SPARC WORKSHOP

Machine Learning in Solar Physics and Space Weather

28 June - 2 July 2022, IISER Kolkata

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ABSTRACT BOOKLET

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SPARC

Scheme for Promotion of Academic and Research Collaboration

SPARC WORKSHOP: Machine Learning in Solar Physics and Space Weather

The "Machine Learning in Solar Physics and Space Weather" Workshop will be held at the Center of Excellence in Space Sciences India (CESSI), IISER Kolkata during 28 June - 02 July, 2022. The workshop is an outcome of the Indo-Swedish SPARC project and will be conducted in hybrid mode. The focus of this workshop is to introduce the application of advanced machine learning tools to the solar physics and space weather community. The 5-day workshop consists of a set of expert lectures in the disciplines of machine learning and big data analytics, heliophysics, physics of predictability in turbulent systems such as solar-stellar convection zones, and the science of space weather. A novel component of the workshop is a set of hands-on data analysis sessions by computer science and machine learning experts. This workshop is sponsored by the Ministry of Education under the SPARC program (project grant SPARC/2018-2019/P746/SL).

Workshop Statistics

Total number of talks: 14

Total number of hands-on tutorial sessions: 4

Number of registered participants: 182

Contacts

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Workshop Details

Host

1. Center of Excellence in Space Sciences India.
2. Indian Institute of Science Education and Research Kolkata.

Sponsors

1. Ministry of Education SPARC Program, project grant SPARC/2018-2019/P746/SL.
2. Center of Excellence in Space Sciences India (CESSI), IISER Kolkata.

Scientific Organizing Committee

- Dibyendu Nandi (CESSI, IISER KOLKATA) (Chairperson)
- Axel Brandenburg (Stockholm Observatory, NORDITA, Stockholm)
- Dhrubaditya Mitra (NORDITA, Stockholm)
- Saikat Chatterjee (KTH Royal Institute of Technology, Stockholm)
- Sourangshu Bhattacharya (IIT Kharagpur)

Local Organizing Committee

- Suvadip Sinha (CESSI, IISER Kolkata) (Chairperson)
- Prosenjit Lahiri (CESSI, IISER Kolkata)
- Arnab Basak (CESSI, IISER Kolkata)
- Chitradeep Saha (CESSI, IISER Kolkata)
- Soumyaranjan Dash (CESSI, IISER Kolkata)
- Yoshita Baruah (CESSI, IISER Kolkata)
- Om Gupta (CESSI, IISER Kolkata)
- Souvik Roy (CESSI, IISER Kolkata)
- Sakshi Gupta (CESSI, IISER Kolkata)

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Workshop Schedule

All times are in IST (UTC + 5:30)

Day 1: 28 June

Inauguration (10:15am - 10:30am) Sourav Pal (Director, IISER Kolkata), Dibyendu Nandi (SOC Chair, IISER Kolkata)		
Time (IST)	**Title**	**Speaker / Instructor**
Morning Session; Session Chair: Dhrubaditya Mitra (NORDITA)		
10:30am – 11:15am	New physical insight into solar magnetism using machine learning	Shravan Hanasoge (TIFR)
11:15am – 12:00pm	AI/ML in Astronomy and Beyond	Ajit Kembhavi (IUCAA)
Lunch Break		
Afternoon Session; Session Chair: Arnab Basak & Sakshi Gupta (CESSI, IISER Kolkata)		
2:00pm – 4:00pm	ML lecture series 1: Foundations of data science	Sourangshu Bhattacharya (IIT Kharagpur)
4:00pm- 5:00pm	Tutorials / Hands-on session	Sourangshu Bhattacharya (IIT Kharagpur)
End of Day 1		

