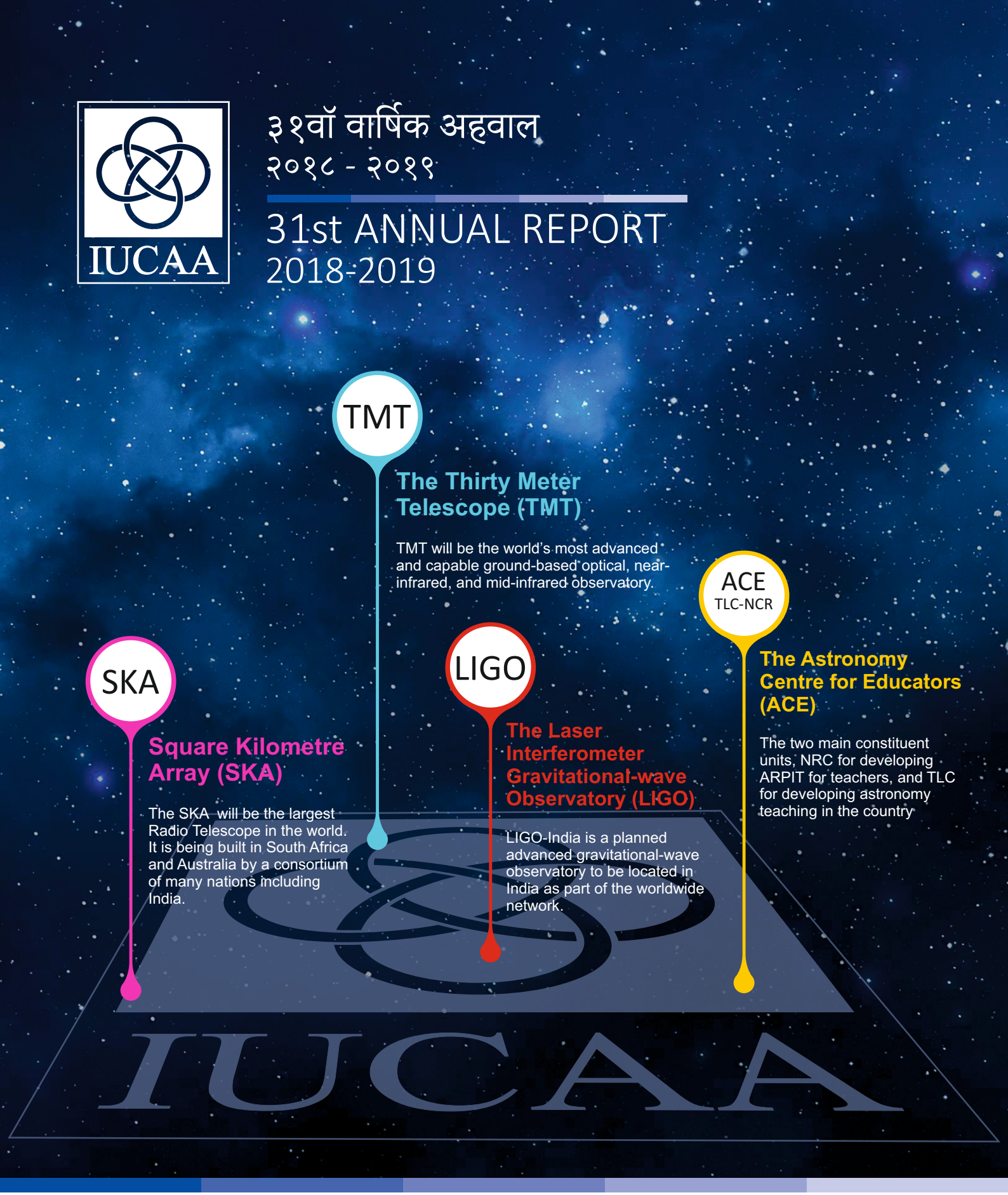

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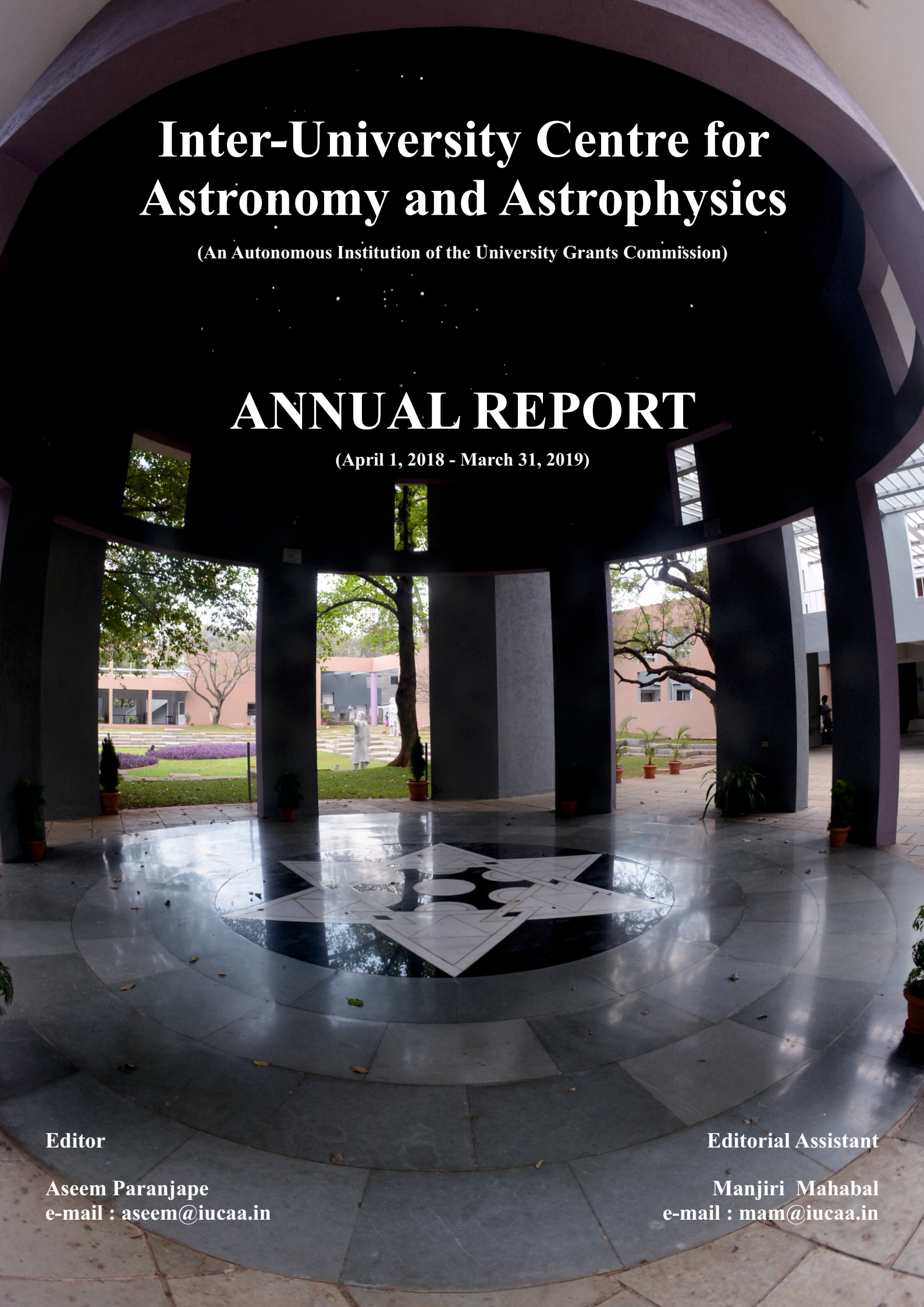
ANNUAL REPORT

(April 1, 2018 - March 31, 2019)



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154.	Vikram Soni,	Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
155.	K. Sriram,	Department of Astronomy, University College of Science, Osmania University, Hyderabad.
156.	Parijat Thakur,	Department of Basic Sciences and Humanities, Guru Ghasidas Central University, Bilaspur.
157.	Arun Varma Thampan,	Department of Physics, St. Joseph's College, Bengaluru.
158.	Sunil Kumar Tripathy,	Department of Physics, Indira Gandhi Institute of Technology, Dhenkanal.
159.	Pranjal Trivedi,	Department of Physics, Sri Venkateswara College, Delhi.
160.	Vinutha Tummala,	Department of Applied Mathematics, Andhra University, Visakhapatnam.

161. Paniveni Udayashankar, Department of Physics, NIE Institute of Technology, Mysuru.
162. Rashmi Uniyal, Department of Physics, Government Degree College, Narendranagar,
163. Sanil Unnikrishnan, Department of Physics, St. Stephen's College, Delhi.
164. Sudhaker Upadhyay Department of Physics, KLS College, Nawada.
165. Anisul Ain Usmani, Department of Physics, Aligarh Muslim University.
166. Deepak Vaid, Department of Physics, National Institute of Technology, Surathkal.
167. Bhargav P. Vaidya, Discipline of Astronomy, Astrophysics and Space Engineering, IIT, Indore.
168. Murli Manohar Verma, Department of Physics, University of Lucknow.
169. Jaswant Kumar Yadav, Department of Physics, Central University of Haryana, Mahendergarh.

The Twenty - Ninth batch (2018) of Visiting Associates, who were selected for a tenure of three years, beginning, August 1, 2018.


PIYALI BHAR


LAXMI KANT CHAWARE


SHANTI PRIYA DEVARAPALLI


V. H. DODDAMANI


SUMAN GHOSH


JESSY JOSE


SOURAV MITRA


KAMAKSHYA PRASAD MODAK


UMA PAPNOI


RATHIN SARMA


SUDHAKER UPADHYAY

The photographs for Anoubam Senorita Devi, Tuhin Ghosh, Jeena K., Nishikanta Khandai, Chayan Ranjit and Bhargav Pradeep Vaidya are not available.

Appointment of the following Visiting Associates of the Twenty-Sixth batch was extended for three years:

Gazi Ameen Ahmed, Rizwan Ul-Haq Ansari, Shyamal Kumar Banerjee, Prasad Basu, Ritabrata Biswas, Debasish Borah, Koushik Chakraborty, Mamta Dahiya, Broja Gopal Dutta, Jibitesh Dutta, Sarbari Guha, Priya Hasan, Joe Jacob, Deepak Jain, Charles Jose, Minu Joy, Soumen Mondal, Hemwati Nandan, Rajesh Kumble Nayak, Biswajit Pandey, Sanjay Kumar Pandey, Bikash Chandra Paul, Amit Pathak, Ananta Charan Pradhan, Farook Rahaman, C.D. Ravikumar, Sanjay Kumar Sahay, Prasant Samantray, Asoke Kumar Sen, Somasri Sen, Sandeep Sahijpal, Ranjan Sharma, Alkendra Singh, Parijat Thakur, Pranjal Trivedi, and Sanil Unnikrishnan.

ORGANIZATIONAL STRUCTURE OF ACADEMIC PROGRAMMES

(As on March 31, 2019)

THE DIRECTOR
Somak Raychaudhury

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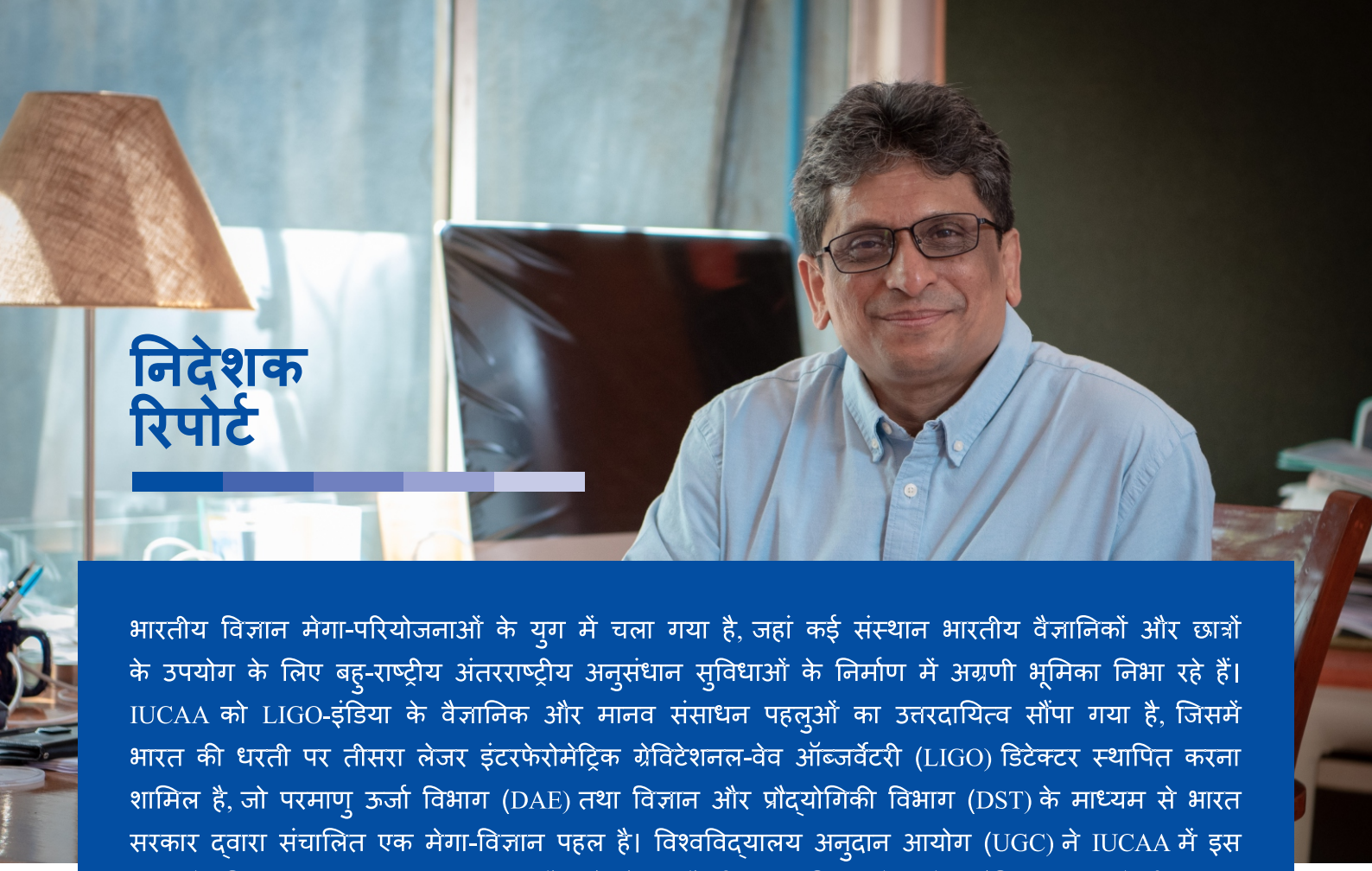
Head, Grievance Cell
Kandaswamy Subramanian



निदेशक रिपोर्ट

भारतीय विज्ञान मेगा-परियोजनाओं के युग में चला गया है, जहां कई संस्थान भारतीय वैज्ञानिकों और छात्रों के उपयोग के लिए बहु-राष्ट्रीय अंतरराष्ट्रीय अनुसंधान सुविधाओं के निर्माण में अग्रणी भूमिका निभा रहे हैं। IUCAA को LIGO-इंडिया के वैज्ञानिक और मानव संसाधन पहलुओं का उत्तरदायित्व सौंपा गया है, जिसमें भारत की धरती पर तीसरा लेजर इंटरफेरोमेट्रिक ग्रेविटेशनल-वेव ऑब्जर्वेटरी (LIGO) डिटेक्टर स्थापित करना शामिल है, जो परमाणु ऊर्जा विभाग (DAE) तथा विज्ञान और प्रौद्योगिकी विभाग (DST) के माध्यम से भारत सरकार द्वारा संचालित एक मेगा-विज्ञान पहल है। विश्वविद्यालय अनुदान आयोग (UGC) ने IUCAA में इस पहल के लिए उपलब्ध आवश्यक नए पदों एवं संसाधनों की स्वीकृति करके इसे प्रारंभिक चरण से ही अपना समर्थन दर्शाया है। साथ ही, DAE और DST द्वारा वित्तपोषित तथा जापान, चीन, कनाडा और यूएसए के कई संस्थानों के सहयोग से बनने वाले थर्टी मीटर टेलीस्कोस (30 मीटर दूरदर्शक यंत्र) की मुख्य पहलुओं का नेतृत्व भी IUCAA कर रहा है।

इसके अलावा, इसरो के वैज्ञानिक कार्यक्रमों में भारतीय विश्वविद्यालयों की ओर से IUCAA बहुत ही महत्वपूर्ण भूमिका निभा रहा है। इसरो के सहयोग से IUCAA में एस्ट्रोसैट साइंस सपोर्ट सेल (खगोलीय उपग्रह विज्ञान समर्थन कक्ष) की स्थापना की गई है, जो भारतीय विश्वविद्यालयों में हर स्तर पर शोधकर्ताओं तथा IUCAA सदस्यों को एस्ट्रोसैट (AstroSat) संबंधी वैज्ञानिक अनुसंधान करने के लिए अनूठा अवसर प्रदान करता है। IUCAA की एक उत्कृष्ट टीम सौर पराबैंगनी इमेजिंग टेलीस्कोप (SUIT) का भी निर्माण कर रही है, जो सूर्य के अध्ययन हेतु इसरो के भावी आदित्य-L1 मिशन के लिए एक अंतरिक्ष उपकरण (पेलोड) है। विज्ञान के क्षेत्र में कई भावी अंतरिक्ष परियोजनाओं को परिकल्पित करते हुए IUCAA में काफी ठोस काम शुरू हो गया है, जिसका उपयोग प्रक्षेपण (लांच) के लिए इसरो द्वारा किया जा सकता है।

वर्तमान में, IUCAA में 23 संकाय सदस्य (फैकल्टी) और सेवामुक्त संकाय सदस्य (एमेरिटस फैकल्टी), 35 पोस्ट-डॉक्टरेट फैलो और 41 पीएचडी शोध छात्र हैं, जिन्होंने 5.49 के औसत इंपैक्ट फैक्टर वाले कुल 130 पीयर-रिवीव्ड पेपर (पूर्व समीक्षित शोधपत्र) प्रकाशित किए हैं। मुझे इन आकड़ों पर बहुत गर्व है, क्योंकि यह दर्शाता है कि मेरे सहयोगी अपने शोध में न केवल बहुत उन्नतिशील हैं, बल्कि वे विषय पर पर्याप्त प्रभाव भी डाल रहे हैं। इस वर्ष के दौरान, सात IUCAA छात्रों ने पीएचडी की डिग्री प्राप्त की है। इससे भी अधिक प्रसन्नता की बात यह है कि IUCAA के 169 विजिटिंग एसोसिएट्स द्वारा इसी अवधि के दौरान 318 पीयर-रिवीव्ड पेपर (3.48 औसत इंपैक्ट फैक्टर वाले इन पेपरों में वर्षभर वृद्धि देखी गई है) प्रकाशित किए हैं। ये

सभी विजिटिंग एसोसिएट्स भारतीय विश्वविद्यालयों और कॉलेजों में संकाय सदस्य हैं, जिनके अनुसंधान कार्य में IUCAA ने सहयोग किया है। यह स्पष्ट रूप से पूरे देश के उच्च शिक्षा संस्थानों में खगोल विज्ञान और खगोल भौतिकी (A & A) संबंधी अनुसंधान को विस्तारित और पोषित करने में IUCAA के प्रभाव को दर्शाता है।

इस वर्ष के दौरान, हमारे कोर फैकल्टी (वैज्ञानिक - F) में ससम्मान श्री सुरहुद मोरे शामिल हुए, जो इससे पहले कवली इंस्टीट्यूट ऑफ फिजिक्स एंड मैथमेटिक्स ऑफ यूनिवर्स (IPMU), टोकियो, जापान में अपनी सेवा दे रहे थे। इसके अलावा, LIGO-इंडिया मेगा विज्ञान परियोजना के मद्देनजर और सशक्त होने के लिए तकनीकी और वैज्ञानिक श्रेणी में UGC द्वारा स्वीकृत नए पदों पर पांच नियुक्तियां की गईं। इनमें से तीन LIGO-इंडिया के लिए इंस्ट्रूमेंटेशन साइंटिस्ट के रूप में शामिल हुए। इनके नाम हैं- श्री सुरेश दोरावरी (जो इससे पहले अल्बर्ट-आइंस्टीन-इंस्टीट्यूट, मैक्स-प्लैंक-इंस्टीट्यूट फ्युअर ग्रेविटेशन्सफाइसिक, हनोवर, जर्मनी में कार्यरत थे); श्री शिवराज कंदासामी (जो इससे पहले LIGO-लिविंग्स्टन लेबोरेट्री, लुइसियाना, संयुक्त राज्य अमेरिका में कार्यरत थे) और सुश्री मनसादेवी पी तिरुगनानसंबंदम (जो इससे पहले कैनसस स्टेट यूनिवर्सिटी, संयुक्त राज्य अमेरिका में कार्यरत थीं)। सुश्री अनुप्रीत मोरे की नियुक्ति डेटा साइंटिस्ट के रूप में हुई, जो इससे पहले कवली IPMU में थीं, जबकि श्री दीपक बंकेर की नियुक्ति कंप्यूटर ऑफिसर के रूप में हुई, जो इससे पहले सावित्रीबाई फुले पुणे विश्वविद्यालय में कार्यरत थे।

IUCAA भारत के विश्वविद्यालयों और कॉलेजों में A & A के शिक्षण का समर्थन करने के लिए प्रतिबद्ध है। एस्ट्रोनॉमी सेंटर फॉर एजुकेटर्स (ACE) विश्वविद्यालयों और संघटक कॉलेजों की एक विस्तृत विविधता में A & A में शैक्षणिक गतिविधियों को स्थापित करने और बढ़ाने के लिए IUCAA की एक नई पहल है। मानव संसाधन विकास मंत्रालय (HRD) की एक पहल, पंडित मदन मोहन मालवीय नेशनल मिशन ऑन टीचर्स एंड टीचिंग के तहत इसका एक अंग IUCAA में टीचिंग लर्निंग सेंटर के रूप में स्थापित है। जनवरी 2019 में, यूजीसी के माननीय अध्यक्ष ने ACE के लिए नए भवन की आधारशिला रखी, जिसे वर्ष के अंत तक पूरी तरह से तैयार कर लिए जाने की संभावना है। हम आईआईटी (IITs) और आईआईएसईआर (IISERs) सहित विश्वविद्यालयों के भौतिकी, विज्ञान और इंजीनियरिंग विभागों में पूर्वस्नातक और स्नातकोत्तर स्तरों पर परिचयात्मक A & A पाठ्यक्रमों को प्रारंभ करने के लिए यूजीसी द्वारा प्रोत्साहित किए जाने वाले पाठ्यक्रमों के नए विकल्प पर आधारित तंत्र का लाभ उठाने के लिए पहले ही कई विश्वविद्यालयों की सहायता कर चुके हैं। हम भारत में किसी भी उच्च शिक्षा संस्थान के किसी भी विभाग में इस तरह की शिक्षण गतिविधियों को प्रारूपित करने और कार्यान्वित करने का समर्थन करना जारी रखे हुए हैं, और इस प्रकार से देशभर में A & A के शुरू होने से बनने वाले अपार अवसरों के लिए छात्रों को प्रशिक्षित करने में सहायता करते आ रहे हैं।

MHRD के पहल के तहत, पिछले वर्ष ही स्थापित किए गए ACE का द्वितीय भाग A & A का राष्ट्रीय संसाधन केंद्र (NRC) है। इस पहल के तहत IUCAA द्वारा विश्वविद्यालय और कॉलेज के शिक्षकों के लिए इस विषय की सभी गतिविधियों का समन्वय किया जाता है। इन गतिविधियों में से पहला स्वयं पोर्टल के लिए परिचयात्मक A & A पर 55 व्याख्यानों के मूल रूप से पहले ऑनलाइन पाठ्यक्रमों का प्रस्तुतीकरण है,

जिसके लिए एक हजार से अधिक छात्रों द्वारा नामांकन किए गए थे।

IUCAA के शैक्षणिक सदस्य पूरे देश के साथ ही पूरे विश्व में A & A, और संबंधित विषयों में महत्वपूर्ण योगदान देने तथा बैठकों, कार्यशालाओं और सम्मेलनों के आयोजन के साथ ही उनमें भाग लेना जारी रखे हुए हैं। पिछले वर्ष के दौरान, IUCAA के सदस्यों को विभिन्न शैक्षिक सम्मान प्राप्त हुए। एक दशक से हमारे सार्वजनिक और विद्यालयी आउटरीच कार्यक्रमों के मुख्य अंग रहे श्री अरविंद गुप्ता को IUCAA में उनके द्वारा बड़े स्तर पर किए गए कार्यों के लिए भारत के माननीय राष्ट्रपति द्वारा पद्मश्री से सम्मानित किया गया। श्री वरुण साहनी को DST के जे.सी. बोस फेलोशिप, INSA से होमी जहांगीर भाभा पदक से सम्मानित किया गया तथा साथ ही इन्हें TWAS का फेलो भी बनाया गया है। श्री असीम परांजपे को युवा वैज्ञानिकों के INSA पदक से सम्मानित किया गया है। श्री संजीव वी. धुरंधर को NASI वरिष्ठ वैज्ञानिक प्लेटिनम जुबली फैलोशिप से सम्मानित किया गया है। श्री संजीत मित्रा और श्री तरुण सौरदीप कॉस्मिक माइक्रोवेव बैकग्राउंड का अध्ययन करने वाले उस अंतर्राष्ट्रीय प्लैंक टीम के अंग हैं, जिसे ग्रुबर कॉस्मोलॉजी पुरस्कार 2018 से सम्मानित किया गया है। श्री सुरहुद मोरे को अमेरिकन फिजिकल सोसाइटी के 2019 मार्श लेक्चररशिप से सम्मानित किया गया है।

इस वर्ष के दौरान, हमारे यहां पहले दो सहायक संकाय सदस्यों (ऐजंगक्ट फैकल्टी मेंबर्स) की नियुक्ति तीन-तीन वर्षों के लिए की गई। ये हैं- लिस्बन विश्वविद्यालय, पुर्तगाल के श्री डेविड हिल्डिच तथा कैलिफोर्निया इंस्टीट्यूट ऑफ टेक्नोलॉजी, यूएसए के श्री आशीष महाबल।

हाई स्कूल के छात्रों और आम जनता के लिए IUCAA में बराबर सार्थक रूप से आउटरीच गतिविधियां होती रहती हैं। स्थानीय स्कूल के छात्रों के लिए नियमित रूप से हर दूसरे शनिवार को व्याख्यान / प्रदर्शनी कार्यक्रम आयोजित किए जाते हैं और इस वर्ष किए गए ऐसे आयोजनों से 10,000 से अधिक छात्र लाभान्वित हुए हैं। उल्लेखनीय है कि इस वर्ष हमारे द्वारा आयोजित राष्ट्रीय विज्ञान दिवस की गतिविधियों में 12,000 से अधिक लोग शामिल हुए हैं। हर वर्ष, राष्ट्रीय विज्ञान दिवस के करीब आते ही, IUCAA परिसर के साथ ही IUCAA गिरवाली वेधशाला क्षेत्र में वैज्ञानिक गतिविधियां और विज्ञान प्रतियोगिताएं आयोजित होना शुरू हो जाती हैं। इसके अलावा, इस वर्ष, हमारे द्वारा महाराष्ट्र के हिंगोली जिले के छात्रों और अध्यापकों को शामिल करते हुए समानांतर कार्यक्रम आयोजित किए गए। हर महीने में आकाशीय परिस्थितियों के अनुसार गुरुवार को सार्वजनिक यात्राएं (पब्लिक विजिट) तथा शुक्रवार को स्काई वॉचिंग कार्यक्रम आयोजित किए गए हैं। महाराष्ट्र के पुणे, सतारा और औरंगाबाद जिलों के ग्रामीण क्षेत्रों में विद्यालयों के छात्रों और अध्यापकों के लिए वैज्ञानिक गतिविधियों और विज्ञान प्रतियोगिताओं के रूप में पब्लिक आउटरीच कार्यक्रम आयोजित किए गए, जो IUCAA के विज्ञान लोकप्रियकरण कार्यक्रम के एक नियमित अंग हैं।

हम तीन दशक से राष्ट्रीय और अंतरराष्ट्रीय स्तर पर A & A, ब्रह्मांड विज्ञान और सैद्धांतिक भौतिक की लगभग सभी शाखाओं में मौलिक शोध और शिक्षा शास्त्र के विकास कार्य में अग्रणी हैं। IUCAA में तथा भारतीय विश्वविद्यालयों में IUCAA के विजिटिंग एसोसिएट्स के नेटवर्क के माध्यम से विश्व स्तरीय अनुसंधान में लगे IUCAA के प्रतिभाशाली एवं कड़ी मेहनत करने वाले कर्मचारियों (नियमित और

संविदात्मक दोनों) के प्रति IUCAA सदैव ऋणि रहेगा। मैं उनमें से हर एक के प्रति, अपने सलाहकारों के प्रति, गवर्निंग बोर्ड और उसके अध्यक्ष डॉ. के कस्तुरीरंगन (और हाल ही में अध्यक्ष पद पर कार्यरत डॉ श्रीकुमार बनर्जी) तथा परिषद और उसके अध्यक्ष डॉ. धीरेंद्र सिंह, यूजीसी (UGC) के अध्यक्ष के प्रति पूरी ईमानदारी से कृतज्ञता व्यक्त करता हूं। हम विश्वविद्यालय अनुदान आयोग तथा इसके अधिकारियों और कर्मचारियों के साथ ही मानव संसाधन विकास का, उनकी सहायता, सुझाव और समर्थन के लिए हार्दिक आभार व्यक्त करते हैं।

सोमक रायचौधरी
निदेशक,
IUCAA.

DIRECTOR'S REPORT

Indian science has moved into the era of mega-projects, where several institutions take leading roles in building multi-national international research facilities for the use of Indian scientists and students. IUCAA has been made responsible of the scientific and human resource aspects of LIGO - India, which involves setting up the third Laser Interferometric Gravitational-Wave Observatory (LIGO) detector on Indian soil, a mega-science initiative taken up by the Government of India through the Departments of Atomic Energy (DAE), and Science and Technology (DST). The University Grants Commission (UGC) has shown support even at this early stage by sanctioning new positions and resources available to this initiative at IUCAA. Also, IUCAA leads key aspects of the Thirty Meter Telescope, also funded by the DAE and DST, to be built in collaboration with Japan, China, Canada, and several institutions in the USA.

In addition, IUCAA plays a very important role, on behalf of the Indian Universities, in ISRO's scientific programmes. The AstroSat Science Support Cell has been established at IUCAA, supported by ISRO, providing a unique opportunity for researchers at Indian Universities at all levels, and IUCAA members, to carry out their scientific research with AstroSat. An excellent team at IUCAA is also building the Solar Ultraviolet Imaging Telescope (SUIT), a payload for ISRO's future Aditya - L1 mission to study the Sun. Substantial work has begun at IUCAA conceptualizing many of the future space projects in science that might be taken up by ISRO for launch.

IUCAA currently has 23 Faculty and Emeritus Faculty, 35 Post-Doctoral Fellows, and 53 PhD Scholars. They have collectively published 130 peer-reviewed papers, with a mean impact factor of 5.49. I am very proud of this statistic, since it shows that my colleagues are not just very productive in their research, but they are making a substantial impact on the subject. During this year, seven IUCAA students have obtained PhD degrees. Even more gratifying is the fact that the 169 Visiting Associates of IUCAA, who are faculty members at Indian Universities and Colleges, supported in their research by IUCAA, have published 318 peer-reviewed papers during the same period (with a mean impact factor of 3.48, which has been increased through the years). This clearly indicates the impact IUCAA has had in promoting and nurturing Astronomy and Astrophysics (A & A) research at institutions of higher education all over the country.

During this year, we welcomed Surhud More to our Core Faculty (Scientist - F), who has joined us from the Kavli Institute of Physics and Mathematics of the Universe (IPMU), Tokyo, Japan. Further, five appointments were made in the new positions in Technical and Scientific category, sanctioned by the UGC for augmenting capacity in view of the LIGO - India mega science project. Three have joined

as Instrumentation Scientists for LIGO - India: Suresh Doravari joined us from Albert-Einstein-Institut, Max-Planck-Institut fuer Gravitationsphysik, Hannover, Germany, Shivaraj Kandhasamy from LIGO-Livingston Laboratory, Louisiana, USA, and Manasadevi P Thirugnanasambandam from Kansas State University,USA. Anupreeta More joined as a Data Scientist from the Kavli IPMU, and Deepak Bankar joined as a Computer Officer from the Savitribhai Phule Pune University.

IUCAA is committed to support the teaching of A & A at Universities and Colleges in India. The Astronomy Centre for Educators (ACE) is a new initiative at IUCAA to establish and enhance pedagogic, and training activities in A & A in a wide variety of Universities and constituent Colleges. A part of this is the Teaching Learning Centre in A & A at IUCAA, under the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching, an initiative of the Ministry of Human Resource Development (HRD). In January 2019, the Hon'ble Chairman of the UGC laid the foundation stone for the new building for ACE, which is set to be completed for use by the end of the year. We have helped several Universities already to take advantage of the new choice-based system of courses, being encouraged by the UGC, to initiate introductory A & A courses at the under-graduate and post-graduate levels in Physics, Science and Engineering departments of Universities, including IITs and IISERs. We continue to support the design and implementation of such teaching activities in any department at any Higher Education Institutions in India, and thus, help students get trained for the immense opportunities in A & A opening up in the country.

A the second part of ACE, which was also established during the past year, is the National Resource Centre (NRC) for A & A. Under this initiative of the MHRD, IUCAA coordinates all activities in the subject for University and College teachers. The first of these activities has been the production of the very first online course of 55 lectures on Introductory A & A, for the Swayam portal, which had an enrolment of over a thousand students.

The academic members of IUCAA continue to make significant contributions to research in A & A, and related subjects, and to organise and participate in meetings and workshops all over the country, and indeed all over the world. During the previous year, among the various academic honours bestowed upon members of IUCAA, Arvind Gupta, who had led parts of our public and school outreach programme for a decade, has been awarded the Padma Shri by the Hon'ble President of India, for his work done largely at IUCAA. Varun Sahni has been awarded the J. C. Bose Fellowship of the DST, the Homi Jehangir Bhabha medal from INSA, and has been made fellow of TWAS. Aseem Paranjape has been awarded an INSA medal for Young Scientists. Sanjeev V. Dhurandhar has been awarded the NASI Senior Scientist Platinum Jubilee Fellowship. Sanjit Mitra and Tarun Souradeep are part of the International Planck team for studying the Cosmic Microwave Background, that has been awarded the Gruber Cosmology prize 2018. Surhud More has been awarded the 2019 Marshak Lecturership of the American Physical Society. During this year, we have appointed the first two Adjunct Faculty members for a period of three year each: David Hilditch of the University of Lisbon, Portugal, and Ashish Mahabal of the California Institute of Technology, USA.

IUCAA's very substantial outreach activities for high school students and the general public

continues to grow and thrive. Regular Second Saturday Lecture/Demonstration Programmes for local school students have been conducted, and just this activity has reached to over 10,000 students this year, while the National Science Day activities have been attended by more than 12,000 people. Every year, closer to the National Science Day, we have activities and science competitions in IUCAA campus, and in IUCAA Girawali Observatory region. In addition to this, this year, we have conducted parallel programmes involving students and teachers of schools in the Hingoli district of Maharashtra. Public visits have been conducted on Thursdays, and sky watching programmes on Fridays every month, as per the sky conditions. Public outreach in the form of activities and science competitions for students and teachers of schools in rural areas, in Pune, Satara, and Aurangabad districts of Maharashtra, is a regular feature of the IUCAA's science popularisation programme.

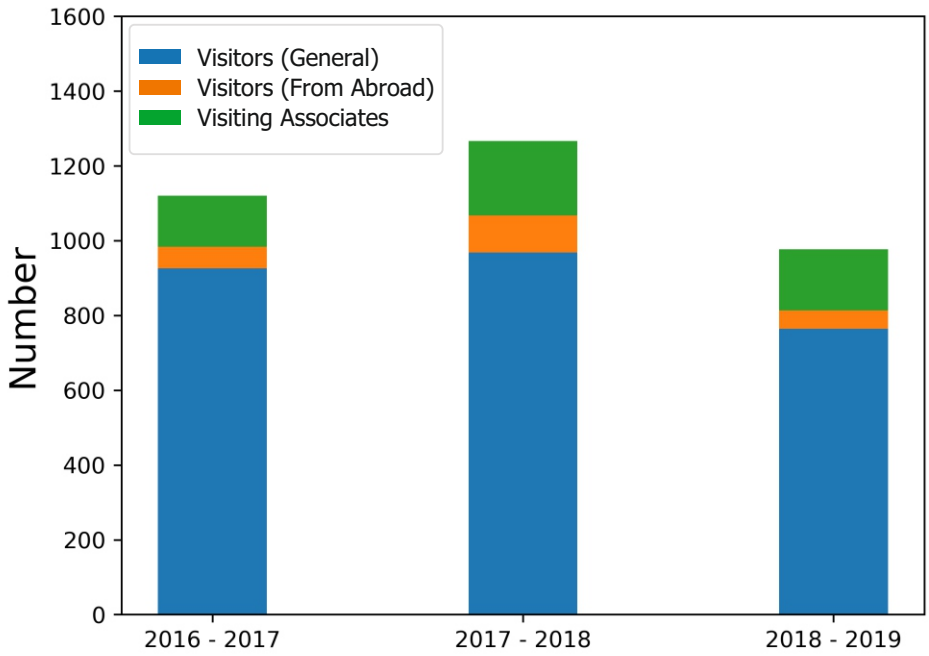
We have been at the forefront of fundamental research, and the development of teaching pedagogy, in almost all branches of A & A, Cosmology and Theoretical Physics at the national and international level, for three decades. The world-leading research at IUCAA, and at Indian Universities through the network of IUCAA Visiting Associates, owes a great deal to the hard-working and talented staff (both core and contractual) working at our institution.

I wish to express my sincere gratitude to every one of them, and to our mentors, the Governing Board with Dr. K. Kasturirangan (and until recently Dr. Srikumar Banerjee) as Chair, and the Council, chaired by Dr. Dhirendra P. Singh, Chairman of the UGC. We sincerely acknowledge the help, advice and support from the University Grants Commission, its officers and staff, and from the Ministry of Human Resource Development.

Somak Raychaudhury
Director,
IUCAA, Pune.

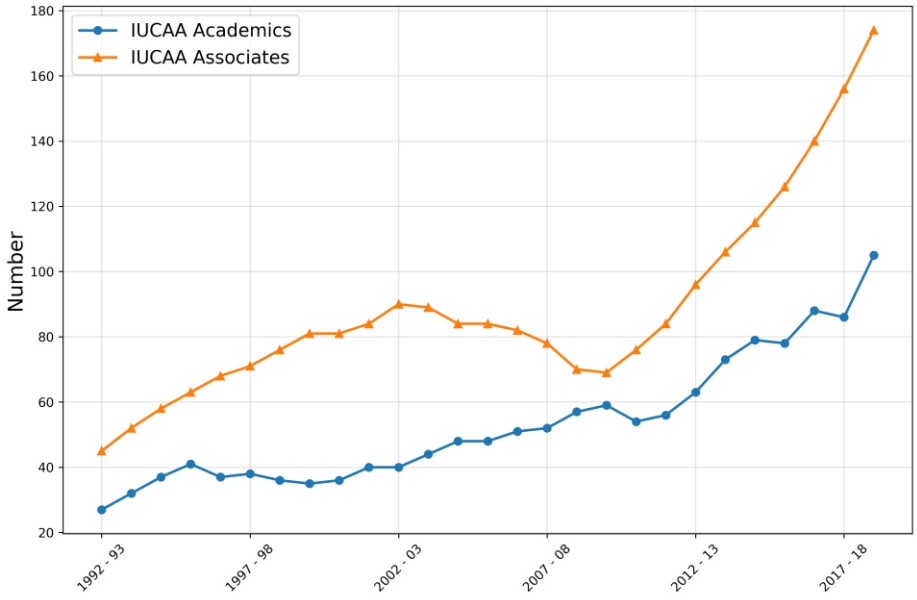
IUCAA IN NUMBERS

Visitors to IUCAA

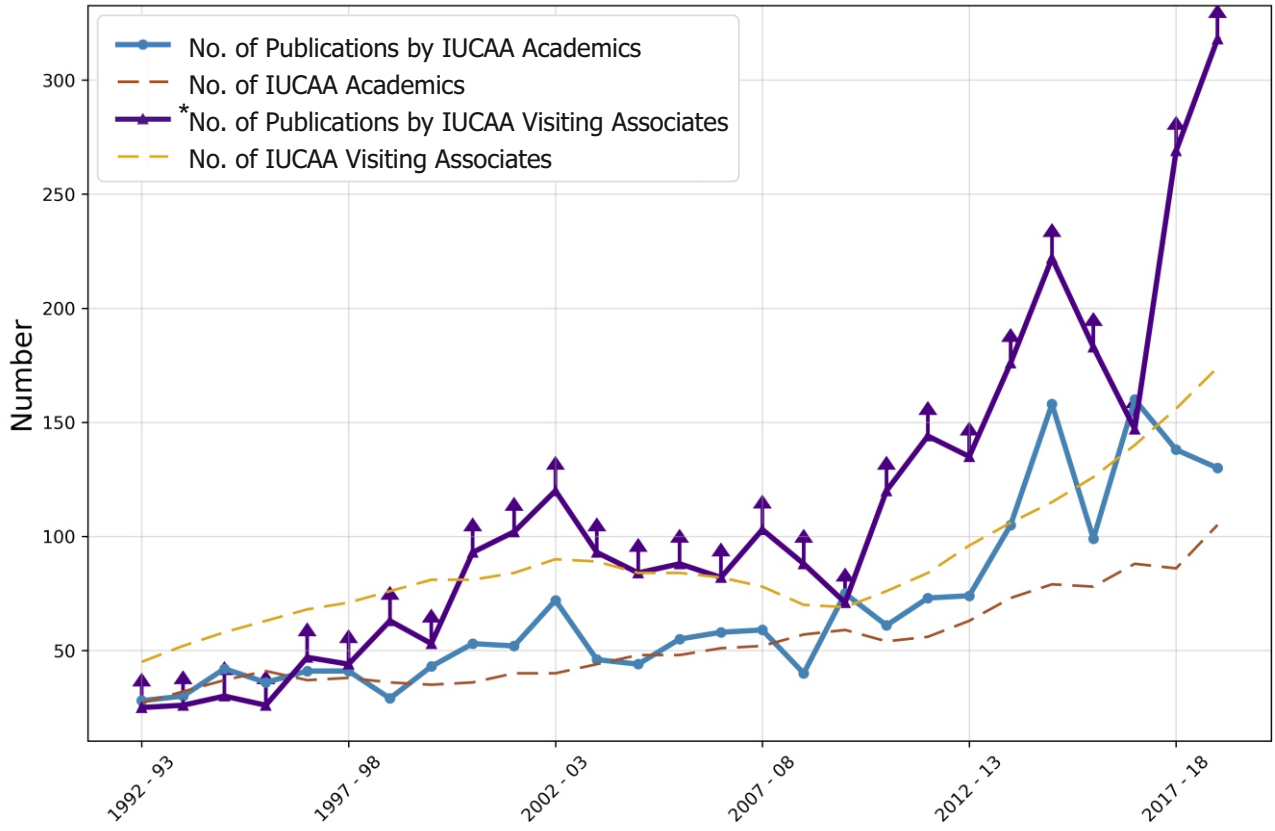


Since its inception, the IUCAA extended family of Visiting Associates has seen a steady growth over time,with an academic strength today nearly thrice its original number.

IUCAA Family across the Years



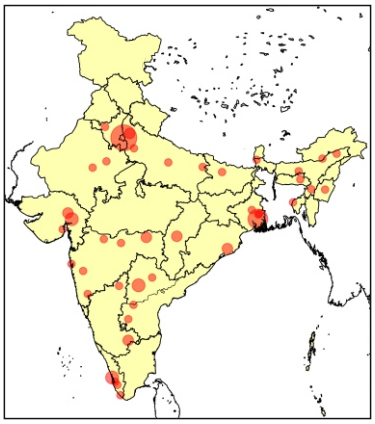
Publications across the Years



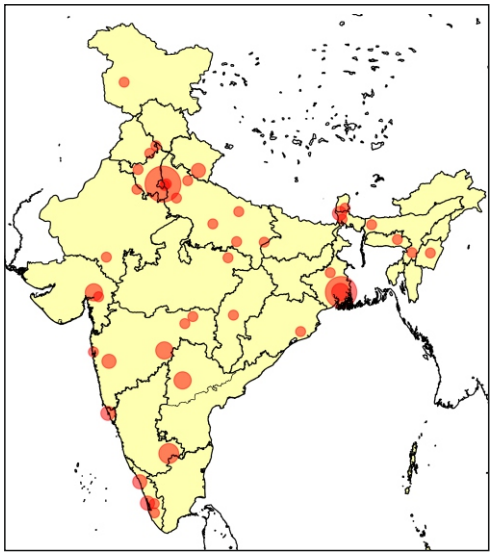
*Number of Publications by IUCAA Visiting Associates are underestimated.

The increasing academic strength has gone hand-in-hand with a corresponding increase in scientific output.

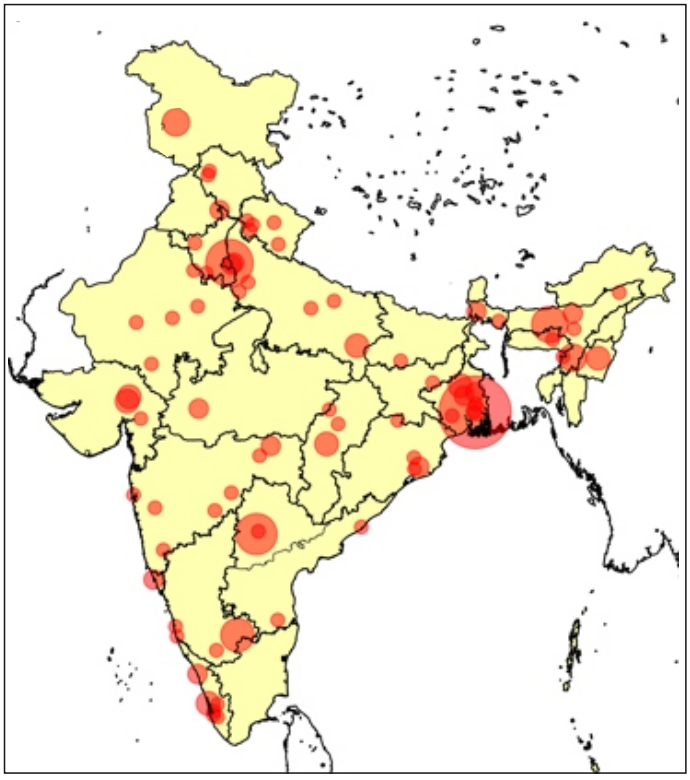
IUCAA Visiting Associates across India



1997-1998



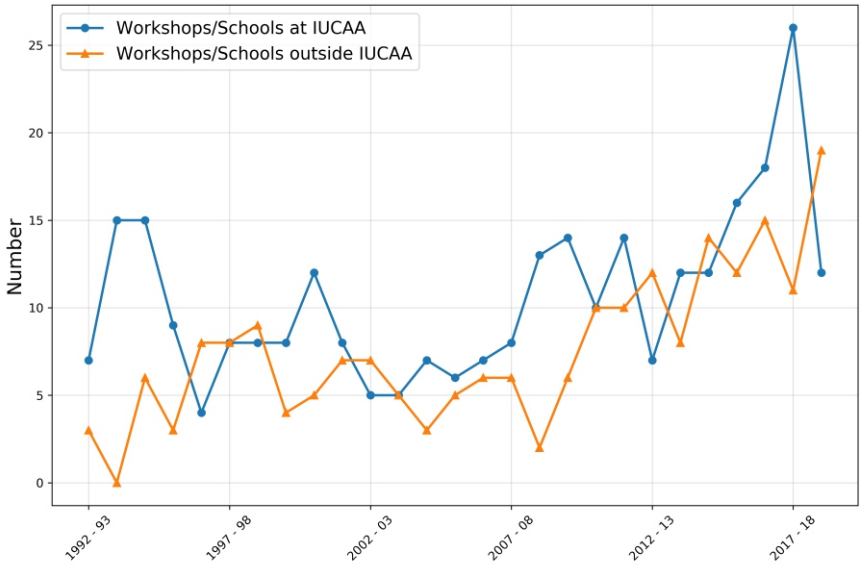
2007-2008



2017-2019

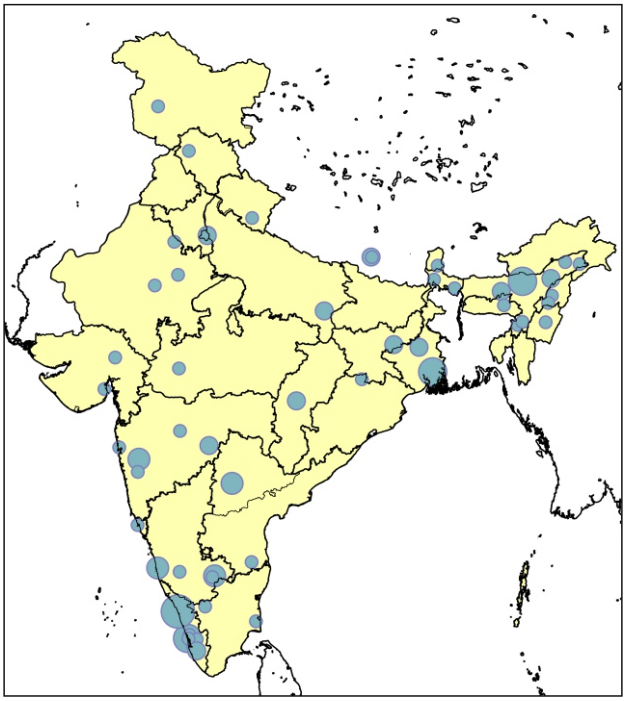
Diverse set of IUCAA Visiting Associates has continued to expand both in numbers as well as geographically, with significant representation today from the remotest parts of the country.

Workshops / Schools at IUCAA and outside IUCAA



IUCAA is committed to fostering Astronomy and Astrophysics in the Universities, primarily through an increasing frequency of Workshops and Schools, both at and outside IUCAA.

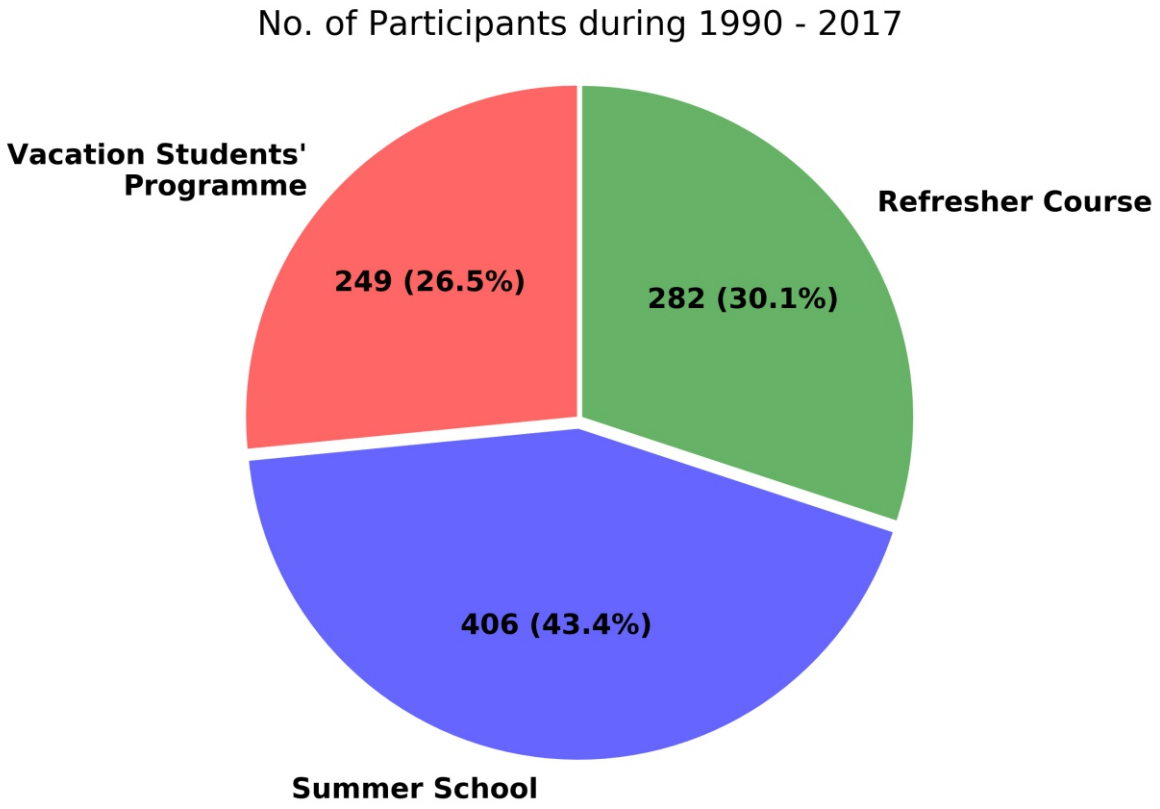
IUCAA Sponsored Workshops / Schools across India



Number of participants in workshops / schools at IUCAA is approximately 500 per year during 2015-2019

Summer Programmes at IUCAA

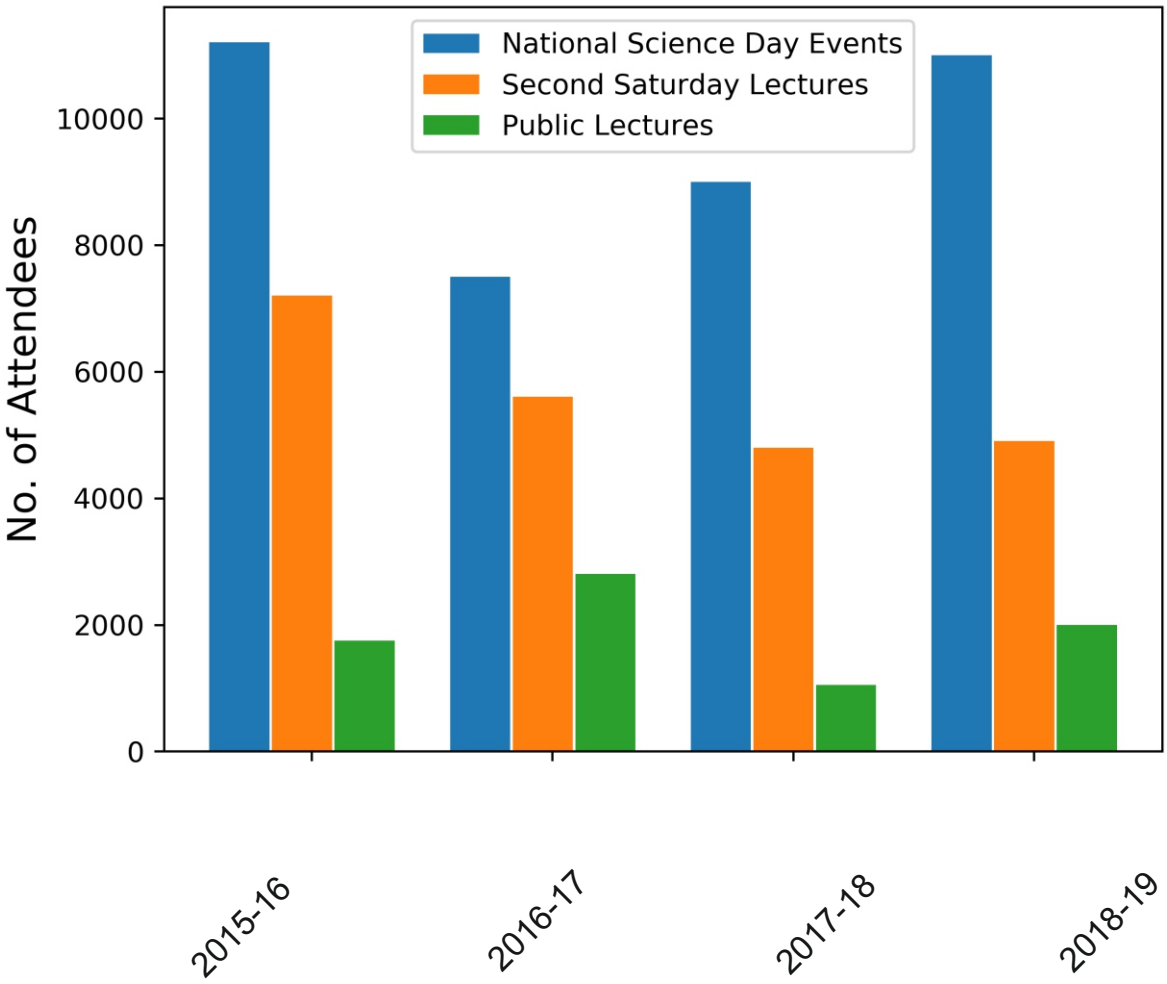
IUCAA's Summer Programmes provide short, intense crash-courses in Astronomy and Astrophysics to budding researchers at the under-graduate and post-graduate levels through the Summer School and Vacation Students' Programme, as well as to seasoned teachers through the Refresher Courses.



IUCAA also reaches about 200 students per year through the School Students' Summer Programme and Astronomy Camp, in addition to many other Outreach Activities and Events throughout the year.

Public Outreach Events at IUCAA

IUCAA also touches the lives of thousands of lay citizens each year through a variety of Public Outreach activities.



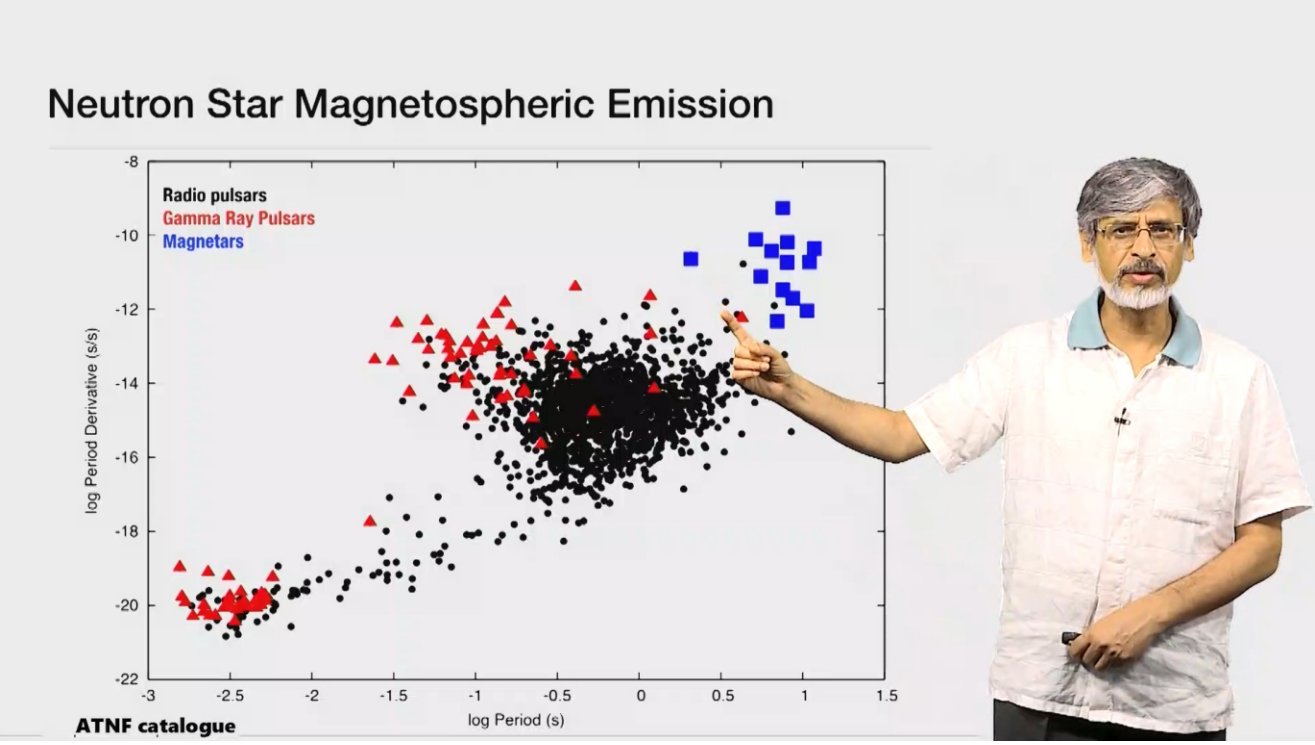
2018-19 की गतिविधियां

शिक्षक खगोल विज्ञान केंद्र

IUCAA में एक शिक्षक खगोल विज्ञान केंद्र (ACE) की स्थापना की गई है, जिसका मुख्य उद्देश्य प्रशिक्षण और कार्यशालाओं एवं विद्यालयों जैसे संबद्ध कार्यक्रमों तथा उपयुक्त संसाधन सामग्रियों के विकास के द्वारा हमारे उच्च शिक्षा संस्थानों में खगोल विज्ञान और खगोल भौतिकी के क्षेत्र में शिक्षण एवं अनुसंधान को बढ़ावा देना है। IUCAA के संस्थापक निदेशक, श्री जयंत वी नार्लीकर ने इसकी महत्ता को प्रतिपादित करते हुए, इसे IUCAA के मुख्य उद्देश्यों में जगह दी है। वर्तमान में, ACE की दो मुख्य घटक इकाइयां हैं। पहली, शिक्षकों के लिए वार्षिक शिक्षण पुनश्चर्या कार्यक्रम (एनुवल रिफ्रेशर प्रोग्राम इन टीचिंग-ARPIT) के विकास के लिए राष्ट्रीय संसाधन केंद्र (NRC) तथा दूसरी, उच्च शिक्षा के क्षेत्र में महत्ता को प्रतिपादित करने वाली देश में अग्रसर खगोल विज्ञान शिक्षण के विकास के लिए शिक्षण अधिगम केंद्र (टीचिंग लर्निंग सेंटर-TLC)। ये कार्यक्रम पंडित मदन मोहन मालवीय शिक्षक एवं शिक्षण राष्ट्रीय मिशन (PMMMNMTT) के तत्वावधान में, मानव संसाधन विकास मंत्रालय (MHRD), भारत सरकार द्वारा वित्त पोषित किए जा रहे हैं। विश्वविद्यालय अनुदान आयोग के अध्यक्ष, श्री डीपी सिंहजी ने 4 जनवरी 2019 को TLC अनुदान द्वारा वित्त पोषित नए भवन का शिलान्यास किया। भवन का सतत निर्माण प्रगति पर है तथा 2019 की समाप्ति से पहले ही इसके पूर्ण हो जाने की उम्मीद है।

वार्षिक शिक्षण पुनश्चर्या कार्यक्रम (एनुअल रिफ्रेशर प्रोग्राम इन टीचिंग-ARPIT)

NRC द्वारा ARPIT 2018-19 के लिए खगोल विज्ञान और खगोल भौतिकी पर एक वैविध्यपूर्ण व्यापक पाठ्यक्रम विकसित किया गया, जिसमें प्रत्येक वीडियो के लिए बहु-विकल्पीय प्रश्न और आगे पढ़ने के लिए सुझावों सहित 11 मॉड्यूलों में विस्तारित 57 वीडियो हैं। मॉड्यूलों में सापेक्षता सामान्य सिद्धांत, गुरुत्वाकर्षण तरंगों, क्वांटम गुरुत्व, ब्रह्मांड विज्ञान और बड़े पैमाने पर संरचना, आकाशगंगाओं और आकाशगंगा समूहों, ठोस पदार्थों की भौतिकी, सूर्य, सौर वायु और ग्रह व्यवस्था, अवलोकन संबंधी खगोल विज्ञान, अभिलेखीय डेटा से खगोल विज्ञान, समय-क्षेत्र खगोल विज्ञान तथा खगोल-सांख्यिकी जैसे विषयों की व्यापक शृंखला समाहित थीं। ये वीडियो प्रजेंटेशन देश भर में फैले उच्च शिक्षा और अनुसंधान के 11 संस्थानों में कार्यरत 27 विशेषज्ञों द्वारा तैयार किए गए थे। इन विशेषज्ञों ने इस क्षेत्र में मूल रूप से आवश्यक शिक्षा विज्ञान को भी स्पर्श करने के साथ ही उभरते क्षेत्रों पर जोर देते हुए संबंधित क्षेत्रों में हाल में हुई प्रगतियों पर प्रकाश डाला। इस पाठ्यक्रम के लिए लगभग 1350 प्रतिभागियों ने पंजीकरण किया, और इस पाठ्यक्रम को 5 में से 4.8 की अच्छी रेटिंग प्राप्त हुई।



टीएलसी (TLC) गतिविधियां

TLC का ध्यान देश में खगोल विज्ञान की शिक्षा के प्रसार और उसकी मजबूती से संबंधित कई पहलुओं पर रहा है। इनमें संबंधित संसाधन सामग्री के साथ-साथ विभिन्न स्तरों पर पाठ्यक्रम विकसित करना, प्रायोगिक और सैद्धांतिक दोनों क्षेत्रों में क्षमता निर्माण के लिए कार्य करना तथा कार्यशालाओं, विद्यालयों, विशेष संगोष्ठियों तथा रिफ्रेशर एवं अभिविन्यास कार्यक्रमों के माध्यम से संबद्ध विषय के वर्तमान तथा भावी अध्यापकों का प्रशिक्षण एवं सहयोग शामिल है। वर्ष 2018-19 के दौरान, IUCAA में तीन कार्यशालाएं आयोजित की गईं। उनमें से एक खगोल विज्ञान-विषयक प्रयोगों के विकास पर केंद्रित थी, जो कि एस्ट्रोनॉमिकल सोसाइटी ऑफ इंडिया पब्लिक आउटरीच एंड एजुकेशन कमेटी (ASI POEC) के सहयोग द्वारा संपन्न हुई। अन्य दो कार्यशालाओं का विषय एक हॉर्न एंटीना और नाइट स्काई फोटोमीटर फैब्रिकेशन के उपयोग से रेडियो अवलोकन था। दो और कार्यशालाएं IUCAA के बाहर भी संयोजित की गईं। ये दोनों प्रोविडेंस वीमेंस कॉलेज, कोझीकोड में एक्स-रे एस्ट्रोनॉमी डेटा एनालिसिस पर तथा सेंट जेवियर्स कॉलेज फॉर वूमेन, अलुवा में सौर खगोल भौतिकी (सोलर एस्ट्रोफिजिक्स) पर थीं। इन दोनों का आयोजन एकेडमी ऑफ फिजिक्स टीचर्स, केरल के सहयोग से किया गया।

खगोल विज्ञान विषयक प्रयोगों के विकास पर कार्यशाला

खगोल विज्ञान विषयक प्रयोगों के विकास पर कार्यशाला का आयोजन 18 से 20 जून, 2018 के दौरान IUCAA में किया गया। इस कार्यशाला का उद्देश्य पूर्वस्नातक एवं स्नातकोत्तर स्तरों पर भौतिकी प्रयोगशालाओं में विषय पर केंद्रित होने के लिए सहयोग करना था। देश के विभिन्न भागों से लगभग 50 खगोलविदों और महाविद्यालय

/ विश्वविद्यालय के शिक्षकों द्वारा सक्रिय रूप से इस कार्यशाला में भाग लिया गया और इनके द्वारा रेडियो, ऑप्टिकल और एक्स-रे तरंगों संबंधी कई विषयों पर प्रयोगों की चर्चा की गई। विषयों में विद्युत चुम्बकीय विकिरण के गुण, खगोल विज्ञान / दूरबीनों में प्रकाशिकी, उच्च ऊर्जा और गुरुत्वाकर्षण तरंग खगोल विज्ञान, स्थितीय खगोल विज्ञान और कक्षीय यांत्रिकी, स्पेक्ट्रोस्कोपी और वर्णक्रमीय विश्लेषण, रेडियो एंटीना, इंटरफेरोमेट्री एवं खगोलीय डेटा विश्लेषण शामिल थे। इस कार्यशाला का समन्वय समीर धुर्डे (IUCAA), प्रिया हसन (MANU, हैदराबाद) तथा जो जैकब (न्यूमैन कॉलेज, थोडुपुझा) द्वारा विशेषज्ञों के रूप में ASI-POEC सदस्यों सहित कई खगोलविद समूहों के सहयोग से किया गया था।

हॉर्न एंटीना के उपयोग से रेडियो अवलोकनों पर कार्यशाला

IUCAA में 9 से 11 मार्च 2019 के दौरान आयोजित हॉर्न एंटीना के उपयोग से रेडियो अवलोकनों पर कार्यशाला में आधा दर्जन संस्थानों के संकाय सदस्यों ने भाग लिया। इस कार्यशाला का उद्देश्य गलैक्टिक प्लेन से आने वाले 1420.4 मेगाहर्ट्ज के न्यूट्रल परमाण्विक हाइड्रोजन के HI लाइन का पता लगाने के लिए एक हॉर्न एंटीना और एक पूर्ण प्रणाली बनाना तथा इसके पीछे की भौतिकी को समझना था। इस कार्यशाला में प्रतिभागियों ने माउंट के साथ हॉर्न एंटीना के निर्माण के लिए सभी यांत्रिक भागों को एसेंबल किया तथा साथ ही हाइड्रोजन लाइन का पता लगाने के लिए सभी प्रारंभिक इलेक्ट्रॉनिक्स को भी एसेंबल और कनेक्ट किया। एंटीना तैयार हो जाने के बाद, इसे गैलेक्टिक प्लेन की ओर प्वाइंट किया गया, जिससे प्रतिभागी स्क्रीन पर स्पेक्ट्रम देख सकें। हमारी आकाशगंगा के घूर्णन के कारण शेष आवृत्ति की तुलना में 1420 मेगाहर्ट्ज लाइन में परिवर्तन हुआ था। इस गतिविधि को IUCAA रेडियो फिजिक्स लेबोरेटरी, विशेषकर जमीर मनूर और आशीष म्हस्के की तकनीकी देखरेख में किया गया था। विद्यालय का समन्वय IUCAA के सयाली अवाचट, जॉयदीप बागची और मनोजेंदु चौधरी द्वारा किया गया था और ये तीनों इस कार्यशाला में विशेषज्ञ भी थे।




नाइट स्काई फोटोमीटर फैब्रिकेशन पर कार्यशाला

नाइट स्काई फोटोमीटर फैक्रिकेशन पर कार्यशाला का आयोजन 12 से 16 मार्च 2019 के दौरान किया गया, जिसमें 5 संस्थानों के संकाय सदस्यों द्वारा भाग लिया गया।

IUCAA के इंस्ट्रूमेंटेशन प्रयोगशाला द्वारा विकसित एक डिजाइन का उपयोग करते हुए, प्रतिभागियों ने नाइट स्काई फोटोमीटर बनाने के लिए सभी इलेक्ट्रॉनिक घटकों को एसेंबल किया। IUCAA के विशेषज्ञों द्वारा प्रतिभागियों को विभिन्न घटकों को सोल्डर और संयोजन करने की कला सिखाई गई। फोटोमीटर तैयार हो जाने के बाद प्रतिभागियों द्वारा साधन को कैलिब्रेट किया गया तथा IUCAA, पुणे की छत एवं IUCAA गिरावली वेधशाला से एक छोटे दूरबीन के उपयोग से आकाश एवं चमकीले तारों का अवलोकन किया गया। इस कार्यशाला का आयोजन IUCAA इंस्ट्रूमेंटेशन प्रयोगशाला, विशेष रूप से IUCAA के भूषण जोशी और विलास मेस्त्री और IUCAA के रंजन गुप्ता तथा नेहरू तारामंडल के अरविंद परांजपे अतिरिक्त विशेषज्ञ के रूप में शामिल थे। की

तकनीकी देखरेख में किया गया। कार्यशाला का समन्वयन सयाली अवाचट, मनोजेंदु चौधरी और रंजन गुप्ता द्वारा किया गया।

एक्स-रे खगोल विज्ञान डेटा विश्लेषण पर मिनी-स्कूल

भौतिकी शिक्षक अकादमी (APT), केरल तथा IUCAA, पुणे के साथ भौतिकी विभाग, प्रोविडेंस वीमेंस कॉलेज, कोझिकोड द्वारा 22 से 26 मई 2018 के दौरान महाविद्यालयीन शिक्षकों के लाभ के लिए, एक्स-रे खगोल विज्ञान डेटा विश्लेषण पर एक मिनी-स्कूल का आयोजन किया गया।

मिनी स्कूल का मुख्य उद्देश्य प्रतिभागियों को मल्टीवेवलेंथ खगोल विज्ञान के सैद्धांतिक और प्रेक्षणमूलक पहलुओं और इस क्षेत्र की वर्तमान चुनौतियों से अवगत कराना था। प्रतिभागियों की संख्या बीस तक सीमित रखी गई थी। मिनी स्कूल केवल प्रायोगिक सत्रों पर केंद्रित था। इसमें AstroSat, LAXPC & SXT के एक्स-रे पेलोड्स के विस्तृत डेटा विश्लेषण किए गए। प्रतिभागियों को समूहों में विभाजित किया गया था तथा प्रत्येक ग्रुप को LMXB's, AGNs आदि जैसे एक्स-रे ऑब्जेक्ट्स के एस्ट्रोसैट डेटा एसाइन किए गए थे। कार्यक्रम के अंत तक, प्रतिभागी प्रारंभिक विश्लेषण को पूरा करने में सक्षम थे, और साथ ही प्रारंभिक परिणाम भी मिले। इसमें सावित्री एझिकोड (सेंट थॉमस कॉलेज, कोजेनशरी), रंजीव मिश्रा (IUCAA), स्नेहा प्रकाश (क्राइस्ट, बेंगलुरु) और जितेश वी. (IUCAA) विशेषज्ञ थे। इस कार्यक्रम का समन्वयन जीना करुणाकरण (प्रोविडेंस वीमेंस कॉलेज, कालीकट) और रंजीव मिश्रा (IUCAA) द्वारा किया गया।

सौर खगोल भौतिकी के परिचय पर कार्यशाला

सेंट जेवियर्स कॉलेज फॉर वूमेन, अलुवा में 2 से 3 मार्च 2019 के दौरान भौतिकी शिक्षक संघ (APT) के सहयोग से 'सौर खगोल भौतिकी का परिचय' विषय पर दो दिवसीय राष्ट्रीय कार्यशाला का आयोजन किया गया। कार्यशाला में शिक्षकों, युवा शोधकर्ताओं और स्नातकोत्तर छात्रों को लक्षित किया गया। इस कार्यशाला में कुल मिलाकर 49 प्रतिभागी थे। कार्यशाला में सुबह में व्याख्यान सत्र तथा दोपहर बाद प्रायोगिक सत्र रखे जाते थे। इस कार्यशाला में विशेषज्ञ के रूप में सरगम मुले, श्रीजीत पधिनजत्तेरी और दुर्गेश त्रिपाठी (सभी IUCAA से) तथा अवीक सरकार (PRL, अहमदाबाद से) शामिल थे। इस कार्यशाला का समन्वयन जो जैकब (न्यूमैन कॉलेज, थोडुपुझा), दुर्गेश त्रिपाठी (IUCAA) और सुजाता एन.वी. (सेंट जेवियर्स कॉलेज, अलुवा) द्वारा किया गया था।

NRC और TLC स्टॉफ

IUCAA NRC और TLC दोनों की गतिविधियों का प्रबंधन डी जे सैकिया, प्रमुख NRC और TLC द्वारा संजीत मित्रा, संकाय-समन्वयक; मनोजेंदु चौधरी, शैक्षिक समन्वयक; सयाली अवाचट, वरिष्ठ अनुसंधान कर्मचारी; प्रीति के और चैत्रा नारायण, परियोजना सहायक तथा अनिकेत कडु और शिवराज के क्षत्रिय, इंटर्न्स के सहयोग से किया गया। सुचित हस्बनीस (SPPU), विवेक कन्नडी और परमेश्वर एस यादव (IISER पुणे) तथा कमला कन्नन (IIT मद्रास) ने वीडियो रिकॉर्डिंग करने में मदद की।

HIGHLIGHTS OF 2018 - 2019

Astronomy Centre for Educators

An Astronomy Centre for Educators (ACE) has been established at IUCAA with the primary objectives of promoting the growth of teaching and research in Astronomy and Astrophysics in our institutions of higher education via training and allied programmes such as workshops and schools, and development of appropriate resource material. These have been among the core objectives of IUCAA as outlined by its Founder Director, Jayant V. Narlikar. The two main constituent units of ACE at present are the National Resource Centre (NRC) for developing the Annual Refresher Programme In Teaching (ARPIT) for teachers, and the Teaching Learning Centre (TLC) for further developing astronomy teaching in the country with an emphasis in the higher education sector.The programmes are being funded by the Ministry of Human Resource Development (MHRD), Government of India, under the aegis of Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching (PMMMNMTT) Scheme. Chairperson of the University Grants Commission, Professor D. P. Singh, laid the foundation stone for the new building funded by the TLC grant on the January 4, 2019. The construction is making steady progress, and the building is expected to be completed before the end of 2019.

Annual Refresher Programme in Teaching (ARPIT)

The NRC has developed a broad-based course on Astronomy and Astrophysics for ARPIT, consisting of 57 videos spread across 11 modules, along with multiple-choice questions for each video and suggestions for further readings. The modules covered a wide range of topics which included the general theory of relativity, gravitational waves, quantum gravity, cosmology and large scale structure, galaxies and clusters of galaxies, physics of compact objects, the Sun, solar wind and planetary systems, observational astronomy, astronomy from archival data, time-domain astronomy and astrostatistics. These video presentations were made by 27 resource persons from 11 institutions of higher education and research spread across the country. They have highlighted recent developments in the respective areas while also touching upon the basic required pedagogy, and emphasising emerging areas in the field. About 1350 participants have registered for the course, which was well received with the course being rated as 4.8 out of 5.

