# SPACE RESEARCH IN INDIA

## HIGHLIGHTS OF 2024-2025

FOR THE FORTY-SIXTH COSPAR SCIENTIFIC ASSEMBLY

# SPACE RESEARCH IN INDIA

## Highlights of 2024-2025

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

For the 46th COSPAR Scientific Assembly
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अध्यक्ष / Chairman

## FOREWORD

I am happy to introduce the 2026 edition of the report on Space Research in India, prepared for the upcoming COSPAR Scientific Assembly. This report presents an extensive overview of the nation's significant accomplishments, technological advancements, and research activities across planetary science, astronomy, heliophysics, and near-Earth space between January 2024 and December 2025.

The years 2024 and 2025 have been exceptionally transformative for the Indian space programme. The period commenced with the successful launch of India's X-ray Polarimeter Satellite (XPoSat), on January 1, 2024, followed closely by the insertion of the Aditya-L1 solar observatory into its halo orbit around the Sun-Earth Lagrange point 1 on January 6, 2024. We also commemorated the historic soft landing of the Chandrayaan-3 lander by celebrating the day as our first National Space Day in August 2024, honoring the landing site officially named "Statio Shiv Shakti" by the International Astronomical Union (IAU).

Building upon our commitment to advancing space transportation and exploration technologies, ISRO crossed several major milestones during this period. We successfully conducted successive Reusable Launch Vehicle Autonomous Landing Missions (RLV LEX-02 and LEX-03), showcasing precision autonomous landing capabilities under challenging conditions. The year 2024 also witnessed the successful third developmental flight of the Small Satellite Launch Vehicle (SSLV-D3) injecting the EOS-08 satellite, and the launch of the European Space Agency's Proba-3 mission aboard PSLV-C59. Moving into early 2025, India achieved a landmark breakthrough in space robotics with the Space Docking Experiment (SpaDeX), successfully docking two independent satellites in orbit on January 16, 2025.

Significant strides have also been made toward our human spaceflight endeavors. In July 2025, ISRO Gaganyatri Group Captain Shubhanshu Shukla completed the historic Axiom-4 mission to the International Space Station (ISS), successfully executing seven microgravity experiments. To further prepare for upcoming crewed Gaganyaan missions, ISRO accomplished first Integrated Air Drop Test (IADT-01) for Gaganyaan program, towards performance validation of the critical parachute-based deceleration system of the

Crew Module. ISRO also established the Himalayan Outpost for Planetary Exploration (HOPE) analog mission setup in Ladakh, India.

Looking ahead, the Government of India has outlined a bold 'Space Vision 2047', envisioning the Indian Space Station, named the Bharatiya Antariksha Station (BAS) in the Low Earth Orbit, by year 2025, and Indians landing on Moon using indigenous technologies, by year 2040. The Government of India has accorded approval for landmark missions including the Venus Orbiter Mission (VOM), Chandrayaan-4 lunar sample return mission and the Chandrayaan-5 / LuPEX mission (collaboration between ISRO and JAXA).

The science, technology, and innovation of India showcased in this report are the outcome of the concerted efforts of our national academia, research institutes, and industry partners. India looks forward to contributing more to global space exploration and promoting the peaceful, sustainable use of outer space. I hope the information detailed herein will serve as an important reference for the global scientific community.

I wish the 46th COSPAR Scientific Assembly every success.

Date: July 20, 2026

**(डॉ. वी. नारायणन / Dr. V Narayanan)**

# भारतीय भूचुम्बकत्व संस्थान

(विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार के अंतर्गत एक स्वायत निकाय)

# INDIAN INSTITUTE OF GEOMAGNETISM

(AN AUTONOMOUS BODY UNDER THE DEPT. OF SCIENCE & TECHNOLOGY, GOVT. OF INDIA)

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30th June 2026

## PREFACE

I am happy to introduce the report on Space Research in India, prepared for the upcoming COSPAR Scientific Assembly by the Indian National Committee for Space Research (INCOSPAR), the Indian National Science Academy (INSA), and the Indian Space Research Organisation (ISRO). This report provides an overview of the important accomplishments, achievements, and research activities conducted across India in the domains of near-Earth space, the Sun, planetary sciences, and astrophysics during the period of January 2024 to December 2025. It also highlights India's expanding capacity-building activities, ground-based and space-borne facilities, and international collaborations that are driving India's space exploration forward.

The years 2024 and 2025 have been a monumental period for India's space science ecosystem, particularly propelled by the solar maximum of Solar Cycle 25. A defining highlight of this era was the operationalization of Aditya-L1, India's first dedicated solar observatory, which was successfully inserted into a halo orbit around the Sun-Earth Lagrange Point 1 (L1) on January 6, 2024. Operating continuously from this unique vantage point, Aditya-L1 has revolutionized our understanding of the space weather. During the historic geomagnetic storms of May 2024 and June 2025, our observatories comprehensively mapped how prompt penetration and disturbance dynamo electric fields caused severe perturbations in the equatorial ionosphere.

Our understanding of the Sun-Earth connection and geomagnetism has been significantly enriched by the extensive research and regional modeling led by the Indian Institute of Geomagnetism (IIG) and its partner laboratories. Utilizing a robust network of dip-equatorial ground stations, scientists tracked Equatorial Ionization Anomaly (EIA) dynamics and the "equatorial fountain effect" triggered by severe solar storms. Furthermore, polar geomagnetic research was expanded at India's Antarctic research stations, Maitri and Bharati, where researchers successfully mapped Southern polar ionospheric responses to space weather events, differentiating the impacts of high-latitude plasma convection and auroral particle precipitation. Beyond solar drivers, vital progress was made in lithosphere-ionosphere coupling, where researchers isolated ionospheric anomalies triggered by the acoustic gravity waves of earthquakes, detecting them mere minutes after seismic ruptures.

Progress in planetary sciences extended far beyond our terrestrial neighborhood. We gained invaluable ground-truth data from the historic Chandrayaan-3 landing, and domestic archives were utilized to develop tools like the Solitary Wave Identification Tool (SWIT) to unravel the highly turbulent Martian plasma environment. Additionally, India expanded its planetary analog testing footprint by identifying and unifying over 50 unique high-altitude and saline-alkaline sites across the subcontinent to simulate Martian and Lunar surfaces for future missions.




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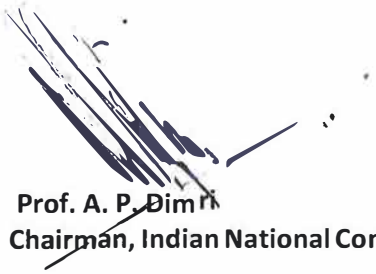
The Indian astronomy and astrophysics community also crossed major milestones. Concurrently, under the Department of Science and Technology's (DST) National Telescope Scheme (NTS), we are witnessing a rapid expansion of ground-based observational infrastructure, including the National Large Solar Telescope (NLST) and the National Large Optical-Infrared Telescope (NLOT) in Ladakh. The 4-meter International Liquid Mirror Telescope (ILMT) at Devasthal achieved regular operational cadences, utilizing the advanced AI-driven PyLMT pipeline to automatically detect extragalactic transients and supernovae. Furthermore, India has escalated its engineering and scientific contributions to the international Thirty Meter Telescope (TMT) project, commanding a major work-share in instruments like the Wide Field Optical Spectrometer (WFOS).

I thank the scientists across various national institutes, universities, and laboratories who have provided their valuable inputs on the space research activities detailed in this document. I acknowledge the hard work of the Science Programme Office, ISRO Headquarters, for compiling and editing this comprehensive report on behalf of INCOSPAR. I hope this report will serve as a vital reference for the global scientific community and inspire further exploration of our universe.



**Prof. A. P. Dimri**
**Chairman, Indian National Committee for COSPAR**

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## MESSAGE

In the last couple of years, India has made significant strides in space-based exploration, marking a remarkable era in planetary science, solar physics, astronomy, and human spaceflight. Following the historic milestones of 2023, the period from January 2024 to December 2025 has witnessed a profound expansion of India's scientific endeavors, yielding rich data and unprecedented discoveries.

India's journey in solar physics reached a new vantage point when our maiden solar observatory, Aditya-L1, was successfully inserted into a halo orbit around the first Sun-Earth Lagrange point (L1) on January 6, 2024. Operating during the peak of solar activity, Aditya-L1's Solar Ultraviolet Imaging Telescope (SUIT) captured the first-ever high-resolution Near Ultra-violet (NUV) images of an X6.3-class solar flare, revealing the complex energy dynamics of the Sun's lower atmosphere. Furthermore, the Visible Emission Line Coronagraph (VELC) captured the onset of a Coronal Mass Ejection (CME) in the 5303 Å emission line, providing vital clues about space weather phenomena. In May 2024, Aditya-L1 joined a global fleet of satellites to map a massive 1.3-million-kilometer magnetic reconnection region during the historic "Gannon's Storm," drastically improving our understanding of how extreme solar storms evolve.

The year 2024 also commenced with the successful launch of India's first dedicated X-ray polarimetry mission, XPoSat, on January 1. Serving as a powerful tool to understand the complex emission mechanisms of the universe, XPoSat has opened a new observational window. XPoSat has since detected significant X-ray polarization from transient black holes and neutron star binary systems, allowing scientists to characterize the geometry of cosmic coronas and magnetic fields.

In the realm of planetary science, data from the historic Chandrayaan-3 mission—released to the public on the maiden National Space Day in August 2024—continues to reshape our understanding of the Moon. The Alpha Particle X-ray Spectrometer (APXS) onboard the Pragyan rover revealed an anomalous depletion of sodium and potassium but an enrichment of sulfur, suggesting the presence of primitive lunar mantle materials excavated during the ancient South Pole-Aitken basin impact. The ChaSTE experiment provided the first in-situ thermal profiling of the top 10 centimeters of the lunar regolith, while the RAMBHA-LP instrument recorded surprisingly high electron densities near the lunar surface. Simultaneously, the Chandrayaan-2 orbiter, now in its fifth year of operation, continues to provide critical insights, recently making the first-ever observation of a solar CME's physical impact on the dayside lunar exosphere.

India's deep-space multi-wavelength observatory, AstroSat, proudly completed a decade of service in September 2025. During this period, it decoded the rapid 70 Hz

flickers (Quasi-periodic Oscillations) of the black hole GRS 1915+105 and exposed the rejuvenation mechanisms of "vampire stars" using its sharp ultraviolet imaging capabilities.

Ground-based observatories have remarkably complemented these space-borne achievements. Scientists at the Physical Research Laboratory (PRL) discovered a dense, "sub-Saturn" exoplanet (TOI-6038A b) using the indigenous PARAS-2 spectrograph at the Mt. Abu Observatory and profiled the interstellar comet 3I/ATLAS as it exited our solar system. Meanwhile, researchers at the National Atmospheric Research Laboratory (NARL) developed a breakthrough machine-learning algorithm capable of predicting Equatorial Plasma Bubble formation, safeguarding satellite-based navigation systems.

An important step was achieved in India's human spaceflight program with the Axiom-4 Mission in July 2025. ISRO Gaganyatri Group Captain Shubhanshu Shukla completed a historic 18-day mission aboard the International Space Station (ISS). He successfully conducted seven critical microgravity experiments developed by Indian institutions, studying muscle regeneration, tardigrade resilience, and the growth of space microalgae and crop seeds.

None of these milestones would have been possible without the deeply symbiotic relationship between ISRO and the nation's academic and research institutes. Our space science exploration program is driven by a vibrant ecosystem of capacity building and community engagement. Through the funded science mission data-analysis programme, RESPOND program, ISRO continues to fund academic research. The ISRO-START program successfully trained nearly 1.6 lacs of undergraduate and postgraduate students, as well as space enthusiasts, nurturing the next generation of space scientists. ISRO has expanded collaborative footprint by establishing Space Technology Cells (STCs) and Space Technology Incubation Centres (S-TICs) across premier institutes. In September 2024, ISRO signed an MoU with the Indian Institute of Geomagnetism (IIG) to jointly explore the Sun-Earth connection and space weather dynamics.

To ensure the maximal utilization of our space data, ISRO organized major National Meets, officially opening Aditya-L1 and XPoSat scientific data to the public and inviting researchers through the "Guest Observer" program to propose new celestial targets. ISRO also hosted a National Science Meet to refine the scientific plan for the upcoming Venus Orbiter Mission (VOM).

As India looks toward the horizon of 'Space Vision 2047', the concerted efforts of the national academia, research institutes, as well as International Cooperation remain the programme's greatest strength.

This report presents a comprehensive overview of the space science activities carried out across India. I believe it will serve as an insightful reference for the global scientific community. I wish the 46$^{th}$ COSPAR Scientific Assembly every success.

Date: July 20, 2026

Dr. Tirtha Pratim Das

**भारतीय अन्तरिक्ष अनुसंधान संगठन /Indian Space Research Organisation**

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## ISRO / DEPARTMENT OF SPACE



## INDIAN ACADEMIC / RESEARCH INSTITUTIONS

# MAJOR ACHIEVEMENTS AND EVENTS (2024 – 2025)

The years 2024 and 2025 are marked by significant milestones in India's space science exploration journey that followed a series of significant events. During this time, India's primary space-based observatories and lunar missions generated a wealth of scientific data, greatly enhancing our understanding of the Sun, the Moon, and the distant universe.

These achievements were bolstered by a deliberate strategy to expand national engagements with universities and research laboratories, focusing on training the next generation of scientists and establishing centers of excellence to ensure India remains a global leader in space exploration. Furthermore, international cooperation continued to be a cornerstone of India's approach, facilitating the sharing of expertise and global infrastructure through complex multi-national missions and partnerships reaching from the lunar surface to the International Space Station. This chapter provides a comprehensive overview of the major achievements and the strategic collaborations that defined India's space journey during this transformative period.

## Major Science Results from Scientific Missions

The years 2024 and 2025 marked an extraordinary period for Indian space science. Following historic launches, India's primary space-based observatories and lunar missions yielded significant scientific data that enhanced our understanding of the Sun, the Moon, and the distant universe.

### **Aditya-L1:** Study of the Sun

Launched to a special vantage point called the L1 point (1.5 million kilometers from Earth in the Sun-Earth line where the gravitational pulls of the Sun and the Earth cancel each other), Aditya-L1 became fully operational in early 2024 to observe the Sun continuously without interruption. Aditya-L1 started observing the Sun in the high solar activity period, and hence, could capture several solar events.

- **Catching Solar Explosions in the Act:** In July 2024, the Visible Emission Line Coronagraph (VELC) captured the very first detailed images of the start of a **Coronal Mass Ejection (CME)**—a massive bubble of hot gas and magnetic energy thrown out by the Sun. Scientists found that as these bubbles erupt, they cause the Sun's outer atmosphere to "dim" significantly for about six hours because so much material is being thrown away. This discovery helps researchers better predict "space weather" that can interfere with satellites and power grids on Earth.
    - **ISRO URL:** https://www.isro.gov.in/Aditya_L1_CME_Observations.html

    - **Citation:** R. Ramesh et al., "New Results on the Onset of a Coronal Mass Ejection from 5303 Å Emission Line Observations with VELC/ADITYA-L1," *The Astrophysical Journal Letters*, 976, L6 (2024).
- **Mapping the Giant Solar Storm of May 2024:** India's solar observatory played a key role in a global study of "Gannon's Storm," the strongest solar storm to hit Earth in over two decades. Aditya-L1's sensors discovered that within this storm, magnetic field lines were snapping and rejoining—a process called **magnetic reconnection**—across a massive region 100 times the size of Earth. This provided the first-ever look at how these giant magnetic "ropes" break apart as they travel through space.
    - **ISRO URL:** https://www.isro.gov.in/AdityaL1_Solar_Storm_Study.html
    - **Citation:** Shibotosh Biswas et al., "Pinching of ICME Flux Rope: Unprecedented Multipoint Observations of Internal Magnetic Reconnection during Gannon's Superstorm," *The Astrophysical Journal Letters*, (2025).

## **Chandrayaan-3:** In-Situ Discoveries at the Lunar South Pole

Following its historic landing in August 2023, the data released to the public in August 2024 revealed that the "Shiv Shakti" landing site is a treasure trove of lunar history.

- **Evidence of an Ancient Magma Ocean:** The Pragyan rover used its Alpha Particle X-ray Spectrometer (APXS) to analyze the lunar soil at 23 different spots. The measurements confirmed that the lunar soil is uniform in its mix of elements, supporting the **Lunar Magma Ocean hypothesis**, which suggests the Moon's surface was once a sea of molten rock. Surprisingly, the rover also found "primitive" material likely thrown up from deep within the Moon's mantle during the giant impact that created the South Pole-Aitken basin billions of years ago.
    - **ISRO URL:** https://www.isro.gov.in/Chandrayaan3_APXS_Nature_Paper.html
    - **Citation:** Vadawale et al., "Chandrayaan-3 APXS measurements of the lunar south polar region," *Nature*, (2024); Sinha et al., "Primitive lunar mantle materials at the Chandrayaan-3 landing site," *Communications Earth and Environment*, 6, Article #321 (2025).
- **The Moon's "Fluffy" Layer's Temperature:** The ChaSTE experiment achieved a unique feat by probing the temperature of the top 10 centimeters of the Moon's "fluffy" soil (regolith). It found that even though the Sun heats the surface, the temperature drops sharply just a few centimeters down. This variability at small scales is vital for future missions that might try to harvest water-ice trapped in the cold layers beneath the surface.
    - **ISRO URL:** https://www.isro.gov.in/Chandrayaan3_ChaSTE_Results.html

- **Citation:** "Higher surface temperatures near south polar region of the Moon measured by ChaSTE experiment on-board Chandrayaan-3," *Communications Earth & Environment*, (2025).

## **Chandrayaan-2:** Over 6 years in Lunar Orbit

Even five years after its launch, the Chandrayaan-2 orbiter continues to provide sophisticated insights into the lunar environment.

- **Sun-Moon Interactions:** Using its CHACE-2 instrument, the orbiter observed how a solar explosion (CME) physically impacts the Moon's thin atmosphere. The CME's impact significantly increased the pressure on the Moon's day-side exosphere, "knocking off" atoms from the lunar surface. This is the first time such an effect has been directly measured, and it warns future lunar habitat designers that solar storms can temporarily change the lunar environment.
  - **ISRO URL:** https://www.isro.gov.in/Chandrayaan2_CME_Moon_Impact.html
  - **Citation:** Dhanya, M. B. et al., "Impact of a Coronal Mass Ejection on the Lunar Exosphere as Observed by CHACE-2 on the Chandrayaan-2 Orbiter," *Geophysical Research Letters*, 52(15) (2025).

## **AstroSat:** India's Multi-wavelength Eye on the Deep Universe

India's first dedicated multi-wavelength space telescope celebrated a decade of service in 2025, continuing to solve several cosmic mysteries.

- **"Vampire Stars" Caught Rejuvenating:** Astronomers used AstroSat's ultraviolet eye to find a "vampire star"—a star that looks younger and bluer than it should be because it has recently "sucked" material from a neighboring star. This discovery provided the "missing link" in how these exotic stars, called Blue Stragglers, are formed and rejuvenated.
  - **ISRO URL:** https://www.isro.gov.in/AstroSat_Vampire_Star_Discovery.html
  - **Citation:** "Discovery of a Barium Blue Straggler Star in M67 and Sighting of Its White Dwarf Companion," *The Astrophysical Journal Letters*, (2024).
- **The Rhythms of a Black Hole:** Indian scientists used AstroSat to monitor the black hole GRS 1915+105. They discovered that when the black hole is at its brightest, it emits X-rays that flicker rapidly—about 70 times every second—a phenomenon called **Quasi-periodic Oscillations**. These rhythms disappear when the black hole dims, offering a rare window into how matter behaves under extreme gravity.
  - **ISRO URL:** https://www.isro.gov.in/AstroSat_Black_Hole_Rhythms.html

### **XPoSat:** Probing X-ray Polarimetry

Launched on January 1, 2024, XPoSat is only the second mission of its kind globally to study the "orientation" (polarization) of X-rays from cosmic sources like black holes and neutron stars.

- **Crab Pulsar Observations:** Shortly after launch, its primary instrument, POLIX, began scientific observations and successfully generated a pulse profile for the Crab pulsar, a famous rapidly spinning star remnant. This mission adds a new "dimension" to astronomy by helping scientists understand the geometry and magnetic fields of these extreme objects.
    - **ISRO URL:** https://www.isro.gov.in/XPoSat_Scientific_Data_Release.html

### **Axiom-4**: Experiments in Microgravity

In July 2025, ISRO's Gaganyatri Shubhanshu Shukla completed a joint mission to the International Space Station (ISS), where he conducted a suite of biological experiments.

- **Farming and Healing in Space:** The mission successfully carried out experiments on how edible algae grow in radiation, how human muscles regenerate with supplements in weightlessness, and how crops like methi and moong grow in microgravity. These findings are essential for ensuring the health and nutrition of future Indian astronauts.

*ISRO URL:* https://www.isro.gov.in/Axiom4_Microgravity_Experiments.html

## Significant Discoveries / Achievements from Ground Observations

While India's space-borne observatories made headlines, ground-based facilities provided essential data and independent discoveries that were equally vital to the nation's scientific progress. Using high-resolution telescopes and sophisticated atmospheric sensors located across India, researchers observed phenomena ranging from new worlds around distant stars to the invisible structures in our own atmosphere.

## **Physical Research Laboratory (PRL**): Discovery of a Dense 'Sub-Saturn' Exoplanet

In February 2025, scientists at PRL's Mount Abu Observatory achieved a major milestone in exoplanet research.

- **A "Missing Link" Planet:** Using the indigenously developed **PARAS-2 spectrograph**—the most precise instrument of its kind in Asia—attached to a 2.5-meter telescope, researchers discovered a new planet called **TOI-6038A b**. This planet is roughly the size of a "sub-Saturn" and is about 78 times as heavy as Earth. This discovery is scientifically significant because planets of this specific size and density are absent in our own solar system. By measuring the "wobble" of its host star with incredible precision, the team determined that the planet likely has a massive rocky core making up 75% of its total mass, surrounded by a thin layer of hydrogen and helium gas.
    - **ISRO URL:** https://www.isro.gov.in/PRL_Exoplanet_TOI6038Ab_Discovery.html
    - **Citation:** S. Baliwal, R. Sharma, A. Chakraborty, et al., "TOI-6038 A b: A dense sub-Saturn in the transition regime between the Neptunian ridge and savanna," *The Astronomical Journal*, (2024).

## **National Atmospheric Research Laboratory (NARL):** Predicting Ionospheric "Bubbles"

Researchers at NARL in Gadanki developed a breakthrough method to predict a phenomenon that frequently disrupts modern technology.

- **Protecting GPS and Aviation:** The Earth's upper atmosphere often develops "Equatorial Plasma Bubbles" (EPBs)—invisible, wedge-like regions where the air becomes thin and electrically unstable after sunset. These bubbles can "scramble" signals from GPS satellites and interfere with communication for aircraft and ships. In March 2025, NARL announced a new algorithm that can predict the formation of these bubbles **one hour in advance** with a remarkable **99.86% accuracy**. By monitoring the upward movement of the atmosphere using ground-based sensors in Trivandrum, Sriharikota, and Gadanki, scientists can now provide an "early warning" to industries that rely on precise satellite navigation.
    - **ISRO URL:** https://www.isro.gov.in/NARL_EPB_Prediction_Technique.html
    - **Citation:** Patra, A. K., & Das, S. K., "Prediction of equatorial plasma bubble formation using ionosonde observations from India," *AGU Advances*, 6, e2024AV001323 (2025).

### **Physical Research Laboratory (PRL):** Profiling the Comet 3I/ATLAS

In November 2025, the 1.2-meter telescope at Mt. Abu was turned toward a rare guest passing through our solar system.

- **Studying the Interstellar Comet 3I/ATLAS:** Scientists conducted detailed imaging and spectroscopic analysis of the **interstellar comet 3I/ATLAS** as it exited our inner solar system. By analyzing the colors of light reflected by the comet, the team measured its "production rate"—essentially calculating how much gas and dust the comet was shedding into space as it was heated by the Sun. The study found that this interstellar visitor behaved very similarly to "typical" comets born in our own solar system, providing clues that the chemical building blocks of other star systems may be remarkably like our own.
    - **ISRO URL:** https://www.isro.gov.in/PRL_Interstellar_Comet_ATLAS.html

### **Udaipur Solar Observatory (USO-PRL):** Ground Support for Solar Storms

During the massive solar events of May 2024, ground-based observations were critical in providing a complete picture of the Sun's activity.

- **Coordinated Solar Monitoring:** While the Aditya-L1 spacecraft monitored the Sun from space, the **USO-PRL ground-based facility** captured simultaneous data on the erupting active region (AR13664). This dual-perspective approach—from both space and the ground—allowed scientists to track the "magnetic ropes" of solar storms from the moment they left the Sun’s surface until they reached the Earth's orbit, significantly improving our ability to model solar explosions.
    - **ISRO URL:** https://www.isro.gov.in/AdityaL1_Solar_Storm_Study.html

## Major National Engagements with Institutes and Academia

Between January 2024 and December 2025, ISRO significantly expanded its collaboration with Indian universities and research laboratories. These engagements focused on sharing scientific data, training the next generation of space scientists, and establishing centers of excellence to ensure India remains a global leader in space exploration.

### **Aditya-L1:** Building a National Solar Physics Community

Following the successful arrival of India’s solar observatory at its destination in January 2024, ISRO launched a series of initiatives to involve the wider academic community in solar research.

- **Sharing Solar data with the World:** On January 6, 2025, exactly one year after the spacecraft entered its orbit, ISRO released the first full year of scientific data from all seven instruments to the global community. This event brought together experts from 15 different Indian universities to discuss how this data could be used to predict space weather and protect our satellites. To support this, "Support Cells" at institutes like ARIES (Nainital) and IIT Indore conducted workshops for PhD students to learn how to analyze this complex solar data.
    - **ISRO URL:** https://www.isro.gov.in/AdityaL1_Data_Release_National_Meet.html
    - **Citation:** "ISRO Organises National Meet on Aditya L1 Data Release and Payload Performance Appraisal," (2025).

## **Chandrayaan-3 Mission:** Inspiring a Nation on Space Day

The historic success of Chandrayaan-3 led to new annual traditions and opportunities for researchers to study lunar science.

- **National Space Day and the 'NM 2.0' Meet:** August 23 is now celebrated as National Space Day to honor the 2023 lunar landing. In 2024 and 2025, ISRO organized massive "National Meets" at Bharat Mandapam in New Delhi. These events saw thousands of students and hundreds of teachers interacting directly with ISRO scientists and Gaganyatris (astronauts). In 2025, the meet (NM 2.0) specifically focused on leveraging space technology for the vision of a developed India by 2047.
    - **ISRO URL:** https://www.isro.gov.in/NSpD2025_Celebrations.html
    - **Citation:** "National Space Day 2025: Celebrating India's Space Journey from Aryabhatta to Gaganyaan," (2025).

## **XPoSat:** Opening the X-ray Universe to Guest Observers

Launched on New Year's Day 2024, XPoSat became India's second astronomy observatory, designed to study X-rays from mysterious objects like black holes.

- **The Guest Observer Program:** In October 2025, ISRO held a national meet where it officially opened the mission’s data to the public. Crucially, ISRO announced a "Guest Observer" program, allowing researchers from any Indian college or institute to propose specific targets in the sky for the satellite to observe. This initiative aims to build a large community of X-ray astronomers across the country.
    - **ISRO URL:** https://www.isro.gov.in/XPoSat_National_Meet_Data_Release.html

- **Citation:** "ISRO organises XPoSat National Meet and Opens up the Scientific Data from the XPoSat Mission," (2025).

### **Venus Orbiter Mission (VOM):** A Collaborative Endeavour

With the Government of India approving the mission to Venus in late 2024, ISRO immediately began seeking academic input to maximize the mission's scientific goals.

- **Preparing for the Venus Orbiter Mission:** In October 2025, a two-day national science meet brought together 150 experts from 40 different institutions to refine the scientific plan for the 2028 Venus launch. ISRO also released an "Announcement of Opportunity" for researchers to begin studying existing data from previous global missions to Venus, ensuring Indian scientists are ready to handle the data once India's own mission arrives.
  - **ISRO URL:** https://www.isro.gov.in/National_Science_Meet_Venus_Orbiter.html
  - **Citation:** "ISRO Organised National Science Meet on Venus Orbiter Mission (VOM)," (2025).

### **Gaganyaan & Axiom-4:** Towards the Human Element in Space

Engagements during the microgravity experiments and the joint mission to the International Space Station (ISS) focused heavily on student interaction.

- **Talking to Astronauts from Space:** In July 2025, Gaganyatri Shubhanshu Shukla conducted live video and radio sessions from the ISS with hundreds of students in Lucknow, Trivandrum, and the Northeast. These students had the rare chance to ask questions about life in zero-gravity and the scientific experiments being performed on algae and crops in space. Additionally, ISRO partnered with several IITs and the Institute for Aerospace Medicine to conduct the "HOPE" analog mission in Ladakh, simulating planetary surface operations in the high-altitude Himalayas.
  - **ISRO URL:** https://www.isro.gov.in/Gaganyatri_Student_Interaction_ISS.html
  - **Citation:** "ISRO conducts student interactions with Gaganyatri onboard ISS," (2025); "ISRO organizes Space Analog Mission in Ladakh," (2025).

## Broad Academic Initiatives: ISRO-START & RESPOND

Beyond specific missions, ISRO maintained a steady flow of support for general research and capacity building.

- **Training and Research Baskets:** The **ISRO-START** (Space Science and Technology Awareness Training) program continued its annual run, training nearly 40,000 undergraduate and postgraduate students online each year through ~300-500 nodal centers. For advanced researchers, ISRO released the **"RESPOND Basket - 2025"** in December 2025, which listed 125 critical research problems for which ISRO is providing funding to academic faculty to solve.
    - **ISRO URL:** https://www.isro.gov.in/ISRO_Academia_Day_2025.html
    - **Citation:** "ISRO Academia Day - 2025," (2025).

## National Cooperation in Magnetospheric and Space Weather Studies

On September 4, 2024, ISRO and the Indian Institute of Geomagnetism (IIG), an autonomous institute under the Department of Science and Technology (DST), Government of India, signed a **Memorandum of Understanding (MOU)** to foster scientific collaboration in the domains of space science, technology, and exploration. This partnership is intended to facilitate the **formulation of joint programmes** specifically aimed at advancing the scientific understanding of the **Sun-Earth connection** and the exploration of space. The collaboration leverages IIG's specialized expertise in diverse fields, including **space weather**, ionospheric research, and terrestrial and planetary magnetospheric physics. By integrating data from ISRO's space-borne missions, such as **Aditya-L1**, with IIG's extensive ground-based observations and theoretical modelling, the initiative aims to build a more holistic understanding of solar-terrestrial interactions. Additionally, this partnership supports the development of indigenous technologies, such as high-precision **magnetometers**, which are critical for monitoring geomagnetic variations and improving the nation's ability to predict space weather events that can disrupt the space assets.

- **ISRO URL:** https://www.isro.gov.in/ISRO_IIG_SignMOU_Scientific_Collaboration.html

## Major International Cooperation Engagements in Space Science (2024-2025)

International cooperation is a cornerstone of India's space exploration strategy, allowing the Indian Space Research Organisation (ISRO) to share expertise, leverage global infrastructure, and participate in complex multi-national missions. Between January 2024 and December 2025, these partnerships reached new heights, spanning from joint lunar exploration to scientific research aboard the International Space Station.

## **ISRO and NASA:** Training for the ISS and Beyond

The collaboration between India and the United States saw historic progress, particularly in the realm of human spaceflight and Earth observation.

- **Axiom-4: An Indian 'Gaganyatri' on the ISS:** In July 2025, ISRO Group Captain Shubhanshu Shukla successfully completed an 18-day mission aboard the **International Space Station (ISS)** as part of the joint ISRO-NASA effort. During the mission, Shukla conducted seven sophisticated **microgravity experiments**, studying topics such as how human muscles change in space and how crops like moong and methi grow without gravity. This mission provided Indian scientists with invaluable experience in managing space station operations and preparing for India's own future space station.
    - **ISRO URL:** https://www.isro.gov.in/Axiom4_Mission_ISS_Return.html
- **NISAR: Mapping a Changing Earth:** The **NISAR (NASA-ISRO Synthetic Aperture Radar)** satellite entered its final stages of assembly and testing in 2024 and 2025. This joint satellite will use advanced radar to map the entire Earth every 12 days, helping scientists track changes in ice sheets, forests, and wetlands.
    - **ISRO URL:** https://www.isro.gov.in/NISAR_Mission_Status.html

**ISRO and JAXA:** The Search for Lunar Water (LUPEX)

India and Japan are working together on the **Lunar Polar Exploration (LUPEX)** mission, also known as **Chandrayaan-5**, which received financial approval from the Indian government in March 2025.

- **Understanding the lunar Permanently Shadowed Region (PSR):** The LUPEX mission aims to land a rover in the Moon's South Pole regions that are **permanently in shadow** to search for water-ice. In May 2025, technical teams from ISRO and the Japan Aerospace Exploration Agency (JAXA) met in Bengaluru, India to finalize the design of the lunar lander (made by India) and the rover (made by Japan). The mission will carry scientific instruments from several global agencies, including NASA and the European Space Agency, to analyze the lunar soil on-site.
    - **ISRO URL:** https://www.isro.gov.in/ISRO_JAXA_LUPEX_Meet.html

## **ISRO and ESA:** Advancing Human Spaceflight Capabilities

The European Space Agency (ESA) has become a key partner in supporting India's **Gaganyaan** (human spaceflight) program.

- **Astronaut Training and Mission Support:** In late 2024, ISRO signed an agreement with ESA to collaborate on **astronaut training** and biomedical research. This framework allows Indian researchers to use ESA facilities on the ISS for experiments and provides technical support for integrating Indian scientific payloads into global space infrastructure. Additionally, ESA ground stations provided critical communication support for the Aditya-L1 and Chandrayaan missions.
    - **ISRO URL:** https://www.isro.gov.in/ISRO_ESA_Agreement_Human_Spaceflight.html

## **ISRO and CNES:** Monitoring Earth's Heat (TRISHNA)

The partnership between India and France (CNES) focused on a specialized "heat-sensing" satellite mission.

- **The TRISHNA Mission:** Teams from both nations completed critical design reviews for **TRISHNA**, a satellite designed to provide high-resolution thermal imaging of Earth. In November 2024, an international workshop was held in Ahmedabad to discuss how data from TRISHNA will help farmers manage water more efficiently and help scientists understand "urban heat islands" in large cities.
    - **ISRO URL:** https://www.isro.gov.in/TRISHNA_Mission_Science_Workshop.html

## **ISRO and ASA:** A Safety Net in the Southern Ocean

To ensure the safety of Indian astronauts during the ascent and return phases of the Gaganyaan mission, ISRO partnered with the **Australian Space Agency (ASA)**.

- **Crew Recovery and Ground Stations:** An agreement signed in 2024 enables Australian authorities to support **search and rescue operations** if the Gaganyaan module has to land in the sea near the Australian coast. The two agencies also made significant progress in establishing a temporary **ISRO ground station** on Cocos (Keeling) Island to track Indian rockets as they fly over the Indian Ocean.
    - **ISRO URL:** https://www.isro.gov.in/ISRO_ASA_Gaganyaan_Recovery_Agreement.html

## Global Science and Multilateral Initiatives

Beyond bilateral ties, India played a leading role in global space forums and multi-national projects.

- **Leading the Global Conversation:** ISRO actively participated in major international conferences, including the **45th COSPAR Scientific Assembly** in South Korea (July 2024) and the **75th International Astronautical Congress** in Italy (October 2024). India also proposed a **G20 Satellite for Environment and Climate Studies**, inviting other nations to contribute scientific instruments to a shared platform for monitoring the planet's health.
    - **ISRO URL:** https://www.isro.gov.in/International_Cooperation_Overview.html

# HUMAN SPACE FLIGHT CENTRE

**BANGALORE**

Website: https://www.hsfc.gov.in

## About HSFC

Mandate - To serve as the national lead centre for the development and integration of crew-focused systems, infrastructure, and capabilities essential for human spaceflight. HSFC shall drive activities related to astronaut training, biomedical engineering, crew operations, crewed mission planning, crew safety systems, safety assurance, and microgravity research, in alignment with India's long-term human spaceflight and exploration goals.

Vision - To lead the national endeavour towards safe and sustainable human space exploration through technological innovations, contributing to socio-economic development and inspiring future generations to explore, discover & thrive beyond earth.

Mission - Building capabilities for crewed space missions
Advancing Human-Centric Space Systems
Fostering Space Innovation and Research for National Growth

## Major Research Domains

**Crew Operations and Recovery Area** focuses on building a comprehensive ecosystem for crewed space missions. It includes establishing a dedicated Mission Control Centre and developing real-time visualization tools for monitoring crew schedules and procedures. High-fidelity simulators and distributed training systems enable realistic mission rehearsals, including critical phases like launch and landing. AI-supported tools assist in autonomous procedure execution and feedback. A certification framework

ensures preparedness of ground teams, while coordinated recovery protocols integrate multiple agencies. Dedicated recovery control rooms enhance real-time response. Additionally, platforms for pre- and post-mission debriefs analyse physiological, procedural, and cognitive performance to improve mission effectiveness and crew safety.

**Crew Centric Engineering Systems Area** focuses on designing and validating human-centred systems for space habitats. It includes developing crew seating with impact protection and testing using anthropomorphic devices. Visual systems like viewports are engineered for safety, durability, and optical performance. Cabin interiors—such as sleeping areas, galley, hygiene systems, and furnishings—are tailored for comfort and usability in microgravity. High-fidelity mock-ups support ergonomic evaluation and habitability trials. Hygiene systems address waste management and microbial control. Human Factors Engineering guides design through anthropometric and ergonomic studies, while specialized training systems prepare crews for long-duration missions, ensuring safety, efficiency, and overall well-being in space environments.

**Crew Training and Biomedical Research Group** focuses on astronaut selection, training, and space life sciences. It includes defining selection criteria, mission-specific training, and rehabilitation protocols. Advanced training facilities like centrifuges and neutral buoyancy labs support mission readiness, while analytics integrate simulation and biomedical data to assess performance. Personalized countermeasures cover exercise, nutrition, and medication. Research in space biology and medicine studies the effects of space on humans and other organisms, enabling sustainable life support and space nutrition. EVA/IVA suits are developed with enhanced mobility and monitoring. Analog missions simulate real conditions, and integrated data systems refine training, supported by a national framework for space medicine research

**Microgravity Platforms and Research Group** focuses on enabling microgravity research through advanced platforms like drop towers, sounding rockets, parabolic flights, and orbital systems. It includes modular payload integration frameworks and standardized racks for flexible experiment deployment. Ground-based simulation facilities support validation, while a coordinated ecosystem ensures alignment of multi-institutional research with mission and crew requirements. Crew-centric workflows and human-in-the-loop protocols enhance experiment operation in space. Training programs and digital twin environments prepare astronauts for payload handling. Dedicated labs and testbeds validate usability, while centralized data systems enable secure storage, sharing, and collaboration, maximizing scientific output and operational efficiency in crewed missions.

**Safety, Reliability & Quality Area** focuses on establishing a robust safety and quality framework for human spaceflight. It includes governance structures, compliance monitoring, and regular audits to ensure adherence to standards. A Flight Safety Database enables data-driven risk analysis and root-cause tracking, while international safety standards are integrated into operations. Human performance limits are defined using

biomedical data to enhance mission safety. The program contributes to human-rating certification, ensuring system reliability and crew survivability. Training modules and simulations prepare crew and ground teams for emergencies. Digital safety logs, decision-support tools, and crew-in-loop assessments further strengthen anomaly detection, response, and continuous improvement in mission safety.

## Major Scientific Applications / Results

### 1) Protein Nano-Bioactives Against Microgravity-Induced Endothelial Dysfunction

Published in *npj Microgravity* (2026), this study from IIT Madras, ISRO-SAC, and HSFC addresses the critical challenge of vascular dysfunction in astronauts during prolonged spaceflight. Simulated microgravity (SMG) was found to trigger excessive reactive oxygen species (ROS) generation, mitochondrial membrane depolarization, oxidative DNA damage, and apoptosis in endothelial cells, along with pathological upregulation of angiogenic genes (VEGFA, HIF-1α, eNOS, iNOS, FGF-2, ANG1). To counter these effects, a multifunctional zein nanocage-based therapeutic formulation (ZNT) was developed, encapsulating five antioxidants — ascorbic acid, resveratrol, luteolin, coenzyme Q10, and glutathione. ZNT demonstrated excellent biocompatibility (~95% cell viability) and restored redox balance, preserved mitochondrial integrity, prevented DNA damage, blocked apoptosis, and normalized angiogenic gene expression in endothelial cells under SMG. These protective effects were independently validated in vivo using

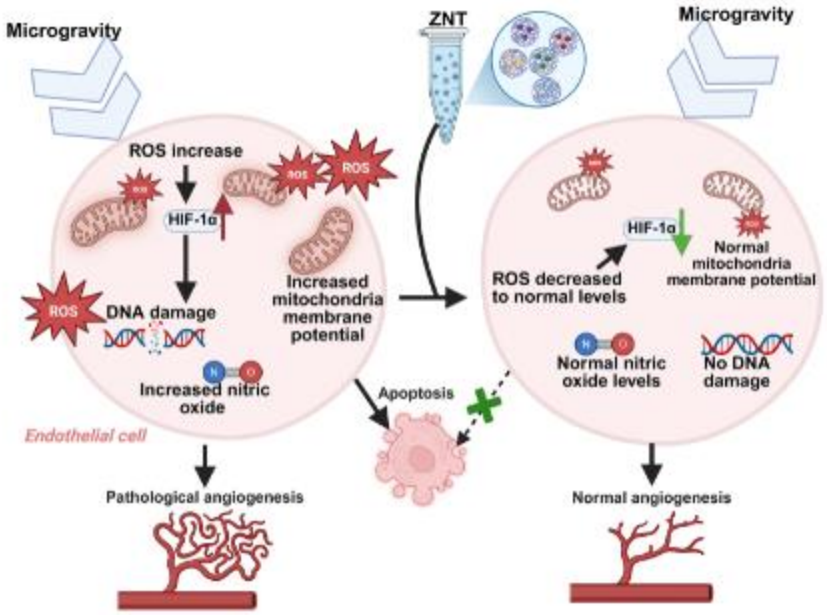



*Fig. 1 Graphical representation of the overall process. The multimodal effects of ZNT on endothelial cells in SMG conditions.*

zebrafish larvae and chick embryo chorioallantoic membrane (CAM) models. This dual-action nanotherapeutic strategy — targeting both oxidative stress and pathological angiogenesis — represents a promising countermeasure for safeguarding cardiovascular health during space missions.

**Access publication:** https://doi.org/10.1038/s41526-025-00554-0

2) **Protein Bioactive Complexes Promote Osteogenesis Under Microgravity Environment**

Published in *International Journal of Biological Macromolecules* (2025), this study from IIT Madras, ISRO-SAC, and HSFC investigates microgravity-induced bone loss — a major health challenge for astronauts on extended space missions. SMG was shown to elevate ROS levels in osteoblast cell lines (MC3T3 and MG63), causing cytoskeletal disruption and significant downregulation (~5-fold) of key osteogenic genes including RUNX2, ALP, Col1A1, osteopontin, and BSP. A protein-based zein nanocage antioxidant cocktail (ZNAC), encapsulating ascorbic acid, resveratrol, luteolin, coenzyme Q, and glutathione in an optimized molar ratio, was formulated using flash nanoprecipitation. ZNAC exhibited excellent stability (retaining >90% antioxidant activity over 30 days) and near-complete cell compatibility (~98%). Treatment with ZNAC effectively quenched SMG-induced ROS, preserved cytoskeletal integrity, restored alkaline phosphatase (ALP) activity, and upregulated osteogenic gene expression. These findings were further validated in a regenerating zebrafish scale model, where ZNAC improved calcium deposition, elevated Ca/P ratio, and enhanced expression of bone formation markers — underscoring its translational potential as a bone-health countermeasure for space medicine.

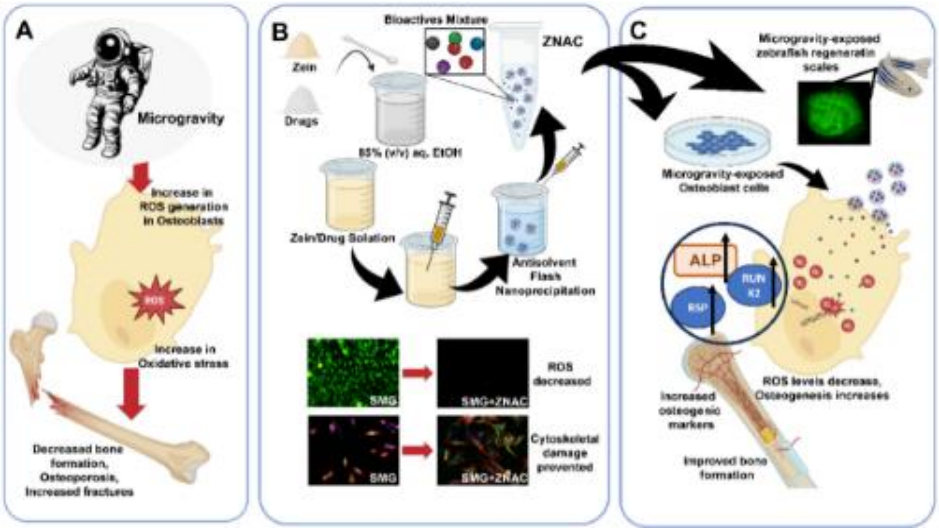



*Fig. 2. Schematic representation showing the way ZNAC counteracts the effect of microgravity by attenuating the oxidative stress in osteoblasts, thus promoting bone formation. (A) ROS formation causes increased oxidative stress, leading to osteoporosis under a microgravity environment. (B) Protein nanocages encapsulated with a repertoire*

*of chimeric bioactives using the flash nanoprecipitation method result in quenching of the ROS molecules and preventing cytoskeletal damage. (C) The nanoformulation effectively increased the transcription and expression of various osteogenic marker genes, including ALP, RUNX2, and BSP, and promoted scale regeneration in zebrafish.*

**Access publication:** https://doi.org/10.1016/j.ijbiomac.2025.140483

3) **Development and Realization of Spacesuit — A Historical Overview**

Published by the Biomedical Research, Crew Administration and Training Group, Human Space Flight Centre (HSFC), ISRO, this review traces the evolution of spacesuit technology from the early USSR Vostok SK-1 suit (1961) through contemporary designs by SpaceX, Boeing, and NASA's Artemis-generation Extravehicular Mobility Units (xEMU). The paper systematically covers IVA (Intravehicular Activity), EVA (Extravehicular Activity), and IEVA suit categories, with a detailed functional and design comparison of the American ACES suit and Russian Sokol KV-2 suit — the latter being worn by Gaganyaan astronauts for the first mission. The study highlights critical spacesuit

functionalities including pressure maintenance, crew health monitoring, thermal regulation, radiation shielding, and life support. Looking ahead, the paper outlines HSFC's indigenization roadmap for developing India's own IVA spacesuit, including ongoing collaborations with academic and industrial partners for critical technology development such as pressure valves, garment materials, and leak-proof seals. The work provides a foundational reference for India's long-term, self-reliant human spaceflight programme.

**Access publication:** https://www.isro.gov.in/HSFC.html

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

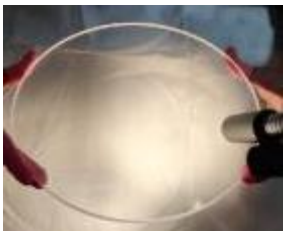
### Crew Seat Assembly (CSA)

Ergonomically designed Crew Seat Bucket which provides adequate support to the crew during dynamic phases of the Gaganyaan mission

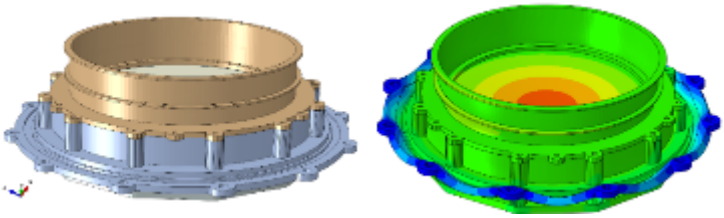
- Structural design of the crew seat bucket with adequate structural Strength for withstanding Gaganyaan loads
- Restrain system designed to provide appropriate support to the crew and appropriate foam liner which eliminates any pressure hotspots.


*G1 CSA Structural testing test fixture*

## Viewport Development



*Fused Silica Glass Pane*



*FE Model and 1st global mode for Pressure Pane sub-assembly (fixed at CMIS-VP interface)*

- Various configuration of Viewport generated and assembled with Coating design and carrying out qualification using glass samples of fused silica glass pane.
- Panel level On-orbit transient thermal analysis for the updated interface conductivity for the following condition:
  - ✓ Without Thermal Pane failure
  - ✓ Considering complete thermal pane shattering

## Capacity Building in Space Science Research

The following training programs have been conducted at HSFC for Capacity Building of Scientists/ Engineers.

| | | |
|---|---|---|
| HMI Design for Space Application | 10 Person | 09 to 11-May 2024 |
| One Day Space Medicine Workshop | 25 Persons | 09 Jun 2025 |
| Ten days training program on Biomedical Engineering at IITM | 10 Persons | 11-21 Feb-2025 |
| Structured Training programme-2025 | 32 Persons | 17-21 Nov-2025 |
| Karmayogi Training Programme | 5 batches - 190 persons | December-2025 to January-2026 |
| VHDL Training | 25 persons | 17, 18, 23-26 March-2026 |

## Courses offered on Space Science and Technology

Currently HSFC is not offering any courses

## Laboratories and Facilities Available for Space Instrumentation

- **HERG Lab** - It consists of the following Equipment –

1. The **Human Strength Assessment Machine** commissioned in HSFC is used to measure the strength of various joints in the human body. The equipment consists of a dynamometer, an adjustable chair and various attachments to measure the joint strength in different modes – isokinetic (constant velocity motion), isotonic (constant torque) and isometric (no motion). The data is used in the design of crew interfaces, rehabilitation and strength database generation for Indian population.

2. **Inertial Measurement Unit (IMU) based Motion Capture System** is a wearable motion tracking technology that utilizes multiple IMU sensors to measure the acceleration of the human at various joints and create a digital avatar of the human performing various activities. The motion data is used to verify the functional range of motion (ROM), operational volume generation, reduced ROM for suited astronauts, and input for musculoskeletal modelling.

3. A **Virtual Reality Headset (HTC Vive Pro-2)** provides Virtual environment for performing tasks within Gaganyaan CM to evaluate cognitive load and carry out preliminary human factor studies

- **CTS Lab -** It consists of the following facilities –

**Desktop Training Simulator** is primarily aimed at familiarization of the Crew with Crew control interface, both electrical and mechanical. It necessitates similar user interface as that of Crew Module such as Display systems, page and button layouts, and Crew control buttons.

**Virtual Reality Simulator** focuses on imparting an immersive experience to the Crew members using a digitally created virtual environment. The objective of virtual reality is to provide the user with a sense of feeling of being present in the virtual world (created digitally) and interacting directly with the objects by means of suitably designed control devices.

**Static Mock-up Simulator** provides a close to realistic ambience and acquaintance with the Crew Module including the distance and approach estimation of the Crew control buttons and display systems. The available space for any Crew activity will be same as that of in actual Crew Module.

**Mission Control Training Room** is a critical facility that support the execution, monitoring, and simulation of missions. These environments enable efficient decision-making, coordination, and preparedness of personnel involved in mission operations.

# INDIAN INSTITUTE OF REMOTE SENSING DEHRADUN, INDIA

https://www.iirs.gov.in

## About IIRS, Dehradun

The Indian Institute of Remote Sensing (IIRS) is a constituent Unit of Indian Space Research Organisation (ISRO), Department of Space, Government of India. Since its establishment in 1966, IIRS is a key player in the Southeast Asia for training and capacity building in the field of remote sensing and its applications through training and education programmes at postgraduate level. The capacity building programmes of the Institute are designed to meet the requirements of professionals at multiple levels from fresh graduates to decision makers including academia. It is one of the most sought after institutes for conducting customized training courses for the officers from Central and State Government Ministries and stakeholder departments for the effective utilization of Earth Observation (EO) data and geospatial technology. IIRS is identified as the nodal centre for conducting the short-term courses to international participants under the Indian Technical and Economic Cooperation (ITEC) programme of the Ministry of External Affairs, Government of India. Apart from on-campus courses, online courses are also offered in two modes: (i) interactive live courses, and (ii) e-learning (MOOC) courses in Remote Sensing and Geo-information Science.

The Institute has a strong, multi-disciplinary and solution-oriented research agenda that focuses on developing improved methods/ techniques for processing, visualization and dissemination of EO data & Geo-information for various societal applications and better understanding of Earth's system processes. Some of these studies are highlighted in this document.

IIRS hosts headquarters of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), affiliated to the United Nations, and provides support in conducting the Remote Sensing and GIS training and education programmes.

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

## Major Research Domains

The Institute has a multi-disciplinary and problem-oriented research agenda that focuses on technology development as well as land/ocean/atmosphere applications in the area of

geo-information (GI) science and earth observation. The various thematic broad areas include- Remote Sensing for Earth's Resources and Environment - Forestry & Ecology Studies, Marine & Atmospheric Studies, Geoinformatics Activities, Photogrammetry & Remote Sensing activities, Disaster Management Studies, Forest fire risk index and fire spread model development, Planetary Sciences, Urban Studies.

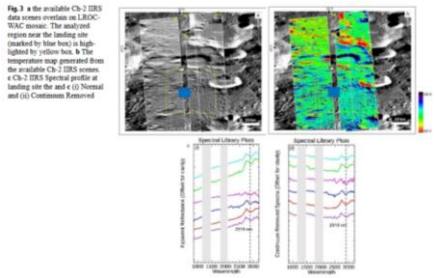
## Major Scientific Applications / Results

- Estimated the paleo flood flow for Martian outflow channels
- Quantified the water dynamics for Mars years MY 34 and 35 using Mars Climate data on Water Vapor, Water Ice, CO2 ice, Relative Humidity and Deliquescence
- Estimated the surface reflectance spectra for Europa's Surface
- Completed the Raman, XRD and hyperspectral spectra generation for ground-based samples for Mars-Earth Analog sites of Jaisalmer and Ladakh

## Journal Publications:

- Link: https://onlinelibrary.wiley.com/doi/10.1111/maps.70037


- https://link.springer.com/article/10.1007/s12524-025-02355-0



- https://www.sciencedirect.com/science/article/pii/S0273117724000061

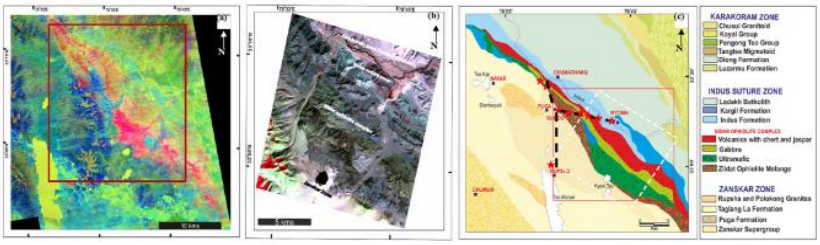
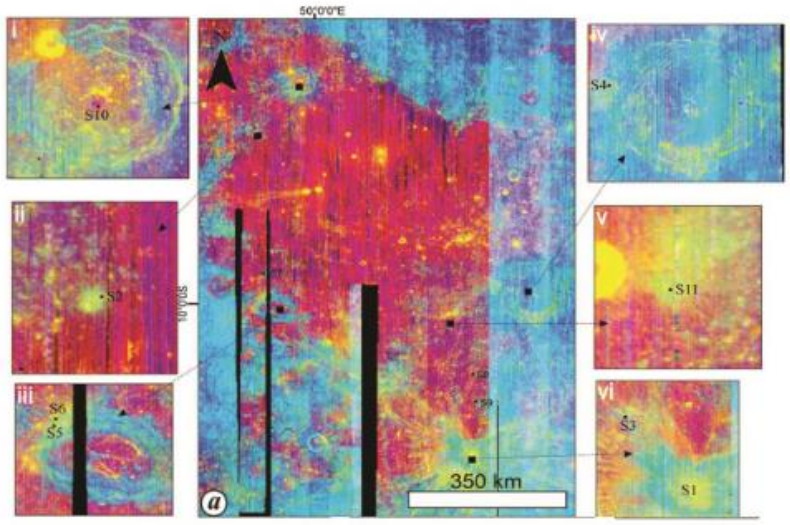



Fig. 4. (a) Colour composite map from ASTER-TIR based spectral indices for the Nidar region with R = MI (Mafic Index); G = CI (Carbonate Index) and B = QI (Quartz Index) (b) The False colour composite (FCC) image from PRISMA data with R = 907 nm, G = 1466 nm and B = 2217 nm displaying various lithological units (as marked) in the region distinctively (Modified after Chauhan et al., 2022) and (c) Geological Map of the Nidar ophiolite complex (Modified after Thakur and Misra, 1984 and Chauhan et al., 2022) showing the coverage of ASTER-TIR (4a) marked in red box and PRISMA (4b) in white stippled box. The stars and stippled black lines indicate the sampling location and traverse of the field work.

- https://www.currentscience.ac.in/Volumes/126/08/0883.pdf




*Chandrayaan-1 M3 derived rock composite mosaic of Mare Fecunditatis (a) using method proposed by Pieters et al. 28 with some of the spinel containing units highlighted by green colour (i–v);*

## Conference Proceedings:

- https://www.hou.usra.edu/meetings/lpsc2025/pdf/1876.pdf
- https://www.hou.usra.edu/meetings/lpsc2025/pdf/1932.pdf
- https://www.hou.usra.edu/meetings/lpsc2025/pdf/2053.pdf
- https://www.hou.usra.edu/meetings/lpsc2025/pdf/2611.pdf
- https://www.hou.usra.edu/meetings/lpsc2024/pdf/1821.pdf
- https://www.hou.usra.edu/meetings/lpsc2024/pdf/1905.pdf
- https://www.hou.usra.edu/meetings/lpsc2024/pdf/1976.pdf
- https://www.hou.usra.edu/meetings/lpsc2024/pdf/2216.pdf

## Capacity Building in Space Science Research

- Added one credit course (15 lectures) on Space Science as part of IIRS PGD course
- Contributed to ISRO Yuvika course(s) at IIRS
- Organized ISRO's National Space day celebrations in Zone-2 in 2024 & 2025.
- Conducted 3 online training and capacity building programmes on mass scale awareness and skill development in India in Space Science with specific focus on ISRO's space exploration Missions. In these online courses 40620 students from 500+ academic Institutions in India have participated out of which 18982 students have successfully completed the course and awarded with Merit Certificate.

## Courses offered on Space Science and Technology

Table: Training programmes conducted by IIRS

| S. No. | Course title | Course level | Start date | End date | No of participants | Sub. of specialization in Sp, Science & tech. | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Exploration of the Solar System | UG/PG | 24.04.2024 | 10.05.2024 | Participants-16244 Certificate Awarded-6643 | Solar System | ISRO START Programme (Online Mode |
| 2 | Future of India's space exploration | UG/PG | 09.01.2025 | 29.01.2025 | Participants-20725 Certificate Awarded-11687 | Space Exploration | |
| 3 | Overview of Space Exploration | School | 05.06.2024 | 04.08.2024 | Participants-3651 Certificate Awarded-652 | Space Exploration | Massive Open Online Course (MOOC) |
| 4 | Planetary Exploration with Emphasis on Indian Missions | PG and Research Scholars | 10.11.2025 | 14.11.2025 | 11 | Planetary Geology | n/a |
| 5 | One week MOOC course on | PG and Research Scholars | 10.11.2025 | 14.11.2025 | 41 | Planetary Geology | n/a |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | "Remote Sensing of the Moon and Mars' | | | | | | |
| **6** | DLP Online Workshop on Martian Surface, Analogues and Atmosphere | PG and Research Scholars | 12.03.2025 | 12.03.2025 | 4112 | Planetary Geology | n/a |

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)<br>*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

- **GNSS and Seismic stations network for geodynamics studies:** Established 11 permanent GNSS stations, 02 seismic stations and 01 Earthquake early warning system in different parts of the Western Himalaya.
- **GNSS receivers:** For coordinate and survey data collection and precise positioning and orientation.
- **Snow Pack Analyser & Snow Depth Sensors:** Installed 01 snowpack analyser and 04 snow depth sensors in the Western Himalaya for measurement of snow properties.

- **Skyradiometer:** Established at Dehradun to provide Aerosol Optical Depth, Aerosol Angstrom exponent, Asymmetric parameter, direct and diffuse solar radiation in 7 narrow bands within 315-2010 nm wavelength range.
- **Trace Gas Laboratory:** Established at Dehradun for continuously monitoring air pollutants like ozone, CO and NOx.
- **Ceilometer:** Established at Dehradun by Physical Research Laboratory (PRL), Ahmedabad for measurement of cloud base height and boundary layer height based on backscatter LiDAR signal in 900-910 nm wavelength range.
- **Spectroradiometer:** Operating in 350-2500 nm spectral region for spectral measurements.
- **Terrestrial Laser Scanner:** For acquisition of ultra-high-density 3D point cloud in the visible and near infrared wavelengths.
- **Underwater Spectroradiometer:** For measuring spectral response of water (surface and below surface) in 400–2500 nm wavelength range.
- **Echo-sounder with Autonomous Floating Device:** For hydrographic/ bathymetric studies of inland water bodies.
- **IIRS Learning Management System:** Developed for online training courses.
- **Hyperspectral spectroradiometer**

# INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

## THIRUVANANTHAPURAM, INDIA

www.iist.ac.in

## About the IIST

The Indian Institute of Space Science and Technology (IIST), established in 2007 by the Department of Space under the UGC Act 1956, is Asia's first Space University and a premier institution dedicated to excellence in space science, technology, and research. Located in Thiruvananthapuram, IIST has emerged as a multidisciplinary centre of learning, offering specialized programs in Aerospace, Avionics, Earth and Space Sciences, Mathematics, Physics, Chemistry, and Humanities. The NAAC Peer Team visited IIST and conducted a comprehensive evaluation under seven criteria. Following the assessment, the Institute was awarded an 'A+' grade.

Guided by a vision of advancing knowledge and innovation in space science and technology, IIST promotes interdisciplinary education, research excellence, and technological advancement. Its mission is reflected in its strong academic framework, cutting-edge research, industry collaborations, patents, and international partnerships that address both national and global challenges. Through its close association with Indian Space Research Organisation (ISRO), the institute nurtures future scientists, engineers, and researchers who contribute to India's space exploration and scientific progress.

Partnering with ISRO, IIST serves as a strategic hub that translates research into space technologies. Students gain exclusive access to ISRO internships and placements, creating a vital talent pipeline. Through advanced infrastructure and interdisciplinary innovation, IIST continues to develop leaders dedicated to India's space missions and national progress. Further expanding its role in India's space missions, IIST is also developing the Integrated Diagnostics Module (IDM) — a cutting-edge payload for an upcoming electric propulsion satellite, scheduled for launch aboard the PSLV later this year.

Rooted in a strong **heritage** of scientific excellence, IIST continues to uphold its **legacy** by fostering innovation, academic rigor, and societal impact. Through Doctoral and Post-

Doctoral programs, the institute encourages students to pursue transformative, interdisciplinary research aligned with the National Education Policy (NEP), contributing meaningfully to science, technology, and the nation's space ambitions.

## Major Research Domains

IIST has a well-defined research policy that encourages faculty members to take up fundamental and applied research to benefit society with a focus on Space Science and Technology. The major domains of the research at IIST, relevant to Space Science and Technology are mentioned here.

**Department of Aerospace Engineering**

1. Aerodynamics and Flight Mechanics
2. Materials manufacturing & Industrial engineering
3. Structures and Design
4. Thermal and Propulsion

**Department of Avionics**

1. Control systems
2. Power Electronics and Power Systems
3. RF and Microwave Engineering
4. Semiconductors and IC Design

**Department of Chemistry**

1. Chemical/ Electrochemical Sensors
2. Electrochemical Energy Storage
3. High Temperature Materials
4. Materials for Sustainable Applications
5. Nanocomposites
6. Space Biology

**Department of Earth & Space Sciences**

1. Astronomy & Astrophysics
2. Atmospheric Sciences
3. Geology
4. Remote Sensing and Geoinformatics

**Department of Humanities and Social Sciences**

1. Space Economics and Policy
2. Supply chain management

3. Technology Diffusion and Economic Development
4. Technology management

**Department of Mathematics**

1. Industrial Mathematics and soft computing
2. Mathematical Control Theory
3. Mathematical Elasticity, Homogenization, Partial Differential Equations
4. Numerical Analysis
5. Suspension Rheology
6. Time Series Analysis

**Department of Physics**

1. Applied and Adaptive Optics
2. Atomic and Molecular Physics
3. Quantum Optics, Quantum Information & Quantum Technologies
4. Solid State Physics: Nanotechnology, Condensed Matter Physics, Device Physics
5. Statistical Physics & Nonlinear Dynamics

## Major Scientific Applications / Results

IIST has published 223 and 303 articles in refereed journals in 2024 and 2025 respectively**.** The articles highlight the rigorous research activities in the domains mentioned in the previous section. Since the numbers are large, the list of publications is provided as **Annexure I**. Further details may be obtained from the link : https://iist.irins.org/

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

| Payload/Satellite | Description | Mission and Launch Date |
|---|---|---|
| ARIS-201F | Advanced Retarding Potential Analyser for Ionospheric Studies; a Payload for Low Earth Orbit (LEO) Ionospheric studies | PSLV C55 in April 2024 |
| PILOT | A payload with indigenously developed sub-systems at IIST, such as the On-Board Computer (OBC), intended for future missions & upcoming IIST student satellites | PSLV C55 in April 2024 |

| | | |
|---|---|---|
| PILOT-G2 (GRACE) | The pay load is an advanced ionospheric monitoring instrument aiming to enhance data interface and telecommanding capabilities for future space missions | PS4-POEM platform of PSLV C60 SpaDex mission on December 30, 2024. |

ARIS II Payload

ARIS II Electronics

- Space data analysis CROP SEEDS on ISS: The post flight experiments for the payload 'CROP SEEDS on ISS' are in progress. The seeds were grown out in poly houses at the Kerala Agricultural University, CoA Vellayani and the sample collection for omics studies were planned.

Indian Astronaut Group Captain Shubhanshu Shukla onboard ISS with CROP SEEDS

- Other activities include
  - Mission design for **InspireSat-3** and payload design for **ADVIT** and **SAP-3**.
  - **EPS-TDS 01 Mission:** Managed **IDM payload** works and successfully cleared the **SRMC** (Sept 2025).
  - **Venus Mission:** Contributed to **ARIS payload** development and **Preliminary Design Review (PDR)** preparation.
  - **Astrobiology:** Designed the **SAP payload** within the Small Spacecrafts and Payload Centre.
  - **Design & Review:** Ongoing involvement in **IDM package** and **RPAV payload** development for TDS01 and Venus missions.
  - **Nanosatellite Tech:** Designed and realized **UHF/VHF transceivers** for small satellite systems.

- **OBC & EPS**: The On-Board Computer and Electrical Power System components developed for the InspireSat program are flight-proven and qualified for future payload variants.
- **Satellite Structures**: Includes indigenously developed 1U and 3U structures created through subtractive and laser-based additive manufacturing.

## Capacity Building in Space Science Research

- **Conscientia 2024 and 2025**

Conscientia the technical fest showcased innovation through technical talks, workshops and competitions. The event featured expert sessions by **ISRO** scientists and hands-on learning in emerging technologies. As part of Conscientia 2025, IIST students conducted workshops on Robotics, Rocketry, and Aeromodelling at St. Benchman's College and Assumption College. The workshops received enthusiastic participation and media recognition for their success.

- **Science camp-NIRMAAN**

In 2024 and 2025 NIRMAAN the social outreach club of IISTconducted science outreach camps to encourage scientific learning among students. The programme include interactive sessions, experiment and career guidance activities. The club organized 15 school sessions introducing students to rocketry, flight, and astronomy and hosted thousands of students on campus. Volunteers participated in outings, workshops, and the THRIVE program, supporting tribal school students academically and inspiring them to explore STEM and space careers.

- **Rocketry club Activities**

The vihAan rocketry club at IIST provide advanced hands on learning in model rocketry through motor testing, flight date analysis and design innovation. The club, achieved key milestones in 2024–25, clearing PDR and CDR for IN-SPACe competitions, testing fiberglass rocket bodies, avionics, and CanSat structures, and qualifying for Türkiye's International Rocketry Competition. The club also conducted outreach sessions for school students, demonstrating rockets and inspiring future space enthusiasts.

