IUCAA

# 36th ANNUAL REPORT 2023-24

अंतर–विश्वविद्यालय केंद्र : खगोलविज्ञान और खगोलभौतिकी

INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS

(An Autonomous Institution of the University Grants Commission)

# INSIDE




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# THE COUNCIL AND THE GOVERNING BOARD



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**Dr Karbhari Kale,**
[Additional Charge]
Vice-Chancellor,
S.P. Pune University

**Ravindra D. Kulkarni,**
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University of Mumbai

**A. N. Ramaprakash,**
Dean,
Core Academic Programmes,
IUCAA

**Ravindra Kumar Sinha,**
Vice-Chancellor,
Gautam Buddha University,
Noida.

## THE GOVERNING BOARD (As of March 31, 2024)

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**K. Kasturirangan**

### MEMBERS

**J. Gowrishankar**

**Yashwant Gupta**

**Manish R. Joshi**

**K. N. Satyanarayana**

**Nagesh Thakur**

### MEMBER SECRETARY

**R. Srianand**

### SPECIAL INVITEE

**Jitendra Kumar Tripathi**
Joint Secretary,
University Grants Commission,
New Delhi

### The following members have served on the Governing Board for part of the year

**Shashi K. Dhiman**

**Suresh Gosavi**

**Karbhari Kale**

**A. N. Ramaprakash**

**Ravindra Kumar Sinha**

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Delhi University

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Manipal

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Caltech, USA

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**Suresh Gosavi**
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**Ranjeev Misra,**
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Visitor Academic Programmes

**A.N. Ramaprakash,**
Dean,
Core Academic Programmes

**Shantanu Rastogi**
D.D.U. Gorakhpur University

**Rajbir Singh,**
Vice Chancellor,
Maharshi Dayanand University,
Rohtak

**R. Srianand**
Director,
IUCAA

# STATUTORY COMMITTEES (As on March 31, 2024)

## THE ACADEMIC PROGRAMMES COMMITTEE

**R. Srianand,**
Officiating Director
(Chairperson)
(till 30 November 2023)

**R. Srianand,**
Director
(Chairperson)
(from 01 December 2023)

**R. Srianand**
(Convener)
(till 06 December 2023)

**A. N. Ramaprakash**
(Convener)
(from 07 December 2023)

Ranjeev Misra

**Anupam Bhardwaj**
(from 01 March 2024)

**Sukanta Bose**
(till 26 July 2023)

**Debarati Chatterjee**

**Subhadeep De**

**Gulab Chand Dewangan**

**Rajeshwari Dutta**
(from 03 July 2023)

**Neeraj Gupta**

**Shasvath Kapadia**

**Sanjit Mitra**

**Surhud S. More**

**Dipanjan Mukherjee**

**Sowgat Muzahid**

**Vaidehi S. Paliya**

**Aseem S. Paranjape**

**Kanak Saha**

**Nishant K. Singh**

**Durgesh Tripathi**

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**R. Srianand,**
Officiating Director,
IUCAA
(till 30 November 2023)

**R. Srianand,**
Director,
IUCAA
(from 01 December 2023)

**Manoj Joshi,**
Secretary,
UGC

**Sudeep S. Jain,**
Financial Advisor,
UGC

**A. N. Ramaprakash,**
IUCAA
(from 24.01.2024)

**Yashwant Gupta,**
Centre Director,
NCRA

**Niranjan V. Abhyankar,**
Non-member Secretary

## THE STANDING COMMITTEE FOR ADMINISTRATION

**R. Srianand,**
Officiating Director
(Chairman)
(till 30 November 2023)

**R. Srianand,**
Director
(Chairman)
(from 01 December 2023)

**A.N. Ramaprakash,**
Dean,
Visitor Academic Programmes
(until 06 December 2023)

**Ranjeev Misra,**
Dean,
Visitor Academic Programmes
(from 07 December 2023)

**R. Srianand,**
Dean,
Core Academic Programmes
(until 06 December 2023)

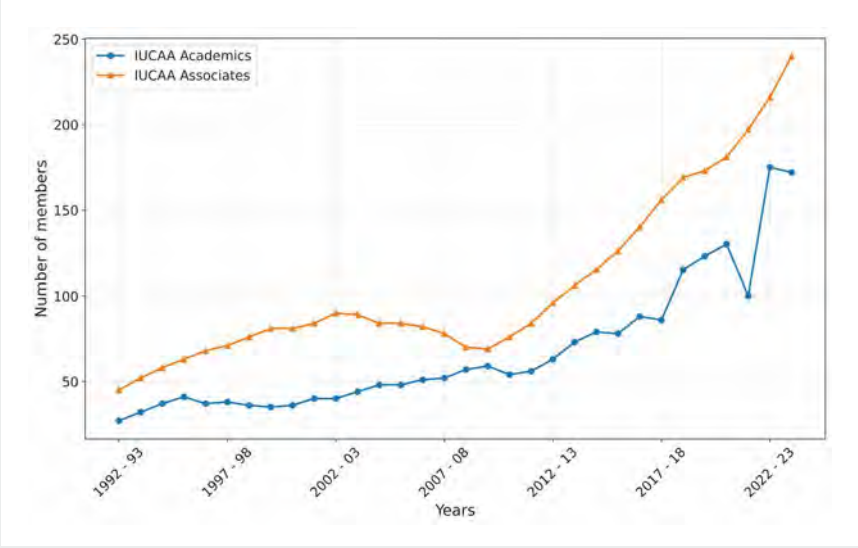
**A.N. Ramaprakash,**
Dean,
Core Academic Programmes
(from 07 December 2023)

**N.V. Abhyankar, SAO**
(Member Secretary)

# IUCAA IN NUMBERS

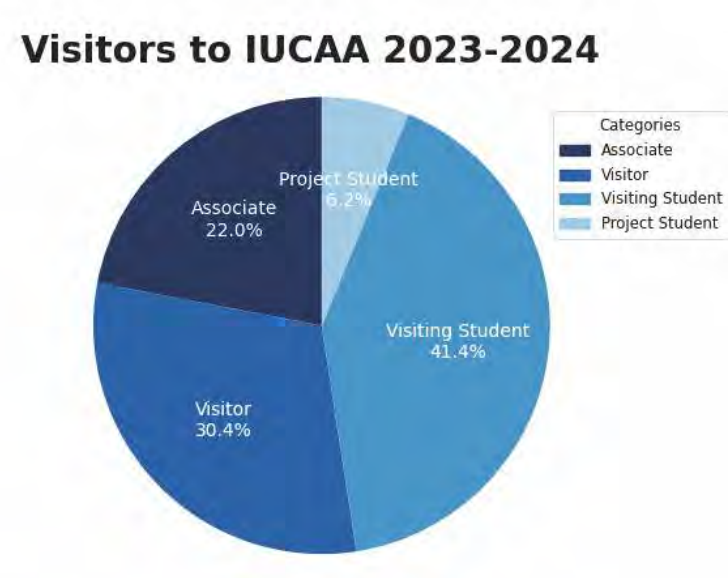
## IUCAA Family

The graph depicts the threefold growth of the academic strength and the IUCAA extended family of Visiting Associates since its inception.



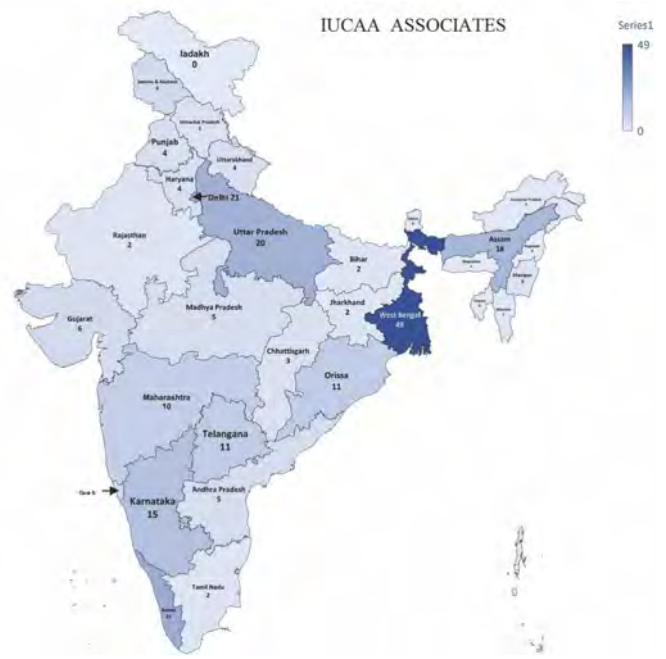

## Visitors to IUCAA

In addition to hosting Visiting Associates (22%), IUCAA hosted official visitors comprising university academics (30.4%), students (41.4%) pursuing their Ph.Ds. from other universities / institutes, and project students (6.2%) working on projects supervised by IUCAA faculties. The total number of visitors in the period 2023-24 comprising the abovementioned categories was 677.



## IUCAA Visiting Associates across India

The number of IUCAA Visiting Associates has continued to expand in numbers and geographically, with significant representation today from the remotest part of the country. The state wise distribution of IUCAA Associates is depicted in the map. The number of Visiting Associates across India during 2023-24 was 238.