TLC Activities

The focus of the TLC has been on a number of aspects related to the spreading and strengthening of Astronomy education in the country. These include developing course curricula at different levels along with the associated resource material, working towards capacity building in the subject in both experimental and theoretical areas, and training and supporting present and future teachers of the subject via workshops, schools, specialised seminars and refresher and orientation programmes. During the year 2018-19, three workshops were held at IUCAA, which were on developing astronomy-themed experiments, done in collaboration with the Astronomical Society of India Public Outreach and Education Committee (ASI-POEC), radio observations using a horn antenna, and night sky photometer fabrication; and two outside IUCAA. These were on X-ray astronomy data analysis at Providence Women's College, Kozhikode, and on solar astrophysics at St. Xavier's College for Women, Aluva, both held in collaboration with the Academy of Physics Teachers, Kerala.

Workshop on Developing Astronomy-Themed Experiments

The workshop on Developing Astronomy-Themed Experiments, which would help get the subject into physics laboratories at under-graduate and post-graduate levels was held at IUCAA from June 18 to 20, 2018. There were about 50 astronomers and college/university teachers from various parts of the country, actively participating in the workshop which discussed experiments on a number of themes at radio, optical and X-ray wavebands. The themes included properties of electromagnetic radiation, optics in astronomy/telescopes, high energy and gravitational waves astronomy, positional astronomy and orbital mechanics, spectroscopy and spectral analysis, radio antennas, interferometry and astronomical data analysis. This workshop was coordinated by Samir Dhurde (IUCAA), Priya Hasan (MANU, Hyderabad) and Joe Jacob (Newman College, Thodupuzha) with several groups of astronomers including ASI-POEC members as resource persons.

Workshop on Introduction to Solar Astrophysics

A two-day national workshop was conducted at St. Xavier's College for Women, Aluva, during March 2 to 3, 2019, in collaboration with the Association of Physics Teachers (APT), Kerala, on the theme of Introduction to Solar Astrophysics. The workshop targeted teachers, young researchers and post-graduate students, and there were 49 participants in all. The programme consisted of lectures in the morning and hands-on sessions in the afternoon. The resource persons included Sargam Muley, Sreejith Padhinhatteeri and Durgesh Tripathi (all from IUCAA), and Aveek Sarkar from PRL, Ahmedabad. The Workshop was co-ordinated by Joe Jacob (Newman College, Thodupuzha), Durgesh Tripathi (IUCAA) and Sujatha N.V. (St. Xavier's College, Aluva).

Workshop on Radio Observations using a Horn Antenna

Faculty members from half a dozen institutions participated in the workshop on Radio Observations using a Horn Antenna at IUCAA from March 9 to 11, 2019. The goal of this workshop was to build a horn antenna and a complete system to detect the HI line of neutral atomic hydrogen at 1420.4 MHz coming from the Galactic plane and understand the physics behind it. In this workshop participants assembled all the mechanical parts to construct the horn antenna along with the mount and also assembled and connected all the front-end electronics to detect the hydrogen line. Once the antenna was ready, it was pointed towards the Galactic plane and the participants could see the spectrum on the screen. There was a shift in the 1420 MHz line compared to the rest frequency due to the rotation of our Galaxy.

This was done under the technical supervision of IUCAA Radio Physics Laboratory, particularly Jameer Manur and Ashish Mhaske. The school was coordinated by Sayali Avachat, Joydeep Bagchi and Manojendu Choudhury, all from IUCAA, who were also resource persons for the workshop.

Workshop on Night Sky Photometer Fabrication

The Workshop on Night Sky Photometer Fabrication was held from March 12 to 16, 2019 and attended by faculty members from 5 institutions. Using a design developed by the Instrumentation Laboratory of IUCAA, the participants assembled all the electronic components to make the night sky photometer. The IUCAA resource persons taught them the art of soldering and assembling the various components. Once the photometer was ready, the participants calibrated the instrument, made observations of the sky and bright stars using a small telescope from both the terrace at IUCAA, Pune and the site of the IUCAA Girawali Observatory. This workshop was carried out under the technical supervision of IUCAA Instrumentation Laboratory, in particular Bhushan Joshi and Vilas Mestry, and with Ranjan Gupta from IUCAA and Arvind Paranjpye from Nehru Planetarium, Mumbai were the additional resource persons. The workshop was coordinated by Sayali Avachat, Manojendu Choudhury and Ranjan Gupta, all from IUCAA.

Mini-school on X-ray Astronomy Data Analysis

The Department of Physics, Providence Women's College, Kozhikode in collaboration with Academy of Physics Teachers (APT), Kerala and IUCAA, Pune, organized a Mini-School in X- ray Astronomy Data Analysis, for the benefit of college teachers during May 22-26, 2018. The main aim of the mini-school was to make the participants aware of the theoretical and observational aspects of multi-wavelength Astronomy and the present challenges in this field. The number of participants was restricted to twenty.

The mini -school focused on hands-on sessions only, and the detailed data analyses of the X-ray payloads of AstroSat, LAXPC and SXT were carried out. Participants were divided into groups and AstroSat data of X-ray objects like, LMXB's, AGNs, etc. were assigned to each group. By the end of the programme, participants were able to complete the preliminary analysis, and come up with early results. Savithri Ezhikode (St.Thomas College, Kozhenchery), Ranjeev Misra (IUCAA), Sneha Prakash (Christ University, Bengaluru) and Jithesh V. (IUCAA) were the resource persons. The coordinators of the school were Jeena Karunakaran (Providence Women's College, Calicut) and Ranjeev Misra (IUCAA).

NRC and TLC staff

The activities of both NRC and TLC have been overseen by D. J. Saikia, Head, NRC and TLC, with Sanjit Mitra as Faculty Coordinator, Manojendu Choudhury as Academic coordinator, Sayali Avachat as Senior Research Staff, Preethi K. and Chaitra Narayan as Project Assistants, and Aniket Kadu and Shivraj K. Kshatriya as Interns. Suchit Hasabnis (SPPU), Vivek Kannadi and Parmeshwar S. Yadav (IISER Pune) and Kamala Kannan (IIT Madras) helped in recording the videos.

RESEARCH HIGHLIGHTS

In 2018-19 IUCAA completed another successful year of cutting-edge research on diverse topics at the forefront of Astronomy and Astrophysics.

Highlighted is a small selection of them.

DARK MATTER

Over the years, astronomical measurements have led to the conclusion that nearly 90% of the matter in the universe is of a nature yet unknown. Called "Dark Matter" (DM) due to its near-absent interaction with electromagnetic waves, its presence is revealed only through its gravity. At IUCAA, several ongoing research programmes are aimed at developing an understanding of the nature of DM. The standard hypothesis is that the DM consists of weakly interacting massive particles, but despite long-running experiments, no evidence for such particles has yet been found. Researchers at IUCAA have explored other possibilities, one of them being Primordial Black Holes. Such black holes may have been formed in the early universe and would not be directly visible today. However, when such a black hole crosses our line of sight to a star, gravitational deflection of light would cause a temporary brightening of the star's apparent brightness, which is called a microlensing event. IUCAA astronomers have searched for microlensing of stars in our companion galaxy Andromeda, and found at most one case. The rarity of these events has led the team to conclude that Primordial Black Holes can at best account for only a small fraction of DM, the main contribution must come from some other form of material.

Structures like Galaxies and Clusters of Galaxies in the universe are thought to form by DM condensing into large self-bound Halos, the gravity of which attracts ordinary matter to flock to them and create the visible structures. The shape and density distribution of these Halos would depend sensitively on the nature of DM. While much is known about the expected properties of Halos created by the standard model of Cold Dark Matter (CDM) composed of massive leptons, IUCAA scientists have explored the properties of Halos that could be generated by an alternative form of matter composed of light Bosons, named the Fuzzy Dark Matter. Their investigations reveal a feature-rich dynamics, with Halo shells first collapsing and then expanding, leading to collisions between shells and a density distribution, quite different from that expected of CDM. Detailed observations should, in time, be able to distinguish between these two possibilities.

In order to understand the progression of structure formation in the universe, one needs to resort to large numerical simulations. Given the high costs involved in carrying them out, it is a challenging task to study structures at multiple scales. Scientists at IUCAA have now devised a novel method to combine a small number of simulations of different spatial extents to accomplish this at a much reduced cost.

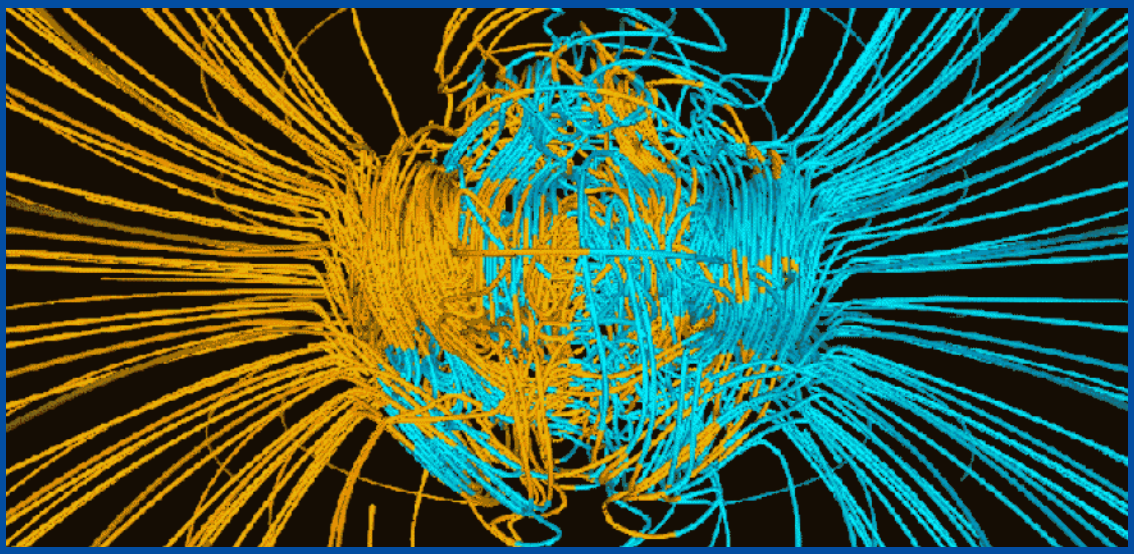
GALAXIES

The process of cosmological structure formation gives rise to bound structures like galaxies. Galaxies present themselves in a wide variety of shapes -- some resulting from the original assembly of material, some due to the merger of multiple early galaxies, and yet others due to the stripping of gas as the galaxy moves through a dense surrounding medium. IUCAA scientists have suggested a new mechanism for the formation of a type of galaxy called Lenticular, distinguished by a dominant, spheroidal stellar bulge. They show via numerical simulations that certain spiral galaxies with prominent disks can become unstable, causing the disk to break up, clump and contribute to the bulge formation.

MAGNETIC FIELD

Galaxies consist of dark matter and gas, where some of the gas condenses to form stars. The diffuse gas inhabiting the space between stars exists in the form of a partially ionised plasma. One ubiquitous entity that threads through all this gas is a magnetic field, whichis present everywhere in the universe at varying strengths. The origin of these magnetic fields continues to remain an unsolved mystery. Scientists at IUCAA, while exploring a popular mechanism called the Dynamo, have discovered that this operates on two different scales. The process is at first driven at small scales by turbulent motion of gas and as that saturates, the large scale differential motion of gas takes over to amplify the field manifold. The Dynamo mechanism is in fact an amplification process, the success of which depends on the existence of an initial seed field, however weak. Some say that the seed field originated in the very early universe, during a phase of rapid expansion called the Inflation. Scientists at IUCAA have demonstrated that such an origin will be accompanied by the generation of Gravitational Waves that would be detectable by the future generation of instruments.

Magnetic fields play a key role in the dynamics of the outer layers of the Sun, especially the chromosphere and the Corona. Sunspots and solar active regions harbour very strong magnetic fields. Research at IUCAA has uncovered the role of inclined magnetic fields in the transport of energy from the lower to the upper layers of the solar atmosphere. Waves of millihertz frequency travelling along these field lines are seen to be responsible for this energy transfer. This may help explain why the outermost parts of the solar atmosphere, namely the corona, can stay much hotter than the solar surface.



BLACK HOLES

Very massive stars at the end of their lives would undergo core collapse to generate a Black Hole. This is usually accompanied by a most spectacular explosion, known as a Gamma Ray Burst (GRB). Extensive research is going on at IUCAA on the study of black holes and the matter around them. At the centre of this activity is the Indian X-ray/UV astronomy satellite AstroSat. IUCAA, in collaboration with ISRO, operates the Science Support Cell for this mission, and interacts with a wide cross section of researchers across India, especially from the university sector.

Over 50 birth events of black holes, namely GRBs, have been detected by the AstroSat team at IUCAA during the year. Several stellar mass black holes that are accreting material from a normal stellar companion have been studied extensively with AstroSat. In one such system, 4U1630-47, these observations have revealed that the black hole is spinning extremely rapidly, near the maximum allowed limit. In another system, Cygnus X-1, detailed modelling of intensity fluctuations has led to the conclusion that inward-propagating temperature fluctuations in the ``accretion disk'' created by matter falling into the black hole explains the observed variability pattern. Many supermassive black holes, millions of times heavier than the sun and residing at the centres of galaxies, have also been studied. Simultaneous multi-wavelength observations of the blazer 1H0323+342, an object of this class, have shown how, from time to time, material from the accretion disk is ejected at high speed forming jet-like outflow along the spin axis of the black hole.

A more detailed description of the above, and of many other results from IUCAA's research activities this year, may be found in the section "Research at IUCAA" later in this report.

IUCAA
IN NEWS

TIMES CITY | PUNE

40 Indians in star collision discovery team

2nd Biggest Find After G-Waves From Black Holes

THE EUREKA MOMENT

'Colliding neutrons bolster gravitational wave claim'

Telescopes that made a huge difference

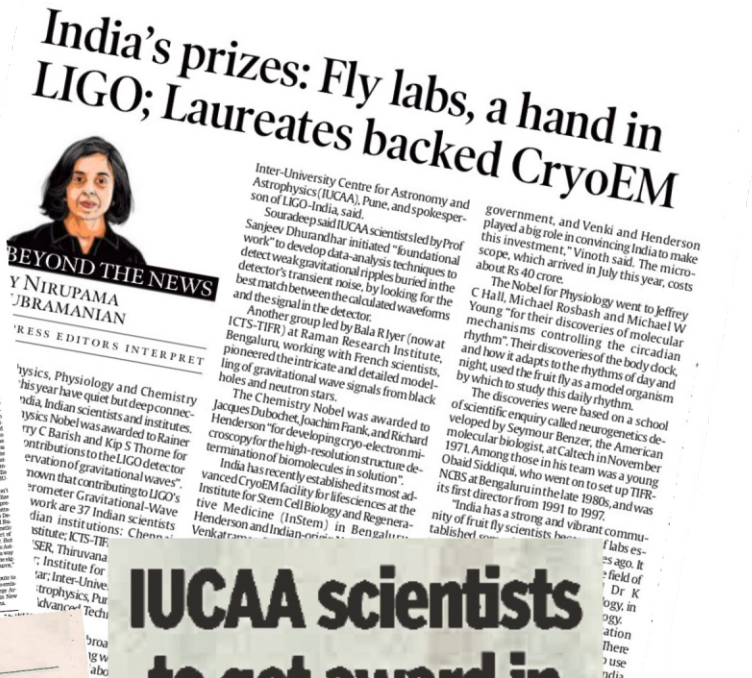
Frequency low, but sensitivity high

Missing flashes helped detection

Images from the Himalayan heights

All eyes now on LIGO-India detector

IUCAA scientists contributed most to country's share



India's prizes: Fly labs, a hand in LIGO; Laureates backed CryoEM

BEYOND THE NEWS

Y NIRUPAMA
UBRAMANIAN

RESS EDITORS INTERPRET

Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, and spokesperson of LIGO-India, said.

Souradeep said IUCAA scientists led by Prof Sanjeev Dhurandhar initiated "foundational work" to develop data-analysis techniques to detect weak gravitational ripples buried in the detector's transient noise, by looking for the best match between the calculated waveforms and the signal in the detector.

Another group led by Bala R Iyer (now at ICTS-TIFR) at Raman Research Institute, Bengaluru, working with French scientists, pioneered the intricate and detailed modelling of gravitational wave signals from black holes and neutron stars.

The Chemistry Nobel was awarded to Jacques Dubochet, Joachim Frank, and Richard Henderson "for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution".

India has recently established it's most advanced CryoEM facility for lifesciences at the Institute for Stem Cell Biology and Regenerative Medicine (InStem) in Bengaluru.

government, and Venki and Henderson played a big role in convincing India to make this investment," Vinoth said. The microscope, which arrived in July this year, costs about Rs 40 crore.

The Nobel for Physiology went to Jeffrey C Hall, Michael Rosbash and Michael W Young "for their discoveries of molecular mechanisms controlling the circadian rhythm". Their discoveries of the body clock, and how it adapts to the rhythms of day and night, used the fruit fly as a model organism by which to study this daily rhythm.

The discoveries were based on a school of scientific enquiry called neurogenetics developed by Seymour Benzer, the American molecular biologist, at Caltech in November 1971. Among those in his team was a young Obaid Siddiqui, who went on to set up TIFR-NCBS at Bengaluru in the late 1980s, and was its first director from 1991 to 1997.

"India has a strong and vibrant community of fruit fly scientists bas-

10 | The Economic Times magazine cover story
AUGUST 26-SEPTEMBER 01, 2018

REACHING FOR THE STARS

Shedding its reticence about spending on major, multi-country science projects, India is emerging as a big partner in the pursuit of fundamental truths

:: Mauni Goyal

"The big shift is that India is moving from the periphery to the core of such mega global science projects"
RA Mashelkar
former director general, CSIR

"This government has been very positive and took some bold decisions by backing projects like LIGO"

The Shift

Global era: Frontier-exploring projects are becoming multi-country and big-budget

Individual to institution: Individually, Indian scientists have been part of many government is backing such projects

Economic dividend: Indian economy, past the $2.6 trillion mark, now has the economic bandwidth to fund such mega projects

Trickle effect: The government realises the multiplier effect of such projects on knowledge, talent and the science ecosystem

The Hurdles

Talent supply: India needs to nurture enough world-class researchers and scientists to work on such mega projects

Funding glitches: Bureaucratic lag between fund commitment and release creates challenges for projects on tight deadlines

Project management: Instead of being managed by an empowered CEO, mega projects in India are driven by directors coming in for short tenures

DAE shadow: Mega projects are funded by Department of Atomic Energy or the space agency, leading to security challenges like issuing visas

Big Bang Ambition

Over the last decade, India's science ambitions have grown bigger and global. From small, India-focused projects, the government is increasingly betting big on mega, multi-country projects. The country wants a seat at the high table of global science. It is true that the buzz around science under the Narendra Modi government has acquired a needless mythological air, with talk of Ganesha's head transplant and Pushpak Viman. But the government has also taken some serious steps in putting India on the world science map.

In 2017, India formally agreed to build a Laser Interferometer Gravitational-Wave Observatory, or LIGO, in India, and joined the global LIGO project. In 2016, India became an associate member of the famous CERN project, the world's largest nuclear and particle physics laboratory in Europe.

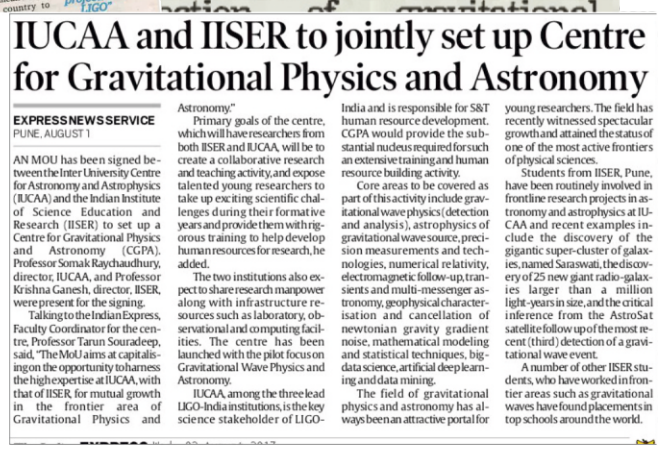
In 2015, India became a full member of the SKA project, which is building the world's largest radio telescope. From nuclear fusion project (to study evolution of universe) in Germany and from cancer genome project to deep ocean exploration, India is increasingly an unprecedented participant in the world's most ambitious projects.

Individually, Indian scientists have been participating in global projects from the 1960s. The narrative research is a case in point. "The big shift is that India is moving from the periphery to the core of such mega global science projects. This shift has happened over the last decade and is significant," says R A Mashelkar, former director general of the Council of Scientific and Industrial Research (CSIR).

India's science dreams are fuelled by two trends – one global and the other Indian. In society and economy, while globalisation seems to be in retreat, in the world of science it is thriving. Today's mega science projects that explore new frontiers have become costly and resource-intensive, difficult for any single country to

IUCAA scientists to get award in astrophysics

Nine researchers of the Inter-University Centre for Astronomy and Astrophysics (IUCAA) are part of a group of contributers to be rewarded at a grand ceremony in Mountain View, California, USA, on Monday for their work on de-



IUCAA and IISER to jointly set up Centre for Gravitational Physics and Astronomy

EXPRESS NEWS SERVICE
PUNE, AUGUST 1

AN MOU has been signed between the Inter University Centre for Astronomy and Astrophysics (IUCAA) and the Indian Institute of Science Education and Research (IISER) to set up a Centre for Gravitational Physics and Astronomy (CGPA). Professor Somak Raychaudhury, director, IUCAA, and Professor Krishna Ganesh, director, IISER, were present for the signing.

Talking to the Indian Express, Faculty Coordinator for the centre, Professor Tarun Souradeep, said, "The MoU aims at capitalising on the opportunity to harness the high expertise at IUCAA, with that of IISER for mutual growth in the frontier area of Gravitational Physics and Astronomy."

Primary goals of the centre, which will have researchers from both IISER and IUCAA, will be to create a collaborative research and teaching activity, and expose talented young researchers to take up exciting scientific challenges during their formative years and provide them with rigorous training to help develop human resources for research, he added.

The two institutions also expect to share research manpower along with infrastructure resources such as laboratory, observational and computing facilities. The centre has been launched with the pilot focus on Gravitational Wave Physics and Astronomy.

IUCAA, among the three lead LIGO-India institutions, is the key science stakeholder of LIGO-India and is responsible for S&T human resource development. CGPA would provide the substantial nucleus required for such an extensive training and human resource building activity.

Core areas to be covered as part of this activity include gravitational wave physics (detection and analysis), astrophysics of gravitational wave source, precision measurements and technologies, numerical relativity, electromagnetic follow-up, transients and multi-messenger astronomy, geophysical characterisation and cancellation of newtonian gravity gradient noise, mathematical modeling and statistical techniques, big-data science, artificial deep learning and data mining.

The field of gravitational physics and astronomy has always been an attractive portal for young researchers. The field has recently witnessed spectacular growth and attained the status of one of the most active frontiers of physical sciences.

Students from IISER, Pune, have been routinely involved in frontline research projects in astronomy and astrophysics at IUCAA and recent examples include the discovery of the gigantic super-cluster of galaxies, named Saraswati, the discovery of 25 new giant radio-galaxies larger than a million light-years in size, and the critical inference from the AstroSat satellite follow up of the most recent (third) detection of a gravitational wave event.

A number of other IISER students, who have worked in frontier areas such as gravitational waves have found placements in top schools around the world.

विद्यार्थ्यांचा सहभाग : राष्ट्रीय विज्ञान दिनानिमित्त शैक्षणिक संस्थांमध्ये उपक्रम

गिरवले वैज्ञानिकतेचे धडे

पुणे : आयुका, सी-डॅक, सावित्रीबाई फुले पुणे विद्यापीठासह शहरातील विविध शैक्षणिक व वैज्ञानिक संस्थांमध्ये विज्ञान दिनानिमित्त मंगळवारी आयोजित केलेल्या विविध कार्यक्रमांना हजारो विद्यार्थी व विज्ञानप्रेमींनी हजेरी लावली. ग्रह, तारे, गुरुत्वीय लहरी, आकाशगंगा, गुरुत्वाकर्षण, मानवी शरीराची रचना, अवकाशवेळी यांच्यासह दृष्टिभ्रमाचे विविध प्रकार उपग्रह, रोबोट आदींची माहिती घेतली. तसेच तज्ज्ञांकडून वैज्ञानिक संकल्पना समजावून घेतल्या.

विज्ञान दिनाच्या निमित्ताने आयुका सर्वांसाठी खुले करण्यात आले होते. त्यामुळे पुणे शहरासह राज्यातील व राज्याबाहेरील विज्ञानप्रेमींनी व विद्यार्थ्यांनी सकाळपासूनच आयुकातील विविध संशोधनपर गप्पा केली होती. सूर्याचील डाग, गुरुत्वीय लहरींबाबच न्यूट्रॉन गॅलिलिओ, आईनस्टाईन आदी शास्त्रज्ञांनी लावलेल्या शोधांची विद्यार्थ्यांना माहिती घेतली. विद्यार्थ्यांना विज्ञानाची गोडी लागावी या उद्देशाने अनेक शाळांनी सर्व विद्यार्थ्यांना आयुकातील विज्ञान प्रदर्शन दाखवण्यासाठी आणले होते. विद्यार्थी विविध प्रयोग करून पाहण्यात दंग झाले होते. तसेच विज्ञानातील विविध संकल्पना समजून घेऊन तज्ज्ञांना प्रश्नही विचारत होते.

विज्ञान दिनानिमित्त मंगळवारी आयोजित करण्यात आलेल्या विज्ञान प्रदर्शनात माहिती घेताना विद्यार्थिनी.

विज्ञानाविषयी शाळेत मिळणाऱ्या माहितीपेक्षा विविध प्रकल्पांची प्रत्यक्ष माहिती घेता आली. याचे खूप समाधान वाटते. पृथ्वी पलीकडच्या विश्वाला अनुभवताना मजा आली. शाळेत पक्षात शास्त्रज्ञांबद्दल माहिती दिली जाते. तसेच पुस्तकात ही माहिती वाचायला मिळते. मात्र, आयुकाच्या आवारातील शास्त्रज्ञांचे पुतळे पाहून मला खूप आनंद झाला.

- प्रनिकेत मदने, विद्यार्थी

अनेक प्रकारच्या दुर्बिणी, ताऱ्यांशी झालेली ओळख आणि विविध प्रकल्प पाहता आज मजा आली. महाविद्यालयात अनेकदा विज्ञानातील घडामोडींविषयी फक्त चर्चा होते. या प्रदर्शनातून विज्ञानाच्या विविध तंत्रज्ञानाशी ओळख झाली.

- धनंजय महानुभव, विद्यार्थी

महाविद्यालयात सहसा या वैज्ञानिक घडामोडींबद्दल माहिती मिळण्यात येत नाही. म्हणून प्रदर्शन, अभ्यासी सहल, पो... माध्यमांतून मिळालेली मा... विद्यार्थ्यांना खूप उपयोगी जगातील विविध संशोध... प्रयोगांची माहिती मिळ... उत्तम व्यासपीठ होते.

- वैशाली सद...

उपग्रह म्हण... दुर्बिणीचा ग्रह, तारे कसे पाहा... मिळाली. पुस्तकां... समजून घेता आल... पुस्तकामध्ये जे ... प्रत्यक्षात अनुभ... रेडिओ लहरी, ... ट्रान्समीटर आ... घेता आल्या. आपणही या... अशी इच्छा.

पाहता ... प्रेझेंटेश... संकल्प... मॉन्सू... प्रमा... प्रक... वर्त... प्रा...

कृष्ण पदार्थाचा थ्री-डी नकाशा

'आयुका'तील डॉ. मोरे यांचा संशोधनात सहभाग

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डॉ. सुहृद मोरे

विश्वाचे २० ते २५ टक्के वस्तुमान व्यापणाऱ्या कृष्ण पदार्थाचा (डार्क मॅटर) तपशीलवार, त्रिमितीय (थ्री-डी) नकाशा बनवण्यात खगोलशास्त्रज्ञांच्या आंतरराष्ट्रीय गटाला यश आले आहे. नकाशा तयार करण्यासाठी गुरुत्वाकर्षणाच्या ...ावातून प्रकाशाचे वक्रीभवन ...ाच्या (ग्रॅव्हिटेशनल लेन्सिंग) ...कयेचा आधार घेण्यात आला आहे. ...ोलशास्त्रज्ञांनी त्यासाठी तब्बल ...क कोटी दीर्घिकांच्या (गॅलेक्झी) ...याचित्रांचा अभ्यास केला. पुण्यातील 'आयुका'त नव्याने रुजू झालेल्या डॉ. सुहृद मोरे या तरुण शास्त्रज्ञाचा या संशोधन प्रकल्पात प्रमुख सहभाग आहे. टोकियो येथील कावली इन्स्टिट्यूट फॉर द फिजिक्स अँड मॅथेमॅटिक्स ऑफ द युनिव्हर्स या संस्थेच्या शिआकी हिकागे यांच्या नेतृत्वाखाली सहा शास्त्रज्ञांच्या गटाने हे संशोधन केले आहे.

मोरे आणि त्यांच्या सहकाऱ्यांनी सुमारे एक कोटी दीर्घिकांचे आकार तपासून त्यांच्या आकारात 'ग्रॅव्हिटेशनल लेन्सिंग'मुळे झालेला अतिसूक्ष्म बदल नोंद केला. दीर्घिकांच्या आकारातील या बदलावरून आकाशाच्या ठराविक भागामध्ये कृष्ण पदार्थाचे असणारे अस्तित्व तर सिद्ध झालेच; पण त्या भागामध्ये असणारे त्याचे प्रमाणही समजले. या नोंदींच्या आधारेच कृष्ण पदार्थाचा त्रिमितीय नकाशा बनवण्यात त्यांना यश आले. हवाई बेटांवरील ८.२ मीटर व्यासाचा सुबारू टेलिस्कोप आणि ८२० मेगापिक्सलच्या कॅमेरा वापरून शास्त्रज्ञांनी अब्जावधी प्रकाशवर्षे दूर असणाऱ्या सुमारे एक कोटी दीर्घिकांची छायाचित्रे घेतली.

'कृष्ण पदार्थ' म्हणजे काय?

वेश्वातील आपल्याला दिसणारा पदार्थ हा एकूण वस्तुमानाच्या फक्त ...ाच टक्के असून, उर्वरित ... ...क्के पदार्थ आपल्याला दिसू शकत ...ाही. त्यांमध्ये २० ते ... कृष्ण पदार्थाचा, तर ७० ते ७५ ...क्के भाग क... ...मानले जाते. कृष्ण पदार्थाच्या वेशाल ... ...न पुढे ताऱ्यांची निर्मिती होते.

...काय?

...णेच त्याच्यामधील ...यीही शास्त्रज्ञांना ...ात दीर्घिकांची ... प्रसरण किती ... उपयुक्त

'चांद्रयान-१'चा 'आयुका'त वाढदिवस

खगोलप्रेमींसाठी व्याख्यानाचे आयोजन

संग्रहित छायाचित्र

पुणे : पृथ्वीचा उपग्रह असणाऱ्या चंद्राच्या संशोधनात्मक अभ्यासासाठी भारतातर्फे अवकाशात पाठविण्यात आलेले पहिलेवहिले यान अर्थात, 'चांद्रयान-१'ला दहा वर्षे पूर्ण झाल्याचे औचित्य साधून 'आयुका'तर्फे चांद्रयानाचा वाढदिवस सोमवारी साजरा करण्यात आला. चंद्राच्या अभ्यासासंदर्भातील पुढची महत्त्वाकांक्षी मोहीम असणारे 'चांद्रयान-२' लवकरच मोहिमेवर निघणार आहे. त्या पार्श्वभूमीवर 'चांद्रयान-१'च्या आठवणी जागवून त्या मोहिमेचे महत्त्व या वेळी विषद करण्यात आले. त्याचप्रमाणे रात्रीच्या मिट्ट काळोखात खगोलप्रेमींनी

व्याख्यानातून प्रकाश टा...

नाईक म्हणाले, 'देशाच्या... ऑक्टोबर २००८ हा दिवस सु... नोंदला जावा, असा आहे. चंद्रावि... अनेक अज्ञात गोष्टी या मोहिमेमुळे ... येऊ शकल्या. विशेष म्हणजे, आप... देशाने यशस्वीपणे पूर्ण केलेली ही मोही... आपल्यापेक्षाही प्रगत असणाऱ्या अनेक देशांच्या तुलनेत किफायतशीर आणि अधिक प्रभावी ठरली. अमेरिकेसारख्या देशांनाही याची दखल घ्यावी लागली. याचे श्रेय अर्थातच भारतीय अवकाश संशोधन संस्थेच्या (इस्रो) शास्त्रज्ञांच्या

'लायगो इंडिया'ची निर्मिती लवकरच

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गुरुत्वीय लहरींच्या शोधाशी निगडित 'लायगो इंडिया' अर्थात, लेझर इंटरफेरोमीटर ग्रॅव्हिटेशनल वेव्ह ऑब्झर्वेटरी या प्रकल्पास पंतप्रधान नरेंद्र मोदी यांनी मान्यता दिली असून, लवकरच हा प्रकल्प प्रत्यक्षात येणार आहे. जगात भारताचे भौगोलिकदृष्ट्या असलेले स्थान आणि या विषयात काम करत असलेल्या शास्त्रज्ञांची असलेली भक्कम फळी या गोष्टी लायगो इंडियाच्या दृष्टीने फायदेशीर ठरणार आहेत, अशी माहिती 'आयुका'चे शास्त्रज्ञ प्रा. सौमेंद्र धुरंधर यांनी पुरवतीय दिली.

'पुणे इंटरनॅशनल (पीआयसी) आयोजित व्याख्यानमालिकेत 'कृष्ण अबाउट सायन्स अँड टेक्नॉलॉजी' या व्याख्यानाअंतर्गत प्रा. धुरंधर यांचे 'एआरव्ही'विषयी व्याख्यान आयोजित करण्यात आले होते. या वेळी ते बोलत होते. गौतमकाशातील नोबेल पुरस्कार २०१७ : गुरुत्वीय लहरींचा शोध' या व्याख्यानाचा विषय त्यांच्या होता.

'एआरव्ही'विषयी व्याख्यान

'कृष्ण अबाउट सायन्स अँड टेक्नॉलॉजी' या व्याख्यानमालेत दर दोन महिन्यांनी विज्ञानातील विषयावर मान्यवर चर्चा अशा, आंतरविषयक व्याख्यान घडविण्यात येणार आहे. यामुळे इंटरनॅशनल' दर

'पीआयसी'च्या कार्यक्रम समितीचे अध्यक्ष प्रा. अमिताभ मलिक, प्रा. संगीता काळे, पीआयसीचे सदस्य आणि विद्यार्थी उपस्थित होते.

प्रा. धुरंधर यांनी न्यूट्रॉन आइनस्टाइन या महान शास्त्रज्ञांनी गुरुत्वाकर्षणासंबंधी मांडलेले नियम, आता प्रत्यक्ष गुरुत्वीय लहरींचा शोध सिद्ध होण्यापर्यंतचा विज्ञानाचा प्रवास त्यांनी उलगडला. 'लायगो' प्रकल्पात काम करणाऱ्या आपला अनुभव आणि याच शोधासाठी मिळालेल्या नोबेल पुरस्कार यांविषयी प्रा. धुरंधर यांनी सांगितले.

संशोधन प्रकल्पांसाठी 'इनोव्हेशन कौन्सिल'

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केंद्रीय मंत्री प्रकाश जावडेकर यांची माहिती

आयुकामध्ये आयोजित कार्यक्रमात केंद्रीय मंत्री प्रकाश जावडेकर, प्रसिद्ध शास्त्रज्ञ जयंत नारळीकर एका प्रसन्न क्षणी. (मध्यभागी) कुलगुरू नितीन करमळकर.

शिक्षकांच्या क्षमतांसाठी तंत्रज्ञान

पुणे : 'एकीकडे देशात विद्यार्थ्यांच्या ज्ञानकक्षा रुंद व्हाव्यात म्हणून तंत्रज्ञानाचा उपयोग मोठ्या प्रमाणावर वाढत असताना, आपण आता शिक्षकांच्या क्षमता विकसित व्हाव्यात, म्हणूनही तंत्रज्ञानाचा उपयोग करायला सुरुवात केली आहे. केंद्र सरकारने सुरू केलेल्या 'स्वयं' या ... माध्यमातून आता यूजीसीच्या इंटर युनिव्हर्सिटी सेंटर्सचा होणारा उपयोग' या विषयावर झालेल्या शोध-शिक्षा-समीक्षा परिषदेत जावडेकर बोलत होते. या वेळी ज्येष्ठ शास्त्रज्ञ प्रा. जयंत नारळीकर, विद्यापीठ अनुदान आयोगाचे (युजीसी) अध्यक्ष व्ही. एस. चौहान, 'आयुका'चे संचालक डॉ. सोमक रायचौधरी आदी उपस्थित होते.

जावडेकर म्हणाले, 'इंटरनेट ऑफ ... तयारी आहे.

संशोधनच देशाला समृद्धी कडे नेणार, यात शंका नाही. 'इनोव्हेशन' हेच येत्या काळाचे प्रमुख सूत्र असणार आहे. अशक्य ते शक्य होऊ शकते, ते केवळ इनोव्हेशनच्या आधारेच. देशात येत्या काळात संशोधन आणि नवनिर्मितीच्या आधारावरच उच्च शिक्षण पुढे नेण्यात येणार आहे.'

चौहान म्हणाले, 'निरनिराळ्या ... जोडणाऱ्या

नोबेल विजेत्या शोधात आयुकाचा सहभाग ही अभिमानास्पद बाब- प्रा. धुरंधर

...तिनिधी, पुणे

गुरुत्वीय लहरींच्या संशोधनाबद्दल नोबेल पुरस्कारप्राप्त ज्येष्ठ शास्त्रज्ञ प्रा. संजीव धुरंधर यांनी सोमवारी विद्यार्थ्यांशी संवाद साधला.

कोशिका विज्ञान केंद्राचे शास्त्रज्ञ डॉ. जानेश कुमार आणि डॉ. अमिताभ मजुमदार यांनी अनुक्रमे भौतिकशास्त्र, रसायनशास्त्र आणि शरीरविज्ञान शाखांमधील २०१७ चे नोबेल पुरस्कारप्राप्त शास्त्रज्ञ आणि त्यांच्या संशोधनाविषयी विद्यार्थ्यांना मार्गदर्शन केले.

२०१६ मध्ये जाहीर केली. ऑक्टोबर २०१७ मध्ये या संशोधनाची दखल नोबेल पुरस्काराकडून घेण्यात आली. गुरुत्वीय लहरींचे संशोधन हे भौतिकशास्त्रातील अतिशय महत्त्वाचे संशोधन असून या लहरींचे अस्तित्व सिद्ध झाल्याने ...

मायक्रोस्कोपी' या नोबेल पुरस्कार विजेत्या संशोधनाची माहिती डॉ. जानेश कुमार यांनी विद्यार्थ्यांना दिली. जॅक्स डबचेट, जोशिम फ्रँक आणि रिचर्ड हेन्डरसन या शास्त्रज्ञांनी विकसित केलेल्या या तंत्रज्ञानामुळे अतिसूक्ष्म जैव रेणूंचे चित्र घेणे शक्य झाले असल्याचे डॉ. कुमार यांनी स्पष्ट केले. क्रायो इलेक्ट्रॉन मायक्रोस्कोपीमुळे अति सूक्ष्म जैव रेणूंच्या प्रतिमा टिपणे शक्य होणार असून त्याचा उपयोग अनन्यसाधारण असल्याचेही ते म्हणाले. माणसांचा दिनक्रम घड्याळाच्या काट्यावर असतो तसा शरीराचाही दिनक्रम असतो. त्यासाठी शरीराचेही जैविक घड्याळ असते. ...

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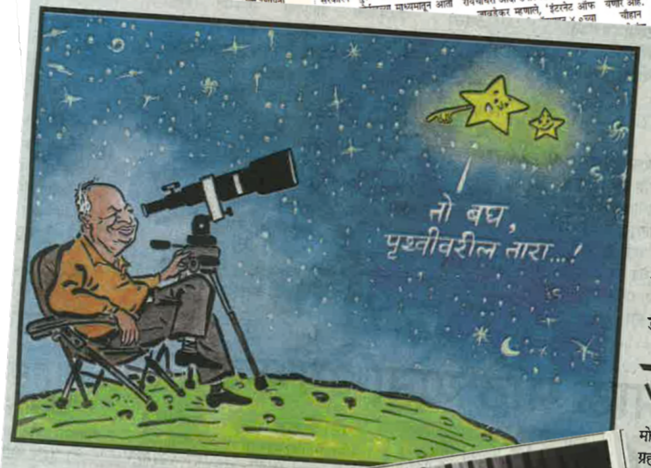


आकाशाशी नाते जोडणारा माणूस!

जागतिक कीर्तीचे खगोलशास्त्रज्ञ डॉ. जयंत नारळीकर यांचा आज ८० वा वाढदिवस. कुतूहलापायी आकाशाशी नाते जोडणाऱ्या या शास्त्रज्ञाचे पाय मात्र जमिनीवर घट्ट आहेत. त्यांच्या व्यक्तिमत्त्वातील लोभस पैलूंना सुहृदाने दिलेला उजाळा.

डॉ. प्रकाश तुपे

जयंतराव नारळीकरांकडे पाहिलं की मी चकित होतो. त्यांच्या बुद्धिवैभवाचे मोजमाप करायला आकाशातील ग्रह-नक्षत्रांची वजनमापे आणायला लागतील. दोन ध्रुवांचा तराजू उभा करावा लागेल.

खगोलशास्त्रज्ञ डॉ. जयंत नारळीकरांबाबत मराठी माणसाच्या मनातील ही भावना प्रसिद्ध इतिहासकार बाबासाहेब पुरंदरे यांच्या या शब्दांत नेमकी व्यक्त झाली आहे. ५३ वर्षांपूर्वी मी या आंतरराष्ट्रीय कीर्तीच्या शास्त्रज्ञाला पाहिले. 'जयंत नारळीकर या भारतीय युवकाने खगोलशास्त्रात फार मोठा शोध लावला आहे,' असे वृत्त प्रसिद्ध झाले. हा युवक भारतभेटीवर आला असल्याचे त्यात म्हटले होते. मोठ्या उत्सुकतेने आम्ही काही शालेय विद्यार्थी त्यांना पाहण्यासाठी नि ऐकण्यासाठी 'फर्ग्युसन'मध्ये गेलो. ॲम्फी थिएटरचा परिसर गर्दीने फुलून गेला होता. कसाबसा प्रवेश मिळाला. स्टेजवरील सुटाबुटातील त्या तरुणाच्या चेहऱ्यावरील निर्व्याज, लोभस भाव आजही लक्षात आहेत. ''ट्विंकल ट्विंकल लिटल स्टार, हाऊ आय वंडर व्हॉट यू आर'', या बालगीताने सुरवात करीत त्यांनी श्रोत्यांना जिंकून घेतले. पुढे तासभर अस्खलित इंग्रजीत आपल्या संशोधनाचे मर्म त्यांनी विशद केले. अर्थात, त्या वेळी ते भाषण आम्हा मुलांच्या डोक्यावरून गेले. मात्र, तेव्हापासून मी या खगोलशास्त्रज्ञाच्या प्रेमात पडलो. त्यांना भेटावे, जमल्यास त्यांची स्वाक्षरी मिळावी, असे वाटत होते. मात्र, कार्यक्रम संपल्यानंतर, त्यांच्या भोवतालची पान ७ वर »

ज्येष्ठ खगोलशास्त्रज्ञ डॉ. जयंत नारळीकर यांच्या ऐंशीव्या वाढदिवसानिमित्त 'आयुका'मध्ये विशेष कार्यक्रमाचे आयोजन करण्यात आले होते.

'आयुका'त जेव्हा लोकनाट्य होते...

डॉ. जयंत नारळीकर यांना लोकनाट्यातून मुजरा

म. टा. प्रतिनिधी, पुणे

विज्ञान, शिक्षण, कला अशा विविध क्षेत्रांतील मान्यवरांच्या उपस्थितीने भरलेल्या चंद्रशेखर सभागृहात एकाएकी ढोलकीचा ताल उमटू लागतो... विश्वरचनेवरील सैद्धांतिक आणि धीरगंभीर चर्चांमध्ये रमणारे खगोलशास्त्रज्ञ चक्क पारंपरिक गवळणीवर ठेका धरतात. 'फलाने' गावावरून आलेल्या मंडळींनी लोकनाट्यामधून दिलेल्या शुभेच्छांचा मग 'आयुका नगरीचा विठ्ठल' ही मनापासून स्वीकार करतो.

ज्येष्ठ खगोलशास्त्रज्ञ डॉ. जयंत नारळीकर यांचा ऐंशीवा वाढदिवस त्यांचे 'आयुका'मधील सहकारी आणि स्नेही यांनी अनोख्या पद्धतीने साजरा केला. ज्येष्ठ दिग्दर्शिका आणि डॉ. नारळीकर यांच्या स्नेही सई परांजपे यांनी स्वतः लिहिलेल्या आणि दिग्दर्शित केलेल्या 'आभाळाला गवसणी' या लोकनाट्यामधून डॉ. नारळीकर यांचे अभिष्टचिंतन करण्यात आले. डॉ. नारळीकर यांच्या कथांचा आणि 'आयुका'च्या आठ कलमी उद्दिष्टांचा आधार घेऊन सादर करण्यात आलेल्या या लोकनाट्याला उपस्थितांसह स्वतः डॉ. नारळीकरांनी मनापासून दाद दिली.

या लोकनाट्यामध्ये पुण्या- मुंबईतील कलाकारांसह आयुकातील विद्यार्थी आणि स्वतः डॉ. अजित केंभावी यांनीही भूमिका केली. कार्यक्रमाला डॉ. मंगला नारळीकर, डॉ. नारळीकर यांचे देशभरातून आलेले सहकारी, विद्यार्थी, पुण्यातील संशोधन संस्थांचे संचालक, विविध क्षेत्रांतील मान्यवर, तसेच डॉ. नारळीकर यांचे स्नेही मोठ्या संख्येने उपस्थित होते. कार्यक्रमात डॉ. नरेश दधिच, डॉ. गोविंद स्वरूप, डॉ. अरुण निगवेकर, डॉ. केंभावी, डॉ. सायलो मुखर्जी, डॉ. एस. के. पांडे, प्रा. पंच पकेशन, चेल्लदुराई, तसेच सई परांजपे आदींनी डॉ. नारळीकरांसोबतच्या आठवणींना उजाळा देत त्यांना शुभेच्छा दिल्या. 'आयुका'चे संचालक डॉ. सोमक रायचौधरी आणि 'नेहरू तारांगण'चे संचालक अरविंद परांजपे यांच्या संकल्पनेतून कार्यक्रमाचे आयोजन करण्यात आले.

नारळीकरांवर येणार माहितीपट

म. टा. प्रतिनिधी, पुणे

विज्ञानासारखा एरवी अनेकांना ...ष्ट वाटणारा विषय आपल्या रोचक ...नशैलीत मांडून लहान-थोरांत ...नाची आवड निर्माण करणारे आणि ... सहा दशकांहून अधिक काळ ...त संशोधनासोबतच विज्ञान प्रसाराचे ...पणारे ज्येष्ठ खगोलभौतिकशास्त्रज्ञ ...यंत नारळीकर यांचा जीवनपट ...का माहितीपटाच्या माध्यमातून ...णार आहे.

...ळीकरांच्या आयुष्यातील अनेक ...त पैलूंवर या माहितीपटातून ...टाकण्यात येणार असून, ...कांना आपल्या या लाडक्या ... वेगळी ओळखच होणार ... चित्रपट अभ्यासक अनिल ... माहितीपटाचे दिग्दर्शक ...च त्याचे काम पूर्ण होणार ... अकादमीच्या माध्यमातून ...होत आहे.

...ट दोन भागांत बनत ...ा एक तासाचा असणार ...ग हा या भागाचेच २७ ...रूप असणार आहे. ...करण पुण्यात झाले ...री (१९ जुलै) डॉ. ...याची ऐंशी वर्षे पूर्ण करीत आहेत. त्याचेच औचित्य साधून 'मटा'ने झणकर यांच्याशी संवाद साधून या माहितीपटाविषयी जाणून घेतले.

झणकर म्हणाले, 'एक उत्तुंग प्रतिभेचे शास्त्रज्ञ असण्यासोबतच उत्तम लेखणी आणि अमोघ वाणीचा संगम असणारे डॉ. नारळीकर यांच्या जीवनावरील माहितीपटाचे दिग्दर्शन करण्याची संधी मला साहित्य अकादमीने दिली, याचा मला विशेष आनंद वाटतो आहे. साहित्य अकादमीचा हा प्रकल्प गेल्या वर्षी सुरू झाला. येत्या दोन ते तीन महिन्यांत त्याचे काम पूर्ण होणे अपेक्षित आहे. हा माहितीपट बनविणे हा माझ्यासाठी खूप छान अनुभव ठरत आहे. या कामात मला 'आयुका' आणि 'आयसर' या संस्थांची मोलाची मदत झाली. एक वैज्ञानिक, एक विज्ञानलेखक तसेच एक विज्ञानप्रसारक अशा नारळीकरांच्या तिहेरी योगदानावर माहितीपटातून प्रकाश टाकण्यात आला.'

माहितीपटात काय पाहाल?

- ज्येष्ठ शास्त्रज्ञ आणि डॉ. नारळीकरांचे 'आयुका'तील सहकारी असणारे डॉ. नरेश दधिच, डॉ. अजित केंभावी आणि डॉ. शोमक रायचौधरी यांच्यासह अनेकांच्या मुलाखती व त्यातून उलगडणारे नारळीकर.
- डॉ. नारळीकर यांच्या पत्नी आणि ज्येष्ठ गणिती डॉ. मंगला नारळीकर यांची मुलाखत.
- सर्वसामान्य लोकांपर्यंत विज्ञान पोहचवण्यासाठी नारळीकर यांनी आकाशवाणीसह विविध ठिकाणी आजवर दिलेल्या व्याख्यानांचे अंश तसेच विद्यार्थ्यांशी साधलेल्या संवादाचा काही भाग.
- कुटुंबासमवेतच्या काही आठवणी
- नारळीकरांचे साहित्य वाचलेल्या विविध क्षेत्रांतील लोकांचे मनोगत.
- डॉ. नारळीकर यांची सविस्तर मुलाखत. यात नारळीकर आपण लिहिलेल्या पहिल्या कथेपासून तर आपले गुरू खगोलशास्त्रज्ञ डॉ. फ्रेड हॉयल यांच्याकडून मिळालेल्या प्रेरणेपर्यंत अनेक गोष्टींवर बोलताना पाहायला मिळतील

PUBLIC LECTURES

April 17, 2018 :
Matthew Colless (Australian National University) on *It's Not Aliens!*

October 22, 2018 :
Suresh Naik (Indian Space Research Organisation) on *Chandrayaan I*

November 26, 2018 :
Helen Mason (University of Cambridge) on *Reaching for the Sun*

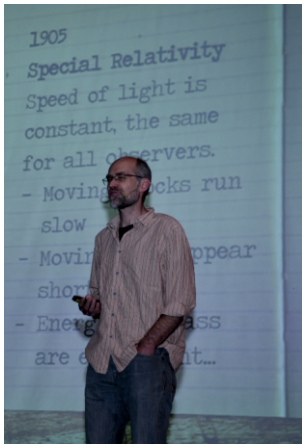
November 27, 2018 :
Ajit Kembhavi (IUCAA) on *History of Cosmology: From Hubble's Law to Hubble-Lemaitre Law*

November 28, 2018 :
Surhud More (IUCAA) on *Hunting for Planet 9 in Our Solar System*

November 29, 2018 :
Ashish Mahabal (California Institute of Technology) on *Vedh Badalatya Avkashacha*

December 04, 2018 :
Saku Tsuneta (National Astronomical Observatory of Japan) *on The Sun and Life on Planets*

December 11, 2018 :
Nils Andersson (University of Southampton) on *Catching Einstein's Waves*



ACADEMIC CALENDAR

ANNUAL EVENTS AT IUCAA

2018

April 23 - June 1
School Students' Summer Programme and Astronomy Camp

May 14 - June 29
Vacation Students' Programme

December 14 - 24
IUCAA - NCRA Radio Astronomy Winter School - XI

December 29
Foundation Day

2019

February 28
National Science Day

EVENTS AT IUCAA

2018

April 12
Workshop on Teaching and Learning with Science Toys

May 14 - June 15
Introductory Summer School in Astronomy and Astrophysics
(for College and University Students)

June 18 - 20
Workshop on Developing Astronomy Themed Experiments
(for Colleges and Universities at UG/PG Levels)

August 7 - 10
Workshop on Physics and Astrophysics at the eXtreme (PAX - IV)

September 27 - 28
Meeting on Astronomy in Universities
(JVN@80 and IUCAA@30)

2019

January 10 - 16
SITARE: Advanced Workshop on Astrophysics

January 19 - 20
Newton - Bhabha Meeting
(India - UK Entrepreneurial)

January 23 - 24
Workshop for Teacher from Rural Schools Near IUCAA Girawali Observatory

January 28 - 31
National Space Sciences Symposium
(Jointly with ISRO, NCRA, and SPPU)

February 11
Meeting on International Day for Women in Science

March 9 - 11
Workshop on Radio Observations Using Horn Antenna

March 12 - 16
Workshop on Night Sky Photometer Fabrication

March 20
Brainstorming Meeting on Interdisciplinary Centre for Experimental Sciences and Technology (iCEST)

EVENTS OUTSIDE IUCAA

2018

April 5 - 6
Introductory Workshop on Astronomy and Astrophysics
At: Kohima Science College, Jotsoma, Nagaland

May 22 - 26
Mini School on X-ray Astronomy Data Analysis
At: Providence Women's College, Kozhikode
(In collaboration with the Academy of Physics Teacher, Kerala)

June 13 - 15
SITARE: Introductory Workshop on Astrophysics for Nepal
At: Tribhuvan University, Kathmandu, Nepal

August 16 - 18
SITARE: Introductory Workshop on Astrophysics
At: Pt. Ravishankar Shukla University, Raipur

September 3 - 5
Workshop on Observing Universe with AstroSat
At: Manipal Academy of Higher Education, Manipal

September 4 - 6
Workshop on Engineering Applications in Astronomy
At: Christ (Deemed to be) University, Kengeri Campus, Bengaluru

September 13 - 15
Introductory Workshop on Astronomy and Astrophysics for Women
At: Alphonsa College, Pala, Kerala

September 17 - 19
SITARE: Introductory Workshop on Astrophysics
At: Newman College, Thodupuzha, Kerala

October 9 - 10
Workshop on Recent Advances in Astrophysics and Cosmology
At: Cooch Behar Panchanan Barma University, Cooch Behar, West Bengal

November 26 - 28
North - East Meet on Astronomers (NEMA - IV)
At: Assam University, Silchar

November 26 - 28
Workshop on Introductory Astronomy
At: Banaras Hindu University, Varanasi

November 30 - December 1
Introductory Workshop in Astronomy and Astrophysics
At: Digboi College, Digboi, Assam

2019

January 7 - 11
Workshop on Celestial Mechanics and Dynamical Astronomy (CMDA - 2019)
At: Central University of Rajasthan, Bandarsindri

Januaty 7 - 13
Winter School in Astronomy, Astrophysics and Cosmology
At: Gauhati University, Guwahati

January 15 - 18
International Conference on Multi-Messenger Astronomy in the Era of LIGO - India (LIMMA - 2019)
At: The Dukes Retreat, Khandala, Maharashtra
(Supported by Navajbai Ratan Tata Trust, Mumbai)

January 17 - 20, 2019
Workshop on Telescope Making
At: Vigyan Parishad, Goa

January 21 - 24
Conference on Formation and Evolution of Star Clusters
At: Maulana Azad National Urdu University, Hyderabad

February 1 - 2
National Student Seminar in Frontiers in Physics
At: Fergusson College, Pune

February 3 - 7
Workshop on Multi-Wavelength Sky Observations: AstroSat and Beyond
At: Indian Institute of Technology, Indore

February 7 - 10
Mini School on Gravitation and Cosmology
At: Providence Women's College, Kozhikode

February 8 - 9
Regional Meeting on Research in Astronomy: Opportunities and Challenges
At: Cochin University of Science and Technology, Kochi

February 14 - 15
Workshop on Science Toys Demonstration and Basic Astronomy
At: Jayaramswami Vidyalaya, Khatav, Satara, Maharashtra

February 22 - 24
Workshop on Telescope Making
At: Science Centre, Latur, Maharashtra

February 26 and March 1
Workshop on Basic Astronomy for Teachers
At: Indian Institute of Science Education and Research, Pune

March 2 - 3
National Workshop on Introduction to Solar Astrophysics
At: St. Xavier's College for Women, Aluva, Kerala
March 5 - 7
School on Introductory Astronomy
At: Central University of Tamil Nadu, Thiruvarur

March 7 - 8
Workshop on Astronomy
At: Indian Institute of Technology, Gandhinagar

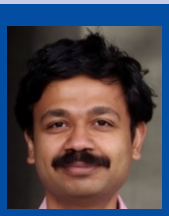
March 11 - 14
Workshop on Fundamental Science
At: Kohima, Nagaland

March 18 - 20
Workshop on Telescope Making and Science Popularisation
At: Visva Bharati University, Santiniketan

March 29 - 31
Workshop on Astronomy and Astrophysics
At: Sikkim University, Gangtok

AWARDS AND RECOGNITIONS

SANJEEV DHURANDHAR
on being selected for ***Meghnad Saha Memorial Gold Medal (2018)***
by The Asiatic Society, Kolkata.



SURHUD MORE
on being awarded ***2019 Marshak Lecturership of the American Physical Society***

JAYANT NARLIKAR
on being Conferred with the ***Mahatma Jyotirao Phule Puraskar***
from Maharashtra Rajya Sahitya Ani Sanskruti Mandal, Mumbai.

T. PADMANABHAN
on being awarded Fourth Prize in Gravity Essay Contest
(Awarded by the Gravity Research Foundation, USA), 2018

ASEEM PARANJAPE
on being awarded **INSA Medal for Young Scientist** (2018)

VARUN SAHNI
on being awarded ***J.C. Bose Fellowship***,
by Department of Science and Technology, Government of India.

RESEARCH GRANTS AND FELLOWSHIPS

JOYDEEP BAGCHI

- CEFIPRA Grant for the project: Radio Properties of Clusters and Galaxy Lenses.

DIPANKAR BHATTACHARYA

- ISRO Grant to set up the AstroSat Science Support Cell (ASSC).
- DST Indo - Italian Gant for the project: AstroSat: A New Window on General Relativity.

SANJEEV DHURANDHAR

- NASI Senior Scientist Platinum Jubilee Fellowship.

Neeraj Gupta

- CEFIPRA Grant for the project: Cosmological Evolution of Cold Gas from Quasar Absorption Lines.
- DST - SERB Grant for the project: Quasar Evolution of Cold Gas in Galaxies using Absorption Lines.
- DST Indo - South Africa Grant for the project: Evolution of Cold Gas in Galaxies: Large Surveys using Radio and Optical Telescopes under Enhanced Exchange Programme.

AJIT KEMBHAVI

- NKN Grant for the project: Data Driven Initiative in Astronomy and Biology.
- DST Indo – US Science and Technology Forum (IUCCTF) Grant for the project: Pragadh; Indo – US Centre for Pan Astronomical Deep Learning.
- DAE Raja Ramanna Fellowship (Track - 1).

Navajbhai Ratan Tata Trust Grant for the project: Gravitational Wave Data and Science Centre (GWDSC).

RANJEEV MISRA

- UGC – UKERI Partnership Grant for the project: New Frontiers in Multi-wavelength Astronomy Correlated Variability of Accreting Black Holes and Neutron Stars from Optical to X-rays.
- Southampton University Grant for the project: Southampton - IUCAA Training for Astronomy Research and Education (SITARE).

SANJIT MITRA

- DST SwarnaJayanti Fellowship for the project: Gravitational Waves Astronomy with a Network of Ground-based Detectors.

T. PADMANABHAN

- DST J.C. Bose (Second) Fellowship.

ISHA PAHWA

- DST INSPIRE Fellowship.

ASEEM PARANJAPE

- DST - SERB: Ramanujan Fellowship.

A. N. RAMAPRAKASH

- Participation Grant in Thirty Metre Telescope Project.
- ISRO Grant for Design, Development and Supply of Solar Ultraviolet Imaging Telescope (SUIT) for Aditya - L1 Mission.
- Infosys Foundation Grant for Resurgent Caltech - IUCAA Collaboration for Advanced Instrument Development and Scientific Discoveries.
- Grants to develop Optical Telescope Integral Field Spectrograph (DOTIFS) for Devasthal, ARIES, Nainital, India, and Korea Institute of Advanced Studies, Seoul, South Korea.
- Grants to develop Wide Area Linear Optical Polarimeter (WALOP) for Institute of Plasma Physics, Crete, Greece, and South African Astronomical Observatory, Cape Town.
- Grant to develop Detector Controller and Data Handling System for MIRADAS, University of Florida, USA.
- Grant to develop Large Binocular Telescope Interferometer for LBT Observatory, University of Arizona, USA.

KANAK SAHA

- CEFIPRA Grant for the project: The Assembly History of Disk Galaxies over the Last 8 Billion Years.
- DST Indo – South Africa Grant for the project: Galaxy Evolution: Simulation, Observation and Data Analysis under Enhanced Exchange Programme.

VARUN SAHNI

- DST J.C. Bose Fellowship.

DURGESH TRIPATHI

- DST – Max – Planck Society Indo – German Grant for Partner Group on Coupling and Dynamics of Solar Atmosphere.
- Max – Planck Partner Group Research Grant.

OTHER GRANTS TO IUCAA

- Teaching Learning Centre (TLC) Grant for the project under the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching (PMMMNMTT).
- Annual Refresher Programme in Teaching (ARPIT) for Astronomy and Astrophysics Grant under the PMMMNMTT.
- DST - DAE Grant for Technology Development and Capacity Building for Gravitational Waves Detection (LIGO - TDCB).
- DST - DAE Grant for LIGO - India SEED.

RESEARCH AT IUCAA

Quantum Theory and Gravity

Quantum correlators in Friedmann spacetimes: The omnipresent de Sitter and the invariant vacuum noise

The study of quantum fields in Friedmann universes is relevant to identify the seeds of structure formation as the quantum fluctuations in the early universe. Numerous investigations in this direction have highlighted several theoretical issues, which are rather special to this context, especially for the de Sitter (dS) universe. To shed more light on some of these issues, we revisit the study of a massive scalar field minimally coupled to a Friedman universe with the scale factor proportional to some power of the conformal time coordinate.

- **Equivalence between dynamics of a quantum field in one Friedmann universe and that of another field in another Friedmann universe**: **T. Padmanabhan** and **Karthik Rajeev** have shown that the dynamics of a massive scalar field (say ϕ, m) on a cosmological Friedmann background (with scale factor, say, a) can be mapped to that of another scalar field (ψ, m') in another Friedmann universe (with scale factor b). A special case of this equivalence is of particular interest; a *massless* scalar field in any power law cosmology (i.e., when $a(\eta) \propto \eta^{-q}$) can be mapped to a *massive* field in a dS spacetime, where the mass, M, of the field in the dS spacetime is determined by $M^2 = (2+q)(1-q)$. A massive field in dS is well-studied and fairly well-understood system, hence, through this mapping, one can gain insights about the features of a massless field in the background of a less symmetric spacetime, namely the power-law Friedmann universe. In particular, massless scalar fields in different phases of the Universe (e.g., radiation era, matter era, etc.) can be studied using this approach.

- **Massless field in dS:** The two-point correlation function for massive scalar field in dS background is a well studied subject. The massless limit of this correlation function is known to be pathological. This feature is usually attributed to breakdown of a symmetry in the case of a massless scalar field in dS. **Padmanabhan** and **Karthik** have shown that the divergences (pathologies) for massless scalar fields occur in any power law cosmology with a negative equation of state parameter (w). Note that, such power-law cosmologies, with $-1 < w < 0$, have no special symmetries unlike the dS background, which corresponds to $w = -1$. Hence, they find that the divergent two-point function is intimately coupled with the character of the source supporting the geometry. In particular, the pathology in dS is also due to the negative value of the equation of state parameter, namely $w = -1$, and has no special relationship to dS invariance or its breakdown.

- **Power spectrum through Killing directions:** Power spectrum is one of the important characterizations of the quantum fluctuations of a field. **Padmanabhan** and **Karthik** have developed a machinery to obtain the power spectrum in a Friedmann universe through its Killing vectors. This new approach provides a geometric picture of the power spectrum for different cosmologies, including the dS universe.

- **Persistent vacuum noise: Padmanabhan** and **Karthik** have demonstrated that a quantum scalar field in a Friedmann universe hosts a curvature-dependent minimum vacuum noise (vacuum power spectrum). This persistent noise corresponds to the large wavelength limit in the power spectrum. For example, the dS spacetime always has a $\sim H^2$ vacuum noise, a feature that is reflected in the well known scale invariant power spectrum. By adopting trajectories for which the chosen state does not remain the 'natural vacuum', one can enhance this noise. In particular, using the co-moving/static observer correspondence in the dS spacetime, they show how the persistent vacuum noise gets enhanced by *stimulated emission*. An analogous result holds in the

context of inertial/Rindler observer correspondence in Minkowski spacetime.

Generalized Schwinger effect and particle production in an expanding universe

T. Padmanabhan and **Karthik Rajeev** discuss several aspects of two important examples of particle production in external background: (a) quantum field theory of a complex scalar field in an external, homogeneous, electric field and (b) quantum field theory of a scalar field in an expanding Friedmann background.

- They show that there exists a *purely algebraic* correspondence between the differential equations governing the scalar field in the cases (a) and (b) mentioned above. For example, it turns out that the constant electric field case can be mapped to a radiation dominated universe, while the dS universe maps back to a singular electric field. Further, the Milne universe maps to an electric field in flat spacetime, which produces a Planckian spectrum of particles, in a specific limit, thereby providing yet another 'black hole analogue'.
- The particle production in the expanding universe vanishes, either analytically or non-analytically when the parameter describing the expansion of the universe goes to zero. This is analogous to the case in an external electric field, where the particle production vanishes either analytically or non-analytically in the coupling constant, depending on the nature of time-variation of the electric field. They obtain a criterion for analytic versus non-analytic dependence of the coupling constant in the context of particle production in an expanding universe.
- The conventional method for studying the particle production in an expanding background is based on calculating the Bogoliubov coefficients between the in-modes and the out-modes. The straightforward application of this method works in a dS background only when $(M/H) > 3/2$ (where M is the mass of the scalar field quanta and H is the Hubble constant), and fails when $(M/H) < 3/2$. They provide a careful discussion of this failure, and show how particle production can be computed for all values of (M/H) by using a different method based on the instantaneous diagonalization of the Hamiltonian.

Cosmology and Structure Formation

Emulating ΛCDM-like expansion on the phantom brane

Cosmological expansion appears to be speeding up. The source of cosmic acceleration may be a novel constituent called dark energy (DE) which violates the strong energy condition $\rho + 3p \geq 0$. An alternative to this scenario rests on the possibility that general relativity (GR) inadequately describes late-time cosmic expansion and needs to be supplanted by a modified theory of gravity. Of the various DE models suggested in the literature the cosmological constant Λ occupies a special place since its equation of state $p = -\rho$ is manifestly Lorentz invariant. Λ, when taken together with cold dark matter (CDM), constitutes ΛCDM cosmology. The ΛCDM universe appears to agree remarkably well with a slew of cosmological observations. Yet some data sets also appear to support a phantom universe possessing a strongly negative equation of state (EOS) of dark energy (DE), $w < -1$. While current data sets are unable to unambiguously differentiate between these orthogonal models, high quality data expected from future DE experiments are likely to do so.

Of all the phantom DE models the phantom brane is perhaps the most appealing since it has an effective equation of state whose value becomes phantom-like, $w_{\rm eff} < -1$, at the present epoch. The phantom brane also does not possess any of the singularities which usually afflict conventional phantom models.

Satadru Bag, **Swagat Mishra** and **Varun**

Sahni have shown that for a suitable choice of $\Omega_{DE}(x) \equiv \rho_{DE}(x)/\rho_{cr,0}$, braneworld expansion

$$h(x) = \sqrt{\Omega_{m0}x^3 + \Omega_{DE}(x) + \Omega_\ell} - \sqrt{\Omega_\ell}\ , \quad x = 1+z \tag{1}$$

can easily mimic the ΛCDM model

$$h_{\Lambda CDM}(x) = \sqrt{\Omega_{m0}x^3 + \Omega_\Lambda}\ . \tag{2}$$

It is interesting that there is a precise form of the Quintessence potential, $V(\phi)$, which gives rise to ΛCDM-like expansion on the brane. Consequently $\Omega_{DE}(z)$ in (1) is replaced by Ω_φ. Remarkably the reconstructed potential has precisely the same late-time form as $V = V_0 \coth^2(\lambda\varphi)$.

Figure shows that the expansion rate on the Braneworld containing a scalar field with a coth-like potential coincides with the expansion rate of the ΛCDM model. However it is important to emphasize that perturbation growth in the two models is quite different, and therefore these two models: (i) Braneworld with a coth-like potential, (ii) the ΛCDM model, can easily be distinguished even though their expansion history is virtually identical.

Global analysis of luminosity- and colour-dependent galaxy clustering in the Sloan Digital Sky Survey

Halo model is a statistical tool to describe the population and distribution of various types of galaxies inside dark-matter halos. The free parameters of the model are constrained by matching with the observed abundance and clustering data of the galaxies. A key ingredient to compute the two-point correlation function (2PCF) of galaxies in the halo model framework is to compute the 2PCF of dark-matter halos and then take a weighted average. However, the correlation of dark-matter halos calculated from the simplest flavour of halo model suffers from several issues, like scale-dependent bias, halo-exclusion, etc., which are difficult to be modelled in a purely analytical framework. So an accurate technique would be to measure the 2PCF of halos directly from N-body simulations and then use the halo model framework to model the clustering of galaxies. To accurately model the galaxies of a range of luminosity, colour and HI mass, one needs to resolve halos of small masses as well as needs to have a sufficient number of high mass halos to model the large-scale clustering properly. For this, one typically needs a simulation of very large box size ($\sim$ 1 Gpc) with huge number of particles ($\sim$ 30 billion) resulting in a huge computational budget. The situation becomes worse as one needs several realizations of those simulations to reduce the error in the estimation of the correlation function of the dark matter halos.

To overcome this difficulty, **Niladri Paul**, **Isha Pahwa**, and **Aseem Paranjape** came up with a novel approach of combining simulations of three different box sizes. They used simulations performed by **Paranjape** and **Pahwa** with a single realization of 150 Mpc box, 10 realizations of 300 Mpc boxes and 3 realizations of 600 Mpc boxes each with 1 billion particles. In this way, effectively they could resolve halos of small masses and also get a substantial number of high mass halos. They measured the halo mass function, halo density profile and two-point correlation function of halos directly from all the simulation boxes as a function of halo mass.

They combined these measurements weighted by the available number of dark matter particles in each of the measurements in each halo mass bin. Error from the simulation measurements was $\sim 3\%$, much less compared to that from the error in the observations. They introduced a global constraint of the HOD parameters combining all the available luminosity bins to account for the possible correlation between the HOD parameters across different luminosity thresholds, and also imposed the information of colour-dependent clustering in the analysis, which improved the constraints on the HOD parameters. While doing this, they also modelled the red fraction of satellite galaxies as a function of luminosity, and the calibration of this quantity is free from the assumptions of galaxy group catalogues. Their calibrations were accurate enough to describe the correlation and abundance data together within a good precision level. They could provide robust fitting formulae for the HOD parameters as a function of magnitude thresholds, and

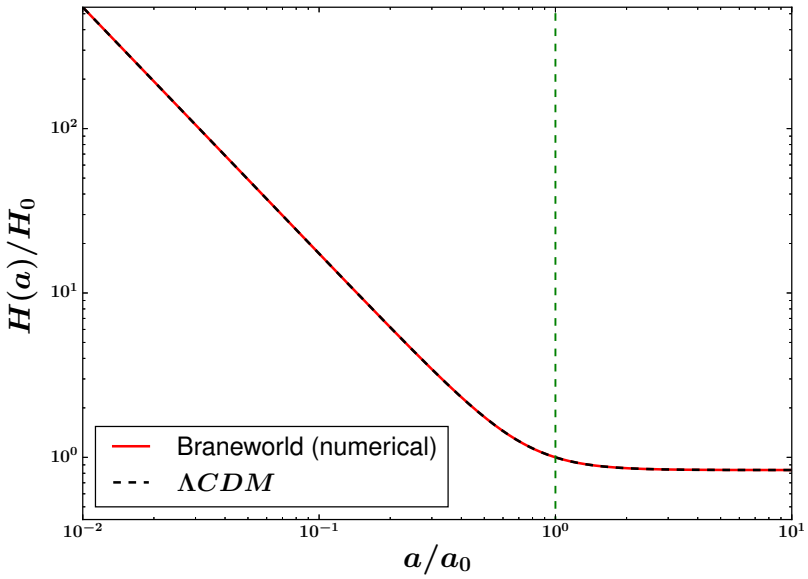


Figure 1: This figure shows that the expansion rate on the braneworld containing a Quintessence field with a coth-like potential coincides with the expansion rate of the ΛCDM model.

those formulae could be valid for a wide range of magnitude thresholds. Figure 2, shows the 2PCF and luminosity function coming from our model using the fitting formulae of the HOD parameters.

Constraining the dark energy statefinder hierarchy in a kinematic approach

A popular model towards understanding dark energy is the cosmographic approach. **Niladri Paul**, Ankan Mukherjee and H.K. Jassal adopted a kinematic approach for constraining the extended null diagnostic of concordance cosmology, known as the statefinder hierarchy. They made a Taylor series expansion of the Hubble parameter for the reconstruction of the parameters. The coefficients of the Taylor series expansion were related to the kinematical parameters like the deceleration parameter, cosmological jerk parameter, etc. They constrained the present values of the kinematical parameters from the estimated values of those series coefficients. A Markov chain Monte Carlo analysis was carried out using the observational measurements of Hubble parameter at different redshifts, the distance modulus data of type Ia supernovae and baryon acoustic oscillation data to estimate the coefficient of series expansion of the Hubble parameters. The parameters in the statefinder diagnostic are related to the kinematical parameters. The present values of statefinder parameters were constrained. They found that the first set in the statefinder hierarchy allows LCDM to be well within the $1-\sigma$ confidence region, whereas the second set was in disagreement with the corresponding LCDM values at more than $1-\sigma$ level. Another dark energy diagnostic, namely the Om-parameters, has been found to be consistent with concordance cosmology. Figure 3 shows the plot of $Om(z)$ from their model-independent approach as a function of redshift. It is seen that that ΛCDM model value is still within $1-\sigma$ region of the model-independent value.

Perturbation growth on the phantom brane

According to the braneworld paradigm, the Universe is a four-dimensional hypersurface (the

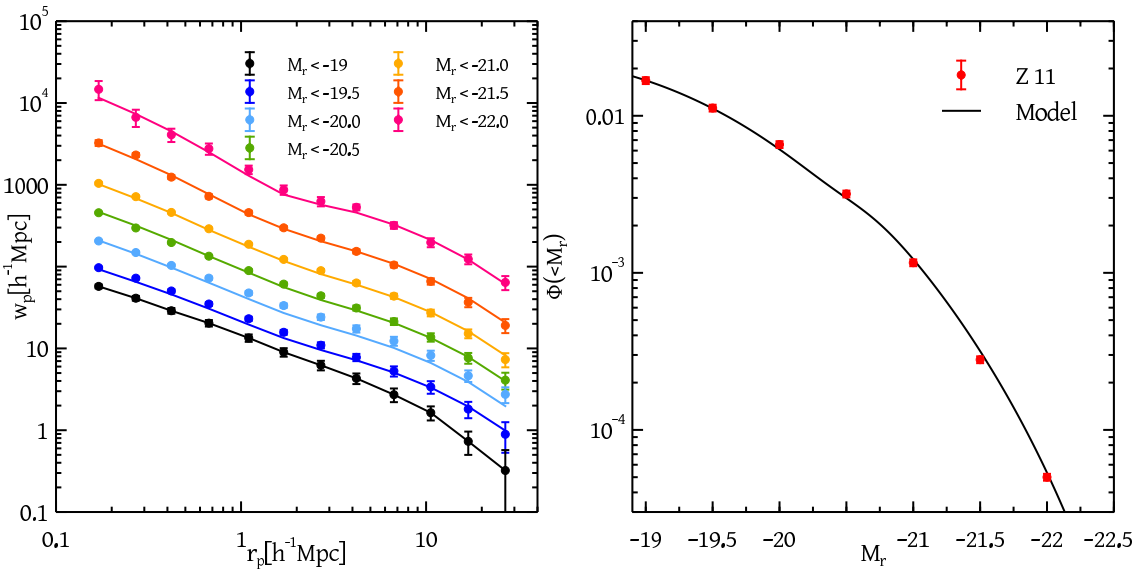


Figure 2: Comparison of clustering and abundance computed using HOD fitting functions with measurements. *(Left panel)* Projected correlation function for different magnitude thresholds. Solid circles with error bars show measurements from *Zehavi, et al. 2011*. Solid curves show the correlation function computed using fitting form of the HOD parameters combined with the simulation-based theoretical model of halo clustering. (For clarity, 0.25dex staggering has been introduced in the measurements and models for all thresholds other than $M_r < -20.5$.) *(Right panel)* Cumulative luminosity function as a function of magnitude. Black solid line shows the curve obtained from the theoretical model and red circles show the measurements from *Zehavi, et al. 2011*.