- **Hands-on Activity – Glider Design**

Students designed and built gliders using Depron sheets, applying aerodynamic principles by testing wing shape, balance, and structure. The hands-on activity reinforced UAV concepts through flight trials, enhancing practical understanding of aerodynamics.

- **Summer project**

Aero club summer projects included work on aerobatic RC aircraft (Dynam–Aerobatic Racer), VTOL systems, and the Ūrdhvam reusable high-altitude ballooning project. Students gained hands-on experience in aerodynamics, propulsion, and design, including control systems and stratospheric balloon recovery concepts.

- **Astronomy Club (Celestials) Activities**

The astronomy club of IIST conducted lectures, observation events and outreach activities during 2024-2025. The club also achieved notable success in the international Asteroid search campaign with multiple discoveries. The Astronomy club organized a Night sky observation session for school students at Manvila, Thiruvananthapuram, solar observation session at Nedumangad college using specialized equipment and solar filter, and a hands-on solar observation workshop at VSSC central school, Trivandrum. Highlights of the club's activities include Comet Tsuchinshan-ATLAS viewing, Conscientia events, and extensive outreach such as school sky watches, observatory tours, public sessions at Napier Museum and Technopark, engaging hundreds of students and visitors. The club also conducted

- **GIS Day –outreach**

In 2024 and 2025, the GIS day outreach programme promoted awareness of GIS and remote sensing among school students through lecture and quiz competitions. A UAV based survey demonstration was also conducted to provide practical exposure to geospatial technologies.

- **Schools @ IIST**

IIST hosted multiple school outreach visit during 2024, offering students hands on exposure to advance laboratories and space science facilities. These interactions inspired young minds and strengthened awareness of science, technology and space research

- **IIST @ Schools**

IIST@schools 2024 inspired students across Kerala through interactive science and sustainability sessions. the programme promoted scientific learning and academic excellence among young learners.

- **Session on origin and geology of the Moon**

A special session on the origin and geology of the moon conducted for school students. Session enhanced scientific curiosity and understanding of Lunar science.

- **SPARK – Outreach Programme at North Eastern Space Applications Centre (NESAC)**

IIST conducted an outreach program at NESAC, Umiam (March 21–24, 2025) for Class 8–9 students from Meghalaya, offering hands-on sessions in physics, astronomy, optics, and remote sensing.

- **Science and Technology Exposure Visits**

IIST conducted Science and Technology exposure visits (2024–25) where students toured labs and research facilities and interacted with faculty to understand academic and research activities.

- **National Space Day- Open House**

As part of National Space Day Open House, a session was held showcasing aerospace models and exhibits to introduce basic concepts and spark interest among participants.

- **World Space Week Celebrations -2025**

For National Space Day 2024, IIST hosted an Open House on August 7 for 405 students from 17 schools and 2 colleges, offering guided tours of labs, research facilities, and the library. To raise public awareness, IIST also conducted flash mob performances at Mall of Travancore, Shankumugham Beach, and Kanakakkunnu Palace in August.

- **Public Lecture by NASA scientist Craig Deforest**

A public lecture on NASA's PUNCH mission was delivered by Dr. Craig Edward DeForest at Christ University Nodal Centre on 15 October 2025 as part of IIST outreach. The session covered solar wind imaging, mission design, and open science practices.

- **Talk on Avenues of Computer Science in the Space Domain**

A talk on "Avenues of Computer Science in the Space Domain" was held at Indian Institute of Space Science and Technology on 15 October 2025, highlighting key applications of computing in space systems and research opportunities.

- **Lecture Series by Prof. Jean Surdej on "Interferometry in Astronomy**

lecture series on "Interferometry in Astronomy" was delivered by Prof. Surdej at Indian Institute of Space Science and Technology from 10–14 November 2025, featuring optical, infrared, and radio band studies with hands-on sessions.

- **Punching Through the Heliosphere with Polarized Light- A Seminar by Dr. Ritesh Patel on 06th November 2025**

A talk on NASA's PUNCH mission was delivered by Dr. Ritesh Patel, highlighting solar corona imaging using wide-field polarimetry and its relevance to Aditya-L1.

- **Visit of Wing Commander Rakesh Sharma, Astronaut, to IIST**

A distinguished lecture by Wing Commander Rakesh Sharma was held at Indian Institute of Space Science and Technology on 29 October 2025, where he spoke about India's space future and ISRO's mission.

**Ph.D. awarded**

- Vidya V (SC18D027) - Integrated Battery Charging and Powertrain Schemes for All-Wheel Drive Electric Vehicles - Dr Sudarshan Kaarthick / Avionics/January 11,2024.
- Resmi V L (SC19D003) - Fractional Order Cardiovascular System Model with Baroreflex Control - An Optimization Approach - Prof. N Selvaganesan/ Avionics / January22, 2024.
- Anjuna Dileep (SC18D034) - Inverse Source Problems for the Damped Euler-Bernoulli Beam and Kirchhoff Plate Equations - Dr K Sakthivel / Mathematics / February 09, 2024.
- Pramod Martha (SC18D046) - Suspended Gate Field Effect Transistor (SGFET)-based CMOSMEMS Accelerometer - Dr Seena V / Avionics / February 09, 2024.

- Athira T S (SC18D036) - Nonlinear phase accumulation of the resultant optical field for a linear phase delay between interfering fields - Dr Dinesh N Naik / Physics / February 14,2024
- Lekshmi S R (SC18D042) - Investigations on Turbulence Impacted Structured Laser Beams for Free-Space Optical Communications - Prof. C S Narayanamurthy / Physics /March 15, 2024.
- Rithwik N (5C16D034) - Optimal Mission Design to Lagrangian Points - Dr R Venkata Ramanan / Aerospace Engineering / March 19, 2024.
- Anuja Vijayan (SC14D017) - Experimental Characterisation and Numerical Modelling of Planar Cavitating Venturis - Dr Pradeep Kumar P / Aerospace Engineering /March20, 2024.
- Kavita Patnaik (SC19D019) - Hybrid Monte CarloGear's Solver to Retrieve the Vertical Profiles of Minor Atmospheric Constituents for Cloud Microphysical Modelling - Prof AChandrasekhar & Dr Amit P Kesarkar /Earth and Space Sciences / March 22,2024.
- Ramyakrishna Enugonda (SC19D027) - Signal Processing and Statistical Analysis of the Weather and Atmospheric Signals using Radar Observations - Prof. Basudeb Ghosh, IIST & Dr V K Anandan / Avionics /March 22,2024.
- Ms. Soumya Asokan (5C18D037) - Some aspects of entanglement in paraxial light fields - Prof. Solomon Ivan )/ Physics / April 17, 2024.
- Smt. Anjitha R G (SC18D050) - Design and Development of Chemiresistive Sensor for the Selective Detection of CH4 and CO - Prof. Palash Kumar Basu / Avionics /April 24, 2024.
- Ms. Sonia Saini (SC16D023)- Carbon nanotube based composite thin film coatings for stray light control space applications - Dr Kuntala Bhattacharjee / Physics / May 22, 2024.
- Ms. Sreekala K (SC18D039) - Novel Nanostructured Multi-Functional Materials for High-Energy LithiumSulfur Batteries - Prof. Mary Gladis ) / Chemistry /June 7, 2024.
- Shri. Govind Kumar Sharma (SC19D032)- Flexible, Electrospun Polyacrylonitrile Based Carbon Nanofiber Composites for Electromagnetic Interference Shielding - Prof. Nirmala R James / Chemistry /June 14, 2024.
- Shri. Vibin Jose (SC18D033) - Modelling and observational studies of soil moisture over the Indian region - Prof. A Chandrasekar / Earth and Space Sciences /June 18, 2024.

- Smt. Sandhya G Nair (SC19D015)- Investigation on Preceramic Polymers for Mullite Matrix Composites and Ceramic Foams for Thermal Protection Applications - Prof. K Prabhakaran and Dr Sreejith K J / Chemistry / June 28, 2024.
- Ms. Ann Mary Tomy (SC18D031) - Nickel Based Nanomaterials For Electrochemical - Prof. Jobin Cyriac | Chemistry / June 28, 2024.
- Shri. Manohar Kumar C V'S S (SC16D052) - Benchmark Studies on Spectral Un-mixing of Multi-Sensor Hyperspectral Imagery - Prof. Ramarao Nidamanuri / Earth and Space Sciences /July 2, 2024.
- Shri. Anil Painuly (SC17D023)- Studies on the Processing of SiBOC Foams from Methylvinylborosiloxane - Prof. K Prabhakaran and Dr Benny K George / Chemistry / July22, 2024.
- Shri. Abhijith Ajayakumar (5C19D010) - Controllability and Observability of Networked Systems- Prof. Raju K George / Mathematics / August 9, 2024.
- Shri. Dayal G (SC17D020)- Pattern Recognition using Pulsed Laser Deposited BiFe03 Neuromorphic Devices for Advanced Artificial Intelligence- Prof. Jinesh K B / Physics / September 4, 2024.
- Shri. Sandip Paul (SC16D007)- Low Complexity Networks and Edge Enhancement for Monocular Depth Estimation- Prof. Deepak Mishra & Dr M Senthil Kumar / Avionics / September 10, 2024.
- Shri. Asif Igbal Kakkassery (SC17D027) - Exploring the surficial process on low-mid latitudinal Mars using planetary datasets and terrestrial analogues - Prof. Rajesh V ] / Earth and Space Sciences / September 17, 2024.
- Ms. Reetambhara Dutta (SC20D011)- Investigation of the lower atmospheric wave forcing on the Mesosphere Thermosphere lonosphere (MTI) system- Dr. P R Sinha and Dr S Sreedharan / Earth and Space Sciences / September 19, 2024.
- Ms. Sonali Maurya (SC20D045) - Observational Studies on Turbulence in Atmos-pheric Surface Layer - Prof. A Chandrasekar and Dr KV S Namboodiri / October 14, 2024.
- Shri. Manu Mohan (SC16D053)- Local electronic states of Atomic tin (Sn) grown on tungsten disulfide (WS2) surface- Dr. Kuntala Bhattacharjee /Physics / October 28, 2024. .
- Shri. B Vishweshwar Rao (SC15D017) - Specific Investigations on Freeform optics for Space Applications - Prof. C S Narayanamurthy and Dr K V Sriram / Physics / November 14, 2024.

- Ms. Sindhu S (SC20D036)- Role of Volatile Organic Compounds and Trace Gases in the Chemistry of Rural Atmosphere - Dr. P R Sinha and Dr. Chaithanya D. Jain / Earth and Space Sciences / November 14, 2024.
- Shri. Suraj Reddy Rodda (SC19D041) - Reducing Tropical Forest Biomass Mapping Uncertainty — Integrating Field plot data with 3D forest structure from LiDAR - Prof. Rama Rao Nidamanuri, Dr. Chandra Shekar Jha and DrVinay Kumar Dadhwal / Earth and Space Sciences / November 21, 2024.
- Shri. Debojit Sarkar (SC18D015) - Role of collision-coalescence mechanisms in the occurrence of cloudburst event - Prof. A Chandrasekar and Dr.Amit Kesarkar / Earth and Space Sciences /November 29, 2024.
- Shri. Venkatesh N (SC11D009) - Influence of feedline configuration and its thermal mass distribution on cryogenic chilldown performance- Prof. A Salih and Dr.S Sunil Kumar / Aerospace Engineering / December 24, 2024.
- Shri. Prasoon Chandran Mavila (SC17D003) - Virtual Voltage Vector based Control Schemes for Fivephase Induction Motor Drive - Prof. Rajeevan P P / Avionics /December 27, 2024.
- Shri. Sonu Bose (5C18D008) - Efficient Uniformly Accurate Approach to Numerical Solution and Scaled Derivatives for System of Singularly Perturbed Differential Equations - Dr Kaushik Mukherjee / Mathematics / December 30, 2024.
- Shri. R S Mohan Kumar (SC14D008) - Robust Fractional Order LQI Controller Design for Quadruple Tank Process and its Feasibility Study in Bond Graph Domain - An Optimisation Approach - Prof. N Selvaganesan and Dr M Jayakumar / Avionics /January 6, 2025.
- Shri. Ritwik Sankar A (SC19D008) - Daughters of Tradition and Negotiation: A Culture-Gender Critique of Devakooth - Dr. Babitha Justin / Humanities and Social Sciences /January 6, 2025.
- Shri. Syamprasad (SC19D033) - Mapping Spaces, Journeys and Subjectivities: A Geocritical Exploration of Benyamin’s Novels - Dr. Gigy ] Alex / Humanities and Social Sciences / January 15, 2025.
- Shri. Saurabh Chatterjee (SC14D016) - Augmentation of Camera based Non-Destructive Testing using Robotics and Motion Tracking - Prof. Kurien Issac / Aerospace Engineering / January 22, 2025.
- Shri. Anbarasan S (SC20D001) - Supersonic Mixing and Combustion of Gaseous and Liquid Hydrocarbon Fuels using Curved Pylons - Prof. Aravind V / Aerospace Engineering / January 27, 2025.

- Shri. Anindya Saha (SC19D031) - Massive Stars: Formation and Feedback - Prof. Anandmayee Tej and Prof. Michael De Becker /Earth and Space Sciences /January 29, 2025.

## Courses offered on Space Science and Technology

| Title of the course | Level of the course | Intake Capacity | Subject of specialization in Space Science and Technology |
|---|---|---|---|
| BTech | undergraduate | 75 | Aerospace Engineering |
| BTech | undergraduate | 75 | Electronics & Communication Engineering (Avionics) |
| BTech+ MTech | Dual Degree | 24 | B.Tech. in Engineering Physics + M.Tech. in Earth System Science |
| BTech+ MTech | Dual Degree | | B.Tech. in Engineering Physics + Master of Science in Astronomy & Astrophysics |
| BTech+ MTech | Dual Degree | | B.Tech. in Engineering Physics + M.Tech. in Optical Engineering |
| BTech+ MTech | Dual Degree | | B.Tech. in Engineering Physics + Master of Science in Solid State Physics |
| MTech | post-graduate | 18 | Aerodynamics and Flight Mechanics |
| MTech | post-graduate | 12 | Structures and Design |
| MTech | post-graduate | 18 | Thermal and Propulsion |
| MTech | post-graduate | 12 | Control Systems |
| MTech | post-graduate | 12 | Digital Signal Processing |
| MTech | post-graduate | 12 | Power Electronics |
| MTech | post-graduate | 12 | RF and Microwave Engineering |

| | | | |
|---|---|---|---|
| MTech | post-graduate | 18 | VLSI and Microsystems |
| MTech | post-graduate | 12 | Materials Science and Technology |
| MTech | post-graduate | 12 | Earth System Science |
| MTech | post-graduate | 10 | Geoinformatics |
| MTech | post-graduate | 12 | Machine Learning and Computing |
| MTech | post-graduate | 12 | Optical Engineering |
| MTech | post-graduate | 10 | Quantum Technology |
| MSc | post-graduate | 10 | Astronomy and Astrophysics |
| Doctor of Philosophy (PhD) Degree | PhD coursework | | |

## Laboratories and Facilities Available for Space Instrumentation/Research

- **IIST Ponmudy Climate Observatory (A high-altitude site for Atmospheric Science study)**
  The Ponmudi Climate Observatory of the Indian Institute of Space Science and Technology (IIST-PCO) is located at the confluence point of the Arabian Sea, Indian Ocean, and Bay of Bengal atop the southern end of Western Ghats (8.76°N, 77.12°E, 1.0 km, AMSL). It serves as a natural laboratory for conducting high quality measurements of aerosol and cloud for an improved representation of aerosol-cloud interaction in climate models.
- **SSPACE (Small-Spacecraft systems and Payload Centre)**
  Small-Spacecraft Systems and Payload Centre established at IIST is a central facility that fosters student-led small satellite projects with active involvement from IIST faculty, ISRO centers, startups and other R&D organizations. It promotes interdisciplinary collaboration, subsystem specialization, and hands-on training. Students are highly benefited from this unique platform of comprehensive learning experience that includes participation in space mission design contests and credit internships, which are integral to developing industry-ready skills and advancing space research.

a) Works related to Integrated Diagnostics Module (IDM) payload for EPS-TDS 01 Mission (Standing Review and Monitoring Committee (SRMC) Conducted in the month of September 2025)

- **Satellite Ground Station**
  An indigenously developed ground station & first of its kind in academic community across the country. It is used for IIST's own missions such as INSPIRESat-1 etc., as well as to support some of the external missions including some start-up initiatives.
- **VHF/UHF SDR Ground Station Unit**
- **Architecture**: A standalone unit utilizing state-of-the-art wideband **Software Defined Radio (SDR)** and a fully integrated network-based architecture.
- **Technical Design**: To minimize RF loss, power amplifiers are co-located near the antenna pedestal, while an Intel-NUC computer running GNU-Radio on Linux manages operations.
- **Tracking Capabilities**: Features rotators capable of 0-360° azimuth and 0-90° elevation motion, controlled by **TLE-based tracking software**.
- **Performance**: Successfully tested for uplink and downlink operations with **InspireSat-1**, demonstrating the ability to decode beacon packets and commands without frame loss.
  **Collaboration**: Developed with guidance from VSSC, URSC, and ISTRAC, and managed by SSPACE and IIST's manufacturing lab
- **Advanced Propulsion and Laser Diagnostics Lab (APLD)**
  The Advanced Propulsion and Laser Diagnostics (APLD) facility is a leading research centre dedicated to advancing propulsion and aerospace technology. APLD conducts comprehensive studies on various propulsion systems. APLD serves as a pivotal hub for academic research, national-level initiatives, and technological development within the aerospace industry.
- **Computer Vision and Virtual Reality Center**
  CVVR lab in IIST is established with the aim of excellence in the area of virtual reality and intelligent computer vision for cutting edge space science, societal and technological applications. The lab is well equipped with highly efficient GPUs that help in accelerating the pace of research Image processing and Computer Vision lab sessions for the UG and PG students are also conducted in the CVVR lab.
- **Nanoscience and Technology Centre**
  Center for Nanoscience and Energy Materials was established in IIST to carryout focused research in the area of nanoscience and energy storage materials. The center undertakes research for development of silicon based anode and sulphur based cathode for the realization of high capacity lithium ion batteries.
- **STIIC- The Innovation Hub**
  Space Technology Innovation and Incubation Centre(STIIC),is the innovation hub of Indian Institute of Space Science and Technology (1IST) Thiruvananthapuram and acts as an umbrella for advancement of entrepreneurship and innovations at IIST.STIIC

manages a business incubator which envisages to provide systematized scientific guidance and infrastructure support to young entrepreneurs within its campus.

- **The Quantum Optical Technology Lab (QOTL)**
  To perform the experimental research activities in several forefront areas of quantum optical technologies. Currently, QOTL is involved in the Generation and Characterization of Quantum Squeezed/Entangled Light beams, Quantum Sensing, Quantum Metrology and Quantum Imaging, and Engineering Spatial Quantum Correlations for Quantum Cryptography and Quantum Communication.
- **IIST 5G Use Case Laboratory**
  The 5G Use Case Laboratory at the Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram, was established to explore and demonstrate next-generation wireless communication technologies and their integration with space-based and terrestrial systems.
- **Multidisciplinary Computing Centre (MCC)**
  The Multidisciplinary Computing Centre (MCC) provides 120 teraflops, 40 high end workstations, 2 GPU servers, and 200 TB storage for cutting-edge computational research. In addition, the academic departments have very specific computational labs equipped with workstations and computers.

For further details on the inputs as provided in the document, please contact the office of the Vice Chancellor Prof. Dipankar Banerjee, Vice Chancellor, vc@iist.ac.in

# NATIONAL ATMOSPHERIC RESEARCH LABORATORY GADANKI, INDIA

www.narl.gov.in

## About the Laboratory

National Atmospheric Research Laboratory (NARL), Gadanki, an autonomous organization under the Department of Space, is engaged in research in atmospheric and space sciences and Technology. The activities at NARL primarily focus on experimental research on atmosphere and space, development of radio and optical instruments and modelling for weather and climate research. Currently more than 52 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, X-band polarimetric radar, Airglow imager, GPS-sonde, Instrumented towers, and radiation, aerosol and trace gases measuring instruments along with a High-Performance Computing (HPC) system. In addition, new observatories and networks were set up in the recent past to address issues of national importance. NARL has a vibrant research program, capacity building and public outreach activities. NARL also provides necessary experimental and computational facilities to atmospheric science community, both national and international, for conducting research and disseminates data.

## Major Research Domains

- The major objectives of the Ionosphere and Space Physics Group (ISPG) are to understand the basic plasma processes of the Earth's ionosphere, ionospheric

variability and plasma irregularities including those associated with space weather, and ionosphere of other planets.

- The major objectives of the Atmospheric Structure and Dynamics Group (ASDG) are to investigate the dynamical coupling among different regions of the Earth and Planetary atmospheres through observations, model simulations and analysis.
- The major objectives of the Clouds and Convective System Group (CCSG) are to study the microphysics and dynamics of clouds, precipitation and other high impact weather systems, boundary layer processes, monsoon dynamics, impact of urbanization, and GNSS meteorology.
- The major objectives of the Aerosols Radiation and Trace gases Group (ARTG) are to investigate the role of aerosols and trace gases in the regional and global climate.
- The Weather and Climate Research Group (WCRG) focuses on developing high resolution model and parameterization schemes. One of the prime goals of this group is to develop high resolution model for accurate weather forecast for rocket launches from SDSC SHAR.
- The Radar Research and Development Group (RRDG) is responsible for the indigenous development of new radar systems for atmospheric and planetary studies, operation and day to day maintenance of the MST radar, LAWP, GIRI and beacon receiver.
- The Lidar Research and Development Group (LRDG) is responsible for the indigenous development of new lidar systems for atmospheric research, operation and day-to-day maintenance of various lidars at NARL.
- The focus of the Space-borne Instrument Development (SBID) is to develop instruments that can be flown for balloon-borne and satellite-borne experiments for scientific investigations
- The main activities of the Computers and Data Management Group (CDMG) are to maintain the Data Centre, archival and dissemination of data and maintenance of internet facility. It also designs and develops web portals for the workshops/conferences conducted by NARL.

## Major Scientific Applications / Results

### A new approach for prediction of equatorial plasma bubble

Prediction of equatorial plasma bubbles (EPBs), which adversely affect the modern communication/navigation systems, remains a challenge. A novel approach has been developed to predict the formation of EPBs overhead. The temporal variation of the bottom height of F layer (h'F) has been used as an indicator for the localized upwelling, whereas the scanning capability of GIRI has been employed to find the onset location of EPBs within its field-of-view (FOV) (Figure 1).

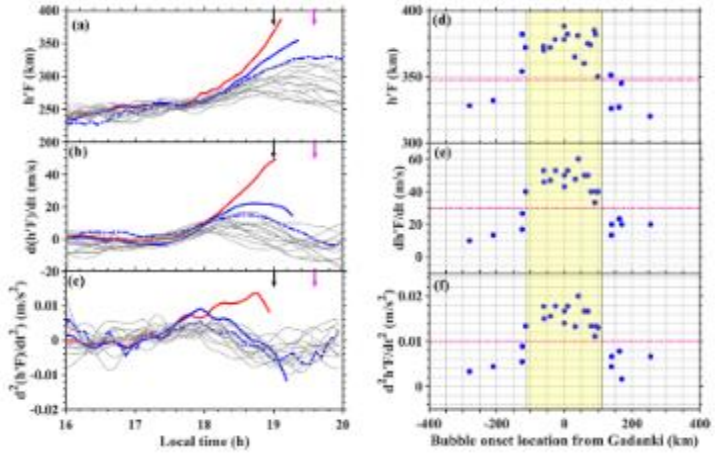



*Figure 1. Temporal variation of (a) h'F, (b) dh'F/dt, and $d^2h'F/dt^2$ observed on 11 March 2015 (solid-red), 4 April 2015 (solid-blue), and 10 February 2015 (dashed blue) along with 13 non-EPB cases (solid-black). The black and pink vertical arrows represent sunsets at the E region at ~ 10° magnetic latitude and 350 km over magnetic equator, respectively. Values of (d) h'F, (e) dh'F/dt, and (f) d2 h'F/dt2 with respect to the zonal location of EPB origin from Gadanki on 26 EPB events observed within FOV of GIRI. Yellow rectangular box represent the zonal span of ±120 km around Gadanki. (https://doi.org/10.1029/2024AV001323)*

This study shows that $d^2h'F/dt^2$ can serve as a precursor for overhead EPB development and nowcasting of EPBs about an hour in advance. The prediction accuracy has been found to be 99.86%.

**Mars nightside ionospheric response during the disappearing solar wind event**

The evolution of Mars' climate over time is influenced by interactions between the solar wind and the planet. The Corotating interaction region mostly produces the extreme low-density solar wind, known as Disappearing Solar Wind (DSW), which affects planetary environments in multiple ways. Beyond Earth, the impact of DSW on other planetary atmospheres remains largely unexplored. Our analysis reveals a denser ionosphere during DSW compared to non-DSW periods, with peak nightside electron density increasing by ~2.5 times and ion densities by over an order of magnitude relative to quiet-time conditions. This enhancement likely results from ionospheric expansion due to increased internal pressure in response to low solar wind pressure (Figure 2). Additionally, plasma transport from the dayside to the nightside may further contribute to this density increase. This study, for the first time, provides new insights into the influence of this rare solar wind phenomenon on the Martian ionosphere.

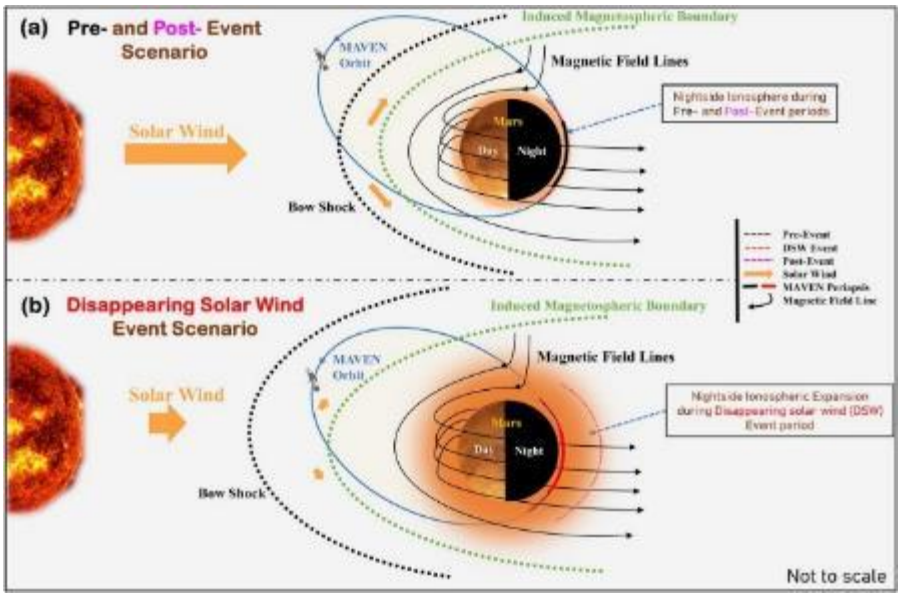



*Figure 2: Schematic (not to scale) portrays the Mars-solar wind interaction. Top panel: Martian ionosphere during pre- and post-event periods. Bottom panel: DSW period (26 December 2022). (https://doi.org/10.1029/2024GL113377)*

**Small-scale (few tens of meters) ionosphere plasma bubbles generated through plasma blobs over Gadanki**

During the 17 March 2015 super geomagnetic storm period, the all-sky airglow CCD imager (630 nm emissions at ~250 km height) at NARL, Gadanki observed the generation of enigmatic ionosphere plasma blobs. When a new blob starts to grow in size and intensity in the northeastern side (Fig. 3a), some kind of plasma instability generates ionospheric plasma bubbles in the eastern edge of the blob. Initially, the plasma bubbles are broad and few in number (3 in Fig. 3b) when the blob is slightly inclined towards the west in the northern side of the imager. When the plasma blob tilts more in the westward direction, more number (7 at 01:34 IST on 18 March in Fig. 3i) of plasma thin bubbles start to appear. Even though the blobs are highly tilted, all the plasma bubbles (plasma depletion) sprouting out all along the eastern edge of the blob tend to align along the north-south direction. This would indicate that while the bubbles are ionospheric polarization electric and geomagnetic fields controlled, the blobs are more controlled by thermospheric winds.

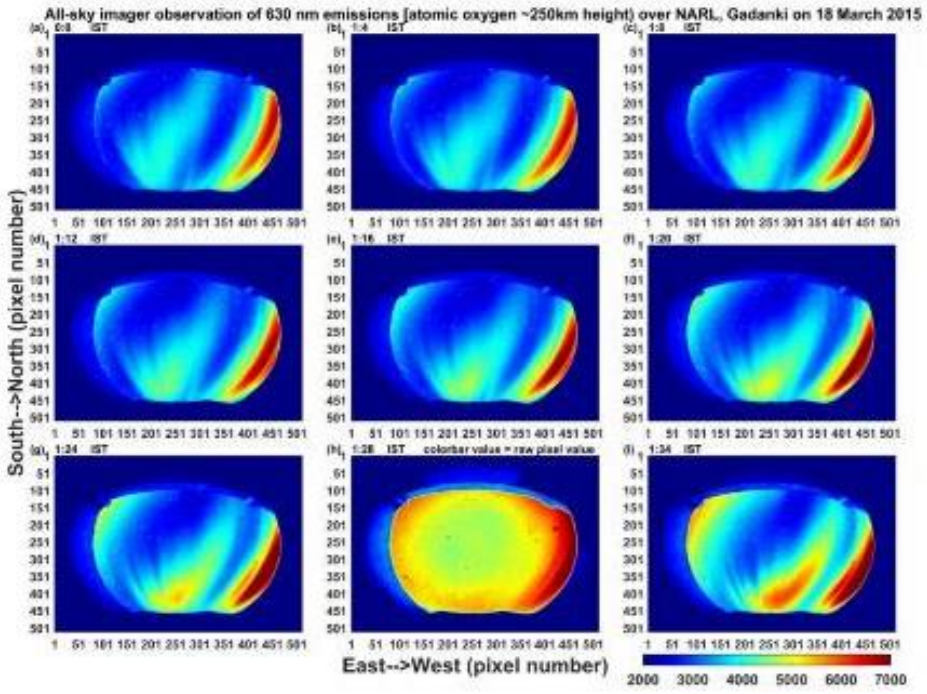



*Figure 3: All-sky CCD airglow imager observation of geographical map of 630 nm emissions occurring at the height of ~250 km over NARL on 18 March 2015.* (*https://doi.org/10.1038/s41598-025 00627-w)*

## 25-Year analysis of tropical cirrus clouds from NARL LIDAR observations

A 25-year (1998–2023) dataset of cirrus cloud properties from ground-based LIDAR at NARL are analysed. Cirrus macro-physical, thermodynamic, and optical properties, along with long-term trends in the Tropical Tropopause Layer (TTL) have been analyzed. Results show an increasing trend in TTL thickness and Cold Point Tropopause Height (~0.003 km/year), while cirrus base, top, and thickness declined (Figure 4). Mid-cloud altitudes of sub-visible, thin, and thick cirrus showed significant declines, accompanied by rising mid-cloud temperatures. A reduction in geometrical thickness (sub-visible) and optical thickness (thin and thick cirrus) is also observed. Comparisons with 18 years (2006–2023) of CALIOP satellite data showed general agreement, though with notable differences in magnitude, highlighting implications for radiative impact assessments.

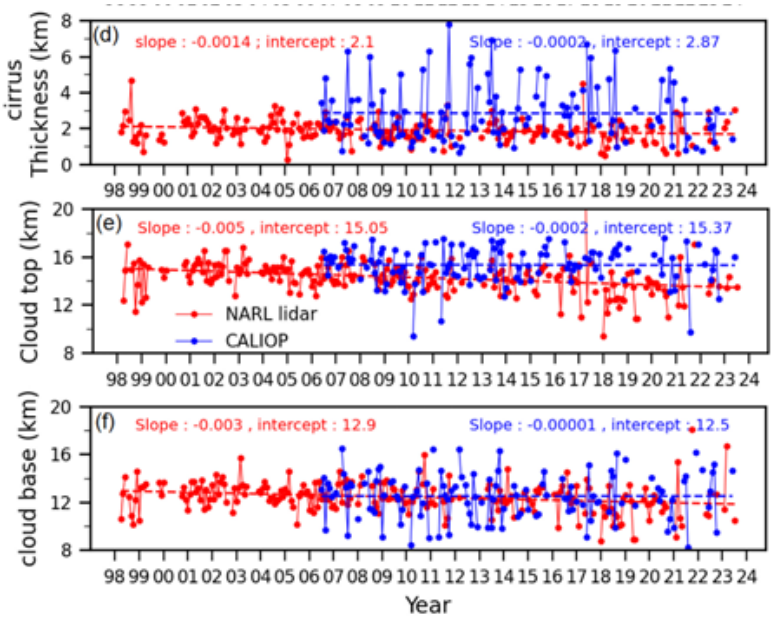



*Figure 4: Trends observed in the cirrus cloud properties. (a) Cirrus cloud thickness obtained using both NARL lidar (red solid line with dots) and CALIOP (blue solid line with dots). (b) Cirrus top altitude and (c) cirrus base altitude. (https://doi.org/10.1016/j.atmosres.2025.108158)*

## Cloudburst over Western Himalaya: Physical Mechanisms

Idealized simulation of the cloudburst event over Sauni Binsar, Uttarakhand, India revealed sustained accumulation/stagnation of moisture at near surface level over Sauni Binsar associated with the northward movement of the southwest monsoon, supersaturating the atmospheric column. The advection of warm air (dry) from the monsoon heat low towards event location at 700 hPa level leads to the development of potential instability indicated by the vertical profile of Richardson's number at the mid-upper troposphere. Orographic lifting due to topography and an increase in moisture convergence over this region caused moist convection. Just a few hours prior to the cloudburst event (02-06 UTC of 10 June, 2021), the reduction in potential vorticity indicated the squashing of the super-saturated columns. The sudden squashing of supersaturated conditions with respect to liquid and solid water significantly enhanced the cloud droplet concentration, thereby further enhancing the collision-coalescence rate. The vapor deposition, nucleation, and collision-coalescence processes occurred at the same height level, as indicated by the coincidence of the LCL and LDL heights during the cloudburst. Moreover, high turbulence and a large terminal velocity of raindrops might have produced a high rain rate and been responsible for the cloudburst.

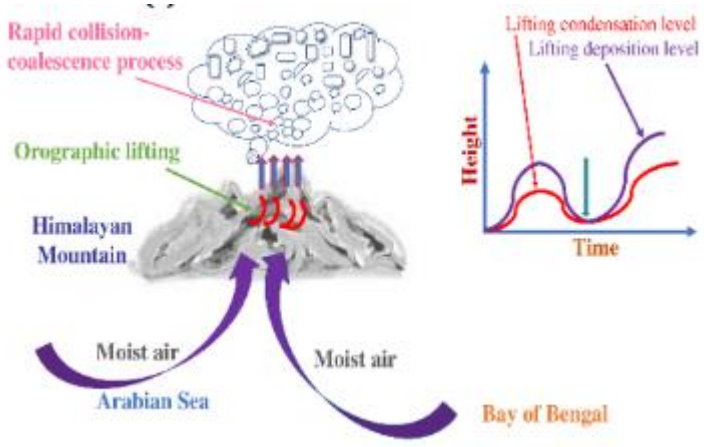



*Figure 5 Schematic of the cloudburst formation mechanism (10.1016/j.atmosres.2024.107626).*

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

### Indigenous development of 445 MHz wind profiling radar

NARL has designed and developed a cost-effective 445 MHz atmospheric radar, which is the first of its kind, to study the lower atmosphere up to ~ 8-10 km.

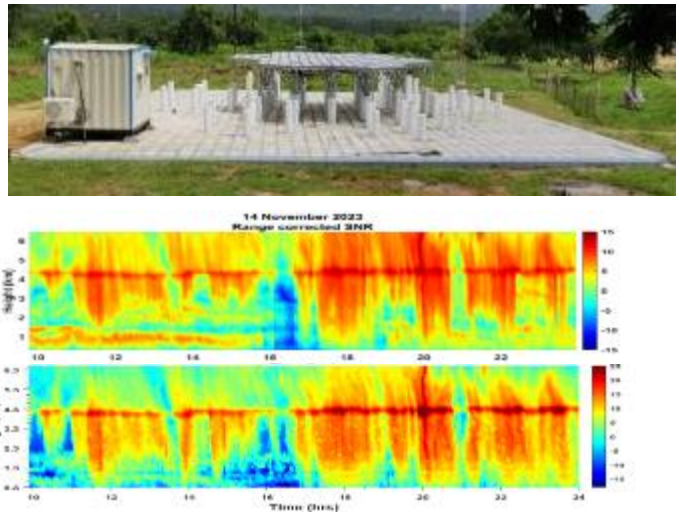


*Figure 6: Photograph of 445 MHz radar(top). Height time variation of Signal-to-noise ratio during the passage of cyclone Mithili obtained by 445 MHz wind profiling radar (middle) and LAWP (bottom).*

The radar antenna array comprising 252 microstrip patch elements are arranged in 7 subgroups. All four groups (presently 4 groups are operated) radiate with a peak power of 8 kW (each subgroup radiates 2 kW), during the transmit mode with a 3-dB beam width of

5.3$^{o}$. Full-correlation analysis (FCA) is applied to the four receive channels data to derive the horizontal wind (zonal and meridional) components. Observations by the radar during the passage of cyclone Mithili on 14$^{th}$ November 2023 were analysed and compared with those obtained from Lower Atmospheric Wind Profiler (LAWP).

***A Patent has been received for the development of 445 MHz Spaced antenna wind profiling radar.***

**Establishment of a Smart Data-Centre**

A data centre has been established featuring a smart rack. The implemented system demonstrates exceptional storage efficiency and maintains low access latency, utilizing a 100G network in conjunction with advanced NVMe primary storage of 360TB and 1PB of secondary SAS. This data centre safeguards three decades of critical atmospheric instrumental data and facilitates processing.

**Venus Advanced Radar for Topside Ionosphere and Subsurface Sounding**

Venus Advanced Radar for Topside Ionosphere and Subsurface Sounding (VARTISS) is one of the payloads for the upcoming Venus mission. A low frequency radar sounder (1-10 MHz) has been developed, which is meant for probing the topside ionosphere of Venus continuously and at all solar zenith angles. An Engineering Model (EM) has been developed with industrial grade components. The system has been used to detect Earth's ionospheric echoes from the ground.

## Capacity Building in Space Science Research

NARL conducted the following workshops/conferences

- A school on "Radio Probing of the atmosphere" at NARL during 11-22 March 2024
- Workshop on "Data Assimilation in Weather and Climate models" along with ICTS and IIST during 6-17 May 2024 at ICTS, Bengaluru
- Workshop on "Emerging trends in Aerosol Science and Technology" at Vikarama Simhapuri University, Nellore on 4 December 2024
- Workshop on "Data Science and Technologies: Applications in Atmospheric and Space Sciences" at NARL during 20-31 January 2025

No. of NARL students completed their Ph.D's: 11

- 1-D Model to Retrieve the Vertical Profiles of Minor Atmospheric Constituents for Cloud Microphysical Modelling

- An Integrated Modeling Approach to predict the ambient particulate matter concentration and human exposure at high spatial resolution for megacity Delhi
- Dictionary learning approach to lidar sensing of the atmosphere
- Role of collision-coalescence Mechanisms in the Occurrence of Cloudburst Event
- Roughness effects in turbulent channel flow
- Investigation of the lower atmospheric wave forcing on the MesosphereThermosphere-Ionosphere (MTI) system
- Role of Volatile Organic Compounds and Trace Gases in the Chemistry of Rural Atmosphere
- Quantification of Radiative Impacts of the Asian Tropopause Aerosol Layer
- A study on the microphysics of tropical extreme precipitating systems using X-band dual-polarization radar
- Machine Learning Techniques for Prediction of Storms using GNSS Receiver measurements
- Factors influencing cloud condensation nuclei over a tropical rural location: Insights from long-term observations and machine learning methods

## Courses offered on Space Science and Technology

NARL conducts regular course works to their Ph.D. students. NARL also conducts thematic schools in Space and Atmospheric Sciences.

## Laboratories and Facilities Available for Space Instrumentation

NARL is presently operating more than 50 instruments for probing the atmosphere and ionosphere. These instruments, include high power radio/microwave radars (Advanced Indian MST Radar (AIR), Lower Atmospheric Wind profiler, 445 MHz wind profiler, X-band Dual-polarization radar; 30 MHz radar); high-power Lidars (Rayleigh/Mie lidar, Doppler Lidar, Sodium lidar, micropulse lidar, cloud lidar); Meteorological Observatory, and Climate Observatory; along with a 1.7 petascale HPC system.

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

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# 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.

- Main Campus at Balanagar, Hyderabad for Administration, Remote Sensing Applications and Aerial Services.
- The Campus at Shadnagar for Satellite Data Reception, Data Processing and Dissemination, Earth and Climate Studies and Disaster Management Support.
- Five Regional Centres at Sector 9, KBHB in Jodhpur (Regional Centre-West), Sadhiknagar at New Delhi (Regional Centre-North), New Salt Lake City in Kolkata (Regional Centre-East), Amaravathy Road in Nagpur (Regional Centre-Central), Karthik Nagar in Bangalore (Regional Centre-South) for promoting remote sensing applications for various states.
- Outreach facility at Jeedimetla in Hyderabad for providing training for professionals, faculty and students and for general outreach. Aircraft operations facility at Begumpet Airport, Hyderabad

## Major Research Domains

NRSC encompass key functional areas including Satellite Data Acquisition, Data Processing & Dissemination, Aerial Services & Data Management, Remote Sensing Applications including Region Specific Services and the provision of end-to-end Geospatial Services through platforms such as Bhuvan and Bhoonidhi. Additionally,

emphasis is placed on Capacity Building and Outreach, enabling a wider user base to access and effectively utilise geospatial information. The plans also focus on Facility and Infrastructure augmentation, along with ensuring System Reliability and Quality Assurance to maintain operational excellence.

**Satellite Data Acquisition**: The NRSC has established a state-of-the-art ground station facility at Shadnagar, known as the Integrated Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS), near Hyderabad, for acquiring Earth Observation (EO) data from Indian Remote Sensing (IRS) satellites as well as various foreign satellites. The ground station operates in a fully automated, 24/7 environment, ensuring uninterrupted data acquisition and processing. NRSC also extends support for the establishment of ground stations for both national and international users.

**Satellite Data Processing & Dissemination:** The NRSC serves as the nodal agency for the acquisition and processing and dissemination of satellite data from both Indian Remote Sensing (IRS) and non-IRS satellites. To ensure high-quality data products, sensor calibration is performed using NRSC's world-class Calibration and Validation (Cal-Val) facility, maintaining the reliability and accuracy of the satellite data.

**Aerial Services & Data Management:** Focuses on generation of large-scale topographic maps and very high-resolution Digital Terrain Models (DTMs). The entity supporting sensor validation through test flights for a variety of advanced satellite instruments.

**Remote Sensing Applications**: The NRSC spearheads a wide range of remote sensing applications to support national development, resource management, and disaster monitoring. Utilizing data from Indian and foreign Earth Observation satellites, NRSC delivers geospatial solutions across diverse sectors such as agriculture, soil, water resources, forestry, geosciences, land use/land cover, & urban planning, etc.

**Earth and Climate Science Area:** Focuses on investigating both natural processes and human-caused impacts on the Earth's climate system, with the goal of understanding past, present, and future climate conditions through satellite measurements, ground observations and modelling.

**Regional Remote Sensing Centers**: Regional Remote Sensing Centres (RRSCs), located at Kolkata (RC-East), Jodhpur (RC-West), Bangalore (RC-South), Nagpur (RC-Central) and at Delhi (RC-North), are working in close coordination with NRSC for execution of various national level and region-specific remote sensing application projects, capacity building.

**Bhuvan Geospatial Services**: NRSC offers a suite of geospatial services through state-of-the-art platform, Bhuvan, enabling wide access to satellite data and value-added geospatial information.

**Safety, Reliability & Quality Assurance**: Safety, Reliability and Quality Assurance (SRQA) plays a pivotal role in ensuring that all processes at NRSC align with established Quality Management System (QMS) practices.

**Training & Outreach**: The NRSC actively undertakes training and Outreach initiatives to promote awareness, skill development, and knowledge dissemination in the field of Earth Observation and geospatial technologies.

**Facility & Infrastructure:** The NRSC has developed and maintains state-of-the-art facilities and infrastructure to support the end-to-end lifecycle of satellite data acquisition, processing, storage, analysis, and dissemination.

## Major Scientific Applications / Results

The National Information system for Climate and Environment Studies (NICES), implemented by National Remote Sensing Centre under the Indian Space Research Organization, represents a coordinated national effort to generate and disseminate Essential Climate Variables (ECVs). It integrates satellite and in situ observations to produce long-term, quality-controlled climate datasets. These datasets support climate monitoring, reanalysis and evidence-based policy decisions. Initially, twelve ECVs were operationally generated and disseminated via the NICES web portal. The addition of 'Merged Stratospheric Water Vapour' increases the total available ECVs to thirteen. Furthermore, under its Climate Services component, the portal currently hosts operational products such as ENSO outlook and hot weather outlook services, supporting climate monitoring and informed decision-making.

Moreover, the spatiotemporal variation of GHG emission ($CO_2$, $CH_4$, $NO_x$) and hot-spot identification using space-based observations has been carried out by utilizing multi-satellite data (OCO2, GOSAT, AIRS). The annual average atmospheric $CO_2$ for the entire country ranges from 371 ppm to 424 ppm. The study indicates that the Indian region is experiencing an $XCO_2$ accumulation rate of 2.31 ppm/year in the atmosphere. Similarly, the $CH_4$ concentration also increased from 1750 ppb in the year 2002 to 1950 ppb in the year 2024. Impact of neighbouring land use/land cover (LU/LC) changes and fire emissions on atmospheric carbon dioxide ($CO_2$) and methane (CH4) concentrations in the suburban region of Shadnagar, India by using continuous measurements from 2013 to 2022 using a greenhouse gas analyzer was investigated. Further, using EMIT data $CH_4$ hotspots and plumes were successfully detected which were compared with TROPOMI data.

The INSAT 3D parameters (OLR, CMV, LST) were utilized to identify the potential lightning prone regions in about 3 hours in advance. The results were validated with ground based Lightning Detection Sensor Network data. This method, combined with the WRF based lightning now-casting provides significant improvement in the probability of detection as far as the lightning hot-spots are concerned.

Further, our research advances the use of Earth Observation data to generate robust Essential Climate Variables, enabling improved carbon–climate modeling, better understanding of precipitation extremes and Himalayan cloudbursts, and enhanced

insights into polar sea-ice–climate feedbacks. Following are key outcomes of our research: 1) INSAT-3d data revealing a significant increase of cloud cover across India in recent decade causing in decline surface solar radiation, there by affecting the biophysical processes; 2) shift of timing of monsoon rainfall peak over the Indo-Gangetic Plain in recent time, likely driven by changes in aerosol loading in changing climate; 4) Generation of harmonized merged data products of tropospheric and stratospheric water vapor (SWV), and columnar perceptible water from multi-satellite observation with enhance trends in the tropics; 5) Evaluated cloud optical depth from Oceansat-3 sensor and millimeter wave humidity sounder; 6) Mapped sea-ice variability using ISRO scatterometer data and identified declining Himalayan snow cover, providing key insights into cryosphere change and its impacts on regional climate and water resources; 7) Increase of precipitation on the background of warming climate enhances the greening of the vegetation across India; 8) Indian Ecosystem is a net sink of atmospheric CO2, with mean uptake 80 TgC/year (increase rate 6 TgC/year2) during past two decades (2001-2025); Remote transport is being the major driver (upto 80%) in controlling annual atmospheric CO2 budget (aprox 1.8 ppm/year) over India, and local fluxes is responsible (<8%).

Future developments under NICES program aim to expand the ECV portfolio with high-resolution, region-specific products addressing critical gaps in the Himalayan and ocean-atmosphere domains. These include evapotranspiration dynamics, river-linked hydrological variables, glacier mass balance and kinematics, advanced snow parameters (cover, depth, wetness, SWE), precipitation and lightning climatology, land surface temperature, atmospheric water vapour profiles, and biogeochemical fluxes such as NPP, NEP, and ocean carbon parameters ($pCO_2$, DIC). Additionally, emerging datasets on aerosols, greenhouse gases, air quality, and agricultural residue burning will strengthen climate forcing assessments. This next-generation ECV framework positions NICES towards a comprehensive GeoAI-enabled climate information system, enhancing predictive analytics, climate services, and decision support for national resilience and sustainability.

## Capacity Building in Space Science Research

- Two CSSTEAP Courses on Satellite Remote Sensing for Ocean Applications were conducted in 2024 and 2025 where a total of 31 participants have undergone training on Ocean Applications.
- Internship Projects: 28

## Laboratories and Facilities Available for Space Instrumentation

- **Atmospheric Laboratory at Shadnagar:** Towards advanced Aerosol monitoring, Cloud parameterization, precipitation, and GHG measurements, a laboratory having appropriate instruments have been established at Shadnagar, a semi-

urban/suburban site in India, since 2013. Isotopic $\delta^{13}C$ measurements were added in 2018 to further strengthen source attribution and advanced greenhouse gas characterization studies.

FTIR (125M) measurements are being carried out at Shadnagar for columnar observations, along with portable FTIR measurements across different regions of the country. Ultra-portable and micro-portable greenhouse gas analysers are also being utilized for airborne campaigns, UAV-based studies, and Arctic and Antarctic expeditions.

- **Oceanography laboratory:** Hosts specialized instrumentation facility for marine research, including physical, chemical and biological oceanography.

| S. No. | Name of the Equipment | Make | Year of purchase | No. of samples analysed |
|---|---|---|---|---|
| 1. | Milli-Q Water System for producing Distilled Water | Thermo Scientific | 2019 | Continuous water generation |
| 2. | Skalar SAN++ Auto Analyser | Skalar | 2018 | 4500 |
| 3. | Coulometer DIC (Dissolved In-Organic Carbon) | UIC Inc | 2014 | 3000 |
| 4. | pH Meter | Metrohm India (P) Ltd. | 2013 | 2000 |
| 5. | Auto Titrator<br>TA Analyser | Metrohm India (P) Ltd. | 2021 | 2500 |
| 6. | HPLC | SHIMADZU | 2018 | 2000 |

- **Observational Networks: (1)** Flux tower network has been established at multiple locations, including NESAC, J&K, Ooty, Kolkata, CCRI, and Kavaratti (Lakshadweep). A regional $CO_2$ observation network comprising seven stations across India has also been developed, and the observational data are hosted on the Bhuvan portal. Ozonesonde observational network at 4 Locations across the India. **(2)** Lightning Detection Sensor Network has been established with 55 sensors located across India to detect the hazardous cloud-to-ground lightning occurrences. The data collected is utilized for lightning ECV preparation and lightning hazard mapping with data being hosted on BHUVAN and NDEM portals. **(3)** Radiosonde network with 6 location (Jammu, Jodhpur, Medinapur, Pachal and Nagpur) regular balloon sounding to monitor Rh, Temperature and Wind profiles has been established.

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

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## **List of Publications** (Jan 2024 – Dec 2025)**:**


1. Agarwal, N., Jishad, M., Kumar, J., Baliarsingh, S. K., Swetha, N., Smitha, R., Bhowmick, S. A., Ramakrishnan, R., Chakraborty, A., Shikakoli, R., Shiva Shankar, M., Mathew, R., Suhail, M., Mishra, S. K., Udaya Bhaskar, T. V. S., Nagamani, P. V., Balakrishnan Nair, T. M., Thapliyal, P., Sharma, R., Chauhan, P. (2025). Synergistic use of scatterometer and ocean colour monitor onboard EOS-06 satellite for various oceanographic applications. Journal of Indian Society of Remote Sensing, 53, 2965 – 2976. https://doi.org/10.1007/s12524-025-02208-w.
2. Chacko, N., Jayaram, C., Suhail, M., Prasad, D. V., and Nagamani, P. V. (2025). Utilization of EOS-06 observations in tropical cyclone research: A case study on cyclone Mocha. Journal of Indian Society of Remote Sensing, 53, 2915 – 2927. https://doi.org/10.1007/s12524-024-02013-x.
3. Shaik, I., Nagamani, P. V., Pathakoti, P., Rao, G. S. (2025). Assessment of Air-Sea CO2 flux in global surface oceans using satellite data. Imaging and Sensing, 26, 160. https://doi.org/10.1007/s11220-025-00676-5.
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9. Swapna, M., Sikhakolli, R., Prasad, T. D. V., Suhail, M., Nagamani, P. V., Rao, G. S., Bothale, R. V., Chauhan, P. (2025). Unravelling algal bloom signatures: synergistic use of EOS-04 C-Band SAR, OCM3, OLCI and in-situ observations. Journal of Indian Society of Remote Sensing, 53, 2989 – 3005, https://doi.org/10.1007/s12454-025-02205-z.

10. Warrior, H., Nagamani, P. V. (2025). Understanding chlorophyll dynamics in aquatic ecosystems in Bay of Bengal. Current Science, 129, 151 – 157. Doi. 10.18520/cs/v129/i2/151-157.
11. Bhowmick, S.A., Chakraborty, A., Sikhakolli, R. et al. Generation, Calibration, Retrieval and Validation of EOS-06 Scatterometer Data Products. J Indian Soc Remote Sens 53, 2753–2775 (2025). https://doi.org/10.1007/s12524-025-02225-9
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# NORTH EASTERN SPACE APPLICATIONS CENTRE SHILLONG, INDIA

https://nesac.gov.in

## About the Centre

The North Eastern Space Applications Centre (NESAC) was established in 2000 as an autonomous organization under the Department of Space, Government of India, with the objective of facilitating the effective utilization 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)-based natural resource information system to support planning, development, and management of natural resources, infrastructure, and governance in the region; (ii) to deliver operational satellite communication application services in areas such as education, healthcare, disaster management support, and developmental communication; (iii) to undertake research in space and atmospheric sciences, including the establishment of regional instrumentation facilities and collaboration with academic and research institutions; (iv) to enable single-window delivery of comprehensive space-based support for disaster risk reduction; and (v) to establish regional-level infrastructure for capacity building in geospatial technologies. Over the past two and half decades, the Centre has successfully completed more than 400 projects across diverse thematic areas. NESAC has emerged as a key institution in leveraging space technology for enabling sustainable and holistic development of the North Eastern Region of India.

## Major Research Domains

The major research domains at NESAC are outlined below

- **Satellite Remote Sensing and Geospatial Applications:** NESAC utilizes multi-source satellite data and advanced geospatial techniques to develop operational and research-driven solutions for natural resource management, environmental monitoring, sustainable infrastructure planning, and site suitability analysis across the North Eastern Region.
- **Adoption of Artificial Intelligence and Data Analytics:** The Centre applies Artificial Intelligence (AI), Machine Learning (ML), and deep learning approaches for automated feature extraction, spatio-temporal analysis, weather nowcasting, and development of intelligent decision support systems for diverse applications.
- **Disaster Risk Reduction and Early Warning Systems:** NESAC undertakes research and development of advanced methodologies for multi-hazard risk

assessment, early warning, and disaster management support, covering floods, lightning, landslides, forest fires, and vector-borne diseases, with an emphasis on operationalization.

- **UAV-based Remote Sensing and High-Resolution Mapping:** The Centre developed innovative applications using Unmanned Aerial Vehicles (UAVs) for on-demand, high-resolution data acquisition, mapping, monitoring, and emergency response, enabling localized and time-critical assessments.
- **Space and Atmospheric Sciences:** Research efforts are focused on improving short- and medium-range weather forecasting, severe weather prediction, and understanding atmospheric processes including aerosols, boundary layer dynamics, aerosol–cloud interactions, and climate variability & impact assessment, and space weather phenomenon.

## Major Scientific Applications / Results

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

(i) **Development of location-based lightning nowcasting system for NE region of India:** Developed and operationalised the lightning nowcasting system for the NER of India using the lightning data from Indian Institute of Tropical Meteorology (IITM), Pune network. The lightning nowcasting is also done over the NER of India with lead time upto 6 hours by assimilating the ground based data in the WRF - Elec model. The Probability of detection of such lightning alerts is from 0.7 to 0.91 depending on lead time. The forecast is used by state level authorities to alert people who are likely to be impacted by impending lightning.

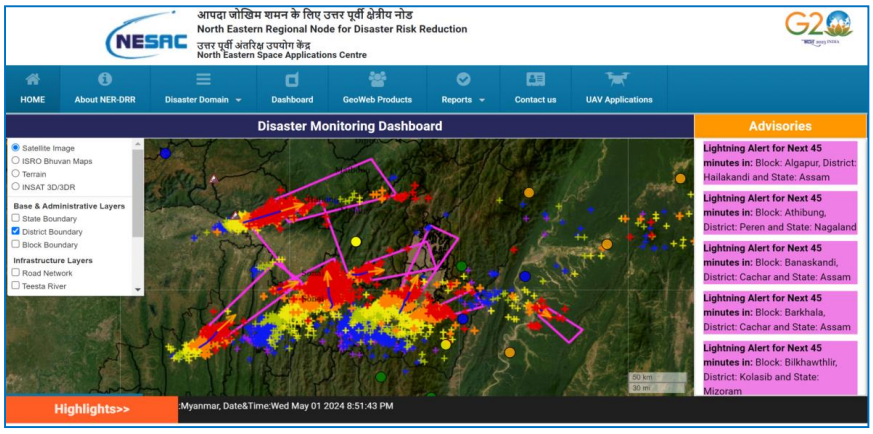


*Figure 1: Lightning early warning using the severe weather tracking system over the NER*

(ii) **Ensemble based Numerical weather prediction using the WRF Model:** 50 Member ensemble-based numerical weather prediction has been operationalised for

the NE region of India using the Weather Research and Forecasting model. The model is run at 3 km spatial resolution that shows significant improvement in wet-bias in rainfall prediction over the extreme rainfall zones in NER compared to single model forecast.

(iii) **Ionosphere TEC Monitoring for Earthquake Precursor Detection:** The analysis of Ionosphere Total Electron Content (TEC) is essential for understanding ionospheric variability, particularly in relation to thunderstorms, lightning activity, space weather phenomena, and seismic events. NESAC generates ionospheric TEC maps at 30-minute intervals utilizing data from 120 Continuously Operating Reference Stations (CORS) established across the NER of India by the Survey of India. The dataset is derived from observations collected through the Global Navigation Satellite System (GNSS). The resulting TEC products enable near-real-time monitoring of ionospheric conditions, capturing variations influenced by diurnal cycles, geomagnetic activity, and atmospheric processes.

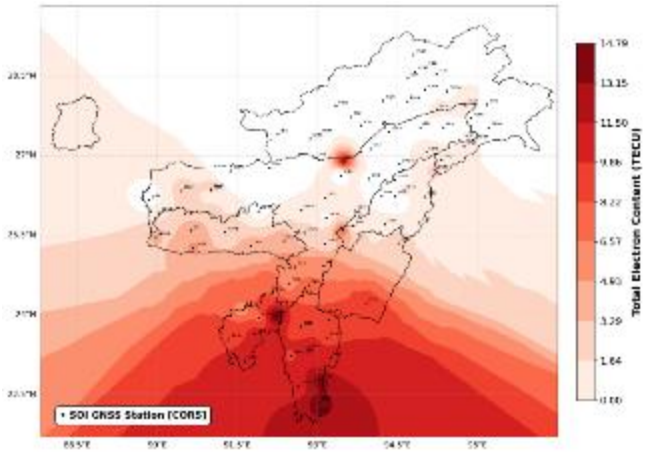


*Figure 2. Map representing TEC Anomaly on 11-04-2026 in the NER of India*

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

(v) **Bamboo Resource Mapping in Northeast India:** Bamboo, a fast-growing and renewable bioresource, plays a critical role in climate mitigation, ecosystem restoration, and rural livelihoods. As an efficient carbon sink, it is increasingly integrated into global climate frameworks such as REDD+ and carbon credit mechanisms. It also supports land restoration and reforestation efforts, particularly

in combating land degradation and desertification. NESAC is undertaking comprehensive mapping of bamboo plantations across Northeast India using satellite-based geospatial techniques. The resulting datasets enable robust estimation of bamboo biomass and carbon sequestration potential. These outputs are being utilized by multiple agencies to support carbon credit assessments, sustainable livelihood generation, and the development of biofuel and other value-added products.

(vi) **Simulation and Prediction of Rice Yield through Remote Sensing-Based Models in the Hilly Terrain of Northeast India:** Developed a robust and scalable methodological framework for rice yield estimation in the complex agro-ecological conditions of the NER, addressing challenges such as heterogeneous landscapes, fragmented agricultural fields, and persistent cloud cover. To overcome these constraints, multi-source satellite data during the crop growing period (June-November) were utilized for consistent monitoring, growth analysis and yield estimation in Sung valley, Meghalaya. Multiple modelling approaches, including semi-physical models, process-based DSSAT simulations, and ML-based models are being implemented to capture the variability in crop growth and yield across different transplanting windows.

(vii) **Flood Early Warning System (FLEWS) for NER:** Flood is one of the most chronic disasters impacting NER of India. Flood early warning is done for Assam and other priority flood prone regions of NER with lead time upto 48 hours. The forecast leverages the strength of numerical model based rainfall forecasting as well as near real time space based weather monitoring using INSAT 3DR and INSAT 3DS satellites, both integrated in a hydrological framework supported by ground level information collected using satellite imagery. The operational flood early warning over NER has success score exceeding 80%

(viii) **Remote sensing & GIS based input for Hazard, Vulnerability and Risk Assessment (HRVA):** NER of India is affected by several severe disasters**.** 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 has been done. The HRVA assessment helps in better planning for disaster management and resilience.

(ix) **Development of GeoGPT for AI-driven Geospatial Decision Support:** GeoGPT, an LLM-based geospatial assistant, is under development to enable natural-language queries, metadata interpretation, and RAG-enabled analytics across platforms such as NeSDR and NER-DRR, improving data access and decision support for government users.

(x) **UAV Technology & Applications:** UAVs are increasingly becoming popular for on-demand services particularly over the NER of India because of its high cloud cover. Different types of UAVs fitted with verities of sensors including Hyperspectral camera, LIDAR, etc. have been used for survey and mapping across NER and other parts of India covering very critical applications like, embankment mapping, rescue and relief operations, fire assessment, flood extent mapping, landslide mapping and assessment, etc.

(xi) **Aerosol Radiative Forcing over India – NER Scenario:** NESAC operates three aerosol observatories in NER including two at high altitude sites. Focus has been given to understand the aerosol-radiation-cloud interaction and new particle formation. Preliminary short-term WRF-Chem simulations with and without aerosols, along with a long-term assessment of aerosol loading and associated precipitation pattern changes are being carried out over the NER of India to study the impact of aerosols.

(xii) **Integrated Satellite and ground observations to characterize thunderstorm electrification over Northeast India:** This work integrates satellite and ground observations to characterize electrified thunderstorms over the complex terrain of Northeast India. An algorithm using INSAT-3DR/3DS WV and TIR1 channels with lightning data identifies electrified convective regions. Field campaigns around Sohra, employing DWR, electric field mills, and laser precipitation monitors, examine cloud microphysics and electrical properties, improving understanding of relationships among electric field, precipitation, and satellite–radar observations for better severe weather prediction.

(xiii) **Development of a high-resolution Regional Climate Model for improved understanding of current drying scenario:** NER of India has been projected to be one of the most severely impacted region by climate change. To have a clear assessment of future climate over NER, a study has been taken up to generate 9 km bias corrected historical and future projections of precipitation and temperature. Evaluating and ranking the CMIP6 climate models on their performance over the NER of India has been completed. Four best CMIP6 models are selected based on the evaluation and ranking of models for bias correction and downscaling.

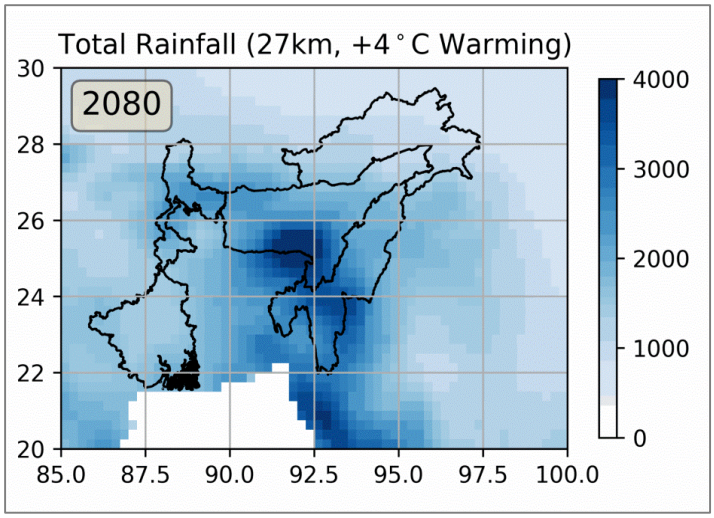


*Fig. 3: High resolution climate projections for NER to facilitate climate resilient planning*

(xiv) **Deep learning-based lightning nowcasting using INSAT 3D/3DR/3DS data for the Indian region–LightningCast:** Artificial Intelligence (AI), specifically deep learning has been used to nowcast lightning occurrence over the Indian region. Multi-channel inputs from INSAT-3D/3DR/3DS (WV, TIR, and visible bands) along with lightning observations from IITM, Pune and National Remote Sensing Centre (NRSC), Hyderabad are used to train the model. By leveraging convolutional neural networks (CNNs), the system learns complex spatiotemporal patterns and provides very short-term (0–1 hour) high-resolution probabilistic forecasts of lightning strikes.

## Indigenously Developed Instruments / Products / Sensors / Detectors

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

(i) Improved satellite rainfall estimate using non-stationary merging scheme.

(ii) Total Electron Content (TEC) map over NER of India at 30 minute interval.

(iii) Location based lightning warning products.

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

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

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

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

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

(ix) 3D wind data for height upto 8 km using UHF wind profiler

## 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.

NESAC runs regular short term training course on RS and GIS application in different thematic areas like Agriculture, Forestry, Geosciences, etc. More than 15 regular training courses and 10-15 customized training courses of 1-2 weeks duration are conducted every year. In addition, NESAC conducts 2 weeks course on basics of RS and GIS as well as on UAV remote sensing. In addition to the scheduled courses, NESAC has been organizing the ISRO's "Young Scientist Program (YUVIKA)" every year for the students from NE region of India. Summer school on Space weather has also been planned at NESAC.

## Courses offered on Space Science and Technology

NESAC offers the following short term courses (one to two weeks duration)

- Advances RS & GIS Technology and Applications
- Geospatial AI: Foundation, emerging trends and real-world applications
- RS & GIS applications in Agriculture and Soil
- Advanced training course on UAV Remote Sensing
- RS & GIS Applications in Water Resources, Hydrology and flood management
- 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
- SATCOM & SATNAV: Technologies & Application.
- ISRO Young Scientist Program
- North-East Students Program for Awareness, Reach, and Knowledge on Space

In addition to the above, NESAC also provides tailor made courses for project specific requirements for one to two week duration.

## Laboratories and Facilities Available for Space Instrumentation

- High Performance Computing System with 120 TFlops computation capacity and GPU servers for development of Machine learning applications.
- Laboratory with high end systems and software. map plotters, printers, GPS systems and cameras including GAGAN, NAVIC & DGPS
- Laboratory for development of Mobile Apps, Dashboard applications, Geo-web services, disaster management support services.
- Unmanned Aerial Vehicles with Hyper-spectral and Multi-spectral camera, LIDAR, etc., fabrication using 3D printers, drone pilot training, etc.
- Three laboratories including two at high altitude Himalayan region for optical and physical characterization of aerosols.

- Instruments for physical, optical, and chemical characterization of aerosols, atmospheric boundary layer, trace gas chemistry, cloud micro-physics, etc.
- Network of Laser precipitation monitor, electric field mills, lightning detectors, etc. covering entire NER of India.
- S Band dual-polarimetric Doppler Weather Radar.
- 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 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

*Physical Research Laboratory, Navrangpura, Ahmedabad – 380 009, India*

*Website: https://www.prl.res.in  Report Period: 2024–2026*

www.prl.res.in

## About PRL

Physical Research Laboratory (PRL), Ahmedabad is a premier research institution under the Department of Space, Government of India. Founded in 1947 by Dr. Vikram Sarabhai, PRL conducts research in Space and Atmospheric Sciences, Solar Physics, Astronomy & Astrophysics, Planetary Sciences, Atomic & Molecular Physics, Geosciences, and Theoretical Physics. PRL operates several observing facilities including the Udaipur Solar


Observatory (USO), the Mount Abu Infrared Observatory, and contributes to national space exploration and space weather missions including Lunar (Chandrayaan), Solar (Aditya-L1) and planetary (Mars Orbiter, Venus Orbiter) missions. PRL offers a vibrant research and post-doctoral fellowship programs in all the niche research domains of PRL.

