence the FIP Effects will also be studied.



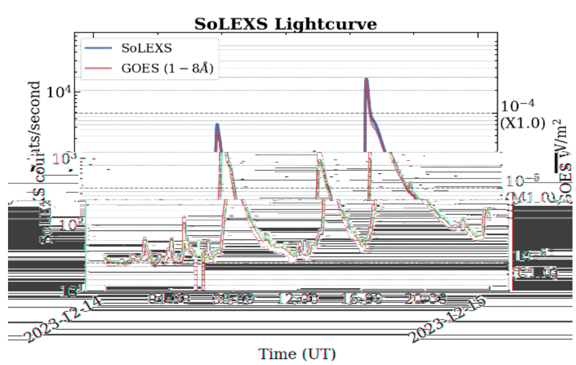


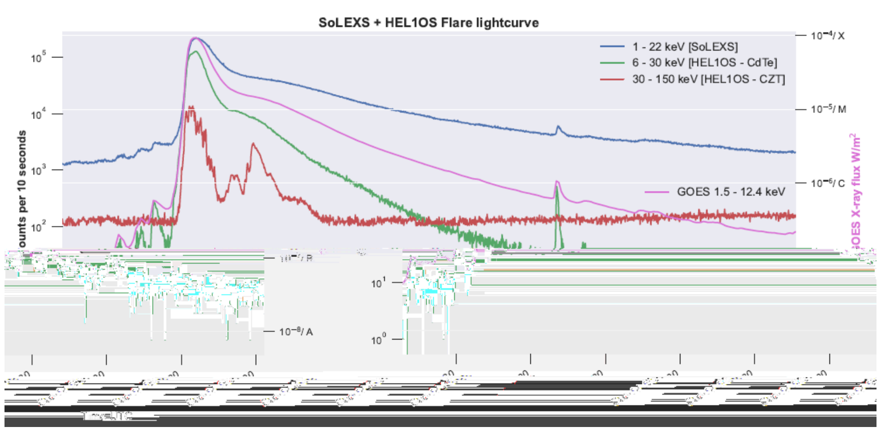
Figure: *SoLEXS payload model; Light curve in soft X-rays showing the flare observations from SoLEXS*

Silicon Drift Detectors (SDD), which have high count rate capabilities are used. The charge signal from SDD detector is readout using in-house developed preamplifier unit and associated analog conditioning circuits. The spectroscopic signal processing modules like shaper, baseline restorer, peak detector, pile-up rejecter etc. are developed in digital domain, entirely into FPGA module. The low and high voltages are derived into the power distribution card. Key instrument specifications are; energy range 1-22 keV, Spectral resolution: < 250 eV @ 5.9 keV keV, Flare coverage: A to X-class

HEL1OS: High Energy L1 Orbiting X-ray Spectrometer

HEL1OS on Aditya-L1 is a hard X-ray spectrometer (10 keV to 150 keV) to observe Sun as a star continuously from L1 point. The main science goals of HEL1OS are to study particle acceleration processes during flares, via emission of hard X-rays (HXR) during the impulsive phase of solar flare. It is an instrument supporting multi-wavelength observations of eruptive solar phenomena.

The instrument consists of two types of detectors, Cadmium Zinc Telluride (CZT) and Cadmium Telluride (CdTe), to cover the required spectral range (10 keV – 150 keV). Analog signal conditioning, digital signal processing, High Voltage bias generation, Spacecarft interfaces, House Keeping ADC, are key electronics modules. A collimator is mounted in front of the detectors to limit the Field Of View (FOV) to 6° x 6°. Heat pipes and radiator plate are attached to detector tray to cool the detectors to their operating temperature.



Figures: *Top - Mechanical QM model of HEL1OS payload at vibration table. Bottom – Light curve of a flare from SoLEXS and HEL1OS.*

SUIT: Solar Ultraviolet Imaging Telescope

SUIT observes the Sun in the 200-400 nm spectral range with 11 channels (3 Broadband & 8 Narrowband filters). SUIT is a collaborative project between IUCAA, LEOS, IISU and SAG. A 4K x 4K CCD detector is used for capturing the solar disc image.

Space Astronomy Group (SAG) has developed the SUIT payload Electronics package, which includes the CCD detector electronics, FPGA-based CCD clock and bias generation circuit, constant current based LED control circuit, SDRAM-based storage for Image formation and storage and motor electronics modules. In addition, integration, testing, and calibration of SUIT is also worked in collaborative mode utilizing the Class 100 and Class 1000 facility of SAG.

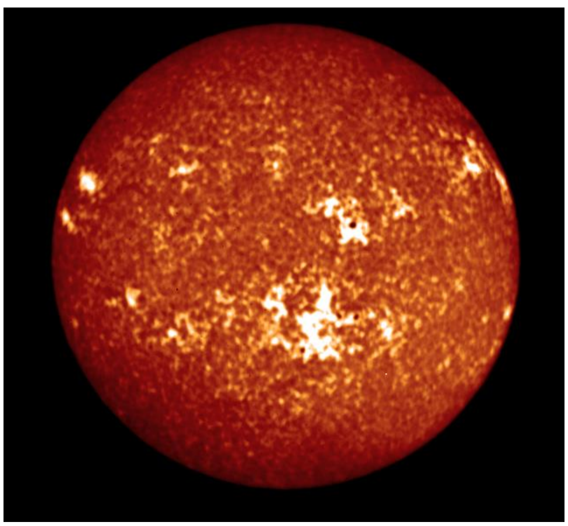
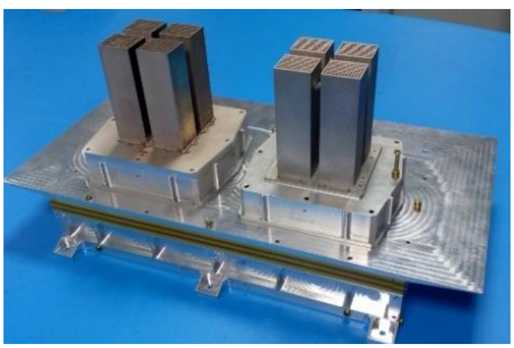


Figure: *SUIT Mg filter image of the Sun observed on-board Aditya-L1.*

XSPECT: X-ray spectroscopy and Timing on XPoSAT

XPoSat is India's X-ray polarimeter mission carrying POLIX (A Thomson scattering polarimeter) and XSPECT (X-ray Spectroscopy and Timing) payloads. XSPECT is large area spectrometer payload and has a unique opportunity to observe astrophysical sources for very long durations to study their spectral and temporal variability in 0.8 to 15 keV x-ray band. Some of the major science objectives of XSPECT include studying the emission mechanisms in bright X-ray binaries, long-term spectral and timing evolution of select X-ray binaries, soft excess and iron line studies of X-ray pulsars, spin measurement of black hole X-ray binaries through continuum fitting and iron line profile study, study of temporal variabilities on different time scales (seconds to months) and unique opportunity to address both spectroscopic and polarization properties.

XSPECT payload is mounted alongside POLIX instrument and is aligned with its viewing axis. XSPECT is configured as two detector packages connected to a single electronics packages, which powers the detectors and does the necessary signal conditioning and has interface with spacecraft. Two different Field Of Views (FOV) collimators, 2°X2° and 3°X3 are used enabling us to efficiently model-out the X-ray sky background. Swept Charge Device (SCD)s are used as detectors (16 numbers; total 64 cm2 with effective area of ~35cm2 @ 6keV. These detectors enable XSPECT to have pile-up free observations at the expected count-rates with a very good energy resolution of less than ~ 200 eV @ 5.9keV at an operating temperature of ~-20°C. XSPECT provides a timing resolution of ~2 msec, necessary for studying the timing properties of most of the millisecond pulsars and transient stars.



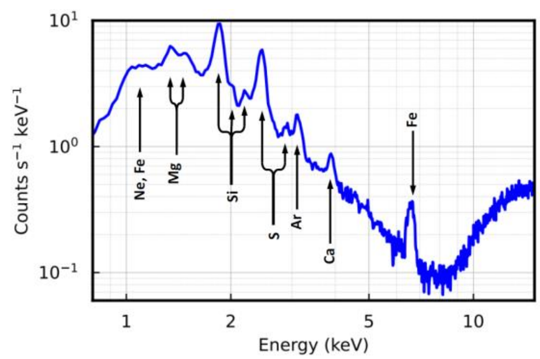
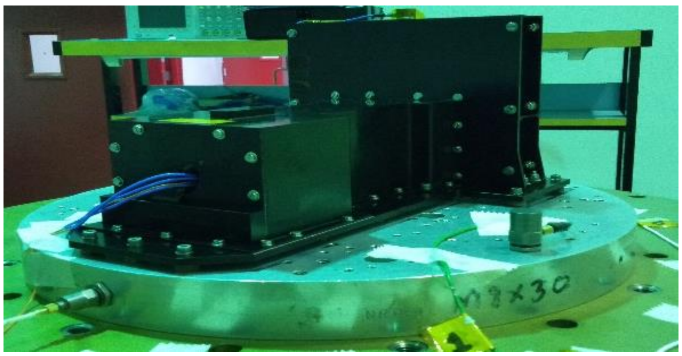


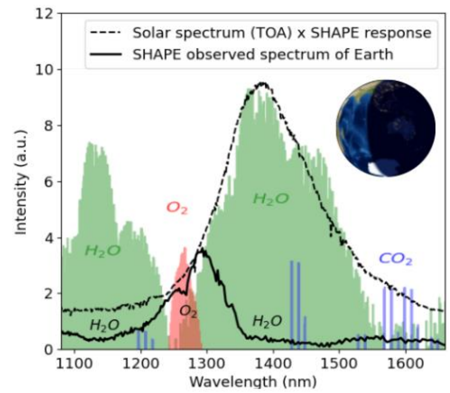
Figure: *Left: XSPECT detector package. Right: XSPECT observation of Super Nova Remnant (SNR) CasA on-board XPoSat.*

SHAPE: Spectro-polarimetry of Habitable Planet Earth onboard CH-3

SHAPE is an experiment on-board Chandrayaan-3 Mission for the study of spectro-polarimetric signatures of the habitable planet Earth in the near-Infrared (NIR) wavelength range (1 – 1.7 µm). The spectro-polarimeter is mounted on the Propulsion Module (PM) of Chandrayaan-3 mission. The payload will observe full-disc Earth from a distant vantage point, Moon, in order to 'mimic' Earth-like Exo-planets.

SHAPE is designed with two packages: (1) Electro-optical Detector System (EODS) and (2) Radio Frequency Source (RFS). The EODS package consists of various sub-systems – Telescope optics, Acousto-Optic Tunable Filter (AOTF), Linear Array Indium-Gallium-Arsenide (InGaAs) detectors, Front-end Electronics (FE), Processing Electronics (PE) and Power Distribution Electronics (PDE). The RFS package will interface with AOTF and drive the AOTF by RF input with ~1.5 Watt power in 75 MHz to 140 MHz.





Figures: *Left – Mechanical QM EODS-Optics package at vibration table. Right – Earth spectra observation on-board Ch-3 Propulsion Module.*

SHAPE is being designed with two packages: (1) Electro-optical Detector System (EODS) (2) Radio Frequency Source (RFS). The EODS package consists of various sub-systems – Telescope optics, Acousto-Optic Tunable Filter (AOTF), Linear Array Indium-Gallium-Arsenide (InGaAs) detectors, Front- End (FE) electronics, Processing Electronics (PE) and power distribution. The RFS package will interface with AOTF and drive the AOTF by RF input with ~1.5 Watt power in 75 MHz to 150 MHz.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE

Space Astronomy Group (SAG) in URSC has four well equipped laboratories with several facilities established over the years to cater to space science payload developments. Different class of clean rooms as specified by ISO standard have been established for carrying out contamination sensitive experiments. Class 1000 and Class 100 clean rooms have been established to carryout assembly and testing of contamination sensitive instruments like SUIT (Solar Ultra-violet Imaging Telescope) payload on-board Aditya L1 mission. Class 100,000 and Dark Room facilities have been established for carrying out various payload assembly and testing activities of Flight and Qualification Models.

Cleanliness levels are maintained through continuous monitoring of particle and molecular contamination levels using instruments such as Laser Airborne Particle Counter, Surface Particle Counter, and Particle Fallout Photometer. The laboratories are equipped with the following;

1. Baking chambers and Vacuum chambers - 1m dia and D-type twin chambers, for experiments on payloads and detectors.
2. Optical tables of different sizes – for regular optics based experiments, dark room experiments, and clean room experiments
3. Interferometer
4. High Resolution Spectrograph,
5. Laminar flow tables for assembly and storage.
6. Cryo cool Dewar for detector (CCD) cooling
7. Ultrasonic cleaning machines of different sizes.
8. Recirculating chillers: (i) -20C (ii) -40C
9. Vacuum pumping and gas filling system for gas filled detector activities.
10. Nuclear Instrument Modules (NIM) of different types along with BINs for all standard experiments related to semiconductor, scintillator and gas filled detectors
11. N2 Gas distribution system for clean rooms and labs.
12. Compressed air lines in all the labs.
13. Standard radio-active sources for test & characterisation and calibration of the instruments.
14. X-ray guns: 1-40 keV; Ag and W targets
15. Hard X-ray generator: 1-90 keV; W target; Max power 8 W
16. Standard detectors available: Si-PIN, SDD, CdTe
17. Table top small lathe machine and drilling machine in workshop for fabrication of test jigs.

Apart from the above specific laboratories, URSC has other environmental facilities like vibration, thermos-vacuum, and others required to qualify the payloads individually or along with spacecrafts.

Institutions / Academia beyond the Department of Space (DOS), Government of India

AMITY CENTER OF EXCELLENCE IN ASTROBIOLOGY, AMITY INSTITUTE OF BIOTECHNOLOGY, AMITY UNIVERSITY, MUMBAI, MAHARASHTRA, INDIA

https://www.amity.edu/mumbai/

Vision Statement

To become India's first and leading Centre for Studies of the Origin and Survival of Life in the Universe.

Mission Statement

By establishing a multifaceted research strategy, the Centre will undertake:

1. **Scientific Research**: Habitability and Preservation of Bio signatures in Extraterrestrial environments. Survival and sustenance of microbial life exposed to space environments.
2. **Mission Design**: Develop Exploration Roadmaps and Mission Architectures for future Astrobiology missions in Analogue and Low-Earth Orbit environments.
3. **Technology**: Design and performance analysis of Surface systems for Astrobiology missions. Design and develop microgravity-based biological experiment hardware.
4. **Scientific Community and Public Engagement**: Co-organize meetings and workshops for scientific and education and public outreach in Astrobiology.
5. **Education**: Conduct virtual and physical workshops and courses to initiate students into Astrobiology.

Amity Centre of Excellence in Astrobiology has been established in February 2019, keeping in mind the critical need to have an integrated centre in India that focuses on all pursuits towards studying the origin of life and its evolution, distribution on Earth and in the Universe. The centre, in partnership with national and international labs, currently leads astrobiology-focused field studies and simulation with a focus on understanding the habitability potential of regions on Mars. The centre is also involved in the development of biology experiments in the upper atmospheric and Low Earth Orbit (LEO). The centre has been involved in has been conducting scientific field expediton program in Ladakh. The centre has plans to establish India's first Planetary Science, Education and Experience Station in a remote, off-Earth like environment. The station aims to support Astrobiology and Space Biology research, help monitor Climate change, inspire students to pursue STEM education and spread awareness about Space in India.

MAJOR RESEARCH DOMAINS

Space Biology

Microgravity and Space Mutagenesis

1. We have developed two biological payloads for understanding microgravity effects on plant callus
2. We are designing a Random Positioning Machine (RPM) to generate microgravity. This device is aimed to analyse the microgravity effects on plant seeds and microbes.

Space Biofilms and Space Medicines

- We are conducting research on how different space environments, including microgravity, temperature variations, and UV radiation, affect space pathogens. The aim is to enhance our understanding of these conditions to ultimately improve astronaut health.
- Additionally, we are investigating the influence of space environments on drugs, with a specific focus on antibiotics, addressing concerns related to antimicrobial resistance.

Extremophiles

This pioneering project involves the comprehensive study of extremophiles from Ladakh, specifically the TsoKar and Puga regions. Through culturing, identifying, characterizing, and preserving these extremophiles the work will help to deepen our understanding of microbial characteristics and diversity in extreme environments, providing valuable insights into potential life forms on other planets.

Geomagnetism and Space Weather

- Radiation Belt Dynamics & Remote Sensing – We work on the effects of different solar drivers and magnetosheath events on the outer radiation belt relativistic electron flux using space and ground-based data. We also work on the Very Low Frequency (VLF) waves to understand the coupling dynamics of ionosphere-magnetosphere system at low latitudes.
- Space Weather studies – Solar cycle 24 shown a drastic reduction of the geomagnetic storms when compared to previous cycles We tried to establish the reason behind the reduced geo-effectiveness in terms of source which resulted in the geomagnetic storm as well as the response into the magnetosphere by means of energy transfer.

Planetary Science Analogue Studies

- A meta-analysis of impact craters: The study aimed to investigate the relationship between impact craters, their geological composition and the morphological and genetic makeup of organisms living in these regions. It focused on five main craters, including Chesapeake, which have undergone shock-metamorphic effects, contain different geological and mineral compositions and microorganisms that thrive in extreme conditions.
- Numerical Modeling of Puga hot springs: An Analogue Study: The aim of this study is to construct a 2D numerical model of two-phase flow using a finite volume method to understand the hydrothermal circulation of Puga hot spring system and to understand its evolution.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Prospective Use of Probiotics to Maintain Astronaut Health during Spaceflight This review article summarizes the importance of maintaining astronaut health during space travel, noting changes in the gut microbiome and immune system observed in astronauts aboard the International Space Station (ISS). Probiotics offer promising solutions by inhibiting pathogens, enhancing barrier function, and providing anti-inflammatory effects. Studies demonstrate the effectiveness of probiotics in microgravity and potential benefits for immune function and microbiota balance. Further research is warranted to explore probiotics' efficacy in simulated microgravity and spaceflight conditions, aiming to mitigate gut dysbiosis and associated health issues during space missions. https://doi.org/10.3390/life13030727

Prospects of Astrogeology and Astrobiology research in India: Ladakh as an example: This article highlights Ladakh's significance for geographers, geologists, astrogeologists, and astrobiologists, showcasing its diverse landscapes and sedimentary deposits along the Indus River. It explores potential research opportunities, from studying sedimentary processes to extremophiles in hyper saline lakes and permafrost, emphasizing Ladakh's relevance as a Mars analogue. https://www.jpsonline.co.in/index.php/jop/article/view/24

Ladakh: diverse, high-altitude extreme environments for off-earth analogue and astrobiology research: Our 2016 expedition to Ladakh, India, explored unique sites with significant astrobiological potential. These sites, ranging from glacial passes to saline lake shorelines, offer diverse and extreme environments at high altitudes. We conducted geological and environmental assessments, focusing on regolith-landform mapping for cold high passes. Using the ExoMars Mission instrument mockup HABIT, we investigated the diurnal water cycle's impact on salt deliquescence, revealing interactions conducive to habitable liquid water reservoirs. Life detection assays were also conducted to optimize biomass measurements in various environments, confirming the relevance of clays and brines as targets for Mars research on biomarker preservation and life detection. doi:10.1017/S1473550419000119

Astrobiology as a Driver to Connect India's Public, Scientists, and Space Missions : This article emphasizes the crucial role of astrobiology in inspiring both students and the public towards space exploration. It underscores the interdisciplinary nature of astrobiology, which unites scientists from diverse backgrounds and fosters collaboration in India's scientific community. Additionally, astrobiology significantly influences space exploration programs, including those of the Indian Space Research Organization (ISRO). The formation of the Indian National Space Promotion and Authorization Centre (IN-SPACe) and the growing New Space ecosystem in India are highlighted as avenues to address cost, time, and programmatic challenges associated with astrobiology missions. https://www.liebertpub.com/doi/abs/10.1089/space.2021.0041

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

- Two biological payloads have been designed for the ISRO PS4 orbital platform

- 1st payload Amity space biology experiment (ASBE-1) - Was handed for to Satellize in April 2022

Fig 1: ASBE-1 Payload and its handing over at satellize

- 2nd payload Autonomous Life growth Experiment (ALGE1) - was developed to be handed over directly through ISRO SIPO for ISRO PS4 orbital platform

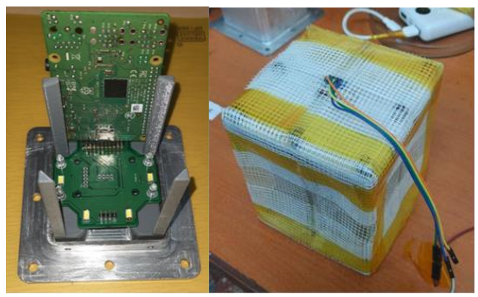


Fig 2: Electronic assembly of payload and sealed model of payload

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Earth Space Exploration Program: 10th July – 7th August 2022 (3 batches)

This expedition brought together a diverse group of Earth and Planetary scientists and engineers to work together on understanding the changing ecosystem in Ladakh and prepare for exploration of other worlds.

International workshop on Introduction to Astrobiology: 9-10th August 2022

The workshop was attended by students, researchers, and faculty members. The workshop covered the origin of life, solar system formation, habitable planets, rock formation, geology, evolution, space missions and challenges, space medicine, and group discussions on life on Mars and future policies. Its goal was to facilitate students' entry into astrobiology through informal discussions with researchers.

ISRO's START Program - Nodal Center

Amity University Maharashtra, Mumbai was recognized as a Nodal center for the ISRO's Space science and Technology Awareness Training (START) program during 20th July to 07th August 2023. 35 students from different institutes of Amity University actively participated in the program, scientific talks and contributed to many interesting and thought-provoking questions during the talk.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Amity University Maharashtra, Mumbai has started M.Sc., in Astrobiology and Space Sciences in August 2023 which is offered for the first time in India.

Title of the course	Level of the course	Total number of students
Astrobiology and Space Sciences	Master's in science	9

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

All facilities to do biological sampling is available at Amity Institute of Biotechnology. We have collaboration with Indian Institute of Geomagnetism (IIG) and Physical Research Laboratory (PRL) and are using their lab facilities, for sample elemental analysis.


Laminar Air Flow


HPLC


UV -Vis


PCR Machine


Gel documentation unit

For further details on the inputs as provided in the document, please contact

Dean of Research: Amity University, Mumbai, E mail: deanresearch@mum.amity.edu

Registrar: Amity University, Mumbai, E mail: registrar@mum.amity.edu

AMITY INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY, AMITY UNIVERSITY UTTAR PRADESH , GAUTAM BUDHHA NAGAR (NOIDA), INDIA

Website: https://www.amity.edu/aisst/

ABOUT THE INSTITUTE

AISST was established in 2008 with a vision to impart holistic education in Space Science, aircraft engineering and spacecraft avionics. The institute endeavours to provide students an industry-oriented knowledge and undertake cutting edge research in the field. The institute has extremely good laboratory facilities in Avionics, Radar and other electronics subsystems as well as a System Simulation lab with software & hardware interface. AISST is engaged in the design and development of Un-manned Aerial Vehicle and associated subsystems. AISST is also a designated industry interface for "UAV rules, guidelines and certification. At present AISST has a project for the design and development of a low earth orbit 3U-CUBESAT having a pay load capability of Automatic Identification System (AIS) for marine data collection.

FOR FURTHER INFORMATION: https://www.amity.edu/aisst/infrastructure.asp and https://www.amity.edu/aisst/

MAJOR RESEARCH DOMAINS

The Amity Institute of Space Science and Technology is dedicated to space research, working on diverse and cutting-edge areas of research. The major research domains of the Institute are**:-**

Satellite Image Processing (SAR/ Optical):

The institute is engaged in advanced research related to satellite image processing, focusing on both Synthetic Aperture Radar (SAR) and optical imagery. Researchers work on developing algorithms and techniques to enhance the quality, resolution, and interpretability of satellite imagery. Applications range from environmental monitoring and resource management to disaster response and urban planning.

Space Data Analysis:

Space data is vast and complex, comprising information from satellites, telescopes, and other spaceborne instruments. The institute conducts research in data analysis techniques to extract meaningful insights from this wealth of information. This involves studying celestial bodies, space phenomena, or even cosmic events, contributing to our understanding of the universe.

Autonomous Systems:

Research in autonomous systems for space applications involves the development of intelligent and self-operating systems. This includes autonomous spacecraft, rovers, or drones designed for exploration, observation, or data collection in space. The institute has focused on enhancing the autonomy of these systems, allowing them to adapt to unforeseen challenges and make decisions independently.

AI/ Cognitive Systems for Spacecraft:

Artificial Intelligence (AI) and cognitive systems are increasingly crucial in space exploration. The institute delves into the application of AI for spacecraft operations, navigation, and communication. This research aims to improve the efficiency and reliability of spacecraft, enabling them to perform complex tasks and adapt to dynamic space environments.

Intelligent Anomaly Detection for NGC Applications:

NGC (Next-Generation Computing) applications in space science involves advanced computational methods for solving complex problems. The institute works on developing intelligent anomaly detection systems to identify irregularities or unexpected events in space data. This research is critical for ensuring the integrity and security of space missions and data transmission.

Amity Institute of Space Science and Technology endeavors to contribute significantly to advancements in satellite image processing, space data analysis, autonomous systems, AI/cognitive systems for spacecraft, and intelligent anomaly detection for NGC applications.

LINK : https://www.amity.edu/aisst/research_publication.asp

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Project Title: AI based detection of a person based on Physiological Parameters

An increasing number of crimes goes unsolved due to criminals taking advantage of masks/ cloth. Considerable research has been carried out to examine different biometric modalities like face, iris scan and fingerprint recognition. However sometimes it may not be possible to use this contact based biological identification system. Such scenarios motivated us for designing an intelligent, non-invasive system for recognition of a person based on immutable parameters This groundbreaking system leverages AI to detect and identify individuals through their physiological parameters, ushering in a new era of human-centric applications. The name "Divya Dristhi" translates to "Divine Vision" in Sanskrit which harnesses the power of physiological parameters – the intrinsic characteristics of a person's body functions. It is based on a unique concept of fusion of data of three immutable physiological parameters, like Gait, Skeletal and Movement, with Face data and is capable of recognizing miscreants who are conducting illegal activities under disguise or hidden identity. Divya Drishti is a novel and ground-breaking Artificial Intelligence Based Human Recognition System, which can recognize a person under all possible circumstances, be it, occluded face, low-light conditions or induced abnormalities. Till date, the physiological parameters have been used individually just for clinical purposes/trials. The uniqueness of our product lies in the fact that an integrated approach is being followed wherein different physiological parameters are being correlated with each other and integrated with face data on AI based platform to recognize a subject. Our approach is an improvement in recognition system, based on data fusion and Artificial Intelligent engine i.e., Intelligent Neural Architecture. Divya Drishti, is an Intelligent inferencing system with built-in high accuracy of recognition (95% and above) and very low false alarm rate.

The technical solution includes:

(i) Intelligent Person Recognition software, with fusion of Physiological parameters and face data, driven by AI engine along with classical techniques of fingerprints etc. The software has been developed as per DOD2167A/ IEEE / Joint Services Standards.

(ii) User Interaction Software for data acquisition in field by the user: This provides a facility to enrol a person to be recognised later.

(iii) Data Collection & Analysis: It works on the information provided by street surveillance cameras or common night vision cameras.

We have tested our product with the large amount of data available online. We have approached number of law enforcement agencies for beta testing of our product. This product is suitable for law enforcement agencies and defense forces. It can also be used by large organizations to automate their systems based on human presence. This product has been developed as a project under Technology Development Fund (DRDO), for promoting Atmanirbhar Bharat scheme initiated by Government of India and has been awarded first prize in Dare to Dream 2.0 DRDO contest. The innovator has also registered a start-up named “Ingenious Research Solutions Private Limited” for taking the product to the market.

1) Project Title: AMISAT (3U- CUBESAT) : AISST is developing cubesat to acquire the indispensable technology in developing super-small satellite system. The objectives include

- Space science and engineering techniques
- Design of a mission specific sub Systems
- Integration and testing of subsystem to get 99% mission success.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

1) Software-Based:

- Pose estimation of Spacecraft for Docking: Developed software for accurate pose estimation to facilitate safe and precise spacecraft docking.
- Gait & Skeletal Analysis (for astronauts): The institute has developed software for analyzing the gait and skeletal structure of astronauts, aiding in optimizing their physical health during space missions.
- Chandrayaan-2 Data Analysis: Amity's software solutions include data analysis tools specifically tailored for processing and interpreting data from the Chandrayaan-2 mission.
- Trajectory Optimization of a Satellite: The institute has created software for optimizing satellite trajectories, enhancing mission efficiency and resource utilization.
- AI-Based Detection of Ship and Aircraft in Satellite Images: Amity's software incorporates artificial intelligence for the automated detection of ships and aircraft in satellite imagery.
- AI-Based Change Detection in Low-Resolution Satellite Images: The institute's software utilizes AI algorithms to detect and analyze changes in low-resolution satellite images, aiding in monitoring dynamic environments.
- AI-Based SAR Image Analysis: Amity's software focuses on the analysis of Synthetic Aperture Radar (SAR) images using artificial intelligence for enhanced interpretation and applications.
- Intelligent System for Exoplanet Detection: The institute has developed intelligent systems for the detection of exoplanets, contributing to the exploration of celestial bodies beyond our solar system.
- Cognitive System for Spacecraft Health Analysis: Amity's software incorporates cognitive systems to analyze and ensure the health and performance of spacecraft during missions.

2) Hardware-Based:

- Autonomous Unmanned Ground Vehicle: The Institute has designed and developed a hardware-based autonomous unmanned ground vehicle, showcasing advancements in robotic technology for space exploration and applications on Earth.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- ATAL FDP conducted on Space Data Analytics in September 2021
- Developing AmiSat, 3U cubesat

LINK : https://www.amity.edu/aisst/gallery.asp AND https://www.amity.edu/aisst/alumni_achievers.asp

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Amity institute of Space Science & Technology (AISST) conducts three programs to enable students to get into Aerospace and Space industry / organizations.

(a) B.Tech (Avionics) with Minor degree in Space Science: Designed to impart knowledge about design and development of aviation electronics for aircrafts & space crafts in line with foreign university.

(b) M.Tech. (Avionics) : Specialization in Aviation Electronics, Navigation Guidance and Control of Aircraft/Spacecraft.

(c) B.Tech (Aerospace) + M.Tech (Avionics)-Integrated. : Design to get a complete knowledge of Aircraft/Spacecraft Design, Mechanical Structures and All Associated Electronics and Control (i.e. Avionics)

(d) Ph.D. (SS&T) Part Time/Full Time

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

The institute has good laboratory facilities in Avionics, Radar and other electronics subsystems as well as a System Simulation lab with software & hardware interface.

- Lab with high end NVIDIA based computer systems for efficiently working on the graphics.
- Cleanroom facility

LINK : https://www.amity.edu/aisst/infrastructure.asp

DETAILS OF PERSONS FOR FURTHER INFORMATION

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Dr. Shivani Verma, Associate Professor, Amity Institute of Space Science & Technology email : sverma2@amity.edu, Mobile :9810308732

ARYABHATTA RESEARCH INSTITUTE OF OBSERVATIONAL SCIENCES (ARIES), NAINITAL, INDIA

ABOUT THE INSTITUTE

ARIES is an autonomous institute under the Department of Science & Technology, Govt. of India since March 22, 2004. It came into existence as the erstwhile Uttar Pradesh State Observatory at Nainital on April 20, 1954. The mandate of the institute is to promote, guide and carry out front-line basic research in Astronomy and Astrophysics, climate change, space physics, Atmospheric science and in particular to create a climate for research at the highest level by enabling individuals to work at the Institute on a full time, honorary or visiting basis, by establishing a state-of-the-art facility for basic research in observational and theoretical areas of activities of the Institute. ARIES aims to: (a) Build and operate state-of-the art observational facilities and back-end instruments to carry out frontline research in Astronomy & Astrophysics and Atmospheric Sciences, and make them accessible to the scientific community. (b) Establish a strong synergy between all the facilities at ARIES and other national and international ground-based facilities and space programs. (c) Create an engineering R&D centre to cater to in-house development, value addition and optimize performance of back-end instruments. Extend the R&D laboratories, expertise and technology to the industries and educational institutions.

KEYWORDS :

Sun, Star-formation, Supernova, Gamma-ray burst, Active-galaxies, multi messenger astronomy, Climate change, Air pollution, Trace species, Meteorology-dynamics.

MAJOR RESEARCH DOMAINS :

The Sun and related phenomena, Galactic Astronomy:, Extragalactic Astronomy, Numerical Astrophysics, Atmospheric Meteorology and Dynamics, Trace Gases Studies, Aerosols Studies, and Boundary Layer Studies.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

- **Understanding the solar corona:** The thermodynamic properties of the core of a CME that occurred on July 20, 2017, were examined using the data from ground-based instruments and space-based telescopes. Figure 1 shows the CME observed in the K-Cor, the CoMP Fe XIII 10747 Å channel, the Atmospheric Imaging Assembly (AIA) 193 Å channel, and the variation of temperature and density with height and time. The effective temperature (Teff) (obtained from Fe XIII line width eff measurements) and the temperature (TEM) of the CME core (estimated using the Differential Emission Measure (DEM) inversion technique) displayed similar variations and remained almost constant as the CME propagated from ~ 1.05 to 1.35 R⊙. The temperature of the CME core is found to be of the order of million degrees kelvin, indicating that the CME core is not associated with a prominence. Meanwhile, the density of the CME core decreased approximately 3.6 times as it moved outward. An intriguing finding of this study is that the temperature of the CME core remains almost constant despite expected adiabatic cooling due to the expansion of the CME core, which suggests that the CME core plasma must be heated as it propagates. This study concluded that the expansion process of the CME core behaves more like an isothermal process rather than an adiabatic one. The study highlights the potential of India's future multi-channel coronagraph, Visible Emission Line Coronagraph (VELC), aboard Aditya-L1. By performing spectroscopy and imaging CMEs in the inner corona, VELC could provide new insights into the evolution of CME thermodynamic properties in this region. [Sheoran et al. 2023, Front. Astron. Space Sci.].
- **Lunar occultation events:** So far, around 40 lunar occultation events have been observed with ARIES telescopes to constrain the geometry (angular size) and binarity of these sources. Figure 2 shows the lunar occultation data of two events. These observations have led to the measurement of one small-separation binary star and two stellar angular diameters. This study indicated that the lunar occultation technique can be used to detect sources down to K~9 mag with SNR = 1 on DOT. Angular diameters larger than ~ 1 milli-arcsecond (mas) could be measured with SNR above 10, or K ~ 6 mag. These numbers are indicative and

will depend strongly on observing conditions such as lunar phase and rate of lunar limb motion. None-the-less, the available statistics points toward several thousand lunar occultation events observable with ARIES telescopes and instruments. [Sharma et al. 2022, Jr. Astron. Instru.].

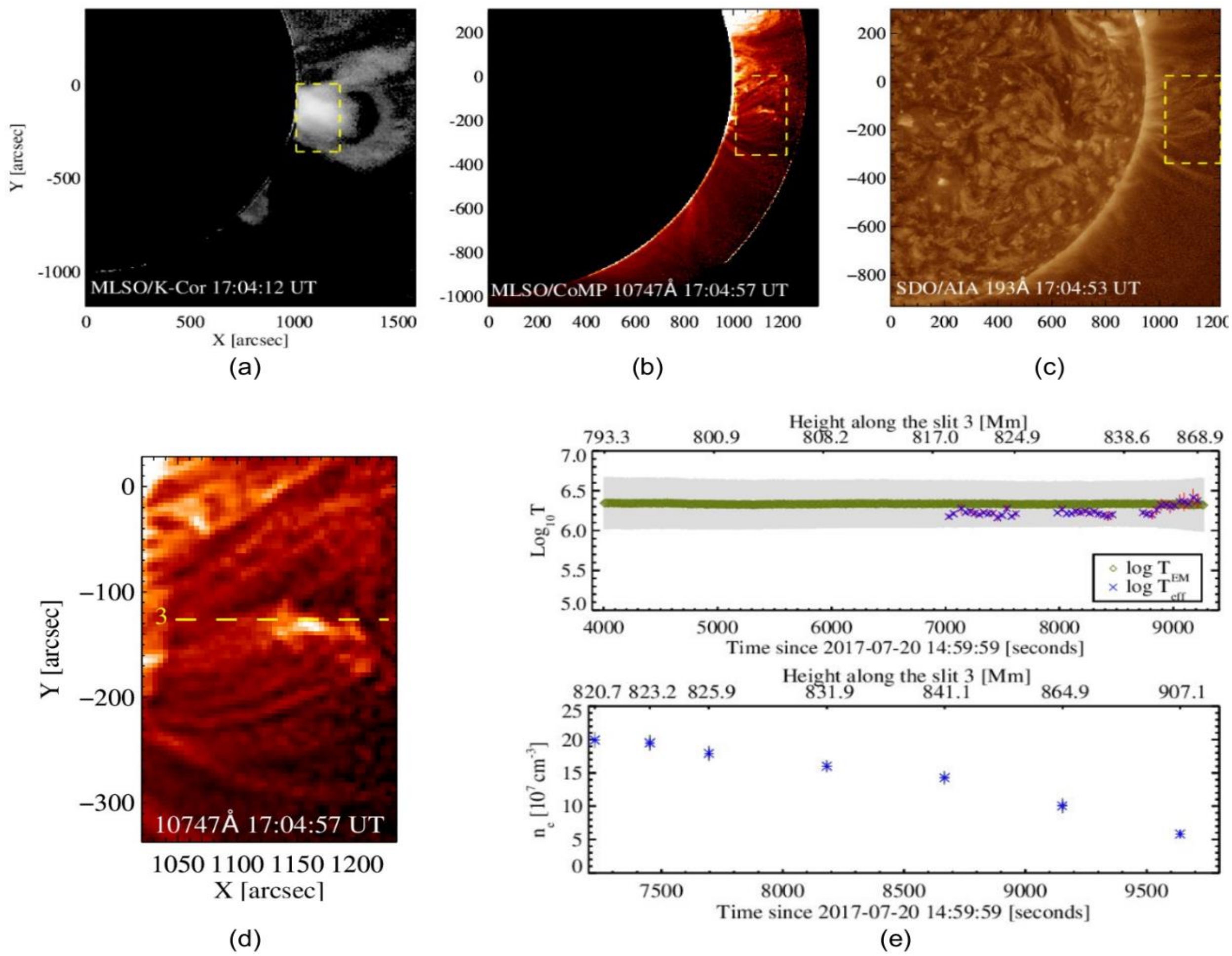

Figure 1: (a) July 20, 2017, CME observed by MLSO/K-Cor. All three parts of the CME are clearly visible. (b) MLSO/CoMP10747 Å channel image, and (c) SDO/AIA 193 Å channel image. Only the core of the CME is visible in CoMP & AIA FOV. The yellow rectangular box shows the ROI chosen for analysis. (d) The zoomed version of CoMPROI and an artificial slit 3 is shown by a yellow dashed line. (e) The evolution of log temperature and electron density with height and time.

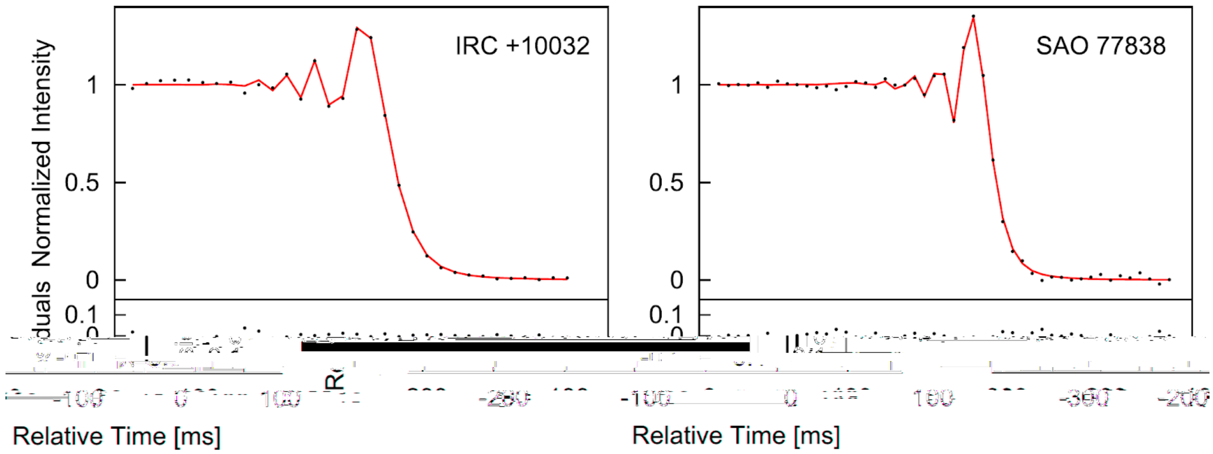

Figure 2: Lunar occultation data normalised in intensity for IRC +10032 (left) and SAO 77838 (right) along with the best fit model.

- **Time Domain Astronomy:** A detailed SED modelling of five GRB host galaxies, observed with DOT (Figure 3), using a stellar population synthesis model called Prospector, showed that generally, GRB hosts are massive with high star formation rates. The amount of dust extinction and gas in the bursts' local environment was also assessed. The extracted physical parameters of these hosts were more common to normal star-forming galaxies in the high-redshift Universe. [Gupta, Rahul, et al, (2022). Jr. Astrophy. Astron., 43 (2), 82 (15pp)].

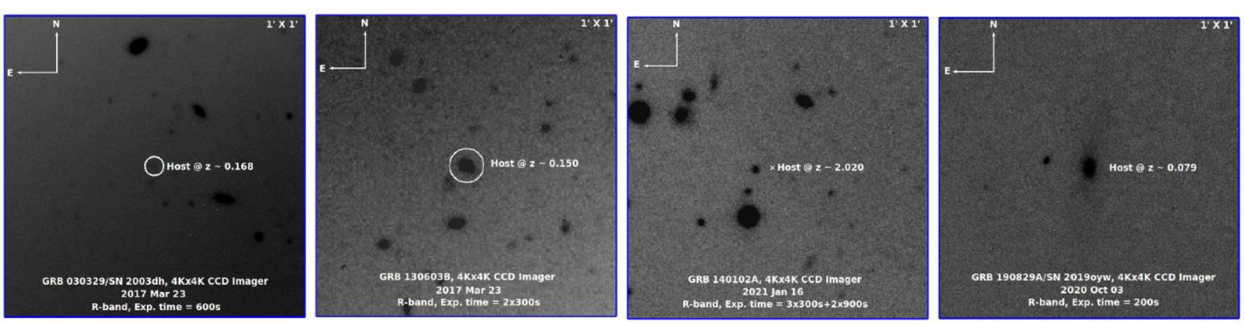

Figure 3: The R-band finding charts of the host galaxies of GRB 030329 (left), GRB 130603B (second from the left), GRB 140102A (third from the left) and GRB 190829A (right) were obtained using 4K×4K CCD imager mounted on the DOT. The position of the host galaxies in the frames is marked with circles.

- **Optical Turbulence study over the Central Himalayas using ARIES ST Radar:** Optical turbulence observations from a stratosphere troposphere radar (206.5 MHz) that is co-located with the optical telescope facilities in the central Himalayas, are used for the estimation of index structure contant C^2n. The integrated profile of C^2n and winds over about 2–20 km have been used to estimate seasonal and diurnal variation of “seeing", wavefront coherence time, isoplanatic angle and scintillation rate. The mean C^2n over the site varies from $10^{-15.7}$ to 10^{-19} $m^{-2/3}$ with the largest values in the monsoon and post-monsoon season. The best “seeing" conditions are observed in the winter and post monsoon season with median “seeing" varying from 0.39” to 0.81”. The largest contribution to the diurnal variation of “seeing" comes from turbulence at 2–5 km height region. This study is expected to have a positive impact on the optimization of the operation of adaptive optical techniques, observing time and scheduling of scientific programmes for optical telescope facilities in this region of the central Himalayas.

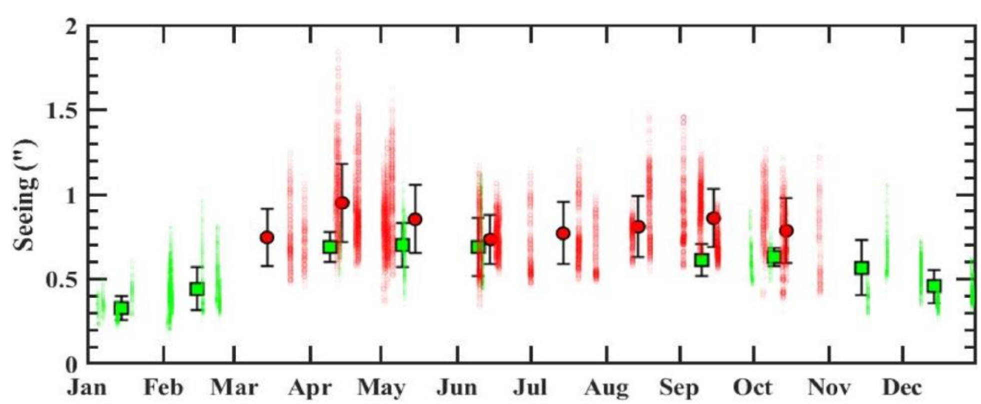

Figure 4: Monthly variations in “seeing" values estimated using ARIES ST Radar observations. Green squares denote the days of better “seeing" observations (mean “seeing" ≤0.7”) and red circles denote the days of poorer “seeing" observations (mean “seeing" > 07”).

List of Publications (January 2021 – December 2023) is given at https://www.aries.res.in/research/list-publication

INSTRUMENTS / PAYLOADS / PRODUCTS DEVELOPED / SENSORS / DETECTORS

- **4-m International Liquid Mirror Telescope (ILMT):** The 4m International Liquid Mirror Telescope (ILMT) project is a joint collaboration between ARIES, India, University of Liège, Belgium and many Canadian Universities. It employs liquid mirror technology, where the 4m primary mirror is made up of a thin film of liquid mercury. A 4k x 4k CCD camera, operating between 4000 to 11000 Å is mounted at the prime focus of the ILMT. Pointing towards the zenith, it takes observations in g', r', i' filters in Time Delayed Integration (TDI) mode resulting in a 27 arcmin field of view. It is the first optical survey telescope in the country and the survey images are used for deep photometric and astrometric studies of transients. The first light was received on 29th April, 2022 and it was formally inaugurated on 21st of March, 2023. Science observations have already commenced and the data is publicly available for the scientific community.