Day 2: 29 June

Time (IST)	**Title**	**Speaker / Instructor**
Morning Session; Session Chair: Yoshita Baruah (CESSI, IISER Kolkata)		
10:30am – 11:15am	Accelerating space weather forecasts with deep learning and interpretable A.I	Vishal Upendran (IUCAA)
11:15am – 12:00pm	Catalyzing Academic and Private Partnerships in the Use of Big Data for Human Benefit: The Frontier Development Lab	Madhulika Guhathakurta (NASA, GSFC)
12:00pm – 12:45pm	Physical Origin of Space Weather	Dibyendu Nandi (CESSI, IISER Kolkata)
Lunch Break		

Afternoon Session; Session Chair: Arnab Basak & Sakshi Gupta (CESSI, IISER Kolkata)		
2:00pm – 4:00pm	ML lecture series 2: Data-limited scenarios and Feature Selection	Saikat Chatterjee (KTH, Stockholm)
4:00pm- 5:00pm	Tutorials / Hands-on session	Anubhab Ghosh (KTH) & Saikat Chatterjee (KTH)
Break		
Evening Session; Session Chair: Om Gupta (CESSI, IISER Kolkata)		
7:00pm – 7:45pm	Aditya L1 Mission and the Activities of the Support Cell	Dipankar Banerjee (ARIES)
7:45pm – 8:30pm	Can we predict where magnetic active regions are going to emerge on the solar surface?	Lekshmi Biji (MPI)
End of day 2		

Day 3: 30 June

Time (IST)	Title	Speaker / Instructor
Morning Session; Session Chair: Yoshita Baruah (CESSI, IISER Kolkata)		
10:30am – 11:15am	Big Data Analytics in Solar Activity	Piet Martens (GSU)
11:15am – 12:00pm	Identifying Flare-productive Active Regions using Machine Learning Techniques	Suvadip Sinha (CESSI, IISER Kolkata)
Lunch Break		
Afternoon Session; Session Chair: Arnab Basak & Sakshi Gupta (CESSI, IISER Kolkata)		
2:00pm – 4:00pm	ML lecture series 3: Deep Neural Networks (DNNs)	Sourangshu Bhattacharya (IIT Kharagpur)
4:00pm- 5:00pm	Tutorials / Hands-on session	
End of Day 3		

Day 4: 1 July

Time (IST)	Title	Speaker / Instructor
Morning Session; Session Chair: Yoshita Baruah (CESSI, IISER Kolkata)		
11:15am – 12:00pm	Imaging magnetic fields in the Sun and other stars	Srijan Bharati Das (Princeton University)
12:00pm – 12:45pm	Leveraging a Deep Learning Model to Efficiently Label Solar Flux Emergence Videos	Subhamoy Chatterjee (SWRI)
Lunch Break		
Afternoon Session; Session Chair: Arnab Basak & Sakshi Gupta (CESSI, IISER Kolkata)		
2:00pm – 4:00pm	ML lecture series 4: Sequential Data Analysis	Saikat Chatterjee (KTH)
4:00pm- 5:00pm	Tutorials / Hands-on session	Anubhab Ghosh (KTH) & Saikat Chatterjee (KTH)
Break		
Evening Session; Session Chair: Yoshita Baruah (CESSI, IISER Kolkata)		
6:15pm – 7:00pm	Using Recurrent Neural Networks to Forecast Sunspot Cycle 25	Dhrubaditya Mitra (NORDITA)
7:00pm – 7:45pm	Machine Learning Dataset with SDO Observations	Paul Wright (HEPL, Stanford University)
7:45pm – 8:30pm	Distinguishing between Flaring and Non-Flaring Active Regions	Soumitra Hazra (UMass Lowell)
Closing Remarks: Dibyendu Nandi (CESSI, IISER Kolkata)		
End of day 4		

Day 5: 2 July

Discussion on future collaborations

Workshop Instructors

- Saikat Chatterjee (KTH Royal Institute of Technology, Stockholm)
- Anubhab Ghosh (KTH Royal Institute of Technology, Stockholm)
- Sourangshu Bhattacharya (IIT Kharagpur)