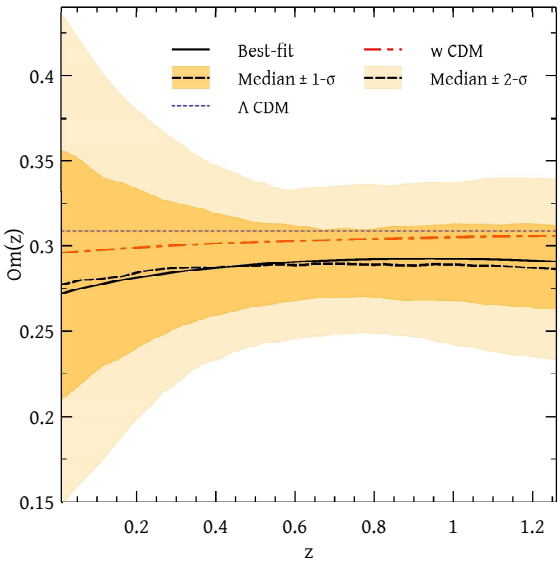


Figure 3: Shows the $Om(z)$ plot (best fit and median with $1-\sigma$ and $2-\sigma$ confidence regions) for the present estimated values of the coefficients of the Taylor expansion of the Hubble parameter.

'brane') embedded in a five-dimensional spacetime (the 'bulk'). In this scenario, the matter and gauge fields of the standard model are confined to the brane, while gravity can propagate in the extra dimension.

An important class of braneworld models, known as the Dvali–Gabadadze–Porrati (DGP), contains the so-called 'induced-gravity' term in the action for the brane, which modifies gravity on relatively large spatial scales. Depending upon the embedding of the brane in the bulk space, this model has two branches of cosmological solutions: the 'self-accelerating' branch and the 'normal' branch. The self-accelerating branch is plagued by the existence of ghost excitations while no ghosts appear on the normal branch. Because of the ghost problem, the self-accelerating branch is of limited interest, while the normal branch is physically viable and consistent with current cosmological observations.

Varun Sahni and Yuri Shtanov, have shown that the normal branch has a phantom-like effective equation of state $w_{\rm eff} < -1$ for dark energy, which serves as a smoking-gun test for this scenario.

An important feature of the phantom brane is that its expansion rate *is slower than* ΛCDM, i.e., $H(z)|_{\rm brane} < H(z)|_{\Lambda{\rm CDM}}$. This intriguing property allows the braneworld to better account for measurements of $H(z)$ at $z \sim 2$, which appear to be in some tension with ΛCDM.

To test braneworld cosmology at the linear perturbative level, one needs to know the behaviour of matter density perturbations in this model. This is usually described in terms of the growth rate:

$$f \equiv \frac{d\,\ln \delta_m}{d\,\ln a}\,.$$

where $\delta_m = \delta\rho_m/\rho_m$ is the matter density contrast. For the ΛCDM model and for a large variety of dynamical dark energy models with slowly varying w, the growth rate can be approximated as:

$$f = \Omega_m^{\gamma}\,, \quad \text{with} \quad \Omega_m = \frac{8\pi G\rho_m}{3H^2}\,,$$

where γ is the growth index. For low redshifts, γ is a slowly varying function of z, close to some constant γ_0. The value of γ_0 depends on the equation of state w, and thus the growth index can be used to discriminate between different models of the dynamical dark energy. For example, when $w = -1$ (as in the ΛCDM model), we have $\gamma_0 = 6/11$.

Alexander Viznyuk, Yuri Shtanov, **Satadru Bag** and **Varun Sahni** have demonstrated that the traditional parametrization is not successful for the phantom brane. The evolution of the matter density contrast $\delta_m = \delta\rho_m/\rho_m$ for the braneworld model in the quasi-static approximation is given by

$$\ddot{\delta}_m + 2H\dot{\delta}_m = g_{\scriptscriptstyle E}\,(4\pi G\rho_m\delta_m)\,,$$

where $g_{\scriptscriptstyle E}$ is a time-dependent function that can be regarded as a renormalization factor for the gravitational constant.

Based on a power series expansion at large redshifts, they have proposed a versatile parametrization for this model

$$f = \Omega_m^{\gamma}\left(1 + \frac{b}{\ell H}\right)^{\beta}\,, \qquad (3)$$

where

$$\gamma \approx 6/11 + 0.00729\,(1-\Omega_m) + \frac{\alpha_0}{\ell H}\,, \quad \alpha_0 = 0.025\,, \qquad (4)$$

and $\beta = 0.084$, $b = 3.383$.

Figure shows the comparison of the ansatz (3)–(4) with the exact solution obtained by solving () numerically. One finds that the exact solution of f is very well described by the ansatz, the error being of the order 0.1% for values of Ω_ℓ consistent with the observations.

A study of the epoch of reionization using percolation analysis and Shapefinders

The epoch of reionization (EoR) is one of the most important but least understood epochs in the history of our universe. During this epoch, the diffuse hydrogen in the intergalactic medium (IGM) gradually changed its state from being neutral (HI) to ionized (HII). Our knowledge about this epoch has been guided so far by observations of the Thomson

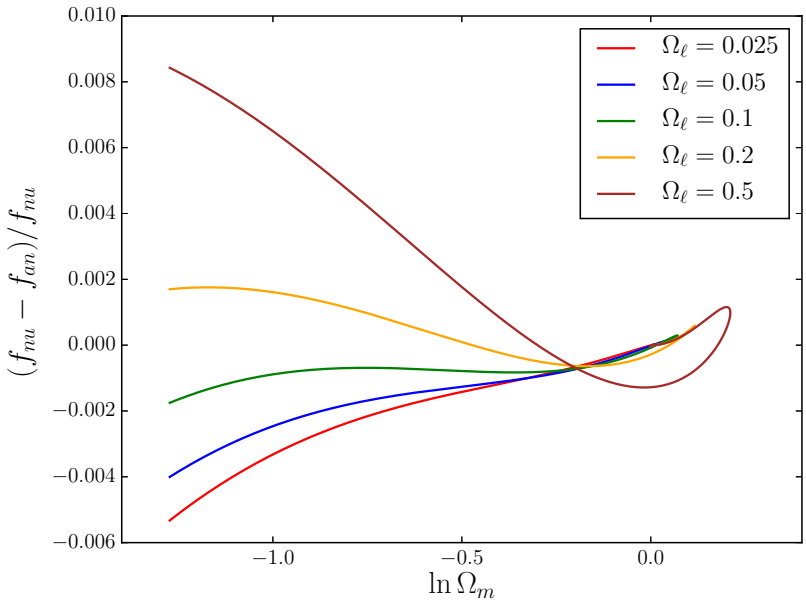


Figure 4: Percentage error of the ansatz (3)–(4) is shown for different values of the brane parameter Ω_ℓ, starting from the matter domination until the present epoch. Here, f_{nu} and f_{an} represent the numerical solution for f and the ansatz (3) respectively. Note that, during matter domination $\Omega_m \to 1$ and, at the present epoch, $\Omega_m = \Omega_{m0} = 0.28$.

scattering optical depth of the CMB photons, observations of the Ly-α absorption spectra of the high-redshift quasars and the luminosity function and clustering properties of high-redshift Ly-α emitters. These observations suggest that this epoch extended over a broad redshift range $6 \lesssim z \lesssim 15$. However, our understanding on most of the fundamental issues associated with this epoch, such as the properties of ionizing sources, topology of neutral hydrogen and the morphology of ionized HII regions etc. at different stages of the reionization remains uncertain.

Observations of the redshifted HI 21-cm signal which provides a direct window to the state of hydrogen in the IGM have the potential to probe this complex epoch. There is considerable effort underway to detect the EoR 21-cm signal using radio interferometry from HI surveys such as GMRT, LOFAR, MWA, PAPER, SKA and HERA.

The analyses of the redshifted 21-cm signal have so far been performed on the basis of traditional N-point correlation statistics. However, beyond the simplest two-point function (power spectrum), higher order correlations are difficult to calculate. By contrast, the Minkowski functionals (MFs) are extremely useful tools in quantitatively describing morphology because they contain information of all the higher order moments. The MFs have been extensively employed to study the morphology of the large scale structure of the universe (the cosmic web) and the CMB. Since the reionization landscape is similarly rich in geometrical properties, studying the morphology of reionization using MFs is both compelling and feasible. The physics underlying the reionization process is expected to be manifested in the geometry and morphology of HI and HII regions.

Satadru Bag. **Varun Sahni**, (Rajesh Mondal, Tirthankar Roy Choudhury, Prakash Sarkar and Somnath Bharadwaj) have explored this vibrant reionization landscape using percolation analysis, the Minkowski functionals and the Shapefinders.

In percolation analysis a key role is also played by the following quantities which can be defined, for a

given density threshold, for both the HI overdense and underdense excursion sets separately:

The filling factor (FF)

$$FF = \frac{\text{total vol. of all neutral / ionized regions}}{\text{volume of the simulation box}} . \quad (5)$$

The "largest cluster statistic" (LCS)

$$\text{LCS} = \frac{\text{vol. of the largest cluster}}{\text{total vol. of all the clusters}} , \quad (6)$$

$$ff_{\text{largest}} = \frac{\text{vol. of the largest cluster}}{\text{vol. of the simulation box}} \quad (7)$$

$$= FF_{\text{ionized}} \times \text{LCS} \quad (8)$$

$$ff_{\text{other}} = \frac{\text{vol of all clusters except largest cluster}}{\text{vol. of the simulation box}} \quad (9)$$

$$\equiv FF_{\text{ionized}} - ff_{\text{largest}} = FF_{\text{ionized}} \times (1 - \text{LCS}) .$$

The fractions ff_{largest} and ff_{other} are essentially the filling factors of the largest cluster and the rest of the clusters (all the clusters excluding the largest cluster) respectively.

Satadru Bag, et al. have studied the shapes of the ionized regions at different redshifts (various stages of reionization) using Shapefinders, which are derived from Minkowski functionals. The morphology of a closed two dimensional surface embedded in three dimensions is well described by the four Minkowski functionals: (i) Volume: V, (ii) Surface area: S, (iii) Integrated mean curvature (IMC): $C = \frac{1}{2}\oint(\kappa_1 + \kappa_2)\, dS$, (iv) Integrated Gaussian curvature or Euler characteristic: $\chi = \frac{1}{2\pi}\oint(\kappa_1\kappa_2)dS$

Here κ_1 and κ_2 are the two principle curvatures at any point on the surface. The fourth Minkowski functional (Euler characteristic) is a measure of the topology of the surface. It can be written in terms of the genus (G) as $G = 1-\chi/2$. The 'Shapefinders' are ratios of these Minkowski functionals, namely (i) Thickness: $T = 3V/S$, (ii) Breadth: $B = S/C$, (iii) Length: $L = C/(4\pi)$.

The Shapefinders T, B, L, have dimension of length, and can be interpreted as providing a measure of the three physical dimensions of an object. Using the Shapefinders they have determined the morphology of an ionized region by means of the following dimensionless quantities which characterize its planarity and filamentarity

$$\text{Planarity} : P = \frac{B-T}{B+T} , \quad \text{Filamentarity} : F = \frac{L-B}{L+B}. \quad (10)$$

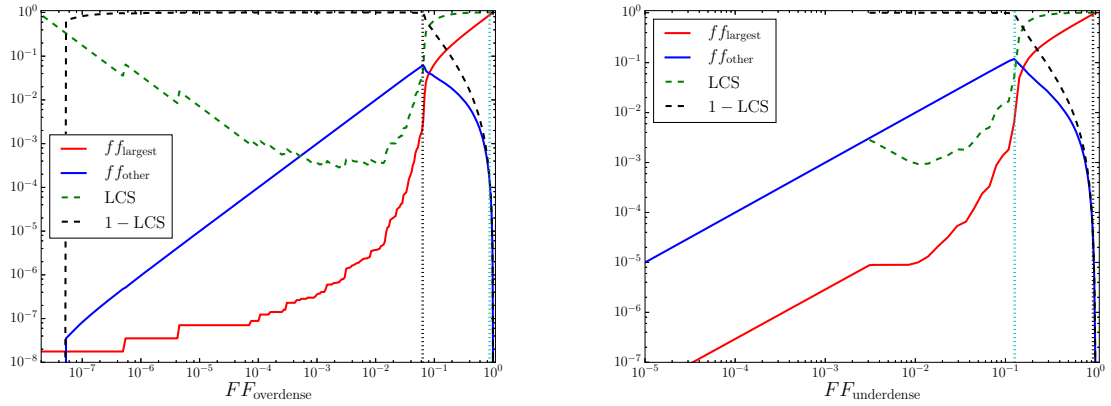
For a planar object (such as a sheet) $P \gg F$, while the reverse is true for a filament which has $F \gg P$. A ribbon will have $P \sim F \gg 0$ whereas $P \simeq F \simeq 0$ for a sphere. In all cases $0 \leq P, F \leq 1$.

The results in Figures 5 and 6 can be summarized as follows:

1. The overdense and underdense segments percolate at different critical density thresholds corresponding to different values of the respective filling factors. To explore this asymmetry in percolation more quantitatively, one can study the so called "percolation curves" which are essentially plots of the filling factors of the largest cluster against the corresponding FF_{ionized} for overdense and underdense segments. The area under the percolation curve is a robust geometric measure of non-gaussianity. They find that the area under the hysteresis in the percolation curves at redshifts 13,11 and 10 increases as reionization proceeds which in turn indicates that the non-gaussianity in the HI density field increases.

2. Since most of the large clusters appear just before percolation, they have studied the behaviour of the Minkowski functionals for values of density thresholds corresponding to the onset of percolation in both overdense and underdense segments. The clusters have different Minkowski functionals but their ratios, defined as Shapefinders, show interesting properties.

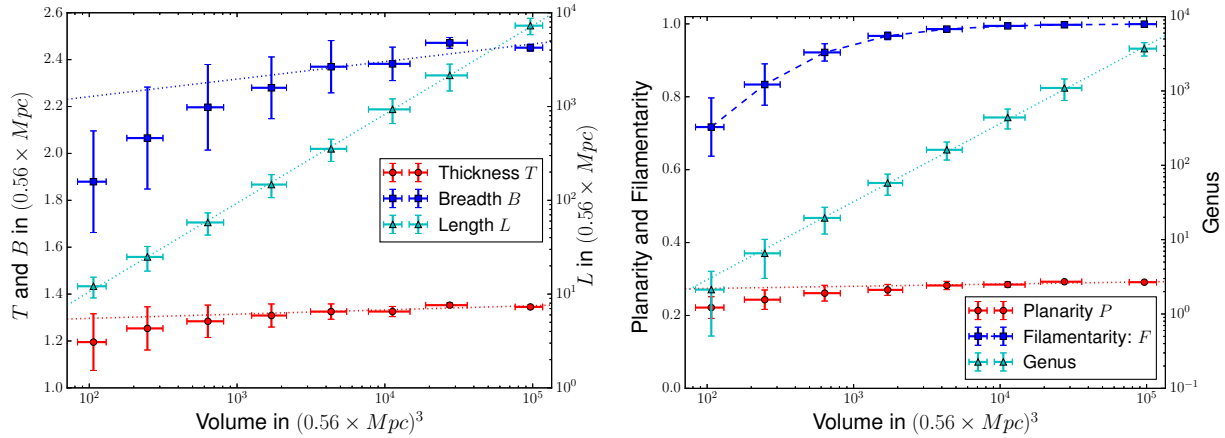
   The thickness (T) and breadth (B) of large clusters in both overdense and underdense segments are of similar values but the length (L) increases almost linearly with the volume of



(a) HI overdense segment

(b) HI underdense segment

Figure 5: The cluster statistics at $z = 13$: The four fractions, $ff_{\rm largest}$, $ff_{\rm other}$, LCS and $(1-{\rm LCS})$ for HI overdense and underdense segments are plotted against corresponding filling factors in left and right panel respectively. In both panels the percolation transition for overdense region is shown by black dotted vertical line while the cyan dotted vertical line represents the percolation in the underdense segment. In both the cases, during percolation, the fractions $ff_{\rm largest}$ and LCS rise steeply while the other two fractions $ff_{\rm other}$ and $(1-{\rm LCS})$ decay sharply. These sharp changes in these 'ordered parameters' can also independently define the percolation transition in either segment.



(a) Thickness, breadth and length

(b) Planarity and filamentarity

Figure 6: Shapefinders, planarity, filamentarity and genus of HI overdense clusters at $z = 13$ are binned in volume for a threshold just before percolation. Note that the values of Shapefinders are quoted in comoving scale. In the left panel T, B and L are fitted to straight lines shown by the dotted lines with respective colours. The slopes of the best fit straight lines to T, B are negligible. On the other hand, the best fit straight line to $\log L$ vs $\log V$ has slope 0.945 ± 0.01 which is $\mathcal{O}(1)$. This shows T and B of sufficiently large clusters increase very slowly with the cluster volume V but L almost increases linearly V. From the right panel it is evident that the filamentarity increases with cluster volume and almost saturates to unity for large clusters. Filamentarity in volume bins are joined by dashed line for visual guidance. But the planarity does not increase much, hence the best fit straight line again has a negligible slope. Genus of clusters also increases almost linearly with the volume.

the cluster. Hence the filamentarity (F) of large clusters in both overdense and underdense segments increases with their volume and saturates to unity for extremely large clusters. The similar values of T and B imply that the filament-like large clusters have similar cross sections (estimated by the product of the first two Shapefinders $T \times B$) and their shapes only differ in terms of their lengths. The reason is that the larger clusters form due to mergers of relatively smaller clusters which are themselves large enough to possess similar values of T and B. They find that the genus of the cluster too increases with the volume. A high value of genus makes the clusters porous with many tunnels passing through. One can thus imagine the large clusters have multiply connected structures made of many filamentary branches and sub-branches.

Spherical collapse of fuzzy dark matter

Fuzzy Dark Matter (FDM) has been proposed as an alternative to Cold Dark Matter (CDM). FDM is comprised of ultra light Bosons, of masses in the range of $10^{-24} - 10^{-22}$ eV, which exists as a Bose-Einstein condensate. Due to the very low mass of FDM, the de Broglie wavelength of these Bosons is of the order of kpc and the quantum effects manifest at those scales. Hence, unlike CDM, FDM experiences quantum pressure along with gravitational attraction. In this work, **V. Sreenath** investigated the gravitational collapse of a spherically symmetric FDM overdensity.

The equation of motion of a spherically symmetric shell containing an overdense region of FDM contains contributions from both gravity as well as quantum pressure. Assuming a power law density profile, he could obtain a parametric solution to the evolution of radius L, of the spherical shell for the case of non-interacting Bosons, as $L = A(1-e\cos\vartheta)$ and $t = \sqrt{mA^3/k}\,(\vartheta - e\sin\vartheta)$, where A and k are quantities that depend on the mass of the Bosons m, the mass of the overdense region M, and the first integral of motion E. In the above expression, e is given by $e = \sqrt{1 + \frac{E\hbar^2}{G^2 M^2 m^3}\frac{(2\gamma-\gamma^2)}{2}}$, where γ is the index of the power law profile. Since, for a bound system $E < 0$, $e < 1$, from the solutions for L, one can see that the shell will initially expand along with the Hubble flow, then turn around and start to collapse. Since $e < 1$, unlike CDM, the shell will not collapse to zero radius, but it will start expanding again once it reaches the minimum radius $L = A(1-e)$. Thus, this toy model captures partly the competing effects of gravity and pressure. From the expression for e, one can also see that in the limit $\hbar/m \to 0$, CDM. behaviour is retrieved.

Finally, as a shell is contracting, it will interact with inner shells which are expanding again after their initial contraction. When they interact, different shells will repel each other due to the quantum pressure and repel or attract each other according to their force of interaction. This would cause the density profile to depart from its initial power law shape, which in turn would imply that the solutions derived above will not be valid much beyond the turn around radius. Using virial theorem, he derived expressions for averaged overdensity in collapsed halo in the linear theory (taking the small ϑ limit) and the full theory. The results have been summarized in the Table 1. It shows that in this model, when the linear averaged overdensity reaches a critical value, $\bar{\delta} \simeq 1.69/e^{2/3}$, the overdense region would have virialized to form a halo.

t	Linear theory	Full theory
t_{ta}	$\frac{1.06}{e^{2/3}}$	$\frac{9}{2}\frac{\pi^2}{(1+e)^3} - 1$
t_{vir}	$\frac{1.69}{e^{2/3}}$	$18\,\pi^2\frac{8}{(1+e)^3} - 1$

Table 1: The averaged overdensity $\bar{\delta}$, in the linear and the full theory at turn around and virialization. It can be verified that the averaged overdensity matches with the CDM result in the limit $e \to 1$.

Observational Cosmology

Cosmology from cosmic shear power spectra with Subaru Hyper Suprime-Cam first-year data

The gravitational lensing effect in Einstein's general theory of relativity causes the shapes of background galaxies to get distorted due to the gravitational field of the intervening large scale structure. By measuring the exquisite images of about 9 million galaxies taken with the Subaru telescope using the Hyper Suprime-Cam (HSC) camera, which measured the weak lensing effect. The cosmic weak lensing shear power spectra were measured using the data from the Subaru HSC survey first-year shear catalogue covering 137 sq deg of the sky. A careful accounting of various uncertainties in the analysis including the intrinsic alignment of galaxies, scatters and biases in photometric redshifts, residual uncertainties in the shear measurement, and modelling of the matter power spectrum, allows to infer the amplitude of density fluctuations in the Universe.

For a flat lambda-dominated cold dark matter model, **Surhud More** and collaborators were able to constrain the amplitude of density fluctuations with an accuracy of 3.5 percent. In comparison with Planck cosmic microwave background constraints, these results prefer slightly lower values of these amplitude of density fluctuations, although metrics such as the Bayesian evidence ratio test do not show significant evidence for discordance between these results. The ongoing full HSC survey data will contain several times more area, and will lead to significantly improved cosmological constraints.

Assembly bias of cool core clusters traced by Hα nebulae

Do galaxy clusters with cool-core (CC) live in different environments compared to those with a non-cool-core (NCC)? By making novel use of the Hα emission lines in the central galaxies of optically selected galaxy clusters as proxies to construct large (1,000's) samples of CC and NCC clusters, the relative assembly bias of these galaxy clusters was measured using both clustering and weak lensing. The measurements of cross-correlation of these galaxy clusters with an external galaxy redshift catalog from the Sloan Digital Sky Survey III, the LOWZ sample, allowed for an increase in the statistical significance of the results. These cross-correlations can be used to constrain assembly bias up to a statistical uncertainty of 6 percent. Given the Hα criteria for CC and NCC, the study involving **Surhud More** and collaborators, found no significant differences in the clustering amplitude. Interpreting this difference as the absence of halo assembly bias, these results rule out the possibility of having different large-scale (tens of Mpc) environments as the source of diversity observed in cluster cores. Combined with recent observations of the overall mild evolution of CC and NCC properties, such as central density and CC fraction, the results suggest that either the cooling properties of the cluster core are determined early on solely by the local ($\geq$ 200 kpc) gas properties at formation or that local merging leads to stochastic CC relaxation and disruption in a periodic way, preserving the average population properties over time. Studying the small-scale clustering in clusters at high redshift would help shed light on the exact scenario.

Fourier Power Function Shapelets (FPFS) shear estimator: Performance on image simulations

Surhud More and collaborators have reinterpreted the shear estimator used to measure shapes of galaxies for weak gravitational lensing developed by Zhang and Komatsu within the framework of shapelets, and have proposed the Fourier Power Function Shapelets (FPFS) shear estimator. Four shapelet modes are calculated from the power function of every galaxy's Fourier transform after deconvolving the point-spread function (PSF) in Fourier space. They proposed a normalization scheme to construct dimensionless ellipticity and its corresponding shear responsivity using these shapelet modes. Shear is measured in a conventional way by averaging the ellipticities and responsivities over a

large ensemble of galaxies. With the introduction and tuning of a weighting parameter, noise bias is reduced below one per cent of the shear signal. An iterative method is used to reduce selection bias. The FPFS estimator is developed without any assumptions regarding galaxy morphology or any approximations for PSF correction. Moreover, the method does not rely on heavy image manipulations or complicated statistical procedures. The FPFS shear estimator was calibrated using several Subaru HSC-like image simulations and the main results are as follows: (i) For simulations that only contain isolated galaxies, the amplitude of the multiplicative bias is below 1 percent. (ii) For more realistic simulations, which also contain blended galaxies, which are deblended by the first-generation HSC deblender before shear measurement a multiplicative bias of (-5.71 ± 0.31) percent is found. The blending bias is calibrated by image simulations.

Can primordial black holes constitute dark matter?

Primordial black holes (PBHs) have long been suggested as a viable candidate for the elusive dark matter (DM). The abundance of such PBHs has been constrained using a number of astrophysical observations, except for a hitherto unexplored mass window of $M_{PBH}=[10^{-14},10^{-9}]M_{\odot}$. **Anupreeta More**, **Surhud More** and collaborators have carried out a dense-cadence (2 min sampling rate), 7 hour-long observation of the Andromeda galaxy with the Subaru Hyper Suprime-Cam to search for microlensing of stars in Andromeda by PBHs lying in the halo regions of the Milky Way and Andromeda. Given the simultaneous monitoring of tens of millions of stars in Andromeda, if such light PBHs make up a significant fraction of dark matter, they expected to find many microlensing events for the PBH-dark matter scenario. However, they identified only a single candidate event, which translates into the most stringent upper bounds on the abundance of PBHs in the mass range $M_{PBH}=[10^{-11},10^{-6}]M_{\odot}$.

Extragalactic Astronomy

Forming lenticular galaxies via violent disk instability

The aim of this project has been to understand the formation of lenticular (S0) galaxies which are generally thought to have descended from spirals via morphological transformation, although recent numerical simulations have shown that minor or even major mergers can also lead to an S0-like remnant. These mechanisms, however, are active in a dense environment such as a group or a cluster of galaxies making it harder to explain the remarkable fraction of S0s found in the field.

Kanak Saha and Arianna Cortesi propose a new mechanism to form S0 galaxies using the classic Toomre instability that leads to disk fragmentation. It is shown that an isolated cold ($Q < 1$) disk settled into rotational equilibrium becomes violently unstable leading to fragmentation and formation of stellar clumps that, in turn, not only cause the bulge to grow, but also increase the stellar disk velocity dispersion optimally in less than a billion years. Subsequently, the galaxy evolves passively without any conspicuous spiral structure. The final galaxy models resemble remarkably well the morphology and stellar kinematics of the present day S0s observed by the Planetary Nebulae spectrograph (See Figure 7). The findings suggest a natural link between the high-redshift clumpy progenitors and the present-day S0 galaxies.

Evidence for radial variations in the stellar mass-to-light ratio of massive galaxies from weak and strong lensing

The initial mass function (IMF) for massive galaxies expresses the mass distribution of newly formed stars in a galaxy. The IMF can be constrained by combining stellar dynamics with strong gravitational lensing. However, this method is limited by degeneracies between the density profile of dark matter and the stellar mass-to-light ratio (M/L). **Surhud More** and his collaborators reduced this degeneracy by combining weak lensing

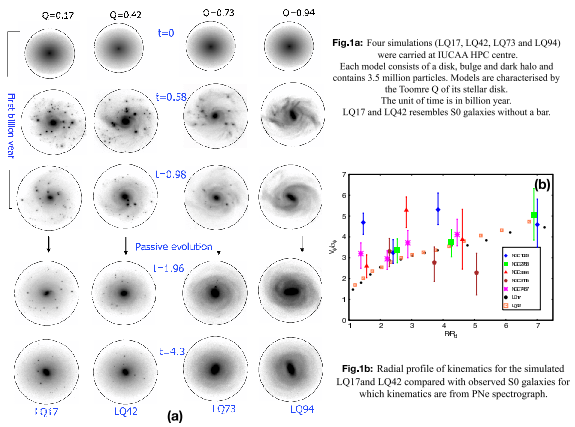


Fig.1a: Four simulations (LQ17, LQ42, LQ73 and LQ94) were carried at IUCAA HPC centre. Each model consists of a disk, bulge and dark halo and contains 3.5 million particles. Models are characterised by the Toomre Q of its stellar disk. The unit of time is in billion year. LQ17 and LQ42 resembles S0 galaxies without a bar.

Fig.1b: Radial profile of kinematics for the simulated LQ17and LQ42 compared with observed S0 galaxies for which kinematics are from PNe spectrograph.

Figure 7: .

together with strong lensing and stellar kinematics. The analysis was based on two galaxy samples: 45 strong lenses from the SLACS survey and 1700 massive quiescent galaxies from the Sloan Digital Sky Survey main spectroscopic sample with weak lensing measurements from the Hyper Suprime-Cam survey. A Bayesian hierarchical approach was used to jointly model all three observables. The data was fit with models of varying complexity, and it was shown that a model with a radial gradient in the stellar M/L is required to simultaneously describe both galaxy samples. This result is driven by a subset of strong lenses with very steep total density profile that cannot be fitted by models with no gradient. The measurements are unable to determine whether M*/L gradients are due to variations in stellar population parameters at fixed IMF, or to gradients in the IMF itself. The inclusion of such gradients decreases dramatically the inferred IMF normalization, compared to previous lensing-based studies, with the exact value depending on the assumed dark matter profile. The main effect of strong lensing selection is to shift the stellar mass distribution towards the high-mass end, while the halo mass and stellar IMF distribution at fixed stellar mass are not significantly affected.

Constraining the stellar IMF with gravitational lenses

The determination of the stellar initial mass function (IMF) of massive galaxies is one of the open problems in cosmology. Strong gravitational lensing is one of the few methods that allow us to constrain the IMF at cosmological distances. The goal of this study was to statistically constrain the distribution in the IMF mismatch parameter, defined as the ratio between the true stellar mass of a galaxy and that inferred assuming a reference IMF, of massive galaxies from the BOSS CMASS sample. **Anupreeta More** and collaborators have taken 22 gravitational lens systems drawn from the CMASS sample, measured their Einstein radii and stellar masses using multi-band photometry from HSC, then fitted a model distribution for the IMF mismatch parameter and dark matter halo mass to the whole sample. They use a prior on halo mass from weak lensing measurements and account for strong lensing selection effects. Assuming an NFW density profile for the dark matter distribution, they infer a value $\mu_{\rm IMF} = 0.03 \pm 0.11$ for the average base-10 logarithm of the IMF mismatch parameter, defined with respect to a Chabrier IMF. A Salpeter IMF is in tension with this measurement.

Uniform modelling of quadruply lensed quasars

Gravitational lens systems with quadruply imaged quasars (quads) are unique probes to address several fundamental problems in cosmology and astrophysics. Although, they are intrinsically very rare, ongoing and planned wide-field deep-sky surveys are set to discover thousands of such systems in the next decade. It is, thus, paramount to devise a general framework to model strong-lens systems to cope with this large influx without being limited by expert investigator time. **Anupreeta More** and collaborators have proposed such a general modelling framework (implemented with the publicly available software LENSTRONOMY), and apply it to uniformly model three-band Hubble Space Telescope Wide Field Camera 3 images of 13 quads. This is the largest uniformly modelled sample of

quads to date and paves the way for a variety of studies. To illustrate the scientific content of the sample, they have investigated the alignment between the mass and light distribution in the deflectors. The position angles of these distributions are well-aligned, except when there is strong external shear. However, they find no correlation between the ellipticity of the light and mass distributions. It is also shown that the observed flux-ratios between the images depart significantly from the predictions of simple smooth models. The departures are strongest in the bluest band, consistent with microlensing being the dominant cause in addition to millilensing. Future research will exploit this rich data set in combination with ground-based spectroscopy and time delays to determine quantities such as the Hubble constant, the free streaming length of dark matter, and the normalization of the initial stellar mass function.

Search for lensed quasars in Pan-STARRS1

Anupreeta More and collaborators have carried out a systematic search for gravitationally lensed quasars in Pan-STARRS1. The final sample of candidates comprises of 91 systems. They have also rediscovered 25 lensed quasars and quasar pairs. Amongst the independently discovered quads is 2M1134 2103, for which they have obtained spectroscopy for the first time, finding a redshift of 2.77 for the quasar. There is evidence for microlensing due to stars from the lensing galaxy in at least one image. They have performed detailed mass modelling of this system using archival imaging data. It is found that the unusal configuration of lensed images can be explained due to a faint companion galaxy (4 arcsec away), and a galaxy group/cluster (30 arcsec away).

Constraining the mass density of free-floating black holes

Strong gravitational lensing of active galactic nuclei, at radio wavelengths, can result in razor-thin arcs, with angular widths of less than a milliarcsecond, if observed at the resolution achievable with very long baseline interferometry (VLBI). Such razor-thin arcs provide a unique window on the coarseness of the matter distribution between a distant source in the background and observer on Earth. **Anupreeta More**, **Surhud More** and collaborators investigate to what extent such razor-thin arcs can constrain the number density and mass function of free-floating black holes, defined as black holes that do not, or no longer, reside at the centre of a galaxy. These black holes can be either primordial in origin or arise as by-products of the evolution of supermassive black holes in galactic nuclei. When sufficiently close to the line of sight, free-floating black holes cause kink-like distortions in the arcs, which are visually detectable in the VLBI images as long as the black hole mass exceeds 1000 solar masses. Using a crude estimate for the detectability of such distortions, they analytically compute constraints on the matter density of free-floating black holes resulting from non-detections of distortions along a realistic, fiducial arc, and find them to be comparable to those from quasar millilensing. They also use predictions from a large hydrodynamical simulation for the demographics of free-floating black holes that are not primordial in origin and show that their predicted mass density is roughly four orders of magnitude below the constraints achievable with a single razor-thin arc.

Environments and line-of-sight structures of lensing galaxies

Anupreeta More and collaborators have investigated the local and line-of-sight overdensities of strong gravitational lens galaxies using wide-area multiband imaging from the Hyper Suprime-Cam Subaru Strategic Program. They present 41 new definite or probable lens candidates discovered in Data Release 2 of the survey. Using a combined sample of 87 galaxy-scale lenses out to a lens redshift of ~ 0.8, they compare galaxy number counts in lines of sight toward known and newly discovered lenses in the survey to those of a control sample consisting of random lines of sight. They also compare the local overdensity of lens galaxies to a sample of "twin" galaxies that have a similar red-

shift and velocity dispersion to test whether lenses lie in different environments from similar non-lens galaxies. It is found that lens fields contain higher number counts of galaxies compared to the control fields, but this effect arises from the local environment of the lens. Once galaxies in the lens plane are removed, the lens lines of sight are consistent with the control sample. The local environments of the lenses are overdense compared to the control sample, and are slightly overdense compared to those of the twin sample, although the significance is marginal. There is no significant evidence of the evolution of the local overdensity of lens environments with redshift.

Gravitational Waves

Gravitational wave signature of a mini creation event

In light of the recent discoveries of binary black hole events by the advanced LIGO (aLIGO) and advanced Virgo (aVirgo) detectors, **Sanjeev V. Dhurandhar** and **Jayant V. Narlikar** propose a new astrophysical source, namely, the mini creation event (MCE) as a possible source of gravitational waves (GW) to be detected by advanced detectors. The MCE is at the heart of the quasi steady state cosmology (QSSC), and is not expected to occur in standard cosmology. Generically, the MCE is anisotropic and they assume a Bianchi tpye I model for its description. They compute its signature waveform and assume masses, distances analogous to the events detected by aLIGO and aVirgo. By matched filtering the signal, they find that for a broad range of model parameters, the signal to noise ratio of the randomly oriented MCE is sufficiently high for a confident detection by aLIGO. They, therefore, propose the MCE as a viable astrophysical source of GW. The detection or non-detection of such a source also holds implications for QSSC, namely, whether it is a viable cosmology or not.

Hierarchical search for detecting gravitational waves from compact coalescing binaries

Standard searches are currently restricted to a smaller parameter space which assumes aligned spins. Construction of a larger and denser parameter space, and optimising the resultant increase in false alarms, pose a serious computational challenge. **Bhooshan Gadre**, **Sanjit Mitra**, and **Sanjeev V. Dhurandhar** present a hierarchical strategy to search for compact coalescing binaries from a network of detectors, and demonstrate the computational advantage of about 20 over the flat search in real data.

Optimal chi squared vetos for Sine-Gaussian glitches

The traditional chi squared veto has been applied to the gravitational wave data with fair amount of success. However, this test is ad hoc and is not guaranteed to be optimal. **Sanjeev Dhurandhar**, **Sukanta Bose**, and Rahul Dhurkunde have constructed an optimal chi squaredtest for glitches in the data, which can be modelled as Sine Gaussians, and which are ubiquitous. The method for constructing any chi squared has been fully discussed in the previous work on unified chi squares. The parameter space of Sine-Gaussians is adequately sampled and a subspace of the space of data trains is obtained. Using the singular value decomposition, one may construct subspace of much lower dimension and orthogonal to the signal. This is then the required chi squared.

Cosmic Magnetic Fields

Varying the forcing scale in low Prandtl number dynamos

Small-scale dynamos are expected to operate in all astrophysical fluids that are turbulent and electrically conducting, for example, the interstellar medium, stellar interiors, and accretion disks, where they may also be affected by or competing

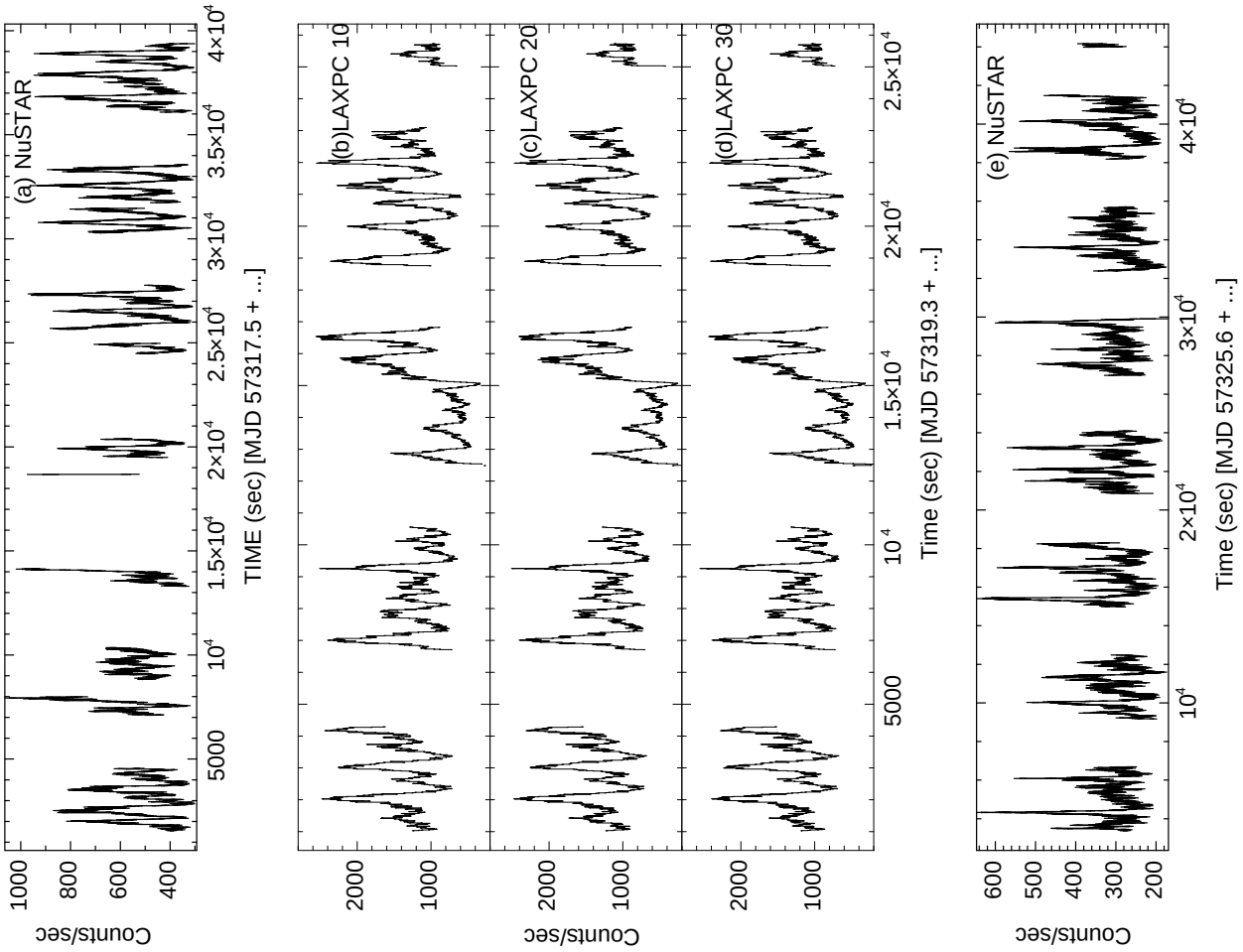


Figure 8: Background subtracted light curves in 3-79 keV energy band obtained from the NuSTAR observations are shown in panels, (a) MJD 57317.5 and (e) MJD 57325.6. Background subtracted 3-80 keV lightcurves for the 3 LAXPCs units (LAXPC 10, 20 and 30) on MJD 57319.3 are shown in panels (b), (c) and (d), respectively. The gaps in the light curve are due to the passage of the satellite through the South Atlantic Anomaly regions.

with large-scale dynamos. However, the possibility of small-scale dynamos being excited at small and intermediate ratios of viscosity to magnetic diffusivity (the magnetic Prandtl number) has been debated, and the possibility of them depending on the large-scale forcing wavenumber has been raised. Axel Brandenburg, N. E. L. Haugen, Xiang-Yu Li, and **Kandaswamy Subramanian** showed, using four values of the forcing wavenumber, that the small-scale dynamo does not depend on the scale-separation between the size of the simulation domain and the integral scale of the turbulence, i.e., the forcing scale. Moreover, the spectral bottleneck in turbulence, which has been implied as being responsible for raising the excitation conditions of small-scale dynamos, is found to be invariant under changing the forcing wavenumber. However, when forcing at the lowest few wavenumbers, the effective forcing wavenumber that enters in the definition of the magnetic Reynolds number is found to be about twice the minimum wavenumber of the domain. This work is relevant to future studies of small-scale dynamos, of which several applications are being discussed.

Turbulent transport coefficients in galactic dynamo simulations using singular value decomposition

Coherent magnetic fields in disc galaxies are thought to be generated by a large-scale (or mean-field) dynamo operating in their interstellar medium (ISM). A key driver of mean-field growth is the turbulent electromotive force (EMF), which represents the influence of small-scale velocity and magnetic fields on the mean-field. This is usually expressed as a linear expansion in the mean-field and its derivatives, with dynamo coefficients as expansion coefficients. **Abhijit B. Bendre**, **Kandaswamy Subramanian**, Detlef Elstner, and Oliver Gressel have adopted the singular value decomposition (SVD) method to directly measure these dynamo or turbulent transport coefficients in a simulation of the turbulent ISM that realizes a large-scale dynamo. Specifically, the SVD is used to least square fit the time series data of EMF with that of mean-field and its derivatives, to determine these coefficients. They demonstrate that the profiles of reconstructed EMF with SVD match well with that obtained directly from the simulation. Also as a direct test, they use these coefficients to simulate a 1-D dynamo model and find an overall similarity in the evolution of the mean-field between the dynamo model and the direct simulation. They also compare the results with that obtained previously using the test-field method and find reasonable agreement. Overall, the SVD method provides an effective post processing tool to determine turbulent transport coefficients from simulations. (see Figures 9 and 10).

Efficient quasi-kinematic large-scale dynamo as the small-scale dynamo saturates

Large-scale magnetic fields in stars and galaxies are thought to arise by mean-field dynamo action due to the combined influence of both helical turbulence and shear. Those systems are also highly conducting, where turbulence leads to a fluctuation (or small-scale) dynamo, which more rapidly amplifies magnetic field fluctuations on the eddy scales and smaller. Will this then interfere with and suppress the mean (or large-scale) field growth? Using direct numerical simulations of helical turbulence (with and without shear), Pallavi Bhat, **Kandaswamy Subramanian,** and Axel Brandenburg identify a novel quasi-kinematic large-scale dynamo, which operates as the small-scale dynamo saturates. Thus, both dynamos operate efficiently, one after the other, and lead to the generation of significant large-scale fields.

The origin of large-scale magnetic fields in low-mass galaxies

The origin of large-scale magnetic fields, detected in some low-mass (dwarf and irregular) galaxies via polarised synchrotron emission and Faraday rotation, remained unexplained for a long time. Prasanta Bera, Anvar Shukurov, and **Kandaswamy Subramanian** suggest that mean-field dynamo

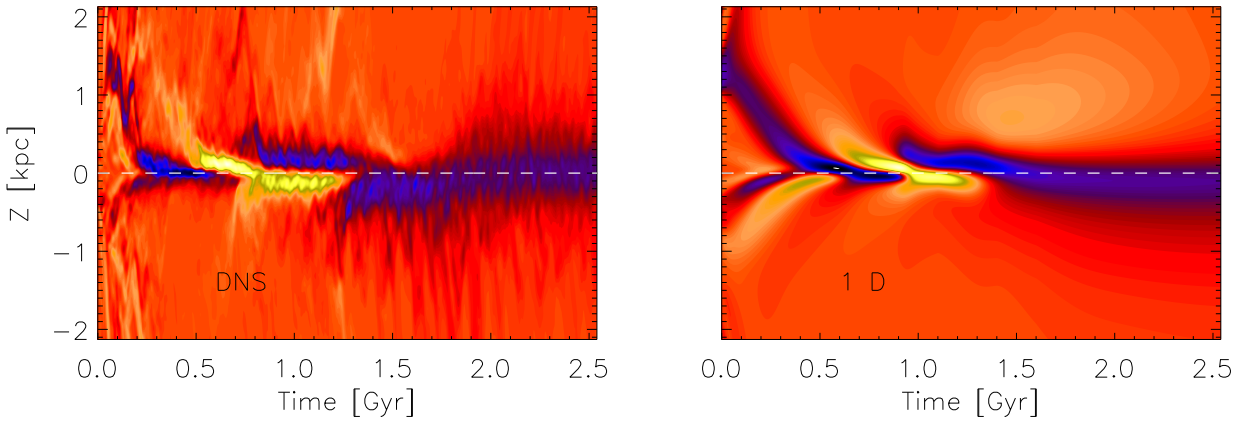


Figure 9: **Left panel**: Shows the space-time contour of the azimuthal component of mean-field result from realistic MHD simulations of turbulent ISM. **Right panel**: Shows the same but for the azimuthal field components obtained from 1-D dynamo simulations, with same colour code. Note the overall similarity in both contours.

can be active in galaxies of this class despite their slow rotation because their discs are relatively thick. Earlier assessments of the possibility of the mean-field dynamo action in low-mass galaxies relied on estimates applicable to *thin* discs, such as those in massive spiral galaxies. Using both order-of-magnitude estimates and numerical solutions, they show that the strength of differential rotation required to amplify magnetic field reduces as the aspect ratio of the galactic gas layer increases. Thus, the puzzle of the origin of large-scale magnetic fields appears to be solved. As a result, this class of galaxies provides a new ground for testing the understanding of galactic magnetism.

Gravitational wave generation in a viable scenario of inflationary magnetogenesis

Generation of magnetic fields during inflation is a promising scenario for the origin of the seed magnetic fields in the universe. A popular mechanism suggested by Ratra is one where one takes a coupling between the inflaton and electromagnetic field. For certain choices of this coupling, the fields generated satisfy all observational constraints. However, it turns out that this model suffers from the strong coupling and back-reaction problems. It is also severely constrained by particle production due to the Schwinger mechanism. In the earlier work, Ramkishor Sharma, **Kandaswamy Subramanian**, and T. R. Seshdari suggested a model which avoids these problems, while satisfying all observational constraints. This, model, however, requires a low scale for reheating, and generates magnetic fields with blue spectrum, and power concentrated on the Hubble scale at reheating. The anisotropic stress associated with such fields can source the production of a stochastic background of gravitational waves. For helical fields, the generated gravitational waves can also be circularly polarized. They have calculated this gravitational wave background to compare with the current limits set by pulsar timing arrays and those expected from space based gravitational wave detectors like LISA. The detection of (or limts on) the stochastic background of gravitational waves in the future will strongly constrain such models of inflationary magnetogenesis.

Cosmic Microwave Background

Bayesian estimation of SI violation

The Bipolar Spherical Harmonic (BipoSH) representation proposed a decade back has been steadily

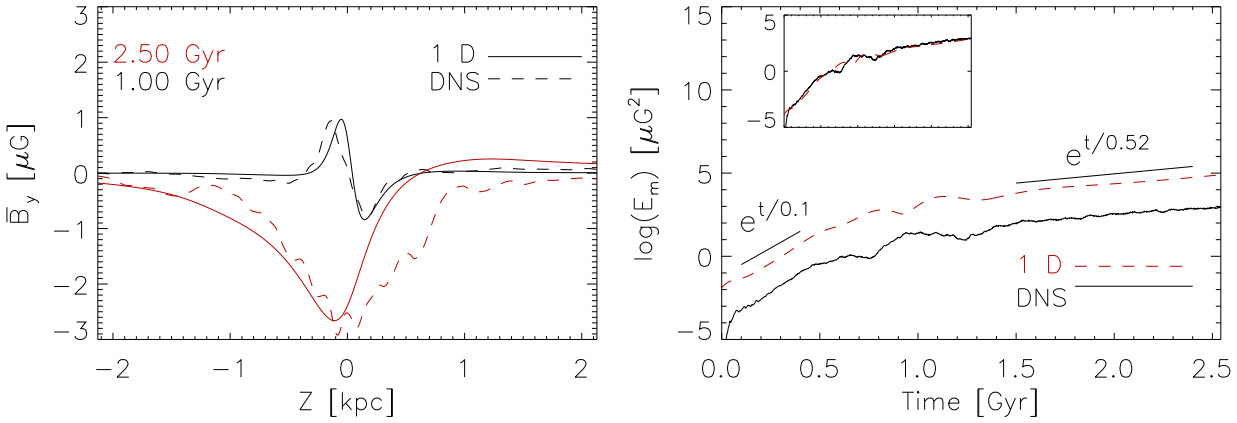


Figure 10: **Left Panel**: Compares the vertical (space) profiles of azimuthal components of mean-field obtained from direct MHD simulations (dashed lines) and from 1-D dynamo simulations (solid lines) at various times in the evolution. **Right Panel**: Shows time evolution of magnetic energy from direct simulations (black-solid lines) and 1-D simulations (red-dashed lines), to avoid the clutter the red line is shifted up by 2 orders of magnitude, although they match reasonably well as shown in the inset.

established in the cosmology community as the most robust and natural measure of violation of statistical isotropy (SI) in the cosmic microwave background anisotropy.

One of most intriguing and highlighted results from Planck is a cosmic hemispherical asymmetry (CHA) in the CMB sky challenging the fundamental cosmological principle is established through the BipoSH analysis at about 3 sigma significance. **Shabbir Shaikh**, Suvodip Mukherjee, Santanu Das, **Tarun Souradeep** and Ben Wandelt have worked on the Bayesian assessment of the CHA with the Planck maps.

Early universe from CMB

The remarkable progress in CMB studies over past decade has led to the era of precision cosmology in striking agreement with the LCDM model. However, the estimation of cosmological parameters is based on the assumed form of the primordial power spectrum (typically, power-law). It is important to assess the impact that the assumed specific form of primordial power spectrum may have on the inferred cosmological parameters from CMB data. With Arman Shafieloo and Dhiraj Hazra, **Tarun Souradeep** has worked on projecting the current tension in the local and global estimates of the Hubble constant on the primordial power spectrum.

High Energy Astrophysics

Cyclotron Resonance Scattering Features

Cyclotron Resonance Scattering Features (CRSFs) in an energy spectrum are an indicator of a strong magnetic field. The central line energy of the CRSF is used to estimate the local magnetic field. Observations of such features in the X-ray spectrum places the observed magnetic field at a few times 10^{12} G. Such high fields are expected from neutron star (NS) sources with matter accreting onto its surface. Due to the compact nature of NS, the speed of rotation is quite high and it provides views of different parts on the surface which inherently differ. To probe these differences **Yash Bhargava** performed a pulse-phase resolved spectroscopy of Cepheus X-4, an outbursting high mass neutron star X-ray binary.

The outburst of Cepheus X-4 in 2014 was captured by Suzaku and NuSTAR at two epochs, the first one at the peak, and the second during the

decline. The high brightness and long exposure of the observations enabled to conduct a pulse-phase resolved spectroscopy, where the spectra were extracted corresponding to different phases in the pulse profile, which captures different regions on the surface of NS. He found that the line parameters change in tandem with the pulse profile indicating the magnetic field is not constant across the surface of the NS but correlates with the flux in the pulse profile. (See Figures 11 and 12). Also, it explains the previously noted asymmetric nature of the cyclotron line as the effect of averaging over the variation in the CRSF over the pulse profile.

Core-collapse Supernovae and Supermassive Black Holes

Rupak Roy has worked on the disruption of massive stars at the end of their life-time, known as Core-collapse Supernovae (CCSNe), and also on the disruption of stars through tidal forces of the Supermassive Black Holes (SMBHs) at the centers of the galaxies. These are known as Tidal Disruption Events (TDEs). The CCSNe events produce a compact remnant (Neutron star or stellar-mass black hole) due to collapse of the core and the outer material is ejected into space.

Recently, astronomers have discovered stellar disruptions, which are 10-100 times more luminous than canonical CCSNe. These are called Superluminous Supernovae (SLSNe), the physics of which is still unknown. These extremely energetic phenomena (liberated energy $\sim 10^{50} ergs$) exist for several months and are observable mainly in X-ray, UV, and optical wavebands. These are also efficient probes to study the SMBHs in the inactive galaxies. He studied these energetic transients by observing them in optical, UV and X-ray wavelengths using ground and space-based telescopes.

Spectro-polarimetric study of two Gamma Ray Bursts

Dipankar Bhattacharya, **Shabnam Iyyani**, and collaborators have been studying the spectro-polarimetric emission of two Gamma Ray Bursts GRB 160802A and GRB 171010A and these have been carried out using simultaneous observations with the AstroSat CZTI and other missions including Fermi and Swift. The availability of polarization measurements place strong constraints on the emission mechanism and view geometry. In GRB 160802A, subphotospheric dissipation appears to dominate the emission, with the observer's sight line close to the edge of the GRB jet. In GRB 171010A, time variability of polarization indicates a fragmented fireball or ongoing dissipation of Poynting flux.

Ionized wind from accretion disk of stellar mass black hole

A simultaneous observation by **Dipankar Bhattacharya**, **Gulab C. Dewangan** and collaborators, of an accreting stellar mass black hole 4U 1630-47 with AstroSat, Chandra and MAXI missions has revealed the presence of an ionized wind from the accretion disk, outflowing at about 350 km/s. The broadband spectral shape measured from these observations indicate that the accreting black hole is spinning very rapidly, near the maximum allowed limit.

AstroSat timing of a neutron Star

The launch of AstroSat was on September 28, 2015 and the LAXPC instrument was turned on and became operational on October 19, 2015. On being alerted that 4U 0115+63 was undergoing a major outburst (Ballhausen, et al. 2015), the AstroSat was pointed at this Be/X-ray binary pulsar, and observations were made with the LAXPC instrument on October 24, 2015 during the peak of a giant type II outburst. Prominent intensity oscillations (quasi-periodic oscillations) at $\sim$1 and $\sim$2 mHz frequency were detected in LAXPC and Nuclear Spectroscopic Telescope Array (NuSTAR) observations during this outburst by **Jayashree Roy**, and collaborators (see Figure 8). The slowest 1mHz oscillation detected from this source in transient X-ray binary pulsars was detected upto 50 keV by LAXPC. Millihertz oscillations from this source are also observed from Rossi X-ray Timing

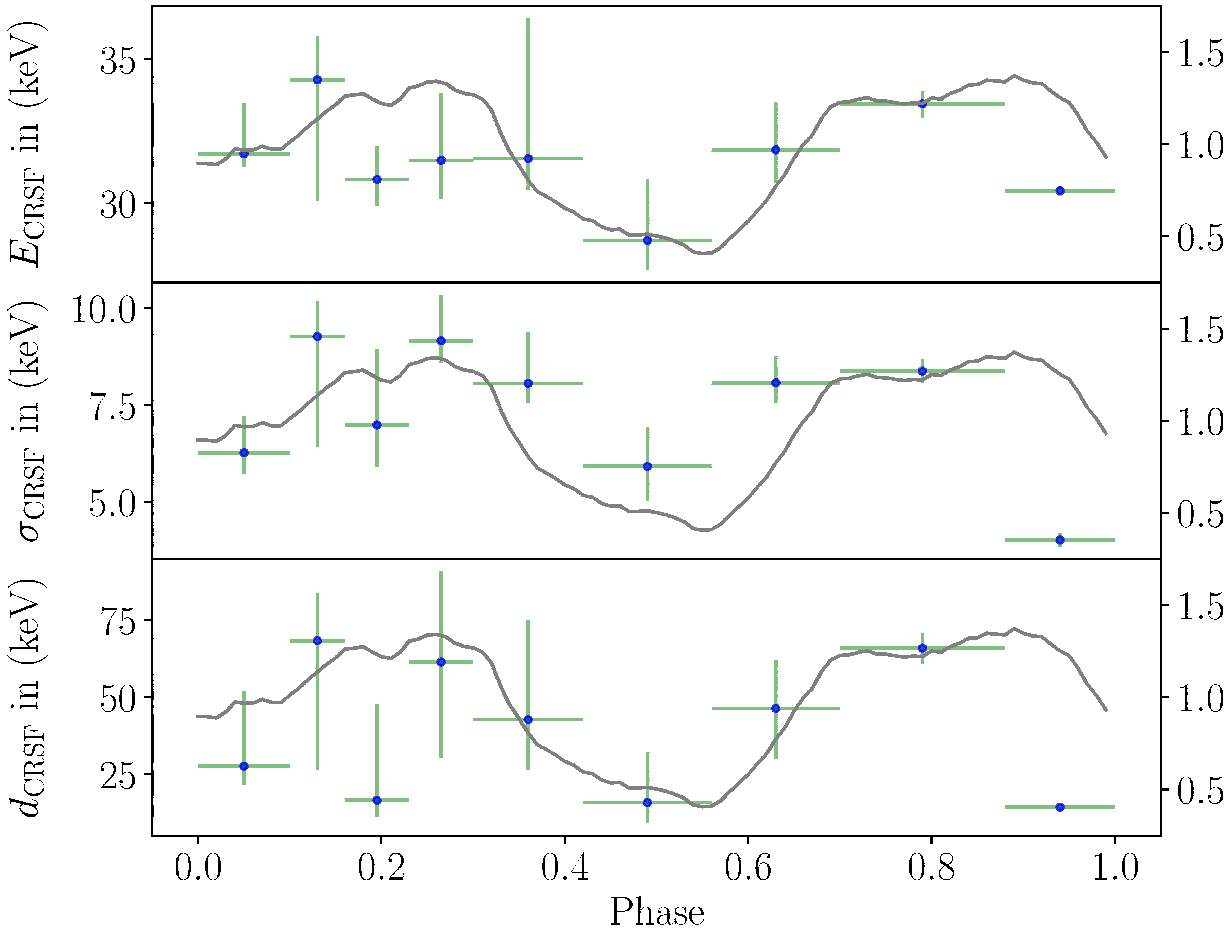


Figure 11: The variation of CRSF line parameters is shown with pulse profile in the background (in grey). It can be seen that the line parameters follow the trend of the pulse profile indicating that there is a variation in the region scattering the hard X-ray photons. The variation also indicates that the strength of the magnetic field is correlated with the flux from the region.

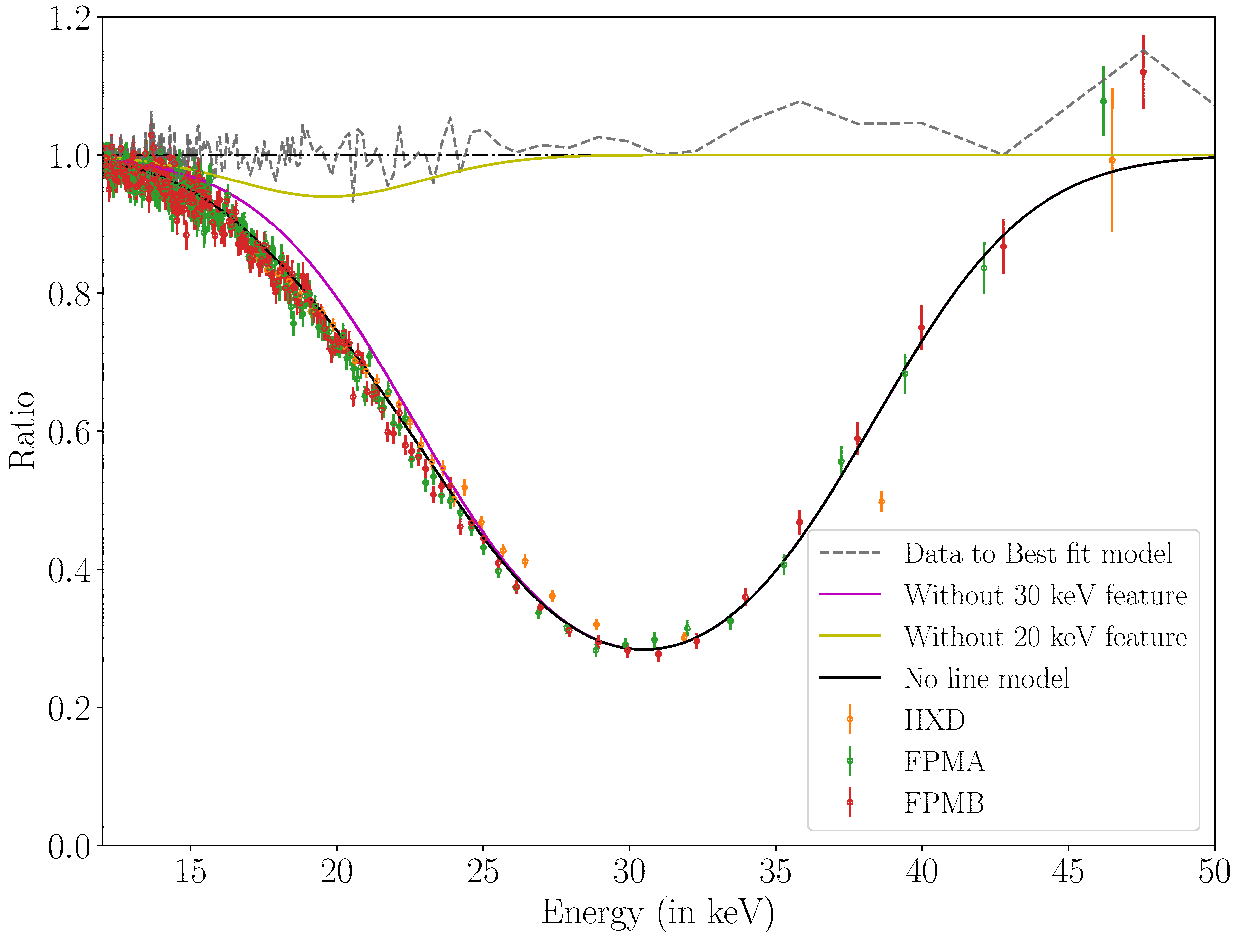


Figure 12: Shows simulated spectrum by combining the model with symmetric CRSF lines in different phase bins and weighing them with corresponding exposures. The resultant spectrum successfully reproduces the asymmetric nature of the cyclotron line as seen in Furst, et al. 2015. The difference between the magenta line and solid black line indicates the asymmetry introduced due to the averaging of the spectrum with symmetric lines at slightly different energies.

Explorer/Proportional Counter Array data during the 2004, 2008 and 2011 outbursts. This suggests the possibility of this phenomenon being related to the elliptical binary orbit of the Be/X-ray pulsar. There are ∼225 known X-ray pulsars, among them only ∼ 9 transient X-ray binary pulsars including 4U 0115+63, show milliHertz oscillations. These type of oscillations are observed from other X-ray binary sources like black hole and neutron star binaries. The quasi-periodicity timescale is independent of the accretor and depends on accretion and physical parameters of the binary system that are distinct from other smaller-timescale QPOs observed from this and other binary systems.

Evolution of magnetars

Vikram Soni, **Dipankar Bhattacharya** and collaborators have examined the evolution of magnetars in a model where an ultra-strong magnetic field is generated in the core of a massive neutron star due to a spin-alignment phase transition, which eventually emerges at the surface aided by ambipolar diffusion. A characteristic dependence of the ratio of spin-down luminosity and X-ray luminosity on the spin period of the neutron star is predicted, which can be used to verify this model once a large sample of magnetars can be studied.

Study on temporal and spectral behaviour of 3C 279

Blazars are a special class of active galactic nuclei (AGN) with powerful relativistic jets of plasma pointing close to the line of sight of the observer. This close pointing of the jet towards the observer results in extreme properties in the blazar emission, viz. rapid variability, non-thermal emission extending from radio to GeV energy, highly polarized emission in the optical and radio bands of spectrum, typical double humped spectral energy distribution shape, etc. Based on the presence/absence of strong emission line features in their optical spectrum, blazars are classified into flat spectrum radio quasars (FSRQs) and BL Lacs. **Zahir Shah**, **V. Jithesh**, Sunder Sahayanathan, **Ranjeev Misra**, and Naseer Iqbal Bhat have carried out a detailed investigation of the temporal and spectral behaviour of the recent January, 2018 flaring event from FSRQ 3C 279 by using the multi-wavelength observations from Swift-XRT, Swift-UVOT and Fermi-LAT. Based on the temporal analysis of the γ-ray light curve, they found a lag of $\sim$ 1 d between the low energy (0.1–3 GeV) and high energy (3–5 GeV) γ-ray emission. Additionally, they found that the γ-ray light curve shows asymmetric behaviour with slow rise-fast decay in the energy band 0.1–3 GeV and fast rise–slow decay in the 3–500 GeV band. They interpret the asymmetry as a result of a shift in the Compton spectral peak, which is supported by correlation studies between the flux and the parameters of the log-parabola fit to the source spectra in the energy range 0.1–500 GeV. Also the flux correlates well with the peak spectral energy, and the log-parabola fit parameters show a harder spectrum with large curvature at high flux states. During January 27 - 28, 2018, significant enhancement in the very high-energy γ-ray emission (VHE) was also detected from 3C 279 by the HESS. However, Fermi γ-ray light curve did not show substantial flux enhancement during the VHE flaring period. Interestingly, they found the hardest γ-ray spectrum with large curvature to be synchronous with VHE flare. Their study of the spectral behaviour of the source suggests that the γ-ray emission is most likely to be associated with the Compton up-scattering of IR photons from the dusty environment. Moreover, based on the spectral energy distribution (SED) fit parameters, they showed that the increase in bulk Lorentz factor of emission region is a dominant cause for the flux enhancement. (See Figure 13).

Statistical study of simulated flux distributions

Zahir Shah, **Ranjeev Misra** and Atreyee Sinha have carried out a detailed statistical study of simulated flux distributions. There is considerable long-term observational evidence that the high energy light curves of blazars follow a log-normal flux distribution. Based on the simulation, they quantitatively identify the minimum number of flux points needed in the distribution in order to reject the nor-

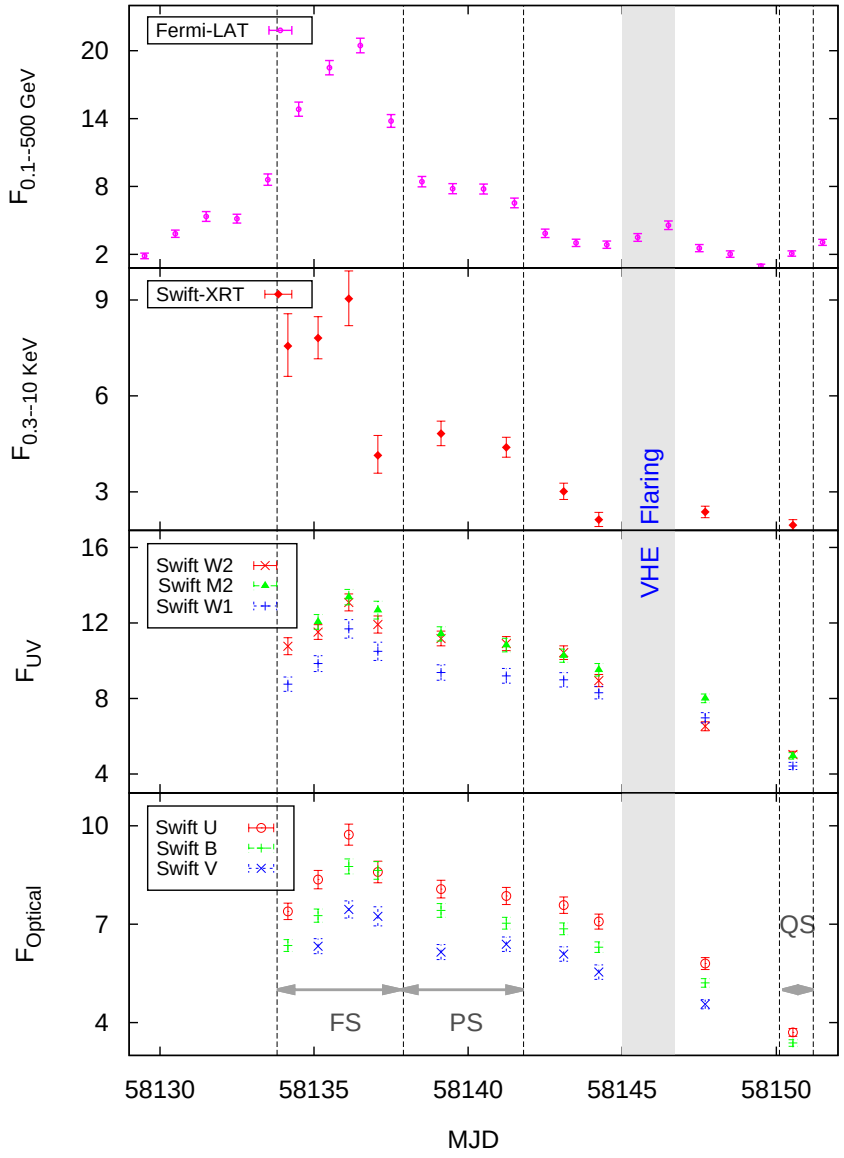


Figure 13: Multi-wavelength light curve of 3C 279 during period MJD 58129–58152. The γ-ray flux points are one day binned in units of 10^{-6}ph cm^{-2} s^{-1}, *Swift*-XRT (0.3–10 keV) flux points are in units of 10^{-11} erg cm^{-2} s^{-1}, and *Swift*-UVOT fluxes are in units of 10^{-15} erg cm^{-2} s^{-1} A^{-1}. The vertical dotted lines with horizontal gray arrow headed lines represents the time slots corresponding to three flux states, viz. 'flaring state (FS)', 'plateau state (PS)' and 'quiescent state (QS)' for which time averaged SEDs are obtained. The vertical solid gray region corresponds to VHE flaring time of 3C 279.

mality of the flux distribution. In case of skewness analysis, they showed that the sample size (number of flux points in the distribution) should be greater than 200 for the skewness significance of 3 or more. They also showed that AD test requires lesser number of points compared to skewness test for the rejection of normality of flux distribution. They also demonstrated that the slope of error distribution in which errors are weighted with the flux values was significant only for large percentage of error, and the binning of log-normal flux distribution did not change the log-normal behaviour of the distribution. On applying these results to eight year monthly binned γ-ray light curve of bright Fermi blazar, viz. 3FGL J0730.2-1141, they found that the AD test results were more significant to confirm the log-normality of distribution than the skewness test. Moreover, they studied the power-law noise generated with Timmer and Koenig algorithm for three slopes β= 0.0, 0.5, 1.0, and they found that AD test rejected the normality of power-law noise for large sample size of blazars with non-zero spectral slope. However, power law noise generated with Timmer and Koenig algorithm being essentially normal distribution, advocates for modification in the critical values of AD test. They generated new AD critical values for the power-law noise with slopes 0.5 and 1.0 such that new critical values did not reject the normality of the generated power law noise.

Spectral-timing analysis of Seyfert 1 galaxy Mrk 1044

Gulab C. Dewangan, **Labani Mallick**, **Ajit K. Kembhavi**, **Ranjeev Misra**, and collaborators have performed a detailed spectral-timing analysis of a long (130 ks) XMM-Newton observation and quasi-simultaneous NuSTAR and Swift observations of the highly accreting narrow-line Seyfert 1 galaxy Mrk 1044. The broad-band (0.3-50 keV) spectrum reveals the presence of a strong soft X-ray excess emission below 1.5 keV, iron K emission complex at 6-7 keV and a 'Compton hump' at 15-30 keV. They find that the relativistic reflection from a high-density accretion disc with a broken power-law emissivity profile can simultaneously explain the soft X-ray excess, highly ionized broad iron line and the Compton hump. At low frequencies, the power-law continuum-dominated 1.5-5 keV band lags behind the reflection-dominated 0.3-1 keV band, which is explained with a combination of propagation fluctuation and Comptonization processes, while at higher frequencies, a soft lag is detected which is interpreted as a signature of X-ray reverberation from the accretion disc. The fractional root-mean-squared variability of the source decreases with energy, and is well described by two variable components: a less variable relativistic disc reflection and a more variable direct coronal emission. The combined spectral-timing analyses has suggested that the observed broad-band X-ray variability of Mrk 1044 is mainly driven by variations in the location or geometry of the optically thin, hot corona.

Broad-band spectral study of Seyfert 1 galaxy 1H 0323+342

Ritesh Ghosh, **Gulab C. Dewangan**, **Labani Mallick** and Biplab Raychaudhuri have performed a detailed broad-band spectral study of the radio-loud narrow-line Seyfert 1 galaxy 1H 0323+342, based on multi-epoch observations performed with Nuclear Spectroscopic Telescope Array on March 15, 2014 and two simultaneous observations performed with Suzaku and Swift on July 26, 2009 and March 1, 2013. They found the presence of a strong soft X-ray excess emission, a broad but weak Fe line and hard X-ray excess emission. They used the blurred reflection and the intrinsic disc Comptonization (optxagnf), two physically motivated models, to describe the broad-band spectra and to disentangle the disc/corona and jet emission. The relxill model is mainly constrained by the strong soft X-ray excess although the model failed to predict this excess when fitted above 3 keV and extrapolated to lower energies. The joint spectral analysis of the three data sets above 3 keV with this model resulted in a high black hole spin and moderate reflection. The optxagnf model fitted to the two simultaneous data sets resulted in an excess emission in the ultraviolet (UV) band. The simultaneous UV-to-hard X-ray spectra are best de-

scribed by a model consisting of a primary X-ray power-law continuum, a blurred reflection component, Comptonized disc emission as the soft X-ray excess, optical/UV emission from a standard accretion disc and a steep power law component, most likely the jet emission in the UV band.

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Modelling the energy dependent temporal behaviour of Cygnus X-1

In the last two decades, there have been extensive studies on the rapid temporal behaviour of X-ray binaries primarily using *Rossi X-ray Timing Explorer (RXTE)* data. The X-ray variability of these sources are characterized by their power density spectra (PDS), which show broad band continuum noise like features, and sometimes peaked features known as quasi-periodic oscillations (QPOs). The origin of the broad band continuum noise could be due to perturbations, which occur throughout the disk and propagate inwards causing the X-ray variation. Since these variations occur at different radii and are expected to have a multiplicative effect on the accretion rate of inner disk, the scenario provides an explanation for the linear relationship of the root mean square (rms) variability with the flux. Additionally, the model also makes predictions on energy dependent temporal properties of the system. In particular, the variation of the fractional rms and time-lag as a function of energy can provide clues to the geometry of the system within this paradigm. **Bari Maqbool Bhat**, **Ranjeev Misra** and others have studied the results from six observations of Cygnus X-1 by Large Area X-ray Proportional Counter (LAXPC) and Soft X-ray Telescope (SXT) on-board *AstroSat*, when the source was in the hard spectral state as revealed by the broad band spectra. The spectra obtained from all the observations can be described by a single temperature Comptonizing region with disk and reflection components. The event mode data from LAXPC provides unprecedented energy dependent fractional rms and time-lag at different frequencies, which they fit with empirical functions. They invoked a fluctuation propagation model for a simple geometry of a truncated disk , with a hot inner region. Unlike other propagation models, the hard X-ray emission (> 4 keV) was assumed to be from the hot inner disk by a single temperature thermal Comptonization process. The fluctuations first cause a variation in the temperature of the truncated disk and then the temperature of the inner disk after a frequency dependent time delay. They were successful in showing that the proposed model could explain the energy dependent rms and time-lag at different frequencies. (See Figure 14).

UV to X–Ray Comptonization delay in Mrk 493

The broadband X–ray emission from Type 1 AGN, dominated by a power–law continuum, is thought to arise from repeated inverse Compton scattering of seed optical/UV photons by energetic electrons in a hot corona. The seed optical/UV photons are assumed to arise from an accretion disk, but direct observational evidence has remained elusive. Adegoke Oluwashina, **Pramod Pawar, Gulab C. Dewangan**, and Main Pal have reported the first direct observational evidence for the accretion disk being responsible for the seed photons for thermal Comptonization in the hot corona based on $\sim$ 100 ks XMM–Newton observations of the narrow–line Seyfert 1 galaxy Mrk 493. They find that the UV emission leads by ~ 5 ks relative to the X–ray emission. The UV lead is consistent with the time taken by the UV photons to travel from the location of their origin in the accretion disk to the hot corona, and the time required for repeated inverse Compton scattering converting the UV photons into X–ray photons.

