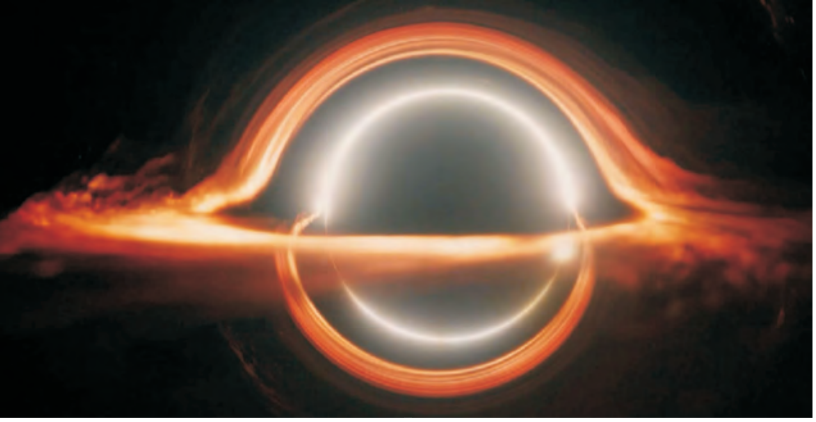

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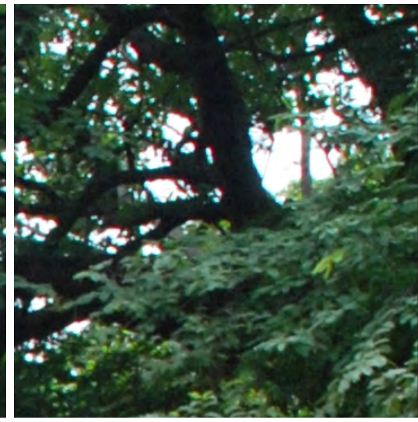

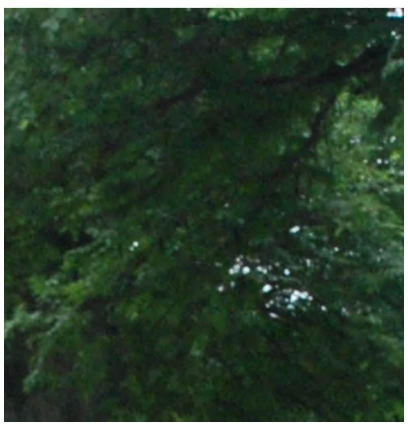
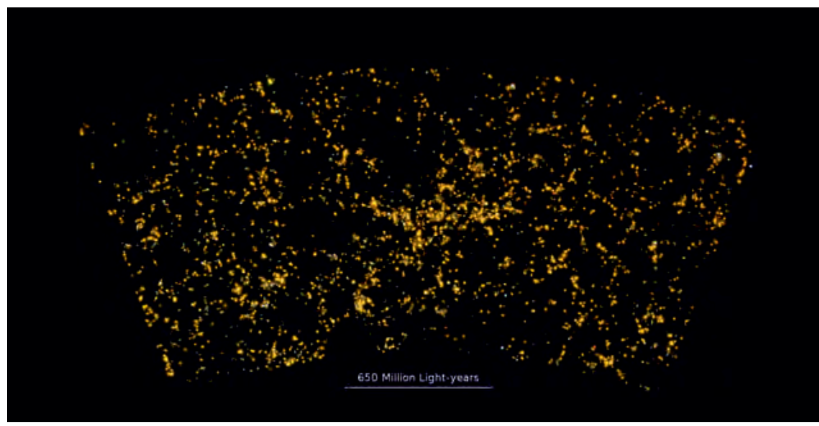

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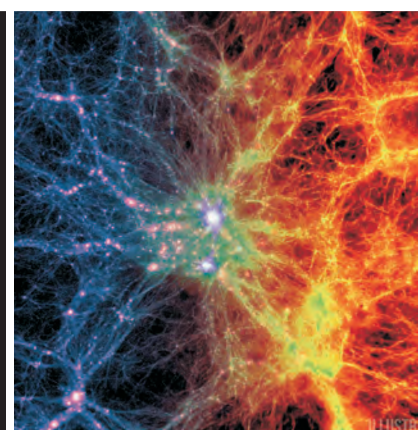

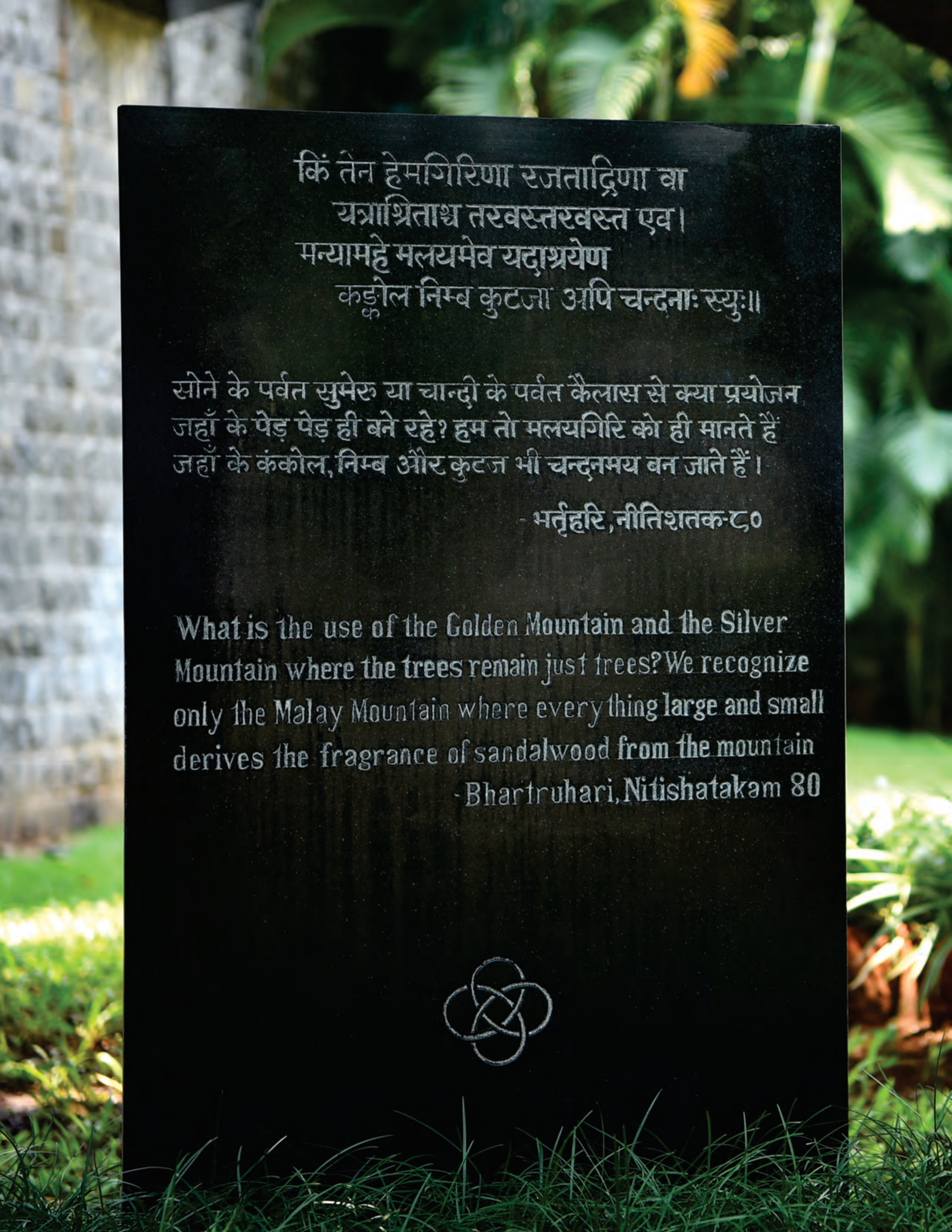
किं तेन हेमगिरिणा रजताद्रिणा वा
यत्राश्रिताश्च तरवस्तरवस्त एव।
मन्यामहे मलयमेव यदाश्रयेण
कङ्कोल निम्ब कुटजा अपि चन्दनाः स्युः॥
सोने के पर्वत सुमेरु या चान्दी के पर्वत कैलास से क्या प्रयोजन,
जहाँ के पेड़ पेड़ ही बने रहे? हम तो मलयगिरि को ही मानते हैं
जहाँ के कंकोल, निम्ब और कुटज भी चन्दनमय बन जाते हैं।
- भर्तृहरि, नीतिशतक-८०
What is the use of the Golden Mountain and the Silver
Mountain where the trees remain just trees? We recognize
only the Malay Mountain where everything large and small
derives the fragrance of sandalwood from the mountain
-Bhartruhari, Nitishatakam 80

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असीम परांजपे | ASEEM PARANJAPE

e-mail: aseem@iucaa.in

संपादकीय सहाय्यक | EDITORIAL ASSISTANT

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106. Anirban Saha, Department of Physics, West Bengal State University, Kolkata.