Keynote Speakers

- Piet Martens (Georgia State University, GA (GSU))
- Shravan Hanasoge (Department of Astronomy and Astrophysics, TIFR)
- Soumitra Hazra (University of Massachusetts Lowell)
- Vishal Upendran (IUCAA, Pune)
- Suvadip Sinha (CESSI, IISER Kolkata)
- Dhrubaditya Mitra (NORDITA, Stockholm)
- Dibyendu Nandi (CESSI, IISER KOLKATA)
- Madhulika Guhathakurta (NASA, GSFC)
- Dipankar Banerjee (ARIES, Nainital)
- Ajit Kembhavi (IUCAA, Pune)
- Lekshmi B (MPI, Göttingen, Germany)
- Srijan Bharati Das (Princeton University)
- Subhamoy Chatterjee (Southwest Research Institute)
- Paul Wright (HEPL, Stanford University)

Abstracts of Keynote Presentations

New physical insight into solar magnetism using machine learning

Speaker: Shravan Hanasoge (TIFR)

Machine learning can build sophisticated models of complex solar phenomena such as flares and flux emergence from multiple lines of observation. Unpacking well-trained machines, although challenging, can shed new light on correlations between the underlying processes. In this talk, I will describe some experiments that we have carried out in the recent past and what we have learnt from them.

Artificial Intelligence and Machine Learning in Astronomy and Beyond

Speaker: Ajit Kembhavi (IUCAA)

Machine Learning, Deep Learning and other Artificial Intelligence (AI) techniques have now become an integral part of development in every sphere of activity, including applications like facial recognition and driverless cars. These techniques are also important in the basic sciences and are now an inseparable part of scientific data analysis. The techniques are particularly important in astronomy, where powerful telescopes routinely generate vast quantities of data, and in biology for addressing various complex tasks. In my talk I will describe the basics of Machine and Deep Learning and some interesting applications of these techniques to Big Data in Astronomy, Biology and Chemistry.

Physical Origin of Space Weather

Speaker: Dibyendu Nandi (CESSI, IISER Kolkata)

The dynamic activity of the Sun has its origin in magnetohydrodynamic processes that sustain the solar dynamo mechanism in its interior. Magnetic fields generated in the solar interior emerge through the photosphere and evolve, driven by internal plasma flows, plasma relaxation mechanisms and magnetic reconnection in the outer atmosphere. These physical processes lead to a diversity of solar phenomena such as enhancements in solar radiation, energetic events such as flares and coronal mass ejections (CMEs), solar wind and solar open flux modulation. These activities have consequences for our space environment through their modulation of space weather and space climate. In this lecture I shall discuss the theoretical foundations necessary to understand the magnetohydrodynamic processes that are at the heart of solar activity, and their impacts on planetary space environments.

Accelerating space weather forecasts with deep learning and interpretable A.I

Speaker: Vishal Upendran (IUCAA)

As we cruise through the 21st century, our ever-increasing dependence on technology brings us closer and closer to the realms outside the Earth. This brings us in direct contact with the weather in space, which at its worst is vastly catastrophic to humanity at large. Hence understanding and forecasting various aspects of space weather with an aim to generate accurate forewarning becomes very important. With a steep rise in data availability, we are ideally suited to leverage algorithms like Deep Learning (DL) that thrive on big data. In this talk, I shall present two examples of deep learning massively accelerating workflow in space weather. First, we shall look at the application of a Convolutional Neural Network-Long Short Term Memory cell (LSTM) based solar wind forecasting model, which operates on solar coronal full disc image data. We shall see how such DL models may be probed by feature activation methods to understand what aspects of the input are important for WindNet to generate a particular forecast. When applied to our model, we clearly find strong evidence of salient associations between the solar wind modalities and the source regions on the Sun. Next, we shall look at an application of incorporating known physics into deep learning to perform forecasts of geomagnetic perturbations, given changing conditions in the solar wind. Incorporating known physics lets us perform very fast forecasts at high spatial and temporal cadence. Such models are imperative for accurate and timely space weather forecasting, especially in the era of space exploration. Finally, we shall also see the potential caveats in using DL techniques, especially for inferring physics, while also discussing how DL potentially eases multiple aspects of heliophysics workflows through open-source codebases.