AGN feedback in the core of a galaxy cluster A2626

Sonali Kadam, Satish Sonkamble, **Pramod Pawar**, and Madhav K. Patil have analyzed the publicly available two Chandra observations and 1.4 GHz VLA radio data on A2626 to asesses the appropriateness of the AGN heating with the cooling of the ICM on the basis of the radio power of the central black hole. This study confirmed the

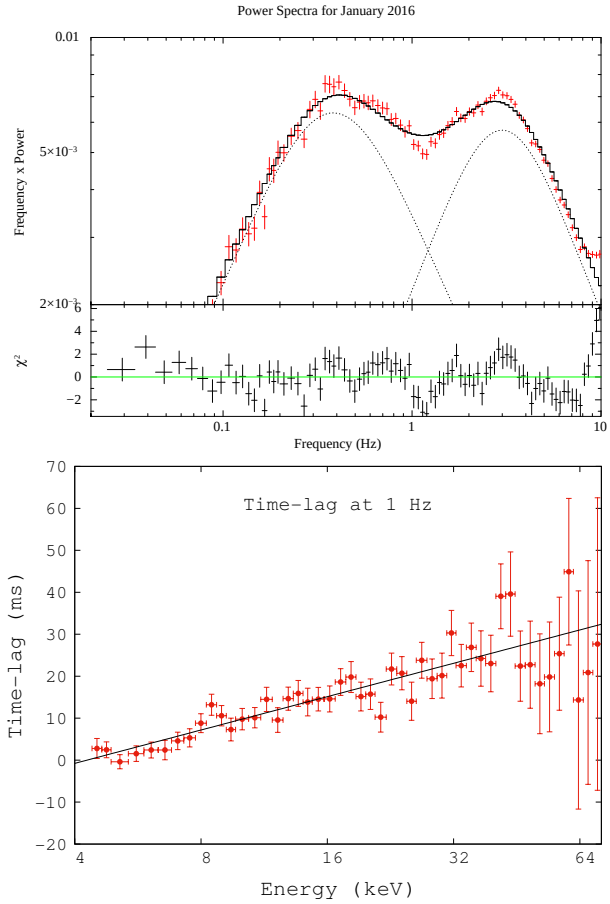

Figure 14: The frequency times the power density spectrum of Cygnus X-1 for photons in the 4–80 keV energy band for the month of January 2016. The power density spectrum has been fitted with two Lorentzian components (left panel). The right panel shows the time-lag as a function of energy at 1 Hz for the same month. The time-lags are increasing with the increase in energy and have been fitted using the fluctuation propagation model.

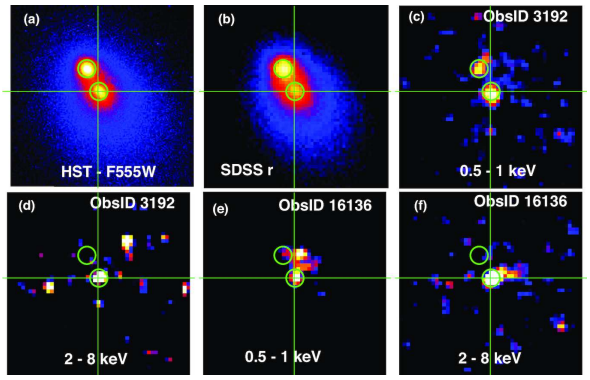

Figure 15: Optical and X-ray images of the central $25'' \times 25''$ of A2626. (a) HST F555W image, (b) SDSS r–band image, (c), (d) Chandra images using ObsId 3192, (e) and (f) Chandra images using ObsId 16136. Each of the Chandra images is divided into two different energy bins, the soft (0.5–1 keV) and the hard (2–8 keV), and are smoothed using a 2-pixel-wide Gaussian.

previous detection of the east cavity at 13 kpc and reports the detection of a new cavity at 39 kpc to the west of the X–ray peak. The average mechanical power injected by the active galactic nucleus outburst is found to be $\sim$ 30 times more than that required to compensate the cooling luminosity. The edges in the surface brightness are spatially associated with arcs in the temperature and metallicity maps, and are attributed due to the merging cold fronts. A systematic study of the nuclear twin sources exhibited dramatic changes over the span of 10 years (See Figure 15). The NE source that emitted mostly in the soft X–ray band in the past had disappeared in the recent observations. Instead, an excess emission has been seen at 2.2 arcsec to its west that required an unrealistic line–of–sight velocity of $675c$ if it is due to its relative motion. The count rate and spectral analysis exhibited a change in the state of the SW source from a soft to a hard state due to the change in the mass accretion rate.

UV and X-ray variability in Seyfert 1 galaxies

The emission from active galactic nuclei (AGN) has been found to be variable at all observed wavelengths. The variability time-scales in different bands can range from years to months or even hours. Previous studies have shown that the variations in the optical/UV continuum in Seyfert galaxies are well correlated with the variations in the X-rays. But the exact origin of optical/UV variability in AGN is not yet clearly understood. In an ongoing work, **Savithri H. Ezhikode, Gulab C. Dewangan, Ranjeev Misra**, Krishnapriya K. V. and Geethika B. R. study the UV and X-ray variability of two Seyfert type 1 AGN in the nearby universe, Mrk 110 (redshift = 0.035) and Mrk 926 (redshift = 0.047). Both the sources have been observed in UV and X-ray wavelengths for years by different missions. They analyse the multi-wavelength data from AstroSat, Swift, XMM-Newton, GALEX, Suzaku and NuSTAR observations to study the short and long term variability of the sources in UV and X-ray bands. The study allowed then to investigate the origin of UV variability in these sources, and how it is connected to the X-ray variability. There are two possibilities: (i) either the observed UV variability may be arising from the accretion rate fluctuations, or (ii) it may be due to the X-ray reprocessing mechanism.

AstroSat observations of the HBL blazar 1ES 1959+650

Blazars constitute a special subclass of AGN with a relativistic jet aligned close to the line of sight of the observer. They emit non-thermal radiation extending from the radio to the very high energy gamma-rays (E $>$ 100 GeV), and exhibit strong flux variability in all observed bands. **Savithri H. Ezhikode, Ranjeev Misra, Zahir Shah**, and Rajalakshmi T. R. have studied the nearby (redshift = 0.047) TeV-detected high-frequency BL-Lac (HBL) object 1ES 1959+650 which is very bright in the X-ray (0.3-10 keV) band. The source

has also been showing strong X-ray flaring activity at various epochs. They have studied the X-ray variability of 1ES 1959+650 using the simultaneous observations with SXT and LAXPC in October 2017 when the source was in a flaring cycle, and have investigated the evolution of X-ray spectral properties during the observation of the source using the method of time-resolved spectroscopy. They observed a weak anti-correlation between the photon index and X-ray flux of the source at zero time lag. However, the preliminary results suggest a stronger positive correlation between the parameters with a time delay of about 40 ks.

Disc-jet connection in the NLS1/Blazar 1H 0323+342

The launching of jets in astrophysical systems with black hole mass ranging over nearly 10 orders of magnitude is not yet a well-understood phenomenon. The accretion disc, which is present in all systems with jets, is thought to play a major role in determining the launching and properties of the jet. Radio-loud AGN (RL-AGN) are associated with strongly collimated jets, the origin of which remains unclear. The radio-loud narrow line Seyfert 1 galaxies (RL-NLS1s) are a special class of RL-AGN that show similar properties to that of NLS1s in the optical and X-ray bands. They are characterised by low black hole mass, high accretion rate, and relativistic jet emission. **Gulab C. Dewangan, Ranjeev Misra, Abhishek Paswan**, Biny Sebastian, Preeti Kharb, Ritesh Ghosh, Ninan Sajeeth Philip have worked on the gamma-ray detected RL-NLS1/NLS1-blazar 1H 0323+342. The highly variable emissions from disc/corona component and relativistic jet make the source ideal to investigate the disc-jet connection. Using the simultaneous radio, infrared, optical, UV and X-ray data from the coordinated observations from Astrosat, HCT and GMRT they could study the disc-jet coupling in the source by investigating the correlated variability properties associated with accretion flow, line emission regions and jet emission.

Stars, Interstellar Medium and Planetary Studies

Modelling of mid-infrared polarization in dust around young stars

Recently, crystalline silicates (SiC) have been detected in circumstellar envelops of several young pre-main sequence stars. **Ranjan Gupta** and collaborators have probed the presence of SiC in the dust around protoplanetary disks in a sample of young stars. The only detection of SiC has been in a young star SVS13 based on studies of MIR polarization in its disc/envelop. They have modelled the linear polarization of composite dust grains in the mid-infrared (MIR: 813 μm) using silicates as the host with various inclusions of SiC and graphites using the Discrete Dipole Approximation (DDA) and the Effective Medium Approximation (EMA) T-Matrix methods. The results are compared with polarimetric observations made in the protoplanetary disks surrounding two Herbig Be stars and one T-Tauri star with the 10 μm silicate feature using CanariCam mounted over the Gran Telescopio Canarias (GTC).

This model has the host spheroid made up of silicates with inclusions of either silicon carbide (SiC) or graphite (Gr) at a time. The sites external to the grain are assumed to be vacuum, and internal sites are given to the silicate host. They have used oblate (axial ratio AR > 1) spheroids since interstellar extinction curves produced using models with grains in the form of oblate spheroids have been seen to show best fits with observed data. They used a dust grain size, $a_{min} = 0.1\mu m$ to $a_{max} = 0.5\mu m$, where a represents the radius of a sphere such that its volume is equal to that of the dust grain spheroid and used three different fractions by volume, f = 0.1 (10%), 0.2 (20%) and 0.3 (30%) for SiC, graphite as well as porous grain inclusions (in compliance with the findings of other workers).

As seen in Figures (16), (17), and (18), all the three objects in this sample of study: MWC 1080A, MWC 297 and HL Tau, show polarization in absorption, but only the MWC 1080A polarization seems to have been caused due to SiC mixed with

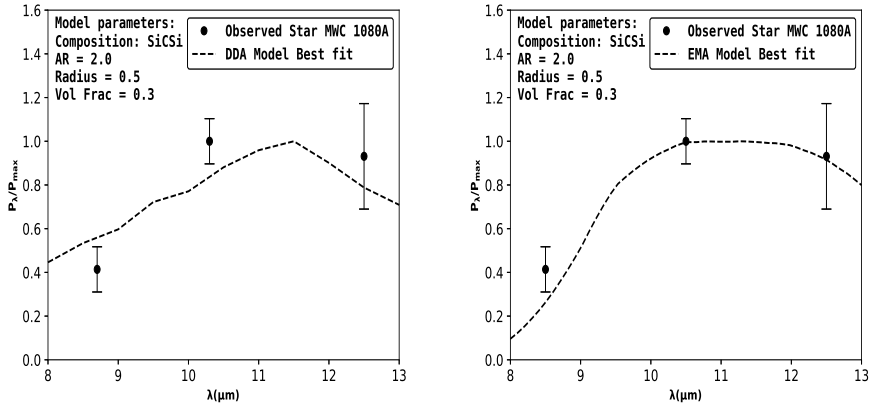

Figure 16: Composite grain models: DDA (left panel) and EMA (right panel) models with various combinations showing best fits to observed star MWC 1080A.

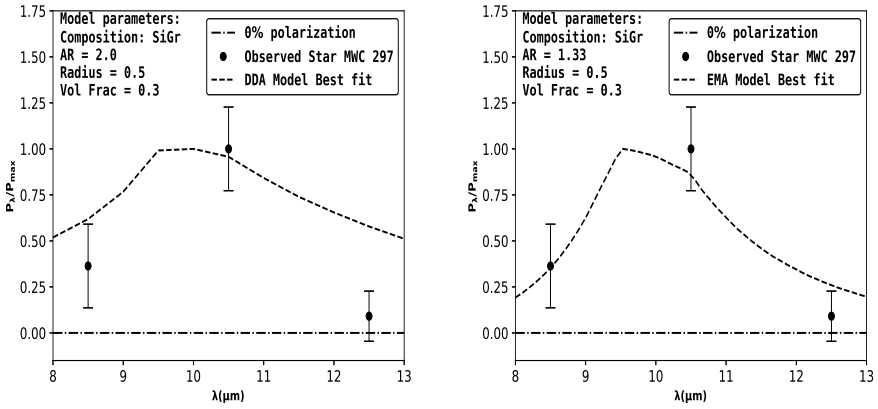

Figure 17: Composite grain models: DDA (left panel) and EMA (right panel) models with various combinations showing best fits to observed star MWC 297.

silicates. The dust grains accountable for the crystalline silicate features in absorption seem to originate in outer regions which are cold. Since MWC 1080A is a very young but massive star with a small disk size, most of the observed polarization is caused due to the envelope which consists of material flowing in from the ISM.

We have also checked the validity of the composite dust models with the polarization data of SVS13 (V*V512 Per) presented in Figure 19. SVS13 polarimetry data is from UKIRT 3.8m telescope with IRPOL on CGS4 (Cooled Grating Spectrometer). The DDA based calculations give a model with SiCSi, having 0.3 volume fraction of inclusions, for oblate spheroidal dust grains (AR = 1.5) of effective radius 0.5 μm to best fit the SVS13 polarization data. The EMA T-Matrix based calculations are in agreement with the type of inclusion, i.e., SiC, but vary in the degree of oblateness (AR = 2.0), and volume fraction of inclusions (0.2).

Solar Astrophysics

Observations and modelling of chromospheric evaporation in coronal loops

The problem of solar coronal heating has been one of the most stubborn in the field of astrophysics. One of the essential pieces of observations that has been missing is chromospheric evaporation in quiescent coronal loops. Note that such evaporation flows have been observed in large flares. So, the question remains that if the physics of solar flares is similar to that which is involved in small scale events such as small transient brightenings and even the coronal loops. Girjesh Gupta, Aveek Sarkar and **Durgesh Tripathi** have for the first time shown the presence of chromospheric evaporation related to small transient brightenings that leads to the formation of coronal loops (see Figure 20). For this purpose, they have used the observations from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) and the Interface Region Imaging Spectrograph (IRIS) and the Extreme-ultraviolet Imaging Spectrometer and X-Ray Telescope, both onboard Hinode. They have also aided the data with the magnetic field measurements in the photospheric from the Helioseismic and Magnetic Imager (HMI), also onboard SDO. The observations from these instruments are complemented with 1D hydrodynamic simulations and forward modelling. They have found evidence of chromospheric evaporation at the two footpoints of a coronal loop after the occurrence of two transient brightenings. In hotter channels of AIA, such as 131, 94, and 335Angstrom appeared nearly simultaneously, and that the evaporation flows were the fastest in these channels. The temperature attained a maximum of 10 MK during the evaporation. At the footpoints, they have also observed redshifts in transition that were co-temporal and co-spatial with the observation of the evaporation. The simulated results were qualitatively in agreement with those observed.

Energetics of tiniest EUV brightenings ever observed in solar atmosphere using Hi-C

The first Hi-C rocket experiment of NASA has provided the highest spatial and temporal resolution observations of the solar corona. However, Hi-C carried only one science filter onboard. Therefore, it was essential to combine the Hi-C observations with those taken using AIA on board SDO that provides views using 6 EUV channels, albeit with lesser spatial and temporal resolution. Srividya Subramanian, Vinay L. Kashyap, **Durgesh Tripathi**, Maria S. Madjarska, and John G. Doyle have made use of Hi-C and AIA observations to study the thermal structure and energetics of the point-like extreme ultraviolet (EUV) brightenings, which occurred within a system of fan loops. By using an automatic procedure, they identified 27 brightenings in Hi-C and also in AIA. Though AIA's resolution is much poorer in comparison with Hi-C, the code could still identify those brightenings in 193 *Angstrom* images. They have employed the Differential Emission Measure (DEM) techniques to study the energetics of these brightenings. These are the smallest brightenings in EUV ever detected and for the first time they provide such a compre-

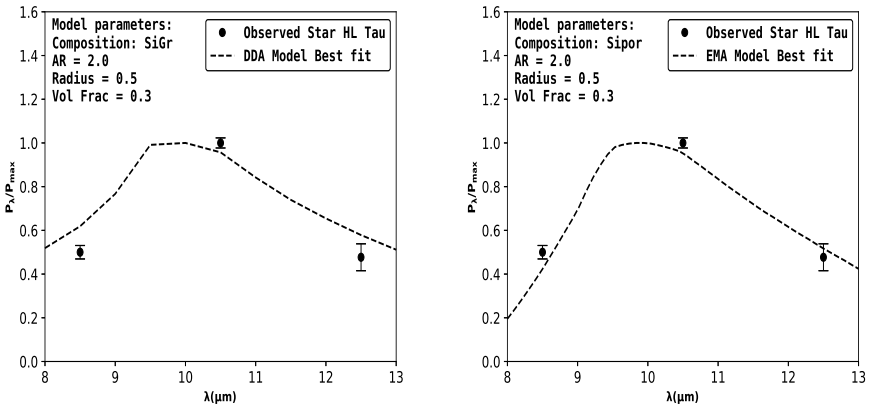

Figure 18: Composite grain models: DDA (left panel) and EMA (right panel) models with various combinations showing best fits to observed star HL Tau.

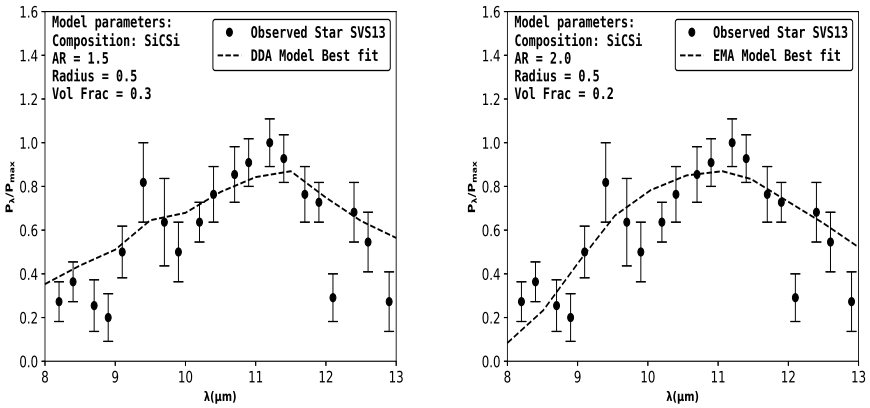

Figure 19: Composite grain models: DDA (left panel) and EMA (right panel) models with various combinations showing best fits to observed star SVS13 (Fujiyoshi et al. 2015).

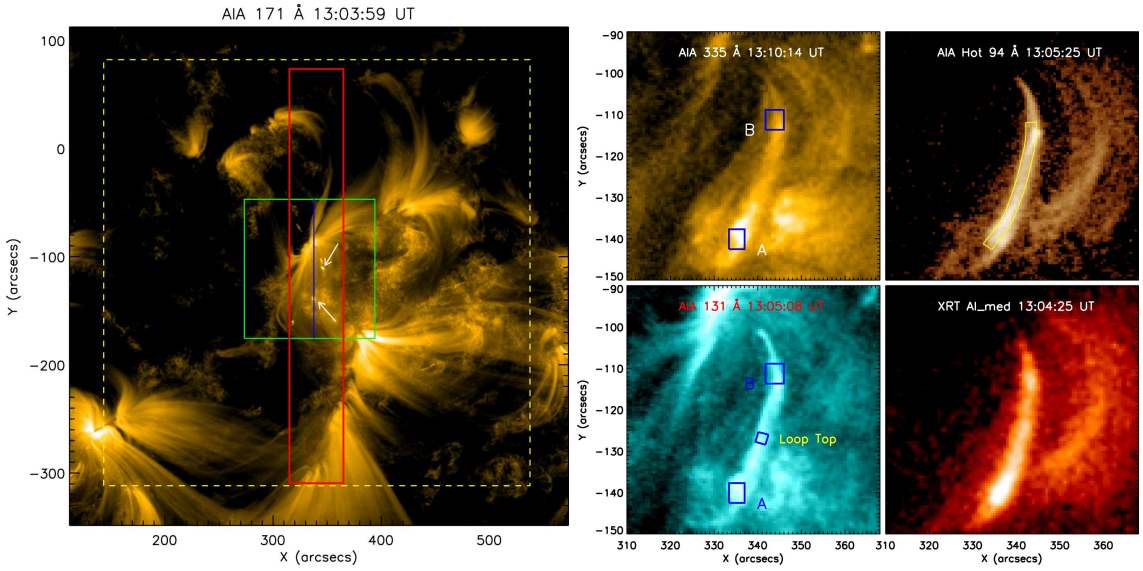

Figure 20: Left panel: AIA 171 ∼ Angstrom image showing the transient brightening, which are located with arrows. The FOV of EIS, IRIS and XRT FOV are highlighted with red, green and yellow boxes, respectively. The vertical blue line located the IRIS slit position. Right panel: The loops are brightened up due to the transient brightening. The images show the loops at their peak brightening in different panels as labelled.

hensive measure of the energetics of such brightenings. The measurements show that the DEM weighted temperatures of these transients are in the range $\log T(K) = 6.2 - 6.6$ with radiative energies $\sim 10^{24-25}$ ergs and densities approximately equal to a few times 10^9 cm^{-3}. Further study of energy loss using these results showed that the dominant mechanism of energy loss for all the identified brightenings is conduction rather than radiation, which is usually believed (See Figure 21).

Mg II line intensities in quiet-Sun and coronal Holes

Coronal holes (CH) and quiet Sun (QS)regions are two areas on the Sun, which are uniquely identified in coronal images. However, they are hardly distinguishable in the chromosphere and photosphere. From the point of view of using Mg II indices as proxies for modelling the Sun-climate relationships, it is crucial to understand the behaviour of the Mg II line in coronal holes and quiet Sun regions at chromospheric heights. Pradeep Kayshap, **Durgesh Tripathi**, Sami K. Solanki and Hardi Peter have used the high-resolution spectra that are obtained by the Interface Region Imaging Spectrometer (IRIS). Just by visual inspection as well as from the over-all distribution, they find that the distribution of intensities of Mg II lines is very similar in coronal holes as well as in the transition region. However, after invoking the magnetic field, it is found that Mg II intensities are significantly lower in CH than in QS for the areas with similar magnetic flux density (see Figure 22). The wing intensities that represent the photospheric emission, however, do not show such behaviour. This analysis further reveals that the difference between Mg II intensities in coronal holes and quiet Sun increases with increasing magnetic flux density. These findings have significant importance for using Mg II index as a proxy for the modelling of solar spectral irradiance as well as the general supply of mass and energy from the lower atmosphere to the upper.

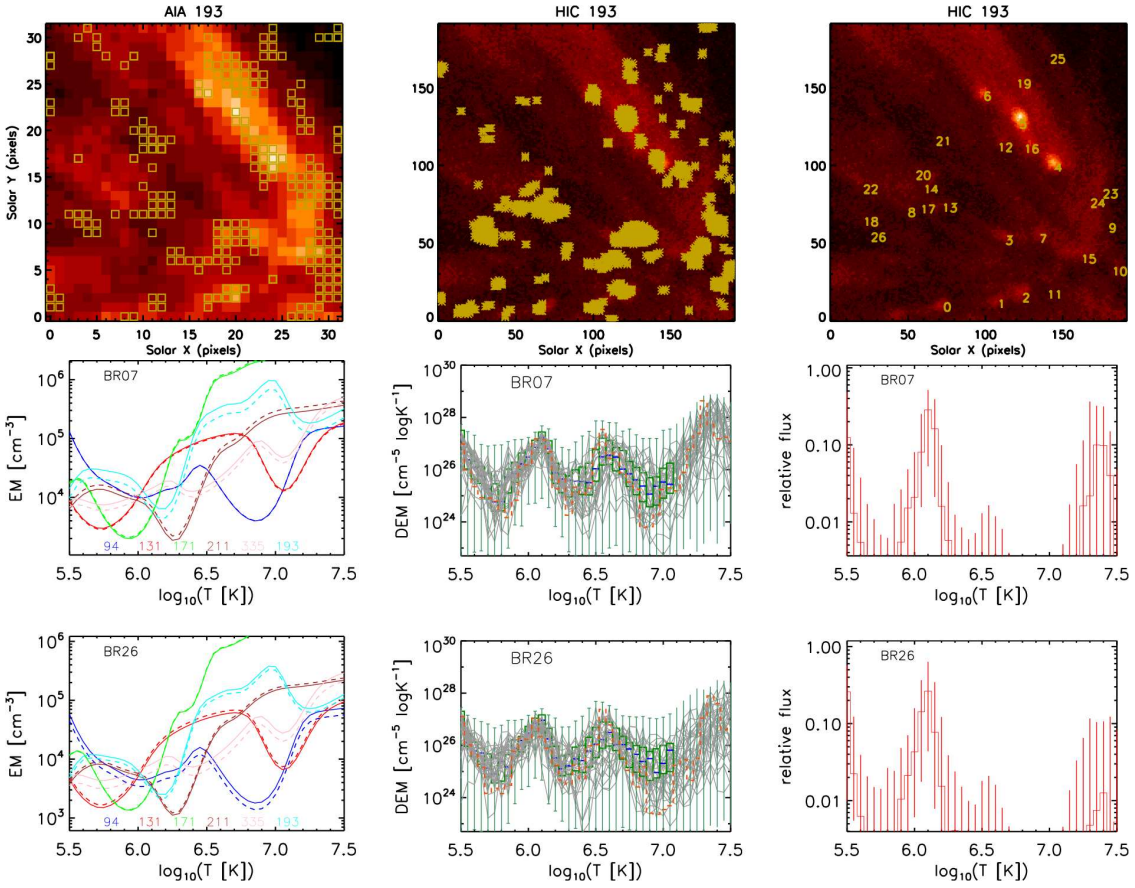

Figure 21: Top row: Identified brightening pixels shown in AIA 193 (left), Hi-C 193 in yellow (middle). The brightening which are studied are numbered (right). Middle and bottom rows: Thermal analysis of two brightenings. EM loci curves (left), DEM distributions (middle) and flux contribution of the DEM at different temperatures (right). The flux contribution is an estimate from the DEM. The blue horizontal segments in the middle panels mark the modes of distribution of DEM at each temperature bin. The green boxes indicate 50% coverage of solutions.

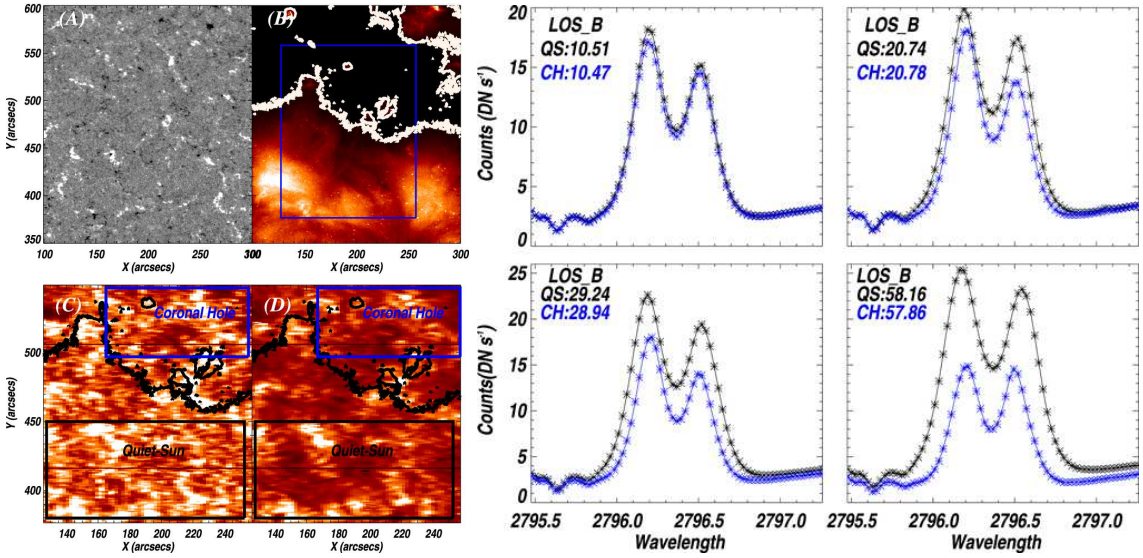

Figure 22: Left: Line-of-sight magnetic field (panel (A) and the corresponding AIA 193 *Angstrom* image that is studied. The AIA image conspicuously shows that the regions contains coronal hole as well as quiet Sun, which are identified over-plotted white contours. The over plottted blue-box in panel (B) represents the FOV that was rastered with IRIS. The IRIS intensity images obtained in Mg II k2v and Mg II k3 are shown in (C) and (D). The black and blue boxes in (C) and (D) locates the QS and CH regions which are studied. Right: Line profiles of Mg II k line averaged over the QS (black) and CHs (blue) in four bins of different pixel-averaged LOS magnetic field, as labelled in each panel. The values represent the average of $\langle B_{\rm LOS}\rangle/\mu$ in the respective bin in the units of Gauss.

Transport of energy to the solar chromosphere through low-frequency acoustic waves

The problem of the heating of the solar chromosphere remains to be solved. Several studies have shown that magnetic fiels, especially the inclined ones, play an essential role in transporting waves from the photosphere to the chromosphere, where they are expected to steepen in shocks and contribute to the coronal heating. S. Paul Rajaguru, C. R. Sangeetha and **Durgesh Tripathi** have revisited some of those works and used the state-of-the-art observations from AIA (1600 and 1700 *Angstrom*, and HMI to study the relationships between magnetic field properties (inclination and strength) and the propagation of acoustic waves (phase travel time). The obtained energy estimates in waves with frequencies 2–5 mHz frequency range are about a factor of two higher than those reported earlier. These new observations also reveal that a significant amount of waves with frequencies lower than the cut-off frequency gets channelled through the inclined field lines. Note that, in the presence of the inclined field, the cut-off frequency reduces.

Instrumentation

Wide Area Optical Linear Polarimeter

Wide Area Linear Optical Polarimeter (WALOP) instruments are being developed to survey the polarization of around a million stars in the Galactic polar regions. This instrument will combine a wide field of view capability(35 *arcminutes* × 35 *arcminutes*) with high polarimetry accuracy of 0.1% to enable a fast and accurate survey. Two such polarimeters are currently being designed and developed at IUCAA, by **A. N. Ramaprakash**, **Siddharth Maharana** and Ioannis Kypriotakis one each for the 1 m SAAO Telescope, South Africa and the 1.3 m Skinakas Observatory Telescope, Greece.

Wollaston prisms are the most common polarization analyzer optics used in optical polarimeters due to their high polarization efficiency. The biggest challenge in building polarimeters with a field of view as large as WALOP is the chromatic aberrations caused by Wollaston prisms: a small dispersion is introduced in the outgoing beams from the Wollaston prisms. **Siddharth Maharana** has obtained a solution to this problem and has made an optical design that can achieve an approximately seeing limited PSF (point spread function), which will enable high accuracy imaging polarimetry. The simulated PSF for a star corrected for the dispersion in WALOP design is shown in Figure 23. The PSF is small, giving a crisp image spread over a very few pixels. For comparison, Figure 24 shows a simulated spot digram without correction for chromatic aberrations introduced by the Wollaston prisms.

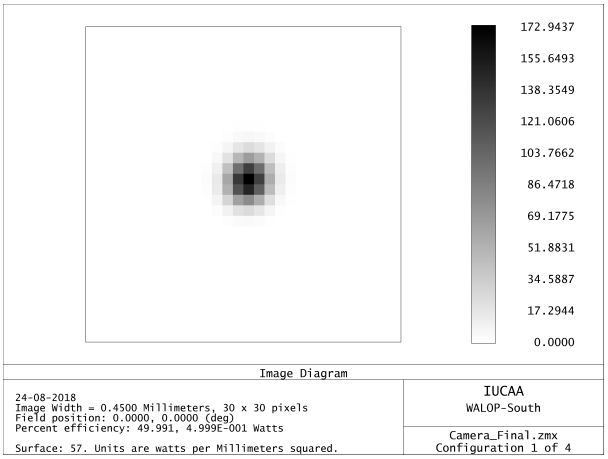

Figure 23: Simulated PSF for a star in WALOP, corrected for the dispersions caused by the Wollaston prisms. The images are sharp without any dispersion.

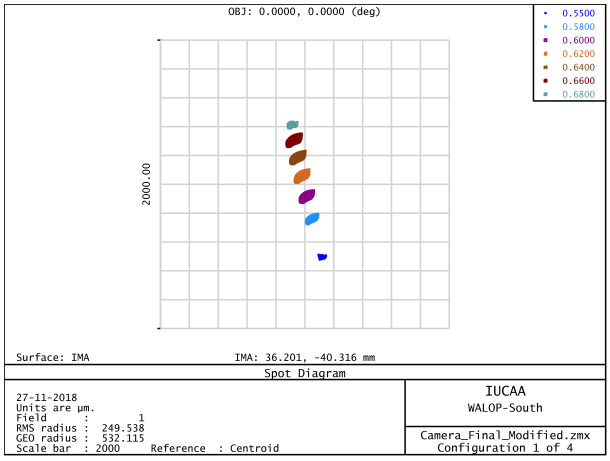

Figure 24: Simulated spot diagram for a star affected by chromatic dispersion caused by the Wollaston prisms

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(b) PROCEEDINGS

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3. A. Anumarlapudi, E. Aarthy, Varun Bhalerao, **Dipankar Bhattacharya,** A. R. Rao, et al. **(**2019) *FRB181228: AstroSat CZTI upper limits*, Astronomers' Telegram No. 12370.

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5. **Vadakkumthani Jithesh, Bari Maqbool Bhat, Gulab C. Dewangan,** and **Ranjeev Misra** (2019) *Large flares from GRS 1915+105 in its unusual low state as observed by AstroSat,* Astronomers'Telegram No. 12805.

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9. **Tanazza Khanam, Vidushi Sharma, Ajay M. Vibhute,** Varun Bhalerao, **Dipankar Bhattacharya,** et al. (2018) *GRB 181201A: AstroSat CZTI detection*, GCN Circular No. 23501.

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11. **Tanazza Khanam, Vidushi Sharma, Dipankar Bhattacharya, Ajay M. Vibhute,** Varun Bhalerao, et al. (2019) *GRB 190103A: AstroSat CZTI detection*, GCN Circular No. 23609.

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52. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A. R. Rao, and Santosh Vadawale (2018) *GRB 180728A: AstroSat CZTI detection*, GCN Circular No. 23102.

53. **Vidushi Sharma, Ajay M. Vibhute, Dipankar Bhattacharya,** Varun Bhalerao, A. R. Rao, et al. (2018) *GRB 180806A: AstroSat CZTI detection*, GCN Circular No. 23122.

54. **Vidushi Sharma, Tanazza Khanam, Dipankar Bhattacharya,** A. R. Rao, and Santosh Vadawale (2018) *GRB 180809B: AstroSat CZTI detection*, GCN Circular No. 23144.

55. **Vidushi Sharma, Tanazza Khanam,** Varun Bhalerao, **Dipankar Bhattacharya,** A. R. Rao, et al. (2018) *GRB 180914A: AstroSat CZTI detection*, GCN Circular No. 23248.

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57. **Vidushi Sharma, Tanazza Khanam, Dipankar Bhattacharya,** Varun Bhalerao, A. R. Rao, et al. (2018) *GRB 181020A: AstroSat CZTI detection*, GCN Circular No. 23436.

58. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A. R. Rao, and Santosh Vadawale (2018) *GRB 181119A: AstroSat CZTI detection*, GCN Circular No. 23438.

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62. **Vidushi Sharma, Dipankar Bhattacharya, Tanazza Khanam, Ajay M. Vibhute,** Varun Bhalerao, et al. (2019) *GRB 190206A: AstroSat CZTI detection*, GCN Circular No. 23892.

63. **Vidushi Sharma, Tanazza Khanam, Dipankar Bhattacharya, Ajay M. Vibhute,** Varun Bhalerao, et al. (2019) *GRB 190215A: AstroSat CZTI detection*, GCN Circular No. 23901.

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65. **Vidushi Sharma, Dipankar Bhattacharya, Ajay M. Vibhute, Tanazza Khanam,** Varun Bhalerao, et al. (2019) *GRB 190323A: AstroSat CZTI detection*, GCN Circular No. 24025.

(d) BOOKS

Jayant V. Narlikar

- *Me shastradnya kasa zalo?* (in Marathi) (How did I become a scientist?), Sakal Media Pvt. Ltd., Pune (2018).
- *Navya sahasrakache nave vidnyan* (in Marathi) (New science from new millennium), Sakal Media Pvt. Ltd., Pune (2018).

(e) POPULAR ARTICLES

Jayant V. Narlikar

- *The many joys of learning science*, The Asian Age, April 24, 2018.
- *No work but full pay defies all logic*, The Asian Age, May 25, 2018.
- *Abolishing merit ranking a good idea*, The Asian Age, July 5, 2018.
- *Prapte tu shodashe varshe* (in Marathi) (When they reach the age of sixteen), Chaturang, Loksatta, June 16, 2018.
- *Chaos, catastrophe and mathematics*, The Asian Age, September 16, 2018.
- *Our society is ridden with superstition*, The Asian Age, December 8, 2018.
- *Vaidnyanik andhashraddha* (in Marathi) (Scientific outlook and superstitions), Sanvad Sarjanshil Mananshi, Diwali Issue, 34 (2018).
- *Me vaidnyanik ka aani kasa zalo?* (in Marathi) (Why and how I became a scientist?), Mouj, Diwali Issue, 202 (2018).
- *Vidyanagariche aavhan* (in Marathi) (The challenge of a science city), Sakal, January 2, 2019.
- *Marathi bhashetun vidnyan* (in Marathi) (Science in Marathi), Rachna, 11(2019).

PEDAGOGICAL

(a) IUCAA-NCRA GRADUATE SCHOOL

Dipankar Bhattacharya

Methods of Mathematical Physics I (14 lectures) (August – September 2018).

Sukanta Bose

Electrodynamics and Radiative Processes II (14 lectures) (October – December 2018).

Sanjit Mitra

Methods of Mathematical Physics II (14 lectures) (October – December 2018).

T. Padmanabhan

Quantum and Statistical Mechanics I (21 lectures) (August – September 2018).

Kanak Saha

Galaxies: Structure, Dynamics, and Evolution (21 lectures) (August – September 2018).

Raghunathan Srianand

Introduction to Astronomy and Astrophysics I (14 lectures) (August – September 2018).

Kandaswamy Subramanian

Quantum and Statistical Mechanics II (14 lectures) (October – December 2018).

Durgesh Tripathi

Introduction to Astronomy and Astrophysics II (14 lectures) (October – December 2018).

(b) SAVITRIBAI PHULE PUNE UNIVERSITY, M.Sc. LECTURES
(Department of Physics, and Department of Space Science)

Aseem S. Paranjape

Astronomy and Astrophysics II (18 lectures).

Ranjan Gupta

Astronomy and Astrophysics Laboratory Course (Theory 10 lectures), and related to Observational Astronomy (10 Laboratory and Night Experiments).

(c) SUPERVISION OF Ph.D. THESES (DEGREES AWARDED)

Dipankar Bhattacharya

Title: *Strongly Magnetized Degenerate Stars.*
Student: Prasanta Bera (IUCAA).

Gulab C. Dewangan

Title: *Energy-Dependent Variability of Active Galactic Nuclei.*
Student: Labani Mallik (IUCAA).

Sanjit Mitra

Title: *Sources of Gravitational Waves and Efficient Observation with Laser Interferometric Detectors.*
Student: Anirban Ain (IUCAA).

Title:*Efficient Methods for Detection of Gravitational Waves from Compact Binary Coalescences.*
Student: Bhooshan U. Gadre (IUCAA).

Title: *Characterization and Reduction of Noise in Gravitational Wave Detectors.*
Student: K. Nikhil Mukund (IUCAA).

A.N. Ramaprakash

Title: *Some Aspects of Design and Development of a Fibre-Fed 2 D Spectrograph for the 3.6 m Devasthal Optical Telescope.*
Student: Sabyasachi Chattopadhyay (IUCAA).

Varun Sahni

Title: *Exploring New Vistas in Cosmology.*
Student: Satadru Bag (IUCAA).

(d) SUPERVISION OF Ph.D. THESES (ONGOING)

Dipankar Bhattacharya

Title: *Study of the Magnetic Fields of Neutron Stars through Cyclotron Resonance Scattering Features.*
Student: Suman M. Bala (IUCAA).

Title: *Spectro-Timing Study of Accretion Disks.*
Student: Yash D. Bhargava (IUCAA).

Title: *Probing the Central Engine and Early Emission of Gamma Ray Bursts.*
Student: Vidushi Sharma (IUCAA).

Title: *Indirect Imaging in Astronomy.*
Student: Ajay M. Vibhute (IUCAA).

Sukanta Bose

Title: *Constraining the Equation of State of Neutron Stars with Gravitational Wave Observations.*
Student: Bhaskar Biswas (IUCAA).

Title: *Gravitational Waves from Compact Binaries as Probes of Neutron Star Equation of State and Extra-Spatial Dimension.*
Student: Kabir Chakravarti (IUCAA).

Title: *Improved Methods for Discriminating Gravitational Wave Signals of Compact Binary Coalescences from Noise Transients.*
Student: Sunil Choudhary (IUCAA).

Title: *Spacetime Mapping.*
Student: Sayak G. Datta (IUCAA).

Title: *Numerical Study of Wave Propagation in General Relativity.*
Student: Shalabh Gautam (IUCAA).

Title: *The Physics and Astrophysics of Binary Black Hole Mergers and their Gravitational Radiation.*
Student: Vaishak Prasad (IUCAA).

Title: *Strategies for Searches of Electromagnetic Counterparts of Gravitational Wave Signals.*
Student: Javed Rana Sk. (IUCAA).

Gulab C. Dewangan

Title: *Multi-Wavelength Observations of Accretion Disks in Active Galactic Nuclei.*
Student: Pranoti Y. Panchbhai (IUCAA).

Title: *Soft X-ray Excess and Accretion Disk/Corona Emission from Active Galactic Nuclei.*
Student: Prakash Tripathi (IUCAA).

Co-guide
Title: *Radio-Loud AGN.*
Student: Ritesh Ghosh (Visva-Bharati University, Santiniketan).

Co-guide
Title: *BroadIron Lines from Neutron Star Low Mass X-ray Binary.*
Student: Aditya Sow Mondal (Visva-Bharati University, Santiniketan)

Sanjit Mitra

Title: *Algorithms for Gravitational Waves Data Analysis and Detector Controls Based on Modern Techniques.*
Student: Sreejit P. Jadhav (IUCAA).

Surhud More

Title:*Cosmology from Galaxy Clusters.*
Student:Arindam Sharma (IISER, Pune).

Aseem S. Paranjape

Title: *Aspects of Semi-Classical Limit and the Backreaction Problem.*
Student: Rajeev Karthik (IUCAA).

Title: *Analytical and Semi-Numerical Techniques for Next Generation Observations of LSS.*
Student: Niladri Paul (IUCAA).

Title: *Halo Dynamics and Kinematics: Applications to Large-Scale Structure and Cosmology.*
Student: Sujatha Ramakrishnan (IUCAA).

A. N. Ramaprakash

Title: *Alternative Techniques for Adaptive Optics for Future Large Telescopes.*
Student: Sorabh Chhabra (IUCAA).

Title: *Design and Development of Wide Field Optical Polarimeters (WALOP) for Dust Cloud Tomography.*
Student: Siddharth Maharana (IUCAA).

Somak Raychaudhury

Title: *The Evolution of Galaxies on the Cosmic Web.*
Student: Ruchika Seth (IUCAA).

Varun Sahni

Title: *Dark Matter, Dark Energy and the Early Universe.*
Student: Swagat S. Mishra (IUCAA).

Tarun Souradeep

Title: *Physics beyond Statistical Isotropy at Late Universe.*
Student: Debabrata Adak (IUCAA).

Title: *Precision Physics from CMB Polarisation Anisotropies.*
Student: Rajorshi S. Chandra (IUCAA).

Title: *Study of CMB Spectral Distortions.*
Student: Debajyoti Sarkar (IUCAA).

Title: *Study of Cosmic Microwave Background: Anomalies and Weak Lensing.*
Student: Shabbir I. Shaikh (IUCAA).

Raghunathan Srianand

Title: *Probing the Astrophysical and Cosmological Aspects of Intergalactic Medium using Quasar Spectra.*
Student: Soumak Maitra (IUCAA).

Title: *Probing Environment of High Redshift Quasars using Diffuse Lyman-α Emission.*
Student: Gitika P. Shukla (IUCAA).

Durgesh Tripathi

Title: *Energetics of the Solar Atmosphere.*
Student: Abhishek Rajhans (IUCAA).

(e) SUPERVISION OF PROJECTS

Dipankar Bhattacharya

Ankita Chakravarty (BITS, Pilani)
Observing Gamma Ray Bursts through Coded Masks.

Nandini Hazra (IISER, Pune)
Timing Analysis of Compact X-ray Binaries.

Madhurima Kumar (Kalinga Institute of Industrial Technology, Bhubaneswar) (Vacation Students' Programme, IUCAA)
Polarization of Gamma Ray Bursts.

Anwesha Maharana (IISER, Pune)
Accretion onto Magnetically Confined Mounds on Neutron Stars.

Wrishik Naskar (IIT, Kanpur) (Academy of Sciences, Summer Research Fellow)
Compact Objects and their Stability.

Viushwangi Shah (BITS - Pilani, Hydrabad)
Standardizing Time.

Sukanta Bose

Pawan Kumar Gupta (CEBS, University of Mumbai, Kalina Campus), and Tanmaya Mishra (NISER, Bhubaneswar) (Vacation Students' Programme, IUCAA)
Using Gravitational Waves to Probe the Composition of Neutron Stars.

Gulab C. Dewangan

Janmesh Ukey (IIT, Roorkey) (Vacation Students' Programme, IUCAA)
AstroSat/UVIT Grating Spectroscopy.

Savithri H. Ezhikode

Geethika B. R., and Krishnapriya K. V. (Providence Women's College, Kozhikode)
X-ray Variability in Mrk 110.

Neeraj Gupta

Deepali Gaba (IIT, Kanpur) (Vacation Students' Programme, IUCAA)
Using Rotation Measure Techniques to Probe Magnetic Fields in ISM

Shabnam Iyyani

Yatish Kaushik (IIT, Roorkee) (Vacation Students' Programme, IUCAA)
Quantifying the Band Model Crisis in Gamma Ray Burst Spectral Analysis.

Vadakkumthani Jithesh

Parimal D. Darne (SGGS Institute of Engineering and Technology, Nanded) (Vacation Students' Programme, IUCAA)
Estimating the Black Hole Mass of ULX M33 X-8 from Relativistic Accretion Disk Model.

Sanjit Mitra

Jyothis Chandran (IISER, Thiruvananthapuram), and Rahul Maroju (IIT, Hyderabad) (Vacation Students' Programme, IUCAA)
Exploring Techniques for Noise Reduction in Laser Interferometric Gravitational Waves Detector.

Surhud More

Bhavana Bhat (Fergusson College, Pune)
Cosmological Constraints from Weak Gravitational Lensing.

Pinaki Roy (Christ University, Bengaluru)
Simulations of the LSST Supernova Survey.

Shubham Mallik Thakur (IISER, Pune)
Gravitational Lensing Cross-Sections for Gravitational Wave Events.

Jayant V. Narlikar

Hritam Chakraborty (Pt. Ravishankar Shukla University, Raipur) (Vacation Students' Programme, IUCAA)
Discrete Source Surveys.

Arun Kumar R. M. (University of Madras, Chennai) (Vacation Students' Programme, IUCAA)
The Microwave Background.

Aseem S. Paranjape

Raghav Arora (BITS - Pilani, Goa)
Application of Numerical Relativity to Cosmological Structure Formation.

Payaswinee Dhoke (MP Deo Memorial College, Nagpur)
Environmental Effects on Mass Accretion Warm Dark Matter Cosmologies.

Aditya Vidhate (BITS - Pilani, Hyderabad)
Environments of Damped Lyman - α Systems.

Somak Raychaudhury

Tathagata Pal (IISER, Kolkata) (Vacation Students' Programme, IUCAA)
Pilot Spectroscopic Survey of Saraswati Supercluster using SALT.

Malavika Unni (Central University of Tamil Nadu, Thiruvarur) (Vacation Students' Programme, IUCAA)
The Evidence of Dark Matter in the Milky Way from the Dynamics of Stars Measured with the GAIA Observatory.

Rupak Roy

Prathamesh Dash (NIT, Rourkela) (Vacation Students' Programme, IUCAA)
Understanding the Properties of the Exploding Supergiants.

Haqnawaz Rafiq (University of Kashmir, Srinagar) (Vacation Students' Programme, IUCAA)
Spectroscopic Study of the Nuclear-Transients.

Sonali Sachdeva

Archana Aravindan (Pondicherry University) (Vacation Students' Programme, IUCAA)
An Analysis of Image Detection Techniques in Astronomy.

Varun Sahni

Apoorva Shah (Fergusson College, Pune)
Dark Energy and the Accelerating Universe.

Kandaswamy Subramanian

Kishore Gopalakrishnan (BITS, Pilani) *Practice School II.*

Kishore Iyer (IISER,Thiruvananthapuram) *Summer Project.*

K. S. Sreekara Sabarish (BITS, Pilani) *Practice School I.*

Jishnu Suresh

Sambit Panda (BITS, Pilani) (Vacation Students' Programme, IUCAA) *Probing the Anisotropies of Stochastic Gravitational Waves Background using Regularised Deconvolution Methods.*

Shyam N. Tandon

Jayatee Kanwar (University of Delhi) (Vacation Students' Programme, IUCAA) *Photometric Calibration of Various Spectra.*

Durgesh Tripathi

Shilpi Buniya (IISER, Pune) *Source of Coronal Mass Ejections.*

Nived V. (IISER, Pune) *Coronal Holes and Quiet Sun in Transition Region.*

(f) SEMINARS, COLLOQUIA, AND LECTURES

Md. Shah Alam

CZTI Data Analysis, Broadband Spectral and Timing Studies with Astrosat, Chandra, and XMM-Newton, COSPAR Capacity Building Workshop, IISER, Mohali, March 9 - 20, 2019.

Joydeep Bagchi

Saraswati: An Extremely Massive 200 Megaparsec Scale Supercluster, IMSc, Chennai.

Relativistic Jets in Super Massive, IISER, Tirupati.

The Radio Physics Lab Facility at IUCAA, IISER, Tirupati.

The Saraswati Supercluster, SAC, Ahmedabad.

Abhijit B. Bendre

Simulating Galactic Dynamo: Turbulent Transport Coefficients Using SVD, International Conference on Multi-Messenger Astronomy in the Era of LIGO - India (LIMMA - 2019), The Dukes Retreat, Khandala, January 15 - 18, 2019.

Dipankar Bhattacharya

AstroSat Mission Status, 13th IACHEC Meeting, TenutadeiCiclamini, Italy, April 9, 2018.

Results from the AstroSat Mission, University of Torino, Italy, April 13, 2018.

Multi-Wavelength Facilities for Neutron Star Research, 42nd COSPAR Scientific Assembly, Pasadena, USA, July 15, 2018.

Major Astronomy Projects at IUCAA: A Status Report, Meeting on Astronomy in Universities, September 27, 2018.

X-ray Astronomy Data Analysis, GROWTH Winter School, IIT - Bombay, Mumbai, December 3, 2018 (Tutorial).

Observing the Cosmos: Achievements and Aspirations of the Indian Space Programme, Vikram Sarabhai Memorial Lecture, SAC, Ahmedabad, December 6, 2018.

Compact Star Observations with AstroSat, Annual Meeting of the ASI, Christ University, Bengaluru, February 21, 2019.

An Introduction to High Energy Astronomy, COSPAR Capacity Building Workshop, IISER, Mohali, March 9, 2019.

Sukanta Bose

Constraining the Densest Form of Matter with Gravitational Wave Observations, Exploring the Universe: Near Earth Space Science to Extragalactic Astronomy, SNBNCBS, Kolkata, November 2018.

The Long and Short of Gravitational Waves: From a Measurement of the Hubble Constant to Bounding the Neutron Star Radius, Meeting of the IAGRG, BITS - Pilani, Hyderabad, January 3 - 5, 2019.

What New Physics is Multi-Messenger Astronomy with Gravitational Waves Unravelling?, SERB School on Nuclear Astrophysics, SINP, Kolkata, February 2019.

Testing Strong Field Gravity and Dense Matter with Gravitational Waves, Conference on Exploring the Universe: Near Earth Space Science to Extragalactic Astronomy, SNBNCBS, Kolkata, February 2019.

Savithri H. Ezhikode

An Introduction to X-ray Astronomy, Alphonsa College, Pala, September 13 - 15, 2018.

Multi-Wavelength Studies of Mrk 0926 and Mrk 0110, Annual Meeting of the ASI, Christ University, Bengaluru, February 18 - 22, 2019.

Gulab C. Dewangan

UV/X-ray Connection in Seyferts with AstroSat, 9th Fero Meeting: Finding Extreme Relativistic Objects, Crete, Greece, May 25, 2018.

X-ray Astronomy, Module VI of NRC Course on Astronomy and Astrophysics, Recording Studio, Savitribai Phule Pune University, September 25, 2018.

UVIT Spectroscopy, Meeting to Celebrate Professor Prajwal Shastri's 60th Birthday, IIA, Bengaluru, November 14, 2018.

UVIT Grating Spectroscopy and Implications for ExoWorlds, ExoWorlds Meeting, IIST, Thiruvananthapuram, January 4, 2019.

X-ray/UV Emission from AGN Central Engines, IUCAA, November 29, 2018 (Colloquium), and AstroSat Meeting, IIA, Bengaluru, March 5, 2019.

Multi-Wavelength (UV/X-ray) Astronomy with AstroSat, COSPAR Capacity Building Workshop, IISER, Mohali, March 12, 2019.

Neeraj Gupta

The MeerKAT Absorption Line Survey, International Workshop on HI Absorption with SKA Precursors, ASTRON, The Netherlands, August 29, 2018.

Galaxies in HI absorption, Galaxy Fidelity Workshop on Galaxy Analysis with MeerKAT and other Decimetre Radio Telescopes, Cape Town, South Africa, November 9, 2018.

MALS-SALT: Large Survey to Discover High-z Quasars for MALS, Pretoria, South Africa, November 16, 2018.

uGMRT and MeerKAT Absorption Line Surveys, The Metre Wavelength Sky - II, NCRA, Pune, March 20, 2019.

Ranjan Gupta

India's Mega Projects, Fifty Years of Vainu Bappu Observatory, Kavalur, IIA Campus, August 11, 2018.

Exploring the Universe: Near Earth Space Science to Extra-Galactic Astronomy, Dust in Astrophysics and its Modelling, SNBNCBS, Kolkata, November 14 - 17, 2018.

Use of Automated Methods in Stellar Astronomy, NOAC, Beijing, China, December 19, 2018.

India's Involvement in Astronomy Mega Projects, IIT, Guwahati, January 26, 2019.

Shabnam Iyyani

Prompt Emission Properties of GRB170817A, Workshop on Physics and Astrophysics at the eXtreme (PAX-IV), IUCAA, August 7 - 10, 2018.

Reju Sam John

Cosmological Simulations, St. Aloysius College, Edathua, Kerala, February 6, 2019.

Manufacturing Cosmic Rays in the Evolving Dynamical States of Galaxy Cluster, Regional Meeting in Astronomy: Opportunities and Challenges, CUSAT, Kochi, February 8, 2019.

Shivaraj Kandhasamy

Introduction to Gravitational Wave Data Analysis, Newton - Bhabha (India-UK Entrepreneurial) Meeting, IUCAA, January 19, 2019.

LIGO - India Status and Calibration Plans, Gravitational Wave Metrology Workshop, Boulder, USA, March 15, 2019.

Anupreeta More

Machine Learning Applied to Gravitational Lens Systems, IUCAA, July 25, 2018.

The Universe as a Telescope: Probing the Cosmos at All Scales with Strong Lensing, Milan, Italy, September 7, 2018.

SuGOHI: Strong Lens Systems from the Subaru Hyper Suprime Cam Survey, Annual Meeting of the ASI, Christ University, Bengaluru, February 21,2019.

Surhud More

Cosmological Constraints from the Subaru Hyper Suprime Cam Survey, University of

Tokyo, Hongo Campus; IUCAA, October 18, 2018; Meeting of the IAGRG, BITS - Pilani, Hyderabad, January 5, 2019; and Workshop on Cosmology: The Next Decade, ICTS - TIFR, Bengaluru, January 22, 2019.

(i) *The Search for Planet Nine in the Outer Solar System*, and (ii) *Introductory Cosmology,* IIT - Bombay, Mumbai, February 8, 2019.

Sargam M. Mulay

The Spatial Association of Non-Thermal Type - III Radio Bursts with Active Region Jet, and Magnetic Field Modelling, IUCAA-NCRA-IISER Journal Club Meeting, Pune, November 22, 2018.

Joint EIS and IRIS Observation of an Active Region Jet, International Space Science Institute (ISSI) Team Meeting, Bern, Switzerland, January 21- 25, 2019.

Temperature Structure of Sigmoids in the Solar Atmosphere, Annual Meeting of the ASI, Christ University, Bengaluru, February 18 - 22, 2019.

Solar Physics and Solar Data Reduction, National Workshop on Introduction to Solar Astrophysics, St. Xavier's College for Women, Aluva, Kerala, March 2 - 3, 2019 (Tutorial).

Jayant V. Narlikar

How Well do we Know our Universe?, CEBS, University of Mumbai, Kalina Campus, April 4, 2018; Institute of Science, BHU, Varanasi, April 6, 2018; and IIT, Tirupati, March 29, 2019.

Searches for Life outside the Earth, Space Physics Laboratory, VSSC, Thiruvananthapuram, April 23, 2018.

Searches for Extraterrestrial Life, IISER, Kolkata, Mohanpur, June 14, 2018.

Spectral Shifts in General Relativity, Special P.C. Vaidya Birth Centenary Lecture, Meeting of the IAGRG, BITS - Pilani, Hyderabad, January 4, 2019.

Gravitational Wave Signature of a Mini Creation Event, International Conference on Multi-Messenger Astronomy in the Era of LIGO- India (LIMMA - 2019), The Dukes Retreat, Khandala, January 16, 2019.

T. Padmanabhan

Gravity, the Information Content of Spacetime and the Cosmological Constant, ETH, Zurich, May 17, 2018.

Spacetime Micro-Structure Gravity and the Cosmos, The 2nd Information Universe Conference, Groningen, The Netherlands, July 3, 2018.

Statistical Mechanics of Gravitating Systems, ETH Astronomy Seminar, Zurich, July 12, 2018.

Vacuum: Much Ado about Nothing, Regional Meeting in Astronomy: Opportunities and Challenges, CUSAT, Kochi, February 8, 2019.

Introduction to Gravity - Thermodynamics Connection, Mini-School on Gravitation and Cosmology, Providence Women's College, Kozhikode, February 9, 2019.

Niladri Paul

Halo Model of HI Galaxies and their Scaling Relations: Cosmology in the Next Decade, ICTS - TIFR, Bengaluru, January 22 - 25, 2019.

Halo Model of Galaxies and Gas, RRI, Bengaluru, January 21, 2019; and IISc, Bengaluru, January 29, 2019.

Jayashree Roy

LAXPC/AstroSat Study of ~ 1 and ~ 2 mHz Quasi-Periodic Oscillations in the Be/X-ray Binary 4U 0115+63 during its 2015 Outburst, International Conference on Exploring the Universe: Near Earth Space Science to Extragalactic Astronomy, SNBNCBS, Kolkata, November 14 - 17, 2018.

Timing Analysis with AstroSat, SITARE: Advanced Workshop on Astrophysics, IUCAA, January 10 - 16, 2019 (Hands-on-session).

AstroSat Data Analysis, Workshop on Multi-Wavelength Sky Observations: AstroSat and Beyond, DAASE, IIT, Indore, February 3 - 7, 2019 (Tutorial).

Rupak Roy

The Natures of the Nuclear-Transients, EXUNIV - 2018, SNBNCBS, Kolkata, November 14 - 17, 2018.

Transients near the Centres of the Galaxies, GROWTH Conference, IIT - Bombay, Mumbai, December 5 - 7, 2018.

Kanak Saha

Angular Momentum Transport in Lopsided Galaxies, Galactic Angular Momentum, IAU General Assembly, Vienna, August 22, 2018.

AstroSat/UVIT Deep Imaging Survey of Galaxies in the GOODS South Field, CRAL, Lyon, France, August 31, 2018;

AstroSat/UVIT Deep Imaging Survey of Galaxies in the GOODS South Field, Geneva Observatory, Switzerland, September 4, 2018;

Escape of Lyman Radiation from Galactic Labyrinths, OAC, Kolymbari, Crete, September 14, 2018;

Evolution of Galaxies, BM Birla Planetarium, Jaipur, January 10, 2019.

Varun Sahni

Dark Energy, Fifth Korea-Japan Workshop on Dark Energy: Starobinsky's Universe, KASI, Daejeon, Korea, August 6 - 10, 2018.

Tarun Souradeep

LIGO - India, Workshop on Physics and Astrophysics at the eXtreme (PAX-IV), IUCAA, August 7-10, 2018.

Quests Drive Tech: LIGO - India and CMB - Bharat Stories, SAC, Ahmedabad, October 24, 2018; and IIT, Gandhinagar, November 20, 2018.

Blame it on RIO (Rigged Inflationary Outcomes), TIFR, Mumbai, October 26, 2018.

Driven by Quests: Hearing Aids and Polarized Glasses for Spacetime Murmurs, IISER, Kolkata, October 31, 2018; BITS - Pilani, Hyderabad, November 15, 2018.

LIGO - India: Origins and Site Search, International Conference on Multi-Messenger Astronomy in the Era of LIGO - India (LIMMA-2019), The Dukes Retreat, Khandala, January 17, 2019.

ECHO: Exploring Cosmic History and Origin, Advanced Tera-Hertz Technology and CMB Payload Proposal, January 21 - 22, 2019; and Workshop on Cosmology: The Next Decade, ICTS - TIFR, Bengaluru, January 24, 2019.

Evidence for Cosmic Hemispherical Asymmetry, Cosmology Seminar Series, MPA, Garching, Germany, February 12, 2019.

Intriguing Aspects of Cosmic Hemispherical Asymmetry, Cosmology Seminar, University of Geneva, February 15, 2019.

Concordances and Challenges after Planck, Sexten Centre for Astrophysics, Alta Pusteria, Italy, February 18 - 22, 2019.

Status of LIGO - India, LVC Meeting, Lake Geneva, March 20, 2019.

LIGO - India: A Mega-Science (Ad) Venture, Laser Light Sources and Application, RRCAT, Indore, March 26, 2019.

Vijayakumar Sreenath

Non-Gaussianity in Loop Quantum Cosmology, 15th Marcel Grossmann Meeting, University of Rome, La Sapienza, Italy, July 1 - 7, 2018.

Spherical Collapse of Fuzzy Dark Matter, Virtual Institute of Astroparticle Physics, Paris, France, September 28, 2018; and Meeting of the IAGRG, BITS - Pilani, Hyderabad, January 3 - 5, 2019.

Inflationary Cosmology, Regional Meeting in Astronomy: Opportunity and Challenges, CUSAT, Kochi, February 8 - 9, 2019.

Raghunathan Srianand

Influence of Ionising UV Background on the Inferred Properties of Metals, IGM Conference on Revealing Cosmology and Reionization History with the Intergalactic Medium, IPMU, Japan, September 18 - 23, 2018.

Observational Aspects of Cosmic Reionization, Cosmology Winter School, Kodaikanal Observatory, December 2018 (Review talk).

Science with TMT, Workshop on Cosmology: The Next Decade, ICTS - TIFR, Bengaluru, January 23, 2019.

Detailed Science Cases in the HROS White Paper, HROS Per - ASI Meeting, IIA, Bengaluru, February 16, 2019.

(i) *Science Requirements for HROS*, and (ii) *IGM Science Cases for NLOT,* Annual Meeting of the ASI, Christ University, Bengaluru, February 18 - 22, 2019.

Baryons in the Universe as Probed by the Absorption Line Spectroscopy, NCRA, Pune, February, 2019.

Kandswamy Subramanian

(i) *Magnetizing the Universe I: Fluctuation Dynamos*, (ii) *Magnetizing the Universe II: The Large Scale Dynamo*, and

(iii) *Magnetic Fields in the Early Universe*, Excellence Cluster Universe, Munich, Germany, July 2018.

A Unified Large/Small-Scale Turbulent Dynamo in Stars and Galaxies, Hamburg Observatory, Germany, August 2018;

A Unified Large/Small-Scale Turbulent Dynamo in Stars and Galaxies, Leibniz-Institut fur Astrophysik, Potsdam, Germany, August 2018.

Origins of Cosmic Magnetism, IAU Focus Meeting 8: New Insights in Extragalactic Magnetic Fields, Vienna, Austria, August 2018; and Meeting of the IAGRG, BITS - Pilani, Hyderabad, January 3 - 5, 2019.

Turbulent Origin of Magnetic Fields in Galaxies and Clusters, Workshop on Cosmology: The Next Decade, ICTS - TIFR, Bengaluru, January 2019.

Batteries and Dynamos in the Universe, Regional Meeting in Astronomy: Opportunities and Challenges, CUSAT, Kochi, February 8 - 9, 2019.

Durgesh Tripathi

It's Hot, Magnetic and Happening: The Solar Corona, IUCAA, May 17, 2018.

Coronal Holes and Quiet Sun in Mg II Lines Observed, IRIS- 9 Workshop, Goettingen, Germany, June 25 - 29, 2018.

Heating and Dynamics of Sun's Atmosphere, IIT, Kanpur, February 8, 2019.

Reaching for the Sun, CUSAT, Kochi, March 1, 2019;

Reaching for the Sun, Indian Association of Physics Teachers, Goa, February 1 - 2, 2019;

Reaching for the Sun, IITM, Pune, March 22 - 23, 2019.

(g) LECTURE COURSES

Md. Shah Alam

Study of Cygnus X-1 using AstroSat and CZTI Data Reduction Techniques (2 lectures), and *Hands-on- Sessions on CZTI Data Analysis,* Workshop on Multi-Wavelength Sky Observations: AstroSat and Beyond, IIT, Indore, February 3 - 7, 2019.

Joydeep Bagchi

Large Scale Structures/Jets (2 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, June 13 - 14, 2018.

Abhijit B. Bendre

Radiation Processes and Gas Dynamics (6 Lectures) Fergusson College, Pune.

Dipankar Bhattacharya

Structure and Evolution of Stars (4 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 15 - 17, 2018.

An Advanced Course on Pulsar Astrophysics (20 lectures) NCRA, Pune, June - September 2018.

Physics of Compact Objects (5 lectures) Module VI of NRC Course on Astronomy and Astrophysics, Recording Studio, Savitribai Phule Pune University, October 9 - 11, 2018.

X-ray Emission Mechanisms (2 lectures) COSPAR Capacity Building Workshop, IISER, Mohali, March 10 - 11, 2019.

Sukanta Bose

General Relativity and Black Holes (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 21 - 23, 2018.

Naresh K. Dadhich

Spacetime and Gravitation (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 18 - 22, 2018.

Gulab C. Dewangan

X-ray Astronomy and Active Galactic Nuclei (2 lectures) Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May -June 2018.

AstroSat and AGN (2 lectures) SITARE: Introductory Workshop on Astrophysics, Pt. Ravishankar Shukla University, Raipur, August 16 - 18, 2018.

Sanjeev V. Dhurandhar

General Relativity and Gravitational Waves: Einstein's Equation, Linearized Theory of GR, Transverse-Traceless Gauge and an Overview (6 lectures) Workshop on Gravitation and Gravitational Waves, Assam University, Silchar, October 7 - 13, 2018.

Neeraj Gupta

Interstellar Medium and Radio Astronomy (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, June 11 - 13, 2018.

Ranjan Gupta

Introductory Workshop on Astronomy and Astrophysics (2 lectures) Kohima Science College, Jotsoma, Nagaland, April 5 - 6, 2018.

Observational Astronomy (2 lectures) Orientation Cum Selection Camp of Indian Astronomy Olympiad, Nehru Centre, Mumbai, May 1 - 3, 2018.

Spectroscopy and Spectroscopic Instrumentation (2 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA. May 24 - 25, 2018.

Observational Astronomy (2 lectures) University of Wuerzburg, Hubland Campus, Germany, June 13, 2018.

Interstellar Dust and ANNs in Astronomical Spectroscopy (2 lectures) University of Liege, Belgium, June 21 - 22, 2018.

Spectrographs and Spectra - Observation and Data Reduction Techniques (2 lectures) 4th Indo-French School on Spectroscopy 2D/3D, Lyon, France, July 9 - 16, 2018.

Basics of Observational Astronomy, Artificial Neural Networks: Applications

to Astronomical Spectra, India's Involvement in Mega Projects in Astronomy and IUCAA (4 lectures) Workshop on Celestial Mechanics and Dynamic Astronomy, Central University of Rajasthan, Bandarsindri, January 7 - 11, 2019.

Basics of Astronomy (4 lectures) Advance Meteorological Training Course for Naval Officers and IMD Recruits, IMD - CTI, Pune, January 30 - 31, 2019.

Ajit K. Kembhavi

Galaxy Photometry and Space Programmes (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, June 1 - 5, 2018.

Ranjeev Misra

Radiative Process and Introduction to Time Series (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 16 - 18, 2018.

Sanjit Mitra

Gravitational Waves (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, June 11 - 13, 2018.

Introduction to Cosmic Microwave Background (2 lectures) SITARE: Introductory Workshop on Astrophysics for Nepal, Tribhuvan University, Kathmandu, June 13 - 15, 2018.

Aseem S. Paranjape

Cosmology with Large Scale Structure (4 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 30 - 31, 2018.

A. N. Ramaprakash

Optical Astronomy and Techniques (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 30 - June 1, 2018.

Somak Raychaudhury

Cosmic Distance Ladder and Galaxy Environment (4 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 14 - June 15, 2018.

Kanak Saha

Galaxies: Structure and Evolution (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 14 - June 15, 2018.

Dynamics and Structure of Galaxies (3 lectures) SITARE: Introductory Workshop on Astrophysics for Nepal, Tribhuban University, Kathmandu, Nepal, June 13 - 15, 2018.

Galaxy Evolution: From High Redshift to Now (2 lectures) Workshop on Recent

Advances in Astrophysics and Cosmology, Cooch Behar Panchanan Barma University, Cooch Behar, October 9 - 10, 2018

Introduction to Dynamics and Orbital Structures: Application to Planetary System and Galaxies (3 lectures) Workshop on Celestial Mechanics and Dynamical Astronomy (CMDA-2019), Central University of Rajasthan, Bandarsindri, January 7 - 11, 2019.

Galaxies (2 lectures) SITARE: Advanced Workshop on Astrophysics, IUCAA, January 10 - 16, 2019.

Galaxies and their Evolution (4 lectures) Workshop on Astronomy and Astrophysics, Sikkim University, Gangtok, March 29 - 31, 2019.

Varun Sahni

Dark Matter and Dark Energy (2 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 28 - 29, 2018.

Dark Energy (3 lectures) Workshop on Cosmology: The Next Decade, ICTS - TIFR, Bengaluru, January 2019.

Dhruba J. Saikia

21 cm Observation of Galaxies (2 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, June 14 - 15, 2018.

Tarun Souradeep

Cosmic Microwave Background (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 28 - 29, 2018.

Kandswamy Subramanian

Fluids and Plasma (4 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May14 - 18, 2018.

Galaxy Formation: The Dirty Business (3 Lectures) Workshop on Cosmology: The Next Decade, ICTS- TIFR, Bengaluru, January 2019.

Shyam N. Tandon

UV Astronomy and Instrumentation (3 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, June 1 - 5, 2018.

Durgesh Tripathi

The Sun (4 lectures) Introductory Summer School in Astronomy and Astrophysics (for College/University Students), and Vacation Students' Programme, IUCAA, May 23 - 28, 2018.

(h) POPULAR/PUBLIC LECTURES

Dipankar Bhattacharya

AstroSat – India's Observatory in Space, INSPIRE Conclave 2019, Miranda House, Delhi, January 18, 2019.

Gulab C. Dewangan

The Universe in X-rays (in Hindi), Government Kakatiya PG College, Jagdalpur, August 19 , 2018.

Sanjeev V. Dhurandhar

Nobel Prize in Physics 2017: Gravitational Waves - Einstein's Messengers, Sahyadri College of Engineering and Management, Mangaluru, April 4, 2018; and College of Engineering, Pune, October 4, 2018.

Gravitational Waves: A Perspective, Assam University, Silchar, October 12, 2018.

Nobel Prize in Physics 2017: The Discovery of Gravitational Waves, Indian Physics Association, Pune Chapter, Annasaheb Magar College, Hadapsar, Pune, October 25, 2018; and IISER, Pune (Organised by the Pune International Centre) , November 23, 2018..

The Discovery of Einstein's Waves, Annasaheb Awate College, Manchar, Pune District, December 20, 2018.

Anupreeta More

Unravelling the Dark side of the Universe, Nehru Planetarium, Mumbai, August 23, 2018.

Beyond Earth for Home Schooling, Baner, Pune, October 26, 2018.

Surhud More

Frontiers of Astronomy, Nehru Planetarium, Mumbai, August 25, 2018.

The Search for Planet Nine in the Outer Solar System, Pulastya Science Festival, IUCAA, November 28, 2018; Jyotirvidya Parisanstha, February 7, 2019; and College of Engineering, Pune, February 26, 2019.

Jayant V. Narlikar

Cambridge ki yadein (Memories of Cambridge) (in Hindi), Banaras Hindu University, Varanasi, April 7, 2018.

Pruthvi palikade jeev shrusticha shodh (Searches for Life Outside the Earth) (in Marathi) Vasant Vyakhyanmala, Nashik, May 13, 2018.

Convocation Address, IISER, Pune, May 26, 2018; and University of North Bengal, Siliguri, October 5, 2018.

Cosmic Illusions, Nehru Planetarium, Mumbai, June 21, 2018; 2nd Saturday Lecture Demonstration Programme, IUCAA, January 5, 2019; and *Diste tase naste ... kadhikadhi* (in Marathi), 2nd Saturday Lecture Demonstration Programme, IUCAA, January 5, 2019.

The Lighter Side of Gravity, Raj Bhawan, Dehradun, August 10, 2018.

Kya brahmand mein hum akele hain? (Are we Alone in the Universe?) (in Hindi), Gurukula Kangri Vishwavidyalaya, Haridwar, August 13, 2018.

Learning to Live in the 21st Century, National Scientific Temper Day, All India People's Science Network, and Maharashtra Andhashraddha Nirmulan Samiti, Pune, August 19, 2018;

Break through Science Society, Conference on Integrating Science with Society, Jadavpur University, Kolkata, December 15, 2018.

In What Century are we Living?, Sixth Annual Dabholkar-Kalburgi Memorial Lecture, Azim Premji University, Bengaluru, October 31, 2018.

Aapulki akashashi: Khagol vidnyanacha galiv ethihas (Selected History of Astronomy) (in Marathi), Pulastya Science Festival, IUCAA, November 28, 2018.

Vaidnyanik drushtikon (Scientific Temper) (in Marathi), Mahatma Gandhi Mission and Saket Prakashan, Aurangabad, December 1, 2018.

Micro-Life in the Earth's Atmosphere, TEDxKITCoEK 2019 Conference, Kolhapur, February 3, 2019.

T. Padmanabhan.

Cosmic History and Mysteries, The Second Information Universe Conference, Groningen, The Netherlands, July 3, 2018.

Vijayakumar Sreenath

Story of our Universe: Standard Model of Cosmology, National Seminar on Space Science and Nano-Science, Little Flower College, Guruvayur, Kerala, October 11, 2018.

Introduction to Cosmology, Mini-School on Gravitation and Cosmology, Providence Women's College, Kozhikode, February 7 - 10, 2019.

(i) RADIO/TV PROGRAMMES

Sanjeev V. Dhurandhar

Discovery of Gravitational Waves, Door Darshan TV Channel, Silchar, October 11, 2018.

Pioneering Work on Gravitational Waves done in IUCAA from 1989 till Now, Creative Channel of Vigyan Prasar (Interview), November 30, 2018.

Jayant V. Narlikar

Interview by All India Radio, Mumbai, November 7 and 8, 2018.

Ani suryahasla (Marathi Science Fiction), All India Radio, Mumbai, January 14, 2019.