# ORGANISATIONAL STRUCTURE OF IUCAA'S ACADEMIC PROGRAMMES

[As on March 31, 2024]

**The Director**

## R. Srianand

**(from December 01, 2023)**

**(Officiating Director from 01.01.2023 till 30.11.2023)**

## Dean, Core Academic Programmes

R. Srianand

A. N. Ramaprakash

## Head, Computing Facilities

Sanjit Mitra

## Head, Publications

Dipanjan Mukherjee

## Head, Instrumentation & IGO

A.N. Ramaprakash

## Head, Teaching Programmes

Gulab C. Dewangan

Aseem Paranjape

## Head, Library

Durgesh Tripathi

Kanak Saha

## Head, Rajbhasha Committee

Durgesh Tripathi

Vaidehi Paliya

## Head, Infrastructural Facilities

R. Srianand

## Head, Grievance Cell

Gulab C. Dewangan

## Chairperson, IUCAA Committee Against Sexual Harassment (ICASH)

Nirupama Bawdekar

## Chairman, Special Cell for Scheduled Cast and Scheduled Tribes

Nitin Ohol

## Dean,
## Visitor Academic Programmes

A. N. Ramaprakash

Ranjeev Misra

## Head,
## Observing Programmes (IGO and SALT)

R. Srianand

Gulab C. Dewangan

## Head,
## Scientific Meetings and ICARDs

Ranjeev Misra

Durgesh Tripathi

## Head,
## Public Outreach Programmes

Nishant Singh

## Annual Events at IUCAA 2023-24

**Introductory Summer School in Astronomy & Astrophysics 2023**
Date: May 15 to June 16, 2023

**Refresher Course on Astronomy and Astrophysics**
Date: May 15 to June 16, 2023

**Vacation Students' Programme**
Date: This is an ongoing programme

**Foundation Day**
Date: December 29, 2023

**National Science Day**
Date: February 28, 2024

## Events at IUCAA - 2023-24

**Workshop on the limiting compactness objects: Black holes and Buchdahl stars**
**Date:** October 30 - November 03, 2023
**Coordinators:** Naresh Dadhich
**Participants:** 15

**Indo-French Astronomy School (IFAS 8) 3D Spectroscopy**
**Date:** November 06 - 12, 2023
**Coordinators:** Kanak Saha
**Participants:** 20

**Radio Astronomy Winter School 2023**
**Date:** December 12 - 22, 2023
**Coordinators:** Rajeshwari Dutta | D. J. Saikia
**Participants:** 24

**Data Science Meeting**
**Date:** December 12 - 14, 2023
**Coordinators:** Surhud More | Ashish Mahabal
**Participants:** 90

**Teachers Training Workshop, OAE, India**
**Date:** February 16 - 17, 2024
**Coordinators:** Surhud More | Moupiya Maji
**Participants:** 46

**OSMU24 (Octonions, Standard Model, and Unification [Online]**
**Date:** February 16 - December 13, 2023
**Coordinators:** T.P. Singh | Durgesh Tripathi
**Participants:** online on Zoom

**Mumbai-Pune Cosmology meeting at IUCAA**
**Date:** February 23 - 24, 2024
**Coordinators:** Surhud More | Aseem Paranjape
**Participants:** 50

## Events outside IUCAA - 2023-24

**Workshop on Python Programming in Astronomy, Astrophysics & Cosmology**
**Date:** April 07 - 08, 2023
**Place:** The Department of Applied Sciences of G. H. Raisoni College of Engineering, Nagpur
**Coordinators:** Saibal Ray | Praveen Kumar Dhankar | Bhagwat Thakran.
**Participants:** 80

**Summer School in Theoretical Physics 2023**
**Place:** The Department of Physics and Electronics, St Xavier's College (Autonomous), Ahmedabad,
**Date:** May 29 - June 09, 2023

**Coordinators:** Gurudatt Gaur (SXCA) | Ranjeev Misra, IUCAA
**Participants:** 38+online participants

**Beginning Astronomy v2: Start a Data Driven Journey**
**Place:** Central University of Himachal Pradesh
**Date:** July 06 - 08, 2023
**Coordinators:** Hum Chand | Souradeep Bhattacharya | Preetish Kumar Mishra | Chayan Mondal | Megha Anand
**Participants:** 25

**Workshop on Python Programming in Astronomy, Astrophysics & Cosmology**
**Place:** GLA University, Mathura
**Date:** July 20 - 22, 2023
**Coordinators:** Saibal Ray | Ranjeev Misra
**Participants:** 35

**Himalayan Meet of Astronomers**
**Place:** Islamic University of Science and Technology, Awantipora Pulwama (IUST), Kashmir (J&K)
**Date:** September 25 - 26, 2023
**Coordinators:** Naseer Iqbal | Hum Chand
**Participants:** 60

**INDO-South Africa Workshop on Astrophysics (ISAWA 2023)**
**Place:** Centre for Theoretical Physics, Jamia Millia Islamia
**Date:** September 27 - 29, 2023
**Coordinators:** Sushant Ghosh | Tabish Qureshi
**Participants:** 40

**Statistical Techniques in Astrophysics and Cosmology Using Python**
**Place:** Bharathidasan University, Tiruchirappalli,
**Date:** October 16 - 20, 2023
**Coordinators:** T. R. Seshadri | V. Madhurima | P. Muruganandam
**Participants:** 40

**Radio Astronomy Fundamentals for Engineering Students**
**Place:** RSET, Kakkanad, Kerala
**Date:** 28 October 2023
**Coordinators:** R. Jacob | J. Jacob | Neeraj Gupta
**Participants:** 40

**Pedagogic Workshop on Astronomy, Astrophysics and Cosmology**
**Place:** St. Stephen's College, Delhi
**Date:** November 06 - 10, 2023
**Coordinators:** G. Sethi | V. Paliya | D.J. Saikia
**Participants:** 30

**North-East Meet of Astronomers (NEMA) - IX**
**Place:** Mizoram University
**Date:** November 20 - 22, 2023
**Coordinators:** Lalthakimi Zadeng | Ranjeev Misra
**Participants:** 62

**Workshop on Gravitational Waves and LIGO India**
**Place:** Goa University
**Date:** November 27 - 01 December, 2023
**Coordinators:** R.R. Raut | Sanjit Mitra | Apratim Ganguly
**Participants:** 43

**Meghnad Saha Memorial Workshop on Solar Astronomy focused on "Aditya -L1 Mission"**
**Place:** Department of Physics, University of Allahabad
**Date:** December 04 - 06, 2023
**Coordinators:** V. K. Tiwari | U. Kushwaha | Durgesh Tripathi
**Participants:** 80

**Beginning Astronomy v3: Start a Data-driven Journey**
**Place:** IIT, Hyderabad
**Date:** December 11 - 13, 2023
**Coordinators:** Mayukh Pahari | Shantanu Desai | Ranjeev Misra | Souradeep Bhattacharya | Chayan Mondal | Megha Anand
**Participants:** 53

**Workshop on Gravitation: Theory and Observation**
**Place:** Department of Physics, Cooch Behar Panchanan Barma University (CBPBU)
**Date:** January 03, 2024
**Coordinators:** Ranjan Sharma | Kanak Saha
**Participants:** 80

**Pedagogic Workshop on Astronomy, Astrophysics and Cosmology: A Faculty Development Programme**
**Place:** Gauhati University
**Date:** January 04 - 10, 2024
**Coordinators:** S. Kalita | S. Muzahid | D.J. Saikia
**Participants:** 30

**Research in Astronomy: Opportunities and Challenges - RAM IX**
**Place:** Manipal Centre for Natural Sciences, Manipal Academy of Higher Education (MAHE), Manipal
**Date:** January 10 - 11, 2024
**Coordinators:** Debbijoy Bhattacharya | Ranjeev Misra
**Participants:** 122

**Two-day exhibition: Evolution of Astronomy**
**Place**: Fergusson College, Pune
**Date:** January 2024
**Coordinators:** R. Dabhade | D. Tripathi
**Participants:** open for students

**X-ray workshop -- Astrosat and XpoSat**
**Place:** Department of Physics, Providence Women's College, Malaparamba, Kozhikode
**Date:** February 28 - March 03, 2024
**Coordinators:** Gireesh V. | Jeena K. | Ranjeev Misra
**Participants:** 42

**Conference on Relativistic Astrophysics and Cosmology**
**Place:** Department of Physics, Malda College, Malda, West Bengal
**Date:** February 29 - March 01, 2024
**Coordinators:** Shyam Das | Ranjeev Misra
**Participants:** 35

**Workshop on SUIT Science and Data Analysis**
**Place:** Department of Physics, Tezpur University
**Date:** March 06 - 07, 2024
**Coordinators:** G. Ahmed | J. Sarkar | D. Tripathi
**Participants:** 53

**Workshop on Gravity, Cosmology and Raychaudhuri's Equation**
**Place:** Jadavpur University, Kolkata
**Date:** March 13 - 14, 2024
**Coordinators:** A. Mukherjee | S. Mondal | R. Misra
**Participants:** 100

**Frontiers in Physics XVIIth**
**Place:** Fergusson College, Pune
**Date:** March 13 - 14, 2024
**Coordinators:** R. Dabhade | D. Tripathi
**Participants:** open to students

**Workshop on Formation and Evolution of Galaxies**
**Place:** Central University of Haryana, Mahendragarh
**Date:** March 18 - 20, 2024
**Coordinators:** J. Yadav | A. Paranjape
**Participants:** 60

**Workshop on Advancement in AGN, Galaxy, Cluster and IGM Research**
**Place:** Central University of Himachal Pradesh Dharamshala, H.P.
**Date:** March 29 - 31, 2024
**Coordinators:** Hum Chand | Sowgat Muzahid
**Participants:** 21

# AWARDS AND DISTINCTIONS

## Shasvath Kapadia

- Awarded the SERB Startup Grant, and the SERB MATRICS grant.
- The following collaborative work with colleagues at ICTS-TIFR was selected as the Editor's Suggestion in Physical Review Letters (PRL).
  Souvik Jana, Shasvath J. Kapadia, Tejaswi Venumadhav, Parameswaran Ajith, *Cosmography using strongly lensed gravitational waves from binary black holes*, arXiv:2211.12212, PRL, 130, 261401, (2023).