107. Sanjay Kumar Sahay, Department of Computer Science and Information Systems, BITS - Pilani, Goa.
108. Sandeep Sahijpal, Department of Physics, Panjab University, Chandigarh.
109. Tarun Deep Saini, Department of Physics, IISc, Bengaluru.
110. Pramoda Kumar Samal, Post-Graduate Department of Physics, Utkal University, Bhubaneswar.
111. Prasant Samantray, Department of Physics, BITS - Pilani, Hyderabad.
112. Saumyadip Samui, Department of Physics, Presidency University, Kolkata.
113. Sudipta Sarkar, Department of Physics, IIT, Gandhinagar.
114. Sanjay Baburao Sarwe, Department of Mathematics, St. Francis De Sales College, Nagpur.
115. Anjan Ananda Sen, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
116. Asoke Kumar Sen, Department of Physics, Assam University, Silchar.
117. Somasri Sen, Department of Physics, Jamia Millia Islamia, New Delhi.
118. Anand Sengupta, Department of Physics, IIT, Gandhinagar.
119. T.R. Seshadri, Department of Physics and Astrophysics, University of Delhi.
120. K. Shanthi, UGC Human Resources Development Centre, University of Mumbai, Kalina Campus.
121. Ranjan Sharma, Department of Physics, Cooch Behar Panchanan Barma University.
122. Alkendra Singh, Department of Physics, Institute of Science, Banaras Hindu University, Varanasi.
123. Harinder Pal Singh, Department of Physics and Astrophysics, University of Delhi.
124. Surendra Nadh Somala, IIT, Hyderabad.
125. Vikram Soni, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
126. K. Sriram, Department of Astronomy, University College of Science, Osmania University, Hyderabad.
127. Parijat Thakur, Department of Basic Sciences and Humanities, Guru Ghasidas Central University, Bilaspur.
128. Arun Varma Thampan, Department of Physics, St. Joseph's College, Bengaluru.
129. Pranjal Trivedi, Department of Physics, Sri Venkateswara College, Delhi.
130. Paniveni Udayashankar, Department of Physics, N.I.E. Institute of Technology, Mysuru.
131. Sanil Unnikrishnan, Department of Physics, St. Stephen's College, Delhi.
132. Anisul Ain Usmani, Department of Physics, Aligarh Muslim University.
133. Murli Manohar Verma, Department of Physics, University of Lucknow.
134. Jaswant Kumar Yadav, Department of Physics, Central University of Haryana, Mahendergarh.

FROM AUGUST 2017

1. Dharam Vir Ahluwalia, Department of Physics, IIT, Guwahati.
2. Arunima Banerjee, Department of Physics, IISER, Tirupati.
3. Nand Kumar Chakradhari, School of Studies in Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur.
4. Ayan Chatterjee, Department of Physics and Astronomical Sciences, Central University of Himachal Pradesh, Dharamshala.
5. Shantanu Desai, Department of Physics, IIT, Hyderabad.
6. Gaurav Goswami, School of Engineering and Applied Science, Ahmedabad University.
7. Nandita L. Kalita, Department of Physics, Girijananda Chowdhury Institute of Management and Technology, Guwahati.
8. Arun V. Kulkarni, Department of Physics, BITS - Pilani, Goa.
9. Smriti Mahajan, Department of Physics, IISER, Mohali.
10. Saptarshi Mondal, Department of Statistics, Bethune College, Kolkata.
11. Mahadev B. Pandge, Department of Physics, Dayanand Science College, Latur.
12. Rutu Parekh, Dhirubhai Ambani Institute of Information and Communication Technology, Gandhinagar.
13. Swarup Poria, Department of Applied Mathematics, University of Calcutta, Kolkata.
14. Prabir Rudra, Department of Mathematics, Asutosh College, Kolkata.
15. Mohit Kumar Sharma, Amity Centre for Astronomy and Astrophysics, Amity University Campus, Noida.
16. Gyan Prakash Singh, Department of Mathematics, Visvesvaraya National Institute of Technology, Nagpur.
17. Heisnam Shanjit Singh, Department of Physics, Rajiv Gandhi University, Rono Hills, Papumpare.
18. Monika Sinha, Department of Physics, IIT, Jodhpur.
19. Sunil Kumar Tripathy, Department of Physics, Indira Gandhi Institute of Technology, Dhenkanal.
20. Vinutha Tummala, Department of Applied Mathematics, Andhra University, Visakhapatnam.
21. Rashmi Uniyal, Department of Physics, Government Degree College, Narendranagar, Tehri Garhwal.
22. Deepak Vaid, Department of Physics, NIT, Surathkal.

The Twenty–Eight batch (2017) of Visiting Associates, who were selected for a tenure of three years, beginning, August 1, 2017.


DHARAM VIR AHLUWALIA


ARUNIMA BANERJEE


NAND KUMAR CHAKRADHARI


AYAN CHATTERJEE


SHANTANU DESAI

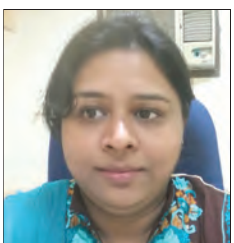

GAURAV GOSWAMI


ARUN KULKARNI


SMRITI MAHAJAN


SAPTARSHI MONDAL


MAHADEV PANDGE


RUTU PAREKH


SWARUP PORIA


PRABIR RUDRA


MOHIT KUMAR SHARMA


GYAN PRAKASH SINGH


HEISNAM SHANJIT SINGH


MONIKA SINHA


SUNIL KUMAR TRIPATHY


VINUTHA TUMMALA


RASHMI UNIYAL


DEEPAK VAID

Appointment of the following Visiting Associates of the Twenty-Fifth batch was extended for three years : Bijan Kumar Bagchi, Sarmistha Banik, Naseer Iqbal Bhat, Ramesh Chandra, Suresh Chandra, Ritaban Chatterjee, Suchetana Chatterjee, Asis K. Chattopadhyay, Surajit Chattopadhyay, Tanuka Chattopadhyay, Sudipta Das, Dhurjati P. Dutta, Ujjal Debnath, Jishnu Dey, Mira Dey, Sunandan Gangopadhyay, Suresh Kumar, Manzoor A. Malik, Soma Mandal, Titus Mathew, Irom A. Meitei, Hamida Mir, Pradip Mukherjee, Dibyendu Nandi, Rahul Nigam, S. K. Pandey, Kishor Dnyandeo Patil, Surajit Paul, Ninan Sajeeth Philip, Shantanu Rastogi, Saibal Ray, Sanjay Baburao Sarwe, Saumyadip Samui, Anand Sengupta, T. R. Seshadri, Vikram Soni, K. Sriram and Arun Varma Thampan.

ORGANIZATIONAL STRUCTURE OF IUCAA'S ACADEMIC PROGRAMMES

(As on March 31, 2018)

The Director
Somak Raychaudhury

Dean, Core Academic Programmes
Varun Sahni

Dean, Visitor Academic Programmes
Kandaswamy Subramanian

Head, Computing Facilities
Dipankar Bhattacharya

Head, Public Outreach Programmes
Sanjit Mitra

Head, Publications
Aseem Paranjape

Head, Scientific Meetings
Ranjeev Misra

Head, Instrumentation
A. N. Ramaprakash

Head, IRCs, IUCs, and INAADs
Ranjeev Misra

Head, Library
Durgesh Tripathi

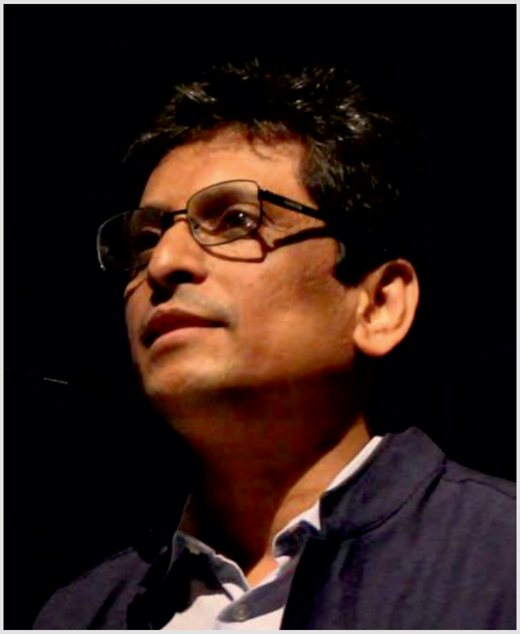
Head, Infrastructural Facilities
Tarun Souradeep