SCIENTIFIC MEETINGS AND OTHER EVENTS

INTRODUCTORY SUMMER SCHOOL IN ASTRONOMY AND ASTROPHYSICS

The biennial Introductory Summer School in Astronomy and Astrophysics (for College and University Students) was conducted during May 14 - June 15, 2018, at IUCAA. The faculty coordinator for the school was Kanak Saha. (For details, see KHAGOL No. 115, July 2018)

VACATION STUDENTS' PROGRAMME

The Annual Vacation Students' Programme (VSP) was held during May 14 - June 29, 2018 at IUCAA. The faculty coordinator of this programme was Gulab C. Dewangan.
(For details, see KHAGOL No. 115, July 2018)

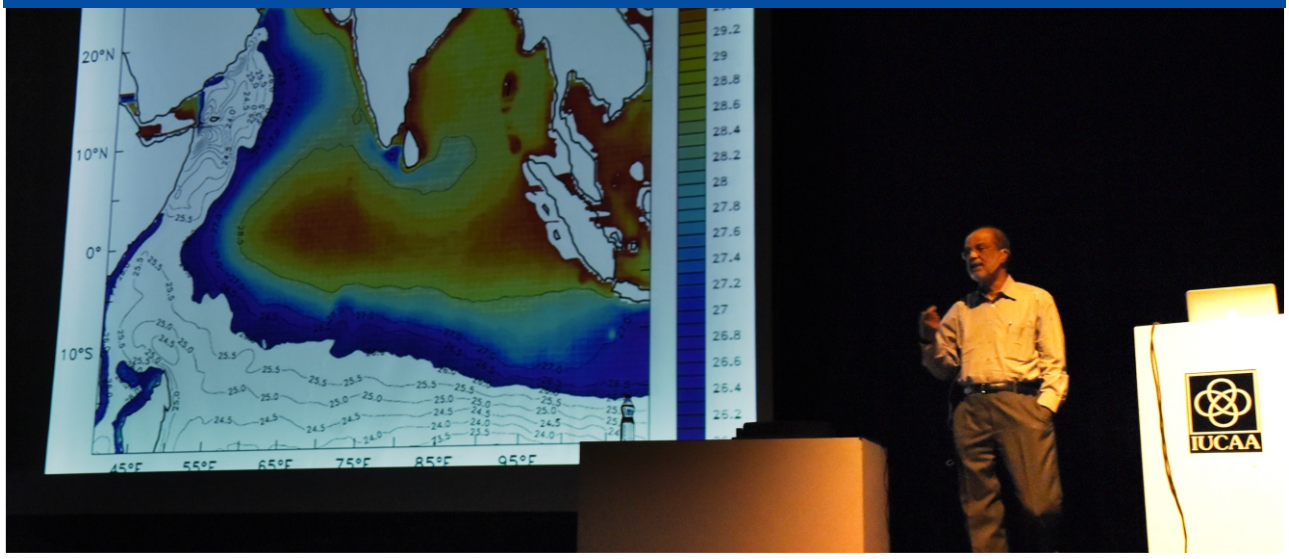
MEETING ON ASTRONOMY IN UNIVERSITIES (IUCAA@30 + JVN@80)

To commemorate 30 years of IUCAA, and to celebrate Professor Jayant Narlikar becoming 80 years old, a meeting was held at IUCAA during September 27 - 28, 2018, on Astronomy in Universities. The meeting was coordinated by Ajit Kembhavi and Ranjeev Misra. (For details, see KHAGOL No. 116, October 2018)

MEETING ON PHYSICS AND ASTROPHYSICS AT THE EXTREME (PAX)

The fourth edition of the Meeting on Physics and Astrophysics at the eXtreme (PAX) was held at IUCCA, during August 7 - 10, 2018. The organizers were Sukanta Bose, Ajit Kembhavi, Sanjit Mitra, Somak Raychaudhury, and Tarun Souradeep. (For details, see KHAGOL No. 116, October 2018)

THE 30TH IUCAA FOUNDATION DAY LECTURE



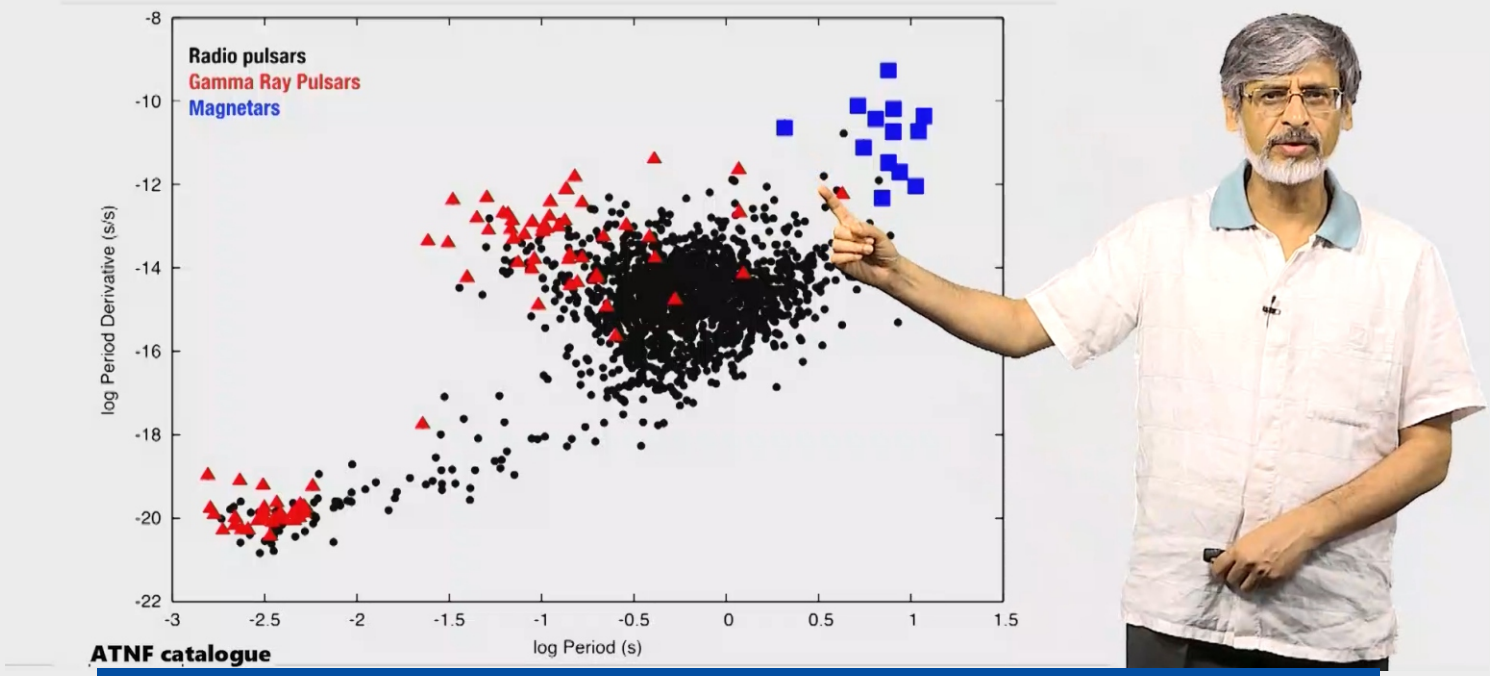
The 30th Foundation Day Lecture of IUCAA was delivered by Professor Satish R. Shetye on December 29, 2018 in the Chandrasekhar Auditorium. (For details, see KHAGOL No. 117, January 2019)

ASTRONOMY CENTRE FOR EDUCATORS

The Astronomy Centre for Educators (ACE) has been established recently at IUCAA. (For details, see KHAGOL No. 118, April 2019)

SITARE: ADVANCED WORKSHOP ON ASTROPHYSICS

Advanced Workshop on Astrophysics at IUCAA, during January 10 - 16, 2019. The workshop was coordinated by Ranjeev Misra and Ajit Kembhavi (For details, see KHAGOL No. 118, April 2019)



ANNUAL REFRESHER PROGRAMME IN TEACHING (ARPIT 2018)

The National Resource Centre at IUCAA has developed a broad-based course on astronomy and astrophysics for the Annual Refresher Programme in Teaching (ARPIT 2018), consisting of 57 videos spread across 11 modules, along with multiple - choice questions for each suggestions for further readings.
(For details, see KHAGOL No. 118, April 2019)

ACTIVITIES OF TEACHING LEARNING CENTRE

NRC AND TLC STAFF

The activities of both NRC and TLC have been overseen by Dhruba J. Saikia (Head, NRC and TLC), with Sanjit Mitra (as Faculty Coordinator), Manojendu Choudhury (as Academic Coordinator), Sayali Avachat (as Senior Research Staff), Preethi K. and Chaitra Narayan (as Project Assistants), and Aniket Kadu and Shivraj K. Kshatriya (as Interns). Suchit Hasabnis (SPPU), Vivek Kannadi and Parmeshwar S. Yadav (IISER Pune), and Kamala Kannan (IIT Madras) helped in recording the videos.

WORKSHOP ON DEVELOPING ASTRONOMY THEMED EXPERIMENTS

The Workshop on Developing Astronomy-Themed Experiments, was conducted during June 18 - 20, 2018. This workshop was coordinated by Samir Dhurde (IUCAA), Priya Hasan (Maulana Azad National Urdu University, Hyderabad), and Joe Jacob (Newman College, Thodupuzha) with several groups of astronomers including ASI-POEC members as resource persons. (For details, see KHAGOL No. 115, July 2018)

WORKSHOP ON NIGHT SKY PHOTOMETER FABRICATION

The Workshop on Night Sky Photometer Fabrication was held at IUCAA, during March 12 - 16, 2019. The workshop was coordinated by Sayali Avachat, Manojendu Choudhury and Ranjan Gupta. (For details, see KHAGOL No. 118, April 2019).

WORKSHOP ON RADIO OBSERVATIONS USING HORN ANTENNA

Faculty members from half a dozen institutions participated in the Workshop on Radio Observations using Horn Antenna at IUCAA, during March 9 - 11, 2019.

The workshop was coordinated by Sayali Avachat, Joydeep Bagchi and Manojendu Choudhury (all from IUCAA). (For details, see KHAGOL No. 118, April 2019)

PUBLIC OUTREACH

GLOBAL ASTRONOMY MONTH

On the occasion of the Global Astronomy Month (GAM) - April 2018, IUCAA SciPOP organised a themed public sky-gazing event on April 28, 2018. The event was coordinated by Sonal Thorve. (For details, see KHAGOL No. 115, July 2018)

WORKSHOP ON TEACHING AND LEARNING WITH SCIENCE TOYS

A Workshop on Teaching and Learning with Science Toys for volunteers was held at IUCAA on April 12, 2018. The workshop was coordinated by Shivani Pethe and Rupesh Labade. (For details, see KHAGOL No. 115, July 2018)

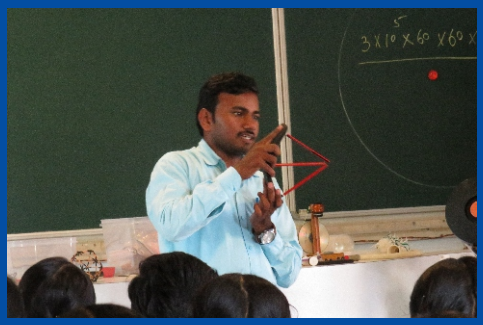
SCHOOL STUDENTS' SUMMER PROGRAMME AND ASTRONOMY CAMP

The annual School Students' Summer Programme and Astronomy Camp were held at IUCAA, during April 23 - June 1, 2018. These were coordinated by Samir Dhurde and Sonal Thorve, with the help of other MVS personnel. (For details, see KHAGOL No. 115, July 2018)

IUCAA VISIT AND SKY WATCH FOR RURAL TEACHERS

A group of 100 teachers from different rural parts of Maharashtra visited IUCAA on June 7, 2018 under a Teachers' Training Programme, organised by Sakal NIE and IISER - Pune. Somak Raychaudhury (Director, IUCAA) interacted with these teachers, sharing information about IUCAA and the mega-projects in progress.

TEACHERS' WORKSHOP ON SCIENCE TOYS AND BASIC ASTRONOMY



A workshop for science teachers of government Marathi medium schools was held on July 21, 2018, at Muktangan Vidnyan Shodhika (MVS), IUCAA. The workshop was coordinated by Sonal Thorve and Maharudra Mate (both from IUCAA).
(For details, see KHAGOL No. 116, October 2018)

WORKSHOP ON TEACHING SCIENCE WITH TOYS

A Workshop on Teaching Science with Toys for school teachers from Karve Shikshan Sanstha, Pune, was held on August 25, 2018, at MVS, IUCAA. The workshop was coordinated by Shivani Pethe and Rupesh Labade (both from IUCAA). (For details, see KHAGOL No. 116, October 2018)

SALLY RIDE EARTHKAM, MISSION 63

For the first time, IUCAA participated in the Sally Ride EarthKAM (Earth Knowledge Acquired by Middle School Students) run by NASA, and was organised at the Modern High School (English Medium), Shivajinagar, Pune, on September 30, 2018. The programme was coordinated by Shivom Gupta (IUCAA). (For details, see KHAGOL No. 117, January 2019)

SCIENCE AND ASTRONOMY OUTREACH PROGRAMMES

The Science and Astronomy Outreach Programmes were organised at Belagavi, Karnataka, during September 29 - October 1, 2018.

CELEBRATION OF 150TH ANNIVERSARY OF HELIUM DISCOVERY

A special talk was organised on August 18, 2018, by the Delhi Public School, Kondhwa, Pune.

SPACE SCIENCE AND TECHNOLOGY TALK

A special talk on Space Science and Technology was organised by the Priyadarshani School, Dighi, Pune, on August 30, 2018, in collaboration with the Pimpri - Chinchwad Science Park. Sonal Thorve was invited as a resource person.

TENTH ANNIVERSARY OF CHANDRAYAAN I AND INTERNATIONAL OBSERVE THE MOON NIGHT

On the occasion of 10th anniversary of launch of Chandrayaan I, a special public lecture was delivered on October 22, 2018 by Suresh Naik (Former Group Director, ISRO), on Chandrayaan I: Celebrating 10th Launch Anniversary. This was followed by the public sky-watching activity, celebrating the International Observe the Moon Night 2018.

SRUJAN BATCH -1

A three month programme, Srujan, was started as a part of Vigyan-Tarang Lab at MVS, IUCAA in August 2018.

Jan - Jan JNU

Jan-Jan JNU, an open day programme for school students was organised by Jawaharlal Nehru University, Delhi, on November 30, 2018. Sonal Thorve (IUCAA) presented the science outreach activities at IUCAA, and demonstrated science toys and astronomy experiments at the event.

JIGNYASA

Agastya International Foundation, in collaboration with IISER, Pune, had organised the Jignyasa at IISER, Pune, during December 14 - 15, 2018. Rupesh Labade, and Tushar Purohit (both from IUCAA) coordinated the telescope exhibition. In the evening of December 14, a moon-watching session was organised for the student volunteers, at which about 150 students observed moon through the telescopes.

METEOR SHOWER SKY-WATCH

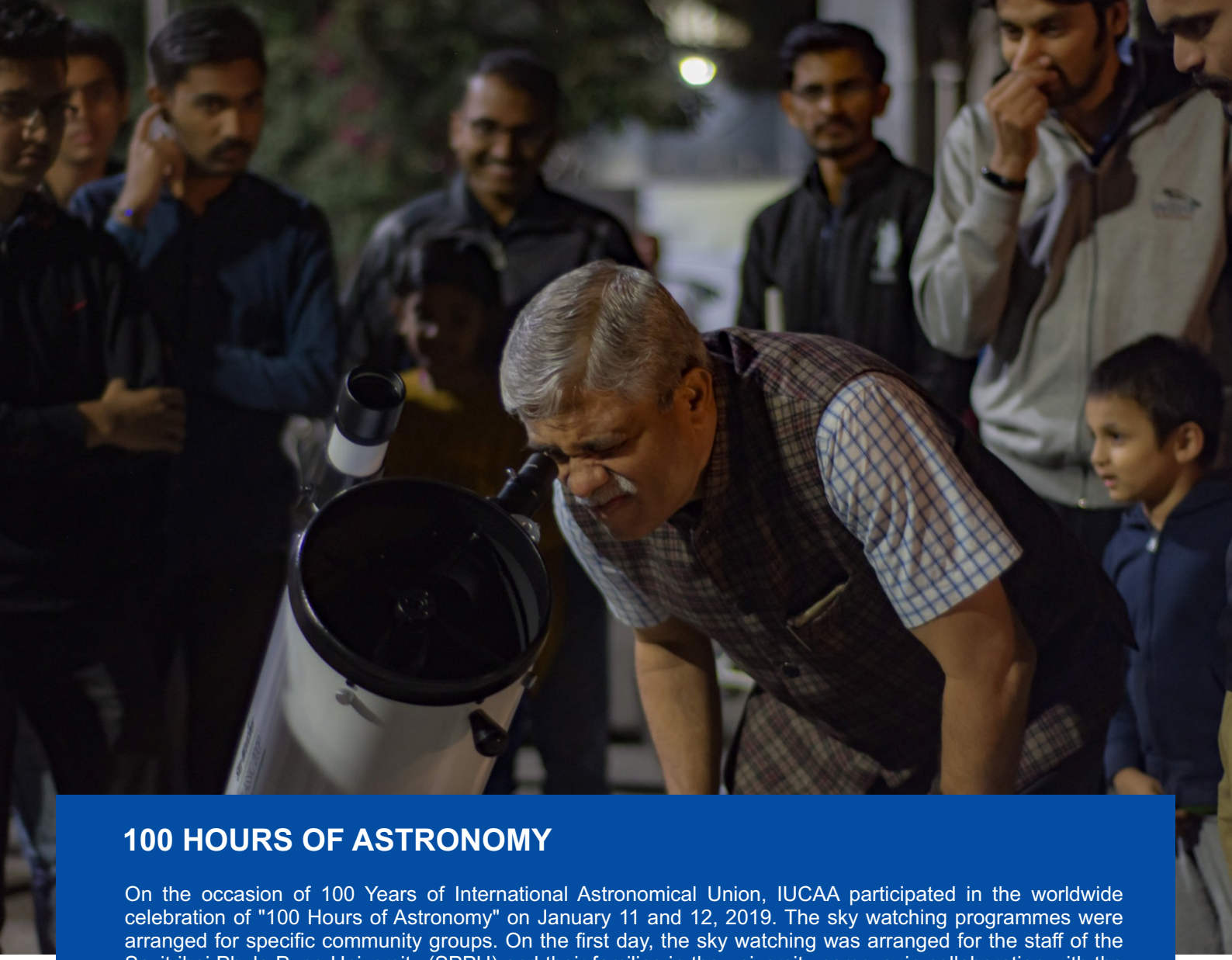
An overnight sky-gazing session along with a talk on meteor shower, and introduction to the universe was organised at Warananagar, by Warana Science Innovation and Activity Centre, Kolhapur, in collaboration with IUCAA SciPOP on the occasion of Geminid meteor shower, on December 15 - 16, 2018. About 350 school students along with their parents and teachers actively participated in observing the sky throughout the night. The programme was coordinated by Sonal Thorve and Maharudra Mate (both from IUCAA).

SCIENCE TOYS DEMONSTRATION AND SKY-WATCH

A full day workshop for science teachers of Marathi medium government schools was held at the Government School, Hinjawadi, Pune, on December 17, 2018. The workshop was coordinated by Sonal Thorve and Maharudra Mate. (For details, see KHAGOL No. 117, January 2019)

PULASTYA SCIENCE FESTIVAL

To commemorate the birth anniversary of Late Shri P. L. Deshpande, November 8, PuLastya Science Festival was organised during November 26 - 29, 2018, at IUCAA. The programme included day-time sessions for school students on astronomy without telescopes, and interaction with IUCAA PhD research scholars for the students to get the feel of doing research. There were 4 public lectures followed by sky-watching sessions, and these were delightful for public. In total, around 3,600 people visited IUCAA on this occasion.



100 HOURS OF ASTRONOMY

On the occasion of 100 Years of International Astronomical Union, IUCAA participated in the worldwide celebration of "100 Hours of Astronomy" on January 11 and 12, 2019. The sky watching programmes were arranged for specific community groups. On the first day, the sky watching was arranged for the staff of the Savitribai Phule Pune University (SPPU) and their families in the university campus, in collaboration with the Science Park of the university. On the second day, sky watching programme was arranged for performing artists from the Department of Performing Arts of the SPPU in the Science Park of IUCAA. In total, about 800 people visited and appreciated the programmes.

WORKSHOP ON TELESCOPE MAKING

A Workshop on Telescope Making was conducted at the Department of Physics, Visva - Bharati University (VBU), Santiniketan, during March 18 - 20, 2019.The workshop was funded by IUCAA and VBU. Sudipta Das (VBU) and Samir Dhurde were the coordinators of the workshop.

BASIC ASTRONOMY LECTURE AND SKY-WATCH

The Basic Astronomy Lecture by Sanjeev Dhurandhar (IUCAA) at Annasaheb Awate College, Manchar, was conducted on December 20, 2018. The key demonstrations coordinated by the IUCAA outreach personnel, Rupesh Labade, and Nilesh Pokharkar.

TALK, AT RANI LAKSHMIBAI MULINCHI SAINIKI SHALA, MULSHI

IUCAA Public Outreach team visited Rani Lakshmibai Mulinchi Sainiki Shala, Mulshi (near Pune) on January 9, 2019.

IGNITE, AT BITS - PILANI, HYDERABAD

Nirmaan Organization from BITS - Pilani, Hyderabad organised an event: Ignite, on February 10, 2019.

INTERNATIONAL DAY FOR WOMEN IN SCIENCE

On the occasion of the International Day for Women in Science, IUCAA Science Outreach personnel organised a special event for girl students from Marathi medium schools in and around Pune, on February 11, 2019, at IUCAA. Pushpa Khare, senior astrophysicist, delivered an inspirational talk on Let us Know Our Universe. This was followed by a talk on Astronomy: Do it Yourself by Sonal Thorve.

The event was coordinated by Samir Dhurde (IUCAA) and Sonal Thorve.

TEACHERS' TRAINING

IUCAA SciPOP personnel with the help of Rayat Shikshan Sanstha, Satara Region, organised a Teachers' Training Programme at Satara, during June 25 - 26, 2018, for science teachers from Zilla Parishad schools. About one hundred teachers from 13 Talukas of Satara District participated enthusiastically. These teachers discovered how basic concepts of Physics and Astronomy can be taught using simple hands-on activities.

Sonal Thorve coordinated and conducted the training with the help of Maharudra Mate.

WORKSHOPS ON TELESCOPE MAKING, AT GOA AND LATUR

IUCAA Science Outreach team, in collaboration with Vigyan Parishad, Goa, conducted a Workshop on Telescope Making, at Science Film Festival, Goa, during January 17 - 20, 2019. During February 22 - 24, 2019 a similar workshop was organised at Latur Science Centre. Twenty six large (5 inch) reflector telescopes were made by school teachers.

WORKSHOP ON FUNDAMENTAL SCIENCE, AT NAGALAND

A workshop on Fundamental Science was organised by IUCAA Public Outreach team to students of classes from VI to X, in and around Kohima, Nagaland, during March 11 - 14, 2019.

EQUINOX EVENT, AT NEW ENGLISH SCHOOL, TILAK ROAD, PUNE

On March 21, 2019, IUCAA in collaboration with New English School, conducted a workshop on measuring the circumference of the Earth using Eratosthenes method.

WORKSHOP FOR TEACHERS FROM RURAL SCHOOLS NEAR IGO, AT IUCAA

A two day workshop for secondary school teachers from rural areas in and around IUCAA Girawali Observatory (IGO) was held during January 23 - 24, 2019, at IUCAA

REGULAR EVENTS

During 2018-19, the IUCAA Outreach personnel have conducted 18 Science Toys Workshops, 20 Basic Astronomy Workshops, 28 Campus Visits, 07 Sky-watches with reach to about 4100 people.

SECOND SATURDAY LECTURES/ DEMONSTRATION

July 14, 2018
Somak Raychaudhury *on The Dark Universe*

August 11, 2018
Bhooshan Gadre *on Datum*

September 08, 2018
Shekhar C. Mande (NCCS) *on Who are We?*

October 13, 2018
Pradeep Kurulkar (DRDO) *on Recent Achievements in Space and Technology*

December 08, 2018
Kaustubh Vaghmare, Kaushal Sharma *on Artificial Intelligence in Astronomy*

January 05, 2019
Jayant Narlikar *on The Cosmic Illusions*

February 09, 2019
Rupesh Labade, and Shivani Pethe *on Science Toys Demonstration*

IUCAA - NCRA GRADUATE SCHOOL

PH.D. PROGRAMME

During the year of this report, seven IUCAA Research Scholars have defended their Ph.D. theses, namely: **Anirban Ain** (Guide: Sanjit Mitra), **Satadru Bag** (Guide: Varun Sahni), **Prasanta Bera** (Guide: Dipankar Bhattacharya), **Sabyasachi Chattopadhyay** (Guide: A.N. Ramaprakash), **Bhooshan Gadre** (Guide: Sanjit Mitra), **Labani Mallick** (Guide: Gulab Dewangan), and **Nikhil Mukund** (Guide: Sanjit Mitra). Their Ph.D. degrees have been awarded by the Jawaharlal Nehru University, New Delhi. The synopses of their theses are given below :

ANIRBAN AIN

Sources of Gravitational Waves and Efficient Observation with Laser Interferometric Detectors

In the past few years, the field of gravitational wave research has leaped forward significantly. The first detection of gravitational wave marked the beginning of a new frontier, gravitational wave astronomy, which is sure to open a new window to nature and help us understand the universe better. Different kinds of gravitational wave sources are expected to be discovered in the coming years. One of these sources is the stochastic gravitational wave background. The thesis is on the estimation of stochastic gravitational wave background and ways to observe it more efficiently.

We estimated the contribution of certain gravitationally bound systems to the stochastic gravitational wave background. There are two kinds of sources we looked into, galaxies in clusters and exoplanets. In a galaxy cluster, galaxies are chunks of localized mass, moving in a smoother dark matter halo. Assuming that these galaxies are in bound orbits, we calculated the spectrum of the gravitational waves they emit. Therefore, we could estimate the spectrum of the stochastic gravitational wave background generated by the Virgo cluster, and then we calculated the spectrum for all clusters by integrating over the whole universe. The results were underwhelming, as the spectrum only had significant power in very low frequency, outside the reach of any gravitational wave detector. But we remain hopeful about its contribution in weak lensing of the cosmic microwave background.

The next source we considered was exoplanets. Gravitational waves emitted from a single planet may be negligible but considering the fact that there are of the order of hundred billion planets in the galaxy we wanted to get a proper estimate of it. We used the statistics from existing exoplanet observations to simulate the entire galactic planet population and their contribution in the stochastic gravitational wave background. We were pleasantly surprised by the results. The typical orbital period of planets is years, which corresponds to gravitational waves of frequencies, which are detectable by pulsar timing arrays. We expected the peak of exoplanet contribution to be in the range where pulsar timing arrays can detect them. But to our surprise, the peak was in a much higher frequency, very close to the reach of space-based detectors. It is highly possible that in the coming decades, space-based detectors will be able to probe galactic planet population.

This thesis makes a major contribution towards the analysis to detect a stochastic gravitational wave background using ground based detectors by introducing a dramatic improvement in the computational efficiency of the searches. Cross-correlation statistics is used to detect and map a stochastic background. We found that the existing methods of detecting and mapping a stochastic background has a lot of room for improvements. We introduced data folding and an original program meto the stochastic pipeline.

When we cross-correlate data from two detectors, the terrestrial noise tend to cancel each other, because they are independent for two different detectors. But the correlation due to the extra-terrestrial stochastic signal builds up. This is the standard scheme used for detecting a stochastic background, and is commonly known as the radiometer algorithm.

Folding exploits a temporal symmetry in the radiometer algorithm, and adds the cross-correlation results from same sidereal times, when the relative position of the sky with respect to the detector baseline is the same. This simple technique speeds up the map calculation process by hundreds of times. We demonstrated the algorithm and the accuracy of implementation by applying the method on real LIGO data, and running the standard LIGO stochastic pipeline.

We then wrote another code `PyStoch` to make the analysis even more efficient, partly by taking advantage of folded data. Since folding compresses the data without loosing any generality for stochastic search, the whole data can be loaded in the memory (RAM) of an ordinary laptop, and loops in the pipeline can be replaced by matrix multiplications. This is exactly what `PyStoch` does, which makes the process almost hundred times faster than how it used to be. Moreover, `PyStoch` is based on HEALPix, which is the standard pixelization scheme used in cosmic microwave background analysis for several advantages and its Python based implementation, `healpy`, offers a host of tools to conveniently deal with anisotropic skymaps.

Folding and `PyStoch` together have sped up the searches for stochastic background in data from ground-based gravitational wave detectors by around ten thousand times, and have made the analysis highly convenient in many different ways. The method and implementation are ready to play a lead role in stochastic analysis in the era of gravitational wave astronomy with a network of detectors, a new era in astronomy that has just began.

SATADRU BAG

Exploring New Vistas in Cosmology

Majority of the present day observations indicate that the evolution of our universe is consistent with the ΛCDM model based on Einstein's general relativity (GR). However, this concordance model of cosmology, consisting of cold dark matter and cosmological constant (Λ), encounters quite a few issues pertaining to both theoretical and observational aspects. In this thesis, we try to shed light on several aspects of cosmology that are not yet understood fully. In particular, the thesis discusses (i) an alternative to the *Big-Bang* initial singularity, (ii) dark energy models beyond ΛCDM, and (iii) the epoch of reionization during which neutral hydrogen in the intergalactic medium was ionized within the redshift range $6 \lesssim z \lesssim 20$ from the first light sources.

- An alternative to the 'Big-Bang' paradigm is explored in Chapter 2. Since inflation cannot be past-eternal, implying it must have a beginning, the standard model of cosmology runs into an initial singularity, known as Big-Bang singularity from which the spacetime comes into existence. We explore an alternative scenario to the Big-Bang paradigm, known as *emergent cosmology*, from the effective potential formalism. In this scenario, the universe 'emerges' into the inflationary phase from a past eternal static or quasi-static state, usually associated with the *Einstein Static Universe* (ESU). In GR framework, the emergent scenario is unstable due to the fact that the ESU, associated with the maximum in the effective potential, is also unstable. We show that in certain modified theories of gravity, including braneworld, loop quantum cosmology, asymptotically free gravity, the effective potential possesses minima, which can give rise to stable ESU and stable emergent scenario in turn. In these models, in addition to being static, the universe can also oscillate around the ESU fixed point before dynamically escaping into the inflationary phase. Therefore, the appearance of the minima in effective potential evades the requirement of any fine-tuning of parameters. But such an oscillating universe should be accompanied by *particle production*. We tested the stability of emergent cosmology against

this semi-classical effect of *graviton* production in a past-eternally oscillating universe prior to inflation. We show that the parameter space is significantly restricted in order to avoid copious particle production through parametric resonances.

- In Chapter 3 of this thesis, we extensively study dark energy models based on the phantom braneworld or the 'normal'-branch of Dvali–Gabadadze–Porrati (DGP) braneworld. The phantom braneworld, having *phantom-like* equation of state of the *effective dark energy* near the present epoch, smoothly evolves to the de-Sitter universe in the future without running into a 'big-rip' future singularity. One of the major advantages of the phantom braneworld is that the past-expansion of the universe was slower than in the ΛCDM model. Phantom braneworld, thus, can resolve the significant tension between the high redshift Baryon Acoustic Oscillations (BAO) observation in Baryon Oscillation Spectroscopic Survey (BOSS) and the ΛCDM model. We attempt to constrain the cosmology of the phantom brane using distance measures, such as type-Ia supernovae (SNeIa), BAO, and the *compressed* Cosmic Microwave Background (CMB) data. The distance measures allow the presence of the extra dimension with the following constraint on the brane parameter: $\Omega_\ell \lesssim 0.1$ at 1σ. Interestingly, we find that the universe is allowed to be closed or open, $-0.5 \lesssim \Omega_\mathbb{k} \lesssim 0.5$, even on including the compressed CMB data.
- Understanding the growth of cosmological perturbations on the brane is very important for testing this model at the linear perturbative level. In Chapter 4, we obtain a closed system of equations for scalar perturbations on the phantom brane, assuming the marginally closed limit. In addition to matter and radiation, the braneworld possesses a new effective degree of freedom – the 'Weyl fluid' or 'dark radiation' – which stems from the projection of the five-dimensional Weyl tensor onto the brane. Setting initial conditions on super-Hubble spatial scales at the epoch of radiation domination, we evolve perturbations of radiation, pressureless matter and the Weyl fluid until the present epoch. We observe a gradual decrease in the amplitude of the Weyl fluid perturbations after Hubble-radius crossing, which results in a minimal effect of the Weyl fluid perturbation on the evolution of matter perturbations on spatial scales relevant for structure formation. Consequently, the quasi-static approximation provides an excellent fit to the exact results during the matter-dominated epoch.

We show that the matter density perturbation on the brane grows at a faster rate than that in ΛCDM during the late matter dominated epoch. Additionally, at $z \lesssim 50$, the gravitational potentials Φ and Ψ evolve differently on the brane than in ΛCDM, for which $\Phi = \Psi$. For example, the ratio Φ/Ψ on the brane exceeds unity during the late matter-dominated epoch. These features may serve as *smoking gun* tests of phantom brane cosmology and allow predictions of this scenario to be tested against observations of galaxy clustering and large-scale structure.

- In Chapter 5, we also find an accurate ansatz for the growth rate ($f \equiv \mathrm{d}\ln\delta_m/\mathrm{d}\ln a$) of the matter perturbation on the phantom brane. The ansatz is quite different from the usual parametrization, $f(z) = \Omega_m(z)^\gamma$, which is commonly used in the literature even in the context of modified gravity.
- Chapter 6 shows that a canonical scalar field propagating on the phantom brane can give rise to an expansion rate exactly as in the ΛCDM model. We reconstruct the exact form of the quintessence potential required in this 'mimicry' model. Interestingly, the exact potential can be well approximated by a simple form, $V \propto \coth^2(\lambda\phi)$, which belongs to the α-attractor set of potentials.
- In Chapter 7, we introduce a new class of quintessence models of dark energy (DE) based on the α-attractor set of potentials, originally discussed in the context of inflation. A prominent member of this class of models is based on the quintessence potential, $V \propto \coth^p(\lambda\varphi)$ which, resembles the alphabet "L". At early times, the model behaves like the inverse power law (IPL) potential: $V \propto 1/\varphi^p$, implying that L-model has the same tracking properties as the IPL model. Thus, the L-model avoids any requirement of fine-tuned initial conditions. At late times, $V \to V_0$ ensures that the equation of state of DE at present epoch (w_0) is significantly smaller than that in the IPL. Therefore, the model can easily satisfy current observations from a large initial basin of attraction.
- Chapters 8 and 9 explore the reionization process from the geometrical perspective. As an alternative to the traditional N-point correlation statistics, our novel approach is based on Minkowski functionals and their ratios, known as Shapefinders. Using Shapefinders, we study the morphology of neutral hydrogen density fields, simulated using semi-numerical techniques, at various stages of reionization. Accompanying the Shapefinders, we also employ the 'largest cluster statistic' (LCS), to study the percolation in both neutral (HI) and ionized (HII) hydrogen. In Chapter 8, we study the shape and size distribution of ionized hydrogen at different redshifts corresponding to various stages of reionization. We find that the largest ionized region is percolating

below the neutral fraction $x_{HI} \lesssim 0.728$ (or equivalently $z \lesssim 9$). The study of Shapefinders reveals that the largest ionized region starts to become highly filamentary with non-trivial topology near the percolation transition. During the percolation transition, the first two Shapefinders – 'thickness' (T) and 'breadth' (B) – of the largest ionized region do not vary much, while the third Shapefinder – 'length' (L) – abruptly increases. Consequently, the largest ionized region tends to be highly filamentary and topologically quite complex. The product of the first two Shapefinders, $T \times B$, provides a measure of the 'cross-section' of a filament-like ionized region. We find that, near percolation, the value of $T \times B$ for the largest ionized region remains stable at ~ 7 Mpc^2 (in comoving scale), while its length increases with time. Interestingly, all large ionized regions have similar cross-sections. However, their length shows a power-law dependence on their volume, $L \propto V^{0.72}$, at the onset of percolation.

- Chapter 9 studies the morphology of the HI fields during reionization from the excursion set approach at various redshifts during reionization. Subject to a density threshold, the two excursion sets – HI overdense and underdense – would represent "hot spots" and "cold spots" respectively in future 21-cm radio surveys. Using the *percolation curves*, we demonstrate that the non-Gaussianity in the HI field increases as reionization progresses. The large clusters (in either excursion set) possess similar values of thickness (T), as well as breadth (B), but their length (L) is almost proportional to their volume. Therefore, the cross-sections of the large clusters at the onset of percolation do not vary much with volume which differs in terms of length only. The large clusters in both HI overdense and underdense segments are overwhelmingly filamentary. We also find that the cross-sections of large HI overdense clusters are more alike at lower redshifts, which correspond to an advanced stage of reionization.

The above analyses can be extended for distinguishing different models of reionization using Shapefinders and percolation. It would be interesting to investigate as to whether the HI intensity mappings from the low-frequency radio interferometers can be used for similar analyses. This exercise would involve computing Minkowski functionals and Shapefinders in the presence of instrument noise and astrophysical foregrounds.

PRASANTA BERA

Strongly Magnetized Degenerate Stars.

At the end of nuclear burning, stellar cores are squeezed to form very dense objects as the thermal support against gravitational force is depleted. The density in these cores reach such high values that the electrons enter a degenerate state - namely their Fermi energy far exceed the thermal energy. The ultimate state of such a compact degenerate star depends on its mass. White dwarfs (WDs), remnants of relatively low mass main sequence stars, are stabilised against gravitational collapse by the pressure arising from electron degeneracy. However, electron degeneracy pressure can support a maximum of about 1.4 $M_\odot$, known as Chandrasekhar mass limit. If this limit is exceeded, a WD would undergo a catastrophic collapse and depending on the internal composition either produce a neutron star or ignite runaway nuclear burning resulting in a type Ia supernova explosion (SNIa). However, recently a small subset of SNIa (e.g., 2003fg, 2006gz) have been found to have a higher luminosity than normal. This would require a WD progenitor mass close to 2 $M_\odot$, well in excess of the Chandrasekhar limit. Such a configuration would require additional sources of support against gravity. Strong magnetic field in the WD interior is one possible agent to provide such extra support.

In this thesis, we address some of the key issues related to the influence of strong magnetic field on degenerate stars, specifically WDs. We construct axisymmetric equilibrium configurations with strong magnetic field for different field geometries, and investigate the effects of Landau quantization, electrostatic interactions and general relativistic gravity on the structure. We also study the stability of these configurations via perturbation analysis.

Many of the known WDs are members of accreting binary systems. Matter from its companion star is pulled and deposited on the WD due to its strong gravity. If the WD is strongly magnetized, then such objects are called Magnetic Cataclysmic Variables (MCVs).

Strongly magnetized WDs with super-Chandrasekhar mass can only be possible if there is a valid equilibrium configuration. To obtain the equilibrium structure of magnetic configurations, we solve time independent magnetohydrodynamic (MHD) equations. Our results show that WDs with pure poloidal field of strength $\sim 10^{10}$ T at the core can sustain mass upto 1.9 $M_\odot$ due to the presence of Lorentz force. For a purely toroidal field, the outward component of the Lorentz force is more effective, and hence the maximum mass is beyond 5 $M_\odot$. The strongly magnetized configurations are prolate for a pure poloidal magnetic field configuration, whereas it is in the oblate shape for a pure toroidal configuration. The axisymmetric configurations with a strong mixed field, containing poloidal and toroidal components, have masses in between these extremes.

We also estimate the modification to the above results owing to (i) the general relativistic description of gravity, which we incorporate using public numerical codes XNS & LORENE, (ii) the change of matter equation of state due to Landau quantization in strong magnetic fields, and (iii) the inclusion of electrostatic effects arising from the presence of ions in the configuration. We find that (i) and (iii) can change the maximum mass estimate by at most a few per cent, while (ii) has a much smaller effect on the maximum mass.

Although the equilibrium configurations with the strong magnetic field can provide WD with a mass of about 2 $M_\odot$ or more depending on the magnetic field geometry, this does not guarantee long-term dynamical stability of the configuration. If the objects are dynamically stable then one can have a chance to find them observationally. Earlier studies based on the minimum energy principle have identified instabilities of axisymmetric field configurations near magnetic neutral regions. To test the stability properties of strongly magnetized WDs we study the dynamical evolution of perturbed configurations in the linear and the non-linear regime. We have developed a domain decomposed mpi based linear evolution code to study the evolution of a specified azimuthal mode on the background equilibrium solution. Such linear perturbations of the magnetized configurations show a growth of the perturbations near magnetically neutral regions, with a time scale comparable to the Alfvén crossing time. Single mode perturbations are likely to grow independently only for a short time before transferring energy into a multitude of modes. This requires a study of the non-linear phase, which we perform using the MHD code PLUTO. Our results demonstrate unstable growth of the perturbations. Hence, the linear and the non-linear study suggest that the super-massive magnetic configurations are highly unstable in time scales of a fraction of a second. This imposes a strong constraint on the formation and survival of such an object.

The accretion flow on to a magnetic WD star is strongly influenced by the magnetic field. A subclass of MCVs called Polars exhibit polarised emission due to the strong magnetic field. The WDs in these systems have the strongest known magnetic fields. The observed optical quasi-periodic oscillations (QPOs) with the period of about a second from these systems are attributed to the instability of the accretion column. To estimate the relative amplitude of expected QPOs in optical and X-ray bands we study, using the PLUTO code, the one-dimensional structure of the accretion column. The radiation in the X-ray and UV/optical bands are attributed to bremsstrahlung and cyclotron processes respectively. We find that the cyclotron process significantly reduces the oscillation amplitude. The expected QPO amplitudes are finally limited by non-linear evolution of the accretion shock.

The thesis is organized as follows: Chapter 1 provides a brief review of strongly magnetized degenerate stars and their astrophysical significance. In Chapter 2, we discuss the methods and tools used to obtain the results which are presented in this thesis. In Chapter 3, we use the 'self-consistent field technique' to find the axisymmetric strongly magnetized configurations. The mass-radius relation of the strongly magnetized white dwarfs is discussed here. In Chapter 4, we provide further improvements to the mass-radius relation due to the consideration of (i) Landau quantization, and (ii) electrostatic effects in the degenerate equation of state, as well as (iii) general relativistic formalism of gravity. The study of the dynamical stability of strongly magnetized configurations is discussed in Chapter 5. In Chapter 6, we study the dynamics of the accretion flow near a magnetic white dwarf and its observable properties. In Chapter 7, we summarise the main results of the work done in the thesis, and discuss future directions.

SABYASACHI CHATOPADHYAY

Some Aspects of Design and Development of a Fibre-Fed 2 D Spectrograph for the 3.6 m Devasthal Optical Telescope.

The technique of astronomical spectroscopy has a long history. Started in the early 1900, the classical method of long-slit spectroscopy has been instrumental in several discoveries. Despite this success, long-slit spectroscopy suffers from various limitations including optimal slit width, instrument flexibility, atmospheric dispersion and inefficiency of doing extended object and multi-object spectroscopy. The use of an optical fiber as a light carrier element has given a new dimension to this field with the introduction of the method called Integral Field Spectroscopy (IFS). Out of the many forms of IFS, the fiber-microlens approach is of interest due to several factors. The technique is suitable for scanning large areas of sky, extended target observations, modular instrument design, etc. Scientifically, IFS is useful to understand the different but coupled physio-chemical processes that are associated with an extended object or cluster of objects. The key component of an IFS is the integral field units (IFU). An IFS can have one or more IFUs which can be fixed or deployable.

Devasthal Optical Telescope Integral Field Spectrograph (DOTIFS) is a new multi-object integral field spectrograph being built by the Inter-University Centre for Astronomy and Astrophysics (IUCAA),for the 3.6 m Devasthal Optical Telescope, (DOT). The Devasthal Observatory has been constructed by the Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital. DOTIFS is mainly designed to study the physics and kinematics of ionized gas, star formation and H II regions in the nearby galaxies. A magnifier at the Cassegrain side port of the telescope feeds sixteen integral field units (IFUs). Each IFU is comprised of a microlens array and optical fibers offering 144 spaxels at a sampling of 0.8 per 300 μm hexagonal microlens and a total field of view of 8.7×7.4. The fibres feed eight identical spectrographs that will produce 2,304 spectra at R 1800, over a wavelength range of 370-740 nm in a single exposure. The sampling scale can be changed by changing the magnifier and/or by dithered observations and proper data processing. The IFUs can be deployed over an 8 diameter focal plane by x-y actuators.

DOTIFS requires the development of fiber-microlens based IFUs with a fiber positioning accuracy of $\pm$7.5 μm. The accuracy requirement can be achieved through the development and application of a new IFU fabrication technique. The deployment method of the IFUs needs to overcome the limitations of currently available schemes.

A new technique based on photolithography is used to fabricate the IFUs. The IFU is based on the use of both microlens array and fibers to achieve a fill factor in excess of 96% and a continuous coverage of the target objects. Photolithography is used to transfer a desired pattern from a specially printed design to metal plates, foils and films by a physio-chemical process. It is used to create a mask to hold the fibers at the focal-plane-end of an integral field unit. We have aligned these extremely thin masks (100 μm) and glued them. The glued masks were polished with aluminium oxide slurry to achieve high surface finish of 0.3 μm at the fiber tips. Each fiber can be positioned with a maximum error of 4.9 μm radially from the desired position within a fiber array, compared to a requirement of 7.5 μm. The resulting positioning accuracy of fiber placement behind the microlens array ensures that there is no loss of light due to misalignment. The slit-end is made by standard wire cutting technology by which fiber positions are controlled to an accuracy of 0.6 pixels compared to a 6.75 pixel centre-to-centre gap between two spectra on the detector.

A new field re-configuration technique, Multiple Rooks of Chess, for multiple deployable IFSs has been developed. The method involves a unique mechanical design (termed as Geometry) as well as an optimized algorithm. The technique is built upon the instrument requirements of the DOTIFS. The

instrument deploys 16 IFUs of 12×12 fiber-microlens pairs over a field of 8' diameter. The proposed technique can cater to the need of DOTIFS, and can be modified for an instrument with different number of IFUs without a significant change in the flow. The algorithm initially assigns the IFUs to the targets. Based on the initial and final positions of the IFUs, the algorithm devises a movement sequence. The proposed geometry and algorithm combination is found to be superior in all of the aspects.

A mechanical system has been designed for IFU deployment which has a novel geometry, and is being used for the first time in a deployable fiber instrument anywhere in the world. In this geometry, two orthogonal actuators are responsible for the movement of a single IFU. Thirty two actuators are distributed in two sides of the focal plane in two layers. The actuators are characterized to posses a repeatability of ~ 1 μm and with suitable look up table it can provide $\pm$ 8 μm accuracy.

IUCAA Digital Sampling Array Controller (IDSAC) is a flexible and generic yet powerful CCD controller, which can handle a wide range of scientific detectors. Based on an easily scalable modular backplane architecture ,consisting of Single Board Controllers (SBC), IDSAC can control large detector arrays and mosaics. Each of the SBCs offers the full functionality required to control a CCD independently. and can handle data up to four video channels with or without dummy outputs at speeds up to 500 kilo pixels per second (KPPS) per channel with a resolution of 16 bits. Communication with Linux based host computer is through a USB3.0 interface, with the option of using copper or optical fibers. A Field Programmable Gate Array (FPGA) is used as the master controller in each SBC. Elimination of thermal kTC noise is achieved via Digital Correlated Double Sampling (DCDS). We present the results of noise performance characterization of IDSAC through simulation, theoretical modeling, and actual measurements. The contribution of different types of noise sources is modelled using a Python tool to predict noise of a generic DCDS signal chain analytically. Using a cryogenic test set up in the lab, we obtain 2.6 electrons (11.7 μV) RMS noise using 8 samples at 200 KPPS CCD throughput for the optimized analog signal chain which is lower than the CCD noise of 3.7 electrons (16.65 μV). This noise is much smaller than the sky background noise, which is typically 25 electrons. Hence, for the purpose of spectroscopy, the detector readout controller will not introduce significant noise.

BHOOSHAN U. GADRE

Efficient Methods for Detection of Gravitational Waves from Compact Binary Coalescences

During September 2015 to August 2017, the twin advanced-LIGO (aLIGO) detectors have observed gravitational waves (GWs) from six compact binary coalescences (CBCs) in their first (O1) and second (O2) observing runs; five of which turn out to be binary black holes (BBHs) and one among them is the collision of binary neutron stars (BNS). The collision of the BNS was also simultaneously observed by many telescope spanning the entire electromagnetic (EM) spectrum. The first direct detection of GWs on 14 September 2015 emitted by a merging BBH marked the beginning of the era of GW astronomy and astrophysics. Simultaneous observations of BNS merger and its afterglow via GWs and EM waves signify the dawn of multi-messenger astronomy (MMA). These new frontiers in physics have opened up a completely new dimension to experience the universe and to understand it better. There are a few other sources which can emit GWs detectable by ground-based interferometric detectors like LIGOs, but CBCs are the only detected sources so far and are the most abundant sources, which have allowed us to peep into GW universe.

Searching for the CBC signals in noisy data is computationally very demanding. Also, the current detectors are improving and more GW detectors like VIRGO, KAGRA and LIGO-India are expected to join the network of detectors soon. This means that we will observe GW events at a much higher rate and most of them will likely to be CBCs. Also, faster detection of GWs would mean better

chances to observe the sources via EM telescopes. Hence, we tried in the course of the current studies to make transient GW detection quicker and optimal. The challenge in the near future will not only be to find as many sources as possible in the data but to understand the dynamics of the sources much more precisely. Speeding up the current searches can help not only with faster GW detections but also to free up the computational resources for the detailed studies of the detected sources, which are even more computationally intensive. Primarily due to computational limitations, the standard searches are currently restricted to a smaller parameter space, which assumes aligned spins for the CBC components.

Cross-correlation (CC) search is the simplest and cheapest method to search for the signal common in the data from two detectors. This method has already been shown to work for long and intermediate duration for GW signals. We have demonstrated the possible use the CC search method in the detection of loud and short duration transient signals, for which we may not be able to model the phase evolution. Also, CC method can be used to speed-up the search for short duration GW signals. This is achieved by discarding the part of the data that is very unlikely to contain any detectable GW burst signal. We have found that we can make the other detection pipelines used in the detection of GW burst sources faster by reducing the data volume to be searched by retaining most of thee detectable short duration GW signals in the data. It works for loud enough signals. *The triggers can then be followed up by the usual matched filtering or equivalent analysis.*

To speed-up the usual template based search for CBCs, we have developed a two-stage hierarchical strategy. We demonstrate the computational advantage in the real-life scenario by introducing it in the standard `PyCBC` pipeline with the usual aligned-spin parameter space. *With this strategy, in simulated data containing Gaussian stationary noise, we obtain a computational gain of more than an order of magnitude over the flat search while detecting almost all the injected CBC signals.* In real data, we expect the computational gain up to a factor of a few. We expect this reduction in the performance of the search due to non-Gaussian, transient noise artefacts present in the data. This saving in the computational effort will, in turn, may allow us to search for the precessing binaries. Freeing up computation time for the regular analyses will provide more options to search for sources of different kinds and to fulfil the never-ending urge for extracting more science out of the data with limited resources.

The presence of transient noise artefacts in the LIGO data, gives rise to many false alarms (FA) in the matched filter search. This hampers the search sensitivity badly. Hence, to discriminate these glitchy artefacts from the actual CBC signals, various signal consistency methods are employed. Using a generic formalism for development of the χ^2 based signal consistency vetoes for the signals, we propose a family of ambiguity χ^2 discriminators, which can be used,in conjunction with the other χ^2 based vetoes which are already in use. This can help to improve the search sensitivity further without adding much of the computational cost.

Developing efficient analysis strategies to find CBCs in data from a network of GW detectors is the primary focus of this thesis.

LABANI MALLIK

Energy-Dependent Variability of Active Galactic Nuclei.

Active galactic nuclei (AGNs) are the most luminous continuously emitting objects in the Universe with bolometric luminosity ranging from 10^{41} to 10^{47} erg s^{-1} and powered by accretion of matter onto the central supermassive black holes (SMBHs) of mass $M_{\rm BH}$ $\sim 10^5 - 10^{10} M_{\odot}$. Understanding the physics of accretion flow and its role in shaping the Universe, is one of the major challenges of modern astrophysics

research. AGNs emit radiation across the entire electromagnetic spectrum and they are highly variable in the X-ray band. The observed fast X-ray variability indicates that the X-ray emitting region is very compact and located in the vicinity of the black hole. Hence, the X-ray waveband provides an excellent window to probe the physics of accretion onto the black holes. The observed spectral energy distributions (SEDs) and spectral variability are two primary tools used for comprehending the physical processes taking place surrounding the SMBH. In this thesis, I will present several studies with the aim of better understanding the energy-dependent variability mechanism and hence the accretion processes onto the SMBHs. I will focus on SMBHs at the centres of active galaxies, especially those of the Seyfert 1 class.

The optical/UV-to-hard X-ray SEDs of Seyfert 1 galaxies usually exhibit the following main components: a big blue bump (BBB) peaking in the optical/UV band, a soft excess component below ∼1−2 keV, a primary power-law continuum with a high-energy cut-off, Fe K line complex at ∼6−7 keV, Compton reflection hump at ∼20−40 keV and absorption. However, the central engines of AGNs consisting of the accretion disc, corona and the immediate environment are complex, and the spectral fitting often results in model degeneracy problems, e.g., there are competing models for the soft excess in terms of relativistic reflection and low-temperature Comptonization. To get rid of the spectral model degeneracy, we will study the variability of spectral components or spectral variability which adds an auxiliary dimension to the spectral modeling.

We use optical/UV and X-ray data from the high-class space-based observatories (XMM-Newton, NuSTAR, Suzaku and Swift) and perform a detailed physical spectral modeling to identify various spectral components as well as timing and spectral variability analyses to probe the underlying variability processes and the causal connection between emission mechanisms. We devise a method to model the fractional root-mean-squared (RMS) spectrum and measure the variability power in different spectral components. We apply this method to investigate the origin and nature of energy-dependent variability of four Seyfert 1 galaxies including a radio-loud narrow-line Seyfert 1 galaxy (RX J1633.3+4719), a radio-quiet broad-line Seyfert 1 galaxy (Ark 120) and two radio-quiet narrow-line Seyfert 1 galaxies (PG 1404+226, Mrk 1044).

The thesis begins with an introductory chapter (Chap. 1) which provides the current status of AGN research and the objectives of our work. This is followed by a more technical chapter (Chap. 2), presenting the analysis methods employed in the subsequent chapters. The thesis has four main science chapters (Chap. 3, 4, 5 and 6) with each chapter probing a unique variability process depending on the nature of the source. I end with the summary (Chap. 7) of each science chapter along with some concluding remarks.

We now present the work done and progress accomplished in detail: The existence of the fundamental plane of black hole activity suggests that the physical processes responsible for the disc-accretion and jet launching mechanisms are universal across mass scales. Although there exists a phenomenological disc-jet paradigm in black-hole binaries, the disc-jet connection is not well explored in AGNs. In Chap. 3, we investigate the possible presence of the accretion disc/corona and jet emission in the broadband UV-to-X-ray (3 eV−10 keV) spectrum and study the broadband X-ray (0.3−10 keV) spectral variability of the radio-loud narrow-line Seyfert 1 galaxy RX J1633.3+4719. We report the existence of an ultra-soft excess emission below ∼0.6 keV, which can be interpreted as the high-energy tail of the standard Shakura-Sunyaev disc emission peaking at ∼40 eV in the far-UV band. The excess emission in the near-UV (NUV) band cannot be explained by the disc or host galaxy contribution, and we need an additional steep power-law without intrinsic absorption for the NUV continuum. The NUV spectrum is steep ($\Gamma_{\rm UV} \sim 3$; $N_E \propto E^{-\Gamma_{\rm UV}}$) which most likely represents the high-energy tail of the Synchrotron emission from a jet.

The X-ray spectrum above ∼1 keV is dominated by the hot coronal emission and described by a power-law continuum of photon index $\Gamma_{\rm X} \sim 2$. However, we find no evidence for the disc reflection which suggests the lack of strong illumination of the disc by the hot corona. This could happen when the coronal emission is beamed away from the disc and the corona forms the base of the jet. The modeling of the X-ray fractional variability spectrum not only confirms the presence of disc/coronal emission but also reveals that the disc emission is steady and the coronal emission is variable with the flux and spectral shape being anti-correlated. We find that the observed energy-dependent X-ray variability of RX J1633.3+4719 is due to intrinsic variations in the hot corona and not driven by variations in the seed photon flux.

The origin of the canonical soft excess emission, broadband X-ray variability and its connection with the optical/UV variability in AGNs is still an open question. In Chap. 4, we study the origin of the soft excess emission, nature of broadband X-ray (0.3−10 keV) variability and UV/X-ray connection in the radio-quiet broad-line Seyfert 1 galaxy Ark 120 using a long ∼500 ks XMM-Newton observation over four consecutive orbits. We find the presence of an optically thin, hot coronal emission along with relativistic

reflection off the disc truncated at $\sim 10 r_g$ ($r_g = GM/c^2$) from the central SMBH and non-relativistic reflection off the distant material. The modeling of the soft excess component requires emission from an optically thick, warm corona with an electron temperature of $\sim$0.4 keV and an optical depth of $\sim$12. The nature of broadband X-ray variability is found complex and non-stationary. For observations in the first and third orbits, the fractional variability amplitude declines with increasing X-ray energy whereas for observations in the second and fourth orbits, the shape of the fractional RMS spectra is observed to be inverted-crescent and crescent-shaped, respectively. The modeling of all four fractional RMS spectra requires two reflection components to be non-variable and suggests the presence of a less variable warm and a more variable hot coronal emission. We find that the optical/UV variability is weaker (a factor of $\sim 2-3$) than the X-ray variability which indicates that the intrinsic optical/UV emission originates from the more distant regions like the outer disc or broad line region. The source spectrum gets softer with the increase in both the UV and soft excess luminosities which confirms the Comptonization scenarios, where the soft excess and primary power-law continuum are produced by inverse-Compton scatterings of the UV or UV/soft X-ray seed photons in the warm or hot coronae, respectively, and the observed two-temperature coronal variability is mainly caused by variations in the Comptonizing seed photon luminosity.

There exists a degeneracy between low-temperature Comptonization and relativistic reflection scenarios for the origin of the soft excess emission in many Seyfert 1 AGNs. In Chap. 5, we break that degeneracy and ascertain the origin of the puzzling soft excess emission in the radio-quiet narrow-line Seyfert 1 galaxy PG 1404+226 by employing a combination of spectral-timing methods. We observed the source with XMM-Newton for $\sim$100 ks in 2016 January. The X-ray time-series clearly shows a short-term, large-amplitude variability event in which the source count rate increased exponentially by a factor of $\sim$7 in $\sim$10 ks and declined sharply. Both the intrinsic disc Comptonization and relativistic disc reflection models can fit the time-averaged as well as the time-resolved broadband X-ray (0.3$-$8 keV) spectra equally well. However, the fitting of the fractional RMS spectrum with the disc Comptonization model cannot reproduce the observed variability pattern and prefers the relativistic reflection scenario where the spectral variability is explained as a result of changes in the flux of both primary coronal emission and the reflected emission from an ionized disc of inner radius $\sim 2 r_g$. The nature of broadband X-ray variability suggests that the origin of the soft X-ray excess in PG 1404+226 is the relativistic reflection caused by strong gravitational bending of coronal emission onto the innermost accretion disc around a rapidly rotating black hole.

The density of the disc atmosphere in the standard reflection models is fixed at $n_e = 10^{15} \mathrm{cm}^{-3}$, which sometimes results in a super-solar iron abundance and a slight excess emission in the soft X-ray band. Garćia et al.(2016) have attempted to resolve these issues and extended the reflection models by making the disc density a free parameter varying over the range $n_e = 10^{15} - 10^{19} \mathrm{cm}^{-3}$. For highly accreting black holes, the inner regions of the disc are radiation-pressure dominated, and the disc density depends on the black hole mass, accretion rate and coronal power. In Chap. 6, we test the new high-density reflection model for the origin of soft as well as hard X-ray excess emission and probe the underlying physical processes (propagation fluctuation, Comptonization and reverberation) in the low-mass, highly-accreting AGN Mrk 1044. The source was observed by XMM-Newton in 2013, and quasi-simultaneously by NuSTAR and Swift in 2016. We find that the soft X-ray excess below $\sim$1.5 keV, highly-ionized broad Fe line at $\sim$6.8 keV and the Compton hump at $\sim 15-30$ keV can be self-consistently explained by the relativistic reflection from an ionized, high-density ($\sim 10^{16} - 10^{17} \mathrm{cm}^{-3}$) disc of broken power-law emissivity profile with a break radius of $\sim 3 r_g$. We also measure the time-delay between different energy bands at various Fourier-frequencies. On longer timescales ($\sim 20-50$ ks), we detect a hard lag between the direct coronal 1.5$-$5 keV band emission and disc reflected 0.3$-$1 keV band emission, which we explain with a combination of two physical processes: propagation of fluctuations from the inner disc to the edge of the corona and multiple inverse Compton scatterings of the soft photons within the corona. The observed soft lag is a signature of X-ray reverberation from the inner disc and dominates on shorter timescales ($\sim 5-10$ ks). The fractional variability is found to be higher on shorter timescales which implies that the variability mechanisms dominating on shorter timescales have been originated in a more compact emitting region or closer to the central SMBH. The modeling of the fractional RMS spectrum implies the presence of two-component variability: a less variable reflected disc emission and a more variable direct coronal emission, and the observed broadband variability is mainly caused by variations in geometry or location of the corona.

K. NIKHIL MUKUND

Characterization and Reduction of Noise in Gravitational Wave Detectors.

Advanced gravitational wave (GW) interferometers, like LIGO and Virgo, have reached a sensitivity necess to detect the coalescence of compact objects like binary black holes and neutron stars. Six confirmed detections, which includes the historic discovery of binary blackhole merger (GW150914) and the inspiral signal from binary neutron stars (GW170817) which also had an electromagnetic counterpart, have provided tremendous insights into the nature of Einstein's theory of gravity and ushered an era of multi-messenger astronomy. Further improvement in sensitivity along with higher uptime will respectively help in probing the similar sources at higher redshifts, and at the same time increase the chance of detecting GWs from the burst, continuous and stochastic sources. The current GW detectors are sensitive to astrophysical signals in the frequency range of 25 Hz to a few KHz. Making the detectors sensitive at lower frequencies is essential, where compact binaries spend a significant portion of their orbital evolution. The sensitivity in those frequencies is generally limited by a number of noise sources, one dominant contributor being the seismic waves. Their effect span a wide range of frequencies (30 mHz to 30 Hz) and lead to loss of interferometer lock, misalignment of optics, enhanced levels of scattering noise, and local density perturbations leading to Newtonian Noise (NN), a.k.a. gravity gradient noise. NN in particular, due to its direct coupling to the test masses, cannot be shielded using any kind of vibration isolation and is predicted to be a limiting noise for ground-based detectors in the frequency range 10 - 20 Hz. This thesis explores multiple aspects of these noise sources and discusses various strategies to minimize their effect on both the day-to-day detector operation as well as on GW strain data. This involves designing and placement of optimal sensor arrays for NN cancellation, development of early earthquake warning systems based on accurate ground motion prediction and techniques for system identification using static and adaptive filters. We also look into non-astrophysical transients or glitches, which trigger false alarms in various data analysis pipelines lowering the significance of true detections. Also, we access the impact of such transients on the detector, use automated techniques to classify them, obtain their relative distribution in strain and auxiliary channels, and probe the reason of origin for some of those glitch classes. Finally, we describe the various machine learning tools that were developed to aid detector characterization and commissioning efforts at the sites.

FACILITIES AT IUCAA

COMPUTER CENTRE

The Computer Centre at IUCAA continues to offer the state-of-the-art computing hardware and technology rich mobile work space for IUCAA Members, Visiting 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 315 servers and desktops, 75 laptops, 70 printers and scanners, two large HPC systems over a PetaByte of storage, in addition to diverse equipments deployed for an extensive, high throughput wired and wireless campus-wide network. The number of registered Wi-Fi devices is over 800, and e-mail accounts served by the computing facility to members and associates amount to nearly 550. IUCAA has its own registered domain, “iucaa.in”. The WAN services are provided by the National Knowledge Network on a 1 Gbps fibre connectivity, with a fallback arrangement on a 50 Mbps line from TATA VSNL.

DATA CENTRE INFRASTRUCTURE

The HPC facility houses some of the major IT assets of IUCAA, and services for general users are provided through the 1504 core 30 TF system, “Perseus”, which also has a 750 TB storage attached to it. The cluster has been available for general use with Load Sharing Facility (LSF) as the job scheduler, and utilized by more than 35 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, Magneto-hydrodynamics, Plasma Physics, and analysis of diverse astronomical data. One major data analysis application has been to compute 35 statistical parameters from each of the 500 Million optical light curves of astronomical sources observed in the Catalina Real-time Transient Survey (CRTS), by going through the entire repository collected over the years.

The Data Centre infrastructure has been augmented to host additional HPC clusters. The existing one, Perseus and the storage attached to it are nearly six years old, and have reached the end of life. Procurement of a new HPC cluster has, therefore, been initiated. In order to host the new cluster and storage, three additional liquid cooling packages (LCP), each having a capacity of 55 KW in n + 1 redundancy, along with racks, were procured and installed.

The order has been placed for a new 100 TF Lenovo HPC cluster, which will have 60 compute nodes, two head nodes, two login nodes and two graphics nodes for visualization purposes. A DDN parallel file system storage of 1 PB capacity will be attached to the cluster

HIGH PERFORMANCE COMPUTING CLUSTER: VROOM

A dedicated HPC cluster, Vroom, has been acquired for the MeerKAT Absorption Line Survey (MALS), which is one of the ten large surveys to be carried out with the MeerKAT telescope in South Africa, and is led by IUCAA. The data processing and pipeline development for the survey will be carried out at IUCAA using the Vroom cluster. This cluster has 16 compute nodes (Dell), which delivers 25 TF computing speed, and has a parallel file system (DDN) of 1PB usable capacity attached to it.

Expansion of File Server: NetApp FAS 8020

The existing file server NetApp FAS 8020 serves the home area for all academic members of IUCAA, and visitors. Due to additional storage demands from Muktangan Vindyan Shodhika (MVS, the Science Centre), other projects, and various academic users, the file server has been further expanded to 100 TB.

Upgradation of VMware Software

The Computer Centre has four ESX host servers, and its consolidated resources like, CPU, RAM, etc. are being shared with all the Virtual Machines, being used by the Administrative Staff, visitors and students. Since the number of staff members and users have been increased, and they need latest Operating Systems like, Windows 10, CentOS-7.x with USB redirection facility, upgradation of existing VMware software, hardware and storage has been carried out with additional 50 TB.

During this year, in addition to existing wireless connectivity, wired LAN connectivity has been extended to Library, Takshashila Flatlets, and Type IV D housing for better connectivity. Dedicated newly procured indoor Wi-Fi access points H320 are also implemented for the VIP Flatlets in the IUCAA Guest House for stable internet connectivity.

HP Elite Desktop 800 G3 with Monitor (15), Dell Optiplex 5060 desktops (Small Form Factor) (35), Multi-Function Printers (8) and Laptops (Dell Latitude 3490, Mac-book pro) (11), have been acquired for the academic community, visitors and administrative officers.

The Daily Functions of the Six Computer Centre Staff

1. Architecting overall IT solution/technologies required for IUCAA, and present it to the Computer Users' Committee for consensus.
2. Framing policy documents and finalizing them in consultation with the Computer Users' Committee members.
3. Drawing up specification of the RFP (Request for Proposal) tender document for IUCAA IT required to be purchased and oversee all purchases related procedure and follow up.
4. Maintenance of IT hardware in the campus, including servers, desktops, mobile computing equipment, printers, etc.
5. Providing in-house design, development and maintenance support to the Administration automation software (iOAS), and IUCAA website.
6. Successful implementation of the Seventh Pay Commission payments, using software developed in-house.
7. Designing web portals, consisting of online application modules for jobs, workshops/ schools, etc.
8. Maintaining Zimbra e-mail servers and mirror sites hosted at IUCAA, and their day-to-day administration.
9. Configuration and management of data backups.
10. Design, management and administration of network topology and firewall rules.
11. Administration of Ruckus wireless network covering the entire office as well as residential campus. Providing end users support for Wi-Fi devices, such as laptops, mobile devices, etc.
12. Day-to-day administration of VMware infrastructure and various servers catering to Administration, such as AD, etc.
13. Maintenance of Video Conferencing equipments and end user support.
14. Management of inventory of Computer Center consumable items and Assets and Furniture and their tracking.
15. Procurement of SSL certificates and software for all the relevant web servers.
16. End user service support to Members of IUCAA, Visitors and Associates.
17. Infrastructure, management and coding support to IT intensive projects such as Big Data, AstroSat, LIGO - India, etc.
18. Procurement, installation and periodic upgradation of mathematical software, such as Matlab, IDL, Mathematica meant for general IUCAA users and cluster users.
19. Hardware maintenance and administration of clusters in coordination with OEM.
20. Assisting Estate Department with Data Centre management activities.
21. Architecting new hardware solutions to address operational needs. (POC for Nutanix Hyper-Converged Infrastructure is under evaluation.)

IUCAA LIBRARY

The IUCAA Library provides users access to a comprehensive collection of books and journals in astronomy, astrophysics and related areas. During this year the library has added 44 books and 159 eBooks, the Springer Physics and Astronomy collection 2019 comprising of 355 titles, and renewed its subscription to Grammarly for the year 2019.

The library renewed its subscription to 87 journals and has been receiving access to the following seven e-resources comprising e-Journals and Databases (Courtesy of E-Shodh Sindhu: Consortium for Higher Education Electronic Resources, Ministry of Human Resource Development, Government of India):

1. American Institute of Physics.
2. American Physical Society.
3. Institute for Studies in Industrial Development (ISID) database.
4. JGate Plus.
5. Springer Link.
6. Taylor and Francis.
7. Web of Science.

IUCAA library with a staff of four professionals facilitated the below-listed activities:

Assistance to users regarding the following:

- General information about the library and facilities.
- Searching and locating reading material.
- Accessing photocopying and scanning facility

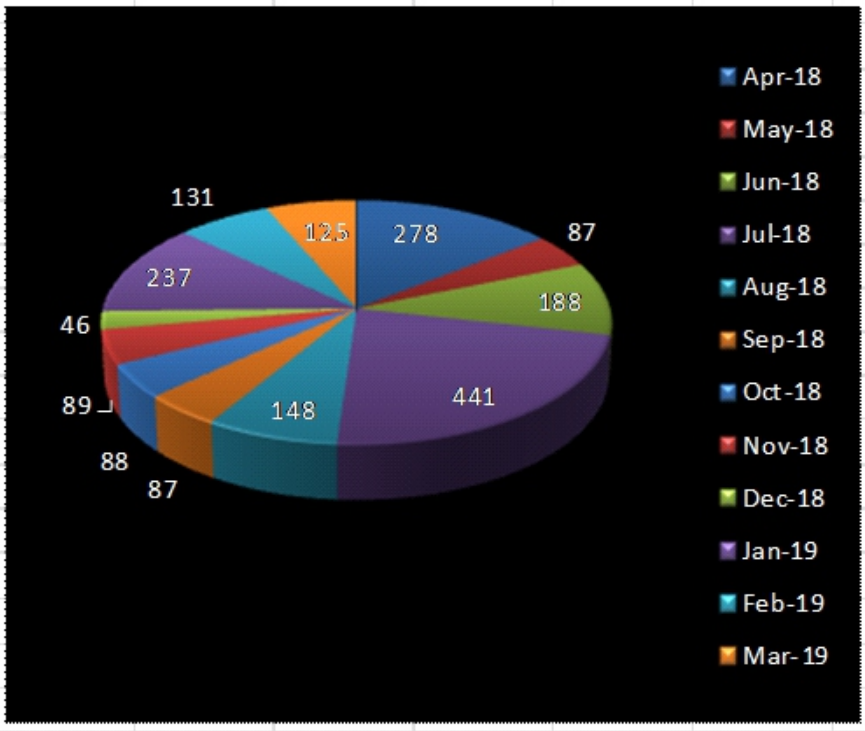
- Ezproxy access and authentication software to facilitate off-campus access to the e-resources subscribed by the library (http://www.iucaa.in/~library/) by IUCAA Members and Visiting Associates. The facility is extensively used, since it provides full-text access to all the e-resources subscribed by the library.

The following e-resources have been accessed by users, which include 25 Visiting Associates of IUCAA:

- American Association of Physics Teachers
- American Institute of Physics
- American Scientist
- Annual Reviews of Astronomy and Astrophysics
- Applied Optics
- American Physical Society
- Cambridge University Press
- EDP Sciences
- Institute of Physics
- Nature
- New Scientist
- Physics Today
- Physics Education
- Popular Science
- Science Direct
- Springer
- Taylor and Francis
- Web of Knowledge
- World Scientific

Ezproxy usage during April 01, 2018 - March 31, 2019

Month	Count
Apr-18	278
May-18	87
Jun-18	188
Jul-18	441
Aug-18	148
Sep-18	87
Oct-18	88
Nov-18	89
Dec-18	46
Jan-19	237
Feb-19	131
Mar-19	125
	1945



- Fulfilled 163 requests for articles and book chapters, received from 109 academics comprising IUCAA users, Associates and Visitors. References not available in the IUCAA library were requested from other libraries in India and abroad. The library also obtained 03 books using the inter-library loan facility, and responded to inter-library loan requests from 07 libraries, under which 10 books were loaned using the inter-library loan facility. As a policy, article/book chapter requests are handled on priority and the library endeavours to provide the requested reference on the same day.
- Online access to IUCAA publications, photo and video archive, library YouTube channel.
- Processing of page charge requests.
- Processing applications received to obtain an IUCAA Preprint number
- Assistance to users in ordering books from their contingency grant.
- Plagiarism report for research papers.
- Involved in the compilation of the Annual Report. The content about contributions received from Visiting Associates and IUCAA Resource Centres was compiled by the library staff

RADIO PHYSICS LAB

Radio Physics Lab (RPL) is a unique facility at IUCAA, where students from physics and engineering background can explore their skills and learn Astronomy and Astrophysics. Our aim has been to design and demonstrate important experiments related to Radio Astronomy in an innovative way for scientific purpose and for educating students, enthusiasts and the general public. The areas being pursued here range from cosmic ray detection to communication using LASERs. Apart from this, RPL is also active in public outreach. Public lectures and demonstrations are organized for students and enthusiasts. Radio Astronomy Winter School (RAWS) is conducted for under-graduate students, introducing them to the field of Radio Astronomy. Over the past 10 years, several students have been benefited from this platform. More than 90 percent of these students are pursuing PhD in Astronomy and related areas, and many are currently active in the research field in some form or the other.

FARADAY ROTATION EXPERIMENT FOR COMMUNICATION

The polarization of light is quite frequently observed in nature, and with other properties like amplitude, frequency and phase of an electromagnetic (EM) wave, it constitutes one of the most fundamental quantities, which completely describes it. In Physics and Optics, the polarization of light is studied through ”Faraday Rotation Effect” using optical materials like glass, crystals, chemicals etc. Its analogue in radio waves is transmission of polarized wave in ferrites materials. The idea is to study the potential of fast polarization modulation for data communication, which is not much explored yet.

The study of the polarization of light through Faraday Rotation Effect, rotation of the plane of a polarized wave when travelling through crystals placed inside solenoid; subjected to a strong axial magnetic field can be a novel approach in communication. The experiment shows the conversion of polarization-modulated light into intensity-modulated light, and phase shifted demodulated waveform w.r.t. input modulating the signal. Insertion of properly matched and tuned circuit before coil and amplifier after demodulation leads to better reception of the signal.

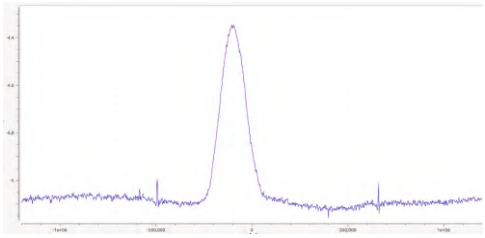
The laser will act as a carrier and the audio is given as a modulating signal to the solenoid, the audio signal modulated in the presence of Faraday material (TGG) and demodulated by converting polarization modulation into intensity modulation at the photo detector. The power requirement is very low as compared to the existing analog modulation techniques. The system is successfully working over the audio bandwidth.

HORN ANTENNA FOR 21 CM HYDROGEN LINE

The 21 cm hydrogen line is a spectral line emitted by atomic hydrogen. Since hydrogen is the most abundant element in the universe, this makes the hydrogen line a very crucial line in the field of radio astronomy. A horn antenna was designed for detecting this 21 cm line from our galaxy. A primary limitation of radio astronomy is noise, either man-made or naturally occurring. Hence we require new techniques to reduce noise from our detector. The horn antenna is a high performance, high gain and low noise antenna, specially designed for detection of the 21 cm hydrogen line. The antenna is able to pick up radiation from the hydrogen clouds in our galaxy while suppressing terrestrial interferences due to the low side lobes of the antenna. The antenna is easy to handle and is superior to a parabolic dish in terms of noise performance.

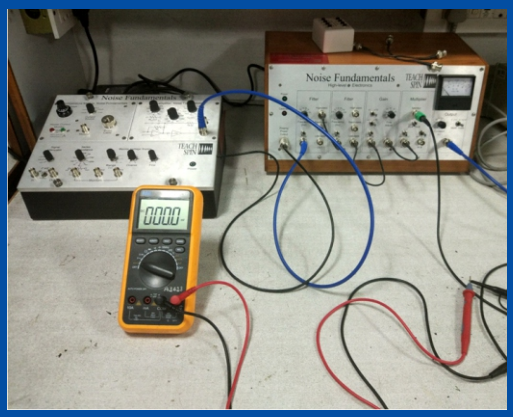
The horn has enabled us to study hydrogen line profiles from the galaxy. The spiral structure of the galaxy can be estimated. It has also made it possible to estimate the rotation curve of the galaxy.

The antenna is a dual mode conical horn, and is easy to construct as compared to other antennas with similar noise performance. Software Defined Radio (SDR) receivers were used with great success with this antenna. SDR is a new advancement in radio technology. The limitation of the conventional radio is its inability to configure the hardware. SDR can be configured to serve any purpose of the user. Such a receiver was implemented successfully for detection of hydrogen line. Important techniques like Dicke switching were implemented with SDR. This has made the telescope low cost and hence, accessible to amateur radio enthusiasts. The antenna has proven to be very reliable. It has been used in MSc practical in radio astronomy, as well as in Radio Astronomy Winter Schools. The antenna has also been used to demonstrate principles of radio astronomy to amateurs as well as for public outreach.



NOISE FUNDAMENTAL EXPERIMENT

The Noise Fundamental Experiment is one of the most important tools to study the noise in any electronic system and instrument. The noise present in all electronic signals limits the sensitivity of many measurements. The thermal noise generated by a resistor at room temperature or the shot noise in diode and transistor can be studied by using this setup. The noise can be observed on the display of an oscilloscope and also manipulate it by changing the parameter of noise like temperature, bandwidth and other parameters.



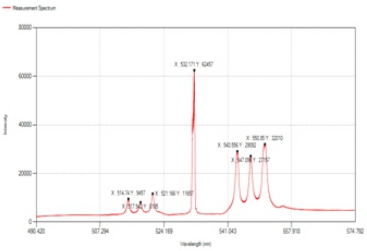
THE COSMIC RAY MUON DETECTOR (CRMD)

The Cosmic Ray Muon Detector (CRMD) is a particle detector, which can detect and observe products of cosmic ray particles, which were created and accelerated by very violent mechanisms in the Universe. The CRMD at IUCAA Radio Physics Lab is one of its kind, and was built in 2011 by Bachelor degree level students. It is the only detector of its type running in entire Asia. The material to build the detector was imported from Fermi Lab (USA).

This detector is used to take readings of constant muon flux and determine mean muon lifetime. It is quite a rich experiment as it enables students to not only study astroparticle physics, but also quite a lot about nuclear and particle physics in general. Mean muon lifetime also serves as a test for Einstein's special theory of relativity. Since 2012, the detector has been used for experiments in Savitribai Phule Pune University, MSc Astronomy and Astrophysics specialization course as well in Radio Astronomy Winter School.

RAMAN SPECTROSCOPY

The Raman Spectroscopy is one of the important tools in physics and chemistry to identify the elements. Raman Spectroscopy is an inelastic scattering of mono-chrome light, at which frequency of light changes upon interaction with a sample. Frequency of the re-emitted photons is shifted up or down in comparison with original mono-chromatic frequency, which is called the Raman Effect. This shift provides information about vibrational, rotational, and other low frequency transitions in molecules. Raman Spectroscopy can be used to study solid, liquid and gaseous samples.