Catalyzing Academic and Private Partnerships in the Use of Big Data for Human Benefit: The Frontier Development Lab

Speaker: Madhulika Guhathakurta (NASA, GSFC)

The recent advances in Artificial Intelligence (AI) capabilities are particularly relevant to NASA science and exploration goals because there is growing evidence that AI techniques can improve our ability to model, understand and predict our environment using the petabytes of data already within NASA archives. In particular this represents a strategic opportunity in Heliophysics, since the need to improve our understanding of space weather is not only mandated by directives such as the National Space Weather Action Plan and the Presidential Executive Order for Coordinating Efforts to Prepare the Nation for Space Weather Events, but also because space weather is a critical consideration for astronaut safety as NASA moves forward leave LEO and return to the Moon.

I will also talk about the Frontier Development Lab (FDL) which is an AI research accelerator that was established in 2016 to apply emerging AI technologies to space science challenges which are central to NASA's mission priorities and provide some examples. FDL is a partnership between

NASA Ames Research Center and the SETI Institute, with corporate sponsors that include IBM, Intel, NVidia, Google, Lockheed, Autodesk, Xprize, Space Resources Luxembourg, as well as USC and other organizations. The goal of FDL is to apply leading edge Artificial Intelligence and Machine Learning (AI/ML) tools to space challenges that impact space exploration and development, and even humanity. Six prior FDL sessions have demonstrated that meaningful progress could be industrialized by bringing together individuals at the PhD and Post Doc level as well as members from industry together to work on connected, but adjacent problems in a shared space mentored by senior scientists with a deep knowledge of the problems. FDL uses sprint methodologies for faster results, uses interdisciplinary teams for better results, and public-private partnerships to lower costs. FDL results will be shared that demonstrate the power of bridging research disciplines and the potential that AI/ML has for supporting research goals, improving on current methodologies, enabling new discovery and doing so in accelerated timeframes.

Aditya L1 Mission and the Activities of the Support Cell

Speaker: Dipankar Banerjee (ARIES)

The Aditya-L1 mission is India's first dedicated spacecraft mission to study the Sun. It will enable a comprehensive understanding of the dynamical processes of the Sun and address some of the outstanding problems in solar physics and heliophysics. In this presentation I will first provide an overview on the seven payloads which are going to be hosted in this observatory. As a joint effort of ISRO and ARIES, the Aditya-L1 Science Support Cell (AL1SSC) has been set up to act as a community service centre for the guest observers in preparing science observing proposals and analyzing science data. This support cell will provide tools and documentations required to understand, download and analyse the data. The AL1SSC will be organising several workshops before and after the launch of Aditya-L1 mission to familiarize students with the basic processes happening on the Sun, current open problems, the Aditya-L1 mission and observational data analysis so that the scientific data can be explored by a larger community leading to the exciting scientific outcomes. The initial plan of the support cell will be announced in this meeting.

Can we predict where magnetic active regions are going to emerge on the solar surface?

Speaker: Lekshmi Biji (MPI)

The complex dynamics of solar active regions, the strong magnetic field regions on the Sun initiate the eruption of mass and energy in the form of flares and Coronal Mass Ejections. These events will lead to extreme space weather conditions, disrupting the life on Earth. Predicting the emergence and behaviour of the active regions becomes crucial in this context. I will be talking about the efforts made by our group to predict the emergence of active regions using surface velocity and magnetic field observations with machine learning as a tool. The difficulties in this approach and the possibilities of improvement to devise a method to forecast the emergence of active regions will also be discussed.