## Surhud More

- Best paper award for 2023 by the Publications of the Astronomical Society of Japan: *Cosmological constraints from cosmic shear two-point correlation functions with HSC survey first-year data.* Takashi Hamana, et al. Publ Astron Soc Jpn (2020) 72 (1): 16, doi.org/10.1093/pasj/psz138.

## J. V. Narlikar

- Rashtriya Gunakar Muley Award (2021) from the Madhya Pradesh Government, Culture Department, September 14, 2023.
- Fellowship of the Gwalior Academy of Mathematical Sciences, Gwalior, December 11, 2023.

## Durgesh Tripathi

- Vishal Upendran was the recipient of the K.D Abhyankar Best Thesis Presentation Award for his thesis Heating and Dynamics of the Solar Atmosphere.
- Janmejoy Sarkar, Senior Research Fellow (SRF) of the Department of Physics, Tezpur University, Assam, was felicitated with the Distinguished Student Achiever Award 2023 for his contribution in developing the SUIT module of India's space mission ADITYA-L1.

# RESEARCH GRANTS AND FELLOWSHIPS

**Souradeep Bhattacharya**

- DST-INSPIRE Faculty Fellowship.

**Subhadeep De**

- DST grant for the project: DST -Quantum Information Technologies with ion-trap and optical-lattice devices of Interdisciplinary Cyber Physical Systems (ICPS).
- **Synchronization of the optical atomic clocks located at IUCAA and IISER Pune by ultra-stable fiber optic channel**, Chanakya doctoral fellowship under this project (2022-27).
- **Sub-micron resolution imaging system to detect individual ions/ atoms -** Project funded by the DAE Board of Research in Nuclear Sciences (BRNS) (2021-24)
- I-HUB Chanakya Doctoral Fellowship (2022-27) - **Synchronization of the optical atomic clocks located at IUCAA and IISER Pune by ultra-stable fiber optic channel.**

**Samir Dhurde**

- International Astronomical Union (OAO Grant).

**Shasvath Kapadia**

- SERB Start-up grant.
- SERB MATRICS grant.

**Ajit Kembhavi**

- Pune Knowledge Cluster (PKC):
  - National Centre for Biological Science.
  - BASF Chemicals India grant:
  - For a mentoring and scholarship program for women in chemistry and sustainability - Wenyan.
  - A platform for Gamified Learning in Chemistry and STEM Education.
  - Lenovo India grant for Teach with Tech.
  - PKC Tree Project.

**Ranjeev Misra**

- ISRO Grant to set up the AstroSat Science Support Cell (ASSC).

**Sanjit Mitra**

- LIGO India TDCB and DAE.
- LIGO India SEED and DST.

**Anupreeta More**

- DST SERB Power (Promoting Opportunities for Women in Exploratory Research) Grant.

**Dipanjan Mukherjee**

- Indo-French Centre for the Promotion of Advanced Research (IFCPAR) Grant for the project: Resolving the impact of AGN feedback on gas and star formation through simulations and observations.
- DST sponsored Indo-Italian grant for the exchange of researchers.

**Sowgat Muzahid**

- DST grant - The Role of Gaseous Halos in Galaxy Evolution.

**A.N. Ramaprakash**

- Participation Grant in Thirty Metre Telescope (TMT) Project at Mauna Kea, Hawaii, USA.
- Institute of Plasma Physics Crete WALOP N.
- Infosys Foundation Grant for Resurgent Caltech – IUCAA Collaboration for Advanced Instrument Development and Scientific Discoveries.
- Institute of Arizona LBT1.

**Kanak Saha**

- Grant for the project: Exploring the Nature of Lyman Continuum Emitting Sources in the AstroSat-UV Deep Field (AUDF).

**Dhruba J. Saikia**

- UGC Malaviya Mission Teachers Training Grant.

**Durgesh Tripathi**

- ISRO Solar Flares P&F.
- Indo-French grant for 'Investigating the origin of switchbacks in the solar corona via interchange reconnection -- A statistical and multi-instruments approach including machine learning'.

### Stellar Astrophysics and Cosmic Distance Scale

The IUCAA 'STARS group led by Anupam Bhardwaj is interested in stellar evolution and pulsation across the Hertzsprung-Russell diagram, Galactic archaeology, resolved stellar populations in star clusters and nearby galaxies, and near-field cosmology. Dr. Anupam Bhardwaj, new faculty member at IUCAA, works on precision stellar astrophysics and the cosmic distance scale using multi-wavelength photometric and spectroscopic observations of classical pulsating variable stars. The current focus of research in stellar group is on improving the calibration of stellar standard candles in the first rung of the cosmic distance ladder used to determine the present expansion rate of the Universe. Dr. Bhardwaj and his group uses Cepheid, RR Lyrae, and Mira variable stars as stellar population tracers for Galactic archaeology and near-field cosmology with observational data from 4-8 m class telescopes. The group is involved in several multi-wavelength time-domain surveys such as VVV, ZTF, upcoming LSST, and in specific projects with TESS and Gaia space missions. On the theoretical front, ongoing efforts include stellar evolution and pulsation modeling with the Modules for Experiments in Stellar Astrophysics (MESA), open-source 1D stellar evolution code.

### Physics of Compact Objects

Debarati Chatterjee and her research group at IUCAA are involved in studying Neutron Stars, ultra-dense compact objects which show a myriad of extreme properties and serve as cosmic laboratories to investigate fundamental Physics. Their strong gravity can bend space-time significantly, and their collisions or perturbations can result in strong gravitational wave emission. The recent ground-breaking detection of gravitational waves from Neutron Stars has opened up a new window to the Universe and a novel method to probe their interior.

The team is developing theoretical models to describe the interior of Neutron Stars, consistent with state-of-the-art information from multidisciplinary domains, such as Nuclear, Particle and Condensed Matter Physics from terrestrial experiments and multimessenger astrophysical data. In the past few years, several investigations were conducted by them to look for signatures of the internal composition of Neutron Stars in gravitational wave emission from unstable oscillation modes. The studies demonstrated how our understanding of dense matter properties can be significantly improved using signals from such oscillations, in both isolated or binary systems, with current or planned future generation gravitational wave detectors. They also investigated how such detections may allow us to distinguish between Neutron Stars and other stable families of compact stars or probe the nature of possible phase transitions or presence of dark matter. Other works also demonstrated how tidal heating during Neutron Star mergers could be a novel probe of the presence of exotic particles in their interior.

### Quantum Metrology and Precision Measurements

Since the conceptualization of Quantum Mechanics, we are now in an era of a second quantum revolution, when several countries in the world, including India, are advancing cutting-edge quantum-enhanced technologies in

computation, communication, sensing, and metrology.

Subhadeep De and his team at the Precision & Quantum Measurement Laboratory (PQM lab), IUCAA is developing a state-of-the-art facility dedicated to explore the fundamental aspects of science using optical atomic clocks as a quantum sensor. The lab's research interests involve developing quantum phenomena-based technologies for metrology-grade measurements and accurate sensing. The heart of the experimental setup is a trapped ytterbium-ion-based quantum clock. For this, we shall probe the highly forbidden electric octupole (E3) transition at 467 nm wavelength of a single trapped and laser-cooled ytterbium-ion. To excite that clock transition, an ultra-stable sub-Hz line-width laser will be produced by referencing the laser to an indigenously developed ultra-stable Fabry-Pérot cavity. Upon development, the change in the tick rates of such clocks is altered by unimaginably tiny perturbations of the energy states associated with the clock transition. The resulting shift in tick rates of the clock could be caused by variations of the fundamental constants, breaking of fundamental symmetries, gravitational red-shifts at the submillimeter scale, gravitational waves, cosmic microwave background, and so on. For such scientific explorations, the lab-based clocks must be part of a geographically distributed "quantum clock network." To pursue this, the reference clock photons must be disseminated from one node to another within the clock network using "phase stabilized optical fibers"; the PQM lab has already developed the required technology.

**X-ray Observational Studies of Active Galactic Nuclei**

The enigmas of Black Holes are not easy to study due to the lack of any light information coming directly from them. However, black holes in X-ray binary systems and at the centres of active galaxies accrete material that results in copious amounts of radiation primarily in the X-ray and Ultraviolet bands. India's first multi-wavelength space observatory AstroSat has been vital and has allowed Indian astronomers to study the immediate environments near stellar mass black holes in X-ray binaries and super-massive black holes in active galaxies.