In this experiment, we see the stokes and anti-stokes line on both side, and the Raman scattering. A powerful green (532 nm) laser, and astronomical grade cool CCD camera are used to detect the Raman scattering.

NATIONAL SCIENCE DAY

Celebration of the National Science Day, on February 28, 2019, is an important event in IUCAA. It is the time of the year when IUCAA is open to the general public all day long, and the staff exhibits and explains the experiments and activities which are conducted in IUCAA, to the general public. The Radio Physics Lab has been demonstrating and explaining various astronomy related experiments. This year in addition to the horn, 3 m parabolic radio telescope, ASRT, Raman Spectroscopy and Muon Detector, the recently discovered Saraswati Supercluster LED model, which was made by RPL project students were presented. This supercluster was discovered in this lab by a team of scientist and students lead by Joydeep Bagchi. A brief explanation on the history of Radio Astronomy, detailed working of a radio telescope represented in block diagram for an easy understanding for the general public and different types of radio telescopes working on different types of bands around the world were also displayed. On science day, thousands of people visited IUCAA. The volunteers representing RPL were from Vishwakarma Institute of Technology, Cummins College of Engineering, and D.Y. Patil College of Engineering, Pune.

On the occasion of the National Science Day, Shishir Sankhyayan and Jameer Manur (both from RPL) gave two public talks on: How we study the Large Scale Structures in the Universe? and Observe our Universe in multi wavelength, respectively.

WORKSHOP ON RADIO OBSERVATIONS USING HORN ANTENNA

Teaching and Learning Centre (TLC), in collaboration with the RPL, organized a workshop on Radio Observations using Horn Antenna, during March 9 - 11, 2019, at IUCAA. The aim of this workshop was to initiate and promote radio astronomy observations to college and university teachers, who came from different parts of the country. There were 6 participants.

On the first day, talks on basic theory, various other aspects of radio astronomy and horn antenna theory were covered. On the second day, the participants fabricated the horn antenna under expert guidance. Post-fabrication, training of observations (such as observing 21 cm hydrogen line from the Milky way) with the instrument was carried out on the third day of the workshop. This was followed by the training on the software used for data analysis of the spectrum obtained from the horn antenna.

The participants were extremely enthusiastic during the activities and talks in the workshop. They understood the details in the theory of antenna and radio astronomy, the electronic equipment used in the experiment. After fabrication of the horn antenna, the participants saw the hydrogen line through their antennas and analyzed the spectrum. The coordinators were **D.J. Saikia** and **Joydeep Bagchi**.

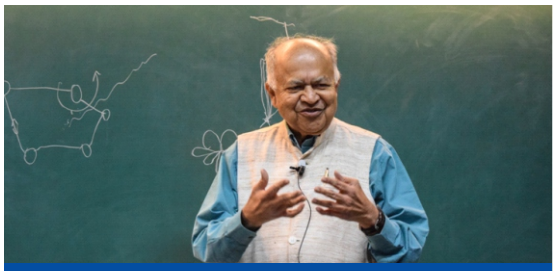
PUBLIC OUTREACH

RPL gives special attention to public outreach and is open to enthusiastic individuals for any help/advice they require regarding astronomy related activities. RPL members deliver informative lectures related to astronomy and instrumentation in astronomy in schools and colleges to make students aware of the career opportunities in the field of astronomy, and on latest developments in this field.

The RPL members also have initiated the process of making videos for general public, which will describe key radio astronomy concepts in lucid manner and documenting the working of big international facilities run by India like the GMRT (which is one the world's largest radio telescopes). All these material will be freely available on our RPL website and Youtube channel. RPL has also launched pages on the social media like Facebook, Twitter and Youtube for propagation of radio astronomy in India.

RADIO ASTRONOMY WINTER SCHOOL

Radio Astronomy Winter School (RAWS) has been organized every year, jointly by IUCAA and NCRA. The school is largely meant for under-graduate students in science, pursuing BSc (Physics/ Electronics/ Astronomy), and Engineering (BE/ BTech). Bright and highly motivated high school/ junior college students involved in amateur Astronomy, have been also encouraged to apply. Through lectures and hands-on radio astronomy experiments, the winter school exposes the participants to astronomy in general, and radio astronomy in particular. The school has been immensely popular, and so far ten such schools have been organized since 2008. The experiments are conducted by RPL. The hands-on experiments included: (I) Observations of Sun with the 4 m telescope to determine the antenna power pattern, (ii) Observations of HI 21 cm line to neutral hydrogen from the Galaxy, and (iii) Measuring power patterns of various types of antennas using the antenna trainer kit. These experiments are designed to educate the students about techniques and instrumentation used in radio astronomy.



On the occasion of 11th winter school, Jayant Narlikar, Founder Director, IUCAA, was invited to give his insights, and he interacted with the participantss.

Msc PRACTICALS

Msc students have to perform experiments as a part of the curriculum, and to appear for practical exam to complete their course. Every year 3 to 4 experiments are performed by the students in RPL, and these have been a great success and will continue. Some of the experiments are antenna radiation pattern measurement, detection of 21 cm hydrogen line, Faraday rotation and noise fundamentals.

PROJECT AND VISITING STUDENTS

Two students from Vishwakarma Institue of Technology are doing a project under the guidance of Prof J.Bagchi and Mr Jameer Manur.The project is about developing a cost effective control system for an optical telescope, which will be later implemented on a new 3m radio telescope. Four students from the same college did their summer internship in the lab on different small projects.

Two M. Sc. students from Kerala and one student from Pune under the guidance of Prof Joydeep Bagchi and Mr Pratik Dabhadeare working in the field of radio galaxies,where they are cataloging the radio galaxies found in the SDSS. Two students Indian Institute of Space science and Technology (IIST) visited RPL and learn about the working of a horn antenna and how to take observation of H1 line and analayse the data. Two students from Nanded University and four students from Jaipur also visited Lab and learn the radio astronomy techniques and observations using small radio telescope.

SPECIAL GUEST

Well know actor and singer Ayushmann Khuranna had shown interest and promised to meet Prof. Joydeep Bagchi and team earlier after the discovery of the Saraswati galaxy supercluster. He visited IUCAA and Radio Physics Lab and interacted with Prof. Joydeep Bagchi, Prof. Somak Raychaudhaury and other team member. He is an astronomy enthusiast and he wanted know more about the discovery and other things going on in this field.

AWARDS

Best poster award 2018: General Relativity and Cosmology: Shishir Sankhyayan for the poster: Large Scale Structures in SDSS.

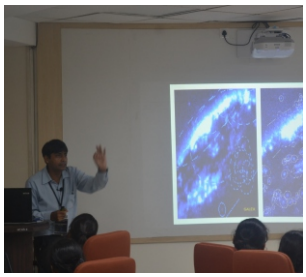
SPONSORED MEETINGS AND EVENTS OUTSIDE IUCAA

INTRODUCTORY WORKSHOP ON ASTRONOMY AND ASTROPHYSICS

An Introductory Workshop on Astronomy and Astrophysics was held at the Kohima Science College, Jotsoma (KSCJ), Nagaland, during April 5 - 6, 2018. The workshop was sponsored by IUCAA and coordinated by Ranjan Gupta. (For details, see KHAGOL No. 115, July 2018)

WORKSHOP ON OBSERVING UNIVERSE WITH ASTROSAT

Workshop on Observing Universe with AstroSat was conducted at Manipal Centre for Natural Sciences (MCNS), Manipal Academy of Higher Education (MAHE), during September 3 - 5, 2018. This workshop was jointly funded by MCNS, MAHE and IUCAA. Debbijoy Bhattacharya and Ranjeev Misra were the coordinators. (For details, see KHAGOL No. 116, October 2018)



SITARE: INTRODUCTORY WORKSHOPS ON ASTROPHYSICS

With an objective to motivate enthusiastic students to pursue a research career in Astronomy and Astrophysics (A & A), IUCAA in collaboration with the Southampton University (SoU) conducted the SITARE (Southampton IUCAA Training for Astronomical Research and Education): Introductory Workshop on Astrophysics, sponsored by the Science and Technology Facilities Council (STFC), UK. (For details, see KHAGOL No. 116, October 2018)

The workshop at **Pt. Ravishankar Shukla University (PRSU), Raipur**, was conducted on August 17 - 19, 2018 and was coordinated by Ajit Kembhavi, Ranjeev Misra (IUCAA), and S. K. Pandey (PRSU).

The workshop at Department of Physics, **Newman College, Thodupuzha,** was conducted on September 17 - 19, 2018 and was coordinated by Ajit Kembhavi, Ranjeev Misra (IUCAA), Joe Jacob (Newman College) were the co-ordinators.

INTRODUCTORY WORKSHOP ON ASTRONOMY AND ASTROPHYSICS FOR WOMEN

The Department of Physics, Alphonsa College, Pala, Kerala, oraganised the Introductory Workshop on Astronomy and Astrophysics for Women, during September 13 - 15, 2018. The programme was organised to foster the interest in Astronomy and Astrophysics among the girls in the region and bring up more women astronomers. (For details, see KHAGOL No. 116, October 2018).

NORTH-EAST MEET OF ASTRONOMERS (NEMA-4)

The North-East Meet of Astronomers (NEMA - 4) was held at the Bipin Chandra Pal Seminar Hall of the Assam University, Silchar, during November 26 - 28, 2018. The coordinators of the meeting were Ranjeev Misra (IUCAA) and Himadri Sekhar Das (Assam University). (For details, see KHAGOL No. 117, January 2019).

THE WORKSHOP ON RECENT ADVANCES IN ASTROPHYSICS AND COSMOLOGY

The Workshop was held at the Department of Physics, Cooch Behar Panchanan Barma University (CPBU), during October 9 - 10, 2018, jointly organized by the IUCAA Resource Centre, University of North Bengal (NBU) and the Department of Physics, CPBU, and was sponsored by IUCAA. B. C. Paul (NBU), Prabir Kumar Haldar (CPBU), and Kanak Saha (IUCAA) were the coordinators. (For details, see KHAGOL No. 117, January 2019).

THE INTRODUCTORY WORKSHOP ON ASTRONOMY AND ASTROPHYSICS

In association with IQAC Digboi College and the Department of Physics, Tezpur University, sponsored by IUCAA, the Introductory Workshop on Astronomy and Astrophysics was organized by the Department of Physics, Digboi College, during November 30 - December 1, 2018. (For details, see KHAGOL No. 117, January 2019).

WORKSHOP ON CELESTIAL MECHANICS AND DYNAMICAL ASTRONOMY

To motivate enthusiastic students to pursue a research career in Celestial Mechanics, Astronomy and Astrophysics, the Department of Mathematics, Central University of Rajasthan (CURAJ), Ajmer, in collaboration with IUCAA, conducted a five day Workshop on Celestial Mechanics and Dynamical Astronomy (CMDA - 2019), during January 7 - 11, 2019. Ram Kishor and Kanak Saha were the coordinators of the workshop. (For details, see KHAGOL No. 118, April 2019).

WORKSHOP ON MULTI-WAVELENGTH SKY OBSERVATIONS: ASTROSAT AND BEYOND

The Discipline of Astronomy, Astrophysics and Space Engineering, IIT - Indore, organised a Workshop on Multi-Wavelength Sky Observations: AstroSat and Beyond, during February 3 - 7, 2019, in association with TIFR, Mumbai and AstroSat Science Support Cell at IUCAA. Manoneeta Chakraborty (IIT - Indore), and Ranjeev Misra (IUCAA) were the coordinators of the workshop. (For details, see KHAGOL No. 118, April 2019).

CONFERENCE ON FORMATION AND EVOLUTION OF STAR CLUSTERS

A Conference on Formation and Evolution of Star Clusters was organised at Maulana Azad National Urdu University (MANUU), Hyderabad, during January 21 - 24, 2019. The coordinators of the conference were Priya Hasan (MANUU), Shantanu Rastogi (DDU Gorakhpur University), and Ranjeev Misra (IUCAA). (For details, see KHAGOL No. 118, April 2019).

NATIONAL WORKSHOP ON INTRODUCTION TO SOLAR ASTROPHYSICS (ASTRONOMICAL DATA ANALYSIS SERIES)

The National Workshop on Introduction to Solar Astrophysics was conducted at the Department of Physics, St. Xavier's College for Women, Aluva, during March 2 – 3, 2019. Durgesh Tripathi (IUCAA), Sujatha N. V. (St. Xavier's College), and Joe Jacob (Newman College, Thodupuzha) were the coordinators of the workshop. (For details, see KHAGOL No. 118, April 2019).

WORKSHOP ON ASTRONOMY AND ASTROPHYSICS

A Workshop on Astronomy and Astrophysics was held at Sikkim University, Gangtok, during March 29 - 31, 2019. The workshop was coordinated by Subir Mukhopdhyay (Sikkim University), and Dhruba J. Saikia (IUCAA). (For details, see KHAGOL No. 118, April 2019).

MINI-SCHOOL ON X-RAY ASTRONOMY DATA ANALYSIS

The Department of Physics, Providence Women's College, Kozhikode, in collaboration with Academy of Physics Teachers (APT), Kerala and IUCAA, organized a Mini-School on X- ray Astronomy Data Analysis for the benefit of college teachers, during May 22 - 26, 2018. The coordinators of the school were Jeena Karunakaran (Providence Women's College), and Ranjeev Misra (IUCAA). (For details, see KHAGOL No. 118, April 2019)

WINTER SCHOOL IN ASTRONOMY, ASTROPHYSICS AND COSMOLOGY

National level Winter School in Astronomy, Astrophysics and Cosmology was organised during January 7 - 13, 2019, by the Department of Physics, Gauhati University (GU), Guwahati, and was sponsored by IUCAA. Sanjeev Kalita, Biman J Medhi (GU), and Ranjeev Misra (IUCAA) were the coordinators.
(For details, see KHAGOL No. 118, April 2019).

NATIONAL STUDENT SEMINAR ON FRONTIERS IN PHYSICS

The 12th series of FiP was conducted at Fergusson College, Pune, during February 1 - 2, 2019.

An Observational Astronomy session was arranged for the participants on the evening of the first day. Raka Dabhade (Head, Department of Physics, Fergusson College), and Ranjeev Misra (IUCAA) were the coordinators.
(For details, see KHAGOL No. 118, April 2019).

REGIONAL MEETING ON RESEARCH IN ASTRONOMY: OPPORTUNITIES AND CHALLENGES

The 5th edition of the Regional Meeting on Research in Astronomy: Opportunities and Challenges was held during February 8 - 9, 2019 at the Department of Physics, Cochin University of Science and Technology (CUSAT), Kochi. The coordinators of the meeting were Charles Jose, Titus Mathew (both from CUSAT), and Ranjeev Misra (IUCAA).

RESEARCH BY VISITING ASSOCIATES

Dharam Vir Ahluwalia

Magnetic-field creation by solar-mass neutrino jets

Parity violation and its effects for neutrinos in astrophysical contexts have been considered earlier in pioneering papers of Hawking and Vilenkin. But because even the largest magnetic moments predicted by physics beyond the Standard Model are some twelve orders of magnitude smaller than the Bohr magneton, their implications for magnetic-field generation and neutrino oscillations are generally considered insignificant. Here, we show that since in astrophysical scenarios, a huge number of neutrinos may be emitted, the smallness of the magnetic moment, when coupled with parity violation, is compensated by the sheer number of neutrinos. The merger of neutron stars would leave behind a short pulse of electromagnetic synchrotron radiation even if the neutrino jet in the merger points away from the neutrino detectors. We show that the magnetic field can be as large as 10^6 Gauss and comment on the possibility of direct detection. Observation of such a pulse would lend strong support for neutrino magnetic moments and resolve the missing neutrino problem in neutron star merg-ers. This work has been done in collaboration with Cheng-Yang Lee.

Elko under spatial rotations

Under a rotation by an angle θ, both the right-and left-handed Weyl spinors pick up a phase fac-tor $exp(\pm i\theta/2)$. The upper sign holds for the posi-tive helicity spinors, while the lower sign holds for the negative helicity spinors. For $\theta = 2\pi$ radians, this produces the famous minus sign. However, the four-component spinors are built from a direct sum of the indicated two-component spinors. The effect of the rotation by 2π radians on the eigenspinors of the parity - that is, the Dirac spinors - is the same as on Weyl spinors. It is because, for these spinors the right- and left-transforming components have the same helicity. And the rotation-induced phases, being the same, factor out. But for the eigenspinors of the charge conjugation operator, i.e., Elko, the left- and right-transforming components have opposite helicities, and, therefore, they pick up opposite phases. As a consequence, the behaviour of the eigenspinors of the charge conjugation operator (Elko) is more subtle: for $\theta < \theta < 2\pi$ a self-conjugate spinor becomes a linear combination of the self - and antiself-conjugate spinors with $\theta-$ dependent superposition coefficients - and yet the rotation preserves the self-/antiself-conjugacy of these spinors! This apparently paradoxical situation is fully resolved. This new effect, to the best of our knowledge, has never been reported before. The purpose of this communication is to present this result and to correct an interpretational error of a previous version. This work has been done in collaboration with Sweta Sarmah.

G. Ambika

Degree weighted recurrence networks for the analysis of time series data

Recurrence networks (RNs) have become very popular tools for the non-linear analysis of time-series data. They are unweighted and undirected complex networks constructed with specific criteria from time series. In this work, we propose a method to construct a 'weighted recurrence network' from a time series and show that it can reveal useful information regarding the structure of a chaotic attractor, which the usual unweighted RN cannot provide. Especially, a network measure, the node strength distribution, from every chaotic attractor follows a power law (with exponential cut off at the tail) with an index characteristic to the fractal structure of the attractor. This provides a new class among complex networks to which networks from all standard chaotic attractors are found to belong. Two other prominent network measures, clustering coefficient and characteristic path length, are generalized and their utility in discriminating chaotic dynamics from noise is highlighted. As an application of the proposed measure, we present an analysis of variable star light curves whose behaviour has been reported to be strange non-chaotic in a recent study. Our numerical results indicate that the weighted recurrence network and the associated measures can become potentially important tools for the analysis of short and noisy time series from the real world. This work has been done in collaboration with Rinku Jacob, H. P. Harikrishnan, and Ranjeev Misra.

Link deletion in directed complex networks

We present a systematic and detailed study of the robustness of directed networks under random and targeted removal of links. We work with a set of network models of random and scale free type, generated with specific features of clustering and assortativity. Various strategies like random deletion of links, or deletions based on betweenness centrality and degrees of source and target nodes, are used to breakdown the networks. The robustness of the networks to the sustained loss of links is studied in terms of the sizes of the connected components and the inverse path lengths. The effects of clustering and 2-node degree correlations, on the robustness to attack, are also explored. We provide specific illustrations of our study on three real-world networks constructed from protein-protein interactions and from transport data. This work has been done in collaboration with G. Kashyap.

Bijan Kumar Bagchi

Quantum, non-commutative and MOND corrections to the entropic law of gravitation

Quantum and non-commutative corrections to the Newtonian law of inertia are considered in the general setting of Verlinde's entropic force postulate. We demonstrate that the form for the modified Newtonian dynamics (MOND) emerges in a classical setting by seeking appropriate corrections in the entropy. We estimate the correction term by using concrete coherent states in the standard and generalized versions of Heisenberg's uncertainty principle. Using Jackiw's direct and analytic method, we compute the explicit wavefunctions for these states, producing minimal length as well as minimal products. Subsequently, we derive a further selection criterium restricting the free parameters in the model in providing a canonical formulation of the quantum corrected Newtonian law by setting up the Lagrangian and Hamiltonian for the system. This work has been done in collaboration with Andreas Fring.

Tanwi Bandyopadhyay

Bouncing universe in the contexts of generalized cosmic Chaplygin Gas and variable modified Chaplygin gas

In this work, we have considered the Friedmann-Robertson-Walker (FRW) model of the universe, where bounce occurs and the universe is filled with Generalized Cosmic Chaplygin Gas (GCCG) or Variable Modified Chaplygin Gas (VMCG). We have studied the stability analysis through dynamical system for both models and found the critical points in flat, open and closed universe. In presence of scalar field, the dynamical behaviour of scale factor and Hubble parameter are described in both models. Finally, we have analyzed the energy conditions for both the models in bouncing universe.This work has been done in collaboration with Ujjal Debnath.

Thermodynamic prescription of cosmological constant in Randall Sundrum-II brane

In this work, we apply quantum corrected entropy function derived from the Generalized Uncertainty Principle (GUP) to the Holographic Equipartition Law to study the cosmological scenario in Randall-Sundrum (RS) II brane. An extra driving term has come up in the effective Friedmann equation for a homogeneous, isotropic and spatially flat universe. Further, thermodynamic prescription of the universe constraints this term eventually with order equivalent to that of the cosmological constant.

Prasad Basu

Gravitational wave emission from binary mergers: Ideal versus real picture

We give here a brief review of the works studying the signatures of accretion disks on the gravitational wave signals generated by extreme mass ratio binary systems of compact objects. An example of such a system is a stellar mass compact star (typically a neutron star or a black hole) orbiting a central super-massive black hole embedded in a massive accretion disk. We particularly focus on the effects produced by hydrodynamic drag of the disk on the orbiting companion and find that the drag effects produced by the disk matter are indeed capable of modifying the companion's motion and hence, the gravitational wave signal emitted from the system. The nature and significance of the effect depends crucially on the flow parameters of the disk, e.g., velocity, density profiles of the flow. Therefore, on one hand, one needs to incorporate these effects while theoretically modelling the gravitational wave signal emitted from such systems. On the other hand, by studying the emitted gravitational wave signals profile, one

could infer about the nature of the accretion disk, which has been, till date, done only by observing the electro-magnetic signals coming from it. This multi-messenger astronomy was for the first time conceived and worked out during our research work.

Piyali Bhar

Anisotropic compact star model: A brief study via embedding

In the present work, a new model of compact star is obtained in the framework of general relativity, which does not suffer from any kinds of singularity. We assume that the underlying fluid distribution is anisotropic in nature along with a new form for the metric potential e^{λ}, which is physically reasonable. Though the model parameters depend on four constants a, b, A and B, but we have shown that the solutions depend on two free constants since these four constants are correlated to one another. Our proposed model of anisotropic compact star obeys all the necessary physical requirements, which have been analyzed with the help of the graphical representation, where n lies in the range of $-200 \leq n \leq 200$. We have shown that the model satisfies all the energy conditions as well as the causality condition. The model is potentially stable and also satisfy Harrison-Zeldovich-Novikov's stability condition.

Naseer Iqbal Bhat

Log-normal flux distribution of bright Fermi blazars

We present the results of the γ-ray flux distribution study on the brightest blazars, which are observed by the Fermi-LAT. We selected 50 brightest blazars based on the maximum number of detection reported in the LAT third AGN catalog. We performed standard unbinned maximum likelihood analysis on the LAT data during the period between August 2008 and December 2016, in order to obtain the average monthly flux. After quality cuts, balazars for which at least 90% of the total flux was survived were selected for the further study, and this includes 19 FSRQs and 19 BL Lacs. The Anderson-Darling and χ^2 tests suggest that the integrated monthly flux follow a log-normal distribution for all sources, except for three FSRQs for which neither a normal nor a log-normal distribution was preferred. A double log-normal flux distribution tendency were observed in these sources, though it has to be confirmed with improved statistics. We also found that the standard deviation of the log-noraml flux distribution increases with the mean spectral index of the blazar, and can be fitted with a line of slope 0.24 ± 0.04. We repeat our study on three additional brightest unclassified blazars to identify their flux distribution properties. Based on the features of their log-normal flux dstribution, we infer these unclassified blazars may be closely associated with FSRQs. We also highlight that considering the log-normal behaviour of the flux distribution of blazars, averaging their long term flux in linear scale can largely under-estimate the normal flux, and this discrepancy can propagate down to the estimation of the source parameters through spectral modelling. This work has been done in collaboration with Zahir Shah, N. Mankuzhiyil, A. Sinha, Ranjeev Misra, and S. Sahayanathan.

Study on temporal and spectral behaviour of 3C 279 during 2018 January flare

We present a detailed temporal and spectral study of the blazar 3C 279 using multi-wavelength observations from *Swift*-XRT, *Swift*-UVOT, and *Fermi*-LAT during a flare in 2018 January. The temporal analysis of γ-ray light curve indicates a lag of $\sim 1d$ between the $0.1-3GeV$ and $3-500GeV$ emission. Additionally, the γ-ray light curve shows asymmetry with slow rise-fast decay in energy band $0.1-3GeV$ and fast rise-slow decay in the $3-500GeV$ band. We interpret this asymmetry as a result of shift in the Compton spectral peak. This inference is further supported by the correlation studies between the flux and the parameters of the log-parabola fit to the source spectra in the energy range $0.1-500GeV$. We found that the flux corrrelates well with the peak spectral energy and the log-parabola fit parameters show a hard index with large curvature at high flux states. Interestingly, the hardest index with large curvature was synchronous with a very high energy flare detected by H.E.S.S. Our study of the spectral behaviour of the source suggests that γ-ray emission is most likely to be associated with the Compton up scattering of IR photons from the dusty environment. Moreover, the fit parameters indicate the increase in bulk Lorentz factor of emission region to be a dominant cause for the flux enhancement. This work has been done in collaboration with Zahir Shah, V. Jitesh, S. Sahayanathan and Ranjeev

Misra.

Ritabrata Biswas

Evolution of universe as a homogeneous system: Changes of scale factors with different dark energy EoSs

We analyze the universe as a thermodynamic system, homogeneously filled up by exotic matters popularly named as dark energies. Different dark energy models are chosen. We start with the equation of continuity and derive the time and scale factor relations for different EoSs of different dark energy models. To do the time-scale factor relation analysis, nature of dependences on different dark energy modelling parameters have been studied. For this, the help of different plots are used. In general, different dark energies show different properties while occurrences of future singularities are considered. Those properties can be supported by the graphical analysis of their cosmic time-scale factor studies. This work has been done in collaboration with Promila Biswas.

Geometrothermodynamic analysis and PV criticality of higher dimensional charged Gauss-Bonnet black holes with first order entropy correction

We consider a charged Gauss-Bonnet black hole in d-dimensional spacetime and examine the effect of thermal fluctuations on the thermodynamics of the black hole. At first, we take the first order logarithmic correction term in entropy and compute the thermodynamic potentials like Helmholtz free energy F, enthalpy H and Gibbs free energy G in the spherical, Ricci flat and hyperbolic topology of the black hole horizon, respectively. We also investigate the P-V criticality and calculate the critical volume V_c, critical pressure P_c and critical temperature T_c using different equations when P-V criticality appears and show that there is no critical point without thermal fluctuations for this type of black hole. We find that the presence of logarithmic correction in it is necessary to have critical points and stable phases. Moreover, we study the stability of the black holes by employing the specific heat. Finally, we study the geometrothermodynamics and analyse the Ricci scalar of the Ruppeiner metric graphically for the same.

Subenoy Chakraborty

Is Cold/Warm in ationary scenario a consequence of particle creation process ?

The present work describes a model of inflationary scenario with particle creation mechanism, in the frame work of non-equilibrium thermodynamics. In the background of homogeneous and isotropic spatially flat FLRW model of the Universe, the cosmic substratum is chosen as dissipative fluid. Here dissipation in the form of bulk viscous pressure is assumed to be due to particle creation formalism. For constant and slow–roll phases of (cold) inflationary scenario, the particle creation rate has been derived and an analogous inflaton field has been calculated. Finally, an equivalence of the warm inflation with the present particle creation mechanism has been shown. This work has been done in collaboration with Dipanjana Das, and Sourav Dutta.

Cosmological consequences in the framework of generalized Rastall theory of gravity

The work deals with generalized Rastall theory of gravity and its cosmological consequences in the background of homogeneous and isotropic flat FLRW model with perfect fluid as the matter context. The model shows a non singular era (emergent scenario) at the early phase of expansion for a particular choice of the Rastall parameter. Also the model finds to be equivalent to the particle creation mechanism in Einstein gravity in the framework of non-equilibrium thermodynamics. Universal thermodynamics is briefly presented, and it is found that the entropy function in Rastall theory is the usual Bekenstein entropy and there is no correction to it. Finally, a complete cosmic history starting from inflation to late time acceleration is presented for suitable choices of the Rastall parameter. This work has been done in collaboration with Dipanjana Das, and Sourav Dutta.

Nand Kumar Chakradhari

Broad-line type Ic supernova SN 2014ad

Optical and ultraviolet photometric, and spectroscopic results of a broad-line type Ic supernova SN 2014ad in the galaxy PGC 37625 (Mrk 1309) are presented. Observations cover the evolution of supernova during -5 to $+87$ d with respect to the date of maximum in B-band. Study of a late phase spectrum obtained at $+340$ d is also presented.

With an absolute V band magnitude at peak of $M_V = -18.86 \pm 0.23$ mag, SN 2014ad is fainter than Gamma Ray Burst (GRB) associated supernovae, and brighter than most of the normal and broad-line type Ic supernovae without an associated GRB. The spectral evolution indicates the expansion velocity of the ejecta, as measured using the Si II line, to be as high as $\sim$ 33,500 km s^{-1} around maximum, while during the post-maximum phase, it settles down at $\sim$ 15,000 km s^{-1}. The expansion velocity of SN 2014ad is higher than all other well observed broad-line type Ic supernovae except the GRB associated SN 2010bh. The explosion parameters, determined by applying the Arnett's analytical light curve model to the observed bolometric light curve, indicate that it was an energetic explosion with a kinetic energy of $\sim (1 \pm 0.3) \times 10^{52}$ ergs, a total ejected mass of $\sim (3.3 \pm 0.8)$ $M_\odot$, and ~ 0.24 $M_\odot$ of ^{56}Ni was synthesized in the explosion. The metallicity of the host galaxy near the supernova region is estimated to be ~ 0.5 $Z_\odot$. This work was carried out in collaboration with D. K. Sahu, G. C. Anupama, S. Srivastav, Masaomi Tanaka, Keiichi Maeda, and K. Nomoto.

The Nainital Cape Survey Project

The Nainital-Cape Survey is a dedicated search programme initiated in 1999 in coordination of astronomers from SAAO South Africa, ARIES Nainital and ISRO Bangaluru Over the last 17 years, a total of 345 chemically peculiar stars were monitored for photometric variability, making it one of the longest ground-based survey to search for pulsation in chemically peculiar stars in terms of both time span and sample size. Under this survey, we discovered rapid pulsation in the Apstar HD12098, while δ Scuti-type pulsations were detected in seven Am stars. Those stars in which pulsations were not detected have also been tabulated along with their detailed astrophysical parameters for further investigation. This work was carried out in collaboration with Santosh Joshi.

Ramesh Chandra

Observations of two successive EUV waves and their mode conversion

In this work, we present the observations of two successive fast-mode extreme ultraviolet (EUV) wave events observed on 2016 July 23. Both fast-mode waves were observed by the Atmospheric Imaging Assembly instrument on board the Solar Dynamics Observatory satellite, with a travelling speed of $\approx$ 675 and 640 km s^{-1}, respectively. These two wave events were associated with two filament eruptions and two GOES M-class solar flares from the NOAA active region 12565, which was located near the western limb. The EUV waves mainly move toward the south direction. We observed the interaction of the EUV waves with a helmet streamer further away to the south. When either or one of the EUV waves penetrates into the helmet streamer, a slowly propagating wave with a traveling speed of $\approx$ 150 km s^{-1} is observed along the streamer. We suggest that the slowly moving waves are slow-mode waves, and interpret this phenomenon as the magnetohydrodynamic wave-mode conversion from the fast mode to the slow mode. Furthermore, we observed several stationary fronts to the north and south of the source region. This work has been done in collaboration with D.F. Chen, R. Joshi, B. Joshi, and B. Schmieder.

Can high-mode magnetohydrodynamic waves propagating in a spinning macrospicule be unstable due to the Kelvin-Helmholtz instability?

We investigate the conditions at which high-mode magnetohydrodynamic (MHD) waves propagating in a spinning solar macrospicule can become unstable with respect to the Kelvin-Helmholtz instability (KHI). We consider the macrospicule as a weakly twisted cylindrical magnetic flux tube moving along and rotating around its axis. Our study is based on the dispersion relation (in complex variables) of MHD waves obtained from the linearized MHD equations of an incompressible plasma for the macrospicule and cool ($\beta = 0$, with β the plasma to the magnetic pressure) plasma for its environment. This dispersion equation is solved numerically using appropriate input parameters to find out an instability region or window that accommodates suitable unstable wavelengths on the order of the macrospicule width. It is established that an m = 52 MHD mode propagating in a macrospicule with width of 6 Mm, axial velocity of 75 km/s, and rotating one of 40 km/s can become unstable against the KHI with growth times of 2.2 and 0.57 min at 3 and 5 Mm unstable wavelengths, respectively. These growth times are much shorter than the macrospicule lifetime, which lasts about 15 min. An increase or decease in the width of the jet would change the KHI growth times, which

remain more or less of the same order when they are evaluated at wavelengths equal to the width or radius of the macrospicule. It is worth noting that the excited MHD modes are super-Alfvenic. A change in the background magnetic field can lead to another MHD mode number, m, that ensures the required instability window. This study has been carried out in collaboration with I. Zhelyazkov.

Suresh Chandra

Suggestion for search of ethylene oxide (c-C_2H_4O) in a cosmic object

Because of their potential role in the formation of amino acids, ethylene oxide (c-C_2H_4O) and its isomer acetaldehyde (CH_3CHO) are important organic molecules. The c-C_2H_4O is b-type asymmetric top molecule and due to half-spin of each of its four hydrogen atoms, it has two distinct ortho (nuclear spin one) and para (nuclear spin zero and two) species. It has been identified in the galactic source Sgr B2N. Using the spectroscopic information (rotational and centrifugal distortion constants, and the electric dipole moment), we have calculated energies of 100 rotational levels of each of the ortho and para species of molecule and the Einstein A-coefficients for radiative transitions between the levels. Using scaled values for collisional rate coefficients along with the values of Einstein A-coefficients, we have solved a set of statistical equilibrium equations coupled with the equations of radiative transfer for each of the species. Brightness-temperatures of five rotational transitions of each of the ortho and para species of c-C_2H_4O are investigated. Out of these ten transitions, three transitions are found to show the anomalous absorption and rest seven are found to show the emission feature. We have also investigated seven transitions observed unblended in Sgr B2(N). It is found that the transitions $3_{30} - 3_{21}$ (23.139 GHz), $2_{20} - 2_{11}$ (15.605 GHz), and $3_{31} - 3_{22}$ (39.686 GHz) may play important role in the identification of ethylene oxide in a cosmic object. This work has been done in collaboration with Mohit K. Sharma, and Monika Sharma.

Strengths of rotational lines from H_2CC molecule: Addressing tentative detection

Though H_2C, H_2CCC, H_2CCCC, H_2CCO, H_2CO, H_2CS molecules have been identified in cool interstellar clouds, identification of H_2CC is still awaited. Formation of H_2CC in the interstellar medium is quite probable as the cosmic abundance of carbon is 20 times larger than that of the sulpher, and the molecule H_2CS has already been identified in the interstellar medium. To our knowledge, no laboratory study for H_2CC is available in literature. Physical conditions in the interstellar medium are quite different as compared to those in a terrestrial laboratory. Using the rotational and centrifugal distortion constants for H_2CC, we have calculated the energies of rotational levels and the strengths of lines between the levels up to 270 cm^{-1}. We have found that 88 and 87 lines of ortho-H_2CC and para-H_2CC, respectively have Einstein A-coefficient larger than 10^{-5} s^{-1}. These lines may help in the identification of H_2CC in the interstellar medium. Tentative detection of H_2CC has been addressed. This work has been done in collaboration with Mohit K. Sharma, and Monika Sharma.

Ayan Chatterjee

Quasi-local first law of black hole dynamics from local Lorentz transformations

Quasi-local formulations of black hole are of immense importance since they reveal the essential and minimal assumptions required for a consistent description of black hole horizon, without relying on the asymptotic boundary conditions on fields. Using the quasi-local formulation of Isolated Horizons, we construct the Hamiltonian charges corresponding to local Lorentz transformations on a spacetime admitting isolated horizon as an internal boundary. From this construction, it arises quite generally that the *area* of the horizon of an isolated black hole is the Hamiltonian charge for local Lorentz boost on the horizon. Using this argument further, it is shown that observers at a fixed proper distance l_0, very close to the horizon, may define a notion of horizon energy given by $E = A/8\pi G l_0$, the surface gravity is given by $\kappa = 1/l_0$, and consequently, the first law can be written in the quasi-local setting as $\delta E = (\kappa/8\pi G)\delta A$. This study has been carried out in collaboration with Avirup Ghosh.

Joining spacetimes on fractal hypersurfaces

The theory of fractional calculus is attracting a lot of attention from mathematicians as well as physicists. The fractional generalisation of the

well- known ordinary calculus is being used extensively in many fields, particularly in understanding stochastic process and fractal dynamics. In this work, we apply the techniques of fractional calculus to study some specific modifications of the geometry of submanifolds. Our generalisation is applied to extend the Israel formalism, which is used to glue together two spacetimes across a timelike, spacelike or a null hypersurface. In this context, we show that the fractional extrapolation leads to some striking new results. More precisely, we demonstrate that in contrast to the original Israel formalism, where many spacetimes can only be joined together through an intermediate thin hypersurface admitting effective matter fields violating standard energy conditions, the fractional generalisation allows these spacetimes to be smoothly sewed together without any such requirements on the stress tensor of the matter fields. We discuss the ramifications of these results for spacetime structure and the possible implications for gravitational physics. This work has been done in collaboration with Ankit Anand.

Ritaban Chatterjee

The accretion disk-jet connection in blazars

The power spectral density (PSD) of the X-ray emission variability from the accretion disk-corona region of black hole X-ray binaries and active galactic nuclei has a broken power-law shape with a characteristic break timescale T_B. If the disk and the jet are connected, the jet variability may also contain a characteristic timescale related to that of the disk-corona. Recent observations of the blazar Mrk 421 have confirmed the broken power-law shape of the PSD of its jet X-ray variability. We model the time variability of a blazar, in which emitting particles are assumed to be accelerated by successive shock waves flowing down the jet with a varying inter-shock timescale (T_{IS}). We investigate the possible relation between the characteristic timescales in the disk and jet variability based on the above model, along with mathematically and physically simulated disk variability. We find that both the PSD of the jet and disk variability may have a broken power-law shape, but the break timescales are not related in general, except only in systems with a small range of BH mass. The break in the jet and disk PSD are connected to the interval between large amplitude outbursts in the jet (T_{IS}) and to the viscous timescale in the disk, respectively. In frequency bands where multiple emission processes are involved or emission is from lower energy particles, the break in the PSD may not be prominent enough for detection. This work has been done in collaboration with Sagnick Mukherjee and Kaustav Mitra.

Probing the jets of blazars using the temporal symmetry of their multi-wavelength outbursts

We analyze X-ray light curves of the blazar Mrk 421 obtained from the Soft X-ray Imaging Telescope and the Large Area X-Ray Proportional Counter instrument onboard the Indian space telescope *AstroSat* and archival observations from *Swift*. We show that the X-ray power spectral density (PSD) is a piece-wise power-law with a break, i.e., the index becomes more negative below a characteristic "break-timescale". Galactic black hole X-ray binaries and Seyfert galaxies exhibit a similar characteristic timescale in their X-ray variability that is proportional to their respective black hole mass. X-rays in these objects are produced in the accretion disk or corona. Hence, such a timescale is believed to be linked to the properties of the accretion flow. Any relation observed between events in the accretion disk and those in the jet can be used to characterize the disk-jet connection. However, evidence of such link have been scarce and indirect. Mrk 421 is a BL Lac object, which has a prominent jet pointed towards us and a weak disk emission, and it is assumed that most of its X-rays are generated in the jet. Hence, existence of the break in its X-ray PSD may indicate that changes in the accretion disk, which may be the source of the break timescale are translating into the jet, where the X-rays are produced. This work has been done in collaboration with Namrata Roy, Manasvita Joshi, and Aritra Ghosh.

Suchetana Chatterjee

X-ray surface brightness profiles of optically selected active galactic nuclei: Comparison with X-ray AGNs

We use data from the All Wavelength Extended Groth Strip International Survey to construct stacked X-ray maps of optically bright active galactic nuclei (AGNs), and an associated control sample of galaxies at high redshift ($z \sim 0.6$). From our analysis of the surface brightness profiles obtained

from these X-ray maps, we find evidence of feedback from the active nuclei. We find that excluding galaxies and AGNs, residing in group environments, from our samples enhances the significance of our detection. Our results support the tentative findings of Chatterjee et al., who use X-ray-selected AGNs for their analysis. We discuss the implications of these results in the context of quantifying AGN feedback, and show that the current method can be used to extract an X-ray source population in high-redshift galaxies. This study has been done in collaboration with Sagnick Mukherjee, Anirban Bhattacharjee, Jeffrey A. Newman, and Renbin Yan.

Direct detection of quasar feedback via the Sunyaev-Zeldovich effect

The nature and energetics of feedback from thermal winds in quasars can be constrained via observations of the Sunyaev-Zeldovich Effect (SZE) induced by the bubble of thermal plasma blown into the intergalactic medium by the quasar wind. In this work, we present evidence that we have made the first detection of such a bubble, associated with the hyperluminous quasar HE 0515-4414. The SZE detection is corroborated by the presence of extended emission line gas at the same position angle as the wind. Our detection appears on only one side of the quasar, consistent with the SZE signal arising from a combination of thermal and kinetic contributions. Estimates of the energy in the wind allow us to constrain the wind luminosity to the lower end of theoretical predictions, ~ 0.01 per cent of the bolometric luminosity of the quasar. However, the age we estimate for the bubble, ~ 0.1 Gyr, and the long cooling time, ~ 0.6 Gyr, means that such bubbles may be effective at providing feedback between bursts of quasar activity. This research work has been done in collaboration with Mark Lacy, Brian Mason. Kraign Sarazin, Kristina Nyland, Amy Kimball et al.

Asis Kumar Chattopadhyay

Clustering of gamma-ray bursts through kernel principal component analysis

We considered clustering of gamma-ray bursts through kernel principal component analysis, in which our proposed kernel outperforms results of other competent kernels in terms of clustering accuracy, and we obtain three physically interpretable groups of gamma-ray bursts. The electiveness of the suggested kernel in combination with the kernel principal component analysis in revealing natural clusters in noisy and non linear data while reducing the dimension of the data is explored in two artificially created data sets. This work has been carried out in collaboration with Soumita Modak and Tanuka Chattopadhyay.

Surajit Chattopadhyay

A study of modified holographic Ricci dark energy in the framework of $f(T)$ modified gravity and its statefinder hierarchy

Inspired by the work of Bamba et al. 2012), the present study reports on the reconstruction of modified holographic Ricci dark energy (MHRDE) in the framework of modified gravity taken as $f(T)$ gravity. A correspondence between modified Chaplygin gas (MCG) and MHRDE has also been considered, and thereafter the $f(T)$ gravity has been reconstructed via reconstruction of the Hubble parameter. The reconstructed equation of state (EoS) parameter obtained this way has been found to be able to cross the phantom boundary. In the next phase of the work, a viable model of $f(T)$ gravity has been considered and MHRDE has been discussed in this modified gravity frame. The EoS parameter due to the torsion contribution obtained this way has been found to behave like quintessence. The transition of the universe from the dark matter (DM) dominated to dark energy (DE) phase is apparent from this model. Also, the model is exhibiting DE domination of the current universe. Finally, the statefinder hierarchy has been discussed through the statefinder and snap parameters. The model has been found to be able to attain the ΛCDM fixed point in the statefinder trajectory. This work has been carried out in collaboration with Arkaprabha Majumdar.

Reconstruction of $f(T)$ gravity in the context of standard Chaplygin gas as tachyon scalar field and study of the stability against gravitational perturbation

The present work, carried out in collaboration with Soumyodipta Karmakar, reports a study on the $f(T)$ gravity reconstruction scheme in the context of considering standard Chaplygin gas as tachyon scalar field model of dark energy. The solution for reconstructed $f(T)$ gravity has been obtained from

reconstructed potential and scalar field of tachyon based on the standard Chaplygin gas. It has been observed that the equation of state parameter due to the reconstructed torsion contribution to the density and pressure behaves like quintom, and is consistent with the observational value of the equation of state parameter for the current universe. The reconstructed $f(T)$ has then been tested for gravitational perturbation by deriving the frictional term, the effective mass and the sound speed parameter for the gravitational potential, and it has been found to be stable against gravitational perturbations through positive value of the squared speed of sound. Finally, statefinder diagnostics has been carried out and the reconstructed $f(T)$ gravity is found to interpolate between dust and ΛCDM phases of the universe.

Tanuka Chattopadhyay

Star formation under explosion mechanism in a magnetized medium

The model of star formation has been developed as a result of explosive phenomena in the central region of our Galaxy. The shock wave generated as a result of such explosion, during its propagation, cools and compresses the ambient medium in a thin layer, which subsequently fragments into molecular clouds. These clouds finally form star clusters or field stars under gravitational collapse. We primarily consider the central region of our Galaxy under the influence of a magnetic field for modelling such explosive phenomena and derive the minimum Jeans mass for gravitational collapse. It is found that under an inverse variation of temperature with density, a wide range of fragments can be formed. The mass range is enhanced in the presence of a constant as well as varying magnetic field. Under suitable physical conditions a burst of star formation is possible. It is also found that rotation of such fragmented clouds of the order of few km $s^{-1}kpc^{-1}$, might lead to a stable structure. This work has been done in collaboration with Debasish Mondal.

Fragmentation of molecular cloud in a polytropic medium

In search of the scenario of the star formation process, fragmentation of molecular clouds has been modelled under two different conditions. In the first case, thermal instability along with an equation of state with negative polytropic indices (n) has been considered, which give rise to minimal fragment masses in the range $0.001M\odot$ to $8.5M\odot$ for $-10 < n < 0, \neq -1$. In the second case, an opacity limited fragmentation along with positive polytropic indices is considered, which leads to a wide range of minimal fragment masses resulting in field stars, massive stars, and star bursts. This might be due to the effect of opacity, which is responsible for slow dissipation of heat in a compressed medium. This work has been done in collaboration with Ashok Mondal.

Raghavendra Chaubey

Dynamical analysis of anisotropic cosmological model with quadratic dark sector coupling

The present work deals with the dynamical evolution of LRS Bianchi type I (LRS BI) cosmological model with quadratic dark sector coupling. We investigate the phase-plane analysis of LRS BI model with dark energy, when it is modelled as exponential quintessence, and is coupled to dark matter via energy exchange. The evolution of cosmological solutions is studied by using dynamical systems method. Stability and viability of the models are discussed for four different choices of quadratic dark sector coupling parameter. In each model, we have obtained a late-time accelerating fixed point (future attractor), which is not a scaling solution. This work has been done in collaboration with Rakesh Raushan.

Aspects of non-flat FRW bouncing models with quadratic equation of state

In this work, we investigate the possibility of a non-singular model of universe in the framework of general relativity in non-flat FRW geometries with quadratic equation of state and bulk viscosity. We study whether a non-singular bounce requires violation of energy conditions. We discuss the thermodynamical aspects of the resulting models with equilibrium description. In particular, we discuss the validity of the generalized second law of thermodynamics for resulting cosmologies. This work has been done in collaboration with Ashutosh Singh, Rakesh Raushan, and T. Singh.

Bhag Chand Chauhan

Bounds on sterile neutrino component in the solar neutrino flux

Solar neutrinos studies have played a crucial role in the development of neutrino physics. It took decades to understand the mysterious nature of neutrinos and to identify a leading solution to the Solar Neutrino Problem (SNP). The mystery of the missing neutrinos deepened as subsequent experiments were performed. The energy spectrum of solar neutrinos, as predicted by standard solar models, is seen by different experiments as they are sensitive to different neutrino energy ranges. More than 98% of the calculated standard model solar neutrino flux lies below 1MeV. The rare ^8B neutrino flux is the high energy tail of solar neutrinos, for which statistically significant measurements have been made so far, but this is just tip of an iceberg. As such, the study of low energy neutrinos can give us better understanding and showcase the possibility of species other than three active neutrino flavours, mainly the sterile neutrinos (ν_s) in solar neutrino flux. In the light of latest data available from various solar neutrino experiments including Borexino and KamLAND Solar phase we derive, in a model independent way, the bounds on sterile neutrino component present in the solar neutrino flux. We update the limits on the sterile component and compare them with the previous results obtained using data from SNO solar salt phase and Super Kamiokande experiments. We retrieve the upper bounds existing in the literature and present the more stringent bounds on the sterile neutrino component. This work has been done in collaboration with Govind Singh, Ashish Sharma, Shankita Bhardwaj, and Surender Verma.

Quark-lepton complementarity model based predictions for θ_{23}^{pmns} with neutrino mass hierarchy

After the successful investigation and confirmation of non-zero θ_{13}^{pmns} by various experiments, we are standing at a square, where we still encounter a number of issues, which are to be settled. In this work, we have just extended our recent work towards a precise prediction of the θ_{23}^{pmns} mixing angle, taking into account the neutrino mass hierarchy, In the QLC model, a non-trivial correlation between CKM and PMNS mixing matrices is obtained by taking into account the phase mismatch between quark and lepton sectors as a diagonal matrix $\Psi = \mathrm{diag}(e^{\iota\psi_i})$. After doing Monte Carlo simulations, we estimated the texture of the correlation matrix (V_c) and compared the results with the standard Tri-Bi-Maximal (TBM) and Bi-Maximal(BM) structures. We obtained predictions for θ_{23}^{pmns} for the two cases of neutrino mass hierarchies, i.e., normal hierarchy (NH) and inverted hierarchy (IH). The precise values of θ_{23}^{pmns} , thus obtained for the two cases are about 3σ away from each other, which can give a strong hint for the hierarchy of neutrino masses. This study has been done in collaboration with Gazal Sharma, Shankita Bhardwaj, and Sudender Verma.

Himadri Sekhar Das

Dependence of light scattering properties on porosity, size and composition of dust aggregates

In this work, we study the light scattering properties of dust aggregates ($0.7\mu m \lesssim R_c \lesssim 2.0\mu m$) with a wide range of porosity ($\mathcal{P} = 0.59$ to 0.98). The simulations are executed using the Superposition T-matrix code with BCCA, BA, BAM1 and BAM2 clusters of varying porosity. We investigate the nature and dependencies of the different scattering parameters on porosity, size and composition of the aggregated particles for wavelengths 0.45 μm and 0.65 μm. We find that the scattering parameters are strongly correlated with the porosity of the aggregated structures. Our results indicate that, when the porosity of the aggregates decreases, keeping characteristic radius of the aggregates (R_c) same for all structures, there is an enhancement in the negative polarization branch (NPB), which is accompanied by a substantial increase in the anisotropies present in the material. Also at the exact backscattering region, the anisotropies are found to be linearly correlated with the porosity of the aggregated structure. The computational study reveals that, for low absorbing materials ($k \leq 0.1$), the negative polarization minimum (P_{min}) is strongly correlated with the associated anisotropies. Finally, we put forward a qualitative comparison between our computationally obtained results and some selected data from the Amsterdam Light Scattering Database for both low and high absorbing materials. The experimental results also suggest that an increase in the NPB is always accompanied by an enhancement in the anisotropy at the backscattering region. This work has been done in collaboration with Prithish Halder

and Parizath Deb Roy.

Generation of sheath in magnetized plasma under the impact of slow rotation

In this study, we have tried to investigate the generation of sheath in magnetized plasma rotating with a uniform angular velocity about an axis making an angle with the direction of plasma acoustic wave propagation. In a marked contrast to the earlier studies, here the simultaneous impact of slow rotation and external magnetic field have been taken into consideration. Previous studies have revealed that the Coriolis force generated from rotation has a tendency to produce an equivalent magnetic field effect as and when the ionized medium rotates. The variations of sheath potential with normalized distance for different values of angles of rotation as well as for different values of Mach number have also been investigated for typical plasma parameters. This work has been done in collaboration with Jaydeep Paul, and Apratim Nag.

Sudipta Das

A new parametrization of dark energy equation of state leading to double exponential potentia

We show that a phenomenological form of energy density for the scalar field can provide the required transition from decelerated ($q > 0$) to accelerated expansion ($q < 0$) phase of the universe. We have used the latest type Ia supernova (SNIa) and Hubble parameter datasets to constrain the model parameters. The best fit values obtained from those datasets are then applied to reconstruct $\omega_\phi(z)$, the equation of state parameter for the scalar field. The results show that the reconstructed forms of $q(z)$ and $\omega_\phi(z)$ do not differ much from the standard ΛCDM value at the current epoch. Finally, the functional form of the relevant potential $V(\phi)$ is derived by a parametric reconstruction. The corresponding $V(\phi)$ comes out to be a double exponential potential, which has a number of cosmological implications. Additionally, we have also studied the effect of this particular scalar field dark energy sector on the evolution of matter overdensities. This work has been done in collaboration with Abdulla Al Mamon, and Manisha Banerjee.

Abhirup Datta

The galaxy cluster pipeline for X-ray temperature maps: ClusterPyXT

ClusterPyXT is a new software pipeline to generate spectral temperature, X-ray surface brightness, pressure, and density maps from X-ray observations of galaxy clusters. These data products help to elucidate the physics of processes occurring within clusters of galaxies, including turbulence, shock fronts, non-thermal phenomena, and the overall dynamics of cluster mergers. ClusterPyXT automates the creation of these data products with minimal user interaction, and allows for rapid analyses of archival data with user defined parameters and the ability to straightforwardly incorporate additional observations. In this work, we describe in detail the use of this code and release it as an open source Python project on GitHub. This work has been done in collaboration with B. Alden, E. J. Hallmann, D. Rapetti, and J. O. Burns.

Study of diffuse emission in cluster MACSJ0417.5-1154 from 76 MHz to 18 GH

We present new radio observations of the massive and X-ray luminous galaxy cluster MACS J0417.51154, at 1.387 GHz and 18 GHz, from the Giant Metrewave Radio Telescope (GMRT) and the Australia Telescope Compact Array (ATCA) respectively. We estimate diffuse emission in the central region of the cluster at 1.387 GHz and 18 GHz. We combine these data with previously published results and present the spectrum of diffuse emission from 76 MHz to 18 GHz. This is possibly a unique study of the radio halo emission in galaxy cluster over this wide range of frequencies. Such studies lay the prospects of future studies with radio telescopes with wide-range of frequencies like the Square Kilometre Array (SKA). Our 1.387 GHz data, with $2''$ angular resolution, provides a better estimate of point source emission than previous L-band observations, which is crucial, given the claim of sharp steepening of the radio halo spectrum at 0.61 GHz reported earlier. We find that the spectrum of the radio halo has a spectral index fit up to 18 GHz, and yields a spectral index between 76 MHz and 18 GHz that fits the available data better than earlier L-band observations. We discuss possible reasons for the peculiar spectral characteristics of the diffuse emission. This work has been done in collaboration with Pritpal Sandhu, Ramij Raja,

Majidul Rahaman, and Siddharth Malu.

Kanan Kumar Datta

Impact of inhomogeneous CMB heating of gas on the HI 21-cm signal during dark ages

Observations of redshifted HI 21-cm signal appear to be the most promising probe of the cosmic dark ages. The signal carries information about the thermal state along with density distribution of the intergalactic medium. The Cosmic Microwave Background Radiation (CMBR), through its interaction with charged particles, plays a major role in determining the kinetic and spin temperature of neutral hydrogen (HI) gas in the IGM during dark ages. Spatially fluctuating ionization fraction, which is caused by inhomogeneous recombinations, causes heat transfer from the CMBR to the IGM gas inhomogeneous. We revisit impact of this inhomogeneous heat transfer on spatial fluctuations in the observed HI 21-cm signal over a large redshift range during dark ages. Our study shows that the effect negatively impacts fluctuations in the HI spin temperature and results in enhanced HI 21-cm power spectrum. We find that the effect is particularly important during the transition of the gas kinetic temperature being coupled to the CMBR to fully decoupled from it, i.e., in the redshift range $30 < z < 300$. It is found that, on the average the HI power spectrum $P_{T_b}(k, z)$ is enhanced by $\sim 4\%$, $\sim 10\%$, $\sim 20\%$ and $\sim 30\%$ at redshifts 60, 90, 140 and 200 respectively at $k = 0.1\,\mathrm{Mpc}^{-1}$. The effect becomes even more significant at lower values of $k_\parallel^2/k^2$ due to reduced dominance of the peculiar velocity. It is observed that the power spectrum is enhanced by $\sim 49\%$ and $\sim 93\%$ at redshifts 140 and 200 respectively at $k = 0.1\,\mathrm{Mpc}^{-1}$ for $k_\parallel^2/k^2 = 0$. This enhancement has a weak k-mode dependence. This study has been done in collaboration with Sioree Ansar, and Dhruba Dutta Chowdhury.

A method to determine the evolution history of the mean neutral hydrogen fraction

The light-cone (LC) effect imprints the cosmological evolution along the frequency axis, which is the line of sight $\sim$ (LoS) direction of the redshifted 21-cm signal $T_\mathrm{b}(\hat{\boldsymbol{n}}, \nu)$. The effect is particularly pronounced during the Epoch of Reionization (EoR) when the mean hydrogen neutral fraction $x_\mathrm{HI}(\nu)$ falls rapidly as the universe evolves. The multi-frequency angular power spectrum (MAPS) $\mathcal{C}_\ell(\nu_1, \nu_2)$ quantifies the entire second-order statistics of $T_\mathrm{b}(\hat{\boldsymbol{n}}, \nu)$ considering both the systematic variation along ν due to the cosmological evolution and also the statistically homogeneous and isotropic fluctuations along all the three spatial directions encoded in $\hat{\boldsymbol{n}}$ and ν. Here we propose a simple model where the systematic frequency (ν_1, ν_2) dependence of $\mathcal{C}_\ell(\nu_1, \nu_2)$ arises entirely due to the evolution of $x_\mathrm{HI}((\nu)$. If valid, this provides a new method to observationally determine the reionization history. Considering a LC simulation of the EoR 21-cm signal, we use the diagonal elements $(\nu_1 = \nu_2)$ of $\mathcal{C}_\ell(\nu_1, \nu_2)$ to validate our model. We demonstrate that it is possible to recover the reionization history across the entire observational bandwidth provided we have the values $x_\mathrm{HI}((\nu_c)$ at a single frequency ν_c as an external input. This work has been done in collaboration with Rajesh Mondal, Somnath Bharadwaj, Ilian Iliev, Suman Majumdar, Abinash K. Shah, et al.

Sukanta Deb

Geometry of the Large Magellanic Cloud using multiwavelength photometry of classical Cepheids

We determine the geometrical and viewing angle parameters of the Large Magellanic Cloud (LMC) using the Leavitt law based on a sample of more than, 3,500 common classical Cepheids (FU and FO) in optical (V, I), near-infrared (JHKs), and mid-infrared ([3.6] μm and [4.5] μm) photometric bands. Statistical reddening and distance modulus free from the effect of reddening to each of the individual Cepheids are obtained using the simultaneous multiband fit to the apparent distance moduli from the analysis of the resulting Leavitt laws in these seven photometric bands. A reddening map of the LMC obtained from the analysis shows good agreement with the other maps available in the literature. Extinction-free distance measurements along with the information of the equatorial coordinates (α, δ) for individual stars are used to obtain the corresponding Cartesian coordinates with respect to the plane of the sky. By fitting a plane solution of the form z = f(x, y) to the observed three-dimensional distribution, the following viewing angle parameters of the LMC are obtained: inclination angle $i = 25\overset{0}{.}110 \pm 0\overset{0}{.}365$, and position angle of line of nodes $\theta_{lon} = 154\overset{0}{.}702 \pm 1\overset{0}{.}378$. On the other hand, modelling the observed three-dimensional distribution of the Cepheids as a triax-

ial ellipsoid, the following values of the geometrical axes ratios of the LMC are obtained: $1.000 \pm 0.003 : 1.151 \pm 0.003 : 1.890 \pm 0.014$ with the viewing angle parameters: inclination angle of $i = 11.^0_. 920 \pm 0.^0_. 315$ with respect to the longest axis from the line of sight and position angle of line of nodes $\theta_{lon} = 128.^0_. 871 \pm 0.^0_. 569$. The position angles are measured eastwards from north. This work has been done in collaboration with Chow-Choong Ngeow, Shashi M. Kanbur, Harinder P. Singh, Daniel Wysocki, and Subhash Kumar.

Ujjal Debnath

Anisotropic quintessence strange stars in f(T) gravity with modified Chaplygin gas

We have studied the existence of strange star in the background of f(T) modified gravity, where T is a scalar torsion. In KB metric space, we have derived the equations of motion using anisotropic property within the spherically strange star with modified Chaplygin gas in the framework of modified f(T) gravity. Then we have obtained many physical quantities to describe the physical status such as anisotropic behaviour, energy conditions and stability. By the matching conditions, we have explored the unknown parameters to evaluate the numerical values of mass, surface redshift, etc. from our model to make comparison with the observational data. This work has been done in collaboration with Pameli Saha.

Bouncing universe in the contexts of generalized cosmic Chaplygin gas and variable modified Chaplygin gas

We have assumed the Friedmann-Robertson-Walker (FRW) model of the universe where bounce occurs and the universe is filled with generalized cosmic Chaplygin gas (GCCG) or variable modified Chaplygin gas (VMCG). We have studied the stability analysis through dynamical system for both models and found the critical points in flat, open and closed universe. In presence of scalar field, the dynamical behaviour of scale factor and Hubble parameter are described in both the models. Also have analyzed the energy conditions for both the models in bouncing universe. This work has been done in collaboration with Tanwi Bandyopadhyay.

Shantanu Desai

Constraints on differential Shapiro delay between neutrinos and photons from IceCube-170922A

On 22nd September 2017, the IceCube Collaboration detected a neutrino with energy of about 290 TeV from the direction of the gamma-ray blazar TXS 0506+056, located at a distance of about 1.75 Gpc. During the same time, enhanced gamma-ray flaring was also simultaneously observed from multiple telescopes, giving rise to only the second coincident astrophysical neutrino/photon observation after SN 1987A. We point out that for this event, both neutrinos and photons encountered a Shapiro delay of about 6,300 days along the way from the source. From this delay and the relative time difference between the neutrino and photon arrival times, one can constrain violations of Einstein's Weak Equivalence Principle (WEP) for TeV neutrinos. We constrain such violations of WEP using the Parameterized Post-Newtonian (PPN) parameter γ, which is given by $|\gamma_\nu - \gamma_{\rm EM}| < 5.5 \times 10^{-2}$, after assuming time difference of 175 days between neutrino and photon arrival times. This work has been done in collaboration with Sibel Boran, and Enre O. Kahya.

Generalized Lomb-Scargle analysis of ^{90}Sr/^{90}Y decay rate measurements from the Physikalisch-Technische Bundesanstalt

We apply the generalized Lomb-Scargle (LS) periodogram to independently confirm the claim by Sturrock, et al. of an oscillation at a frequency of 11/year in the decay rates of ^{90}Sr/^{90}Y from measurements at the Physikalisch Technische Bundesanstalt (PTB), which, however, has been disputed by Kossert and Nahle. For this analysis, we made two different *ansatze* for the errors. For each peak in the LS periodogram, we evaluate the statistical significance using non-parametric bootstrap resampling. We find using both of these error models evidence for ~ 11/year periodicity in the ^{90}Sr/^{90}Y data for two of the three samples, but at a lower significance than that claimed by Sturrock, et al. This work has been done in collaboration with P. Tejas.

S. Dev

New mixing schemes for (3+1) neutrinos

We propose new mixing schemes for (3+1) neutrinos, which describe mixing among active-active and active-sterile neutrinos. The mixing matrix in these mixing schemes can be factored into a zeroth order flavour symmetric part and another part representing small perturbations needed for generating non-zero U_{e3}, non-maximal θ_{23}, CP violation and active-sterile mixing. We find interesting correlations amongst various neutrino mixing angles, and also, calculate the parameter space for various parameters. This work has been done in collaboration with Desh Raj, Radha Raman Gautam, and Lal Singh.

Shanti Priya Devarapalli

Low resolution spectroscopy of selected Algol systems

The analysis of spectroscopic data for 30 Algol-type binaries is presented. All these systems are short period Algols having primaries with spectral types B and A. Dominant spectral lines were identified for the spectra collected and their equivalent widths were calculated. All the spectra were examined to understand the presence of mass transfer, a disk or circumstellar matter and chromospheric emission. We also present the first spectroscopic and period study for a few Algols, and conclude that high resolution spectra within and outside the primary minimum are needed for better understanding of these Algol type close binaries. This work has been done in collaboration with Jagirdar Rukmini, M. Parthasarathy, D. K. Sahu, Vijay Mohan, B. C. Bhat, et al.

Photometric studies of two solar type marginal contact binaries in the Small Magellanic Cloud

Using the Optical Gravitational Lensing Experiment catalogue, two contact binaries were studied using data in the V and I bands. The photometric solutions for the V and I bands are presented for two contact binaries OGLE 003835.24-735413.2 (V1) and OGLE 004619.65-725056.2 (V2) in Small Maglellanic Cloud. The presented light curves are analyzed using the Wilson-Devinney code. The results show that the variables are in good thermal and marginal geometrical contact with features like the O'Connell effect in V1. The absolute dimensions are estimated and its dynamical evolution is inferred. They tend to be solar type marginal contact binaries. The 3.6 m Devasthal Optical Telescope and the 4.0 m International Liquid Mirror Telescope of the Aryabhatta Research Institute of Observational Sciences (ARIES, Nainithal) can facilitate the continuous monitoring of such kind of objects, which will help in finding the reasons behind their period changes and their impact on the evolution of the clusters. This work has been done in collaboration with Jagirdar Rukmini.

Vijayakumar Honnappa Doddamani

Formation and eruption of sigmoidal structure from a weak field region of NOAA 11942

Using observations from the Solar Dynamics Observatory, we studied an interesting example of a sigmoid formation and eruption from small-scale flux-cancelling regions of active region (AR) 11942. Through an analysis of Helioseismic and Magnetic Imager and Atmospheric Imaging Assembly observations, we infer that initially the AR is compact and bipolar in nature, evolved to a sheared configuration consisting of inverse J-shaped loops hosting a filament channel over a couple of days. By tracking the photospheric magnetic features, shearing and converging motions are observed to play a prime role in the development of S-shaped loops and further flux cancellation leads to tether-cutting reconnection of J-loops. This phase is co-temporal with the filament rise motion, followed by sigmoid eruption at 21:32 UT on January 6. The flux rope rises in phases of slow ($v_{avg} = 26 kms^{-1}$ and fast ($a_{avg} = 55 ms^{-2}$ rise motion categorizing the coronal mass ejection (CME) as slow with an associated weak C1.0 class X-ray flare. The flare ribbon separation velocity peaks at around the peak time of the flare at which the maximum reconnection rate ($2.14\ Vcm^{-1}$ occurs. Furthermore, the extreme ultraviolet light curves of 131, 171 Å have delayed peaks of 130 minutes compared to 94 Å and are explained by differential emission measure. Our analysis suggests that the energy release is proceeded by a much longer time duration, manifesting the onset of the filament rise and an eventual eruption driven by converging and cancelling flux in the photosphere. Unlike strong eruption events, the observed slow CME and weak flare are indications of slow runway tether-cutting reconnection, in which

most of the sheared arcade is relaxed during the extended phase after the eruption. This work has been done in collaboration with N. Vasantharaju, P. Vemareddy, and B. Ravindra.

Recurring coronal holes and their rotation rates during the solar cycles 22-24

Coronal holes (CHs) play a significant role in making the Earth geo-magnetically active during the declining and minimum phases of the solar cycle. In this study, we analysed the evolutionary characteristics of the Recurring CHs (RCHs) from the year 1992 to 2016. The extended minimum of Solar Cycle 23 shows unusual characteristics in the number of persistent CHs in the mid- and low-latitude regions of the Sun. Carrington rotation maps of He 10830 Å and EUV 195 Å observations are used to identify the CHs. The latitude distribution of the RCHs shows that most of them are appeared between $\pm 20^0$ latitudes. In this period, more number of recurring RCHs appeared in and around 100^0 and 200^0 Carrington longitudes. The large sized CHs lived for shorter period and they appeared close to the equator. From the area distribution over the latitude considered, it shows that more number of RCHS with area $< 10^{21} cm^2$ appeared in the southern latitude close to the equator. The rotation rates calculated from the RCHs appeared between $\pm 60^0$ latitude shows rigid body characteristics. The derived rotational profiles of the CHs show that they have anchored to a depth well below the tachocline of the interior, and compares well with the helioseismology results. This work has been done in collaboration with K. Prabhu, B. Ravindra, and Manjunath Hegde.

Broja Gopal Dutta

Evolution of accretion disc geometry of GRS 1915+105 during its χ-state as revealed by TCAF solution

The evolution of the low frequency quasi-periodic oscillations (LFQPOs) and associated time lag in transient black hole sources as function of time can be explained by variation of the Compton cloud size in a Two Component Advective Flow (TCAF) solution. A similar study of a persistent source, GRS 1915+105, has not been attempted. We fit the evolution of QPOs with propagatory oscillating shock (POS) solution for the two sets of χ-state observations, and find that the shock steadily recedes with almost constant velocity $v_s \sim t_d^{0.1}$ and $v_s \sim t_d^{0.4}$ when QPO frequency is declining and the spectral state becomes harder. The shock moves inward with a constant velocity $v_0 = 473.0$ cm s^{-1} and $v_0 = 400.0$ cm s^{-1} when QPO frequency is rising and the spectral state becomes softer. This propagation is similar to what was observed in XTE J1550-564 during 1998 outburst. The time lag measured at the QPO frequency varies in a similar way as the size of the Compton cloud (CENBOL in TCAF). Most interestingly, in both the cases, the lag switches sign (hard lag to soft lag) at a QPO frequency of $\sim 2.3 - 2.5$ Hz irrespective of the energy of photons. We find that at very low frequencies < 1 Hz, the Comptonizing Efficiency (CE) increases with QPO frequency, and at higher frequency, the trend is opposite, and the time lags become mostly positive at all energies when CE is larger than 0.85% for both the sources. This work has been done in collaboration with Partha Sarathi Pal, and Sandip K. Chakrabarti.

Variability properties of galactic black holes

In X-ray binaries, fast variability in X-ray emission on time-scales of milli-seconds to seconds is a common and very complex phenomenon. The variability of astronomical sources is usually expressed as a time series. The study of variability property implies the time series analysis of the light curve obtained from various sources. These study includes the study of Power Density Spectrum (PDS) and time/phase lag spectrum. Studies of energy dependent temporal properties (i.e.,variability properties) in different variability time scale for the nearly edge on (high inclination) and nearly face on (low inclination) compact binary sources could throw light on the detail structure of the accretion geometry. Again, the evolutionary picture of variability parameters, such as QPO frequency, time lag and energy dependent lag for transient and persistent sources can be studied with the simplified framework of Two Component Advective Flow (TCAF) solution. However, even with this simplified model and employing Monte-Carlo simulation technique, the simulated spectral behaviour can be tested with the observational results. Thus, it is possible to answer the cause of hard and soft lag and their transitions in higher inclination sources within the framework of a single TCAF solution. Also the evolution of the low frequency quasi-periodic oscillations (LFQPOs) and associated time lag in tran-

sient and persistently variable black hole sources as a function of time can be explained by variation of the Compton cloud size in a TCAF solution.

Jibitesh Dutta

Cosmological dynamics of brane gravity: A global dynamical system perspective

The braneworld model of gravity is well-known for several notable cosmological features, such as self-acceleration originating from a geometric and not matter source, effective dark energy behaviour with phantom characteristics, but not leading to a big-rip singularity, rough resemblance to the ΛCDM evolution, etc. The dynamical system tools usually allow us to obtain generic conclusions on the global dynamics of a system over a wide range of initial conditions. With this motivation, in order to recover the important features of the braneworld model from a more global perspective, here, we investigate the global cosmological dynamics of the braneworld model using dynamical system techniques. We first analyze the case where there is just a normal matter on the brane and then extend the analysis to the case with an extra scalar field also trapped on the brane. In the presence of a scalar field, potentials belonging to different classes are considered. The stability behaviour of critical points is examined using linear stability analysis and when necessary center manifold theory as well as numerical perturbation techniques are also used. To understand the global dynamics of a dynamical system, we utilized the Poincare compactification method to capture the properties of all possible critical points. Applying dynamical system analysis, we found that brane gravity was consistent with observed actions of the Universe. In particular, our analysis shows that important cosmological behaviours like the long-lasting matter-dominated era, late time acceleration as well as the avoidance of big-rip singularity can be realized in brane gravity for a wide range of initial conditions. This work has been done in collaboration with Hmar Zonunmawia, Wompherdeiki Khyllep, and Laur Jarv.

Thermodynamics of event horizon with modified Hawking temperature in scalar-tensor gravity

In recent past, Hawking temperature has been modified for the validity of thermodynamical laws at the event horizon in general relativity context. This lead to the introduction of modified Hawking temperature, and it has been found that the modified Hawking temperature is more realistic on the event horizon. With this motivation, here we investigate the thermodynamical consistency of scalar-tensor gravity based models by examining the validity of the generalized second law of thermodynamics (GSLT) and thermodynamical equilibrium (TE) at the event horizon. In order to attain our goal, we consider a spatially flat Friedman Robertson Walker Universe filled with ordinary matter and the boundary of the Universe bounded by the event horizon that is in thermal equilibrium with modified Hawking temperature. Next, we calculate the general expressions for the GSLT and TE using modified Hawking temperature in the context of the more general action of scalar-tensor gravity where, there is a non-minimally coupling between the scalar field and matter Lagrangian (as the Chameleon field). From the general expression of GSLT, we find that the null energy condition must hold for a viable scalar-tensor model of the Universe dominated by a perfect fluid. Furthermore, in order to better understand these complicated general expressions of GSLT and TE, we explore the validity of the GSLT and TE for two viable models of scalar-tensor gravity namely Brans-Dicke gravity with a self-interacting potential and Chameleon gravity at the event horizon using special cosmological solutions. Finally, some graphical representation of the GSLT and TE have been presented. From the graphical analysis, we found that the power-law forms of the scale factor and scalar field were much favourable for the study of universal thermodynamics as compared to other choices of the scalar field and the analytic function. This work has been done in collaboration with Binod Chetry, and Asrin Abdolmaleki.

Sunandan Gangopadhyay

Holographic complexity for Lifshitz system

The holographic complexity of a $3+1$-dimensional Lifshitz spacetime having a scaling symmetry is computed. The change in the holographic complexity between the excited state and the ground state is then obtained. This is then related to the changes in the energy and the entanglement chemical potential of the system. The calculation is carried out for both the values of the dynamical scaling exponent z in the Lifshitz spacetime. The relations has a very similar form to the corresponding rela-

tion involving the change in entanglement entropy known to be an analogous relation to the first law of thermodynamics. This work has been done in collaboration with Sourav Karar.

Sunandan Gangopadhyay and nNirban Saha

Footprint of spatial non commutativity in resonant detectors of gravitational wave

The present day gravitational wave (GW) detectors strive to detect the length variation $\delta L = hL$, which owing to the smallness of the metric perturbation $\sim h$, is an extremely small length $\mathcal{O} \sim 10^{-18} - 10^{-21}$ m. The recently proposed non commutative structure of space has a characteristic length-scale $\sqrt{\theta}$, which has an estimated upper-bound in similar length-scale range. We, therefore, propose that GW data can be used as an effective probe of non commutative structure of space and demonstrate how spatial non commutativity modifies the responding frequency of the resonant mass detectors of GW and also the corresponding probabilities of GW induced transitions that the phonon modes of the resonant mass detectors undergo. In this work, we present the complete perturbative calculation involving both time-independent and time-dependent perturbation terms in the Hamiltonian. This work has been done in collaboration with Sukanta Bhattacharyya, and Anirban Saha.

Suman Ghosh

Renormalized stress tensor of a quantized massless scalar field in warped cosmological braneworld background

Energy momentum tensor of a conformally coupled quantum scalar field in five dimensional warped cosmological spacetimes is studied. We look at situations where the four dimensional part represents a cosmological thick brane, and the scale of the extra dimension is time dependent. Renormalization of the components of the energy momentum tensor is done using adiabatic regularization method. The resulting energy and pressure densities explicitly show the effects of warping and the dynamic nature of the extra dimension on the created matter. We discussed how the created matter accumulate to form a thick brane near specific locations along the extra dimension.

Sushant G. Ghosh

Regular black holes in Einstein-Gauss-Bonnet gravity

Einstein-Gauss-Bonnet theory, a natural generalization of general relativity to a higher dimension, admits a static spherically symmetric black hole, which was obtained by Boulware and Deser. This black hole is similar to its general relativity counterpart with a curvature singularity at $r = 0$. We present an exact $5D$ regular black hole metric, with parameter $(k > 0)$, that interpolates between the Boulware-Deser black hole $(k = 0)$ and the Wiltshire charged black hole $(r >> k)$. Owing to the appearance of the exponential correction factor (e^{-k/r^2}), responsible for regularizing the metric, the thermodynamical quantities are modified, and it is demonstrated that the Hawking-Page phase transition is achievable. The heat capacity diverges at a critical radius $r = r_C$, where incidentally the temperature is maximum. Thus, we have a regular black hole with Cauchy and event horizons, and evaporation leads to a thermodynamically stable double-horizon black hole remnant with vanishing temperature. The entropy does not satisfy the usual exact horizon area result of general relativity. This work has been done in collaboration with Dharam Veer Singh, and Sunil D. Maharaj.

Shadows of rotating five-dimensional charged EMCS black holes

Higher dimensional theories admit astrophysical objects like supermassive black holes, which are rather different from standard ones and their gravitational lensing features deviate from general relativity. It is known that a black hole shadow is a dark region due to the falling geodesics of photons into the black hole and if detected, a black hole shadow could be used to determine, in which theory of gravity is consistent with observations. Measurements of the shadow sizes around the black holes can help to evaluate various parameters of black hole metric. We study the shapes of the shadow cast by the rotating five-dimensional charged Einstein-Maxwell-Chern-Simons (EMCS) black holes, which is characterized by the four parameters, i.e., mass, two spins, and charge, in which spin parameters are set equal. We integrate the null geodesic equations and derive an analytical formula for the shadow of five-dimensional EMCS black hole, in turn, to show that size of black hole

shadow is affected due to charge as well as spin. The shadow is a dark zone covered by a deformed circle, and the size of the shadow decreases with an increase in the charge q when compared with the five-dimensional Myers-Perry black hole. Interestingly, the distortion increases with charge q. The effect of these parameters on the shape and size of naked singularity shadow of five- dimensional EMCS black hole is also discussed. This work has been done in collaboration with Muhammed Amir, and Balendra Pratap Singh.