Head, Teaching Programmes
Gulab Dewangan

Head, Observing Programmes and SALT
R. Srianand
Ranjan Gupta

Head, Grievance Cell
Kandaswamy Subramanian

निदेशक रिपोर्ट



जब वर्ष २०१७ के लिए भौतिकी के नोबेल पुरस्कार की घोषणा की गई, तो हम इस तथ्य से बहुत खुश थे कि यह पुरस्कार संयुक्त राज्य अमेरिका में स्थित LIGO वेधशालाओं द्वारा गुरुत्वाकर्षण लहरों की पहचान के लिए दिया गया था, और भौतिकी और संबंधित प्रौद्योगिकी की दुनिया पर इसका काफी असर पड़ा है। इस खोज पत्र से संबंधित एक हजार लेखकों में से ३७ भारतीय संस्थानों से संबद्ध थे, और एक दर्जन IUCAA से थे। वास्तव में, भारतीय गुरुत्वाकर्षण–लहर अवलोकन (IndIGO) की पहल का कार्यक्रम IUCAA में एक दशक पूर्व ही गठित और समेकित किया गया था।

२०१५ में पहली खोज के बाद, खणउ तथा देश के विभिन्न हिस्सों के वैज्ञानिकों एवं छात्रों की गुरुत्वाकर्षण लहर अनुसंधान में भागीदारी तेजी से बढ़ी है, और इस शैक्षणिक वर्ष पर इस विज्ञान में नई खोजों का खास प्रभुत्व रहा है, विशेष रूप से, एक घटना की विद्युत चुम्बकीय पहचान, जो न्यूट्रॉन सितारों की एक जोड़ी साबित हुई।

IUCAA, LIGO-इंडिया के मानव संसाधन एवं वैज्ञानिक पहलुओं के लिए जिम्मेदार संस्था है जिसमें भारतीय जमीन पर तीसरा LIGO डिटेक्टर स्थापित करना शामिल है, जो DE और DST के माध्यम से भारत सरकार द्वारा उठाई गई मेगा–साइंस पहल है। यूजीसी ने IUCAA के इस उपक्रम के शुरुआती चरण में ही नए मानव और अन्य संसाधन प्रदान कर अपना समर्थन दर्शाया है।

जैसा कि आप इस रिपोर्ट से संलग्न रिसर्च हाइलाइट्स में देखेंगे कि यह वर्ष पहला वर्ष था जब अंतरिक्ष में स्थित पहली भारतीय मल्टी वेवलेंथ खगोलीय वेधशाला 'एस्ट्रोसैट' से प्राप्त प्रथम वैज्ञानिक परिणाम प्रकाशित किए गए, और यह सुविधा पहले से ही सितारों के भौतिकी में अग्रणी अंतर्दृष्टि प्रदान कर रही है। IUCAA में ISRO की सहायता से एस्ट्रोसैट विज्ञान सहायता कक्ष स्थापित किया गया है, जो भारतीय महाविद्यालयों और विश्वविद्यालयों के सभी स्तरों के शोधकर्ताओं और IUCAA के सदस्यों के लिए एस्ट्रोसैट के साथ वैज्ञानिक अनुसंधान करने एक अनूठा अवसर प्रदान करता है। IUCAA में एक उत्कृष्ट टीम सौर अल्ट्रावाइलेट इमेजिंग टेलीस्कोप (SUIT) भी बना रही है जो भविष्य में सूर्य के अध्ययन के लिए ISRO के आदित्य–L1 मिशन का हिस्सा होगा। भविष्य की कई विज्ञानं संबंधित अंतरिक्ष परियोजनाओं को संकल्पनात्मक बनाने का ठोस कार्य IUCAA में शुरू हो चूका है। ISRO द्वारा यह परियोजनाएं प्रक्षेपण के लिए चुनी जा सकती हैं।

IUCAA के नेतृत्व वाले शोध के मुख्य परिणामों में से एक जिसने दुनिया भर में मीडिया का ध्यान आकर्षित किया वह लगभग आधा अरब प्रकाश–वर्ष की दूरी पर स्थित ब्रह्मांड में 'सरस्वती सुपरक्लस्टर' नामित आकाशगंगाओं की सबसे बड़ी संरचना की खोज है। इसमें IUCAA शोधकर्ताओं के साथ एसोसिएट्शिप कार्यक्रम के अंतर्गत विभिन्न भारतीय महाविद्यालयों एवमं विश्वविद्यालयों में कार्यरत शोधकर्ता और छात्र शामिल थे। इस शोध का अधिक विवरण इस वार्षिक रिपोर्ट में रिसर्च हाईलाइट्स शीर्षक के तहत देखा जा सकता है।

इस वर्ष हमें भारतीय विश्वविद्यालयों एवं उच्च शिक्षण संस्थानों में शिक्षा एवं अनुसन्धान पर UGC के इंटर–यूनिवर्सिटी केंद्रों के प्रभाव पर प्रकाश डालती एक राष्ट्रीय संगोष्ठी, 'शोध शिक्षा समीक्षा' की मेजबानी करने का अवसर प्राप्त हुआ। इस कार्यक्रम के दौरान हमें मानव संसाधन विकास

मंत्री श्री प्रकाश जावड़ेकर, उच्च शिक्षा विभाग के सचिव डॉ केवल के. शर्मा तथा यूजीसी के अध्यक्ष डॉ वीरेंद्र एस. चौहान का स्वागत करने का सौभाग्य प्राप्त हुआ्। इस संगोष्ठी का विवरण इस वार्षिक रिपोर्ट में पाया जा सकता है।

IUCAA में वर्तमान में २३ फैकल्टी और एमरिटस प्रोफेसर, २७ पोस्ट–डॉक्टरेट फैलो और ४१ पीएचडी रिसर्च स्कॉलर्स हैं जिन्होंने ५.२ के औसत इम्पैक्ट फैक्टर वाले कुल १४९ पीयर–रिवीव्ड पेपर प्रकाशित किए हैं्। इस वर्ष के दौरान दो IUCAA रिसर्च स्कॉलरों ने पीएचडी की डिग्री प्राप्त की है। मुझे इन आंकड़ों पर बहुत गर्व है, क्योंकि यह दिखाता है कि मेरे सहयोगी केवल अपने शोध में बहुत ही उत्पादक नहीं हैं, लेकिन वे इस विषय पर काफी प्रभाव डाल रहे हैं। इससे भी ज्यादा प्रसन्नता यह है कि IUCAA के १५६ विज़िटिंग एसोसिएट्स जो विभिन्न भारतीय महाविद्यालयों और विश्वविद्यालयों में फैकल्टी हैं, उन्होंने इसी अवधि के दौरान IUCAA की सहायता द्वारा अपने शोध से संबंधित २८३ पीयर–रिवीव्ड पेपर प्रकाशित किए हैं। यह स्पष्ट रूप से पूरे देश में उच्च शिक्षा संस्थानों में खगोल विज्ञान और खगोल भौतिकी (A & A) अनुसंधान को पोषित करने में IUCAA के प्रभाव को इंगित करता है।

इस वर्ष IUCAA में शिक्षकों और एचआरडी की शिक्षा पर आधारित पंडित मदन मोहन मालवीया राष्ट्रीय मिशन के अंतर्गत खगोल विज्ञान और खगोल भौतिकी के शिक्षा केंद्र की स्थापना की गई्। भारत में कॉलेजों और विश्वविद्यालयों में A & A की शिक्षा का समर्थन करने के लिए IUCAA प्रतिबद्ध है। पिछले वर्ष के दौरान, कई विश्वविद्यालयों ने UGC द्वारा प्रोत्साहित किए जाने वाले पाठ्यक्रमों की नई पसंद–आधारित प्रणाली का अवसर लेते हुए भौतिकी और विज्ञान विभागों में स्नातक स्तर पर प्रारंभिक A & A पाठ्यक्रम शुरू किया। इसके अलावा भौतिकी विभागों में परास्नातक स्तर पर A & A की शिक्षा को सम्मिलित करने का कार्य जारी है। हम किसी भी महाविद्यालय/विश्वविद्यालय विभागों तथा उच्च शिक्षा संस्थाओं में हर तरह की टेलर–मेड शिक्षा गतिविधियों के डिजाइन और कार्यान्वयन का समर्थन करना जारी रखेंगे, और इस प्रक्रिया में छात्रों को A & A के क्षेत्र में उत्पन्न होने वाले अत्यधिक अवसरों के लिए प्रशिक्षित करने में मदद करते रहेंगे।