## Major Research Domains

### Space and Atmospheric Sciences:

Solar wind, energetic particles, space weather, vertical coupling in the atmosphere, Ionosphere-thermosphere system, Magnetosphere-Ionosphere coupling, Mesosphere-Lower Thermosphere coupling, Ionospheric electrodynamics, Topside ionosphere, optical instrumentation, space weather forecasting using AI-ML, Atmospheric aerosols (physical and chemical properties), atmospheric clouds, boundary layer, emissions and photochemistry governing tropospheric ozone, biomass burning and climate change, air-sea exchange of trace gases, atmospheric modelling and AI/ML, middle atmospheric wave dynamics.

### Solar Physics:

Helioseismolgy, Coronal Heating, Solar magnetic anomalies, Solar energetic particles, spectro-polarimetry of the sun, vector magnetograms, MHD Simulations, solar eruptive

phenomena, CMEs in the interplanetary medium, solar flares, space weather effects of CMEs, Solar Instrumentation, X-ray spectroscopic studies with Chandrayaan-2 XSM.

**Astronomy & Astrophysics:**

Active Galactic Nuclei (AGNs), multiwavelength studies from AstroSat, NuSTAR, XMM-Newton, X-ray bursts, High-Mass X-ray Binaries (HMXBs), Extreme Precision Radial Velocity (EPRV) Measurements using the high-resolution PARAS-2 spectrograph (R ~ 110,000) with the 2.5 m telescope at Mt. Abu Observatory, Development of next-generation X-ray instruments for astrophysical investigations with polarimetry, spectroscopy, and timing techniques.

**Atomic, Molecular, Optical Physics and High Energy:**

VUV photo-absorption spectroscopy and irradiation studies of astrochemical ices, High Intensity Shock Tube for Astrochemistry/Astrobiology (HISTA)

## Major Scientific Applications / Results

Over 500 peer reviewed scientific results have been obtained in the years 2024-2025 from PRL. A few salient are given below.

**Space and Atmospheric sciences**

- First direction-resolved observation of long-duration (~13 hours) particle energization during ICME-ICME interaction in the May-2024 solar event using Solar Wind Ion Spectrometer (SWIS) of ASPEX onboard Aditya-L1, suggesting important role of ICME-ICME interaction in altering geo-effectiveness. DOI: https://doi.org/10.3847/2041-8213/ae2ac9
- First experimental confirmation of isotropic distribution of suprathermal particles in the interplanetary medium during quiet periods — seed populations for Solar Energetic Particles — validating the theoretical framework of particle acceleration. DOI: https://doi.org/10.3847/1538-4357/ae1a46
- Investigated impacts of two super severe geomagnetic storms (May and October 2024) in the Indian sector, demonstrating the role of seasonal-dependent thermospheric winds and dominance of penetration and disturbance dynamo electric fields on ionospheric dynamics. DOI: https://doi.org/10.1029/2025JA034121
- By making use of high spectral resolution optical measurements in the daytime, the first ground-based measurements of daytime Stable Auroral Red arcs have been made and using forward model calculations electron temperature in the 200–650 km altitude range has been estimated to be in the range of 3500–4400 K. DOI: https://doi.org/10.1029/2023GL106292
- The latitudinal distribution of thermospheric NO infrared radiative cooling emission investigated for the two recent severe geomagnetic storms of solar cycle separated exactly by months (10–11 May, and 10–11 October 2024) revealed the significant

role of thermospheric wind in May and the solar energetic radiation (EUV) in October 2024. DOI: https://doi.org/10.1029/2024JA033559

- Atmospheric boundary layer characteristics during severe air pollution and fog events over Delhi studied using ground-based Lidar, satellites and models. DOI: https://doi.org/10.1016/j.atmosenv.2025.121684
- Investigation of excitation mechanism of the zonally symmetric semidiurnal tide (S0) during Sudden Stratospheric Warming showing non-linear interaction with dominant stationary planetary waves. https://www.nature.com/articles/s41598-024-72594-7
- Novel mechanism of interhemispheric coupling via planetary wave modulation observed during boreal summer 2019, where a quasi-2-day wave showed amplitude modulation with a 16-day period. https://www.nature.com/articles/s41598-025-09350-y

**Solar Physics**

- Propagation characteristics of acoustic waves in the quiet-Sun atmosphere using MAST (Multi-Application Solar Telescope) at PRL's Udaipur Solar Observatory show the important role of acoustic waves in heating the solar atmosphere, with frequency and height-dependent phase shift variations indicating non-evanescent nature of acoustic gravity waves beyond the photosphere. DOI: https://doi.org/10.3847/1538-4357/ad5d60
- Using the world's largest low-frequency radio array, PRL scientists estimated sizes and shapes of emission regions of low-frequency solar radio bursts, finding the smallest observable source sizes significantly smaller than previously reported, placing improved constraints on coronal density turbulence. DOI: https://doi.org/10.1051/0004-6361/202450402
- Coronal magnetic loops were traced from the corona to the photosphere, enabling estimation of the magnetic field and plasma-beta along entire magnetic loops. The magnetic field decreased rapidly from the photosphere (2000 G) to the corona (200 G), with plasma-beta <<1 throughout. DOI: https://doi.org/10.3847/2041-8213/ade9be
- Coronal Mass Ejections (CMEs) during heliospheric propagation often experience changes in direction, tilt, and structure due to solar wind interactions. A study of 15 Earth-impacting CMEs (2010–2018) observed by STEREO Heliospheric Imager found that about half followed self-similar expansion up to 40 solar radii, while rotation was relatively rare, aiding space weather forecasting. DOI: https://doi.org/10.3847/1538-4357/ad8e63
- Coordinated ground and space observations provided evidence that spicules can reach coronal temperatures and may play a significant role in replenishing the solar

corona with hot plasma, with strong redshifts in TR emissions resulting from upper atmosphere plasma flow reaching the chromosphere. DOI: https://doi.org/10.3847/1538-4357/ad50d5

- The Interplanetary Flux Rope Simulator (INFROS) was used to investigate six ICMEs observed by two radially aligned spacecraft. For isolated CMEs, INFROS outputs agreed well with in-situ observations, achieving 90% correlation between observed and predicted Bz profiles when constrained with inner-spacecraft observations. DOI: https://doi.org/10.3847/1538-4365/ad5835

**Planetary Sciences**

- First in-situ elemental abundance measurements of lunar soil at the south polar region using APXS onboard Chandrayaan-3 Pragyan rover at 23 locations, supporting the Lunar Magma Ocean hypothesis and detecting higher abundance of magnesium-rich minerals from deeper-layer material ejected during South Pole-Aitken basin formation. DOI: https://doi.org/10.1038/s41586-024-07870-7
- Theoretical studies showed that for certain dust-atmospheric conditions on Mars, electric fields within dust devil vortices can exceed the atmospheric breakdown value, potentially triggering lightning — with implications for lander and rover missions. DOI: https://doi.org/10.1063/5.0240977
- ChaSTE experiment onboard Chandrayaan-3 Vikram lander reported first-ever in-situ temperatures up to 10 cm depth at 69.37°S; 3D model calculations suggest high-latitude sites with slope >14° towards pole may accumulate water ice at shallow depths. DOI: https://doi.org/10.1038/s43247-025-02114-6
- First geological map of the Chandrayaan-3 landing area (Shiv Shakti point, estimated 3.7 Ga) using high-resolution remote sensing datasets; large rocks >5 m likely originated from a 540 m diameter crater 14 km south of the landing site. DOI: https://doi.org/10.1016/j.asr.2025.01.020
- Chandrayaan-3 landed within a buried impact crater (~160 km diameter, ~4.4 km depth), likely older than the South Pole-Aitken (SPA) basin, revealed from analysis of Navigation Camera and Chandrayaan-2 optical images. DOI: https://doi.org/10.1016/j.icarus.2024.116329
- Investigation of ancient chloride-rich basin Terra Sirenum on Mars found landforms and mineralogical evidence suggesting the area had chemicals supporting life, making it a relevant site to search for signs of past life. DOI: https://doi.org/10.1029/2024JE008311
- Study of lunar basaltic meteorite A-881757 provided insights into melting mechanisms in the lunar interior, suggesting it represents hidden cryptomare basalts and the need for more sample returns from unexplored lunar regions. DOI: https://doi.org/10.1111/maps.14257

- Meteorites successfully classified using reflectance spectroscopy and deep learning for the first time using RELAB (USA), C-TAPE (Canada), and PRSL (PRL) data. DOI: https://doi.org/10.1111/maps.14342
- Kopargaon chondrite fall (January 24, 2023) classified as LL5 with mineralogical characteristics aligning with Hayabusa mission asteroid Itokawa samples. DOI: https://doi.org/10.1007/s12040-024-02497-8

**Astronomy and Astrophysics:**

- Discovery and characterization of dense sub-Saturn exoplanet TOI-6651b using PARAS-2 and TESS: mass 61.0 ± 7.8 M⊕, radius 5.09 ± 0.27 R⊕, bulk density 2.52 ± 0.48 g/cm³, among the densest known sub-Saturns, with ~87% mass in a dense rocky/iron core near the edge of the Neptunian desert. DOI: https://doi.org/10.1051/0004-6361/202450934
- Discovery of sub-Saturn exoplanet TOI-6038 A b using PARAS-2 and TESS: mass 78.5 ± 9.7 M⊕, radius 6.41 ± 0.18 R⊕, ~74% mass in a dense core, lying near the transition between the Neptunian ridge and savanna, a promising target for atmospheric escape studies. DOI: https://doi.org/10.3847/1538-3881/ada959
- Discovery of Changing-look Behavior in AGN NGC 3822: A 17-year (2008–2025) multiwavelength study using Swift, XMM-Newton, NuSTAR, VLT, and HCT revealed CL transitions driven by changes in mass accretion rate rather than variable obscuration, confirmed by the appearance and disappearance of broad emission lines. DOI: https://doi.org/10.3847/1538-4357/ae10ae
- Long-term Study of Mrk 50: A 15-year (2007–2022) analysis using multiple X-ray telescopes showed a clear soft excess during 2007–2010 that gradually disappeared in later epochs, with both warm Comptonization and disk reflection explaining the observed behaviour. DOI: https://doi.org/10.3847/1538-4357/adabc0
- Photospheric Radius Expansion (PRE) thermonuclear bursts from neutron star LMXB 4U 1702-429 studied using NICER showed PRE with photospheric radius expanding up to 25 km and temperature dropping to 1.4 keV, enabling constraints on neutron star radius. DOI: https://doi.org/10.3847/1538-4357/adff51
- Multiple thermonuclear bursts were detected from neutron star LMXBs Aql X-1 and SRGA J144459.2-604207 using NICER, NuSTAR, XMM-Newton, and Swift. Broadband spectra revealed disk reflection features constraining disk geometry and magnetic field strength of ~10^8 G. DOI: https://doi.org/10.1016/j.jheap.2025.100387 | https://doi.org/10.1093/mnras/staf1207
- Long-term NICER study of Galactic Ultraluminous X-Ray Pulsar Swift J0243.6+6124 across outbursts (2017–2023) detected QPOs, spin-up during 2023 outburst, double luminosity transitions at ~7.5×10^37 and 2.1×10^38 erg/s, and soft

blackbody component indicating three distinct accretion modes. DOI: https://doi.org/10.3847/1538-4357/ad235d

- Optical and X-ray study of Be/X-ray binary IGR J06074+2205 combining long-term optical spectroscopy with NuSTAR and NICER observations revealed X-ray pulsations at ~374.6 s, a cyclotron absorption feature at ~50.7 keV (magnetic field ~5.7×10^12 G), and strong coupling between disc evolution and X-ray activity. DOI: https://doi.org/10.1093/mnras/stae2282
- JWST-ALMA study confirming a compact, early-stage hub-filament system (HFS) nurturing high-mass protostar G11P1, revealing gas streams driven by gravity and introducing a new observational signature of early HFSs: a wiggled, funnel-shaped structure in position-position-velocity space. DOI: https://doi.org/10.1051/0004-6361/202452189
- Multiwavelength multiscale study of Mon R2 hub-filament system revealing a spiral structure with ALMA observations of accreting filaments, a molecular ring (0.18 pc × 0.26 pc), and a mirrored B-shaped feature suggesting expansion at ~2.25 km/s, supporting a transition from IR-quiet to IR-bright driven by massive star feedback. DOI: https://doi.org/10.3847/1538-3881/ad9b22

**Atomic, Molecular and Optical Physics:**

- Shocks in the interstellar medium can convert non-magnetic interstellar dust into magnetic interstellar dust: ferrocene subjected to ~5.6 Mach shocks produced α-Fe and Fe3C composite responding to external magnetic fields, with implications for interstellar polarization. DOI: 10.1093/mnras/stac2637

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

### Solar Physics

- 50 cm aperture Multi-Application Solar Telescope (MAST) for high-resolution solar observations with back-end instruments: (a) Imaging spectropolarimeter, (b) Filtergraph, (c) Adaptive Optics, (d) Multi-slit spectropolarimeter (MSSP).
- Global Oscillation Network Group (GONG) telescope: PRL/USO is part of this international six-site global network for continuous full-disk solar observations dedicated to Helioseismology and Space Weather.
- e-Callisto Radio Telescope for acquiring radio emissions from the solar atmosphere during flares/transients.
- 15 cm aperture SPAR Telescope for full-disk solar imaging.
- Mirror coating system installed at USO/PRL by M/s HHV, Bangalore with two resistive evaporation and two e-beam evaporation sources, fully automated, capable of coating optics up to 700 mm diameter.

### Space Physics

- Aditya Solar wind Particle Experiment (ASPEX), one of the payloads on Aditya-L1 mission, has been developed in-house and consists of Solar Wind Ion Spectrometer (SWIS) and Supra-Thermal and Energetic Particle Spectrometer (STEPS). ASPEX is providing high quality data of particles in a wide energy range. The data have been released for public on 6 Jan 2025.
- Langmuir Probe to measure ionospheric plasma density and fluctuations, Drift Meter to measure ion drifts and major ion composition, and Airglow Photometer, all payloads planned for ISRO's dual satellite aeronomy mission DISHA (Disturbed and quiet time Ionosphere-thermosphere System at High Altitudes).

### Planetary Sciences

- Dust EXperiment (DEX): First Indian-made instrument to measure flux of Interplanetary Dust Particles (IDPs). A 3 kg dust detector based on hypervelocity principle, consuming only 4.5 W power, flown on PSLV-C58 XPoSat mission (January 1, 2024) at 350 km altitude.
- Venus Radiation environment monitor (VeRad) to fly on Indian Venus Orbiter Mission, studying the impact of supra-thermal and high energy solar energetic particles on Venus atmosphere and nightside ionosphere.
- PRATHIMA Payload to fly on Chandrayaan-5 mission under the Lunar Polar Exploration (LUPEX) programme.
- PRISM Payload to fly on Chandrayaan-5 mission under the Lunar Polar Exploration (LUPEX) programme.

## Capacity Building in Space Science Research

- Ph.D. Awarded: 42
- Summer Internship Programs: 113 students
- Project Training Programs for Science and Engineering Students: 262 students
- PRL hosted Basic Training on 'Space Weather and its Impacts' to employees of Defense Space Agency September 15–26, 2025.

PRL hosted 4$^{th}$ Indian Space Weather Conference during 27 – 28 January 2026.

- Vikram Discussions 1 — Astrobiology and Astrochemistry — January 2024.
- Vikram Discussions 2 — Astrobiology and Astrochemistry — January 2025.
- ISRO Structured Training Program on 'Evolution of Inner Solar System: Remote Sensing Data Analysis and Instruments for Space Missions', November 10–14, 2025, PRL Ahmedabad.
- Karyashala – a workshop on Meteoritics, PRL Ahmedabad, November 18–19, 2024, attended by 50 students.
- Online CSSTEAP Short Course on 'Planetary Science', September 9–13, 2024, 100 students participated.

• CSSTEAP Short Course on Solar Physics and Planetary Science, June 6–20, 2025 (online), attended by 100 students.

## Courses Offered on Space Science and Technology

| Title of Course Offered | Level |
|---|---|
| Solar Interior and Atmosphere | PhD |
| Solar Magnetohydrodynamics | PhD |
| The Active Sun and Space Weather | PhD |
| Solar Instrumentation Techniques | PhD |
| Upper Atmosphere, Ionosphere and Space Weather | PhD |
| Physicochemical Processes of Trace Gases, Aerosols and Atmospheric Radiative Transfer | PhD |
| Dynamical, Chemical and Coupling Processes in the Earth's Atmosphere | PhD |
| Fundamentals of Atmospheres and Climate | PhD |
| Tools and Techniques in Experimental Methods | PhD |
| Remote Sensing: Basics & Applications | PhD |
| Basics of Solar Physics | PhD |
| Solar Internal Structure and Dynamics / Helioseismology | PhD |
| Radiative Transfer and Stellar Astrophysics | PhD |
| Astronomical Instrumentation and Fundamental Astronomy | PhD |
| Galactic and Extragalactic Astronomy | PhD |
| Star Formation and Star Clusters | PhD |

• 3rd Workshop on Space Weather Science and Opportunities (SWSO-3) for ~200 PG students from 100+ academic institutions, January 27–28, 2026 (Hybrid mode).

• Faculty actively teaches in the 14th Space and Atmospheric Sciences (SAS) course, 2025–2026, and short course on 'Earth's Atmosphere and Climate Change' at PRL under CSSTEAP (UN course).

## Laboratories and Facilities Available for Space Instrumentation

• ASPEX (Aditya-L1) Payload Operation Centre (POC): Dedicated facility for monitoring and operating the ASPEX instrument onboard India's Aditya-L1 mission.

• Spectrophotometer for spectral calibration of interference filters used in optical instruments.

• Integrating sphere for radiance calibration of optical instruments.

• Electronics and sensor development laboratories for space payload design and testing.

• Software laboratory for analysis of remote sensing data from space missions.

• Payload Operation Centre (POC) for space mission operations.

• Remote Sensing Laboratory for analysis of spectra from extraterrestrial samples.

• 50 cm MAST telescope with high-resolution back-end instrumentation including adaptive optics, imaging spectropolarimeter, and multi-slit spectropolarimeter.

• Mirror coating system capable of depositing protective and enhanced coatings on optics up to 700 mm diameter, with resistive and e-beam evaporation sources in a high-vacuum system.

• Mechanical workshop, Computer Center, and library facilities supporting instrument development and observations.

For further details on the inputs as provided in the document, please contact Prof. Anil Bhardwaj, Director, Physical Research Laboratory, Ahmedabad. Email: director@prl.res.in.

# SPACE APPLICATIONS CENTRE, ISRO AHMEDABAD, INDIA

https://sac.gov.in

## About Space Applications Centre (SAC)

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. Subsequently, 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

- Planetary Science
- Exoplanet studies
- Multi wavelength astronomy
- MagnetoHydroDynamics simulation studies
- Ionospheric Studies

## Major Scientific Applications / Results

### Terahertz Telescope Site Characterization:

Meteorological parameters play very crucial role to characterize a site and observation planning. To fulfil this need, a comprehensive analysis is done with historical and projected long-term trends (1975 onwards) of meteorological parameters over 9 Indian astronomical observation sites (including Hanle) using ERA5 and CMIP6 model datasets. Statistically significant increase in columnar water vapour is trend is observed for Hanle based on CMIP6 data (Figure 1). To streamline and support the observation plan from Hanle, a source visibility calculator for observations for Hanle is developed that incorporates azimuthal variation of obstruction by surrounding mountains. The algorithm returns altitude and azimuth information for any user defined source and time.

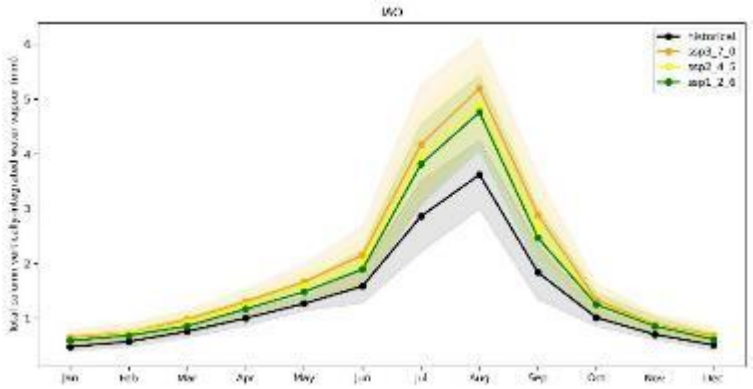

*Figure 1: Projected columnar water vapour variation at Hanle for different climate scenarios.*

Detailed theoretical modelling study was carried out for simulating observations for the SAC-ISRO's proposed THz telescope considering varying atmospheric water vapour (Ref: *Chauhan et al. ISRO-SAC-TR-2026-181*) and instrument noise using archival observations from existing sub-mm telescopes such as JCMT, APEX etc (Figure 2).

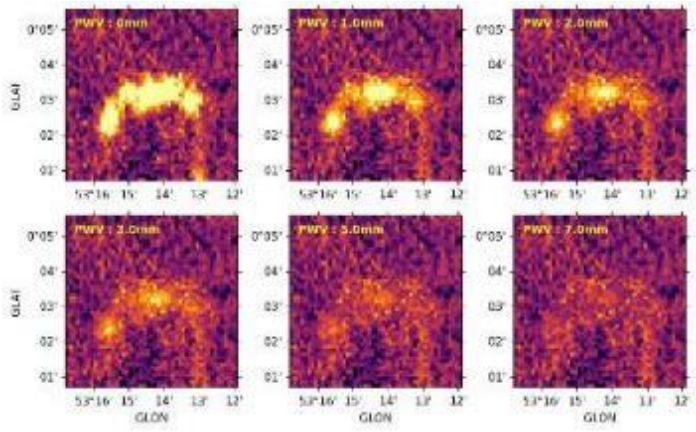


*Figure 2: Simulated impact of water vapour on sub-mm observations for AGAL053.239+00.052.*

**Filament, hub filament system identification and its Characterization:**

Terahertz (THz) astronomy can answer some of the most profound questions related to the cold components of the Universe on scales of galaxies, molecular clouds, star and planets. Precursor studies using multi-wavelength studies using observations from global sub-mm telescopes.

THz observations from Herschel Space Observatory show ubiquitous presence of thread-like filamentary structures in SFR – Stars collapse is driven by filamentary structures. A parameter free, instrument agnostic model (AI/ML, statistical methods) for an automated identification of filaments has been developed. A U-Net model based algorithm (SUTRA) is developed for automated filament identification. The model is trained on DisPerSE and getsf skeleton. Furthermore, an algorithm is developed for extraction of filament physical properties from radial profile and comparative study done on Aquila, Polaris and Orion (Ref: *Kumaran et al. 2026, under review, ApJ*). An example of extracted filament is shown in Figure 3.

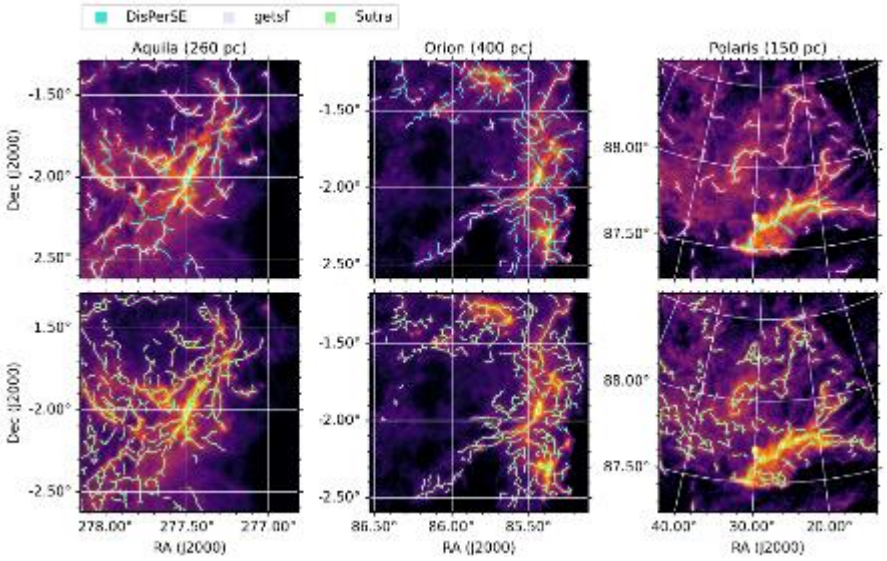


*Figure 3: FIlament skeleton map shown over NH2 column density maps from cutout from 3 fields in HOBYS survey*

H2 column density (N(H2)) maps were generated for the Hi-Gal survey of Herschel consisting of 166 tiles covering the entire Galactic plane. Further, the skeletonization of filaments in these maps was optimized by measuring the similarity between skeleton & probability maps using Structural Similarity Index Matrix (SSIM).

*Figure 4: Mosaic of H2 column density maps for ~ 358o < Gal long(l) < 10.5o and -1.3o < Gal lat(b) < 1.3o (5 tiles).*

Hub-Filament systems (HFSs) are important sites of star formation. Multiple such candidates were analysed and identified across the Galactic plane from images taken by Herschel in FIR and THz wavelengths. The present state-of-art HFS catalogue (MSN Kumar et al. 2020) was also aggregated, investigated & compared with detailed star formation studies of multiple HFSs. A preliminary study is carried out to demonstrate the use of Grad-CAM for dense core localization in the Column density map as shown in Figure 4.

**Multi wavelength astronomy:**

G339.467+0.083 was investigated at multiple wavelengths viz. MIR, FIR, THz. The filaments in the HFS were identified using multiple methods: DisPerse, FilFinder, Getsf,

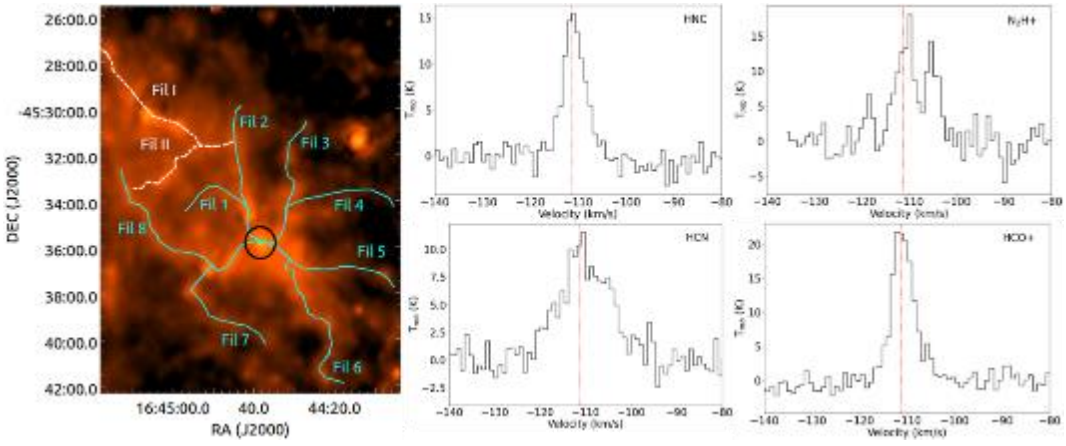


*Figure 5: Left: H2 column density map estimated from cold dust emission overlaid with identified filaments. The hub is shown as a black circle. Right: Molecular line spectra observed towards the hub.*

Sutra on Herschel's FIR/THz images and APEX & Mopra telescopes' CO emission maps. The physical and kinematic properties of the filaments such as their lengths, masses,

velocity and dispersion trends were estimated and studied and inferences were made on the physical processes ongoing in the Hub-filament system. Cold dust clumps in the HFS were also identified through dendrogram based methods and their physical properties were estimated using N(H2) maps. Various star formation tracers were observed towards the hub using archival spectral data from multiple surveys (SEDIGISM, ThrUMMS, MALT90). (**Error! Reference source not found.**).

In addition to HFS, multi wavelength features were used for X-ray source classification. A work has been carried out to study the features and their relations **responsible for** individual source's classification using SHAP analysis. (Ref: *Kumaran, S et al. ApJ , DOI : 10.3847/1538-4357/ae1a45*). (Figure 6).

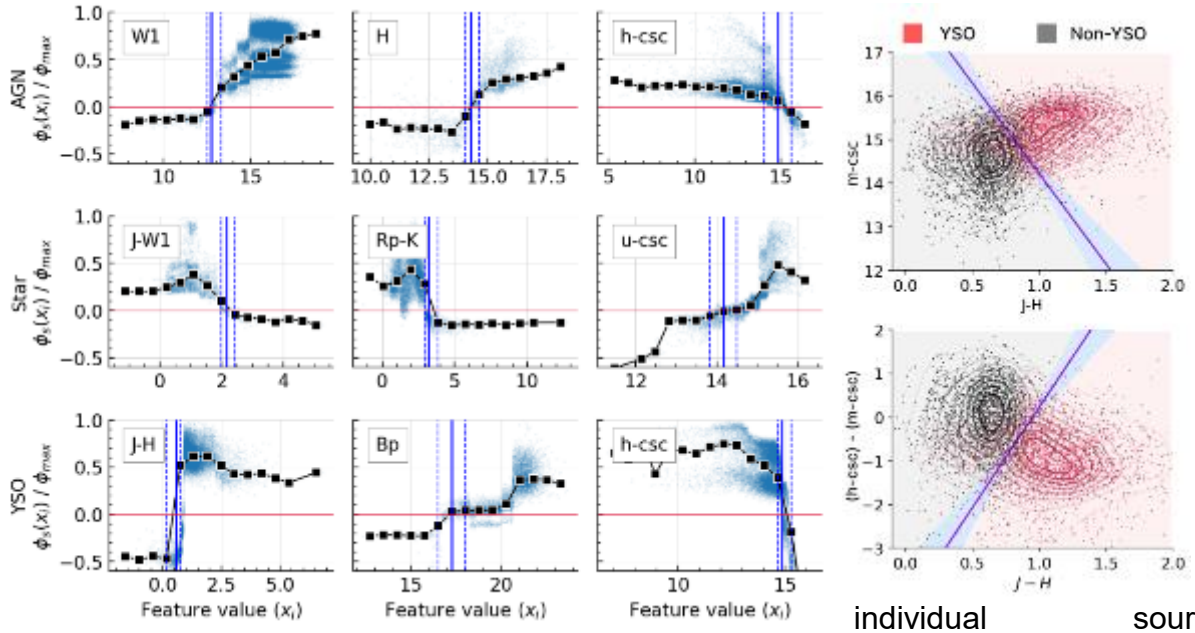


*Figure 6: Relation of MW features magnitudes and their importance in classification for AGN, Stars and YSOs (left) and decision boundary for YSO.*

**MagnetoHydroDynamics (MHD) based numerical experiments:**

RAMSES a three-dimensional MHD adaptive mesh refinement (AMR) code was setup on HPC in SAC. The installed model was systematically and comprehensively tested (Ref: *Gharote et al. ISRO-SAC-TR-2025-136*). Model parameters for merger of filaments was finalized, velocity of approach and angle of merger were left as free parameters for study. A preliminary analysis on formation of over-dense structures due to merger over varied velocities of approach was completed and it showed that higher velocities of approach are more effective in creating over-dense regions. The left panel of Figure 7 is a representative scenario of the initial condition for the merging of two filaments. The contours in the middle

panel show the extracted over-dense regions and thus represents an ongoing merger. The right most panel represents the evolution of peak density within each simulation output over time for various approach speeds.

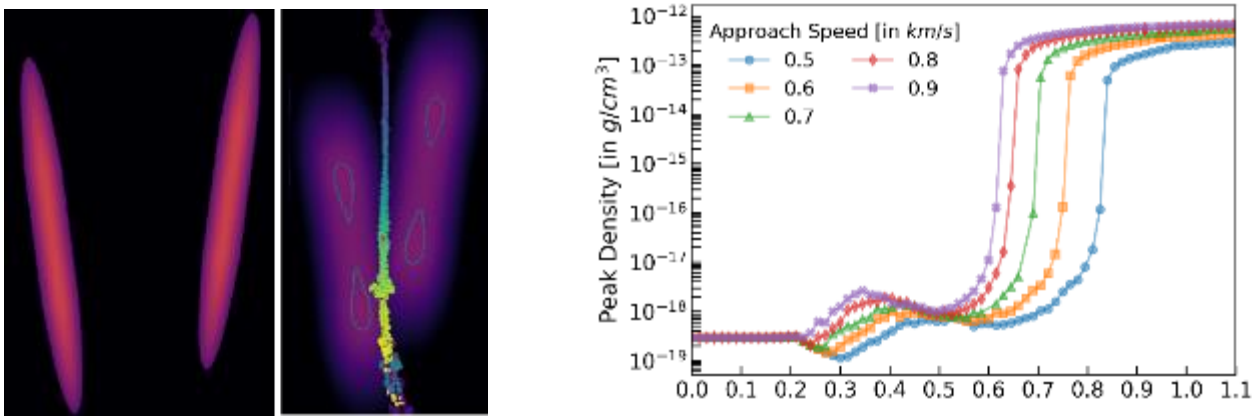


*Figure 7: (left) Representative figure for the initial condition of merger; (middle) Figure representing an ongoing merger, the contours in the figure show the*

**Lightcurve Inversion and R&D activities related to exoplanets:**

A methodology is developed to generate a synthetic training data of diverse shapes and lightcurves using bezier curves and Yuti (Ref: *Bhowmick & Kumaran, Accepted, The Open Journal of Astrophysics*). This training data is used to develop a CNN-based ML models to predict the elliptical components of the transiting shape with simulated lightcurve as input. This study demonstrated the capability of methodology of lightcurve inversion to obtain information of transiting geometries which is useful for future transit photometry missions.

Figure *8* shows various arbitrary shapes and their reconstructed shapes used in the study for the transit curve inversion.

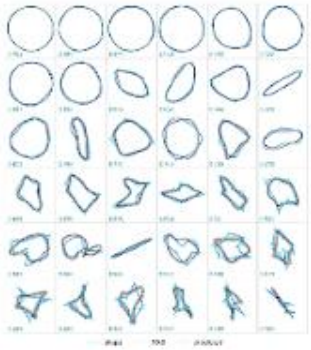

*Figure 8: Examples of simulated arbitrary shapes and their reconstructed shapes. The reconstructed shapes are generated using elliptical Fourier parameters predicted by neural network from transit lightcurve input.*

Significant efforts have been put to Set-up and testing of Instrument-level simulation models: JWST Pandeia, Ariel ExoRad as a precursor study for the ISRO's proposed *ExoWorlds* mission (Ref: *Bhowmick et. al. 2025, LPSC-2025*). A step in this direction is taken by computing noisy transmission spectra scaled to *ExoWorlds* configuration. A study pertaining to extension of photometric analysis to all confirmed exoplanets in Exoplanet Archive is undertaken. Figure 9 shows the statistics of observable exoplanets with number of transits. Figure 10 shows the comparative analysis of SNR simulations done using ExoRad and Pandia software.

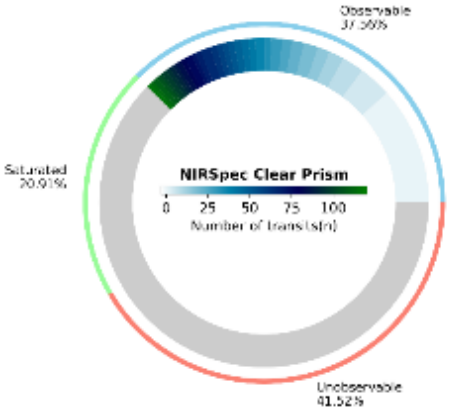


*Figure 9: Statistics of observable exoplanets with NIRSpec Prism (integration time 0.226 s).*

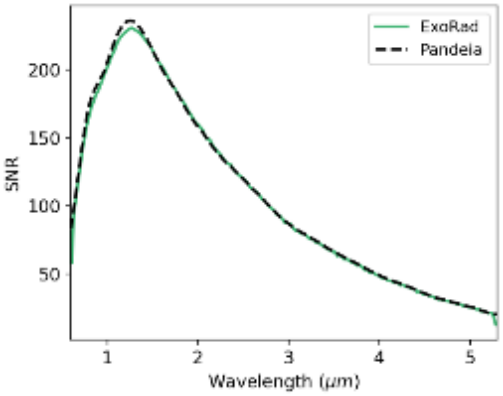


*Figure 10: Comparison of SNR simulations using ExoRad and Pandeia.*

**Simulation of shadows for naked singularity and blackhole spacetimes using relativistic ray tracing:**

A Python based framework is developed to generate shadow intensity profiles and maps for Schwarzschild black holes and JMN-1 naked singularities with optically thin Bondi accretion (Ref: *Patel et al. ISRO-SAC-TR-2025-125*). Since the shadow properties are influenced by both the accretion model and space time geometry of the ultra-compact object, therefore, to understand the effect of accretion physics and underlying space time geometry on shadow properties, particularly shadow intensity profile, three different emissivity models were used to construct the Schwarzschild black hole and JMN-1 naked

singularity undergoing spherical accretion. Figure  shows the simulated shadow images of of Schwarzschild black hole with coarser and high resolution.

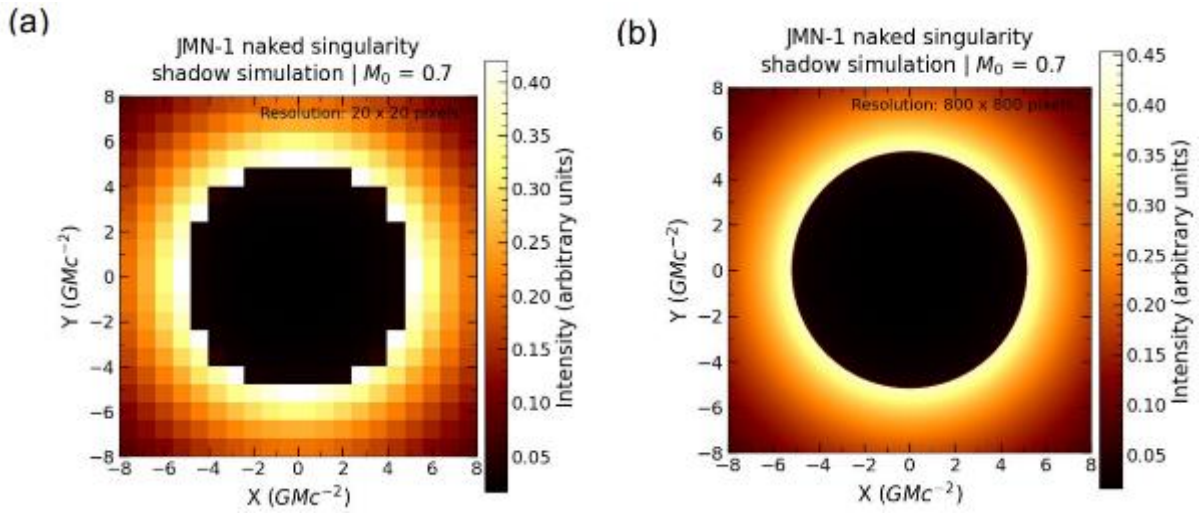


*Figure 10: Schwarzschild black hole shadow with (a) coarser resolution of 20 x 20 pixels and (b) higher resolution of 800 x 800 pixels.*

## 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

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

## About Space Physics Laboratory

Space Physics Laboratory (SPL) at Vikram Sarabhai Space Centre, ISRO is a leading centre for research in atmospheric, space, and planetary sciences. It integrates space-borne and ground-based observations with theoretical and modelling approaches to advance understanding of the Earth–atmosphere system, Sun–Earth interactions, and planetary environments. Through well-structured scientific programmes, SPL contributes to the long-term vision of ISRO while addressing key scientific and societal challenges. A major strength of SPL is its end-to-end capability in developing scientific payloads and experimental systems, from conceptual design to deployment, in close collaboration with other VSSC units. The laboratory has also established strong academic partnerships with universities and national research institutions, enabling nationwide ground-based observational networks and coordinated field campaigns across India. These efforts focus on important issues related to weather, climate, and space weather. SPL has expanded its collaborations both nationally and internationally, strengthening research in atmospheric and planetary sciences. Within India, it partners with over forty institutions to operate extensive observational systems and conducts multi-institutional experiments using balloon-borne and ship-based platforms. In addition to research, SPL plays a key operational role as part of ISRO's Inter-Centre Weather Forecasting Expert Team, providing short-range forecasts to support launch operations from Satish Dhawan Space Centre. Senior scientists also contribute to academic and research programmes through

advisory roles. Overall, SPL continues to evolve as a dynamic institution addressing emerging scientific challenges and societal needs.

## Major Research Domains

Our vision is the scientific understanding of the energetics, dynamics and chemistry of the terrestrial and planetary environments, and implications to the society. The vision is achieved through various research themes through scientific domains such as:

**Atmospheric Dynamics Branch** investigates atmospheric motion and vertical coupling from the troposphere to lower thermosphere, focusing on waves, variability (from gravity waves to solar cycle), stratosphere–troposphere exchange, and large-scale circulation using ground- and space-based observations.

**Aerosol, Trace gases and Radiative Forcing Branch** investigates aerosols and trace gases and their radiative interactions affecting climate. It develops spatiotemporal databases from satellite and ground observations, conducts field campaigns, and integrates data with regional climate models to assess impacts on climate.

**Ionosphere Thermosphere and Magnetosphere Physics Branch** investigates the energetics and dynamics of the upper atmosphere. Research focuses on space weather impacts on the magnetosphere–ionosphere–thermosphere system, vertical coupling with the lower atmosphere, and development of thermosphere–ionosphere models. Studies use indigenous ground, rocket, and space-based experiments and extend to planetary atmospheres.

**Microwave and Boundary Layer Physics Branch** studies atmospheric boundary layer structure, dynamics, surface interactions, and coupling with the free troposphere, clouds, convection, and precipitation, using space- and ground-based microwave remote sensing to retrieve surface properties, water vapour, cloud, and precipitation characteristics.

**Numerical Atmosphere Modelling Branch** studies atmospheric physical and chemical processes using numerical models, including general circulation, weather prediction, climate, transport models, and large eddy simulations, while providing real-time short-range forecasts for ISRO launch operations.

**Planetary Science Branch** studies the Sun, planets, moons, and comets through modelling and experiments, focusing on solar wind interactions, radiation effects, and atmospheric processes, while developing payloads to measure plasma, magnetic fields, and atmospheric constituents.

**Atmosphere Technology Division** develops experimental systems for atmospheric, space, and planetary research, designing and deploying balloon-, rocket-, and space-borne payloads, building ground-based instruments, maintaining facilities, and supporting SPL scientific programmes through collaboration.

## Major Scientific Applications/ Results

### Retrieval of Aerosol Optical Depth and Dust from Indian Satellites

Satellite observations are vital for assessing aerosol impacts on climate. OCM-3 is used to retrieve aerosol optical depth ($\tau_{555}$) at 366 m resolution that showed higher coastal values. Validation at Hanimaadhoo showed r = 0.85. Comparison with MODIS Aqua shows strong agreement; uncertainty is $\varepsilon\tau = 0.1\tau + 0.02$ (Figure 2a). High-frequency aerosol monitoring is achieved using INSAT-3DR AOD retrievals via an XGBoost-based framework. Trained with fused MODIS and ground data (ARFINET, AERONET), the model shows strong agreement (r = 0.955). INSAT-3DR AOD performs well (r ≈ 0.839), capturing sub-hourly variability and regional aerosol hotspots (Figure 2b). Geostationary INSAT-3D observations are used to study dust aerosols via the Infrared Difference Dust Index (IDDI). May 2018 storms show widespread dust over India (Figure 2c).

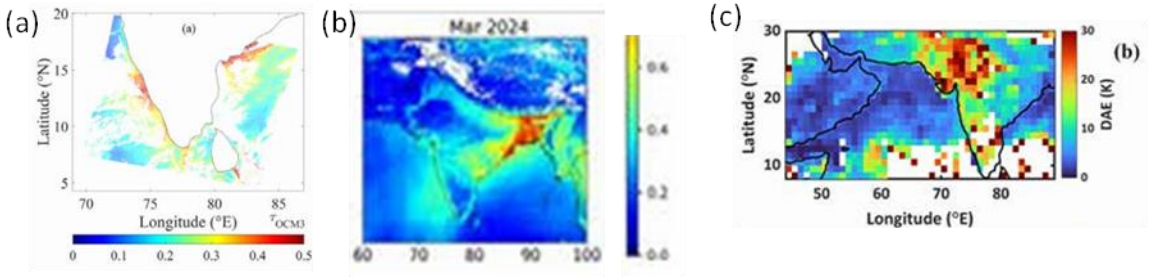


*Figure 1a) Retrieved AOD at 555 nm from EOS-06/OCM-3 on March 04, 2024 [Prijith et al., IEEE Geosci. Remote Sens. Lett., 2024]. (b) variation of AOD from INSAT-3DR [Tandule et al., Atmos. Environ., 2026] and (c) Dust Absorption Efficiency estimated from INSAT-3D from 07th to 09th May, 2018 [Lima et al., Int. J. Remote Sens., 2024].*

### Chemical characterisation of Aerosols at SPL

Black carbon (BC) aging enhances absorption and hygroscopicity. Measurements at Thumba (2018–2021) using laser-induced incandescence show BC core diameters of 181–202 nm with coatings (RCT ≈ 1.3–1.6), highest in polluted continental air. Photochemistry and humidity drive coating formation. Absorption enhancement rises from 1.36 (marine) to 1.58 (continental), indicating stronger warming (Figure 2a and b). Secondary organic aerosol formation at Thumba was studied during pre-monsoon sea- and land-breeze phases. $PM_{10}$ analysis shows oxalic acid dominance, higher photochemical activity during sea breeze, and enhanced aqueous-phase SOA during land breeze. ISORROPIA II indicates higher aerosol water content under land-breeze, influenced by anthropogenic emissions like plastic burning (Figure 2c).

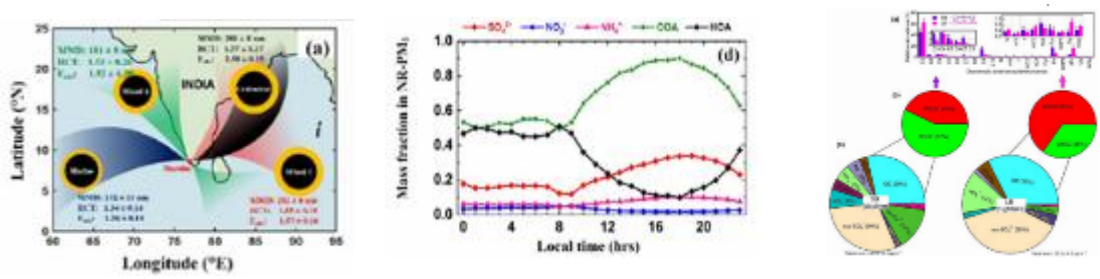


*Figure 2. A summary of BC microphysical characteristics (MMD -mass median diameter, RCT-relative coating thickness, and Eabs –light-absorption enhancement factor) over Thumba, (b) diurnal pattern of non-refractory submicron aerosol species that are potential coating species for BC [Nithin et al., Atmos. Res. 2026]. (c) Relative abundances (%) in (a) molecular distributions of water-soluble organic compounds (d) water-soluble and water-insoluble organic carbon, and (e) chemical composition during SB and LB circulations at Thumba during premonsoon [Boreddy et al. ACS Earth Space Chem., 2025].*

### Characteristics of Monsoon Convection: Insights from ISRO Radar Observations

Monsoon convective storms over Kerala were analyzed using C-band radar (2017–2023). About 60–70% of intense storms occur in southwest and northeast sectors, with stronger convection toward the coast. The **35 dBZ storm-top heights exceed 14 km** over inland regions. Congestus dominate (**60%**), followed by deep (**39%**) and overshooting storms (**1%**). The diurnal cycle (**Figure 3**) shows a peak over land at **14:00–15:00 LT** and 04:00-05:00 LT, 14:00-15:00 LT, and a small peak at 22:00 LT over the oceans. The peak over the land and ocean is associated with deep convection and congestus respectively. The monsoon convection is mainly driven by a moist mid-troposphere and positive moisture convergence.

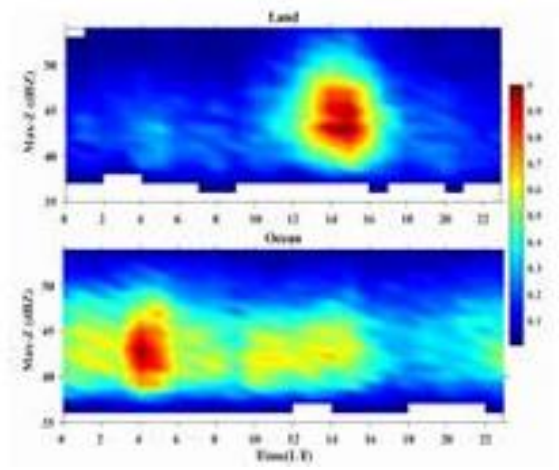


*Figure 3(a) Diurnal variability of Max-Z over (a) land and (b) Ocean. (Uma and Sama, 2025, Climate Dynamics)*

**Radiative effects of deep convective cloud cores using SAPHIR & ScaRaB onboard Megha-Tropiques satellite**

Clouds significantly influence Earth's radiation budget by trapping outgoing long-wave radiation and reflecting incoming solar radiation. Using Megha-Tropiques observations (2012–2018), deep convective cloud cores are classified by vertical extent. They produce longwave warming of 160–180 W $m^{-2}$ and daytime shortwave cooling of −250 to −650 W $m^{-2}$, leading to strong net cooling during the day and moderate warming at night (Figure 5).

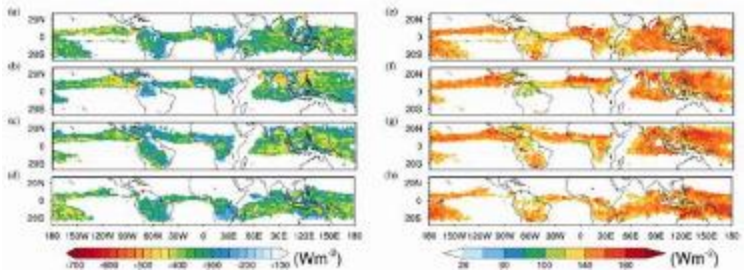

*Figure 4. Seasonal variation of NREC during (a-d) day time and (e-h) night time for March–May, June–August, September–November and December–February seasons during 2012–2018 [Sisma et al., Atmos. Res., 2024]*

## Atmospheric Dynamics

The effect of BDC on stratospheric radiative forcing, the long-term climatic impact of Hadley cell expansion and its role in Earth's radiation budget and the role of deep convection and dynamics on the upper tropospheric/lower stratospheric tracer distribution during active and break monsoon periods are some of the important aspects addressed.

**The teleconnection between Brewer–Dobson Circulation (BDC) and Quasi–Biennial Oscillation (QBO): Implications on ozone and water vapor distribution**

The BDC plays a crucial role in regulating the transport of ozone, water vapor as well as the trace gases between the troposphere and stratosphere. An analysis of 43 years of reanalysis and satellite data reveals that the Brewer–Dobson Circulation strengthens during the westward phase of the Quasi–Biennial Oscillation, particularly in the Northern Hemisphere, influencing ozone and water vapor distributions and causing measurable variations in stratospheric radiative forcing (Figure 5: left panels).

**Impact of Hadley Circulation Expansion on the Distribution of low-level Clouds over its Descending Limbs**

The consequences of Hadley Circulation (HC) expansion on the distribution of subtropical marine stratocumulus clouds (SC) are investigated (Figure 5: middle panels). The analysis of ERA5 reanalysis data (1981–2021) reveals that the poleward expansion of the Hadley circulation caused a corresponding poleward migration of subtropical marine stratocumulus clouds over the northeast Pacific, southeast Pacific and southeast Atlantic,

providing new insights into the long-term climatic impacts of Hadley cell expansion on low-level cloud distribution and its crucial role in regulating Earth's radiation budget.

**Role of Deep Convection and Dynamics on the Tracer Distribution in the Upper Troposphere and Lower Stratosphere Region during Active/ Break Phases of Monsoon**

A comprehensive study on the role of deep convection and dynamics on the tracer distribution during active and break monsoon periods provided new insights into the troposphere-stratosphere exchange processes . The study indicates that the dynamics of the Asian Summer Monsoon Anticyclone (ASMA) modes exhibit a strong day-to-day variability within the active/break phase, causing the tracer and dynamic fields to change accordingly, more so near the tropopause level (Figure 5: right panels).

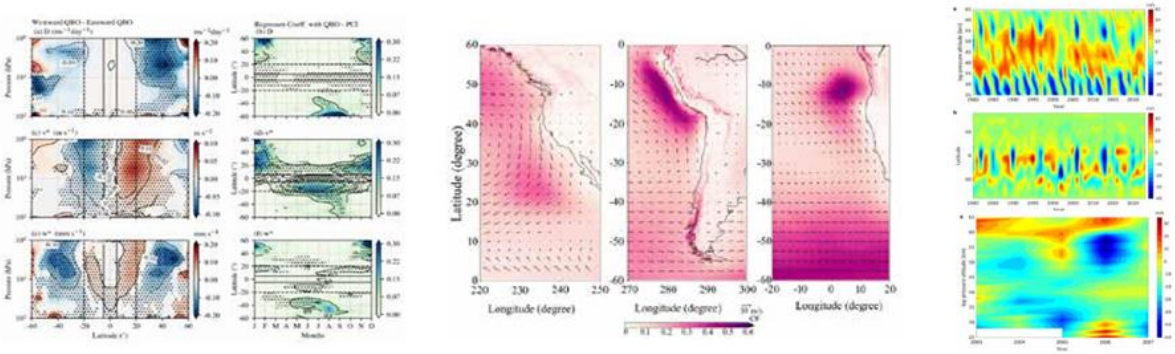


*Figure 5.* ***Left panels****: The composite differences between westward QBO and Eastward QBO for a deseasonalized wave driving, D, (a), residual meridional velocity, v* (c) and residual vertical velocity, w* (e) along with the normalized regression coefficient of the respective variables (b, d, and e) with the first principal component of QBO [Veenus and Das, Clim. Dyn., 2025];* ***Middle panels****: The regional maps of cloud fraction over the study regions along with the background winds at 925 hPa level during their respective peak seasons [Anjana and Kumar, Theor. Appl. Climatol.,2025];* ***Right panels****: Yearly zonal mean zonal winds over the equator for the month of June; (b) Temporal anomalies of zonal mean winds at 0.4 hPa from MERRA-2. (c) Yearly zonal winds in the 25–65 km region measured using rocketsondes over Thumba [Satheesh and Sunilkumar, Clim. Dyn., 2024]*

## Space Science

The influence of altered electrodynamics and neutral dynamics during severe space weather events are addressed using observational and modeling approaches. Some of the important results are given below.

**Unique Signatures of meridional wind variations on the electron density distribution over the dip equator during May 2024 Gannon Superstorm**

The unusual enhancement and undulations in Vertical Total Electron Content(VTEC) during the extreme G5 geomagnetic stormon 11 May2024 over a dip equatorial station in

India,Trivandrum is investigated using an in-house developed physics-based equatorial/low latitude ionospheric model. The electron density profile for the combined Prompt Penetration Electric Field-driven vertical drift and storm-time meridional winds during the 11 May 2024 superstorm is simulated. This study demonstrates the influence of electrodynamics and neutral dynamics in shaping ionospheric responses to severe storms over the Indian dip equatorial region (Figure 6: left panel).

**Rapid Reversal of Hemispheric Asymmetry in the Intensity of EIA Crests During the Geomagnetic Storm of 23 April 2023:A Unique Observation from GOLD satellite**

Using the Global-scale peak electron density (Ne) Observations of the Limb and Disk (GOLD) satellite, the rapid reversal of the intensity of the Equatorial Ionization Anomaly (EIA)crests between the hemispheres during the main phase of 23 April 2023, geomagnetic storm is reported. The Prompt Penetration Electric Field amplified the intensity of both EIA crests while the Thermosphere Ionosphere Electrodynamics General Circulation Model simulations indicated that trans-equatorial wind also played a key role in these variations (Figure 6: middle panel).

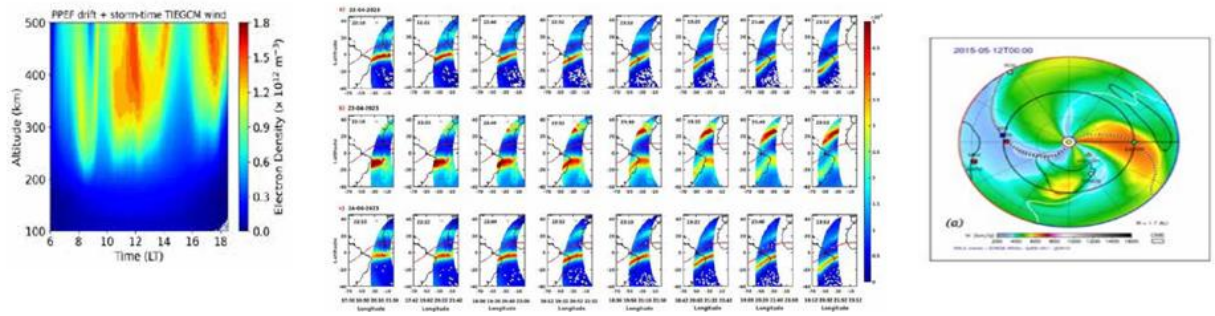


*Figure 6:* ***Left panel****: Simulated electron density profile for the combined Prompt Penetration Electric Field-driven vertical drift and storm-time meridional winds during the 11 May 2024 superstorm [Ashok et al., Geophys. Res. Lett., 2025];* ***Middle panels*** *: Spatio-temporal variation of $N_{max}$ (electrons/cm$^3$) from GOLD observations on (a) 22nd April 2023 22:10 UT to 23:52 UT (b) 23rd April 2023 22:10 UT to 23:52 UT, (c) 24th April 2023 22:10 UT to 23:52 UT [Shimna et al., Geophys. Res. Lett., 2025];* ***Right panel****: Mars, Sun and Earth position in the space during 2015 Mars-Solar Conjunction as seen from the WSA-EnLIL synoptic maps. The background color denotes the velocity of prevailing solar wind derived from WSA-EnLIL model [Richa et al., Mon.Not. R. Astron. Soc., 2024]*

**Impact of the High-Speed Solar Wind stream over the low latitude Ionospheric system - A Study combining Indian MOM and InSWIM observations**

The origin, acceleration, and propagation of the High Speed Solar wind streams (HSS) and their impact on the low-latitude Earth's ionosphere is studied (Figure 6: right panel). The uniqueness of this study is that it connects the propagation of the HSS and its impact

on Near -Earth's environment from the different vantage points in interplanetary space and proposes the application of Radio beacons to improve space weather forecasting.

**PLANETARY SCIENCES:**

**Lunar Surface, Exosphere, and Ionosphere: Results from Chandrayaan-2 & 3 missions**

ChaSTE payload on Chandrayaan-3 made the first in-situ estimation of thermal conductivity of lunar regolith at southern high-latitude. The thermal conductivity of lunar regolith were estimated to be in the range of 0.0115 W $m^{-1}$ $K^{-1}$ and 0.0124 W $m^{-1}$ $K^{-1}$, with uncertainties of 0.0008 W $m^{-1}$ $K^{-1}$ and 0.0009 W $m^{-1}$ $K^{-1}$, respectively (Figure 7a). Further, the daytime temperature variations of lunar regolith with depth exhibits a systematic phase delay in the peaking of the temperature and the phase delay information was used to determine the diffusivity, which was found to be in the range of $0.53 \times 10^{-8}$ - $0.903 \times 10^{-8}$ $m^2s^{-1}$, and thermal properties of the regolith (Figure 7b). From the force required for the penetration of the thermal probe into the regolith,theaverage packing density of the regolith within adepth of ~140 mm was estimated to be 1940 ±10$kgm^{-3}$ [Mathew et al., Adv. Space Res., 2025]. Regarding the exosphere, CHACE-2payload on Chandrayaan-2 orbiter provided the first observational confirmation of the enhancement in lunar exospheric densities during an extreme space weather event (NOAA G5 class) that impacted the Moon on 10 May 2024 (Figure 7c). The total number densities showed an enhancement by more than an order of magnitude, which is consistent with the model results, explained by the enhanced solar wind ion sputter process. In near surface plasma environment, RAMBHA-LP payload on Chandrayaan-3 lander, revealed daytime electron densities of 300–650 $cm^{-3}$ and electron temperatures of 3000–8000 K (Figure 7d). The observations in association with lunar ionospheric model simulations reveals the role of charge exchange related production of ionization in modulating the temporal variation of lunar ionosphere.The two-way radio occultation experiment (RAMBHA-DFRS) from Chandrayaan-2 orbiter, provided for the first time the electron density profile of the lunar ionosphere when the Moon is inside the geomagnetic tail region. The electron density was found to be ~ $2.5 \times 10^4$ $cm^{-3}$ close to the surface of the Moon (~2 km altitude). 3-D lunar ionospheric model simulations showed that such high plasma density is possible inside the geomagnetic tail only in the presence of lunar crustal magnetic fields (Figure 7e).

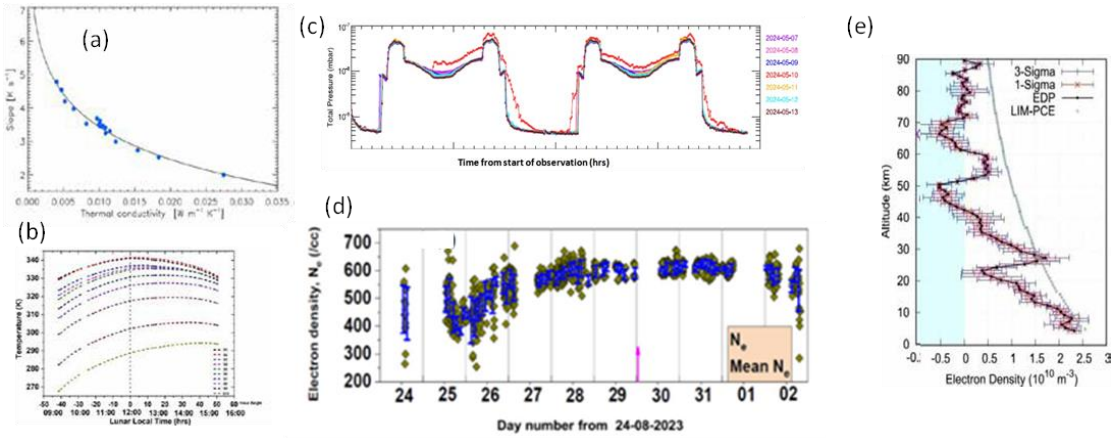


*Figure 7. (a) Variation of thermal conductivity with slope for different self-heating curves of ChaSTE lab experiments [Mathew et al., Sci. Rep., 2025], (b) Daytime variations of lunar regolith temperature at different depths [Renju et al., Mon. Not. R. Astron. Soc., 2025], (c) Time series of the total pressure observed by CHACE-2, from 07 to 13 May 2024, shown in different colors [Dhanya et al., Geophys. Res. Lett., 2025], (d)Temporal variations of electron density (Ne) and its 2 hourly mean from RAMBHA-LP [Manju et al,. Mon. Not. R. Astron. Soc., 2025], (e) Electron density profile (EDP) from the observations on 2022 November 8 at 18:00 UTC. The area shaded in cyan has negative electron density, which stands for noise. The gray-colored profile represents the lunar ionospheric model (LIM) output, and PCE stands for photochemical equilibrium. [Thripathi et al., Astrophys. J. Lett., 2025].*

**Modeling Studies of Planetary Plasma Environments:**

**Electrostatic solitary waves (ESW) in Ganymede's magnetopause and wake**

Multi-component fluid plasma models, consisting of with warm $H^+$, $O^+$, and $H_3^+$ ions along with suprathermal electrons, are employed to investigate the generation and characteristics of ESWs observed in the wake and near the magnetopause boundary of Ganymede. The number density and temperature of $H_3^+$ ions are found to play a decisive role in the existence of ESWs and double layers in the wake. At the magnetopause, an asymmetric electron beam, with differing number densities and drift velocities, reproduces the observed ESWs*[Rubia et al., Astrophys. J., 2025a, 2025b].*

**Role of minor neutrals in determining the characteristic features of the Venus ionosphere at low altitudes**

1D-PCM, a photochemistry model developed in-house, was used to investigate the influence of minor neutrals (NO, $O_2$, C, Ar, $H_2$, and H) in the lower altitude regions of Venusian ionosphere. The results demonstrates that $NO^+$ and $O_2^+$ ions exhibit a notable presence below 140 km, the photoionization of NO results in a net increase in electron density below 115 km and the electron density profiles better match with that of observations by Akatsuki. The results highlight the significant role played by minor

neutrals, particularly below 115 km, in the Venusian ionosphere *[Ambili et al., Mon.Not. R. Astron. Soc., 2024]*.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

**1) Ionization Density and Electric-field Analyser - Version 2 (IDEA-V2) payload on POEM-4:**

A trio of in-house developed plasma payloads namely (a) Electron density and Neutral Wind (ENWi), Langmuir Probe (LP) and (b) Electron Temperature Analyzer (ETA) were flown onboard ISRO's POEM-4 mission (PSLV-C60) to obtain high resolution plasma measurements at 350 km orbit in Earth's ionosphere.

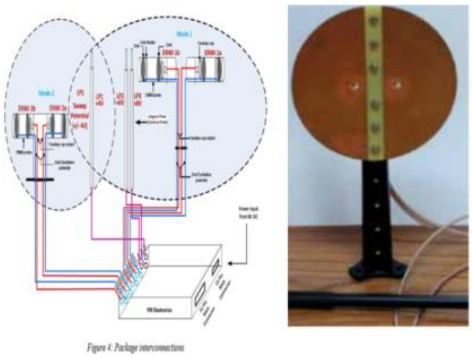

Figure 8.The schematic with ENWi and LP probes; Right panel : The photograph of ETA

**a) ENWi and LP payloads**

A suite of ENWi probes (2 No.) and LP probes (3 No.) were flown for ionospheric $N_e/N_i$ and Electron temperature ($T_e$) measurements at 350 km altitude region. Development of ENWi probes in electron and ion modes as well as LP probes in constant potential mode and sweep modes were completed in-house and the probes were flown successfully to obtain the plasma parameters.

**b) Electron Temperature Analyzer (ETA) payload**

The basic ETA sensor is a circular plane that is divided into two semi-circular planes with a non-conducting gap between the discs, and connected to the ETA electronics, which works near the floating potential. The sensor in the $T_e$ mode measures the floating potential shift when a sinusoidal voltage is applied to one of the semicircles. The $N_e$ measurement is done by sweeping the frequency of the sinusoidal to obtain the upper hybrid resonance.

**2) Plasmaspheric DEnsity Measurements (PlasDEM)**

PlasDEM is a novel payload that measures the topside of the Earth's ionosphere using a dual frequency GNSS/ NAVIC receiver placed onboard POEM-4 mission (PSLV-C60). The PlasDEM involved development of a dual-frequency GNSS Receiver & Antenna system, and software to invert satellite data (Pseudo range, and phase) to science parameters

(TEC, and S4 index). The receiver component of the payload was developed at IISU, and the antenna at VSSC by RFAFD, AVN and the inversion at SPL.

## 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, 106 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 Ramanujam Fellows to pursue their research activities. SPL also has a Visiting Scientist program for senior scientists who have sufficient experience and hold a permanent position elsewhere.SPL also fulfils 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 480 M.Sc. students and 81 M.Tech students have received supervision from SPL Scientists/Engineers. SPL plays an important role in bringing scientific awareness and dissemination of expert knowledge to students, teachers and the general public. These are archived throughvarious outreach programs that include invited lectures at colleges and schools and public lectures duringvarious science events**.**During the last two years 3 Ph.D. have been awarded through SPL through research fellowship program of VSSC/ISRO. The list of Ph.D. thesis is given below.

- Satheesh Chandran P.R. “Ozone Variability in the Upper Troposphere and Lower Stratosphere and its Linkage with Atmospheric Dynamics over the South Asian Region”, University of Kerala, Thiruvananthapuram, February 2024 [Supervisor: Dr. S. V. Sunilkumar]
- Veenus Venugopal "Impacts of Brewer-Dobson Circulation on the Distribution of Stratospheric Ozone and Water Vapour", University of Kerala, September 2025 [Supervisor: Dr. Siddarth Shankar Das].
- Richa Naja Jain “A study on solar wind dynamics and its impact on near-Earth space environment using Radio Science techniques”, University of Kerala, Thiruvananthapuram, July 2025 [Supervisor: Dr. Raj Kumar Choudhary]

## Courses offered on Space Science and Technology

- SPL provides advanced scientific and technical training to Ph.D. students, with coursework spanning boundary layer processes, atmospheric dynamics, ionospheric, thermospheric, and magnetospheric physics, as well as planetary science, modelling, and advanced payload development technologies.
- The intake capacity is about 5 to 6 students in a year and presently SPL is hosting around 20 students for their Ph.D.