Big Data Analytics in Solar Activity

Speaker: Piet Martens (Dept. of Physics & Astronomy, Georgia State University)

Machine Learning (ML) means employing a set of computing algorithms to discover patterns in one's data that may have predictive value. Developing and improving ML methods is a branch of Computer Science (CS) that has rapidly expanded in the last few decades. ML algorithms are now available "off the shelf" for data analysis in almost all research domains, and often used without much attention to the quality of the data and understanding of the ML methods applied. The results are predictable: Garbage in --> Garbage out.

In my presentation I will focus on the making predictions in the domain of Space Weather. I will describe and emphasize the enormous effort that goes into producing high quality ML ready datasets for space weather, given that data have to integrated from various space and ground based observatories that operate with different cadences and resolutions, varying data quality, frequent data gaps, varying calibrations, and more often than one would expect, incorrect data entries, either through machine or human error.

In my presentation I will describe several quality control procedures one has to apply while putting together ML ready space weather databases. I will further point out the proper procedures for training, testing, and verifying ML predictive algorithms. I will comment on the various methods of quantifying the performance of those algorithms.

I will further describe the work of our astro-informatics cluster at GSU in producing and publishing ML ready data bases, and our work for NASA's Space Radiation Analysis Group (SRAG) in producing an ML algorithm that delivers predictions of Solar Energetic Particle storms for astronauts that travel beyond the Earth's protective magnetosphere -- such as the astronauts returning to the Moon under the Artemis project, and for future exploration of Mars and its moons. I will highlight the significant role that Indian students and postdocs play in our cluster.

Identifying Flare-productive Active Regions using Machine Learning Techniques

Speaker: Suvadip Sinha (CESSI, IISER Kolkata)

Solar flares release a huge amount of electromagnetic radiation which can impact the near-earth space weather condition. Forecasting solar flare is crucial for timely taking preventive actions to safeguard our vulnerable technological assets. In this talk, I will discuss the usefulness of machine learning (ML) algorithms for the correct identification of flaring active regions using vector magnetogram data of the solar surface. I will show a comparative analysis on the performance of various ML algorithms in predicting intense (M/X class) solar flares. The magnetic features which play a key role in the identification task of potential active regions will also be explored.

Imaging magnetic fields in the Sun and other stars

Speaker: Srijan Bharati Das (Princeton University)

Turbulent processes in the solar convection zone excite acoustic waves which sound the solar interior. Interference between such waves create global and local modes of oscillations which are sensitive to different physical effects upto varying depths. Measurement of the differential rotation profile is one of the many triumphs of global helioseismology. However, direct seismic imaging of a general magnetic field has, until recently, been difficult in the absence of a formal theoretical machinery. In a recent study, we decisively addressed this long-standing question in theoretical helioseismology, opening up exciting avenues in solar and stellar magnetism. Current efforts in Cartesian mode-coupling show that this can be further extended to study sub-photospheric magnetic fields in active regions, sunspots and supergranules. Inference of such 3D magnetic fields with a general geometry has immediate consequences on models of magneto-convection and flux emergence.

Leveraging a Deep Learning Model to Efficiently Label Solar Flux Emergence Videos

Speaker: Subhamoy Chatterjee (SWRI)

Machine learning is becoming a critical tool for interrogating large complex data. However, labeling large datasets is time-consuming. Here we show that convolutional neural networks (CNNs), trained on crudely labeled astronomical videos, can be leveraged to improve the quality of data labeling and reduce the need for human intervention. We use videos of the solar photospheric magnetic field, crudely labeled into two classes: emergence or non-emergence of large bipolar magnetic regions (BMRs) that can potentially drive space weather events. We train the CNN using crude labeling, manually verify, correct labeling vs. CNN disagreements, and repeat this process until convergence. This results in a high-quality

labeled dataset requiring the manual verification of only ~50% of all videos. Furthermore, by gradually masking the videos and looking for a maximum change in CNN inference, we locate BMR emergence time without retraining the CNN. This demonstrates the versatility of CNNs for simplifying the challenging task of labeling complex dynamic events.