IUCAA के अकादमिक सदस्यों द्वारा A & A और संबंधित विषयों पर अनुसंधान में महत्वपूर्ण योगदान देना और इस विषय पर केवल देश में ही नहीं पर समूचे विश्व में सम्मेलनों और कार्यशालाओं का आयोजन करना जारी हैं्। हम तीन दशक से मौलिक शोध एवं राष्ट्रीय और अंतर्राष्ट्रीय स्तर पर A & A, ब्रह्मांड विज्ञान एवं सैद्धांतिक भौतिकी में शिक्षा शास्त्र के विकास कार्य में अग्रणी रहे हैं्। IUCAA की विश्व स्तरीय तथा IUCAA के विजिटिंग एसोसिएट्स के नेटवर्क के माध्यम से भारतीय महाविद्यालयों / विश्वविद्यालयों में प्रतिभाशाली कर्मचारियों की कड़ी मेहनत द्वारा जारी रिसर्च के लिए IUCAA सदैव उनका ऋणी रहेगा। मैं उनमें से प्रत्येक के प्रति, हमारे सलाहकारों के प्रति, हमारे गवर्निंग बोर्ड तथा उसके अध्यक्ष डॉ श्रीकुमार बनर्जी, हमारी परिषद् तथा उसके अध्यक्ष प्रोफेसर धीरेंद्र पी. सिंह (और हाल ही में अध्यक्ष पद पर कार्यरत डॉ वीरेंद्र एस. चौहान) के प्रति पूरी ईमानदारी से कृतज्ञता व्यक्त करना चाहता हूं। हम विश्वविद्यालय अनुदान आयोग तथा उसके अधिकारियों विशेषत: सयुंक्त सचिव डॉ मंजू सिंह एवं समस्त UGC कर्मचारियों का उनकी सहायता और समर्थन के लिए मनपूर्वक धन्यवाद प्रकट करते हैं्।

सोमक रायचौधरी
निदेशक

DIRECTOR'S REPORT

When the Nobel Prize for Physics was announced for the year 2017, we were very happy to welcome the fact that it was awarded for the detection of Gravitational Waves by the LIGO Observatories, situated in the USA, and the impact it has had on the world of Physics and associated Technology. Of about one thousand authors of the discovery paper, 37 were affiliated with Indian Institutions, and a dozen were from IUCAA. Indeed, the Indian Initiative in Gravitational-wave Observations (IndIGO), was formed and consolidated at IUCAA, over a decade ago.

Since the first discovery in 2015, scientists and students at IUCAA, and in various parts of the country have been increasingly involved in gravitational wave research, and this academic year has been dominated by the new discoveries in this science, in particular, the electromagnetic detection of the counterpart of an event, which turned out to be a pair of coalescing neutron stars. IUCAA is the institution responsible for the scientific and human resource aspects of LIGO-India, which involves setting up the third LIGO detector on Indian soil, a mega-science initiative taken up by the Government of India through the DAE and DST. The UGC has shown support even at this early stage by sanctioning new positions and resources available to this initiative at IUCAA.

As you would see in the research highlights that follow this report, this was also the first year in which the first scientific results from India's first multi-wavelength astrophysical observatory in space, AstroSat, was published, and already the facility is providing ground-breaking insight into the Physics of stars. The AstroSat Science Support Cell has been established at IUCAA, supported by ISRO, which provides a unique opportunity for researchers at Indian Colleges and 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.

One of the core outcomes of IUCAA-led research that caught the attention of the media worldwide is the discovery of the largest structure of galaxies in the Universe, about half a billion light-years across, named, Saraswati Supercluster. This involved researchers and students working at various Indian Colleges and Universities, collaborating with IUCAA researchers as part of its Associateship Programme. The details of this discovery could be found in this Annual Report under the title, Highlights of Research.

This year we were very happy to host a national symposium, Shodh Shiksha Samiksha, highlighting the Impact of the Inter-University Centres of the UGC on Research and Teaching at Indian Universities and HE Institutions, for which we were fortunate to welcome the HRD Minister, Shri Prakash Javadekar; the Secretary of the Department of Higher Education, Dr Kewal K. Sharma; and the Chairman of the UGC, Dr Virander S. Chauhan, for this event. The details of this symposium could be found in this Annual Report.

IUCAA currently has 23 Faculty and Emeritus Professors, 27 Post-doctoral Fellows and 41 Ph.D. Research Scholars. They have collectively published 149 peer-reviewed papers, with a mean impact factor of 5.2. Over this year, two IUCAA Research Scholars have obtained Ph.D. degrees. I am very proud of this statistics, since it shows that my colleagues are not just very productive in their research, but they are making a substantial impact on the subject. Even more gratifying is the fact that the 156 Visiting Associates of IUCAA, who are faculty members at Indian Colleges and Universities, supported in their research by IUCAA, have published 283 peer-reviewed papers during the same period. This clearly indicates the impact IUCAA has in promoting and nurturing Astronomy and Astrophysics (A & A) research at institutions of higher education all over the country.

This year saw the establishment of the Teaching Learning Centre in Astronomy and Astrophysics at IUCAA under the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching of the HRD. IUCAA is committed to support the teaching of A & A at

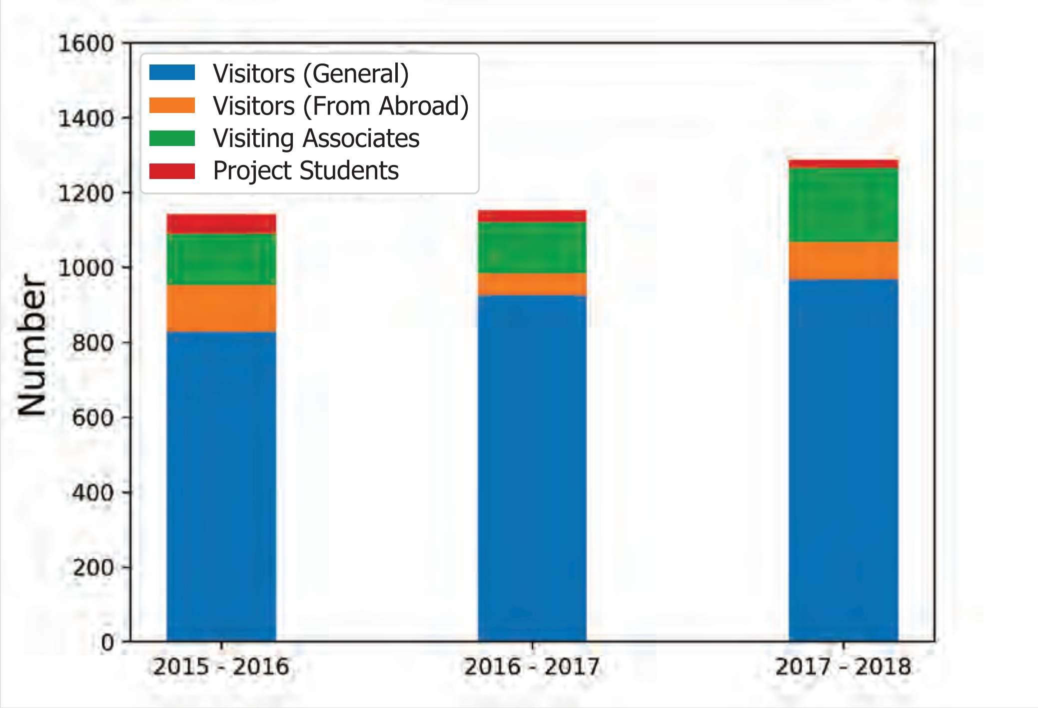
Colleges and Universities in India. During the past year, several Universities taking the opportunity of the new choice-based system of courses, being encouraged by the UGC, to initiate introductory A & A courses at the under-graduate level in Physics and Science departments. This is in addition to the teaching of A & A at the Masters' level in Physics departments, which continues to flourish. We will continue to support the design and implementation of such tailor-made teaching activities in any College/University department, and at any HE Institution in India, and in the process help students get trained for the immense opportunities in A & A opening up in the country.

The academic members of IUCAA continue to make significant contributions to research in A & A, and related subjects, and to organise and participate in conferences and workshops all over the country, and indeed all over the world. 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 Colleges/Universities through the network of IUCAA's Visiting Associates, owes a great deal to the hard-working and talented staff (both core and contractual) working at IUCAA. I wish to express my sincere gratitude to every one of them, and to our mentors, our Governing Board with Dr Srikumar Banerjee as Chair, and our Council, with Professor Dhirendra P. Singh (and until recently Dr Virander S. Chauhan) as Chair. We sincerely acknowledge the help, advice and support from the University Grants Commission, and its officers and staff, in particular, Dr Manju Singh, Joint Secretary.