- SPL is a research Centre recognized by the University of Kerala and Cochin University of Science and Technology for doing Ph.D.

## Laboratories and Facilities Available for Space Instrumentation

With SPL's involvement in the development of space-borneinstruments, the following facilities are setup in SPL.

1) **High Vacuum Space Simulation Facility (HVSSF):** A 1-m class chamber providing vacuum of the order of $10^{-7}$ Torr, as well as ion and electron sources for testing and calibration of plasma analysers and neutral mass spectrometers(Figure 9).
2) **Clean Room Facility:** Two clean rooms of class 10000 and 100000,and two work benches (Laminar flow tables) of class 100 and class 1000 (Figure 9).
3) **Calibrated Integrating Sphere:** Operating in the spectral range from 380nm to 1100 nm, having of 20 inch diameter, with 8inch diameter exit port, installed at the Optical Instrumentation and Calibration Laboratory (OICL) of SPL (Figure 9).
4) **Atomic Oxygen Testing Facility:** ATOXS is an innovative reusable semiconductor-based thin film sensor in development. To calibrate the sensor for the LEO environment, a thermal cracker based Atomic Oxygen Beam Source (OBS) has been procured to generate energetic (5 eV) oxygen atoms typical of LEO conditions.

*Figure 9. High Vacuum Space Simulation Facility (left), Clean room Facility (middle), Calibrated Integrating Sphere installed at Optical Instrumentation and Calibration Laboratory, SPL (right).*

### 5) Payload Operation Centre (POC) at SPL

At present, POC of SPL caters to CHACE-2 and DFRS payloads on Chandrayaan-2 orbiter,as well as PAPA and Magnetometer on Aditya-L1. In the recent past, POC has supported RAMBHA-LP and ChaSTE payloads on Chandrayaan-3 lander. Level-0 data from these payloads arebeing received at POC from Indian Space Science Data Centre (ISSDC). The data products generated in POC for the archival and public release, are uploaded to PRADAN portal of ISSDC. Real time monitoring of payload telemetry parameters are also available in POC.

# U R RAO SATELLITE CENTRE
# BANGALORE, INDIA

https://www.ursc.gov.in

## About U R Rao Satellite Centre

U R Rao Satellite Center (ISAC) previously known as ISRO Satellite Centre (ISAC) is the lead center in Indian Space Research Organization (ISRO) for satellite design, development, and on-orbit operations. They also involved in the development of science missions and scientific payloads. In the period from January 2024 to December 2025, the center has been involved in the development and operation of many satellites, out-of-which the space science related activities are (i) XPoSat mission launch on the 1st January 2024 and its continued operation for science, (ii) Sun-Earth L1 insertion of Aditya-L1 on the 6th January 2024 and its continued operation for science, (iii) Successful project proposal for (a) Chandrayaan-4, a lunar sample return mission, (b) Lunar Polar Exploration (LuPEX) mission with JAXA, and (c) Venus orbiter mission, (iv) Demonstration of Space docking experiment (SPADEX) for capability demonstration of human space program including space station, and (v) NASA-ISRO Synthetic Aperture Radar (NISAR) satellite integration, testing, and onboard operations.


## Major Research Domains

URSC is actively engaged in research and development across four science areas, namely, Astronomy & Astrophysics, Heliophysics, Planetary Sciences, and space Instrumentation. URSC scientists also possesses specialized domain expertise to design and develop advanced space-based instruments across the electro-magnetic spectrum (NIR/Optical to Gamma rays) including high energy particle detection through simulation, front-end detector electronics, calibration, ground processing software, and on-board payload operations. Scientists of the group foster strong science collaborations with national and international centers and universities as well.

- **Astronomy & Astrophysics**

Scientists in the centre have strong research experience with expertise in modelling and theoretical interpretation of observational data from ISRO missions such as *AstroSat* and *XPoSat*, along with international missions including *IXPE*, *NuSTAR*, *XMM-Newton*, *NICER*, and *JWST*. The team led the science and in-flight calibration of the XSPECT instrument on *XPoSat* and developed its data-processing software for science data analysis. Research focuses on black holes, neutron stars, ULXs, active galactic nuclei, star-forming regions, and nearby galaxies. The team has deep expertise in timing, spectroscopy, and polarimetric analysis and modelling to understand physics of compact objects. Recently, capabilities are expanding toward exoplanet science.

- **Heliophysics & Space Weather**

Scientists of the centre are recognized as national experts in heliophysics and space weather science, serving as science leads and instrument designers for SoLEXS and HEL1OS on Aditya-L1. The team also developed data-processing pipeline, enabling the Level-1 data release for SoLEXS, HEL1OS, and MAG payloads on Aditya-L1. Research focuses on thermal flaring plasmas, impulsive-phase high-energy electrons, and quasi-periodic behaviour in eruptive phenomena. The team also investigates deep magnetotail particle energization contributing to auroral dynamics and charged particle events in the geotail environment. Data from Chandrayaan-2, Aditya-L1, and international missions such as GOES, Solar Orbiter, SDO, and Konus-WIND support their research activities.

- **Planetary Sciences**

The planetary science research at URSC spans diverse areas of solar system science and exploration. The team studies lunar composition using X-ray fluorescence spectroscopy with CLASS data from Chandrayaan-2 and models lunar magma-ocean crystallisation. Surface-exosphere interactions are explored through ground- and space-based observations. The team also gained expertise in X-ray diffraction, laser-induced breakdown spectroscopy, and Raman spectroscopy for compositional analysis. Water-ice simulants are used to understand lunar regolith at south polar regions. The group has strong understanding of modelling of atmospheres of planets such as Mars and Venus. Sample curation and analysis are being developed for future sample-return missions, along with community-driven exploration goals.

- **Instrumentation**

Scientists at URSC have strong foundational background in designing and developing of space experiments. The recent missions, like XPoSat, NISAR, and SPADEX shows its

capability for successful development and demonstration of many technologies. Rover decent mechanisms and deployable lander leg mechanisms for large rover are recent technology development of URSC for future scouting missions. On the space science experiments, one of the indigenous developments successfully demonstrated is in-house gas-filled detectors along with front-end electronics to cater to weak signals. High sensitive charge sensitive pre-amplifier development for various solid state detectors are another area of expertise within URSC. The payload team is currently engaged in developing an energetic particle instrument onboard LuPEX for lunar space weather and a spectro-polarimeter onboard Venus Orbiter Mission for atmospheric study of the Venusian atmosphere. Various technology developments targeted for future experiments, like Pin-hole X-ray Imager, XRF/XRD Instrument, Low-noise electronics for X-ray CCD and NIR detector, GEM-based X-ray detector, Diamond-based Spectrometer are already demonstrated. X-ray optics development has been initiated along with industry to cater to niche science areas with targeted payloads planned for near future.

## Major Scientific Applications / Results

URSC has significantly contributed in research and development with publication of more than 100 research articles in national and international journals apart from many conference proceedings in the reported period. All publication details are available on the webpage https://www.ui.adsabs.harvard.edu. Some important scientific findings/results are summarized below for different research domains.

- **Astronomy & Astrophysics**

***Spectral Distribution of Sco X-1: First Science Results from XSPECT/XPoSat****:* Team of scientists from URSC studied Scorpius X-1 (Sco X-1), one of the brightest Neutron Star Low-Mass X-ray Binary (NS-LMXB) source using observational data from XSPECT payload onboard XPoSat. During the long-term observational campaign, source traces a complete 'Z'-shaped pattern in X-ray color-color diagram (CCD) with all branches - referred as Horizontal Branch (HB), Normal Branch (NB) and Flaring Branch (FB). In-depth spectral studies indicate the evolution of the spectral parameters (Optical depth, Photon Index, Disk temperature) are governed by a combination of thermal and non-thermal emission processes. Team argued that observed total luminosity across the Z-track largely contributed by

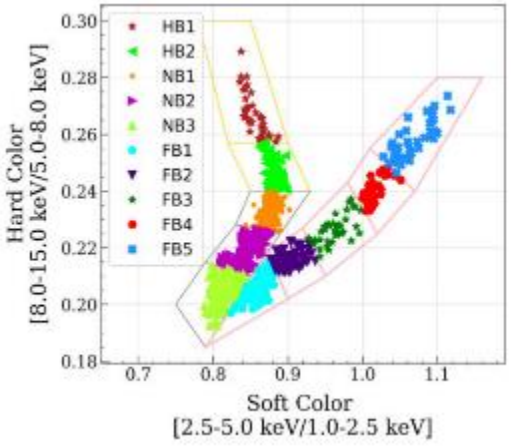


*Figure 1: Color-Color Diagram (CCD) of Sco X-1 observed with XSPECT (Shyam Prakash et al., MNRAS, 2025).*

Comptonized emission, irrespective of change in soft X-ray photons supply from the accretion disk.

***Observations of Radio Reflections from Exoplanet Ionospheres: Prospects of Future Observations:*** Scientist of URSC in collaboration with IISc proposed an investigative idea to capture the reflected radio signal from the ionosphere of 'hot' Jupiter like planets. Accordingly, it is shown that reflected spectrum has a slope which is representative of the plasma density profile of the ionosphere and has a cutoff frequency (~ GHz). Estimating the reflected signal from the ionosphere of a 'hot' Jupiter, team argued that the flux ratio of the planet to the star are about ~ 0.01%. Finally, team put forwarded the possibility of capturing the reflected radio signal from the ionosphere and to constrain the thermal state of the ionosphere, using upcoming Square Kilometer Array (SKA) telescope.

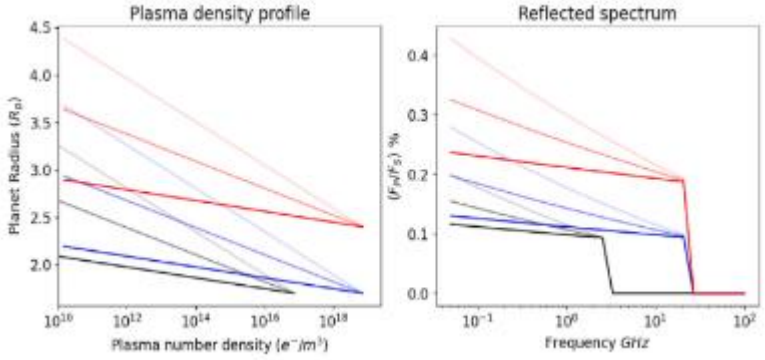


*Figure 2: Plasma density profile along with reflected spectrum (Jaiswal et al., Icarus, 2025).*

***Decoding the Rhythms of a Black Hole (GRS 1915+105): Evidence with AstroSat****:* A research team from multi-institutes including U R Rao Satellite Centre study the black hole source GRS 1915+105 using observations from *AstroSat*. Team observed that the X-ray brightness from GRS 1915+105 fluctuates dramatically over time. It exhibits a unique pattern of alternating low-brightness ('dips') and high-brightness ('non-dips') phases, each lasting a few hundred seconds. During the high-brightness phase, the team discovered something remarkable: rapid flickers in X-rays repeating about 70 times per second (frequency ~ 70 Hz), known as Quasi-periodic Oscillations (QPOs). Interestingly, such 'fast' flickers vanish during the low-brightness phases. The research team uncovered that these rapid QPOs are intimately connected to a compact 'super-heated' cloud of energetic plasma surrounding the black hole, known as corona.

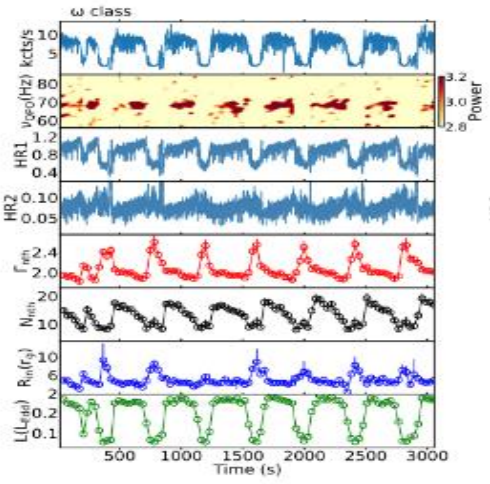


*Figure 3: Dynamical variation of spectro-temporal properties of GRS 1915+105 (Harikesh et al., MNRAS, 2025).*

***First spectro-polarimetric study of the neutron star low-mass X-ray binary GX 9+1***: A spectro-polarimetric study of the bright atoll source GX 9+1 was carried using the simultaneous IXPE, NICER and NuSTAR observations. The source was observed in the soft state. A significant polarization (3.3σ) was detected in the 2–3 keV range, with a polarization degree of 3.3±0.8 per cent and a polarization angle of $11\pm7^0$, without showing any significant detection in 2-8 keV band. This study indicated that observed polarization originates in the standard accretion disc.

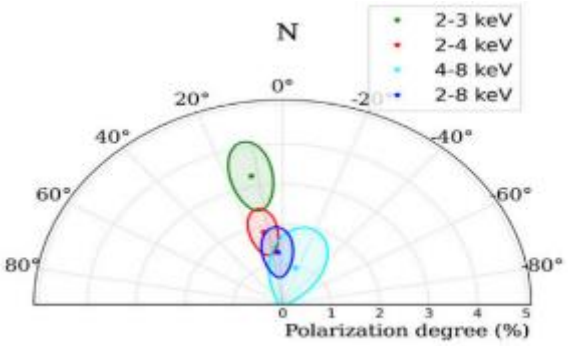


*Figure 4: Confidence contour of PD and PA at different energy bands (Shyam Prakash et al., MNRAS, 2025).*

***AstroSat view of transient low-mass X-ray binary XTE J1701-462***: Scientist at URSC reported first detailed look of X-ray binary XTE J1701-462 with AstroSat during its 2022 outbursts. The source exhibited complete Z-track evolution consisting of horizontal (HB), normal (NB) and flaring branch (FB). This provided a unique opportunity to investigate the evolution of spectral and fast time variability along the Z-track. Horizontal branch oscillations in frequency range of 34 to 40 Hz were detected. In the normal branch the source exhibited 5-7 Hz oscillations. The broad band X-ray spectra (0.7 -30 keV) could be described with a Comptonized emission component and emission from multicolor accretion disk. The evolution X-ray spectra and temporal behavior were studied and model for Z-track evolution and QPOs were discussed in detail.

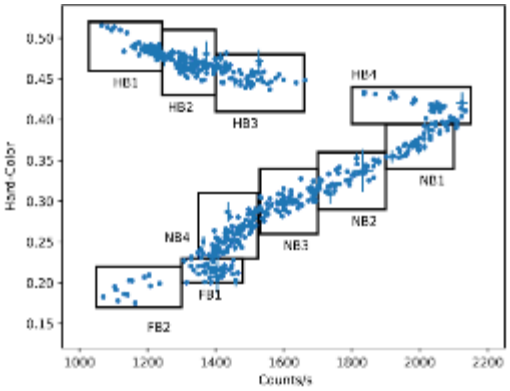


*Figure 5: Hardness-Intensity Diagram (HID) of XTE J1701-462 observed with AstroSat (Agrawal, PASA, 2025).*

***First detection of X-ray polarization in thermal state of LMC X-3****:* We report a comprehensive spectro-polarimetric study of the black hole binary LMC X-3 using simultaneous IXPE, NICER, and NuSTAR observations in 0.5–20 keV energy band. The broad-band energy spectrum (0.5–20 keV) is well described by the disc emission of temperature ~1.1 keV and a weak Comptonizing tail beyond ~10 keV. This evidently suggests a disc-dominated spectral state of the source with disc contribution of ~96 per cent. A significant polarization degree (PD) of 3.04 ± 0.40 per cent (>7σ) at a polarization angle of $-44.24^0 \pm 3.77^0$ (>7σ) is found in 2–8 keV energy range of IXPE. In addition, PD is seen to increase with energy up to ~4.35 ± 0.98 per cent (>3σ) in 4–8 keV band. Based on the spectro-polarimetric results, we infer that the polarization in LMC X-3 is resulted possibly due to the combined effects of the direct and/or reflected emissions from a partially ionized disc atmosphere.

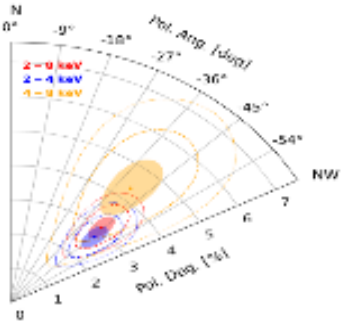


*Figure 6: Confidence contour of energy dependent PD and PA of LMX X-3 (Majumder et al., MNRAS-L, 2024).*

***Discovery of High Energy X-ray Modulation in Black Hole Swift J1727.8-1613 with AstroSat****:* This study reveals that the 'aperiodic modulation' of high-energy X-ray photons resulted in Quasi-periodic Oscillation (QPO) at a fixed frequency in power-frequency space. Remarkably, over a mere 7 days, the QPO frequency of high-energy photons (~100 kilo-electron Volt, equivalently 1 billion Kelvin) evolved from 1.4 Hz to 2.6 Hz, a unique phenomenon detected for the first time in a BH-XRB. Moreover, this study emphasizes that high-energy X-rays (hard X-rays) are generated from the reprocessing of the low-energy photons (soft X-rays) from the 'standard' accretion disk by the 'hot' electrons from the inner disk via the Compton scattering process. During AstroSat observations, Swift J1727.8-1613 was in an accretion state dominated by Comptonized emission (~90%) over thermal disk emission (~10%). These findings ascertain that Comptonized X-ray photons exhibit 'aperiodic modulation' resulting in the QPO features.

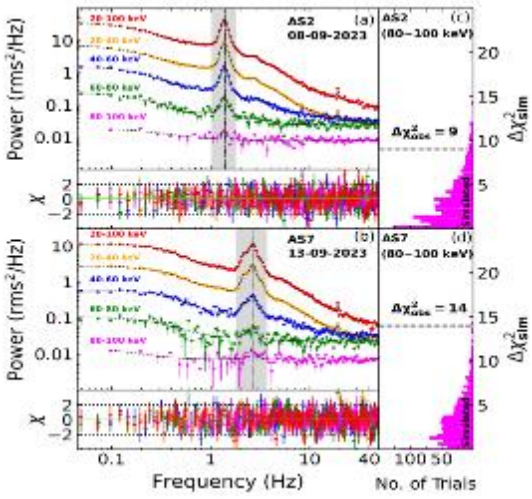


*Figure 7: Evolution of low frequency QPO in hard X-rays (Nandi et al., NNRAS, 2024).*

- **Heliophysics & Space Weather**

***Particle measurement in Lunar Environment****:* CLASS onboard Chandrayaan-2 has capability to detect charged particles in lunar orbit. Team has studied the detection of SEP events by CLASS during a M-class flare associated with a CME. These measurements aid in understanding the near lunar environment as well as to study propagation of such energetic particles in the heliosphere. Enhancement and variation of GOES protons counts are also shown.

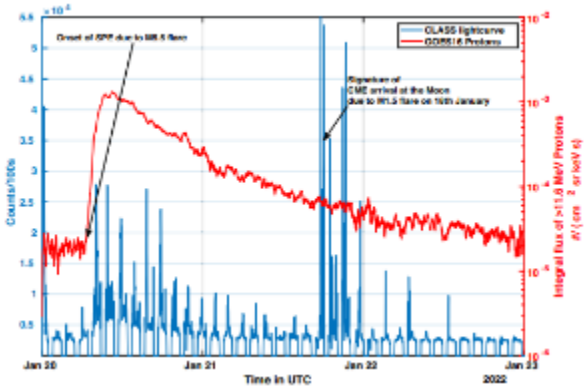


*Figure 8: Particle signature in CLASS during a SEP event (Narendranath et al., JAA, 2025).*

***Catalogue of Solar Flares with XSM****:* We present a three years (September 2019 to November 2022) catalogue of 6266 solar flares detected by the SXM onboard the Chandrayaan-2 lunar orbiter between 1.55 and 12.4 keV. 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. Individual flares are fitted with an exponentially-modified Gaussian function and multi-flare groups are decomposed into individual flares. Findings are validated with flare catalogues made using visual inspection as well as automatic pipelines on GOES and SDO. Findings indicate a clear bimodality in the ratio of the width to decay time between type A and B flares.

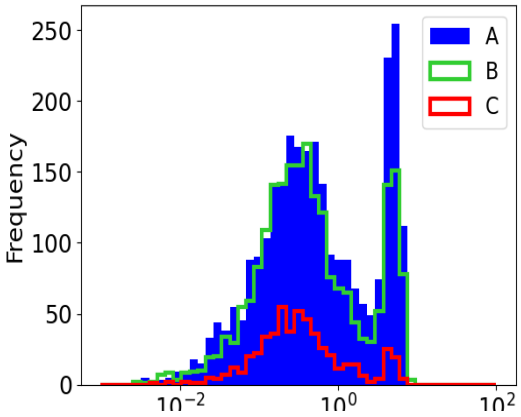


*Figure 9: Temporal characteristics of different flare classes with ratio of EFP function parameters (Valluvan et al., Solar Physics, 2024).*

***Solar Activities and the Geo-magnetic Storm on 11th May 2024****:* An active region numbered as AR13664, a very complex active region had produced many X-ray flares during 08th to 11th May including M- and X-class flares. Many of these flares were accompanied with halo CMEs with high energy particles which are behind the geomagnetic storms observed on early hours of 11th May 2024. This event is one of the biggest geomagnetic storms of the solar cycle 25 until now and probably the strongest of this cycle. Aditya-L1 which is continuously observing the Sun and the in-situ environment at the L1 point have captured these events. X-ray payloads on-board Aditya-L1 (SoLEXS

and HEL1OS) have observed the multiple X- and M-class flares from these regions during the event**,** while the in-situ particle instruments ASPEX and MAG payloads have observed these events as they passed the L1 point**.** Observations connected to the intense geomagnetic storm on 11th May have also been observed by CLASS/Chandrayaan-2 and XSPECT/XPoSat from two vantage points in space providing a unique opportunity for characterizing this event from multiple points in the heliosphere. GRASP on-board GSAT-19 also senses high energy protons in Geo-stationary environment. These measurements are being used for a detailed holistic view of a rare solar event and its effect on Earth and other planets. Some more details available at,
https://www.isro.gov.in/ISROCapturestheSignaturesoftheRecentSolarEruptiveEvents.html

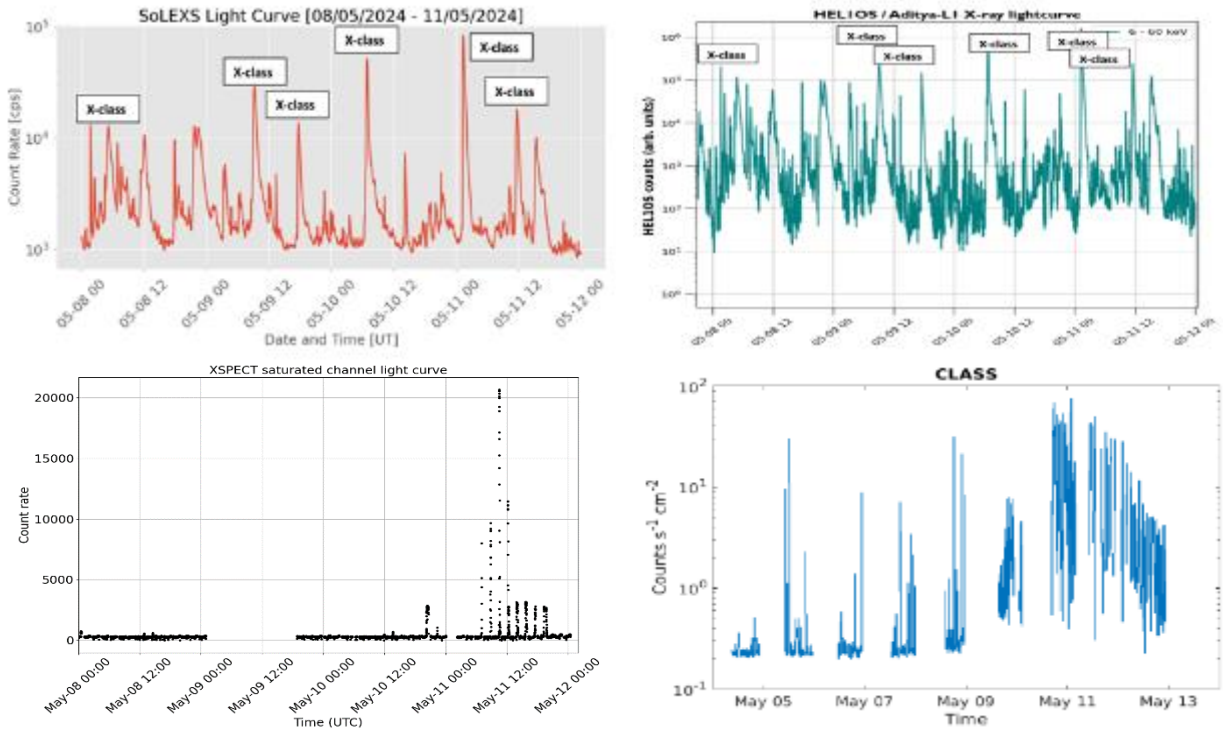


*Figure 10: (Top) X-ray flares observed by SoLEXS and HEL1OS during 8th to 11th May, 2024. (Bottom) XSPECT saturated channel (> 16 keV) lightcurve and CLASS light curve in the higher energy range (7 - 16 keV) shows deposition by particles in its detectors. Enhancements of counts are clearly seen during 11th May, 2024.*

# Planetary Sciences

***Solar EUV-Driven Sodium Release from the Lunar Surface: A Deeper Insights***: A team of scientists from multi-institutes including U R Rao Centre Centre studied the correlation between solar Extreme Ultra-Violet (EUV) radiation and release of Sodium (Na) from the Lunar surface. To investigate this, team used simultaneous observation of EUV photon flux and Na optical spectral line flux from the lunar exosphere using multi-instruments data from Vainu Bappu Telescope (VBT), Extreme Ultraviolet Sensor (EUVS) and Total and Spectral Solar Irradiance Sensor-1 (TSIS-1). Interestingly, team observed a non-linear increase in lunar exospheric sodium with EUV and FUV fluxes, which put a challenge to the previously proposed linear photon-stimulated desorption (PSD) model. Team concluded that the EUV radiation above 10 eV drives the Sodium release with enhance activity during solar flares. Also, the team argued for revised PSD model for better understanding of the observed correlation.

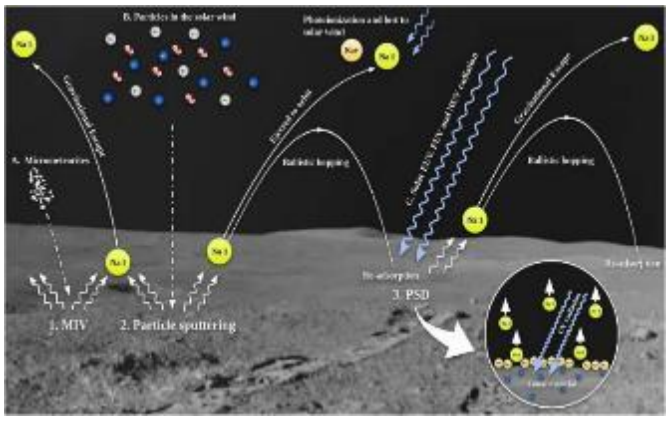


*Figure 11: The lunar surface boundary exosphere is sustained by displacement of atoms from the surface via a variety of processes (Devaraj et al., MNRAS. 2025).*

***Mapping of Lunar elements with CLASS:*** Lunar elemental maps of unprecedented coverage and spatial resolution were derived from X-ray fluorescence spectra from CLASS onboard Chandrayaan-2. High resolution maps of CLASS matched the insitu observations of Chandrayaan-3 APXS measurements providing an additional ground truth for calibration. CLASS maps at JAXA's SLIM mission contributed to understanding the geological context of the landing site.

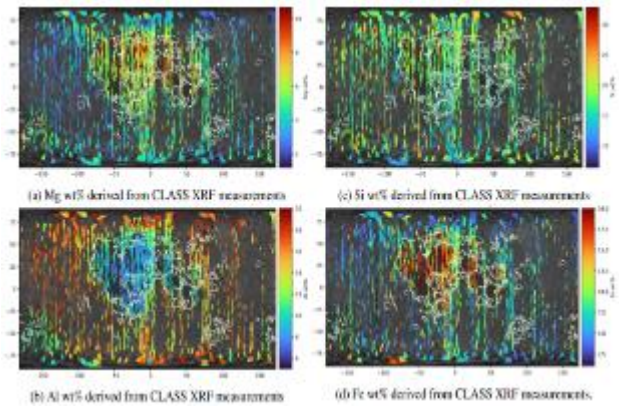

*Figure 12: Lunar elemental maps derived from CLASS measurements (Narendranath et al.. Icarus. 2024).*

## Instrumentation Research

### XSPECT Onboard *XPoSat* – Instrument Configuration and Science Prospects

This manuscript provides a comprehensive overview of the XSPECT instrument onboard *XPoSat*, developed by SAG with configuration details and ground performance. The instrument configuration includes the description and specification of the detector system, collimators, optical blocking filters, mechanical and electrical configuration, and thermal design. Environmental tests and calibration activities, as well as the results, which establishes the instrument performance on ground are also discussed. Finally, the first results from XSPECT with observation of SNR (Cas-A) as well as of Pulsar (Crab) are also highlighted.

*Figure 13: XSPECT payload onboard XPoSat (Vatedka et al., JATIS, 2025).*

Team established the quantitative spectroscopic and timing capabilities of the XSPECT instrument through comprehensive ground and on-board calibration. Using X-ray sources (Cas A, Tycho and Crab) and cross-calibration with SXT and NICER, team has shown the capabilities for spectro-temporal studies of astrophysical sources in soft X-ray band (*Chatterjee et al., JATIS, 2025*).

### SoLEXS Onboard Aditya-L1 – Instrument Configuration and Science Prospects

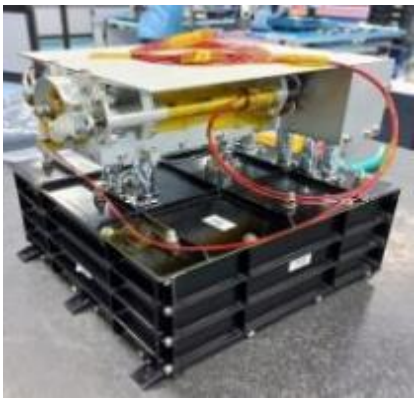

*Figure 14: SoLEXS payload onboard Aditya-L1 (*Sankarasubramanian et al., Solar Physics, 2025).

This manuscript provides a comprehensive overview of the SoLEXS instrument onboard Aditya-L1 mission, developed by SAG of URSC with science objectives, configuration details, ground as well as onboard performance. The instrument configuration includes the description and specification of the detector system, collimators, mechanical and electrical design. The paper also describes the environmental tests and calibration activities, as well as the results, which establishes the instrument performance on ground. Finally, the first results of SoLEXS with detection of C-class and M-class solar flares are briefly presented in the paper.

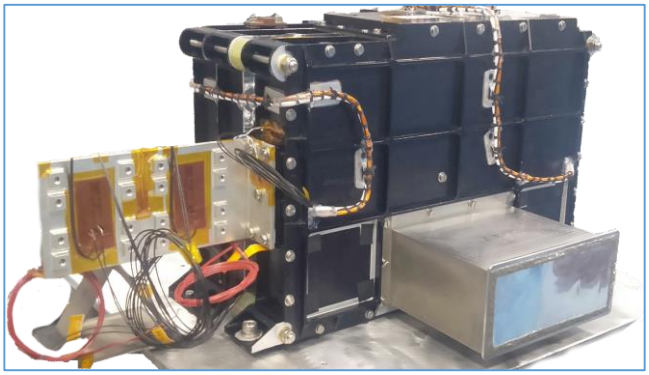

*Figure 15: HEL1OS payload onboard Aditya-L1 (Nandi et al., Solar Physics, 2025).*

The group established the quantitative spectroscopic capabilities of the SoLEXS instrument on Aditya-L1 through comprehensive ground and on-board calibration. Utilizing internal sources and cross-calibration with GOES-XRS and Chandrayaan-2/XSM, the team confirmed high spectral resolution and radiometric accuracy, enabling a 100% duty cycle for the continuous study of solar flare energetics and coronal heating (*Sarwade et al. JATIS, 2025*).

**HEL1OS Onboard Aditya-L1 – Instrument Configuration and Science Prospects**

This manuscript provides a comprehensive overview of the HEL1OS instrument onboard Aditya-L1 mission, developed by SAG of URSC with scientific overview, configuration design details, and ground as well as onboard performance. The instrument configuration includes the description and specification of the detector system, collimators, mechanical and electronic design. The article also highlights the environmental tests and calibration activities, as well as the preliminary results, which establishes the instrument performance on ground. Finally, the first results of HEL1OS with detection of C-class solar flare along with preliminary results of demonstration of Quasi-periodic Pulsation (QPP) and spectral capabilities of X-class solar flares are briefly presented in the paper.

## Indigenously Developed Instruments / Products / Detectors

Two payloads for Venus Orbiter Mission and Chandrayaan-5/LuPEX Mission are under development. Brief highlights are presented below,

**VASP/VOM –** The Venus Atmospheric Spectro-Polarimeter (VASP) is an instrument, which is under development for Venus Orbiter Mission (VOM). Instrument is aimed at investigating the clouds of planet Venus with the technique of multi-wavelength multi-angle

spectro-polarimetry in the near-infrared wavelength band of 900-1700 nm with a spectral resolution of ~ 3 nm.

**LRS/LuPEX –** The Lunar Radiation Spectrometer (LRS) in an instrument, which is under development for Chandrayaan-5 mission. Instrument is mainly aimed to study Solar energetic particles (SEP) and Galactic cosmic rays (GCR) at the lunar surface by detecting Protons (10 – 200 MeV), Alphas (40 – 200 MeV), Heavy ions (> 10 MeV/n) etc.

## Capacity Building in Space Science Research

Scientists of the center were engaged in providing hands-on training to the students related to space science research using data from ISRO's missions apart from guiding research scholars within the group as well as in collaboration with academia.

**World Space Week:** This year's World Space Week celebrations at URSC, held from October 4-10, 2025, included a series of activities to engage the community, particularly students, and inspire curiosity and awareness along with outreach program which included visit to educational institute.

**ARMS 2025 conference:** 14th National Seminar and Exhibition on Aerospace and Related Mechanisms—was held at the U R Rao Satellite Centre (URSC), Bengaluru, on 21 & 22 November 2025, organized by the INSARM– Bangalore chapter in association with URSC. As a premier event in aerospace technology, ARMS-2025 drew immense participation across India & few from US, with 325 delegates representing ISRO, DRDO, CSIR labs, academia, and leading industries.

**Aditya-L1 Workshops**: Team at SAG was involved in training students using data from SoLEXS and HEL1OS as a part of Aditya-L1 Support Cell workshops. Training was conducted at various places of the country during 2024-2025 period. Students were introduced to X-rays from solar flares as well as to the instruments.

**XSPECT Workshop**: A 3-days national workshop (June 2025) was conducted to provide hands-on training using data from XSPECT instruments. Participants engaged in end-to-end XSPECT data handling, including calibration, spectral modelling, and timing analysis, performed on seven diverse astrophysical sources.

**Research Guidance** – Scientists at URSC are also engaged in providing guidance to research scholars from academia under various sponsered program of ISRO such as STC, AO, RESPOND as well as external collaboration with the centre and universities.

**PhDs**: Two research scholars guided by URSC scientists were awarded doctoral degree during the period annuary 2024 – December 2025

(1) Ms. Bhuvana G. R. (2024) – Telltale of Accretion Disc Dynamics around Galactic and Extra-galactic Black Hole Sources (Awarded by DSU)
(2) Mr. Seshadri Majumdar (2025) – Decoding Imprints of Black Hole Accretion: Investigations through X-ray Timing and Spectro-Polarimetry (Awarded by IIT-G)

## Courses offered on Space Science and Technology

Presently, URSC is engaged providing course to Joint Astronomy Program (JAP) of Indian Institute of Science with following details,

**Course Title (PH 377)** - Astronomical Techniques: High Energy Physics. This course covers techniques in instrumentation and data analysis of energetic radiation, X-rays and gamma-rays, as well as energetic particles including astronomical technique related project activity for 3 months.

## Laboratories and Facilities Available for Space Instrumentation

URSC is well equipped with laboratories and facilities,

**Electronics/Instrumentation Laboratory** – These laboratories are functional day-to-day basis to cater to the requirement of design, testing and characterization for ground developmental activities.

**Clean Room** – A dedicated clean room is functional with capabilities of Class 100 and Class 1000 standard for assembly and testing of payloads, those are critical to contamination environment. Apart from these, several Class 1L standard clean room is also available for testing of flight models and integration of payloads on satellites.

**Environmental Test Facility** – URSC has many Vacuum chamber to cater to regular developmental activities required for operation of small subsystem like detectors to large integrated satellite testing in Vacuum.

**Payload Operation Centre** - A dedicated Payload Operations Centre (POC) is functional at the SAG of URSC. The main objectives of a POC are data pipeline processing for generation of science data products, regular operations in coordination with Mission/Operations and general health monitoring of the payload. The current POCs are for the following payloads: AstroSat/SSM, Chandrayaan-2/CLASS, GSAT-19/GRASP, Chandrayaan-3/SHAPE, Aditya-L1/HEL1OS, Aditya-L1/SoLEXS and XPoSat/XSPECT.

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

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# AMITY INSTITUTE OF SPACE SCIENCE & TECHNOLOGY
# AMITY UNIVERSITY

https://noida.amity.edu/aisst/

## About the Institute


https://amity.edu/noida/aisst/

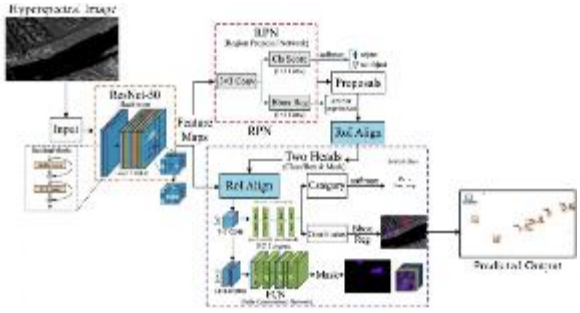
Amity Institute of Space Science & Technology (AISST), Amity University Uttar Pradesh, established in 2008, is dedicated to education, research, and innovation in Space Science, Space Technology, Aircraft Engineering, and Spacecraft Avionics. The institute offers industry-oriented academic programs and promotes multidisciplinary research in emerging space technologies. AISST has established research strengths in Space System Design, Artificial Intelligence for Space Applications, Remote Sensing, Space Situational Awareness, Satellite Mission Planning, and Quantum Computing for Space Systems. It is also exploring emerging areas such as post-quantum space systems, photonic computing, neuromorphic navigation, and intelligent space-based sensing technologies. AISST is actively involved in satellite subsystem development and is pursuing a Low Earth Orbit (LEO) 3U CubeSat platform to provide practical experience in satellite design and development. Recognized as an ISRO START Nodal Centre (2025 & 2026) and a registered ISRO Space Tutor, AISST actively contributes to space education, outreach, and capacity building, while fostering national and international collaborations through an MoU with IN-SPACe, industry partnership with SpaceTS, and interactions with global space stakeholders including cosmonauts, the Russian Science & Culture Centre, and leadership of the European Space Agency (ESA).

## Major Research Domains

- Space Systems Design and Engineering
- Space Situational Awareness (SSA)
- Quantum Computing for Space Systems
- Artificial Intelligence for Space Applications
- Remote Sensing and Earth Observation
- UAVs, Avionics and Space Defence Technologies
- Advanced Computing for Future Space Missions (such as photonic computing, neuromorphic computing, intelligent autonomous systems)

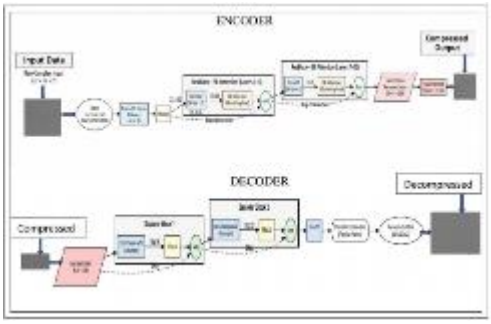
## Major Scientific Applications / Results

### (I) Intelligent Hyperspectral Image Analysis using modified RCNN




The proposed approach integrates advanced AI techniques for automated hyperspectral data analysis, complemented by selective manual inspection across multiple spectral bands using extensive spectral libraries. Simulation results demonstrate the effectiveness of the proposed model, achieving a training accuracy of 97% with a corresponding training loss of 0.0981.

### (II) Complex- Preserving Autoencoder for High Fidelity SAR Signal

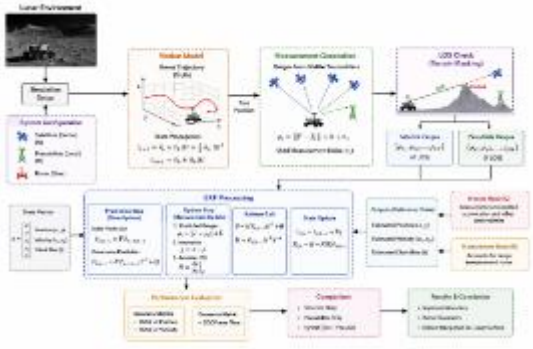



The proposed method is a data-driven approach that integrates deep residual learning with Squeeze-and-Excitation (SE) attention mechanisms to adaptively prioritize phase-critical features during compression. The results demonstrate that CP-ARNet achieves a significant improvement in Signal-to-Quantization Noise Ratio (SQNR), while maintaining high phase coherence and minimizing phase error.

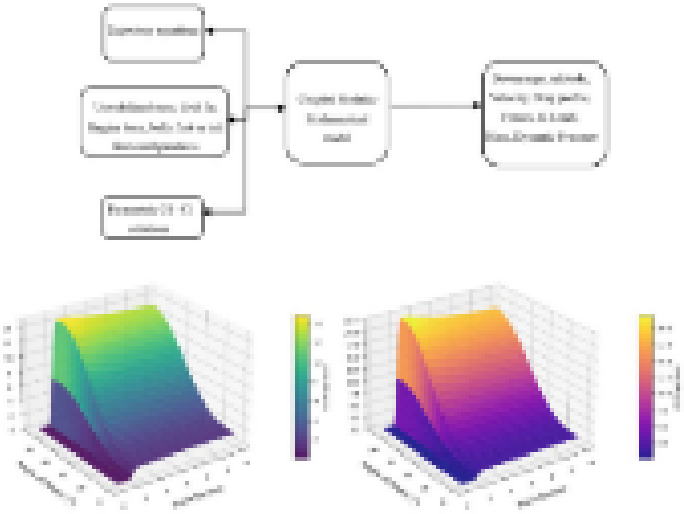
### (III) AI Based Precise Satellite Pose Estimation for Early Course Correction

The proposed approach utilizes monocular grayscale imagery and convolutional neural networks (CNNs), including HRNet, EfficientNet, and ResNet architectures, with transfer learning to improve feature representation and generalization. Comparative analysis of loss functions indicates that PoseNet loss provides improved performance by effectively balancing translation and rotation errors.

### (IV) Integrated Pseudolite with Satellite Based Navigation System for the Lunar Surface



A hybrid navigation system is proposed by combining both satellite-based and pseudolite-based approaches. The results obtained from the simulation show that the hybrid approach performs better in terms of accuracy and reliability compared to the individual systems. The satellite-only configuration shows higher errors due to poor geometry, while the pseudolite-only system



provides better accuracy but is limited in coverage. The hybrid system combines both advantages and provides consistent performance with lower position error.

**(V) Change Detection Using High Resolution Satellite Imagery of Gaza Strip Retrieved Using Sentinel-2, Landsat-8**

This research focuses on the automated assessment of building damage using multi-temporal high-resolution satellite imagery and advanced deep learning techniques. The proposed framework utilizes pre-event and post-event satellite images to identify and quantify structural damage in urban environments. The methodology incorporates a preprocessing pipeline comprising geometric correction, image co-registration, normalization, and patch extraction to ensure reliable analysis.

(VI) **Classical and Hybrid Quantum Optimization for Satellite Scheduling with Overlap Minimization**

This work presents a classical and hybrid quantum classical optimization framework for satellite scheduling under coverage and overlap constraints. The problem is formulated using binary decision variables over discretized time slots, incorporating coverage rewards and overlap penalties. Comparative results across multiple problem scales demonstrate that classical methods offer strong performance with lower computational cost, while hybrid quantum approaches show potential for scalability with further optimization.

**(VII) Reduced Order Modeling of Landing dynamics of Reusable Launch vehicles**

This research proposes an empirical Reduced Order Model (ROM) to accelerate the preliminary design process of reusable launch vehicles. A three-degree-of-freedom trajectory model is integrated to evaluate the effects of engine burns, re-entry orientations, and fin configurations, including planar and grid fins. The framework supports rapid analysis of user-defined flight conditions and vehicle geometries. The proposed approach enables faster design iterations, reduced development costs, and improved decision-making during preliminary booster design, thereby facilitating the advancement of next-generation reusable launch vehicle technologies worldwide.

The list of publications can be accessed through the following links:
https://amity.edu/noida/aisst/research_publication.asp

https://drive.google.com/file/d/1k5Kafp3qYiYBQSsDfmFP5dtEy4ZBUETj/view?usp=sharing

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

**Software Tools:**

- Quantum Assisted Satellite Image Classification (Space Objects)
- Quantum Trajectory Optimization
- Quantum Assisted Space Situational Awareness system
- Maritime Traffic Surveillance using Synthetic Aperture Radar Satellite Imagery
- Classical and Hybrid Quantum Optimization for Satellite Scheduling with Overlap Minimization
- Change Detection Using High Resolution Satellite Imagery of Gaza Strip Retrieved Using Sentinel-2, Landsat-8
- Space Situational Awareness for Real-Time Conjunction Detection and Collision Risk Prediction
- Detection in Hyperspectral Images
- Space Weather Prediction

**Hardware:**

Intelligent Drone Detection system (Acoustic & Visual)

## Capacity Building in Space Science Research

• ISRO-Led Capacity Building: As an ISRO START Nodal Centre (2025 & 2026) and Registered ISRO Space Tutor, AISST contributes to national capacity building in the space sector by fostering space education, skill development, research, and student participation in ISRO programmes.

• Workshops and Academic Events: AISST conducts a wide range of workshops, expert lectures, Faculty Development Programmes, and thematic events, including National Space Day and Aryabhata Day celebrations, to advance knowledge dissemination, research excellence, and capacity building in frontier areas of space science and technology. The institute also facilitates interactions with global space stakeholders, including cosmonauts, the Russian Science & Culture Centre, and leadership of the European Space Agency (ESA), providing valuable international exposure to students and researchers.

• Research-Oriented Learning: Students are actively engaged in research projects, scientific publications, technical report preparation, national and international conferences, and hands-on activities in areas such as Space Systems Design, Remote Sensing, Artificial Intelligence, Space Situational Awareness, and Quantum Computing.

• Doctoral Research Program: The institute currently guides full-time and part-time Ph.D. scholars working on advanced research topics including Design of Intelligent Safety Analysis system for flying bodies, Autonomous drone swarm communication and path planning, and Intelligent Path Planning Of Swarm Of CubeSats for Surveillance.

• Knowledge Dissemination: AISST promotes scientific communication through institutional publications such as *Dhruvtara*, *Space Qubit*, and its Technical Report Series on Quantum Computing in Space, encouraging students and researchers to contribute to emerging areas of space research.

## Courses offered on Space Science and Technology

| **S. No.** | **Programs** | **Level** | **Duration** | **Intake Capacity*** | **Specialization / Focus Area** |
|---|---|---|---|---|---|
| **1** | B.Tech (Space Science) | Undergraduate | 4 Years | 30 | Space Science & Technology |
| **2** | Integrated B.Tech + M.Tech (Space Science) | Postgraduate | 5 Years | 30 | Space Science & Technology |
| 3 | M.Sc. (Space Science) | Postgraduate | 2 Years | 30 | Space Science & Technology |
| 4 | Minor Degree (Spacecraft Engineering) | Undergraduate (Minor) | Along with B.Tech | Open to eligible students | Space Science & Technology |
| 5 | Minor Degree (Avionics) | Undergraduate (Minor) | Along with B.Tech | Open to eligible students | Space Science & Technology ; Avionics |
| 6 | M.Tech (Avionics) | Postgraduate | 2 Years | 20 | Space Science & Technology ; Avionics |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Ph.D. (Space Science) | Doctoral | As per University Regulations | As per availability of supervisors | Space Science & Technology ; Avionics |

## Laboratories and Facilities Available for Space Instrumentation

| Laboratory / Facility | Description |
|---|---|
| **Avionics Laboratory** | Equipped for experimentation in aerospace electronics, |
| **Radar and Remote Sensing Laboratory** | Supports research in radar systems & satellite image analytics |
| **System Simulation and Modelling Laboratory** | Provides software and hardware-in-the-loop simulation capabilities for spacecraft systems, and aerospace system performance evaluation. |
| **Artificial Intelligence and Space Data Analytics Laboratory** | Dedicated facility for research in Intelligent Space data anlysis |
| **ISRO-Supported Research Facility** | Supports research activities in Space debris studies |
| **DRDO-TDF Sponsored Research Laboratory** | Supports defence and strategic technology development involving intelligent surveillance systems & AI-enabled analytics |
| **Clean Room Facility** | |

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

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# ARYABHATTA RESEARCH INSTITUTE OF OBSERVATIONAL SCIENCES (ARIES)
# Nainital, INDIA

Website: https://www.aries.res.in/

## About the Institute

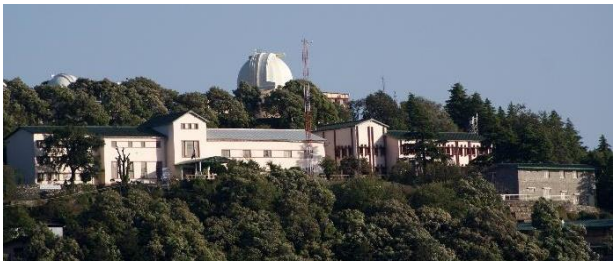

*Figure 1: ARIES's Manora Peak campus.*

ARIES is an autonomous institute under the Department of Science & Technology, Govt. of India since 22 March, 2004. It came into existence as the erstwhile Uttar Pradesh State Observatory on 20 April, 1954. The mandate of the institute is to promote, guide and carry out frontline basic observational and theoretical research in Astronomy & Astrophysics and Atmospheric Sciences; and to create an environment for research by enabling individuals to work at the Institute on a full time, honorary or visiting basis. ARIES aims to: (a) build and operate state-of-the art observational facilities and back-end instruments, and make them accessible to the scientific community**;** (b) establish a strong synergy between ARIES and other national and international ground-based facilities and space programmes; (c) create an engineering R&D centre to cater to in-house development, value addition and optimize the back-end instruments and extend the R&D laboratories, expertise and technology to educational institutions and industries.

## Major Research Domains

The Sun and related phenomena, Galactic Astronomy, Extra-galactic Astronomy, Theoretical and Numerical Astrophysics, Atmospheric Meteorology and Dynamics, Trace Gases, Aerosols, Boundary Layer Studies, Air Pollution, Climate Change, Space Situational Awareness.

## Major Scientific Applications / Results

- **Measuring the elusive Intermediate-Mass Black Holes (IMBHs):** IMBHs, are thought to be the seeds that grow into supermassive black holes. However, unlike their larger counterparts, IMBHs' faint nature and location in small galaxies make them extremely difficult to observe due to the high-spatial-resolution requirement. Using the observations from the 3.6m and 1.3m telescopes at ARIES, the IMBH in a low-luminosity Seyfert 1 galaxy, NGC 4395 was successfully detected and its properties were measured by performing spectrophotometric reverberation monitoring, yielding a black hole mass of ~2.2 ±0.2×$10^4$ $M_\odot$. [Pandey et al., 2024, *ApJ,* 976 116].

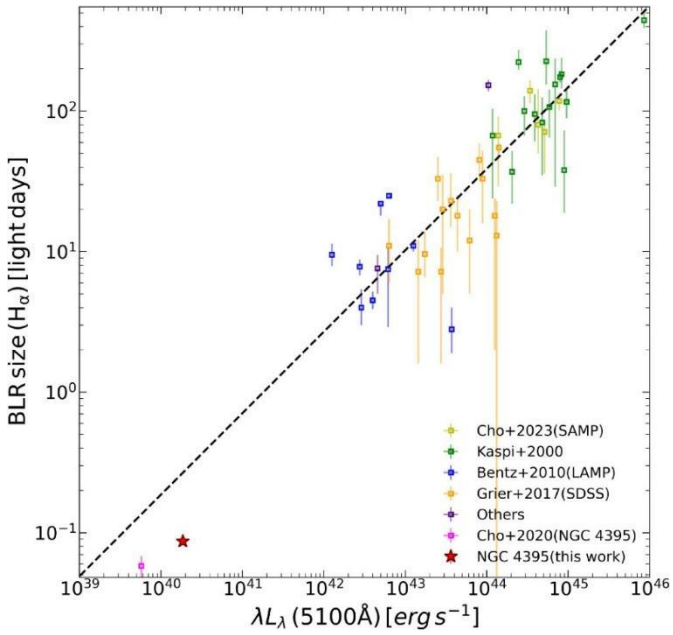


*Figure 2: The size of the Hα BLR, compared to the monochromatic continuum luminosity at 5100 Å, aligns with the relationship across previous studies. The current lag of 125 minutes contrasts with earlier estimates, underscoring the precision of this study.*

- **Effect of Poloidal Magnetic Field on Coronal Mass Ejections (CMEs):** As crucial drivers of space weather, CMEs necessitate a comprehensive understanding of their initiation and evolution in the solar corona. 2.5D MHD simulations of breakout CME initiation incorporating a multipolar magnetic field configuration within a background bipolar magnetic field were performed. The findings reveal that an increase in the strength of the background poloidal magnetic field constrains CME eruptions and the growth rate of absolute net current helicity is the crucial factor that determines the likelihood of CME eruptions. [Vashishtha et al., 2025, *ApJ,* 992 59]

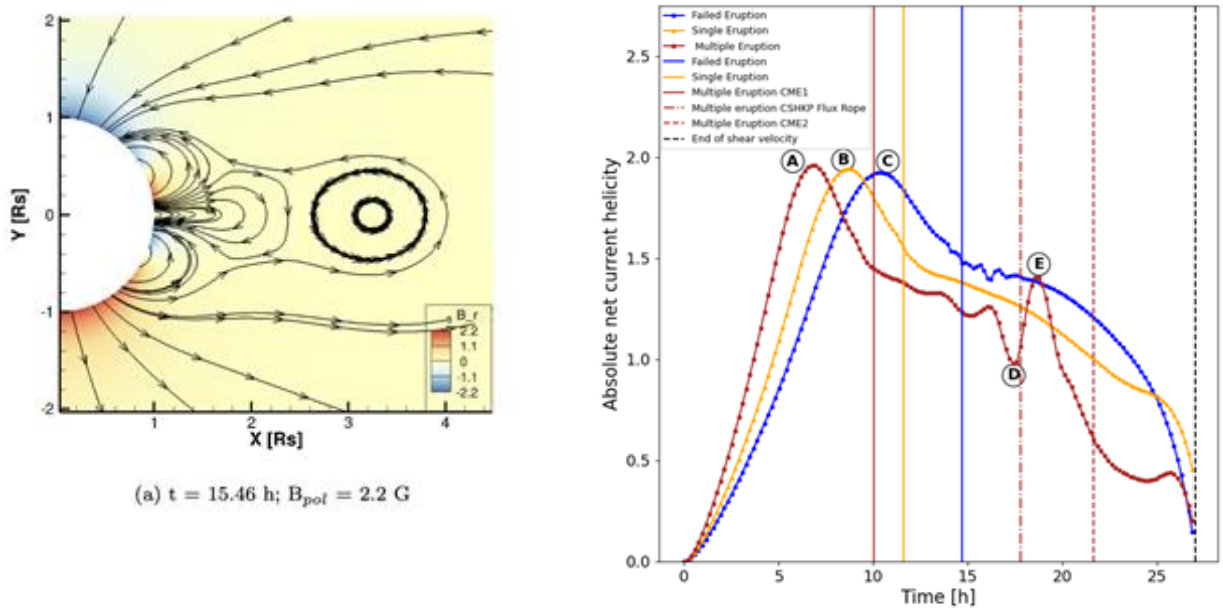


*Figure 3: Left: A snapshot of the numerical simulations showing the solar eruptions being initiated. Right: Temporal evolution of absolute net current helicity (blue, yellow, and red for failed, single, and multiple eruptions, respectively). The blue, yellow and red vertical lines represent the flux rope formation time for the failed, single and multiple eruption cases. The black dotted vertical line represents the end of the shear. Time is measured from the start of the shear.*

- **Machine learning Insights into the diversity of Gamma-Ray Bursts (GRBs)**

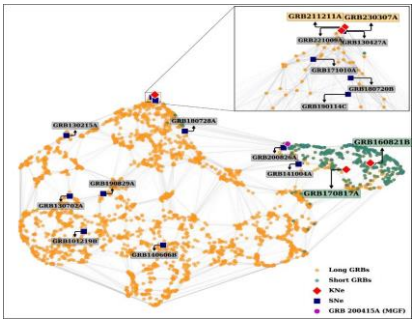


*Figure 4: The connectivity map colour coded as traditional long- and short-duration GRBs. KN-associated GRBs are labelled with their names and respective colours as per their traditional classification. Notably, several SN- and KN-associated GRBs lie at the top of cluster 2. The inset shows that GRBs 211211A and 230307A are adjacent, suggesting similarity in their light curves.*

The classification of GRBs remains a complex challenge in high-energy astrophysics. Using Fermi/GBM data and unsupervised machine learning techniques, 5 distinct GRB clusters were identified, a result consistent with previous studies using the Swift/BAT data. The kilonovae associated GRBs were found to lie in two clusters, including GRB 170817A, supporting its origin from a binary neutron star merger, while the other may correspond to neutron star-black hole mergers. [Dimple et al., 2024, *ApJ*, 974 55]

- **First online observations of greenhouse gases (GHGs) over Central Himalayas:**

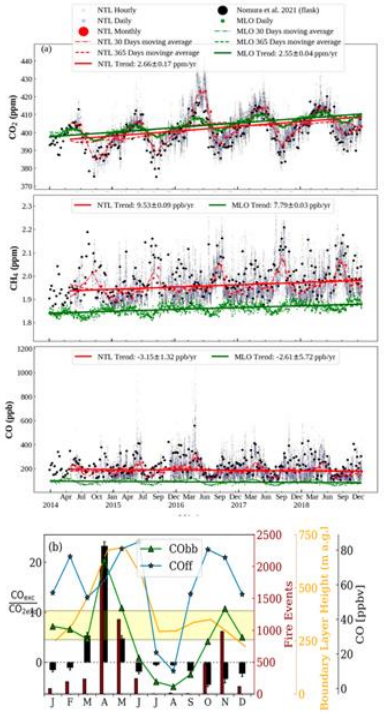


*Figure 5: (a) Trend in $CO_2$, $CH_4$ and CO at Nainital (NTL) and Mauna Loa, a background site, during 2014–2018. (b) Monthly variation in excess CO/$CO_2$, ppb/ppm with CO from fossil fuel combustion (COff) and from biomass burning (CObb), fire events over the Northern Indian region and boundary layer height at the site location. The yellow highlighted region denotes the emission ratios reported for fossil fuel emissions and biomass emissions.*

Ground observations with diurnal variability over the Himalayas are crucial to validate climate mitigation efforts, build accurate emissions inventories and better forecasting. Bridging the acute scarcity of such measurements, the first online observations of $CO_2$, $CH_4$ an CO were carried out continuously for 5 years at a mountain site (24.35° N, 70.89° E) in the Central Himalayas. The results highlight the complex interplay of anthropogenic emissions, biospheric uptake, and weather patterns with mountain features in shaping $CO_2$ and $CH_4$ levels. [Srivastava et al., 2025, *Environ. Sci. Pollut. Res.*, 32, 13726–13740]

- **Space Situational Awareness (SSA):** Through funded projects from ISRO-RESPOND, DRDO–IRDE, BEL Ghaziabad, and industry collaborators, ARIES is strengthening India's science and innovation ecosystem by advancing indigenous CMOS detector development, wide-field SSA telescopes, and autonomous resident space object (RSO) tracking technologies. These efforts promote translational research by converting astronomical instruments and laboratory prototypes into deployable instruments for space and defence applications. Engagement with industry enables technology commercialisation, while collaborations with start-ups and MSMEs in optics, fabrication, electronics, and AI modules help build a domestic supply chain and create

new opportunities. Together, these initiatives reduce import dependence, support self-reliance, and contribute to India's growing ecosystem in advanced sensing, imaging, and SSA technologies.

**Note:** Total number of publications during January, 2024 – December, 2025 is 245. Full list of publications is available at: https://www.aries.res.in/research/list-publication

## Instruments / Payloads / Products Developed / Sensors / Detectors

- **4m International Liquid Mirror Telescope (ILMT):** The ILMT project, a joint collaboration between ARIES (India), Belgium and Canada, is the first optical survey telescope in the country. Science observations have already commenced and the data has been released publicly for the scientific community. An automated transient detection pipeline, PyLMT, for the ILMT data has been developed. Using image subtraction and CNN techniques, it has detected numerous variable stars, catalogued asteroids, and 12 extragalactic transients including 2 new discoveries, demonstrating high classification accuracy and precision.

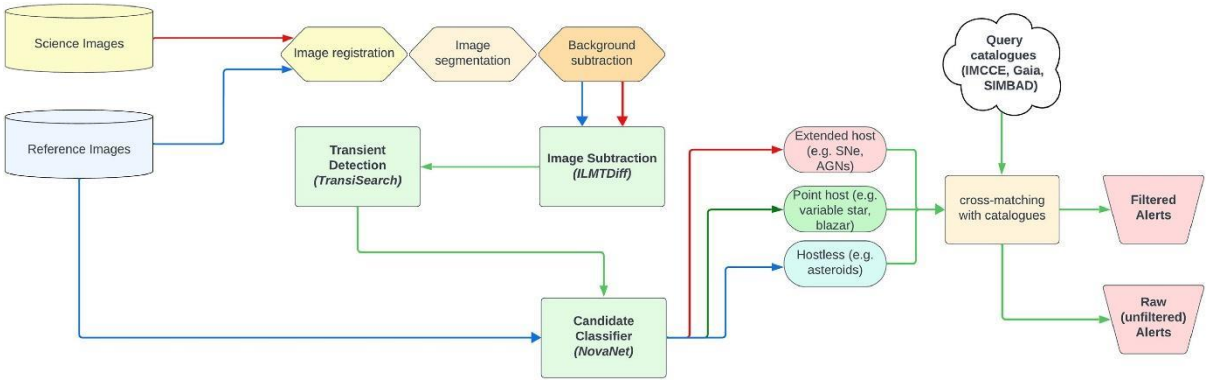


*Figure 6: Schematic diagram of the PyLMT transient detection pipeline. The diagram illustrates the three basic steps for carrying out the image subtraction (ILMTDiff), transient detection (TransiSearch), and candidate classification (NovaNet).*

- **3.6m Devasthal Optical Telescope (DOT):** ARIES operates this 3.6m aperture modern optical telescope with active optics technology as a National Facility. A suite of complex back-end instruments provide optical and near-infrared observations for a wide range of studies on solar system objects, exoplanets, stars, star clusters, galaxies, and extra-galactic sources. Side Port IMager (SPIM), a new back-end instrument started providing uninterrupted optical imaging capability. The development of 2 next-generation instruments, High Resolution Spectrograph (HRS) and TIFR-ARIES Multi-Object Optical Near infrared Spectrograph (TA-MOONS) is ongoing.

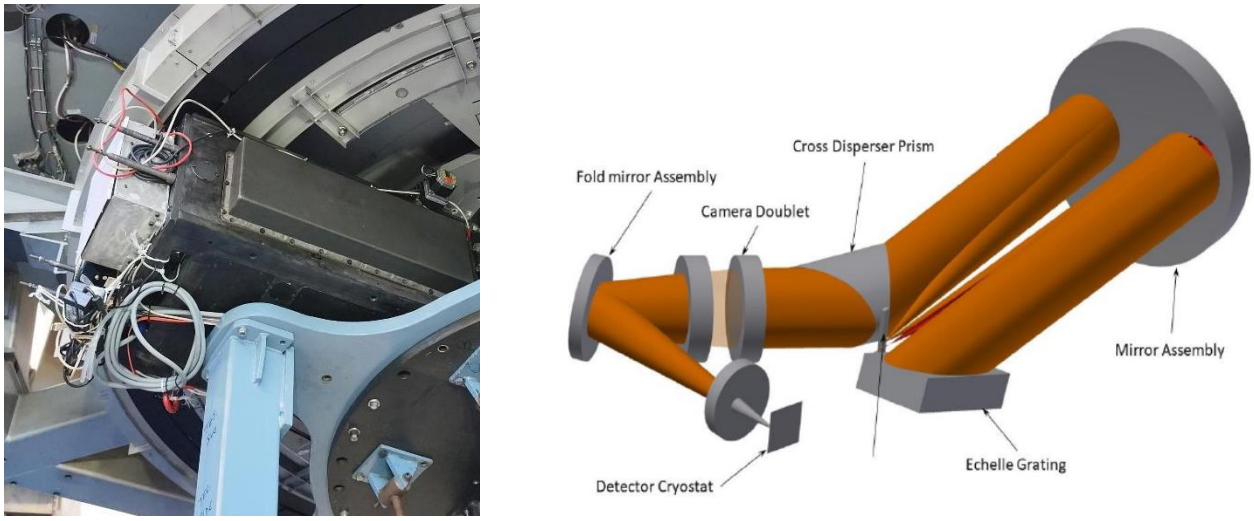


*Figure 7: Left: SPIM instrument integrated with the 3.6m DOT. Right: Schematic diagram of HRS.*

- **206.5 MHz ARIES Stratosphere Troposphere Radar (ASTRAD):** It is a unique and indigenously established radar facility operating at 206.5 MHz to measure the 3D wind field up to 20 km altitude. It is configured as an Active Aperture Distributed Phased Array using state of art Solid State Transmit Receive modules and Digital Signal Processing techniques. Such a high altitude active aperture radar in the VHF band along with antenna elements over the rooftop is a first in the country. Along with regular independent observations, it is also used for campaign mode observations with other

  similar radars in the country. Systematic upgradation of ASTRAD is ongoing, including the replacement of the High-Power Amplifier (HPA) of Transmit Receive Module (TRM) with an in-house designed and fabricated upgraded HPA

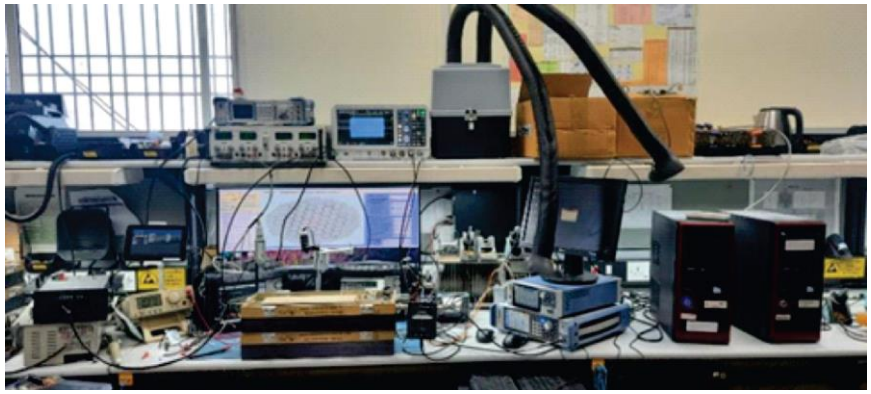

*Figure 8: TRM with new HPA is under testing in the ASTRAD RF Laboratory at ARIES.*

## Capacity Building in Space Science Research

- ARIES offers 5 year PhD in astronomy and atmospheric sciences along with a 6 year integrated MTech-PhD programme in astronomical instrumentation. During January 2024-December 2025, 18 students were awarded/have defended their theses.
- ARIES scientists and engineers supervise B.Sc./M.Sc./B.Tech./M.Tech/M.Phil students for short term internships/projects in the areas of astronomy, atmospheric sciences and engineering. During January 2024-December 2025, 92 students completed their internships.
- Outreach/Training: The ARIES Training School in Observational Astronomy and Atmospheric Sciences (ATSOAA) is ARIES's annual capacity building school aimed for post-graduate students. The school covers a series of lectures on wide ranging topics followed by several hands-on data analysis sessions. About 70 students were trained during 2024 and 2025. 2nd ILMT workshop was conducted in 2025 to train postgraduate and PhD students for handling and analysing ILMT data, focusing on a wide range of astrophysical objects and phenomena. 8 Aditya-L1 Support Cell (AL1SC) Workshops were conducted at ARIES and institutes/universities across the country to train over 250 students, young researchers and college/university level teachers on solar physics concepts and data from the Aditya-L1 mission.