Figure 5: LEFT : Top view of the ILMT showing the liquid mercury mirror covered by a thin mylar film. RIGHT : A panoramic view of 3.6m DOT (left),1.4m DFOT (middle) and 4-m ILMT facility at Devasthal.

- **3.6 m Devasthal Optical Telescope (DOT):** ARIES operates India's largest 3.6 m diameter optical telescope at Devasthal as a National Facility. Ninety-three percent of the time on the telescope is guaranteed for astronomers from India whereas the remaining seven percent is guaranteed for astronomers from Belgium. The DOT facility consists of a modern 3.6 m diameter optical telescope with active optics technology, a suite of complex instruments, a mirror coating plant, and a control room. The instruments can provide astronomical observations at optical and near-infrared wavelengths catering to a wide range of astronomical topics related to solar system objects, exoplanets, stars, star clusters, galaxies, and extra-galactic sources. The 3.6 m DOT was commissioned in March 2016 and it has been put into regular operation since then. The DOT has 392 registered users from 6 different countries, including almost 200 Ph.D. students and 50 postdocs. During the reporting period, some technical up-gradations were made to the existing back-end instruments and for one instrument, a thorough on-sky science verification was performed.

- **ARIES ST Radar (ASTRAD) Facility:** A state of the art Stratosphere-Tropospheric (ST) Radar designed for operating at a frequency of 206.5 MHz and installed in the foothills of the Himalayan region at ARIES, Nainital (29.4°N; 79.2°E; ~1800 m amsl) to understand the intriguing aspects of lower atmospheric dynamics over the data-sparse region of the Central Himalaya. Such high altitude active aperture radar in the VHF band along with antenna elements over the rooftop has been built for the first time in the country . It is configured as an Active Aperture Distributed Phased Array using state of art Solid State TR module and Digital Signal Processing techniques. This system has an array of 588 Yagis of 3 elements in a circular aperture on an equilateral triangular grid arrangement. Following extensive observations, including round-the-clock observations of more than 72 hours, now this radar is operational and frontline research is being pursued in this Himalayan region. Scientists, including Ph.D. students, are welcome to submit the proposals for research utilizing the ARIES ST Radar facility to study a deep insight into synoptic processes and mesoscale systems with high vertical and temporal resolutions over the central Himalayan region.

Figure 6: A bird-eye view of ARIES ST Radar on the roof-top of the building.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- ARIES offers PhD in astronomy and atmospheric sciences. Recently, ARIES started an integrated MTech-PhD program from 2021. From January 2022-December 2023, 18 students have defended their theses and 3 students have submitted their thesis.
- ARIES scientists and engineers guide B.Sc./M.Sc./B.Tech./M.Tech/M.Phil students for their projects in astronomy-astrophysics, solar and atmospheric sciences. From January 2022-December 2023, about 100 students were guided by ARIES faculty.
- Outreach/Training: The ARIES Training School in Observational Astronomy (ATSOA) is ARIES's annual capacity building school aimed for post-graduate students in Physics/Astrophysics. The selected students are exposed to observational astronomy techniques in optical wavelengths with visits to the telescopes/laboratories located in ARIES. The school covers a series of lectures related to basic astrophysics followed by several hands-on data analysis sessions. About 60 students were trained during ATSOA 2022 and 2023.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

PhD coursework: ARIES offers coursework for PhD students only. The details of the coursework are given at https://aries.res.in/opportunities/phd-program

MTech-PhD coursework: ARIES offers coursework for Integrated MTech-PhD students in collaboration with the Department of Applied Optics and Photonics Calcutta University. The details of the coursework are given at https://aries.res.in/opportunities/imp

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

- **Optics and Aluminising workshop:** Optics section is actively involved in the instrumentation activities related to various projects in the institute. The section has various facilities and instruments for aligning, testing and integration of optical systems, including Clean Room Facility. Optical Profiler cum Phase Shift Interferometer, UV-VIS-NIR spectrometer, Laser interferometer, Reflectometer.
- **Electronics Lab:** A modern SCADA based substation system (100KVAand 400KVA) with suitable power backup from DG sets has been developed and installed at ARIES, Devasthal for providing quality electrical power to all observing facilities located at the site.
- **ESD Laboratory:** An Electrostatic Discharge (ESD) Secure RF Electronics Laboratory (Figure 22) has been established at the ARIES ST Radar (ASTRAD) facility to carry out maintenance and development work to keep the ST radar operational.

ATMOSPHERIC AND SPACE SCIENCE RESEARCH LABORATORY, DEPARTMENT OF PHYSICS, BANGALORE UNIVERSITY, BENGALURU, INDIA

Website: https://bangaloreuniversity.karnataka.gov.in

ABOUT THE LABORATORY AND INSTITUTE

The Atmospheric and Space Science Research (ASSR) Laboratory, housed in the Department of Physics at Bangalore University in Bengaluru, is actively engaged in both teaching and research in the fields of Atmospheric Physics, meteorology, space physics, and planetary physics. The Department of physics has been receiving support from the ISROs Space Science Promotion Scheme since 2010. This sponsorship aims to enhance academic and research endeavors in the fields of atmospheric and space science. Currently, there is an ongoing course in Atmospheric and Space Science that includes only a handful of optional courses for post-graduate students studying Physics. The primary research topics encompass atmospheric physics, space physics, meteorology, monsoon dynamics, remote sensing, orbital dynamics, and planetary physics.

MAJOR RESEARCH DOMAINS

The ASSR Lab focuses on a range of topics including atmospheric radioactivity, aerosols, atmospheric electricity, remote sensing, monsoon dynamics and variability, boundary layer processes, the relationship between the sun and Earth, studies on Total Electron Content (TEC), ionospheric investigations, Global Navigation Satellite Systems (GNSS), lightning effects, and the atmospheres of Mars, Moon, and Venus. The group is now focusing on the aforementioned study fields, which encompass theoretical investigations.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Observation and Modelling studies of the Atmospheric Composition of Mars

India's inaugural interplanetary mission to Mars, known as MOM, involved extensive study and observations. Concentration in CO_2 and [O] cross-over was seen at 260 km. Average daily sunspot number correlates 76% with neutral exospheric pressure. After a solar flare, energetic charged particles activated atmospheric neutrals in atmosphere, raising total and partial pressures of primary atmospheric compositions abnormally. The energy imparted helps volatiles leave the atmosphere, forming planetary coronae and expelling atmosphere into space. Initial air samples were taken from the collision-dominated zone during low solar activity. Later orbits in these regions exhibit gravity wave signals between 160-180 km, similar to MAVEN's NGIMS detections. Long-term exposure of sensors and spacecraft to solar radiation and the observational cadence caused exponential decline of volatile outgassing by up to two orders of magnitude compared to early MOM operations. Mars's lack of a global magnetic field caused significant changes in CO2 and [O] production rates, indicating direct control of solar particle radiation. Accurate modelling of the composition of the Martian thermosphere and exosphere is essential for understanding the impact of solar EUV changes associated to the Schwabe cycle in the future.

X-ray flares and CMEs in 2009's calm solar activity

Solar flares are abrupt increases in brightness that occur on the surface of the Sun and are accompanied by a significant release of energy. Flares accompanied by X-ray emission typically trigger the ejection of electrons and ions from the solar environment, known as Coronal Mass Ejections (CMEs). There is evidence indicating that the solar magnetic field is capable of altering its configuration through reconnection, resulting in the release of energy and the acceleration of solar plasma, which in turn leads to the formation of SFs and CMEs. The study used information on solar flares and coronal mass ejections from the SOHO and GOES satellites for 2009, which had very low solar activity, and the year 2002, which had fairly high solar activity. The findings suggest that specific modifications to the current mechanisms for generating SFs/CMEs are required in order to create more accurate forecast models that impact space weather conditions. The objective is to investigate the simultaneous presence and attributes of SFs and CMEs during low solar activity. Correlation between solar flare fluxes and CME speed cannot be easily determined, as it necessitates data about position and movement of active region on sun. However, utilising the CMES speed, it is feasible to retroactively determine the initial time of the occurrence at close proximity to the solar chromosphere/corona.

Possibility of radon at the top of troposphere

The MST Radar facility located at NARL, Gadanki serves as a national facility dedicated to conducting atmospheric observations. A campaign was undertaken between October 17 and 22, 2011, capturing information on the atmosphere's vertical extent from 3 to 50 km using a multi-beam system with a range resolution of 150 m. Additionally, radon measurements were made using the Alpha Guard instrument near the Earth's surface. The campaign examines how convection affects atmospheric parameter vertical profiles. The upward migration of radon, its impact on water vapour dispersion, radar reflectivity vertical structure, and vertical winds are significantly correlated. These are the first findings of a vertical wind range increase during convective activity's peak. A rise in signal intensity above 10 km indicates the upward transport of water vapour from the lower troposphere, and its structure is immediately identifiable. The diffusion of atmospheric gases exhibits an exponential reduction in concentration with increasing altitude. The activity is calculated in respect to a point source by utilizing surface emission. The vertical velocities frequently lie within the 5 m/s range, accompanied by rapid oscillations. There was a notable increase in the wind intensity, which coincided with the peak of convective activity. The Brunt-Vaisala oscillations correspond to the oscillation frequency of an air parcel in a stable environment, which is also reflected in the system. The fluctuations are usually observable due to the influence of the Brunt-Vaisala oscillations and the gravity waves in the atmosphere. The overall amplification of these alterations suggests the existence of an additional causal factor influencing the periodicity of the convective activity observed during the active period.

Linking solar activity, GCR, and ENSO to climatic variability.

Many studies have examined global and regional annual mean temperature data to identify linear temperature trends throughout climatological timescales. Most results indicate a 0.07 °C/decade increase in the 20th century. Spatial and temporal data gaps, non-uniform observing site distribution, superposition of internal/natural fluctuations at different scales with parametric feedbacks, and other fundamental concerns remain unanswered. Analyzed surface-air temperature fluctuations in India using a well-tested, verified, researched and gridded (1°x1°) daily mean temperature data set from 1970-2009. Linear trends with a 0.4 °C increase in yearly mean temperatures is assessed with varied spatial integration. Error analysis indicates less statistical errors at 95% confidence interval than linear trend-determined temperature increase. Annual mean temperature time series exhibits virtually phase coherent shifts spanning 3-5 years, with an average of ±0.4 °C. Potential factors contributing to these temperature patterns are solar activity, GCR, and ENSO. Results indicate a positive correlation of 0.33 with GCR flux and an enhanced correlation with SOI from 0 to +0.34 when a time delay of 1-year is inserted in time series of mean annual temperatures, even if no meaningful correlation is detected with the solar activity. Study comprehends connections between changes in solar activity, GCR fluxes, and El Nino-Southern Oscillation within the framework of climate variability.

Interactions between space weather and ionospheric variability at low latitudes

Grid-based Vertical Total Electron Content (VTEC) maps were generated using ground-based observation data from a network of dual-frequency GPS receivers deployed across India under the GAGAN using a real-time model. A 24-hour model run of all stations generates hourly average data and diurnal VTEC visualizations with 1°x1° latitude-longitude resolution. This real-time model can examine ionosphere fluctuations at high temporal and spatial resolutions in addition to navigation. To standardize variances under small solar activity changes in order to assess the technique's space weather detection sensitivity. VTEC has been approximated by GAGAN, and data archival is ongoing. The results show VTEC's vulnerability to space weather influences. Daily variability of VTEC in winter is ±5 TECU, or 25%, whereas variation from equatorial to anomalous latitude is around 50%. Considering only one group of stations, changes higher than 25% of the mean value could be space weather effects. Solar activity increases VTEC by 1.5-2 for every doubling of sunspot numbers, although the relative day-to-day fluctuations in the absence of any geophysical event would be similar to those during low sunspot years.

INDIGENOUSLY DEVELOPED INSTRUMENTS

Design and development of VLF receiver for Ionospheric studies

An VLF receiver is designed to tune VLF signals from 18 to 80 kHz, amplify signals that are -40 dB ± 2 dB due to noise and HF interference, and demodulate further. High Q-factor and narrow bandwidth of gyrator-based tuning circuits are its main advantages. These properties are crucial to noise and interference reduction. The gyrator-based tuning circuit has a gain of 6.00 dB and tunes to two VLF signals of 19.80 kHz and 22.20 kHz with 330 Hz and 320 Hz bandwidths and Q-factors of 60 and 61, respectively, demonstrating its precision and effectiveness in isolating frequencies of interest. Its ability to drive the signal through an ADC makes this gain significant. This cascade of precision-engineered components transforms the weak and attenuated VLF signals, suffering from noise and interference, into robust digital data ready for further analysis and decoding. The receiver is in testing mode and will be realized soon.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Students are performing PhD in Physics with topics from the atmosphere, space and planetary physics covering wide areas of problems.

1. Study of ionospheric electron content over the Indian region
2. Design and development of VLF receiver for Ionospheric studies
3. Synoptic conditions and thermodynamic indices of thunderstorms

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Department of Physics is offering elective courses in Atmospheric and Space Science for master's students with following titles:

1. Atmospheric and Space Science as elective
2. Space weather and Climate
3. Planetary Physics
4. Laboratory on Atmospheric, space and planetary physics
5. Research work in the field of atmosphere, space and planetary physics

6. Astro and Atmospheric Physics as soft-core paper
7. PhD course work papers on (i) Atmospheric Science, (ii) Atmospheric Electricity, (iii) Monsoon and Weather Prediction and (iv) Meteorology, Weather and Climate

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

The University possesses significant infrastructure, including an Automatic Weather Station, a Mini Boundary Layer Mast, and the World-Wide Lightning Location Network (WWLLN) from the University of Washington, USA. These facilities are used to continuously monitor lightning flashes in the Bengaluru region of India. India's extensive network has been enhanced with the addition of a lightning sensor from Earth Network. The GNSS receiver has been incorporated into the NARL network for the purpose of conducting ionosphere and space weather studies.

For further details on the inputs as provided in the document, please contact

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE , PILANI, INDIA

https://www.bits-pilani.ac.in/pilani

ABOUT BITS PILANI

BITS Pilani, established in 1964, and recognized as an "Institute of Eminence" by the Ministry of Education, Government of India, is a pioneer in higher education in all the major disciplines of Engineering, Sciences, Humanities, Social Sciences, Economics, and Finance. It has four modern, aesthetically beautiful, and fully residential campuses at Pilani, Dubai, Goa, and Hyderabad with state-of-the-art facilities for teaching and research. The primary aim of the BITS Pilani is to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century.

MAJOR RESEARCH DOMAINS

- Observational Astronomy – Research related to star clusters, their normal and exotic stellar populations using the multi-wavelength approach with a focus on the UV-imaging, dynamical evolution
- Cosmology – Theory of cosmological structure formation, dark energy and dark matter models
- Astrophysics – Theoretical studies of gravitational waves from isolated pulsars, pulsar glitches, gravitational physics, black hole physics
- Waveguide based Photonic Device Development
- Optical Signal Modulation and Transmission
- Nonlinear Optics and Advanced Technologies

- Free-Space Optical Communication
- System Design and Network Integration
- Optical Network Architectures
- Instrumentation and Control
- Communication Systems and Networks
- RF, Microwave, Antenna Design & Wireless Systems
- IoT and Embedded Systems
- Robotics and Autonomous Systems
- Electronic Materials, Devices, & Technology
- Digital Signal Processing
- Xplainable AI, Edge-AI/ML

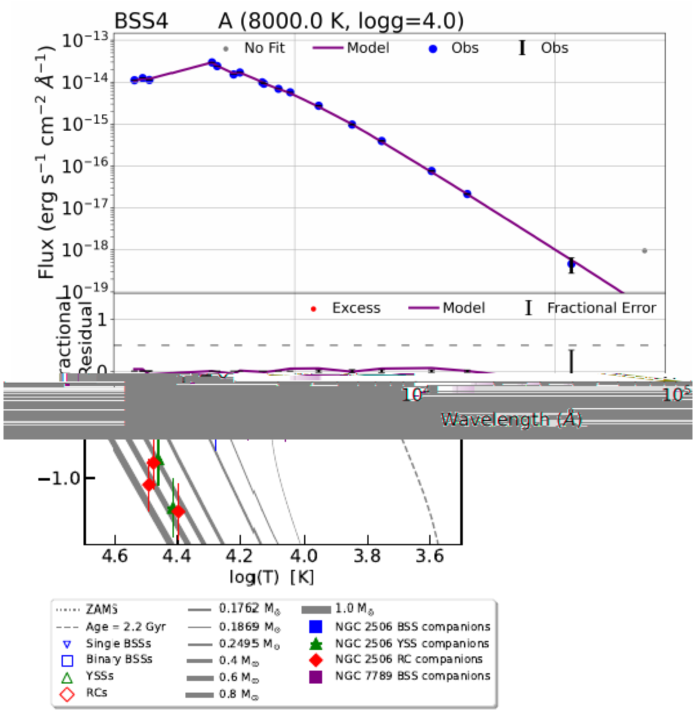
MAJOR SCIENTIFIC APPLICATIONS / RESULTS

The group led by Dr. Kaushar Vaidya of the Department of Physics at the Pilani campus is interested in understanding the formation mechanisms of the exotic stellar populations of the open clusters in particular and studying the properties of the hot stellar populations of star clusters in general. They have been using the Ultraviolet Imaging Telescope (UVIT) on board the AstroSat telescope to address these questions. Here are the highlights from their six papers published in this direction since 2022 till date.

In a 1.6 Gyr old open cluster NGC 7789, located at a distance of ~2000 pc, we study 15 blue straggler stars (BSS) that are known members of the clusters using the UVIT/AstroSat. We discover 5 BSS with UV excess that likely emanates from extremely low-mass white dwarves of masses ~0.18 solar mass. Since extremely low-mass stars cannot form from the evolution of single stars in Hubble time, this discovery provides evidence of mass transfer as the formation mechanism for the five BSS in question. This work is published in the Monthly Notices of the Royal Astronomical Society Journal (DOI 10.1093/mnras/stac207).

In another similarly aged open cluster, NGC 2506, studied with the UVIT/AstroSat, we study one more variety of exotic stars, the yellow straggler stars (YSS), which are considered to be the evolved stages of the BSS in addition to studying the BSS. In this cluster, we discovered hot companions of three BSS, two YSS, and two red clump stars.

This is one of the few open clusters in which we found normal and high-mass hot white dwarves as companions to some of these exotic stars. This led us to conclude that mass transfer in a binary, as well as the merger mechanism, are active for the formation of exotic stars in this cluster. This work is published in the Monthly Notices of the Royal Astronomical Society Journal (DOI: [10.1093/mnras/stac2421](https://doi.org/10.1093/mnras/stac2421)).



The left diagram shows a BSS of NGC 7789 fitted with a single temperature, and the right diagram shows BSS, YSS, and red clump stars and their hot companions of the cluster NGC 7789 and NGC 2506 on an H-R diagram.

As a part of this ongoing UVIT Open Cluster Study (UOCS), we examined two more open clusters, NGC 7142 and NGC 6940. In NGC 7142, we discovered two BSS, which are part of eclipsing binary systems. We derive their properties from the Transiting Exoplanet Survey Satellite data (TESS) light curves and find them to be consistent with the UV-based analysis. Additionally, we find four BSS having a white dwarf companion of masses ranging from extremely low mass to high mass. This work is published in the Monthly Notices of the Royal Astronomical Society Journal (DOI: [10.1093/mnras/stad3750](https://doi.org/10.1093/mnras/stad3750)).

In NGC 6940, we discovered a large number of blue lurker (BL) candidates. In the literature, only a handful of such stars have been discovered, a majority of them from the

UVIT/AstroSat studies. Our analysis provides strong evidence for 3 BL candidates as they are found with hot white dwarf companions. In this paper, we also find hot sub-dwarf companions of two YSS. This work is published in the Monthly Notices of the Royal Astronomical Society Journal (DOI: 10.1093/mnras/stad3887).

For one open cluster, Melotte 66, we used the Swift/UVOT data and studied the properties of the hot stellar populations. Here, out of the 11 BSS that we studied, nine appear to be single, whereas one BSS has formed via the Case-B mass transfer and the other BSS has formed via the Case-A mass transfer mechanism. This work is published in the Monthly Notices of the Royal Astronomical Society Journal (DOI: 10.1093/mnras/stac2241).

The field BSS provide a unique opportunity to test the theories for BSS formation mechanism since they provide clean samples of BSS formed via mass transfer. We answer an important question on the nature of 27 blue metal poor stars, analogous of BSS stars in clusters, using the UVIT/AstroSat data. We confirm 12 of these 27 stars are indeed BSS. Our results provide clues to understand the details of mass transfer, binary properties and chemical enrichment in these systems. This work is published in the Monthly Notices of the Royal Astronomical Society Journal (DOI: 10.1093/mnras/stad2385).

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

1. **Single Polymeric Optical Splitters: Design and Fabrication for Uniform Power Distribution**

   Development of single polymeric optical splitters focuses on achieving uniform power distribution, critical for various applications in optical communication. Design relies on beam propagation simulation software, precisely modeling light propagation within the polymeric structure. Key parameters like waveguide width, branching angles, and taper profiles are optimized to achieve the desired splitting ratio and minimize signal loss.

2. **A Prototype Relative Luminance Detector for Defense Applications**

Development of portable detector for explosive vapors utilizing relative luminance detection, where minute changes in light intensity signal on chemical coated paper in presence of explosives. The prototype is a handheld device equipped with a UV light source and a highly sensitive detectors. The light source bathes the surrounding air, and any explosive vapors present interact with the chemical on paper, subtly altering its intensity. The sensitive detector meticulously measures this minute shift, triggering an alarm if the change crosses a threshold.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Participation of the students/researchers beyond its curriculum in Space Science Research:

Team Anant at BITS Pilani, Pilani campus is a group of passionate undergraduate students working on a dream of making BITS-Pilani's first indigenously built nanosatellite.. Founded in January 2013 by three students, the team now consists of forty students from various disciplines, supervised by a panel of faculty members from diverse engineering and science disciplines. The team is currently designing and **prototyping a 3U CubeSat for vegetation mapping**. The scientific objective is to utilize the blue shift in the inflection point of the visible red wavelength. This will help to supervise the vegetation health and correlate corresponding trends in pollution due to urban growth. This, in turn, would help to model a future with sustainable urban growth without harming our diverse ecosystem. The information about the various subsystems can be found here (https://team-anant.org/otherTabs/subSystems.html).

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Title of the course	Level of the course	Intake capacity
Introduction to Astronomy and Astrophysics	Undergraduate/Masters	100
General Theory of Relativity and Cosmology	Undergraduate/Masters	70
Radio Astronomy	Undergraduate/Masters	70
Cosmology	Undergraduate/Masters	70
Astrochemistry	Undergraduate/Masters	70

Satellite Communication	Undergraduate	200
Advanced Satellite Communication	Masters	100
Antenna Theory and Design	Undergraduate	200
Embedded System Design	Masters	100
Machine Learning for Electronics Engineers	Masters	100
Testable Design and Fault Tolerant Computing	Masters	100
RF and Microwave Engineering	Masters	100
Advanced Wireless Communications	Masters	100
Optical Communication	Masters	100

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

1. **The Embedded Controller Applications Center (ECAC)** in the Department of Electrical and Electronics Engineering serves as one of the crucial center for research and development to its UG, PG, and Ph.D. students in the embedded system domain. The laboratory includes specialized facilities, equipped with the required hardware and software for embedded systems development (CPU,FPGA,GPU based systems). The lab has diverse equipment's for on-board computing system development for various applications, real-time operating system development, Hardware-software codesign, Reconfigurable system development, fault-tolerant system design, wired/wireless data acquisition and monitoring systems, anomaly detection/prediction in safety-critical systems, etc. Embedded Controller Applications Center possess capabilities to:

    1. Smart Wireless/Wired data acquisition systems interfacing for Spacecraft monitoring & testing.
    2. Development of fault-tolerant and explainable Artificial Intelligence (AI) and Deep Learning (DL) based Algorithms for space applications. Implementation of the AI/DL techniques on embedded hardware.
    3. Multi-sensor fusion techniques and gesture based activities for Human space missions
    4. Health Monitoring of Spacecraft
    5. Real Time Anomaly Detection Using AI/ML for Spacecraft applications
    6. Hardware Accelerators for spacecraft applications
    7. Real-time operating system design for spacecraft applications.

8. Intelligent Wireless system design for autonomy in spacecraft applications

2. **The optical communication laboratory** in the Department of Electrical and Electronics Engineering serves as a crucial platform for research and development for our students. The laboratory harbors specialized facilities and workbenches, equipped with instruments and tools to study distinct stages of photonic device development and system design. The lab has a diverse collection of optical fibers, each with unique properties catering to specific applications. This may include single-mode and multi-mode fibers, those can be studied to analyse their physical dimensions, dispersion characteristics, and material compositions. Testing equipment like Optical Power Meters and Source Units precisely measure fiber properties like attenuation, loss, bandwidth, and dispersion, ensuring optimal fiber selection for targeted experiments. Optical Spectrum Analyzers provide detailed analysis of the spectral characteristics of light signals, revealing information about signal quality, laser performance, and the presence of unwanted noise. Digital oscilloscopes and pulse generators evaluate the fidelity of digital signals transmitted through a system, measuring the ratio of error bits to total transmitted bits, which is crucial for assessing system reliability. Powerful software packages like OptiSim, VPIphotonics, and COMSOL enable students to virtually model and simulate the behavior of photonic devices and entire transmission systems, predicting performance metrics before physical implementation. Complex simulations often require substantial computational power.

CENTRE FOR SPACE SCIENCE & TECHNOLOGY (CSST), SCHOOL OF ENGINEERING (SOE), DAYANANDA SAGAR UNIVERSITY (DSU), BANGALORE, INDIA

www.dsu.edu.in

ABOUT CSST

Dayananda Sagar University (DSU) has established Centre for Space Science Technology (CSST) at the Kudlu Gate Innovation campus to encourage Science, Technology, Engineering and Math (STEM) for students to become involved in designing, implementing and testing a real functioning spacecraft system. As the Space Technology is a multi-disciplinary field, students from different disciplines need to team up to design and build CubeSats, which will facilitate interdisciplinary work experience, skill building, tackling complex problems and will bridge the gap between theory and application in Space Technologies. The students are encouraged to participate in Pan-India Competitions of CanSat and Drone with innovative payload ideas and other Space Technology competitions which will further help to develop important skills such as problem-solving, critical thinking, and creativity.

The CSST facility for the Students Satellite programme was inaugurated by Padmashree Prof. R.M.Vasagam on 26th October, 2023 in the presence of Honorable Dr. D. Premachandra Sagar, Vice Chairman, DSI.

OBJECTIVES OF CSST

CSST has been established with the objectives of promoting space science related activities among the students, namely:

1. Student centric satellite development programme which encompasses education, training, making of nano satellites with useful payloads
2. Conduct of orientation courses and induction training programme to student community on various space related topics

3. Students to gain hands-on experience in satellite making, testing, launch and post launch on-orbit operations
4. Students to design and develop payloads and mainframe systems for Cubesat (1U, 3U, 6U, 12U) configurations, realise the hardware with the help of Indian Aerospace Industries, test and launch the same using PSLV/SSLV Launch Vehicles.
5. Payloads for Earth Observation, Multispectral and Hyper spectral are to be developed for societal & defence applications and configured on Cubesat
6. Establishment of dedicated infrastructure & Equipment required for satellite building by students
7. Establishment of Ground Station for satellites tracking and data download
8. Creation of conducive environment for space research, IP and patents.
9. Provide Technical Consultancy and end-to-end solutions to Indian Aerospace Industries in space technology, infrastructure and facility build up for satellites making to aerospace industries as well as for space start-ups.
10. Hand-hold space start-ups to design and develop payloads for POEM (PSLV On-Orbit Experimental Module) Platform
11. Exploring the possibilities of carrying out drone related activities in CSST.
12. Offering Elective Courses on Space Technology to UG and PG inter-disciplinary engineering students.
13. Exploring the possibilities of offering an M.Tech. Course in Defence and Space Technology in DSU, based on the guidelines issued by DRDO and AICTE.
14. In the long run of three years' time frame, CSST to become an incubation centre for start-ups interested in space technology, as a Centre of Excellence in space related activities among the academia
15. Students and space start-ups to build satellites for specific user requirements and launch the same using PSLV or SSLV.

THE ROADMAP

Dayananda Sagar University to become Centre of Excellence in Spacecraft Design & Technology and bringing out Innovative Payloads for societal applications. This further creates opportunity for Publications, Patents and Space Research by DSU Ph.D / M.Tech students.

Dayananda Sagar University to become skill building in Space technology field as a part of our country capacity building and Space Incubation Centre for Start-ups in Space.

All the necessary Infrastructure like cleanroom of class 1Lakh, Mechanical Lab and Testing area has been established at Kudlu Gate Innovation Campus to facilitate students to work exclusive in Space Technology Areas. Further a Spacecraft Integration & Test Establishment (SITE) with all the facilities to make microsats and smallsats is planned at Harohalli Campus in near future. Also planned at Harohalli Campus is a Space Astronomy Lab, to encourage students towards research in Space Astronomy.

As a part of self-sustenance, Centre for Space Science & Technology offers technical consultancy services in the various areas of Spacecraft building and Payload realization. About 5 private space industries have already signed MoUs for various technical consultancy services in space domain and related activities.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Prescribed curriculum and syllabus for the following courses:

1. Title: Satellite Technology

   Level: UG (7th Semester Aerospace Engineering) and Open Elective (8th Semester)

   Intake Capacity: 40, Specialization: Introduction to Space Science & Technology

2. Practical Lab Session on RF & Microwave Engineering to 6th Semester ECE Students

   Intake Capacity: 60, Specialization: RF & Microwave Engineering

3. Practical Lab Session on Antennas Design to 7th Semester ECE Students

   Intake Capacity: 60, Specialization: Design of Antennas

4. Two day workshop on Microwave Engineering & Antenna Design organized on 8th and 9th Dec. 2023, for ECE students from 3 campuses of DSI

5. Hands-on Training and Practical Session on CANSAT for 40 students, selected for Students Satellite Programme - In Progress

6. Hands-on Training and Practical Session on Class Room Model Cubesat for 40 students, selected for Students Satellite Programme - To be initiated in March-2024
7. Hands-on Training and Practical Session on Ground Station Operation for 40 students, selected for Students Satellite Programme - To be initiated in April-2024

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE RELATED ACTIVITIES

1. ISO-08, one Lakh Class Clean Room to make up to 12 U Cubesat and microsat
2. Checkout Lab, Mechanical Lab, Inspection lab etc.
3. Ground Station and Mission Control Centre

For further details on the inputs as provided in the document, please contact:

Dr.V.K.Hariharan, Director, Centre for Space Science & Technology (CSST)

School of Engineering (SoE),Dayananda Sagar University (DSU), Kudlu Gate Innovation Campus,Bangalore - 560 114

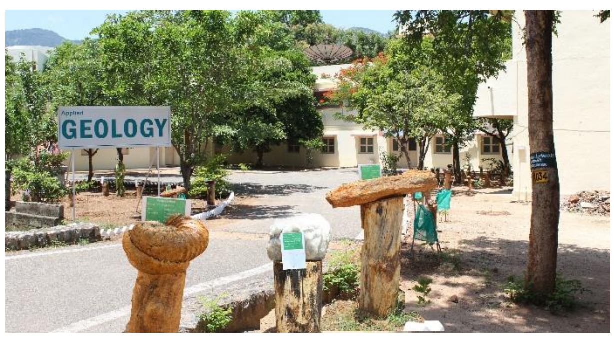
Email: vkhariharan-csst@dsu.edu.in / vkhariharanisro@gmail.com

CENTRE FOR APPLIED GEOLOGY, THE GANDHIGRAM RURAL INSTITUTE- DEEMED TO BE UNIVERSITY ,DINDIGUL, TAMILNADU, INDIA

www.ruraluniv.ac.in

CENTRE FOR APPLIED GEOLOGY, GRI-DTBU

The Institute has started the "Centre for Applied Geology" on 19th January 2012. The center is actively engaged in BSc and MSc degree programs in Geology, as well as research domains focused on mineral exploration and space science utilizing satellite remote sensing technologies. In the areas of planetary exploration, including mineralogical and lithological identification, planetary analogs as well as topographical studies of terrestrial planets like the Moon and Mars, the center has contributed significantly. The Planetary Science and Mineral Exploration projects is led by Dr. S. Arivazhagan, Assistant Professor at GRI-DTBU. Dr. S. Arivazhagan is key member to prepare the development of Lunar Soil Simulant (LSS) for Chandrayaan-2 Rover testing.



Centre for Applied Geology, GRI - DTBU

Major Research Domains

- ### Planetary science

  The laboratory has made contributions to planetary science, encompassing studies on both lunar and Mars surfaces. The focus of these contributions involves the identification of mineralogical compositions, detailed topographical mapping, and lithological analyses. This research plays a crucial role in advancing our understanding of the geological characteristics, evolutionary history, volcanism and potential resources on celestial bodies such as the Moon and Mars**.**

- **Earth exploration studies**

  The centre has made a noteworthy contributions to address the issues in the different realms of Earth. The major studies are related to the mineral and geological mapping of the surface through multispectral and hyperspectral data like ASTER, Landsat, Hyperion, PRISMA etc. In addition to that, the studies are also focused on the creation of localized spectral library to support the future ventures in Earth and Planetary based studies.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

- There are 11 articles published in reputed journals like Ore Geology Reviews, Nuclear Engineering Technology, Remote Sensing Application: Society and Environment, Elsevier – ICARUS, Research in Astronomy and Astrophysics, Journal of Indian Society Remote Sensing, Journal of Earth System Science during the period from January 2022 to December 2023.
- Best paper award 2022, Characterization of Ultramafic–Alkaline–Carbonatite complex for radiation shielding competencies: An experimental and Monte Carlo study with lithological mapping, Published in Ore Geology Reviews, Elsevier.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- Project entitled “New insights into lithological distribution of selected lunar mare regions using Chandrayan- 2 data: implication for lunar magmatism.
- Completed Ph.D thesis entitled “Remote Sensing based Topographical, Chronological, and Compositional Studies of selected Lunar Mare Basins with Akin Studies”.
- Submited Ph.D thesis entitled “Imaging spectroscopic and geochemical studies of selected mafic and ultramafic complexes and their associated mineral resources in parts of Tamilnadu”

GOVERNMENT GIRLS' GENERAL DEGREE COLLEGE, KOLKATA, INDIA

Website: https://www.govtgirlsekbalpur.com

ABOUT THE COLLEGE:

Government Girls' General Degree College stands as the fourth government college for girls in West Bengal. Its strategic location, close to the National Library, Calcutta University Alipur Campus, and other key areas in southern Kolkata, ensures convenient access for numerous students seeking higher education. The college's inception represents a commendable effort to advance women's higher education in West Bengal, responding to a persistent demand for a women's college in the locality over the course of a decade.

Faculty members from all fourteen departments, spanning arts, science, and commerce, tirelessly dedicate themselves to delivering high-quality academic guidance to students and contributing to their holistic development.

Education stands as a powerful catalyst for societal transformation. In this era, recognizing the pivotal role of women's empowerment in national progress is imperative. Many developing nations, including India, prioritize advancing women's higher education. The Government of West Bengal aligns with this mission, exemplified by the establishment of the Government College for Girls in Ekbalpur, Kolkata. This institution aims to elevate education quality across all societal segments, fostering academic, intellectual, moral, and cultural growth. Future plans encompass cultivating educational excellence, fostering scientific acumen, organizing knowledge-enhancing events, promoting holistic student development, and offering opportunities to marginalized girls for educational advancement.

MAJOR RESEARCH DOMAINS:

In the vast realm of space exploration, Government Girls' General Degree College stands out with a focus on three main research domains: X-ray astronomy & astrophysics, and the ingenious application of machine learning in the realm of data science.

Figure 1: Government Girls' General Degree College

➢ X-ray Astronomy & Astrophysics:

Research at the forefront of X-ray astronomy and astrophysics at Government Girls' General Degree College delves deep into understanding the intricacies of accretion physics in specially Low Mass X-ray Binaries (LMXB) and blazars. The focus extends to unraveling the dynamics of these binary systems, deciphering the origin of Quasi-Periodic Oscillations (QPO), and exploring the structural and evolutionary disparities between Z-type and Atoll sources. Leveraging state-of-the-art satellites like *AstroSat, NICER,* and *NuSTAR* allows for a detailed examination of the evolutionary processes within these systems. The research also delves into the captivating realm of theoretical model development, reconciling observed data to elucidate intricate phenomena such as lag and root mean square (rms) behavior. Additionally, current investigations revolve around modeling the observed polarization in NSLMXB, addressing recent trending topics in the field.

➢ Machine Learning application:

On the other hand, The Government Girls' College research group actively engages in this frontier, unraveling the mysteries of the cosmos with unprecedented efficiency and precision using Machine Learning techniques. In the realm of Astrophysics, ML revolutionizes data handling. Algorithms, like neural networks, sift through vast datasets, identifying patterns, and extracting meaningful insights. From classifying celestial objects to predicting cosmic events, ML accelerates the pace of discovery.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS:

❖ **Spectral and Timing evolution of GX 340+0 along its Z-track**

We have presented the results obtained from the spectral and timing analysis of the Z source GX 340+0 using *AstroSat*'s SXT and LAXPC data. Throughout the observation, the source traversed the entire Z-track, allowing for the study of spectral evolution across Horizontal, Normal, and Flaring branches, as well as hard and soft apexes. The spectra are more aptly described by a blackbody component and a hot Comptonizing corona with a varying covering fraction, rather than a disc component. The Comptonized flux and covering fraction monotonically decrease along the track, while the blackbody component exhibits non-monotonic variations, giving rise to the Z-track behavior. Rapid timing analysis reveals a prominent Quasi-Periodic Oscillation (QPO) at approximately 50 Hz in the HB, HA, and upper NB, with a 6 Hz QPO observed in other branches. The fractional root mean square (r.m.s) of the QPOs increases with energy and displays soft lags in all branches except SA and FB. Our interpretation suggests a model where two spectral parameters, such as blackbody radius and covering fraction, vary at the QPO frequency with a time delay. (*Accepted for the publication in Monthly Notice of Royal Astronomical Society*)

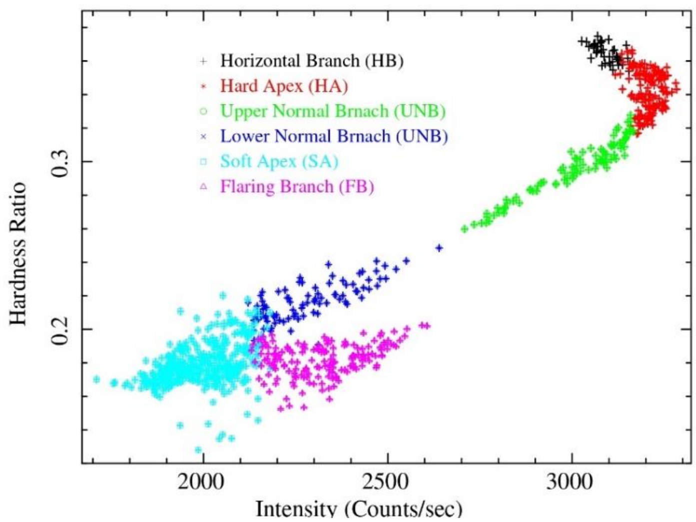


Figure 2: Hardness Intensity diagram with specific branch division

❖ *AstroSat*-NICER Observations of the Neutron Star Low Mass X-ray Binary 4U 1702- 429

We conducted a comprehensive analysis of the broadband spectral and timing characteristics of the atoll source 4U 1702−429, utilizing data from *AstroSat* and the Neutron Star Interior Composition Explorer (*NICER*). The source consistently exhibited a soft state in both instances. Analyzing multiple datasets collected at yearly intervals, we performed spectral analysis based on the source's position in the hardness ratio diagram. The joint spectral analysis within the 0.7-20 keV range revealed a robust reflection signature in the spectra, supported by the high ionization parameter. The use of the relxill routine confirmed a strong reflection feature with nearly four times the solar abundance of Fe. Temporal analysis (3-20 keV) disclosed a kHz Quasi-Periodic Oscillation (QPO) in one observation, while another in the same state showed no kHz QPO but a prominent hump at 8 Hz. Examining rms and time lag variations with energy highlighted differences in their radiative origins.

❖ **Spectral-timing studies of KHz QPOS observed by *AstroSat***

We present a systematic spectral-timing analysis of the kHz QPO in the neutron star low mass X-ray binaries observed by AstroSat. Here we have detected four (4) sources with the upper kHz QPOs in the power density spectrum in the 3-20 keV energy range and we have been able to obtain correlated time lags and fractional r.m.s as a function of energy. Out of the 4 sources we have focused on the sources 4U 1636-536 and 4U 1728-34. The data of the different observations of the sources using SXT and LAXPC has been analysed and strictly simultaneous spectral analysis reveals a clear presence of the Fe line in the spectra. More detailed studies reveal for the first time a strict correlation between the QPO frequency and photon index of the spectra as well as between the iron line width and photon index which further indicates a correlation between iron line width and the QPO frequency. Detailed timing analysis shows an appearance of a hump around 30 Hz which gets prominent as the source reaches the softer end of the HID along with the presence of the upper kHz QPOs with frequency varying from 600-900 Hz. Further study of the increasing r.m.s and soft time lag behaviour gives an indication of single coronal region while hard lag indicates an existence of multiple coronal region.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Govt. Girls General Degree College offers under graduate programme in basic sciences. We encourage students to increase their knowledge in space science and technology by conducting a series of seminars, workshops apart from their core disciplines.

One of the project students (Funded by ISRO), Mr. Suchismito Chattopadhyay has been registered as a Ph.D. student of the University of Calcutta under the guidance of Dr. Soma Mandal. The title of his Ph.D. thesis is "*Study of X-ray timing properties of Neutron Star Low Mass X-ray Binaries*". He has published his research work in the Monthly Notices of the Royal Astronomical Society.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY:

University of Calcutta offers Astronomy and Astrophysics course as a discipline specific subject in the under graduate level.

For further details on the inputs as provided in the document, please contact **Dr. Soma Mandal, Associate Professor & Head, Dept. of Physics, Govt. Girls' General Degree College, soma2778@gmail.com**

GURU GHASIDAS VISHWAVIDYALAYA, BILASPUR
KONI, BILASPUR, CHATTISGARH, INDIA

Website: www.new.ggu.ac.in

ABOUT THE INSTITUTE

Guru Ghasidas Vishwavidyalaya (GGV), a Central University, located at Bilaspur (Chhattisgarh), India. GGV is an active member of the Association of Indian Universities and Association of Commonwealth Universities. Being situated in a socially and economically challenged area, the university is appropriately named to honor the great Satnami Saint Guru Ghasidas Baba (born in 18th century). GGV aims to offer and strengthen innovative academic programs in emerging interdisciplinary areas of Science, Social Sciences and Humanities with quality assurance so as to contribute to the growth of the knowledge base of the university in particular and academic in general. The goal of the University is to provide value based holistic education that will lead to the growth and development of a community better equipped to serve the mankind. Mission of GGV is to promote the academic excellence through state-of-the-art undergraduate, postgraduate, and Doctoral Programs, as well as working in collaboration with National and International Institutions/Universities/Industries to enhance academic, professional, and research capacity

MAJOR RESEARCH DOMAINS

Under the leadership of Prof. Parijat Thakur, the following research programs in the area of the space science are being carried out at the Department of Pure and Applied Physics:

- **Black Hole X-ray binary (BHXRB):** Our main focus of this domain is to understand the accretion mechanism surrounding the stellar-mass black holes and the disk/corona geometry. Transient nature and variability in the X-ray emission make the black hole X-ray binaries ideal targets to understand valuable insights into the properties of black holes, as well as the complex interplay between black holes and their stellar counterpart.

- **Neutron Star X-ray Binary (NSXRB):** We are working on the Quasi-Periodic Oscillations (QPOs) generated by the surrounding of Neutron Star, which helps to understand the origin of the QPOs and may probe the General Theory of Relativity. Furthermore, we are working on the thermonuclear outburst originated by the surface of the Neutron Star, which may provide an insight into the Neutron Star.
- **Extra-solar Planets:** Extra-solar planetary science is a new and burning field of research in astronomy and astrophysics. We are working on transiting Jupiter sized extra-solar planets, also known as hot-Jupiters. Our main objectives are:

➔ Improving the estimates of physical and orbital parameters

➔ Refining the transit ephemeris required for future space missions

➔ Study the transit timing variation (TTV) of extra-solar planets to search for the possible presence of Additional Planet and to test the theoretical predictions of Orbital Decay and Apsidal Precession phenomena in the known extra-solar planetary systems.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

In the field of BHXRB, we perform comprehensive temporal and spectral analysis of the newly discovered X-ray transient MAXI J1803–298 using an AstroSat target of opportunity observation on 2021 May 11 during its outburst. The source was found to be in the hard-intermediate state. We detect type C quasi-periodic oscillations (QPOs) at the frequencies of ~5.4 and ~6.3 Hz along with a sub-harmonic at ~2.8 Hz in the 3–15 keV band. The frequency and fractional rms amplitude of the QPO in the 15–30 keV band are found to be higher than those in the 3–15 keV band. We find soft lags of ~3.8 and ~6.8 ms for the respective QPOs at ~5.4 and ~6.3 Hz, whereas a soft lag of ~4.7 ms is found at the subharmonic frequency. The increase in the soft lags at the QPO frequencies with energy is also observed in other black hole transients and attributed to the inclination dependence of the lags. The rms energy spectra indicate the power-law component to be more variable than the disk and reflection components. We find a broad iron line with an equivalent width of ~0.17–0.19 keV and a reflection hump above ~12 keV in the energy spectrum. Based on the X-ray spectroscopy and considering the distance to the source as 8 kpc, the estimated mass (~8.5–16 $M_\odot$) and spin ($a \gtrsim 0.7$) of the black hole suggest that the source is likely to be a stellar mass Kerr black hole X-ray binary. The detail of this research work is as under:

"AstroSat View of the Newly Discovered X-Ray Transient MAXI J1803–298 in the Hard-intermediate State" 2022, *ApJ,* 933, 69 (DOI:10.3847/1538-4357/ac7154).