Gulab C. Dewangan has played a major role in AstroSat, India's first dedicated multi-wavelength space observatory which has special instruments particularly sensitive to UV and different energies of X-rays. IUCAA researchers are members of instrument teams, run the Astrosat science support cell (ASSC), and host the payload operation centre for the CZTI instrument aboard the satellite. Some of the software for AstroSat was written by members of ASSC. The ASSC also runs training workshops, schools, and instrument calibration meetings which are extremely useful, enabling researchers all over India to use AstroSat, in writing proposals for scientific observations and analysing its data. Using AstroSat, IUCAA researchers are also involved in studying complex processes in the innermost regions close to supermassive black holes (SMBH) in active galaxies (AGN) and stellar-mass black holes in X-ray binaries. They have found accretion disks that do not extend to the innermost stable orbit as predicted by Einstein's general theory of relativity. They have also found the first evidence for a state transition in a changing-look active galaxy where the standard

disk changes its structure and forms a warm medium producing soft X-ray excess emission. As part of an international collaboration, IUCAA researchers observed with AstroSat's Soft X-ray Telescope, and helped unravel a mysterious super bright flash with fast variability, to be a tidal disruption event in which an SMBH in a distant galaxy captured a star and produced a relativistic jet which pointed towards the earth, which produced more light than a 1000 trillion Suns. In a study of a transient black hole X-ray binary MAXIJ1820+070, IUCAA scientists find changes in the inner radius of the accretion disk associated with changes in the structure of and emission from the hot Corona. This study further revealed a captivating connection between the X-ray emission from the inner regions near the black hole and optical/UV emission from the outer region of the accretion disk. In another research data from AstroSat's Cadmium Zinc Telluride Imager (CZTI), reported around 24% polarised high energy X-rays from the black hole X-ray binary Cygnus X-1.

This is much higher than the expected less than 10%, thus hinting that the mechanism of X-ray emission (more energetic than 200 keV) is from the jet, possibly synchrotron radiation in an ordered magnetic field. Moreover, the CZTI detected high X-ray polarisation only in the state that exhibits strong radio emission from the jet. For the first time, therefore, one can confirm the direct connection of the hard X-ray emission to the relativistic jet.

**Probing Coherence in Metal Absorption**

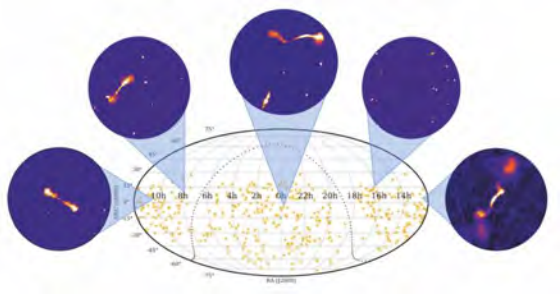
Rajeshwari Dutta and her collaborators recently conducted a unique tomographic analysis of the structure of metal-enriched cool gas in the halos around galaxies at redshifts, z<2. Diffuse gas is detected in absorption in the spectra of two background quasars at z~2-3, which are two of the few currently known quasars with multiple images due to strong gravitational lensing by galaxy clusters at z~0.5-0.6. The angular separations between different pairs of quasar multiple images enabled to probe the absorption over transverse physical separations of ~0.4-150 kpc. The integral field spectroscopic observations of these quasar fields using Multi Unit Spectroscopic Explorer (MUSE) on the Very Large Telescope (VLT) facilitated study of the galaxies associated with the absorbing gas. The results indicate that the metal-enriched gaseous structures around galaxies become less coherent with distance, with a likely coherence length scale of ~10 kpc.

**Science from MeerKAT Absorption Line Survey (MALS)**

The vast expanse of the observable universe is home to countless galaxies. Many of these galaxies have supermassive black holes (SMBHs), which become active when gas infalling towards the black hole results in release of large amounts of energy. The energy output from these Active Galactic Nuclei (AGN), often outshines the light from the entire galaxy. Additionally, they eject "jets": collimated streams of highly-energetic ionized gas particles, piercing through the interstellar medium (ISM) amid the stars.

The interplay between energetic output from AGN and cold gas in host galaxies is central to understanding the fuelling of massive black holes and the evolution of galaxies hosting these. MALS is carrying out a sensitive search of absorption

lines to characterize the properties of cold atomic and molecular gas associated with AGN



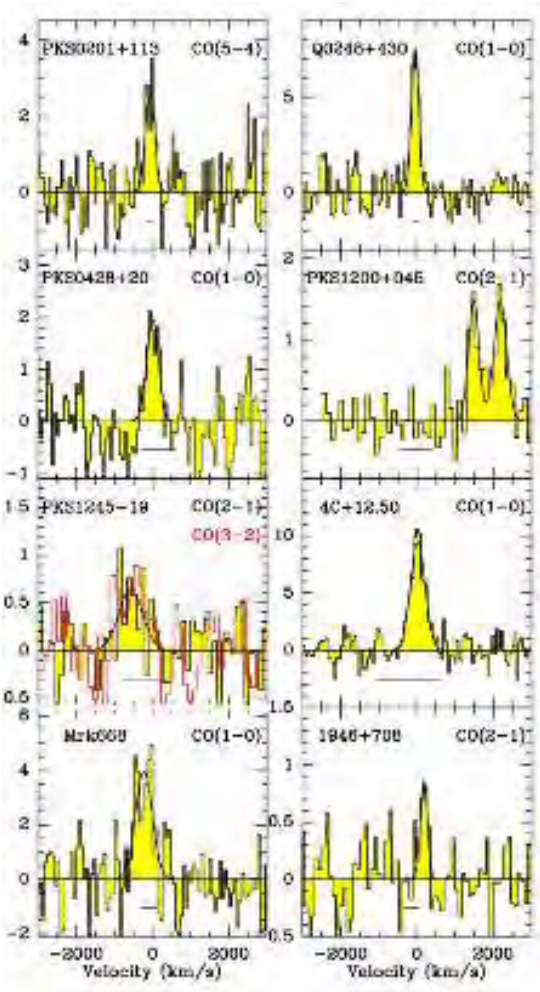
The MALS team led by Neeraj Gupta has released radio continuum images and a catalog of 495,325 radio sources detected over an area of 2289 deg2 from 391 telescope pointings at 1 - 1.4 GHz. "Majority of these radio sources are AGNs and many are detected for the first time, thanks to excellent capabilities of MeerKAT. These radio sources will subsequently be used as background targets to detect signatures of cold gas in and around galaxies, addressing the main theme of the survey." – explains Partha Pratim Deka, currently a PhD student at IUCAA, Pune and the lead-author of the Astrophysical Journal article describing the data release.

The MALS catalogs and images are publicly available at https://mals.iucaa.in. These may be used for a diverse range of scientific objectives by the astronomy community.

**Cold Molecules in HI 21-cm Absorbers across Redshifts 0.1 - 4**

Absorption lines at high redshift in front of quasars are rare in the mm domain. Only five associated and five intervening systems have been reported in the literature. These bring very useful information complementary to emission lines, for instance, to distinguish between inflows and outflows. They are also good candidates to study the variations of the fundamental constants. Neeraj Gupta and his collaborators report the search for molecules in emission and absorption in front of a sample of 30 targets, comprising 16 associated and 14 intervening HI 21-cm absorbers. The observations have been done with the IRAM-30m telescope, simultaneously at 3mm and 2mm, exploring CO ladder and HCO+ lines. Eight targets have been detected in emission, of which five are new. Their molecular gas masses range from 109 to 7 1011 Mo. We also report four new detections in absorption. Two of the associated CO absorption line detections at high redshift (z=1.211 and 1.275) resulted from the high spatial resolution follow-up with NOEMA. The disparity between the mm molecular and HI 21-cm absorption lines for these and another intervening system detected in HNC at z = 1.275, is attributable to radio and mm sight lines tracing different media. Comparing HI and H2 in the 14 known high redshift molecular absorbers, associated HI absorption lines are broad, with multiple components and the molecular absorption corresponds to the broader and weaker 21-cm absorption component. This indicates two distinct phases: one near galaxy

centers with a larger CO-to-HI abundance ratio, and another with lower molecular abundance in the outer regions of the galaxy. The comparison of interferometric and single dish observations shows that the detection of absorption requires sufficient spatial resolution to overcome the dilution by emission, and will be an important criterion for mm follow-up of 21-cm absorbers from ongoing large-scale surveys.




Reference: Cold molecules in HI 21cm absorbers across redshifts 0.1-4; F. Combes and N. Gupta, 2023, A&A, 683, 20

**Forecasting Gravitational Wave merger candidates**

The research group led by Shasvath Kapadia and his collaborators is trying to forecast the kind of massive binary black hole mergers that will be observed by future space based detectors like LISA and DECIGO, using large-scale cosmological hydrodynamical simulation data. It also attempts to come up with a preliminary estimate of the electromagnetic luminosities of these mergers, since such massive black holes will have matter surrounding them, and their mergers will enable electromagnetic counterparts. Another project in that group involves probing line-of-sight acceleration of the centre of mass of merging compact objects as a means to identify their provenance and the environments in which they merge. A third project concerns probing the abundance of compact objects in our Milky Way galaxy using the non-detection of continuous gravitational waves from these spinning compact objects. And finally, the group is also constructing sophisticated methods to identify gravitationally lensed gravitational waves in LIGO-Virgo data, where lensing will result in multiple, time-separated copies of the original signal.