## Courses offered on Space Science and Technology:

**PhD coursework:** ARIES offers coursework for PhD students only as per the following structure for total 40 credits.

| | | **Credit** |
|---|---|---|
| **TERM – 1** | | |
| APC 101 | Basic Astronomy | 4 |
| APC 102 | Mathematical and Statistical Methods | 2 |
| APC 103 | Electrodynamics and Radiative processes in Astrophysics | 3 |
| APC 104 | Introduction to Atmospheric Sciences | 3 |
| APC 105 | Astrophysical Fluid Mechanics | 4 |
| **Total** | | **16** |
| **TERM – 2** | | |
| APC 201 | Formation, Evolution and atmosphere of stars | 2 |
| APC 202 | Observational Technique and Methodology – (Optical, IR, Radio, X-ray, Gamma ray) | 2 |
| APC 203 | Interstellar medium and Stellar Variability | 2 |
| E-204/ 205/206 | General Theory of Relativity and Cosmology / Atmospheric Trace Gases and Aerosol / Solar Physics | 3 |
| **Total** | | **9** |

<table>
<tr><th colspan="5">TERM – 3: Research Methodology, Applied Physics & Project</th></tr>
<tr><td rowspan="5">RPE</td><td colspan="3">Research and Publication Ethics</td><td>2</td></tr>
<tr><td>Theory</td><td colspan="2">Practice</td><td></td></tr>
<tr><td>01 - Philosophy & Ethics</td><td colspan="2">04 - Open Access Publishing</td><td></td></tr>
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<tr><td>03 - Publication Ethics</td><td colspan="2">06 - Databases & Research Metrics</td><td></td></tr>
<tr><td>APC 302</td><td colspan="3">Applied Physics</td><td>3</td></tr>
<tr><td rowspan="2">APC PROJ</td><td>Credit Research</td><td>Credit report & literature survey</td><td>Credit defence via seminar</td><td rowspan="2">10</td></tr>
<tr><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="4">Total</td><td>15</td></tr>
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**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 a class-10000 Clean Room Facility, Optical Profiler cum Phase Shift Interferometer with vertical resolution of 0.1 nm, UV-VIS-NIR spectrometer (wavelength range: 300-1000 nm, resolution: 1 nm), Laser interferometer (fundamental optical resolution 0.5 wavelength or better), Reflectometer (wavelength range: 365-970 nm), Vacuum Pump, $CO_2$ Snow Cleaning Gun and Zemax-EE Software. Aluminium coating plants accommodating mirrors up to 4m at Devasthal and up to 104cm at Manora Peak are also available.
- **Electronics Lab:** A modern SCADA based substation system (100KVA and 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 RF Laboratory:** An Electrostatic Discharge (ESD) Secure RF Electronics Laboratory has been established at the ASTRAD facility at Manora Peak to carry out maintenance, development and upgradation of the radar facility.

# 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 Laboratory (ASSR Lab) in the Department of Physics at Bangalore University is actively engaged in teaching and research in atmospheric, space, and planetary sciences. Supported under the ISRO Space Science Promotion Scheme since 2010, the laboratory has developed strong capabilities in ionospheric physics, space weather, monsoon studies, and planetary research.

## Major Research Domains

The research activities focus on atmospheric physics, including aerosols, atmospheric radioactivity, and boundary layer processes to understand surface-atmosphere interactions and their role in weather and climate variability. Studies on atmospheric electricity and lightning address the electrical structure of the atmosphere and its coupling with ionospheric and space weather processes. Monsoon dynamics and climate variability are investigated to understand regional circulation and large-scale atmospheric behaviour. The laboratory utilizes satellite and ground-based observations for remote sensing and data analysis of atmospheric and space parameters. Ionospheric research is carried out

using GNSS derived Total Electron Content to examine low latitude dynamics, Equatorial Ionization Anomaly, and storm time variability. Indigenous VLF systems are developed and used for studying the D-region ionosphere, including responses to solar flares and eclipses, providing diagnostics of wave propagation in the Earth ionosphere system. Research also focuses on Sun–Earth interaction processes such as geomagnetic storms and solar flares and their influence on the coupled magnetosphere–ionosphere system. Studies extend to planetary atmospheres of Mars, Moon, and Venus, including comparative planetology and orbital dynamics. The Department contributes as subject experts in scientific discussions related to missions such as Chandrayaan, Mars Orbiter Mission, and Shukrayaan, including inputs to scientific payload planning and mission strategies aligned with ISRO.

## Major Scientific Applications / Results

### Study of VLF Signal during Partial Solar Eclipse of 25 October 2022

The work investigates the response of very low frequency signal amplitudes during the partial solar eclipse of 25 October 2022 along the GQD (22.10 kHz) and DHO (23.40 kHz) propagation paths. Amplitude variations were analyzed over 22–28 October 2022 with focus on the greatest eclipse phase using pre and post eclipse days as reference. The eclipse introduced path obstructions of ~11% for GQD and 14% for DHO. During the greatest eclipse phase, the GQD signal decreased by 0.83 dB relative to pre-eclipse conditions, while the DHO signal increased by 0.26 dB and 0.57 dB compared to pre and post eclipse days. Solar flare signatures were also observed, supported by GOES 16 X- ray flux data, under geomagnetically quiet conditions. The results indicate a clear path dependent ionospheric response, with DHO variations primarily driven by eclipse induced changes, while GQD reflects combined effects of eclipse and solar flare activity. The results confirm that partial solar eclipses significantly modulate D region ionosphere and VLF propagation, demonstrating the effectiveness of multipath VLF observations for space weather studies.

### Impact of Geomagnetic Storms and Solar Activity on Low Latitude Ionospheric TEC

Ionospheric Total Electron Content variability over Bangalore and Hyderabad during geomagnetic storms from 2018 to 2024 was analyzed using GNSS derived VTEC. The intense storm of 09-13 May 2024 exhibited strong solar wind–magnetosphere coupling with IMF Bz reaching −35 to −40 nT, Ey exceeding 25 mV/m, solar wind speed increasing to 950–1000 km/s, Kp reaching 8–9, and Dst dropping to −400 nT.

The results show a strong latitude dependent ionospheric response, with initial TEC enhancement at low latitudes due to prompt penetration electric fields and solar flare ionization, followed by depletion during the recovery phase driven by disturbance dynamo effects and thermospheric composition changes. Enhanced TEC over Bangalore and

Hyderabad reflects Equatorial Ionization Anomaly dynamics, while mid and high latitudes show depletion, highlighting the role of electric fields, neutral winds, and solar forcing in storm time ionospheric variability.

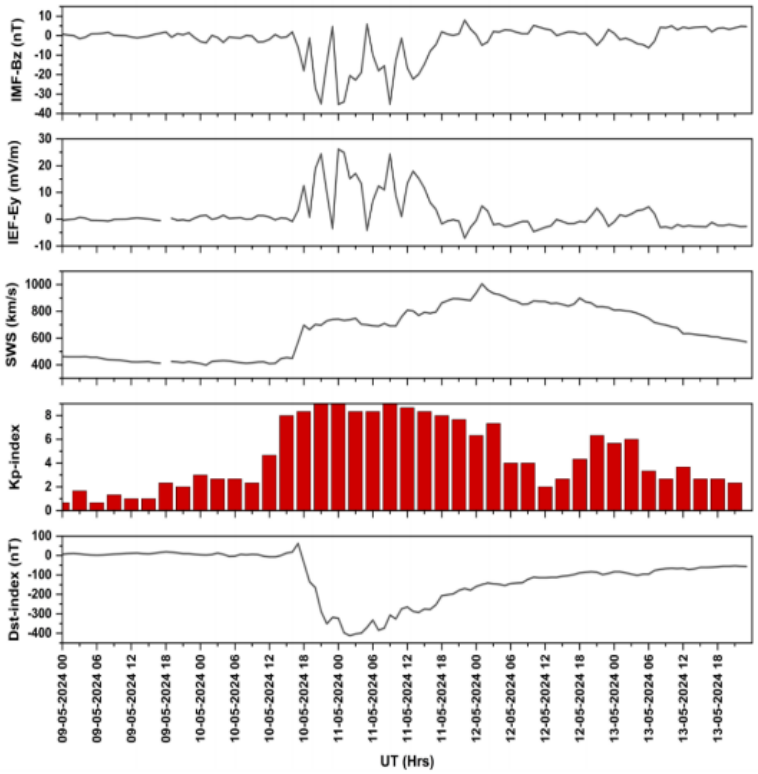



**Figure 1: IMF Bz, Ey, solar wind speed, Kp, and Dst variations during 09–13 May 2024**

### Latitude Dependent TEC Variability during the May 2024 Geomagnetic Storm

The work examines ionospheric Total Electron Content response during the intense geomagnetic storm of 10–11 May 2024 using GNSS observations from six globally distributed stations, including low latitude regions over India. Vertical TEC data from 8–13 May 2024 capture pre storm, main phase, and recovery phase variations. The storm is characterized by strong solar wind–magnetosphere coupling, producing severe geomagnetic conditions and significant ionospheric disturbances across all latitudes.

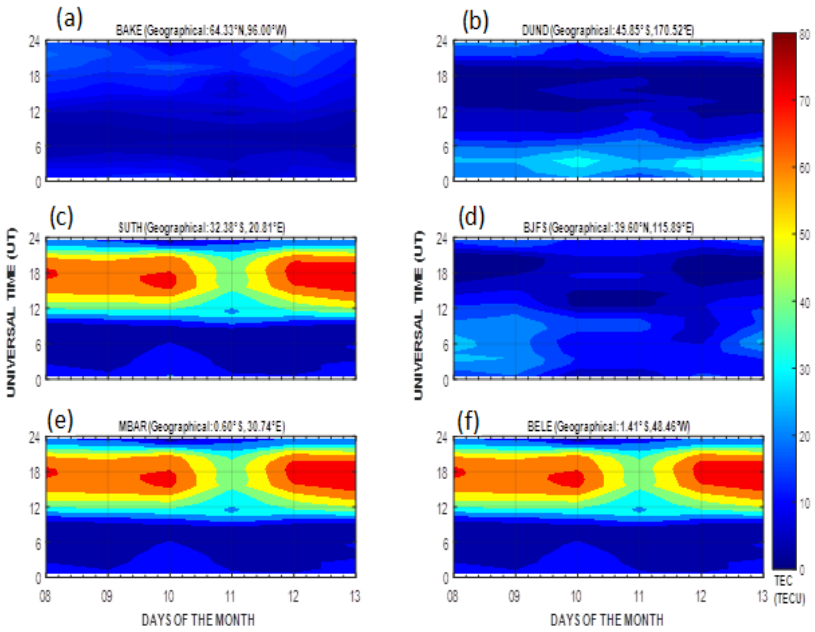



**Figure 2:** Multi-Station TEC Signatures of the 10–11 May 2024 Geomagnetic Storm

The results show a clear latitude dependent response. Equatorial and low latitude regions exhibit strong TEC enhancement with peak values of ~70 TECU during the initial phase due to prompt penetration electric fields and intensified equatorial ionization anomaly dynamics. This response is particularly important for the Indian region, which lies under the influence of the equatorial ionization anomaly crest and is highly sensitive to storm time electric field variations. In contrast, mid and high latitude regions show significant TEC depletion to ~10–20 TECU during the main phase due to enhanced recombination, auroral processes, and thermospheric composition changes. A recovery phase depletion is observed globally, associated with disturbance dynamo electric fields and altered neutral circulation.

From an Indian perspective, these results are important for understanding and predicting space weather impacts on satellite navigation and communication systems such as NavIC and GNSS, where TEC variability directly affects signal propagation accuracy and system reliability. Globally, the study highlights the importance of coordinated multi station observations to capture the coupled ionosphere–thermosphere response during extreme geomagnetic events. The results demonstrate that storm time TEC variability is governed by the combined influence of electric fields, neutral dynamics, and solar forcing, with strong spatial variability across latitudes. This work provides valuable inputs for developing predictive ionospheric models and supports ongoing space weather research efforts under INCOSPAR.

## Indigenously Developed Instruments

This work presents the design, development, validation, and sustained deployment of an indigenous Very Low Frequency receiver system undertaken at Bangalore University to support advanced space science research. The system is specifically developed to investigate D region ionospheric perturbations associated with solar flare activity. High resolution observations demonstrate clear and consistent amplitude and phase variations in VLF signals during M class and X class solar flares, establishing the strong sensitivity of VLF propagation to enhanced ionization in the lower ionosphere.

A significant scientific outcome of this study is the clear identification of frequency dependent response characteristics. It is observed that different VLF frequencies respond distinctly to flare intensity, with stronger flares producing larger perturbations at lower frequencies, while moderate flares exhibit relatively enhanced response at higher frequencies. The behaviour provides experimental evidence that VLF waves probe different effective reflection heights and electron density gradients within the D region, offering insight into vertical ionospheric structuring.

The system captures well defined diurnal variations, including sunrise and sunset terminator transitions, along with superimposed solar flare signatures, demonstrating the ability to resolve short duration ionospheric disturbances with high temporal fidelity. Signal filtering ensures high quality processing by suppressing noise while preserving transient features, enabling reliable quantification of perturbations.

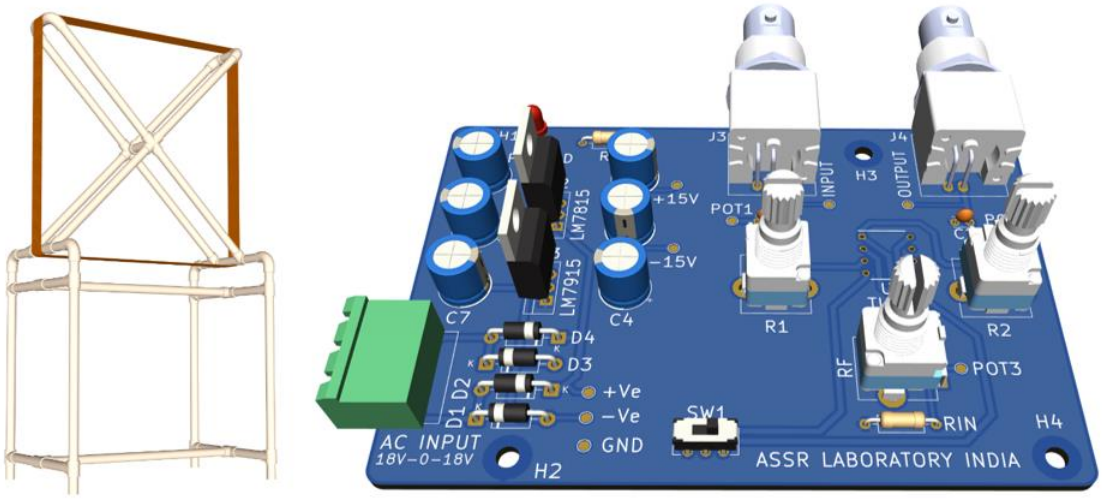



**Figure 3**: VLF antenna and pre amplifier PCB three-dimensional views

A major outcome is the validation of indigenous instrumentation, with the loop antenna and receiver system showing agreement between theoretical and measured parameters within eight percent. The system performance is comparable to international VLF facilities while remaining cost effective and scalable for continuous operation. The results establish

VLF perturbations as a reliable indirect diagnostic of D region electron density variations. This work strengthens indigenous capabilities in space weather research, supports development of ground based ionospheric monitoring, and contributes to solar flare ionosphere coupling studies aligned with ISRO objectives.

## Capacity Building in Space Science Research

The Department contributes to capacity building in atmospheric, space, and planetary sciences through PhD research aligned with national priorities. Students working in the research topics as:

- Study of ionospheric electron content over the Indian region – Chaithra P
- Design and development of VLF receiver for ionospheric studies–Ramesh Krishna B
- Synoptic conditions and thermodynamic indices of thunderstorms – C S Patil
- Investigation of atmospheric processes on terrestrial planets – Venkatalakshmi Y A
- A comprehensive study of ionospheres of the inner planets – Shashikala T G

These works cover ionospheric physics, space weather, atmospheric dynamics, and planetary science, supporting human resource development under ISRO.

## Courses offered on Space Science and Technology

- Astro and Atmospheric Physics as compulsory course for 80-90 students
- Atmospheric and Space Science course for 15 students
- Space Weather and Climate for 15 students
- Planetary Physics for 15 students
- Laboratory on Atmospheric, Space and Planetary Physics for 15 students
- Research Project in Atmospheric, Space and Planetary Physics for 5 students

## Laboratories and Facilities Available for Space Instrumentation

Lightning Detection and Monitoring Facility integrated with Indian Institute of Tropical Meteorology network and Earth Networks sensor for continuous lightning observations. GNSS and Ionospheric Observation Facility integrated with National Atmospheric Research Laboratory network for TEC and space weather monitoring. VLF Receiver and Space Weather Laboratory with indigenously developed system for D region ionospheric studies. Computational and Data Analysis Facility with about 50 systems for data processing, modelling, and simulations.

For further details on the inputs as provided in the document, please contact Dr Kamsali Nagaraja, Professor, Department of Physics, Bangalore University, Bengaluru – 560056
Email: kamsalinagaraj@bub.ernet.in

# BIRLA INSTITUTE OF TECHNOLOGY, MESRA
# Mesra, Ranchi, INDIA

Website: https://bitmesra.ac.in

## About the Institute

Birla Institute of Technology (BIT) was established in 1955 by the visionary industrialist and philanthropist Mr. B.M. Birla, the institute is in Ranchi, the capital of Jharkhand. The institute was recognized by the University Grants Commission (UGC) as a University deemed to be in 1986 under Section 3 of the UGC Act 1956. Our vision is to become a globally recognized academic institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the national needs. The missions of the institute are:

- To educate students at Undergraduate, Postgraduate, Doctoral and Post Doctoral levels to perform challenging engineering and managerial jobs in industry
- To provide excellent research and development facilities to take up Ph.D programs and research projects
- To develop effective teaching and learning skills and state-of-the-art research potential of the faculty
- To build national capabilities in technology, education and research in emerging areas
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society

BIT Mesra was founded with a clear vision to offer its young minds a space, where their imagination could take wings and their ideas fruition. For over 6 decades now, the institute has nurtured minds with a rich heritage of academic excellence, developing learning frameworks that have been well ahead of times.

## Major Research Domains

- **Earth Observation & Geoinformatics:** The Remote Sensing department applies satellite imagery (optical, SAR, LIDAR) for environmental monitoring and resource mapping. Projects include groundwater quality and vegetation assessment, forest biomass and carbon stock estimation, urban growth and land-use analysis, and hydrological modeling using Landsat/Sentinel and SAR datasets.
- **Planetary Science & Remote Sensing:** Research is being carried out on lunar and Martian surfaces using orbiter data. For instance, Chandrayaan-2 SAR/TMC-2 and HiRISE data are used for mapping and morphological characterization of craters, and Chandrayaan-1/2 HySI, $M^3$ and IIRS images are used for mapping lunar FeO/TiO2

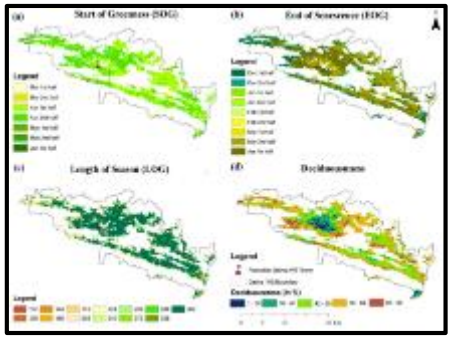
mineralogy. Martian surface temperature, sand dune migration, Thermal Inertia and AOD estimation have been done. AI models have been developed for lunar crater detection.

- **AI & Machine Learning for Space Data:** BIT Mesra incorporates advanced machine learning algorithms to automate the structural classification of planetary impact craters from high-resolution satellite imagery. Deep learning models for the automated analysis have been developed using multi-sensor Lunar orbiter dataset. For example, models for the automated detection of lunar craters using images from the Chandrayaan-2 Terrain Mapping Camera and deep learning models for the downscaling and interpretation of Martian thermal satellite images.
- **Atmospheric & Climate Studies:** Research on weather and climate, using earth observation satellite images, ERA-5 and MERRA-2 reanalysis data and NWP modeling is being carried out. Examples of studies include rainfall and snow/glacier variability studies, land-surface temperature trend studies, hydrometeorological studies, and lightning vulnerability assessment. The studies are useful in understanding climate change effects and weather phenomena.
- **Space Propulsion & Aerodynamics:** Space Engineering department, established in 1964, is dedicated to R&D in aerospace and rocket technology. The R&D activities undertaken by them include experimental and computational fluid dynamics for low/high-speed flows, hybrid and solid rocket propulsion, and propellant combustion studies for India's space program.

## Major Scientific Applications and Results

All the Journal Publications in Space Science and Technology are available here: https://sites.google.com/view/bitmesra-space-sci-exploration/home. Major Applications and results in the form of Journal Publications are list below:

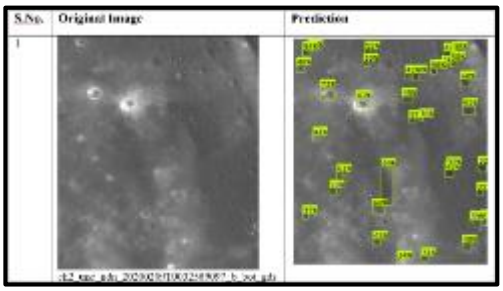
### 1. Vegetation Phenology Monitoring Using Ground Sensors and Satellite Data



An integrated framework of PhenoCam imagery, field sensors, and MODIS NDVI data was employed to track the phenological changes in tropical deciduous forests of Dalma Wildlife Sanctuary in Jharkhand. Time series analysis of Green Chromatic Coordinate (GCC) and Brown Chromatic Coordinate (BCC) data was employed to track major phenological events such as Start of Leaf Flush (SOLF), End of Leaf Flush (EOLF), and End of Leaf Maturity (EOLM). The findings highlighted seasonal variation in vegetation phenology and significant differences in leaf flushing between 2022 and 2023, primarily driven by rainfall and temperature fluctuations. The findings highlight the potential of employing a combined approach of ground-based optical observations and satellite data for effective phenology analysis.

Publication link: https://doi.org/10.1007/s10531-024-02889-8

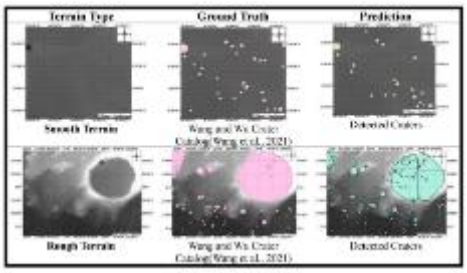
**2. Automated Lunar Crater Detection Using Deep Learning and Chandrayaan-2 TMC-2 Images**




A framework of deep learning was created to carry out the automatic detection of lunar craters through Chandrayaan-2 TMC-2 images. The research used the U-Net model and ResNet-18 to carry out semantic segmentation of crater structures. The model was able to attain 80.95% accuracy through unannotated data and 86.91% through annotated data sets. The method was able to successfully carry out the analysis of crater structures and minimize the need to carry out manual crater mapping.

Publication Link : https://www.nature.com/articles/s41598-024-58438-4

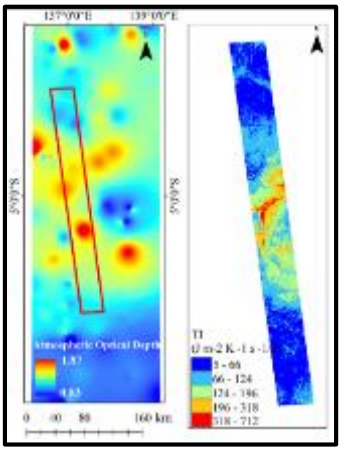
**3. Comparative Deep Learning Architectures for Lunar Crater Detection**




This research aims to compare and evaluate two architectures, namely Mask R-CNN and U-Net, for detecting lunar crater features using geocoded Chandrayaan-2 TMC-2 DEM data. The proposed models are also implemented in both ArcGIS Pro and non-geospatial environments to assess their suitability in planetary mapping applications. The results indicated that Mask R-CNN yielded better precision (~91%) and successfully identified small craters and crater rims, while U-Net yielded better recall and successfully identified overlapping and nested craters.

Publication link: https://doi.org/10.1016/j.pss.2025.106140

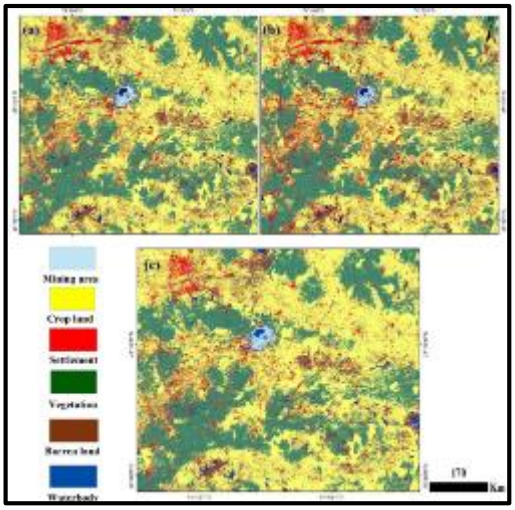
**4. Martian Atmospheric Dust and Thermal Inertia Relationship**



In the present study, the interaction between the atmospheric optical depth (AOD) and the thermal inertia (TI) during the Martian seasons has been explored. The findings of the study show that there exists a regular inverse relationship between the TI and the rover-equivalent AOD. It has also been noticed that there exists a regular inverse relationship between the dust particle size and the atmospheric opacity, thus showing the influence of the dust particles on the atmospheric optical depth.

Publication link: https://doi.org/10.1016/j.pss.2024.105865.

### 5. Detection of Lead–Zinc Open Pit Mines Using Satellite Data and Machine Learning



A remote sensing framework was proposed for detecting lead and zinc open pit mines in the Rampura Agucha region in Rajasthan using Sentinel-2 MSI imagery. Spectral bands, ratios, and indices were optimized using Optimum Index Factor (OIF) and stacked encoders. Fifteen machine learning classifiers were tested for their classification accuracy. The Extra Trees classifier was found to perform better in terms of OA (0.94) and κ (0.93) compared to other classifiers, including LightGBM and Random Forest.

Publication link: https://doi.org/10.1038/s41598-025-89672-z

### 6. Regional Mapping of Leaf Area Index Using Sentinel-2

This research combines digital hemispherical photographs (DHP) and Sentinel-2 multispectral images to estimate leaf area index (LAI) in tropical deciduous forests. Canopy measurements obtained through ground-based DHP were used to inform satellite-based models of LAI to increase their accuracy. The integration of ground-based and satellite-based data can facilitate the reliable assessment of canopy characteristics and vegetation seasonality in forests. The research presents the potential of ground-satellite combined data to monitor vegetation and ecosystems over large areas.

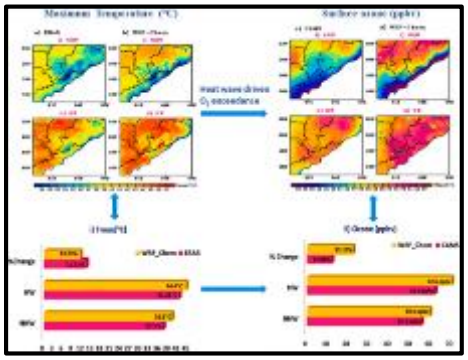
Publication link: https://doi.org/10.1007/s42965-024-00327-y

### 7. Multi-Scale Feature Pyramid Framework for Lunar Crater Detection

A multi-scale feature pyramid deep learning framework has been proposed for the detection of lunar craters from planetary surface images. The framework utilizes the combination of hierarchical feature maps, thereby improving the detection of small as well as large craters. The experimental results show the improved detection of craters, especially in regions where the boundaries of the craters are less distinct. The work emphasizes the role of multi-scale representation in deep learning models for planetary surface mapping.

Publication link: https://doi.org/10.1007/s12145-025-01818-9

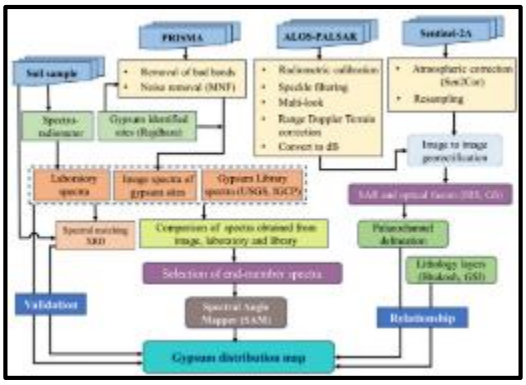
**8. WRF-Chem modeling study of heat wave driven ozone over southeast region, India**



The study used the WRF-Chem atmospheric model to examine the effect of heatwave events on surface ozone concentration in southeast India. The results show that surface ozone concentration is significantly increased during heatwave events because of increased temperatures and mixing in the atmosphere. The study found that during heatwave events, the height of the planetary boundary layer is increased, thus causing the downward mixing of ozone-rich air. The results also show that surface ozone concentration is increased by about 22% during heatwave events.

Publication Link : https://doi.org/10.1016/j.envpol.2023.122744

**9. Mapping of Gypsum Deposits Using Hyperspectral and SAR Data**




The present study was conducted to assess the potential of PRISMA hyperspectral data, Sentinel-2 data, and dual polarimetric SAR data for the identification of gypsum deposits in Bikaner, Rajasthan. Advanced spectral analysis techniques, including Minimum Noise Fraction (MNF) and Spectral Angle Mapper (SAM), were used to identify the spectral signatures of gypsum minerals. The spectral signatures were found to have strong correlation with reference spectral signatures. The field investigations and X-ray Diffraction (XRD) analysis were conducted to validate the results. The findings also indicated strong correlation between gypsum deposits and palaeochannel systems.

Publication Link: https://doi.org/10.1007/s12524-024-01865-7

**10. Photometric correction of images obtained from Chandrayaan-2 Imaging Infra-Red Spectrometer (IIRS) data**

This research aims to develop a methodology for photometric correction of Chandrayaan-2 Imaging Infra-Red Spectrometer data to enhance the reliability of spectral observations from the Moon. In addition, the study examined different photometric correction models to reduce illumination and viewing effects in hyperspectral observations. The corrected reflectance values significantly improved spectral consistency for different observation conditions. Therefore, it is easier to identify the materials on the Moon. The findings emphasize the significance of photometric normalization for planetary remote sensing analysis.

Publication link: https://doi.org/10.1016/j.asr.2023.12.019

### 11. Assessment of Glacial Lake Outburst Flood (GLOF) Risk in the Indian Himalayan Region

This study aims to examine the rising phenomenon of glacial lake outburst floods (GLOFs) in the Indian Himalayan region, focusing on the influence of climate change and terrain conditions. The findings of the study show that the rapid retreat of glaciers, forming vulnerable glacial lakes, has a great influence on the occurrence of GLOFs. It has been noted that both climatic conditions and geomorphological conditions have a significant influence on the occurrence of GLOFs. It has also been emphasized that there is a need to monitor glacial lakes more effectively to avoid potential hazards.
Publication link:
https://www.currentscience.ac.in/show.issue.php?volume=126&issue=11

## Indigenously Developed Algorithms and Software

**Planetary Image-Analysis Software:** Researchers at BIT Mesra have developed deep learning-based software pipelines for the analysis of planetary features. The pipelines include the U-Net and Mask R-CNN frameworks for the detection of craters on the moon using Chandrayaan-2 Terrain Mapping Camera (TMC-2) images. The system allows for the automated mapping of features on the moon's surface, facilitating planetary geomorphological research. The "CraterMorpho" toolbox, developed in ArcGIS Pro, is used for the morphometric analysis of craters on the moon, including diameter, depth, slope, and degradational features.

**Aerosol and Climate Research Lab (ACRL):** The lab is developed under the DST-FIST Level C scheme and is equipped with sophisticated instruments such as Sunphotometer, Aethalometer (AE33), Aerosol Spectrometer, Gas Analyzers (NOx, O3, CO), Hyperspectral Spectroradiometer, and Automatic Weather Station. The lab is useful for high-resolution monitoring of aerosols and trace gases, estimation of radiative forcing, and validation of climate models. With national and international collaborations such as NASA-AERONET, ISRO, MoES, ACRL is playing a vital role as a research and training center.

## Capacity Building in Space Science Research

Training programs and workshops in the areas of remote sensing, geospatial technologies, satellite data analysis, and applications of artificial intelligence in space science are regularly conducted by BIT Mesra.
Courses offered by BIT Mesra: BIT Mesra offers PhD programs in Remote Sensing & Geoinformatics, Space Engineering and Rocketry, and Computer Science & Engineering. The areas of research focus on space science and technology applications. 11 Ph. Ds have been awarded by the institute related to space science and technology in 2024-2025. The title of Ph. D theses are:

1. **Integrated Assessment of River Riparian Dynamics A Geospatial Framework for Watershed Management** by Aditi Majumdar, under the Guidance of Dr. Kirti Avishek
2. **Assessment of Heterogeneity in Satellite Retrieved Atmospheric Pollutants over Residential Industrial and Commercial Regions of Jharkhand India** by Shalini Priya, under the Guidance of Dr. Jawed Iqbal
3. **Thermophysical Property and Crater Morphometry of Martian Gale Crater and Surroundings** by Farzana Shaheen, under the Guidance of Dr. Mili Ghosh Nee Lala, and Dr. A.P. Krishna
4. **Estimation of Fine Particulate Matter and Aerosol Acidity at Ranchi India** by Abisheg D under the Guidance of Dr. R. Naresh Kumar
5. **A Study on Fog Formation, Its Variability and Implications using Statistical Tools and Geospatial Technologies**, by Kanchan Lakra, under the Guidance of Dr. Kirti Avishek
6. **Aeolian activities over Gale crater and its surroundings driven by Martian climatic parameters** by Nayama Valsa Scariah under the Guidance of Dr. Mili Ghosh Nee Lala, and Dr. A.P. Krishna
7. **Mapping of Calcrete and Gypsum deposits along with associated palaeochannels in arid-and semi-region of Rajasthan using combination of microwave and multi-spectral satellite data** by Raja Biswas under the guidance of Dr. V.S. Rathore.
8. **Modelling Grassland Change Dynamics using Time-Series Satellite Data in Himachal Pradesh, India** by Harshit Rajan under the guidance of Dr. C. Jeganathan.
9. **Study of Vegetation Dynamics with Respect to Rainfall Variability and Vulnerability Assessment of Forests in Central Indian Landscape Using Long-Term Time Series Satellite Data** by Beependra Singh under the guidance of Dr. C. Jeganathan, and Dr. V.S. Rathore.
10. **Investigation of Supersonic Free Jets with Tabs** by Lavala Srinivasa Rao under the Guidance of Dr. Sudip Das, and Dr. Partha Mondal.
11. **Investigation of Aerodynamic Drag Reduction of Supersonic Blunt Bodies using Aero Spikes** by Md Gulam Sarwar under the Guidance of Dr. Sudip Das, and Dr. Priyank.

## Courses offered on Space Science and Technology

| ***Course Title (with Specialization)*** | ***Level*** | ***Intake*** | ***Specializations*** |
|---|---|---|---|
| *M.Sc in GeoInformatics* | *Postgraduate* | *20* | • *Geoinformatics* |
| *M.Tech in Remote Sensing* | | *24* | • *Earth Resources*<br>• *Environment and Climate* |

| | | | |
|---|---|---|---|
| *M.Tech in Space Engineering and Rocketry* | | *12* | • *Aerodynamics*<br>• *Rocket Propulsion* |
| *PhD in Remote Sensing and Geoinformatics* | *PhD Coursework* | *As per institute norms* | • *Planetary Surface Analysis*<br>• *Satellite Data Processing*<br>• *Geospatial Modelling*<br>• *Climate and Atmospheric Studies* |
| *PhD in Computer Science and Engineering* | | | • *Artificial Intelligence for Satellite Data Image Processing* |
| *PhD in Space Engineering and Rocketry* | | | • *Rocket Propulsion*<br>• *Aerodynamics*<br>• *Computational Fluid Dynamics*<br>• *High-Speed Flows* |

## Laboratories and Facilities Available for Space Instrumentation

**Remote Sensing and Geoinformatics Laboratory:** Advanced laboratory equipped with high-performance computing systems and geospatial software (ArcGIS Pro, ERDAS Imagine, QGIS) for satellite image processing, GIS modeling, and planetary data analysis.

**Space Engineering and Rocketry Laboratory:** Laboratory facilities supporting experimental and computational research in aerodynamics, rocket propulsion, and fluid dynamics, including simulation platforms for aerospace applications.

**Artificial Intelligence and High-Performance Computing Laboratory:** Dedicated computing infrastructure with GPU-enabled systems for development of deep learning models for satellite image analysis, planetary data processing, and geospatial AI applications.

**Geospatial Data Processing Laboratory:** Facilities for satellite data visualization, terrain analysis, spatial modeling, and climate data processing using multi-sensor Earth observation datasets.

**Aerosol and Climate Research Lab (ACRL):** The lab is equipped with instruments such as Sunphotometer, Aethalometer (AE33), Aerosol Spectrometer, Gas Analyzers (NOx, O3, CO), Hyperspectral Spectroradiometer, and Automatic Weather Station.

**Cloud server merge with GPU node of HPC and Small Scale Computer Vision lab has been established.**

CSE Department of BIT Mesra is setting up a cloud computing lab with 2 private clouds, first cloud setup has been done through Aneka platform where 30 high configuration workstations are connected by using containerization process and second cloud is hosted on HPC through virtualization process. Both the private clouds are interconnected in master-slave configuration. Future plan is to connect these private clouds to public clouds like amazon and Google. CSE Department has also merged this cloud set up with GPU

node for doing a small set up of computer vision lab in miniature form by merging cloud setup and GPU node of HPC for processing high resolution satellite images.

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# BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

# Pilani, INDIA

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

## About the Institute

BITS Pilani, established in 1964 and recognized as an Institute of Eminence by the Ministry of Education, Government of India, is one of India's leading institutions for higher education and research. With campuses at Pilani, Goa, Hyderabad, and Dubai, the Institute pursues excellence in science, engineering, technology, and interdisciplinary research. BITS Pilani has developed strong capabilities in space science and technology through research spanning astrophysics, advanced materials, communication systems, instrumentation, sensing technologies, embedded systems, and aerospace engineering.

The Institute actively collaborates with national agencies including the Indian Space Research Organisation (ISRO) and supports research that contributes to space exploration, satellite technologies, communication systems, propulsion, advanced manufacturing, and instrumentation. Through its faculty expertise, state-of-the-art laboratories, and student-led initiatives, BITS Pilani continues to contribute toward strengthening India's space science and technology ecosystem.

## Major Research Domains

- **Observational Astronomy and Astrophysics**- Research on stellar populations in open clusters using ultraviolet observations from AstroSat/UVIT and other space-based observatories. Studies focus on blue straggler stars, white dwarfs, hot subdwarfs, stellar evolution, cluster dynamics, and related astrophysical phenomena.
- **Space Propulsion Test and Measurement Systems**- Development of high-precision thrust measurement systems for characterization of pulse-mode and low-thrust propulsion technologies intended for future nanosatellite, cubesat, and microsatellite missions. Research includes experimental mechanics, sensor integration, vibration isolation, precision instrumentation, and transient-force measurement.
- **Advanced Materials and Shape Memory Alloys for Aerospace Applications**- Research on microwave-assisted processing of advanced materials and Shape Memory Alloys (SMAs) for aerospace and space applications. Activities include microstructural engineering, phase transformation studies, fatigue optimization,

corrosion resistance enhancement, and development of cost-effective manufacturing methodologies.

- **Quantum Communication and Space Communication Systems** Research in Quantum Key Distribution (QKD), optical wireless communication, free-space optical communication, THz/RF communication systems, reconfigurable intelligent surfaces, non-terrestrial networks, underwater optical communication, and secure communication technologies for future space missions.
- **Intelligent Communication and Network Systems**- Development of analytical, simulation, optimization, and AI-assisted approaches for next-generation satellite communication systems, hybrid space-terrestrial networks, IoT backhaul systems, and resilient communication architectures for future 6G ecosystems.

## Major Scientific Applications / Results

- **Astrophysical Studies Using AstroSat and UV Observations**

The group led by Dr. Kaushar Vaidya has carried out extensive investigations of exotic stellar populations in open clusters using AstroSat/UVIT and Swift/UVOT observations. In the 1.7 Gyr old open cluster NGC 2627, UV observations identified blue straggler stars, yellow stragglers, and blue lurkers exhibiting ultraviolet excess consistent with extremely low-mass white dwarf companions. The findings provide strong evidence supporting mass transfer as a formation mechanism for these stellar populations.

In Berkeley 39, approximately 50% of blue straggler stars exhibited ultraviolet excess, indicating the presence of compact companions and providing insight into binary evolution and stellar interaction processes.

Studies of Trumpler 5 revealed hot compact companions associated with blue straggler and blue lurker populations, including potential hot subdwarf companions. These observations contribute significantly to understanding stellar evolution pathways in intermediate-age open clusters.

The findings have been published in leading international journals including The Astronomical Journal.

- **Development of Pulse-Mode Thrust Measurement Systems**

The research group led by Dr. Arnab Guha is executing the project titled “Development of Thrust Measurement System (TMS) for measuring pulse mode thrust for pulse widths in the range of 8 ms/16 ms/32 ms/64 ms etc.” funded by the Liquid Propulsion Systems Centre (LPSC), ISRO.

The project focuses on developing indigenous capability for precise measurement of short-duration thrust pulses relevant to nanosatellite and microsatellite propulsion systems.

Current activities include system architecture development, sensing methodologies, vibration isolation strategies, precision instrumentation design, and close technical interaction with ISRO scientists to ensure mission-aligned performance specifications.

- **Advanced Shape Memory Alloys for Space Applications**

The research group led by Dr. Radha Raman Mishra is developing microwave-based processing technologies for advanced Shape Memory Alloys intended for aerospace applications. Current work focuses on understanding mechanical, thermal, and shape-memory characteristics of microwave-cast Nitinol alloys.

The project aims to develop cost-effective processing routes while maintaining stringent aerospace-grade performance standards. Research outcomes are expected to contribute to future actuation systems and adaptive aerospace structures.

- **Quantum Communication and Space Network Technologies**

The research group led by Dr. Syed Mohammad Zafaruddin has established significant expertise in optical wireless communication, RIS-assisted communication systems, THz/RF communication, underwater optical communication, and non-terrestrial networks. Several publications from the group have received substantial international recognition, collectively attracting hundreds of citations. A major milestone is the ISRO RAC-S sponsored project entitled “Development of Simulation and System Engineering Toolkit for Quantum Key Distribution (QKD) Protocols.”

The project addresses secure communication technologies essential for future satellite-based quantum communication networks and space-enabled secure information systems.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

- **Pulse-Mode Thrust Measurement System (Under Development):** A high-precision thrust measurement system is being developed to characterize short-duration pulse-mode thrust in future nanosatellite, cubesatellite, and microsatellite propulsion systems. The system is designed to achieve high temporal resolution, thermal stability, and repeatable force measurements under controlled testing conditions.
- **Hybrid Microwave Casting Setup for Shape Memory Alloys**: A custom laboratory-scale hybrid casting system is being designed and assembled for fabrication of Shape Memory Alloys intended for aerospace and space applications. The setup integrates microwave-assisted processing techniques to achieve improved material properties and manufacturing efficiency.
- **Simulation and System Engineering Toolkit for Quantum Key Distribution**: A software platform with graphical user interface is under development for modeling, simulation, and performance evaluation of Quantum Key Distribution protocols. The

toolkit incorporates protocol modeling, analytical and Monte Carlo simulation capabilities, eavesdropping analysis modules, satellite-link models, and optical-fiber integration capabilities for secure communication research and training.

## Capacity Building in Space Science Research

### Student Outreach and Public Engagement-

The Department of Mechanical Engineering conducts annual outreach activities including “Fun with Fluids” and “Science of Mechanisms,” aimed at promoting scientific curiosity and engineering awareness among undergraduate students.

### Student Space Activities-

BITS Pilani supports Team Anant, a student-led nanosatellite initiative engaged in the development of indigenous CubeSat technologies. The initiative provides students with hands-on exposure to spacecraft subsystems, satellite design, embedded systems, communication systems, and mission planning.

### Research Training in Quantum Communication

The QKD simulation platform being developed by the communication systems research group serves as an educational and research tool for training students and researchers in secure quantum communication technologies relevant to future space applications.

## Courses Offered on Space Science and Technology

| Title of Course | Level |
|---|---|
| Introduction to Astronomy and Astrophysics | UG/PG |
| General Theory of Relativity and Cosmology | UG/PG |
| Radio Astronomy | UG/PG |
| Cosmology | UG/PG |
| Astrochemistry | UG/PG |
| Satellite Communication | UG |
| Advanced Satellite Communication | PG |
| Antenna Theory and Design | UG |
| Optical Communication | PG |
| RF and Microwave Engineering | PG |
| Advanced Wireless Communications | PG |
| Embedded System Design | PG |

| Title of Course | Level |
|---|---|
| Machine Learning for Electronics Engineers | PG |
| Testable Design and Fault-Tolerant Computing | PG |

## Laboratories and Facilities Available for Space Instrumentation

1. **Embedded Controller Applications Center (ECAC)-** Facility supporting embedded systems development, FPGA-based computing, real-time operating systems, fault-tolerant architectures, AI-enabled embedded systems, spacecraft health monitoring, anomaly detection, and intelligent wireless systems.
2. **Optical Communication Laboratory**- Advanced facility for optical communication system design, photonic device development, fiber-optic characterization, optical spectrum analysis, and communication system simulation.
3. **Nanoscale Devices Laboratory**- Supports design, fabrication, and characterization of micro- and nanoscale devices, sensors, MEMS, NEMS, and thin-film technologies relevant to space instrumentation.
4. **Cleanroom Facility-** Centralized cleanroom infrastructure supporting photolithography, thin-film deposition, etching, packaging, and fabrication of high-reliability microfabricated devices.
5. **Dynamics and Vibration Laboratory**- Provides experimental capabilities for vibration testing, modal analysis, structural dynamics, and performance evaluation of precision instrumentation and aerospace hardware.
6. **Instrumentation Facility**- Equipped with National Instruments DAQ systems, LabVIEW-based platforms, high-speed measurement systems, and synchronized multi-channel data acquisition infrastructure.
7. **Hybrid Casting and Advanced Materials Facility**- Supports microwave-assisted processing and fabrication of advanced alloys and aerospace materials.
8. **QKD Simulation and Software Development Facility**- Dedicated facility for development and testing of simulation tools for secure quantum communication systems.
9. **COMSOL-Based Optical and Fiber-Link Modeling Facility-** Provides physics-based simulation capabilities for optical communication systems and integrated quantum communication studies.
10. **High-Performance GPU Computing Facility-** GPU-enabled computing infrastructure supporting machine learning, numerical simulation, communication system analysis, and quantum communication modeling.
11. **Software Defined Radio and RF Communication Facility-** Provides SDR-based communication testbeds, RF experimentation capabilities, wireless protocol implementation, and non-terrestrial communication studies.

# GOVERNMENT GIRLS' GENERAL DEGREE COLLEGE
# 7, Mayurbhanj Road, Kolkata 700023, INDIA

Website: https://www.govtgirlsekbalpur.com

## About the College

Government Girls' General Degree College stands as the fourth government college for girls in Kolkata, West Bengal. Strategically located near the National Library, the Calcutta University Alipur Campus, and other prominent areas of South Kolkata, the institution offers convenient access to a large number of students aspiring to pursue higher education.

The establishment of this college represents a progressive and timely initiative by the Government of West Bengal to promote women's higher education. It addresses a long-standing demand for a dedicated women's college in the locality, voiced over more than a decade. The college is affiliated with the University of Calcutta.

Faculty members across all seventeen departments—encompassing arts, science, and commerce—are deeply committed to providing high-quality academic guidance. Their dedicated efforts play a crucial role in nurturing not only academic excellence but also the holistic development of students.

The college strives to enhance educational standards across all sections of society while fostering intellectual, moral, cultural, and academic growth among students.

Looking to the future, the institution aims to cultivate academic excellence, encourage scientific temperament, organize knowledge-enriching programs, and support the overall development of students. It remains firmly committed to empowering young women—especially those from marginalized communities—by providing them with meaningful access to quality higher education.


*Figure 1: Our college and Physics Department laboratory*

## Major Research Domains

In the vast and ever-expanding realm of space exploration, Government Girls' General Degree College distinguishes itself through focused research in key domains, particularly X-ray astronomy, astrophysics, and the innovative application of machine learning in data science.

**X-ray Astronomy & Astrophysics:**

Research at the forefront of X-ray astronomy and astrophysics at the college is dedicated to understanding the complex physics of accretion processes, especially in Low Mass X-ray Binaries (LMXBs) and blazars. Investigations aim to unravel the intricate dynamics of these binary systems, including the origin of Quasi-Periodic Oscillations (QPOs), and to examine the structural and evolutionary distinctions between Z-type and Atoll sources.

Utilizing advanced space-based observatories such as AstroSat, NICER, and NuSTAR, researchers conduct detailed studies of the evolutionary behavior of these systems. The work also emphasizes the development of theoretical models to interpret observational data, particularly in explaining phenomena such as time lags and root mean square (rms) variability. Furthermore, ongoing research explores the modeling of observed polarization in neutron star Low Mass X-ray Binaries (NS-LMXBs), addressing emerging and significant trends in contemporary astrophysical studies.

**Machine Learning Applications:**

Complementing astrophysical research, the college actively integrates machine learning techniques into data analysis, marking a significant step toward modern, data-driven scientific inquiry. In astrophysics, machine learning plays a transformative role in managing and analyzing large datasets. Advanced algorithms, including neural networks, are employed to identify patterns, classify celestial objects, and extract meaningful insights from complex data. This interdisciplinary approach positions the institution at the intersection of traditional astrophysics and cutting-edge computational science.

## Major Scientific Applications / Results:

- *Spectral and Timing evolution of GX340+0 along its Z-track*, https://doi.org/10.1093/mnras/stae389

  We present results from a spectral and timing study of the Z-source GX 340+0 using data from AstroSat's SXT and LAXPC instruments. This study investigates how spectral components evolve along the Z-track and how these changes are linked to the appearance of different QPOs across the different states. During the observation, the source traced out the complete Z-track, enabling a detailed study

of spectral evolution across the horizontal branch (HB), normal branch (NB), and flaring branch (FB), as well as the hard apex (HA) and soft apex (SA).

The spectra are more accurately and physically described by a model consisting of a blackbody component and a hot Comptonizing corona with a variable covering fraction, rather than one including a disc component. Along the Z-track, the Comptonized flux—along with the covering fraction—decreases monotonically. In contrast, the blackbody component, in terms of both temperature and radius, varies non-monotonically, driving the characteristic Z-track behavior.

Rapid timing analysis reveals a prominent quasi-periodic oscillation (QPO) at ~50 Hz in the HB, HA, and upper NB, while a ~6 Hz QPO is observed in the remaining branches. The fractional rms of these QPOs increases with energy and exhibits soft lags in all branches except the SA and FB.

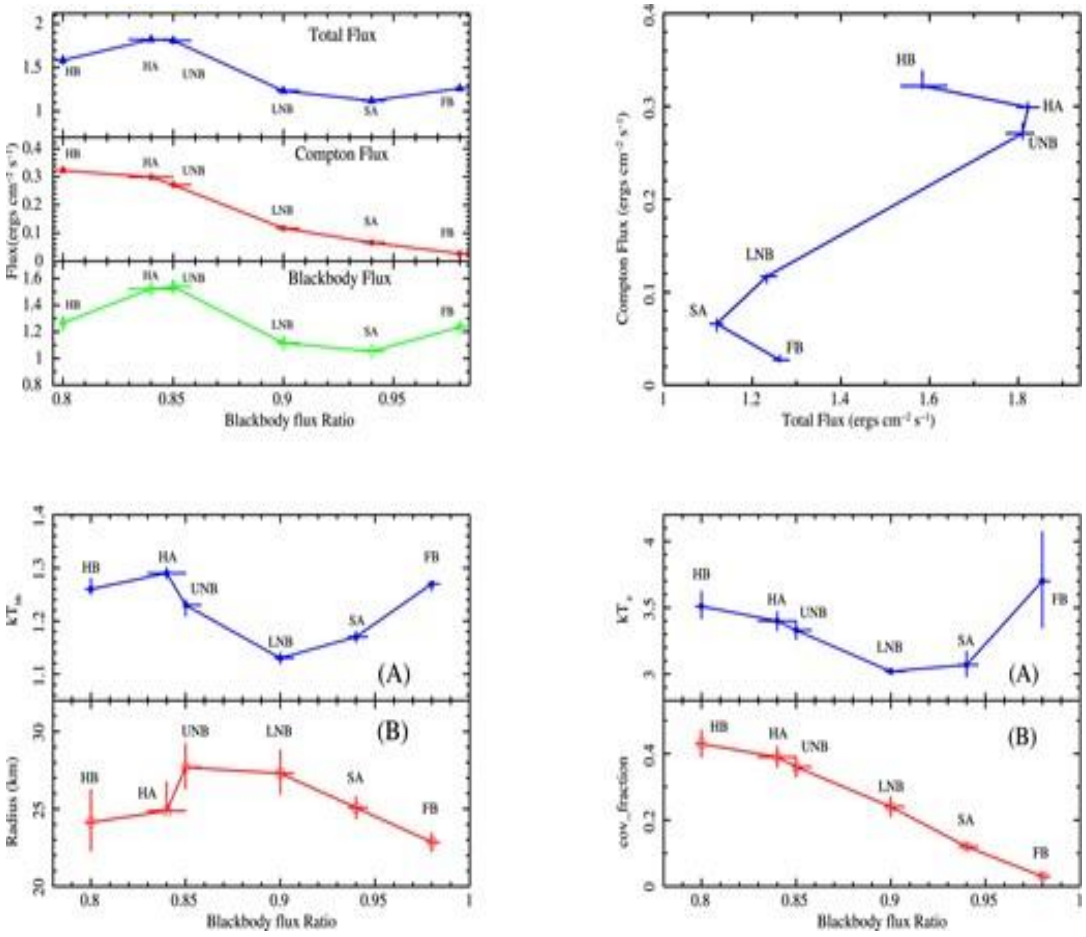



Figure 2: Variation of Different Spectral Parameters

- Spectro-temporal Evolution of 4U1702 − 429 Using AstroSat-NICER, https://doi.org/10.3847/1538-4357/ad9332

  The study focuses on the atoll source 4U 1702−429 and investigates the broadband spectro-temporal properties during different observations to determine whether the observed kilohertz QPO originates from the inner accretion disc or from a compact Comptonizing corona surrounding the neutron star. For both observations, the spectra are well described by a Comptonization model in which blackbody seed photons originate from the neutron star surface. In addition, contributions from an accretion disk and a distant reflection component are required to fit the data adequately. By modelling the energy-dependent rms and time lags, this work provides constraints on the size of the corona and explores its role in generating rapid variability. Modelling the energy-dependent fractional rms and time lags of the kHz QPO suggests a compact corona with a size of ≤30 km. A similar framework successfully explains the energy dependence of the broadband noise component at ~10 Hz in the second observation. These findings indicate that kHz QPOs are likely associated with a compact corona surrounding the neutron star and tend to occur when the accretion disk is truncated at relatively large radii.
  Further broadband observations of this source are required to confirm and refine these results.

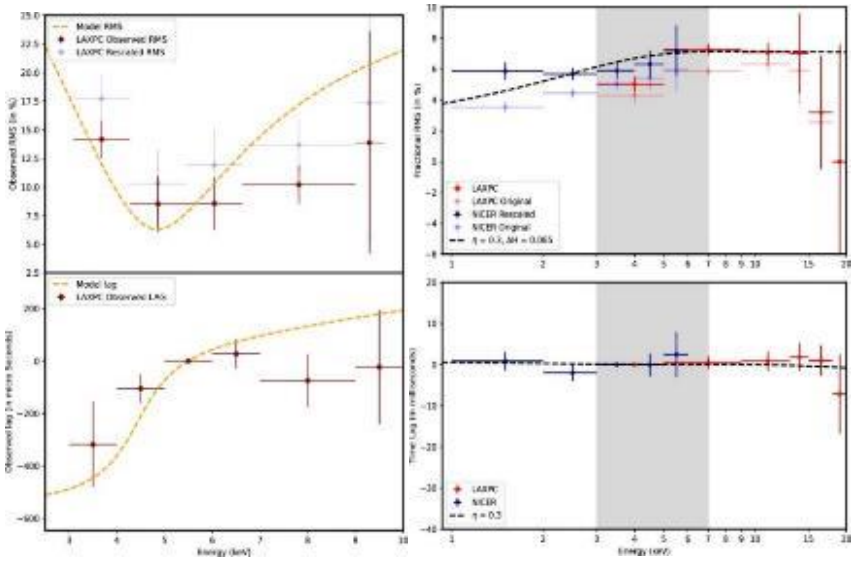


Figure 3: **Left Panel**: The observed rms (top) and lag (bottom) for the kHz QPO ~800 Hz. The model lag and rms variation are based on the variation in the corona's heating rate. **Right Panel**: The fractional rms and time-lag variation with LAXPC 20 within 3–20 keV and NICER within 1–7 keV at 9.37 Hz for Obs. 2.

- *Spectral-timing analysis of the kilo-hertz quasi-periodic oscillations and constraints on the mass of the neutron star in 4U1636−536 using AstroSat observations,* https://doi.org/10.1093/mnras/staf1596

  In this study, we present a systematic investigation of kHz QPOs, their variability, and their connection to spectral properties in $U 1636-536 using AstroSat observations. Our analysis traces the source's evolution from hard to soft spectral states in the hardness–intensity diagram. Broad-band spectral analysis (0.7–25 keV), utilizing data from SXT and LAXPC, reveals a spectrum shaped primarily by reflection from a thermal corona, along with contributions from boundary layer emission and a soft disc component. We observe significant variations in optical depth, blackbody temperature, and inner disc temperature, which likely drive the spectral state transitions. Power density spectra identify three distinct types of variability: a low-frequency QPO (LFQPO; ~30 Hz) and two simultaneous kHz QPOs. Both the LFQPO and the upper kHz QPO are more prominent during soft spectral states.
  The simultaneous presence of LFQPOs and twin kHz QPOs in soft states allows us to estimate the neutron star mass at $2.37 \pm 0.02\ M_{\odot}$ using the relativistic precession model (RPM). Furthermore, time-lag and root mean square (rms) analyses provide additional constraints on the size of the corona and the radiative origin of these variability components.

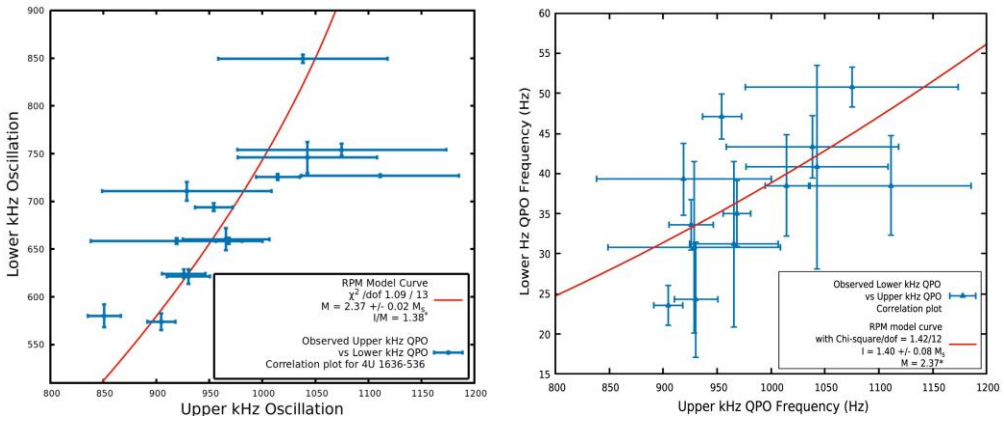



Figure 4: Left panel: The correlation of the upper kHz QPO versus lower kHz QPO Right Panel: shows the correlation of upper kHz QPO versus LFQPO we obtained in different segments. The estimated mass of the system is $2.37 \pm 0.02\ M_{\odot}$ and the $\frac{I}{M} = 1.40 \pm 0.08$ in units of $I_{45}$ assuming a spin frequency of $300$ Hz.

- Quasiperiodic Oscillation Signatures of Disk restoration after Type-I X-ray Bursts from 4U1636 – 536, https://doi.org/10.3847/1538-4357/adf63a

In this study, we investigate the evolution of kHz QPOs before and after TNBs using X-ray observations in the 3–20 keV band. Our results extend the findings of P. Peille et al. (2014) by revealing how burst occurrence modifies the inner accretion environment and influences the presence of high-frequency oscillations. The temporary disappearance of kHz QPOs following Type I bursts and their subsequent recovery on timescales of ~ 100–200 s suggest that bursts can disrupt or evacuate the inner accretion disk, temporarily suppressing the mechanisms responsible for generating high-frequency variability. The observed recovery timescale is broadly consistent with viscous refilling of the inner disk region, supporting the idea that the disk structure and the associated variability are tightly coupled.

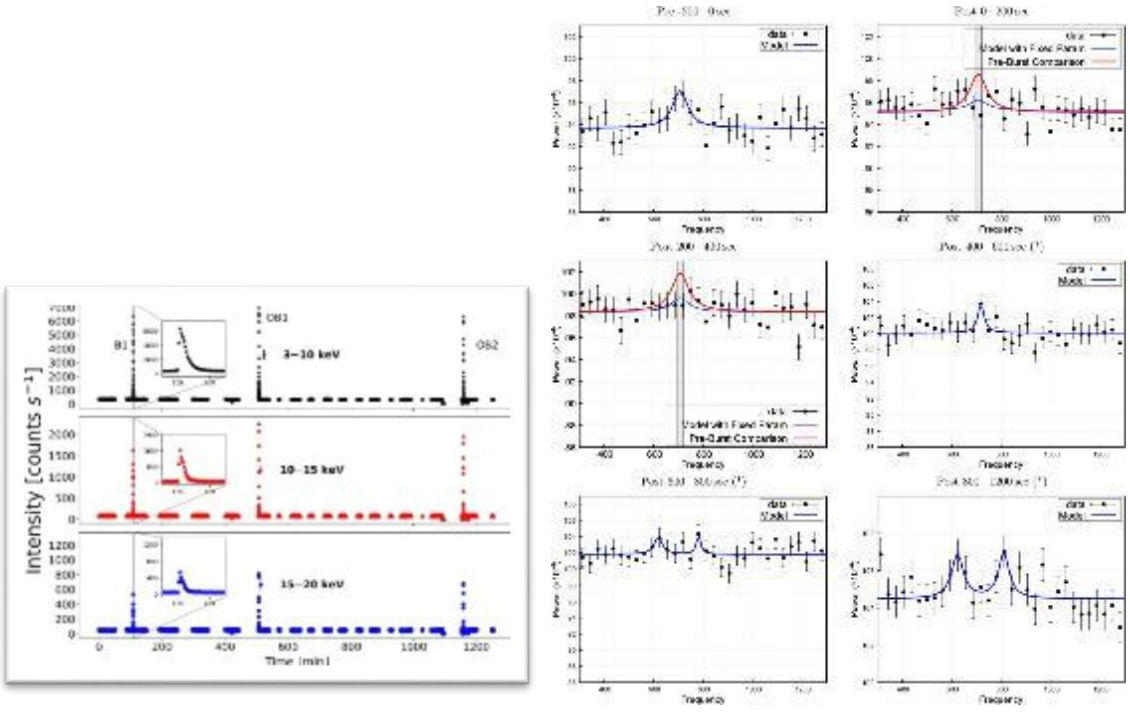



Figure 5: Left Panel: Light curve of observation 1, Right Panel: The evolution of the kHz QPO in the preburst and the postburst zone of the type-I TNB of observation 1

Taken together, the studies presented here therefore contribute to a broader understanding of how accretion proceeds in neutron star systems and how the coupling between disk, corona, and stellar surface shapes the rich phenomenology observed in NSLMXBs. These findings reinforce the importance of simultaneous spectral and timing

analyses across multiple energy bands to constrain the geometry and physical conditions of the inner accretion flow.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

We are not involved in developing any instruments or payloads. These are beyond our scope.

## Capacity Building in Space Science Research

Government Girls' General Degree College offers undergraduate programmes in the basic sciences. Alongside the core curriculum, the institution actively encourages students to expand their knowledge in space science and technology through a series of seminars, workshops, and academic enrichment activities.


While the college does not offer a direct Ph.D. programme, several faculty members are recognized as research supervisors under the University of Calcutta. This affiliation enables students to pursue advanced research opportunities under expert guidance. Notably, one of the project students, Mr. Suchismito Chattopadhyay, whose work was funded by ISRO, has submitted his doctoral thesis to the University of Calcutta under the supervision of Dr. Soma Mandal. His doctoral research, titled *"Study of X-ray Timing Properties of Neutron Star Low Mass X-ray Binaries,"* reflects significant contributions to the field of astrophysics. His research findings have been published in the prestigious journals *Monthly Notices of the Royal Astronomical Society* and *The Astrophysical Journal*.

## Courses offered on Space Science and Technology:

University of Calcutta offers the Astronomy and Astrophysics course as a discipline-specific subject in the undergraduate level. There is no course on space science and

technology specifically. It would be a great opportunity for the students if it were introduced in the curriculum.

## Laboratories and Facilities Available for Space Instrumentation:

We do not have any laboratories or facilities available for space instrumentation.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.wbes@gmail.com**

# GURU GHASIDAS VISHWAVIDYALAYA, BILASPUR

A Central University established by the Central Universities Act 2009 No. 25 of 2009

## Koni, Bilaspur, Chattisgarh, INDIA, 495009

Website: www.new.ggu.ac.in

### About the Centre / Laboratory / Institute

Guru Ghasidas Vishwavidyalaya (GGV), established as a Central University under the Central Universities Act, 2009 (No. 25 of 2009), is located in Bilaspur, Chhattisgarh, India. The university is a member of both the Association of Indian Universities and the Association of Commonwealth Universities. Named in honor of the revered 18th-century Satnami saint Guru Ghasidas Baba, the institution reflects its commitment to serving a socially and economically challenged region. GGV strives to develop and enhance innovative academic programs in emerging interdisciplinary fields across Science, Social Sciences, and Humanities, with a strong emphasis on quality assurance. Its objective is to expand the knowledge base within the university and contribute broadly to the academic community. The university is dedicated to providing value-based, holistic education that fosters the overall growth and development of individuals, enabling them to serve society effectively. The mission of GGV is to promote academic excellence through advanced undergraduate, postgraduate, and doctoral programs. It also seeks to strengthen academic, professional, and research capabilities by collaborating with national and international institutions, universities, and industries.


**Main entrance of GGV**


**Front View of Departyment of Physics**

### Major Research Domains

Under the guidance of Prof. Parijat Thakur, the Department of Pure and Applied Physics is actively engaged in several research programs in the field of space science:

- **Black Hole X-ray Binaries (BHXRBs):** This research focuses on understanding the accretion processes around stellar-mass black holes, along with the geometry of the accretion disk and corona. The transient behavior and variability in X-ray emissions make these systems excellent laboratories for exploring black hole properties and studying the interaction between black holes and their companion stars.

- **Neutron Star X-ray Binaries (NSXRBs):** Research in this domain primarily investigates Quasi-Periodic Oscillations (QPOs) produced in the vicinity of neutron stars. These studies aim to uncover the physical origin of QPOs and provide insights into strong gravity regimes, potentially testing predictions of general relativity. Additionally, work is being carried out on thermonuclear bursts occurring on neutron star surfaces, offering deeper understanding of their structure and behavior.