In the field of extra-solar planets, we have analyzed 58 transit light curves of TrES-3b and 98 transit light curves of Qatar-1b, observed by the Transiting Exoplanet Survey Satellite, plus two transit light curves of Qatar-1b, observed by us, using a ground-based 1.23 m telescope. To increase the baseline of transit observations for decade, the best-quality light curves taken from the Exoplanet Transit Database and the literature were combined with those new light curves. Using the precisely determined midtransit times from these light curves, we obtained refined orbital ephemerides, with improved precision, for both hot Jupiters. From the timing analysis, we find indications of the presence of transit timing variations (TTVs) in both systems. Since the observed TTVs are unlikely to be short-term and periodic, the possibility of additional planets in orbits close to TrES-3b and Qatar-1b is ruled out. The possible causes of long-term TTVs, such as orbital decay, apsidal precession, the Applegate mechanism, and line-of-sight acceleration, are also examined. However, none of these possibilities are found to explain the observed TTV of TrES-3b. In contrast to this, line-of-sight acceleration appears to be a plausible explanation for the observed TTV of Qatar-1b. In order to confirm these findings, further high-precision transit and radial velocity observations of both systems would be worthwhile. The detail of this research work is as under:

"*Revisiting the Transit Timing Variations in the TrES-3 and Qatar-1 Systems with TESS Data"*, 2022, AJ, 164, 198 (DOI: 10.3847/1538-3881/ac91c2).

In addition to above work in the area of extra-solar planets, we have also performed transit timing variation (TTV) and transmission spectroscopy analyses of the planet HAT-P-37b, which is a hot Jupiter orbiting a G-type star. Nine new transit light curves are obtained and analyzed together with 21 published light curves from the literature. The updated physical parameters of HAT-P-37b are presented. The TTV analyses show a possibility that the system has an additional planet that induced the TTVs amplitude signal of 1.74 ± 0.17 minutes. If the body is located near the 1:2 mean-motion resonance orbit, the sinusoidal TTV signal could be caused by the gravitational interaction of a sub-Earth-mass planet with mass of 0.06 $M_\oplus$. From the analysis of an upper-mass limit for the second planet, a Saturn-mass planet with an orbital period less than 6 days is excluded. The broadband transmission spectra of HAT-P-37b favors a cloudy atmospheric model with an outlier spectrum in the B filter. The detail of this research work is as under:
"*The Transit Timing and Atmosphere of Hot Jupiter HAT-P-37b",* 2022, AJ, 163, 77 (DOI: 10.3847/1538-3881/ac416d).

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

The Department of Pure and Applied Physics offers dissertation project work for the students of B.Sc. (Physics) and M.Sc. (Physics) to give them the insights into the various research aspects in the area of Astronomy and Astrophysics. The Department also offers the Ph.D. Degree program in the field of Astronomy and Astrophysics.

- Awarded Ph.D thesis entitled **" Exploring the Environment of Accreting Black Hole with X-ray Binaries"**
- Completed Ph.D. thesis entitled **"Investigating Close-in Extra-solar Planetary Systems through Photometric Follow-up of their Transits"**.

Also, there are three more Ph.D. students are currently working in the field of Astronomy and Astrophysics. The title of thesis are as under:

- **"Probing Black Hole X-ray Binaries with Spectral and Temporal Studies"**
- **"Probing the Neutron Star X-ray Binaries with Spectral and Timing Analysis"**
- **"Probing the Close-in Extra-solar Planetary Systems through Transit Observations"**

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

In our esteemed university, we have prescribed Astronomy and Astrophysics as project work for the final year students of B.Sc. (Physics) and M.Sc. (Physics). We also offers Ph.D. degree program in Astronomy and Astrophysics, especially High Energy Astrophysics (X-ray Binary) and Extra-solar Planets.

Level of the Course	Intake capacity	Subjects of specialization in Space Science and technology
B.Sc. (Physics)	4	Basic Astronomy and Astrophysics, especially Photometry and light curve generation.
M.Sc. (Physics)	4	Basic Astronomy and Astrophysics, especially X-ray Binary and Extra-solar planets
Ph.D. (Physics)	8	Astronomy and Astrophysics

INDIAN CENTRE FOR SPACE PHYSICS, KOLKATA, INDIA

http://csp.res.in

Main building at the Integrated Campus

A few exhibits at the Space Hall of the Museum of Astronomy and Space Science which includes a 1:2 model of Wright Brothers' airplane and various International and National Satellite models. Over 1200 rare and unique exhibits are displayed at the Museum.

ABOUT THE INSTITUTE

The Indian Centre for Space Physics has shifted to its new Integrated Campus on the Eastern Bypass prior to its beginning of Silver Jubilee which started on 8th December, 2023. Apart from its major research activities, which include producing 45 PhDs in various branches in Astronomy, Astrophysics and Space Science, it continues to carry out outstanding public outreach program. The museum construction activity culminated in its inauguration by Astronaut Rakesh Sharma, Ashoka Chakra on the 27th October, 2023.

Astrobiology and Astrochemistry

ICSP created a new frontier in Astrochemistry when Chakrabarti and Chakrabarti first proposed that during the collapse of any generic molecular cloud the in-falling gas will continuously create more and more complex molecules and towards the end, a significant amount of biomolecules such as glycene, alanine, aldehydes, glucose etc. could be produced. This work is now universally recognized in various form and several pre-cursors of these bio-molecules have actually been detected. Further work comprising of realistic hydrodynamics and chemical evolution of rotating gases with extended chemical reaction cross-sections is in progress.

High Energy Astrophysics

Matter in compact binaries often behave counter-intuitively. It is long believed that matter from high mass X-ray binary system, the normal companion ejects matter in the form of winds which is accreted by the compact companion such as the black hole. Thus the accreted mater is supposed to have a low average angular momentum throughout the disk and in presence of some viscosity only a small Keplerian disk could be formed on the equatorial plane. However, in the low mass X-ray binaries, it is believed that the whole accretion is through the Lagrange point and thus the disk is large and always super-Keplerian, unless a significant viscosity transports the angular momentum to make the whole disk just Keplerian. However, our 3-dimensional numerical simulations indicate that for ALL the ratios of M1/M2, the net accretion flow is ALWAYS sub-Keplerian if there is very little viscosity. This justifies the Two-Component Advective Flow or TCAF model where the sub-Keplerian flow encloses high viscosity equatorial Keplerian disk in low mass X-ray binaries.

Facility and activities at IERCOO, Sitapur, West Midnapore, WB, India

The IERCOO/ICSP facility located at about 80km from Kolkata includes a 0.6-meter telescope, the largest in eastern India. A VLF signal monitor runs for 24X7 for ionospheric research. Apart from the observatory, dining etc. there is a 40 capacity hostel at this campus Dhruva. School and college students conduct scientific visits to the campus, engage in sky-watching through optical telescopes and attend lectures.

Photometry of supernova SN 2023ixf using Vasistha, the ICSP 0.6m telescope

The supernova SN 2023ixf data was analyzed through various observations, detecting early signs of highly ionized gases. The burst of energy caused a shift in colors and temperature, suggesting that it broke through a dense material cloud before exploding.

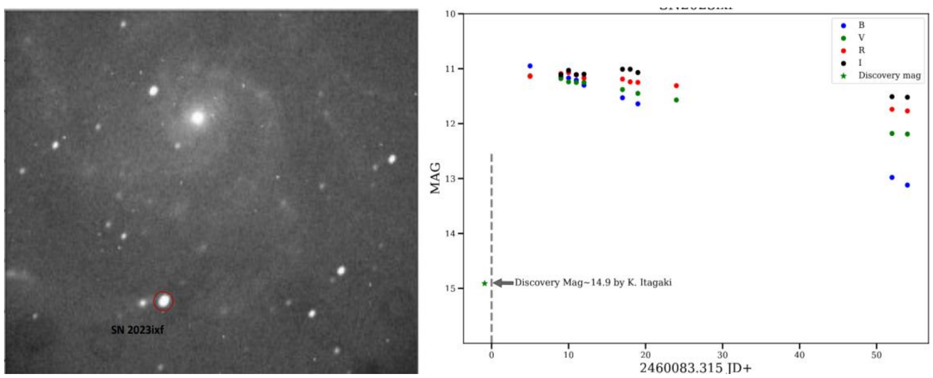
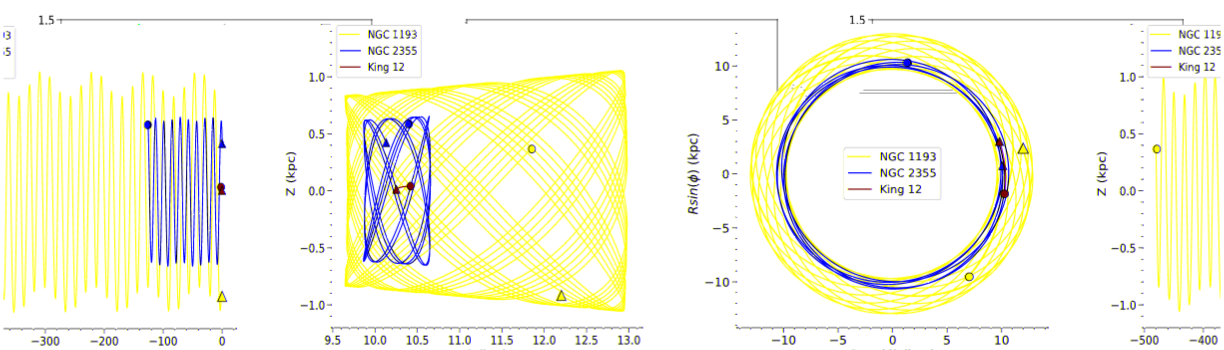


Image of supernova SN 2023ixf taken by ICSP 0.6-meter optical telescope (left) and the respective light curve (right).

Orbital study of open clusters

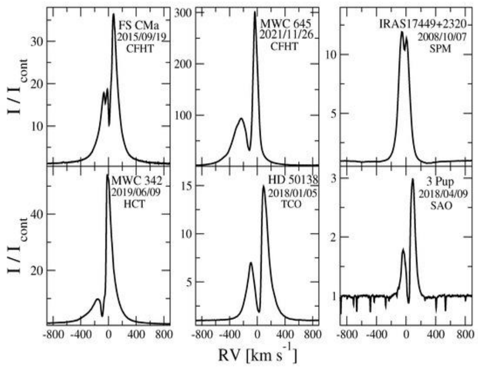
We studied the dynamics of the three clusters in the Galaxy by deriving their orbits with the help of the Galactic model given by Allen & Santillan (1991).



Galactic orbits of NGC 1193 (cyan), NGC 2355 (red), and King 12 (green) depicted in side, top, and Z-direction motion panels. Triangles and circles represent the birth and present-day positions of the clusters.

Finding Binary Systems with the B[e] Phenomenon

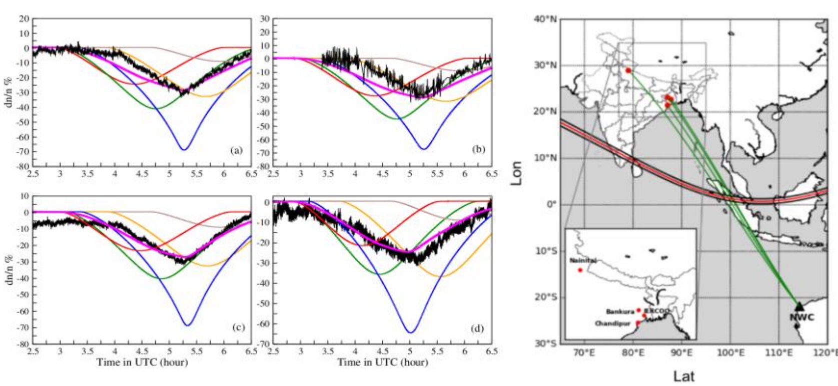
We explore FS CMa-type stars, characterized by the B[e] phenomenon. Emission-line spectra and infrared excesses indicate B-type stars with circumstellar dust. We investigate if dusty clouds result from historical events or ongoing material exchange between stars. Challenges in detecting the second star exist due to the intense light from the primary star. Observed changes in light patterns, notably in stars like MWC 728 and AS 386, provide insights into the evolution of these binary systems.



Hα profiles of some FS CMa group objects with strong emission-line spectra

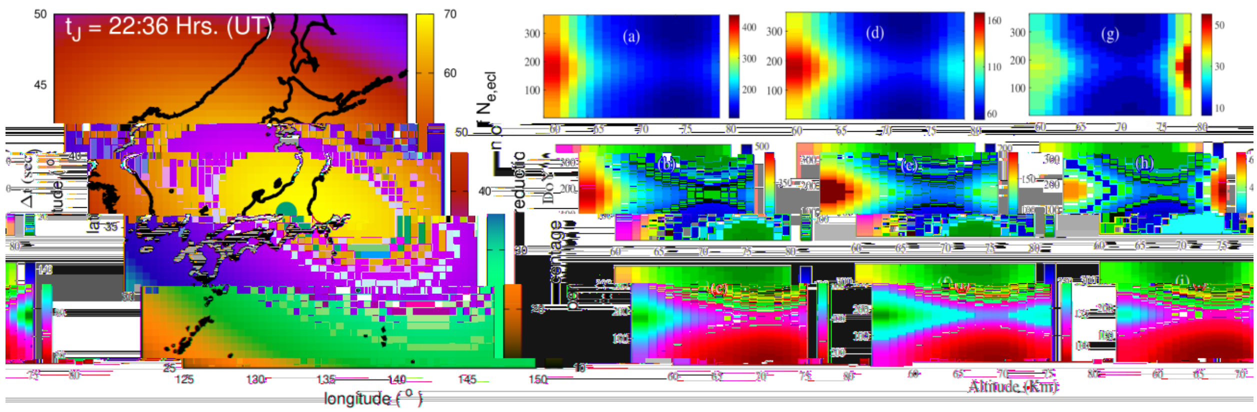
Ionospheric research using Very Low Frequency Radio Waves

We have investigated the lower ionospheric response to the Annular Solar Eclipse (ASE) of December 26, 2019, by analyzing VLF phase modulation as observed from four different locations in India during the campaign organized by the Indian Centre for Space Physics (ICSP), Kolkata.



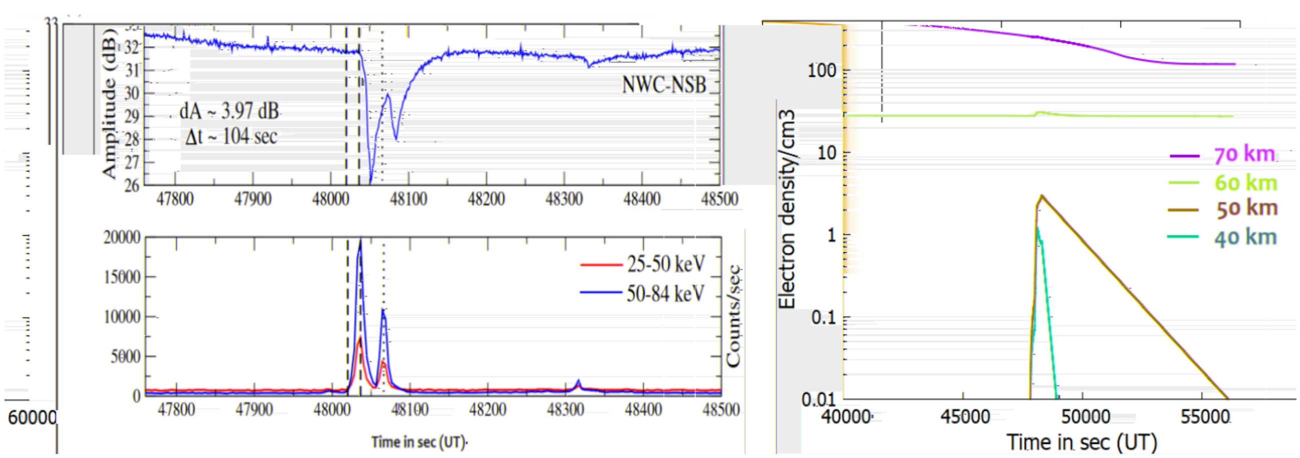
Variation of the electron density fluctuation obtained from the chemical model at five different locations across the signal propagation path with the average variation represented by a pink *curve and those from the VLF for the signal paths (a) Bankura, (b) Chandipur, (c) Sitapur, and (d) Nainital*

Changes in VLF reflection heights during the eclipse and hence perturbed electron density fluctuations over the paths are estimated from the phase modulation and compared with that obtained from an in situ theoretical chemical model using the solar obscuration.



Spatial variation of D-region electron density profile over Japan during Annular Solar Eclipse 2012 as obtained from numerical modeling and VLF signal observations (left side) (Basak et al., 2023). Altitude profile of response delay of D-region ionosphere for X, M and C classes of solar flares (right side) (Chakraborty et al., 2022)

We have performed in situ modeling of ionization-electron density modulation and VLF perturbation due to the effect of a strong Gamma-ray Burst (GRB), which occurred on 9 October 2022. We have been using the GEANT4 Monte Carlo simulation, ion-chemistry model, and LWPC code.



The STIX (Solar Orbiter) X-ray light curve (bottom-left) of the GRB, corresponding VLF modulation at NWC-NSB path (top-left), and calculated electron density values at various heights (Right)

INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU, INDIA

Website: www.iiap.res.in

ABOUT THE INSTITUTE

Indian Institute of Astrophysics is a premier institute devoted to research in astronomy, astrophysics and related physics. It is an autonomous institution under the Department of Science and Technology, Govt. of India. Established in 1971 and headquartered in Bengaluru, it traces its origin back to 1786 to an observatory set up in erstwhile Madras. IIA now runs five field stations. The Indian Astronomical Observatory in Hanle, Ladakh, operates the Himalayan Chandra Telescope and GROWTH-India Telescope working in optical and IR, and hosts two Cerenkov gamma ray telescopes, along with centres in Leh and Merak. The Vainu Bappu Observatory in Kavalur hosts a number of optical telescopes including the 2.34-m Vainu Bappu Telescope. Kodaikanal Solar Telescope, which has one of the oldest continuous records of the Sun in the world, is celebrating its 125th anniversary in 2024. Gauribidanur Radio Observatory has a number of low frequency telescopes mainly to study the Sun. The CREST campus hosts the M.G.K. Menon Laboratory for Space Sciences, which delivered the UVIT and VELC space payloads for AstroSat and Aditya-L1 respectively and also houses the IIA-TMT Optics Fabrication Facility for the Thirty Meter Telescope project. The CREST Campus also has the remote observation facility for the HCT in Hanle.

IIA has scientists working on all aspects of the sun, stars, galaxies, cosmology, and instrumentation. It runs a vibrant astrophysics Ph.D. program with Pondicherry University, an integrated M.Tech.-Ph.D. program on astronomy instrumentation with Calcutta University, as well as internships and project positions to train the astronomers of tomorrow.

MAJOR RESEARCH DOMAINS

IIA scientists and engineers undertake research in every domain of astronomy, astrophysics, and instrumentation. Some of these are described below, with the caveat that the line dividing astronomy and space sciences cannot be said to be well defined.

1. Solar physics and Space weather

Solar astronomers at IIA study the solar cycle, solar flares and coronal mass ejections, coronal heating problem, acceleration of solar wind, MHD simulations, and helioseismology, using multi-wavelength data from various ground and space based instruments from India and globally.

Space weather research at IIA includes the study of propagation of Coronal Mass Ejections and solar wind, prediction of geo-effectiveness of solar storms and space weather, and also solar variability on earth-radiation budget and studies of aerosol optical and radiative properties. Data from the Visible Emission Line Coronagraph (led by IIA) on Aditya-L1 will further boost this area of study.

2. Astrophysics with space telescopes

Scientists at IIA routinely use UVIT onboard AstroSat as well as other space based telescopes for research on star formation in galaxies, stellar evolution and binary star mass transfers, galaxy interactions, AGNs and galaxy feedback, etc.

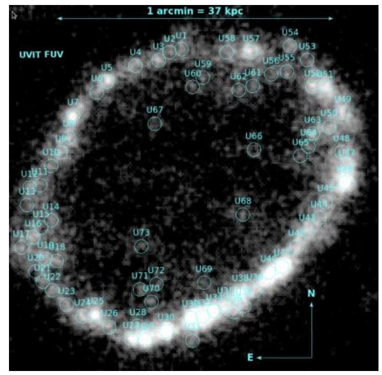
3. Space payload instrumentation

The UltraViolet Imaging Telescope (UVIT) onboard AstroSat, and the Visible Emission Line Coronagraph (VELC) onboard Aditya-L1 were assembled and tested at IIA CREST Campus with substantial support from ISRO. A Class 10 Clean Room developed for VELC integration as well as thermal, vacuum, and vibration testing facilities are available at MGK Menon Lab for Space Sciences at CREST.

4. Small payloads development

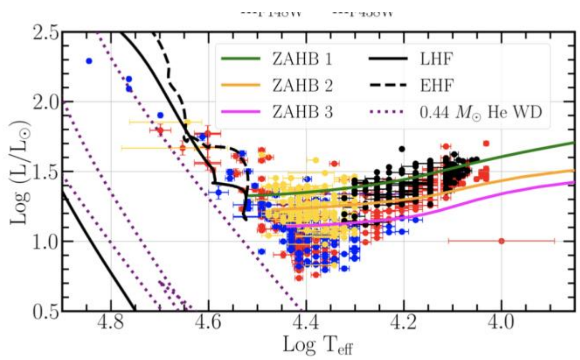
A group is involved in development of small low-cost payloads mainly for UV astronomy, including low cost subsystems like the StarberrySense star sensor which was launched on POEM onboard PSLV-C55.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS



1. Star formation history of Cartwheel Galaxy: The authors find that the UV-selected regions in the spokes trace the star formation triggered by the passage of the expanding wave. The range of ages of the ring stellar populations supports a scenario where some of the stars formed in the wave in the past were dragged along it to the current position of the ring. The bulk of the FUV emission comes from non-ionizing stars with a range of ages $\sim 20 - 150$ Myr (Reference).
2. Extremely low mass white dwarf companions to blue straggler stars: UV data were used to identify extremely low mass White Dwarfs as companions to Blue Straggler stars, blue metal poor stars, etc in many star clusters and other fields.
   a. E.g. a WD (15000 K, radius 0.17 $R_\odot$, luminosity 1.40 $L_\odot$, mass range of 0.19-0.20 $M_\odot$) companion to a blue straggler star in NGC 362, suggesting their formation via the Case A/B mass-transfer mechanism (Reference).
   b. 27 field metal poor stars (Reference) and 4 stars in M 67 (Reference).
   c. Star cluster NGC 6791 was found to have a variety of stellar (pre-)remnants, such as sdBs, sdAs, and ELM white dwarfs, that are by-products of binary evolution, likely to be post mass transfer binaries (Reference).

3. Discovery of Blue Lurker Stars: Discovery of four blue lurkers with low and extremely low-mass white dwarf (ELM WDs) companions in the Galactic globular cluster NGC 362, the first such in a globular cluster (Reference).

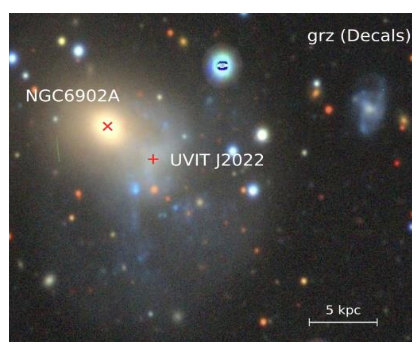


4. UV observations of Omega Centauri: FUV study of ω Cen reveals that the HBs bluer than the knee point in the FUV- optical CMD and the WDs are fainter in the FUV by about ~0.5 mag than canonical expectations and they find that at least five sub- populations with three He-rich ones are needed to explain the observed HB CMDs. (Reference).

5. UVIT study of Centaurus A: Positive AGN feedback in Cen A was studied with UVIT. By modelling the observed colours, the star-forming sources in the Outer region have an age between 25–344 Myr with a median age of 64 Myr, and similarly 4–277 Myr with a median age of 48 Myr for the Inner Region. A catalogue of UV sources likely associated with Cen A was created and observations support jet induced star formation in Cen A. (Reference).

6. Globular Clusters UVIT Legacy Survey (GlobULeS): 8 GCs were studied under the AstroSat/UVIT Legacy Survey program. FUV data was used to detect stellar populations of 11 GCs comprises 2,816 Horizontal Branch (HB) stars (190 Extreme HB candidates), 46 post-HB (pHB), 221 Blue Straggler Stars (BSS), and 107 White Dwarf (WD) candidates. Analysis suggests that FUV-optical plane is the most sensitive to He abundance variations in the HB. (Reference).

7. Discovery of a large diffuse galaxy: UVIT and other data were used to discover a nearby large, diffuse galaxy that shows star formation, UVIT J202258.73-441623.8 at a redshift of 0.00980±0.00018 lying in the foreground of NGC 6902A, which is mistakenly classified as an interacting galaxy. This is an unique



example of triggered star formation in a diffuse galaxy, resulting in the growth of its inner stellar disk (Reference).

8. A Triple AGN in the NGC 7733–7734 Merging Group: nuclear emission from the galaxies in the interacting pair NGC 7733–NGC 7734 was studied using data from UVIT and other telescopes. The galaxy pair NGC 7733–34 shows evidence of a third component, which has Seyfert-like emission. Hence, the galaxy pair NGC 7733–34 forms a triple AGN system. (Reference).

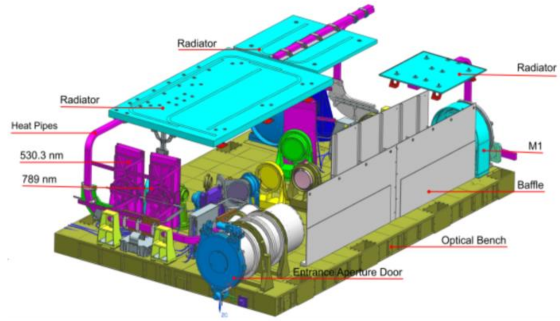
9. Discovery of diffuse emission in planetary nebulae: Several planetary nebulae ranging in morphology from bipolar to wide and diffuse, and in various states of ionization, have been mapped with UVIT. The major unanticipated discovery with UVIT has been the detection of previously undetected, cold, fluorescent, H2 gas surrounding some planetary nebulae. (Reference).

INDIGENOUSLY DEVELOPED INSTRUMENTS, PAYLOADS, AND DETECTORS

1. UltraViolet Imaging Telescope (UVIT) onboard AstroSat

The Ultra Violet Imaging Telescope (UVIT) on Astrosat provides flux calibrated images of the sky at a spatial resolution of ~1.5” in two ultraviolet channels, FUV (1200-1800 A) and NUV (1800-3000 A), simultaneously with ~0.5 degree FOV. Simultaneous imaging is also done in the VIS (3500-5500 A). The ultraviolet range of 1200 - 3000 A, and visible range of 3500 to 5500 A would be covered through the use of broad and narrow band filters. UVIT was developed at MGK Menon Lab for Space Sciences at IIA CREST. (Reference: Kumar et al 2012).

2. Visible Emission Line Coronagraph (VELC) onboard Aditya-L1



VELC on Aditya-L1 is an internally occulted solar coronagraph with simultaneous imaging, spectroscopy and spectro-polarimetry channels capable of imaging the corona from 1.05-3.0 $R_\odot$ with high pixel resolution of 2.5 arcsec and cadence of 3 Hz. Spectroscopic observations will be carried out in emission lines centered at 5303 Å [Fe XIV], 7892 Å [Fe XI] and 10747 Å [Fe XII]. Spectro-polarimetric observations will be carried out in the emission line centred at 10747 Å [Fe XII]. A special Class 10 Clean Room was built at MGK Menon Lab for Space Sciences at IIA CREST to assemble and test VELC before delivery. VELC was made with substantial support from ISRO. (Reference: Prasad et al 2017; Singh et al 2011)

3. StarberrySense Star Sensor onboard POEM / PSLV-C55

A star sensor for astronomy and small satellite CubeSat class missions was developed using commercial/off-the-shelf (COTS) components and was flown on POEM on PSVL-C55. The sensor cost less than 10% of those available in the market and was based on the single-board Linux computer Raspberry Pi. (Reference: Chandra et al 2022)

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Several students at IIA are pursuing research in basically two aspects:

(a) Developing designs for various payloads (star sensors, scanning spectroscopy in FUV, and future 1 m UV-Optical telescope called INSIST) to study astronomical sources in wavelengths that are not accessible to ground-based facilities and

(b) Study astronomical sources using data from space observatories launched by India (ASTROSAT, Aditya-L1) and those operated by others for their Ph.D. degree.

Additionally, IIA also trains graduates who are taken as research trainees in developing data simulators and data reduction pipelines. Some recent Ph.D. thesis being undertaken or completed in these fields since 2020:

1. Multi-wavelength Study of an extra-galactic recurrent Nova in M31
2. Shell region in the North-Eastern SmallMagellanic Cloud: Star formation history, tidal effects and kinematics using AstroSat and Gaia
3. Panchromatic study of star clusters: binaries, blue lurkers, blue stragglers and membership
4. Scatter Studies on Visible Emission Line Space Coronagraph onboard Aditya-L1 Mission"
5. UV stellar populations in Globular Clusters: Horizontal Branch morphologies and Blue Straggler Stars
6. Multiwavelength studies of star formation in nearby galaxies.
7. Spatial heterodyne spectrometer and associated instrumentation for ground and space observatories.
8. Development of UV astronomical instruments for balloon and space payloads.
9. Ultraviolet Space Instrumentation and Studies of Astro- nomical Objects
10. Development of Detectors for Space Missions and Balloon Flights
11. Characterizing Image Quality of Solar Ultraviolet Imaging Telescope On Board Aditya L1-Mission and Long-term Study of The Sun

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

IIA offers Astronomical Technique courses to its Ph.D. students as well as students under the JAP and those enrolled in Pondicherry University for M.Sc and Int. M.Sc programs. Under this course, IIA teaches topics related to Space science and technology, especially the detectors and the type of telescopes used. The courses offered are:

1) JAP Course AA 362 - Radiative Processes in Astrophysics
2) JAP Course AA 363 - Fluid Mechanics and Plasma Physics
3) JAP Course PH217 - Fundamentals of Astrophysics
4) IIA Course - Numerical and Statistical Physics

5) JAP Course AA 365 - Galaxies and Interstellar Medium

6) JAP Course AA 372 - General Relativity and Cosmology

7) IIA Course -- Astronomical Techniques

8) IIA Course -- Research Methodology

(G) Laboratories and Facilities Available for Space Instrumentation

1. M.G.K. Menon Laboratory for Space Sciences, CREST

The M.G.K. Menon Laboratory for Space Sciences, set up at the Centre for Research & Education in Science & Technology (CREST, IIA), for integration and calibration of space payloads and space qualification of components. These include:

1. Clean room with international space instrumentation standards (500 sq m) with Class 10 (ISO 4), Class 100, Class 1000, Class 10K, & Class 100K (ISO 8) as per FED 209E (ISO 14644), including contamination control for uv optics, seismic isolation, and vacuum calibration.
2. Thermal and vacuum chamber made of SS 304, with 1 m dia and 2 m length, pressure of a millionth of a mbar, temperature -85 to +250 ºC, and turbo molecular and dry scale vacuum.
3. Vibration testing facility with armature diameter of 440mm, usable frequency range of 5 2000 Hz, max (sine) acceleration of 100 g, nominal Force of 6000 kgf (sine and random) and 12000 kgf (shocks)

2. UVIT Payload Operation Centre

The Payload Operation Centre for the UltraViolet Imaging Telescope (UVIT) onboard AstroSat was established at IIA in 2015 and is involved in routine UVIT health monitoring and science data processing, and development of software for this purpose. Apart from detecting and solving any instrument related problems as they arise, the POC also supports users of UVIT data and develops tools for AstroSat proposal submission.

3. VELC Payload Operation Centre

The POC for VELC was established at IIA Headquarters in 2023 and is currently operational. Its function is to obtain Level 0 data from ISRO and process it to higher level data that will be sent back to ISSDC for dissemination.

For further details on the inputs as provided in the document, please contact Niruj Mohan Ramanujam; Scientist - E; niruj.mohan@iiap.res.in

INDIAN INSTITUTE OF GEOMAGNETISM, NAVI MUMBAI, INDIA

Website: iigm.res.in

ABOUT THE INSTITUTE

Indian Institute of Geomagnetism (IIG) is a leading institute of research functioning under the Department of Science and Technology (DST), Government of India, with its headquarters at New Panvel. It operates three regional centres: the Dr. K.S. Krishnan Geomagnetic Research Laboratory in Prayagraj, the Equatorial Geophysical Research Laboratory in Tirunelveli and the North-East Geophysical Research Laboratory in Shillong. In addition, it maintains 12 magnetic observatories nationwide to monitor the geomagnetic field. IIG conducts basic and applied research in Geomagnetism and allied fields, including Space and Atmospheric Sciences and Solid Earth Geomagnetism. These research areas cover a wide range of phenomena, from the surface of the Sun to the interior of the Earth. Recently, the Institute has extended its research activities to planetary ionosphere-magnetosphere systems. It continues to maintain the renowned Colaba-Alibag magnetic observatories (Figure 1), which have a heritage of over 182 years of continuous geomagnetic field observations. IIG also supports a World Data Centre (WDC) for Geomagnetism, the only international centre for geomagnetic data catering to the needs of scientists in South Asia. Over the past two years, IIG has continued to strengthen its global presence. Its scientists are involved in multiple collaborations with scientists across the world, contributing to the advancement of geomagnetic research on a global scale.

Figure 1. Photograph of one of the functional units of the Alibag Magnetic Observatory.

MAJOR RESEARCH DOMAINS

- **Space weather research**: Space weather is an extremely important aspect of space science due to high dependence of modern society on satellite technology for navigation and communication. The solar-terrestrial interactions and associated phenomena like geomagnetic storms, sub-storms, energetic particle dynamics etc. are extensively investigated by IIG scientists using a global network of ground and satellite observations. The ultimate aim is to develop a prediction model to assess the impact of space weather phenomena on Earth's space environment with wide ranging practical applications.

- **Atmospheric / Ionospheric Research**: IIG scientists make use of a network of radio and optical remote sensing instruments spread across India to probe and understand a variety of atmospheric and ionospheric phenomena. The objective of this research is to understand the dynamical and electrodynamical coupling of various regions of the Earth's atmosphere-ionosphere system. One research component that has immediate practical application is the study of the dynamics of ionospheric irregularities, which are capable of causing degradation of radio signals by imposing phase and amplitude scintillations.

- **Terrestrial and Planetary Magnetospheric / Space Plasma Research**: The magnetospheres of Earth and other planets offer a natural laboratory to study the dynamics of space plasma waves/instabilities and their role in particle acceleration/deceleration processes. At IIG, a team of modellers/theoreticians are working from the past few decades in the field of space plasmas and their work has been well recognized by world scientific community. High resolution electric and magnetic field, and particle observations on the terrestrial and deep space plasmas from past and present space missions are also used in the ongoing research conducted by IIG in these areas.

- **Polar research**: IIG has been an active participant in almost all Indian Scientific Expeditions to Antarctica since 1981. Within IIG's research domains, polar research is crucial to understand the charged particle precipitation at high latitudes and field-aligned currents, global electric circuit, secular variation of geomagnetic field, locations of geomagnetic poles and their variations, crustal deformation in the polar region etc. IIG has contributed to each of these research areas with its team of students and scientists. A number of experiments are being conducted by IIG scientists at the Indian Antarctic stations, Maitri and Bharati, besides participating in Arctic Expeditions, to address the research problems.

- **Instrument Development**: Motivated by the in-house development of proton precession magnetometers with 0.1 nT accuracy, IIG has recently achieved capabilities of developing Overhauser magnetometers in-house. With a modified design, an Overhauser magnetometer is now part of scientific payloads proposed for a sounding rocket experiment that will also include a pair of electric field probes and a Langmuir probe.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Space Weather

- The Ensemble Kalman Filter (EnKF) method has been adopted by IIG researchers for accurate forecasting of geomagnetic activity, crucial for real-time applications, after validations during severe geomagnetic storms.
- The ionospheric delay, often caused by irregularities and equatorial plasma bubbles, impacts trans-ionospheric radio communication. These bubbles, indicating a decrease in total electron content (TEC), can be detected using mathematical algorithms or visually from TEC values. However, these methods have limitations. To address this, machine learning techniques, specifically the Random Forest Method (RFM), were tested and proved effective in detecting TEC depletions, particularly in the Indian low-latitude region.
- During the St. Patrick's Day storm on March 17, 2015, a significant depletion of ionospheric plasma was observed near the sunset terminator. This depletion severely impacted long-distance high frequency radio wave communications, reducing the usable HF spectrum by over 50% and creating large areas where signals could not be received.

- In another study, the effects of G1-class geomagnetic storms on 3 and 4 February 2022 were analyzed. These storms led to the loss of 38 of 49 SpaceX satellites due to enhanced neutral density. The analysis revealed increased O/N2 and depleted TEC over American low-latitudes, significant morning-noon electron density reductions over southern mid-high latitudes, and a peak in equatorial electrojet on 4 February due to sub-storm related magnetospheric convection.
- IIG researchers have reported a significant and rapid change in the geomagnetic field on ground, indicating potential Geomagnetically Induced Currents (GICs), during the great storm on March 31, 2001. The sudden drop in solar wind density at the front boundary of a magnetic cloud caused a sharp decline of ~350 nT in just 5 minutes at the Indian equatorial station, Tirunelveli. This could pose a risk to electric power systems. The study suggested that the prompt penetration of strong electric fields and ionospheric currents at the equator played a key role in these changes.
- The South Atlantic Anomaly (SAA), a weak spot in the geomagnetic field over South America and the South Atlantic Ocean, allows magnetospheric particles to penetrate to deeper altitudes, lowering the inner boundary of the radiation belt. Over the last 120 years, the SAA's magnetic field has consistently decreased, causing particles of energies 100 keV-50 MeV to move closer to Earth at the rate of km/year. This indicates that the deepening of the geomagnetic field over the SAA will have significant implications for surface instruments and satellites operating in this region.

Terrestrial and Planetary Magnetosphere

- One of the studies pursued recently modelled the development of the ring current, a westward circulation of energetic ions around the Earth, during geomagnetic storms. The model suggests that intense westward ring current can form low and high magnetic field regions (dent and hump) in the Earth's magnetosphere, affecting the altitudinal reach and mirror point of energetic particles. A decrease in ground magnetic field similar to that observed during the historic Carrington event is possible with a peak ring current strength of 20–30 MA.

- Another study examined four distinct substorm events, focusing on the interplay between IMF Bz and sudden impulses. The findings suggest that a strong pressure pulse or large IMF By can influence substorm onset location, particularly when IMF Bz is near zero.
- The variations in ion flux during substorms in the inner magnetosphere were studied, focusing on the effects of substorm-induced magnetic field dipolarization on O^+ and H^+ ion flux. Using data from the Van Allen Probes, an enhancement in ion flux in the 1–50 keV energy range following substorm onset, with a particular dominance in the 20–50 keV range, was reported. The study finds that the O^+ ion flux increases more significantly than the H^+ ion flux in this energy range. The results also highlight a correlation between enhanced oxygen fluxes and interplanetary magnetic field, solar wind velocity, and the auroral electrojet index.
- Another study used seven years of data from the Van Allen Probes to analyze the occurrence of electromagnetic ion cyclotron (EMIC) waves under different geomagnetic conditions. The findings show that EMIC wave occurrence is not solely determined by a specific geomagnetic activity index but varies significantly during different storm phases. The study reveals that EMIC waves occur 2.9 times more often during geomagnetic storms than during non-storm times, with the majority of storm time EMIC waves occurring during the recovery phase. However, the highest occurrence rates are during the pre-onset phase. The study also notes that wave amplitudes are evenly distributed across different Magnetic Local Time (MLT) sectors during all geomagnetic conditions.
- Another study analyzed 450 solitary wave pulses observed by the NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft's Langmuir Probe and Waves instrument on February 9, 2015. These pulses, varying in magnitude and duration, are dominant in the dawn and afternoon-dusk sectors at an altitude of 1000-3500 km. The study suggests that these pulses are ion-acoustic solitary waves, generated by drifted ion and electron populations in the Martian magnetosheath. This is the first study to model these solitary wave structures in the Martian magnetosheath (Figure 2).

- IIG researchers explored the kinetic theory of low-frequency electrostatic waves in the lunar wake plasma, which consists of kappa electrons, kappa-beam electrons, protons, and doubly charged Helium ions. This research was motivated by observations from the Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS) mission. The study identifies these electrostatic waves as ion-acoustic waves, with frequencies matching those observed in the lunar wake. The analysis suggests that low-energy electron beams, although not apparent in observations, are necessary to excite these low-frequency wave modes.

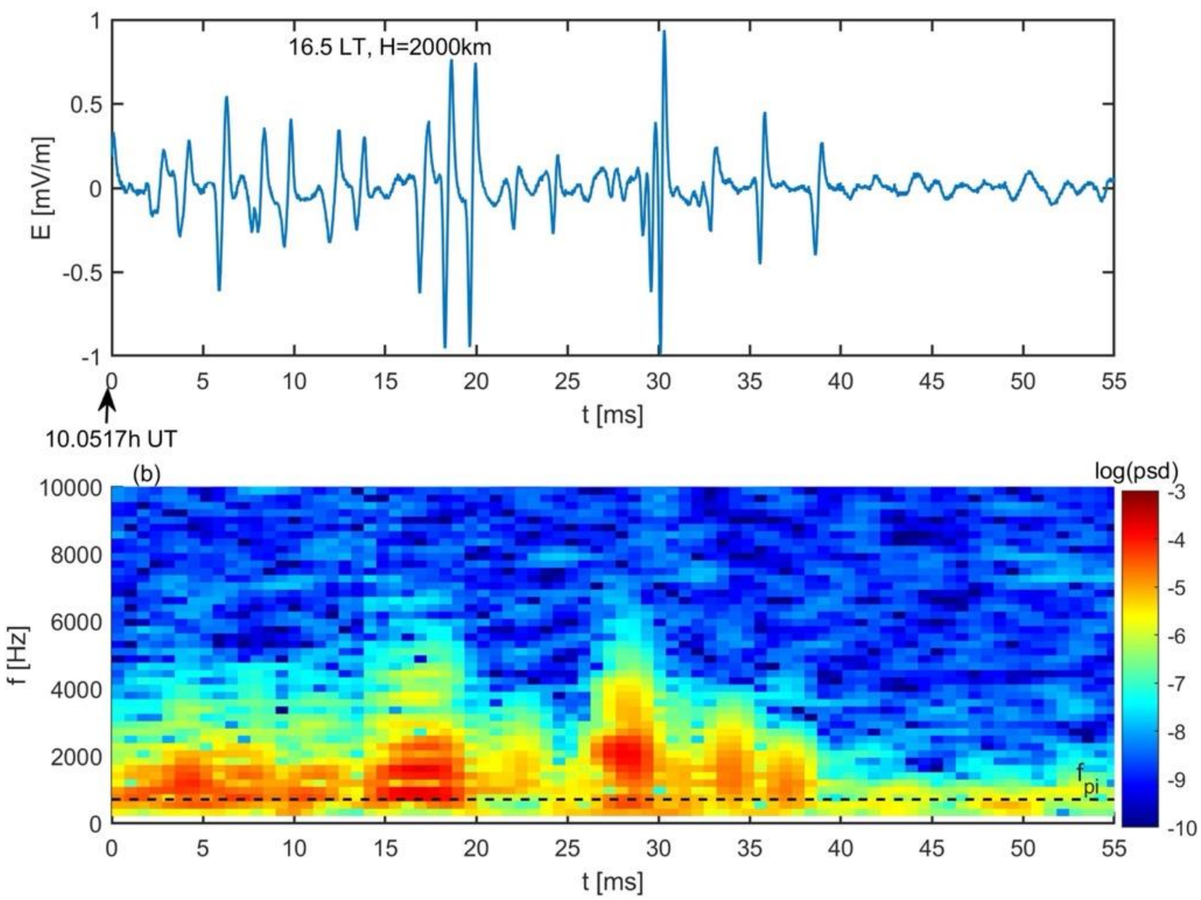


Figure 2: An example of a series of bipolar electric field pulses observed by the LPW instrument on 2015 February 9 is shown in panel (a) and its spectrogram is shown in panel (b). Time is in milliseconds after 10.0517 UT hr. The plotted electric field is the y- component of electric field (E_y) recorded in spacecraft coordinate system. The ion plasma frequency, f_{pi} is shown by the black dotted horizontal line in the lower panel.

- High-frequency plasma waves in the Martian magnetosphere was focus of another study that used electric field data from the MAVEN mission. The research provides evidence of two distinct wave modes occurring around the electron plasma frequency. These waves were observed when MAVEN crossed the magnetopause boundary into the magnetosheath region, exhibiting either broadband or narrowband characteristics. The narrowband waves had spectral peaks above the electron plasma frequency, while broadband waves had peaks below the electron plasma frequency and displayed an 8-14 ms periodic modulation.

Polar Sciences

- A detailed analysis of EMIC waves, crucial for space weather research, observed at the Antarctic station, Maitri, from 2011–2017 was carried out. It was found that EMIC waves predominantly occur in the lower frequency range (0.12–1 Hz), and their occurrence patterns are influenced by parameters like auroral electrojet (AE index) and solar wind pressure. EMIC waves with frequencies > 1 Hz primarily occur in the early morning hours, linked to preceding magnetic activity, while the effect of solar wind pressure and the AE index is noticeable for waves with <1 Hz. About 90% of these waves coincide with a decrease in relativistic electrons in the outer radiation belts.

Atmosphere-Ionosphere Coupling and Dynamics

- The Mw 7.8 and Mw 7.7 earthquakes on the East Anatolian Fault in Turkey on 6 February 2023 caused near-field coseismic ionospheric perturbations (CIP) due to acoustic waves from vertical crustal movements. Notably, CIP periods were longer for the first earthquake, with amplitude variations not fully explained by existing factors. Numerical experiments showed that these variations arose from interference of waves from multiple sources along the fault. Furthermore, amplitudes of CIP from strike-slip earthquakes were typically lower than those from dip-slip earthquakes.

- The focus of another study on the lithosphere-atmosphere-ionosphere coupling has been on the ionospheric perturbations caused by the Rayleigh waves during the Mw 7.4 9 March 2011 Sanriku-Oki and Mw 9.0 11 March 2011 Tohoku-Oki earthquakes. This attempt was aimed at accurately determining the detection altitudes of these perturbations, which is challenging due to the integrated nature of GPS-recorded TEC. To overcome this, 3D ray tracing of acoustic waves generated by Rayleigh waves was used along with realistic GPS station-satellite geometry, enabling the computation of actual detection altitudes. The study also revealed the potential for detecting these perturbations at different altitudes based on varying satellite geometries.