Tuhin Ghosh

Non-Gaussianity study of diffuse Galactic emission at 408 MHz

The redshifted 21 cm signal from epoch of reionization gets contaminated by diffuse Galactic emission, especially by the synchrotron emission. We use 408 MHz map and studied if there exists a clean sky region where the Galactic synchrotron emission can be approximated by a Gaussian random field. Most of the existing component separation methods assume foreground emission to be Gaussian. We apply two statistical tools-binned bispectrum estimator and Minkowski functional to show that the assessment of foreground emission being Gaussian is valid only at low brightness temperature $T < 25K$ and at angular scales of 3 degrees or less. For high brightness regions ($T > 25K$), non-Gaussianity of foreground emission needs to be taken into account in the component separation methods. This work has been done in collaboration with Sandeep Rana, J. S. Bagla, and Pravabati Chingangbam.

Testing statistical isotropy of the Planck CMB map using Minkowski Tensors

Minkowski Tensors (MTs) are recently used to study the statistical isotropy of temperature fluctuations of the Cosmic Microwave Background Radiation (CMBR). Minkowski Tensors are tensorial generalizations of the scaler Minkowski Functionals. Due to its tensorial nature they contain additional morphological information of structures, in particular about shape and alignment. We have calculated MFs directly on the sphere and compute the net alignment of the structures seen in the Planck CMB data. We do not find any significant deviation between the data and statistical isotropic CMB simulations. We further check the alignments obtained from the beam-convolved CMB maps at individual Planck frequencies to those in the corresponding Planck end-to-end simulations. We find no significant departure between the data and the simulations across all Planck frequencies, except for mild 2σ departure in the 30 GHz channel. We suspect that the mild departure could originates from inaccurate estimation of the instrumental beam at 30 GHz in the Planck end-to-end simulations.

Rupjyoti Gogoi

Modelling the mid-infrared polarization in dust around young stars

The presence of crystalline silicates has been detected in the circumstellar environment of several young stars in the recent past, and there is evidence of silicon carbide (SiC) detection in the envelope of pre-main sequence star SVS13. In this work, we have attempted to probe the presence of SiC in the dust around protoplanetary discs in a sample of young stars. We have modelled the linear polarization of composite dust grains in the mid-infrared (MIR: 8 to 13 μm) using silicates as the host with various inclusions of SiC and graphites using the Discrete Dipole Approximation (DDA) and the Effective Medium Approximation (EMA) T-Matrix methods. We have then compared our modelling results with polarimetric observations made in the protoplanetary discs surrounding two Herbig Be stars and one T-Tauri star with particular emphasis towards the 10 μm silicate feature using CanariCam mounted over the Gran Telescopio Canarias (GTC). We report the possible existence of SiC in the outer disc/envelope around one star in our sample, which has been interpreted based on the shape, size, composition, and fraction of inclusions by volume in our dust grain models. This work has been done in collaboration with Gautam Saikia, Ranjan Gupta, and Deepak B. Vaidya.

Influence of energy-dependent particle diffusion on the X-ray spectral curvature of MKN 421

The X-ray spectral curvature of blazars is traditionally explained by an empirical log-parabola function characterized by three parameters, namely the flux, curvature, and spectral index at a given energy. Since their exact relationship with the underlying physical quantities is unclear, interpreting the physical scenario of the source through these parameters is difficult. To attain an insight on

the X-ray spectral shape, we perform a detailed study of the X-ray spectra of the blazar MKN 421, using an analytical model, where the electron diffusion from the particle acceleration site is energy dependent. The resultant synchrotron spectrum is again determined by three parameters, namely, the energy index of the escape time-scale, the quantity connecting the electron energy to the observed photon energy, and the normalization. The X-ray observations of MKN 421, during 2012 July to 2013 April by Nuclear Spectroscopic Telescope Array and Swift-XRT are investigated using this model, and we find a significant correlation between model parameters and the observational quantities. Additionally, a strong anti-correlation is found between the fit parameters defining the spectral shape, which was not evident from earlier studies using empirical models. This indicates the flux variations in MKN 421 and possibly other blazars, may arise from a definite physical process that needs to be further investigated. This work has been done in collaboration with Pranjupriya Goswami, Sunder Sahayanathan, Atreyee Sinha, and Ranjeev Misra.

Shivappa Bharamappa Gudennavar

A stochastic propagation model to the energy dependent rapid temporal behaviour of Cygnus X-1 as observed by AstroSat in the hard state

We report the results from analysis of six observations of Cygnus X-1 by Large Area X-ray Proportional Counter (LAXPC) and Soft X-ray Telescope (SXT) onboard AstroSat, when the source was in the hard spectral state as revealed by the broad-band spectra. The spectra obtained from all the observations can be described by a single-temperature Comptonizing region with disc and reflection components. The event mode data from LAXPC provides unprecedented energy dependent fractional root mean square (rms) and time-lag at different frequencies, which we fit with empirical functions. We invoke a fluctuation propagation model for a simple geometry of a truncated disc with a hot inner region. Unlike other propagation models, the hard X-ray emission (> 4keV) is assumed to be from the hot inner disc by a single-temperature thermal Comptonization process. The fluctuations first cause a variation in the temperature of the truncated disc and then the temperature of the inner disc after a frequency dependent time delay. We find that the model can explain the energy dependent rms and time-lag at different frequencies. This work has been done in collaboration with Bari Maqbool, M. Sneha Prakash, R. Misra, J. S. Yadav, S. G. Bubbly, A. Rao, S. Jogadand, M. K. Patil, S. Bhattacharyya, and K. P. Singh.

Effects of dark matter in star formation

The standard model for the formation of structure assumes that there existed small fluctuations in the early universe that grew due to gravitational instability. The origins of these fluctuations are as yet unclear. In this work, we propose the role of dark matter in providing the seed for star formation in the early universe. Very recent observations also support the role of dark matter in the formation of these first stars. With this, we set observable constraints on luminosities, temperatures, and lifetimes of these early stars with an admixture of dark matter. This work has been done in collaboration with Arun Kenath, A. Prasad, and C. Sivaram.

Sarbari Guha

Five-dimensional warped product spacetime with time-dependent warping and a scalar field in the bulk

We consider gravity in a five-dimensional warped product spacetime, with a time-dependent warp factor and a time-dependent extra dimension. The five-dimensional field equations are derived for a spatially flat FRW brane, and the energy conditions and the nature of bulk geometry are examined. It is found that the expansion of the four-dimensional universe depends on its location along the extra dimension, and is different at different locations in the bulk spacetime. At low energies, the trapping of fields within the brane implies a specific correlation between the warp factor and the extra-dimensional scale factor. Generally, the bulk is not conformally flat. At high energies, the bulk is assumed to be sourced by a scalar field with self-interaction. The analysis shows that the potential of the scalar field source of gravity at a given position along the fifth dimension is related to the Hubble parameter on the brane at that position in the bulk. This work has been done in collaboration with Pinaki Bhattacharya.

Priya Hasan

Spectroscopic study of NGC 281 West

NGC 281 is a complex region of star formation at 2.8 kpc, and is situated 300 pc above the Galactic plane, and appears to be part of a 270 pc diameter ring of atomic and molecular clouds expanding at 22 km/s (Megeath, et al. 2003). It appears that two modes of triggered star formation are at work here: an initial supernova to trigger the ring complex and the initial O stars and the subsequent triggering of low mass star formation by photo evaporation driven molecular core compression. To get a complete census of the young stellar population, we use Chandra ACIS 100 ksec coupled with data from 2MASS and Spitzer. The Master X-ray catalog has 446 sources detected in different bandpasses. We present the spatial distribution of Class I, II and III sources to study the progress of star formation. We also determine the gas to dust ratio N_H/A_K to be $1.93 \pm 0.47 \times 10^{22}$ cm^{-2} mag^{-1} for this region. In this study, we present NGC 281 as a good target to study with the 3.6m Devasthal Optical Telescope (DOT) in spectroscopy. With these spectra, we look for evidence for the pre-main-sequence (PMS) nature of the objects, study the properties of the detected emission lines as a function of evolutionary class, and obtain spectral types for the observed young stellar objects (YSOs). The temperatures implied by the spectral types can be combined with luminosities determined from the near-infrared (NIR) photometry to construct Hertzsprung–Russell (HR) diagrams for the clusters. By comparing the positions of the YSOs in the HR diagrams with the PMS tracks, we can determine the ages of the embedded sources and study the relative ages of the YSOs with and without optically thick circumstellar disks.

A photometric study of the non-relaxed cluster Mayer 3

The astrophysical parameters of the open star cluster Mayer 3 have been estimated using observations at the Newtonian focus (f/4.84) of the 1.88 m telescope at Kottamia Observatory in Egypt. The VRI observations have been carried out down to a limiting magnitude of V$\sim$ 20 mag. To determine membership and estimate the astrophysical parameters, VRI, near-infrared Two Micron All Sky Survey (2MASS) and Gaia DR2 data have been used. The core and tidal radii, radial density distribution, colour-magnitude diagrams, distance, age, and reddening of Mayer 3 are presented. The luminosity and mass functions, and the total mass of the cluster are estimated. Finally, we conclude that Mayer 3 is not dynamically relaxed as the relaxation time estimated is much larger than the clusters age. This work has been done in collaboration with A. L. Tadrass, and R. Bendary.

S.N.A. Jaaffrey

Study of x-ray emission characteristics in solar flares employing SOXS: CZT detector

Our project involves a unique sample of 11 solar flare events observed by the space mission Solar X-ray Spectrometer (SOXS), particularly by CZT detector. We study temporal characteristics of 11 flares in general and rise time characteristics in particular. For this purpose, we got an opportunity to learn newly developed software in IDL. The flares selection is based on the GOES intensity in the range of M1.0-X1.0. The catalogue of all the flares chosen for this work is presented in table. The rise time of flares vary between 123 and 433 secs in $4.0 = 5.5$ keV energy band while shortest rise time of the order of $\sim$ 60 secs has been observed in 20-56 keV high energy bands. Our results reveal unique feature that rise time decays exponentially towards high energy. This result suggests that short rise time at high energy tail may be due to faster acceleration of electrons and thereby producing non-thermal bremesstrahlung via collisions of electrons with ambient plasma in solar flare loops. This work has been done in collaboration with Umang Pandya, and Rajmal Jain.

QPO detection in superluminal black hole GRS 1915+105

We report on the first superluminal black hole GRS 1915+105 observed by the Rossi X-ray Timing Explorer - Proportion Counter Array (RXTE/PCA). We detect the Quasi Periodic Oscillations (QPOs) in the Power Density Spectrum (PDS) of source, which have luminosity very near to Eddington limit and long variability in X-ray light curve. In power density spectrum, we deal with the study of highly variability amplitude, time evolution of the characteristic timescale, quality factor, and full width at half maximum (FWHM). We find significant

QPOs in 15 different observation IDs with frequency around 67Hz, although quality factor nearly 20 but in two IDs frequency is found just double. Typical fractional rms for GRS 1915+105 is dominating the hard band increasing steeply with energy more than 13% at 20-40 keV band. This work has been done in collaboration with Umang Pandya, and Rajmal Jain.

Deepak Jain

Bounds on graviton mass using weak lensing and SZ effect in galaxy clusters

In General Relativity (GR), the graviton is massless. However, a common feature in several theoretical alternatives of GR is a non-zero mass for the graviton. These theories can be described as massive gravity theories. Despite many theoretical complexities in these theories, on phenomenological grounds, the implications of massive gravity have been widely used to put bounds on graviton mass. One of the generic implications of giving a mass to the graviton is that the gravitational potential will follow a Yukawa-like fall off. We use this feature of massive gravity theories to probe the mass of graviton by using the largest gravitationally bound objects, namely galaxy clusters. In this work, we use the mass estimates of galaxy clusters measured at various cosmologically defined radial distances measured via weak lensing (WL) and Sunyaev-Zel'dovich (SZ) effect. We also use the model independent values of Hubble parameter H(z) smoothed by a non-parametric method, Gaussian process. Within 1σ confidence region, we obtain the mass of graviton $m_g < 5.9 \times 10^{-30}$ eV with the corresponding Compton length scale $\lambda_g > 6.82$ Mpc from weak lensing and $m_g < 8.31 \times 10^{-30}$ eV with $\lambda_g > 5.012$ Mpc from SZ effect. This analysis improves the upper bound on graviton mass obtained earlier from galaxy clusters. This work has been done in collaboration with Akshay Rana, Shobhit Mahajan, and Amitabha Mukherjee.

Jessy Jose

The Planck Cold Clump G108.37-01.06: A site of complex interplay between H II Regions, young clusters, and filaments

The Planck Galactic Cold Clumps (PGCCs) are possible representations of the initial conditions and very early stages of star formation. With the objective of understanding better the star and star cluster formation, we probe the molecular cloud associated with PGCC G108.37-01.06 (hereafter PG108.3), which can be traced in a velocity range of -57 to -51 km s^{-1}. The INT Photometric $H\alpha$ Survey images reveal $H\alpha$ emission at various locations around PG108.3, and optical spectroscopy of the bright sources in those zones of $H\alpha$ emission discloses two massive ionizing sources with spectral type O8-O9V and B1V. Using the radio continuum, we estimate ionizing gas parameters and find the dynamical ages of H II regions associated with the massive stars in the range of 0.5-0.75 Myr. Based on the stellar surface density map constructed from the deep near-infrared Canada-France-Hawaii Telescope observations, we find two prominent star clusters in PG108.3; of these, the cluster associated with H II region S148 is moderately massive ($\sim 240\ M_{\odot}$). A careful inspection of James Clerk Maxwell telescope, ^{13}CO (3-2) molecular data exhibits that the massive cluster is associated with a number of filamentary structures. Several embedded young stellar objects (YSOs) are also identified in PG108.3 along the length and junction of filaments. We find evidence of a velocity gradient along the length of the filaments. Along with kinematics of the filaments and the distribution of ionized, molecular gas and YSOs, we suggest that the cluster formation is most likely due to the longitudinal collapse of the most massive filament in PG108.3. This work has been done in collaboration with Somnath Dutta, Soumen Mondal, and Manash R. Samal.

Characterization of stellar and substellar members in the Coma Berenices Star Cluster

We have identified stellar and substellar members in the nearby star cluster Coma Berenices, using photometry, proper motions, and distances of a combination of 2MASS, UKIDSS, URAT1, and Gaia/DR2 data. Those with Gaia/DR2, parallax measurements provide the most reliable sample to constrain the distance, averaging 86.7 pc with a dispersion of 7.1 pc, and age of ∼800 Myr, of the cluster. This age is older than the 400-600 Myr commonly adopted in the literature. Our analysis, complete within 5° of the cluster radius, leads to identification of 192 candidates, among which, after field contamination is considered, about 148 are true members. The members have J $\sim$ 3 mag to $\sim$ 17.5 mag, corresponding to stellar masses 2.3-

0.06 $M_{\odot}$. The mass function of the cluster peaks around 0.3 $M_{\odot}$, and in the sense of dN/dm = $m^{-\alpha}$, where N is the number of members and m is stellar mass, with a slope $\alpha = 0.49 \pm 0.03$ in the mass range 0.3-2.3 $M_{\odot}$. This is much shallower than that of the field population in the solar neighborhood. The slope α = -1.69 $\pm$ 0.14 from 0.3 $M_{\odot}$ to 0.06 $M_{\odot}$, the lowest mass in our sample. The cluster is mass-segregated and has a shape elongated toward the Galactic plane. Our list contains nine substellar members, including three new discoveries of an M8, an L1, and an L4 brown dwarfs, extending from the previously known coolest members of late-M types to even cooler types. This work has been done in collaboration with Shih-Yun Tang, W. P. Chen, P. S. Chiang, Gregory J. Herczeg, and Bertrand Goldman.

Kanti Jotania

Study of coronal mass ejection(CME) and associated geomagnetic storm relation

Coronal mass ejections (CMEs) are the outburst of solar wind plasma from the Sun. If this plasma happens to travel in th Sun Earth line and collide with the Earths magnetosphere, the disturbance can lead to geomagnetic storms (GMS). It is now well understood that most of the GMS are associated with CMEs, and therefore, much attention is paid to studying the relationship between the CMEs and the GMS. In order to establish the relation between the solar origin, and the GMS, it is important to study the initial CME parameters and how it affects the strength of the GMS. We have used SOHO data with a few criteria. Main concern is to understand on what parameters CME and GMS are related. It is believed that GMS arises due to interaction of plasma with Earth's magnetosphere, various parameters like disturbance storm time, and Kp index, etc. In this work, we use the SOHO-LOCO CME catalogue, and lists all the CMEs that have occurred since 1996 and also gives its various parameters like initial speed, location, etc. The events are selected based on initial speed of CME and source location.

Minu Joy

Constraints on tensor to scalar ratio using WKB approximation

Scalar and tensor power spectra are studied using Wenzel-Kramers-Brillouin (WKB) approximation. The spectral indices and spectra generated with WKB approximation are compared with the observational data, and we see that the WKB approximated power spectra could become a viable alternative for slow-roll spectra. The advantage of this method is that it gives the higher order corrections and the precise details of power law model. Running Monte-Carlo chains with CosmoMC and generating the plots with Getdist, the tensor to scalar ratio (r) is also analysed. Constraining the cosmological parameters with WKB approximation, an upper limit at $r < 0.1109$ is obtained. Here r is defined at the pivot scale $k_* = 0.05Mpc^{-1}$. We also report the bounds on $r_{0.002}$, the tensor to scalar ratio at $k_* = 0.002Mpc^{-1}$ as $r_{0.002} < 0.1055$ which is consistent with the Planck results within 1σ limits. This work has been done in collaboration with Aiswarya A.

Md. Mehedi Kalam

Analytical model of compact star in low-mass X-ray binary with de Sitter spacetime

Actually, we are trying to give a generalized metric solution (Heintzmann H., 1969, Z. Phys.,**228**, 489) for compact stars. In this work, we have studied the inner structure of compact stars in low-mass X-ray binary by using Heintzmann metric with desitter spacetime, and the outcome results were compared with observed data. We have proposed a stiff equation of state relating pressure with matter density. From our study we have calculated probable radii, compactness (u) and surface red-shift (Zs) of six compact stars in low-mass X-ray binaries namely, Cyg X-2, V395 Carinae/2S 0921-630, XTE J2123-058, X1822-371 (V691 CrA), 4U 1820-30, and GR Mus (XB 1254-690) and the estimated results were compared with the recent observational data. This work has been done in collaboration with Sajahan Moll, Rabiul Islam, amd Md. A. K. Jafry.

Laxman. N. Katkar

Non-static conformally flat spherically symmetric spacetimes in EinsteinCartan theory

By exploiting the null tetrad formalism of Jogia and Griffiths, and the technique of differential forms on a non-Riemannian spacetime, non-static conformally flat, Petrov-type D, spherically symmetric solutions of the EinsteinCartan field equations; when Weyssenhoff fluid is the source of curvature and spin, are obtained. In general, the solution is expanding, accelerating, rotating and non-shearing. However, the dynamic solution is expanding and rotating with zero acceleration and shear; whereas the static solution is accelerating and rotating with expansion free and shear free "congruences". This solution has been obbained in collaboration with D. R. Phadarate.

A static spherically symmetric solution in Einstein-Cartan theory of gravitation

A static spherically symmetric solution of Einstein-Cartan field equations is obtained by using the techniques of differential forms. The solution is proved to be expansion free, shear free and rotating with non zero acceleration. The pressure and density have been influenced by the spin. The solution is algebraically special Petrov-type D. In the absence of spin, the solution reduces to the solution of Prasanna (Phys Rev D **11**:2076 1975). This solution has been obtained in collaboration with D. R. Phadarate.

Ram Kishor

Normalization of Hamiltonian and non-linear stability of triangular equilibrium points in the photogravitational restricted three body problem with P-R drag in non-resonance case

Normal forms of Hamiltonian are very important to analyze the nonlinear stability of a dynamical system in the vicinity of invariant objects. The Hamiltonian of the system is normalized up to fourth order through Lie transform method, and then to apply the Arnold-Moser theorem, Birkhoff normal form of the Hamiltonian is computed followed by nonlinear stability of the equilibrium points is examined. Similar to the case of classical problem, we have found that in the presence of assumed perturbations, there always exists one value of mass parameter within the stability range at which the discriminant D_4 vanishes, consequently, Arnold-Moser theorem fails, which infer that triangular equilibrium points are unstable in non linear sense within the stability range. Present analysis is limited up to linear effect of the perturbations, which will be helpful to study the more generalized problem. This work has been done in collaboration with M. Xavir James Raj, and Bhola Ishwar.

Nagendra Kumar

Fluid dynamical instabilities in magnetized partially ionized dense dusty plasma

We study fluid dynamical instabilities in magnetized partially ionized dense dusty plasma by taking into account relative flow between dust and neutral gas. We consider a magnetized partially ionized dense dusty plasmas whose dynamics are governed by dust and neutral gas components. The electrons dynamics is not considered, as the electrons have no significant influence on the overall behaviour of dusty plasma. The plasma is considered quasi neutral. Following Hurwitz criterion, the onset criteria for instabilities are derived for different densities of the neutral gas, and dust components across the interface. It is found that in case of no significant magnetic field, stabilization occurs not only due to dust neutral gas collisions but due to relative flow also. Our results might be useful in many situations of astrophysical magnetized dusty plasma namely comets and circumsteller dusty disk e.g., T-Tauri stars. This work has been done in collaboration with Anil Kumar, and Vinod Kumar.

Suresh Kumar

Cosmological bounds on dark matter-photon coupling

We investigate an extension of the CDM model, where the dark matter (DM) is coupled to photons, inducing a non conservation of the numbers of particles for both species, where the DM particles are allowed to dilute throughout the cosmic history with a small deviation from the standard evolution decaying into photons, while the associated scattering processes are assumed to be negligible. In addition, we consider the presence of massive neutrinos with the effective number of species $N_{\rm eff}$ as a free parameter. The effects of the DM-photon coupling on the cosmic microwave background (CMB) and matter power spectra are analyzed. We derive

the observational constraints on the model parameters by using the data from CMB, baryonic acoustic oscillation (BAO) measurements, the recently measured new local value of the Hubble constant from the Hubble Space Telescope, and large scale structure (LSS) information from the abundance of galaxy clusters. The DM-photon coupling parameter Γ_γ is constrained to $\Gamma_\gamma \leq 1.3 \times 10^{-5}$ (at 95% C.L.) from the joint analysis carried out by using all the mentioned data sets. The neutrino mass scale $\sum m_\nu$ upper bounds at 95% C.L. are obtained as $\sum m_\nu \sim 0.9$ eV and $\sum m_\nu \sim 0.4$ eV with and without the LSS data, respectively. We observe that the DM-photon coupling cause significant changes in the best fit value of $N_{\rm eff}$ but yields statistical ranges of $N_{\rm eff}$ compatible with the standard predictions, and we do not find any evidence of dark radiation. Due to non conservation of photons in our model, we also evaluate and analyze the effects on the BAO acoustic scale at the drag epoch. The DM-photon coupling model yields high values of Hubble constant, consistent with the local measurement, and thus, alleviates the tension on this parameter. This work has been done in collaboration with Rafael C. Nunes, and Santosh kumar Yadav.

Cosmological implications of scale-independent energy-momentum squared gravity: Pseudo non-minimal interactions in dark matter and relativistic relics

In this work, we introduce a scale-independent energy-momentum squared gravity (EMSG) that allows different gravitational couplings for different types of sources, which may lead to scenarios with many interesting applications/implications in cosmology. We study a modification of the cold dark matter (ΛCDM) model, where photons and baryons couple to the spacetime as in general relativity, while the cold dark matter and relativistic relics (neutrinos and any other relativistic relics) couple to the spacetime in accordance with EMSG. This scenario induces pseudo non minimal interactions on these components, leading to modification at both the background and perturbative levels. A consequence of this scenario is that the dimensionless free parameter of the theory may induce direct changes on the effective number of the relativistic species, without the need to introduce new extra species. In order to quantify the observational consequences of the cosmological scenario, we use the cosmic microwave background Planck data (temperature, polarization, and lensing power spectrum) and baryonic acoustic oscillations data. We find that the free model parameter is too small to induce statistically significant corrections on the ΛCDM model due to EMSG. We deduce that the model presented here is quite rich with promising cosmological applications/implications that deserve further investigations. This work has been done in collaboration with Ozgur Akarsu, Niham Katirchi, Rafael C. Nunes, and M. Sami.

Badam Singh Kushvah

Halo orbit of regularized circular restricted three-body problem with radiation pressure and oblateness

In this work, computation of the halo orbit for the KS-regularized photogravitational circular restricted three-body problem is carried out. This extends the idea of Srivastava et al. (Astrophys. Space Sci. **362**: 49, 2017), which only concentrated on the (i) regularization of the 3D-governing equations of motion, and (ii) validation of the modelling for small out-of-plane amplitude ($A - z = 110.000km$) assuming the third-order analytical approximation as an initial guess with and without differential correction. This motivated us to compute the halo orbits for the large out-of-plane amplitudes and to study their stability analysis for the regularized motion. The stability indices are described as a function of out-of-plane amplitude, mass reduction factor and oblateness coefficient. Three different Sun planet systems: the Sun Earth, Sun Mars and the Sun Jupiter are chosen in this study. Stable halo orbits do not exist around the L_1 point, however, around the L_2 point, stable halo orbits are found for the considered systems. This work has been done in collaboration with Vineet K. Srivastava, Jai Kumar, and Padmdeo Mishra.

Trajectory of asteroid 2017 SB20 within the CRTBP

Regular monitoring the trajectory of asteroids to a future time is a necessity, because the variety of known probably unsafe near-Earth asteroids are increasing. The analysis is performed to avoid any incident or whether they would have a further future threat to the Earth or not. Recently a new Near Earth Asteroid (2017 SB20) has been observed to cross the Earth orbit. In view of this, we obtain the trajectory of asteroid in the circular restricted

three body problem with radiation pressure and oblateness. We examine nature of asteroids orbit with Lyapunov Characteristic Exponents (LCEs) over a finite intervals of time. LCE of the system confirms that the motion of asteroid is chaotic in nature. With the effect of radiation pressure and oblateness the length of the curve varies in both the planes. Oblateness factor is found to be more perturbative than radiation pressure. To see the precision of result obtained from numerical integration, we show that the error propagation and the numerical stability are assured around the singularity by applying regularized equations of motion for precise long-term study. This monitoring work has been done in collaboration with Rishikesh Dutta Tiwary, and Bhola Ishwar.

Smriti Mahajan

The Star Formation Reference Survey - III: A multi wavelength view of star formation in nearby galaxies

We present multi-wavelength global star formation rate (SFR) estimates for 326 galaxies from the Star Formation Reference Survey (SFRS) in order to determine the mutual scatter and range of validity of different indicators. The widely used empirical SFR recipes based on 1.4 GHz continuum, 8.0 μm polycyclic aromatic hydrocarbons (PAH), and a combination of far-infrared (FIR) plus ultraviolet (UV) emission are mutually consistent with scatter of $\lesssim 0.3dex$. The scatter is even smaller, $\lesssim 0.24dex$, in the intermediate luminosity range $9.3 < log(L_{60}\mu m/L_{\odot}) < 10.7$. The data prefer a non-linear relation between 1.4 GHz luminosity and other SFR measures. PAH luminosity underestimates SFR for galaxies with strong UV emission. A bolometric extinction correction to far-ultraviolet luminosity yields SFR within 0.2 dex of the total SFR estimate, but extinction corrections based on UV spectral slope or nuclear Balmer decrement give SFRs that may differ from the total SFR by up to 2 dex. However, for the minority of galaxies with UV luminosity $> 5 \times 10^9 L_{\odot}$ or with implied far-UV extinction < 1 mag, the UV spectral slope gives extinction corrections with 0.22 dex uncertainty. This work has been done in collaboration with M. L. N. Ashby, S. P. Willner, P. Barmby, G. G. Fazio,..., Somak Raychaudhury, et al.

Ultraviolet and optical view of galaxies in the ComasSupercluster

The Coma supercluster (100 h^{-1} Mpc) offers an unprecedented contiguous range of environments in the nearby Universe. In this work, we present a catalogue of spectroscopically confirmed galaxies in the Coma supercluster detected in the ultraviolet (UV) wavebands. We use the arsenal of UV and optical data, covering $\sim$ 500 deg^2 on the sky to study their photometric and spectroscopic properties as a function of environment at various scales. We identify the different components of the cosmic-web: large-scale filaments and voids using Discrete Persistent Structures Extractor, and groups and clusters using Hierarchical Density-based spatial clustering of applications with noise, respectively. We find that in the Coma supercluster, the median emission in Hα inclines, while the $g-r$ and $FUV-NUV$ colours of galaxies become bluer moving further away from the spine of the filaments out to a radius of $\sim$ 1 Mpc. On the other hand, an opposite trend is observed as the distance between the galaxy and centre of the nearest cluster or group decreases. Our analysis supports the hypothesis that properties of galaxies are not just defined by its stellar mass and large-scale density, but also by the environmental processes resulting due to the intrafilament medium, whose role in accelerating galaxy transformations needs to be investigated thoroughly using multiwavelength data. This work has been done in collaboration with Ankit Singh, and Devika Shobhana.

Manzoor A. Malik

Confronting phantom inflation with Planck data

The latest Planck results are in excellent agreement with the theoretical expectations predicted from standard normal inflation based on slow-roll approximation, which assumes equation-of-state $\omega \geq -1$. In this work, we study the phantom inflation ($\omega < -1$) as an alternative cosmological model within the slow-climb approximation using two hybrid inflationary fields. We perform Chain Monte Carlo analysis to determine the posterior distribution and best fit values for the cosmological parameters using Planck data, and show that current CMB data does not discriminate between normal and phantom inflation. Interestingly, unlike in normal inflation, ω in phantom induced inflation evolves very slowly away from -1 during

the inflation. Furthermore, in contrast to the standard normal inflation for which only upper bound on tensor-to-scalar ratio r are possible, we obtain both upper and lower bounds for the two hybrid fields in the phantom scenario. Finally, we discuss prospects of future high precision polarization measurements and show that it may be possible to establish the dominance of one model over the other. This work has been done in collaboration with Asif Iqbal, and Mussadig H. Qureshi.

Variable Stars in M 37

The CCD photometric observations of open star cluster M 37 (NGC 2099) were carried out up to limiting magnitude of $V \sim 20$ in both B and V filters to search for variable stars using $2k \times 4k$ CCD and 1.3m telescope at Vainu Bapu Observatory, Kavalur. A total of 314 stars have been observed in the first observing run, out of which 60 have been identified as variables. Eight out of the identified 60 variables are classified as W UMa binary stars. For model fitting, we used PHOEBE based on W-D code to estimate the physical parameters of these newly detected W UMa binaries that theoretically best match the observed light curves. This work has been done in collaboration with Ajaz Ahmad dar, S. P. Padmakar, and Parvej Saleh.

Soma Mandal

The flux distribution of individual blazars as a key to understand the dynamics of particle acceleration

The observed lognormal flux distributions in the high-energy emission from blazars have been interpreted as being due to variability stemming from non-linear multiplicative processes generated dynamically from the accretion disc. On the other hand, rapid minute scale variations in the flux point to a compact emitting region inside the jet, probably disconnected from the disc. In this work, we show that linear Gaussian variations of the intrinsic particle acceleration or escape time-scales can produce distinct non-Gaussian flux distributions, including lognormal ones. Moreover, the spectral index distributions can provide confirming evidence for the origin of the variability. Thus, modelling of the flux and index distributions can lead to quantitative identification of the micro-physical origin of the variability in these sources. As an example, we model the X-ray flux and index distribution of Mkn 421 obtained from $\sim$ 9 yr of MAXI observations and show that the variability in the X-ray emission is driven by Gaussian fluctuations of the particle acceleration process rather than that of the escape rate. This work has been done in collaboration with Atreyee Sinha, Ruraiya Khatoon, Ranjeev Misra, Surender Sahayaratham, Rupjyoti Gogoi, et al.

Titus K. Mathew

Expansion law from first law of thermodynamics

Padmanabhan, in his paper [arxiv: 1206.4916] has put forth an intriguing idea calling for the modification of Einstein's gravity theory on cosmic scales by arguing the accelerated expansion of the universe being due to the emergence of cosmic space as cosmic time progresses with the expansion being triggered due to the difference in the degrees of freedom on a holographic surface and the one in its emerged bulk. Applying the first law of thermodynamics to the horizon of a Friedmann-Robertson-Walker (FRW) Universe, we obtain the modified expansion law of the universe as proposed by Sheykhi in (n+1) dimensional Einstein gravity, Gauss-Bonnet, and more general Lovelock gravity theories. We also show that the modified versions of the expansion law due to Cai and Yang, et al. in the case of Gauss-Bonnet gravity show a strong implicit correspondance to each other. This work has been done in collaboration with M. Mahith, and P. B. Krishna.

Entropy maximaization in the emergent gravity paradigm

The accelerated expansion of the universe can be interpreted as a quest for satisfying holographic equi partition. It can be expressed by a simple law, $\Delta V = \Delta t\,(N_{surf} - N_{bulk})$, which leads to the standard Friedmann equation. This novel idea suggested by Padmanabhan in the context of general relativity has been generalized by Cai and Yang, et al. to Gauss-Bonnet and Lovelock gravities for a spatially flat universe in different methods. We investigate the consistency of these generalizations with the constraints imposed by the maximum entropy principle. Interestingly, both these generalizations imply entropy maximization even if their basic assumptions are different. Further, we analyze the consistency of Verlinde's emergent gravity with the maximum entropy principle in the cosmological context. Even though the conceptual

formulations are different, these two emergent perspectives of gravity describes a universe, which behaves as an ordinary macroscopic system. In particular, an asymptotically de Sitter universe that proceeds to satisfy holographic equi partition condition $|E| = \frac{1}{2}N_{surf}k_BT$ also evolves to obey Verlinde's relation $Mc^2 = \frac{1}{2}Nk_BT$. Our results provide a thermodynamic basis to the emergent gravity paradigm. This work has been done in collaboration with P. B. Krishna.

Irom Ablu Meitei

Quantum gravity effects on scalar particle tunneling from rotating BTZ black hole

Tunneling of scalar particles across the event horizon of rotating BTZ black hole is investigated using the Generalized Uncertainty Principle to study the corrected Hawking temperature and entropy in the presence of quantum gravity effects. We have determined explicitly the various correction terms in the entropy of rotating BTZ black hole including the logarithmic term of the Bekenstein-Hawking entropy (S_{BH}), the inverse term of S_{BH} and terms with inverse powers of S_{BH}, in terms of properties of the black hole and the emitted particles - mass, energy and angular momentum. In the presence of quantum gravity effects, for the emission of scalar particles, the Hawking radiation and thermodynamics of rotating BTZ black hole are observed to be related to the metric element, hence, to the curvature of spacetime. This work has been done in collaboration with T.Ibungochouba Singh, S.Gayatri Devi, N.Premeshwari Devi, and K.Yugindro Singh.

Quantization of horizon area of Kerr-Newman-de Sitter black hole

Using the adiabatic invariant action, and applying the Bohr-Sommerfeld quantization rule, and first law of black hole thermodynamics, a study of quantization of entropy and horizon area of Kerr-Newman-de Sitter black hole is carried out. The same entropy spectrum is obtained in two different coordinate systems. It is also observed that the spacing of the entropy spectrum is independent of the black hole parameters. Also, the corresponding quantum of horizon area is in agreement with the results of Bekenstein. This work has been done in collaboration with Y. Kenedy Meitei, and T. Ibungochouba Singh.

Bivudutta Mishra

Dynamics of anisotropic dark energy universe embedded in one-directional magnetized fluid

In this work, we have constructed an anisotropic dark energy cosmological model in a two fluid situations such as the usual dark energy and the magnetized fluid. We have assumed that the dark energy pressure to be anisotropic in different spatial directions. In order to develop the mathematical formalism of the model, we have considered the scale factor, as hybrid scale factor which is a combination of both power law and exponential volumetric expansion law. The physical parameters are derived, analysed and found to be in agreement with the observational limits. This work has been done in collaboration with Pratik P. Ray, and S. K. Tripathy.

Anisotropic cosmological reconstruction in $f(R,T)$ gravity

Anisotropic cosmological models are constructed in $f(R,T)$ gravity theory to investigate the dynamics of universe concerning the late time cosmic acceleration. Using a more general and simple approach, the effect of the coupling constant and anisotropy on the cosmic dynamics have been investigated. In this study, it is found that cosmic anisotropy affects substantially the cosmic dynamics. This work has been done in collaboration with Sankarsan Tarai, and S. K. Tripathy.

Sourav Mitra

First study of reionization in the Planck 2015 normalized closed in ΛCDM inflation model

We study reionization in two non-flat ΛCDM inflation models that best fit the Planck 2015 cosmic microwave background anisotropy observations, ignoring or in conjunction with baryon acoustic oscillation distance measurements. We implement a principal component analysis (PCA) to estimate the uncertainties in the reionization history from a joint quasar-CMB dataset. A thorough Markov Chain Monte Carlo analysis is done over the parameter space of PCA modes for both non-flat ΛCDM inflation models as well as the original Planck 2016 tilted, spatially-flat ΛCDM inflation model. Although both flat and non-flat models can closely match the low-redshift ($z \lesssim 6$) observations, we notice a possible tension between high-

redshift ($z \sim 8$) Lymanα emitter data and the non-flat models. This is solely due to the fact that the closed models have a relatively higher reionization optical depth compared to the flat one, which in turn demands more high-redshift ionizing sources and favours an extended reionization starting as early as $z \approx 14$. We conclude that as opposed to flat-cosmology, for the non-flat cosmology models, (i) the escape fraction needs steep redshift evolution and even unrealistically high values at some redshifts, and (ii) most of the physical parameters require to have non-monotonic redshift evolution, especially apparent when Lymanα emitter data is included in the analysis. This work has been done in collaboration with Tirthankar, R. Choudhaury, and Bharat Ratra.

Can SKA Phase 1 go much beyond the LHC in supersymmetry search?

We study the potential of the Square Kilometre Array in the first phase (SKA1) in detecting dark matter annihilation signals from dwarf spheroidals in the form of diffuse radio synchrotron. Taking the minimal supersymmetric standard model as an illustration, we show that it is possible to detect such signals for dark matter masses about an order of magnitude beyond the reach of the Large Hadron Collider, with about 100 hours of observation with the SKA1. This work has been done in collaboration with Arpan Kar, Biswarup Maukhopadhyaya, and Tirthankar R. Choudhury.

Kamakshya Prasad Modak

Two Component Feebly Interacting Massive Particle (FIMP) dark matter

We explore the idea of an alternative candidate for particle dark matter, namely Feebly Interacting Massive Particle (FIMP) in the framework of a two component singlet scalar model. Singlet scalar dark matter has already been demonstrated to be a viable candidate for WIMP (Weakly Interacting Massive Particle) in literature. In the FIMP scenario, dark matter particles are slowly produced via "thermal freeze-in" mechanism in the early Universe, and are never abundant enough to reach thermal equilibrium or to undergo pair annihilation inside the Universe's plasma due to their extremely small couplings. We demonstrate that for smaller couplings too, required for freeze-in process, a two component scalar dark matter model considered here could well be a viable candidate for FIMP. In this scenario, the Standard Model of particle physics is extended by two gauge singlet real scalars whose stability is protected by an unbroken $Z_2 \times Z_2'$ symmetry and they are assumed to acquire no VEV after Spontaneous Symmetry Breaking. We explore the viable mass regions in the present model that is in accordance with the FIMP scenario. We also explore the upper limits of masses of the two components from the consideration of their self interactions. This work has been done in collaboration with Madhurima Pandey, and Debasish Majumdar.

Neutron star cooling via axion emission by nucleon-nucleon axion bremsstrahlung

Neutron stars generally cools off by the emission of gamma rays and neutrinos. But axions can also be produced inside a neutron star by the process of nucleon-nucleon axion bremsstrahlung. The escape of these axions adds to the cooling process of neutron star. We explore the nature of cooling of neutron stars including the axion emission, and compare our result with the scenario when the neutron star is cooled by only the emission of gamma rays and neutrinos. In our calculations we consider both the degenerate and non-degenerate limits for such axion energy loss rate, and the resulting variation of luminosity with time and variation of surface temperature with time of the neutron star. In short, the thermal evolution of a neutron star is studied with three neutron star masses (1.0, 1.4, and 1.8 solar masses), and by including the effect of axion emission for different axion masses ($m_a = 10^{-5}, 10^{-3}, \text{and} 10^{-2}$eV), and compared with the same when the axion emission is not considered. We compared theoretical cooling curve with the observational data of three pulsars PSR B0656+14, Geminga, and PSR B1055-52, and finally give an upper bound on axion mass limits $m_a \leq 10^{-3}$ eV, which implies that the axion decay constant $f_a \geq 0.6 \times 10^{10}$ GeV. This work has been done in collaboration with Avik Paul, and Debasish Majumdar.

Saptarshi Mondal

Unsupervised classification of galaxies. I. ICA feature selection

In this series of works, an objective classification of 362,923 galaxies from the Value Added Galaxy

Catalogue (VAGC) is carried out with the help of two methods of multivariate analysis. First, Independent Component Analysis (ICA) is used to determine a set of derived independent components that are linear combinations of 47 observed features (viz. ionized lines, Lick indices, photometric and morphological properties, star formation rates, etc.) of the galaxies. Subsequently, a K-means cluster analysis is applied on the nine independent components to obtain ten distinct and homogeneous groups. It appears that the nine independent Components represent a complete physical description of galaxies (velocity dispersion, ionisation, metallicity, surface brightness, and structure). We find that ten groups can be essentially placed into traditional and empirical classes (from colour-magnitude and emission-line diagnostic diagrams, early- vs late-types) despite the classical corresponding features (colour, line ratios and morphology) being not significantly correlated with the nine independent components. The classification has been done in collaboration with Tanuka Chattopadhyay, and with Tanuka Chattopadhyay, and D. Fraix-Burnel.

Soumen Mondal

Spectral properties of the accretion discs around rotating black holes.

We study the radiation properties of an accretion disc around a rotating black hole. We solve the hydrodynamic equations, and calculate the transonic solutions of accretion disc in the presence of shocks. Then we use these solutions to generate the radiation spectrum in the presence of radiative heating and cooling processes. We present the effect of spin parameter of the black hole on the emitted radiation spectrum. In addition, attention has also been paid to the variation in energy spectral index with Kerr parameter and accretion rate. We find that spectral index becomes harder as the spin parameter changes from negative (accretion disc is counter-rotating with respect to the black hole spin) to a positive value. Finally, we compute and compare the spectral characteristics due to a free-fall flow and a transonic flow. We notice significant differences in high energy contributions from these two solutions. The classification has been done in collaboration with Samir Mandal.

A pseudo-Newtonian approach to study the accretion processes around Kerr black holes

A number of ways the potentials are proposed simply to avoid the complexity of the general relativistic (GR) framework. The constraints and limitations, success and failure, have also been addressed. We find that the pseudo-Kerr potential in Mondal and Chakrabarti (MNRAS, **371**:1418, 2006) is one of the best for GR predictions. Using this pseudo-Kerr potential, the particle dynamics and the accretion flow hydrodynamics have also been carried out. The results are compared with the GR and percentage of accuracy are also presented briefly.

Pradip Mukherjee

Galilean gauge theory from Poincare gauge theory

A shift-symmetric Galileon model in presence of spacetime torsion has been constructed for the first time. This has been realized by localizing (or, gauging) the Galileon symmetry in flat spacetime in an appropriate manner. We have applied the above model to study the evolution of the universe at a cosmological scale. Interestingly, for a wide class of torsional structures, we have shown that the model leads to late time cosmic acceleration. Furthermore, as torsion vanishes, our model reproduces the standard results. The classification has been done in collaboration with Rabin Banerjee.

Constrained Hamiltonian analysis of a non relativistic Schrodinger field copuled with C-S gravity

We provide a constrained Hamiltonian analysis of a non relativistic Schrodinger field in 2+1 dimensions, coupled with Chern - Simons gravity. The coupling is achieved by the recently advanced Galilean gauge theory. The calculations are repeated with a truncated model to show that deviation from Galilean gauge theory makes the theory untenable. The issue of non relativistic spatial diffeomorphism is discussed in this context. The classification has been done in collaboration with Abdus Sattar.

Hemwati Nandan and Rashmi Uniyal

Bending angle of light in equatorial plane of Kerr-Sen black hole

We study the gravitational lensing by a Kerr-Sen black hole arising in heterotic string theory. A

closed form expression for the bending angle of light in equatorial plane of Kerr-Sen black hole is derived as a function of impact parameter, spin and charge of the black hole. Results obtained are also compared with the corresponding cases of Kerr black hole in general relativity. It is observed that charge parameter behaves qualitatively similar as the spin parameter for photons travelling in direct orbits while behaves differently for photons in retrograde orbits around black hole. As the numerical value of the black hole charge increases, bending angle becomes larger in strong field limit. Further, it is observed that this effect is more pronounced in case of direct orbits in comparison to the retro orbits. For both the direct and retro motion, the bending angle exceeds 2π, which in turn results in multiple loops and formation of relativistic images. This study has been done in collaboration with Philippe Jetzer.

Hemwati Nandan and Uma Papnoi

Strong lensing and observables around 5D Myers-Perry black hole spacetime

We study the motion of massless test particles in a five dimensional (5D) Myers-Perry black hole spacetime with two spin parameters. The behaviour of the effective potential in view of different values of black hole parameters is discussed in the equatorial plane. The frequency shift of photons is calculated which is found to depend on the spin parameter of black hole and the observed redshift is discussed accordingly. The deflection angle and the strong deflection limit coefficients are also calculated, and their behaviour with the spin parameters is analysed in detail. It is observed that the behaviour of both deflection angle and strong field coefficient differr from Kerr black hole spacetime in four dimensions (4D) in general relativity (GR), which is mainly due to the presence of two spin parameters in higher dimension. This study has been done in collaboration with Ravi S. Kuniyal, Rashmi Uniyal, and K. D. Purohit.

Dibyendu Nandi

Prediction of the strength and timing of sunspot cycle 25 reveal decadal-scale space environmental conditions

The Sun's activity cycle governs the radiation, particle, and magnetic flux in the heliosphere creating hazardous space weather. Decadal-scale variations define space climate and force the Earth's atmosphere. However, predicting the solar cycle is challenging. Current understanding indicates a short window for prediction best achieved at previous cycle minima. Utilizing magnetic field evolution models for the Sun's surface and interior, we perform the first century-scale, data-driven simulations of solar activity and present a scheme for extending the prediction window to a decade. Our ensemble forecast indicates cycle 25 would be similar or slightly stronger than the current cycle and peak around 2024. Sunspot cycle 25 may, thus, reverse the substantial weakening trend in solar activity, which has led to speculation of an imminent Maunder-like grand minimum and cooling global climate. Our simulations demonstrate fluctuation in the tilt angle distribution of sunspots, which is the dominant mechanism responsible for solar cycle variability.This study has been done in collaboration with Prantika Bhowmik.

The association of filaments, polarity inversion lines, and coronal hole properties with the sunspot cycle: An analysis of the McIntosh database

We study the properties of filaments, PILs, and coronal holes in solar cycles 20, 21, 22, and 23 utilizing the McIntosh archive. We detect a prominent cyclic behaviour of filament length, PIL length, and coronal hole area with significant correspondence with the solar magnetic cycle. The spatio-temporal evolution of the geometric centers of filaments shows a butterfly-like structure and distinguishable poleward migration of long filaments during cycle maxima. We identify this rush to the poles of filaments to be co-temporal with the initiation of polar field reversal as gleaned from Mount Wilson and Wilcox Solar Observatory polar field observations, and quantitatively establish their temporal correspondence. We analyze the filament tilt angle distribution to constrain their possible origins. The majority of the filaments exhibit negative and positive tilt angles in the northern and the southern hemispheres, respectively, strongly suggesting that their formation is governed by the overall large-scale magnetic field distribution on the solar photosphere, and not by the small-scale intra-active region magnetic field configurations. We also investigate the hemispheric asymmetry in filaments, PILs, and coronal holes. We find that the hemispheric asymmetry in filaments and PILs is

positively correlated with sunspot area asymmetry, whereas coronal hole asymmetry is uncorrelated. This study has been done in collaboration with Prantika Bhowmik.

Barun Kumar Pal

Mutated hilltop inflation revisited

Applying Hamilton-Jacobi formalism, we solve inflationary dynamics and find that inflation goes on along the $\mathcal{W}_{-1}$ branch of the Lambert function. Depending on the model parameter, mutated hilltop model renders two types of inflationary solutions: one corresponds to small inflaton excursion during observable inflation and the other describes large field inflation. The inflationary observables from curvature perturbation are in tune with the current data for a wide range of the model parameter. The small field branch predicts negligible amount of tensor to scalar ratio $r \sim \mathcal{O}(10^{-4})$, while the large field sector is capable of generating high amplitude for tensor perturbations, $r \sim \mathcal{O}(10^{-1})$. Also, the spectral index is almost independent of the model parameter along with a very small negative amount of scalar running. Finally, we find that the mutated hilltop inflation closely resembles the α-attractor class of inflationary models in the limit of $\alpha\phi \gg 1$.

Gravitationally influenced particle creation models and late-time cosmic acceleration

In this work we focus on the gravitationally influenced adiabatic particle creation process, a mechanism that does not need any dark energy or modified gravity models to explain the current accelerating phase of the universe. Introducing some particle creation models that generalize some previous models in the literature, we constrain the cosmological scenarios using the latest compilation of the yype Ia supernovae data only, the first indicator of the accelerating universe. Aside from the observational constraints on the models, we examine the models using two model independent diagnoses, namely the cosmography and Om. Further, we establish the general conditions to test the thermodynamic viabilities of any particle creation model. Our analysis shows that at late-time, the models have close resemblance to that of the ΛCDM cosmology, and the models always satisfy the generalized second law of thermodynamics under certain conditions. This study has been done in collaboration with Supriyapan, and souvik Pramanik.

Biswajit Pandey

A new method to probe the mass density and the cosmological constant using configuration entropy

We study the evolution of the configuration entropy for different combinations of Ω_{m0} and $\Omega_{\Lambda 0}$ in the flat ΛCDM universe, and find that the cosmological constant plays a decisive role in controlling the dissipation of the configuration entropy, which dissipates at a slower rate in the models with higher value of $\Omega_{\Lambda 0}$. We find that the entropy rate decays to reach a minimum and then increases with time. The minimum entropy rate occurs at an earlier time for higher value of $\Omega_{\Lambda 0}$. We identify a prominent peak in the derivative of the entropy rate, whose location closely coincides with the scale factor corresponding to the transition from matter to Λ domination. We find that the peak location is insensitive to the initial conditions and only depends on the values of Ω_{m0} and $\Omega_{\Lambda 0}$. We propose that measuring the evolution of the configuration entropy in the universe and identifying the location of the peak in its second derivative would provide a new and robust method to probe the mass density and the cosmological constant. This study has been done in collaboration with Supriyapan, and Biswajit Das.

Configuration entropy of the Cosmic Web: Can voids mimic the dark energy?

We propose an alternative physical mechanism to explain the observed accelerated expansion of the universe based on the configuration entropy of the cosmic web and its evolution. We show that the sheets, filaments, and clusters in the cosmic web act as sinks, whereas the voids act as the sources of information. The differential entropy of the cosmic velocity field increases with time and also act as a source of entropy. The growth of non-linear structures and the emergence of the cosmic web may lead to a situation, where the overall dissipation rate of information at the sinks are about to dominate the generation rate of information from the sources. Consequently, the universe either requires a dispersal of the overdense non-linear structures or an accelerated expansion of the underdense voids to prevent a violation of the second law of thermodynamics. The dispersal of the sheets, filaments, and

clusters are not a viable option due to the attractive nature of gravity, but the repulsive and outward peculiar gravitational acceleration at the voids makes it easier to stretch them at an accelerated rate. We argue that this accelerated expansion of the voids inside the cosmic web may mimic the behaviour of dark energy.

Mahadev B. Pandge

A combined X-ray, optical and radio view of the merging galaxy cluster MACS J0417.5-1154

We present a comprehensive multi-wavelength analysis of the merging galaxy cluster MACS J0417.5-1154 at a redshift of $z = 0.44$, using available images red obtained with *Chandra* in X-ray, *Subaru*, *Hubble Space Telescope* (HST) in optical, *Giant Metrewave Radio Telescope* (GMRT) in radio and *Bolocam* at 2.1 mm wavelength. This is an example of a complex merging galaxy cluster, also hosting a steep-spectrum Mpc scale radio halo. The mass distribution obtained by weak lensing reconstruction shows that MACS J0417.5-1154 belongs to the dissociative class of mergers, where one of its sub structures has had its gas content detached after the pericentric passage. The overall structure, surface brightness profile, temperature, and metal abundance of the intra-cluster medium (ICM) all point towards the presence of a cold front and merger induced gas-sloshing motion near the core. We detect a surface brightness edge to the south−east direction at a projected distance of ∼45 arcsec (∼255 kpc) from the centre of this cluster. The X-ray spectral analysis across the inner and outer edge allows us to confirm the detected edge as a cold front. The GMRT 235 MHz observation shows a comet−like extended sychrotron radio halo emission trailing behind the cold front. The peak of the Sunyaev-Zel'dovich decrement is found displaced from the centre of X-ray emission, which is interpreted as consequence of the merger dynamics. The optical HST imaging analysis of the cluster reveals the complex morphology of the BCG, with three surrounding ring-shaped structures with bright knots, which appear to be images of a multiply-imaged strongly lensed background galaxy. In addition two previously unknown giant arcs are found, which are all indications of strong gravitational lensing in this massive system. This study has been done in collaboration with Rogrio Monteiro de Oliveira, Joydeep Bagchi, A. Simionescu, Marceau Limousin, and Somak Raychaudhury.

AGN Feedback in galaxy groups: A detailed study of X-ray features and diffuse radio emission in IC1262

We report a systematic search of X-ray cavities, density jumps, and shocks in the inter-galactic environment of the galaxy group IC 1262 using *Chandra*, GMRT and VLA archival observations. The X-ray imaging analysis reveals a pair of X-ray cavities on the north and south of the X-ray peak, at projected distances of 6.48 kpc and 6.30 kpc respectively. Total mechanical power contained in both these cavities is found to be $\sim 12.37 \times 10^{42}$ erg s^{-1}, and compares well with the X-ray luminosity, within the cooling radius, measured to be $\sim 3.29 \times 10^{42}$ erg s^{-1}, suggesting that the mechanical power injected by the central AGN efficiently balances the radiative loss. We detect a previously unknown X-ray cavity at the position of southern radio lobe in the intra-group medium, and find a loop of excess X-ray emission extending ∼100 kpc southwest from the central galaxy. The X-ray cavity at the position of southern radio lobe probably represents a first generation X-ray cavity. Two surface brightness edges are evident to the west and east−north of the centre of this group. The radio galaxy at the core of the IC 1262 group is a rare low-redshift ultra-steep radio galaxy, its spectral index being $\alpha \sim -1.73$ (including the central AGN), and $\alpha \sim -2.08$ (excluding the central AGN). We detect a radio phoenix embedded within the southern radio lobe, for the first time in a poor group, with a spectral index ($\alpha \leq -1.92$). The spectral index distribution across the phoenix steepens with increasing distance from its intensity peak. This study has been done in collaboration with S. S. Sonkamble, Viral Parekh, Pratik Dabhade, Avni Parmar, M. K. Patil, and Somak Raychaudhury.

Amit Pathak

DFT study of five-membered ring PAHs

This work reports a Density Functional Theory (DFT) calculation of PAH molecules with a five-member ring to determine the expected region of infrared features. It is highly possible that fullerene molecule might be originated from five-membered ring PAH molecules in the ISM. Effect of ionization and protonation on five-membered ring PAH molecule is also discussed. A detail vibrational

analysis of five-membered ring PAH molecule has been reported to further compare with observations and to identify any observational counterpart. This study has been done in collaboration with G. Devi, and M. Buragohain.

Modelling 30 Doradus in the Large Magellanic Cloud

The HII regions in the Large Magellanic Cloud (LMC) provide an ideal laboratory to study various processes of dust formation and evolution. The LMC has been targeted by many space-based telescopes, including NASAs Spitzer Space Telescope, and more recently, JAXAs AKARI satellite owing to its known distance and nearly face-on orientation with respect to the Miky Way (MW). The highest LMC reddening occurs in the 30 Doradus HII region, where the colour excess E_{B-V} reaches a maximum of 0.29. We have done correlation studies in this region between far-ultraviolet (FUV) observations made by the FUSE telescope, and infrared (IR) observations made by AKARI in the recent past. We have attempted to model the FUV scattering by 20 hot stars in the 30 Doradus region within a 1 deg radius. We have chosen an ideal dust distribution facilitating us to study the emission properties around the centre of the nebula. This study has been done in collaboration with Gautam Saikia, Jaikhomba Singha, P. Shalima, and Rupjyoti Gogoi.

Madhav K. Patil

Merging cold front and AGN feedback in the peculiar galaxy cluster Abell 2626

We present the analysis of combined 134 ks Chandra data of a peculiar galaxy cluster Abell 2626. This study confirms the earlier detection of the east cavity at 13 kpc and reports the detection of a new cavity at ∼39 kpc to the west of the X-ray peak. The average mechanical power injected by the active galactic nucleus outburst $P_{cav} \sim 6.6 \times 10^{44}$ erg/s is ∼29 times more than required to compensate the cooling luminosity $L_{cool} = 2.30 \pm 0.02 \times 10^{43}$ erg/s. The edges in the surface brightness (SB) to the west and south-west at ∼ 36 kpc and 33 kpc, respectively, have gas compressions of 1.57 ± 0.08 and 2.06 ± 0.44, and are spatially associated with the arcs in temperature and metallicity maps due to the merging cold fronts. A systematic study of the nuclear sources exhibited dramatic changes over the span of 10 years. The NE source that emitted mostly in the soft band in the past had disappeared in recent observations. Instead, an excess emission was seen at 2.2 arcsec to its west that required an unrealistic line-of-sight velocity of ∼ 675 $\times c$ if it is due to its movement. The count rate analysis and spectral analysis exhibited a change in the state of the SW source from a soft to a hard state due to the change in the mass accretion rate. No such spectral change was noticed for the NE source. This study has been done in collaboration with S. K. Kadam, S. S. Sonkamble, and P. K. Pawar.

Cavities, shocks and a cold front around 3C 320

We present results obtained from the analysis of a total of 110 ks of Chandra observations of the FanaroffRiley class II (FR II) radio galaxy 3C 320, located at the centre of a cluster of galaxies at redshift z = 0.342. A pair of X-ray cavities has been detected at an average distance of ∼38 kpc along the east and west directions, with cavity energy, age, and total power equal to $\sim 7.7 \times 10^{59}$ erg, $\sim 7 \times 10^{7}$ yr and $\sim 3.5 \times 10^{44}$ erg/s, respectively. The cooling luminosity within the cooling radius of 100 kpc was found to be $L_{cool} \sim 8.5 \times 10^{43}$ erg/s. Comparison of these two estimates (total cavity power and cooling luminosity) implies that the cavity power is sufficiently high to balance radiative loss. A pair of weak shocks has also been detected at distances of 47 and 76 kpc surrounding the radio bubbles. Using the observed density jumps of 1.8 and 2.1 at the shock locations along the east and west directions, we estimate the Mach numbers to be ∼1.6 and ∼1.8, respectively. A sharp surface-brightness edge was also detected at a relatively larger radius (∼80 kpc) along the south direction. The density jump at this surface-brightness edge was estimated to be ∼1.6 and it is probably due to the presence of a cold front in this cluster. The far-infrared luminosity yielded a star formation rate of 51 $M_\odot$ yr^{-1}, which is a quarter of the cooling rate ∼192 $M_\odot yr^{-1}$. This study has been done in collaboration with Nilkant D. Vagshethe, and Sachidra Naik.

Bikash Chandra Paul

Emergent Universe with wormhole in massive gravity?

Emergent Universe (EU) is obtained in the Einstein gravity with non-linear equation of state in

a flat universe. It is shown that a universe with non-linear EoS is effectively a cosmological model with a composition of three different fluids. In the original model, one of the drawbacks is that the components of the fluids are fixed for a definite EoS parameter. Subsequently , considering interactions among the fluids it is found that a viable cosmological scenario can be obtained. In the presence of interactions among the fluids, which are permitted by the EoS, it is found to accommodate realistic cosmological models in accordance with observations. It has also been shown that the initial static Einstein phase required in the EU model is permitted with a dynamical wormhole in the framework of massive gravity This study has been done in collaboration with A. S. Majumdar.

Relativistic star in higher dimensions with Finch - Skea geometry

Relativistic solutions of compact objects in hydrodynamical equilibrium with Finch - Skea (FS) metric are obtained in higher dimensions. They are studied to obtain seller models for compact stars in the usual four and in higher dimensions. We study variation of different physical parameters inside the star. Considering the known stars, we obtain stellar models. It is noted that a compact star in 4 - dimensions with Finch - Skea geometry always admits a star with isotropic pressure, however in higher dimensions it always admits anisotropic star. The plausibility of such stars are, also studied here. This study has been done in collaboration with Sagar Dey.

Ninan Sajeeth Philip

Machine learning applications in the time domain astronomy

The Catalina Real Time Transient (CRTS) survey is followed by the ZTF survey, which itself is to be the forerunner of some of the major time domain astronomy surveys that are planned for the coming decade. We study on using deep learning tools to automatically detect and follow up transient events in these surveys. Currently, we work on a method developed by Ashish Mahabal et al., at Caltech, where they converted light curves obtained from CRTS northern periodic variables to images using a two dimensional mapping called dmdt maps. This allows us to work with images that are more stable than the dynamic fluctuations usually observed in their lightcurves. It was noted that instead of training the classifier on the entire data of 17 classes, if we do a binary classification of one against all the rest in rotation, the accuracy in prediction becomes more reliable. The reason for this is the imbalance in the class distributions that biases the classifier, that just try to minimise the error, towards the objects that have higher representation in the dataset. It was observed that the binary classification could improve the prediction accuracy of 53% in 17 classes to the order of 97% and above when addressed as a binary problem of one against all in rotation. This study has been done in collaboration with G. Sindhu, and Linn Abraham.

Application of machine learning in biosciences (ABCD portal)

The Astronomy Biology Combined Data ABCD portal is a joint research programme, funded by NKN for porting some of the tools developed by astronomers to benefit the bioscience community. Species diversity is one of the key parameters biologists use to understand the health of any ecosystem. We could develop a prototype machine learning tool for the automated detection and identification of different freshwater fish from video footings taken with underwater surveillance cameras. The tool could also select and track individual fish with appropriate tracking for their behavioural studies. When working with underwater surveillance video footings, background objects create a lot of uncertainties in the automated classification of the species. We have developed a tool to do automated background subtraction from video footings by considering frame differences much like what astronomers do for sky subtraction. This study has been done in collaboration with Geetha Paul, Blesson George, and Linn Abraham.

Anirudh Pradhan

Diagnosing Tsallis holographic dark energy models with statefinder and $\omega - \omega^{'}$ pair

A useful method, known as statefinder diagnostic, which may differentiate one dark energy model from others is applied in this work to a holographic dark energy model from Tsallis entropy, called the Tsallis holographic dark energy (THDE) model. The evolutionary trajectories are plotted

in the statefinder parameter - planes and $\omega - \omega'$ plane, and it is observed that the parameter δ plays a magnificent role from the statefinder and $\omega - \omega'$ plane viewpoints. Eventually, the evolutionary trajectories are plotted considering two different values of THDE energy density (Ω_T^0), $\Omega_T^0 = 0.69$, in the light of Planck 2018 results VI base-LCDM cosmology and $\Omega_T^0 = 0.73$, in the light of $SNe{+}BAO{+}OHD{+}CMB$ observation data. This study has been done in collaboration with Umesh Kumar Sharma.

Anisotropic compact stars in the Buchdahl models: A comprehensive study

In this work, we present a class of relativistic solutions describing spherically symmetric and static anisotropic stars in hydrostatic equilibrium. For this purpose, we consider a particularized metric potential, namely, Buchdahl ansatz [Ph.Rv.D. **116**, 1027 (1959)], which encompasses almost all the known analytic solution to the spherically symmetric, static Einstein equations with a perfect fluid source, including in particular the Vaidya-Tikekar and Finch-Skea. We have developed the model by considering anisotropic spherically symmetric static general relativistic configuration that plays a significant effect on the structure and properties of stellar objects. We have considered eight different cases for generalized Buchdahl dimensionless parameter K, and analyzed them in an uniform manner. As a result, it turns out that all the considered cases are valid at every point in the interior spacetime. In addition to this, we show that the model satisfies all the energy conditions and maintain hydrostatic equilibrium equation. In the frame work of anisotropic hypothesis, we consider analogue objects with similar mass and radii such as LMC X-4, SMC X-1, EXO 1785-248, *etc.*, to restrict the model parameter arbitrariness. Also, establishing a relation between pressure and density in the form of $P = P(\rho)$, we demonstrate that EoSs can be approximated to a linear function of density. Despite the simplicity of this model, results are satisfactory. This study has been done in collaboration with S. K. Maurya, Ayan Banerjee, M. K. Jasim, J. Kumar, and A. K. Prasad.

Farook Rahaman

Anisotropic strange stars under simplest minimal matter-geometry coupling in the $f(R, \mathcal{T})$ gravity

We study strange stars in the framework of $f(R, \mathcal{T})$ theory of gravity. To provide exact solutions of the field equations it is considered that the gravitational Lagrangian can be expressed as the linear function of the Ricci scalar R and the trace of the stress-energy tensor $\mathcal{T}$, i.e. $f(R, \mathcal{T}) = R + 2\chi\mathcal{T}$, where χ is a constant. We also consider that the strange quark matter (SQM) distribution inside the stellar system is governed by the phenomenological MIT Bag model equation of state (EoS), given as $p_r = \frac{1}{3}(\rho - 4B)$, where B is the Bag constant. Further, for a specific value of B and observed values of the strange star candidates we obtain the exact solution of the modified Tolman-Oppenheimer-Volkoff (TOV) equation in the framework of $f(R, \mathcal{T})$ gravity, and have studied in detail the dependence of the different physical parameters, like the metric potentials, energy density, radial and tangential pressures, anisotropy, etc., due to the chosen different values of χ, also we find maximum anisotropy at the surface which seems an inherent property of the strange stars in modified $f(R, \mathcal{T})$ theory of gravity. To check the physical acceptability and stability of the stellar system based on the obtained solutions we have performed different physical tests, viz., the energy conditions, Herrera cracking concept, adiabatic index, etc., we also have explained the effects, those are arising due to the interaction between the matter and the curvature terms in $f(R, \mathcal{T})$ gravity, on the anisotropic compact stellar system. The present study reveals that the modified $f(R, \mathcal{T})$ gravity is a suitable theory to explain massive stellar systems like recent magnetars, massive pulsars and super-Chandrasekhar stars, which can not be explained in the framework of GR. However, for $\chi = 0$ the standard results of Einsteinian gravity are retrieved. This study has been done in collaboration with Debabrata deb, B. K. Guha, and Saibal Ray.

Solar system tests in constraining parameters of dyon black holes

We examine the possibility of constraining dyon black holes based on the available observational data at the scale of the solar system. For this, we consider the classical tests of general relativity,

viz., the perihelion precession of the planet Mercury and the deflection of light by the Sun. In connection to mathematical analysis, we consider static and spherically symmetric dyon black hole, which carries both the electric and magnetic charge simultaneously, which are encoded it by the parameters λ_0 and β_0. We constrain these two parameters using the solar system tests and obtain the permissible range from theoretical analysis based on our model, and later on compare them with the available observational data. This study has been done in collaboration with Sabiruddin Molla, Amna Ali, and Saibal Ray.

Shantanu Rastogi

Radiative transfer modelling of atmospheric CH4 for satellite measurements in the 1.66 μ m spectral window

Atmospheric methane is the second most important greenhouse gas after carbon dioxide and has significant impact on the atmosphere and climate. Continuous estimation and prediction of atmospheric CH4 concentrations is important for understanding the associated global climate change. To constrain suitable spectral window and detector resolutions for satellite instruments, spectral simulations have been performed considering tropical atmospheric conditions. The study is focused on the 1.66 micron spectral region having CH4 bands that are suitable for its detection and estimation. Both CH4 concentration and spectral resolution are varied to identify optimum spectral resolution limit. The R branch peak at 1.6456$\sim$ μm is found to be the most sensitive and suitable for CH4 estimation. A concentration retrieval scheme is proposed, and it is interpreted that the spectral resolution should not be worse than 0.2 nm. This study has been done in collaboration with P. Prasad, and R. P. Singh.

C.D. Ravikumar

Establishing the spectral turnover of blazar PKS 2155-304 as an outcome of radiative losses

Synchrotron emission from high energy electrons following a broken power-law distribution is usually held responsible for the observed broad-band optical/UV and X-ray spectra of blazars. However, one of the long outstanding problems has been that the observed spectral index change is significantly different from the expected 0.5. Recent, high-quality observations of blazars suggest that their local spectra may not be a power law, but may contain a slight curvature that can be represented by a log-parabola model. We study *XMM-Newton* observations spanning over 12 yr for the BL Lac PKS 2155-304, and show that the optical/UV and X-ray spectra can be well represented by a broken log-parabola model. Further, such a spectrum can indicate the energy dependence of the electron escape time-scale from the main acceleration zone. This novel approach, besides addressing the observed difference in the photon spectral indices, also attempts to explain the spectral turn over in far-UV/soft X-rays as a result of the radiative losses. This study has been done in collaboration with Sitha K. Jagan, Sunder Sahayanthan, Ranjeev Misra, and K. Jena.

Search for anomalous alignments of structures in Planck data using Minkowski Tensors

Minkowski Tensors are tensorial generalizations of the scalar Minkowski Functionals designed to contain additional information of structures, like shape and alignment. We calculate Minkowski Tensors using temperature data from the Planck satellite, directly on the sphere and compute the net alignment in the data, extending the definition of Minkowski Tensors to random fields on curved spaces. This novel method circumvents numerical errors that can be introduced by the stereographic projection. We compare the resulting net alignment parameter values obtained from the frequency coadded CMB temperature data, to those obtained from ΛCDM simulations of the CMB temperature sky with instrumental beam effects and residual foreground and noise. The results show very good agreement between the two within $\approx 1\sigma$. We further compare the alignments obtained from the beam-convolved CMB maps at individual Planck frequencies to those in the corresponding simulations. There is significant difference between observed data and simulations across all Planck frequencies, except for the 30 GHz channel. For the 30 GHz channel, we find $\approx 2\sigma$ difference between the data and the simulations, which could originate from inaccuracies involved in the estimation of the instrumental beam at 30 GHz. This study has been done in collaboration with P. K. Joby, Pravabati.

Saibal Ray

Anisotropic strange stars in Tolman-Kuchowicz spacetime

We attempt to study a singularity-free model for the spherically symmetric anisotropic strange stars under Einstein's general theory of relativity by exploiting the Tolman-Kuchowicz metric. Further, We have assumed that the cosmological constant Λ is a scalar variable dependent on the spatial coordinate r. To describe the strange star candidates, we have considered that they are made of strange quark matter (SQM) distribution, which is assumed to be governed by the MIT Bag equation of state. To obtain unknown constants of the stellar system, we match the interior Tolman-Kuchowicz metric to the exterior modified Schwarzschild metric with the cosmological constant, at the surface of the system. We have predicted the exact values of the radii for different strange star candidates based on the observed values of the masses of the stellar objects and the chosen parametric values of the Λ as well as the Bag constant $\mathcal{B}$. The set of solutions satisfies all the physical requirements to represent strange stars. Interestingly, the study reveals that as the values of the Λ and $\mathcal{B}$ increase the anisotropic system become gradually smaller in size turning the whole system into a more compact ultra-dense stellar object. This study has been done in collaboration with M. K. Jasim, debabrata Deb, Y. K. Gupta, and Sourav Ray Chowdhary.

Exploring physical features of anisotropic strange stars beyond standard maximum mass limit in $f(R,\mathcal{T})$ gravity

We have a specific model of anisotropic strange stars in the modified $f(R,\mathcal{T})$-type gravity by deriving solutions to the modified Einstein field equations representing a spherically symmetric anisotropic stellar object. We take a standard assumption that $f(R,\mathcal{T}) = R+2\chi\mathcal{T}$, where R is Ricci scalar, $\mathcal{T}$ is the trace of the energy-momentum tensor of matter, and χ is a coupling constant. We successfully apply the 'embedding class 1' techniques, and also consider the case when the strange quark matter (SQM) distribution is governed by the simplified MIT Bag model equation of state given by, $p_r = \frac{1}{3}(\rho - 4B)$, where B is the Bag constant. The radius of the strange star candidates by directly solving the modified TOV equation with the observed values of the mass and some parametric values of B and χ has been obtained. The physical acceptability of this solutions is verified by performing several physical tests. Interestingly, besides the SQM, another type of matter distribution originates due to the effect of coupling between the matter and curvature terms in the $f(R,\mathcal{T})$ gravity theory. This study shows that with decreasing the value of χ, the stellar systems under investigations become gradually massive and larger in size, turning them into less dense compact objects. It also reveals that for $\chi < 0$, the $f(R,\mathcal{T})$ gravity emerges as a suitable theory for explaining the observed massive stellar objects like massive pulsars, super-Chandrasekhar stars, and magnetars, etc., which remain obscure in the standard framework of general relativity (GR). This study has been done in collaboration with Debabrata Deb, Sergei V. Ketov, S. K. Maurya, and Maxim Khlopov, and P. H. R. S. Moraes.

Biplab Raychaudhuri

Study of the reflection spectrum of the bright atoll source GX 3+1 with NuSTAR

We report on the NuSTAR observation of the atoll type neutron star (NS) low-mass X-ray binary GX 3+1 performed on 17 October 2017. The source was found in a soft X-ray spectral state with 370keV luminosity of $LX \sim 3 \times 10^{37} ergss^{1}$($\sim$ 16% of the Eddington luminosity), assuming a distance of 6 kpc. A positive correlation between intensity and hardness ratio suggests that the source was in the banana branch during this observation. The broadband 370 keV NuSTAR spectral data can be described by a two-component continuum model consisting of a disk blackbody ($kT_{\rm disc} \sim 1.8keV$) and a single temperature blackbody model ($kT_{\rm bb} \sim 2.7keV$). The spectrum shows a clear and robust indication of relativistic reflection from the inner disc which is modelled with a self-consistent relativistic reflection model. The accretion disc is viewed at an inclination of $i \simeq 22^{0}26^{0}$ and extended close to the NS, down to $R_{in} = (1.2-1.8)R_{\rm ISCO}(\simeq 6.19.1Rg$ or 1420.5 km), which allows an upper limit on the NS radius (6 13.5 km). Based on the measured flux and the mass accretion rate, the maximum radial extension for the boundary layer is estimated to be $\sim$ 6.3 Rg from the NS surface. However, if the disc is not truncated by the boundary layer but by the magnetosphere, an estimated upper limit on the polar

magnetic field would be of $B \leq 610^8 G$. This observation has been done in collaboration with Aditya S. Mondal, and Gulab C. Dewangan.

NuSTAR view of the Z-type neutron star low-mass X-ray binary Cygnus X-2

We report on the NuSTAR observation of the Z-type neutron star low-mass X-ray binary Cygnus X-2 performed on 2015 January 7. During this observation, the source exhibited a sudden decrease in count rate (dips) and stronger variability in 379 keV X-ray light curve. The hardnessintensity diagram shows that the source remained in the so-called normal branch of the Z-track, although an extended flaring branch is observed during the dips. The source was in a soft spectral state with the 345 keV luminosity of $L \simeq (0.51.1) \times 10^{38} ergs^1$, assuming a distance of 8 kpc. Both the non-dip and dip X-ray spectra are well represented by models, in which the soft band is dominated by the emission from the disc, while the hard X-ray band is dominated by the Comptonized emission from the boundary layer/corona and its reflected emission from the disc. The X-ray spectrum also revealed a broad Fe K α emission line which is nearly symmetric at the higher flux and asymmetric when the flux is reduced by a factor of $\sim$2. The relativistic reflection model predicts the inner radius of the accretion disc as $R_{\rm in} 2.56.0 R_{\rm ISCO} (\simeq 3073 km)$ for the non-dip state and $R_{\rm in} 2.02.6 R_{\rm ISCO} (\simeq 2432 km)$for the dip state. If the inner disc is truncated due to the pressure arising from a magnetic field, this implies an upper limit of the magnetic field strength of $\leq 7.6 \times 10^9 G$ at the magnetic poles, which is consistent with other estimates. This observation has been done in collaboration with Aditya S. Mondal, and Gulab C. dewangan, and Mayukh Pahari.

Prabir Rudra

Generalised teleparallel quintom dark energy non-minimally coupled with the scalar torsion and a boundary term

We propose a new generalized quintom dark energy model in the teleparallel alternative of general relativity theory, by considering a non-minimal coupling between the scalar fields of a quintom model with the scalar torsion component T and the boundary term B. In the teleparallel alternative of general relativity theory, the boundary term represents the divergence of the torsion vector, $B = 2\nabla_\mu T^\mu$, and is related to the Ricci scalar R and the torsion scalar T, by the fundamental relation: $R = -T + B$. We have investigated the dynamical properties of the present quintom scenario in the teleparallel alternative of general relativity theory by performing a dynamical system analysis in the case of decomposable exponential potentials. The study analyzed the structure of the phase space, revealing the fundamental dynamical effects of the scalar torsion and boundary couplings in the case of a more general quintom scenario. Additionally, a numerical approach to the model is presented to analyze the cosmological evolution of the system. This observation has been done in collaboration with Sebasbian Bahamonda, and Mihai Marciu.