**New techniques in Gravitational Wave data searches**

In the past year Sanjit Mitra worked on various aspect of gravitational wave (GW) data analysis. Kanchan Soni, Sanjeev Dhurandhar and Sanjit

Mitra have developed a two stage (coincident) hierarchical search, which speeds up the search for compact binary coalesces (CBCs) by more than one order of magnitude [Phys. Rev. D 105, 064005 (2022)]. The search was applied to real data and it recovered all the events published in the LIGO-Virgo-KAGRA (LVK) collaboration's first transient catalogue (GWTC-1) with approximately the same significance. They have also developed a novel technique of determining the significance of an event accurately yet fast, without which the computational efficiency would be lost [Phys. Rev. D 109, 024046 (2024)]. Shreejit Jadhav, Mihir Srivastava (IIT Kharagpur) and Sanjit Mitra have developed a method towards making a fully Machine Learning based search algorithm for CBCs. While the method is not yet as efficient as Matched Filtering, which is still the primary search method for these sources, it is a big step towards making a primarily Machine Learning based search. Also, it has the potential to work with the present Matched Filtering based analysis to perform a deeper search (that is, to find low significance events). [Mach. Learn.: Sci. Technol. 4 (2023) 045028]. Sanjit Mitra and his group developed an analysis pipeline, PyStoch, to search for anisotropic GWB, which utilised years' worth of data folded to one sidereal day utilising a mathematical symmetry, which was also developed by the same group. The folded data not only made the standard LVK analysis hundreds of times faster, but enabled making skymaps at every frequency bin, which was not possible before. The LVK collaboration devoted a full publication on All-Sky All-Frequency (ASAF) analysis, where Deepali Agarwal was the lead analyst, Sanjit Mitra led the search. Sukanta Bose and Shivaraj Kandhasamy were part of the LVK review team. [Phys. Rev. D 105, 122001 (2022)]

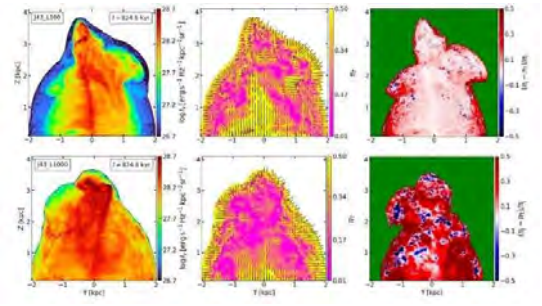
**Cosmology with Weak Gravitational Lensing**

The research group led by Surhud More at IUCAA has focussed on cosmology and astrophysics of the galaxy-dark matter connection using weak gravitational lensing and gravitational waves. One of the main highlights of the research from the research group include the results from the weak gravitational lensing group of the Subaru HSC survey, that measured the amplitude of density fluctuations in the Universe (More et al. 2023, Miyatake et al. 2023, Sugiyama et al 2023, Li et al 2023 and Dalal et al. 2023). The group has also worked on improving methods to use gravitational wave events to constrain the expansion history of the Universe (Abbott et al. 2023, Gray et al. 2023, Ghosh et al. 2023). The weak gravitational lensing signal from the HSC survey was used to probe the stellar mass halo mass relation of galaxies from redshift range of 0.3 to 0.8 (Chaurasiya et al. 2023), to obtain the tightest constraints on the edges of X-ray galaxy clusters from the eROSITA eFEDS survey (Rana et al. 2023), to put the first upper limits on the fraction of orphan satellite galaxies from galaxy clusters (Ratewal et al. 2023), and also to show the linear relation between the sizes of galaxies and the sizes of their dark matter halos (Mishra et al. 2023) for the first time using gravitational lensing. The research also included a method to constrain the asteroid mass primordial black holes using parallax lensing of GRBs (Gawade et al. 2023).

**Computational Astrophysics with High Performance Computing**

Dipanjan Mukherjee and his collaborators are mainly interested in investigating diverse

astrophysical phenomenon using computational techniques. This primary involves performing challenging high resolution simulations of astrophysical systems using high performance computing facilities. A key goal of these simulations is to produce realistic models of different systems, which can be directly compared with observed systems, to constrain the inherent physical models. To achieve these objectives, an important activity involves in-house development of novel computational techniques to address the numerical challenges for a modelling a given problem. In this regard, researchers at IUCAA have made two major contributions in the past year: a) Development of a novel parallel multi-grid Poisson solver for the widely used PLUTO MHD code, b) Running a suite of simulations of evaluate the impact of external turbulent magnetic field on the synchrotron and polarisation structure expected from young relativistic jets. The first project highlights the developmental capabilities of our research group, where the Poisson solver module opens up a wide variety of possibilities to explore many different astrophysical problems involving self-gravitational forces, with a particular focus on studying star formation in galactic and extra-galactic environments. Efforts have already been made to apply this module to investigate the impact of AGN driven winds on the star formation properties in dense turbulent clouds. The second project, highlights the importance of performing state of art high resolution simulations to understand the observational implications of AGN jets evolving in their immediate environment. It has been shown that external turbulent magnetic fields in the galaxy's halo can strongly depolarise the emerging synchrotron emission.



Top figure: Logarithmic total synchrotron emission, polarization fraction for a relativistic jet of power.

Bottom figure: Same as above for jet in an environment with longer correlation lengths of magnetic field lines.

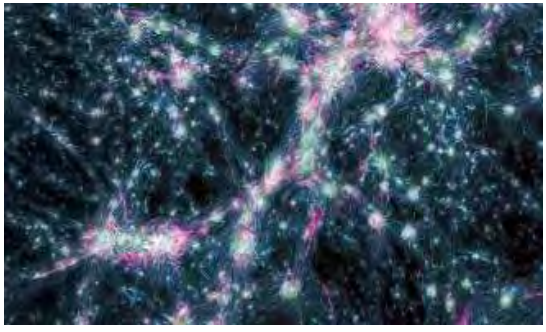
**The Circumgalactic Medium**

In the modern theoretical paradigm of galaxy evolution, the circumgalactic medium (CGM) has been recognized as one of the key components for a comprehensive understanding of how galaxies acquire gas to fuel star formation and expel gas in the form of large-scale winds. Scientists at IUCAA are actively involved in understanding the properties of the CGM of galaxies for a wide range of redshifts.

The research group led by Sowgat Muzahid at IUCAA have discovered a significant enhancement of cool, neutral gas in and around high redshift (z ~ 3) Lyman-alpha emitting galaxies (LAEs). This enhancement is even more pronounced when these galaxies are found in pairs or groups. In an interesting discovery, they identified a strong HI absorber in a quasar spectrum to be originating from cosmic

filaments—the intricate threads that form the universe's vast tapestry.

The group has demonstrated that the quantity of highly ionized, low-density, hot gas in the CGM, traced by OVI, is strongly dependent on the mass of low-redshift, star-forming galaxies. For the first time, they conducted robust measurements of the mass of OVI-bearing gas in the CGM of dwarf galaxies. Their findings reveal that in the CGM, the OVI-bearing gas originates from photoionization in dwarf galaxies and from collisional ionization in high-mass galaxies. Moreover, it has been found that the majority of the OVI-bearing gas detected within the virial radius is gravitationally bound to the galaxies, regardless of their mass.



**Active Galactic Nuclei and Jets**

The Universe is filled with billions of galaxies. One in about one thousand galaxies hosts powerful jets that are collimated fountains of plasma shooting out from the centers of these galaxies. Some of these jets are so powerful that they radiate more energy every second than that emitted by the Sun in its entire lifetime of 10 billion years. The research led by Vaidehi Paliya involves studying these jets using the observations from both space- and ground-based telescopes covering the electromagnetic spectrum, i.e., low-frequency radio to gamma rays. Using radio and near-infrared observations, Vaidehi Paliya and his team endeavors to understand the morphology of the jets and their host galaxies and their possible interactions with the surrounding environment. Additionally, the high-energy X-ray and gamma-ray data taken with space observatories such as Chandra X-ray Observatory and Fermi Gamma-ray Space Telescope enables the IUCAA team to explore the radiative mechanisms powering these jets and observational features, e.g., erratic brightness changes noticed from jets on minutes-to-years timescale. Vaidehi Paliya also supplements the observational findings with theoretical modeling to interpret the results. The larger picture addresses some fundamental questions, such as how galaxies evolve and live their life, interact with their neighbors, and impact their fate.

**Cosmology with Baryon Acoustic Oscillation**

The physics of the early Universe predicts a distinct set of spatial correlations called baryon acoustic oscillations (BAO) that imprint on the large-scale distribution of galaxies in the Universe. The BAO feature shows up as a bump when measuring the pairwise number density of galaxies as a function of pair separation. The length scale at which the BAO feature occurs (typically of order 150 Megaparsec at the present epoch) can act as a standard rod that can be used to constrain cosmological parameters. Measuring the precise value of this scale at different epochs of the Universe is one of the key science drivers of current and upcoming galaxy surveys. Typical analyses in this `BAO cosmology'

programme assume that the underlying model of the Universe is well-approximated by the Lambda-cold dark matter (LCDM) framework. Aseem Paranjape and his collaborators have developed an analysis technique that allows the BAO feature to be used in a model-independent manner, i.e., the same analysis is simultaneously applicable in constraining not only LCDM but also other classes of `modified gravity' or `dark energy' models. The new technique relies on basic physical aspects of cosmological structure formation shared by a wide class of models including and beyond LCDM, combined with a simple data-driven description of the BAO feature using polynomials which is embedded in a fully Bayesian analysis framework. The new technique thus opens the door to using the BAO feature to its full capacity as a probe of primordial cosmology.

**Dwarf Galaxies**

Giant galaxies, like our Milky Way and its neighbour Andromeda, are surrounded by tens of dwarf galaxies - irregular in shape and often forming stars. Looking back in time, we see that galaxies were smaller and more irregular. How these dwarf galaxies assemble their stars and evolve is still one of the outstanding questions of galaxy formation. A recent study using AstroSat shows how the star-forming clumps in the outskirts of a dwarf galaxy migrate towards the central region due to dynamical friction and contribute to its growth in mass and luminosity. The discovery of this process in several dwarf galaxies has been made for the first time by the research group led by Kanak Saha at IUCAA in collaboration with Indian university students and international scientists.