Somak Raychaudhury
Director

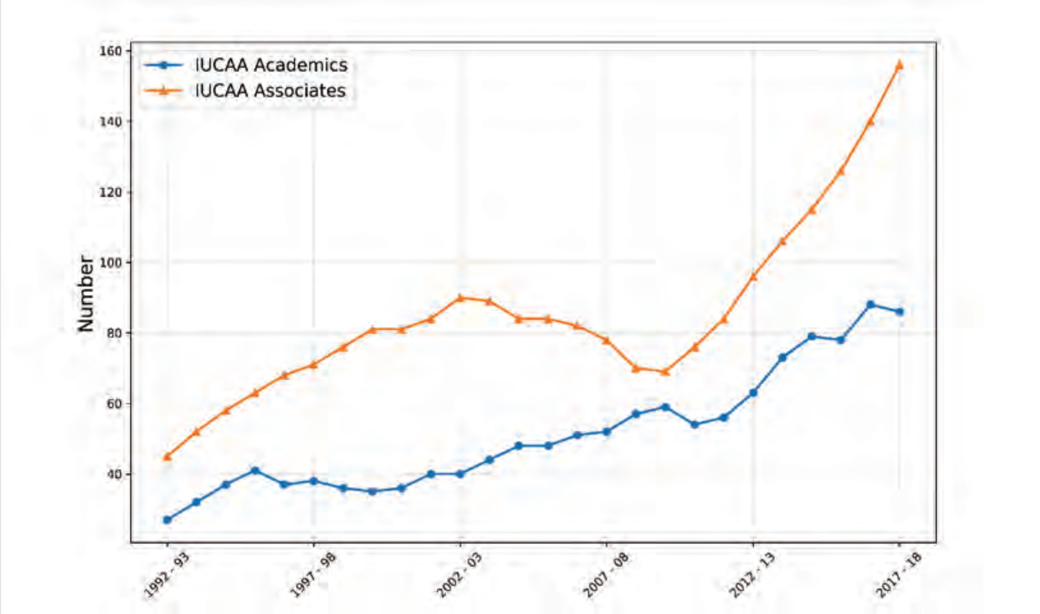
IUCAA IN NUMBERS

Visitors to IUCAA

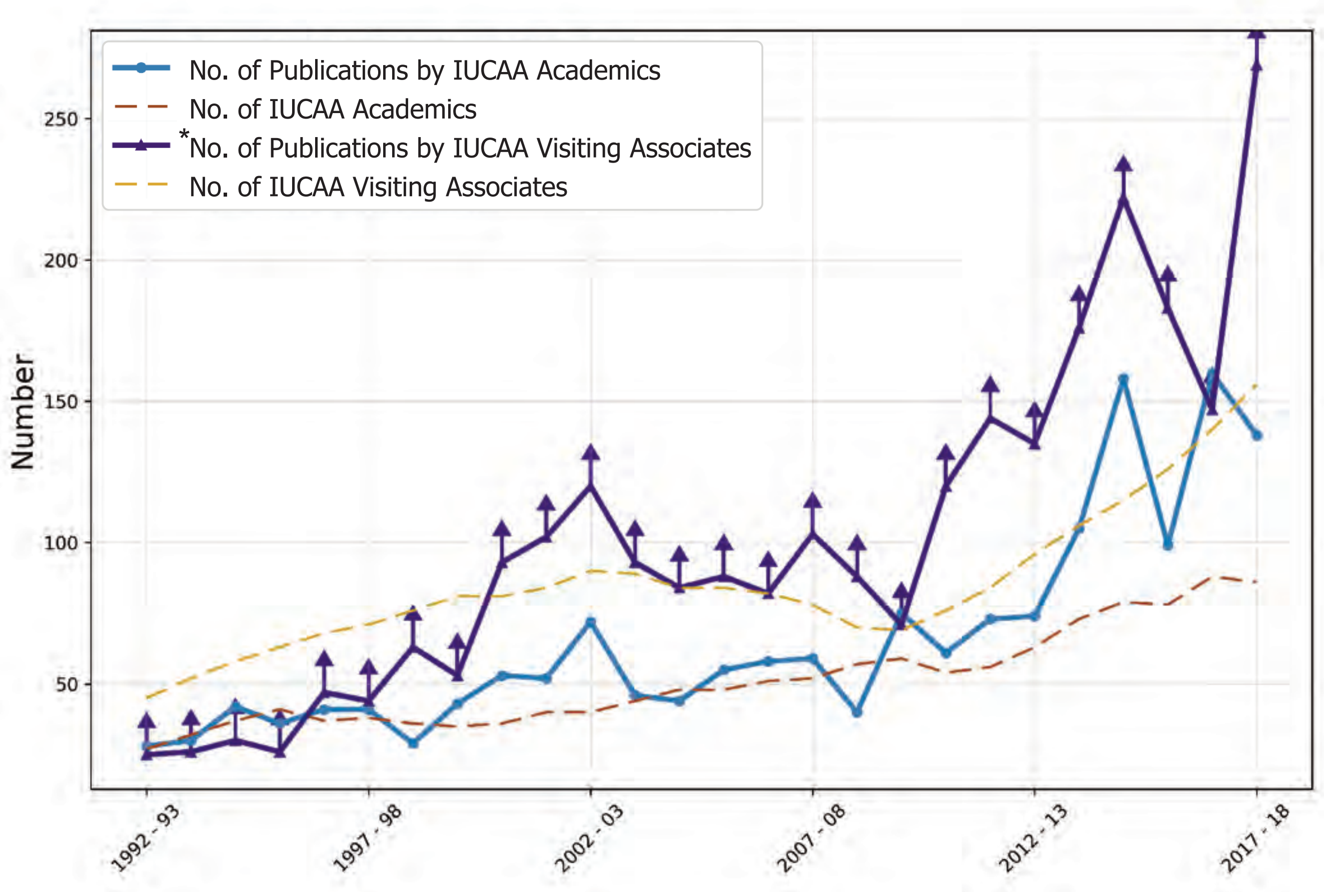


Since its inception, the IUCAA extended family of Visiting Associates has seen a steady growth over time, with an academic strength today nearly thrice its original number.

IUCAA Family across the Years



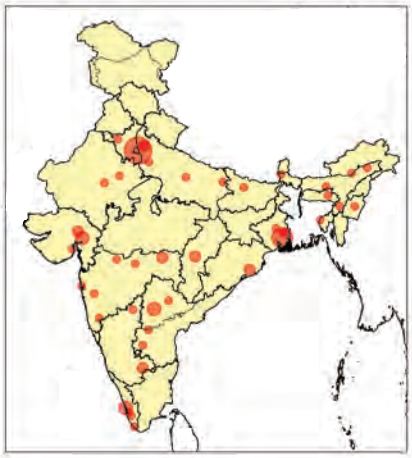
Publications across the Years



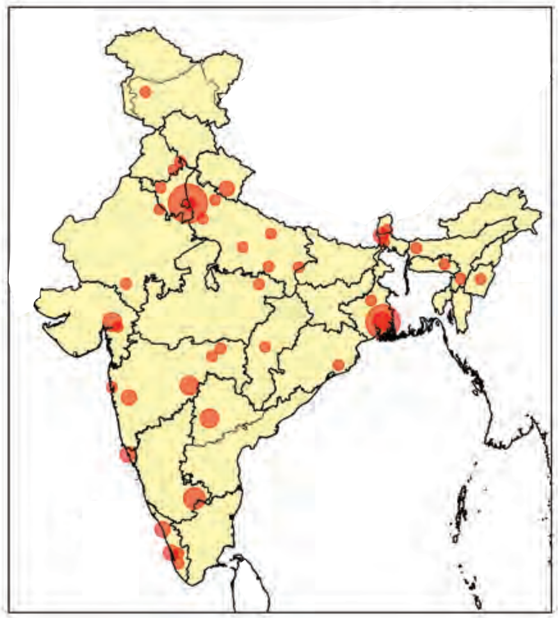
Number of Publications by IUCAA Visiting Associates are underestimated.