- The impact of the 26 December 2019 solar eclipse on the equatorial and low latitude ionosphere over Indian and Southeast Asian longitudes was investigated. Using a combination of ground and space-based observations, the findings revealed significant variations in electron density and thermospheric cooling. Notably, a strong sporadic E layer was observed during the eclipse maximum, and satellite traces were detected indicating the presence of short-period gravity waves. TEC data analysis revealed a decrease of 30-40% on the eclipse day for multiple stations and identified wave-like structures with periodicities of 18-24 minutes. Satellite observations confirmed an increase and decrease in hmF2 and NmF2, respectively, aligning with ionosonde observations. Temperature profiles demonstrated a decrease in the lower E regions and an increase in the upper E regions.
- During a special observational campaign in December 2018, an All-Sky Airglow Imager at Silchar, India, captured two simultaneous mesospheric fronts propagating orthogonally. An additional mesospheric front was observed two days later. The fronts were characterized using temperature and OH intensity measurements from the SABER instrument onboard the TIMED satellite. While one front resembled a mesospheric bore, the others did not meet all the necessary criteria. The study also noted the modulation of the OH emission layer by the mesospheric front.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

- One of the notable indigenously developed instruments is the Overhauser magnetometer, which was designed to measure the Earth's magnetic field with high precision. Associated electronics for this magnetometer are also developed in-house. Recent focus has been on miniaturizing the sensor and electronics packages to suit the payload constraints of space missions. Another significant instrument development has been on the electric field probe, which is designed for deployment on sounding rockets.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- IIG conducts basic and applied research in Geomagnetism and allied fields like Solid Earth Geomagnetism/Geophysics, Magnetosphere, Space and Atmospheric Sciences. IIG has several active research groups involved in theoretical, experimental, and observational work. The Institute has a modern laboratory for design and fabrication of instruments used in Geomagnetism and allied fields. In collaboration with various Universities along the length and breadth of the country, IIG offers Doctoral Programme in Geomagnetism and Allied Fields pertinent to studies of Space and Atmospheric sciences and Solid Earth.

- IIG has been engaged in capacity building activity for many years in space science and research. Currently, more than forty graduate students are engaged as Research Scholars in the Institute. IIG also offers a post-doctoral programme, besides the reputed Nanabhai Moos Research Fellowship (NMRF) programme.

- Apart from the regular course-work, to attract, motivate and train young talent to undertake research in geomagnetism and allied fields, the Institute has been conducting the Inspiring the Minds of Post-graduates for Research in Earth and Space Science (IMPRESS) programme with an in-take of 25-30 (which has increased to 50-60 in recent years) Masters students from Indian universities every year. The IMPRESS programme has been bridging the gap with universities and also has been yielding knowledge resources for students covering a wide spectrum of topics with adequate field training and hands-on experience.

- IIG has been actively involved in training international students under the SCOSTEP Visiting Scholar (SVS) programme. Similarly, Doctoral students from IIG are visiting various other countries under the SVS program to get exposed to international research and laboratory experience.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

- Essentially, they are the Pre-Ph.D. courses offered by IIG for its Research Scholars, which are recognised by the Universities wherein IIG students register for their Ph.D. The Pre-Ph.D. course-work covers a range of topics like Statistics & Signal Processing, Electrodynamics and Plasma Physics, Atmospheric & Ionospheric Physics, Geomagnetism, Applied Geology, Geophysical Prospecting, Geopotential Mapping, Environmental geomagnetism, Earthquake Seismology, Lithosphere-Atmosphere-Ionosphere Coupling & Ionospheric Seismology, etc.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

- IIG is establishing laboratories and facilities dedicated to the development of space instrumentation. The Electronics Lab is a key facility, equipped with cutting-edge tools and instrumentation for the development of electronic circuits for the Overhauser magnetometer and other devices. The Magnetic Sensor Lab is another crucial facility, where the sensor solvent for the Overhauser magnetometer is prepared and developed. In addition to these, IIG's Tirunelveli campus hosts a facility which is focused on the development of instruments for space-borne electric field experiments. This lab has already had the experience of flying electric field probes on a high altitude balloon that reached stratospheric altitudes of ~35 km and this centre is now gearing up for a sounding rocket experiment.

For further details on the inputs as provided in the document, please contact

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Professor ‘G’

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INDIAN INSTITUTE OF INFORMATION TECHNOLOGY SRI CITY , TIRUPATI, INDIA

Website: www.iiits.in

ABOUT THE INSTITUTE

Indian Institute of Information Technology Sri City is an institute of national importance focusing on research-oriented education with highly qualified faculties and research infrastructures. The spatial Analytics and Machine Intelligence Lab at IIIT Sri City is focusing on developing novel advanced and explainable machine learning approaches for addressing various issues in Earth and Planetary Remote Sensing. The lab is equipped with drones, sensors, data processing softwares, and indigenously developed repositories. Additionally, FPGA boards and simulation softwares are being used to deploy the developed deep-learning models onboard. The ISRO project has also facilitated the group to secure funding from other agencies including Science and Engineering Research Board (SERB), and other private agencies. The institute is contributing to the space technology domain, particularly in developing machine learning and data analytics algorithms and related benchmark datasets. Ongoing research focuses on basic algorithm development and several applications such as precision agriculture, industrial safety, mineral prospectivity modeling, and disaster management. The institute, particularly, the spatial analytics group, also conducts several outreach programmes for disseminating the research in space programmes and utilization of the same for societal applications. Additionally, several programmes are also organized to enhance the industry-academia interaction and collaboration in the space technology domain.

MAJOR RESEARCH DOMAINS

Spectral Unmixing: The current research explores autoencoders, spatial-spectral attention transformer networks, deep learning-driven approaches, Graph Neural Networks, etc. to resolve the issues prevalent in spectral unmixing. Graph-based approaches have been also adopted to make the deep-learning-based strategies interpretable. In addition to the conventional evaluation metrics, explainability-based evaluation metrics are also being developed. Novel datasets applicable for spectral unmixing are also being developed. FPGA-based hardware design of the developed algorithms will be explored to implement onboardable solutions. Interpretable deep-learning strategies are also being investigated for spectral and spatial denoising.

Spatial Super Resolution: The research, ongoing at the institute, explores convolutional sparse coding and deep autoencoder techniques, to enhance the spatial resolution of hyperspectral images. Additionally, we focus on developing benchmark datasets, explainability-based evaluation metrics, and hardware implementations. The focus of the current research is not only on improving the reconstruction accuracy but also on improving the interpretability and spatial and spectral fidelity. Additionally, collaborative unmixing-based strategies are explored to improve the generalizability of the approaches.

Spectral Super Resolution: The 3-D convolutional neural networks and sparse-coding-based strategies are currently being explored for spectral super-resolution, re-projecting coarse images to finer wavelength bands. AVIRIS-NG and drone-derived datasets have been used to generate benchmark datasets. GANs and transformers, along with graph-based strategies, are also being explored for effective spectral super resolution.

Explainable EO Data Processing & Analysis: The current research projects explore post-hoc and anti-hoc explainability-based approaches for EO data processing and analyses. The models, developed in our research, enhance the interpretability of the latent manifold through novel regularizations, architectures, and loss functions.

Multimodal Data Fusion: Generative adversarial networks, variational encoder-based strategies, and latent space transformations are being explored for multimodal data fusion, enhancing the assimilation and processing of data from multiple sources. The methods, developed in our research, primarily aim to improve interpretability and generalizability. Also, the developed approaches use novel architectures, strategies, and regularizations to reduce the requirement of cross-domain samples. Additionally, the developed approaches are being optimized and simulated for onboard deployment.

Optimization of Deep Learning Models for Onboard Deployment: The current research at the institute also focuses on developing strategies and pruning techniques to ensure that the neural networks are both lightweight and accurate for efficient onboard deployment. The emphasis is on ensuring model generalizability, and interpretability, reducing parameters and training sample requirements, reducing memory footprint, enabling online updates, etc. Furthermore, the ongoing research also focuses on implementing memory optimization, profile-guided techniques, and refining architectures to boost computational performance.

Planetary Remote Sensing: The ongoing research leverages the multi-modal payloads of Chandrayaan-1 and Chandrayaan-2 for advanced mapping of lunar surface material composition. Incorporating machine learning, the research explores spectral unmixing, spatial, and spectral super-resolution, addressing sensor-specific challenges. Novel deep learning approaches, including sparse coding and graph convolution, enhance interpretability, enabling mineral and volatile abundance mapping for geological insights. The developed strategies will also be used for mapping other planetary data as well.

Precision Agriculture: Multimodal data handling capability, explainability, and generalizability, consideration of spectral variability, reduction of training sample requirement, etc. are being considered as priorities in the recent research for developing frameworks for crop monitoring, irrigation stress detection, and yield estimation.

Hardware design of deep learning approaches: The current research also focuses on implementing advanced algorithms tailored for logic hardware design using FPGA. Renowned for its low latency, high computational speed, and energy efficiency through dedicated hardware, FPGA serves as a key technology. The developed novel models are being optimized using tools like fpgaConvNet, CNN2Gate, and Caffeine, ensuring superior performance and efficiency.

MAJOR SCIENTIFIC APPLICATIONS

Unmixing in latent space: A novel unsupervised approach for geological mapping of the lunar surface: Proposing a novel autoencoder-based approach to improve spectral unmixing accuracy by utilizing encoded representations for noise reduction and relevant feature extraction. This approach takes into account factors such as accuracy, computational costs, explainability, generalizability, noise sensitivity, and training sample requirements. (Table: 1) (Link: https://ingarss.org/accepted-poster-presentations/)

Efficient Graph Formulation and Latent Space Integration for Lunar Hyperspectral Image Classification: This study pioneers research in lunar mineral mapping using Chandrayaan-2's IIRS sensor. The goal is to improve Graph Convolutional Networks' interpretability and performance by introducing an efficient graph formulation and incorporating latent space projection for feature extraction and generalization. (Table:1)

(Link:https://ris.utwente.nl/ws/portalfiles/portal/328326930/WHISPERS2023_Oct_15_programme.pdf)

Spectral Unmixing In Generative Space: 3D-GAN Based Approach: This study introduces 1D-GAN and 3D-GAN models to improve planetary spectral unmixing, addressing challenges like noise and limited samples. The goal is to demonstrate the effectiveness of these GANs, particularly the proposed models, in enhancing spectral unmixing tasks with applications to Chandrayaan-2 mission hyperspectral images.

(Table:1)(Link:https://easychair.org/conferences/submission?submission=6671798&a=31655170)

Decoding the Moon's Surface: A Graph Neural Network-Based Analysis of Chandrayaan-2 Lunar Data Classification: This study aims to enhance geological classification of the Chandrayaan-2 IIRS Dataset using a novel model that integrates deep learning (CNNs) and graph-based methods (GCNs). The goal is to improve classification accuracy by addressing challenges like high data dimensionality, limited training data, spectral range limitations, sensor noise, and lunar atmosphere complexity.

(Link:https://2023.ieeeigarss.org/view_paper.php?PaperNum=5072)

Spatial-spectral Attention for Geological Mapping of Hyperspectral Sensor on Board Chandrayaan-2 Mission: The goal is to improve lunar hyperspectral remote sensing for mineralogy mapping using an encoder-only transformer network with spatial positional encoding. The proposed model is evaluated on the Cuprite dataset, compared with state-of-the-art models, and applied to Moon mineralogy mapper and IIRS-data. (Link:https://www.researchgate.net/publication/374882318_Spatial-Spectral_Attention_for_Geological_Mapping_of_Hyperspectral_Sensor_on_Board_Chandrayaan-2_Mission)

Advancing Hyperspectral Image Quality: Deep Learning-Driven Denoising with Sure Loss Function for Chandrayaan-2 IIRS Dataset: This paper introduces a deep learning approach for denoising Chandrayaan-2 IIRS hyperspectral images. Using a CNN with the SURE loss function, the goal is to enhance image quality by effectively removing noise, with potential applications in remote sensing.

(Table:2)https://www.ieee-whispers.com/wp-content/uploads/2023/09/WHISPERS2023_SV.pdf)

Latent Space Graph Convolutional Networks for Accurate Classification of Chandrayaan-2 Lunar Hyperspectral Images: This paper proposes a machine learning model combining a convolutional autoencoder and Graph Convolutional Network (GCN) for improved classification of Chandrayaan-2 Imaging Infrared Spectrometer (IIRS) data. The goal is to address challenges in lunar geology and mineral identification through the synergy of CNNs and GCNs in an end-to-end fine-tuning process.(Fig:1)(https://www.scribd.com/document/683259396/Decoding-the-Moons-Surface-a-Graph-Neural-Network-Based-Analysis-of-Chandrayaan-2-Lunar-Data-Classification)

Enhancing Hyperspectral Classification Through Graph Convolutional Networks with Adaptive Graph Construction: This study proposes leveraging Graph Convolutional Networks (GCN) to improve hyperspectral data analysis, specifically addressing interpretability and spatial-spectral challenges in the Chandrayaan-2 IIRS dataset. The goal is to achieve state-of-the-art results by incorporating noise reduction techniques and adaptive graph construction methods. (Fig:2) (Poster #38 at https://sservi.nasa.gov/nesf2023/posters)

Interpretable Spectral Unmixing Approaches for IIRS Data Onboard Chandrayaan -2 Mission: The goal is to improve planetary data unmixing by assessing existing techniques for accuracy and efficiency. Our proposed Graph-based approach, measuring nonlinearity with reconstruction error, enhances interpretability and generalizability, requiring fewer training samples for accurate and efficient analysis.

(Fig:3)(Link:https://agu23.ipostersessions.com/default.aspx?s=E5-C0-C1-38-E6-65-01-F1-B5-F6-8B-B2-B3-3B-50-E9)

Interpretability and Explainability of Hyperspectral Image Classification Techniques for Lunar Surface Mapping: This study introduces a novel deep learning-based spectral unmixing technique for improved geological mapping of the lunar surface using Chandrayaan-2 hyperspectral imaging. The approach aims to enhance interpretability and correlate effectively with physics-based models, advancing lunar exploration.

(Table:1)(Link:https://2023.ieeeigarss.org/papers/accepted_papers.php)

Table 1: Spectral Unmixing using various machine learning and deep learning

based models using IIRS, M3, and cuprite dataset

Cuprite		Model	RMSE			
			IIRS		M3	
Real Data	Data in Latent space		Real Data	Data in Latent space	Real Data	Data in Latent space
16.72	**15.11**	**FCLSU**	**37.98**	11.75	25.03	**18.25**
14.73	**12.55**	**UnDIP**	30.2	**23.2**	30.2	**23.2**
38.48	**13.68**	**CNNAEU**	38.99	**21.66**	38.99	**21.59**
25.33	**20.56**	**EndNet**	25.15	**25**	25.15	**20**
12.65	**12.65**	**MiSiCNet**	38.99	**21.66**	38.99	**21.66**
97.0092		**CNN**	**96.0288**		76.5822	
97.3201		**Spectral Non-Linearity**	61.5442		67.9451	
26.5458		**Spectral-Spatial Linearity**	43.3028		26.3509	
98.2295		**Spectral-Spatial Non-Linearity**	**90.9916**		**81.4529**	
77.3122		**K-Means**	68.165		71.0727	
93.5825		**Mutual KNN**	74.6404		78.062	
		PPNM	9.159			
		1D-GAN	7.378			
		3D-GAN	5.119			

Table 2: The Peak Signal-to-Noise-Ratio and Signal-to-Noise Ratio values for various datasets, including both the noisy data (with added Poisson noise and Gaussian noise) and the corresponding denoised data using SURE base CNN.

Dataset	Noise	PSNR		SNR	
		Noisy	Denoised	Noisy	Denoised
M3	Gaussian noise	13.1	**14.5**	1.7	**3.19**
	Poisson noise	11.1	**12.8**	0.47	**2.95**
IIRS	Gaussian noise	13.3	**20.17**	0.97	**2.89**
	Poisson noise	13.57	**22.4**	0.22	**1.66**
Cuprite	Gaussian noise	12.3	**19.4**	3.3	**9.1**
	Poisson noise	8.3	**18.8**	1.04	**8.8**

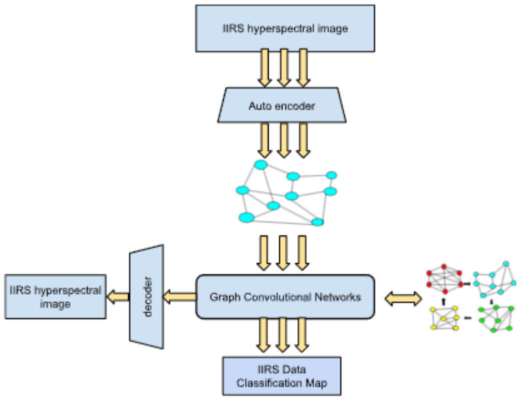

Figure 1: Latent Space Graph Convolutional Networks for Accurate Classification of Chandrayaan-2 Lunar Hyperspectral Images.

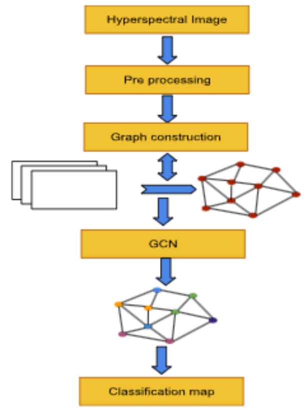

Figure 2: Enhancing Hyperspectral Classification Through Graph Convolutional Networks with Adaptive Graph Construction

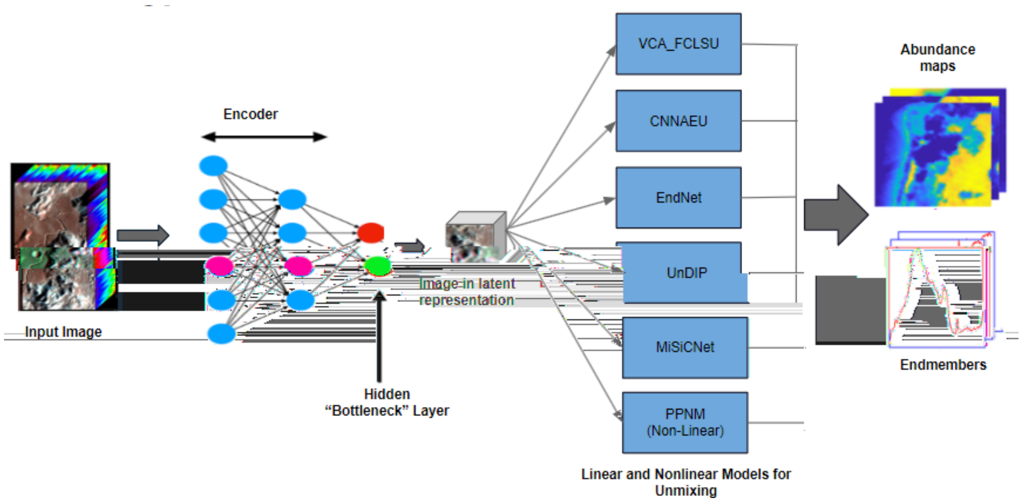

Figure 3: Interpretable Spectral Unmixing Approaches for IIRS Data Onboard Chandrayaan -2 Mission

INDIGENOUSLY DEVELOPED ALGORITHMS/SOFTWARES

- Spatial Super Resolution Algorithms
- Spectral Super Resolution Algorithms
- Multimodal Data Fusion Algorithms
- Spectral Unmixing Algorithms
- Spatial Data Warehousing Framework

- Image to Map Translation Framework
- Optimization of deep learning frameworks for onboard deployment
- Hardware design of deep learning approaches

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- B.Tech, B.Tech (Honors), and M.Tech Projects in space technology and allied areas
- PhD in Remote Sensing & Spatial Data Analytics (3 Ongoing)
- SERB sponsored workshop on Spatial Data Analytics, Karyashala, and AICTE sponsored Faculty Development Programme on space technology
- Outreach programmes in nearby colleges and institutes sharing our research advancements

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Course Name	No. of Times the Course Offered	No. of Students Enrolled	UG/PG/PhD
Geospatial Technology & Applications	3	300	UG/PG/PhD
Hyperspectral Image Processing	1	2	PhD
Satellite Image Processing	–	–	PG/PhD
Spatial Data Analytics	–	–	UG/PG/PhD
Remote Sensing	–	–	PG/PhD

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

Lab Name	Instruments	Purpose	Sponsor
Spatial Data Analytics & Machine Intelligence Lab	Drone	Data Collection	SERB
		Onboard Deployment of Developed Algorithms	
	Micro Weather Station	Data Collection	SERB
	Computational Facilities	Algorithm Development	ISRO, SERB, IIIT Sri City

CENTER OF EXCELLENCE IN SPACE SCIENCES INDIA, IISER KOLKATA, INDIA

http://www.cessi.in

ABOUT THE INSTITUTE

The Center of Excellence in Space Sciences India (CESSI) is a multi-institutional Center of Excellence hosted by the Indian Institute of Science Education and Research (IISER) Kolkata and has been established through funding from the Ministry of Human Resource Development. CESSI aims to explore the Sun's activity, generate the understanding necessary for space weather forecasting, hunt for gravitational waves, support national space science initiatives, participate in international capacity building activities and pursue public-private partnerships in space science research. The Center takes advantage of high-performance computing facilities, cloud computing and the high-speed National Knowledge Network grid to achieve its goals.

Head of the center: Prof. Dibyendu Nandi, email: dnandi@iiserkol.ac.in

MAJOR RESEARCH DOMAINS

1. **Solar physics:** CESSI has been involved in developing numerical models to study the effects of plasma flows on the evolution of magnetic fields deep within the solar convection zone and on the solar surface. CESSI also develops models for the magnetic structuring of the solar corona.
2. **Star-planet interactions:** CESSI has developed a numerical model for the first time in India for studying the interaction between solar wind and planetary magnetospheres which is important for predicting environments of solar system planets and planning space missions.
3. **Space weather:** CESSI has developed unique research methodologies for predicting the Earth's space environment, or space weather, and forecast impact of solar magnetic storms on the Earth's magnetosphere. Numerical simulations and multi-spacecraft observations are relied upon for these efforts.
4. **Space instrumentation:** One of CESSI's space optics instrumentation projects involves the development of a payload, the SUIT (Solar UltraViolet Imaging

Telescope) onboard the Aditya-L1 mission, in collaboration with other institutes/organizations and led by IUCAA.

5. **Space mission support:** Using in-house numerical models, CESSI is providing support to research outcomes from missions such as Aditya-L1, Chandrayaan-2.
6. **Gravitational waves:** At CESSI, we are also working on gravitational wave data analysis where we use statistical techniques to extract and analyze the signals detected by instruments like LIGO. We also provide support to the LIGO-India mega project for deploying a third LIGO detector in Indian soil**.**

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

- First century scale, data driven simulation of solar magnetic cycle and a model-based ensemble prediction of sunspot cycle 25 indicating that space radiation environment and upper atmospheric forcing over next 10 years is going to be similar to that observed during solar cycle 24. No Maunder-like grand minima expected in solar activity.
- Development of the first magnetohydrodynamic star planet interaction module in India which has the capability to model and simulate the solar forcing of the Earth's magnetosphere and the magnetosphere and atmosphere of other solar system planets
- Development of a unique model with the solar wind, Earth and moon in the same system to simulate the lunar space environment during its orbit around the Earth.
- Development of Machine Learning and Artificial Intelligence based operational solar flare forecasting techniques.
- Development of the first comprehensive space weather assessment and prediction Center in India.
- Involvement in the detection of the first binary black hole merger event from LIGO
- Involvement in the first detection of a black hole neutron star merger event with LIGO-VIRGO network.

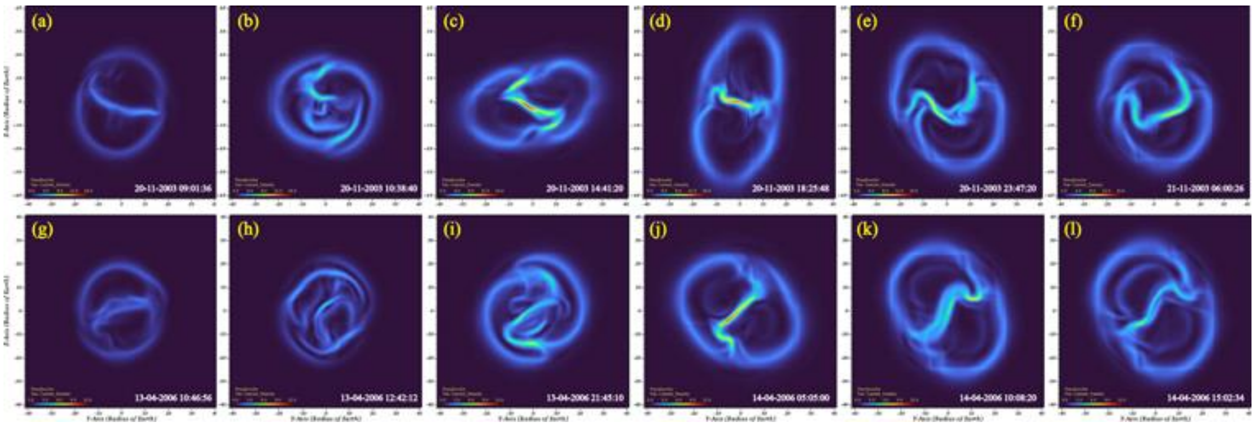

Fig. 1: *Numerical simulation showing the formation and evolution of θ-shaped magnetic current systems in the Earth's magnetotail during the passage of a solar storm past the Earth. The colormap depicts regions of high current induced due to the interaction of the geomagnetic storm with the Earth's magnetosphere. From Roy and Nandy (2023).*

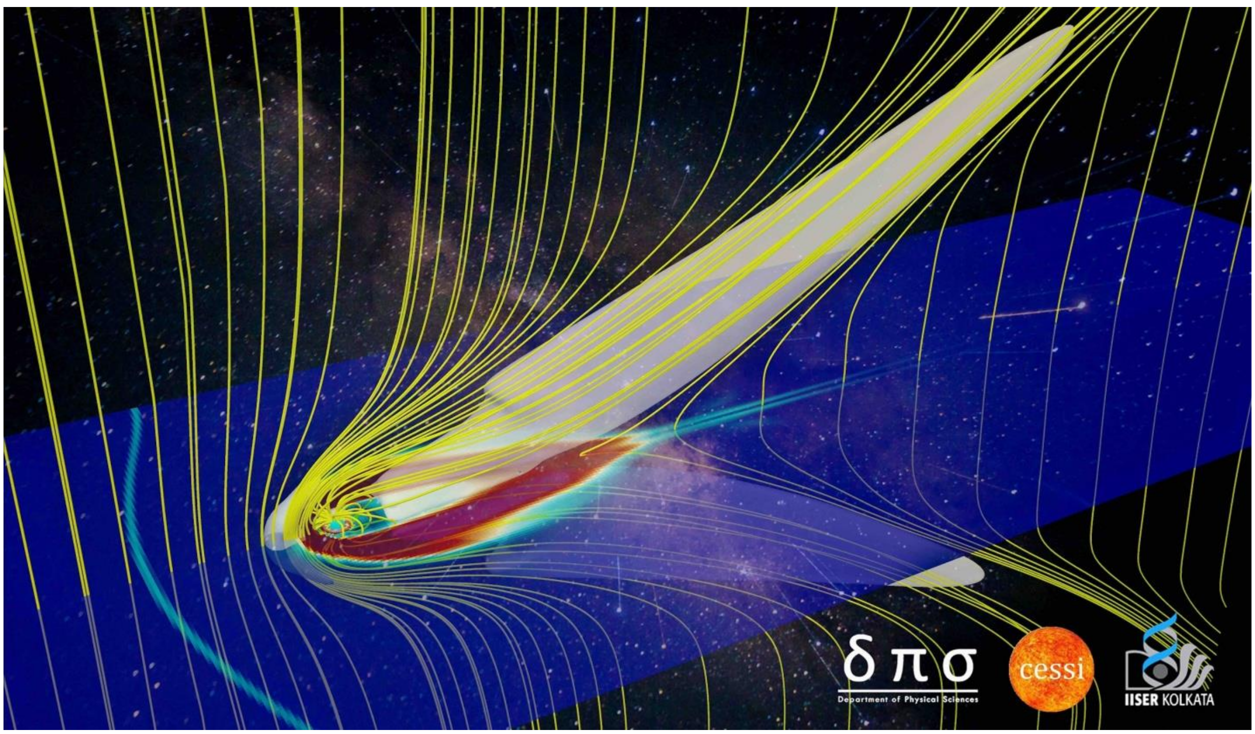

Fig. 2: *A computer simulation showing the interplay of cosmic magnetic fields that can result in the loss of a planet's atmospheres and their ability to host life. It also demonstrates the formation of a wing-like structure in the planetary magnetotail – known as the Alfvén Wing, named after Hannes Alfvén – due to interaction with the stellar wind. The colormap depicts magnetic currents while the yellow lines denote magnetic fields. From, Gupta, Basak and Nandy (2023).*

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

1. At CESSI, we are developing a space optics instrumentation laboratory. CESSI personnel has also been involved in the development of a payload, the SUIT (Solar UltraViolet Imaging Telescope) onboard the Aditya-L1 mission, in collaboration with other institutes/organizations which is being led by IUCAA.
2. The machine learning (ML) algorithm of CESSI is able to forecast the potential of solar flares – which are a major cause of severe space weather – with reasonable accuracy.
3. For the first time in India, CESSI has developed numerical simulation frameworks namely, Star-Planet Interaction Module (CESSI-SPIM) and Storm Interaction Module (CESSI-STORMI) which are essential for understanding the impact of solar and stellar magnetic activity on planetary space environments and planning space missions.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Programs offered by CESSI are as follows.

PhD in space physics: The goal of the doctoral program is to train future generations of space scientists who are equipped with the necessary skills to lead national and international endeavors in the astrophysical space sciences. Students interested in pursuing research in space science and allied fields of interest to CESSI can apply for PhD positions.

MS in space physics: The program aims to attract highly motivated B.Tech. and B.E. students with an engineering background who are desirous of contributing to fundamental research and mission-development in space sciences. The courses in this degree are aimed towards equipping students with the basic knowledge for tackling research problems in astrophysics.

Scientists from reputed institutes within India and abroad visit CESSI year round to deliver lectures and explore research collaborations. CESSI cultivates an open academic atmosphere wherein students are encouraged to take advantage of the ensuing interactions to forge scientific collaborations across institutional borders.

Statistics of students are given below.

- Current PhD: **10**
- Current BS-MS: **2**
- CESSI alumni (including PhD, MS, BS-MS and Postdoc): **55**

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Courses taught by CESSI faculty at IISER Kolkata:

1. Introductory Astrophysics (PH4102)
2. Space Astronomy (SS4202)
3. Fluid and Magneto-hydrodynamics (SS4201)
4. General Theory of Relativity and Cosmology (PH4205)
5. Electricity and Magnetism (PH3202)
6. Advanced Electricity, Magnetism, and Optics (PH4107)
7. Advanced Optics Laboratory (PH4201)
8. Atomic and Optical Physics (PH4212)

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

CESSI is developing a space optics instrumentation laboratory.

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH (IISER) PUNE, INDIA

Website: www.iiserpune.ac.in

MAJOR RESEARCH DOMAINS

Solar coronal mass ejections, Solar-terrestrial physics, space weather

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Refereed journal publications from Jan 2022 to Dec 2023

1) "On modeling ICME cross-sections as static MHD columns", Debesh Bhattacharjee, Prasad Subramanian, Volker Bothmer, Teresa Nieves-Chinchilla, Angelos Vourlidas, 2022, Solar Physics, vol 297, p 45

2) "On the specific energy and pressure in near-Earth magnetic clouds", Debesh Bhattacharjee, Prasad Subramanian, Angelos Vourlidas, Teresa Nieves-Chinchilla, Niranjana Thejaswi, Nishtha Sachdeva, 2023, Astronomy and Astrophysics, vol 669, p 153

3) "Turbulence and anomalous resistivity inside near-Earth magnetic clouds", Debesh Bhattacharjee, Prasad Subramanian, Teresa Nieves-Chinchilla, Angelos Vourlidas, 2023, Monthly Notices of the Royal Astronomical Society, vol 518, p 1185

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Title of ongoing/completed PhD thesis are given below.

1. Relativistic outflows from active galactic nuclei and their connection to accretion disks
2. Characterizing magnetic clouds associated with solar coronal mass ejections through in-situ observations
3. Thermal conduction and electron heating in solar coronal mass ejections

COURSES OFFERED ON SPACE SCIENCE

IISER Pune offers two advanced undergraduate courses in Astronomy and Astrophysics, one in Gravitation and one in Cosmology.

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
GUWAHATI, INDIA

www.iitg.ac.in

ABOUT THE INSTITUTE

Established in 1994, the Indian Institute of Technology Guwahati has quickly risen to prominence as one of the premier technical institutions in India. Nestled amidst the scenic beauty of Assam, along the banks of the Brahmaputra River, the institute offers a dynamic learning environment conducive to academic excellence and innovation. The institute offers a wide range of undergraduate, postgraduate, and doctoral programs in engineering, sciences, design, and humanities, complemented by state-of-the-art facilities and laboratories. The faculty comprises distinguished scholars and researchers who actively contribute to cutting-edge research across various domains, while also providing mentorship to students. The campus buzzes with activity, from cultural festivals and sports events to technical competitions and hackathons, fostering holistic development and a strong sense of community. With collaborations with leading international institutions and a global alumni network, IIT Guwahati continues to make significant contributions to academia, industry, and society, shaping the future of engineering and technology in India and beyond.

MAJOR RESEARCH DOMAINS

At the forefront of astrophysics exploration, the Indian Institute of Technology Guwahati conducts ground breaking research works. Led by a team of dedicated faculty members, the research endeavors at IIT Guwahati delve into various aspects of black holes, ranging from their formation and evolution to their astrophysical consequences and observational signatures. Faculty members and researchers at IIT Guwahati employ a multi-faceted approach to studying black holes, utilizing theoretical modeling, observational data analysis, and computational simulations. They investigate the mechanisms of black hole formation in various astrophysical environments, such as stellar collapse and galactic mergers, shedding light on the underlying physics driving these cataclysmic events. Moreover, the department is actively involved in studying the astrophysical implications of black holes, including their role in shaping the dynamics of galaxies, their influence on the surrounding matter, and their potential as cosmic laboratories for testing fundamental theories of gravity and spacetime. Collaborations with national and international research institutions, as well as access to cutting-edge observational facilities and computational resources, further enhance the impact and scope of black hole astrophysics research at IIT Guwahati. Through their innovative research endeavors, faculty and students at IIT Guwahati contribute to advancing our understanding of black holes and their role in shaping the universe, paving the way for new discoveries and insights into one of the most intriguing phenomena in astrophysics.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

- Wide-band view of high-frequency quasi-periodic oscillations of GRS 1915+105 in 'softer' variability classes observed with AstroSat. (https://ui.adsabs.harvard.edu/abs/2022MNRAS.512.2508M/abstract)

  In this work, we performed a comprehensive temporal and spectral analysis of the 'softer' variability classes (i.e. θ, β, δ, ρ, κ, ω and γ) of the source GRS 1915+105 observed by AstroSat during the 2016−2021 campaign. Our present findings infer that HFQPOs are possibly the result of the modulation of the 'Comptonizing corona'. Further, we find that the bolometric luminosity (0.3−100 keV) of the source lies within the sub-Eddington (3–34 per cent LEdd) regime.

- Unveling the accretion scenario of BH-ULXs using XMM-Newton Observations (https://ui.adsabs.harvard.edu/abs/2023MNRAS.526.2086M/abstract)

  In this work, we performed a comprehensive spectro-temporal analysis of five ultra-luminous X-ray sources (ULXs) with central object likely being a black hole, using archival XMM–Newton observations. We find that NGC6946 X−1 and NGC5408 X−1 seem to accrete at sub-Eddington accretion rate provided their central sources are rapidly rotating, whereas IC342 X−1 and NGC1313 X−1 can accrete in sub/super-Eddington limit irrespective to their spin values.

- First detection of X-ray polarization in thermal state of LMC X-3: Spectro-polarimetric study with IXPE

  (https://ui.adsabs.harvard.edu/abs/2024MNRAS.527L..76M/abstract)

  In this work, we reported a comprehensive spectro-polarimetric study of the black hole binary LMC X-3 using simultaneous Imaging X-ray Polarimetry Explorer (IXPE), NICER, and NuSTAR observations in 0.5–20 keV energy band. Our efforts reveals the first detection of polarized emissions in a thermally dominated persistent extragalactic BH-XRB, namely LMC X-3.

- On the origin of core radio emissions from black hole sources in the realm of relativistic shocked accretion flow

  (https://ui.adsabs.harvard.edu/abs/2022MNRAS.514.1940D/abstract)

  In this work, we aim to address the core radio luminosity of intermediate-mass black hole (IMBH) sources and indicate that relativistic viscous accretion flow model formalism is adequate to explain core radio emission of IMBH sources in the sub-Eddington accretion limit.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

The Ph.D. program in Astrophysics at IIT Guwahati offers a comprehensive and rigorous curriculum, providing students with advanced training in theoretical modeling, observational techniques, and computational simulations. Led by distinguished faculty members, the program covers diverse research areas including black hole astrophysics, cosmology, and high-energy astrophysics. Students engage in cutting-edge research projects, benefiting from collaborative opportunities with national and international institutions. Access to state-of-the-art facilities and resources enhances the research experience. Upon completion, graduates emerge as skilled researchers equipped to make significant contributions to the field of astrophysics, both academically and professionally.

Moreover, conference and workshops are regularly organized to train the manpower in the field of astronomy and space science. Several PhD thesis works are completed. The title of few notable thesis title are as follows.

- Investigation of magnetized dissipative accretion flow around Black Holes
- Accretion-ejection mechanism from advective accretion disc around rotating Black Holes
- Relativistic advective accretion flow around Black Hole

For further details on the inputs as provided in the document, please contact –

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INDIAN INSTITUTE OF TECHNOLOGY , KANPUR, INDIA

https://www.iitk.ac.in/

ABOUT THE INSTITUTE

The ISRO-IITK Space Technology Cell established on March 02, 2001 with the signing of MOU between the Chairman, Indian Space Research Organization and the Director, Indian Institute of Technology Kanpur.

Objective: Realization of growing importance to the extending scope for generation of knowledge through advanced space research & development efforts to ensure a truly self-reliant and self-generating Space Programmes for our nation in future years.

KEYWORDS

Soil moisture (SM), land surface temperature (LST), antennas for S, C, Ku and Ka bands, metasurfaces, Visible and near-infrared (VNIR) and Mid-IR reflection/transmittance spectroscopy, Calibration-Validation, Corner reflector, Low-cost GNSS, Semiconductor quantum dots, Hexagonal boron nitride, Molecular clusters, Molecular spectroscopy, Infrared spectroscopy, Coaxial injectures, Lagrangian Particle tracking(LPT), Deflagration-to-Detonation Transition (DDT), Detonation-based Combustors, Ignition Chemistry, LDMOS, Compact Modeling, Incremental forming, residual stress, Localized heating, Lithium-ion batteries; solid-state battery; lithium metal anode, LES, Hypersonics, SWBLI, Diffusion Couples, Inter-diffusion

MAJOR RESEARCH DOMAINS

- Space Science: Physics of the ionosphere and magnetosphere; meteorology, dynamics of the atmosphere; geophysics, geology; astronomy; cosmology; astrophysics; planetary and interplanetary space physics and climatology.
- Space Technology: Rocket and satellite technology; propulsion systems design and optimization; aerodynamics and heat transfer problems related to space vehicles; guidance and control systems for launch vehicles and spacecraft; polymer chemistry, propellant technology; ultra-light-weight structure; satellite energy systems; space electronics, Space communication systems; orbital

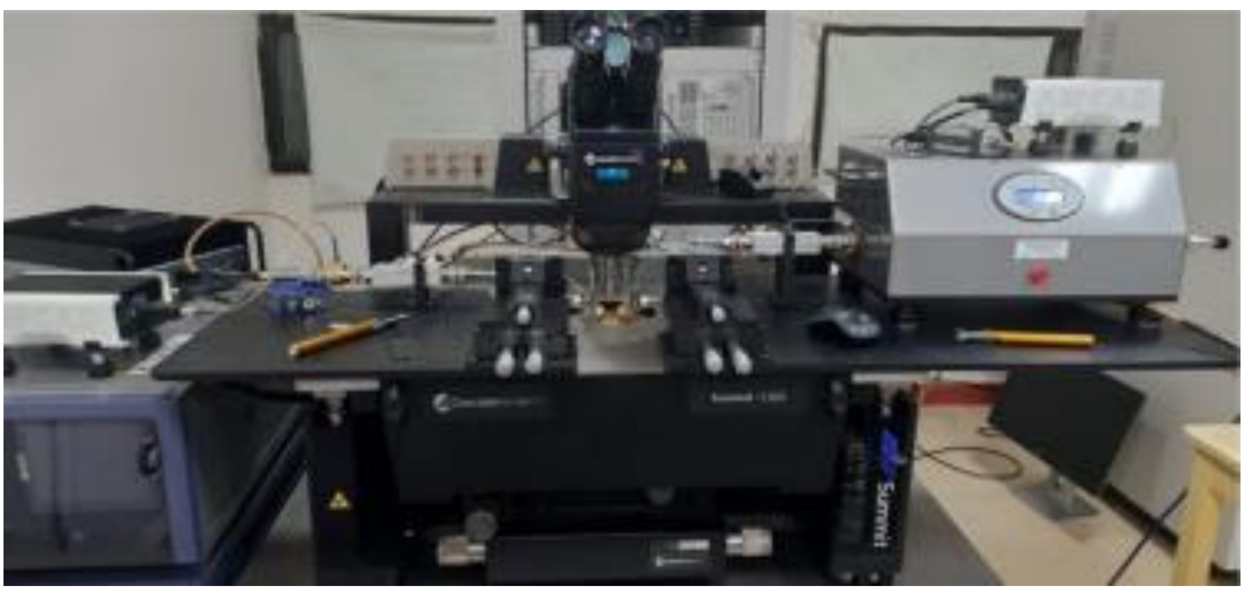
mechanics, computer sciences and new material development, Smart Structures and Meta-structures.

- Space Application: Remote sensing of the earth’s resources: space communication; satellite geodesy image processing, satellite meteorology including weather forecasting, Space Education and Ecology.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

PDK development and modeling support for ISRO’s GaN HEMT technology- Prof. Yogesh Singh Chauhan, Department of Electrical Engineering, IIT Kanpur

We have performed DC, Pulsed IV, and S-parameter (CW) characterization at various temperatures (25 C, 50 C, and 100C) on the received GaN devices (WxNF: 75x4 um, 100x4 um, 125x4 um, 150x4 um, 100x6 um, 150x6 um, 100x8 um, 150x8 um) from ISRO. In addition, the DC, CW S-parameter measurement and modeling of the devices (200x10 µm, 220x10 µm and 250x10 µm) have been done and subsequently, the PDK has been developed for the 200x10 µm, 220x10 µm and 250x10 µm device. Furthermore, the load pull simulation is also performed on 200x10µm, 220x10 µm and 250x10 µm device, and its results are compared with the measured data for power sweep on various biasing conditions.



Maury Load Pull Characterization system

- Publication
  M. Nazir et.al., "Characterization and modeling of drain lag using a modified RC network in the ASM-HEMT framework", Solid State Electronics, 2022. https://doi.org/10.1016/j.sse.2022.108490

Optical characterization of wetlands from Earth Observations- Prof. Rajiv Sinha, Department of Earth Science, IIT Kanpur

The OWTs are aquatic counterpart of the terrestrial classification and can be created by clustering of optically sensitive parameters like chlorophyll-a, turbidity, dissolved organic and inorganic matter using remote sensing reflectance, absorption and, scattering parameters. This project explores the possibility of deciphering the OWTs using the Sentinel-2 datasets of Chilika (Coastal wetland along the East coast of India) and Kaabar Tal (Inland wetland in the North Bihar Ganga plains) using various experimental methods. Another wetland, Nal Sarovar, was also added as suggested by the Committee.

Forel Ule color scale is not suitable to the wetland with dense vegetation and Iso clustering method using the optically sensitive spectral indices does not provide the information related to the physical characteristics of the individual clusters. The thresholding method using the primary indices (NDVI, NDWI and NDTI) is able to classify the wetlands using their optical properties. The AVIRIS hyper spectral datasets are used to analyze the unique spectral characteristics of OWTs. Field validation parameters such as water quality, hyper spectral and multi spectral imageries are used to validate the OWT clusters. The method is able to classify the brackish water types of the Chilika wetland, sediment dominated water types of the Kaabar wetland, and Nal Sarovar wetland. Hence, the method is simple and robust and useful to understand the dynamics within the wetland.