The resolving power of Astrosat's UltraViolet Imaging Telescope and AstroSat UV Deep Field (AUDF) imaging has been the key to spotting such extremely blue, young star-forming clumps that in-spiral inside the optical boundary within a billion years (much shorter than a galaxy's lifetime) timescale to grow these galaxies. One of the key challenging tasks has been to establish the detection of these. Another key research activity of the Galaxy group at IUCAA is to search for extended UV emission in the outskirts of dwarf galaxies, some of which are seen now at a stage when our universe was less than half its current age. In parallel, the group is actively hunting for such distant dwarf galaxies (at redshift z>1) that might have contributed to the reionization history of the universe.

**Theoretical Solar Physics**

Two important goals of solar physics are to understand its dynamo mechanism and to be able to make an early prediction of energetic events, such as coronal mass ejections and solar flares, which directly influence the terrestrial life. These phenomena are powered by magnetic fields which are generated within the Sun. Moreover, the Sun supports a wide variety of waves that carry useful information about the inhomogeneous solar structure. Based on simulations of turbulent magneto-convection we study the generation of concentrated magnetic fields in a self-consistent manner, and also analyse observational data to look for imprints of subsurface magnetic fields on helioseismic modes. We find that the solar surface gravity or the f-mode displays strengthening about two days prior to active region (AR) formation and thus it provides a new precursor for AR formation. This has implications for space weather forecasting and can potentially be important for constraining dynamo paradigms

aiming at understanding the global magnetic activity of the Sun.

Nishant Singh and his team are working on making more advanced models to further understand the nature of interaction between the surface gravity mode of the Sun and its magnetic fields. Conventional understandings on turbulent dynamo are also being revisited in light of recent studies where one aims to look for observational signatures which can be probed by modern data from the Sun. As the data from SUIT (Solar and Ultraviolet Imaging Telescope) on board the Aditya-L1 has started coming in, we plan to investigate the nature of various types of waves in solar atmospheres in order to understand the heating mechanisms of solar corona.

**Observational Solar Physics**

The Sun, our star, is the source of all life-giving energy and also of the ever-varying space weather. It also provides knowledge about fundamental Physics in conditions not possible on the Earth. The atmosphere of the Sun presents several intriguing, mysterious phenomena e.g. the strange existence of a million-degree temperature layer called the Corona that lies above cooler, lower atmospheric layers, such as the photosphere and chromosphere. Moreover, it continuously engulfs the interplanetary medium with charged particles through the solar wind. In addition, Sun also produces large explosions such as flares and coronal mass ejections. During the high solar activity phase, there may be as many as 20 or even more highly energetic explosions in a day which produces sudden release of magnetised plasma into the interplanetary space. They directly influence terrestrial life, space weather, and space-reliant technologies and may cause electric power blackouts in countries at higher latitudes on Earth. Humankind stands to gain a lot from the study of these phenomena.

The Solar Physics group at IUCAA led by Durgesh Tripathi works on the overall understanding of the dynamic coupling of the magnetized solar atmosphere. In the last few years, among others, the IUCAA group has proposed a unified scenario to explain the solar atmospheric heating and the origin of the solar wind; presented an alternative explanation for Doppler shifts Observations in the solar transition region and discovered evidences for further strengthening the support for nano-flare heated solar corona. Important studies of the Sun also need to be made through the radiation it emits at high energies, such as ultraviolet, extreme ultraviolet, and X-rays. These cannot be seen from the Earth due to their absorption in the atmosphere. For this the IUCAA solar and instrumentation group together have built the Solar Ultraviolet Imaging Telescope (SUIT) that is now operating onboard the successful Aditya-L1 mission to study the Sun from Space. As the observational data from SUIT starts coming in, the group is investigating the nature of various physical phenomena, including the explosions, occurring in the solar atmosphere to understand the dynamic coupling of the magnetised solar atmosphere.

# PEDAGOGICAL

## IUCAA-NCRA graduate school

The IUCAA-NCRA graduate school (conducted jointly with the National Centre for Radio Astrophysics (NCRA), Pune) is meant for the Ph.D. students of IUCAA and NCRA. Coursework is divided into two semesters (four terms) over one year. Each term is roughly seven weeks in duration. Students are taught relevant advanced courses in physics and are also introduced to courses in astronomy and asical Techniques - I

- Electrodynamics and Radiative Processes I
- Extragalactic Astronomy I
- Interstellar Medium
- Introduction to Astronomy and Astrophysics
- Introduction to Astronomy and Astrophysics II
- Methods of Mathematical Physics II
- Quantumtrophysics.
- Astronom and Statistical Mechanics I
- Quantum and Statistical Mechanics II
- Research Methods and Statistical Techniques

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Number of students enrolled in the graduate school: 05 - IUCAA, 03 - NCRA

## SPPU-IUCAA JOINT M.Sc. (PHYSICS WITH ASTROPHYSICS) PROGRAMME and The DEPARTMENT OF PHYSICS, SPACE SCIENCES, SPPU, M.Sc. (ASTRO)

- Astrolab-II
- Astronomical Techniques
- Astrophysical Dynamics
- Astrophysics Laboratory I
- General Relativity and Cosmology
- High-Energy Astrophysics
- Introduction to Astronomy and Astrophysics I and II
- Relativistic Electrodynamics and Radiation Processes

Number of students enrolled in the SPPU-IUCAA Joint M.Sc. (Physics with Astrophysics) Programme: 12

## Supervision of PhD Thesis:

- Ph.Ds. awarded: 06
- Ongoing Ph.Ds.: 38
- Ongoing Ph.D. (Other than IUCAA): 06

## Seminars / Colloquia and Academic Activities

Number of Seminars: 32

Number of Colloquia: 05

Lectures delivered by IUCAA academics in courses/workshops: 33

Talks delivered by IUCAA Academics during 2023-24: 158

Popular talks delivered by IUCAA Academics during 2023-24: 21

Radio/TV shows: 01

# PUBLIC OUTREACH ACTIVITIES

### 50th Rashtriya Bal Vaigyanik Pradarshani (RBVP) 2023:

The IUCAA Inter-University Centre for Astronomy & Astrophysics Scipop team had put up a stall at RBVP from 26 to 31 December 2023. Posters mentioning information about IUCAA and its academic activities were displayed. Astronomy Concept models and our iconic "Velo-Gyaneshwari" bicycle, which consists of 40 hands-on experiments, were also displayed. A telescope made at the IUCAA was displayed as a part of the IUCAA Telescope-making workshop. A sky-observation session was conducted with Pimpri Chinchwad Science Park for around 500 RBVP attendees. Approximately 20,000 students from 200 schools with 1000 teachers and 3000 general public attended the event.

### Science Toys Demonstrations and Basic Astronomy sessions:

During 2023-24, the Scipop team organised 23 Science Toys Demonstrations and Basic Astronomy sessions at the following locations:

- Dyanaganga Vishwa Vidyalaya, Shirur, Pune
- Tara Mobile Creche, Pune
- Balvantrao Zele School
- Manvya Sanstha, Kothrud
- Dattakala Shikshan Sanstha, Daund
- Ryan International School, Bavdhan
- Dapodi Kanya Shala no. 31
- Vibgyor Rise, Chinchwad
- New English School, Landewadi
- St. Mary's College, Thoothukudi, Tamilnade
- Bharatiya Jain Sanghatana School, Wagholi
- Saraswati Vishwavidyalaya, Talwade
- Dnyanaganga Vishwavidyalaya, Shirur
- Chandranarayan Balwade English School, Jaysingpur
- Agastya International Foundation, Baramati
- SVS High School, Khadi

### Science Toys Demonstrations and Sky watching sessions:

During 2023-24, the Scipop team organised 23 Science Toys Demonstrations and Sky watching sessions at the following locations:

- Samarth Engineering College, Velhe
- Gramin Vidnyan Kendra, Andur, Tuljapur
- S.P. College, Pune
- Avasara Academy, Lavale
- SBES College, Chatrapati Sambhaji Nagar
- Indapur (organised by the Panchayat Samiti)

### Telescope Making workshops:

During 2023-24, the Scipop team organised three Telescope Making workshops at the following locations:

- IIT, Gandhinagar
- IUCAA (on the occasion of the IUCAA Foundation Day)
- GLA University, Mathura
- MVPS, Nashik

### 2nd Saturday Lectures

During 2023-24, the Scipop team organised two lectures as follows:

- 14th October: "Formation of Black Holes" by Prof. Surhud More (Marathi) and Dr. Moupiya Maji (English).
- 11th December: "Detecting the Invisible through Gravitational Waves" by Dr. Pushpa Khare (English and Marathi).

### Public Talks

During 2023-24, the Scipop team organised two public talks in the Chandrasekhar Auditorium as follows:

- 13 December 2023: A Public lecture was organised by IUCAA Scipop on "ZARTH: How to

catch a Supernova". The speaker was Dr. Ashish Mahabal.

- 29 December 2023: The 35th IUCAA Foundation Day Lecture titled "Innovate to Transform" was delivered by Padma Bhushan Prof. Jyeshtharaj Bhalchandra Joshi, a well-known chemical engineer and nuclear scientist.