Time dependent geometry in massive gravity

We analyze a time dependent geometry in a massive theory of gravity. This is done by analyzing Vaidya spacetime in such a massive theory of gravity. The Vainshtein and dRGT mechanisms are used to obtain a ghost free massive gravity, and to construct such time dependent solutions. Singularities formed, The nature and strength of singularies formed are studied in detail. We also study the thermodynamical aspects of such a geometry by calculating the important thermodynamical quantities for such a system, and analyze the thermodynamical behaviour of such quantities. This observation has been done in collaboration with Yaghoub Heydarzade, Behnam Pourhassan, Mir Faizal, Ahmed Farag Ali, and Farhad Darabi.

Anirban Saha

Footprint of spatial non commutativity in resonant detectors of gravitational wave

The present day gravitational wave (GW) detectors strive to detect the length variation $\delta L = hL$, which owing to the smallness of the metric perturbation $\sim h$, is an extremely small length $\mathcal{O} \sim 10^{-18} - 10^{-21}$ meter. The recently proposed noncommutative structure of space has a characteristic length-scale $\sqrt{\theta}$, which has an estimated upper-bound in similar length-scale range. We, therefore, propose that GW data can be used as an effective probe of noncommutative structure of space. In this work we demonstrate how spatial non commutativity modifies the responding frequency of the

resonant detectors of GW, and also the corresponding probabilities of GW induced transitions that the phonon modes of such resonant detectors undergo. We present the complete perturbative calculation involving both time-independent and time-dependent perturbations in the Hamiltonian. This work has been done in collaboration with Bhattacharyya, and Sunandan Gangopadhyay.

Sanjay Kumar Sahay

Group-wise classification approach to improve Android malicious apps detection accuracy

In the fast-growing smart devices, Android is the most popular OS, and due to its attractive features, mobility, ease of use, these devices hold sensitive information such as personal data, browsing history, shopping history, financial details, etc. Therefore, any security gap in these devices means that the information stored or accessing the smart devices are at high risk of being breached by the malware. These malware are continuously growing, and are also used for military espionage, disrupting the industry, power grids, etc. To detect these malware, traditional signature matching techniques are widely used. However, such strategies are not capable to detect the advanced Android malicious apps because malware developer uses several obfuscation techniques. Hence, researchers are continuously addressing the security issues in the Android based smart devices. Therefore, in this work using *Drebin* benchmark malware dataset, we experimentally demonstrate how to improve the detection accuracy by analyzing the apps after grouping the collected data based on the permissions and achieved 97.15% overall average accuracy. Our results outperform the accuracy obtained without grouping data. The analysis also shows that among the groups, *Microphone* group detection accuracy is least while *Calendar* group apps are detected with the highest accuracy, and for the best performance, one shall take 80-100 features. This work has been done in collaboration with Ashu Sharma.

An investigation of a deep learning based malware detection system

In the investigation, we experiment with different combination of deep learning architectures including Auto-Encoders, and Deep Neural Networks with varying layers over Malicia malware dataset, on which earlier studies have obtained an accuracy of (98%) with an acceptable False Positive Rates (1.07%). But these results were done using extensive man-made custom domain features and investing corresponding feature engineering and design efforts. In this proposed approach, besides improving the previous best results (99.21% accuracy and a False Positive Rate of 0.19%) indicates that deep learning based systems could deliver an effective defense against malware. Since it is good in automatically extracting higher conceptual features from the data, deep learning based systems could provide an effective, general and scalable mechanism for detection of existing and unknown malware. This investigation has been done in collaboration with Mohit Sewak, and Hemant Rathore.

Sandeep Sahijpal

A Monte Carlo based simulation of the galactic chemical evolution of the Milky Way galaxy

The formation and chemical evolution of the Milky Way galaxy is numerically simulated by developing a Monte Carlo approach to predict the elemental abundance gradients and other galactic features using the revised solar abundance. The galaxy is accreted gradually by using either a two-infall or a three-infall accretion scenario. The galaxy is chemically enriched by the nucleosynthetic contributions from an evolving ensemble of generations of stars. We analyse the role of star formation efficiency. The influence of the radial gas inflow as well as radial gas mixing on the evolution of galaxy is also studied. The SN Ia delay time distribution (DTD) is incorporated by synthesizing SN Ia populations using random numbers based on a distribution function. The elemental abundance evolutionary trends corroborate fractional contributions of ~ 0.1 from prompt (< 100 Myr) SN Ia population. The models predict steep gradients in the inner regions and less steep gradients in the outer regions, which agrees with the observations. The gradients indicate an average radial gas mixing velocity of ≤ 1 km/s^{-1}. The models with radial gas inflows reproduce the observed inversion in the elemental abundance gradients around 2 billion years. The three-infall accretion scenario performs better than the two-infall accretion model in terms of explaining the elemental abundance distributions of the galactic halo, thick and thin discs. The accuracy of all the models has been monitored as a c umulative error of $< 0.15 M_{\odot}$ in the mass bal-

ance calculations during the entire evolution of the galaxy. This simulation has been done in collaboration with Tejpreet Kaur.

Thermal evolution of the early Moon

The early thermal evolution of Moon has been numerically simulated to understand the magnitude of the impactinduced heating and the initially stored thermal energy of the accreting moonlets. The main objective of the present study was to understand the nature of processes leading to coremantle differentiation, and the production and cooling of the initial convective magma ocean. The accretion of Moon was commenced over a time scale of 100 yr after the giant impact event around 30100 million years in the early solar system. We studied the dependence of the planetary processes on the impact scenarios, the initial average temperature of the accreting moonlets, and the size of the protomoon that accreted rapidly beyond the Roche limit within the initial 1 yr after the giant impact. The simulations indicate that the accreting moonlets should have a minimum initial averaged temperature around 1600 K. The impacts would provide additional thermal energy. The initial thermal state of the moonlets depends upon the environment prevailing within the Roche limit that experienced episodes of extensive vapourization and recondensation of silicates. The initial convective magma ocean of depth more than 1000 km is produced in the majority of simulations along with the global coremantle differentiation in case the melt percolation of the molten metal through porous flow from bulk silicates was not the major mode of coremantle differentiation. The possibility of shallow magma oceans cannot be ruled out in the presence of the porous flow. This simulations indicate the coremantle differentiation within the initial 10^2 to 10^3 yr of the Moon accretion. The majority of the convective magma ocean cooled down for crystallization within the initial 10^3 to 10^4 yr. This simulation has been done in collaboration with Vishal Goyal.

Asoke Kumar Sen

The variation of photon speed with photon frequency in quantum gravity

An expression for Planck mass or Planck energy is derived by equating the Compton wavelength with the gravitational radius of the Kerr rotating body. Using the modified photon energymomentum dispersion relation, the variation of the photon propagation speed with photon frequency is derived. It is found that, the photon propagation speed, depends on the frequency of the photon, the rotation parameter of the Kerr rotating body, and also on the polarization state of the photon. Quantum gravity effect could be seen from the derived results for the photon propagation speed. This work has been done in collaboration with Anuj Kumar Dubey, and Sonarekha Nath.

T.R. Seshadri

Generation of helical magnetic field in a viable scenario of inflationary magnetogenesis

The generation of helical magnetic fields during inflation, which is free from the strong coupling and backreaction problems has been investigated. The helical fields are generated by considering a term $f^2\tilde{F}_{\mu\nu}F^{\mu\nu}$ in the Lagrangian. It has been shown that the standard difficulties in most models of inflationary magneto genesis (strong coupling and backreaction problems) can be addressed in a scenario, in which f increases during inflation and decreases post inflation to reheating. If the evolution of f is chose to be of the form, $f \propto a^2$ during inflation, a fully helical magnetic field with a blue spectrum is obtained. The reheating scale, for this to be achieved, should be less than 4000 GeV. Bounds from the γ-ray observations are satisfied. For reheating scale of 100 GeV, magnetic field strength of 4×10^{-11} G with a coherence length of 70 kpc is obtained. If the reheating takes place at QCD scales of 150 MeV, the fields of nano Gauss strength, with coherence scale of 0.6 Mpc is obtained. This investigation has been done in collaboration with Ramkishor Sharma, and Kandaswamy Subramanian.

Mohit Kumar Sharma

Suggestion for search of 2-aminoethanol in a cosmic object

The 2-aminoethanol is considered as a precursor to amino acid in the interstellar space. Thus, the scientists, searching for life in the universe, have great interest in its investigation, and therefore, its laboratory spectrum has been analyzed from time to time. It has a large electric dipole moment with components along all the three principal inertial axes: $\mu_a = 2.75$ D, $\mu_b = 1.07$ D, and μ_c

= 0.77 D. Corresponding to each component, the energy levels can be classified into two sets. For each of the six sets, using the spectroscopic data of 2-aminoethanol, we have calculated energies of 150 rotational levels in the ground vibrational state and ground electronic state. For rotational transitions, we have calculated the line intensities and Einstein A-coefficients. For each set, using the Einstein A-coefficients and scaled values of the collisional rate coefficients, we have solved a set of 150 statistical equilibrium equations coupled with the equations of radiative transfer. In the model, there is cosmic microwave background corresponding to a temperature of 2.73 K. Brightness temperatures of all the b-type and c-type transitions are found nearly equal to the background temperature. Eight a-type transitions are found to show the anomalous absorption. These transition may play important role for the identification of 2-aminoethanol in a cosmic object. This work has been done in collaboration with Monika Sharma, and Suresh Chandra.

Suggestion for search of silanone (H_2SiO) in interstellar medium

Thirteen silicon bearing molecules are detected in the cosmic objects. Carbon (C) and silicon (Si) elements have similar chemical properties, and the formaldehyde (H_2CO) is identified in a large number of cosmic objects. Hence, there is a possibility of Silanone (H_2SiO) being present in the ISM. For each of the ortho and para species of H_2SiO, we have calculated energies of 100 lower rotational levels (up to 284 cm^{-1}) and the Einstein coefficients for radiative transitions between the levels. We have solved a set of 100 statistical equilibrium equations coupled with the equations of radiative transfer for each specie, where the collisional rate coefficients are taken from a scaling law. For the ortho-H_2SiO, five transitions, $1_{10} - 1_{11}$, $2_{11} - 2_{12}$, $3_{12} - 3_{13}$, $4_{13} - 4_{14}$, and $5_{14} - 5_{15}$ are found to show the anomalous absorption, and one transition $2_{12} - 1_{11}$ is found to show the emission feature. For the para-H_2SiO, four transitions, $1_{01} - 0_{00}$, $2_{02} - 1_{01}$, $6_{60} - 5_{14}$, and $6_{61} - 5_{42}$ are found to show the emission feature. These lines may help in the identification of H_2SiO in a cosmic object, *e.g.*, in IRC+10216. This work has been done in collaboration with Monika Sharma, and Suresh Chandra.

Ranjan Sharma

A family of solutions to the EinsteinMaxwell system of equations describing relativistic charged fluid spheres

We present a formalism to generate a family of interior solutions to the EinsteinMaxwell system of equations for a spherically symmetric relativistic charged fluid sphere matched to the exterior ReissnerNordstrm spacetime. By reducing the Einstein-Maxwell system to a recurrence relation with variable rational coefficients, we show that it is possible to obtain closed-form solutions for a specific range of model parameters. A large class of solutions obtained previously are shown to be contained in this general class of solutions. We also analyse the physical viability of the new class of solutions. This work has been done in collaboration with K. Komathira.

Gyan Prakash Singh

Thermodynamical and observational aspects of cosmological model with linear equation of state

A cosmological model with linear equation of state in the framework of general relativity is studied. We explore the thermodynamical aspects of the cosmological model with equilibrium description. In particular, we discuss the validity of generalized second law of thermodynamics for resulting cosmologies. General conditions for this model to satisfy the slow roll conditions for inflation are discussed. This work has been done in collaboration with Nikhil Hulke and Ashutosh Singh.

Cosmological study of particle creation in higher derivative theory

we have presented accelerated expanding cosmological models with particle creation in flat FRW background within the framework of higher derivative theory. In order to explore the role of particle creation on dynamical parameters, we have considered hybrid, intermediate and emergent forms of scale factor. Further, we have considered the well accepted values of free parameters to explore the possibility of transition from a decelerated to accelerated period of expansion based on deceleration parameter and effective equation of state. Finally, the effect on statefinder parameters $\{r, s\}$, measuring the deviation of the considered models from the concordance model have also been discussed. This

work has been done in collaboration with Nikhil Hulke and Ashutosh Singh.

Harinder Pal Singh

On the variation of light curve parameters of RR Lyrae variables at multiple wavelengths

We present a detailed light curve analysis of RR Lyrae variables at multiple wavelengths using Fourier decomposition method. The time-series data for RR Lyrae variables in the galactic bulge and the Magellanic Clouds are taken from the Optical Gravitational Lensing Experiment survey, while the infrared light curves are compiled from the literature. We also analyse the multiband theoretical light curves that are generated from the stellar pulsation models of RR Lyrae stars for a wide range of metal-abundances. We find that the theoretical light curve parameters with different metal abundances are consistent with observed parameters in most period bins at both optical and infrared wavelengths. The theoretical and observed Fourier amplitude parameters decrease with increase in wavelength, while the Fourier phase parameters increase with wavelength at a given period. We use absolute magnitudes for a subset of theoretical models that fit the observed optical RR Lyrae light curves in the Large Magellanic Cloud to estimate a distance modulus, $\mu_{\rm LMC} = 18.51 \pm 0.07$, independent of the metallicity. We also use Fourier analysis to study the period-colour and amplitude-colour relations for RR Lyrae stars in the Magellanic Clouds using optical data, and find that the slope of period-colour relation at minimum light is very shallow or flat and becomes increasingly significant at the maximum light for RRab stars. We also find that the metallicity dependence of the period-colour relations increases as we go from minimum to maximum light, suggesting that the mean light results are indeed an average of the various pulsational phases. We summarize that the average variation in these relations is consistent between theory and observations, and supports the theory of the interaction of the stellar photosphere and the hydrogen ionization front. This analysis has been done in collaboration with Susmita Das, Anupam Bhardwaj, Shashi M. Kanbur, and Marcella Marconi.

Search for extra-tidal RR Lyrae stars in Milky Way globular clusters from Gaia DR2

We used extra-tidal RR Lyrae stars to study the dynamics of galactic globular clusters, and know how effects like dynamical friction and tidal disruption affect these clusters. The Gaia DR2 catalogue for RR Lyrae stars (Clementini, et al. 2018) is used along with the proper motions and tidal radii data for the globular clusters compiled from literature. A sample of 56 galactic globular clusters is analysed. Out of these 56, only 11 have extra-tidal RR Lyrae stars. However, only two clusters, namely, NGC 3201 and NGC 5024, have enough extra-tidal RR Lyrae stars to draw interesting conclusions. NGC 3201, has 13 extra-tidal RR Lyrae stars, which are asymmetrically distributed around its centre with more number of stars in its trailing zone than its leading part. We conclude that these asymmetrical tidal tails are due to the combined effect of tidal disruption and the stripped debris from the cluster. On the other hand, NGC 5024 has five extra-tidal RR Lyrae stars, four of them are concentrated in a region which, is at a distance of about three times the tidal radius from its centre. These may be the stars that are being ripped apart from the cluster due to tidal disruption. The presence of these extra-tidal RR Lyrae stars in the clusters can be an indication that more cluster stars are present outside their tidal radii, which may be revealed by deep wide field colour-magnitude diagrams of the clusters. This work has been done in collaboration with Richa Kundu, and Dante Minniti.

Vikram Soni

A new solution for city water: Quality drinking water from the river floodplains

Cities world over are facing drinking water problem. The planners are often over emphasizing on sourcing surface water from far off places. This will involve exorbitant cost, and many a times diversion of river flow beyond the permissible limit. Obviously such river flow diversions will have adverse ecological consequences. In this context, the study reinvents traditional knowledge with sound scientific rigour. It argues for ecologically sustainable local solutions for meeting the drinking water need of cities from floodplain of rivers. A case of river Yamuna in Delhi has been discussed to highlight the potential of floodplain aquifer as a drink-

ing water source. This study has been done in collaboration with Shashank Shekhar, S. V. N. Rao, Suman Kumar, and Diwan Singh.

Magnetar signature the U curve

This work looks at some definitive signatures of magnetars, in particular, of period closures accompanied by a decline of X-ray radiation in two models. We review some of the previous works which are based on the well-known dynamo model in which the star is born with a period of a few milliseconds at high temperatures. In such a convection regime, the dynamo mechanism can amplify the magnetic fields to the magnetar value. This is in contrast to a screened core model which posits that a high-density phase transition occurs in the inner core of magnetars that dynamically aligns all the neutron magnetic moments producing a large magnetic field in the core. The accompanying change of flux gives rise to shielding or screening currents in the surrounding high conductivity plasma that do not permit the field to exit to the surface. Ambipolar diffusion then transports the field to the crust dissipating energy in neutrinos and X-rays. The upwelling field cleaves the crust resulting in flares and X-ray radiation from Ohmic dissipation in the crust till the screening currents are damped and the surface polar field attains its final value. In the dynamo model, the polar magnetic field decreases with time, whereas in our screened model it increases to its final value. One consequence is that in the latter model, as a function of time and period, the ratio of the dipole radiation loss, E to the X-ray luminosity, LX, is a U curve, indicating that it is the exponential decline in LX that brings closure to the spin periods that are observed for magnetars. This work has been done in collaboration with Dipankar Bharracharya, Sameer Patel, Sajal Gupta, and Prasanta Bera.

Parijat Thakur

Investigating extra-solar planetary system Qatar-1 through transit observations

We report the results of the transit timing variation (TTV) analysis of the extra-solar planet Qatar-1b using thirty eight light curves. Our analysis combines thirty five previously available transit light curves with three new transits observed by us between June 2016 and September 2016 using the 2m Himalayan Chandra Telescope (HCT) at the Indian Astronomical Observatory (Hanle). From these transit data, the physical and orbital parameters of the Qatar-1 system are determined. In addition, the ephemeris for the orbital period and mid-transit time are refined to investigate the possible TTV. We find that the null-TTV model provides the better fit to the (O-C) data. This indicates that there is no evidence for TTVs to confirm the presence of additional planets in the Qatar-1 system. The use of the 3.6m Devasthal Optical Telescope (DOT) operated by the Aryabhatta Research Institute of Observational Sciences (ARIES, Nainital, India) could improve the photometric precision to examine the signature of TTVs in this system with a greater accuracy than in the present work. This analysis has been done in collaboration with V. K. Mannaday, I. Jiang, Devendra Kumar Sahu, and Swadesh Chand.

Joint XMM-Newton and NuSTAR View of the rising phase of the 2016 outburst of the low-mass black-hole X-ray binary H 1743-322

we have been working on the temporal and spectral study of the rising phase of the 2016 outburst of the low-mass black-hole X-ray binary H 1743-322 using the joint views by XMM-Newton and NuSTAR on March 13 and 15, 2016. H 1743-322 is a transient source and frequently shows outburst in the interval of $\sim$ 200 days. We have found low-frequency QPO along with an upper harmonic at around 0.95 and 1.15 Hz, respectively in the first observation. However, the same features are also present in the second observation but they are shifted to higher value, at $\sim$ 1.15 and 2.38 Hz, respectively. The inherent properties such as the quality factor and fractional rms amplitude of the QPO suggest the detected QPO to be of type C nature. We have also found that the shape of the PDS is independent of energy for both the observations. Moreover, we have also studied the energy dependent variability of the characteristics frequency and the fractional rms amplitude of the QPO, upper harmonic, as well as the zero centered BLN (band limited noise), which shows the lack of variability with the energy. The presence of broad iron line peaking at 6.8 keV and a reflection hump around 15-30 keV due to the Compton back-scattering is clearly visible in the X-ray energy continuum. These features have been taken care with the relativistic reflection model RELXILL along with the consideration for the thermal emission from the accretion disc

and galactic absorption. We have also probed the relation between the spectral and temporal parameters. It is found that the fractional rms amplitude anti-correlates the QPO centroid frequency, whereas disk inner radius correlates the QPO centroid frequency. More interestingly, it is observed from the obtained values of the disk fraction and the Comptonized fraction from the time resolved spectroscopy that the maximum amount of the total flux is coming from the Comptonized photons, where the Comptonized flux in the 0.7-79 keV region is always >95%. From these results, it is confirmed that only the Comptonized photons are responsible for the variability in the system. All the above mentioned results obtained from the temporal and spectral analysis well agree with the LHS state behaviour of the system during the rising phase of the 2016 outburst. This work has been done in collaboration with Swadesh Chand, Gulab C. Dewangan, and Vivek Agrawal.

Sunil Kumar Tripathy

Bianchi-V cosmological model with dark energy anisotropy

The role of anisotropic components on the dark energy and the dynamics is investigated. An anisotropic dark energy fluid with different pressures along different spatial directions is assumed to incorporate the effect of anisotropy. One dimensional cosmic strings aligned along x-direction supplement some kind of anisotropy. Anisotropy in the dark energy pressure is found to evolve with cosmic expansion at least at late times. At an early phase, the anisotropic effect due to the cosmic strings substantially affect the dynamics of the accelerating universe. This study has been done in collaboration with B. Mishra, and Pratik P. Ray.

Anisotropic cosmological reconstruction in $f(R,T)$ gravity

Anisotropic cosmological models are constructed in f(R,T) gravity theory to investigate the dynamics of the universe concerning the late time cosmic acceleration. Using a more general and simple approach, the effect of the coupling constant and anisotropy on the cosmic dynamics have been investigated. It is found that cosmic anisotropy substantially affects the cosmic dynamics. This study has been done in collaboration with B. Mishra, and Sankarsan Tarai.

Pranjal Trivedi

Magnetic heating across the cosmological recombination era: Results from 3D MHD simulations

The origin of cosmic magnetic fields is an unsolved problem and magnetogenesis could have occurred in the early Universe. We study the evolution of such primordial magnetic fields across the cosmological recombination epoch via 3D magnetohydrodynamic numerical simulations. We compute the effective or net heating rate of baryons due to decaying magnetic fields, and its dependence on the magnetic field strength and spectral index. In the drag-dominated regime ($z \gtrsim 1500$), prior to recombination, we find no real heating is produced. The simulations allow us to smoothly trace a new transition regime ($600 \lesssim z \lesssim 1500$), where magnetic energy decays, at first into the kinetic energy of baryons. A turbulent velocity field is built up until it saturates, as the net heating rate rises from a low value at recombination to its peak towards the end of the transition regime. This is followed by a turbulent decay regime ($z \lesssim 600$), where magnetic energy dissipates via turbulent decay of both magnetic and velocity fields, while net heating remains appreciable and declines slowly. Both the peak of the net heating rate and the onset of turbulent decay are delayed significantly beyond recombination, by up to 0.5 Myr (until $z \simeq 600 - 700$), for scale-invariant magnetic fields. We concentrate on low magnetic field strength to avoid confusion with magnetic field-generated density fluctuations. Analytic approximations are provided and we present numerical results for a range of field strengths ($\simeq 10^{-3} - 2 \times 10^{-2}$ nG) and spectral indices, illustrating the redshift-dependence of dissipation and net heating rates. These can be used to study cosmic microwave background constraints on primordial magnetic fields. This study has been done in collaboration with Johannes Reppin, Jens Chluba, and Robi Banerjee.

Vinutha Tummala

Dark energy cosmological models with cosmic string

We have studied the anisotropic KantowskiSachs, locally rotationally symmetric (LRS) Bianchi type-I and LRS Bianchi type-III geometries filled with dark energy, and one dimensional cosmic string in the Saez-Ballester theory of gravitation. To get physically valid solution, we take hybrid expansion

law of the average scale factor, which is a product of power and exponential type of functions that results in time dependent deceleration parameter (q). The equation of state parameter of dark energy (ω_{de}) has been discussed and we have observed that for the three models it crosses the phantom divide line (ω_{de} = -1) and shows quintom like behaviour. The density of dark energy (ρ_{de}) is an increasing function of redshift and remains positive throughout the evolution of the universe for the three models. Moreover, in KantowskiSachs and LRS Bianchi type-I geometries, the dark energy density dominates the string tension density (λ) and proper density (ρ) throughout the evolution of the universe. The physical and geometrical aspects of the statefinder parameter (r, s), squared speed of sound (v_s^2) and $\omega_{de} - \omega'_{de}$ plane are also discussed. This study has been done in collaboration with V. U. M. Rao, Bekele Getaneh, and Molla Mengesha.

Bianchi type-III generalized ghost pilgrim dark energy model in a scalar tensor theory of gravitation

This study is devoted to the Bianchi type-III anisotropic generalized ghost pilgrim dark energy (GGPDE) cosmological model in the frame work of Saez-Ballester scalar-tensor theory of gravitation. With the help of hybrid expansion law of scale factor (i.e., $a(t) = (t^l e^t)^{\frac{1}{k}}$), a cosmological model is obtained, which yields a time dependent deceleration parameter, and exhibits a transition of the Universe from early decelerated phase to the recent accelerating phase. We also discuss the equation of state (EoS) parameter and statefinders $r-s$, and $\omega_{de} - \omega'_{de}$ planes for the obtained model. The EoS parameter and $r - s$ plane analysis provide quintessence-like behaviour of the model. Moreover, the $\omega_{de} - \omega'_{de}$ cosmological plane corresponds to thawing region. This study has been done in collaboration with V. U. M. Rao, and Molla Mengesha.

Paniveni Udayashankar

A study of supergranulation through its parameters

Supergranulation is examined through its various parameters such as area, perimeter, circularity and fractal dimension. A connection amongst these parameters throws light on the turbulent aspect of this convective feature. The spread shows an asymmetric dispersion with a minimum dimension at around $\pm 25^\circ$ because there is a theoretical calculation which indicates that the enhanced fields will reduce the supergranular cell sizes (Chandrasekhar, 1961) around these latitudes. A different technique of analysis on a larger sample could consolidate these findings.

Sudhaker Upadhyay

Logarithmic corrected Van der Waals black holes in higher dimensional AdS space

We consider the anti-de Sitter black hole in d-dimensional spacetime, and calculate the logarithmiccorrected thermodynamics quantities. We study the effects of thermal fluctuations on the thermodynamics of higherdimensional AdS black holes. We exploit such logarithmic corrected fluctuations on the equation of state. We find that the Van der Waals black hole is completely stable in the presence of the logarithmic correction. This study has been done in collaboration with Behnam Pourthassan.

Thermodynamics and phase transitions of galactic clustering in higher-order modified gravity

We study the thermodynamics of galactic clustering under the higher-order corrected Newtonian dynamics. The clustering of galaxies is considered as a gravitational phase transition. In order to study the effects of higher-order correction to the thermodynamics of gravitational system, we compute more exact equations of state. Moreover, we investigate the corrected probability distribution function for such a gravitating system. A relation between order parameter and the critical temperature is also established. This study has been done in collaboration with Behnam Pourhassan, and Salvatore Capozziello.

Deepak Vaid

Regular bardeen AdS black hole as a heat engine

Interpreting cosmological constant as thermodynamic pressure, we study the thermodynamics using T-S and P-v plots. Specific heat studies also carried out in detail. A first order phase transition is evident from these studies. These are followed by the construction of a heat engine, considering the black hole as working substance. The efficiency is obtained via a thermodynamic cycle in the P-v

plane, which receives and ejects heat. The heat engine efficiency is improved by adding a quintessence field. The analytical expression for heat engine efficiency is derived in terms of quintessence dark energy parameter. This result may deepen our understanding about thermodynamics of asymptotically AdS black holes. This study has been done in collaboration with V. K. Ranjani, C. L. Ahmed Rizwan, A. Naveena Kumara, and K. M. Ajith.

Effect of dark energy in geometrothermodynamics and phase transitions of regular bardeen AdS black hole

We investigate thermodynamics and geometrothermodynamics of regular Bardeen AdS black hole with quintessence. The thermodynamics of the black hole is studied using temperature-entropy (T-S) and Pressure-Volume (P-v) plots, which indicate critical behaviour. This is also confirmed from the divergence of specific heat against entropy, which shows a second order phase transition. Using the concept of thermodynamic Ruppeiner and Weinhold geometry, we calculate the thermodynamic curvature scalar in the quintessence dark energy regime. While these curvature scalars enable us to identify the critical behaviour, they do not show divergence at the phase transition points observed in specific heat study. To resolve this puzzle, we have adopted the method of geometrothermodynamics proposed by Hernando Quevedo. Choosing a Legendre invariant Quevedo metric, the curvature scalar shows singularity at the same point as seen in specific heat study. This investigation has been done in collaboration with C. L. Ahmed Rizwan, A. Naveena Kumara, K. V. Ranjani, and K. M. Ajith.

Bhargav Pradeep Vaidya

A particle module for the PLUTO Code: I. An Implementation of the MHD-PIC equations

We describe an implementation of a particle physics module available for the PLUTO code appropriate for the dynamical evolution of a plasma consisting of a thermal fluid and a non-thermal component represented by relativistic charged particles or cosmic rays (CRs). While the fluid is approached using standard numerical schemes for magneto-hydrodynamics, CR particles are treated kinetically using conventional Particle-In-Cell (PIC) techniques. The module can be used either to describe test-particle motion in the fluid electromagnetic field or to solve the fully coupled magneto-hydrodynamics (MHD)-PIC system of equations with particle back-reaction on the fluid as originally introduced by Bai, et al. Particle back-reaction on the fluid is included in the form of momentum-energy feedback and by introducing the CR-induced Hall term in Ohms law. The hybrid MHD-PIC module can be employed to study CR kinetic effects on scales larger than the (ion) skin depth provided that the Larmor gyration scale is properly resolved. When applicable, this formulation avoids resolving microscopic scales, offering substantial computational savings with respect to PIC simulations. We present a fully conservative formulation that is second-order accurate in time and space, and extends to either the Runge-Kutta (RK) or the corner transport upwind time-stepping schemes (for the fluid), while a standard Boris integrator is employed for the particles. For highly energetic relativistic CRs and in order to overcome the time-step restriction, a novel sub-cycling strategy that retains second-order accuracy in time is presented. Numerical benchmarks and applications including Bell instability, diffusive shock acceleration, and test-particle acceleration in reconnecting layers are discussed. This work has been done in collaboration with Andrea Mignone, Gianluigi Bodo, and G. Maltia.

A particle module for the PLUTO Code: II. Hybrid framework for modelling non-thermal emission from relativistic magnetized flows

We describe a new hybrid framework to model non-thermal spectral signatures from highly energetic particles embedded in a large-scale classical or relativistic magneto-hydrodynamic (MHD) flow. This method makes use of Lagrangian particles moving through an Eulerian grid, where the (relativistic) MHD equations are solved concurrently. Lagrangian particles follow fluid streamlines and represent ensembles of (real) relativistic particles with a finite energy distribution. The spectral distribution of each particle is updated in time by solving the relativistic cosmic ray transport equation based on local fluid conditions. This enables us to account for a number of physical processes, such as adiabatic expansion, synchrotron, and inverse Compton emission. An accurate semi-analytically numerical scheme that combines the method of characteristics with a Lagrangian discretization in the energy coordinate is described. In the presence of (relativis-

tic) magnetized shocks, a novel approach to consistently model particle energization due to diffusive shock acceleration is presented. Our approach relies on a refined shock-detection algorithm and updates the particle energy distribution based on the shock compression ratio, magnetic field orientation, and amount of (parameterized) turbulence. The evolved distribution from each Lagrangian particle is further used to produce observational signatures like emission maps and polarization signals, accounting for proper relativistic corrections. We further demonstrate the validity of this hy-brid framework using standard numerical bench-marks and evaluate the applicability of such a tool to study high-energy emission from extra-galactic jets. This work has been done in collaboration with Andrea Mignone, Gianluigi Bodo, Poola Rossi, and Silvano Massaglia.

Murli Manohar Verma

Dark matter as scalaron in $f(R)$ gravity models

We explore the scalar field obtained under the conformal transformation of the spacetime metric $g_{\mu\nu}$ from the Jordan frame to the Einstein frame in $f(R)$ gravity. This scalar field is the result of the modification in the gravitational part of the Einstein's general relativistic theory of gravity. For $f(R) = \frac{R^{1+\delta}}{(R_c)^{\delta}}$, we find the effective potential of the scalar field and calculate the mass of the scalar field particle "scalaron". It is shown that the mass of the scalaron depends upon the energy density of standard matter in the background (in solar system, $m_\phi \sim 10^{-16}$eV). The interaction between standard matter, and scalaron is weak in the high curva-ture regime. This linkage between the mass of the scalaron and the background leads to the physi-cal effects of dark matter and is expected to reflect the anisotropic propagation of scalaron in moving baryonic matter fields as in merging clusters (Bullet cluster, the Abell 520 system, MACS, etc.). Such scenario also satisfies the local gravity constraints of $f(R)$ gravity. We further calculate the equation of state of the scalar field in the action-angle vari-able formalism, and show its distinct features as the dark matter and dark energy with respect to energy density of the scalar field at different val-ues of the model parameter δ. This study has been done in collaboration with Bal Krishna Yadav.

Cosmological wheel of time: A classical perspective of f(R) gravity

It is shown that the structures in the universe can be interpreted to show a closed wheel of time, rather than a straight arrow. An analysis in f(R) gravity model has been carried out to show that due to local observations, a small arc at any given spacetime point would invariably indicate an arrow of time from past to future, though on a quantum scale, it is not a linear flow but a closed loop, a fact that can be examined through future observations. This study has been done in collaboration with Bal Krishna Yadav.

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14. Gazal Sharma, Shankita Bhardwaj, **Bhag Chand Chauhan,** and Surender Verma (2018) *Quark-lepton complementarity model based predictions for θ_{23} ^{PMNS} with neutrino mass hierarchy*, XXII DAE-HEP Symposium, Springer Procds. Phys., **203,** 251.

15. Surender Verma, **Bhag Chand Chauhan,** Shankita Bhardwaj, and Gazal Sharma (2018) *Probing CP violation in neutrino oscillation experiments and leptonic unitarity quadrangle*, XXII DAE-HEP Symposium, Springer Procds. Phys., **203,** 257.

16. Govind Singh, Ashish Sharma, Gazal Sharma, Shankita Bhardwaj, ..., and **Bhag Chand Chauhan** (2018) *Bounds on sterile neutrino component in the solar neutrino flux*, XXII DAE-HEP Symposium, Springer Procds. Phys., **203,** 713.

17. Ankush, Rishu Verma, Gazal Sharma, and **Bhag Chand Chauhan** (2018) *Chi-square analysis and bounds on sterile neutrino component in the solar neutrino flux*, Procds. Conf. Sci.: Emerging Scenario and Future Challenges (SESFC - 2018).

18. Kumar Anshuman, and **Bhag Chand Chauhan** (2018) *A model for estimating the unexplained matter*, Procds. Conf. Sci.: Emerging Scenario and Future Challenges (SESFC -2018).

19. Rishu Verma, Ankush, Gazal Sharma, and **Bhag Chand Chauhan** (2018) *Neutrino: A potential candidate for dark matter!*, Procds. 3rd Himachal Pradesh Science Congress, IIT, Mandi.

20. **Kanan Kumar Datta,** Rajesh Mondal, Raghunath Ghara, Somnath Bharadwaj, Tirthankar Roy Choudhury (2018) *Understanding the impact of light cone effect on the EoR/CD 21 cm power spectrum*, Peering towards Cosmic Dawn, Procds. IAU Symp., **333,** 12.

21. Raghunath Ghara, Tirthankar Roy Choudhury, **Kanan Kumar Datta,** Garrelt Mellema, Samir Choudhuri, et al. (2018) *Prospects of detection of the first sources with SKA using matched filters*, Peering towards Cosmic Dawn, Procds. IAU Symp., **333,** 122.

22. **Shanti Priya Devarapalli,** Jagirdar Rukmini, P. Ravi Raja, and V. Mounika (2018) *Photometric investigation of ultra-short period M - type eclisping binaries from OGLE galactic bulge survey,* Procds. 36th Annual Meeting of the ASI, Osmania Univ., Hyderabad.

23. M. Raghu Prasad, Jagirdar Rukmini, **Shanti Priya Devarapalli,** and Syed Aslam Ahmed (2018) *First photometric analysis of neglected contact binaries from ASAS,* Procds. 36th Annual Meeting of the ASI, Osmania Univ., Hyderabad.

24. Jagirdar Rukmini, P. Ravi Raja, M. Raghu Prasad, and **Shanti Priya Devarapalli** (2018) *First investigations of fundamental parameters of later spectral type W Uma binaries in OGLE fields,* Procds. 36th Annual Meeting of the ASI, Osmania Univ., Hyderabad, EA - 40.

25. M. Raghu Prasad, Jagirdar Rukmini, and **Shanti Priya Devarapalli** (2019) *First photometric and spectroscopic study of a pre-contact binary TYC 809-569-1,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

26. Jagirdar Rukmini, **Shanti Priya Devarapalli,** and G. Vinay Kumar (2019) *Long term photometric and spectroscopic study of EPIC 211778150 with interesting period and activity variations,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

27. Devika Divakar, Sivarani Thirupathi, and **Vijayakumar H. Doffamani** (2018) *UV - optical evolutionary tracks of the Milky Way satellite galaxies,* Procds, National Conf. Exploring the Universe: Near Earth Space Science to Extra Galactic Astronomy, S.N. Bose Inst., Kolkata.

28. Drisya Karinkuzhi, Sphi Van Eck, Alain Jorrissen, Stefane Goriely, ..., and **Vijayakumar H. Doddamani** (2018) *When binaries keep track of recent AGB nucleosynthesis as an efficient S-process diagnostic,* Procds. 3rd Intl. Conf. Why do Galaxies Care about AGB Stars III: A Continuing Challenge through Cosmic Time, Vienna, Austria.

29. **Vijayakumar H. Doddamani,** and P. Vedavathi (2019) *Long term monitoring study of MRK 335 with IUE satellite,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

30. P. Vedavathi, and **Vijayakumar H. Doddamani** (2019) *Emission line and continuum variability study of active galaxies for redshift 0 < z < 1.0",* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

31. Brian R. Miranda, Annapurni Subramanian, Ram Sagar, and **Vijayakumar H. Doddamani** (2019) *Study of UV bright stellar population in King2,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

32. N. Vasantharaju, B. Ravindra, and **Vijayakumar H. Doddamani** (2019) *Temporal evolution of magnetic field parameters leading to the largest flare (X9.3) of solar cycle 24,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

33. P. Meenakshi, Aruna Goswamy, and **Vijayakumar H. Doddamani** (2019) *Abundance of neutron capture elements in extrinsic carbon enhanced metal poor stars,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

34. Devika K. Diwakar, Sivarani Thirupati, and **Vijayakumar H. Doddamani** (2019) *Study of horizontal btanch stars in the faint Milky Way satellite galaxies,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

35. **Vijayakumar H. Doddamani** (2019) *AstroSat - India's first astronomical multi-wavelength satellite,* Procds. Conf. Recent Trends Che. Phy. Sci., Thakur College of Science and Commerce, Mumbai.

36. P. Vedavathi, and **Vijayakumar H. Doddamani** (2019) *Ultraviolet variability study of a quasar MRK 1338 by IUE satellite,* Procds. Conf. Recent Trends Che. Phy. Sci., Thakur College of Science and Commerce, Mumbai.

37. P. Vedavathi, and **Vijayakumar H. Doddamani** (2019) *Long term UV variability in continuum and line emission in MRK 279 from IUE data,* Procds. 11th Annual Conf. Asso. NMKRV College for Women, Bengaluru.

38. P. Vedavathi, and **Vijayakumar H. Doddamani** (2019) *Ultraviolet spectral properties of PG1211+143 quasar,* Procds. 11th Annual Conf. Asso. NMKRV College for Women, Bengaluru.

39. **Broja Gopal Dutta** (2018) *Variability properties of galactic black holes*, Exploring the Universe: From Near Space to Extragalactic. Eds. B. Mukhopadhyay, and S. Sasmal, Procds. Ap&SS, **53**.

40. **Broja Gopal Dutta,** Partha Sarathi Pal, and Sandip Kumar Chakrabarti (2018) *Evolution of accretion disc geometry in GRS 1915+105 during Chi state*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

41. **Broja Gopal Dutta,** and Sandip Kumar Chakrabarti (2018) *Implication of accretion geometry on variability properties in galactic black hole sources,* Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

42. **Broja Gopal Dutta,** and Sandip Kumar Chakrabarti (2018) *Inclination dependent variability properties of compact binary source*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

43. **Broja Gopal Dutta,** and Sandip Kumar Chakrabarti (2018) *Implication of soft lag in high inclination black hole transients*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

44. **Broja Gopal Dutta,** and Sandip Kumar Chakrabarti (2018) *Time lag properties of the black hole X-ray Transients: A comparison of high and low inclination sources*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

45. Gautam Saikia, Jaikhomba Singha, P. Shalima, **Rupjyoti Gogoi,** and **Amit Pathak** (2018) *Modelling 30 Doradus in the Large Magellanic Cloud,* Procds. Cosmic Wheel Legacy of the AKARI Archive: From Galaxies and Stars to Planets and Life, JAXA Special Pub., 137.

46. Neal Titus Thomas, **Shivappa B. Gudennavar,** S.G. Bubbly, Ranjeev Misra, and J.S. Yadav (2018) *Comprehensive spectral and temporal variability studies of Cygnus X - 2 with RXTE data,* Procds. Young Astronomers' Meet, PRL, Ahmedabad.

47. M. Sneha Prakash, Bari Maqbool Bhat, **Shivappa B. Gudennavar,** S.G. Bubbly, Ranjeev Misra, eta al. (2018) *Energy dependent rapid temporal behaviour of Cygnus X - 1,* Procds. Young Astronomers' Meet, PRL, Ahmedabad.

48. Ayesha Anjum, C.S. Stalin, Suvendu Rakshit, and **Shivappa B. Gudennavar** (2019) *Variability studies of Fermi LAT blazars,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

49. **Shivappa B. Gudennavar,** and C. Sivaram (2019) *Alternate to dark matter: MOND, MONG or MORG,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

50. Neal Titus Thomas, **Shivappa B. Gudennavar,** S.G. Bubbly, and Ranjeev Misra (2019) *Comprehensive spectral and temporal variability studies of Scorpius X - 1 using RXTE data,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

51. G.R. Bhuvana, Neal Titus Thomas, **Shivappa B. Gudennavar,** S.G. Bubbly, and Ranjeev Misra (2019) *A comprehensive spectral and timing analysis of LMC X - 2 using RXTE data,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

52. Sabhya, M. Sneha Prakash, **Shivappa B. Gudennavar,** S.G. Bubbly, and Ranjeev Misra (2019) *Temporal properties of the black candidate MAXI J1820+070 using AstroSat,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

53. M. Sneha Prakash, A. Rao, **Shivappa B. Gudennavar,** Ranjeev Misra, and S.G. Bubbly (2019) *Broadband spectral studies of LMC X - 1 using AstroSat,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

54. Ranjeev Misra, Bari Maqbool Bhat, M. Sneha Prakash, ..., **Shivappa B. Gudennavar,** ..., **Madhav K. Patil,** et al. (2019) *AstroSat observation of Cygnus X - 1: Spaectro-timing results,* Procds. 37th Annual Meeting of the ASI, Christ Univ., Bengaluru.

55. Kenath Arun, **Shivappa B. Gudennavar,** and C. Sivaran (2019) *Alternate models to dark matter: MOND, MONG or MORG,* Procds. 30th Meeting of the IAGRG, BITS - Pilani, Hyderabad.

56. **Sarbari Guha** (2018) *Non-adiabatic spherical collapse in f(R, T) theory of gravity,* Procds BRICS Symp. on Gravity, Astrophysics and Cosmology, Durban, South Africa.

57. **Sarbari Guha** (2019) *Universal thermodynamics with Chaplygin gas models,* Procds. 30th Meeting of the IAGRG, BITS - Pilani, Hyderabad.

58. Samarjit Chakraborty, **Sarbari Guha,** and Dibyendu Parigrahi (2019) *Evolution of FRW universe in variable modified Chaplygin gas model,* Procds. 30th Meeting of the IAGRG, BITS - Pilani, Hyderabad.

59. Sukanta Das, and **Sarbari Guha** (2019) *Noether symmetry analysis of anisotropic universe in presence of non-minimally coupled tachyon field,* Procds. 30th Meeting of the IAGRG, BITS - Pilani, Hyderabad.

60. T. Swetha, Syed N. Hasan, and **Priya Hasan** (2018) *Effect of gas physics on the thickening of disk in multiple minor mergers,* Procds. 36th Annual Meeting of the ASI, Osmania Univ., Hyderabad, EA - 40.

61. P. Nagamani, Syed N. Hasan, and **Priya Hasan** (2018) *Correlation between structural properties of galaxies in coma clusters,* Procds. 36th Annual Meeting of the ASI, Osmania Univ., Hyderabad, EA - 43.

62. **Priya Hasan** (2018) *The enigma of star formation at high galactic latitudes,* Procds. 36th Annual Meeting of the ASI, Osmania Univ., Hyderabad, SG - 46.

63. **Priya Hasan** (2018) *In the pursuit of astronomy education and outreach in India*, Astronomy in Focus, FM 15: Astronomy for Development, Procds. IAU Symp., GA, Vienna.

64. **Priya Hasan** (2018) *Standardization in the UV with Astrosat and its issues related to star cluster studies*, Astronomy in Focus, FM 12: Calibration and Standardization Issues in UV-VIS-IR Astronomy, Procds. IAU Symp., GA, Vienna.

65. **Priya Hasan** (2018) *The open universe and data-driven astronomy*, Astronomy in Focus, FM 14: IAU's Role on Global Astronomy Outreach, The Latest Challenges and Bridging Different Communities, Procds. IAU Symp., GA, Vienna.

66. Syed N. Hasan, **Priya Hasan,** and P. Nagamani (2018) *Dwarf galaxies in the core of Coma Cluster,* Dwarf Galaxies: From the Deep Universe to the Present, Procds. IAU Symp. 344, GA, Vienna.

67. **Priya Hasan** (2018) *Kinematics and dynamics of young star clusters with TMT,* Early Science with ELTs (EASE), Procds. IAU Symp. 347, GA, Vienna [arXiv: 1809.09917 [astro-h.SR]].

68. Yashpal Bhulla, and **S.N.A. Jaaffrey** (2018) *QPO detection in superluminal black hole GRS1915-105*, AIP Conf. Procds., **1953,** 140124.

69. Avaneesh Vaishwar, Devi Prasad Mishra, and **Badam Singh Kushvah** (2019) *Radiation influence on stability of triangular points in elliptic restricted three-body problem*, AIP Conf. Procds., **2061,** 20001.

70. **Soumen Mondal** (2018) *A pseudo-Newtonian approach to study the accretion processes around Kerr black holes*, Exploring the Universe: From Near Space to Extra-Galactic, Procds. Ap&SS**, 53,** 195 **[**ISBN 978-3-319-94606-1].

71. **Soumen Mondal** (2018) *Relativistic accretion hydrodynamics around rotating black holes*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

72. **Soumen Mondal** (2018) *On the properties of standing and dissipative shocks in accretion and wind flows*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

73. **Soumen Mondal,** and **Prasad Basu** (2018) *Probing the accretion disk with the gravitational wave*, Procds. 42nd COSPAR Scientific Assembly, Pasadena, California, USA.

74. Debabrata Deb, Sourav Ray Chowdhury, **Saibal Ray, Farook Rahaman,** and Bichitra Kumar Guha (2018) *A model for anisotropic strange stars*, XXII DAE HEP Symposium, Springer Procds. Phys., **203,** 65.

75. **Sanjay K. Sahay,** and Ashu Sharma (2018) *A survey on the detection of windows desktops malware,* Procds. Ambient Comm. Comp. Sys., AISC, Springer, **904,** 149.

76. Hemant Rathore, Swati Agarwal, **Sanjay K. Sahay** and Mohit Sewak (2018) *Malware detection using machine learning and deep learning*, Procds. Big Data Analytics 6th Intl. Conf., Warangal, India, Springer, LNCS, **11297,** 402.

77. Mohit Sewak, **Sanjay K. Sahay,** and Hemant Rathore (2018) *An investigation of a deep learning based malware detection system*, Procds. 13th Intl. Conf. Availability, Reliability and Security, Hamburg, Germany, ACM, 26.

78. Mohit Sewak, **Sanjay K. Sahay,** and Hemant Rathore (2018) *Comparison of deep learning and the classical machine learning algorithm for the malware detection,* Procds. 19th IEEE/ACIS Intl. Conf. on

Software Engg., Artificial Intelligence, Networking and Parallel/Distributed Computing, Busan, South Korea. 293.

79. Anupam Bhardwaj, Lucas M. Macri, Shashi M. Kanbur, Chow–Choong Ngeow, **Harinder Pal Singh** (2018) *Near infrared observations of OGLE classical and type II Cepheid variables in the LMC*, Southern Horizons in Time-Domain Astronomy, Procds. IAU Symp., **339,** 2018,

80. Anupam Bhardwaj, Shashi M. Kanbur, Marcella Marconi, **Harinder Pal Singh,** M. Rejkuba, et al. (2018) *Multi-wavelength light curve analysis of Cepheid variables*, Southern Horizons in Time-Domain Astronomy, Procds. IAU Symp., **339,** 2018.

81. Kaushal Sharma, **Harinder Pal Singh,** A. Kashyap, and Philippe Prugniel (2018) *Estimating stellar atmospheric parameters by automated methods using SSLs*, Procds. Intel. Workshop on Spectral Stellar Libraries (IWSSL2017), Sao Paulo, Brazil.

82. Shashi M. Kanbur, Marcella Marconi, Anupam Bhardwaj, Richa Kundu, and **Harinder Pal Singh** (2018) *The role of opacities in stellar pulsation,* Procds. Workshop on Astrophys. Opacities, ASPCS, Michigan University, Kalamazoo, USA, 515.

83. Anupam Bhardwaj, Shashi M. Kanbur, Marcella Marconi, Susmita Das, ..., **Harinder Pal Singh,** et al. (2018) *Time-series analyses of Cepheid and RR Lyrae variables in the wide-field variability surveys,* Early Science with ELTs, Vienna, Procds. IAU Symp, **347**.

84. Anupam Bhardwaj, Marcella Marconi, Shashi Kanbur, E. Bellinger, and **Harinder Pal Singh** (2018) *Predicting physical parameters of Cepheid and RR Lyrae variables,* Procds. Conf. Galactic Bulge at the Crossroads (GBX2018), Pucon, Chile.

85. **Harinder P. Singh,** Susmita Das, Anupam Bhardwaj, Shashi Kanbur, and Marcella Marconi (2019) *Light curve parameters of Cepheid and RR Lyrae variables at multiple wavelengths: Models vs. observations*, Procds. 2nd Belgo-Indian Network Astron. Astrophys. (BINA) Workshop, Brussels, Belgium.

86. Bal Krishna Yadav, and **Murli Manohar Verma** (2018) *Dark matter as scalar field in f (R) gravity models*, Procds. Summer School on Cosmology, Abdus Salam ICTP, Trieste, Italy.

(c) BOOK AUTHORED

Suresh Chandra, Mohit Kumar Sharma, and Monika Sharma (2018) *Textbook of Optics,* Ane Books Pvt. Ltd., New Delhi [ISBN: 978-93-8676-156-9].

(d) SUPERVISION OF Ph. D. THESES

Naseer Iqbal Bhat

Title: *Geometry of accretion flow in compact object systems.*
Student: Naveel Wani (Department of Physics, University of Kashmir, Srinagar).

Title: *Understanding the spectral and temporal behaviour of high energy blazars using multi-wavelength observations.*

Student : Zahir A. Shah (Department of Physics, University of Kashmir, Srinagar).

Asis Kumar Chattopadhyay (Jointly with **Tanuka Chattopadhyay**)

Title: *Uncovering astrophysical phenomena related to galaxies and other objects through statistical analysis*.
Student: Soumita Modak (Department of Statistics, University of Calcutta, Kolkata).

Himadri Sekhar Das

Title: *Photopolarimetric study of some selected dark clouds*.
Student: Arup Das (Department of Physics, Assam University, Silchar).

Title: *Photometric and polarimetric studies of some selected dark clouds*.
Student: Ajoy Barman (Department of Physics, Assam University, Silchar).

Title: *A theoretical study of double layers and sheaths in various plasma configurations.*
Student: Jaydeep Paul (Department of Physics, Assam University, Silchar).

Manzoor A. Malik

Title: *CCD and photoelectric photometry of RS Cvn and W UMa binary stars*.
Student: Ajaz Ahmad (Department of Physics, University Of Kashmir, Srinagar).

Sheo Kumar Pandey (Jointly with Jagdish Singh Yadav, and Ranjeev Misra)

Title: *Study of accretion process and jets in X-ray binaries.*
Student: Kalyani Bagri (School of Studies in Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur)

Sheo Kumar Pandey (Jointly with Sushanshu Barway)

Title: *Central region of lenticular galaxies.*
Student: Mehndra Verma (School of Studies in Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur)

Madhav K. Patil

Title: *Star formation and nuclear accretion history of some IRAS detected early-type galaxies*.
Student: Swati P. Deshmukh (School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded).

Anirudh Pradhan

Title: *Some cosmological models in Einstein's and its modified gravity theories with time dependent deceleration parameter.*
Student: Dinesh Chandra Maurya (GLA University, Mathura).

Title: *On some homogeneous anisotropic cosmological models in Einstein's modified field equations*.
Student: Umesh Kumar Sharma (GLA University, Mathura).

Farook Rahaman (Jointly with K. Ghosh)

Title: *Theoretical models of mass transfer in close binary stars.*
Student: Prabir Ghorami (Department of Mathematics, Jadavpur University).

Farook Rahaman

Title: *Modelling of stars and wormholes in different dimensions.*
Student: Sumita Banerjee (Department of Mathematics, Jadavpur University).

Title: *Some Astrophysical phenomena based on the Finslerian structure spacetime.*
Student : Nupur Paul (Department of Mathematics, Jadavpur University).

Saibal Ray

Title: *Studies on compact stars under general relativity.*
Student: Dibyendu Shee (Indian Institute of Engineering Science and Technology, Shibpur).

Title: *Astrophysical systems under alternative gravity,*
Student: Amit Das (Indian Institute of Engineering Science and Technology, Shibpur).

Title: *A study on gravastars*.
Student: Shounak Ghosh (Indian Institute of Engineering Science and Technology, Shibpur).

Title: *Compact stars under general relativity and alternative gravity.*
Student: Debabrata Deb (Indian Institute of Engineering Science and Technology, Shibpur).

(e) AWARDS AND DISTINCTIONS

Piyali Bhar

Venus International Research Award (2018), Young Scientist in Mathematics.

Selected as a member of the editorial board of International Journal of Mathematics and Systems Science.

Ritabrata Biswas

Young Scientist Award in Mathematics (2018), by Dr. Ram Manohar Lohia Avadh University, Faizabad (Ayodhya), and International Academy of Physical Sciences, Allahabad.

Subenoy Chakraborty

Honorable Mention (2018) Essay Competition of Gravity Research Foundation, USA, for the essay,

Cosmic evolution with a general Gaussian type scale factor, IJMPD, **27,** 1847019.

Tanuka Chattopadhyay

Selected as an Individual Member of the International Astronomical Union (2018).

Selected as a Visiting Scholar during fall 2018, Department of Mathematics and Statistics, Concordia University, Montreal, Canada, for teaching and research.

Awarded Fellow of West Bengal Academy of Sciences (2018).

Bhag Chand Chauhan

Appinted as the Dean, School of Physical and material Sciences, Central University of Himachal Pradesh, Dharamshala.

Tuhin Ghosh

Elected as an Associate of Indian Academy of Sciences (2019).

Priya Hasan

Zubin Kembhavi Award (along with Niruj Ramanujan and the *POEC* members), 37th Meeting of the Astronomical Society of India, Christ University, Bengaluru (2019).

Joe Jacob

The New Discovery Award (along with Joydeep Bagchi and team) for the discovery of *Saraswati Supercluster*, Astronomical Society of India (2018).

Mehedi Kalam

Apointed as the Dean, Faculty of Science and Technology, Aliah University, Kolkata.

Smriti Mahajan

Selected as an Associate of the Indian National Academy of Sciences.

Kamakshya Prasad Modak

India Top Cited Author Award in Astronomy and Astrophysics, by IOP Publishing, Bristol, UK (2018).

Hemwati Nandan

Visiting Scientist Scholarship, Institute of Physics, University of Zurich, Switzerland (2018).

Dibyendu Nandi

Vice-Chair, Panel of Space Weather, Committee on Space Research (COSPAR).

Co-Lead, VarSITI SEE Programme, Scientific Committee on Solar-Terrestrial Physics (SCOSTEP).

Biswajit Pandey

Selected as an Individual Member of the International Astronomical Union (2018).

Mahadev B. Pandge

Selected as a Junior Member of the International Astronomical Union (2018).

Bhargav Vaidya

Appointed as the Head of the Partner Group of the Max Planck Institute for Astronomy, IIT, Indore.

Murli Manohar Verma

Visiting Scientist Scholarship, Theoretical Physics Division, CERN, Geneva (2018 - 19).

Visiting Scientist Scholarship, Kavli IPMU, University of Tokyo (March - April 2018).

Visiting Scientist Scholarshio, High Energy, Cosmology and Astroparticle Physics Section, ICTP, Trieste, Italy (June 2018).

Visiting Professor Scholarship, IHEP, Chinese Academy of Sciences, Beijing (October - November 2018).

Selected as a Member of International Society on General Relativity and Gravitation.

IUCAA
RESOURCE CENTRES

DEPARTMENT OF STATISTICS, UNIVERSITY OF CALCUTTA, KOLKATA

Coordinator:
Asis Kumar Chattopadhyay

Joint Coordinator:
Narayan Banerjee

AREAS OF RESEARCH

- Big data analysis related to astronomical objects
- Star formation rate
- Explosion triggered star formation
- Thermal instability driven star formation
- Distance determination of nearby as well as far off stars
- Measure of chaos in the presence of SMBH under different halos
- Episodic model of star formation with small scale dissipation
- Large scale simulation

Research scholars and faculty members of various colleges and universities in and around Kolkata were very much involved in the use of mathematical and statistical software as well as development of computer programmes for analysis of astronomical data.

The following project works have been carried out by the post-graduate students:

Supervised by: **Asis Kumar Chattopadhyay**, Department of Statistics, University of Calcutta, Kolkata.

Determination of outlying astronomical objects, by Manan Mukherjee.

Identification of habitable exoplanets: A statistical approach, by Debosmita Sett.

Supervised by: **Tanuka Chattopadhyay**, Department of Applied Mathematics, University of Calcutta, Kolkata.

Modelling of eclipsing binaries using Kepler data, by Srijan Datta.

Fundamental planes of elliptical galaxies and globular clusters, by Sarmistha Poddar.

Toy model of galaxy classification using spectro-photometric data from SDSS dr-15, by Anisha Sen.

Initial mass function, by Dipanjan Das.

Limit cycle model of episodic star formation, by Subhadip Karmakar.

H-R diagram using sky-map pro-7, by Priyanka Chatterjee.

LIST OF PUBLICATIONS

1. Soumita Modak, **Asis Kumar Chattopadhyay**, and **Tanuka Chattopadhyay** (2018) Clustering of gamma-ray bursts through kernel principal component analysis, Comm. Stat. Sim. Comp., 47(4), 1088.

2. Krishna Sankar Ganguly, Krishnendra Sankar Ganguly, **Asis Kumar Chattopadhyay**, Ambar Dutta, Tapan Kumar Mukherjee, et al. (2018) Spatial clustering of dengue fever: A baseline study in the city of Calcutta, IJHMS, **4(10)**, 170.

3. **Tanuka Chattopadhyay**, Didier-Fraix Burnet, and Saptarshi Mondal (2019) Unsupervised classification of galaxies. I. ICA feature selection, PASP (in Press).

4. Debasish Mondal, and **Tanuka Chattopadhyay** (2019) Star formation under explosion mechanism in a magnetized medium, BlgAJ, **31**, 16.

5. Ashok Mondal, and **Tanuka Chattopadhyay** (2019) Fragmentation of molecular cloud in a polytropic medium. NewA, **66**, 45.

AWARDS/ DISTINCTIONS

Tanuka Chattopadhyay

Awarded Fellow of West Bengal Academy of Sciences (2018).

Selected as an Individual Member of the International Astronomical Union (2018).

Selected as a Visiting Scholar during fall 2018, Department of Mathematics and Statistics, Concordia University, Montreal, Canada, for teaching and research.

LECTURES BY THE COORDINATOR OF IRC

International Conference on Small Area Estimation and other Topics of Current Interest in Surveys, Official Statistics and General Statistics, East China Normal University, Shanghai, China, June 16 - 18, 2018.

Training on Life Tables and Population Projection for Bhutanese Officers, Indian Statistical Institute, Kolkata, July 2 - 13, 2018.

Astrostatistics: Astrophysics through Statistics, Carleton University, Canada, November 9, 2018.

Series of talks on Astrostatistics, Department of Mathematics and Statistics, Concordia University, Canada, October 5,19, and November 23, 2018.

Independent Component Analysis and Robust Clustering Related to Pollution and Astronomical Data, Department of Mathematics and Statistics, Concordia University, Canada, November 26, 2018.

Workshop on Data Analysis and Machine Learning, Indian Institute of Science Education and Research, Tirupati, May 24 - 28, 2019.

SCHOOL OF STUDIES IN PHYSICS AND ASTROPHYSICS
PT. RAVISHANKAR SHUKLA UNIVERSITY, RAIPUR

Coordinator: Sheo Kumar Pandey

RESEARCH ACTIVITIES

Kalyani Bagri has submitted her PhD thesis entitled, "Study of Accretion Process and Jets in X-ray Binaries" under the supervision of Jagdish Singh Yadav (TIFR, Mumbai), Sheo Kumar Pandey, and Ranjeev Misra (IUCAA). The work is focused on the spectral and timing analysis of Black Hole X-ray Binaries (BHXBs). RXTE observations of GX339-4 from the four outbursts during 2002 - 2011 were analyzed. The system was found to be in the hard state and showed a broad Fe line. The model fit shows that the reflection component does not completely explain the puzzle of existence of broad Fe line. Detailed monitoring of GRS 1915+105 in its delta class was done using the AstroSat during September 25 - 27, 2016. Simultaneous spectral fitting of LAXPC and SXT data shows that the spectrum fits well with a thermal Comptonization component along with the disk blackbody component. The photon index is very steep, indicating that the source is in the soft state. The timing properties of the source indicate a state transition within the delta class.

Mahendra Verma has been working for his PhD thesis entitled, "Central Region of Lenticular Galaxies", under the supervision of **Sheo Kumar Pandey**, and Sudhanshu Barway (IIA, Bengaluru).

Nand Kumar Chakradhari (Senior Assistant Professor) has been collaborating with G. C. Anupama, and Devendra Kumar Sahu (both from IIA, Bengaluru) on Supernovae. An extensive study of type Ia supernovae SN 2009ig and SN 2012cg has been carried out. Optical photometric data obtained using 2-m Himalayan Chandra Telescope (HCT), and UV- optical photometric data of these events archived from Swift-UVOT were analyzed. A series of optical spectra obtained using HCT were also analyzed. Both SN 2009ig and SN 2012cg exhibit similar properties. They are relatively slow decliner and luminous event. Their early spectra show high velocity features in Si II and Ca II lines. The strong Fe III, Si III, and weak Si II λ5972 lines during pre-maximum phase are indicative of hot photosphere. The post-maximum velocity evolution shows a plateau like phase. Both events show spectral evolution similar to normal SNe Ia, and the observed spectra could be well reproduced by synthetic spectra.

To strengthen the astronomical activities, an MoU has been signed with ARIES, Nainital. Students of MSc (IV semester) (Dipanjan Bhattacharya, Khushboo Soni, Tarak Chand, Manisha Bandhe, Leena Dili, Chhaya Sahu, and Chandra Prakash Navarange) have visited ARIES to carry out project works.

Priyanjali Patel has been selected for PhD programme at the Department of Astronomy, Universidad de Chile, Santiago, Chile.

VISITORS

Following Eminent Scientists visited the School and interacted with Students/Faculty members:
Ranjeev Misra, Gulab C. Dewangan, Samir Dhurde, Sonali Sachdeva (all from IUCAA), Nandita Srivastava (Udaipur Solar Observatory), Jeewan Chand Pandey, Amitesh Omar (both from ARIES, Nainital), Poshak Gandhi (University of Southampton, UK), Devendra Kumar Sahu, Sudhanshu Barway (both from IIA, Bengaluru), Naba K. Mondal (Saha Institute of Nuclear Physics, Kolkata), Bipash Das Gupta (Birla Planetarium, Kolkata), Rajiv Gavai (TIFR, Mumbai), Parijat Thakur (GGU, Bilaspur), and Sudhanwa Patra (IIT, Bhilai).

ASTRONOMICAL ACTIVITIES AND PUBLIC OUTREACH PROGRAMMES

Planetarium Shows, Sky Watching, and Telescope Demonstrations were organized time to time at various places.

Sheo Kumar Pandey, and Nand Kumar Chakradhari have delivered lectures in several schools, colleges and public forums, as a part of Astronomical Science Popularization and Public Outreach Programmes.

National Workshop on "Zero Shadow Day" was organized at IRC, SoS in Physics and Astrophysics, Pt. Ravishankar Shukla University (PRSU), in association with Chhattisgarh Vigyan Sabha, during April 21 - 22, 2018. The programme was supported by Vigyan Prasar, DST, New Delhi, and Astronomical Society of India. The main objective of the workshop was to provide training to participants to organize ZSD at their own place. The participants include 35 trainees from Chhattisgarh, Madhya Pradesh, Maharashtra, Orissa, and West Bengal. Along with the trainees, the students of SoS in Physics and Astrophysics, and Centre for Basic Sciences, also participated in the workshop. The resource persons were Samir Dhurde, Bipash Das Gupta, M.L. Nayak, Vishwash Meshram, B.K. Lal, Y.K. Sona, Laxmi Kant Chaware, Nand Kumar Chakradhari, Dinesh Kumar, Nidhi Singh, P.C. Rath, S.R. Azad, Anju Meshram, Sekhar Nag, Arunkant Shukla, and members of Chhattisgarh Vigyan Sabha.

जिस दिन नहीं बनती परछाई, वह है 'जीरो शेडो डे'

■ नवभारत रिपोर्टर। रायपुर.

छत्तीसगढ़ विज्ञान सभा एवं पं. रविशंकर शुक्ल विश्वविद्यालय के संयुक्त तत्वावधान में जीरो शेडो डे को लेकर दो दिवसीय मास्टर ट्रेनर्स की राष्ट्रीय कार्यशाला का आयोजन विश्वविद्यालय के सभागार में किया जा रहा है. कार्यशाला में छत्तीसगढ़, मध्यप्रदेश, महाराष्ट्र, ओड़िशा एवं पश्चिम बंगाल से 35 मास्टर ट्रेनर्स भाग ले रहे हैं. सभी मास्टर ट्रेनर्स प्रशिक्षण के बाद अपने-अपने राज्य में लोगों को शून्य छाया दिवस के घटनाक्रम से अवगत कराएंगे.

कार्यक्रम का शुभारंभ कुलपति केसरी लाल वर्मा, छत्तीसगढ़ विज्ञान सभा के कार्यकारी अध्यक्ष प्रो. एम. एल. नायक, खगोल शास्त्री समीर धुरडे, जन विज्ञानी बी. के. लाल, खगोलशास्त्री बिपाशा दासगुप्ता एवं विज्ञान सभा के वरिष्ठ सदस्य अशोक प्रधान के आतिथ्य में हुआ. सर्वप्रथम श्री धुरडे ने जीरो शेडो डे क्या है? इस विषय के बारे में जानकारी दी. उन्होंने बताया कि परछाई न बनने के घटनाक्रम को खगोल विज्ञानी जीरो शेडो डे या शून्य छाया दिवस कहते हैं. शून्य छाया दिवस की घटना कर्क रेखा और मकर रेखा के बीच ही घटित होती है. जन विज्ञानी डॉ. लाल ने जीरो शेडो डे पर प्रकाश डालते हुए कहा कि इस दिन परछाई एकदम से न तो गायब होती है और न ही हमारा साथ छोड़ती है बल्कि वह हमारे अंदर ही कुछ समय के लिए समाहित हो जाती है. इसी खगोलीय घटनाक्रम को जीरो शेडो डे कहते हैं. इस दिन मध्यान्ह के समय सूर्य सिर के ऊपर होता है. इस दौरान भूमध्य रेखा से कर्क रेखा के बीच कुछ स्थानों पर सूर्य की किरणें सीधी पड़ती हैं, जिस कारण वहां लंबवत खड़ी किसी चीज की परछाई नहीं बनती.

खास बातें

- जीरो शेडो डे को लेकर मास्टर ट्रेनर्स की दो दिवसीय राष्ट्रीय कार्यशाला
- छत्तीसगढ़ विज्ञान सभा व पं. रविशंकर शुक्ल विवि का संयुक्त आयोजन

कुलपति ने की सराहना

पं. रविशंकर शुक्ल विश्वविद्यालय के कुलपति प्रोफेसर केसरी लाल वर्मा ने खगोल विज्ञान पर आधारित दो दिवसीय कार्यशाला की सराहना की. उन्होंने मास्टर ट्रेनर्स को संबोधित करते हुए कहा कि जिन राज्यों में जीरो शेडो डे को देखा जा सकता है, वहां जरूर लोगों के मध्य प्रदर्शन कर उन्हें इस खगोलीय घटना के बारे में बतायें. स्कूलों में कार्यक्रम कर छात्रों को जानकारी दें तथा उनकी जिज्ञासाओं को शांत करें.

सावधान... 26 मई को गायब हो जाएगी आपकी छाया!

पांच राज्यों के 35 ट्रेनर्स को दी शून्य छाया दिवस पर जानकारी

रायपुर ● छत्तीसगढ़ विज्ञान सभा और पंडित रविशंकर शुक्ल विश्वविद्यालय के संयुक्त तत्वावधान में दो दिवसीय मास्टर ट्रेनर्स की राष्ट्रीय कार्यशाला रविवि के मानव संसाधन केंद्र में आयोजित की गई। इस कार्यशाला में छत्तीसगढ़, मध्यप्रदेश, महाराष्ट्र, ओडिशा और पश्चिम बंगाल से 35 मास्टर ट्रेनर्स शामिल हुए। वे अपने राज्यों में लोगों को शून्य छाया दिवस के घटनाक्रम से अवगत कराएंगे।

समीर धुरडे ने बताया, परछाई ना बनने के घटनाक्रम को खगोल विज्ञानी जीरो शेडो डे या शून्य छाया दिवस कहते हैं। रविवि के कुलपति प्रोफेसर केसरी लाल वर्मा ने कहा कि जिन राज्यों में जीरो शेडो डे को देखा जा सकता है वहां जरूर लोगों को इस घटना के बारे में जरूर बताएं। संचालन विश्वास मेश्राम व आभार प्रदर्शन पीसी रथ ने किया। जनविज्ञानी डॉ बीकेके लाल ने कहा, जीरो शेडो डे के समय परछाई एकदम से न तो गायब होती है और ना ही हमारा साथ छोड़ती है बल्कि वह हमारे अंदर ही कुछ समय के लिए समाहित हो जाती है।

26 मई को 12 बजे रायपुर में जीरो शेडो डे

प्रसिद्ध भारतीय वैज्ञानिक प्रो. मेघनाथ साहा द्वारा स्थापित फोजिशनल एस्ट्रोनॉमी इंस्टीट्यूट कोलकाता के वैज्ञानिक रहे, वर्तमान में एमपी बिरला प्लेनेटोरियम के वैज्ञानिक अधिकारी बिपाश दासगुप्ता ने पोसिशनल एस्ट्रोनॉमी के बारे में जीरो शेडो डे से जुड़ी महत्वपूर्ण जानकारियां दी। उन्होंने बताया, शून्य छाया दिवस की घटना कर्क रेखा और मकर रेखा के बीच ही घटित होती है। इस दौरान भूमध्य रेखा से कर्क रेखा के बीच कुछ स्थानों पर सूर्य की किरणें सीधी पड़ती है जिस कारण वहां के लंबवत खड़ी किसी चीज की परछाई नहीं बनती। रायपुर में 26 मई को दोपहर करीब 12 बजे जीरो शेडो डे की घटना होगी।

SITARE: INTRODUCTORY WORKSHOP ON ASTROPHYSICS

SITARE (Southampton IUCAA Training for Astronomical Research and Education): Introductory Workshop on Astrophysics was organized at SoS in Physics and Astrophysics, PRSU, in association with IUCAA, and University of Southampton, UK, during August 17 - 19, 2018. There were 60 participants, representing different parts of India, and 90 participants from PRSU. The main objective of the workshop was to provide a suitable platform to young students to pursue a research career in Astronomy and Astrophysics. The resource persons included: Poshak Gandhi, Ranjeev Mishra, Gulab Chand Dewangan, Sonali Sachdeva, Sudhanshu Barway, Sheo Kumar Pandey, Laxmi Kant Chaware, and Nand Kumar Chakradhari. The lectures were given covering a broad areas, like Physics of Stars, Galaxies, Virtual Observatories, Black Holes, Relativistic Jets, Accretion Disc, and Radiative Processes in Astrophysics. The programme also included sessions for questions answers, general discussions, and interactions. Ten outstanding participants were selected for SITARE: Advanced Workshop on Astrophysics at IUCAA, held during January 10 - 16, 2019.

चंद्रग्रहण की खगोलीय घटना को लेकर विद्यार्थियों में दिखा उत्साह

बादलों के बीच ब्लड मून देखने की कोशिश, देर रात तक रविवि और केंद्रीय विद्यालय-2 में रोमांच

चिकित्सा PLUS रिपोर्टर

रायपुर • चंद्रग्रहण को लेकर रायपुराइट्स में एक्साइटमेंट देखा गया। पं. रविवि और केंद्रीय विद्यालय-दो में इसे देखने की विशेष व्यवस्था की गई थी। टेलीस्कोप के जरिए स्टूडेंट्स ने इस खगोलीय घटना को करीब से देखा। केंद्रीय विद्यालय-2 में बच्चों द्वारा विज्ञान प्रसार के वैज्ञानिकों की मदद से तैयार की गई दूरबीन से अद्भुत नजारा देखा गया।

पं. रविशंकर विश्वविद्यालय

केंद्रीय विद्यालय-2

अनेजिंग मोमेंट

यह एक दिव्य संयोग है। इससे पूर्व 16 साल पहले वर्ष 2000 में ऐसा संयोग बना था। मेरे लिए यह अमेजिंग मोमेंट रहा।

खुशबू सोनी

याटगार लम्हा

इस तरह की घटनाओं का साक्षी बनना मेरे लिए यादगार लम्हा है। मैं व्हीलचेयर पहले से एक्साइटेड थी।

हेमलता साहू

जानने की थी जिज्ञासा

मुझे बचपन से चांद को लेकर काफी जिज्ञासा थी। आज मुझे पता चला कि चांद ग्रहण के दौरान पृथ्वी की छाया की वजह से धरती से चांद काला दिखाई देता है, लेकिन कुछ सेकंड के लिए चांद पूरी तरह से लाल भी दिखाई पड़ता है।

वैष्णव

पं. रविशंकर शुक्ल विश्वविद्यालय के छात्रों ने लगाया न्यूटनोनियन टेलिस्कोप

तांबे के रंग का दिखा चांद, एक घंटा 43 मिनट तक चली लुकाछिपी

Nand Kumar Chakradhari was invited as an expert for a discussion on Total Lunar Eclipse of July 27, 2018 in a TV programme, broadcasted by IBC 24 hour TV channel, on the same day.

PUBLICATIONS

Divya Rawat, Mayukh Pahari, Jagdish Singh Yadav, Pankaj Jain, Ranjeev Misra, et al. (2019) *Study of timing evolution from non- variable to structured large amplitude variability transition in GRS 1915 + 105 using AstroSat,* ApJ, **870**, 4.

IUCAA
BALANCE SHEET

The Bombay Public Trust Act, 1950. Schedule VIII [Vide Rule (1)]

Name of the Trust : INTER-UNIVERSITY CENTRE FOR ASTRONOMY & ASTROPHYSICS

Address: Post Bag-4,Ganeshkhind, Pune-7. **Registration No. :F-5366 (PUNE) dated 27.1.1989.**

BALANCE SHEET AS AT 31ST MARCH 2019

Sr No.	FUNDS & LIABILITIES	Schedule No.	31.03.2019 Rs.
1	Trust Fund / Corpus	6	**1,78,88,207**
2	Grant-In-Aid from UGC	7	**1,35,55,92,729**
3	Other Earmarked Funds and Project Grants	8	**28,07,59,870**
4	Projects and Other Payable	9	**19,14,58,045**
5	Current Liabilities	10 & 10A	**15,88,59,478**
6	Income and Expenditure a/c	14	**(27,53,71,019)**
	Total		**1,72,91,87,310**

Sr No.	ASSETS & PROPERTIES	Schedule No.	31.03.2019 Rs.
1	Fixed Assets	11	**69,31,72,223**
2	Investments / Deposits	12	**85,51,76,573**
3	Project & Other Receivables	13	**3,44,47,309**
4	Current Assets -	13	
	a) Cash, Bank balances & Revenue Stamps		**5,99,58,709**
	b) Loans and Advances	13A	**4,03,80,072**
	c) Deposits		**27,52,616**
	d) Prepaid Expenses		**70,79,464**
	e) Advance to Suppliers	13B	**3,62,20,344**
	Total		**1,72,91,87,310**

For Inter-University Centre for Astronomy & Astrophysics

M.S.Sahasrabudhe
Admin. Officer (Accounts)

N. V. Abhyankar
(Sr.Admn.Officer)

Prof. Somak Raychaudhury
(Director / Trustee)

Place : Pune
Date : 29.05.2019

As per Report of even date
For Kirtane & Pandit LLP
Chartered Accountants
FRN- 105215W/W100057

Parag Pansare
(Partner)
Membership No.117309

Chairperson
Governing Board

KIRTANE & PANDIT LLP ★ Chartered Accountants ★ FRN 105215W/W100057

IUCAA

अंतर - विश्वविद्यालय केंद्र : खगोलविज्ञान और खगोलभौतिकी

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