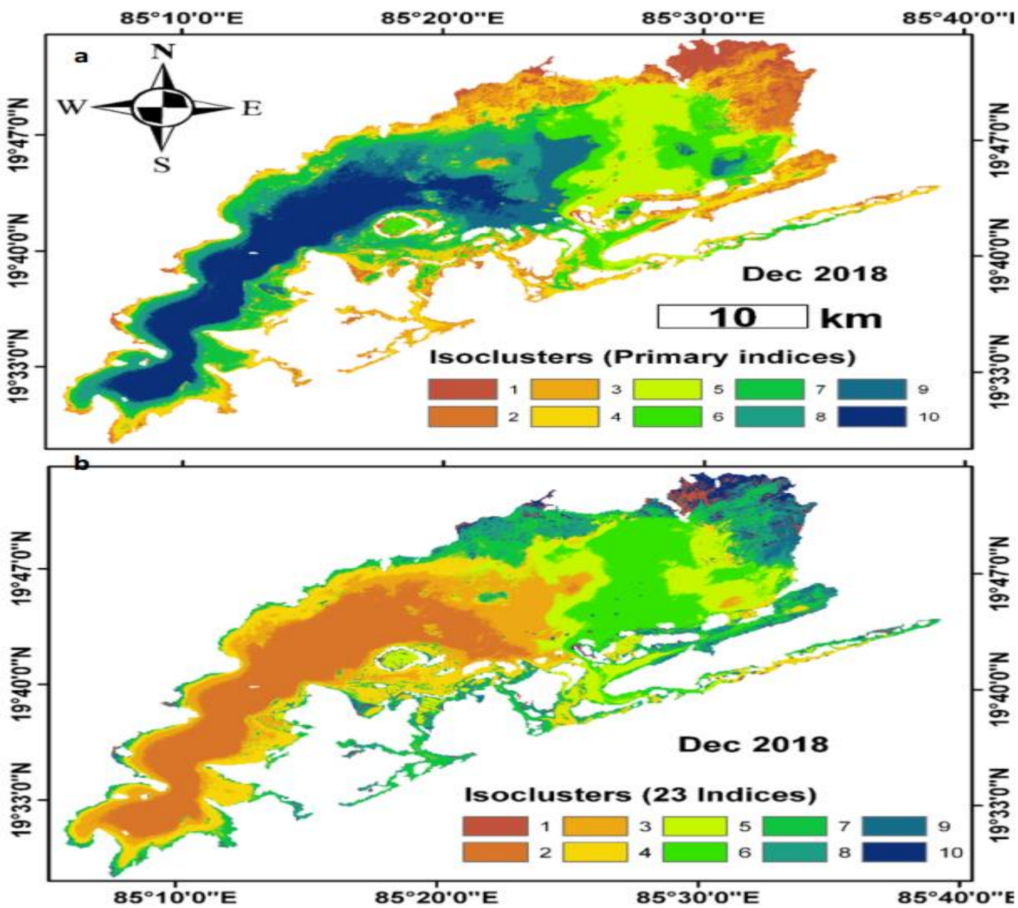


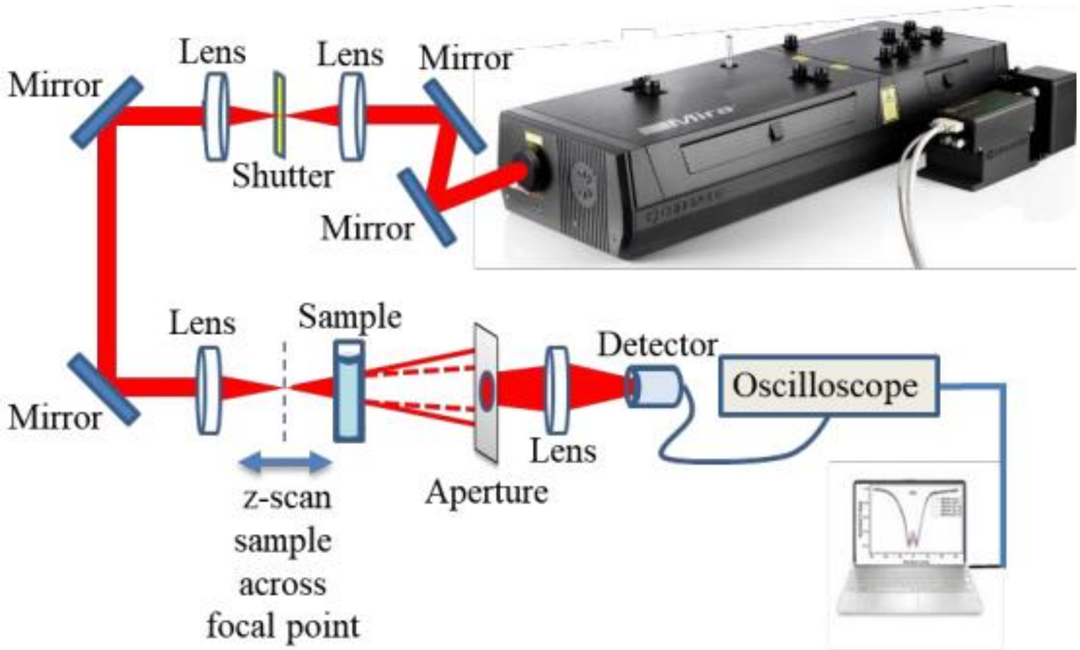
Figure: Iso-Clustering of Chilika lake using (a) primary indices (NDVI, N DWI, NDTI) and (b) 23 spectral indices.

- Publication

  Singh et.al., Deriving wetland-cover types (WCTs) from integration of multispectral indices based on Earth Observation data. Environmental Monitoring and Assessment. https://doi.org/10.1007/s10661-022-10541-7 .

Molecular size and mass sensitive ultrasensitive thermal spectrometer applications – Prof. Debabrata Goswami Department of Chemistry, IIT Kanpur

Thermal Lens (TL) is an omnipresent effect that can be utilized—significantly, the TL induced by femtosecond lasers can even be used for volatile samples. TL depends on the molecular environment and shows variation across the gas-liquid interface. The cumulative heating of the infinitesimal heating with femtosecond pulses is a very effective scheme for an extensive range of samples that are impossible with continuous heating. The main objectives of this work have been to show the applications of thermal lens spectroscopy in the molecular analysis of liquids and gases individually or in binary mixtures as well as in the analyses across interfaces.



- Publications

  Achieving molecular distinction in alcohols with femtosecond thermal lens spectroscopy", A.K. Rawat et.al., Chemical Physics, 2022. https://doi.org/10.1016/j.chemphys.2022.111596

  Sensing non-ideal microheterogeneity in binary mixtures of dimethyl sulfoxide and water", S.N. Bandyopadhyay et.al., Journal of Optics, 2022. DOI:10.1088/2040-8986/ac50ff

INSTRUMENTS / PAYLOADS / PRODUCTS DEVELOPED / SENSORS / DETECTORS

- Prof Rajiv Sinha, Department of Earth Science, has developed a new protocol to obtain the OWTs using indices such as Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Turbidity Index (NDTI) derived from the multispectral EO dataset.
- Prof Debabrata Goswami, Department of Chemistry, has developed a Femtosecond thermal lens instrumentation for several applications, including sensitive trace detection in liquids and gases.

- Prof Yogesh Sing Chauhan, Department of Electrical Engineering, has developed an Acquired Server/Workstation and CAD tools.
- Prof Vaibhav Srivastava, Department of Electrical Engineering, has designed and developed the optically transparent microwave absorbers which provide at least 15 dB return loss from 4 to 18 GHz which itself is very good results and nowhere in literature it is reported for the optically transparent absorber. This sample is also measured by ISRO.
- Prof Adrish Banerjee, Department of Electrical Engineering has developed a matlab based Polar and Turbo codes.
- Prof. Deepak Gupta, Department of Materials Science and Engineering & National Center for Flexible Electronics has developed a LC filling and sealing related techniques and facilities at IIT, Kanpur.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

A large number of courses are offered across the departments of Aerospace Engineering, Mechanical Engineering, Electrical Engineering, Material Science and Engineering and the newly established Space, Planetary and Astronomical Science and Engineering department which are relevant.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

Advance Propulsion Laboratory, Computational Fluid Dynamics Laboratory, Hypersonic Experimental Aerodynamics Laboratory, Artificially Engineered Materials and Structures Laboratory, Smart Materials structures and Systems (SMSS) Laboratory, Flight Laboratory, Space Dynamics and Flight Control Laboratory

INDIAN INSTITUTE OF TECHNOLOGY MADRAS, CHENNAI, INDIA

https://www.iitm.ac.in/

ABOUT THE INSTITUTE

The Indian Institute of Technology Madras was established in 1959 by Government of India, is known both nationally and internationally for excellence in technical education, basic and applied research, innovation, entrepreneurship, and industrial consultancy. A faculty of international repute, a highly motivated and brilliant student community, excellent technical and supporting staff and an effective administration have all contributed to the pre-eminent status of IIT Madras. Institute has 17 Academic Departments, 2 Schools and several advanced research centres in various disciplines of engineering and sciences, along with nearly 100 laboratories. IIT Madras has been consistently ranked as the No.1 Institution in the Category of Overall and Engineering in India right from the inception of the National Institutional Ranking Framework of Govt. of India since 2016. Institute continues to strive for excellence in education, research, and technological service to the nation as per its vision objective. It undertakes research and technology developments to help in building national capabilities in the domains of science, medicine, technology, sustainability, humanities, management, among others. More details on the Institute can be accessed at: https://www.iitm.ac.in/.

MAJOR RESEARCH DOMAINS

IIT Madras undertakes research in several areas of engineering and technology and thus contributing also to the domains of Space Science, Space Technology and Space Applications. Few of the Institute's focussed research domains are as follows:

- Aerodynamics and Flight Mechanics and Aerospace Propulsion & Structures

- Atomistic Modelling and Materials Design
- Cancer Genomics and Molecular Therapeutics
- Critical Transitions in Complex Systems
- Data Science and Artificial Intelligence
- Emergent Materials including Diamond
- Energy generation, storage, conversion, and distribution
- Geophysical Flows
- Healthcare and Assistive Technologies
- Maritime Experiments to Maritime Experience
- Molecular Materials and Functions
- NDE 5.0 – Industrial Assets and Process Management
- Quantum Information, Communication and Computing
- Radio Frequency, Analog, and Mixed Signal Integrated Circuits
- Sports Science and Analytics
- Technologies for Low Carbon and Lean Construction

MAJOR SCIENTIFIC APPLICATIONS/ RESULTS

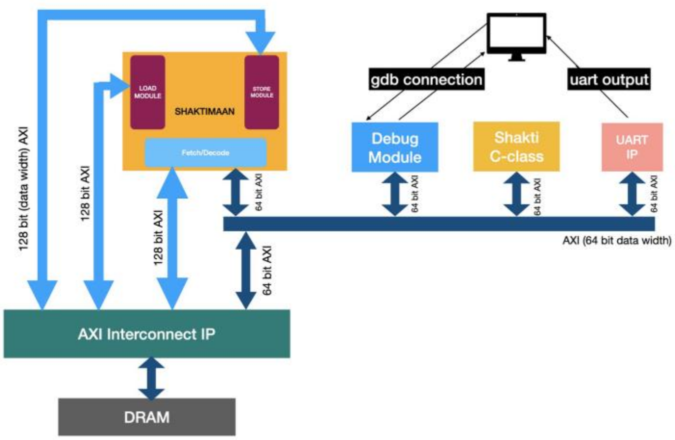
Researchers at the Institute (Faculty members and Students) continues to publish their research findings in the refereed journals and presents in both National and International Conferences. During the last two years (2022 & 2023), ~5100 publications in indexed Journals and ~1300 Conference proceedings were published by the researchers from the Institute. The details of publications can be accessed at the Institute's Annual Reports, available at: https://www.iitm.ac.in/annual-reports.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

A significant number of technologies, prototypes and products including Sensors & Detectors are developed through research in the Institute. Few of the Space related indigenous developed technology through projects funded by IITM-ISRO Space Technology Cell are illustrated below:

- **High Performance Computing (HPC) architecture for Autonomous Space Systems:**
  - ➢ Developed accelerator - SHAKTIMANN which was tested with the Shakti C-Class for full functionality on FPGA testbed.
  - ➢ Developed the software toolchain in C that will be required for creating applications on top of the SoC in which the accelerator will be integrated.

The design of the accelerator is reconfigurable in bus data width size, size of buffers and the number of parallel components.



- **Polymer Derived Zr-B-C based Rare Earth Metal Containing High Temperature Resistant Coatings for Space Applications**
  - ➢ Sintering & thermal characterization studies on ZGB PF30-Si
  - ➢ Development of ZGB PF30-Si spray coating on SiC, C/SiC & stellite substrates
  - ➢ Obtained Optimization of coating parameters for a crack-free coating
- **Development of solid propellant based low temperature gas generator for inflatable aerodynamic decelerator**
  - ➢ Developed solid propellant based low temperature gas generator issuing gases at 150 ± 15º C.

Also, research findings/ knowledge generated in the Institute are protected through filing Patent applications both in India and Foreign. About 550 Patents Applications were filed and about 500 Patents were granted during the last two years (2022 & 2023).

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Manpower trained/graduated:

IIT Madras continues to provide trained and skilled manpower to the nation building and ~ 60,000 were graduated from the Institute so far. IIT Madras is proud to have several of its alumni working in various ISRO/Space establishments like in other organisations. It is to be noted that about 12 scientists/engineers who were part of the historic Chandrayaan-3 mission are alumni of the Indian Institute of Technology Madras and they were felicitated in the Institute campus on 9th October, 2023. Few of them could be seen in the images depicted below:

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

IIT Madras offers a large number of courses related to Space Science and Technology, among others. Few of such specialised academic programmes / short term courses are listed below.

M. Tech Programs

- M. Tech in Aerospace Engineering (both Offline & online)

- M. Tech in Aerospace Engineering with specialisation in Ammunition Technology (Online)

Short-Term courses through National Programme on Technology Enhanced Learning (NPTEL) (Online)

- Aerospace Structural Analysis
- Aircraft Design
- Combustion of Solid Fuels and Propellants
- Computational Science in Engineering
- Fundamentals of Supersonic and Hypersonic Flow
- Fundamentals of Theoretical and Experimental Aerodynamics
- Gas dynamics: Fundamentals and Applications
- Introduction to Aircraft Control System
- Introduction to Ancient Indian Technology
- Introduction to Atmospheric and Space Sciences
- Introduction to Experiments in Flight
- Lighter than Air Systems
- Rocket Propulsion

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

IIT Madras has established state of the art laboratories with sophisticated advanced equipment/facility to undertake research in most of the Science and Engineering disciplines including space science and technology. Few of the existing laboratories/ facilities are listed below:

- Advanced Aerosol Characterisation Laboratory
- Algorithm and Complexity Facility
- Atomic Force Microscopy
- Center for Nondestructive Evaluation Laboratory
- XRD Laboratory (Crystal & Powder)
- Clean Room
- Composites Technology facility
- DSC/TGA (Thermal Analysis) facility
- Electrochemical Laboratory
- Electrophysiology Laboratory
- Environmental and Water Resources Engineering Lab.
- Femtosecond Laser Facility

- Flow Cytometry Facility
- Fuel Characterization Laboratory
- Gas Hydrates and Flow Assurance Laboratory
- GC-Mass Spectroscopy
- High Performance Super Computing Machine
- HR-SEM & TEM Facilities
- Laboratory for High Performance Ceramics
- Laser Diagnostics Laboratory
- Laser Scanning Microscope Laboratory
- Low Temperature Physics Laboratory
- Material Science Research Centre
- Materials Processing Section (MPS) Laboratory
- Microbiology Genetics Laboratory
- Nano Synthesis and Nano Tech. Laboratory
- Nanomechanics and Nanomaterials Laboratory
- National Cancer Tissue Biobank Laboratory
- National Facility for Atom Probe Tomography
- Fuel Characterisation Laboratory
- Spray Combustion Lab.
- Networks Lab.
- Photochemistry Lab.
- Physical Property Measurement System
- Raman Spectroscopy
- Sensing and Networked Systems Engineering Lab
- Smart Material Characterization Laboratory
- Soft Materials Laboratory
- Wave Energy and Fluids Eng. Laboratory
- X-ray Fluorescence
- X-ray photoelectron spectrometer (XPS) with ultraviolet photoelectron spectroscopy
- Inductively Coupled Plasma-Mass Spectrometry
- High Resolution FT-NMR Spectrometer -400 MHz
- Ultra High Resolution Electron Beam Lithography System
- Universal Testing Machine

INSTITUTE OF SEISMOLOGICAL RESEARCH (ISR), GANDHINAGAR, GUJARAT, INDIA

Website: https://isr.gujarat.gov.in

ABOUT THE INSTITUTE

The Institute of Seismological Research (ISR) has been established by the Science and Technology Department, Government of Gujarat (Figure 1). The ISR is unique in India being the only institute fully dedicated to Earthquake and crustal deformation studies. ISR is operating a densenetwork of BBS, SMA and GNSS stations in the western part of the Indian plate, besides ISR is also working in various segments of Himalaya for the seismological research as part of projects,funded by Govt. of India.

Figure 1: The main campus of the Institute

MAJOR RESEARCH DOMAINS RELEVANT TO THE SPACE SCIENCE AND TECHNOLOGY PROGRAM:

1. Crustal deformation study

1.1 **GNSS:** The Global Navigation Satellite System (GNSS) is one of the most essential technique that can precisely detect horizontal and vertical crustal deformations up to millimeter level. In this technique the position of the ground based receiver can be calculated using the signals transmitted by Space based GNSS satellites and making it possible to track the movement of points on the Earth’s surface over time. To understand the tectonic process along with deformational pattern of different faults/thrust systems, long-term analysis of GNSS results are required and therefore, ISR has established Gujarat Permanent GNSS Network (GPGN) since 2007, which at present contains 24 continuous and 30 campaign mode stations in different parts of Gujarat and adjoining states.

1.2 **InSAR:** The space based technique, InSAR measurements provides higher accuracy level and globally accepted for the deformation and ground subsidence measurement and provides wide ground coverage at the level of millimeter. Our institute (Institute of Seismological Research; ISR) has also started to use this space based technique and at present, we are using the Sentinel 1A data-set as provided by the European Space Agency (ESA) (https://sentinel.esa.int) for the various applications specially related to the surface displacement. We are planning to use the NISAR dataset once available in the coming years.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

1. **GPS and InSAR derived evidences of intra-basin stress and strike-slip tectonics in the vicinity of 2001 (M7.7) earthquake, Kachchh, western India,** (Dumka et al., 2023) (https://doi.org/10.1002/gj.4618):

   This research focused on the Kachchh Rift Basin (KRB), the seismically most active intra-plate region of the Indian Plate, which has seen three ≥ M 7.0 earthquakes in the last two centuries. The GPS stations on the northern and southern margins show SSW and NNE directed motion, indicating that the KRB is currently under the influence of regional compressive stress on both flanks and the same is reflected in the form of earthquake activity in the center portion. Furthermore, the existence of intrabasin stress, in addition to regional stress, increases strain accumulation and results in the creation of a Principal Deformation Zone (PDZ) in the central part of the KRB (Figure 2). The average annual deformation in the middle of KRB remains 1.0 ± 0.5 mm/year, while sites near the South Wagad Fault (SWF) experience 1.2 mm/year of fault parallel motion. The non-significant variation in GRACE-derived TWS values (from 2009 to 2018) rules out non-tectonic deformation in the vicinity of EAF and thus points to tectonic activity as the cause of the derived deformation in the region.

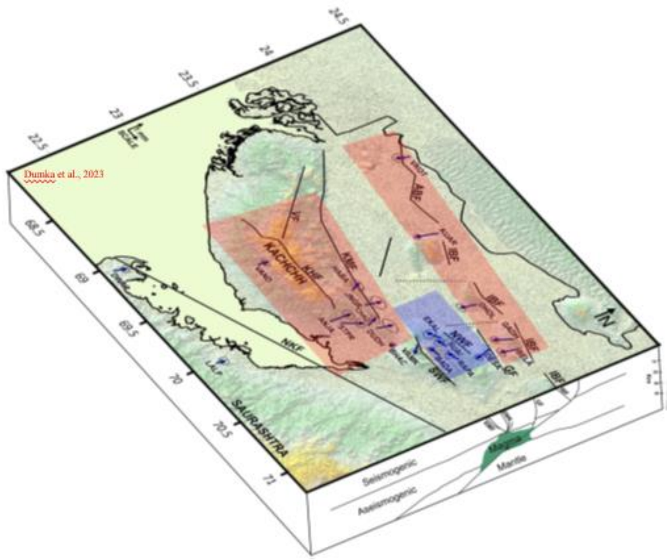


Figure 2: Velocity of GPS sites to the north and south indicate NE–SW directed motion while the sites in the middle reveal SWW directed motion. (Source: Dumka et al., 2022; **https://doi.org/10.1002/gj.4618***)*

2. **PSInSAR and GNSS derived deformation study in the west part of Narmada Son Lineament (NSL), western India; (**Dumka et al., 2022**), (**https://doi.org/10.1016/j.qsa.2021.100035).

The Narmada Son Lineament located in the middle part of the Indian plate is to be considered seismically active part and already experienced six moderate earthquakes in the last century. The geological studies summarize that the reactivation of existing faults of the paleo-rift are the main source of the tectonic deformation in this part. In the present study the PSInSAR technique with Sentinel 1A dataset, 2016–2019, is being applied for the measurement of deformation pattern of NSL. The derived results were collectively analyzed with the time-series dataset (2009–2019) of a GNSS site located in the study area. The results reveal association of very low amount of deformation along the Son Narmada Fault (SNF). The area towards south of the SNF portrays approximately 2.0 mm of annual Line of Sight (LoS) displacement, which we believe is significant for this region. The estimated deformation lies mainly along the Tapti North Fault (TNF) and Barwani Sukta Fault (BSF) and represented by the existence of a number of transverse faults in the area. The presence of seismic activity in this part justifies the area of maximum deformation accumulation (Dumka et al., 2022 https://doi.org/10.1016/j.qsa.2021.100035).

3. **PSI and GNSS derived ground subsidence detection in the UNESCO Heritage City of Ahmedabad, Western India, (**Dumka et al., 2022**), (**https://doi.org/10.1080/10106049.2021.1980618):

   Presently, ground subsidence in urban areas is becoming a peril to the infrastructure and society. In this study, we conducted a detailed analysis of the results, based on the Persistent Scatterer Interferometry (PSI), Global Navigation Satellite System (GNSS) and groundwater in the 'World Heritage City' of Ahmedabad, a major metro city in western India. The PSI technique is applied to measure the ground subsidence using the Sentinel 1 A dataset for the period 2017 to 2020. The results reveal a subsidence, maximum up to the level of 25mm/yr in the areas of the southeast and west parts of the city. Analysis derived from GNSS results indicates a significant amount of ground subsidence based on the 2009–2020 dataset. Groundwater data (1995–2019) were analyzed to identify factors likely to cause ground subsidence and the results are in close agreement with the PSI and GNSS results.

4. **Identification of crustal deformation in the Saurashtra region, western India: insights from PSI and GNSS derived investigation, (**Suribabu et al., 2022**), (**https://doi.org/10.1007/s40328-022-00399-z)

   The Persistent Scatterer Interferometry (PSI) and Global Navigation Satellite System (GNSS) techniques were used to identify the deformation rates in the Saurashtra region, western India. A sizable number of mild to severe earthquakes (with up to M5.1) have been observed in this part of the Indian plate. In order to calculate the crustal deformation, 241 Sentinel 1A images of path 107 with frame numbers 518 and 523, acquired between 2017 and 2020, were used. Similarly, processing of the GNSS dataset was done for four sites between 2009 and 2020. The foremost geodetic results from Saurashtra indicate the existence of a significant amount of deformation. PSI results show movements towards the satellite line of sight (LOS) of up to 5.0 ± 2.0 mm/year at several places and GNSS results indicate horizontal movements of less than 1.0 ± 0.4 mm/year and vertical movements of up to 2.3 ± 0.5 mm/year in the Saurashtra region. The projected LOS displacement of the GNSS is closely comparable with the PSI derived displacement. The results highlight isolated deformation pockets in various parts of the study area. Further, two loci with significant linear displacement were observed in south and east Saurashtra. Considering the seismic activity of the region, the inferred deformation rates may pose increased seismic risk for the region.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

1. Training to master degree university students in GNSS and InSAR techniques as part of Institute's curriculum.
2. Ph.D. Degree in the topic entitleled "Crustal Deformation study along Katrol Hill Fault (KHF) using GPS, PS-INSAR in Kachchh, Gujarat" in the year 2023.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Training to the students of National Institute of Technology, Rourkela (NITR) on the GNSS and data processing.

For further details on the inputs as provided in the document, please contact

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INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS , PUNE, INDIA

Website: https://www.iucaa.in/

ABOUT THE CENTRE

The Inter-University Centre for Astronomy and Astrophysics (IUCAA) is an autonomous institution set up by the University Grants Commission (UGC) of India to promote the nucleation and growth of active groups in astronomy and astrophysics at Indian universities. IUCAA aims to be a centre of excellence within the university sector for teaching, research and development in astronomy and astrophysics.

MAJOR RESEARCH DOMAINS

Research at IUCAA spans a wide range of fields. Current areas of active research include:

1. Cosmic Magnetic Fields
2. Extragalactic Astronomy
3. High Energy Astrophysics
4. Quantum Metrology and Precision Measurements
5. Gravitational lensing (Strong, Weak and Micro)
6. Gravitational Waves
7. Instrumentation for Astronomy
8. Mega Science
9. Solar and Stellar Physics

Description of the research activites in each of the sub-topics is available at https://www.iucaa.in/en/research/research-at-iucaa

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

IUCAA members have authored more than 300 publications between Jan 2022 to Dec 2023. Of these 45 publications (43 refereed and 2 non-referred) were based on AstroSat, which are listed in:

https://ui.adsabs.harvard.edu/search/filter_aff_facet_hier_fq_aff=AND&filter_aff_facet_hier_fq_aff=aff_facet_hier%3A%220%2FIUCAA%22&fq=%7B!type%3Daqp%20v%3D%24fq_database%7D&fq=%7B!type%3Daqp%20v%3D%24fq_aff%7D&fq_aff=(aff_facet_h

ier%3A%220%2FIUCAA%22)&fq_database=(database%3Aastronomy%20OR%20database%3Aphysics)&q=%20abs%3A%22astrosat%22%20year%3A2022-2023&sort=date%20desc%2C%20bibcode%20desc&p_=0

Two major highlights of the research activites using AstroSat data are:

'AstroSat' captures escaping ionizing photons from galaxies at cosmic noon

An international team of astronomers have been successful in detecting ionizing photons from a rare type of galaxies known as Lyman Continuum Leakers using the Ultraviolet Imaging Telescope (UVIT) onboard **AstroSat**. "Detecting ionizing UV radiation from such galaxies is extremely challenging and was possible only because of the unique capabilities and high sensitivity of UVIT", said Suraj Dhiwar, the lead author of the research published in ***'The Astrophysical Journal Letters'***.

Within the first billion years after the Big Bang, our Universe went through a major phase transition known as reionization, a process in which neutral hydrogen atoms dissociated into protons and electrons when they are struck by high energy UV radiation below wavelengths 912 Å known as Lyman Continuum emission. Understanding the cosmic reionization and the sources responsible for this process remains one of the frontier problems in astronomy.

"The Lyman continuum emission can be easily absorbed or scattered by the interstellar medium or the cir-cumgalactic medium of their host galaxies. Even when some of these ionizing photons manage to come out of the galaxy's environment, they maybe absorbed by the vast intergalactic medium between us and the galaxy. This is what makes their discovery a rare event in astrophysics. Thanks to UVIT's resolution and sensitivity that allowed us to create UV deep field in the far-ultraviolet filter." says Prof. Kanak Saha. In the current discovery, astronomers detected 10 Lyman continuum emitting galaxies from the peak era of cosmic star formation history, making it the first coherent sample of Lyman continuum leakers at this epoch. More interestingly, these Lyman Continuum photons have wavelength ~600 Å, falling in the Extreme Ultraviolet regime, the shortest ultraviolet wavelength with which a galaxy has been imaged so far. These galaxies are about 8 - 9 billion light years away from the Earth and have intense star formation rates, with some of them forming massive young stars at a rate 100 times higher than our Milky

Way Galaxy. Prof. Rogier Windhorst said “the discovery would fill an important niche in understanding the evolution of these rare objects, which are at an epoch when the star formation was at its peak in the cosmic star formation history.”

AstroSat uses its full Multi-Wavelength Capability for the first time to unravel the Secrets of the Black Hole X-ray Binary MAXI J1820+070

In a study recently accepted in The Astrophysical Journal, an international team of scientists has utilized AstroSat’s full multi-wavelength capability, featuring all four co-aligned payloads, to paint a comprehensive portrait of an X-ray binary system hosting a black hole. By capturing soft and hard X-ray emissions with its three X-ray payloads and far ultraviolet radiation with its UV telescope, AstroSat has unveiled a treasure trove of insights into both the near and distant regions surrounding the black hole in the X-ray binary system MAXI J1820+070. Additionally, optical data from Las Cumbres Observatory and soft X-ray data from NASA’s NICER mission further bolstered AstroSat’s findings. This study marks a pivotal achievement in the history of AstroSat as the first instance where its full multi-wavelength capabilities have been harnessed. The collaborative team includes researchers from India, the United Kingdom, Abu Dhabi, and Poland.

The research, titled "*A multi-wavelength study of the hard and soft states of MAXI J1820+070 during its 2018 outburst*", presents a comprehensive analysis of the 2018 outburst of MAXI J1820+070. Led by Dr. Srimanta Banerjee and Prof. Gulab Dewangan, the research team utilized AstroSat's far UV, soft and hard X-ray data alongside quasi-simultaneous observations from Las Cumbres Observatory (optical) and NICER (soft X-ray). Their findings indicate that, in the hard state, the accretion disk recedes significantly from the black hole, making way for a structured corona comprising two distinct components with unique physical properties. Conversely, during the soft state, the disk moves closer to the black hole, while the corona's emission diminishes. Notably, the study reveals a perplexing emission component in the soft state, identified as residual emission cascading into the black hole. AstroSat’s Soft X-ray Telescope (SXT) played a crucial role in underpinning the inner accretion disk, while the Large Area X-ray Proportional Counter (LAXPC) and the Cadmium Zinc Telluride Imager (CZTI) instruments provided high quality high energy X-ray spectra down to 150 keV, and helped to infer a two component corona geometry in the hard state. Figure 2 depicts a plausible global accretion geometry for the hard and soft states of MAXI J1820+070 inferred from this study. Moreover, the researchers employed advanced techniques to measure the black hole's spin, one of its two fundamental properties (alongside mass), revealing the black hole to be moderately to highly spinning.

This study further revealed a captivating connection between the X-ray emission from the inner regions near the black hole and optical/UV emission from the outer region of the accretion disk. The researchers found that X-rays undergo substantial reprocessing in the outer accretion disk, representing the primary mechanism for generating optical/UV photons in this system. Importantly, the proportion of reprocessed radiation is notably higher in the hard state, suggesting the existence of a warped or convex outer disk during this phase. Previous studies of this source, as well as other X-ray binaries, have predominantly relied on photometric optical/UV data for multi-wavelength study. However, for a precise determination of the properties of the outer accretion disk, spectroscopic data play a crucial role. In this context, the AstroSat mission assumes a pivotal role by providing a unique opportunity to acquire spectroscopic data across diverse wavelengths, spanning from far UV to hard X-rays. Additionally, the exceptional energy resolution of NICER data, along with the extensive coverage of AstroSat's three-pointing X-ray instruments, enables a detailed investigation of the region proximal to the source through reflection analyses.

Due to the limited availability of such multi-wavelength spectroscopic data for X-ray binaries, often hindered by significant reddening resulting from their proximity to the Galactic plane, this work, focusing on MAXI J1820+070, underscores its importance. The study not only advances our understanding of this specific object but also lays the foundation for future endeavors, demonstrating the comprehensive capabilities of AstroSat in facilitating exploration across a wide array of astrophysical phenomena.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

1. **Software package for AstroSat/UVIT grating spectroscopy**

A software package UVITTools.jl for the FUV/NUV grating spectroscopy and aperture photometry of astronomical sources observed with the Ultra-Violet Imaging Telescope (UVIT) on-board the Indian space observatory AstroSat was developed and tested. The package is compatible with the processed data generated with the CCDLAB pipeline. This package has been made available though GITHUB (https://github.com/gulabd/UVITTools.jl) for general users.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

IUCAA hosts the ISRO sponsored AstroSat Science Support Cell, which provides, help desk, tutorials, workshops, up to date calibration and software information, among other utilities that has helped users across the world to analyze AstroSat data. IUCAA conducts more than 10 workshops/meetings across the country with a significant number of them having space astronomy component (https://www.iucaa.in/en/iucaa-events/events-outside-iucaa). IUCAA has about 50 Ph.D students with more than 10 involved directly in space astronomy. Moreover, IUCAA faculty co-guide more than 20 University Ph.D students whose thesis involves space astronomy.

IUCAA and TIFR jointly conducted an interdisciplinary workshop at IUCAA during 5-9 December 2022. This workshop introduced intermediate to advance concepts of GEANT4 toolkit to graduate students (MSc and PhD), early career researchers and scientific staff in high-energy physics and/or in X-ray/gamma-ray astronomy. The workshop had a series of lectures and hands-on tutorials delivered by international and national experts where participants learned to build and run their own GEANT4 models. The main aim of the workshop was capacity building towards experimental projects in high energy physics, space astrophysics, and particle physics and gathering a community of GEANT4 users in India.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

(i) Course title: High Energy Astrophysics (intake 20)
(ii) Level : Post-graduate (IUCAA-SPPU MSc (Physics with Astrophysics) programme)

KADI SARVA VISHWAVIDYALYA , GANDHINAGAR, INDIA

Website: http://svkm.org.in

Vision -

- To provide need-based education and develop courses of contemporary relevance.
- To be a University of excellence by providing research-based activities which would foster higher economic growth.
- To provide education to all irrespective of caste, creed, religion etc.
- The University has at present 19 Constituent Colleges/Departments at Gandhinagar and Kadi.

Mission -To attain higher and higher standards of quality education to serve the coming generation.

Heritage and legacy-

"Sarva Vishwavidyalaya Kelavani Mandal" (SVKM) the trust which has been in existence for more than eight decades (Since From 1919) is a well reputed prestigious educational trust in North Gujarat. The alumni of SVKM have managed and nurtured the trust to its present eminence.

The trust commenced its activities with a school and student residential "Ashram" at Kadi in 1921 through the generous donation from the society and through the visionary efforts of "Chhaganbha" who is the establisher of the Mandal.

The trust has setup as many as 30 different educational institutions, ranging from Primary schools to postgraduate courses. Engaged in the right pursuit of contributing to the noble cause of education the trust, which started with a school and a handful of students, has today to its credit two mega campuses at Kadi and Gandhinagar. More than 50,000 young students are being groomed at these campuses. Having provided primary, secondary and higher secondary for almost seven decades, the trust has started imparting higher education and being sensitive to the needs of environment, has added technology, management and computer-oriented courses to prepare youth of the region to take up the challenges of the future. Be it quality of students, quality of faculty or quality of infrastructure at Sarva.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

website link which shows the list of publications: https://ksv.ac.in/index.php/research#Publications

- Study of solar cycle – prediction of the characteristics of the solar cycle by using the precursor method
- Study of solar activity- Study of the temporal and spectral characteristics of Solar flare.
- Study of lunar craters- Moon is heavily cratered at higher latitudes and near the equatorial zone.
- Study of Coastal erosion - Monitoring shoreline changes and associated erosion along the coastal districts using multi-temporal Landsat digital data over the period from 1978 to 2020.
- Nanoparticles and liposomes as drug delivery systems -used in treatment of various fungal infections, Developed and validated many chromatographic analytical methods for detection of drug and related substances
- Extracted and isolation of many compounds from herbal and indigenous plants- These compounds are evaluated by various in silico methods.

LABORATORIES AND FACILITIES

- Horn antenna (radio wave)
- Nexstar 4se computerized telescope (optical waves)
- Super computer
- Microwave oven, hot air oven, muffle furnace
- Soxhlet apparatus, sonicator flame photometer, Survismeter, Rotaevoporator, Filtration pump, ball mill
- Assemble polarizing optical microscope.
- U.V transilluminator

- Electrophoresis unit,ph meter, Laminar air flow, Autoclave
- Cyclo mixer, cooling, and small centrifuge machine
- HPLC, UV, HPTLC, Dissolution apparatus, Conductometer, Elisa readers, High shear homogenizer, extraction assembly, in vitro animal model apparatus, Tablet machine, Polarometer, Brookfiled viscometer, microscopes, etc
- Advance CAD/CAM & CAE software and computational tools;
- FFT analyzer (Vibration Measurement Instrument) etc.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Under- graduate (B.Sc. Sem-1) Intake-96	Indian Astronomy-I(IKS202-1C)
Post-graduate (M.Sc.) intake capacity-60	Astronomy and Astrophysics - I (MPET – 304A)
	Astronomy and Astrophysics - II (MPET – 404A)

MANIPAL CENTRE FOR NATURAL SCIENCES, MANIPAL ACADEMY OF HIGHER EDUCATION, MANIPAL, INDIA

https://manipal.edu/mcns-manipal.html

MANIPAL CENTRE FOR NATURAL SCIENCES

The Manipal Centre for Natural Sciences (MCNS) was started in 2011. The primary aim of MCNS is to nurture fundamental research in the Natural Sciences and grow into a hub of excellence within Manipal Academy of Higher Education. In 2012, the fledgling MCNS came into its own as a Centre of Excellence under the Manipal Academy of Higher Education. MCNS has a unique and vibrant academic program, integrated with existing research at partner institutions in India and abroad. The Centre presently has an academic program including Ph.D and a 5-year Integrated MSc-Ph.D (Physics) and a strong research programs in the areas of Heliophysics, Astronomy & Astrophysics, Cosmology, Particle physics, Nuclear physics, Computational chemistry and Evolutionary biology.

MAJOR RESEARCH DOMAINS

In the last couple of years, MCNS has been involved in many space science and technology programs. Specific research areas are listed below:

- **Solar Physics and Space-weather:** MCNS faculty is deeply engaged in addressing some of the key issues related to Solar physics and Space-weather. The niche area of research in solar physics mainly covers the study of magnetic features and activities on the Sun, solar flares, space weather, and its effects on Earth's atmosphere. These studies are pursued mainly by using observations from different ground and space-based facilities.
- **Observational study of Astrophysical objects:** A group of MCNS faculties are pursuing research on distant astrophysical sources through their multi-wavelength properties and modeling of the observed data. The research area is mainly around exploding stars, disruption of stars due to supermassive Black Holes, Formation of

dust in various astrophysical environments, Active Galaxies and their episodic activities, and the creation of large-scale structures in the Universe.

- **Theoretical study of compact objects and cosmology:** MCNS faculties are involved in the theoretical study of Black Holes, and the inflation theory of the cosmology related to the initial evolution of the Universe. Relativistic accretion, Energy extraction from Black Holes, effect of magnetic fields, (Sub) Solar-mass (Primordial & Transmuted) Black Hole formation, Dark matter, and strong gravity are among the prime research areas being conducted at MCNS.
- **Solar and Astronomical instrumentation:** The Indian Space Research Organisation (ISRO) launched the space mission ADITYA-L1 to carry out multi-wavelength research on the Sun. MCNS faculty as Project Scientist, was instrumental in building the Solar Ultraviolet Imaging Telescope (SUIT) onboard ADITYA-L1. MCNS faculties are also involved as Chair / co-Chair / member of senior reviews of ISRO's science payloads on ISRO missions (ADITYA-L1 and XpoSat).
- **Computational Astrophysics:** Numerical simulations combined with radio observations with telescopes such as uGMRT and LoFAR are used to address self-similarity and energy distribution in clusters, especially towards the lower mass end. The group is also involved in preparing a catalog of interacting galaxies and its classification into merging systems or not.

MAJOR SCIENTIFIC RESULTS

New results in different fields of space sciences were obtained in the last one year. The highlights from some of the major publications are listed below.

- **Structure and composition of the dusty torus of AGN NGC 1365:** The AGN unification scheme suggests existence of a torus like structure comprising gas and dust, potentially obscuring central regions depending on the observer's line of sight. However, the structure and composition of torus remain poorly understood. Recent near-IR interferometry and reverberation mapping revealed the inner radius of AGN NGC 1365 to be ~0.03pc. To confirm this, we carried out dust radiative transfer modeling of UV-IR SED of NGC 1365 using the SKIRT code, incorporating a graphite dusty ring within the torus and a bipolar conical structure perpendicular to it, consistent with observed bipolar outflows. The UV-IR SED was constructed for the first time for this AGN using high resolution UV data from UVIT onboard AstroSat and IR data from literature. We find that the polar model with hot graphite dust at 0.03 pc at a temperature of 1216K and cooler ISM-type graphite-silicate mixture at 0.1 pc with a temperature of 914 K, provide the best fit to the observed SED. We also find that the location of the hottest dust component at 0.03pc puts it in the Broad Line region (BLR) of AGN which is usually devoid of dust. *(S. Swain, **P. Shalima** & K.V.P. Latha, 2024, MNRAS, 527, 2, 3592–3601)***.**

- **Signatures of the inflation model using upcoming the Square Kilometer Array (SKA):** Inflation is a hypothetical extraordinary expansion of the universe at its beginning that magnified a subatomic region in space to cosmological scales. The rapid expansion explains the observed homogeneity of the universe at large scales. Interestingly, inflation also explains the origin of the tiny deviation from the homogeneity, as observed in Cosmic Microwave Background (CMB) anisotropy and the large-scale distribution of the galaxies, as fluctuations of a quantum field beyond the Standard Model of particle physics. Thus, we can probe physics at the shortest distance scales by observing density fluctuations in the universe. Our recent work demonstrated the potential of yet another probe of density fluctuations - the redshifted 21 cm signal, a characteristic line from the neutral hydrogen. We focused on a class of inflation models that predicts distinct signatures in the density fluctuations. We showed that the next-generation radio telescope, the Square Kilometer Array (SKA), will be able to measure the parameters (A_I, k_b) of the signatures of the inflation model. *(**S. S. Naik**, P. Chingangbam and **K. Furuuchi**, 2023, JCAP 04, 058)*.
- **Gravitational Larmor Precession and its consequences:** Inspired by the reported existence of substantive magnetic fields in the vicinity of the central supermassive black holes in Sagittarius A* and Messier 87*, a neutral test particle motion is considered around a non-rotating black hole (BH) in the presence of magnetic fields (B) in its vicinity. It is shown that the orbital-plane precession frequency in such a BH does not vanish, surpassing earlier folklore that only a rotating BH can generate such a precession. This is a new phenomenon that arises in the mere presence of magnetic fields, and is called Gravitational Larmor Precession. Intriguingly, the same test

particle could not continue its regular motion around a ultra-strong magnetized BH, hence the accretion disk could not be formed, and the motion of other stellar objects around the BH could be absent. As the BHs are generally detected by watching for their effects on nearby stars and gas, a ultra-strong magnetic field could be able to shield a BH in such a way that it could remain undetectable. For example, a $M=10^9M_\odot$ BH surrounded by $B > 10^6$ G or a BH with $M=10M_\odot$ surrounded by $B > 10^{14}$ G could remain undetectable. *(**Chandrachur Chakraborty** and Parthasarathi Majumdar, 2023, Eur. Phys. J. C (Letter), 83, 714)*

- **Transients associated with the instability in the accretion disk:** In this work, using multi-wavelength observation we have shown that the disk-instability at the center of merged system can also produce emissions that mimics stellar disruption phenomena, although these are not disruption of stars due to tidal force of central Black Hole. We monitored and analyzed the evolution of the nuclear transient AT2020ohl associated with the center of nearby galaxy NGC6297 over a time duration of ~700 days in multi-wavelength using Swift, CHANDRA, HCT, and JVLA telescopes. The event was initially classified as a disruption of a star by the central Black Hole. We showed that NGC6297 is a merger of two galaxies. The central Black Hole has a mass of $\sim 10^7$ $M_\odot$. Due to disk instability, an emission system with Blazar like geometry was created which produced an UV-optical emission from the disk with radiated power $\sim 10^{43}$ ergs/sec along with X-ray and radio emissions from an ejected Blob. *(**Rupak Roy**, Samir Mandal, D. K. Sahu, G. C. Anupama, **Sumana Nandi,** and Brijesh Kumar, 2024, MNRAS, (accepted))*
- **Development of a novel algorithm to quantify large-scale structures in the universe and to better constrain cosmological models of the Universe:** At the present epoch, the Universe is understood to be a network of matter-overdense and underdense regions called the cosmic web structure. This 3D structure of the Universe is so far best revealed through cosmological large-volume simulations and large-scale galaxy redshift surveys. Appropriate identification and quantification of these structures are important to the understanding of the evolution of the Universe and test the cosmological models. However, the currently available algorithms based on the friends of friends (FoF) or spherical overdensity (SO) models are not designed suitably

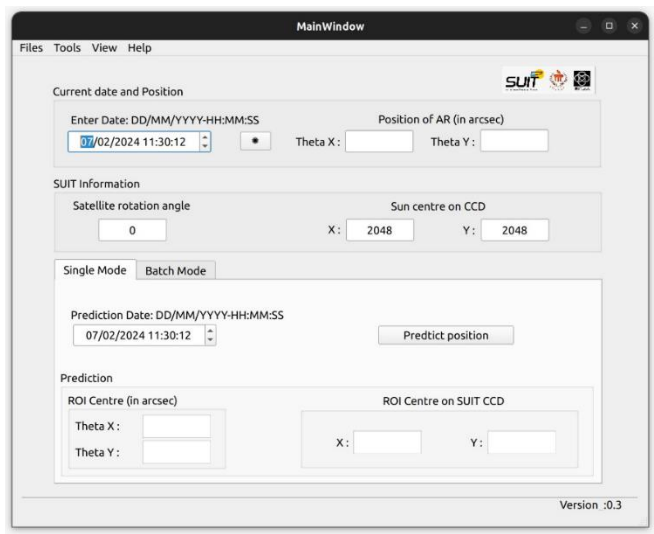
to capture the actual geometry and real gravitationally bound structures. In this work, we present an algorithm called the Measure of Increased Tie with gRavity Order (MITRO), which is fundamentally new that successfully captures the physically relevant over-densities with real unstructured geometries of the objects. In this algorithm, we introduced a novel concept of physically relevant arm length for each element depending on their mass leading to a distinct linking length for each unique pair of elements. We further demonstrate the unique applicability of our code, both in large-volume cosmological simulations as well as in galaxy redshift surveys indicating its usefulness in cosmological studies, especially in the Rubin-LSST era. Publication: Gupta & **Paul** 2023 (PRD): 10.1103/PhysRevD.108.103509

- **Multiwavelength study of radio galaxy Pictor A: detection of western hotspot in far-UV and possible origin of high energy emissions.** The particle acceleration and emission processes in astrophysical jets around supermassive black holes in active galaxies are still debatable even after more than 70 years of their discovery. We have carried out a comprehensive study of the nucleus and western hotspot of the jet of the active galaxy Pictor A using AstroSat observations, 13 yr of Fermi gamma-ray space telescope, and archival Swift observations along with other published data. We report the first detection of the western hotspot of Pictor A in the far-UV band using observations from AstroSat-UVIT. The broad-band SED of the western hotspot is explained by a multi-zone emission scenario, where X-ray emission is caused by synchrotron emission process in the substructures embedded in the diffuse region, while the emission in radio to optical is caused by synchrotron emission process in the diffuse region. Our broad-band spectro-temporal study and associated modelling of the core and hotspot of Pictor A suggests that (a) gamma-rays originate in the nuclear jet and not from the hotspot, (b) X-ray emission from the core of Pictor A has nuclear jet-origin instead of previously reported disc-origin.