- **Extra-solar Planets:** Exoplanetary science is an emerging and rapidly growing area in astrophysics. The group focuses on transiting Jupiter-sized exoplanets, commonly known as hot Jupiters. The key objectives of this research include:

➔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 a comprehensive timing and broadband spectral analysis using an AstroSat observation of the low-mass black hole X-ray binary H 1743–322 during its 2017 outburst. Additionally, we use two Swift/XRT observations, one of which is simultaneous with AstroSat and the other taken three days earlier, for timing analysis. The hardness–intensity diagram indicates that the 2017 outburst was a failed one, unlike the previous successful outburst in 2016. We detect type C quasi-periodic oscillation (QPO) in the simultaneous AstroSat and Swift/XRT observations at ∼0.4 Hz, whereas an upper harmonic is noticed at ∼0.9 Hz in the AstroSat data only. Although these features are found to be energy-independent, we notice a shift of ∼0.08 Hz in the QPO frequency over the interval of three days. We also investigate the nature of variability in the two consecutive failed outbursts in 2017 and 2018. We detect soft time lags of 23.2 ± 12.2 ms and 140 ± 80 ms at the type C QPO frequencies in 2017 AstroSat and 2018 XMM-Newton data, respectively. The lag–energy spectra from both the outbursts suggest that the soft lags may be associated with reflection features. The broadband spectral analysis indicates that the source was in the low/hard state during the AstroSat observation. Modeling of the disk and reflection continuum suggests the presence of an accretion disk that is significantly truncated by at least $27.4r_g$ from the innermost stable circular orbit when the source luminosity is ∼1.6% of the Eddington luminosity. The detail of this research work is as under:

**“2017 Outburst of H 1743–322: AstroSat and Swift View” Pragati Sahu**, Swadesh Chand, **Parijat Thakur (Corresponding Author)**, G. C. Dewangan ,V. K. Agrawal, Prakash Tripathi, and Subhashish Das 2024, *ApJ,* 975:165 (13pp) (DOI: https://doi.org/10.3847/1538-4357/ad7a6d).

In the field of extra-solar planets, We present Transit Timing Variations (TTVs) of HAT-P-12b, a low-density sub-Saturn mass planet orbiting a metal-poor K4 dwarf star. Using 14 years of observational data (2009-2022), our study incorporates 7 new ground-based photometric transit observations, three sectors of Transiting Exoplanet Survey Satellite (TESS) data, and 23 previously published light

curves. A total of 46 light curves were analyzed using various analytical models, such as linear, orbital decay, apsidal precession, and sinusoidal models to investigate the presence of additional planets. The stellar tidal quality factor ($Q'_* \sim 28.4$) is lower than the theoretical predictions, making the orbital decay model an unlikely explanation. The apsidal precession model with a $\chi^2_r$ of 4.2 revealed a slight orbital eccentricity (e = 0.0013) and a precession rate of 0.0045 rad/epoch. Frequency analysis using the Generalized Lomb-Scargle (GLS) periodogram identified a significant periodic signal at 0.00415 cycles/day (FAP = $5.1\times10^{-6}$ %), suggesting the influence of an additional planetary companion. The sinusoidal model provides the lowest reduced chi-squared value ($\chi^2_r$) of 3.2. Sinusoidal fitting of the timing residuals estimated this companion to have a mass of approximately 0.02 $M_J$ , assuming it is in a 2:1 Mean-Motion Resonance (MMR) with HAT-P-12b. Additionally, the Applegate mechanism, with an amplitude much smaller than the observed TTV amplitude of 156 s, confirms that stellar activity is not responsible for the observed variations. The detail of this research work is as under:

**"Transit Timing Variations of the Sub-Saturn Exoplanet HAT-P-12b"**, 2025, New Astronomy, 119, 102390, DOI: https://doi.org/10.1016/j.newast.2025.102390

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors (if any): Nil

## Capacity Building in Space Science Research

To promote scientific understanding and awareness in the field of space science, now the Department of Pure and Applied Physics provides Astronomy and Astrophysics course for students enrolled in B.Sc. (Physics) as per the rule followed by new education policy (NEP) 2020. As well as M.Sc. (Physics) students do their dissertation in Astronomy and Astrophysics domian. These projects are designed to offer students practical exposure and deeper insights into various research areas within Astronomy and Astrophysics. In addition, the department offers a Ph.D. program specializing in Astronomy and Astrophysics. In this context, one of the research scholars, Swadesh Chand, has been awarded his Ph.D. degree for his thesis titled *"**Exploring the Environment of Accreting Black Hole with X-ray Binaries**."* He is currently working as a postdoctoral fellow at Institute of Astronomy, NTHU, Taiwan. Furthermore, another Ph.D. scholar, Vineet Kumar Mannaday, has been awarded his Ph.D degree for thesis titled *"**Investigating Close-in Extra-solar Planetary Systems through Photometric Follow-up of their Transits.**" Currently he is working as an Assistant professor at Department of Physics, Govt. Niranjan Kesharwani College, Kota, Bilaspur (C.G.)-495113, India. On the other hand, Ms. Pragati Sahu has already submitted her Ph.D. thesis entitled "**Probing Black Hole X-ray Binaries with Spectral and Temporal Studies**".*

*Currently, two additional Ph.D. scholars are actively pursuing research in the domain of Astronomy and Astrophysics. The titles of their theses along with their names are listed below:*

- **“Probing the Neutron Star X-ray Binaries with Spectral and Timing Analysis”** by Mr. Subhasish Das
- “**Transit Timing Variations and Atmospheric Characterization of Transiting Exoplanets**” by Ms. Harleen Babra

## 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) | 75 | Basic Astronomy and Astrophysics (Theory as well as corresponding Experiments using virtual observatory) |
| M.Sc. (Physics) | 4 | Basic Astronomy and Astrophysics, especially X-ray Binary and Extra-solar planets |
| Ph.D. (Physics) | 8 | Astronomy and Astrophysics |

**Laboratories and Facilities Available for Space Instrumentation:** Not Applicable

**Payload Operation Centre (POC):** Not applicable

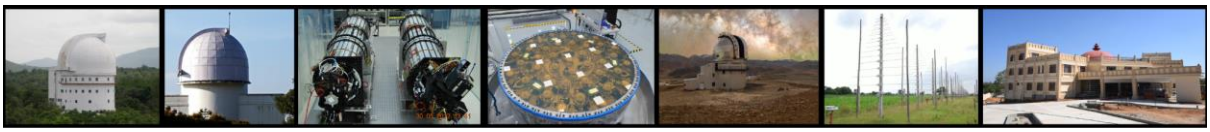
**Environmental test Facility:** Not applicable

**Cleanroom for development:** Not applicable

# INDIAN INSTITUTE OF ASTROPHYSICS BENGALURU, INDIA

Website: https://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, Government 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 currently runs six field stations and campuses across the country. 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, celebrated its 125th anniversary in 2024. Gauribidanur Radio Observatory (run with RRI) 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, along with the remote observation facility for the HCT in Hanle. COSMOS-Mysuru, one of the world's first LED Dome planetaria, will be inaugurated in the coming months as well.

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 a special focus on astronomy domains related to space sciences.

1. **Solar physics and Space weather**

- Solar Physics: 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: 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, as well as solar variability on earth-radiation budget and studies of aerosol optical and radiative properties.

**2. Space payload instrumentation**

The UltraViolet Imaging Telescope (UVIT) onboard AstroSat (operational since 2015), and the Visible Emission Line Coronagraph (VELC) onboard Aditya-L1 (since 2023) 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 its MGK Menon Lab for Space Sciences. The facility is now being increasingly used by other space start-ups as well as universities for testing and integrating their space payloads.

**3. 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.

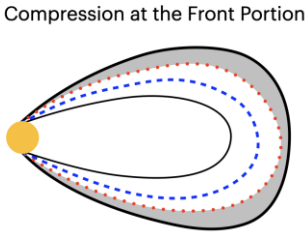
**4. Astrophysics with space telescopes**

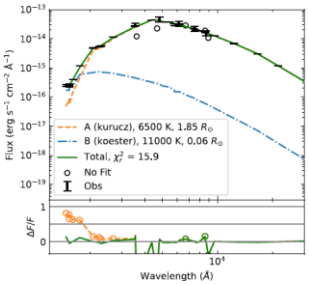
Scientists at IIA routinely use UVIT onboard AstroSat and the payloads on board Aditya-L1, as well as other space based telescopes launched by NASA, ESA etc, for research on star formation in galaxies, stellar evolution and binary star mass transfers, galaxy interactions, AGNs and galaxy feedback, etc.

## Major Scientific Results

Though the Institute published a large number of papers on almost all branches of astrophysics, only those that relate to Indian space telescopes and space weather are summarised here.

**(1) Coronal Mass Ejections and Space Weather**: Several studies of CMEs and their propagation dynamics in near-Earth space have been carried out at IIA. One study examines six Earth-directed CMEs from May 2024, showing that their interactions produced complex ejecta at 1 AU and altered their thermal evolution (Reference). Another study analysed the September 2023 CME using closely spaced STEREO-A and Wind data revealing mesoscale structural differences in its magnetic cloud (Reference).



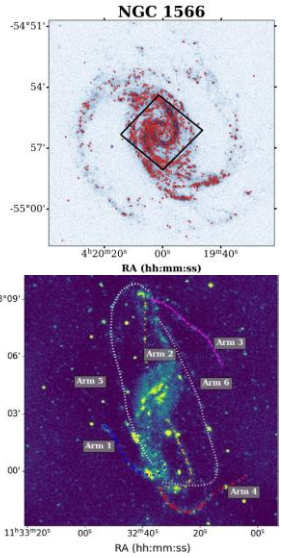



**(2) Discovery of a Barium BSS and a white dwarf companion:** The first evidence for a white dwarf companion to the Barium Blue Straggler Star WOCS 9005 came from multiwavelength SED with crucial far-UV data from the UVIT/AstroSat. The white dwarf was estimated to have a T_eff of 9750–15250 K. The observed enhancements in the BSS are attributed to a recent mass transfer from a companion AGB star, now a young WD (Reference)

**(3) UVIT Study of the MAgellanic Clouds (U-SMAC):** The UVIT/AstroSat was used to make the first far-UV map of the NE Small Magellanic Cloud (SMC)-Shell region. Arm-like and arc-like structures detected in the FUV stellar density map are the spatial stellar over-densities formed over multiple episodes of star formation, but without apparent kinematic distinction (Reference).

**(4) Feedback Effects in AGN:** Feedback effects in AGN were studied using multi-wavelength data including from UVIT/AStroSat and outflows were found across all AGN types and are primarily driven by radiation, with radio jets contributing secondarily, and signatures of both AGN and supernova feedback were detected (Reference).

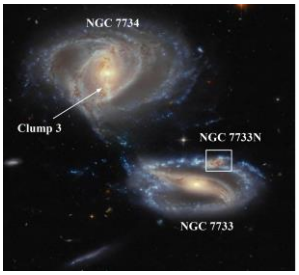
**(5) Fractal-like star formation in nearby galaxies:** Using the large fov of UVIT/AstroSat, a two-point correlation function was used to quantify the spatial arrangement of star-forming clumps in spiral arms, revealing a fractal-like hierarchy up to ~1 kpc in four nearby spiral galaxies. The extent of hierarchical star formation was found to depend on galaxy-specific properties, indicating that it is not universal (Reference).



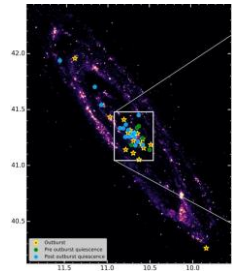

**(6) Star formation in a tidally disturbed galaxy NGC 3718:**

A multiwavelength study of star-forming complexes in the nearby peculiar galaxy NGC 3718 with a disturbed morphology was carried out, including data from UVIT/AstroSat. Using UV images, the warped star-forming disk, the extended tidal arms, and the distribution and sizes of the 182 SFCs were investigated. The study reveals that minor mergers can trigger the inside-out growth of galaxy disks, where the younger SFCs are in outer tidal arms (Reference).

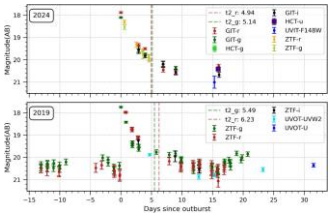
**(7) Central kinematics in the triple-AGN NGC 7733-7734 interacting group:** The interacting triple AGN system NGC 7733-34 was studied focusing on stellar kinematics, ionized gas characteristics, and star formation within the central region and stellar bars of both galaxies, using archival data from UVIT/AstroSat and other telescopes. A disc-like bulge was identified in both NGC 7733 and NGC 7734 (Reference).




**(8) A Search for Novae in UVIT Snapshots of M31:** For the first time, a UV catalog of novae in M31 using the archival data from UVIT/AstroSat was presented. 42 novae were found, of which 15 were detected in multiple filters in the FUV and NUV. The novae detected at quiescence and in outburst show signatures of an accretion disk and a pseudo-photosphere respectively, illustrating the importance of UV surveys in illuminating theoretical predictions for novae (Reference).

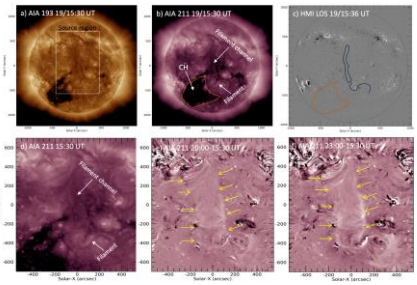


**(9) The rapidly recurring nova M31N 2017-01e in a BeWD system:** A multi-wavelength analysis of the fastest known recurrent nova M31N 2017-01e in M 31 was done combining optical and UV (UVIT/AstroSat) data across multiple phases. They propose a rare Be–white dwarf (Be–WD) binary scenario, where accretion occurs from the decretion disc of the Be star, challenging the standard paradigm of nova progenitors and highlights a distinct evolutionary channel for interacting systems (Reference).



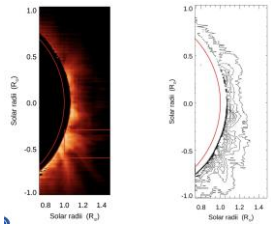

**(10) Survival of the Accretion Disk in LMC Recurrent Nova 1968-12a:** The 2024 eruption of the recurrent nova LMCN 1968-12a was studied using coordinated UV and X-ray observations from AstroSat and other observatories. Analysis revealed evidence that the accretion disk around the white dwarf remained largely intact throughout the eruption and resumed activity shortly, adding to the growing evidence that accretion disks in rapidly recurring novae can survive powerful outbursts and recover quickly (Reference).

**(11) Stealth CMEs Producing Intense Geomagnetic Storms:** Unlike most intense geomagnetic storms driven by powerful CMEs that can readily be identified in remote-sensing solar observations, stealth CMEs can erupt without warning and can produce severe geomagnetic disturbances. The intense geomagnetic storm on 23–24 Mar 2023 was studied using archival data and was traced to a subtle CME on 19 March. This eruption lacked conventional precursors and was likely aided by

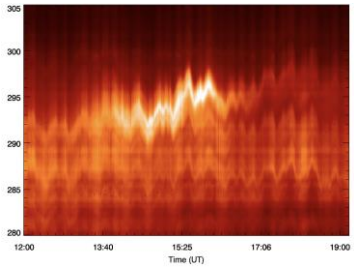


a nearby coronal hole to travel all the way from the Sun to Earth, highlighting the role of coronal holes in subtle CME propagation. (Reference).

**(12) Near-Sun characteristics of a CME using VELC data:** A CME at 1.06 R_sun on 13 Sep 2024 was studied using observations of the solar corona in the 530.3 nm (Fe XIV) emission line with the VELC/Aditya-L1 and various CME parameters were estimated. The procedure can be used to understand CMEs in the visible range, particularly close to their onset (Reference).



**(13) Temporal variations in the 530.3 nm line emission during a flare-less CME:** Long-duration (7 hrs) observations of the line emission associated with a flareless CME from an active region using the VELC/Aditya-L1 shows a steady intensity followed by a gradual decrease, with an opposite effect on line width. Changes in the doppler velocity and effective temperature were also measured (Reference).




**(14) Onset of a CME using 530.3 nm line emission from VELC:**

The onset of a CME on 16 July 2024 associated with an X1.9 class soft X-ray flare as observed in the 530.3 nm line using VELC/Aditya-L1. The results constrain the onset time of the CME and indicate a ~50% decrease in the coronal intensity near the source region of the CME due to mass depletion with corresponding changes in line width and doppler velocity (Reference).

## Indigenously Developed Instruments

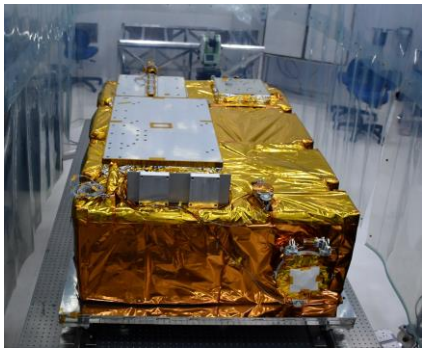
1. **UltraViolet Imaging Telescope (UVIT) onboard AstroSat**

The Ultra Violet Imaging Telescope (UVIT) on Astrosat images the sky at a resolution of ~1.5” in the FUV (120-180 nm) and NUV (180-300 nm) channels simultaneously, with ~0.5 degree FOV, along with a Vis channel (3500-5500 A). The UV and visible wavebands are covered through the use of broad and narrow band filters. UVIT was developed at the MGK Menon Lab for Space Sciences at IIA’s CREST campus. (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 a resolution of 2.5 arcsec, a cadence of 3 Hz, and spectroscopic capability in four channels. 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. At 10% the market price, the sensor was based on the single-board Linux computer Raspberry Pi. (Reference: Chandra et al 2022)

4. **INdian Spectroscopic and Imaging Space Telescope**

The Indian Spectroscopic and Imaging Space Telescope (INSIST), proposed by IIA to ISRO, is a next-generation 1-meter UV-optical space observatory designed to fill a major gap in space-based UV astronomy. It combines an ultra-wide 0.25 square-degree field of view with 0.2” resolution for simultaneous multi-band UV, *u*, and *g* imaging. INSIST employs innovative Digital Micro-Mirror Device (DMD) technology as configurable slits for multi-object spectroscopy. IIA has deployed a functional DMD spectrograph on its 1.3-meter JCBT telescope as a demonstrator. The Python Image Simulation and Testing Application (PISTA) has also been developed, whose simulated images match Hubble-quality photometric consistency while providing a wider field of view.

## Capacity Building in Space Science Research

- Several students at IIA are pursuing research in studying celestial sources using data from observatories launched by India (ASTROSAT, Aditya-L1) as well as those operated by other agencies, for their Ph.D. degree. Five students are currently pursuing their Ph.D.s using VELC/Aditya-L1 data.

- 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 Jan 2024:

## Courses offered on Space Science and Technology

IIA offers Astronomical Technique courses to its Ph.D. students enrolled in Pondicherry University and AcSIR. Under this course, IIA teaches topics related to space science and technology. The courses offered are:

- Radiative Processes in Astrophysics
- Fluid Mechanics and Plasma Physics
- Stellar Astrophysics

- Numerical and Statistical Physics
- Galaxies and Interstellar Medium
- General Relativity and Cosmology
- Solar Physics
- Astronomical Techniques
- Research Methodology and Research Ethics

In addition, students pursuing the integrated 6-year M.Tech-PhD program in collaboration with Calcutta University undergo various courses on detector, optics and adaptive optics at both CU and IIA before undertaking their M. tech and PhD dissertation work at IIA

## 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 millibar, 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. 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 scope@iiap.res.in

# INDIAN INSTITUTE OF GEOMAGNETISM
# NAVI MUMBAI, INDIA

https://iigm.res.in

## About Indian Institute of Geomagnetism

The Indian Institute of Geomagnetism (IIG), established in 1971, is a premier and autonomous research institute under the Department of Science and Technology, Govt. of India. IIG pursue advanced research in understanding the Earth's magnetic environment, space weather, and their societal impacts through cutting-edge research, international collaboration, and capacity building. IIG is also mandated to maintain and modernize a nationwide network of magnetic observatories, and generating high-quality long-term data to study processes ranging from Earth's interior dynamics to Sun–Earth interactions. The institute also emphasizes on technology development, consultancy services, Ph.D and training programs to strengthen scientific human resources.


*Indian Institute of Geomagnetism, Navi Mumbai, India*

## Major Research Domains

- Space Weather and Solar–Terrestrial Interactions: IIG pursue advanced research on Space Weather and Solar-Terrestrial interactions by investigating the impacts of solar variability on Earth's magnetosphere-ionosphere-thermosphere systems using observations, modelling, and simulations.
- Magnetospheric Physics and Particle Dynamics: IIG conducts theoretical, observational and numerical simulation-based studies of charged particle behavior in Earth and planetary magnetospheres. This includes wave–particle interactions and radiation belt dynamics, contributing to understanding satellite radiation hazards and Earth and planetary magnetic environment variability.
- Ionospheric Physics and Radio Propagation: The institute studies equatorial and low-latitude ionospheric dynamics, with an emphasis on equatorial electrojet and equatorial

plasma bubble irregularities. It has developed EEJ model and a radio wave propagation simulator through the ionosphere.

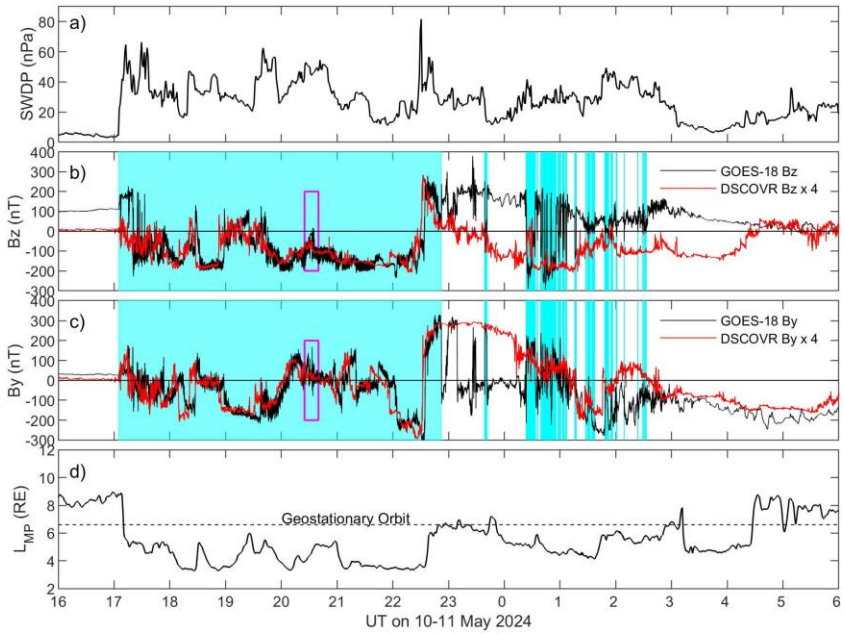
- Geomagnetism and Magnetic Observatory Network: Through a nationwide network of magnetic observatories, IIG monitors variations in Earth's magnetic field. These observations are crucial for studying magnetospheric processes, geomagnetic storms, and long-term field changes affecting space-based technologies.
- Space Instrumentation and Indigenous Technology Development: IIG is currently developing advanced instruments such as Proton Precession Magnetometers, Overhauser Magnetometer, and ionospheric sensors such as Fabry-Perot Interferometer (FPI) and scintillation receivers.
- Polar and High-Latitude Geospace Studies: The institute operates experiments such as magnetometers, NaI scintillation detectors, Riometer in Antarctic and Arctic regions to study high-latitude space weather phenomena. These observations improve global understanding of magnetosphere–ionosphere coupling at high-latitude/polar regions.
- Modelling, Simulation, and AI/ML Applications: IIG integrates physics-based models with AI/ML techniques to simulate geospace processes. These tools enhance forecasting accuracy of ionospheric and geomagnetic disturbances, supporting strategic applications in defence, navigation, and satellite operations.

## Major Scientific Applications / Results

Magnetosonic (MS) waves: The Magnetosonic waves are generated by Maxwellian ring-distributed protons in different plasma environments. In Earth's magnetosphere, the theoretical model developed in IIG shows that such protons can excite MS waves across a wide frequency range, including harmonic structures, with growth influenced by ring velocity, thermal speeds, and background plasma conditions. Extending this to Mars, where the plasma environment is weaker and ion-rich, the research demonstrates that ring protons (~100 eV) can still effectively drive MS waves, though growth rates depend on factors like heavier ion concentration and temperature (https://doi.org/10.1029/2024GL112947). Together, these results enhance understanding of wave generation and particle heating in space plasmas.

Super-intense Geomagnetic Storm of 10–11 May 2024: A complex ICME with extreme solar wind conditions has produced one of the most intense geomagnetic storm of the space age on 10-11 May 2024 due to strong solar wind-magnetosphere coupling (https://doi.org/10.1029/2024SW004126). It led to dramatic ionospheric effects, including an unprecedented super-fountain and equatorial ionization anomaly expansion beyond ±30°, with electron densities in the topside ionosphere increasing up to ~500% (https://doi.org/10.1029/2024JA033340). Strong and sharp IMF-By and Bz rotations generated enhanced dawn-to-dusk electric fields, causing significant plasma uplift near the equator (https://doi.org/10.1029/2024GL112569) and sharp westward current pulses

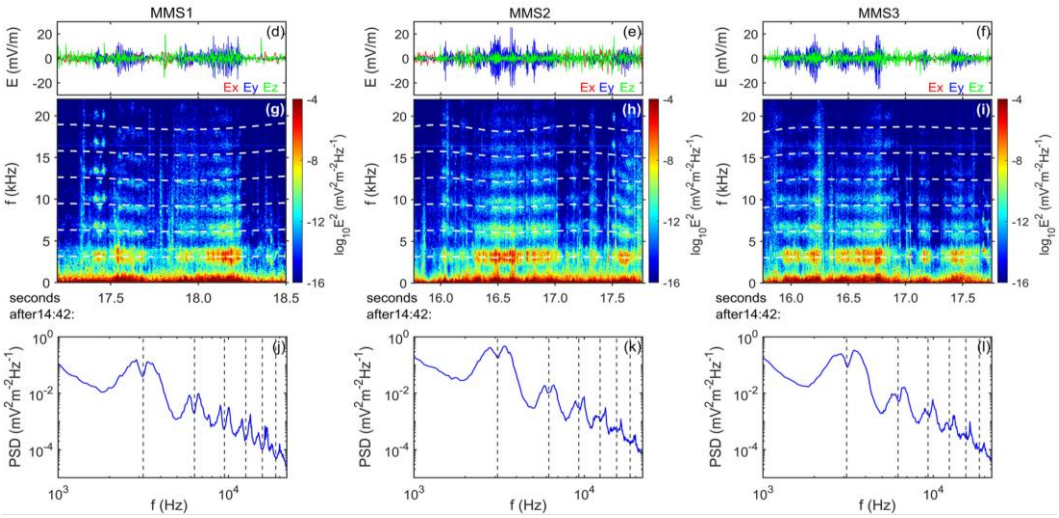
penetrating deep into low latitudes (https://doi.org/10.1029/2025GL117032 and https://doi.org/10.1029/2025GL119914). Overall, the storm revealed complex electrodynamic processes, highlighting intensified coupling, extreme plasma redistribution, and significant impacts on low-latitude ionospheric dynamics.




*Severe compression of Magnetosphere with magnetopause pushed below the Geostationary orbit (6.6 RE) continuously for six hours on 10-May-2024 super-intense storms*

Effects of north magnetic pole drift on magnetospheric particle precipitation: The drift of the north magnetic pole alters Earth's magnetic field configuration, affecting the motion and penetration altitude of charged particles in the magnetosphere. Simulation results indicate that the penetration altitude of MeV-keV range protons are increased by 400–1200 kms over Siberian longitudes due to changes in magnetic field gradients over this region.

Electron Cyclotron Harmonic (ECH) Waves: Banded Electron Cyclotron Harmonic (ECH) waves, are first time observed, near Earth's subsolar magnetopause by MMS satellites. Fundamental (n = 1) and higher harmonics (n = 2–6) show distinct lower and upper bands separated at *nfce*. Electron distributions exhibit a loss cone and weak beam, modeled by a subtracted bi-Maxwellian. Dispersion analysis indicates growth only in upper bands (> nfce), suggesting ECH as-yet-unknown processes. These results provide new insight into electron-scale plasma dynamics and call for further study of banded ECH wave generation (https://doi.org/10.1029/2025GL120903).

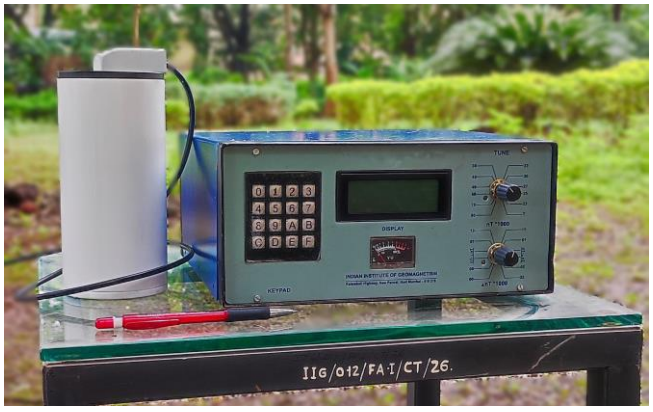



*Banded Electron Cyclotron Harmonic (ECH) waves observed near sub-solar magnetopause by MMS spacecraft*

Scientific publications of IIG can be found at https://iigm.res.in/publications/scientific-papers

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

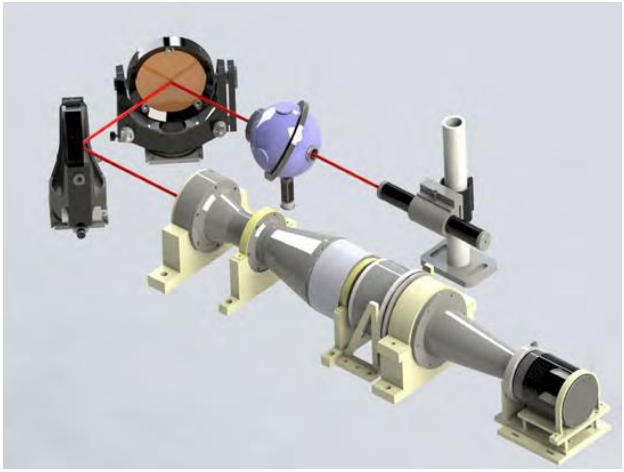
- Overhauser Magnetometer: A state-of-the-art Overhauser scalar magnetometer has been developed in-house at IIG for highly accurate geomagnetic field measurements. It offers high sensitivity (0.1 nT) with high sampling rates (1 sec), and efficient over conventional systems. This instrument enhances long-term geomagnetic monitoring and supports both ground-based and space applications, marking a significant advancement in indigenous instrumentation. (Indian Patent Nos. 578281, 578557)




*Overhauser Magnetometer developed at IIG*

- Fabry–Pérot Interferometer (FPI): A novel Fabry-Perot Interferometer system is developed indegeneously to measure thermospheric winds and temperatures. This

system contributes to studies of atmosphere–ionosphere coupling and improves understanding of space weather impacts on the upper atmosphere.



*Schematic of Table-top FPI*

- Advanced Digital Ionospheric Sounding System: An advanced digital ionosonde system has been developed in collaboration with SAMEER and deployed Prayagraj, India. This system enables measurements and profiling of ionospheric electron density and plays important role in studying ionospheric variability and space weather effects on communication and navigation systems.
- Electrometer for Atmospheric Electric Field: An Electrometer with boom-deployable electric field probes has been indigenously developed for measuring the atmospheric electric fields using balloon and/or rocket-borne platforms. This electrometer provides high sensitive measurements of atmospheric electric fields and supports research in atmospheric electricity, thunderstorm dynamics, and electrical coupling between atmospheric layers.

## Capacity Building in Space Science Research

- Ph.D. Programme and Research Training: IIG conducts regular Ph.D. programme in collaboration with leading universities in India, on the topics of geomagnetism, space physics, and allied areas. Research scholars work on advanced topics such as solar–terrestrial interactions, ionospheric dynamics, planetary magnetosphere, Plasma physics, and space weather. The institute also supports postdoctoral fellowships and promotes interdisciplinary research, producing skilled human resources for national and international scientific communities.
- Summer Training / Internship Programme: IIG supports summer training programmes for undergraduate and postgraduate students, offering hands-on experience in data analysis, instrumentation, and modelling in space science.
- IMPRESS: Inspiring Minds of Postgraduates for Research in Earth & Space Sciences (IMPRESS) is a flagship initiative of IIG aimed to attract talented postgraduate students

to research careers in Earth and space sciences. The programme includes lectures by experts, interactive sessions, and exposure to advanced research facilities.

- SCOSTEP Visiting Scholar (SVS) Programme: Under the international SCOSTEP SVS programme, IIG hosts young scientists and graduate students from developing countries for short-term research training (1–3 months).
- ISSW-2026: Recently, IIG has organized the ISWI–SCOSTEP International School on Space Weather (ISSW-2026) during 5–9 January 2026. The school aimed to train Master's and Ph.D. students in understanding Sun–Earth interactions and various aspects of space weather, including solar-heliospheric processes, magnetospheric and ionospheric current systems, and their impacts on technology and society.

## Courses offered on Space Science and Technology

| Title of the course | Level of the Course | Intake capacity | Subjects of specializations |
|---|---|---|---|
| Ph.D | Ph.D Coursework and Thesis work | 10-15 per year | Earth, Atmospheric and Space Sciences |

## Laboratories and Facilities Available for Space Instrumentation

- Word Data Centre for Geomagnetism, Mumbai: IIG operates a nationwide network of geomagnetic observatories equipped with suit of high-precision instruments, including 3-axis Fluxgate, Proton Precession, Overhauser, and Induction coil magnetometers. These observatories provide continuous measurements of Earth's magnetic field for monitoring the highly dynamic short-term to long-term secular variations of geomagnetic field over the Indian region. The data from this observatory network are openly made available through the World Data Centre for Geomagnetism, Mumbai at https://wdc.iigm.res.in/.
- Instrumentation Laboratory for Magnetometers and Sensors: IIG has a dedicated instrumentation laboratory for the indigenous development of advanced magnetometers, including fluxgate and Overhauser systems. The lab focuses on sensor design, calibration, signal processing, and system integration. It also supports the development of electric and magnetic field sensors for space and ground applications.
- MF Radar Facilities: The Medium Frequency (MF) radar facilities at Tirunelveli and Kohapur are available to study lower and middle atmospheric dynamics via measurement of winds and temperatures in the mesosphere and lower thermosphere. It provides high temporal resolution data essential for investigating atmospheric coupling processes and their influence on ionospheric variability.

- Ionosonde Laboratory: The Ionosonde laboratories at Tirunelveli and Prayagraj enables continuous monitoring of ionospheric electron density profiles using advanced digital ionospheric sounding systems. It supports studies of ionospheric variability, equatorial electrodynamics, and space weather impacts on communication and navigation systems.
- High-Performance Computing (HPC) Facility: The HPC facility at IIG supports advanced numerical simulations and data-intensive analysis of magnetospheric, ionospheric, and solar wind processes. It enables modelling of space weather events, geomagnetic storms, and coupled Sun–Earth systems.

For further details on the inputs as provided in the document, please contact Director (iig.director@iigm.res.in) or Dr. S. Tulasiram, Professor-F, Indian Institute of Geomagnetism. Email: tulasiram.s@iigm.res.in.

# INDIAN INSTITUTE OF INFORMATION TECHNOLOGY SRI CITY
# TIRUPATI, INDIA

Website: www.iiits.in

## About the Institute

Indian Institute of Information Technology Sri City, an Institute of National Importance, is committed to research-driven education with a strong emphasis on innovation, interdisciplinary collaboration, and advanced technological infrastructure. The institute actively promotes cutting-edge research in areas of electronics, communication, computer science, artificial intelligence, and data analytics. Situated near the Satish Dhawan Space Centre and the Satyavedu Reserve Infra Limited ecosystem, the institute leverages its location to promote collaboration between industry and academia in advancing technologies.

Within the institute, the Spatial Analytics and Machine Intelligence (SAMI) Lab (https://www.samilab.in/) serves as a key research hub for geospatial AI and explainable machine learning in Earth and planetary remote sensing. The lab specializes in physics-guided and interpretable AI models, with focus on spatial analytics, embeddable hardware design, hyperspectral data processing, reinforcement learning, and multimodal data fusion. The lab is equipped with drones, sensors, advanced software, indigenously developed datasets, and FPGA platforms for real-time, on-board deployment. The research is led by Dr. Arun P V and has 4 PhD students, 10 Honors students, and 20-30 B. Tech students working on various research projects. Also, the group works in close collaboration with experts including Prof. Alok Porwal (IIT Bombay) and Dr. Guneshwar Thangjam (NISER Bhubaneswar). The lab is supported by major funding agencies including Indian Space Research Organisation (ISRO), Anusandhan National Research Foundation (ANRF), and the Indian Army, along with private organizations, working on projects related to hyperspectral analysis, explainable AI, spatial data systems, and edge computing. The group’s research extends to applications such as precision agriculture, mineral mapping, disaster management, and industrial safety, while also promoting outreach and industry–academia collaboration in the space technology domain.


## Major Research Domains

**Physics-Inspired Modeling:** A key focus of the research is the integration of physical principles governing spectral mixing and imaging processes into deep learning frameworks. Instead of relying purely on data-driven learning, the models are designed to incorporate domain knowledge such as material-specific behavior, underlying physics, and sensor characteristics. This enables the development of models that are not only accurate but also interpretable and physically consistent. Such approaches help in reducing the ambiguity associated with black-box models, improving generalization across datasets, and producing meaningful outputs. This direction forms a unifying theme across multiple domains, particularly data preprocessing, data analytics, domain-specific inferencing, and planetary data analysis.

**Spectral Unmixing:** The research focuses on addressing the limitations of black-box deep learning models by integrating the underlying physics of spectral mixing into advanced learning frameworks. Methods such as autoencoders, spatial–spectral attention transformers, generative models, and Graph Neural Networks are explored to achieve accurate and interpretable estimation of endmembers and abundances. The work also includes the development of explainability-driven evaluation metrics, benchmark datasets, and FPGA-based implementations for onboard applications, along with strategies for spectral and spatial denoising. The developed approaches are being explored for Geological mapping, defense applications, and precision agriculture.

**Spatial Super-Resolution:** Research in this area explores convolutional sparse coding and deep autoencoder-based techniques for enhancing spatial resolution while preserving spectral consistency. Emphasis is placed on maintaining the physical relationships between spatial and spectral information, improving interpretability, and ensuring high reconstruction fidelity. Benchmark dataset creation, explainability metrics, and hardware-efficient implementations are also key components.

**Spectral Super-Resolution:** The work involves 3D CNNs, sparse coding approaches, GANs, and transformer-based models for reconstructing fine spectral details from coarse

inputs. The methods are designed to ensure consistency across spectral bands while improving reconstruction accuracy. AVIRIS-NG and drone-based datasets are used for benchmarking, along with graph-based and generative approaches.

**Explainable EO Data Processing & Analysis:** The research explores both post-hoc and inherently interpretable approaches for EO data analysis. Models are designed with constraints, regularizations, and architectures that align learned representations with real-world processes, enhancing transparency and reliability.

**Multimodal Data Fusion:** Generative adversarial networks, variational autoencoders, and latent space transformation techniques are used for integrating multi-source data such as satellite imagery, sensor observations, and environmental variables. The focus is on improving interpretability and generalization while reducing dependency on large labeled datasets and enabling efficient deployment.

**Optimization of Deep Learning Models for Onboard Deployment:**
The research develops lightweight and efficient deep learning models through pruning, compression, and architectural optimization. Emphasis is placed on reducing memory footprint, improving generalizability, and enabling real-time onboard processing with minimal computational resources.

**Planetary Remote Sensing:** The research utilizes data from Chandrayaan missions for mapping lunar surface composition. Advanced learning approaches incorporating spectral unmixing, super-resolution, and graph-based modeling are used to derive meaningful geological insights while addressing sensor-specific challenges.

**Precision Agriculture:** The work focuses on developing robust frameworks for crop monitoring, irrigation assessment, and yield prediction by leveraging multimodal data, improving generalization, and reducing training data requirements while accounting for spectral variability.

**Hardware Design of Deep Learning Approaches:** The research includes FPGA-based implementation of advanced models, enabling low-latency and energy-efficient deployment. Tools such as fpgaConvNet, CNN2Gate, and Caffeine are used to optimize models for real-world applications.

## Major Scientific Applications/Results

Our research work mainly addresses the black-box limitations of deep learning models in hyperspectral image analysis through the development of physics-informed spectral unmixing approaches. By integrating the underlying principles of spectral mixing with advanced deep learning techniques such as latent space modeling, generative adversarial networks, and graph-based methods, the studies aim to produce interpretable and

physically meaningful outputs, particularly in terms of endmember extraction and abundance estimation. This direction ensures that the models are not only accurate but also transparent, explainable, and consistent with real-world spectral behavior, thereby bridging the gap between data-driven learning and domain knowledge. In addition, efforts are made to translate these models into efficient FPGA-based implementations for real-time, onboard processing, enabling practical deployment in remote sensing platforms. The detailed list of publications contributing to this work is presented in Table 1 and representative results are visualized in Figs. 1 and 2.

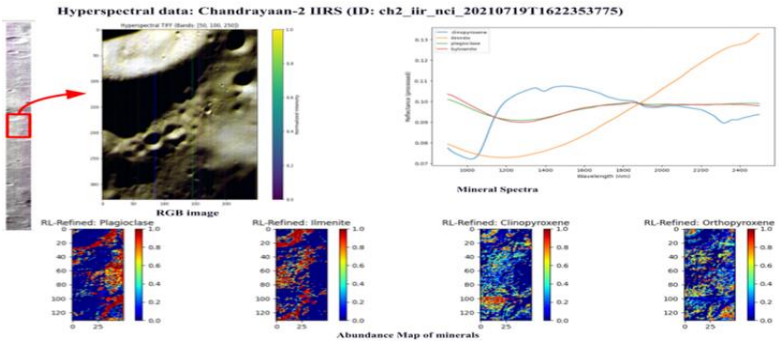



Fig. 1. Spectral Unmixing on Lunar data

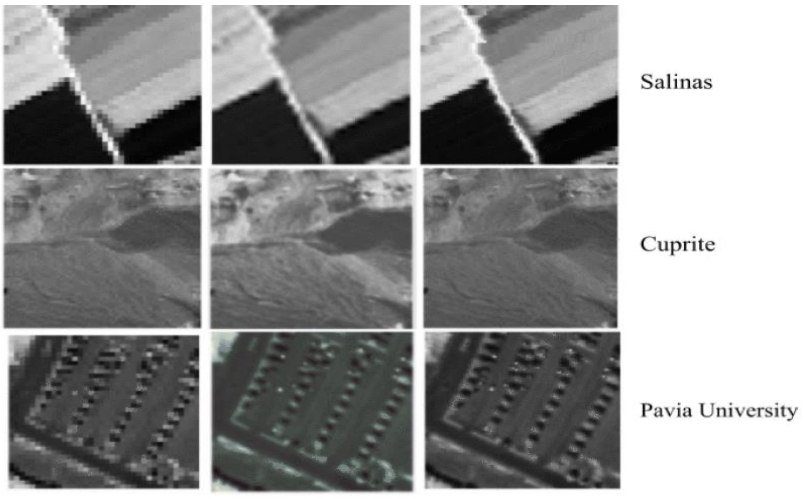



*Fig. 2. Super-resolution result*

*Table. 1. List of Publications*

| Sl. No. | Title of the Paper | Journal/Conference /Book | Link |
|---|---|---|---|
| 1 | Low-Rank Spectral-Spatial Super-Resolution of Hyperspectral Images Using KAN-based GAN | IEEE Transactions on Geoscience and Remote Sensing (TGRS) - Journal | https://doi.org/10.1109/TGRS.2026.3651549 |
| 2 | CIGGAN: A Ground-Penetrating Radar Image Generation Method Based on Feature Fusion | IEEE Transactions on Geoscience and Remote Sensing (TGRS) - Journal | https://doi.org/10.1109/TGRS.2025.3544392 |
| 3 | OCSCNet-Tracker: Hyperspectral Video Tracker | Remote Sensing - Journal | https://doi.org/10.3390/rs17040693 |
| 4 | Hyperspectral video tracker based on spectral difference matching reduction | Optics & Lasers in Engineering - Journal | https://doi.org/10.1016/j.optlaseng.2025.109124 |
| 5 | SiamSTU: Hyperspectral video tracker | Infrared Physics & Technology - Journal | https://doi.org/10.1016/j.infrared.2025.105919 |
| 7 | Spatial non-stationarity in DL-based crop phenology | IEEE Geoscience and Remote Sensing Society Letters (GRSL) - Journal | https://doi.org/10.1109/LGRS.2025.3558852 |
| 8 | Open-set mineral identification from CRISM hyperspectral data | Planetary & Space Science - Journal | https://doi.org/10.1016/j.pss.2025.106218 |
| 9 | Hyperspectral video object tracking with cross-modal spectral complementary and memory prompt network | Knowledge-Based Systems - Journal | https://doi.org/10.1016/j.knosys.2025.114595 |
| 10 | SASU-Net: Hyperspectral video tracker based on spectral adaptive aggregation weighting and scale updating | Expert Systems with Applications - Journal | https://doi.org/10.1016/j.eswa.2025.126721 |
| 11 | SRTE- Net: Spectral- Spatial Similarity Reduction and Reorganized Texture Encoding for Hyperspectral Video Tracking | IEEE Signal Processing Letters - Journal | https://doi.org/10.1109/LSP.2025.3602380 |
| 12 | Explainable ML for mineral mapping | Journal of Geophysical Research (JGR) - Journal | https://doi.org/10.1029/2024jh000391 |
| 13 | Reinforced deep learning approach for analyzing | Journal of Geophysical Research (JGR) - Journal | https://doi.org/10.1016/j.jag.2024.103984 |

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|---|---|---|---|
| | spaceborne-derived crop phenology | | |
| 14 | Hyperspectral Anomaly Detection Based on Empirical Mode Decomposition and Local Weighted Contrast | IEEE Sensors - Journal | https://doi.org/10.1109/JSEN.2024.3455258 |
| 15 | Visibility estimation via near-infrared bispectral real-time imaging in bad weather | Infrared Physics - Journal | https://doi.org/10.1016/j.infrared.2023.105008 |
| 16 | Modelling spectral unmixing of geological mixtures: An experimental study using rock samples | Remote Sensing - Journal | https://doi.org/10.3390/rs15133300 |
| 17 | An ISAR and Visible Image Fusion Algorithm Based on Adaptive Guided Multi-Layer Side Window Box Filter Decomposition | Remote Sensing - Journal | https://doi.org/10.3390/rs15112784 |
| 18 | DSP-Net: A Dynamic Spectral–Spatial Joint Perception Network for Hyperspectral Target Tracking | IEEE Geoscience and Remote Sensing Society Letters (GRSL) - Journal | https://doi.org/10.1109/LGRS.2023.3324967 |
| 19 | Hyperspectral Video Tracker Based on Spectral Deviation Reduction and a Double Siamese Network | Remote Sensing - Journal | https://doi.org/10.3390/rs15061579 |
| 20 | GAN Based Non-Linear Hyperspectral Unmixing Using Patch Transformer | International Geoscience and Remote Sensing Symposium (IGARSS-2025) - Conference | https://doi.org/10.1109/IGARSS55030.2025.11242941 |
| 21 | Sparse Coding Inspired GAN for Hyperspectral Unmixing | Workshop on Hyperspectral Imaging and Signal Processing(WHISPERS-2024) - Conference | 10.1109/WHISPERS65427.2024.10876499 |
| 22 | Spectral Unmixing in Generative Space: 3D-GAN | Workshop on Hyperspectral Imaging and Signal Processing(WHISPERS-2024) - Conference | https://doi.org/10.1109/WHISPERS61460.2023.10431191 |
| 23 | GNN-based Interpretable Spectral Unmixing | International Geoscience and Remote Sensing Symposium (IGARSS-2023) - Conference | https://doi.org/10.1109/IGARSS52108.2023.10283097 |

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|---|---|---|---|
| 24 | Latent Space Unmixing for Lunar Mapping | IEEE India Geoscience and Remote Sensing Symposium (InGARSS-2023) - Conference | https://doi.org/10.1109/InGARSS59135.2023.10490382 |
| 25 | Interpretable Spectral Unmixing for IIRS | American Geophysical Union (AGU-2023) - Conference | 2023AGUFM.P51D2722S |
| 27 | Segmentation + GCN with Relaxation Labeling | IEEE India Geoscience and Remote Sensing Symposium (InGARSS-2023) - Conference | https://doi.org/10.1109/InGARSS61818.2024 |
| 28 | Semantic Segmentation & Relationships | Workshop on Hyperspectral Imaging and Signal Processing(WHISPERS-2024) - Conference | https://doi.org/10.1109/WHISPERS65427.2024.10876420 |
| 29 | Morphological CNN with Denoising | International Geoscience and Remote Sensing Symposium (IGARSS-2024) - Conference | https://doi.org/10.1109/IGARSS53475.2024.10640918 |
| 30 | Accelerating Hybridsn with Dynamic Step Quantization for HSI Classification | International Geoscience and Remote Sensing Symposium (IGARSS-2024) - Conference | https://doi.org/10.1109/IGARSS53475.2024.10641617 |
| 31 | A Dual-Branch Approach to Hyperspectral Image Super-Resolution Using Diffusion Models and Spectral Attention Blocks | IEEE India Geoscience and Remote Sensing Symposium (InGARSS-2023) - Conference | https://doi.org/10.1109/InGARSS61818.2024.10984276 |
| 32 | Efficient Spectral Attention Block for Cascaded Hyperspectral Image Super-Resolution Architectures | Workshop on Hyperspectral Imaging and Signal Processing(WHISPERS-2024) - Conference | https://doi.org/10.1109/WHISPERS65427.2024.10876498 |
| 33 | Spatial Super Resolution of Hyperspectral Images: Novel Approaches for Learning Deep Spatial-Spectral Prior. | Workshop on Hyperspectral Imaging and Signal Processing(WHISPERS-2024) - Conference | https://doi.org/10.1109/WHISPERS65427.2024.10876544 |
| 34 | Efficient Graph Formulation and Latent Space Integration for Lunar Hyperspectral Image Classification | Workshop on Hyperspectral Imaging and Signal Processing(WHISPERS-2024) - Conference | https://doi.org/10.1109/WHISPERS61460.2023.10431156 |
| 37 | Analysis of Complex Valued Neural Network for SAR Image Classification | IEEE India Geoscience and Remote Sensing Symposium (InGARSS-2023) - Conference | https://doi.org/10.1109/InGARSS61818.2024.10984177 |

| | | | |
|---|---|---|---|
| 39 | Machine learning techniques for crop identification | Agricultural Insights from Space (2026) - Book Chapter | https://doi.org/10.1016/B978-0-443-34113-7.00016-X |
| 40 | Explainable AI for Earth Observation Data Analysis | Taylor & Francis group - CRC Press 2025 - Book | https://doi.org/10.1201/9781003597025 |
| 46 | Spatial Intelligence for a Greener Planet | Taylor & Francis - CRC Press 2025 - Book | https://doi.org/10.1201/9781032718323 |

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

- 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 (4 Ongoing)
- ANRF sponsored workshop on Spatial Data Analytics, Karyashala, and AICTE sponsored Faculty Development Programme on space technology
- ANRF-Sponsored Workshop on Geospatial Intelligence: Applications and Challenges in the Big Data Era
- 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 | 2 | 3 | PhD |
| Satellite Image Processing | – | – | PG/PhD |
| Spatial Data Analytics | – | – | UG/PG/PhD |

| | | | |
|---|---|---|---|
| Remote Sensing | 2 | 2 | PG/PhD |

## Laboratories and Facilities Available for Space Instrumentation

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

For further details on the inputs as provided in the document, please contact: Principal Investigator: **Dr. Arun P V, Assistant Professor, CSE Group, arun.pv@iiits.in**

# 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

- Probing the accretion geometry of black hole X-ray binaries: A multi-mission spectro-polarimetric and timing study (https://doi.org/10.1093/mnras/staf1933)
- Possible detection of HFQPOs associated with 'unknown' variability class of GRS 1915+105 (https://www.cambridge.org/core/journals/publications-of-the-astronomical-society-of-australia/article/possible-detection-of-hfqpos-associated-with-unknown-variability-class-of-grs-1915105/4A090382CDC00FC6272921CE7C4AD72B)
- Revisiting Disc-Jet Coupling in Black Hole X-ray Binaries: On the Nature of Disc Dynamics and Jet Velocity (https://doi.org/10.1093/mnras/staf1107)
- Evidence of oscillating 'compact' Comptonized corona in GRS 1915+105: Insights into HFQPOs with AstroSat (https://doi.org/10.1093/mnras/staf926)
- Long-term evolution of BH-ULX candidates: An 'unusual' $L_{disc} - T_{col}$ correlation associated with spectral states (https://doi.org/10.1093/mnras/staf617)
- Long term wide-band spectro-temporal studies of outbursting black hole candidate sources GX 339−4 and H 1743−322: AstroSat and NuSTAR results (https://doi.org/10.1093/mnras/stae1753)
- Discovery of evolving low-frequency QPOs in hard X-rays (~100 keV) observed in black hole Swift J1727.8-1613 with AstroSat (https://doi.org/10.1093/mnras/stae1208)
- 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 present 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 present 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 report 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.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

Not Applicable.

## 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

## Courses offered on Space Science and Technology

Not Applicable

## Laboratories and Facilities Available for Space Instrumentation

Not Applicable

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

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# INDIAN INSTITUTE OF TECHNOLOGY KANPUR
# Kanpur, INDIA

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

## About the Institute

The Indian Institute of Technology Kanpur (IIT Kanpur), established in 1959, is one of India's leading institutions for higher education, scientific research, and technological innovation. Renowned for its excellence in engineering and science, the Institute has made significant contributions to national missions through cutting-edge research and interdisciplinary collaborations.

IIT Kanpur's vision is to advance knowledge and innovation for societal benefit through world-class education, research, and technology development. The Institute's mission is to foster scientific excellence, nurture future leaders, and develop solutions to address national and global challenges.

Over the years, IIT Kanpur has built a strong legacy in aerospace engineering, astronomy, planetary sciences, remote sensing, artificial intelligence, advanced materials, robotics, communication systems, and computational sciences. Through the Space Technology Cell (STC), established in collaboration with the Indian Space Research Organisation (ISRO), the Institute actively supports research in Space Science, Space Technology, and Space Applications. Faculty members and researchers undertake projects aligned with ISRO's strategic objectives, contributing to the development of innovative technologies, scientific discoveries, and indigenous capabilities for India's space programme.

With state-of-the-art laboratories, interdisciplinary research centres, and a vibrant research ecosystem, IIT Kanpur continues to play a vital role in advancing space science and technology, thereby strengthening India's position in global space exploration and scientific research.

## Major Research Domains

- **Combustion and Propulsion**
  Research focuses on advanced combustion processes, propulsion systems, fuel efficiency, and high-temperature fluid dynamics for launch vehicles, spacecraft propulsion, and future space transportation systems.
- **Computational Mechanics and Fluid Dynamics**

Development of numerical models and simulations for fluid flow, structural mechanics, aerodynamics, and multiphysics problems relevant to launch vehicles, re-entry systems, and spacecraft design.

- **Advanced Communication and Photonics**
  Research encompasses next-generation communication technologies, photonic devices, optical networks, and high-speed data transmission systems to support reliable space-based communication and navigation services.
- **High-Performance Materials (Synthesis, Characterization & Simulation)**
  Development and characterization of advanced materials capable of operating under extreme thermal, mechanical, and radiation environments encountered in space missions and aerospace applications.
- **Smart Structures and Advanced Manufacturing**
  Research on intelligent materials, adaptive structures, additive manufacturing, and advanced fabrication techniques for lightweight, durable, and multifunctional aerospace components.
- **Image Processing and Remote Sensing**
  Development of algorithms and analytical tools for satellite image processing, Earth observation, environmental monitoring, resource mapping, and geospatial data interpretation.
- **Thermal Management of Space Systems**
  Research focuses on heat transfer, thermal control systems, cooling technologies, and thermal protection solutions to ensure reliable spacecraft and satellite operation in harsh space environments.
- **Planetary Atmosphere Studies**
  Investigation of atmospheric processes, climate dynamics, and planetary environments through theoretical modelling, data analysis, and interpretation of observations from planetary missions.
- **Radiation-Hardened Electronics**
  Design and development of robust electronic systems capable of withstanding radiation effects in space, ensuring long-term reliability of spacecraft, satellites, and onboard instruments.
- **Laser-Based Optical Communication**
  Research on free-space optical communication, laser transmitters and receivers, high-bandwidth communication links, and secure data transmission technologies for future space missions.
- **Micromachining & Microfabrication for Lunar Systems**
  Development of micro-scale devices, sensors, and fabrication techniques for lunar exploration systems, in-situ resource utilization, and next-generation planetary mission technologies.

- **Sensors, Devices, and Fuel Cell Design**
  Research on advanced sensing technologies, microelectronic devices, energy conversion systems, and fuel cell technologies for aerospace, planetary, and satellite applications.
- **Biological Systems in Space Environments**
  Studies focus on the effects of microgravity and space environments on biological systems, supporting future human spaceflight, life-support technologies, and space biology research.

## Major Scientific Applications / Results

**1. Emergence of Two Inertial Subranges in Solar Wind Turbulence: Dependence on Heliospheric Distance and Solar Activity**

This study investigated turbulence characteristics in the solar wind and identified the existence of two distinct inertial subranges whose properties vary with heliospheric distance and solar activity. The results provide improved understanding of energy transfer and dissipation mechanisms in space plasmas, which are essential for modelling solar wind dynamics and space weather processes. The findings contribute to heliophysics research and the interpretation of observations from solar and interplanetary missions.
Publication Link: https://doi.org/10.3847/1538-4357/adba54

**2. Universal Energy Cascade and Relaxation in Three-Dimensional Inertial Electron Magnetohydrodynamic Turbulence**

This work examined energy cascade and relaxation processes in magnetized plasma turbulence using theoretical and computational approaches. The study demonstrated universal scaling behaviour in electron magnetohydrodynamic turbulence and provided insights into energy transport mechanisms operating in astrophysical and space plasma environments. The results contribute to the understanding of plasma dynamics in planetary magnetospheres, solar wind, and other space systems.
Publication Link: https://doi.org/10.1063/5.0280826

**3. Transport Dynamics of an Ellipsoidal Particle in Free Molecular Gas Flow Regime**

A theoretical framework was developed to investigate the transport behaviour of ellipsoidal particles under free molecular flow conditions. The study improves understanding of particle dynamics in rarefied environments encountered by spacecraft, satellites, and atmospheric-entry systems. The outcomes are useful for predicting particle trajectories, spacecraft contamination effects, and interactions between space structures and the surrounding environment.
Publication Link: https://doi.org/10.1063/1.5081074

**4. Effects of Hugoniot Properties on Jet Onset Conditions**

This study investigated the influence of shock-compression properties of materials on jet formation during high-velocity impacts. The results provide valuable insights into impact-induced material behaviour and crater formation processes on planetary surfaces. The findings are relevant to planetary science, impact mechanics, and the interpretation of observations from lunar and planetary exploration missions.

Publication Link: https://doi.org/10.1016/j.ijimpeng.2024.104930

**5. Effect of Layering on Brittle Deformation: Results from Hypervelocity Impact Experiments on Gneiss**

Hypervelocity impact experiments were conducted to examine the role of geological layering in brittle deformation processes. The study demonstrated how material heterogeneity influences fracture propagation and impact response under extreme loading conditions. The results enhance understanding of planetary surface evolution and impact cratering mechanisms relevant to the Moon, Mars, and other planetary bodies.

Publication Link: https://doi.org/10.1016/j.ijimpeng.2025.105406

**6. Role of Curvature in Controlling SWBLI Behavior in a Hypersonic Double Ramp Flow**

This work investigated the influence of surface curvature on shock-wave boundary-layer interactions in hypersonic flows. The study provides improved understanding of flow separation, shock structure, and aerodynamic heating effects encountered by atmospheric-entry vehicles. The findings support the development of advanced aerodynamic designs for hypersonic and reusable space transportation systems.

Publication Link: https://doi.org/10.3389/fmech.2025.1550464

**7. Evaluating the Effect of Ignition Energy on Gaseous Hydrogen-Oxygen Detonations**

This study examined the role of ignition energy in determining the characteristics of hydrogen-oxygen detonations. The results improve understanding of combustion initiation and detonation dynamics in high-energy propulsion systems. The findings are relevant to rocket propulsion technologies employing hydrogen-based fuels and contribute to the development of safer and more efficient propulsion systems.

Publication Link: https://doi.org/10.1016/j.ijhydene.2024.07.121

**8. Effect of Initial Conditions on the Inhibition Process of $H_2$-$O_2$/Air Detonations Using $CF_3I$, $CO_2$, and $H_2O$**

The research investigated suppression mechanisms of hydrogen-air detonations using different inhibitors under varying initial conditions. The study identified factors affecting detonation inhibition efficiency and combustion stability. The results provide useful insights for propulsion safety, fuel handling systems, and the design of combustion control strategies in aerospace and space applications.

Publication Link: https://doi.org/10.1007/s00193-024-01172-7

**9. Field Emission Study on Atomically Heterogeneous Micro-Metallic Emitters Produced by Ion Beam from Inert Gas Plasmas**

This work explored the field emission characteristics of micro-metallic emitters fabricated using ion-beam-assisted plasma processing. The study demonstrated enhanced emission behaviour associated with atomically heterogeneous surfaces and provided insights into electron emission mechanisms. The results have potential applications in advanced electronic devices, plasma technologies, and future space-based instrumentation systems.

Publication Link: https://doi.org/10.1088/1361-6463/adae1f

**10. Investigation of Flow Characteristics Inside a Dual Bell Nozzle with and without Film Cooling**

This study examined flow behaviour inside dual-bell rocket nozzles designed for altitude-compensating propulsion systems. The influence of film cooling on flow separation, thermal protection, and nozzle performance was analysed under different operating conditions. The findings contribute to the development of efficient rocket engines and advanced launch vehicle propulsion technologies.

Publication Link: https://doi.org/10.1016/j.ast.2020.105741

**11. Correlations for Aerodynamic Coefficients for Prolate Spheroids in the Free Molecular Regime**

This work developed aerodynamic correlations for prolate spheroidal bodies operating in free molecular flow conditions. The generated correlations enable accurate prediction of aerodynamic forces and moments on spacecraft and atmospheric-entry vehicles in rarefied environments. The results provide valuable design tools for spacecraft trajectory analysis, attitude dynamics, and mission planning.

Publication Link: https://doi.org/10.1016/j.compfluid.2021.104934

The publications have appeared in reputed journals such as Vacuum, International Journal of Impact Engineering, Materials Today Energy, Polymer, International Journal of Hydrogen Energy, Shock Waves, Physics of Plasmas, Physical Review E, The Astrophysical Journal, Physics of Fluids, and Journal of Physics D: Applied Physics.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

**GNSS Post-Processing Software**

An indigenous software suite was developed for post-processing Global Navigation Satellite System (GNSS) observations. The software supports Single Point Positioning, Relative Code-Based Positioning, and Carrier-Phase Baseline Processing, providing positioning accuracies ranging from 5–10 m to approximately 5 cm in three dimensions. The tool can support high-precision navigation, geodesy, and space-based positioning applications.

**Three-Dimensional Radiative Transfer Equation (3D-RTE) Solver**

A fully vectorized finite-element-based 3D Radiative Transfer Equation (RTE) solver with spatially varying phase functions was developed for modeling multi-component cloud systems. The software, along with documentation and implementation guidelines, was transferred to SAC. The tool represents one of the few fully three-dimensional mesh-based atmospheric radiative transfer models available within ISRO.

**Femtosecond Thermal Lens Spectroscopy (FTLS) System**

Indigenous single-beam and dual-beam Femtosecond Thermal Lens Spectroscopy techniques were developed for molecular-level investigations in fluids. The system enables highly sensitive detection of intermolecular interactions and concentration-dependent effects in pure and binary fluids. The experimental setup, methodology, and theoretical framework were established and validated for advanced spectroscopic applications.

**Transition Detection and Flow Separation Measurement System**

A complete methodology for identifying laminar-to-turbulent transition and flow separation on reusable launch vehicle configurations was developed. Deliverables include transition-sensitive paint (TSP) coating procedures, measurement protocols, image-processing software in MATLAB, and training modules for VSSC personnel. The system provides aerodynamic characterization data critical for launch vehicle design.

**Lanthanum Hexaboride ($LaB_6$) Hollow Cathode Technology**

An indigenous process was developed for the synthesis of high-purity Lanthanum Hexaboride ($LaB_6$) and fabrication of hollow cathodes suitable for Hall Effect Thrusters. The technology includes powder synthesis, purification, hollow tube fabrication, and emissivity characterization. The development supports indigenous electric propulsion technologies for future satellite and deep-space missions.

**Carbon-Coated Aluminum Nanoparticles for High-Energy Propulsion Applications**

A novel laser-ablation-based process was developed for synthesizing carbon-coated aluminum nanoparticles. The technology improves oxidation resistance and enhances combustion performance compared to conventional aluminum nanoparticles. Characterization methods and optimized synthesis parameters were established, making the product suitable for advanced energetic materials and propulsion applications.

**Quantitative Phase-Field Model for Multi-Variant Microstructure Evolution in Ti-6Al-4V Alloy**

An indigenous quantitative phase-field model was developed to predict two-phase microstructure evolution involving multiple orientation variants in Ti-6Al-4V alloy. Thermodynamic free-energy data extracted from CALPHAD databases were integrated into the model for accurate prediction of temporal microstructural evolution. The framework includes elastic field effects associated with HCP/BCC orientation relationships between matrix and precipitate phases. The model has been successfully implemented in both 2D

and 3D and is capable of capturing all possible orientational variants in the Ti-6Al-4V system, enabling advanced design and optimization of aerospace-grade titanium alloys.

**Computational Framework for Modelling Plant Growth in Microgravity Environments**

An indigenous theoretical and computational framework was developed to study plant growth under microgravity conditions relevant to space biology research. The model represents plant roots and shoots as geometrically nonlinear growing rods capable of large deformation and buckling. Gravity-sensing mechanisms were incorporated through biomechanical and biochemical coupling to simulate plant responses in reduced-gravity environments. A finite-element-based numerical procedure was developed for solving the governing equations and predicting growth behavior. The framework provides a scientific tool for understanding plant adaptation and development in space habitats and long-duration human space missions.

**Helium and Hydrogen Gas Sensing System Based on Vanadium Pentoxide Nanostructures**

An indigenous gas sensing system was developed for the detection of helium and hydrogen gases using hydrothermally synthesized vanadium pentoxide ($V_2O_5 \cdot 1.6H_2O$) nanostructures. Novel nanostar and nanowire morphologies, along with noble-metal-functionalized nanocomposites (Ag, Au, and Pd), were investigated to enhance sensing performance. The developed sensing elements demonstrated high sensitivity, rapid response and recovery times, and room-temperature operation. A portable gas sensing device was also developed for practical deployment. The technology is relevant for monitoring helium leakage in inflatable space structures and cryogenic systems, as well as hydrogen leak detection for spacecraft safety applications.

## Capacity Building in Space Science Research

The Space Technology Cell (STC), IIT Kanpur has significantly contributed to capacity building in Space Science and Technology through ISRO-sponsored research projects. During the period **2018–2025**, STC projects supported a total of **208 research personnel**, including **40 Ph.D. students, 65 Research Associates (RAs), 46 Junior Research Fellows (JRFs), 44 Senior Research Fellows (SRFs), and 13 M.Tech. students**.

The supported researchers worked on diverse areas of space science and technology, including propulsion systems, computational fluid dynamics, advanced materials, remote sensing, planetary sciences, space electronics, optical communication, thermal management, and space biology.

The projects provided opportunities for advanced research training, hands-on experience with experimental and computational tools, and interaction with scientists from various ISRO centres.

Through these activities, STC has strengthened the human resource base in space-related research and fostered the development of skilled manpower for academia, research organizations, and the Indian space programme.

## Courses offered on Space Science and Technology

The Department of Space, Planetary & Astronomical Sciences & Engineering (SPASE) at Indian Institute of Technology Kanpur offers structured academic programmes and coursework in Space Science, Planetary Science, Astronomy, Space Technology, and Space Engineering. The curriculum is designed to provide interdisciplinary training in both fundamental and applied aspects of space research and technology.

**Major Programmes and Courses Offered:**

- **M.Tech. in Space Science and Engineering**
  - **Level:** Postgraduate (M.Tech.)
  - **Specialization Areas:** Space Science, Planetary Science, Astronomical Sciences, Space Instrumentation, Space Missions, Space Technology, and Space Systems Engineering.
- **Ph.D. in Space Science & Engineering**
  - **Level:** Doctoral Programme
  - **Research Areas:** Astronomy and Astrophysics, Planetary Sciences, Space Instrumentation, Space Missions, Space Engineering, Space Physics, and related interdisciplinary areas.
- **Minor in Space Science**
  - **Level:** Undergraduate Minor Programme
  - **Specialization Areas:** Astronomy, Astrophysics, Space Technology, Satellite Systems, Planetary Science, Space Missions, and Space Instrumentation.