Machine Learning Dataset with SDO Observations

Speaker: Paul Wright (HEPL, Stanford University)

The Solar Dynamics Observatory Machine Learning Dataset (SDOML v2.0) Since its launch in 2010, NASA's Solar Dynamics Observatory (SDO) has continuously monitored Sun's activity, delivering over 18 PB of scientific data for Heliophysics researchers. While the level-1 SDO data are easily accessible, pre-processing these data for scientific analysis requires specialised heliophysics (and instrument-specific) knowledge. The corrections required may be an unnecessary hurdle for non-heliophysics machine learning researchers who want to experiment with datasets from the physical sciences or Heliophysicists who wish to experiment with machine learning. Here we will discuss the changes for version 2.0 of the SDOML dataset (http://sdoml.org), including the addition of metadata and an updated time-dependent degradation correction (since v1.0). In this version, we store the data in the cloud-friendly `.zarr` format, and we will discuss how we access this data and the lessons learned along the way.

Distinguishing between Flaring and Non-Flaring Active Regions

Speaker: Soumitra Hazra (UMass Lowell)

Large-scale solar eruptions significantly affect space weather and damage space-based human infrastructures. It is necessary to predict large-scale solar eruptions; it will enable us to protect the vulnerable infrastructures of our modern society. In this talk, I will focus on different artificial intelligence techniques to distinguish flaring regions from non-flaring ones. It is possible to distinguish a flaring active region from a non-flaring region with good accuracy using artificial intelligence techniques. I will also discuss the possibility of real-time solar flare forecasting using artificial intelligence techniques.

Using Recurrent Neural Networks to Forecast Sunspot Cycle 25

Speaker: Dhrubaditya Mitra (NORDITA)

The dynamic activity of the Sun, governed by its cycle of sunspots modulate our solar system space environment creating space weather. Severe space weather leads to disruptions in satellite operations, telecommunications, electric power grids and air-traffic on polar routes. We use four different machine-learning algorithms, all of them belonging to a class called recurrent neural networks, to forecast the fate of the ongoing solar cycle based on solar sunspot data. By comparing forecasts for cycles 22, 23, and 24 we conclude that the algorithm called Echo State Network (ESN) performs the best. We also explore whether it is possible to forecast beyond the ongoing cycle by applying the ESN to magnetic field data generated by a stochastic dynamo model. We find that the forecast is inaccurate for times longer than the first cycle. The ESN algorithm forecasts the solar cycle 25 to last 10 years and to produce a peak amplitude of 108 (±14) sunspots in July 2024. A minor variation of this algorithm forecasts a maxima that is flatter, almost constant between June 2023 and August 2024, with a maximum number of 104 ± 1 sunspots. Both forecasts show that the cycle 25 is expected to reach a minima near the beginning of the year 2030. Qualitatively, cycle 25 is going to be weaker than cycle 23 but slightly stronger than cycle 24.