### National Science Day 2024

The National Science Day was celebrated with an Open Day on 28th February 2024 at IUCAA and other events throughout February. Like every year, IUCAA responded to people's enthusiasm to associate better with Science and Scientists. The celebrations attracted numerous students from Pune and other parts of Maharashtra, including teachers, parents, and the public. As per tradition, there were also events for school students before the open day. IUCAA Public Outreach personnel conducted a science quiz, essay writing, and drawing competitions for the rural students of the Ambegaon Taluka on February 17, 2024. Prajakta Mane, Rutuja Pilgar, Jitendra Joshi, Ravi Kesarwani, and the Scipop Team (all from IUCAA) enthusiastically encouraged students from 15 rural schools, who competed at the venue generously provided by the Government Polytechnic, Awasari.

### OAE-India Teachers Training Workshop

The OAE-India node organised the training at IUCAA; 51 teachers (local and from other states) participated in this training.

36th ANNUAL REPORT 2023-24

## PH.D. DEGREES AWARDED

| S. No. | Title | Name of the Student | Supervisor |
|---|---|---|---|
| 1 | Radiometer Searches for Persistent Sources of Gravitational Waves Using Ground-based Detectors | Deepali Agrawal | Sanjit Mitra |
| 2 | Analytical and machine-learning solutions for hunting binary black holes and dark matter constituents | Sunil Choudhary | Sukanta Bose |
| 3 | Probing the Nature, Environment, and Evolution of Ultrastrong Mg II Absorption Systems | Labanya Kumar Guha | R. Srianand |
| 4 | Algorithms for Gravitational Wave Data Analysis and Detector Controls Based on Modern Techniques | Sreejith Jadhav | Sanjit Mitra |
| 5 | Probing ultra-fast outflows in BAL quasars using multi-epoch spectroscopy | Aromal P. | R. Srianand |
| 6 | Probing cosmology using large scale structure correlations | Divya Rana | Surhud More |

# FACILITIES AT IUCAA

## The Computer Centre

The IUCAA Computing Facility offers state of the art computing hardware and technology rich environment for IUCAA members, associates and visitors. It also extends an array of specialized High-Performance Computing (HPC) environments to the academic community for their research.

The hardware and devices currently managed by the computing facility include about 350+ servers and desktops, 100+ laptops, 80+ printers and scanners, three large High-Performance Computing systems and over 9.5 PiB of storage, in addition to diverse equipment deployed for an extensive, high throughput wired and wireless campus-wide network. The number of registered Wi-Fi devices are over 900 and e-mail accounts served by the computing facility are nearly 825.

IUCAA provides e-mail services to its members and associates, the total number of accounts being nearly 825. IUCAA has its own registered domain name as "iucaa.in", "associates.iucaa.in", "ligo-india.in" and "mailman.gw.iucaa.in". The WAN services are provided by the National Knowledge Network over a 1 Gbps fibre connectivity, with a fall back arrangement over a 50 Mbps line from BSNL.

**In the year April 2023- March 2024 emphasis was given to implementation of:**

### 1) Expansion of the Pegasus cluster

The Pegasus cluster deployed in 2019 consists of two head nodes, four login nodes, two graphics nodes, four GPU nodes, 2560 compute cores, and 2PiB Parallel File System (PFS) storage. Several new users have been added in the last two years, and all users use the cluster extensively. The average cluster utilisation is more than 90%, resulting in a considerable wait time for many jobs. To cater for the ever-increasing need of computational power for large-scale computational jobs and reduce the computational job's wait time, the Pegasus cluster will be augmented by adding 20 compute nodes

### 2) Replacement of 40KVA UPS system with 60 KVA modular UPS

IUCAA has a 40 KVA UPS dedicated to supporting the Rack LCPs, Chiller pumps, BMS utilities, Carel setup and power supply to the Utility room and data centre. Due to the increasing load, we needed a Higher-capacity modular UPS system. The old 40 KVA UPS has been replaced with a new 60 KVA UPS system to support the expanding load.

### 3) Installation of 200 TB Unified storage

IUCAA has dedicated 200TB enterprise class storage for the virtualization infrastructure(VI) setup (Server Virtualisation and Virtual Desktop Infrastructure). This storage is more than nine years old and has reached the end of life and support with more than 80% of storage capacity utilised, affecting the storage performance. To enable the smooth functionality of the VI setup, better support and performance, the storage has been replaced with the new 200TB unified storage.

### 4) Expansion of MALS archival storage by 1PiB

The next phase of MALS observations focusing on the UHF band (remaining ~1100 hrs) was scheduled to start in 2023. To process MALS data, we have procured 4PB PFS storage (hot), 1PB (archival storage), and 1PB tape storage(cold). Till now, we have received about 150 tapes containing L band data. We expect 81 tapes containing UHF band data by next month and will receive around 250 in the near future. We have moved about 1PB of processed L band data to archival storage, and still, 1.5PB of the processed data is on PFS storage. Hence, the archival storage is expanded by an additional 1 PiB, so processed L-band data may be moved from the PFS storage to archival storage, enabling the processing of UHF datasets.

### 5) Network monitoring and Analysis Software setup

IUCAA has an extensive network (wired LANS and W-LAN). As the number of users increases, the network complexity increases, and keeping the network system secure and running is paramount. A new network monitoring and management software, has been procured that helps in monitoring, manage, and providing ease of maintenance, reducing significant network issues and to ensure the utmost uptime.

### 6) Replacement of existing Email Servers hardware

IUCAA hosts Zimbra email services on the two dedicated servers with the warranty is about to expiring. Two new servers have been procured to ensure uninterrupted mail services.

### 7) Renewal of Astronomical software services.

Scientists at IUCAA carry out research in a wide range of Astronomy and Astrophysics, such as Classical and quantum gravity, Cosmic magnetic fields, cosmology, large-scale structure, Galactic and extragalactic astronomy, Gravitational waves, High energy astrophysics, Instrumentation for astronomy, Observational Astronomy (Optical, UV, X-ray, and Radio), Quantum metrology for precision measurements, Solar Physics, and many more. Many of these fields require high-level data visualizations out of complex numerical data. To help create such meaningful visualizations, IUCAA procured the licenses for Mathematica, Matlab, and IDL software services.

## High Performance Computing

IUCAA currently has three major independent HPC clusters dedicated to different applications, namely Pegasus, SARATHI and VROOM.

The **Pegasus Cluster** is to serve the general computing requirement of the astronomy community associated with IUCAA. It has 80 compute nodes, 4 gpu nodes with 32 cores and 384 GB (on old) & 512GB RAM (on new). It uses InfiniBand EDR (100Gbps) as an inter-connect, and Portable Batch System (PBS) as a job scheduler. For visualisation purposes, there are two dedicated graphics nodes equipped with NVIDIA Tesla P100 GPU cards. The cluster consists of more than 2600 Physical cores. The cluster is attached to a 2 PiB parallel file system (Lustre), which is capable of delivering 15 Gbps throughput. Theoretical computing speed of the Pegasus Cluster is 150 TF. The Pegasus cluster has been utilized by about 70 high volume users

from IUCAA and various Indian Universities, running applications for Molecular Scattering, Molecular Dynamics, Stellar Dynamics, Gravitational N-Body Simulations, Cosmic Microwave Background Evolution, Fluid Mechanics, Magnetohydrodynamics, Plasma Physics, and the analysis of diverse astronomical data.

The **Sarathi Cluster** is primarily used for gravitational wave research and is mostly used by national and international members of the LIGO Scientific Collaboration (LSC), which includes many IUCAA members and Associates. The cluster is comprised of heterogeneous compute servers, it is built in three phases. The cluster consists of more than 8000 Physical cores. The theoretical peak performance of the compute node CPUs of the cluster is nearly 530 TFlops. The cluster has 2PiB PFS storage with 30Gbps write and read (1:1) throughput

The **Vroom cluster** is used solely for the MeerKAT Absorption Line Survey (MALS). This cluster has 21 compute nodes, 2 MDS nodes, 4 GPU notes and 2 head node which delivers 25 TF computing speed and has a parallel file system of 3.5 PiB usable capacity attached to it. The cluster is also attached to 2 PiB archival storage for archiving/serving the processed data to international community.

## HPC clusters listed in Top Supercomputers in India

Sarathi Cluster Phase III, Pegasus Cluster, and Sarathi Cluster Phase II are listed at 36th, 50th and 53rd rank respectively in the list of top Supercomputers in India published on January 31, 2024. The list is maintained and supported by CDAC's Terascale Supercomputing Facility (CTSF), CDAC, Bangalore. The list is available at https://topsc.cdacb.in/filterdetailstry?page=60&slug=January2024

## The IUCAA Library

The IUCAA library provides users access to a comprehensive collection of books and journals in astronomy, astrophysics, and related areas. The library acquired 64 new print titles and 361 eBooks from the Springer Physics and Astronomy collection for 2023-24 and renewed the subscription to Annual Reviews. The library maintained its renewals to the Grammarly Premium software and Overleaf, the collaborative cloud-based LaTeX editor for writing, editing and publishing scientific documents. The library renewed its subscriptions to 63 journals for 2023.

In addition to e-journal subscriptions, the library continued to receive access to seven e-resources, courtesy of the E-Shodh Sindhu Consortium for Higher Education Electronic Resources, MHRD, Government of India and two NDL e-resources as listed below:

1. **American Institute of Physics**
2. **American Physical Society**
3. **Institute for Studies in Industrial Development (ISID) Database**
4. **JGate Plus (JCCC)**

5. **Springer Link 1700 Collection and Nature Journal**
6. **Taylor and Francis**
7. **Web of Science**

**NDL e-Resources**

1. **World e-Book Library (Now available through NDLI only)**
2. **South Asia Archive (SAA) (Under National Licensing (Perpetual)**

**In addition to the usual library business, the library team of five professionals and one library intern facilitated the following activities and services:**

- **VIDWAN:** Created IUCAA faculty profiles on the VIDWAN portal (https://vidwan.inflibnet.ac.in/), which is developed and maintained by the Information and Library Network Centre (INFLIBNET) with financial support from the National Mission on Education through ICT (NME-ICT).