**Representative Space Science and Technology Courses:**

- Introduction to Astronomy and Astrophysics (SPA201)
- Galaxies and Observational Cosmology (SPA401)
- Introduction to Manmade Satellite Systems and its Environment (SPA402)
- Introduction to Space Technology (SPA404)
- Introduction to Space & Astronomical Instrumentation (SPA601)
- Solar System Processes and Space Missions (SPA603)
- Radio Astronomy (SPA611)
- Planetary Surface Processes (SPA621)
- Introduction to Celestial Mechanics (SPA614M)
- Introduction to Radiative Processes in Space (SPA618M)
- Introduction to Astrobiology (SPA633)
- Spacecraft Dynamics (SPA637)

The SPASE curriculum provides comprehensive training in space science and technology through classroom instruction, laboratory courses, computational studies, and research-oriented projects, thereby contributing to the development of skilled manpower for India's space programme

## Laboratories and Facilities Available for Space Instrumentation

The Department of Space, Planetary & Astronomical Sciences & Engineering (SPASE) at Indian Institute of Technology Kanpur has established dedicated laboratories and research facilities to support education, research, and technology development in Space Science, Space Instrumentation, Astronomy, and Planetary Sciences. The department's facilities are complemented by advanced institute-wide experimental and computational infrastructure.

## Major Space Instrumentation and Research Facilities

- **Space Instrumentation Laboratory**
  Dedicated to the design, development, testing, and characterization of space and astronomical instruments, sensors, detectors, and associated subsystems for space missions and scientific investigations.
- **Optical and Infrared Astronomy Laboratory**
  Supports research and training in optical and infrared instrumentation, astronomical observations, detector characterization, imaging systems, and observational astronomy.
- **Planetary Science Laboratory**
  Facilitates research in planetary geology, lunar science, mineral spectroscopy, impact cratering, planetary surface processes, and remote sensing investigations.
- **Radio Astronomy Laboratory**
  Provides facilities for studies in radio astronomy, radio instrumentation, signal processing, and analysis of astronomical observations.
- **Advanced Institute-Wide Research Facilities**
  Researchers have access to specialized facilities at IIT Kanpur, including the Central Cryogenic Facility, Liquid Helium Facility, SQUID Facility, EMI/EMC and Electrical Safety Test Facility, Advanced Imaging Centre, Centre for Lasers and Photonics, National Centre for Flexible Electronics, and high-performance computational resources. These facilities support the development, testing, and qualification of space instrumentation and related technologies.

This integrated ecosystem provides a strong foundation for research, development, testing, and validation of space instrumentation, payloads, sensors, detectors, and mission technologies relevant to India's space programme.

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

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**List of Publications:** The complete list of refereed journal publications and their corresponding web links is provided:

| S. No. | Principal Investigator | Publication Title | Research Area | DOI / Publication Link |
|---|---|---|---|---|
| 1 | Prof. Supratik Banerjee | Emergence of Two Inertial Subranges in Solar Wind Turbulence: Dependence on Heliospheric Distance and Solar Activity | Solar Wind Physics / Heliospheric Science | https://doi.org/10.3847/1538-4357/adba54 |
| 2 | Prof. Supratik Banerjee | Universal Energy Cascade and Relaxation in Three-Dimensional Inertial Electron Magnetohydrodynamic Turbulence | Space Plasma Physics | https://doi.org/10.1063/5.0280826 |
| 3 | Prof. Rakesh Kumar Mathpal | Transport Dynamics of an Ellipsoidal Particle in Free Molecular Gas Flow Regime | Rarefied Gas Dynamics, Spacecraft Aerodynamics, Space Environment | https://doi.org/10.1063/1.5081074 |
| 4 | Prof. Amar Agarwal | Effects of Hugoniot Properties on Jet Onset Conditions | Planetary Impact Processes | https://doi.org/10.1016/j.ijimpeng.2024.104930 |
| 5 | Prof. Amar Agarwal | Effect of Layering on Brittle Deformation: Results from Hypervelocity Impact Experiments on Gneiss | Planetary Surface Evolution and Cratering | https://doi.org/10.1016/j.ijimpeng.2025.105406 |
| 6 | Prof. Rajesh Ranjan | Role of Curvature in Controlling SWBLI Behavior in a Hypersonic Double Ramp Flow | Atmospheric Entry Physics | https://doi.org/10.3389/fmech.2025.1550464 |

| S. No. | Principal Investigator | Publication Title | Research Area | DOI / Publication Link |
|---|---|---|---|---|
| 7 | Prof. Ajay Vikram Singh | Evaluating the Effect of Ignition Energy on Gaseous Hydrogen-Oxygen Detonations | Space Propulsion Science | https://doi.org/10.1016/j.ijhydene.2024.07.121 |
| 8 | Prof. Ajay Vikram Singh | Effect of Initial Conditions on the Inhibition Process of $H_2$-$O_2$/Air Detonations Using $CF_3I$, $CO_2$, and $H_2O$ | Propulsion and Combustion Physics | https://doi.org/10.1007/s00193-024-01172-7 |
| 9 | Prof. Sudeep Bhattacharjee | Field Emission Study on Atomically Heterogeneous Micro-Metallic Emitters Produced by Ion Beam from Inert Gas Plasmas | Space Electronics and Plasma Devices | https://doi.org/10.1088/1361-6463/adae1f |
| 10 | Prof Ashoke De | Investigation of Flow Characteristics Inside a Dual Bell Nozzle with and without Film Cooling | Space Propulsion and Launch Vehicle Aerodynamics | https://doi.org/10.1016/j.ast.2020.105741 |
| 11 | Prof. Rakesh Kumar Mathpal | Correlations for Aerodynamic Coefficients for Prolate Spheroids in the Free Molecular Regime | Spacecraft Aerodynamics, Free Molecular Flow Physics | https://doi.org/10.1016/j.compfluid.2021.104934 |

These publications contribute to key areas of Space Science, including solar wind turbulence, plasma dynamics, planetary impact processes, atmospheric-entry physics, propulsion science, and space electronics. The outcomes support scientific investigations related to heliophysics, planetary exploration, spacecraft environments, and future deep-space missions.

# 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 18 Academic Departments, 1 School of Interdisciplinary studies 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 Engineering in India right from the inception of the National Institutional Ranking Framework of Govt. of India, since 2016.The Institute also secured First position in the Overall Category for the seventh consecutive years (2019-2025); First position in Innovation category and Sustainable Development Goals (SDG) Institution Category and Second position in the Research Institution Category of NIRF Ranking 2025.


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, engineering, 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

- Blue Economy
- 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
- Environment and Water
- 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
- Space and Defense
- Sports Science and Analytics
- Technologies for Low Carbon and Lean Construction
- Telecommunications

## 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 (2024 & 2025), ~5100 publications in indexed Journals and ~1600 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. A few of the publications related to Space science and technology published during the last two years (2024 & 2025) are listed below.

- Brij Chaun and Shankar Ghosh, "Numerical Simulation of Non-Equilibrium Effects on Hypersonic Flow Over a Cylinder", Proceedings of the AIAA Aviation, U.S.A., AIAA paper 2024-4370, 2024.

- Kabir A., Mukilarasai B., Manohar A., Gadani M., Sinha A.K., Sharma P., Verma A., Selvaraj V.*, Sudhakar S.* (2024). Protein bioactive complexes promote

osteogenesis under microgravity environment. International Journal of Biological Macromolecules, Elsevier

- Basha SS., Kaviya VB., Kabir A., Raj T., Sudhakar, S.* (2024). Microgravity as a platform to enhance drug loading efficiency in nanomaterials. J. Drug Deliv. Sci. Technol. 2024, 98, 105869.

- Sudhakar, S., Kabir A., Selvaraj V., Manohar A., Narendran S., Gadani M., Sharma P., Verma A. (2024). Protein nanocages promote osteogenesis and prevent cytoskeletal damage from oxidative stress induced under microgravity conditions.

- Process parameter optimization for laser directed energy deposition (LDED) of Ti6Al4V using single-track experiments with small laser spot size A Gonnabattula,
  RS Thanumoorthy, S Bontha, ASS Balan, VA Kumar, AK Kanjarla. Optics &Laser
  Technology 175, 110861. 2024

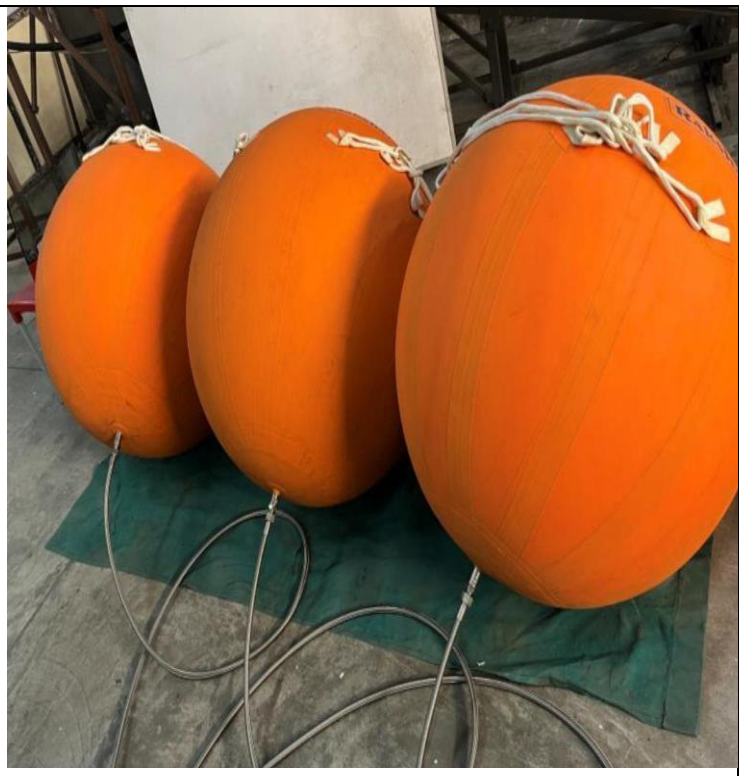
- A. Madhubala, SGK Manikandan, R.Uma Rani, M. Kamaraj, 2024, Synthesis and evaluation of thermal and optical properties of Fe2AlB2 phase alloy for thermal control in space applications, Journal of Alloys and compounds 1007, 176353.

- P Dhanalakota, MM Rahaman, PSMahapatra, AR Anand and A Pattamatta(2024) Insights into Pool boiling heat transfer on minichannel surfaces through point and field measurements. Journal of Heat and Mass Transfer

## 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:

- **Development and demonstration of a compact and light weight solid fuel based low temperature gas generator for inflation of CMUS floats.**

| | |
|---|---|
|  |  |
| **Primary Float after inflation** | **Secondary Float after inflation** |

- Ground tests conducted on both primary and secondary floats and stable temperature and pressure characteristics demonstrated
- FE analysis carried out and flight optimized hardware is designed and realized
- 5 nos. flight optimized hardware are realized and ready for delivery

- **Development of therapeutic strategies to mitigate oxidative stress and cytoskeletal damage in astronauts for the Gaganyaan space mission**
  - Mechanistically investigated cytoskeletal dynamics in extracellular conditions under simulated microgravity.
  - Nano-cocktail solution was developed as a therapeutic strategy against microgravity induced bone loss.
  - ZNAC solution was developed as a therapeutic strategy against microgravity induced vascular dysfunction due to altered shear and normal forces on endothelial cells due to microgravity

Also, research findings/ knowledge generated in the Institute are protected through filing Patent applications both in India and Foreign. About 850 Patents Applications were filed and about 580 Patents were granted during the last two years (2024 & 2025).

## Capacity Building in Space Science Research

IIT Madras conducts special Lectures, Short term courses, workshops, seminars, symposia and conferences for the students/researchers beyond its curriculum. At present around 170 PhD scholars are pursuing research in the areas of Aerospace and allied areas. IIT Madras continues to provide trained and skilled manpower to the nation building and ~ 64200 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 Chandrayaan3 mission are alumni of the Indian Institute of Technology Madras.

## Courses offered on Space Science and Technology

IIT Madras offers the following academic programmes:

• BTech • Dual Degree (BTech + MTech) • MTech • MS • PhD

About 55 courses are offered under Core and Elective subjects related to Space Science and Technology. In addition few specialised academic programmes / short term courses are offered and are listed below.

- **BS in Aeronautics and Space Technology**

- **M. Tech Programs & PG Diploma (since 2018)**
  - M. Tech in Aerospace Engineering (both Offline & online)
  - M. Tech in Aerospace Engineering with specialisation in Ammunition Technology (Online)
  - Industrial Artificial Intelligence
  - Communication and Signal processing
  - Integrated Circuits and Systems
  - Micro-electronics
  - Multimedia Signal Processing
  - RF and Microwave
  - Automotive Technology
  - Mechanical Design

- **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
- Array Tester with Semiconductor test systems
- Atomic Force Microscopy
- Center for Nondestructive Evaluation Laboratory
- Clean Room
- Composites Technology facility
- DSC/TGA (Thermal Analysis) facility
- E-beam evaporator with load-lock facilities
- Electrochemical Laboratory
- Electrophysiology Laboratory
- Environmental and Water Resources Engineering Lab.

- Femtosecond Laser Facility
- Flow Cytometry Facility
- Fuel Characterisation Laboratory
- Gas Hydrates and Flow Assurance Laboratory
- GC-Mass Spectroscopy
- High Performance Super Computing Machine
- High Pressure Combustor Rig
- High Resolution FT-NMR Spectrometer -400 MHz
- High Resolution NMR-400 MHz
- High Resolution SEM & TEM Facilities
- Inductively Coupled Plasma-Mass Spectrometry
- Laboratory for High Performance Ceramics
- Laser Diagnostics Laboratory
- Laser Scanning Microscope Laboratory
- Low Temperature Physics Laboratory
- Magnetic Sputtering systems
- Magneto-electrical transport systems
- 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
- Networks Laboratory
- Performance Network Analyser
- Photochemistry Laboratory
- Physical Property Measurement System
- Raman Spectroscopy
- Sensing and Networked Systems Engineering Laboratory
- Small Angle X-ray Diffraction (Scattering) System

- Smart Material Characterization Laboratory
- Soft Materials Laboratory
- Spray Combustion Laboratory
- Ultra High Resolution Electron Beam Lithography System
- Universal Testing Machine
- Vertical Microfiber
- Wave Energy and Fluids Eng. Laboratory
- X-Ray Fluorescence
- X-Ray photoelectron spectrometer (XPS) with ultraviolet photoelectron spectroscopy
- XRD Laboratory (Crystal & Powder)

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# INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS PUNE, INDIA

Website: www.iucaa.in/

## About IUCAA

The Inter-University Centre for Astronomy and Astrophysics (IUCAA) is a Centre of Excellence for research in astronomy and astrophysics (A & A), and related areas. The main objectives are, besides conducting rigorous research by its own members, to provide a Centre of Excellence within the university sector for teaching, research and development in A & A, as well as to promote nucleation and growth of active groups in this area in universities. The centre enables workers from Indian universities, teachers as well as students, to visit the centre to use the facilities for various durations.

## Major Research Domains

Cosmic Magnetic Fields
Cosmology and Large Scale Structure
Computational Astrophysics
Extragalactic Astronomy
Gravitational Lensing
Gravitational Waves
High Energy Astrophysics
Instrumentation for Astronomy
Mega Science
Quantum Metrology and Sensing
Solar and Stellar Physics

## Major Scientific Applications / Results

**Galaxy Evolution:** Galaxy evolution is governed by various physical processes such as gas inflows, gas outflows, stellar feedback, and galaxy mergers. These mechanisms regulate the growth and development of galaxies over cosmic time. The UltraViolet Imaging Telescope (UVIT) onboard AstroSat has made valuable contributions to this field through deep ultraviolet observation. The AstroSat UV Deep Field (AUDF) is a deep ultraviolet imaging survey conducted using the UVIT instrument on AstroSat. The survey covers selected regions of the sky and provides some of the deepest ultraviolet observations available. These observations allow astronomers to detect faint and distant galaxies that are difficult to observe in other wavelength.

**Cosmology and Structure Formation:** It has been demonstrated that formation of primordial black holes may result from small bumps or dips in the inflation potential of the early universe. A new cosmological estimator, called the Voronoi Volume Function, has been proposed, and shown to be a sensitive probe of galaxy evolution physics, dark matter

and dark energy. It has been found that the internal properties of a dark matter halo and its correlation with large scale clustering is strongly influenced by the tidal environment. In an exploration of the nature of dark energy, it was found that phantom brane could reproduce the observed expansion history of the universe well, but predicted a different rate of growth of perturbations than in the conventional description using a cosmological constant.

**Gravitational Waves:** A new method has been developed to identify optical transient counterparts of gravitational wave (GW) sources efficiently. A procedure has been introduced to estimate a map of the stochastic GW background sky using Bayesian regularization scheme. The impact caused by low magnitude regional earthquakes on GW detectors have been studied. A hierarchical strategy to search for GW signals from coalescing binaries has been proposed, and an optimal chi-square test for glitches in the data has been developed. A new source of GW in the mini creation event has been proposed.

**High Energy Astrophysics:** Polarisation measurements of the prompt emission of bright Gamma Ray Bursts detected by AstroSat operations have been presented and time resolved analysis of bright events undertaken. Detailed study of AstroSat observations of black hole binary systems revealing Quasi-Periodic Oscillation (QPO) and the dependence of the QPO properties on spectral ones were studied. For one source, the QPO frequency is shown to be just as predicted by the relativistic standard accretion disk. Further, detailed study of the energy continuum variability of black hole systems using AstroSat has been undertaken and a stochastic propagation model to explain the observations have been developed. QPOs have also been discovered using XMM-Newton and NuSTAR data.

Detailed long term spectral evolution studies have been undertaken on Active Galactic Nuclei (AGN) to determine differences in broad and narrow line AGN and the relativistically blurred reflection has been studied for several sources. Time delays between the X-ray and UV emission from AGN were measured and interpreted. Study of a jet dominated AGN (Blazar OJ 287) showed a soft excess in its X-ray spectrum and a delayed UV emission. Multi-wavelength study of a flare from a blazar was performed.

**Extragalactic Astronomy:** Forming lenticular galaxies via violent disk instability. In a new mechanism to form S0 galaxies, it has been shown that an isolated cold disk settled into rotational equilibrium becomes violently unstable leading to fragmentation and formation of stellar clumps that causes the bulge to grow and increase the stellar disk velocity dispersion optimally in less than a billion years. Variation in the absorption of X-ray radiation emitted from an AGN is a phenomenon seen in the X-ray spectra of several active galaxies. A comparative analysis of the X-ray spectrum of NGC 3783 during unobscured and obscured states has enabled one to put independent constraints on the density and location of the obscuring gas.

**Stars, Interstellar Medium and Planetary Studies:** Variability of interstellar lines in the direction of the Vela supernova remnant. A comparison of high-resolution SALT

optical spectroscopy of stars in the direction of the Vela supernova remnant and those taken two decade earlier show changes in radial velocity (1 - 2 km/s) and/or increases/decreases in the equivalent widths over the two decades. Small-scale variations in line profiles across the face of the remnant suggest that a linear scale for interactions is a small fraction of the 40 pc size of the present remnant.

**Solar Astrophysics:** Two important goals of solar astrophysics are to understand the cyclic global magnetic activity of the Sun, and to make an early prediction of energetic events, such as coronal mass ejections and solar flares. These phenomena are powered by magnetic fields generated within the Sun. The sunspot formation mechanism is the missing part of the overall distributed turbulent dynamo paradigm of the solar magnetism, as in most studies the sunspot-like magnetic concentrations do not form in a self-consistent manner. This is remedied to some extent in a numerical work that shows the first hints of spot-like structures appearing spontaneously on the surface.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

NA

## Capacity Building in Space Science Research

IUCAA conducts more than 5 training workshops in house and more than 10 in different Universities and Colleges, every year. A substantial part of these workshops are for data analysis of space based mission.

IUCAA hosts the ISRO sponsored AstroSat Science Support Cell (ASSC) which provides support to the large AstroSat User Community in India and abroad. It provides the latest software, documentation, data analysis tutorials and supports the AstroSat proposal processing system. The Cell conducts workshops in different parts of the country on AstroSat data analysis.

## Laboratories and Facilities Available for Space Instrumentation

The IUCAA Computing Facility provides advanced computing infrastructure and technical support for researchers, students, associates, and visitors. It manages over 350 servers/desktops, 100+ laptops, 80+ printers/scanners, three HPC clusters, and more than 9.5 PiB of storage.

IUCAA host two Payloads Operation Centre (POC). (A) For the CZTI instrument onboard AstroSat and (B) For the SUIT instrument onboard ADITYA L-1.

There is an Instrumentation laboratory at IUCAA which developed the Solar Ultraviolet Imaging Telescope (SUIT) for the Aditya-L1 mission of ISRO.

For further details on the inputs as provided in the document, please contact: Ranjeev Misra, Senior Professor, rmisra@iucaa.in

# KADI SARVA VISHWAVIDYALAYA
# GANDHINAGAR, INDIA

Website: **http://svkm.org.in**

## About the Centre / Laboratory / Institute

**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 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 Research Domains

- Radio and optical astronomy, Solar physics
- Algal Technology, Plant tissue culture, Bioremediation, Fermentation, Cancer Biology
- Static and Dynamic investigations of machines
  - Linear and non-liner vibrations.
  - IC engine testing rig(fuel blend).
  - Friction stir processing (surface processing, welding (spot, lap, butt welding))
  - Stir castings.
  - CAD-Computer aided Design
  - CAM-Computer aided manufacturing

  FEA-Finite element analysis.
- Metal Organic Ionic Frameworks, Nanoparticles synthesis, Heterocyclic synthesis, Liquid crystals synthesis, Organic synthesis.
- Develop new drug delivery systems, analysis, screening of drug; extraction of various phytoconstituents from different herbs and plants and analysis

## 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.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

- Horn antenna (radio wave)
- Nexstar 4se computerized telescope (optical waves)
- e-Callisto solar spectrometer (not working due to technical issue)
- 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 like ANSYS , COMSOL , UG Nx, Solid Edge , AUTOCAD and PRO-E with latest computing systems;
  - FFT analyzer (Vibration Measurement Instrument) With Typical Real-time Analysis Functions Math (+,-,*, /), integration, differentiation, FFT, averaging, windowing, auto power spectra, cross spectra, FRF, coherence, real-time filters, RMS, octave, order tracking, limiting, alarm/abort and more.
  - CNC turning center, Vertical machining center with surface finish capabilities in microns made by GreenField Control Systems Ltd.
  - Well performing IC engine laboratory with exhaust gas analyzer.
  - Department also have various conventional machines like lathe, milling machines, welding machines.
  - Heat and mass transfer laboratory with conventional instrumentations.
  - Fluid Mechanics laboratory with conventional instrumentations.
  - Mechanical Measurement lab with conventional instrumentations.
  - Pneumatics trainer kit from Festo.
  - Mitutoyo Surface Roughness Tester.
  - Conventional metallurgical microscope, Basic IOT kits.

## Courses offered on Space Science and Technology

| | |
|---|---|
| Under- graduate (B.Sc. Sem-1) Intake-96 | Indian Astronomy-I(IKS202-1C) |

# MILLIYA ARTS, SCIENCE & MANAGEMENT SCIENCE COLLEGE
# BEED, (MAHARASHTRA) INDIA

https://milliyasrcollege.org/

## About the Centre / Laboratory / Institute

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 are to nurture graduates equipped for various facets of life, including the 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 NAAC accreditation 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

The major research domains focus on hyperspectral and microwave remote sensing for lunar and terrestrial applications. Hyperspectral remote sensing is extensively used for detecting hydroxyl (OH) and water ($H_2O$) on the lunar surface through diagnostic absorption features near 2.8–3.0 μm. These signatures vary with latitude, temperature, and solar illumination, reflecting a dynamic hydration cycle influenced by solar wind interaction and thermal effects. While effective for surface hydration detection, hyperspectral methods are limited in identifying subsurface ice, particularly in permanently shadowed regions, and are therefore complemented by radar observations.

Hyperspectral data also enables detailed analysis of mineral composition, identifying minerals such as pyroxene, olivine, plagioclase, and ilmenite. The lunar regolith is highly heterogeneous due to prolonged space weathering processes, including solar wind irradiation and micrometeorite impacts, which modify spectral characteristics and provide insights into regolith maturity and evolution.

Microwave remote sensing, particularly polarimetric SAR, is employed to detect potential subsurface water ice using parameters such as Circular Polarization Ratio (CPR) and Degree of Polarization (DoP). High CPR and low DoP signatures indicate porous, heterogeneous, and potentially ice-bearing regions. Additionally, microwave techniques are widely used for geophysical parameter retrieval, including soil moisture and surface

roughness, enhanced through hybrid models and machine learning approaches for improved accuracy and large-scale applications.

## Major Scientific Applications / Results

**1) Detection of Water ice over polar regions of the Moon using Chandrayaan-2 DFSAR data.**

The detection of water ice in the lunar polar regions represents a critical scientific objective for understanding volatile evolution and resource potential in the inner Solar System. Building upon the discoveries of Chandrayaan-1, this research utilizes Chandrayaan-2 DFSAR (L-band and S-band) polarimetric SAR data to identify potential water-ice-bearing regions through advanced radar analysis. Microwave polarimetry enables the identification of subsurface and volume scattering mechanisms, particularly within Permanently Shadowed Regions (PSRs), where extremely low temperatures facilitate the long-term preservation of water ice. These results confirm the capability of DFSAR to detect subsurface volatile signatures under space weathering conditions.

Key polarimetric indicators such as Circular Polarization Ratio (CPR) and Degree of Polarization (DoP) are integrated to distinguish between surface roughness effects and true subsurface multiple scattering, which is indicative of ice–regolith mixtures. The study further includes a multi-parameter convergence analysis, in which overlapping anomalies in CPR, DoP, and polarimetric decomposition outputs define high-confidence volatile candidate zones. These signatures are interpreted in the context of space weathering processes, including solar wind implantation, micrometeorite-induced fracturing, and regolith evolution, which influence porosity and enhance ice trapping.

The results from polarimetric analysis reveal that volume scattering is the dominant radar scattering mechanism, as confirmed by Pauli RGB representation, H–α plane clustering in Zones 5 and 8, and Yamaguchi decomposition, indicating a highly porous and heterogeneous regolith with strong subsurface contributions. Additionally, the observed combination of high CPR (≥ 1.1) and low DoP (≤ 0.35) highlights regions of enhanced multiple scattering and depolarization, consistent with porous, fragmented, and potentially volatile-bearing subsurface structures. The derived probabilistic water-ice candidate map identifies convergence zones where these signatures overlap, providing a radar-based framework for locating potential ice–regolith mixtures rather than direct detection.

This work helps resolve key uncertainties regarding the origin, distribution, and physical state of lunar water, thereby supporting future in-situ resource utilization (ISRU) strategies and human exploration missions.

**2) Spectral Deconvolution of Chandrayaan-2 IIRS Data using Bidirectional Reflectance Modelling.**

Understanding lunar mineralogy requires accurate interpretation of hyperspectral data affected by space weathering and complex regolith mixing. This study applies BRDF-based radiative transfer modelling to Chandrayaan-2 IIRS data, integrating spatial mapping and spectral analysis in the VNIR–SWIR regions to identify key minerals such as pyroxene, olivine, plagioclase, and ilmenite. By incorporating parameters like grain size, porosity, and submicroscopic iron (SMFe), the approach improves mineral quantification, regolith maturity assessment, and understanding of lunar surface evolution.

3) **Development of a Hybrid Model for Soil Geophysical Parameter Retrieval using SAR Data.**

Accurate retrieval of soil parameters, such as soil moisture, surface roughness, and dielectric constant, from SAR data is challenging due to complex surface interactions. This study develops a hybrid model combining physics-based (IEM, Modified Dubois) and empirical (Oh model) approaches, enhanced with machine learning (RF, SVR), to improve accuracy. Using Sentinel-1 data, the model demonstrates strong performance (as evidenced by $R^2$ and RMSE) and supports applications in agriculture, drought monitoring, and hydrology.

## Publications during the year 2024-2025


1) Vivek Dabhole, Sayyad Shafiyoddin, "Detection of Potential Lunar Water-Ice Regions Using Multi-Parameter Polarimetric Analysis of Chandrayaan-2 DFSAR Observations", International Journal of Scientific Research in Science and Technology, 2025, pp 334-346, https://doi.org/10.32628/IJSRST26131043
2) Rajeshwari Pangarkar, Dheeraj Raut, Sidheshwar Raut, Pradnya Maheshmalkar, Shafiyoddin Sayyad, “Fine Resolution PolSAR Data Analysis with Compensation Theory for Improved Interpretation”, J Inform Systems Eng, 9(4), https://doi.org/10.52783/jisem.v9i4.94
3) Dheeraj Bhima Raut, Rajeshwari Pangarkar, Sidheshwar Raut, Shafiyoddin Sayyad, "Integration of SAR Data and Machine Learning for Soil Moisture Estimation using SMAP Validation", J Inform Systems Eng, 9(4), https://doi.org/10.52783/jisem.v9i4.95
4) Sidheshwar Raut, Neha Andure, Rajeshwari Pangarkar, Vaibhav Misal, Shafiyoddin Sayyad, Sandipan Sawant, "Soil Moisture Retrieval from Sentinel-2 Data Using the Optical Trapezoidal Model (OPTRAM)", J Inform Systems Eng, 9(4), https://doi.org/10.52783/jisem.v9i4.96
5) Rajeshwari Pangarkar, Pradnya Maheshmalkar, Shafiyoddin Sayyad, “Study of the Influence of Polarization Orientation Angle on Polarimetric Signature Extraction from RISAT-1A Data”, MDPI Remote Sensing accepted in September 2025
6) Sidheshwar Raut, Neha Andure, Ankush Kadam, Ashok Dongare, Akash Fulari, Gaus Mohiuddin Sayyad , Shafiyoddin B. Sayyad, Saba Kaosar Shaikh, Sandipan Sawant,” Surface Clay and Mineral Exploration Using Hyperspectral Imaging:

Advanced Techniques for Geospatial Analysis", ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2025, Vol X-G-2025, pp. 697—703, https://doi.org/10.5194/isprs-annals-X-G-2025-697-2025

7) Rajeshwari C. Pangarkar, Shafiyoddin Sayyad, Pradnya Maheshmalkar, "Comparative Analysis of Polarimetric Orientation Angle Effects on C-Band and L-Band PolSAR Data Using RADARSAT-2 and ALOS-2", V 12 (2), pp. 1405-1413, 2025, https://doi.org/10.32628/IJSRST251222817
8) Dheeraj Bhima Raut, Vaibhav Misal, Rajeshwari Pangarkar, Sidheshwar Raut, Shafiyoddin B. Sayyad, "Nonlinear Soil Moisture Retrieval from Sentinel-1 SAR Using Ensemble Machine Learning", International Journal of Scientific Research in Science and Technology, 12(5) 100-108, 2025, https://doi.org/10.32628/IJSRST25126387
9) Monika S. Khole, Sandip M. Anpat, Shafiyoddin B. Sayyad, and Sanjay K. Tupe. 2025. "Soil Moisture Index (SMI) Estimation Using Raw Landsat-8 OLI Data, NDVI and Land Surface Temperature for Agricultural Drought Assessment". Journal of Geography, Environment and Earth Science International 29 (9):33–42. https://doi.org/10.9734/jgeesi/2025/v29i9941
10) Vishal Shirst, Sanjay Tupe, Shafiyoddin Sayyad, "Integrating Remote Sensing and Field Survey for Vegetation Classification based on Chlorophyll content using NDVI and Random Forest Techniques", Recent Trends in Applied Physics and Material Science, Eds Sudhir Bharadwaz et.al., 2026, Taylor and Francis Group, London, pp.274-276, https://doi.org/10.1201/9781003684718-90

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

At present, we are developing an indigenously designed multi-sensor analytical framework for the detection and characterization of hydroxyl (OH), molecular water, and water ice on the lunar surface. This framework integrates Chandrayaan-2 IIRS hyperspectral data with dual-frequency DFSAR (L-band and S-band) polarimetric datasets, enabling a comprehensive and physically consistent analysis of both surface and subsurface signatures. The methodology utilizes the spectral sensitivity of IIRS data to detect diagnostic absorption features of OH and $H_2O$ in the VNIR–SWIR region, while DFSAR data provides critical insights into subsurface scattering mechanisms through parameters such as Circular Polarization Ratio (CPR) and Degree of Polarization (DoP). These microwave indicators help distinguish multiple scattering environments associated with ice-regolith mixtures from surface roughness effects.

The framework further incorporates spectral deconvolution using radiative transfer modeling (BRDF-based) along with polarimetric decomposition techniques and POA-corrected SAR analysis to improve the accuracy and reliability of interpretation. Special emphasis is given to the role of space weathering processes, including solar wind implantation, micrometeorite impacts, and regolith evolution, which influence porosity and

volatile retention. By combining hyperspectral and microwave remote sensing with advanced modelling and data-driven approaches, this indigenously developed system provides a robust, scalable, and high-precision tool for identifying volatile-bearing regions and potential ice deposits on the Moon. The framework is validated using polarimetric thresholds and multi-parameter fusion techniques. The framework is highly relevant for future lunar missions, in-situ resource utilization (ISRU), and planetary exploration programs, and represents a significant step toward self-reliant advanced space science research.

## Capacity Building in Space Science Research

We have established a Microwave and Imaging Spectroscopy Research Laboratory with funding from ISRO. This facility supports advanced research and is actively used by over 20 students, providing hands-on experience in microwave and imaging spectroscopy. It plays a key role in strengthening research activities and enhancing the institution's academic environment.

**Titles of Awarded PhD. Dissertations**

1) Image Restoration in Microwave Active Remote Sensing using Frequency Domain Techniques.
2) Study of Polarimetric Responses for Target Characterization with Various Orientations

**Titles of Ongoing PhD. Dissertations**

1) Detection of Water Signature on Lunar Surface Using Chandrayan-2 Microwave Synthetic Aperture Radar Dataset
2) Remote Sensing of The Characteristics of Water, Snow, And Its Constituents Using Imaging Spectroscopy
3) Estimating Geophysical Parameter Retrieval Using Machine Learning for SAR Imagery
4) Identification of minerals of airless planetary bodies using bidirectional reflectance function
5) Space-based Water Quality Monitoring using Physics-Based Modelling
6) Estimation of Microphysical Properties of Clouds with Regards To Thermodynamic Phase

## Courses offered on Space Science and Technology

Presently, we operate ISRO-IIRS and ISRO-START study centres dedicated to offering courses in space studies.

## Laboratories and Facilities Available for Space Instrumentation

- ✓ Milliya College has an advanced Microwave and Imaging Spectroscopy Research Laboratory, established through ISRO-funded research projects from two significant ISRO research projects led by Dr Sayyad Shafiyoddin.
- ✓ The Imaging Spectroscopy Research Laboratory is equipped with two High-Performance Workstations featuring ENVI Software. This facility is designed to

extract information from remote sensing images and integrate it for various applications.

- ✓ The Microwave Imaging Laboratory is equipped with a C-band microwave bench, an SHOOL Soil parameter sensor (developed by ISRO-SAC), a Soil testing kit, and a surface roughness apparatus. The primary objective of this laboratory is to collect real-time ground truth data on soil surfaces.

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

**Contact person's Name**: Dr Sayyad Shafiyoddin
**Designation:** Professor of Physics, **Email:**Sayyad.shafiyoddin@gmail.com

# NARULA INSTITUTE OF TECHNOLOGY
# KOLKATA, INDIA

Website: ------ https://www.nit.ac.in/

## About the Institute

### Our Mission & Vision

To drive cutting-edge research and innovation through strategic collaborations with academic institutions, professional societies, R&D organizations and industries, creating a vibrant and dynamic ecosystem that addresses global challenges.

To be a premier institution of excellence in education, research, and innovation, fostering globally competent professionals with ethical values, entrepreneurial mindset, and a strong commitment to societal progress through comprehensive and multidisciplinary learning.

### Our Heritage and Legacy

To create an environment to empower the students with solid foundation in mathematical, scientific, engineering, managerial, entrepreneurial fundamentals and incorporate research-based curriculum thorough establishing continuous wide network with the industries in order to initiate long term academic excellence in the institution.

## Major Research Domains

### 1) Planetary Remote Sensing

- Detection of lunar water and hydroxyl ion and their diurnal changes from CHACE-2 orbiter observation.
- Study of short term and long-term variations of exospheric helium at magnetotail passage in active sun as well as quiet sun period.
- Study of Lunar Exospheric Oxygen from CHACE-2 Orbiter during the strom time a well as quiet time.

**Future Work:**

- Study of short- and long-term variations of density of $H_2$, $CO_2$, $N_2$ in lunar exosphere.
- Study of short term and long-term variations of exospheric hydrogen at magnetotail passage in active sun as well as quiet sun period.

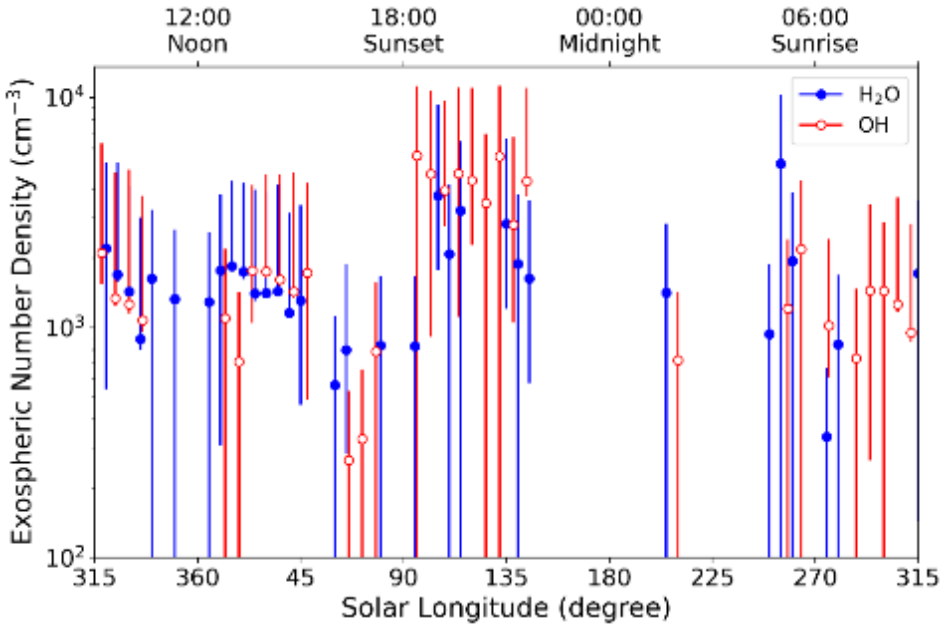
**2) GNSS/NaVIC related navigational studies**

- Characteristic studies on diurnal/seasonal variation of ionospheric scintillation using long term IRNSS/GNSS/GAGAN receiver data with a focus to estimation of scintillation over equatorial and low latitude region.
- Relationship of estimated positioning error with iono scintillation at L1 and L5 frequencies using IRNSS/GNSS/GAGAN receiver over low latitude/ equatorial anomaly region.
- Study of temporal variability of estimated positioning error and its impact on position accuracy and availability over low latitude/equatorial region using IRNSS/GNSS/GAGAN receiver over low latitude/ equatorial anomaly region using Kalman Filter approach.
- Future work will focus on extending the scintillation prediction framework by incorporating multi-constellation data and real-time adaptive learning.
- Comparative analysis between GEO and GSO satellite signals will be completed to quantify propagation differences. Advanced hybrid models combining ionospheric parameters with deep learning will be developed. Additionally, robustness of positioning accuracy under severe scintillation will be evaluated, and optimized Kalman filtering strategies will be implemented for enhanced navigation reliability in equatorial and low-latitude regions.

## Major Scientific Applications / Results

## Publication:

The spatial and diurnal variations of the number densities of lunar molecular water (H2O), amu 18 and hydroxyl (OH), amu 17 over low (0°-30°), middle (31°-60°) and high (61°-80°) latitudinal regions of the lunar exosphere during the pre-sunrise, noon, sunset and midnight periods using CHACE-2. Both $H_2O$ and OH exhibit, particularly in the low latitude regions, a trend of increasing number density after the sunrise and up to noon, followed by a decrease till sunset. An overall higher density of $H_2O$ is obtained compared to the previous reports. The findings are justified in terms of the polar orbital height of the instrument and the duration of data procurement. The maximum number density for the low, middle and high latitudes reaches $5225\,cm^{-3}$, $5135\,cm^{-3}$ and $3747 cm^{-3}$, respectively. The corresponding OH abundances are found to be $5079\,cm^{-3}$, $5565\,cm^{-3}$ and $5720\,cm^{-3}$. The diurnal variations of $H_2O$ and OH and their comparisons, similar to those of the present report may provide suitable means for tracing the lunar water cycle. The CHACE-2 observations imply that the influence of magnetotail passage on volatiles like water is to be further quantified in future missions with other sensors.




*Number density of $H_2O$ and OH at lunar exosphere for different solar longitudes for a typical mid-latitude range (31° to 60°). Solar longitude of 315°– 45°, 45°–135°, 135°–225° and 225°–315° represents noon, sunset, midnight, and sunrise respectively.*

## Publication list Link:

https://docs.google.com/document/d/1ECZtG7v8R4pOP4mzqW5cC5LrDcSCg53T4eyIb1W0ZzY/edit?usp=sharing

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

Not Applicable

## Capacity Building in Space Science Research

- Nearly 100 students have undergone training under START Program of ISRO 2024 and 2025
- Five Students have undergone internship for 2024-2025 – (Both paid and unpaid
- One Ph. D. Student Enrolled

## Courses offered on Space Science and Technology

| Sl. no | Title of the course offered | Level of the course | Intake capacity |
|---|---|---|---|
| 1 | Satellite Communication | Electronics and Communication Engineering Undergraduate (as elective) | 180 |
| 2 | | Electronics and Computer Science Engineering (Undergraduate) | 30 |

| | | | |
|---|---|---|---|
| 3 | | Electronics and Communication Engineering (Post Graduate) (as elective) | 18 |

## Laboratories and Facilities Available for Space Instrumentation

EMI/EMC Lab----Characterization studies of Various Antenna types
Satellite transmitter and receiver---For UG student training purposes.
GNSS Navigational Studies---Antenna,
Receiver—Total Electron Content and Scintillation Studies--- For PG and PhD students.
For further details on the inputs as provided in the document, please contact ---------
Name- Dr. Swastika Chakraborty
Designation- Professor
Email- swastika.chakraborty@nit.ac.in

# SCHOOL OF EARTH AND PLANETARY SCIENCES, NATIONAL INSTITUTE OF SCIENCE EDUCATION AND RESEARCH (NISER) BHUBANESHWAR, INDIA

Website: https://www.niser.ac.in/seps/

## About the Centre / Laboratory / Institute

School of Earth and Planetary Sciences, NISER is a unique research-driven academic center in India that has been established to emerge and excel in high quality and interdisciplinary scientific research works in Planetary Sciences, Earth Sciences, and Atmospheric-Ocean Sciences. National Institute of Science Education and Research (NISER), Bhubaneshwar, is affiliated with Homi Bhabha National Institute (HBNI), Mumbai, a deemed research university that oversees academic programs at Institutions that are part of the Department of Atomic Energy (DAE) structure https://www.niser.ac.in/seps/.

Fig. 1: NISER Bhubaneswar

## Major Research Domains

The major research domains in SEPS are Planetary Sciences, Earth Sciences, and Atmospheric-Ocean Sciences. The thrust areas in planetary science are:

- Planetary surface remote sensing & Mineral science
- Exoplanetary science (planet formation, atmosphere)
- Cosmochemistry

## Major Scientific Applications / Results

Publications related to planetary Science:

● Davydok, A., Singh, K. & Rout, S. S., ...[et al.]. "Efficient detection of deformation-induced microstructural modifications in polycrystalline micropillars using scanning X-ray nanodiffraction." *Journal of Applied Crystallography*, 59(1), 85–92.

● Arora, R. & *Majumdar, L.* "Quantifying the differences in transmission and emission spectra of hot irradiated gaseous exoplanet atmospheres: A comparison of 1D and 3D modelling using JWST." *Monthly Notices of the Royal Astronomical Society*, 546(1), staf2122.

● Dhoundiyal, S., Dey, M. S. & *Thangjam, G.*, ...[et al.]. "Open-set mineral identification from CRISM hyperspectral data." *Planetary and Space Science*, 269,106218.

● *Rout, S. S.*, Kentsch, U. & Dohmen, R., ...[et al.]. "High-temperature He+ Irradiation of Low-iron-bearing Olivine: Laboratory Simulations of Space Weathering on Mercury." *The Planetary Science Journal*, 6(11), 269.

● Srivastav, S., Barone, V. & *Majumdar, L.*, ...[et al.]. "Formation routes, structures, and spectroscopic parameters of butyl isocyanides: The case of t-C4H9NC isomer in TMC-1." *Monthly Notices of the Royal Astronomical Society*, 544(4), 3472–3495.

● Dutrey, A., Denis-Alpizar, O. & *Majumdar, L.*, ...[et al.]. "Edge-On Disk Study (EODS): III. Molecular stratification in the Flying Saucer disk." *Astronomy & Astrophysics*, 704, A33.

● Foucher, C., Dutrey, A. & *Majumdar, L.*, ...[et al.]. "Edge-On Disk Study (EODS): II. HCO+and CO vertical stratification in the disk surrounding SSTTau042021." *Astronomy & Astrophysics*, 704, A32.

● Baghel, P., *Goyal, J. M.* & Shukla, G., ...[et al.]. "Revisiting the atmosphere of HD-149026 b: The role of stellar abundances and choice of opacities in exoplanet atmospheremodelling." *Monthly Notices of the Royal Astronomical Society*, 544(1), 113–131.

● Chirumamilla, M., Krishnamurthy & *Rout, S. S.*, ...[et al.]. "2D photonic crystal emitter at 1, 400°C for thermophotovoltaic energy harvesting." *Cell Reports Physical Science*, 6(10), 102850.

● Tasa-Chaveli, A., Fuente, A. & *Majumdar, L.* "Gas phase Elemental abundances in Molecular cloudS (GEMS): XI. The evolution of HCN, HNC, and N2H+ isotopic ratios in starless cores." *Astronomy & Astrophysics*, 700, A226.

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

NA

**Capacity Building in Space Science Research** Courses yet to start

- PhD program already started (since 2019-2020; ~15 students enrolled)

**Courses offered on Space Science and Technology** A 5 year Integrated MSc program in Earth and Planetary Sciences is yet to start.

- PhD program already started

## Laboratories and Facilities Available for Space Instrumentation

There are no proper lab facilities (No electronics and sensor development laboratories, No software laboratory; No Payload Operation Centre (POC); No environmental test facility (vibration test, thermal tests, thermovacuum test, etc.); No cleanroom for development and assembly of sophisticated instruments).

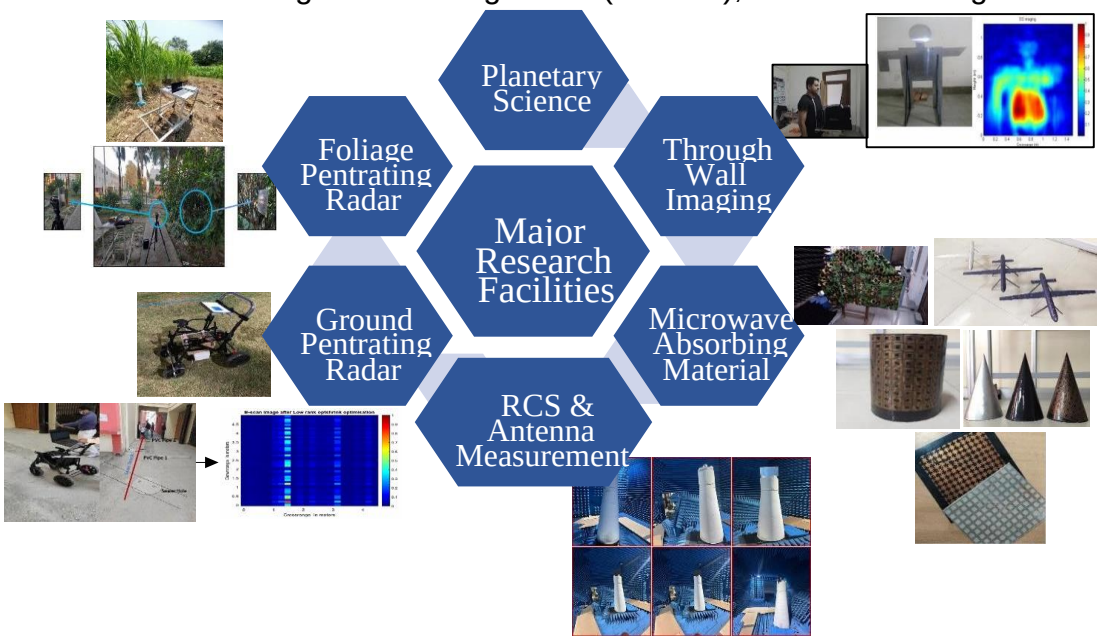
Some of the initiated works are listed but not yet in a mature development stage.

- A reflectance spectroscopy lab is initiated. A low cost reflectance spectrometer is in the developing stage (referring to literature) and the calibration is in progress (Guneshwar Thangjam / SEPS)
- Concept study and development of a Muon spectrometer for space science (Guneshwar Thangjam / SEPS, with Dr. Raveendrababu Karnam / CMRP)

# REMOTE SENSING LAB, DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, ROORKEE, INDIA

## About the Laboratory

Remote Sensing Lab (RSL) is established by Prof. Dharmendra Singh in 2004 with the help of students and support of IIT Roorkee and various funding agencies like: DRDO, ISRO, DST. RailTel, JAXA (Japan), MHRD, INRIA (France) etc. Lab has the main motive to impart knowledge in microwave imaging and space technology applications, from foundational to advanced levels, and to deliver technology-driven solutions to end users. RSL is an interdisciplinary laboratory exploiting microwave technology across a wide range of field including Artificial Intelligence Based Target Monitoring Using Drone and Satellite Data, Satellite Based Agriculture Monitoring, Radar-based Planetary Science (Lunar Science), Ground Penetrating Radar (GPR), Through Wall Imaging (TWI), Ground-Based Foliage Penetrating Radar (FOPEN), Radar Absorbing Material (RAM) for




Stealth Application. More than 50 PhDs have graduated from lab; 10 researchers are currently pursuing their doctoral degrees. The Lab plays a major role in national space science and technology projects. Students are the main strength of the lab.

## Major Research Domains

### 1) Satellite Based Agriculture Monitoring

- India's first satellite data-based online information system for agriculture monitoring (SBAIS) has been developed for Uttarakhand. It analyzes multi-temporal satellite

data using classification and NDVI-based crop health modules to enable district- and tehsil-level monitoring of crop health, season-wise changes, and year-on-year vegetation variation

- Early weed detection in Sugarcane field
- Automated Row counting in Vegetation field

**2) Artificial Intelligence Based Target Monitoring Using Drone and Satellite Data**

 AI-driven monitoring frameworks integrating UAV and satellite imagery for surveillance and analysis of dynamic environments. Applications include camouflaged object detection in UAV images, construction project tracking, and terrain monitoring using deep learning models.

**3) Lunar Science**

 Polarimetric characterization of lunar polar regions for water-ice detection and surface roughness estimation. Research primarily uses Mini-SAR (Chandrayaan1) and DFSAR (Chandrayaan-2) data, supplemented by other sensor data like Moon Minerology Mapper, Diviner thermal imager, Neutron spectrometer data for validation of radar-based results.

**4) Antenna and Microwave System Design**

 Development and optimization of microwave antenna systems tailored for remote sensing and space instrumentation applications.

## Major Scientific Applications / Results

**1) Land cover mapping of mixed classes using 2D CNN with multi-frequency SAR data**

Classifying mixed land cover classes with similar SAR backscattering response is challenging. Arbitrary ordering of SAR features in conventional CNNs leads to underutilization of multifrequency data. This study introduced a novel 2D-PolFeat-EnsembleDiCNN model that transforms SAR features from 1D to 2D space. An ensemble of dilated convolutions with varying rates then extracts discriminative features from this transformed space. The model was trained on ALOS-2 PALSAR-2 and Sentinel-1 dual-polarization data. It achieved an average F-score and kappa coefficient of 0.97, outperforming 1D, 2D, and 3D CNN baselines by up to 11% in overall accuracy.

Link: https://doi.org/10.1016/j.asr.2024.03.066

**2) A case study on Lagrange polynomials and machine learning for yield prediction**

Cloud cover creates gaps in multispectral time series data, reducing the performance of crop yield prediction models. This study applied Lagrange polynomial interpolation to fill missing time series data caused by cloud cover. The interpolated data was used as input features for machine learning and deep learning models for yield prediction. Neural network models outperformed XGBoost and Support Vector Regressor in prediction accuracy. The fusion of statistical gap-filling with ML-DL models

outperformed traditional approaches. Results demonstrate the strong potential of combining statistical interpolation with advanced ML-DL methods for robust and timely crop yield prediction.

Link: https://doi.org/10.1016/B978-0-443-34113-7.00014-6

**3) Synthetic data generation using microwave modeling with efficient application of machine learning for bare land soil moisture retrieval: a case study**

Retrieving soil moisture (SM) from SAR data requires large training datasets, which are difficult to obtain in real-world settings. This study developed a multilayer HFSS-based electromagnetic model to generate synthetic SAR backscatter data under varying moisture contents, soil textures, incidence angles, and frequencies. The synthetic dataset was used to train a Gaussian Process Regression (GPR) model for SM estimation without prior site information. The trained model was tested on real SAR data using in-situ SM measurements.

Results showed strong performance with RMSE of 0.032 and MAE of 0.027, demonstrating the viability of synthetic-data-driven ML models for cost-effective SM retrieval.

Link: https://doi.org/10.1016/B978-0-443-34113-7.00019-5

**4) Synthetic Imaging Radar Data Generation in Various Clutter Environments Using Novel UWB Log-Periodic Antenna**

Collecting real experimental data for short-range microwave imaging is tedious and laborintensive. This study explored cost-efficient synthetic data generation using electromagnetic simulations with a 3D antenna model instead of a point source. A novel printed scalable UWB log-periodic antenna with a tapered feed line was designed, offering more than 6 dBi gain across its bandwidth. Two antenna variants were developed: Antenna_1 (1.5–5.5 GHz) for Through-Wall Imaging and Antenna_2 (0.7–2.7 GHz) for Through-Foliage Imaging. Synthetic B-scans were generated across diverse clutter scenarios. The resulting datasets are suitable for training ML-based target detection models.

Link: https://www.mdpi.com/3082054

**5) Use Of Machine Learning On SAR Data To Classify Submerged And Flooded Regions**

Classifying fully flooded, submerged, and non-flooded regions is essential for flood management. However, mixed scattering responses from these classes make classification difficult using conventional techniques. This study applied XGBoost and Random Forest models to optimum features extracted from Sentinel-1 SAR time series data. The ML models effectively distinguished between submerged and flooded areas with acceptable accuracy. Combining ML algorithms with time series SAR data enables accurate and timely flood monitoring. The approach enhances flood management strategies and helps reduce the impact on vulnerable communities.

Link: https://ieeexplore.ieee.org/abstract/document/10984156

**6) Synergetic Use of Random Forest and H3 Grid Cell for the Flood Monitoring Using Sentinel-1 Data**

Floods cause severe damage to lives, infrastructure, and agriculture worldwide. This study used Sentinel-1 SAR data to monitor flood occurrences over the Begusarai region. The methodology combined the H3 global grid system for spatial aggregation with Random Forest classification of SAR images. Pre- and post-flood periods were analyzed to map flood extent and assess agricultural vulnerability. Polarization patterns were found to correlate consistently with flood severity. The model uses historical data on permanent water bodies to improve floodprone area identification. The approach can be extended to hydrological drought analysis and emergency response planning.

Link: https://ieeexplore.ieee.org/document/10984268/

**7) An Approach to Model Lunar Regolith with HFSS for Synthetic SAR Data Generation**

Acquiring real SAR data for lunar exploration is expensive and limited. This study used HFSS electromagnetic simulations to generate synthetic L-band SAR data for lunar regolith. Key parameters such as incidence angles, polarizations, and dielectric properties were varied in the simulations. The resulting synthetic backscatter coefficients were validated against Chandrayaan-2 DFSAR data and showed strong agreement. The synthetic dataset offers a cost-effective resource for training machine learning models for lunar surface analysis. This work supports future SAR-based planetary missions, including prospective Chandrayaan follow-on missions.

Link: https://doi.org/10.1109/InGARSS61818.2024.10984053

**8) Efficient application of deep neural networks for identifying small and multiple weed patches using drone images**

Weed in sugarcane fields is difficult to detect due to its green-on-green color merging with the crop. This study proposed a Deep Neural Network (DNN) approach to detect small and multiple weed patches from UAV imagery. Color and texture features were extracted and used to train the DNN at a pixel level. The model achieved detection at a minimal resolution of 2.13 cm/px. It performed accurately under varying illumination conditions. The classifier achieved an overall accuracy of 90.5%, outperforming traditional supervised learning models.

Link: https://ieeexplore.ieee.org/abstract/document/10533244

**9) Potential Assessment of SAR and Optical Data with Machine Learning to Monitor Temporal Changes in Tall Vegetation**

This study maps tall vegetation (TV) cover changes at 10 m resolution using Sentinel-1 SAR and Sentinel-2 multispectral data fusion. Fourteen features are tested with six ML classifiers; Random Forest achieves 96.5% accuracy with fused data, followed by XGBoost and LightGBM. Applied to the Roorkee–Dehradun Bypass (2016–2018), consistent TV decline is detected, attributed to highway construction and urbanization.

Results confirm that SAR– optical data fusion significantly enhances classification performance for reliable fine-resolution environmental change monitoring.
Link: https://link.springer.com/article/10.1007/s12524-024-02056-0

## Indigenously Developed Products

1. Satellite Based Agriculture Information System (SBAIS): India's first satellite databased online information system for agriculture/crop monitoring at district and tehsil level in Uttarakhand. It uses multi-temporal satellite data for land classification and NDVI-based crop health monitoring, with both season-wise and year-wise analysis modules.
2. SAR Feature Extraction and ML Toolbox: An internally developed software toolbox for extracting and evaluating polarimetric SAR features (backscatter coefficients, decomposition parameters, vegetation indices) and applying ML models (XGBoost, LightGBM, Random Forest, KNN) for crop parameter estimation and land cover classification.

## Capacity Building in Space Science Research

- More than 50 PhD scholars have graduated from RSL with research in areas directly relevant to space science: polarimetric SAR, lunar remote sensing, microwave imaging, and satellite-based agriculture monitoring. 10 PhD scholars are currently enrolled.
- The lab regularly mentors M.Tech. and B.Tech. students through project-based training in SAR data processing, microwave modeling, and AI-based remote sensing - extending well beyond standard curricular requirements.
- RSL actively collaborates with national (ISRO, DRDO, DST) and international (JAXA, INRIA) agencies, providing students and researchers exposure to real-world space science projects.

## Courses offered on Space Science and

The following courses relevant to space science and technology are offered at IIT Roorkee through the Department of Electronics & Communication Engineering:

| Course Title | Specialization in Space Science & Technology |
|---|---|
| M.Tech. RF & Microwaves | Microwave Imaging, SAR Data Analysis, Space Technology applications |
| Ph.D. | Polarimetric SAR, Lunar Remote Sensing, Agricultural Monitoring, AI for Earth Observation |

## Laboratories and Facilities Available for Space Instrumentation

- Remote Sensing Laboratory (RSL): Fully equipped computational laboratory with high-performance workstations for processing polarimetric SAR data (ALOS PALSAR, Sentinel-1, Chandrayaan Mini-SAR/DFSAR). Supports PolSAR & Hyperspectral data analysis, ML model development, and microwave imaging research.
- Microwave Anechoic Chamber: Available for microwave antenna measurements and radar cross-section (RCS) experiments. Equipped for controlled electromagnetic characterization of targets relevant to RAMs and antenna design research.
- HFSS Electromagnetic Simulation Facility: High-performance computing setup running Ansys HFSS for electromagnetic modeling of soil, vegetation, and complex targets. Used for generating synthetic SAR training data and antenna design validation.

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

**Prof. Dharmendra Singh**, Professor, Department of Electronics & Communication Engineering, IIT Roorkee. E-mail: dharmfec@iitr.ac.in.

# LABORATORY FOR EARTH RESOURCES INFORMATION SYSTEMDEPARTMENT OF GEOLOGY, UNIVERSITY OF KERALA
# THIRUVANANTHAPURAM, INDIA

www.sajinkumar.com

## About the Laboratory

The Laboratory for Earth Resources Information System (LERIS), housed in the Department of Geology at the University of Kerala, is dedicated to understanding the formation and evolution of planetary bodies through integrated analysis of impact cratering processes, surface morphology, and mineralogical signatures. Our vision is to bridge terrestrial analog studies with planetary exploration through cutting-edge remote sensing techniques and field investigations. With over a decade of legacy in planetary research, we have established ourselves as a leading contributor to studies of the lunar and Martian surface processes, combining traditional geological approaches with advanced machine learning. The laboratory fosters interdisciplinary collaboration, training the next generation of planetary scientists while contributing to international space missions through landing site characterization and scientific payload development.

## Major Research Domains

- Impact Crater Morphology and Evolution
  Investigation of terrestrial and planetary impact craters using integrated remote sensing, field geology, and numerical modeling. Our research resolves morphological controversies (e.g., the Ramgarh Crater debate) and reconstructs crater evolutionary histories through innovative techniques, including PSInSAR and paleo-DEM reconstruction, thereby establishing frameworks for understanding crater modification processes on Earth, the Moon, and Mars.
- Lunar Polar Science and Exploration
  Characterization of lunar south pole regions for future exploration missions through detailed terrain analysis, permanently shadowed region (PSR) assessment, and volatile potential evaluation. Our landing site studies integrate slope analysis, illumination modeling, surface roughness, and temperature mapping to identify technically feasible yet scientifically optimal locations for resource utilization.
- Martian Geological Processes
  Reconstruction of Martian crater histories to understand volcanism, fluvial activities, and collapse structures. Using multi-instrument datasets (MOLA, CTX, CRISM) and crater size-frequency dating, we establish chronological sequences of events-from impact-induced volcanism to outflow channel formation-providing insights into Mars' climatic and tectonic evolution.
- Planetary Analog Studies

Documentation of terrestrial mineral assemblages and processes analogous to Martian environments. Our investigations of halotrichite formation in acid rock drainage conditions and impactite mineralogy provide ground-truth references for interpreting remote sensing data from Mars, particularly for sulfate deposits and impact-related mineralization.

- Machine Learning in Planetary Science
  Development of specialized deep learning architectures (MarsLS-Net with PEN-Attention) for automated feature detection and segmentation on planetary surfaces. The creation of benchmark multimodal datasets for Martian landslides addresses the unique challenges of feature identification on airless/desert bodies, where traditional vegetation-based detection methods are inapplicable.

## Major Scientific Applications / Results

1. Short-term erosion rate of impact craters using radar data: implications for their morphology
   The first application of PSInSAR radar analysis resolved the long-standing debate over Ramgarh Crater's morphology by quantifying short-term erosion rates (2017-2022). The 2.4 km relict structure showed insignificant erosion (−0.83 mm/yr), while the purported 10 km outer rim exhibited higher rates (−2.02 to −6.9 mm/yr) due to agricultural practices. Field observations confirmed the absence of a raised rim at the 10 km scale, conclusively classifying Ramgarh as a simple crater with a 2.4 km rim-to-rim diameter. This demonstrates PSInSAR's value as a tool for resolving geological controversies in planetary science.
   [*Link:* https://doi.org/10.1016/j.geomorph.2025.109923]
2. Reconstructing the geological and geomorphological history of Morella crater, Mars
   Morella Crater (77 km) on Mars preserves evidence of multiple geological processes through five evolutionary stages from late Noachian formation (~3.7 Ga) to the present. Crater size-frequency distribution and hyperspectral data revealed impact-induced volcanism infilling, followed by the formation of the Ganges Cavus collapse structure, lake development from melted cryosphere, and eventual breaching to form the Elaver Vallis outflow channel (3.0 Ga). Hydraulic modeling estimated flood volume of $3.27 \times 10^{12}$ $m^3$ and peak discharge of $3 \times 10^7$ $m^3/s$. This multi-stage reconstruction provides a template for understanding complex crater evolution on Mars. [*Link:* https://doi.org/10.1016/j.geomorph.2025.109740]
3. Spatio-temporal interpolation of ~530 ma paleo-dem to quantify denudation of a terrestrial impact crater
   The first paleo-digital elevation model reconstruction quantified 530 million years of erosion at Ramgarh Crater using GPlates reconstruction and mathematical modeling. Two formation age scenarios (528 Ma and 395 Ma) with derived rim heights yielded a cumulative erosion volume of 0.41-0.58 $km^3$. Projectile characteristics and progressive morphology changes through time were

reconstructed. This novel framework quantifies long-term denudation rates of impact structures, with implications for understanding landscape evolution and preservation potential of terrestrial impact craters through deep time. [*Link:* https://doi.org/10.2139/ssrn.4755175]

4. Revised chronology and expanded insights: geologic perspective on the Luna impact event and its influence on the Harappan civilization

   Optically stimulated luminescence dating of impactites at the Luna structure yielded an age of 4045 ± 182 years—significantly younger than previously estimated and placing the impact event closer to the decline of the Harappan Civilization. Impactites revealed mineral assemblages dominated by wüstite, kirschsteinite, spinel, olivine, and quartz, with three melt classes identified. Major oxide geochemistry showed both terrestrial-affinity samples and non-terrestrial trends, indicating target-projectile mixing. This revised chronology suggests potential cultural impacts requiring re-evaluation of Harappan decline narratives. [*Link:* https://doi.org/10.1111/maps.14308]

5. Formation of halotrichite in the South Kerala Sedimentary Basin, SW India: Implications for Martian paleo-environmental studies

   The first documentation of halotrichite in the South Kerala Sedimentary Basin reveals acid rock drainage conditions analogous to those in Martian environments, such as Rio Tinto. Halotrichite forms seasonally through oxidation of pyrite-bearing clay layers and Al-rich leachate from the Youngest Toba Tuff. XRD, EDS, FTIR, and Raman spectroscopy confirmed halotrichite associated with kaolinite, goethite, lepidocrocite, and smectite—matching Mars' layered sulfate deposits in Valles Marineris and Meridiani Planum. This terrestrial analog provides insights into formation conditions and preservation potential of polyhydrated sulfates on Mars. [*Link:* https://doi.org/10.1016/j.pss.2024.105999]

6. MarsLS-Net: Martian landslides segmentation network and benchmark dataset

   MarsLS-Net, a novel deep learning architecture with Progressively Expanded Neuron Attention mechanism, was developed specifically for Martian landslide segmentation, which is challenging due to the absence of vegetation that aids terrestrial detection. The model captures global spatial correlations with significantly fewer parameters than conventional vision transformers. The accompanying multimodal Martian landslide dataset (publicly available) provides the first benchmark for algorithm development on Mars, enabling automated mapping of mass-wasting processes critical for understanding Martian slope stability and climate-influenced modification. [*Link:* https://doi.org/10.1109/wacv57701.2024.00805]

7. The Luna structure, India: a probable impact crater formed by an iron bolide

   A multi-proxy investigation confirmed the Luna structure (1.5-1.8 km) in India's Kutch Basin as an impact crater, based on mineralogical and geochemical

evidence. Melt-like rocks contain wüstite, kirschsteinite, ulvöspinel, hercynite, and fayalite minerals indicative of impact melting. Platinum group element enrichment (Ir: 10.63 ppb, Os: 6.03 ppb) confirms meteoritic contamination. Geochemical modeling points to an iron or stony-iron projectile impacting a clay-rich target. Radiocarbon dating of the underlying silt at 6905 years makes Luna the largest crater formed by an iron bolide in the last 10,000 years.
[Link: https://doi.org/10.1016/j.pss.2023.105826]

## Courses offered on Space Science and Technology

| (i) Title of the course offered | (ii) Level of the course | (iii) Intake capacity | (iv) Subjects of specialization in Space Science and technology |
|---|---|---|---|
| Planetary Science | Undergraduate: Four-Year Undergraduate Program (FYUGP), Semester 1 | 16 | • Elements of the Cosmos<br>• Universe and Nucleosynthesis<br>• Asteroids, Comets, and Exoplanets<br>• Formation of the Solar System<br>• Terrestrial and Gaseous Planets<br>• Impact Cratering<br>• Astrobiology<br>• Craters on Earth and India |

## Laboratories and Facilities Available for Space Instrumentation

- **Laser Raman Spectroscopy Laboratory**- Thermo Fisher DXR3 Raman Microscope; Class 1 laser; 532 nm excitation; True Confocal Geometry (25 µm and 50 µm apertures); Peltier-cooled CCD detector (>55% quantum efficiency); 0.1 mW laser power control; OMNIC software with mineral spectral database; used for planetary analog mineral characterization, including melanterite and gypsum.
- **Geoinformatics Software Laboratory**- Equipped with ArcGIS, QGIS, ENVI, HEC-RAS, and CRISM Analysis Toolkit; used for hyperspectral image processing, spatial data analysis, hydrological modeling, planetary surface mapping, and Martian mineral identification using orbital remote sensing datasets.