List of Participants

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105	PINTU KANTHAL	Ramrick School, Kolkata
106	Prateek Gupta	Savitribai Phule Pune University, Pune
107	Prateek Mayank	Indian Institute of Technology, Indore
108	Priyankush Deka	Indian Institute of Technology Guwahati
109	Purba Mukherjee	IISER Kolkata
110	Purushottam Mehta	Student
111	R SELVAKUMARAN	Space Physics Laboratory, VSSC, ISRO
112	R. K. Manchanda	Mumbai University; University of Southern Queensland
113	Rahul Musale	University of Pune (SPPU)
114	RAVI RAJA P	Department of Astronomy, Osmania University
115	Rekha Sahu	ISBM University
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121	Rushikesh S Mukhare	IISER Kolkata
122	SABEEL P K	Sullamussalam Science College Areekode
123	Sachin Bharadkar	Savitribai phule pune University (SPPU)
124	Sachin Rajkapoor kanaujiya	NIT Calicut
125	Sakshi Gupta	IISER Kolkata
126	Saleemdurai M A	Vellore Institute of Technology
127	Samarth Ganesh Kashyap	Tata Institute of Fundamental Research
128	Sambit Mishra	IISER Berhampur
129	Samik Dutta	University of Calcutta
130	Samik Dutta	University of Calcutta
131	Sampada Sunil Gaonkar	Ramniranjan Jhunjhunwala College, Mumbai
132	Sanghita Chandra	Indian Institute of Science Education and Research Kolkata
133	Satabdwa Majumdar	Indian Institute of Astrophysics
134	Sayantan Pal	CESSI, IISER Kolkata
135	Shaonwita Pal	CESSI, IISER KOLKATA
136	SHATANIK BHATTACHARYA	Tata Institute of Fundamental Research
137	Shirsh Lata Soni	Space Physics Laboratory, Vikram Sarabhai Space Center Trivandrum, Kerala
138	Shivani Ramkrushna Mashitkar	DES Fergusson college autonomous,pune
139	Shravan Hanasoge	Tata Institute of Fundamental Research
140	Shruti Nautiyal	NIT Warangal
141	Shrutika Phanse	MSc (Graduated from Savitribai Phule Pune University)
142	Shubhonkar Paramanick	University of Rochester
143	Sidharth Gupta	IISER Kolkata
144	Smitha V. Thampi	Space Physics Laboratory, VSSC
145	Soumitra Hazra	University of Massachusetts Lowell

146	Soumyadip Mukherjee	IISER Berhampur
147	Soumyajit Dasgupta	Heritage Institute of Technology, Kolkata
148	Soumyaranjan Dash	CESSI, IISER Kolkata
149	SOURADEEP GHOSH	IISER Kolkata
150	Sourav Pal	Chandigarh University
151	Soutan adak	Ramakrishna Mission Residential College, Narendrapur
152	Souvik Roy	Center of Excellence in Space Sciences India
153	Srijan Bharati Das	Princeton University
154	Srimathi C	Vellore Institute of Technology
155	Sruthi T V	Space Physics Laboratory, VSSC, ISRO
156	SUBBU ULAGANATHA PANDIAN K	BHARATHIAR UNIVERSITY, COIMBATORE
157	Subhankar Samanta	Ramakrishna Mission Residential College
158	SUDARSON PAUL	Acharya Prafulla Chandra College, WBSU
159	Sujay Pal	Srikrishna College, Bagula, Nadia
160	SUPRABHA MUKHOPADHYAY	IISER Kolkata
161	Supratick Adhikary	Srikrishna College
162	Surendra Bhattarai	IISER Kolkata
163	Surendra Bhattarai	IISER Kolkata
164	SUTAPA GHOSH	TAKI GOVERNMENT COLLEGE
165	Suvadip Sinha	CESSI, IISER Kolkata
166	Swastik Majumder	Indian Institute of Science Education and Research Kolkata
167	Trilochan Ram Sahu	ISBM University
168	Twinkle	Thapar Institute of Engineering and Technology
169	Umme Amen Cyclewala	NIT Warangal
170	Ushasi Chaudhuri	UIUC
171	V Venkataraman	Space Physics Laboratory, VSSC, Trivandrum
172	Vaishnavi P	Mahatma Gandhi University
173	Vardaan Sahgal	Netaji Subhas University of Technology
174	Varsha Vishwakarma	Fergusson College Pune Maharashtra
175	Veenus Venugopal	Space Physics Laboratory, Vikram Sarabhai Space Centre
176	VIJAYALAKSHMI P	Arul Anandar College

177	Vrinda Mukundan	National Center for Earth Science Studies
178	Yash Shah	Dwarkadas Jivanlal Sanghvi College of Engineering, MUMBAI
179	Yashraj Upase	National Institute of Technology, Karnataka
180	Yashvardhan Jain	IISER Kolkata
181	Yogita Patel	Pt. Ravishankar Shukla University Raipur Chhattisgarh
182	Yoshita Baruah	CESSI, IISER Kolkata