- **IRINS: The Indian Research Information Network System** is a web-based Research Information Management (RIM) service developed by the Information and Library Network (INFLIBNET) Centre. The portal facilitates the academic, R&D organisations, faculty members, and scientists to collect, curate and showcase scholarly communication activities and provides an opportunity to create a scholarly network. The IUCAA faculty profiles are available at https://iucaa.irins.org.

- **Open Journal System (OJS):** Manage and maintain the IUCAA Annual Report, Khagol and Vyom issues on the IUCAA website using OJS (http://publication.iucaa.in/).

- **Document Delivery Service**: Fulfilled 173 article requests from 92 users.

- **Inter-library Loan Service**: Facilitated the loan of six books to three libraries.

- **Publication Charges and Memberships:** Processed seventeen publication charge requests and renewed one arXiv membership for 2023-24.

- **Plagiarism Reports:** Provided plagiarism reports for research papers using Ouriginal software (until 30.09.2023) and DrillBit-Extreme software (01.10.2023 onwards).

- **YouTube Channel:** The library's YouTube channel had 174 videos with 8.07K subscribers and 615,733 views during the period.

- **Publication Assistance:** Assistance to the Publications Department in compiling lists of publications by IUCAA Academics and Visiting Associates and compiling ICARD reports for the 35th Annual Report.

ICARDs have been established at various Universities and Colleges with the primary functions as follows:

1. To contribute to development of innovative teaching methods designed for Astronomy. This includes development of upto date course structures and new kinds of experiment/data analysis sessions which can be a part of a starting or existing Astronomy course in a university. They will try and inculcate distant learning programs and come up with suggestions as to how they can be implemented.

2. To hold frequent workshops/schools/meetings at various levels at the host University/College and at nearby regions.

3. To have an active public outreach program for Astronomy.

4. To be a visiting Centre where nearby Astronomers can visit.

**List of ICARDs**

1. Aliah University, Kolkata
2. BITS-Pilani, Hyderabad
3. Calicut University
4. Central University of Himachal Pradesh
5. Christ (Deemed to be University) Bengaluru
6. Cochin University of Science and Technology (CUSAT), Cochin
7. Cooch Behar Panchanan Barma University
8. Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur
9. Delhi University
10. Department of Applied Mathematics - University of Calcutta
11. Department of Physics, University of North Bengal
12. Gauhati University, Guwahati
13. GLA University, Mathura
14. Goa University, Goa
15. Gurukula Kangri Vishwavidyalya, Haridwar
16. Indian Institute Technology (IIT) Indore
17. Jamia Milia Islamia (CTP), Delhi
18. Kashmir University
19. Manipal Centre for Natural Sciences, Manipal
20. Newman College, Thodupuza, Kerala
21. Providence College, Calicut, Kerala
22. Pt. Ravishankar Shukla University, Raipur
23. Swami Ramanand Teerth Marathwada (SRTM) University, Nanded
24. Tezpur University

# PUBLICATIONS BY IUCAA ACADEMICS

**Number of Publications: 173, Impact Factor: 5.19**

**Journal Titles/ Number of articles**

1. Applied Physics Letters (01)
2. Astronomical Journal (01)
3. Astronomische Nachrichten (01)
4. Astronomy & Astrophysics (18)
5. Astrophysical Journal (21)
6. Astrophysical Journal Letters (06)
7. Astrophysical Journal Supp. Series (04)
8. Astrophysics and Space Science (01)
9. Atom (02)
10. Boletin de la Asociacion Argentina de Astronomia La Plata Argentina (03) *
11. Classical Quantum and Gravity (02)
12. European Physical Journal H (01)
13. Experimental Astronomy (01)
14. Journal of Astrophysics and Astronomy (04)
15. Journal of Cosmology (01) *
16. Journal of Cosmology and Astroparticle Physics (05)
17. Journal of Fluid Mechanics (01)
18. Journal of Physics: Conference Series (01) *
19. Machine Learning: Science and Technology (01)
20. Monthly Notices of the Royal Astronomical Society (76)
21. Physical Review C (01)
22. Physical Review D (16)
23. Physical Review Letters (01)
24. Physical Review X (01)
25. Physics Letters A (01)
26. Science China Physics, Mechanics, and Astronomy (01)
27. Space Science Reviews (02)
28. The Journal of Open Source Software (01) *
29. Universe (02)

**The total number of publications is 173, of which the impact factor value of four journals (marked with *) (06 articles) is not available. Hence, the impact factor is calculated for (173-06), i.e. 167 publications only.*

# PUBLICATIONS BY IUCAA ASSOCIATES

**Number of Publications: 531, Impact Factor: 3.86**

### Journal Titles/ Number of articles

1. ACS Omega (01)
2. Acta Physica Polonica B, Proceedings Supplement (01)
3. Advances in Astronomy (02)
4. Advances in Space Research (06)
5. Annalen der Physik (04)
6. Annals of Physics (12)
7. Applied Soft Computing (01)
8. Applied Surface Science (05)
9. Asia-Pacific Journal of Atmospheric Sciences (01)
10. Astronomical Journal (01)
11. Astronomische Nachrichten (01)
12. Astronomy and Astrophysics (09)
13. Astronomy and Computing (04)
14. Astrophysical Journal (10)
15. Astrophysical Journal Letters (01)
16. Astrophysical Journal Sup. Series (03)
17. Brazilian Journal of Physics (01)
18. Bulletin de la Societe Royale des Sciences de Liege (01)
19. Bulletin of Materials Science (01)
20. Canadian Journal of Physics (07)
21. Chaos Solitons and Fractals (01)
22. Chemical Physics Impact (03)
23. Chinese Journal of Physics (23)
24. Chinese Physics C (01)
25. Classical and Quantum Gravity (05)
26. Communications in Statistics-Simulation and Computation (01)
27. Communications in Theoretical Physics (05)
28. Computational and Theoretical Chemistry (01)
29. Diamond and Related Materials (01)
30. Dynamics of Atmospheres and Oceans (02)
31. Entropy (01)
32. Environmental Science and Pollution Research (09)
33. European Physical Journal A (01)
34. European Physical Journal C (51)
35. European Physical Journal Plus (08)
36. Fortschritte der Physik (09)
37. General Relativity and Gravitation (02)
38. Gravitation and Cosmology (06)
39. Indian Journal of Physics (08)
40. International Journal of Environmental Research (01)

41. International Journal of Geometric Methods in Modern Physics (17)
42. International Journal of Modern Physics A (15)
43. International Journal of Modern Physics B (06)
44. International Journal of Modern Physics D (11)
45. International Journal of Modern Physics E (01)
46. International Journal of Neural Systems (01)
47. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (01) *
48. Journal of Astronomical Telescopes, Instruments, and Systems (01)
49. Journal of Astronomy and Space Sciences (01)
50. Journal of Astrophysics and Astronomy (15)
51. Journal of Chemical Physics (02)
52. Journal of Cosmology and Astroparticle Physics (13)
53. Journal of Earth System Science (01)
54. Journal of High Energy Astrophysics (01)
55. Journal of High Energy Physics (01)
56. Journal of Holography Applications in Physics (02) *
57. Journal of Korean Astronomical Society (01) *
58. 
59. Journal of Molecular Modeling (04)
60. Journal of Molecular Structure (01)
61. Journal of Physics G: Nuclear Physics (01)
62. Journal of Physics: Complexity (01)
63. Journal of Quantitative Spectroscopy and Radiative Transfer (01)
64. Journal of Scientific Computing (04)
65. Letters in High Energy Physics (01) *
66. Mapana – Journal of Sciences (02) *
67. Materials Chemistry and Physics (01)
68. Modern Physics Letters A (09)
69. Molecular Physics (01)
70. Monthly Notices of the Royal Astronomical Society (91)
71. New Astronomy (15)
72. Nonlinear Dynamics (02)
73. Nuclear Physics A (02)
74. Nuclear Physics B (09)
75. Open Journal of Astrophysics (02)
76. Optical and Quantum Electronics (01)
77. Optical Materials (01)
78. Optics and Lasers in Engineering (01)
79. Physica Scripta (12)

80. Physical Chemistry Chemical Physics (01)
81. Physical Review D (05)
82. Physical Review Letters (07)
83. Physics Letters B (15)
84. Physics and Chemistry of Liquids (01)
85. Physics of Plasmas (01)
86. Physics of the Dark Universe (24)
87. Planetary Science Journal (01)
88. Plasma Physics and Controlled Fusion (01)
89. Procedia Computer Science (01)
90. Research in Astronomy and Astrophysics (06)
91. Resonance (01)
92. Review of Scientific Instruments (01)
93. Science (01)
94. Spectrochimica Acta Part A: Molecular Spectroscopy (01)
95. Symmetry (02)
96. The Physics Educator (01)
97. Transportation Research Part F: Traffic Psychology and Behaviour (01)
98. Universe (05)
99. Water Air and Soil Pollution (01)

**The total number of publications is 531, of which the impact factor value of five journals (marked with*) (07 articles) is not available. Hence, the impact factor is calculated for (531-07), i.e. 524 publications only.*

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