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

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https://www.keralauniversity.ac.in/dept/deptHome.php?deptID=9&mID=3

# N. S. S. COLLEGE, PANDALAM, KERALA
# Pandalam, Pathanamthitta District - 689501, Kerala, INDIA

Website: https://nsscollegepandalam.ac.in

## About the College

**N. S. S. College, Pandalam**

N.S.S. College, Pandalam is one of the premier institutions of higher education managed by Nair Service Society, a leading educational agency and a social organization. The founder, Late Padma Bhushan Mannathu Padmanabhan was a great visionary and social reformer who believed that education is the most effective means of social reforms. The college keeps its tradition and identity in the higher education scenario through its vision "Śreyo hi jñānamabhyāsāt (श्रेयो हि ज्ञानमभ्यासात्)". The college is moving forward with a mission to educate and illuminate the young generation with values and tradition. The college was established in the month of February 1949 and started functioning as a second-grade college in the year 1950 offering intermediate courses of the University of Travancore. More courses in the Degree and Post Graduate levels were introduced in the successive years and at present, with a total of sixteen Degree Courses and seven Post Graduate Programmes and the research programmes in Zoology, Botany and Physics, the college is recognized as Post Graduate College affiliated to University of Kerala. The College was re-accredited (IV Cycle) with Grade A (CGPA 3.24) grade by National Assessment and Accreditation Council(NAAC).

## Major Research Domains

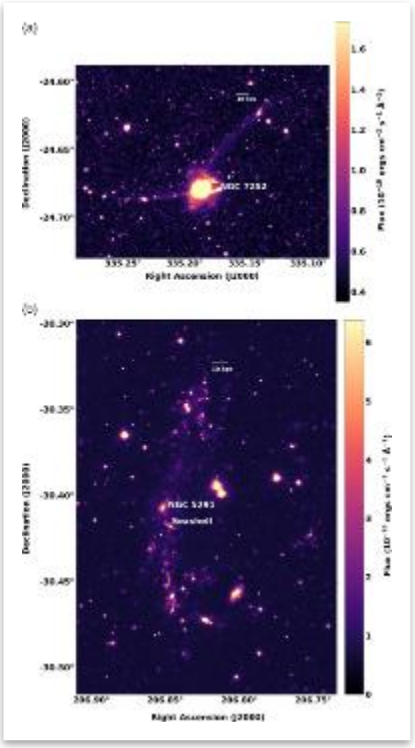
At the Postgraduate and Research Department of Physics, research related to Nano Science and Space science is carried out. Space science research is conducted under the guidance of Dr. **Rakhi R**, Assistant Professor and Research Guide at the department. The major research domains are:

- **Astronomy and Astrophysics**
  The focus is on understanding star formation both within and outside galaxies. The study primarily employs high-resolution imaging observations from the Ultraviolet

Imaging Telescope (UVIT) onboard India's multi-wavelength space telescope, AstroSat. The goal is to enhance our understanding of star formation and, the formation and evolution of galaxies in the Universe.

## Major Scientific Applications / Results

During the period from January, 2024 to December, 2025, the Postgraduate and Research Department of Physics, N. S. S. College, Pandalam contributed to astronomy research with a publication titled "**Star formation in interacting galaxy systems: UVIT imaging of NGC 7252 and NGC 5291"** in the journal *Publications of the Astronomical Society of Australia* (Published on April 2025). This work presents a detailed investigation of star formation in two nearby interacting galaxy systems NGC 7252 and NGC 5291, formed from galaxy-galaxy gravitational interactions such as collisions/mergers. Both systems hosts numerous star-forming knots including confirmed Tidal Dwarf Galaxies (TDGs). The study utilizes high-resolution imaging data from UVIT (Ultra-Violet Imaging Telescope) on board the AstroSat mission to investigate the star-forming knots in the systems and compare their star formation activity. The study reveals that both the Star Formation Rate (SFR) and SFR surface density of the knots in the debris of the NGC 7252 system lies within the range exhibited by those in the NGC 5291 system. This research aims to enhance our understanding of star formation in dynamic environments, far from galactic disks.



**UVIT NUV images of (a) NGC 7252 system and (b) NGC 5291 system (Santhosh et al. (2025)).**

**Access Publication:**
https://doi.org/10.1017/pasa.2025.21

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

N/A

## Capacity Building in Space Science Research

Ph.D. Students in Areas Related to Space Science and Technology

Ms. Geethika Santhosh is a full-time research scholar at the Postgraduate and Research Department of Physics, N. S. S. College, Pandalam, working under the guidance of Dr. Rakhi R, Assistant Professor at the same department. Her thesis is titled "Local characteristics of star formation using high resolution ultraviolet observations from UVIT on board AstroSat". This work reflects the institute's commitment to fostering advanced research skills in space science and technology, providing hands-on experience with observational data and contributing to the broader understanding of star formation.

## Courses offered on Space Science and Technology

| Title of the course offered | Level of the course (undergraduate / post-graduate / PhD coursework, etc.), | Intake capacity | Subjects of specialization |
|---|---|---|---|
| Open Course - Astronomy and Astrophysics | Undergraduate | 48 | Astronomy and Astrophysics |
| Elective- Space Science and Research Methodology | Undergraduate | 48 | Space Science |
| Multi-Disciplinary Course(MDC)- Beyond the Sky | Four-Year Undergraduate | 48 | Astronomy & Astrophysics |
| Elective- Fundamentals of Astrophysics | Four-Year Undergraduate | 48 | Astronomy & Astrophysics |
| Elective- Solar Terrestrial Physics | Four-Year Undergraduate | 48 | Solar Physics |

## Laboratories and Facilities Available for Space Instrumentation

NA

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

**Dr. Rakhi R, Assistant Professor, Department of Physics, N.S.S. College, Pandalam**
**Email: rakhi@nsscollegepandalam.ac.in**

# 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 &l 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 Space Science Office, ISRO, Head Quaters

- Several state and central government projects are on-going using Remote Sensing and GIS for monitoring and modelling Disaster management and Sustainable Agriculture.

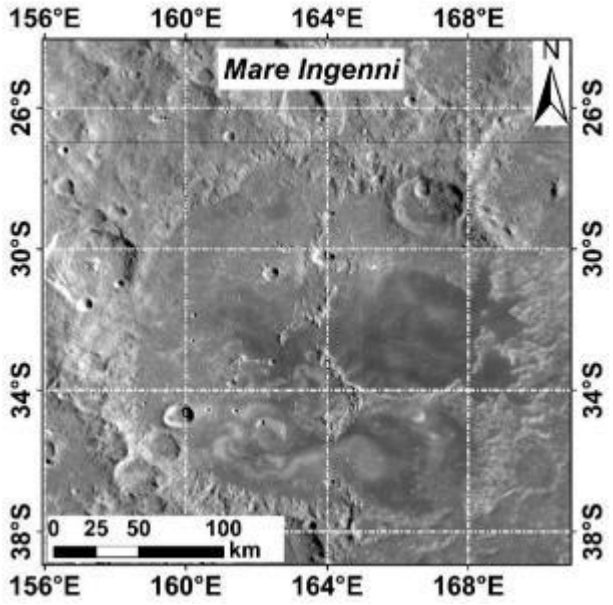



*Figure 1: Ortho-image mosaic of Mare Ingenni impact crater*

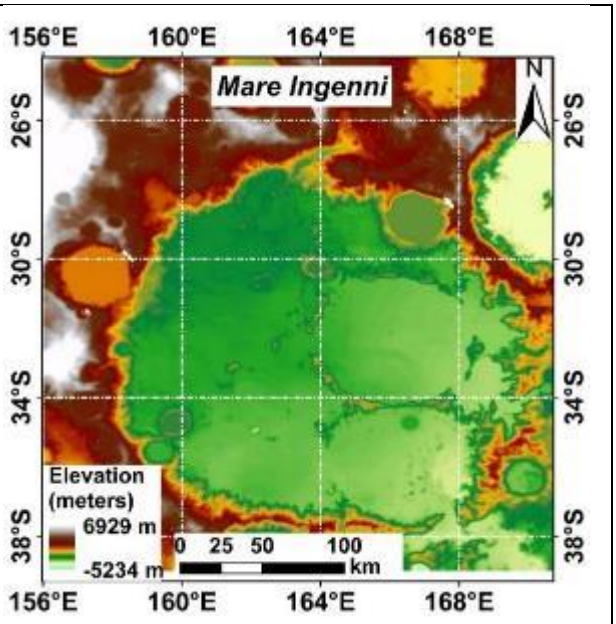



*Figure 2: DEM mosaic of Mare Ingenni impact crater region*

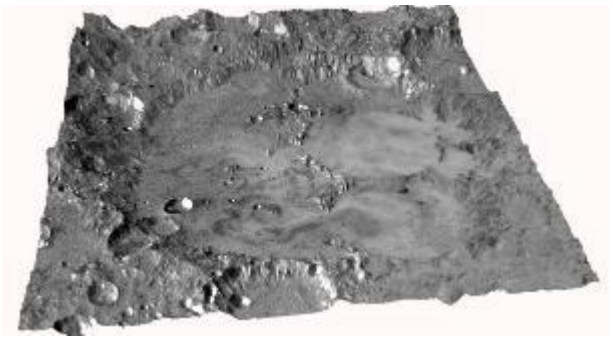


*Figure 3: 3D perspective view of the topography of Mare Ingenni impact crater region*

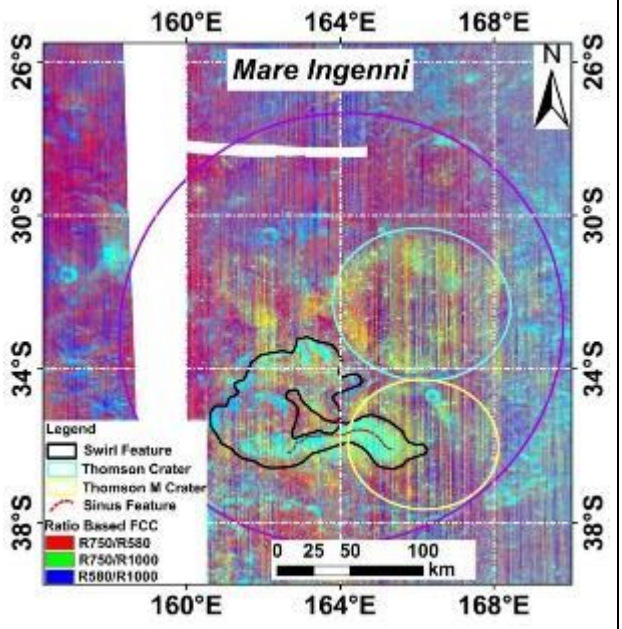



*Figure 4: Morphological Units and M3-based contacts digitalization visualized on top the M3 UVVIS Color Ratio mosaic*

## Publications


- Pundir, E. ., Sur, K. ., Verma, V. K. & Pateriya, B. Mineralogical Insights of the Lunar Near Side Krafft Crater Utilizing Hyperspecral Data Cubes. National Space Science Symposium. Goa University. Feb 2024.
- Sur, K., Pundir, E., Verma, V. K., Chauhan, M., Thapa, J., Chauhan, P., & Pateriya, B. (2025). A Geological Perspective on Lunar Surface Process with Morphological Insights in Mare Ingenni. LPI Contributions, 3090, 2053.
- Thapa, J., Sur, K., Chauhan, M., Ghosh, B., Kundu, A., Pundir, E, Vipan K Verma and Chauhan, P. (2025). Deciphering mineralogical and compositional variations in lunar Basin, Mare Fecunditatis: An in-depth analysis using hyperspectral remote sensing
- techniques. Advances in Space Research, 75(4), 4080-4098.
- Thapa, J., Chauhan, M., Sur, K., Kundu, A., Chauhan, P., & Verma, V. K. (2024).
- Identification and distribution of Fe--Mg spinel bearing lithology in Mare Fecunditatis, the Moon. Current Science (00113891), 126(8).


## Indigenously Developed Instruments

Not Applicable

## 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
# BENGALURU, INDIA

Website: www.rri.res.in

## About the Centre / Laboratory / Institute

The Raman Research Institute (RRI) is a premier research Institute founded by Indian Science Nobel Laureate Professor C. V. Raman. The Institute has a rich heritage of conducting fundamental research in frontier areas of Physics within contemporary research themes. The Institute was founded in 1948. The Institute has, since then, carried forward the legacy of its founder and embarked on several research activities of national importance. Currently, RRI's thrust research areas cover Astronomy and Astrophysics, Light and Matter Physics, Soft Condensed Matter, and Theoretical Physics. The research at the Institute has a strong space science and technology component with past and current efforts in high technology instrumentation and payloads towards X-ray and Radio Astronomy and Quantum Communications.

*The iconic main building and lawn of the Raman Research Institute*

## Major Research Domains

1. X-ray Astronomy:

   i) Experimental:

   2024 began on a high note with the launch of ISRO satellite XPoSat carrying POLIX (Indian X-ray Polarimeter), which was conceived, designed, and built at RRI. Along with X-ray timing and spectroscopy, X-ray polarimetry has emerged as a powerful

tool. POLIX is the only X-ray polarimeter in the 8-30 keV band. Observations of interesting compact objects using POLIX are ongoing.

ii) Observational:

Ultraluminous X-ray sources, cataclysmic variables, and X-ray binaries are studied under this theme. X-ray binaries consist of a compact object — white dwarf, neutron star, or a black hole and a companion 'normal' star. The intense gravity of the compact object causes matter from the companion to accrete onto it, producing X-rays. A plethora of information is obtained from such X-rays.

2. Radio Astronomy:

i) Experimental Cosmology: Signals from the Cosmic Dawn and the Epoch of Reionisation:

PRATUSH (Probing ReionizATion of the Universe using Signal from Hydrogen) is a future lunar-orbiting radiometer that will unravel the mystery of Cosmic Dawn — when the first stars formed. RRI has built a promising laboratory model. Under an MoU with Space Applications Center (ISRO), the researchers are working towards its space-hardened version.

ii) Observational Cosmology:

RRI scientists study the Cosmic Microwave Background (CMB) and its spectral distortions, especially those arising in epochs of recombination through to reionization.

## Major Scientific Applications / Results

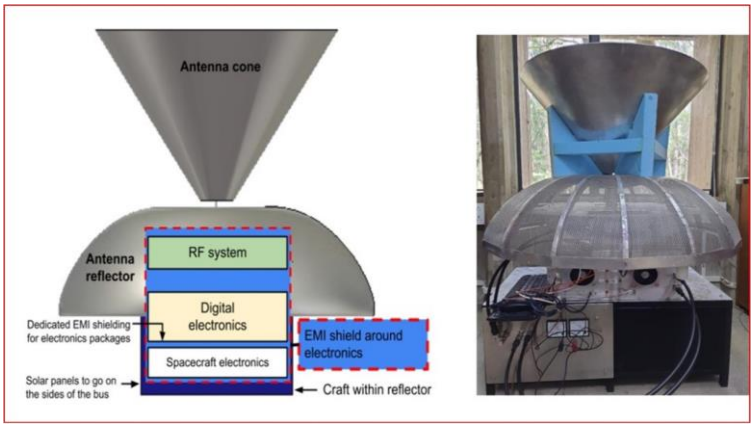
Link to publications: 2 years_LoP

**Radio Astronomy:**

**An SBC-based controller and processor for the laboratory model of PRATUSH digital receiver**

An RRI team developed a controller and processor based on Raspberry Pi (RPi) 4 Model B-based single-board computer (SBC) for the laboratory model of PRATUSH digital

receiver. Probing ReionizATion of the Universe using Signal from Hydrogen (PRATUSH) is a proposed space-based radiometer that aims to detect the 21-cm signal from Cosmic Dawn- when the very first stars in the Universe turned on. PRATUSH will operate in the frequency range of 55-110 MHz. It will conduct observations in low Earth orbit in its first phase, followed by lunar orbit in the second phase. The digital receiver or the digital correlation spectrometer is an integral part of PRATUSH, enabling phase switching, digitisation, and generation of sky spectrum. Using RPi over a conventional computer leads to huge reductions in power, mass, and volume requirements of the laboratory model. At the same time, using an SBC with limited capabilities also leads to certain challenges. This paper covers these challenges, as well as the overall implementation of the laboratory model of the PRATUSH digital receiver. The paper also details the performance of the digital receiver when integrated with the laboratory model of the PRATUSH analog receiver.




*Block diagram and a laboratory concept model of PRATUSH, integrated with subsystems comprising of antenna, analog and the digital receiver*

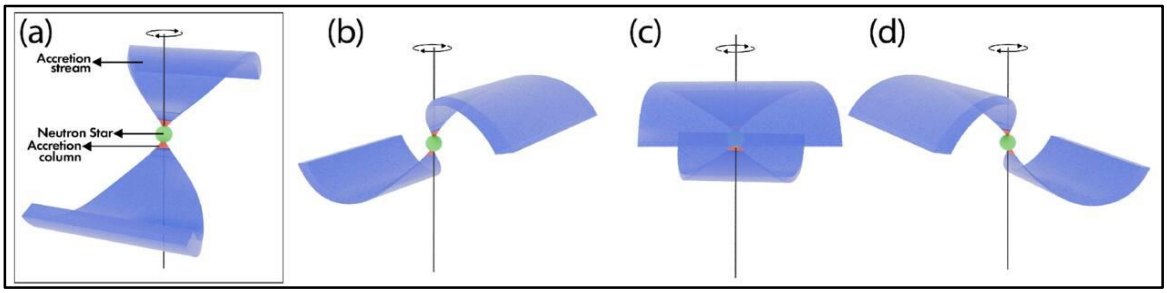
**A multi-site study of the radio environment for cosmology experiments**

An RRI team conducted radio frequency interference (RFI) surveys at four distinct locations: the Gauribidanur Radio Observatory in Karnataka, Twin Lakes in Ladakh, Kalpong Dam in the Andaman Islands, and the Gruvebadet Atmosphere Laboratory in Ny-Ålesund, Svalbard, Norway. The effect of RFI specifically on the performance of the in-house developed SARAS telescope was investigated. RFI, especially in the 30-300 MHz bands, can be a major hindrance in detecting faint cosmological signals such as the red-

shifted 21-cm line from cosmic dawn (CD) and epoch of reionization (EoR). Site selection and data integrity may be compromised without knowledge of the RFI landscape, as wireless communications and satellite transmissions increasingly contribute to RFI. The results provide a comprehensive view of the RFI environment, giving insight into how good each site is for long-term cosmological observations and informing how RFI in radio data could be tackled. The methods developed in the study could also easily spill over into characterising RFI for other locations and experiments.

**Observational X-ray Astronomy**

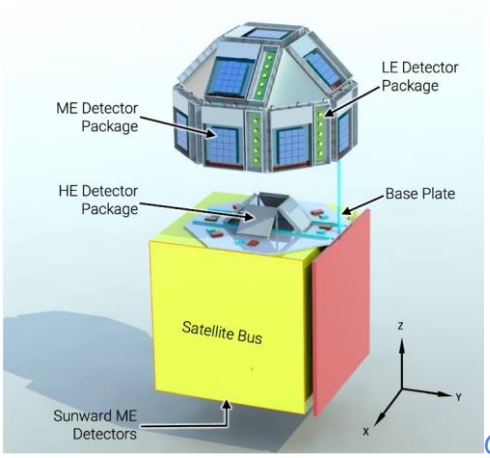
The X-ray group published close to 20 papers on observational and modelling studies of various X-ray binary (XRB) pulsars using archival as well as recent data from various Indian and global X-ray satellites such as AstroSat, XMM-Newton, Swift, NICER, Chandra, and NuSTAR. RRI astronomers investigated the wake structures of X-ray pulsars. They delved into the similarities and differences found when modelling ultraluminous X-ray pulsars as galactic X-ray pulsars, and discussed the implications. They analysed the correlation between cyclotron lines and luminosity. The X-ray group estimated the magnetic field strengths of neutron stars from their absorption line. They studied reprocessed emission from bursts in XRBs during their eclipse phase. RRI scientists detected and characterized periodic signals of cataclysmic variables and XRBs and probed the mechanisms powering their emission. They discovered new cyclotron lines, which helped limit possible accretion geometries.




*The figure shows a schematic representation of Centaurus X–3. Panels (b)–(d) show different lines of sight to the neutron star*

**Daksha**

RRI researchers were part of two papers detailing the technical capabilities and highlighting the science case of a proposed high-energy transients mission Daksha, led by IIT Bombay.




*Overall design of a Daksha satellite*

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

1. POLIX:

2024 began on a high note with the launch of ISRO satellite XPoSat carrying POLIX (Indian X-ray Polarimeter) as its primary payload. POLIX was conceived, designed, and built at RRI. Along with X-ray timing and spectroscopy, X-ray polarimetry has emerged as a powerful tool to reveal unique and crucial information about physical processes and the geometry of astronomical sources. POLIX is the only X-ray polarimeter working in the 8-30 keV band. Ongoing observations of interesting compact objects using RRI's POLIX will provide valuable data for testing theoretical models. RRI also participated in the development and testing of **analysis software** for POLIX.

2. Testing and characterisation of CZT detectors:

The Daksha project is an ambitious proposal to build two high-energy space telescopes for the study of explosive astrophysical sources like gamma-ray bursts and electromagnetic counterparts to gravitational wave sources. Daksha is expected to have

more than 1000 Cadmium Zinc Telluride (CZT) detectors (4 x 4 cm) to cover a large area of the sky. An experimental setup for the test and characterisation of CZT solid-state X-ray detectors (developed by Wipro and GE) was developed here at RRI.

3. PRATUSH (Probing ReionizATion of the Universe using Signal from Hydrogen): PRATUSH is funded for pre-project studies by ISRO, and RRI has built a promising laboratory model. Under an MoU with Space Applications Center (ISRO), the researchers are working towards its space-hardened version. An in-situ **antenna characterization unit** has also been developed for PRATUSH. It has been successfully demonstrated to be accurate to 0.001%, exceeding the performance of standard commercial counterparts. Development of PRATUSH-0, targeting absolute measurements of the radio sky between 30 and 150 MHz for both terrestrial and lunar-orbiter applications, continued during the year.

## Capacity Building in Space Science Research

| S. N. | Name | Current Status of PhD | Research Topic |
|---|---|---|---|
| 1 | Kinjal Roy | Awarded | Study of reprocessing of X-rays in environment of Neutron stars |
| 2 | Hemanth M. | Awarded | X-ray Spectral Studies and Development of a Polarimeter for Accretion powered Pulsars |
| 3 | Mukesh Singh Bisht R. | Defended | A study of physical processes in galaxies and circumgalactic medium |
| 4 | Manish Kumar | Defended | Ultra Luminous X-Ray Pulsars: Comparison with Galactic X-ray Pulsars |
| 5 | Ashwin Devaraj (JAP 2018) | JAP-Defended | Cyclotron line studies of X-ray pulsars |
| 6 | Abhisek Tamang (JAP 2021) | JAP-Research Fellow | X-ray Spectroscopic and Polarimetric Study of High Magnetic Field Accreting Neutron Stars |
| 7 | Barsarani Nayak | Research Fellow | Multi-Wavelength Investigation of Compact Objects: Gamma-ray Pulsar Variability and OB/Be X-ray Binary Systems in the Small Magellanic Cloud |

| | | | |
|---|---|---|---|
| 8 | Ajith B. | Research Fellow | Spectroscopic and Polarimetric Study of X-ray pulsars: magnetic field and wind diagnostics |
| 9 | Anirban Dutta | Awarded | Cataclysmic Variables: Their X-ray Timing and Spectral Characteristics |
| 10 | Kiran M. Jayasurya | Research Fellow | (1st year) |
| 11 | Shuvajit Khatua | Research Fellow | Investigating accretion physics in cataclysmic variables through X-ray observations |
| 12 | Akash Agarwal | Research Fellow | X-ray properties of Cataclysmic Variable Stars and development of X-ray optics |
| 13 | Aman Upadhyay | Research Fellow | Characteristics of Ultraluminous X-ray sources using X-ray data |
| 14 | Suraj Pal | Research Fellow | (1st year) |
| 15 | Narendra S. | Research Fellow | Faint all-sky radio signals - local to cosmological |

## Courses offered on Space Science and Technology

The PhD programme commences with formally credited coursework in advanced topics during the first year. RRI offers select PhD students, who qualify in the coursework and a subsequent comprehensive examination, opportunities for supervised research within the four broad areas of research conducted at the institute, including Astronomy and Astrophysics.

Students at RRI are registered for their PhD degree with Jawaharlal Nehru University, New Delhi. RRI is also a participant in the Joint Astronomy Programme (JAP) with the Indian Institute of Science, Bangalore.

| **Title of the course** | **Level of the course** | **Intake capacity** | **Subjects of specialization in Space Science and Technology** |
|---|---|---|---|
| PhD Programme | PhD | ~25/year | Advanced General Relativity (GR), GR & Cosmology, Galaxies & ISM, Fundamentals of |

| | | | |
|---|---|---|---|
| | | | Astrophysics, Radiative Processes in Astrophysics, Introduction to Fluid Mechanics & Plasma Physics |

## Laboratories and Facilities Available for Space Instrumentation

1. The X-ray astronomy instrumentation facility includes a cleanroom, X-ray generator, beam line, polarizer and monochromator, vacuum systems, mounts and electronics for performance evaluation of detectors. Capability for the design and building of gas-filled proportional counters for use as X-ray detectors is also there.
2. X-ray optics development for future X-ray missions: An automated computer-controlled epoxy dispense machine with three-axis control was developed for manufacturing X-ray optics. The optics will be used to focus X-rays at a suitable focal length. The X-ray mirror assembly technique was demonstrated using 0.3 mm flat glass sheets and curved Aluminium sheets as the mirror substrate.
3. RRI has the necessary infrastructure and testing facilities for characterizing receiver systems operating at wavelengths from decameters to millimeters. RRI built a promising laboratory model of PRATUSH, and under an MoU with Space Applications Center (ISRO), the researchers are working towards its space-hardened version.

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

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Executive Assistant to the Director
Raman Research Institute
ea-director@rri.res.in

# S N BOSE NATIONAL CENTRE FOR BASIC SCIENCES KOLKATA, INDIA

Website: https://newweb.bose.res.in/

## About the Centre / Laboratory / Institute

S. N. Bose National Centre for Basic Sciences is an autonomous research institute engaged in research in basic sciences. The institute was founded under the 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 Physics.

Figure 1. S. N. Bose National Centre for Basic Sciences, JD Block, Sector III, Salt Lake, Kolkata.

## Major Research Domains

The Department of Astrophysics and High Energy Physics pursues theoretical, observational and experimental research works on recent topics of Astrophysics, Cosmology, High Energy Physics, and Quantum information.

(i) In theoretical astrophysics/ cosmology and high energy physics, the major thrust continues to be the physics of primordial black holes, gravitational waves, dark matter and dark energy, study of fermions in curved space-time, quantum gravity, generalized uncertainty principle, quantum foundations and quantum information processing. The department also has ongoing Projects on Quantum Information Science in the QuEST programme of DST.

(ii) In observational and experimental astronomy, works are being pursued to understand problems on massive star formation and extra-solar planets, physics of brown dwarfs, black holes in external galaxies, neutrino physics, stellar evolution, physics of cataclysmic variables, formation of complex molecules in a variety of astrophysical sources, evolution of distant and nearby galaxies, properties of interstellar dust, and astronomical instrumentation. The Observational group is also engaged in establishing an Astronomical Observatory in Purulia, West Bengal.

## Major Scientific Applications / Results

**Magnetic Activities of GJ 1151: Flares in TESS Data and Radio Observation in uGMRT:**.GJ 1151 is a nearby ( 8 pc) , quiescent mid-M dwarf ( M 4.5V) of older age, made especially interesting by the hypothesized presence of a close-in planet invoked to explain its low-frequency radio emission. We analyzed the flaring activity of GJ 1151 to investigate its stellar atmosphere and magnetic properties using 2 minute short-cadence photometry from the TESS and radio observations from the upgraded

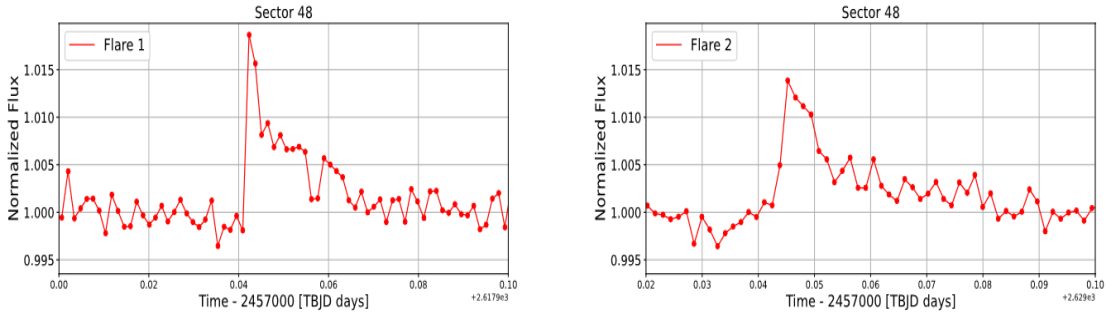


*Figure 2: Flare events of GJ 1151 in TESS light curve.*

Giant Metrewave Radio Telescope ( uGMRT) . Analysis of TESS Sector 48 revealed three flare events, with bolometric flare energies estimated in the range of $10^{30}$ –$10^{31}$ erg, showing that GJ 1151, previously regarded as optically inactive, does in fact exhibit flare activity, placing it in the lower-to-intermediate activity regime (Ram, Diya et al., The Astrophysical Journal, 994, 9 pp., 2025; DOI: 10.3847/1538-4357/ae145a).

**Probing Starspot Dynamics on the Active M Dwarf TIC 272272592: A Multiyear TESS Study:** M dwarfs are the smallest (0.075-0.60 solar mass) cool (2400 -3800 K) hydrogen-burning objects. They are the most abundant and long-lived objects, comprising ~75% of the total stellar population in the Milky Way. M dwarfs are interesting targets in the search for habitable planets and life beyond our solar system. The observable manifestation of stellar activity in M dwarfs are starspots, stellar flares, and long term variability. We analyzed temporal starspot evolution and its distribution on an active M3.0 rapid rotator (Prot = 1.22 days), TIC 272272592, using high-precision time-series photometry from the Transiting Exoplanet Survey Satellite (TESS) spanning over 3 yearss to study the distribution pattern of starspots across the stellar surface and to investigate the spot

evolution over time (Kumbhakar, Rajib, et al., The Astrophysical Journal, 994, 26 pp, 2025; DOI: 10.3847/1538-4357/ae072c).

**Detection of high-frequency pulsation in WR 135:** Classical Wolf-Rayet (cWR) stars are the Hydrogen-depleted class WR stars currently undergoing core He-burning. A long-standing problem is to understand the driving source behind the mass outflow in cWR stars. One possibility is that WR stars undergo envelope inflation due to strong opacity from the Fe-M shell transitions which also sometimes generate strange mode instabilities (SMIs) that are responsible for the excitement of strange-mode pulsations (SMPs) in some cases. We detected such high-frequency pulsations in WR 135 from short cadence (10 minutes) optical photometric (observed by the Transiting Exoplanet Survey Satellite (TESS)) and spectroscopic time series surveys (from Canadian Astronomy Data Centre (CADC) and the 2m-Himalayan Chandra Telescope (HCT)). We find that the optically thick sub-sonic layers of the atmosphere are close to the Eddington limit and are launched by the Fe-opacity. The outer optically thin super-sonic winds are launched by the He ii and C iv opacities. The stratified winds above the sonic point undergo velocity perturbation that can lead to clumps. In the optically thin supersonic winds, dense clumps of smaller size pulsate with higher-order harmonics. The larger clumps oscillate with lower-order harmonics of the pulsation and affect the overall wind variability. (Subhajit Kar *et. al.* 2024, The *Astronomical Journal* 168, 199; DOI: 10.3847/1538-3881/ad77d0).

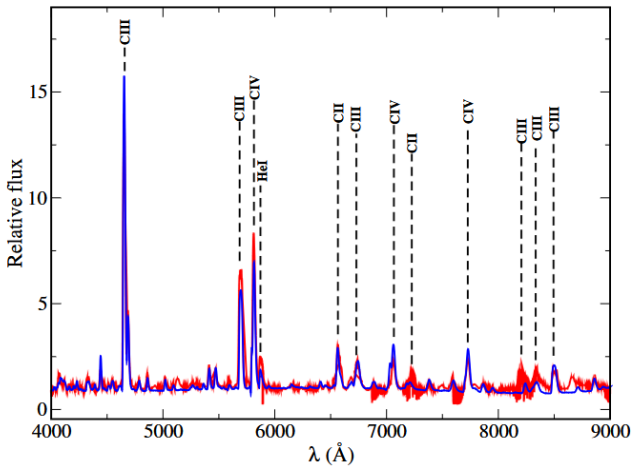


*Figure 3: Normalized observed spectrum (represented in red) of WR 135 fitted with continuum normalized model (represented in blue) spectrum.*

**Spectroscopic study of the quiescent stages in between the 2006 and 2021 outbursts of RS Ophiuchi Open Access:** We analyzed the quiescent stage of the recurrent nova RS Ophiuchi between its 2006 and 2021 outbursts. Using the double-peak features observed in the H-alpha and H-beta lines, we estimated the accretion disc size . The mean accretion rate, calculated from the model. The model results reveal that the accretion rate rose substantially in the later phase. The accreted mass in the 16 months preceding the 2021 outburst exceeds 47% of the critical mass, and more than 88% of the

critical mass was accreted in the last 3 yr. (Gesesew H. Reta *et. al.* 2025, The *Monthly Notices of Royal Astronomical Society, 537*, 2046; DOI:10.1093/mnras/staf119).

**The ALMA-ATOMS Survey: Exploring Protostellar Outflows in HC3N:**The primary goal of this study was to identify a reliable tracer of the low-velocity component of protostellar outflows, which often contains a significant fraction of the outflow mass and energy. Using ALMA observations of 146 massive star-forming regions, we identified $HC_3N$ (cyanoacetylene) as an effective tracer of low-velocity outflowing gas, which is often missed by traditional tracers such as CO and SiO. The study detected numerous bipolar outflows and demonstrated that $HC_3N$ can trace outflow activity across different evolutionary stages of massive star formation, including both highly collimated jets and wide-angle flows. Derived outflow properties, such as mass, momentum, and energy, show correlations with the mass and luminosity of the host clumps, indicating that more massive protostars drive more powerful outflows. This work establishes $HC_3N$ as a powerful new tracer for studying protostellar feedback and massive star formation with ALMA (Ariful Hoque et al. 2025, ApJ, 987, 197; doi: 10.3847/1538-4357/add928).

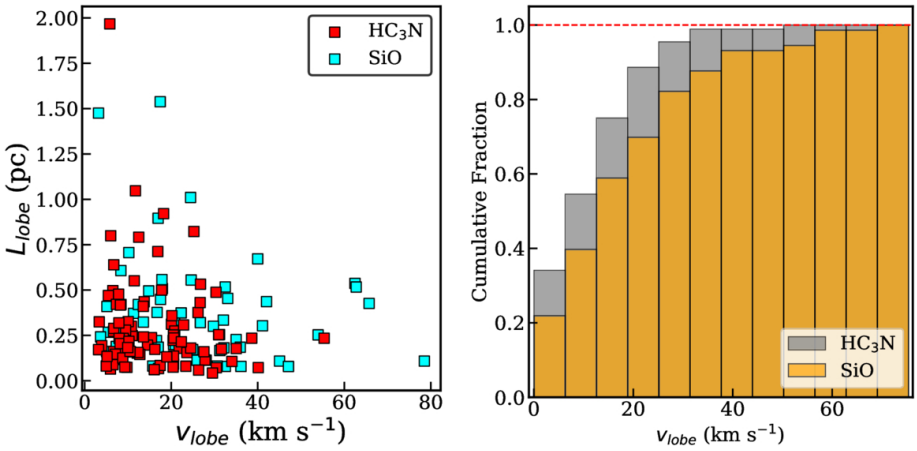


*Figure 4. (Left) Comparison of length of outflow lobe (Llobe) with the outflow terminal veocity (v_lobe) for outflows identified using $HC_3N$ and SiO. (Right) Distribution of cumulative fraction of v_lobe of outflows detected in $HC_3N$ (in gray) and SiO (in orange). Overall these figures show that $HC_3N$ is capable of identifying the low-velocity components of outflows compared to the traditional tracer like SiO.*

## Indigenously Developed Instruments / Payloads / Products / Sensors / Detectors

In view of building an astronomical observatory in the Eastern part of India, SNBNCBCS has taken the initiative to set up a 1.5-m telescope at Panchet hill ($23.6286^0$ N, $86.7668^0$ E), Purulia, West Bengal. The primary aims of this project are – (1) to develop a facility that will be used for cutting-edge scientific observations as all the available optical observing facilities in India are already over-subscribed, (2) to train younger researchers and students in observational astronomy as India is now engaged in the development of several world-class observational facilities, and (3) to fill the longitudinal gap for

uninterrupted monitoring of any astronomical event in the optical/Infrared wavelength regime. The site is relatively dry and unpopulated with typical astronomical seeing of 1.1-1.4 arcseconds. About 150 photometric/spectroscopic nights are expected annually at the site. We have installed a weather station and an all-sky camera at the hilltop for monitoring and recording of weather data. We have also set up an indigenously developed Mobile Observatory equipped with a Differential Image Motion Monitor (DIMM) system for more precise astronomical Seeing measurements, and with a 14-inch telescope for scientific observations.

Figure 5. Clockwise from top left: Panchet hill, the weather station installed at the observatory site, the Mobile Observatory, and the telescopes (12-inch and 14-inch) installed in the observatory.

## Capacity Building in Space Science Research

The Centre regularly offers PhD degrees on different subjects. Below is the list of the PhD thesis degree awarded and as well as submitted under the Department of Astrophysics & High Energy Physics during the said period.

Ph.D. AWARD RECEIVED

1. Some Applications of Quantum Field Theoretic Dualities to Superconducting Systems, Shantonu Mukherjee, Supervisor: Amitabha Lahiri.
2. Application of the Gauge/Gravity Duality in Physical Systems, Ankur Srivastav, Supervisor: Sunandan Gangopadhyay.

3. Investigation of geodesics and shadows of black hole spacetimes, Anish Das, Supervisor: Sunandan Gangopadhyay.
4. A Study Of Cosmology With Gravitational Waves And Primordial Black Holes, Arnab Sarkar, Supervisors: Archan S Majumdar & Rajesh Kumble Nayak (IISER-Kolkata).
5. Thermodynamic Aspects of Black Holes, Neeraj Kumar, Supervisors: Sunandan Gangopadhyay.
6. Study of Novae, Gesesew Reta Habtie, Supervisor: Ramkrishna Das.
7. Some Studies On Exact Solutions Of Models In Noncommutative Spaces, Manjari Dutta, Supervisor: Sunandan Gangopadhyay.
8. Multi-wavelength Study of Wolf Rayet Stars, Subhajit Kar, Supervisor: Ramkrishna Das.
9. Study of Various Aspects of Quantum Communications, Subhankar Bera, Supervisor: Archan S. Majumdar

Ph.D. THESIS SUBMITTED

1. Computation of information theoretic quantities using gauge/gravity correspondence, Anirban Roy Chowdhury, Supervisor: Sunandan Gangopadhyay.
2. Various aspects of quantum measurements and their role in quantum information processing tasks, Arun Kumar Das, Supervisor: Archan S. Majumdar,
3. Effect of inhomogeneities on various astrophysical and cosmological processes in the Universe, Shashank Shekhar Pandey, Supervisor: Archan S Majumdar.
4. Signatures of quantum gravity in relativistic quantum systems, Soham Sen, Supervisor: Sunandan Gangopadhyay.

## Courses offered on Space Science and Technology

As a part of the Integrated PhD (IPhD) programme (M.Sc. and PhD. and PhD course work, following courses are taught at the Centre.

1. Astrophysics & Astronomy (PHY 504),
2. Astronomy (PHY 604), and
3. Astronomical Observational Techniques (PHY 616)

In connection to the Telescope Project, S. N. Bose Centre has already initiated a two-semester Certificate Course on Observational Astronomy in collaboration with the SKBU, Purulia, in January 2025. Around 20 students from different professions and academic backgrounds joined in the first year (2025) and successfully completed the course. The course is designed to introduce students to the fundamentals of observational astronomy, telescope operation, astronomical instrumentation, and basic data analysis techniques. The existing facility on the Panchet hilltop is used to train the participants.

## Laboratories and Facilities Available for Space Instrumentation

We have also built a Role-Off-Roof Observatory on the terrace of the main building of the Centre, where an 8-inch telescope has been installed. This telescope is used to provide

hands-on experience to the students, for public outreach programs, and for testing purposes. We also have a small astronomical laboratory where we perform testing of astronomical instruments. We are planning to develop small instruments in the laboratory.

*Figure 6. Left: The Roll Off Roof Observatory on the terrace of the main building of S. N. Bose Centre, Kolkata. Right: The 8-inch telescope inside the Roll Off Roof observatory.*

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

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iii. Dr. Tapas Baug, Associate Professor, (tapasbaug@bose.res.in)
iv. Dr. Chayan Mondal, Assistant Professor, (cmondal@bose.res.in)

# ST. XAVIER'S COLLEGE (AUTONOMOUS) KOLKATA, INDIA

Website: www.sxccal.edu

## About the College

St. Xavier's College (Autonomous), Kolkata has a long history of involvement in the field of Astronomy and Astrophysics. It all started in 1875 when the college principal, Fr. Eugène Lafont, built a space observatory. He used it to study the sun and planets alongside scientists in Europe. After being closed for many years, the observatory was brought back to life using government funds and college support, reopening in March 2014.

Today, it is called the Father Eugène Lafont Observatory (FELO). It has two parts: a round dome that moves to track stars at night, and a building with a sliding roof just for looking at the sun. The observatory is used to train master's students, run science projects, and host public events. The Physics Department runs the facility, and the current Principal Rev. Fr. Dominic Savio SJ serves as its director. Their main goal is to help students move easily from classroom learning to real-world research in astronomy, space and weather sciences. The faculty members of the Department of Physics, Dr. Shibaji Banerjee (Assistant Director, FELO and Head of the Department), Dr. Sarbari Guha, Dr. Saunak Palit, Dr. Suparna Roychowdhury, Dr. Ashadul Halder and our technical officer of FELO, Mr. Bappaditya Manna are actively involved in teaching Astronomy and Astrophysics courses at the post-graduate level and also run an Astronomy lab at the post-graduate level, with hands on sessions at FELO and other Solar experiments. XAS, The Xaverian Astronomical Society, which partakes and organizes the outreach events in Astronomy and Space Sciences, also closely works with the Department of Physics and FELO. Outreach programmes for high school students, like an Annual Summer School, School visits (both urban and rural schools) and also college student visits and other academic activities for the students of St. Xavier's College (Autonomous), Kolkata on Astronomy and

Astrophysics, Space Sciences and Cosmology are conducted all year round, with events on post presentation, astro photography, quiz and many others.

Inside the dome of Fr. EUGENE LAFONT OBSERVATORy (FELO)

## Major Research Domains

- **High-Energy Astroparticle Physics:**
  - Investigating the dark sector, primordial black holes, heavy particle decays and rotating strange quark stars using modern observational data.
- **Astronomy & Space Science:**
  - Modeling chaotic galactic dynamics and accretion particle dynamics; detecting non-linearities in accretion disk with QPOs using ASTROSAT and other X-ray data
  - Developing telescope instrumentation and image-enhancement techniques for UG/PG students.
  - Research in Relativistic Gravity & Astrophysics: Mainly mathematical and theoretical analysis using Maple software and grtensor package run in Maple. Powerful investigations are undertaken on the evolution of astrophysical objects, characterization of their state in terms of relevant physical quantities, gravitational waves, gravitational entropy and gravitational collapse
  - Conducting West Bengal site characterization at Raghabpur (using BAM 1022)

## Major Scientific Applications / Results

- Uttaran Ghosh and Sarbari Guha, Structure scalars for charged dissipative spherical collapse in f(R, T) gravity, Physics Letters B, Vol. 869 (2025) article 139834 (11pp). https://doi.org/10.1007/s10714-025-03379-0
- Uttaran Ghosh and Sarbari Guha, Formation of singularity and apparent horizon for dissipative collapse in f(R, T) theory of gravity, General Relativity and Gravitation, Vol. 57 (2025) 47 (26pp). https://doi.org/10.1007/s10714-025-03379-0

- Samarjit Chakraborty, Sunil D Maharaj, Sarbari Guha and Rituparno Goswami, Arrow of time and gravitational entropy in collapse, Classical and Quantum Gravity, Vol. 41 (2024) 127003 (13pp). https://doi.org/10.1088/1361-6382/ad494c
- Sucheta Datta and Sarbari Guha, Memory effect of gravitational wave pulses in PP-wave spacetimes, Physica Scripta, Vol. 99, (2024) pp. 075023 (13 pages). https://doi.org/10.1088/1402-4896/ad5389
- Samarjit Chakraborty, Sarbari Guha and D. Panigrahi, Evolution of FRW universe in variable modified Chaplygin gas model, Modern Physics Letters A, Vol. 39 (2024) 2450201 (19 pages), https://doi.org/10.1142/S0217732324502018
- Yeasin Ali, Suparna Roychowdhury, Chaotic dynamics in a galactic multipolar halo with a compact primary, Phys.Rev.E 110 (2024) 6, 064202, DOI: 10.1103/PhysRevE.110.064202
- Uditi Nag, Yeasin Ali, Suparna Roychowdhury, Exploring Chaotic Motion of a Particle in the Centre of a Galaxy with a Prolate Halo, CONSCIENTIA (Dec 2025), ISSN: 2278-6554, XIV (Sp. Issue), 198.
- Rupa Basu, Debasish Majumdar, Ashadul Halder, Shibaji Banerjee, Addressing the self-interaction for ELDER dark matter from the 21-cm signal Int.J.Mod.Phys.A 40 (2025) 27, 2550121, DOI: 10.1142/S0217751X25501210
- Ashadul Halder, Madhurima Pandey, Rupa Basu, Debasish Majumdar, Exploring the effects of dark matter–dark energy interaction on cosmic evolution in viscous dark energy scenario, Eur.Phys.J.Plus 140 (2025) 4, 305, DOI: 10.1140/epjp/s13360-025-06234-y

## 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) **Audience**: PG final year students
(iii) **Intake Capacity**: 20 Students
(iv) **Topics Covered**: Foundations of Astrophysics, General Relativity, Cosmology, Solar, Stellar, Galactic and Extragalactic Astrophysics, Compact Objects, Standard Model of Particle Physics, Astro-particle Physics, Astrophysics Lab, Computational Astrophysics.
(v) **Contact Schedule**: 350 Lecture hours (offline)

• **PhD Level courses**: Currently three students are working in related areas.

• **Standard coursework offered to PhD Students:** Includes course on Computation, Non-linear Dynamics, Fluid Dynamics, Quantum Mechanics, Special and General Relativity, Compact objects and gravitational waves.

## Laboratories and Facilities Available for Space Instrumentation

The Father Eugène Lafont Observatory (FELO) provides a robust suite of observational and laboratory equipment tailored for space instrumentation and research. The primary stellar facility features a 14-inch Schmidt-Cassegrain telescope secured on a high-precision German equatorial mount under the main motorized dome. This instrument is fully integrated with a Charge-Coupled Device (CCD) camera and advanced spectroscopy equipment, allowing for high-resolution imaging and celestial light analysis. For daytime research, the facility houses a specialized Coronado solar telescope designed for safe, detailed viewing of chromospheric features. Additionally, the laboratory features a dedicated experimental setup to measure the solar constant, offering students and researchers foundational data for solar physics and atmospheric energy-budget studies.
Additionally, the facility features a small, custom-built DIY radio telescope. This instrument serves as an excellent hands-on training tool for students, allowing them to understand the fundamentals of radio astronomy, signal processing, and antenna design while detecting cosmic radio emissions beyond the visible spectrum.
Apart from FELO and the Sliding roof solar observatory, there is now a **BAM 1022** setup installed in the Raghabpur rural campus designed to continuously measure and record ambient particulate matter (specifically PM2.5 or PM10).

# TATA INSTITUTE OF FUNDAMENTAL RESEARCH NATIONAL BALLOON FACILITY, HYDERABAD, INDIA

## About TIFR National Balloon Facility

The National Balloon Facility of the Tata Institute of Fundamental Research (TIFR-NBF) was established in 1969 to support scientific ballooning activities in the fields of space astronomy and atmospheric sciences. Over the years, it has evolved into a unique national facility in scientific balloon technology, providing end-to-end solutions for high-altitude research experiments. The facility possesses in-house balloon fabrication capabilities, dedicated launch and recovery infrastructure, a mission control centre for telemetry and telecommand operations, S-band communication systems, and balloon tracking facilities. TIFR-NBF plays a significant role in advancing space research, particularly in astrophysics and atmospheric sciences, through the integration of Telemetry, Telecommand, and Tracking & Control (TT&C) systems into balloon missions. These capabilities enable real-time data acquisition, remote operation of payloads, and enhanced mission safety and reliability. Balloon flights carrying scientific payloads in cosmic ray, X-ray, gamma-ray and infrared astronomy, astrobiology, as well as atmospheric sciences, have been successfully conducted from this facility, yielding several important scientific results. Since its inception, TIFR-NBF has launched more than 530 zero-pressure scientific balloons, in addition to numerous rubber balloon and tethered balloon experiments, establishing itself as a premier centre for scientific ballooning activities.

## Keywords

Zero-pressure balloon, Aerostat, Balloon launch, Control Instrumentation, Payload Integration, Gondola

## Major Research Domains

- **Scientific Ballooning:** Design, fabrication, and launch of zero-pressure balloons, tethered balloons (natural-shape and aerostat types), special-purpose balloons, and sounding balloons from TIFR-NBF.
- **Flight Control Instrumentation:** Provision of telemetry and telecommand support through reliable two-way communication between the airborne scientific payload and the ground station. The onboard GPS system enables continuous tracking of the balloon throughout its ascent, float, and descent phases.

## Scientific Balloon Design and Fabrication

- Five zero-pressure balloons, each with a volume of 300 cu.m and fabricated using 15 µm Antrix film, were designed and manufactured. Of these, three balloons were supplied to M/s StratoStar, USA, and two to M/s AstroX, Japan.
- A zero-pressure balloon with a volume of 585 cu.m and a shell thickness of 15 µm was designed and fabricated for ADRDE-DRDO.

- Four zero-pressure balloons, each with a volume of 1,187 cu.m and a shell thickness of 15 µm, were designed and fabricated for the BATAL campaign in collaboration with NARL-ISRO and NASA.

- Five zero-pressure balloons, each with a volume of 2,348 cu.m and a shell thickness of 15 µm, were designed and fabricated and supplied to M/s B2Space, Spain.

- Seven zero-pressure balloons, each with a volume of 3,026 cu.m and a shell thickness of 15 µm, were designed and fabricated. Of these, four were produced for the BATAL campaign, one was exported to M/s StratoStar, USA, one was supplied to ADRDE-DRDO, and one was fabricated for IIGM.

- A zero-pressure balloon with a volume of 48,803 cu.m and a shell thickness of 38 µm Antrix film was designed and fabricated. The balloon was designed to carry a payload of 750 kg to an altitude of 25 km and was supplied to M/s AstroX, Japan.

- A zero-pressure balloon with a volume of 63,270 cu.m and a shell thickness of 25 µm Antrix film was designed and fabricated for the BEENS experiment of IIGM, Mumbai.

- A zero-pressure balloon with a volume of 143,396 cu.m, featuring a shell thickness of 20 µm and a cap thickness of 30 µm Antrix film, was designed and fabricated. The balloon was designed to carry a payload of 850 kg to an altitude of 32 km and will be used for the TIFR far-infrared balloon experiment.

- A zero-pressure balloon with a volume of 293,440 cu.m, featuring a shell thickness of 20 µm and a cap thickness of 50 µm (25+25) Antrix film, was designed, fabricated, and exported to M/s B2Space, Spain.

- Four double-layer oblate spheroidal balloons were designed and fabricated using 38 µm Antrix balloon film, with lifting capacities of 20 kg and 80 kg. These balloons were supplied to U R Rao Satellite Centre (URSC)-ISRO, Bengaluru, for satellite payload testing applications.

- **Tethered Balloon Fabrication:** Five kytoons, each with a volume of 9.9 cu.m, were fabricated using 75 µm multilayer polyethylene film in milky white and orange colours. Two kytoons were supplied to the Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram, one to IISc Bengaluru, and one to IISER Thiruvananthapuram for aerosol, fog, and boundary-layer studies. The remaining kytoon was supplied to TIFR Headquarters, Mumbai, for demonstrations during outreach and Founder's Day programmes.

## Scientific Balloon Launches / Rubber Balloon and Tethered Balloon Experiments

- During the period from January 2024 to December 2025, a total of 11 zero-pressure balloon flights were conducted. These included two flights for IISc and six flights under the BATAL campaign to study aerosols up to stratospheric altitudes, two flights for infrared astronomy experiments investigating star-forming regions, and one flight for the BEENS experiment to study electrodynamics and the Earth's magnetic field in the stratosphere.

- A total of 22 rubber balloon flights were carried out during the reporting period. These comprised four flights for ADRDE-DRDO for parachute testing and stratospheric weather measurements, ten flights for NARL-ISRO to investigate aerosol, cloud, and meteorological profiles, four atmospheric sounding flights to obtain wind profiles prior to zero-pressure balloon launches, and four flights for startup organisations—Kalam Labs, N Space Technologies, and VU Dynamics—to support technology development activities.

- During the reporting period, 40 tethered balloon experiments were conducted for various national institutions to study atmospheric aerosols and boundary-layer

meteorological parameters, as well as to support student outreach programmes and other scientific activities.

## Publications:

1. Venkata Ramana Gandreti, Sridar Miriyala, **Venkateswara Rao Tanneeru**, Venkat Ratnam Devanaboyina, and Kshitija Deshpande, “Preliminary Results of Scintillation Monitoring at KLEF-Guntur low latitude station using GNSS software defined radio” in *Journal of Applied Geodesy,2024, https://doi.org/10.1515/jag-2024-0004*.
2. Sunilkumar, K., Ajay, A., Anand, N., **Dharmesh, T., Stalin, P. G., Kapardhi**, **B**., et al. (2025). Persistent elevated black carbon aerosol layers in the upper troposphere and its linkage to aircraft emissions. *Geophysical Research Letters*, 52, e2024GL113363, *https://doi.org/10.1029/2024GL113363*.

## Instruments / Payloads / Products Developed / Sensors / Detectors

- Designed and developed a serial data interface circuit for the telemetry encoder. The microcontroller-based circuit receives inputs from the telecommand and timer systems and increases the data update rate to the telemetry encoder.
- Developed a standalone wind measurement and logging system to monitor surface wind patterns before and during balloon launch operations. The system uses an ultrasonic wind sensor, LCD, and microcontroller to acquire and display wind speed and direction every second, and stores average and maximum wind speed and wind direction at two-minute intervals.

- Developed a hollow rectangular aluminium chamber measuring 36 cm × 36 cm × 45 cm (L × B × H) with a wall thickness of 30 mm and lids on both sides using the wire-cut scooping method. It can be used as a vacuum dewar for testing infrared detectors and will house an $LN_2$ tank and detector mounting plate.

- Developed a Wireless Automatic Weather Station (AWS) with data logging and wireless transmission capabilities as part of a student internship programme. The system accurately measures atmospheric parameters including temperature, pressure, relative humidity, gas concentration, wind speed, and wind direction. It incorporates an XBee-based RF module for wireless transmission of measured parameters from remote locations to designated monitoring nodes.

- Developed an interface circuit using an Arduino board for a six-stage Quartz Crystal Microbalance (QCM), integrating telecommand and telemetry functionalities. The system enables remote control of QCM operations while transmitting critical parameters such as flowmeter readings, internal pressure, temperature, and humidity to the telemetry system in the required format.

- Designed and developed a dedicated circuit to acquire environmental parameters such as PM1, PM2.5, PM4.0, PM10, VOC, NOx, temperature, and humidity from a particulate matter sensor. The collected data are stored on an SD card, enabling accurate recording and comprehensive post-flight analysis.

- Developed a LabVIEW-based graphical user interface (GUI) to acquire and display real-time data from the atmospheric science payload. The system was integrated with a custom-designed interface board and sensors, including the Sensirion SEN066 environmental sensor, which was interfaced with an Arduino using the $I^2C$ protocol.

## Capacity Building in Space Science Research

- To promote awareness of scientific ballooning among young students, TIFR-NBF regularly organizes outreach programmes for students from local schools, colleges, and universities. These programmes include lectures, demonstrations of scientific ballooning and flight control instrumentation, laboratory visits, aerostat hoisting demonstrations, and field experiments involving scientific balloons.
- TIFR-NBF also offers project opportunities for undergraduate and postgraduate students.

## Courses offered on Space Science and Technology: NIL

## 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 | Atmospheric Science - Aerosol Radiative Forcing over India (ARFI) | SPL-VSSC, Thiruvananthapuram | Operating Multiwavelength Radiometer (MWR) for Aerosol Optical Depth (AOD) during clear sky days | Data collection and analysis |
| 2 | Trace gases Analysis – Atmospheric Trace Gases – Chemistry, Transport and Modelling | IICT, Hyderabad | Operating trace gas analyzers to measure surface-level trace gases like ozone, $NO_X$, $SO_2$, total solar radiation and CO | Data collection and analysis |

| | | | | |
|---|---|---|---|---|
| | (ATCTM) - IICT Hyderabad | | | |
| 3 | Balloon Campaign to Study the Asian Tropopause Aerosol Layer (BATAL) | NARL – ISRO, Gadanki | Design, fabrication and launch of zero-pressure plastic balloons | To study the physical, chemical and optical properties of the Asian tropopause aerosol layer |
| 4 | Balloon-borne experiments for Aerosol studies | Divecha Centre for Climate Change, IISc, Bengaluru | Design, fabrication and launch of zero-pressure plastic balloons | Measurement of the vertical profile of aerosols and Black carbon |
| 5 | Balloon Experiment on the Electrodynamics of Near Space (BEENS) | Indian Institute of Geomagnetism (IIG), Navi Mumbai | Design, fabrication and launch of zero-pressure plastic balloons | To measure the vector electric fields at stratospheric altitudes |
| 6 | Balloon-borne Measurements of Aerosol Particle Sizes (BMAPS) | NARL-ISRO, Gadanki | Support for the rubber balloon launches and payload recoveries | To study the vertical profiles of aerosols and cloud properties in different seasons |
| 7 | Tethered balloon experiments for aerosols and microbes | CSIR-National Physical Laboratory, New Delhi | Support for the tethered balloon/kytoon hoistings | To study the aerosols and microbes in the boundary layer |
| 8 | Tethered balloon experiments | Nano-Optics and Mesoscopic Optics Laboratory, TIFR, Mumbai | Support for the tethered balloon/kytoon hoistings | To validate the payloads and their sub systems for the future |

| | | | | |
|---|---|---|---|---|
| | | | | stratospheric experiments |
| 9 | Balloon-borne experiments | Aerial Delivery Research and Development Establishment (ADRDE), DRDO (Agra) | Support for the rubber balloon launches and payload recoveries | To collect environmental data at stratospheric altitudes and also to test the parachute deployment mechanism |

## 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 | Far-infrared [C II] observations with a 100-cm balloon-borne telescope to study interaction of massive stars with the star-forming environments | Nagoya University. Japan ISAS-JAXA, Japan Tokushima University, Japan | Balloon flight experiments are being carried out with TIFR 100-cm far-infrared balloon-borne telescope | Japanese Fabry-Perot Spectrometer is being used as a focal plane instrument to map the [C II] line at 158 micron. |

## Laboratories and Facilities Available for Space Instrumentation

- **Thermovac Chamber:** A thermovac chamber of size 1 m diameter × 1.5 m length, capable of achieving a vacuum level of $3.3 \times 10^{-4}$ hPa and temperature control in the range of −20°C to +80°C.

- **Clean Room Facility:** Two Class 10,000 clean rooms, each measuring 8.3 m × 5.1 m × 2.6 m, are available. In addition, four Class 100 laminar airflow benches are available.

- **Cryogenic Thermovac Chamber:** A cryogenic thermovac chamber (Diameter 1.5 m × Length 1.5 m) is installed at TIFR-NBF, Hyderabad. The facility is designed for testing small satellite payloads and subsystems, primarily made of aluminium alloys and copper, with a maximum mass of 50 kg. The cold bench temperature is adjustable between 80 K (−193°C) and 150 K (−123°C). The chamber can achieve

a vacuum level of up to $5 \times 10^{-6}$ mbar using the existing vacuum pumping system. The required temperature is attained by circulating liquid nitrogen ($LN_2$) through pipes beneath the cold bench and through circular $LN_2$ shrouds inside the chamber.

# TATA INSTITUTE OF FUNDAMENTAL RESEARCH, DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS MUMBAI, INDIA

## About Department of Astronomy & Astrophysics, TIFR

Following the success of the Indian X-ray Astronomy Experiment (IXAE) launched on board a remote sensing satellite, IRS-P3 in 1996, ISRO decided to launch AstroSat, a satellite dedicated to astronomy. TIFR astronomers working at the Department of Astronomy & Astrophysics (DAA) played a leading role in this mission, with all three major and pointing X-ray instruments being built at TIFR. These instruments are Soft X-ray Telescope (0.3-8.0 keV), Large Area X-ray Proportional Counters (3-80 keV) and Cadmium Zinc Telluride Imager (15-150 keV). While the Soft X-ray Telescope is the first and so far the only X-ray telescope built in India for astronomy observations, the Large Area X-ray Proportional Counters were the largest area X-ray instrument with fast timing capabilities at the time of its launch. TIFR astronomers also significantly contributed to the AstroSat UV/optical telescope. This satellite was successfully launched on 28 September 2015, with all science instruments switched on as planned. Since then, AstroSat has performed many scientific observations of a wide variety of sources, and scientific research papers are being published.

At present the Department of Astronomy & Astrophysics runs the Payload Operation Centers for the LAXPC and SXT instruments onboard AstroSat. The POCs provide science-ready data products to the national and international community. In addition the scientists at TIFR are working on various research problems using the AstroSat data, which are published regularly in international peer-reviewed journals.

The Infrared astronomers at TIFR have successfully developed the laboratory model for 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. The report for the laboratory model development has been sent to ISRO (Space Science Office) and help is sought from their teams to design the passive cooling system and to tie up other loose ends.

## Major Scientific Applications / Results

1. Kusune et al., Magnetic fields in the massive star-forming region NGC 6334 and their relationship with the properties of dust filaments probed by [CII] and PAH emissions, *Publications of the Astronomical Society of Japan*, **77**, pp. 890-898, 2025. NIR imaging polarimetric observation and [C II] line at 158 micron mapping observation with a 100-cm TIFR balloon-borne FIR telescope toward NGC 6334 star-forming region revealed relationship between the plane-of-sky magnetic fields and [C II] emission lines to investigate star formation in the molecular cloud. These

results show that magnetic fields are believed to play an important role in formation and maintenance of filamentary structures, as well as in star formation process within them.

2. Naik et al., UVIT/AstroSat observation of TW Hya, Accepted for publication in *The Journal of Astrophysics and Astronomy (eprint arXiv:2403.19478),* 2026. The Ultra-Violet Imaging Telescope (UVIT) onboard AstroSat obtained the first far-ultraviolet spectrum of the young star TW Hya. The observations provided valuable information on the star's physical properties and the process by which it accumulates material from its surrounding disk. The study demonstrated the capability of UVIT to investigate young stellar systems and highlighted its potential for supporting future ultraviolet astronomy missions.
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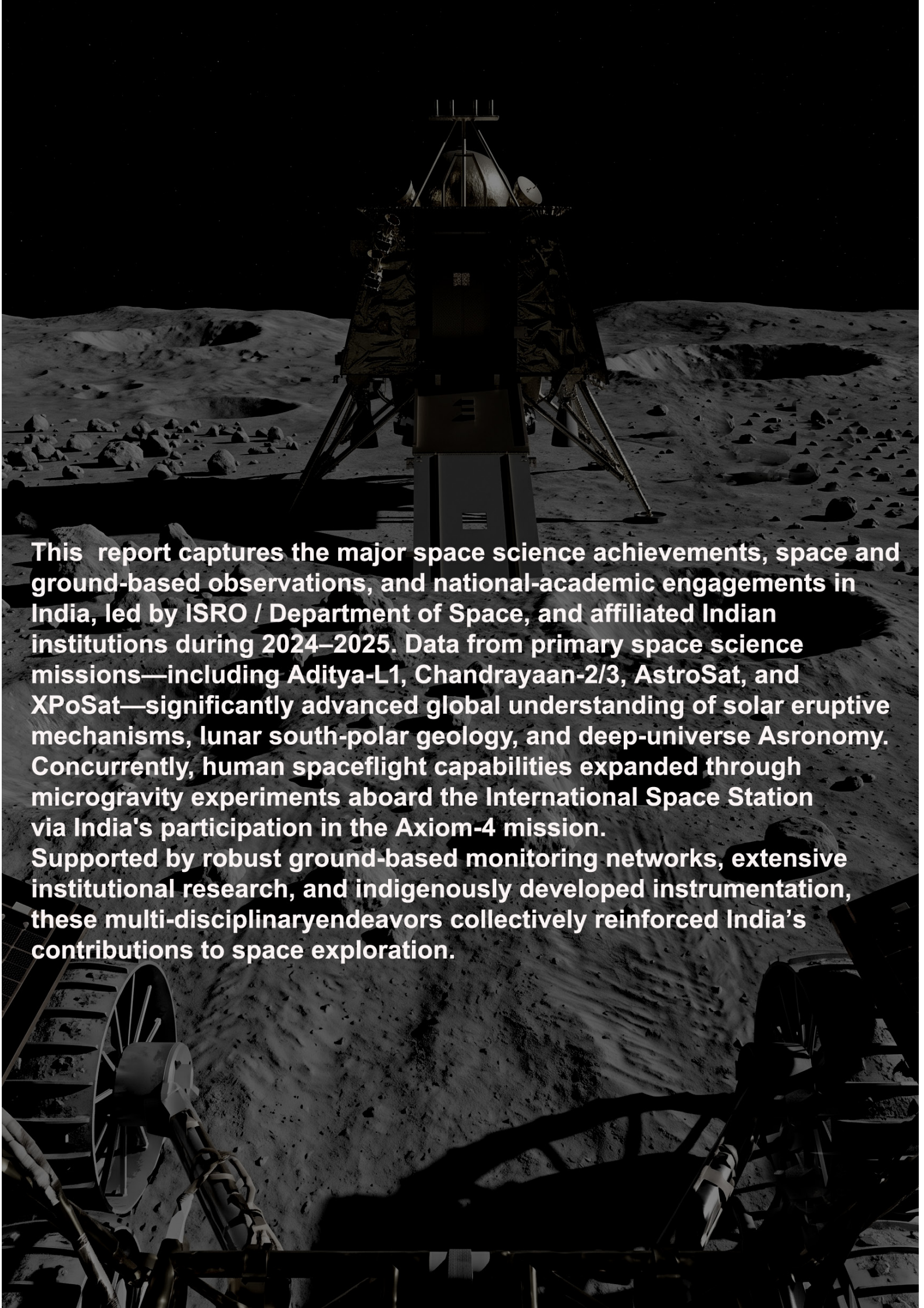
## Instruments / Payloads / Products Developed / Sensors / Detectors

1) After successfully completing the Laboratory Model of the InfraRed Spectroscopic Imaging Survey (IRSIS) payload, a report has been sent to ISRO (Space Science Office) and help is sought from their teams to design the passive cooling system and to tie up other loose ends.

2) A few interaction meetings with URSC-ISRO experts were held and discussions on the optics and thermal designs were at an advanced stage.



This report captures the major space science achievements, space and ground-based observations, and national-academic engagements in India, led by ISRO / Department of Space, and affiliated Indian institutions during 2024–2025. Data from primary space science missions—including Aditya-L1, Chandrayaan-2/3, AstroSat, and XPoSat—significantly advanced global understanding of solar eruptive mechanisms, lunar south-polar geology, and deep-universe Asronomy. Concurrently, human spaceflight capabilities expanded through microgravity experiments aboard the International Space Station via India's participation in the Axiom-4 mission.
Supported by robust ground-based monitoring networks, extensive institutional research, and indigenously developed instrumentation, these multi-disciplinaryendeavors collectively reinforced India’s contributions to space exploration.