  (**S. Gulati**, **Debbijoy Bhattacharya**, M. C. Ramadevi, C. S. Stalin and **P. Sreekumar**, 2023, Monthly Notices of Royal Astronomical Society, 521, 2704; Link: https://doi.org/10.1093/mnras/stad716)

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

- **Solar Ultraviolet Imaging Telescope (SUIT)** onboard Aditya –L1 satellite is a UV telescope to study the Sun. This telescope was developed by Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune in collaboration with multiple institutions, in which Manipal Centre for Natural Sciences is a partner. The SUIT contains many sub-assemblies like thermal filter assembly (TFA), Primary and secondary mirrors, shutter motor assembly, filter wheel assembly, LED assembly, field corrector lens assembly and detector housing assembly. All of these sub-assemblies were developed indigenously in a collaborative effort.
- **SUIT AR Tracker Software module:** This software module was developed by MCNS for the smooth operation of the SUIT payload operation Centre (SUIT POC). This software is used to predict the future location of active regions or any other feature on the solar disk and hence is useful to decide the region of interest to be observed by SUIT. The same software will be released to the public and can be used by anyone to plan Solar Observations.

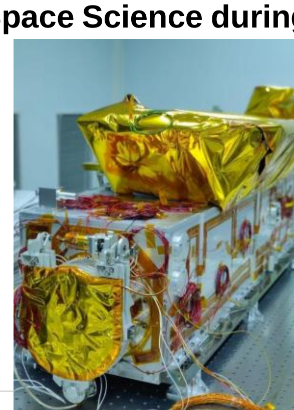


CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

The Institute is engaged in capacity building in space science research:

1. Number of Ph.Ds offered by the institute in Astronomy and Space Science during 2022-23: ongoing: 5, completed:3. Details of completed PhDs:

- Thesis title: *"Understanding Blazar Emission processes using Multiwavelength Spectral and Timing Studies"*
- Thesis title: *"Studies on high energy emission process in misaligned active galaxies"*



- Thesis title: *“Cosmic Inflation: Theoretical Exploration and Observational Constraints”*

2. A few Workshops / Schools during 2022-23:

- Solar Flare Studies using Aditya-L1 – 2022
- Bringing Astronomy: Start a data-driven journey – 2023
- Frontiers in Science – 2023

3. Total number of Summer Research Internship Programs (annual): 10

COURSES OFFERED ON SPACE SCIENCES

Integrated MSc-Phd programme in Physics offered at MCNS, MAHE, Manipal includes

Title Of The Course Offered	**Level Of The Course (Undergraduate / Post-Graduate / PhD Coursework, Etc.)**	**Intake Capacity**	**Subjects Of Specialization In Space Science And Technology**
Introduction to Astrophysics	Post-graduate and PhD Coursework	Post Graduate:20	1. Astronomical scales, coordinate systems, and cosmic rays 2. Introduction to observational astronomy and elementary properties of radiation 3. Stellar astrophysics: atmosphere and interior
Radiative Processes in Astrophysics	Post-graduate and PhD Coursework	Post Graduate:20	1. Elementary properties of radiation 2. Bremsstrahlung Radiation and Plasma Effect 3. Compton and inverse Compton scattering

Laboratories and Facilities Available for Space Instrumentation

MCNS has a strong Am-Be neutron source (16 Curie) used as a general facility for neutron irradiation studies. Samples can be placed at the output port for material related studies, neutron-activated gamma-ray emission studies to derive neutron-absorption cross sections, etc. MCNS also has a table-top proton accelerator (upto 50 keV). Modification of this setup to study PIXE effects in materials, is under consideration. Both these facilities are made available to all researchers outside MCNS for any research studies ; interested faculties can write to the Director, MCNS.

MCNS also has established capabilities for carrying out simulation studies. Computation and simulations to design and optimise experiments as space payloads and to design radiation shielding within space habitation, are in progress.

For further details on the inputs as provided in the document, please contact
Prof. P. Sreekumar. Director MCNS, office.mcns@manipal.edu.

MILLIYA ARTS, SCIENCE & MANAGEMENT SCIENCE COLLEGE, BEED, (MAHARASHTRA) INDIA

https://milliyasrcollege.org/

ABOUT THE COLLEGE

Milliya Arts, Science, and Management Science College, administered by Anjuman Ishat-e-Taleem in Beed, is situated in the gradually developing district of Marathwada, Maharashtra, India. Established in 1991, the college's objectives revolve around nurturing graduates equipped for various facets of life, including social, cultural, political, and economic spheres. The college's vision is encapsulated in the goal of shaping students into not just good human beings but also globally competent individuals. Over the years, the institution has witnessed substantial growth, now offering postgraduate and research programs. Also, the college received accreditation from NAAC with a B+ grade, securing one of the top positions in the town. In addition to conventional courses affiliated with Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, the college has expanded its academic offerings.

Major Research Domains

- **Hyperspectral Remote Sensing**
  - ✓ **Detecting the presence of water ice on the lunar surface**
  - ✓ **Examining mineral blending on the lunar surface**
- **Microwave Remote Sensing**
  - ✓ **Detecting the presence of water ice on the lunar surface.**
  - ✓ **Geophysical Parmeter Retrieval using Microwave remote sensing.**

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

1) **The spectral Deconvolution of the Ch-2 IIRS data Using the Bi-directional Reflectance Function to Study the Mineralogical Composition of the Lunar Surface.**

   Lunar surface spectral signatures are heavily influenced by space weathering, primarily driven by solar wind ion implantation and micrometeorite bombardment. Addressing this involves using a mathematical model based on the radiative transfer equation. This research aims to model Chandrayaan-2's hyperspectral IIRS sensor data using this theoretical model. The model will consider parameters like grain size, porosity, and submicroscopic iron (SMFe), significant in space weathering.

2) **Formulation of a Hybrid Model for Retrieving Geophysical Parameters of Unvegetated Soil through Microwave Remote Sensing.**
   Extracting essential surface soil parameters like moisture, roughness, and dielectric constant poses a challenge with microwave Synthetic Aperture Radar (SAR) data. The Integral Equation Model (IEM) provides a direct link between the backscattering coefficient (σ0) and SAR configuration, while empirical models like the Oh model rely on field parameters. A hybrid approach, combining the simplicity of the Oh model and the direct relationship of the Modified Dubois model (MDB), is explored for soil moisture retrieval using Sentinel-1 C-band SAR data. The study involves stepwise inputs for soil moisture, surface roughness, and incidence angle, with cross-polarized ratio and dielectric constant obtained. The data processing includes model performance evaluation, backscattering coefficient comparison, and soil moisture calculation. The hybrid models show accuracy, emphasizing the sensitivity of parameters to backscattering coefficients.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

We have established the Microwave and Imaging Spectroscopy Research Laboratory with funds received from ISRO. This state-of-the-art facility is currently utilized by more than 20 students at our college. The laboratory serves as a hub for cutting-edge research and provides students with valuable hands-on experience in the field of microwave and imaging spectroscopy.

Titles of Awarded Ph.D. Dissertations

1) Modeling and Simulation of the Hyperspectral Imager (HySI) Sensor Chandrayaan-1 image for Lunar Mineral Mixing Analysis.
2) Microwave SAR Image Analysis in Remote Sensing

Titles of Ongoing Ph.D. Dissertations

1) Remote Sensing of The Characteristics of Water, Snow, And Its Constituent Using Imaging Spectroscopy

2) Estimating Geophysical Parameter Retrieval Using Machine Learning for SAR Imagery
3) Identification of minerals of airless planetary bodies using bidirectional reflectance function
4) Space-based Water Quality Monitoring using Physics-Based Modeling
5) Remote Sensing of The Characteristics of Water, Snow, and Its Constituent Using Imaging Spectroscopy
6) Estimation of Microphysical Properties of Clouds with Regards To Thermodynamic Phase

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

- ✓ Microwave and Imaging Spectroscopy Research Laboratory.
- ✓ The Imaging Spectroscopy Research Laboratory is equipped with two High-Performance Workstations featuring ENVI Software.
- ✓ The Microwave Imaging Laboratory is equipped with a C-band microwave bench, a SHOOL Soil parameter sensor (developed by ISRO-SAC), a Soil testing kit, and a surface roughness apparatus.

Contact person's Name: Dr. Sayyad Shafiyoddin, Professor Physics, E-mail: syedsb@milliyasrcollege.org

NARULA INSTITUTE OF TECHNOLOGY, KOLKATA, INDIA

Website: www.nit.ac.in

ABOUT THE INSTITUTE

Narula Institute of Technology is a leading Engineering and Management Institute at Kolkata under the aegis of JIS Group Educational Initiative since 2001. It is an Autonomous Institute affiliated to MAKAUT, WB with its technical courses approved by AICTE. The Institute has received prestigious NIRF Innovation Ranking 2023, has six NBA accredited degree programmes in Engineering and also prides itself with the prestigious NAAC 'A' accreditation. It has also received recognition under the Scientific and Industrial Research Organization (SIRO) scheme of DSIR and is recognized as one of the Host Institute under MSME for budding entrepreneurs. The Institute aims to achieve excellence in higher education in producing successful and responsible professionals and to develop an environment of multidisciplinary research with emphasis on emerging technical areas including space technology.

MAJOR RESEARCH DOMAINS

- Long and short term characterization of lunar atmosphere
- Short Term Forecast (Now casting) of Orographic Rain for Landslide Prediction analyzing DWR Data over Hilly Regions (Agartala and Mohanbari) and development of associated Warning System.
- Study and modeling of orographic rainfall signature on landslide at hilly regions of north-east India using reliable, accurate, improved range DWR data.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Modeling of Ka-Band Slant Path Rain Attenuation for Hilly Tropical Region - Swastika Chakraborty, et.al., Link: Https://Doi.Org/10.1016/J.Asr.2022.05.002

Experimental measurement of satellite signal at 20.2 GHz using GSAT-14 satellite beacon has been carried out over the hilly tropical location Umiam, Shillong during 2017–2019. Collocated rainfall measurements have been done using a laser precipitation monitor for the same duration. The data have been analyzed to understand the signature of orographic rainfall on the Ka-band signal and to achieve the highest possible reliability of signal reception for a high rainfall tropical location. Complementary cumulative distribution of experimentally obtained rain attenuation is compared with that of conventional ITU-R model calculated rain attenuation and recently developed Chang Sheng model predicted rain attenuation values. The result shows severe over-estimation of the actual measurement by both the ITU-R model and Chang Sheng model. The proposed model is further optimized for operational elevation angle range, rain rate range, and frequency range. The proposed model will help in optimizing the power utilization in the Uplink Power Control technique for rain attenuation mitigation over high rainfall hilly regions.

On collisional drop breakup in orographic rain

On collisional drop breakup in orographic rain – Nitig Singh et.al., Link: https://doi.org/10.1016/j.atmosres.2024.107232

Collisional drop breakup is one of the important processes during evolution of the rain drops and leads to modified shape of the drop size distribution (DSD); a primary parameter in rain retrieval in remote sensing techniques. The present study aims to examine and identify the rain conditions in which collisional drop breakup is prominent and is capable of modifying the shape of DSD in orographic rain over north-eastern India. Even though drop breakup in intense to moderate rain seemed to be in notable percentage (0.2% - 11.2%), the low intensity rain also showed a considerable break-up signature (2.5% - 9%), depending upon the locations. The overall results showed that collisional breakup was more prominent in convective rain (1%–11%) than in stratiform rain (4%–5%), however, breakup is also seen primarily during stratiform rain in two of the locations. The *Z*-R coefficients are found to be significantly different for the break-up and non-break up cases. The results suggest that collisional breakup is an important process in orographic rain over North-Eastern India and it has to be taken care of, while studying rainfall over these regions, particularly in conventional radar derived quantitative precipitation estimates (QPE).

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Narula Institute of Technology is engaged in comprehensive study of sunlit lunar exosphere from CHACE II of Chandrayaan 2 orbiter at mid latitude region with the grant received under AO opportunity. Here one Junior Research Fellow and one intern is working since May 2023.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Table: Courses offered at Narula Institute of Technology

Title of the paper / course offered	**Level of the course (undergraduate / post-graduate / PhD coursework, etc.)**	**Intake capacity**
Satellite Communication	Undergraduate (Pre Final and Final Year)	100 (As Elective)
Remote Sensing	Undergraduate (Pre Final and Final Year)	100 (As Elective)
Satellite Communication	Postgraduate	18
Remote Sensing	Postgraduate	18
Cognitive Radio	Postgraduate	18

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LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

The institute has basic laboratory infrastructure with special focus on emerging technical areas viz. Machine Learning, IoT, Space Instrumentation, etc.Some Relevant Notable Lab Facilities available are as follows:

- Sensor and Embedded System laboratory
- Advanced RF and Microwave Engineering laboratory
- VLSI Circuits and System laboratory

For further details on the inputs as provided in the document, please contact –
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https://www.niser.ac.in/

ABOUT THE INSTITUTE

The National Institute of Science Education and Research (NISER), Bhubaneshwar, is an institution under the Dept. of Atomic Energy, Govt. of India and offers undergraduate and postgraduate education in basic sciences combined with frontline research. Space science exploration and research at NISER is mainly carried out in the School of Earth and Planetary Sciences (SEPS) and School of Physical Sciences (SPS).

SEPS is an interdisciplinary school bridging planetary science, geoscience, astrophysics, astrobiology, and atmospheric-oceanic sciences. Faculty members at SEPS are involved in various space-science related research, including solar system exploration (comets, asteroids, meteorites, and dusts), planetary geology and tectonics, star and planetary formation using ground and space-based telescopes, astrobiology, exoplanet research, planetary/sample-return/exoplanetary missions, and state-of-the-art instrumentation and laboratory techniques.

Faculty members at SPS are involved in research areas like observational cosmology, galaxy formation and evolution, cosmological N-body (and hydrodynamical) simulations, search for primordial gravitational waves, data pipeline development for the wide-field optical polarimeter and state-of-the-art data analysis techniques in simulations and observations.

KEYWORDS

Planetary Atmosphere; Planetary Surface; Planetary Tectonics & Habitability; Cosmochemistry; Extraterrestrial Materials and Meteorites; Planetary Astronomy & Astrophysics; Star and Planet Formation; Extrasolar Planets; Observational Cosmology; Galaxy formation and evolution; Structure Formation; Primordial gravitational waves.

MAJOR RESEARCH DOMAINS

Research at SEPS, NISER is focused on:

• ***Exoplanets and Planetary Formation: Understanding the physical and chemical origins of planetary systems such as our own*** **(PI: Dr. Liton Majumdar, Reader-F):** Dr. Liton Majumdar leads the Exoplanets and Planetary Formation team, exploring the origins and evolution of extrasolar planets, including protoplanetary disks, planet formation, and planetary atmospheres, using observational (e.g. ALMA, JWST, various ground-based Optical/IR telescopes) and modeling methods.

• ***Planetary composition: Understanding the planetary processes in the early solar system*** **(PI: Dr. Guneshwar Thangjam, Reader-F):** Study of surface composition and the geology of various planetary bodies are being carried out along with participation and collaboration at national and international platform (i.e., active participation in NASA Dawn mission to the largest asteroids Vesta and Ceres; ISRO Chandrayaan-2 mission to the Moon, etc.). Besides, study of planetary analogue samples and the meteorites or space rocks are also one of the major activities to decipher the early solar physico-chemical and geologic conditions.

• ***Planetary and Exoplanetary Atmospheres: Characterizing the atmospheres of exoplanets and the planets in our solar system.*** **(PI: Dr. Jayesh Goyal, Assistant Professor):** In our research group we develop and apply theoretical models of the planetary atmospheres. These models include detailed radiative transfer computations, atomic and molecular opacities and various chemistry schemes to simulate the planetary atmospheres. We propose, plan and interpret observations of exoplanet atmospheres from Hubble and James Webb Space Telescope and various ground-based telescopes including those in India, using our theoretical models.

• ***Cosmochemistry and laboratory planetary science*** **(PI: Dr. Surya Snata Rout, Assistant Professor):** In our research group we carry out a coordinated mineralogical, chemical, structural and isotopic composition study of extraterrestrial materials (e.g. meteorites, micrometeorites, fossil meteorites, interplanetary dust particles) to understand early history of the solar protoplanetary disc, changes in surface properties of airless solar system bodies, the past flux of extraterrestrial materials to Earth and stellar nucleosynthesis through study of presolar grains in meteorites.

• ***Planetary tectonics and crustal evolution*** **(PI: Dr. Priyadarshi Chowdhury, Assistant Professor):** This research group focusses on determining the thermo-mechanical evolution of early Earth as an analogue to understand the long-term evolution of rocky planets, and how it shapes planetary habitability. The group uses petrology, geochemistry, and geodynamic modelling to decode the physical conditions prevalent on early Earth and uses them to understand the evolution of rocky planetary bodies including Venus, Mars etc.

Regional hydroclimatology **(PI: Dr. Jaya Khanna, Assistant Professor):** Regional Hydroclimatology (PI: Dr. Jaya Khanna, Assistant Professor): PI's research interests focus on -

(a) modulation of the regional climate and hydrology by large swaths of forests in the Himalayas and Amazonia, and (b) regional climatic impacts and modulation of near surface heat stress by atmospheric water vapor through a control on cloud formation in the tropics.

• ***Crustal deformation and earthquake physics*** **(PI: Dr. Pathikrit Bhattacharya, Assistant Professor):** Research in this group focuses on theoretical and experimental analysis of the physics of deformation and shear failure across scales in earth sciences. Over the last year, the group has worked on a variety of problems spanning cm-scale deformation data gathered in the laboratory to the 10s-of-km scale data accessed through observations of earthquake related deformation in nature.

Research at SPS is focused on:

• ***Galactic astrophysics and cosmology*** **(PI: Dr. Tuhin Ghosh, Reader-F):** Research in this group focusses on three main topics – (a) novel statistical techniques to understand foreground Galactic dust emission, (b) Reconstruction of three-dimensional Galactic magnetic field through starlight polarization measurements (PASIPHAE survey), and (c) component separation techniques to detect primordial gravitational waves for the future CMB missions (e.g. CMB-Bharat mission).

• ***Multiwavelength view of galaxy formation and large-scale structure of the Universe*** **(PI: Dr. Nishikanta Khandai, Associate Professor):** 1. The distribution and evolution of neutral HI gas (21cm) in galaxies. 2. Multiwavelength observations of galaxies and comparison with model predictions to understand the relation between halos and different phases of baryons in galaxies, (hot/cold gas, stars, dust and metals). 3. Role of feedback on (i) galaxy formation and (ii) distribution of metals in the IGM, CGM and ICM. 4. Predictions of Gravitational Wave and Multiwavelength signals from merging supermassive blackholes in galactic centres.

• ***Theoretical Astrophysics of Galactic Magnetic Fields and Merging Binary Star Systems*** **(PI: Dr. Luke Chamandy, Reader-F):** Spiral galaxies generally contain equipartition-strength magnetic fields, ordered on scales up to the size of the galaxy, itself. We try to understand these fields through various modeling approaches. The merger of stars in a binary system is responsible for many astrophysical phenomena. We use global hydrodynamic simulations in 3D to explore such events.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS:

School of Earth and Planetary Sciences:

• ***Exploplanets and Planetary Formation: Understanding the physical and chemical origins of planetary systems such as our own*** **(PI: Dr. Liton Majumdar, Reader-F):** Surveying organic molecules at different stages of planet formation and their relevance to delivering them to habitable planets such as Earth.

https://iopscience.iop.org/article/10.3847/1538-4357/acdb6d

https://iopscience.iop.org/article/10.3847/1538-4365/acd110

• ***Planetary composition: Understanding the planetary processes in the early solar system*** **(PI: Dr. Guneshwar Thangjam, Reader-F):**

https://doi.org/10.1038/s41467-022-28570-8 We provide evidence for the presence of a brine layer below the crust of the dwarf planet Ceres, using data from NASA's DAWN mission. This brine layer likely leads to recent geologic activity on Ceres where some craters show presence of organic- and salt-rich materials.

• ***Planetary and Exoplanetary Atmospheres: Characterizing the atmospheres of exoplanets as well as the planets in our solar system.*** **(PI: Dr. Jayesh Goyal, Assistant Professor):** https://doi.org/10.1038/s41586-022-05269-w We detected Carbon Dioxide (CO2) in the Atmosphere of an Exoplanet for the first time.

https://doi.org/10.1093/mnras/staa2300 An extensive library of exoplanet atmosphere model simulations was developed that has led to discovery of numerous molecules/atoms in exoplanet atmospheres, as well as a stratosphere in one of the exoplanets.

• ***Cosmochemistry and Laboratory Planetary Science*** **(PI: Dr. Surya Snata Rout, Assistant Professor):**

https://doi.org/10.1111/maps.14082. We show that diamond grains in ureilite meteorites form through asteroid scale impacts and not inside a large Mercury-sized planetessimal. Also we show that diamond grains form from graphite through a catalytic process.

• ***Planetary tectonics, crustal evolution, and habitability*** **(PI: Dr. Priyadarshi Chowdhury, Assistant Professor):** We use geodynamic modelling, petrology, and geochemistry to understanding the evolution of other rocky planets.

https://doi.org/10.1038/ngeo3010, https://doi.org/10.1130/G51874.1: We proposed a new tectonic style (called peel-back tectonics) for early Earth, which was also used to explain the surface observables of other rocky planets, including Venus.

https://doi.org/10.1073/pnas.2105746118: We showed how intense magmatism in the crust, followed by its isostatic adjustment, can form a subaerial, felsic crust and lead to habitable conditions on rocky planets.

School of Physical Sciences (SPS):

• ***Galactic Astrophysics and Cosmology:*** **(PI: Dr. Tuhin Ghosh, Reader-F):**

The quest for the CMB Polarization *B*-mode signal, generated by inflationary gravitational waves in the very early Universe, is one of the key scientific goals of proposed CMB-Bharat space mission to the ISRO. The target sensitivity of CMB-Bharat is to detect tensor-to-scalar ratio of $r \sim 10^{-3}$ at 3 sigma significance level. This is the prediction of large class of inflationary models. We test the practicality of two component separation methods (NILC and Commander) to detect `*r*' at the level of 10^{-3} in the presence of realistic foregrounds (*Adak et al. 2022*) and test the importance of high frequency bands for the mission design and optimization (*Sen et al. 2023*). https://doi.org/10.48550/arXiv.2110.12362 and https://arxiv.org/abs/2212.02869.

• ***Multiwavelength view of galaxy formation and large-scale structure of the Universe*** **(PI: Dr. Nishikanta Khandai, Associate Professor):** Redshift Space Three-Point Correlation Function of IGM at z < 0.48. Maitra, S., Srianand, R., Gaikwad, P., Khandai, N. 2022 January, Monthly Notices of the Royal Astronomical Society, 509, 3, 4585. https://doi.org/10.1093/mnras/stab3308. We measure the clustering of Lyman-alpha absorber triplets at low redshift (z< 0.48). Using large cosmological hydrodynamical simulations and find that the effect of feedback is imprinted on the clustering measurement in redshift space.

• ***Theoretical Astrophysics of Galactic Magnetic Fields and Merging Binary Star Systems*** **(PI: Dr. Luke Chamandy, Reader-F):** Y. Zou, L. Chamandy, J. Carroll-Nellenback, E. Blackman, A. Frank, *Jets from main sequence and white dwarf companions during common envelope evolution*, MNRAS, 2022, 514, 3041.

We explore the role of jets launched from the companion during a stellar merger, focusing on its role in removing the stellar envelope and terminating the merger.

Publications list for SEPS: https://oldsite.niser.ac.in/seps/all-publications

Publications lists for SPS: https://oldsite.niser.ac.in/sps/page/publications

NOTE: New website for NISER is being built and the link may not be active after few months.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

I. Academic activities in Space Sciences:

1. Ph.D. program in various different aspects of space sciences from SEPS and SPS
2. Integrated MS program (Major and Minor) in Earth and Planetary Sciences is being developed by SEPS
3. MS/MTech Thesis and Internship program in Space Sciences from SEPS and SPS

II. Present and past outreach and student's activities in Space Sciences:

1. Regular astronomy related activities organized by NISER astronomy club with the help of SEPS and SPS faculties. These events are open to school and college students.
2. Public event on Chandrayaan-2 lunar landing, 7th Sept 2020, with the help of NISER students (Astronomy club, Robotics club, Zaariya club, and Art club). This event was attended by the school and college students.
3. Introductory School on Galaxy Formation, 13-16 March 2018, organized by SPS NISER and IUCAA faculty. This was attended by M.Sc. and Ph.D. students from all over India. The School was followed by a workshop.
4. Public outreach event on Chandrayaan-3 landing and the on various ongoing and future planned missions by ISRO. This was attended by students from various schools in Bhubaneswar and Jatani area.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Title	Level (Course)	Capacity	Specialization
Planetary Sciences	PhD	~10	EPS
Astrochemistry and Astrobiology	PhD	~10	EPS
Formation of planetary system	PhD	~10	EPS
Exoplanets	PhD	~10	EPS
Planetary atmosphere & space weather	PhD	~10	EPS
Planetary surface processes	PhD	~10	EPS
Geophysics	PhD	~10	EPS
Petrology and Mineralogy	PhD	~10	EPS
Geochemistry and Geochronology	PhD	~10	EPS
Fundamentals of Astronomy	Int. MSc.	~30	EPS
Formation & evolution of planetary system	Int. MSc.	~30	EPS
Astrobiology, Origins and Early Evolution of Life	Int. MSc.	~30	EPS
Planetary Surface process	Int. MSc.	~30	EPS
Advanced Cosmochemistry	Int. MSc.	~30	EPS
Planetary and Exoplanetary Atmospheres	Int. MSc.	~30	EPS
Extrasolar Planets: Physics and Detection Techniques	Int. MSc.	~30	EPS
Stellar and Planetary Magnetosphere	Int. MSc.	~30	EPS

Analysis of Planetary materials and space instrumentation	Int. MSc.	~30	EPS
Multi-wavelength Observational Astronomy	Int. MSc.	~30	EPS
Advance Space Science and Technology	Int. MSc./PhD	~30	EPS
Astronomy and Astrophysics	Int. MSc./PhD	~30	Physics
Introduction to Cosmology	Int. MSc./PhD	~30	Physics
Experimental Techniques	Int. MSc./PhD	~30	Physics
General Relativity and Cosmology	Int. MSc./PhD	~30	Physics

EPS = Earth & Planetary Sciences

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

1. Laboratory for simulation of impact of dust particles and solar wind on planetary surface and IR Spectroscopy (PI: Dr. Surya Rout): A nanosecond pulsed laser laboratory in SEPS will be installed in 2022-2023 and will be dedicated for this study along with preparing a large spectrum of planetary analog materials that will be characterized using IR-spectroscopy. The library of data will support any missions of ISRO to terrestrial planets, asteroids and comets.

2. Electron microscopy laboratory for study of geo- and extraterrestrial materials (PI: Dr. Priyadarshi Chowdhury and Dr. Surya Rout): The center of interdisciplinary science (CIS) in NISER houses advanced electron microscopes (e.g., focused ion beam-scanning electron microscopes, transmission electron microscope) and these will be used for studying geomaterials and extraterrestrial materials (e.g., rocks, zircons, meteorites, IDPs, primitive micrometeorites, pre-solar grains, samples returned from asteroids and comets, etc.). This facility can act as an important infrastructure for study of any future sample-return mission by ISRO.

3. Clean room facility for curation of meteorites and extraterrestrial materials (PI: Dr. Surya Rout): A clean room facility is being set up in SEPS that will be dedicated to curation and preparation of extraterrestrial materials. The facility will include an advanced storage facility for rare meteorites and extraterrestrial materials under controlled conditions, facility for extraction of rare pre-solar grains from meteorites, manipulation of small grains using advanced micromanipulators and preparation of small grains for isotope and electron microscope studies.

4. Planetary cryogenic reflectance spectroscopy laboratory (PI: Dr. Guneshwar Thangjam): A lab with an FTIR spectrometer (Bruker Vertex 80V) along with an Oxford cryostat is planned to be set up in 2024-2025. The lab is expected to cover the spectral ranges from UV to VIS and NIR parts (i.e., ~0.3 to 25 microns) with various spectral resolutions (~5 - 50 nm, etc.).

The lab is expected to simulate the cold planetary environment up to the asteroid belt (~up to 3.3 AU).

5. Earth and Planetary remote sensing and Image processing laboratory (PI: Dr. Guneshwar Thangjam): A lab with image processing and analysis software and packages along with high end computers is set up. The remote sensing software (ENVI and ArcGIS) are being used for the satellite data processing and analysis. Open source softwares (like QGIS) are also used. The Planetary Image Processing Software (ISIS, developed by United States Geological Survey) image processing package required for NASA and ESA planetary missions is also being used.

6. Meteorological observatory in the Middle Himalayas (PI: Dr. Jaya Khanna): Under this facility the PI is developing infrastructure for observing meteorological variables and variables related with forest-atmosphere interactions in the forested regions of middle Himalayas. Through these observations the PI envisions to study forest-triggered convective processes and their interactions with hydrology and climate. Some satellite based meteorological data products, specifically related with clouds and precipitation, generated by ISRO are also being used in the project.

7. Crustal Deformation and Friction Physics laboratory (PI: Dr. Pathikrit Bhattacharya): This laboratory will combine state-of-the-art modeling techniques with a dedicated laboratory designed to measure the shear strength of geomaterials to characterize a wide range of processes from large scale fault deformation to rainfall-induced landslides. Among other interests, the laboratory is developing in-house computational models and data inversion frameworks for interpreting data generated by ISRO's ground- and space-based geodetic observations including IIRS and SAC maintained GPS networks and high-resolution InSAR data anticipated from the NASA-ISRO SAR (NISAR) mission to be launched in 2023.

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ABOUT THE INSTITUTE

National Institute of Technology Rourkela is an institute of national importance with a heritage of 63 years. The institute is known for excellence in research, consultancy, and education at the undergraduate, postgraduate, and doctoral levels. NIT Rourkela is consistently ranked among the best professional institutes in the country. As per the latest National Institution Ranking Framework, NIT Rourkela is ranked 37th overall and 16th in Engineering. The institute is also ranked 801-1000 in Times Higher Education World Universities Rankings; 291-300 in QS Asian University Rankings and in the top 500 globally by several other agencies.

The institute's vision is “to become an internationally acclaimed institution of higher learning that will serve as a source of knowledge and expertise for the society and be a preferred destination for undergraduate and graduate studies.” The mission statement reads “to advance and spread knowledge in the area of science and technology leading to the creation of wealth and welfare of humanity.”

MAJOR RESEARCH DOMAINS

NIT Rourkela is actively engaged in various domains of science and technology, spread across computational, electronic, mechanical, and other domains such as biological and social sciences. The major areas are given below:

1. Earth and Atmospheric Sciences
   - SURFACE DEFORMATION USING INSAR TECHNIQUES: Global and Regional Monitoring of Hazards, Atmospheric Correction.
   - EXTREME/HIGH-IMPACT WEATHER EVENTS: Thunderstorms, Tropical cyclones, Heatwaves, Heavy precipitation events, Forest fires using observations (in-situ and Satellite data sets) and numerical modeling techniques.
   - AIR POLLUTION AND AEROSOL-CLOUD INTERACTIONS: Air Pollution, Aerosols and their interaction with clouds, radiation and precipitation, Aerosol-extreme weather interaction using observations (in-situ and Satellite data sets) and numerical modeling techniques.
   - ATMOSPHERE-BIOSPHERE INTERACTIONS: Carbon flux, Ecosystem Change and Climate impacts using observations (in-situ and Satellite data sets) and numerical modeling techniques.
   - IONOSPHERIC DISTURBANCES USING TEC MEASUREMENTS:Geomagnetic storms,Solar Flares, Ionospheric Scintillation, Space Weather Monitoring.
   - LIGHTNING DETECTION SENSOR: Lighting occurrences, Lighting Impulse Voltage, and Condition Monitoring of High Voltage Power System Equipment, Extreme.
   - MACHINE LEARNING & DEEP LEARNING APPLICATIONS: Application of ML/DL techniques in all kinds of weather and climate research areas of interest
2. Mechanical Engineering: Vibration Control, Vibration Energy Harvesting, Computational Multiphysics Lab, Micro Cryogenic Coolers for Phased Array Receiver
3. Physics – A&A
   - Extragalactic astrophysics, stellar astrophysics, solar and planetary physics, compact object (neutron stars and black holes), gravitational wave physics and cosmology.

- Extragalactic star formation, UV-bright stars in Globular clusters, and blazars using UV and X-ray observations of ASTROSAT launched by ISRO.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Ionospheric Disturbances Using TEC Measurements

1. Detecting the 2022 January 15 Hunga Tonga–Hunga–Ha'apai volcanic eruption (SW Pacific) high up in the sky through 'ionospheric resonance'. https://doi.org/10.1093/gji/ggac492
2. Surface Deformation Using InSAR Techniques
3. Co-seismic surface displacement of the June 21, 2022 Khōst MW6, Afghanistan earthquake from InSAR observations. https://doi.org/10.1016/j.geog.2023.08.003.
4. Mechanical Engineering
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Cryocoolers

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18. Rotating hairy black holes and thermodynamics from gravitational decoupling, SubhashMahapatra and Indrani Banerjee, Physics of the Dark Universe, 39, 101172 (2023); arXiv: 2207.09003
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37. Sahu, R.K. and Tyagi, B., 2022. Spatial variation of thermodynamic indices over north-east India during pre-monsoon thunderstorm season. Journal of Atmospheric and Solar-Terrestrial Physics, 232, p.105868.

38. Air Pollution and Aerosol-cloud interactions

39. Tyagi, B., 2022. India's economic growth and disease burden in relation to air pollution. The Lancet Regional Health-Southeast Asia, 7, https://doi.org/10.1016/j.lansea.2022.100081.

40. Barudgar, A., Singh, J. and Tyagi, B., 2022. Variability of Fine Particulate Matter (PM2. 5) and its Association with Health and Vehicular Emissions Over an Urban Tropical Coastal Station Mumbai, India. Thalassas: An International Journal of Marine Sciences, pp.1-14, https://doi.org/10.1007/s41208-022-00442-4

41. Sahu, R.K., Hari, M., Tyagi, B., 2022. Forest Fire Induced Air Pollution over Eastern India during March 2021. Aerosol Air Qual. Res. 22, 220084. https://doi.org/10.4209/aaqr.220084

42. Atmosphere-Biosphere Interactions

43. Hari, M. and Tyagi, B., 2022. Terrestrial carbon cycle: a tipping edge of climate change between atmosphere and biosphere ecosystems. Environmental Science: Atmospheres. DOI: 10.1039/D1EA00102G

44. Hari, M. and Tyagi, B., 2022. India's Greening Trend Seems to Slow Down. What Does Aerosol Have to Do with It?. Land, 11(4), p.538.

45. Machine Learning & Deep Learning Applications

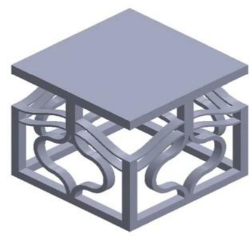
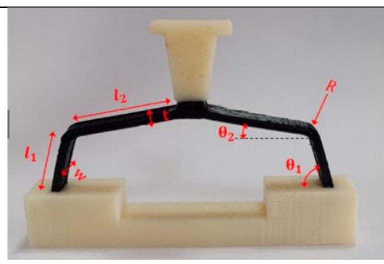
46. Sunder, M.S., Tikkiwal, V.A., Kumar, A. and Tyagi, B., 2023. Unveiling the Transparency of Prediction Models for Spatial PM2. 5 over Singapore: Comparison of Different Machine Learning Approaches with eXplainable Artificial Intelligence. AI, 4(4), pp.787-811.

Website link to list of publications during January 2022 – December 2023

https://nitrkl.ac.in/Research/PublicationsPatents (15,000+)

https://nitrkl.irins.org/ (14,703)

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

SN	Product	Reference link
1	 *Fig1: QZS Metastructure using bistable beam*	• QZS-based Metastructure using the combination of a cosine beam and a semi-circular arch, is designed for a payload capacity of around 5N *https://link.springer.com/article/10.1007/s11071-022-07301-0*
2	 *Figure 2: QZS-based vibration isolator using Single beam Element*	• A novel metamaterial using a single stiffness element designed for three different payload capacities of 8N. • The design exhibits good isolation performance even for excitations of low frequencies. *https://doi.org/10.1177/10775463231198892*
3	3DVAR system	Developed for HWRF system in collaboration with IIT Bhubaneswar and India Meteorological Department (IMD) Delhi, and NCMRWF Noida. https://10.1109/TGRS.2020.2978211
4	Series Connection for Cooling from Room Temperature to 4 K	Achieving 4 K cooling starting from room temperature requires a series of connections of different multistage cryocoolers.The combination of cryocoolers with varying temperature ranges ensures effective cooling.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

1. Six Ph.D. scholars and over 30 post-graduates in ER Department are adept in utilizing satellite data for weather and climate processes and predictions.
2. Three PhD students have recently graduated from A&A group and pursuing their post-doctoral work in different renowned Institutions like IUCAA, PRL and ARIES. The Thesis titles of the graduated students are as follows:
    - Probing the circumgalactic Medium with Quasar Absorption Lines.
    - Probing the Star-formation Activities of Galaxies Residing in Void and Filaments Using AstroSat.
    - Study of UV-bright stars in Galactic globular clusters using Ultraviolet Imaging Telescope (UVIT) observations
3. National Institute of Technology Rourkela participated in an online training on Space Science and Technology (3001-IIRS Outreach Programme) conducted by the Indian Institute of Remote Sensing, ISRO Dehradun, under the ISRO START Programme from July 20 to August 07, 2023. Coordinated by Dr. Anil Kumar Singh from the Department of Physics and Astronomy at NIT Rourkela, 10 students successfully completed the course.
4. Nine projects undertaken through Space Technology Incubation Centre (STIC) are building the capacity of students and faculty in extending their research domains to space science research. Several PhD, M. Tech and B. Tech students have undertaken their dissertation work in these areas. The list of projects is as follows:
    a. Design and Development of Electronic Feeler Gauge
    b. Development of multi-arm Toothed Log-periodic Antenna for Geodetic grade Multi GNSS
    c. UAV-Aided Weather Radar Calibration
    d. Design and development of Software Defined Radio based Telemetry, Tele-command and tracking Processor
    e. Design and development and mm-wave circuits
    f. Integrated Information System for Agriculture Monitoring and Crop Insurance
    g. Development of Hybrid polyhydroxy Urethanes for Aerospace Applications

h. Design and Development of Magneto Resistive Heat Switch
i. Design and Development of Vibration Isolators Using Negative Stiffness Mechanism

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Sl No	Title of the course offered	Level of the course	Intake capacity	Subjects of specialization
1	Doctor of Philosophy (various disciplines)	PhD	–	Antenna, Signal processing, control, Earth and Atmospheric Sciences.
2	Master of Technology	Post-graduate	20	Earth and Atmospheric Sciences
3	Master of Technology	Post-graduate	20	Atmosphere and Ocean Science
4	Master of Technology	Post-graduate	40	Signal and Image Processing

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

1. Four GNSS Stations installed Surrounding Son Narmada Region and One at NIT Rourkela Campus.
2. Weather and Climate Modeling Lab
   a. Workstations for processing satellite data (with support of Space Application Centre, ISRO)
   b. 128-processors server for research activity in simulating and improving weather processes.
3. Materials & Wave Propagation Laboratory
   a. Dynamic Vibration testing setup.
   b. Flash-Forge Guider IIs series is available for rapid prototyping of designs.
   c. Licensed version of ANSYS, MATLAB, SolidWorks are available.
   d. A cleanroom for the development and assembly of sophisticated instruments is available.
4. Computational Multiphysics Lab (CML):
   a. High-performance computing cluster (HPPC), with AMD Genoa 9th series processors, RAM:1 TB, DDR-5, 128 cores.

INSTITUTE OF TECHNOLOGY, NIRMA UNIVERSITY AHMEDABAD, INDIA

Website: www.nirmauni.ac.in

ABOUT THE INSTITUTE

Institute of Technology, Nirma University (ITNU) has well-equipped laboratories with about 700 computer systems for postgraduate and undergraduate students. All blocks in the campus are connected via a fiber-optic cable network to provide high-speed LAN as well as wireless connectivity. These laboratories are used by students to carry out various academic activities. The laboratories also cater to the infrastructure requirements in order to host various student-centric events like hackathons, coding practices, workshops, seminars, expert talks, etc. It has several well-established specialized laboratories. These laboratories provide a home for budding technocrats and faculty mentors to carry out co-curricular and extra-curricular research. The tools/ technology/ software are available for all members of the Institute. The institute is equipped with required hardware equipment, simulators, software, workstations, and multi-GPU-based high-end systems for inculcating practice-oriented skill development among students. The Electronics and Communication department of ITNU has designed and developed a radiation hardened chip, which can absorb radiation, prevent failure and selfheal on the failure of shielding outfits under radiation environment in space. The design has met the approval of SAC-ISRO and has been accepted for presentation at NASA Langley Research Center. The Mechanical department of ITNU is involved in research activities aligned with various areas in Mechanical Engineering discipline viz. Design Engineering, Materials Technology, Manufacturing Technology, Robotics and Automation, Stress Analysis, Thermo-fluid Systems, Energy Systems, etc.

MAJOR THRUST AREAS

- Data Science and Artificial Intelligence
- Cyber-Physical Systems
- Multimedia Processing and Analytics
- Advanced Computing
- Materials and Design Engineering

- Manufacturing Processes and Analysis

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

1. The study employs the AVIRIS-NG hyperspectral sensor for crop type identification using a Parallel Convolutional Neural Networks architecture. Band selection, comparing PCA and ANN, and an automated data augmentation technique are explored. Results favor ANN-selected bands with automated augmentation for higher accuracy. https://ieeexplore.ieee.org/abstract/document/8897897

2. This study proposes a sample selection method for crop mapping using hyperspectral images, addressing limited ground truth data. Leveraging similarity measures and fuzziness, the method outperforms prevailing approaches, demonstrating significant improvements in overall accuracy and kappa coefficient, particularly on the Indian Pines dataset. https://www.sciencedirect.com/science/article/abs/pii/S027311772200518X

3. In remote sensing, hyperspectral datasets face challenges due to numerous narrow bands and limited ground-truth data. This paper introduces a novel band selection algorithm based on spectral information divergence (SID). The algorithm, validated with classifiers like SVM, K-nearest neighbors, and ANN, demonstrates superior performance on AVIRIS-NG, Indian Pines, and Salinas datasets. Achieving an OA of 97.55% with 20 selected bands and marginal improvement to 98.40% for 40 bands, the proposed algorithm outperforms prevailing methods focusing on band correlation analysis. https://link.springer.com/article/10.1007/s12524-022-01545-4

4. Ocean oil spills, whether biogenic or mineral, pose significant threats to the marine ecosystem. This paper presents a three-step framework for detecting oil spills using Synthetic Aperture Radar (SAR) data. It involves dark spot detection, feature extraction, and classification, utilizing the Hysteresis algorithm and a decision tree. The implemented steps in oil spill detection are efficiently carried out in ImageJ, offering a lightweight solution compared to existing software. https://ieeexplore.ieee.org/abstract/document/7449646

5. In crop classification, hyperspectral images (HSIs) offer precise land cover classification, aided by deep learning models like VGG16, VGG19, ResNet, and DenseNet. The paper explores transfer learning approaches, emphasizing the effectiveness of heterogeneous transfer learning models on benchmark HSIs datasets. Results show high accuracy, reaching 99% with only 15% labeled training samples, particularly with homogeneous transfer learning using 2DCNN and 3DCNN models pre-trained on the Indian Pines dataset and adjusted on the Salinas scene dataset. https://link.springer.com/article/10.1007/s40808-022-01608-y

6. High dimensional fidelity is the primary challenge for the large size carbon fiber reinforced polymer (CFRP) antenna reflectors used in space applications. Selection of crucial process parameters governs dimensional control of a composite product. In this paper, the influence of the mould materials, curing cycle, lay-up sequence and laminate thickness on spring-back deformation during autoclave curing is investigated by fabricating a large number of parabolic reflectors using the unidirectional prepreg system. The results reveal that the spring-back deformation of parabolic reflectors is significantly affected by the mould material and laminate thickness, whereas the lay-up sequence and curing cycle do not have a significant effect.

https://www.sciencedirect.com/science/article/abs/pii/S1359835X18303750

7. The present study devises and numerically investigates a new thermal control system for detectors of optical payloads for spacecraft systems. The system uses thermoelectric coolers (TECs) as the active element which maintains the cold finger at the required set point such that temperature of detectors is maintained within the required range throughout its operation. The system doesn't utilize any heat pipe network, but instead, uses radiators attached to the hot-side of TEC to dissipate the heat load into the ambient space environment. System level modelling using effective properties are used to model the performance of TEC without modelling any internal intricate geometry. Temperature dependent current profiles are used as input conditions for the TECs such that the TEC consume only the required amount of external power.

https://www.sciencedirect.com/science/article/pii/S1359431123001308

8. Pulse Tube Refrigeration is considered as an appropriate refrigeration technology in the space, military and other industry, leading to extensive study on increasing and optimizing its thermodynamic efficiency. The acoustic power of pulse tube can be lowered by optimizing the phase difference of pressure and mass flow rate, by adding inertance tube the phase can be easily modified. In this study a model is designed that uses electrical analogy for thermodynamic property and iteratively computes the compliance, inertance and resistance of the inertance tube by discretization of the tube in large number of nodes. To find better performance, the effect of varied cross section of plots are generated in order to facilitate the method to choose an inertance tube geometry that provides necessary phase shift and estimate the required acoustic power. https://link.springer.com/chapter/10.1007/978-981-99-5990-7_44

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

- Development and Testing of NavICSuite: Processing Software Tool for NavIC Receiver – an ISRO-RESPOND project
- Process development for minimization of spring back deformation and enhancement of profile accuracy of carbon fiber reinforced polymers (CFRP) reflectors - an ISRO-RESPOND project.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Title of the course offered	**Level of the course**	**Intake capacity**	**Subjects of specialization**
Remote Sensing, GIS and GPS	Undergraduate	120	Electronics and Communication Engineering
Digital Image Processing and Analysis	Undergraduate	150	Computer Science and Engineering

Deep Learning	Undergraduate, Postgraduate, PhD	250	Computer Science and Engineering
Machine Learning	Undergraduate	480	Computer Science and Engineering
Data Analytics	Undergraduate, Post-graduate	180	Computer Science and Engineering
Satellite Communication	Undergraduate	120	Electronics and Communication Engineering
Heat Transfer	Undergraduate	120	Mechanical Engineering
Finite Element Analysis	Undergraduate and Postgraduate and PhD	150	Mechanical Engineering
CAD/CAM	Undergraduate, Postgraduate, PhD	150	Mechanical Engineering
Computational Fluid Dynamics	Undergraduate, Postgraduate, PhD	150	Mechanical Engineering
Refrigeration and Airconditioning	Undergraduate, Post-graduate, PhD	150	Mechanical Engineering
Dynamics of Machines	Undergraduate, Post-graduate, PhD	150	Mechanical Engineering

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

1. Center for Robotics and Automation
2. National Laboratory for Testing and Development of Thermal Insulations

   The proposal was accepted by AICTE which has partially funded the Laboratory. Also this project is in collaboration with industries and MOUs have been signed with more than 30 industries for its effective utilization and support.