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

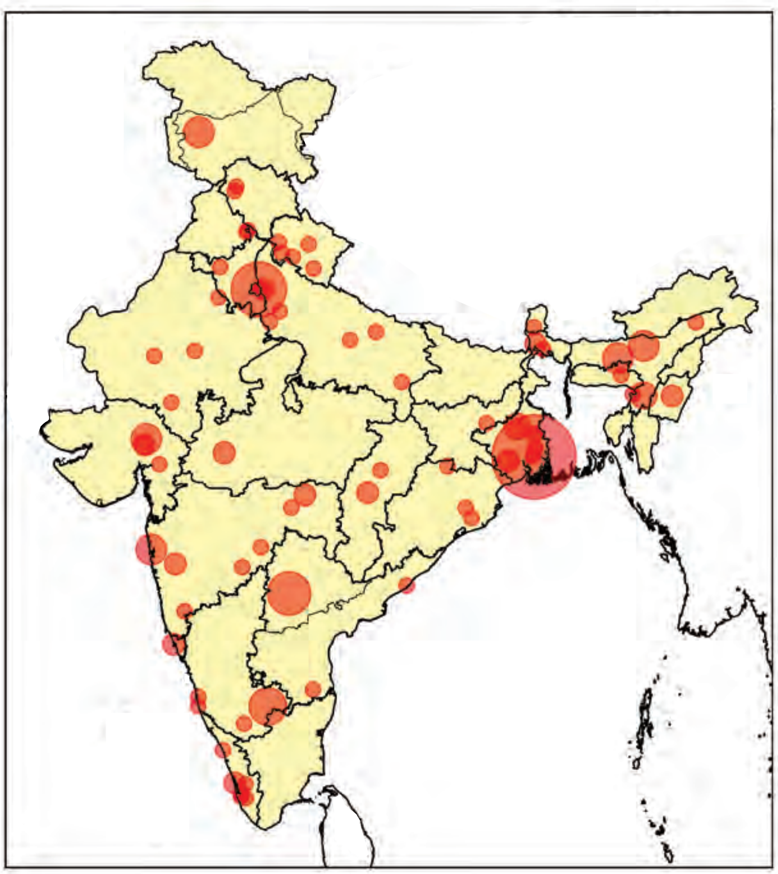
IUCAA Associates Across India



1997-1998



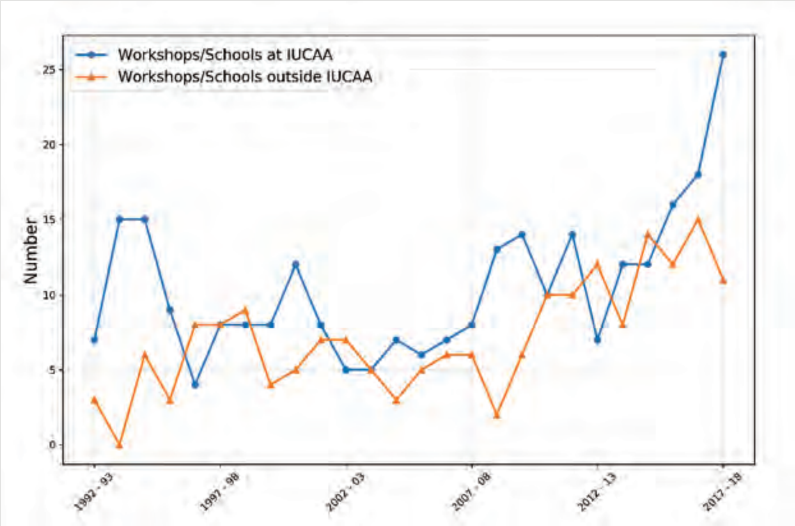
2007-2008



2017-2018

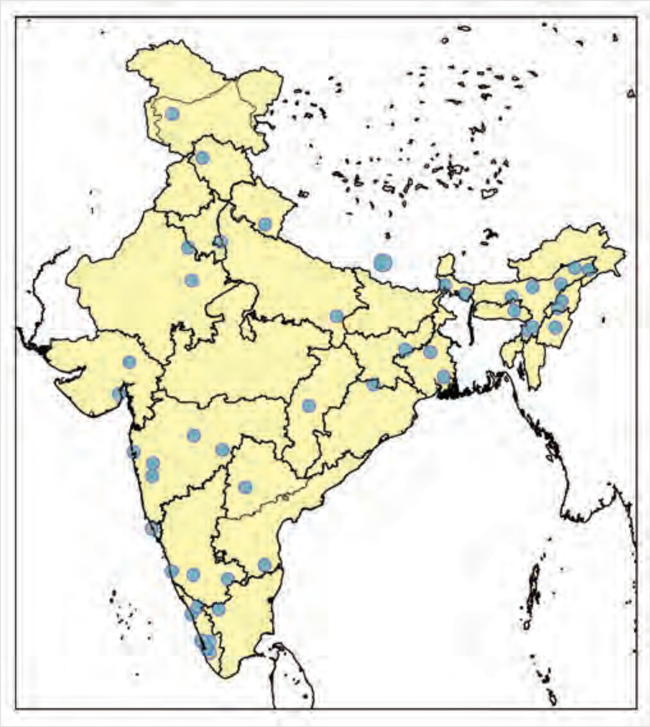
The always diverse set of IUCAA Visiting Associates has continued to expand both in numbers as well as geographically, with significant representation today from the remotest parts of the country.

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.

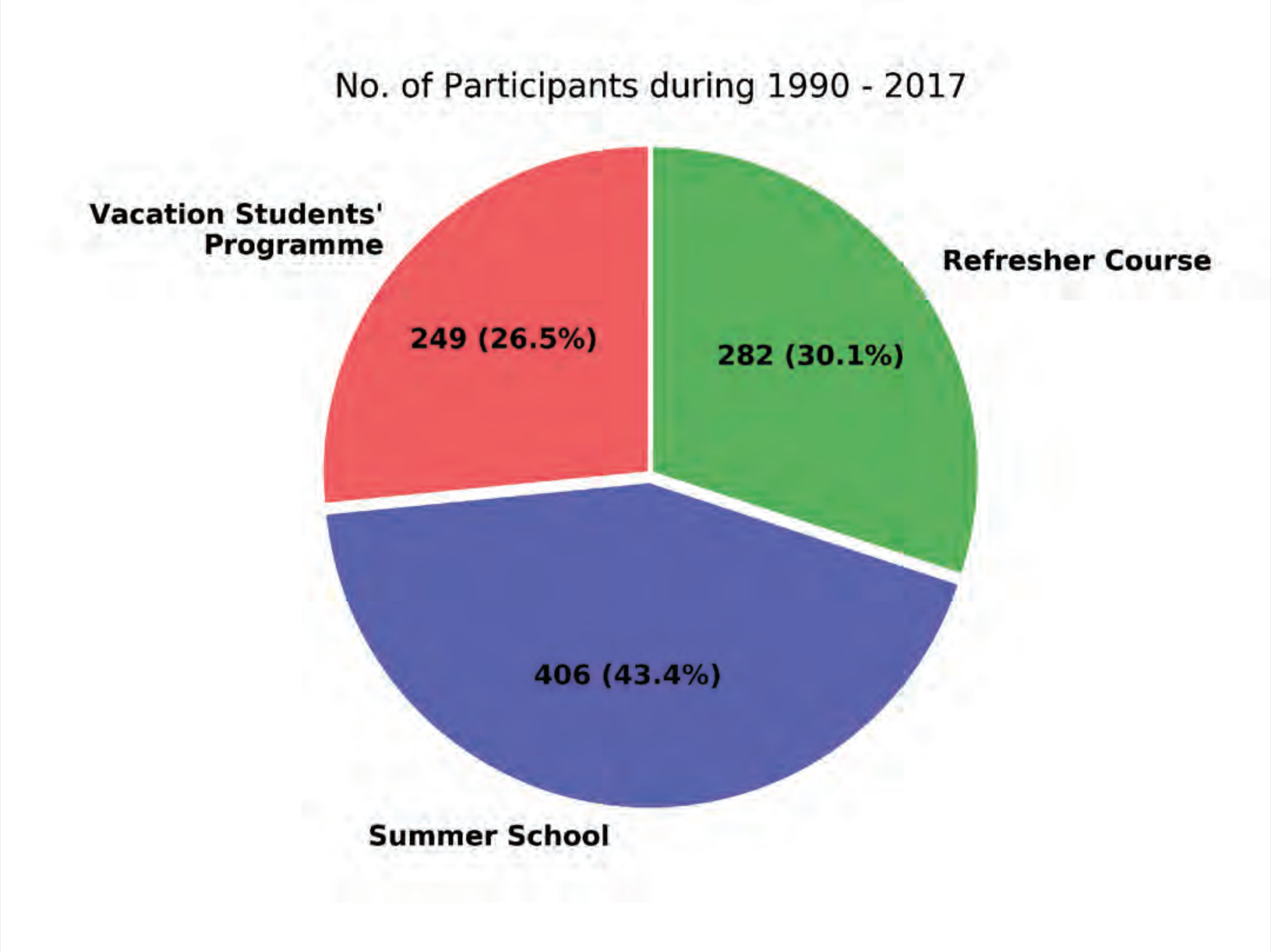
IUCAA Sponsored Workshops / Schools across India 2013- 2018



Number of participants in workshops / schools at IUCAA is approximately 500 per year during 2015-2018.