3. Testing Facilities

a) Testing of Thermal Conductivity as per ASTM C518

The laboratory possesses a Heat Flow Meter system to test thermal conductivity of insulations in the conductivity range 0.015 to 2.5 W / m K and temperature range 0^{o} C to 80^{o} C as per ASTM C 518.

b) Tests as per Indian Standards Undertaken

The laboratory has the facilities of testing mineral wool, expanded polystyrene, rigid cellular insulations and perlite powder.

NSS COLLEGE, PANDALAM, PATHANAMTHITTA, KERALA, INDIA

Website: https://nsscollegepandalam.ac.in/

ABOUT THE COLLEGE

N. S. S. College, Pandalam is a higher education institution in Kerala, affiliated to the University of Kerala. The college was established in the month of February 1949. It is one of the three oldest colleges established and managed by the Nair Service Society. The college keeps its tradition and identity in the higher education scenario through its vision "Sreyohi Jnanam Abhyasath"- *Knowledge indeed is superior to constant practice*. The mission of the college is to educate and illuminate the young generations to build a strong and progressive nation where the rich values and traditions are upheld. The college pursues its academic goals using a holistic approach, focusing on overall excellence. In order to realize its ambitious vision, mission, and aim, the College ensures a peaceful, learner-friendly, progressive, and democratic environment while providing outstanding education.

Major Research Domains

- The major domains of research at the Department of Physics are Experimental Physics, Astronomy and Astrophysics and Space science.
- Dr. Rakhi R of the Department of Physics is the Principal-investigator of the project entitled “Investigations on Environment /Mode dependence of star formation in dwarf galaxies using UVIT data”, which is funded by Department of Space (DOS) under AstroSat (AO) data utilization project.

- Two research students are working the field of Astronomy and Space Science. Among them, one is working under the AstroSat project.
  - The research focus on the study of the Local characteristics of star formation using high resolution ultraviolet observations from UVIT on board AstroSat.
  - The two targets taken under consideration are NGC 5291 and NGC 7252. Both are interacting galaxies. NGC 5291 is an interacting system comprising of the early-type galaxy NGC 5291 and the companion called the Seashell galaxy.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

The major research publication entitles "UVIT view of NGC 5291: Ongoing star formation in tidal dwarf galaxies at ~ 0.35 kpc resolution" (https://doi.org/10.1093/mnras/stad970) .

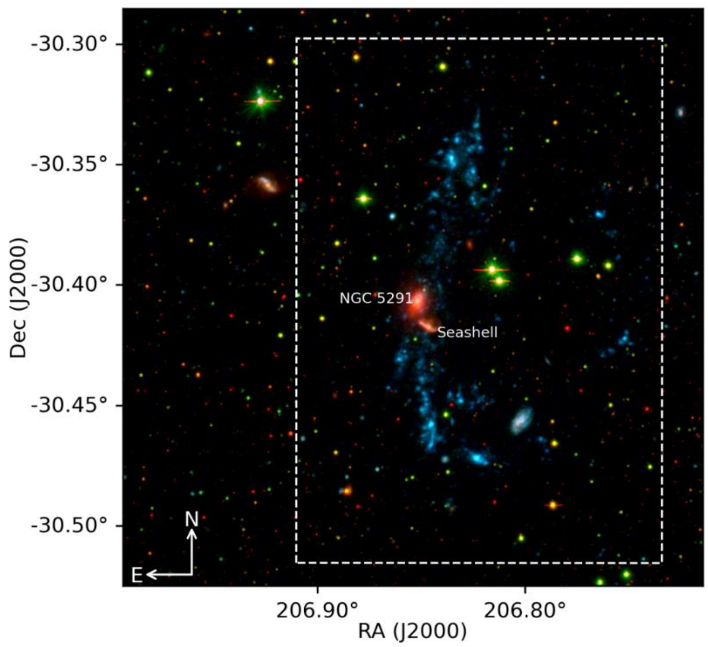


Fig: Colour composite image of the NGC 5291 system

In this work, high-resolution FUV and NUV data from AstroSat's UVIT were used to study the star-forming knots in the NGC 5291 interacting system, which includes three bonafide TDGs and other TDG candidates. By calculating their extinction-corrected SFR values, the star-formation activity in the identified star-forming knots was examined in detail. In comparison with previous UV imaging at lower resolution, .the higher resolution of UVIT has allowed for better de-blending of the structures. Several of the knots in the NGC 5291 system which appeared as single star forming regions in GALEX images are well resolved into smaller star forming knots in the UVIT images.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- Number of Ph.Ds offered by the institute in any area related to space science and technology : Two
- Title of the thesis:
    1. Local characteristics of star formation using high resolution ultraviolet observations from UVIT on board AstroSat
    2. Understanding Various Exchange Processes in the Atmosphere

Courses offered on Space Science and Technology

Programme	Course details	Intake capacity
Undergraduate Programme (BSc Physics)	• Open Course- Astronomy & Astrophysics • Elective Course- Space Science	55
Post-Graduate Programme (MSc Physics)	• Project work in Astronomy, Space Science	15
PhD course work	• Fluid Dynamics- Basics • Physics of the Atmosphere • Basics of Astronomy & Astrophysics • Advanced Astronomy & Astrophysics	

For further details on the inputs as provided in the document, please contact

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OSMANIA UNIVERSITY, HYDERABAD – INDIA

Website: osmania.ac.in

ABOUT THE UNIVERSITY

The Osmania University Department of ECE has its own Advanced GNSS Research Laboratory (AGRL), developed exclusively for research. In this laboratory, real-time data is acquired from global and regional navigation satellite systems and satellite-based augmented systems (Indian NavIC, US GPS, USSR GLONASS, European Galileo, and Indian GAGAN). The lab is equipped with two IRNSS/NavIC receivers provided by Space Applications Centre (SAC), Indian Space Research Organization (ISRO). The laboratory has access to the WLAN network of the department. Also, internet and Wi-Fi facilities are available. The AGRL laboratory was established under the Memorandum of Understanding (MoU) between the University College of Engineering with SAC ,ISRO, Ahmedabad, India. In this laboratory, real-time data is acquired from global and regional navigation satellite systems and satellite-based augmented systems (Indian IRNSS, US GPS, USSR GLONASS, European Galileo, and Indian GAGAN). In this laboratory, the performance evaluation of two IRNSS/NavIC receivers provided by SAC and ISRO is being carried out. The real-time data is acquired throughout the year and is also shared with the SAC, ISRO in India.

MAJOR RESEARCH DOMAINS

1. Ionosphere time delay modelling
2. Analysis of Ionosphere scintillations
3. Multipath error and mitigation techniques
4. Differential Navigation with Indian constellation (NavIC)
5. Indoor Localization techniques
6. Spoofing Techniques
7. Multi constellation position accuracy parameters
8. RAIM Algorithm
9. GNSS Interoperability

MAJOR SCIENTIFIC APPLICATIONS

1. Development of Ionospheric algorithms using GNSS / NAVIC/GAGAN real time data
2. Development of New GUI Software for Ionospheric time Delay analysis.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- Organized Two Days National Workshop on "INDIAN GPS-NaviC and its Future Applications" Jointly organized by Dept. Of Geo informatics, South campus and Communication Engg, UCE, Osmania University.
- Organized Guest lecture on "Breaking Boundaries – Exploring Aerospace Research, Applications and Opportunities" at Department of ECE, UCE, OU on 14th August 2023.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

BE (ECE), VII SEM	Global Navigation Satellite System & Augmentation System (Elective)
BE (ECE), VIII SEM	Satellite Communication (Core)
ME Microwave & Radar Engineering I SEM	Satellite Radio Navigation
ME (MRE) (Microwave & Radar Engineering II SEM	Global Navigation Satellite System LAB

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATIONS

Advanced GNSS Research Laboratory (AGRL) in Department of ECE, University College of Engineering, OU can accommodate more space instruments which will help Students (UG, PG & PhD scholars) in their research work.

PUNJAB REMOTE SENSING CENTRE, LUDHIANA, INDIA

https://prsc.gov.in

ABOUT THE CENTRE

Punjab Remote Sensing Centre (PRSC), an autonomous organization under the Department of Agriculture, Government of Punjab, is the apex body in the State for all Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) related works. It is designated as a Nodal Agency by the Govt. of Punjab for geospatial needs of the State and also acts as the centralized hub for the geo-spatial data to all the user departments.

MAJOR RESEARCH DOMAINS

Geo Data Analytics, Research & Modelling (AI, ML, IoT, Data Science & Analytics) Group (GRAM)

- Advanced Research, Analyses and Modelling of Organic Carbon
- Precision Agriculture using Fusion of Proximity Sensors and Geo-statistical Modelling
- Predict Soil and Water Quality from Multi &I Hyper-spectral Imagery using ML Techniques
- Soil-site suitability analysis for different crops
- Government Applications of Geo-spatial Technology for Optimal Planning on Natural Resources and Cultural Assets

Geo-Informatics & Information Technology Solutions Group (GITS)

- Development of spatial decision support systems (SDSS) for various user departments.
- Development of Web-GIS applications.
- Development of Mobile GIS applications
- State level spatial data infrastructure development and management
- IT resource management and support
- Capacity development in CSE/ITES

Geospatial Resource Mapping and Applications Group (GRMA)

- Planetary and Space Exploration
- Natural Resource mapping and management
- Land use/cover mapping & Change detection.
- Land Resource Inventory, Characterization & Land Use Planning
- Land transformation studies
- Soil resource mapping and land capability classification
- Infrastructure mapping
- Rural & Urban resource mapping & Monitoring
- Water resource mapping and monitoring
- Monitoring and mapping of changes in river courses and river bank erosion
- Flood inundation mapping and monitoring using microwave remote sensing
- Watershed and Irrigation water management using RS and GIS
- Mapping, monitoring and modelling of hazards and risk analysis.
- Mapping and monitoring of Wastelands
- Wetland Ecosystem studies and monitoring
- Integrated resource studies for watersheds and their monitoring
- Delineation and monitoring of degraded lands (dunes, water logging, soil erosion etc)

Space Technology based Agriculture & Farming Support Group (STAF)

- Impact of climate change on agro-ecosystems
- Crop mapping & growth monitoring and Forecasting
- Cropping system analysis
- Soil health mapping and management
- Site-specific nutrient management
- Soil fertility and quality evaluation
- Agricultural drought assessment and monitoring

MAJOR SCIENTIFIC APPLICATIONS/RESULTS

Currently we are working on the mineralogical characterization using hyperspectral datasets M3 and IIRS under the project funded by ISRO (Two abstract in Lunar Planetary Science Conference and National Space Science Symposium, Goa University has been accepted.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Punjab Remote Sensing Centre carries out two academic programs as part of regular course:

(1) M.Tech in Remote Sensing and GIS in collaboration with Punjab Agricultural University, Ludhiana

(2) PG Diploma in Remote Sensing in collaboration with Central University of Bathinda.

Apart from this PRSC contributes to capacity building program by organizing various training programs for different School, Colleges and State Departments

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

Punjab Remote Sensing Centre, Ludhiana has well equipped Geospatial laboratories with almost all required facilities of software (ARC GIS, ENVI, ERDAS, PCI Geomatica), High end computer system. We are recently also looking forward for collaboration from central government for establishment of Space Science Models in Lab in the West Zone.

For further details on the inputs as provided in the document, please contact

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RAMAN RESEARCH INSTITUTE , BANGALORE, INDIA

https://www.rri.res.in/

ABOUT THE INSTITUTE

Raman Research Institute (RRI) is primarily engaged in research in frontier areas of fundamental physics under contemporary research themes spanning sub-atomic to cosmological length scales. Research carried out at RRI broadly covers four areas, namely Astronomy and Astrophysics, Light and Matter Physics, Soft Condensed Matter Physics and Theoretical Physics. RRI is strongly invested in experimental research with major emphasis on instrument development for cutting edge research. Along with stand-alone experiments, RRI also takes part in national and international collaborations for major instrument developments in ground and space based astronomy.

MAJOR RESEARCH DOMAINS

- **Observational X-ray Astronomy**

  Study of X-ray binaries (containing neutron star or black hole), Ultraluminous X-ray sources (ULXs) and Cataclysmic Variables (CVs). In X-ray binaries, we investigate orbital evolution, X-ray reprocessing in the binary environment, cyclotron absorption features, quasi-periodic and periodic intensity variations etc. ULXs are studied to shed light on nature of compact object and their transient behavior. For CVs, we study broadband X-ray characteristics.

- **POLIX**

  POLIX, an X-ray polarimeter, is the main instrument onboard XPoSat. POLIX was conceived, designed and built at RRI. The performance verification phase of XPoSat is ongoing. In addition, RRI is also actively involved in collaborative plans for development of focusing X- ray optics for future X-ray mission. Focusing capability for X-rays (specially >10 keV) has tremendous potential to open a new discovery window in high energy astronomy.

- **Cosmology at Radio frequencies from Space**

  The period of the formation of the first stars and galaxies in the Universe is poorly understood. The redshifted 21-cm signal from Hydrogen is a powerful probe to study this period, and is present as a monopole (all-sky) signal over 40-200 MHz. This signal is a million times fainter than the foreground emissions from our own Galaxy, necessitating custom experiments that are sensitive to one part per million or better. The CMB DISTORTION Lab at RRI is a world leader in building such experiments and has produced major scientific breakthroughs from the SARAS series of (ground-based) experiments. Observations from space and in particular from the lunar far side are expected to provide better conditions for a high confidence signal detections.

- **Space based quantum technologies**

  Secure quantum communications between terrestrial ground stations using a satellite as a trusted node to enable long distance global quantum communications, towards a global quantum internet. RRI is engaged with ISRO on a funded R&D project on this topic since September 2017 under the project "Quantum Experiments using Satellite Technology".

- **Quantum Communications**

  Quantum Communication (QC) represents a promising futuristic technology, revolutionizing secure communication. Photon-based Quantum Key Distribution (QKD) is the most widely explored area in QC research, utilizing the polarisation degree of freedom of photons for both fibre and free-space communication. In this work, we investigate and mitigate the challenges posed by fibre birefringence and atmospheric effects on QKD, using a 50-meter free-space optical link and entanglement-based BBM92 QKD protocol.

QKDSIM

Our invention, qkdSim, provides a tool to design QKD, which circumvents the huge experimental trial-and-error approach. It overcomes the problem by applying the software development model Agifall, whose three-layered architecture conveniently abstracts simulation of real physical processes. qkdSim comprises distinct modules that model different physical processes and components and combine to simulate full end to end QKD. This simulation enables design and testing implementations for validation and optimization.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

- **X-ray Astronomy and POLIX**

(i) https://doi.org/10.1093/mnras/stad3886

This work provides nsights into the phase-dependent cyclotron line feature in a Be/X-ray binary using AstroSat and Insight-HXMT observations.

(ii) https://doi.org/10.1093/mnras/stad2527

This work is an investigation of the ‘10 keV feature’ in the spectra of accretion powered X-ray pulsars with data from NuSTAR

(iii) https://doi.org/10.1093/mnras/stad3395

This work studies the variability of fluorescence emission and the dynamics and geometry of the Neutron star - clumpy wind system in an high mass X-ray binary using XMM_Newton.

(iv) https://doi.org/10.1093/mnras/stad3026

Using AstroSat observations this work communicates the timing and spectral analysis of a magnetar during its first detected X-ray outburst and predicts the nature of the neutron star surface and gives the number of detected outburst and their duration.

(v) https://doi.org/10.3847/1538-4357/acb2cb

Clumpy Wind Studies were undertaken for a HMXB and a novel framework to measure clump size and masses accurately using absorption measdurements and orbital parameters was demonstrated.

(vi) https://arxiv.org/abs/2301.02815

This work discusses the changes in the distribution of circum-binary material around the HMXB GX 301-2 during a rapid spin-up episode of the neutron star

(ix) https://doi.org/10.1093/mnras/stac2804

This work provides updated measurement of orbital period evolution and discovery of a third orbital period glitch

- **SARAS**

(i) https://iopscience.iop.org/article/10.3847/1538-4357/aabae1

In this work RRI conceived, designed and built SARAS 2 places constraints on global 21 cm signals from the Epoch of Reionization.

(ii) https://www.nature.com/articles/s41550-022-01610-5

This work restores faith in the standard cosmological model called into question by an earlier detection of anomalous detection by EDGES group.

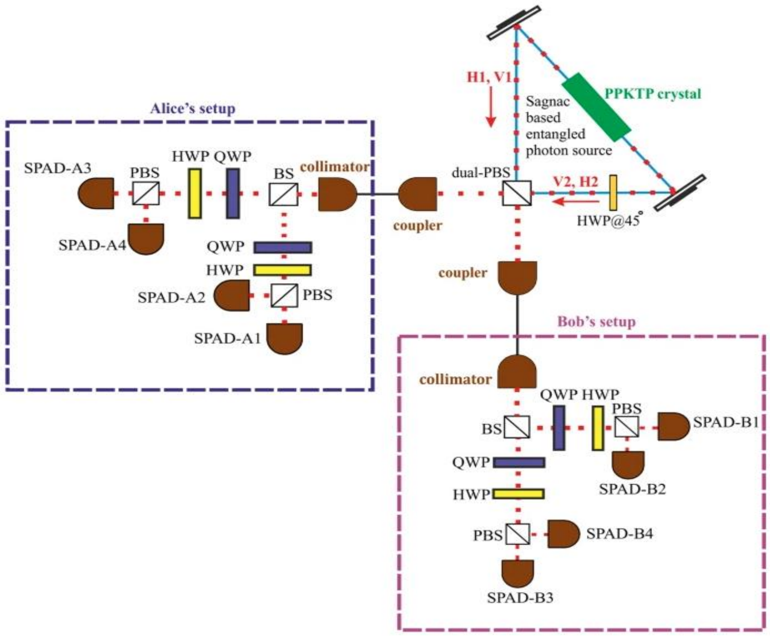
(iii) https://link.springer.com/article/10.1007/s10686-023-09909-5

PRATUSH – Probing ReionizATion of the Universe using Signal from Hydrogen – is a proposed space based (on the pristine radio quiet regions on the far side of the moon) cosmology experiment to detect the global red-shifted 21-cm signal from the Cosmic Dawn and Epoch of Reionization (CD/EoR). This work gives the PRATUSH experiment concept and design overview.

- **QuEST project**

(i) https://www.nature.com/articles/s42005-023-01235-8

This work demonstrates polarization bases compensation towards advantages in satellite-based QKD without active feedback.



Experimental Schematic for the BBM92 protocol

(ii) https://arxiv.org/abs/2310.02115 (under peer review)

Quantum Communication (QC) represents a promising futuristic technology, revolutionizing secure communication. This work presents daytime and nighttime quantum key distribution over an atmospheric free space channel with passive polarisation bases compensation.

(iii) https://wwws.rri.res.in/quic/resources/Patents_qkdSim/LPD.pdf

A software for simulating Quantum Key Distribution (QKD) experiments that could be used to validate such experiments before spending resources on the actual setup, has been granted a patent recently, marking one the first of India's patents on quantum technology.

INDIGENOUSLY DEVELOPED INSTRUMENTS

- **POLIX**

  POLIX, an X-ray polarimeter, is the main instrument onboard XPoSat. POLIX is designed and built at RRI. The basic configuration of the POLIX instrument consists of a collimator, a scatterer and four X-ray detectors surrounding the scatterer, along with the front end electronics and signal processing electronics for each detector.

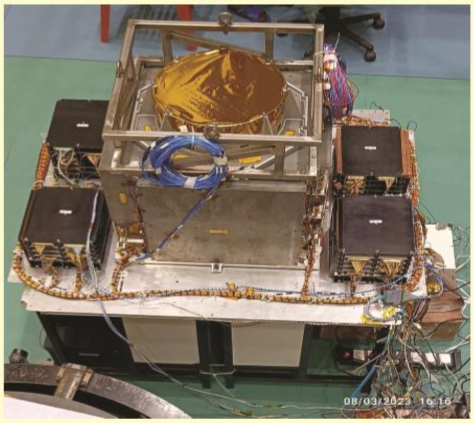
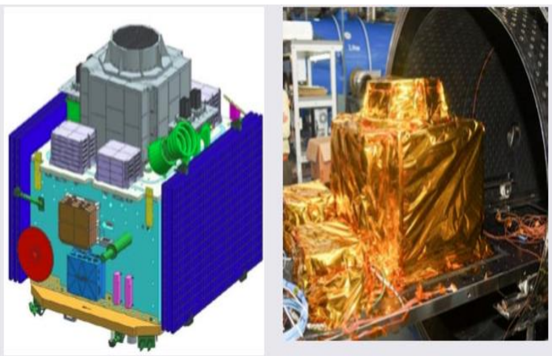


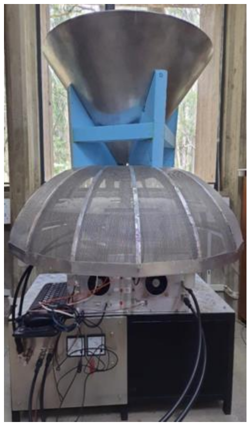
Figure: The Flight Model of POLIX undergoing Integrated Bench Test

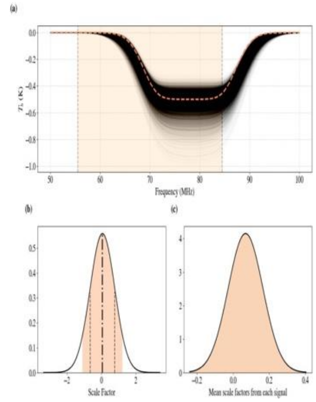


XPoSat drawing showing different component of the satellite. Polix is the main scientific instrument located at the center of the satellite. (Right) POLIX qualification model taken just before environmental tests at UR Rao Satellite Center, ISRO.

- **SARAS**

  The CMB DISTORTION Lab at RRI has legacy in developing indigenous custom precision radiometers. The ground-based SARAS series of experiments have all been developed inhouse including desgin, development, testing, integration, development of the Antenna, Self Calibratable Analog Receiver, High-speed FFT based digital correlation spectrometer, and all the data-analysis pipelines. The same has been done for the engineering model of PRATUSH.





CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- Three PhDs in X-ray astronomy in the last one year.
- The Radio Astronomy lab has engaged multiple Research Assistants (RAs) for developing the sub-systems of the PRATUSH engineering model (antenna, analog receiver, digital receiver). This includes but not limited to custom payload antenna design in the presence of satellite bus, custom vector-network-analyzer for in-situ antenna characterization in space, custom data processing pipelines on SBCs for use in PRATUSH. Further, multiple visiting students (undergraduates -on-going and completed degree) have worked on thermal analysis for effect of antenna thermal cycling space, PRATUSH orbit optimization in Earth Orbit and Lunar Orbit.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

- **X-ray Astronomy Laboratory**

  This laboratory is equipped for design and development of gas filled X-ray detectors, analog and digital signal processing electronics etc. The X-ray detectors and all associated electronics of the X-ray polarimeter instrument POLIX onboard XPoSat were designed and developed here. Cleanrooms for detector an electronics assembly work are available. A climatic chamber is being installed. However, there are no facilities for vibration test, or thermo-vacuum tests. The Payload Operations Centre (POC) for the POLIX payload is also at RRI.

The lab has full in-house capability for data-analysis and signal detection / sensitivity estimates for PRATUSH simulated (and in the future) measured data.

- **Quantum Information and Computing laboratory**

  Quantum Optics lab with a class 10000 clean room environment with highly modulated temperate and humidity for development and assembly of sophisticated optics and optomechanics instruments. Separate smaller lab unit with modulated environment and anti-static arrangements for payload development.

For further details on the inputs as provided in the document, please contact

Dr. V. G. Subramanian,Executive Assistant to Director Email: ea-director@rri.res.in

RAJA RAMANNA CENTRE FOR ADVANCED TECHNOLOGY, INDORE, INDIA

https://www.rrcat.gov.in

ABOUT THE CENTRE

Raja Ramanna Centre for Advanced Technology (RRCAT) is a unit of Department of Atomic Energy, Government of India, engaged in the Research & Technology Development in the frontline areas of Lasers, Synchrotron Light Sources, Particle Accelerators & related Technologies under the motto of “Photons in the Service of Nation”. RRCAT developed in-house facilities and technologies are being extensively utilized for nuclear, material science, industrial, medical and societal applications. In an accelerated manner, RRCAT developed technologies are being shared with National Institutes, Academia, Startups, MSMEs and Industries, under the incubation scheme of Atal Incubation Mission.

Indus-1 & Indus-2 Synchrotron radiation facility at RRCAT

MAJOR RESEARCH DOMAINS

Accelerator

The Centre has indigenously designed, developed, and commissioned two synchrotron radiation sources: Indus-1 and Indus-2, serving as a national facility. Indus-1 is a 450 MeV, 100 mA electron storage ring emitting radiation from mid-IR to soft x-ray with a critical wavelength of ~61 Å. Indus-2 is a 2.5 GeV electron storage ring designed for the production of x-rays. Synchrotron radiation emitted from its bending magnets has broad spectrum covering soft and hard x-ray regions with a critical wavelength of ~2 Å. With its circumference of 172.5 m, and beam energy of 2.5 GeV, Indus-2 is presently the largest and the highest energy particle accelerator in the country. In future, a 6 GeV, 200 mA, Indus-3, facility is being conceptualized at RRCAT.

The Centre is pursuing several other key accelerator activities viz. electron accelerators (LINAC) for food irradiation and industrial applications, free electron lasers (FEL) in terahertz (THz) and infra-red (IR) spectral region, development of a high energy proton accelerator for a spallation neutron source, superconducting and magnetic materials required for accelerators, development of advanced technologies such as superconducting radio-frequency (SCRF) cavities and cryomodules, high power radio-frequency (RF) generators, cryogenics, magnets, ultrahigh vacuum, precision fabrication and control instrumentation to support the various R&D programmes. LINAC based dedicated facility is established at Sabzi Mandi, Indore for food and other product irradiation/sterilization.

Laser

The Centre is also involved in development of a variety of laser systems and their utilization for applications in industry, medicine and research. The laser systems developed include CO_2 lasers, Copper vapour lasers, flash lamp and diode laser pumped Nd lasers, fiber laser, semiconductor lasers, excimer lasers and high energy/intensity pulsed lasers. Crystals of a variety of materials of interest to laser technology have been grown. The industrial applications being pursued include cutting, drilling, welding, surface modifications. A laser additive manufacturing facility is established at RRCAT for fabrication of novel and complex components. Various laser/photonics based instruments such as machine vision based precision metrology systems, uranium analyzer, Fiber Bragg Grating and Raman Scattering based fiber temperature sensor, etc are developed and being extensively utilized. Home-made and commercial lasers are being used for research in the areas of laser plasma interaction, laser-based charged particle acceleration, laser cooling and trapping of atoms, nonlinear optics, ultra-fast dynamics, material processing, laser fluorescence spectroscopy of tissues, effects of narrow bandwidth light on cells and animal models, imaging through turbid media, laser micromanipulation of microscopic objects etc.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

The major scientific applications of RRCAT are in the facility development and utilization of lasers, synchrotrons, accelerators and associated technologies in various domains of S & T such as material processing, fabrication, characterization, sensor development, process development, controls, instrumentation & power supply development, vacuum technology, medical & societal applications.

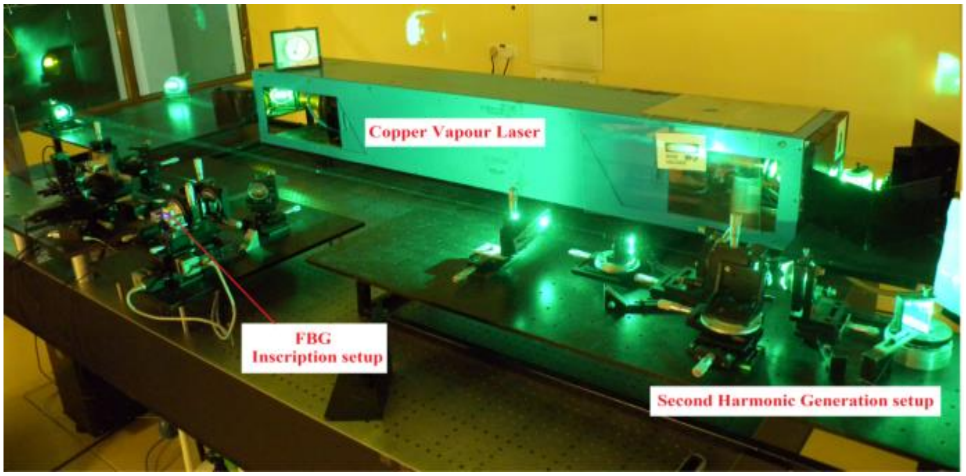
RRCAT published about 200 papers, per year in refereed Journals of high repute. The list of published papers can be seen on the website,

https://www.rrcat.gov.in/organization/cat/public.html

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

In the period, January 2022 to December 2023, following projects are carried out and being pursued further under mutual scientific interaction between RRCAT and various units of ISRO,

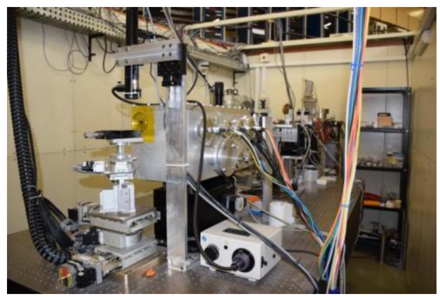
- Sharing of RRCAT fabricated Fiber Bragg and Long period gratings with VSSC, ISRO for temperature and strain sensor development under MoU between RRCAT and VSSC, ISRO signed on 26th Sept, 2023



Fiber Grating fabrication facility developed at RRCAT

- Calibration of various detectors related to Chandrayaan and ADITYA L1 missions using Indus-2 synchrotron beamlines

A view of the Indus-2 experimental Hall

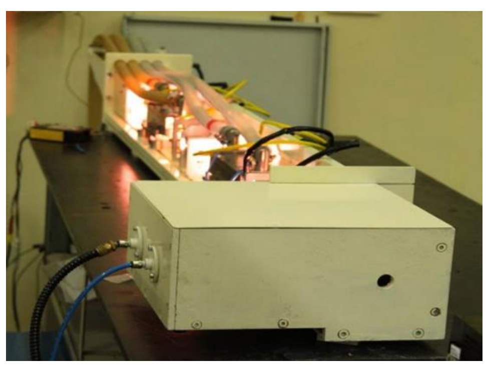


Experimental station at BL-16 beamline

- Calibration of Solid-state drift (SDD) detectors of the SoLEXS (Solar Low Energy X-ray Spectrometer) payload, on-board at the ADITYA-L1 satellite with photon energy in the range 6 - 22 keV
- Calibration of Cadmium telluride (CdTe) & Cadmium Zinc Telluride (CZT) detectors installed on the HEL1OS payload, on board at the ADITYA-L1 satellite with photon energy range of 10 - 27 keV
- Calibration of Swept Charge Device (SCDs) detectors mounted on the XSPECT payload on-board the XPoSat mission with photon energy range of 0.5 – 16 keV
- Development of oxygen bottle of Ni based superalloys using lased powder bed fusion system in collaboration with Vikram Sarabhai Space Centre, ISRO

- Prototype oxygen bottle of Ni based super alloys using LAM technology at RRCAT

- Laser Peening of Sintered Silicon Carbide (SiC) for space application in collaboration with LEOS, ISRO
- Development and installation of 80 watts sealed-off CO2 laser along with control system at, VSSC, ISRO, for testing of rocket fuel
- Development of Materials Property Data base for Laser Directed Energy Deposition printed Ni based super alloys in Collaboration with VSSC, ISRO
- Proposal for indigenous development of compact solid state laser source at 1535 nm for laser altimetry as required by LEOS, ISRO
- Proposal for indigenous development of 10 J, 1 ms Nd:YAG/ Nd:Glass laser for thermal diffusivity measurement of materials for space as required by VSSC, ISRO



- Nd:YAG laser developed at RRCAT
- Proposal for development of pulsed fiber/Nd:YAG laser for LIDAR application in collaboration with SAC, ISRO

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

1. Fiber Grating Fabrication facility is available at RRCAT. Contact person: Dr. Om Prakash, Head, Fiber Sensors Section, E-Mail: oprakash@rrcat.gov.in
2. Laser Additive Manufacturing facility is available at RRCAT for fabrication of specialized components as needed for space program, Contact person: Dr. C. P. Paul, Head, EDMS, E-mail: paulcp@rrcat.gov.in
3. Specialized facility of laser development is available at RRCAT for specific needs of ISRO, Contact persons: Dr. B N Upadhyaya, Head, ILAS, E-mail: bnand@rrcat.gov.in and Dr. P K Mukhopadhyay, Head, SSLS, E-mail: pkm@rrcat.gov.in
4. Engineering Application beamline of Indus-2 is available to carryout diffraction-based experiments with X-rays in energy range of 5 keV to 30 keV. Contact person: Dr. Tapas Ganguli, Head, APSUD, E-mail: tapas@rrcat.gov.in
5. Soft X-ray reflectivity beamline of Indus-2 is available for soft X-ray reflectivity, absorption, fluorescence in the energy range of 100 eV-1200 eV. Contact person: Dr. Tapas Ganguli, Head, APSUD, E-mail: tapas@rrcat.gov.in
6. Microprobe X-ray fluorescence beamline of Indus-2 is available for characterization of instruments in the energy range of 5 keV - 20 keV. Contact person: Dr. Tapas Ganguli, Head, APSUD, E-mail: tapas@rrcat.gov.in
7. Ion assisted electron beam evaporation system is available for the coating of thin films on large area (300 mm ×130 mm) of the materials, gold, chromium, nickel, carbon, silicon, B_4C etc. Contact person: Dr. Tapas Ganguli, Head, APSUD, E-mail: tapas@rrcat.gov.in

For overall coordination: Dr. SK Dixit, Director Laser Group, E-Mail: skdixit@rrcat.gov.in

HVPS RAMNIRANJAN JHUNJHUNWALA COLLEGE, MUMBAI, INDIA

https://www.rjcollege.edu.in/

ABOUT THE COLLEGE

Ramniranjan Jhunjhunwala College, Mumbai-400086

Hindi Vidya Prachar Samiti's R. J. College of Arts, Science and Commerce was established in 1963. In 2018, UGC and University of Mumbai granted autonomous status to the college based on the NAAC reaccreditation. This started a new chapter for all the stakeholders of the institution in participating in the process of empowering our students through focused teaching and research and enabling them to develop as responsible citizens with Nationalistic feelings. We strive to create and enhance teamwork and leadership qualities and to motivate them to provide extension services to serve self and society. In our pursuit for excellence, our alumni, parents and members of the society have contributed immensely. We, at R J College are committed towards our students acquiring values, be ethical and honest and maintain good physical and mental health and thereby help in the process of Nation building.

MAJOR RESEARCH DOMAINS

- **X-ray astronomy**

  Study the temporal and spectral properties of neutron star and black hole X-ray binaries (XRBs). XRBs are detected by telescopes during outbursts. Outbursts are a result of the change in the mass accretion rate. X-ray emission occurs in regions of intense gravity very close to the compact objects. Thus X-rays are used as probes to test the General Theory of Relativity in strong gravity.

- **Time domain astronomy**

Study the evolution of supernovae in X-rays using archival data.

- **Multiwavelength astronomy**

  XRBs emit in all known wavelengths and the emission across the electromagnetic spectrum evolves during the outburst. We collaborate to obtain simultaneous observations.

- **Non-linear studies**

  Light curves of astrophysical systems exhibit changes in their non-linear parameters which are related to dynamical changes, also these parameters also allows us to classify different systems. We are studying these effects in long term X-ray and optical light curves of variable systems.

- **Instrumentation/Calibration of high energy detectors**

  A JRF on our project was involved in the calibration of the CZTI detectors located in TIFR-Mumbai and also contributed to experimental verification of polarimetry capabilities of CZTI detectors.

MAJOR SCIENTIFIC RESULTS

A spectral study of the black hole X-ray binary MAXI J1820+070 with AstroSat and NuSTAR :MAXI J1820+070 is a transient black hole X-ray binary, which showed several spectral and temporal features. We analyse the broadband X-ray spectra from all three simultaneously observing X-ray instruments onboard AstroSat and from NuSTAR during its hard state in March 2018. A combination of multi-colour disc model, relativistic blurred reflection model relxilllpCp and a distant reflection in the form of xillverCp gives a reasonable fit for AstroSat and NuSTAR spectra. The best-fit model suggests a low temperature disc (kT_{in}~0.3 keV), iron overabundance (A_{Fe}~4−5 solar), a short lamp-post corona height (h$\lesssim$ 8Rg), and a high corona temperature (kT_e~115−150 keV). Addition of a second Comptonisation component leads to a significantly better fit, with the kT_e of the second Comptonisation component being ~14−18 keV. Our results from independent observations with two different satellites in a similar source state indicate an inhomogeneous corona, with decreasing temperature attributed to increasing height. Besides, utilising the broader energy coverage of we estimate that the black hole mass to be 6.7−13.9 $M_\odot$. *(https://academic.oup.com/mnras/article/498/4/5873/5902420)*

AstroSat Observations of the Dipping Low Mass X-ray Binary XB1254-690 : We present the results of a long observation of the low mass X-ray binary XB 1254-690 using AstroSat. XB 1254-690 has an orbital period of 3.88 ± 0.15 hrs and exhibits energy-dependent intensity dips, thermonuclear bursts and flares. Dips are seen in the X-ray light curve changes from a high intensity flaring state to a low-intensity state. The hardness intensity diagram shows that the source is in a high-intensity banana state with changing flux, based on this we divide the observation into four flux levels for flux resolved spectral study. The X-ray spectra is explained by a model consisting of absorption, thermal emission from the disc and non-thermal emission from the corona. From our studies, we detect a correlation between the temperature of the thermal component and the flux and we examine the implications of our results for the accretion disc geometry of the source.*(https://ui.adsabs.harvard.edu/abs/2022cosp...44.2269N/abstract)*

Experimental verification of off-axis polarimetry with cadmium zinc telluride detectors of AstroSat-CZT Imager : The cadmium zinc telluride imager (CZTI) on board AstroSat consists of an array of a large number of pixelated cadmium zinc telluride (CZT) detectors capable of measuring the polarization of incident hard x-rays. The polarization measurement capability of CZTI for on-axis sources was experimentally confirmed before the launch. CZTI has yielded tantalizing results on the x-ray polarization of the Crab nebula and pulsar in the energy range of 100 to 380 keV. CZTI has also contributed to the measurement of prompt emission polarization for several gamma-ray bursts (GRBs). However, polarization measurements of off-axis sources such as GRBs are challenging. It is vital to experimentally calibrate the CZTI sensitivity to off-axis sources to enhance the credence of the measurements. In this context, we report the verification of the off-axis polarimetric capability of pixelated CZT detectors through controlled experiments carried out with a CZT detector similar to that used in CZTI and extensive Geant4 simulations of the experimental setup. Our current results show that the CZT detectors can be used to measure polarization of bright GRBs with off-axis angles up to ~60 deg.

(https://ui.adsabs.harvard.edu/abs/2022JATIS...8c8005V/abstract)

Rapid far-IR spectral timing of X-ray binaries : Chapter in the PRIMA General Observer Science Book : PRIMA (The PRobe for-Infrared Mission for Astrophysics) is a concept for a far-infrared (IR) observatory. PRIMA features a cryogenically cooled 1.8 m diameter telescope and is designed to carry two science instruments enabling ultra-high sensitivity imaging and spectroscopic studies in the 24-235 microns wavelength range. Since X-ray binaries emit across the electromagnetic spectrum with the in-flowing matter dominating shorter wavelengths and the out-flowing jet dominating longer wavelengths, we need a suite of fast timing capable facilities to take full advantage of time-domain techniques. X-ray satellites were the first to pioneer such studies of X-ray binaries, but the recent invention of new instrumentation and observing techniques have now allowed us to expand these studies into the optical, infrared, and even the longest wavelength radio/sub-mm bands. PRIMA uniquely probes a wavelength range that we have been so far unable to sample (connecting sub-mm [probed by ALMA] and mid-infrared [probed by JWST]) and thus represents anexciting new possibility for characterizing X-ray binary variability as thejet/accretion flow evolves throughout the outburst.

(https://prima.ipac.caltech.edu/page/go-science-book)

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- Co-curricular projects related to space science are carried out by undergraduate students under the guidance of our faculty
- Students have undertaken activity to build small telescope with the guidance of our faculty and Nehru Planetarium, Mumbai
- Undergraduate students are encouraged to read, study and contribute articles from reliable sources to the departmental wall magazine. This activity develops awareness in them about current advances in space science and also their colleagues who happen to read the displayed wall.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

Course	Level	Intake	
M.Sc. Physics	Post-graduate (sem 3 elective)	5	Introduction to Astronomy
	Post-graduate (sem 4 elective)	5	Advanced Astronomy

For further details on the inputs as provided in the document, please contact :

Dr. Devraj Pawar, Associate Professor, Department of Physics, R. J. College, Mumbai-400086, Email : devrajdp@gmail.com, devrajpawar@rjcollege.edu.in

SPACE TECHNOLOGY CELL, SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE, INDIA

https://unipune.ac.in/isro/

ABOUT THE CELL

Savitribai Phule Pune University, is one of the premier universities in India. The university houses 18 schools consisting of 58 academic departments and centers. It has about 307 recognized research institutes and 612 affiliated colleges offering graduate and under-graduate courses. The university attracts many foreign students due to its excellent facilities. ISRO-UoP Joint Research Programme started in 1998 with the signing of MOU between ISRO and University of Pune (now renamed as Savitribai Phule Pune University (SPPU)) Under this programme, as of now, a total of 200+ research projects relevant for ISRO's research requirements have been undertaken by faculty members and researchers within the campus departments and affiliated colleges.

MAJOR RESEARCH DOMAINS

During the period from January 2022 to December 2023 there were 12 active projects conducted under this joint research program.

List of the Research Projects is as follows:

Sl. No.	Title of the Project	Name of Investigator(s)	Department/ College
1	Process development and optimization of novel electro discharge machining variants for machining of super alloys	Prof Ganesh Dongare	VIT College Pune
2	Development of Nano-polishing technology for metal mirrors	Prof Girish Kotwal	VIT College Pune
3	Development of anti-erosion coatings on polymers for low earth orbit Space applications	Prof Sanjay Dhole	Dept. of Physics, SPPU
4	Effect of altered gravity on gene expression of human blood mononuclear cells and bone cell with special reference immunity and differentiation	Prof Kalpana Pai & Dr Richa Ashma	Dept. of Zoology, SPPU
5	Fusion of thermal and optical image features in classification of space objects to identify debris using deep learning	Dr Sunita Jahirabadkar	Cummins CE for Women, Pune

6	Investigation of Physical and Electrochemical Properties of Phosphonium Based Ionic Liquids for Energy Applications	Dr Santosh Terdale	Dept. of Chemistry SPPU
7	Trends in the glacier recessions from Kanchenjunga National Park (India and Nepal): Studies based on Spatio-temporal variability and paleoclimate signatures	Dr. Swapnil Vyas	Dept. of Geography SPPU
8	Development of image quality improvement algorithms for satellite imagery/radiometric data	Dr Ashwini Deshpande	Cummins CE for Women, Pune
9	Effects of simulated microgravity on expression profile of microRNA in human cardiomyocytes	Dr. Varsha Wankhade	Dept of Zoology, SPPU
10	Synthesis and characterization of Si based nanomaterials for lithium ion cells	Dr Ashish Yengantiwar	Fergusson College Pune
11	Design of accurate & efficient machine learning autonomous algorithm for guidance & navigation of space landing mission	Dr Dipti Patil	Cummins CE for Women, Pune
12	Data driven modeling of morphology and formation of impact craters in basalt: A case study of Lonar	Dr Bhalchandra Pujari	CMS, SPPU

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

List of refereed journal publication

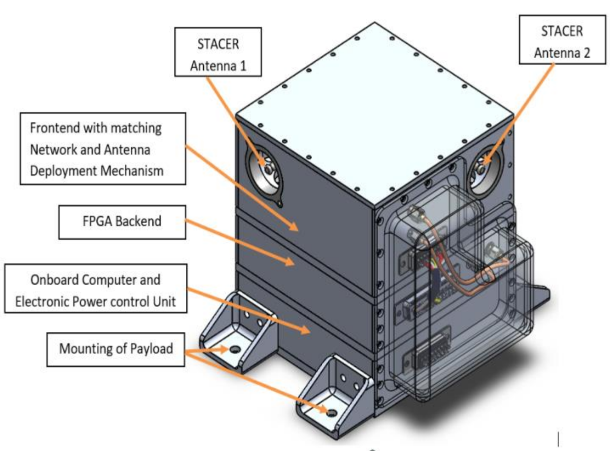
1. *S. Jahirabadkar, P. Pande and Aditya R., "A Survey on Image Processing based Techniques for Space Debris Detection," 2022 IEEE Bombay Section Signature Conference (IBSSC), Mumbai, India, 2022, pp. 1-6 (https://ieeexplore.ieee.org/document/10037480)*
2. *S. Jahirabadkar, P. Pande and Aditya R., "Image Fusion with a Novel Dataset for Space Targets Analysis" Submitted to "International Journal of Advanced Technology and Engineering Exploration", a Scopus indexed journal*
3. *S. Jahirabadkar, S. Chaudhari, G. Deshmukh, S. Gokhale, R. Kadu, and Aditya R. "A Survey of Visible and Infrared Image Fusion Methodologies", 7th Int. Conf. on Inventive Communication and Computer Technologies, Lecture Notes in Network Systems, Vol. 757, 2023*
4. *Pooja Sharma, Mahendra Acharya, Ashish Yengantiwar, Arunava Gupta, Enhanced solar water splitting using bismuth ferrite photoanodes grown by direct liquid injection chemical vapor deposition, Materials Science in Semiconductor Processing, 2024, 169, 107929.*
5. *Firke, N., Gulavani, V., Sapkal, R., Sagdeo, P.R., Yengantiwar, A., Plug and Play Electrodeposition Cell: A Case Study of Bismuth Ferrite Thin Films for*

Photoelectrochemical Water Splitting, ECS Journal of Solid State Science and Technology, 2022, 11(1), 013006

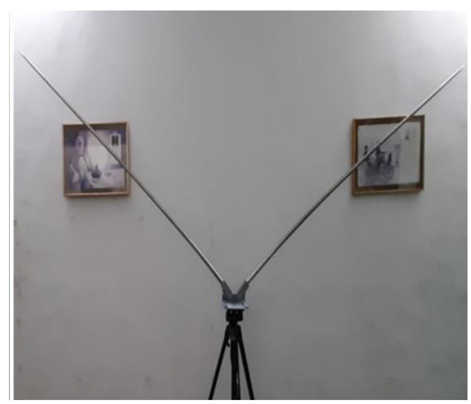
6. *Pooja Sharma, Mahendra Acharya, Ashish Yengantiwar, Arunava Gupta, Enhanced solar water splitting using bismuth ferrite photoanodes grown by direct liquid injection chemical vapor deposition, Materials Science in Semiconductor Processing, 2024, 169, 107929.*
7. *Firke, N., Gulavani, V., Sapkal, R., Sagdeo, P.R., Yengantiwar, A., Plug and Play Electrodeposition Cell: A Case Study of Bismuth Ferrite Thin Films for Photoelectrochemical Water Splitting, ECS Journal of Solid State Science and Technology, 2022, 11(1), 013006*
8. *B. Chindhade, A Ramlingam, S. Chavan, S. Haridas and Dipti Patil, "Advances in Vision Based UAV Maneuvering Techniques", International Symposium on Intellectual Informatics, Smart Innovation, Systems and Technologies,333* https://doi.org/10.1007/978-981-19-8094-7_35
9. *Ambadas B. Phatangare, Sudha V. Bhoraskar, Shailendra S. Dahiwale, Sanjay D. Dhole Vasant N. Bhoraskar, "Novel Nuclear Batteries Based on Radioluminescence", Energy Technology, 10, pp 2200285*

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

Photographs and Name of the instrument:



Boxing and packaging Payload



STACER Antenna

Robot-Assisted Polishing Setup and the Polished mirror surface manufactured

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Researchers associated with the projects pursue M.Tech/ Ph.D

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

A. Space Payload Development Centre (SPDC):

The Dept. of Electronic and Instrumentation Science has been very active in space payload development over nearly ten years now. It feels gratified that both the ADCOS (Advisory Committee on Space) of ISRO as well as the launch team of PSLV have evinced interest in the activity. It is important for the SPPU. Basically a sustainable Space Payload Development Centre (SPDC) is formed. The designing of different subsystems involving various aspects like mechanical structure, thermal issues, Attitude and Orbit Determination and Control System (AODCS), power, tracking, telemetry and telecommunication and onboard data handling, antenna and payload are being handled.

- Image Processing and Machine Vision Applications.
- Pattern Recognition using Artificial Neural Networks.
- Sensors and instrumentation
- RF Antennas, Electromagnetics.
- RF Electronics and circuit design.

These systems are adapted for testing payload operations like antenna deployment in vacuum atmosphere. In order to design and simulate payload system like mechanical as well as thermal aspects we have workstations and university has common facility for

COMSOL software. We have testing instruments like spectrum analyzer, vector network analyzer for RF circuit analysis.

B. Material Synthesis laboratory:

This laboratory includes various equipment's for hydrothermal, sol gel and other chemical route nanomaterial synthesis processes. For thin film preparation, we have spin coater, dip coater, and doctor blade technique. Despite hot air and vacuum oven, tube furnace is used for high temperature synthesis up to 1150 °C in air and inert atmosphere. In our application laboratory, we have different instruments for energy application including solar simulator, electrochemical workstation and 8-channel battery tester.

- Photoelectrochemical/electrocatalytic water splitting for hydrogen generation
- Energy storage devices including Li/Na-ion battery and Supercapacitors
- Additive manufacturing including FDM and DIW 3D printers

C. Electron, Neutrons and Ions irradiation facilities:

An indigenously developed facility of electron, neutrons and ions irradiation with varying energy range that can be utilized as space environment simulator to test the samples. This includes, 6 MeV electron irradiation facility- The electron beam having flux varying from 1011 to 1014 e/cm2, beam diameter of 5 to 10 mm. Neutron generator- The flux of neutrons is ~ 105 to 106 n/cm2, and beam diameter 5 mm and has energy of 14 MeV. Simultaneous 5-10 eV atomic oxygen ion beam and and ultra violet radiation facility- The atomic oxygen having flux varying from 1011 to 1014 ions/cm2, 10 to 100 keV argon nitrogen and oxygen ion irradiation facility having flux 1011 to 1014 ions/cm2.

- Study the effects of space environment radiations on thin coatings for low earth orbit space applications.
- Development of Nuclear Batteries using radioactive source

D. Manufacturing (Fabrication), Test and Measuring Facility

- Robot Assisted Manufacturing Processes -
  - Polishing, Grinding, Machining, Milling, Drilling, Welding
  - Additive Manufacturing
  - Incremental forming

- Laser micro machining setup
- Electro Discharge Machining for super alloys
- Interferometric measurement
- CNC Coordinate Measuring Machine
- Tribological testing facilities
- Material Characterization facilities at cryogenic temperatures

E. Computational and Simulation Facility

- Computational facility for simulation and visualization
- Under the Remote Sensing curriculum open source QGIS tool and Python programming based geospatial data processing lab is prepared.

F. Facility for Microgravity Studies:

The setting up of clinostat has established a facility for studies under micro/ altered gravity conditions suitable for human space missions. Studies on the effect of altered gravity performed on plants from the perspective of growing food for astronauts and Human Blood Mononuclear Cells and bone cell with special reference to bone health.

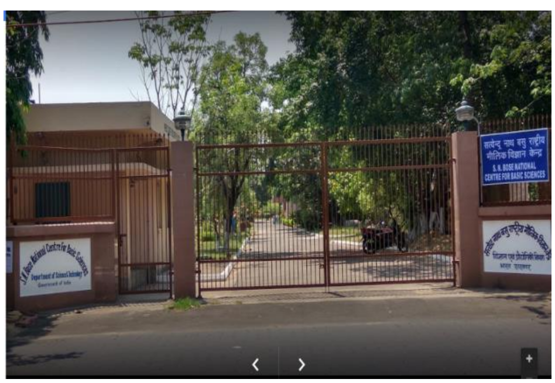
- The counteracting effect of plumbagin against altered gravity in stimulating osteoblast and osteoclast differentiation is being investigated by gene expression analysis.
- *In vitro* effect of plumbagin to counteract the microgravity mediated –inhibition on osteoblast differentiation, enhanced osteoclast differentiation and its molecular mechanism of action on osteoclast formation

S N BOSE NATIONAL CENTRE FOR BASIC SCIENCES, KOLKATA, INDIA

Website: www.bose.res.in

ABOUT THE CENTRE

S. N. Bose National Centre for Basic Sciences is an autonomous research institute engaged in research in basic sciences. The institute was founded under Department of Science and Technology, Government of India in 1986 as a Registered Society. The Centre was established to honour the life and work of Professor S. N. Bose who was a colossal in theoretical physics and has made some of the most fundamental conceptual contributions in the development of Quantum Mechanics and Quantum Statistics. The Centre has emerged as a major institution for research and development in Basic Sciences. Currently, there are four departments: Department of Astrophysics and High Energy Physics, Department of Physics of Complex Systems, Department of Chemical and Biological Sciences and Department of Condensed Matter and Materials.



S N Bose National Centre for Basic Sciences, JD Block, Sector III, Salt Lake, Kolkata.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS IN OBSERVATIONAL ASTRONOMY

In observational Astronomy, works are being pursued to understand some of the outstanding problems about extra-solar planets, brown dwarfs, evolved stars, binary stars, cataclysmic variable stars and young star-forming regions.

Study of 2021 outburst of RS Ophiuchi (RS Oph): RS Oph is a well-known Galactic recurrent nova with an average recurrence time-scale of about 15 years. The system has a CO-type white dwarf (WD) with a mass in the range of 1.2 − 1.4 times solar mass. The WD is most likely increasing in mass due to the accumulation of a fraction of accumulated matter on its surface. Eventually, it may approach the Chandrasekhar limit and explode as a Type Ia supernova. We have studied the evolution of the optical spectra of RS Oph, over a month after it's most recent (2021) outburst. From the evolution of line widths an expanding shocked material into the winds of the red giant companion was detected. This expands freely for 4 days, and afterwards, the shock velocity decreased monotonically with time. The spectra were modeled using the photoionization code CLOUDY.

Stars form in clustered environments within giant molecular clouds. Internal gravitational dynamics prompts cloud fragmentation, with each fragment then collapsing and leading to the onset of prestellar core formation. Alternatively, propagation of the ionizing or explosive shocks from massive stars may compress neighboring clouds, hence triggering the next generation star formation. Molecular clouds exhibit complex geometries, including substructures such as sheets and filaments to elongated networks. The turbulence from expanding H II regions near a filamentary molecular cloud can generate sequential waves of star-forming cores along the long axis of the filament on either side of an H II region, The young protostars are preferentially aligned along the filamentary axis, bearing the imprint of fragmentation of the parental cloud. We study the star formation activity around H II region Sh2-112, is illuminated by the massive star(O8 V)BD+45 3216. The associated molecular cloud extends in angular scales of 2°.0 × 0°.83, corresponding to linear sizes of 73 pc by 30 pc, along the Galactic longitude. The high-resolution (30″) extinction map reveals a chain of dust clumps aligned with the filament-like structure with an average extinction of AV∼2.78 mag, varying up to a maximum of∼17 mag. Our analysis led to identification of a rich population(∼500)of young(average age of ∼1 Myr)stars, plus a numerous number(∼350)of Hα emitters, spatially correlated with the filamentary clouds. Located near the edge of the cloud, the luminous star BD+45 3216 has created an arc-like pattern as the ionizing radiation encounters the dense gas, forming a blister-shaped morphology. Three distinct young stellar groups, all coincident with relatively dense parts of the cloud complex, signifying ongoing star formation were found.

Optical R-band (700 nm) polarization observations of LDN 1616 cometary cloud developed by massive OB stars were analysed. Individual plane-of-sky position angles do not show any preferred alignment. However, their mean values for a 5x5 square-arc-minutes gird follow the large-scale cloud structure. Such alignment indicates a possible scenario for the initial direction of the magnetic field lines perpendicular to the direction of the ionizing radiation and might have been dragged later.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

In view of building the first astronomical observation facility in the Eastern part of India, S. N. Bose National Centre for Basic Sciences, has taken the initiative to set up a 1.5-m telescope at Panchet hill (23.62860 N, 86.76680 E), Purulia district of West Bengal.. The site is relatively dry and unpopulated with average seeing of less than 1.4 arcseconds. About 150 photometric/spectroscopic nights are expected annually at the site. We have installed a Weather Station at the hilltop in November 2022, for recording weather data. We have also set up a Mobile Observatory and installing a Differential Image Motion Monitor (DIMM) system for more precise astronomical Seeing measurements

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

We offer the following courses to the MSC students of Integrated PhD course and the PhD students:

1. Astrophysics & Astronomy,
2. Astronomy and
3. Astronomical Observational Techniques

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

We have built a Role-Off-Roof Observatory on the terrace of the main building of the Centre where a 8-nch telescope has been installed. This telescope is used to provide hands-on to the students, public outreach programs and testing purposes. We have also a small astronomical laboratory where we perform testing of astronomical instruments. We are planning to develop small instruments in the laboratory.

For further details on the inputs as provided in the document, please contact

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ST.THOMAS COLLEGE, RANNI, INDIA

Website: https://www.stthomascollegeranni.com/

ABOUT THE COLLEGE

St. Thomas College, Ranni, is deeply intertwined with the history of its picturesque locale, situated atop a serene hill amidst sylvan surroundings. The college's tranquil setting, away from the urban clamor, is easily accessible and within walking distance from Ranni town. The institution is driven by a mission to cultivate a comprehensive educational environment for the holistic development of young men and women in the globalized e-world. Through value-based instruction spanning various disciplines, the college aspires to mold individuals capable of navigating the complexities of today's world. Guided by a visionary outlook, the college aims to contribute to the nation-building process by providing quality education. The vision is to foster morally upright, intellectually enlightened, constitution-abiding, and socially committed young adults who possess a deep love for fellow humans and their country.

MAJOR RESEARCH DOMAINS

The Physics Department conducts astrophysics research, including an ISRO-funded project on Quasi-Periodic Oscillations in Accretion-Powered X-ray Pulsars with ASTROSAT/LAXPC data. Simultaneously, master's thesis students explore Thermonuclear X-ray Bursts from Low Mass X-ray Binaries, contributing to our understanding of fundamental astrophysical phenomena and highlighting the department's commitment to cutting-edge research.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Article on "Timing and Spectral Analysis of Thermonuclear X-ray Burst from Atoll Source 4U 1636-536" published in Interdisciplinary Research Resource Book 'Josephine Researcher' by St.Joseph's College, Moolamattom.

The work present the results of the Thermonuclear X-ray bursts of 4U1636-536 using ASTROSAT/LAXPC data during the year 2018. Light curve analysis of this source reveals 15 thermonuclear X-ray burst-like events. All the bursts are very strong and the burst peaks to persistent intensity 9 times except for two bursts B2 and B10. Energy resolved burst profile shows the burst-like event disappears above 30 keV. We fitted each burst in a different energy range with model BURS and found that the decay time decreases with energy.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- Workshops on Research Methods in Astrophysics- Swift, NuStar and NICER Data Analysis : Two day workshop organized by Department of Physics on Research Methods in Astrophysics for Master's students who are highly interested in Astronomy and Astrophysics.
- Hands on Training in Python Programming : Department of Physics organized two Hands-on training sessions in Python programing aiming at providing students the practical skills to analyze and interpret data.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

B.Sc Semester six core course

- Nuclear Particle Physics and Astrophysics
- Undergraduate degree
- Intake capacity : 32
- Subject specialization: Astrophysics

For further details on the inputs as provided in the document, please contact **Sneha Elcy Jacob , Principal, St.Thomas College, Ranni (email: stcranni@gmail.com)**

ST. XAVIER'S COLLEGE (AUTONOMOUS), KOLKATA, INDIA

Website: www.sxccal.edu

ABOUT THE COLLEGE

St. Xavier's College (Autonomous), Kolkata (SXC) has a rich legacy of Studies and Research related to Astrophysics. The initial initiative was taken by Fr. Eugène Lafont, S.J, then Rector and Principal, SXC, who built an astronomical observatory in 1875 for spectroscopic studies of the sun and planetary atmosphere in conjugation with other European laboratories. After a period of initial activity, it went into a dormant phase, after which it was revived with the help of the DST FIST grant and college initiatives and started operating from March 2014. Currently, it is a twin observatory (FELO), consisting of a stellar observatory with a motorized dome and a separate sliding roof observatory meant for solar observations. The observatory serves as a center for P.G. Courses offered as specializations in astrophysics, research and outreach activities. The Scientific activities of the observatory are managed by the Department of Physics with Fr. Principal as its Director. The long term vision of the Observatory and the Department of Physics is to narrow down the gap between university education and research in the field of observational astrophysics, atmospheric and space sciences.

MAJOR RESEARCH DOMAINS

- High Energy Astroparticle Physics: Examining the role of exotic compact stars and the role of particle physics candidates towards their contribution towards the predominant dark sector of the universe. The work in based on publications in prominent research journals and relates well to present day observations. Research have been carried out about rotating strange quark stars, primordial black holes and heavy particle decays.

Astronomy and Space Science research:

1) A research scholar, Fr. Simon Murmu, is working under Dr. Sarbari Guha on the characterization of various sites in West Bengal for astronomy and space science research. Preliminary work has begun in the Raghabpur Campus with the help of BAM 1022, Real-Time Portable Beta Attenuation Mass Monitor installed in Raghabpur campus, anemometer, etc.
2) Dr. Suparna Roychowdhury is involved in research on chaotic particle dynamics around compact objects in the centers of galaxies. A research scholar, Mr. Yeasin Ali is working under her supervision, where they are not only looking at theoretical and computational models but are also trying to look at ASTROSAT data for transient X-ray sources. She also works on aspects of feedback from AGNs into galaxy clusters.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

"**Arduino-based high-frequency radio telescope and observations**" by Subham Banerjee et al.,International Journal of Innovative Research in Physics, Volume 5, pp. 1-10 (10) https://doi.org/10.15864/ijiip.5101

A group of students from the Department of Physics built a low-cost, high-frequency radio telescope using Arduino. This telescope operates in the 12-18 GHz range, making it suitable for urban environments with high radio frequency interference. It can be used to observe radio emissions from satellites and other sources. A manual mount was incorporated for the purpose. This work demonstrates a cost-effective way for students to learn about radio astronomy, Observational Astrophysics and potentially be extended for more advanced observations in the future.

"Density Perturbation and Cosmological Evolution in the Presence of Magnetic Field in *f* (*R*) Gravity Models" by Samarjit Chakraborty and Sarbari Guha, Advances in High Energy Physics, Volume 2022, Article ID 5195251, 11 pages, https://doi.org/10.1155/2022/5195251

Here we studied the density perturbations and cosmological evolution in the FLRW universe in the presence of a cosmic magnetic field, which may be assumed to mimic primordial magnetic fields (PMFs). Such magnetic fields have sufficient strength to influence galaxy formation and cluster dynamics, thereby leaving an imprint on the CMB anisotropies. Small-scale PMFs can produce fluctuations in the baryon density field, which can affect the CMB anisotropy. The effect of the magnetic field energy on the expansion of the universe cannot be neglected, and will affect the formation of cosmic defects. It can also influence the baryon to photon ratio and the relic neutrino temperature. The interplay between the magnetic field and baryons is found to increase in higher order gravity theories.

"How appropriate are the gravitational entropy proposals for traversable wormholes?" by Samarjit Chakraborty et.al.,General Relativity and Gravitation (2022) 54:47 https://doi.org/10.1007/s10714-022-02934-3

In this paper we examined the validity of some proposed definitions of gravitational entropy (GE) in the context of traversable wormhole solutions of the Einstein field equations. Gravitational entropy is the entropy measure reflecting the degrees of freedom associated with the free gravitational field. In any physical process involving gravity, the clumping of matter (structure formation) or the intensity of gravitational field in a local region of spacetime can be measured in terms of this quantity. Black hole entropy emerges as a special case of the gravitational entropy of free gravitational fields. The study of GE also tells us how matter and free gravitational fields behave in a particular region or in an overall fashion. For any traversable wormhole to exist, it must have viable gravitational entropy. So it is important to compute the gravitational entropy in this context.

"Heating of the intracluster medium by buoyant bubbles and sound waves" by Asif Iqbal, et.al., Monthly Notices of the Royal Astronomical Society*, Volume 518, Issue 2, January 2023, Pages 2735–2745,* https://doi.org/10.1093/mnras/stac3197

Active galactic nuclei (AGN) powered by the central supermassive black holes (SMBHs) play a major role in modifying the thermal properties of the intracluster medium (ICM). In this work, we implement two AGN heating models: (i) by buoyant cavities rising through stratified ICM (effervescent model) and, (ii) by viscous and conductive dissipation of sound waves (acoustic model). Our aim was to determine whether these heating models are consistent with ICM observables and if one is preferred over the other. We assume an initial entropy profile of ICM that is expected from the purely gravitational infall of the gas in the potential of the dark matter halo. We then incorporate heating, radiative cooling, and thermal conduction to study the evolution of ICM over the age of the clusters. Our results show agreement with the current observational facts and have helped in estimating fraction of the total AGN luminosity available as the AGN mechanical luminosity.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

Training courses organized for the students: (1) St. Xavier's College Rural Outreach Program was held on 5th December 2022 under the NSSS 2022 at the Raghabpur Campus.

Solar observations with mobile telescope were demonstrated by the outreach team from CESSI, ARIES, IIA. (2) B.Sc. and M.Sc. students of St. Xavier's College, Kolkata participated in the Space Science Technology & Awareness Training (START) Programme – 2023.

SXC organizes outreach activities and other observational workshops for students, in both high school level and for college level. One such workshop was organized on 7th and 8th July, 2023 on Astronomy and Space Science.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

- Specialization on Astro-Particle Physics offered at the P.G level (From 2007 onwards)

  (i) Title : Specialization in Astro-Particle Physics

  (ii) PG final year

  (iii) Intake Capacity : 20 Students

(iv) Topics Covered: Foundations of Astrophysics, General Relativity, Cosmology, Solar, Galactic and Extragalactic Astrophysics, Standard Model of Particle Physics, Astro-particle Physics, Astrophysics Lab, Computational Astrophysics.

(v) 350 Lecture hours

- PhD Level courses: Currently three students are working in related areas.
- Standard coursework offered to PhD Students include: Course on Computation, Non-linear Dynamics, Fluid Dynamics, Quantum Mechanics, Special and General Relativity, Compact objects and gravitational waves.

For further details on the inputs as provided in the document, please contact

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TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Website: https://www.tifr.res.in/

TATA INSTITUTE OF FUNDAMENTAL RESEARCH (TIFR)

TIFR has several units working in the area of space sciences. A brief introduction is as follows:

Department of Astronomy and Astrophysics: TIFR is located in the scenic Mumbai campus. The department carries out cutting edge research in theoretical and observational astrophysics with an active interest in instrumentation. The observations are carried out using ground-based facilities as well as balloon-borne and satellite-borne instruments. This is supplemented by the work done in Radio Astronomy and High Energy Cosmic Rays by other groups in the Institute.

Balloon Facility: TIFR Balloon Facility (TIFR-BF) is a unique centre of technology which offers complete solutions in scientific ballooning for high altitude studies. The centre has an in-house balloon production facility as well as ground facilities for balloon launching and recovery operations, a control room for handling the data and command operations. TIFR-BF plays a significant role in advancing space research, particularly in the field of astrophysics and atmospheric science. TIFR-BF has the distinction of launching more than 500 zero pressure balloons since its inception.

National Centre for Radio Astrophysics (NCRA), one of national centres of TIFR, is a premier institution for research in astrophysics. Originating from the radio astronomy group of TIFR started in the 1960s, NCRA has grown steadily to establish its position in the international arena. The group has built and runs, in India, some of the most sensitive radio observatories in the world: the Ooty Radio Telescope (ORT, commissioned in 1970 and still functional) and the Giant Metrewave Radio Telescope (GMRT, commissioned in 2001 and recently upgraded in 2019). The scientists at NCRA carry out cutting edge research in a wide range of topics in astrophysics, using both the in-house facilities, as well as other international facilities. The engineering team, which has built the in-house facilities and supports their operations, also carries out technology innovations for future developments. Further, NCRA also leads India's participation in the Square Kilometre

Array (SKA) project – a large, international collaboration to design and build the next-generation radio astronomy observatory.

KEYWORDS

X-ray Astronomy, Infrared Astronomy, Sub-mm Astronomy, Theoretical Astrophysics, Astronomical Instrumentation, Astronomical Observations, Zero pressure balloon, Aerostat, Balloon launch, Control Instrumentation, Payload Integration, Gondola, Radio astronomy, radio telescopes, ORT, GMRT, uGMRT, RF engineering, optical fibre technology, digital signal processing techniques, astrophysics, pulsars, Milky Way galaxy, radio galaxies, cosmology, the early Universe.

MAJOR RESEARCH DOMAINS

X-ray Astronomy: AstroSat satellite has performed many scientific observations of a wide variety of sources, and scientific research papers are being published.

Infrared Astronomy: Currently, infrared astronomers at TIFR are developing a payload for spectroscopic and imaging survey for a future Indian satellite. The Infrared Spectroscopic Imaging Survey (IRSIS) has been proposed as a payload for the small satellite program of ISRO. It is a two band near infrared spectrometer (1.7 – 3.4 µm and 3.2 – 6.4 µm) having an optic fibre IFU.

Scientific ballooning: Design and fabrication of zero pressure balloons, tethered balloons (natural shaped and aerostats), special balloons, sounding balloons, and launching them from TIFR-BF.

NCRA carries out research in a wide range of areas, including hardware and software instrumentation for radio astronomy, low-frequency studies of the Sun and the heliosphere, pulsar surveys, pulsar timing studies, pulsar radio emission mechanisms, studies of high-redshift galaxies via their HI 21cm, CO, CII-158 micron, Lyman-alpha and stellar emission, tests of fundamental constant evolution, studies of extended radio structures, magnetic fields, and turbulence in galaxy clusters, studies of magnetized stars and other radio transients, studies of various constituents of the Milky Way including supernova remnants, ionized hydrogen regions and atomic gas clouds, studies of fast radio bursts and their environments, studies of quasars and active galactic nuclei, cosmological studies and especially the epoch of reionization.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

1. **Kumar et al., 2023, MNRAS** "Globular Cluster UVIT Legacy Survey (GlobULeS) - II. Evolutionary status of hot stars in M3 and M13"

2. Husain, N. et al. 2023, MNRAS "Probing the soft state evolution of 4U 1543-47 during its 2021 outburst using AstroSat**"**

3. Bhargava et al. 2023, ApJ, "AstroSat view of the neutron star low-mass X-ray binary GX 340+0**"**

4. Kashyap et al 2023, MNRAS "Broad-band spectro-temporal investigation of neutron star low-mass X-ray binary GX 349+2**"**

5. Singh, K. P. 2022, JoAA, " Jets from active galactic nuclei**"**

6. Ghosh, S. K. et al 2022, JoAA " An automated pipeline for Ultra-Violet Imaging Telescope**"**

7. Kumar et al 2022, MNRAS "Extending the energy range of AstroSat-CZTI up to 380 keV with compton spectroscopy**"**

8. Kashyap et al. 2022, MNRAS, "Probing spectral and temporal evolution of the neutron star low-mass X-ray binary 4U 1724-30 with AstroSat**"**

9. Bhargava, et al. 2022, MNRAS "Probing the shot behaviour in Cygnus X-1 using simultaneous AstroSat-NICER observation**"**

10. Antia, H. M., Agrawal, P. C., Katoch, T., et al. 2022, ApJSS "Improved Background Model for the Large Area X-Ray Proportional Counter (LAXPC) Instrument on board AstroSat**"**

11. Singh et al. 2022, MNRAS, "Spectral States of OJ 287 blazar from Multiwavelength Observations with AstroSat**"**

12. Naik et al., 2022, JAI, "Evaluation of Controllers and Development of a New In-House Controller for the Teledyne HxRG Focal Plane for the IRSIS Satellite Payload**"**

13. Kumar et al., 2022, MNRAS "Study of UV bright sources in globular cluster NGC 4590 using Ultraviolet Imaging Telescope (UVIT) observations**".**

14. Rao et al., An Automatic CADI's Ionogram Scaling Software Tool for Large Ionograms Data Analytics, *IEEE Access*, **10**, 22161, 2022.

15. Rao et al., Auto-detection of sporadic E and spread F events from the digital ionograms, *Advances in Space Research*, **70(4)**, 1142, 2022.

16. **NCRA**: Some of the major results from the recent few months are as follows: NCRA scientists lead the Indian Pulsar Timing Array experiment that has contributed to the first tentative detection of nanoHz gravitational waves via high-accuracy timing studies of an ensemble of pulsars. An NCRA group has built a robust unsupervised interferometric imaging pipeline for solar radio imaging, and have used it to obtain important new results for the quiet Sun, active solar regions, as well as for the solar corona. Another group is collaborating with the CDAC to build a real-time commensal survey instrument that will allow the commensal identification and localization of new fast radio bursts (FRBs) and pulsars. Another NCRA group has detected carbon monoxide emission from high-redshift absorption-selected galaxies, finding extremely high molecular gas masses in these systems. They have also carried out the first mapping of CO emission from a high-redshift absorption-selected galaxy, finding clear evidence for a cold, rotating disk. They have also used stacking of the HI 21cm emission signals of a large population of galaxies at high redshifts, z~1, to measure and estimate different aspects of the atomic gas content of the galaxies at this epoch of the Universe. NCRA scientists have also carried out HI 21cm mapping studies of FRB host galaxies, finding evidence that the FRBs may have been born due to galaxy mergers.

INDIGENOUSLY DEVELOPED INSTRUMENTS / PAYLOADS / PRODUCTS / SENSORS / DETECTORS

1) A Laboratory Model for the IRSIS payload was developed and tested and a detailed report on its performance was submitted to ISRO (Space Science Office). Help is sought from their teams to design the passive cooling system and to tie up other loose ends.

2) Designed and developed several hardware and software at the Balloon Facility to implement play back of stored telemetry data, decode, and display in real-time the UDP formatted telemetry data at the ground station, in a user-friendly fashion, station to

receive the ADS-B data from Air Traffic Control (ATC) transponder, Software-Defined-Radio (SDR) was implemented to replace the old ICOMM receivers and a FPGA-based telecommand encoder.

3) The ORT has undergone extensive upgrades to enhance its analog and digital electronics, including the installation of a new pulsar backend, enabling a wider field of view and increased sensitivity for various studies. Additionally, a comprehensive overhaul has been conducted on the entire receiver chain and mechanical, civil, electrical, and servo systems of the ORT. The Giant Metrewave Radio Telescope (GMRT), located 80 km north of Pune, India, comprises 30 large parabolic dishes spread over distances up to 25 km, making it one of India's most ambitious scientific projects. Recently the GMRT was upgraded, it now has enhanced sensitivity with four wideband receiver systems covering the 125−1460 MHz range and new capabilities such as Very Long Baseline Interferometry (VLBI). India, led by NCRA, has been actively involved in the design and early prototyping phases of the Square Kilometre Array (SKA) observatory, contributing significantly to the development of telescope monitor and control software. Recently, the Government of India approved participation in the SKA Observatory at an estimated cost of Rs 1250 Cr, enabling India to become a full member of the SKA Council, with funding shared between DAE and DST, signifying a major advancement for Indian astronomy and reinforcing the country's commitment to international scientific collaboration and technological development.

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

1) The Payload Operation Centre (POC) for two of the payloads for the first Indian astronomy satellite, AstroSat, i.e., the Large Area X-ray Proportional Counter (LAXPC) and the Soft X-ray Telescope (SXT) were established to process and distribute data from these instruments.

2) DAA members presented many AstroSat related lectures in India and outside India, and contributed to the organization of several AstroSat-related conferences.

3) A number of publications in international refereed journals have shown that the Astrosat/LAXPC and SXT data are being used by a wide scientific community (including PhD students and postdocs).

4) To familiarize with scientific ballooning activities amongst youngsters, TIFR-BF invites enthusiastic students from local schools, colleges, and universities for regular outreach programs and also offers projects to undergraduate and post-graduate students.

5) NCRA conducts various capacity-building activities including a PhD program in astrophysics, training programs for undergraduate and graduate students in radio astronomy, and guiding projects for BTech and MTech students from different institutions. Our faculty members also supervise projects for B.Tech, M.Sc, MTech, and M.Phil students in space science and related areas, and the institute offers Ph.D. programs in fields related to space science and technology.

COURSES OFFERED ON SPACE SCIENCE AND TECHNOLOGY

NCRA collaborates with the neighbouring Inter-University Centre for Astronomy and Astrophysics (IUCAA) to run a Graduate School for its and IUCAA's Ph.D. students. The courses in this Graduate School are (1) Methods of Mathematical Physics I and II, (2) Introductory Astronomy and Astrophysics I and II, (3) Quantum and Statistical Mechanics, (4) Electrodynamics and Radiative Processes I and II, (5) Extragalactic Astronomy I and II, (6) Astronomical Techniques I and II, (7) Galaxies, (8) The Interstellar Medium, and (9) Research Methodology and Ethics. In addition, NCRA Ph.D. students are required to carry out two Graduate School astronomy research projects, one of which has to be based on NCRA facilities, with NCRA faculty members before registering for a Ph.D.

LABORATORIES AND FACILITIES AVAILABLE FOR SPACE INSTRUMENTATION

1) Thermovac Chambers: (a)1.5 meter with capacity to test payloads up to 1400 mm (L) x 600 mm (W) x 850 mm (H) and up to 150 kg weight. (b) with size of 1 m dia x 1.5 m length, capable of attaining a vacuum level of 3.3 x 10^{-5} hpa and temperature control in the range of -40^{o} C to +80^{o} C, (c) operational at cryogenic temperatures between 80 to 150 K, designed to test the small satellite payloads and subsystems, mostly of Aluminium alloys/Copper of mass up to 50 Kg (max).

2) Cleanrooms: (a) Class 10000 clean room (3 meter x 4 meter) at DAA, TIFR with 3 Laminar Flow benches that provide class 1000 work area of about 1200 mm x 1000 mm (b)Two small 10000 Class cleanrooms (Size approx. 9 feet x 7 feet) with 100 Class

laminar flow filters suspended over the optical bench (c) Class 10,000 clean room facilities with a room size of 8.3 m x 5.1 m x 2.6 m (2 rooms) (d) 4 class 100 laminar air flow benches

3) Well equipped department workshop with precision lathe machine. Support from TIFR Central workshop with well equipped lathe and CNC milling machines (including 5 axis milling machine).

6) Vibration Chamber Facility: A vibration chamber in the frequency range of 5 to 2000 Hz, capable of producing a force of 35.6 kN sine and random mode of operation and maximum acceleration of 1080 m/s in sine wave and random rms of 735.5 m/s.

7) RF Electronics Lab: The laboratory specializes in advanced radio frequency electronics for applications in radio astronomy, focusing on GMRT and encompassing wideband antenna feed elements, low-noise front-end analog electronics, high-quality filters, and techniques for outdoor use, supported by state-of-the-art measurement instruments and simulation tools.

8) Optical Fibre Lab: This lab deals with optical fiber signal transmission methods and maintaining the GMRT's optical fiber network, excelling in analog and digital transmission schemes, long-distance signal fidelity, noise reduction, and employing cutting-edge practices for high-quality optical fiber systems, supported by state-of-the-art measurement instruments and diagnostic kits.

9) Digital Lab: This laboratory specialises in the development of quality high-speed digital hardware that is needed for next-generation signal processing applications, and other related topics using FPGA, CPU and GPU technologies, high-speed data and compute networks for real-time applications, hardware as well as software-based systems, special signal processing algorithms, and precision time and frequency standards.

10) Monitor and control software development laboratory: This laboratory focuses on the development of next-generation monitor and control systems, both hardware and software.

11) Servo systems laboratory: This laboratory specialises in the development of modern servo systems that are essential for the GMRT antennas.

12) Mechanical engineering laboratory and workshop: This laboratory is concerned with all aspects of mechanical systems and the GMRT, and also runs the central mechanical

workshop that caters to all the in-house needs for all the engineering groups and activities at NCRA.

NATIONAL COLLABORATIONS IN SPACE SCIENCE AND TECHNOLOGY

Sl. No.	Area of Collaboration	Collaborating Institute	Scope of your centre / institute	Scope of the collaborating institute
1.	SKA India Consortium (SKAIC) for coordinating all SKA-related activities in the country. For more details see: http://www.ncra.tifr.res.in/ncra/skaindia)	More than 20 institutions in the country covering major astronomy and space science research institutes, IITs, universities and some colleges.	NCRA is the lead institute in this collaboration	All the other participating countries are equal members of this collaboration.

INTERNATIONAL COLLABORATIONS IN SPACE SCIENCE AND TECHNOLOGY

Sl. No.	Area of Collaboration	Collaborating Institute/agency and country	Scope of your centre / institute	Scope of the collaborating institute / agency
1.	Square Kilometre Array (SKA) observatory (see https://www.skatelescope.org/ for more details)	SKA Organisation and 10 other member countries: Australia, South Africa, UK, Canada, Italy, Portugal, The Netherlands, China, Sweden, and Switzerland.	India has been part of the SKAO for the design and prototyping phase activities, contributing actively to the technical work, and also participating in the science	The SKAO is the parent body of this collaboration, and all the other countries are members, like India, and have respective roles in the technical design and prototyping

			working groups of the SKA.	activities and science groups.

For further details on the inputs as provided in the document, please contact **Prof. Bhaswati Mookerjea**, Professor H, bhaswati@tifr.res.in

LABORATORY FOR EARTH RESOURCES INFORMATION SYSTEMS (LERIS), UNIVERSITY OF KERALA , THIRUVANANTHAPURAM, INDIA

https://www.keralauniversity.ac.in

ABOUT THE CENTRE

LERIS, established in 2015 within the Department of Geology at the University of Kerala, operates under a Memorandum of Understanding (MoU) between the Indian Space Research Organization (ISRO) and the University of Kerala, under the co-ordination of Dr. Sajin Kumar K.S., Assistant Professor, Department of Geology. This lab is actively involved in the study of meteorite impact craters (terrestrial, Mars and Moon), planetary science and geohazards, and focuses on addressing questions related to earth sciences by employing Remote Sensing applications at both regional and global levels. LERIS is committed to conducting high-impact research in the field of earth sciences and aims to contribute valuable insights to the scientific community while fostering interdisciplinary collaboration. Rooted in the collaboration between ISRO and the University of Kerala, LERIS inherits a legacy of scientific excellence and technological innovation. The lab's heritage emphasizes a commitment to advancing the understanding of earth sciences through state-of-the-art approaches.

MAJOR RESEARCH DOMAINS

The LERIS lab conducts research on a diverse array of topics. The major research domains of the LERIS lab broadly includes studies of impact craters on Earth, Moon, Mars, planetary remote sensing and geomorphological evolution, characterization of impact craters, associated melts and breccia, planetary scale reconstruction of paleopositions, paleodistance, paleoclimate and paleobathymetry. The different domains are detailed below as follows:

- Terrestrial Impact Craters (TIC): The TIC studies are normally centred on individual craters. To explore the potential of TIC for understanding geological processes, LERIS has ventured into a diverse range of research domains, employing the entire global crater catalogue as listed here.

- The paleopositions and paleodistances of the 210 TIC were reconstructed for all craters, at appropriate formation ages to identify potential latitudinal dependency for the impact cratering events.
- The paleopositions and paleodistances were linked with the different movement pathways of (paleo)tectonic plates to identify major tectonic events (such as supercontinent formation, continental breakup, orogenic cycles among others).
- For TIC, a denudation index (DI) was put forth, based on extent of fluvial activity. The proportion of 1st order streams maintaining centripetal pattern into the crater centre and radial patterns away from the rim were used a prime controls to derive DI.
- The deflection of streams, as forced by the crater structure is elevated for TIC, by corroborating the finding with field investigations.

Martain and Lunar planetary surfaces:

- Characterization of the Lunar surface is undertaken by identification of the spallation patterns of ejecta across the craters. Based on the changing ejecta spallation patterns with crater sizes, the crustal characteristics can be estimated and studied.
- Select Martian craters such as Morella was used as proxies to build a chronological event chart for Mars, by observing the geomorphological units observed in the craters and dating the terrain using crater count techniques.
- The landslides on Mars are studied to identify mass movement manifestations and influencing factors, especially in the absence of active tectonics events to aid/influence the geomorphological processes.

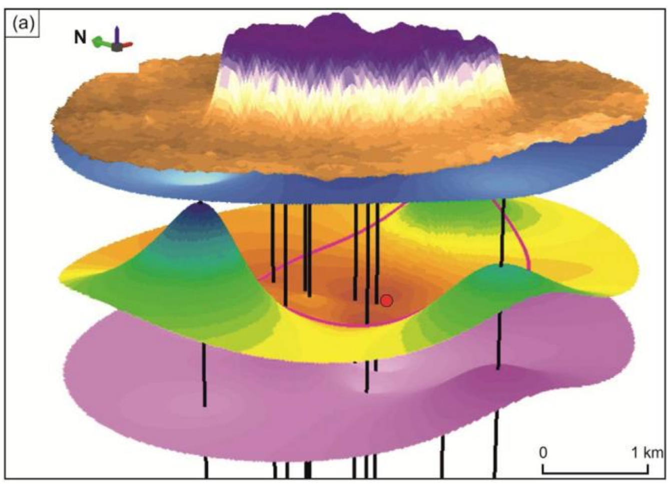
Studies on individual craters, associated processes and products:

- The impact melt and breccia at Dhala, Ramgarh, Lonar and Luna are investigated to identify the extent of target scavenging, age of impact event, potential projectile type, affirm impact markers (planar fractures, planar deformation features), ascertain erosion rates, rim denudation, and to characterize the geochemical signatures.
- The Cretaceous-Paleogene Boundaries in India were revisited to decipher the potential presence of distal ejecta components of Chicxulub crater across India. The study also focused on the potential occurrence of the same across the Deccan Volcanic Province as well.

MAJOR SCIENTIFIC APPLICATIONS / RESULTS

Research findings from different publications of LERIS lab are categorized as follows:

1. The Dhala Crater in the Bundelkhand Craton of Central India, previously considered as a complex crater, has undergone detailed investigation using geoinformatics and subsurface geology. The syn- and post-impact litho-contact, delineating the crater boundary, was determined through visual interpretation of imagery, while borehole data and spatial interpolation were employed to analyze the crater's morphology. The absence of a Central Elevated Area (CEA) and the relatively small diameter suggest a simple impact crater, with a mesa-like structure at the crater's center attributed to denudational processes on Proterozoic sediments. https://doi.org/10.1016/j.pss.2019.07.006



A 3D model created using SRTM DEM and borehole data showing the contact plane between different litho-units. Inscribed circle is also fitted within the 3D model

The paleopositions of confirmed terrestrial impact craters were reconstructed to respective formation ages using GPlates. The paleopositions helped determine the displacement and paleodistance registered by TIC relative to present-day positions. The paleopositions aided in deciphering latitudinal dependency of TICs by correcting for plate-tectonics. Earth depicts good correlation with impact crater proportions on Mars and Moon in equatorial (0-30°) and polar zones (30-60°). https://doi.org/10.1016/j.pss.2022.105575

2. Terrestrial impact craters were used as markers for plate tectonic events. The change in crater velocities was linked to different supercontinent cycles, volcanic events, orogenic cycles among others. The decrease in crater velocity points to potential plate subduction while the acceleration depict movement over hotspots. For example, Gondwana subduction causes a step-wise velocity decrease for craters in Australia, India and South America during 600-580 Ma. https://doi.org/10.1002/gj.4512
3. Drainages were used as proxies for denudation. The parameters used to generate a Denudation Index (DI) for terrestrial impact craters are crater type, age, target lithology, paleoposition and paleoclimate across terrestrial impact craters (since formation) at 1 Ma intervals. Two separate DI were generated for simple and complex craters. We determined that equatorial rainy climate, crystalline target, older craters aid denudation of rim with progressing age. https://doi.org/10.1016/j.geomorph.2021.108007
4. A review on impact events aiding energy resource formation was conducted. A total of 60 craters has resources (e.g., oil, gas, coal, uranium, mercury, critical minerals). The crater formation stages determine resource formation (oil and natural gas formation occurs in late excavation and modification stages only; e.g. Chicxulub). https://doi.org/10.1016/j.engeos.2021.12.006
5. Petrographic works focusing on melt sample of Lonar crater of Maharashtra, India depicted that the impactor scavenged > 550 m of target basalts, to involve Archean basement in impact melting process, through planar deformation feature (PDF; 20-25 GPa), diaplectic glass (>25 GPa), cristobalite (>1470° C) and zircon U-Pb age. https://doi.org/10.1016/j.lithos.2021.106479
6. The potential of Lonar crater as a ‘geoheritage site’ is put forward, by revisiting the crater’s impact signatures, socio-cultural, archeological, and ecological traits to emphasize the need to safeguard the crater in pristine form. https://doi.org/10.1016/j.lithos.2021.106479
7. Petrography work on the evidences aiding impact origin of the Ramgarh structure in India are PDF, shock fabrics, diaplectic glass among others. The projectile type at Ramgarh is estimated to be a differentiated achondrite owing to siderophile

geochemistry (Ni-Cr, Ga-Ni, Co-Ga) of sedimentary target and melt units at Ramgarh. The U-Pb dating (first geochronological date for Ramgarh to be ever reported) constraints the impact age between 528 – 395 Ma (Fig. 6). https://doi.org/10.1016/j.lithos.2022.106779

8. The Luna structure in the tectonically active Kutch Basin, India, suspected to be an impact crater for over a decade, lacks convincing evidence until recent findings. This circular feature in the Banni Plains, measuring 1.5–1.8 km, exhibits a less-prominent rim and is strewn with high-specific-gravity, magnetically varied melt-like rocks. Analysis of minerals like wüstite, kirschsteinite, and geochemical data, including PGE enrichment, suggests an impact into a clay-rich target with elevated calcium and silica content. The thick overlying Quaternary sediments prevent direct exposure, and radiocarbon dating of a silt layer indicates Luna as the largest crater resulting from an iron bolide and is potentially younger than 6905 years. https://doi.org/10.1016/j.pss.2023.105826

CAPACITY BUILDING IN SPACE SCIENCE RESEARCH

- The researchers from the lab are coordinated with the combined field work of Massachusetts Institute of Technology, and University of Texas (Austin) at Lonar, Maharashtra during January 2023 and April 2023.
- Did the combined field work of Planetary and Space Science Centre with the University of New Brunswick, Canada (led by Prof. John G. Spray), at Kuchchh, Gujarat during January- February 2020.
- Additionally, the researchers from the laboratory conducted numerous field studies as part of their PhD research in various impact craters across India, including Ramgarh in Rajasthan, Lonar in Maharashtra, Dhala in Madhya Pradesh, and Luna in Gujarat.

<u>Completed/ Ongoing Ph.D and topics</u>

1. Geology and Geomorphology of Ramgarh Crater, Rajasthan, India.
2. Geology and Geomorphology of Luna Crater, Gujarat, India.
3. Geology and Geomorphology of Dhala Crater, Madhya Pradesh, India.

4. Geology and Geomorphology of Lonar Crater, Maharashtra, India.
5. Meteorite impact-related distal ejecta at the Cretaceous-Paleogene boundary across India: A geological perspective.
6. Quantifying the subsidence and erosion of Ramgarh Crater, Rajasthan, India.
7. An assessment of sepulchring of Martian impact craters using remotely sensed data and hydraulic modelling.
8. Global distribution of Lunar minerals, OH & H_2O: Implications to the Lunar Volatile Cycle.

For further details on the inputs as provided in the document, please contact Dr. Sajin Kumar K.S., Assistant Professor., sajinks@keralauniversity.ac.in).

Chandrayaan-3 lander on Moon's surface: picture shot with the rover camera

Indian Space Research Organisation