Summer Programmes at IUCAA 1990 - 2017

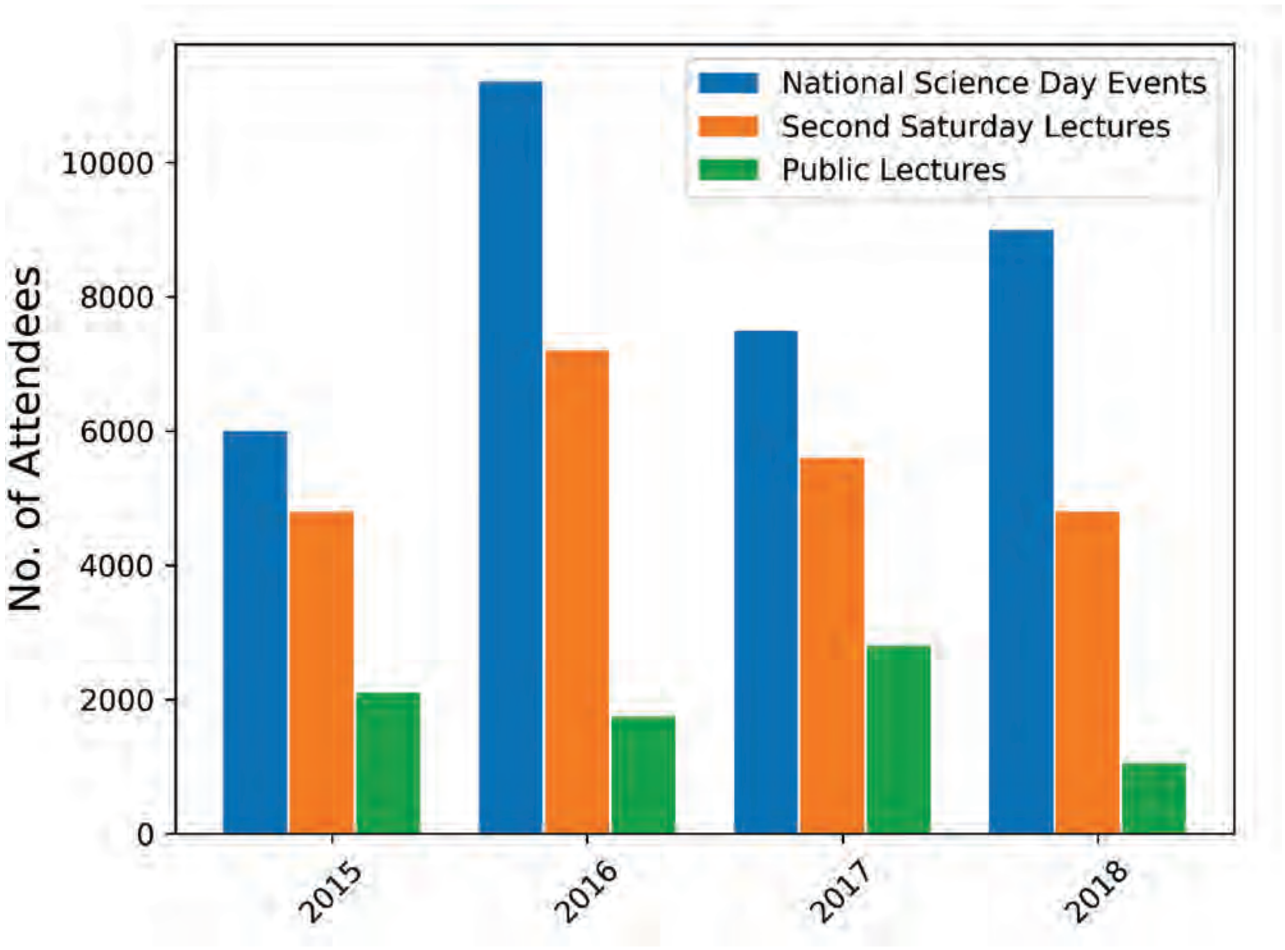
IUCAA's Summer Programmes provide short, intense crash-courses in Astronomy and Astrophysics to budding researchers at the under-graduate and post-graduate levels through the Summer School and Vacation Students' Programme, as well as to seasoned teachers through the Refresher Courses.



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.



शोध शिक्षा समीक्षा

भारतीय विश्वविद्यालयों और उच्च शिक्षा संस्थानों में अनुसंधान और शिक्षण पर यूजीसी के अंतर-विश्वविद्यालय केंद्रों का प्रभाव

शोध शिक्षा समीक्षा | SHODH SHIKSHA SAMEEKSHA

Jagdish Arora, Somak Raychaudhury, Prakash Javadekar, Virander Chauhan, Dinakar Kanjilal and Ajit Sinha

भारतीय विश्वविद्यालयों एवं उच्च शिक्षा संस्थानों में अनुसंधान और शिक्षा पर यूजीसी के अंतर-विश्वविद्यालय केंद्रों के प्रभाव का पता लगाने के लिए एमएचआरडी / यूजीसी की पहल से एक कार्यक्रम, शोध शिक्षा समीक्षा, चंद्रशेखर ऑडिटोरियम, IUCAA, पुणे में रविवार, १ अक्टूबर, २०१७ को आयोजित किया गया।

इस कार्यक्रम में निम्नलिखित अंतर-विश्वविद्यालय केंद्र सम्मिलित थे:

खगोल विज्ञान और खगोल भौतिकी के लिए अंतर-विश्वविद्यालय केंद्र (IUCAA), पुणे, अंतर-विश्वविद्यालय त्वरक केंद्र (IUAC), नई दिल्ली, वैज्ञानिक अनुसंधान के लिए यूजीसी-डीएई कंसोर्टियम (UGC-DE CSR), इंदौर, तथा सूचना और पुस्तकालय नेटवर्क (INFLIBNET) केंद्र, गांधीनगर।

इस आयोजन को, भारत सरकार के माननीय मानव संसाधन मंत्री श्री प्रकाश जावड़ेकर, यूजीसी के अध्यक्ष श्री विरेन्द्र एस. चौहान और उच्च शिक्षा विभाग, एमएचआरडी, भारत सरकार के सचिव श्री केवल के. शर्मा,

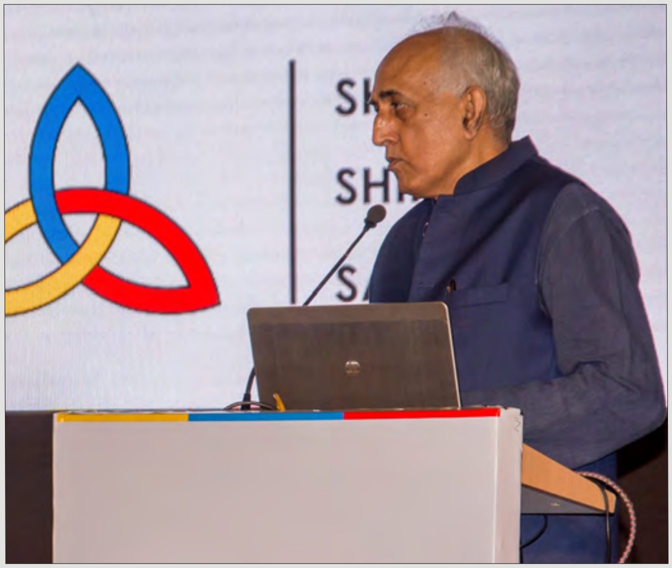
तथा कई प्रतिष्ठित शिक्षाविदों ने, अपनी प्रमुख उपस्थिति से गरिमा प्रदान की।

इस कार्यक्रम में, देश भर के लगभग २५ निजी विश्वविद्यालयों को मिलाकर १२० से अधिक विश्वविद्यालयों और उच्च शिक्षा संस्थानों का प्रतिनिधित्व करने वाले ४०० से अधिक प्रतिभागी सम्मिलित हुए, जो मुख्य रूप से इन अंतर–विश्वविद्यालय केंद्रों के उपयोगकर्ता और संभावित उपयोगकर्ता हैं।

कार्यक्रम का आरंभ विशेष मेहमानों और चार अंतर–विश्वविद्यालय केंद्रों के निदेशकों के सम्मान से किया गया। श्री विरेन्द्र एस. चौहान ने प्रतिभागियों का स्वागत किया और कार्यक्रम की रुपरेखा से अवगत करवाया। उन्होंने उल्लेख किया कि अंतर–विश्वविद्यालय केंद्रों का निर्माण सबसे अच्छा विचार था और यह तब हुआ जब इसकी जरूरत महसूस की गयी। इस बैठक का उद्देश्य चार निदेशकों के विचारों को प्राप्त करना था की यह केंद्र क्या हैं, यह नहीं की ये केंद्र कितने अच्छे हैं, और उन लोगों के बारे में बात करने के लिए जिन्होंने सुविधाओं का उपयोग किया है, और जिन लोगों ने उपयोग नहीं किया है वे किस तरह उनका उपयोग कर सकते हैं। रविवार की सुबह पधारके माननीय मंत्री द्वारा संबोधित करने के लिए श्री चौहान ने उनके प्रति आभार प्रकट किया, और उन्होंने कहा की इस पल को खोना नहीं चाहिए।

अपनी प्रस्तुति में, IUCAA के संस्थापक निदेशक श्री जयंत वी. नारलीकर ने उल्लेख किया कि IUCAA एक सफल संस्थान की कहानी थी, जिसे १९८८ में समय की मांग को देखते हुए तथा अनुसंधान संस्थानों और विश्वविद्यालयों के बीच दूरी को कम करने के लिए एक स्वायत्त संस्थान के रूप में तब स्थापित किया गया था जब श्री यश पाल यूजीसी के अध्यक्ष थे।

माननीय मंत्री श्री प्रकाश जावड़ेकर ने दर्शकों को संबोधित किया, और श्री नारलीकर की IUCAA की स्थापना की ज़िम्मेदारी लेने के लिए सराहना



की। उन्होंने उल्लेख किया की IUCAA दरअसल एक मंदिर है तथा केवल विज्ञान और प्रौद्योगिकी मानव जीवन को बदलती है, और इसलिए, हमें ऐसे अधिक से अधिक मंदिरों की आवश्यकता है। अनुसंधान और विकास एक राष्ट्र की प्रगति और समृद्धि की कुंजी हैं, जो सही ढंग से हमारे देश में उच्च शिक्षा का आधार बनना चाहिए। हम इसे प्रोत्साहित करने और बढ़ावा देने के लिए अपनी पूरी कोशिश करेंगे। नई शिक्षा नीति, पांच स्तंभों अभिगम्यता, न्याय संगतता, गुणवत्ता, जवाबदेही और सामर्थ्य से उभरके निकलेगी।

चार निदेशकों श्री सोमक रायचौधरी, IUCAA, पुणे; श्री दीनाकर कंजिलल, IUAC, नई दिल्ली; श्री अजीत के सिन्हा, UGC-DE, CSR, इंदौर; और श्री जगदीश अरोड़ा, INFLIBNET केंद्र, गांधीनगर ने अपनी प्रस्तुतियां प्रस्तुत की। उनमें से प्रत्येक ने उपलब्ध सुविधाओं पर एक रिपोर्ट दी है कि विश्वविद्यालय समुदाय किस प्रकार इन सुविधाओं उपयोग कर रहा है।

IUCAA से श्री दीपंकर भट्टाचार्य द्वारा IUCAA में उपलब्ध प्रमुख सुविधाओं तथा भविष्य में निर्माण होने वाली सुविधाओं पर, IUAC से श्री एन माधवन द्वारा त्वरण आधारित अनुसंधान और विकास में पुनर्जागरण पर; और UGC-DE CSR से श्री वासुदेव सिरीगुड़ी द्वारा भारत में विश्वविद्यालयों और संस्थानों द्वारा मेगा–प्रोजेक्ट्स के अनुसन्धान में उपयोग पर, प्रस्तुतियां पेश कि गयीं।

तीन अंतर–विश्वविद्यालय केंद्रों के उपयोगकर्ता: (i) दिल्ली विश्वविद्यालय से श्री हरिंदर पाल सिंह ने IUCAA - विश्वविद्यालय संबंध: एक सहयोगी का परिप्रेक्ष्य, (ii) जवाहरलाल नेहरू विश्वविद्यालय, नई दिल्ली से श्री प्रसन्नजीत सेन, ने IUAC में अवसर और उपयोगकर्ता अनुभवों पर, और (iii) सावित्रीबाई फुले पुणे विश्वविद्यालय से श्री शंकर आई. पाटिल ने UGC-DE CSR: एक उपयोगकर्ता का परिप्रेक्ष्य, इन विषयों पर अपने विचार प्रकट किए।

श्री केवल के. शर्मा ने प्रतिभागियों को संबोधित किया और जोर दिया कि भारत में शैक्षणिक परिदृश्य बड़े पैमाने पर विस्तार कर रहा है क्योंकि हम उत्कृष्ट संस्थानों का निर्माण करते हैं। उन्होंने आईआईटी, आईआईएम, और फिर परमाणु ऊर्जा, अंतरिक्ष विज्ञान इत्यादि में लगे वैज्ञानिक संस्थानों की कहानियों का उल्लेख किया। इस प्रक्रिया में, विश्वविद्यालय शिक्षा, जो केंद्रीय और राज्य विश्वविद्यालयों के माध्यम से बड़े पैमाने पर विस्तारित हुई है, जहां बहुत सारे गुणों का अस्तित्व है, कि हानि हो रही हैं। उन्होंने प्रश्न उठाया कि क्या उन लोगों की तलाश को पोषित करने के लिए पर्याप्त सुविधाएं मौजूद हैं जो पहले से शिक्षा प्रदान कर रहे हैं और जो संभावित छात्र हैं? यह शीर्ष नीति निर्माताओं के लिए गहन चिंता का विषय हैं। वास्तविक परिस्थिति का पता लगाना बहुत उपयोगी है, और यहां पर हो रहे विचार–विमर्श इस अवसर को प्रदान कर रहे हैं। उन्होंने उल्लेख किया कि NAAC रैंकिंग में शीर्ष विश्वविद्यालयों को विशेष दर्जा दिया गया है, और उम्मीद की कि सभी विश्वविद्यालयों को शीर्ष स्तर तक आना चाहिए।

श्री जगदीश अरोड़ा, श्री विरेन्द्र एस. चौहान, श्री दीनकर कंजिलल, श्री सोमक रायचौधरी और श्री अजीत के. सिन्हा की अगुवाई में एक पैनल चर्चा हुई। परिचय में, रायचौधरी ने उल्लेख किया कि IUC और UGC कैसे अपने शोध और शिक्षण में विश्वविद्यालयों के साथ बातचीत कर सकते हैं, इस का पता लगाने के लिए, भविष्य में मुख्य और सामान्य चर्चा ही एकमात्र तरीका होगा। वह उन प्रतिभागियों की टिप्पणियों से शुरू करना चाहते थे जिन्होंने IUC सुविधाओं का कभी भी उपयोग नहीं किया है, और यह सुनना चाहते हैं कि वे IUC से कैसे लाभ प्राप्त कर सकते हैं, तथा IUC और क्या कर सकते हैं।

इस चर्चा से निम्नलिखित मुख्य बिंदु उभरकर सामने आये:

(ए) IUC अपनी केंद्रीकृत सुविधाओं के साथ एक बहुत ही महत्वपूर्ण भूमिका निभाते हैं, जो व्यक्तिगत विश्वविद्यालयों के लिए आसानी से उपलब्ध नहीं हैं, लेकिन विश्वविद्यालय समुदाय आकर जिनका उपयोग कर सकते हैं।

(बी) सभी विषयों को इन IUC में शामिल नहीं किया गया है, और अन्य विषयों के लिए ऐसे अन्य केंद्र बनाने का सुझाव दिया गया है।

(सी) कई सहभागी ऐसी केंद्रीय सुविधाओं को केंद्रीकृत करने के पक्ष में हैं। विशेष रूप से, क्षेत्रीय केंद्रों को शाखाकृत करने की आवश्यकता है, जहाँ स्थानीय प्रशिक्षण केंद्रों से कम सुविधाएं हो सकती हैं।

(डी) कॉलेजों और विश्वविद्यालयों में छोटी स्तर की सुविधाओं के जरिए सुविधाओं के दायरे को बढ़ाने के लिए रूचि व्यक्त की गयी।

(ई) शिक्षकों को शोध करने के लिए समय की उपलब्धता के बारे में प्वाइंट उठाया गया था, जो वास्तव में सप्ताह में १६ से १८ घंटे पढ़ाने और स्नातक और स्नातकोत्तर छात्रों के लिए बड़ी संख्या में शोध परियोजनाओं का समर्थन करने के लिए है।

(एफ) ग्रामीण भारत में कॉलेजों और विश्वविद्यालयों पर जोर दिया गया। इनमें भी उत्कृष्ट विज्ञान संबधित कार्य किये गए हैं। वहां सृजित जनशक्ति के पास कम अवसर हैं, और इस तरफ ध्यान देने की जरुरत है।

(जी) उत्कृष्ट विश्वविद्यालयों में व्याख्यान ई–मॉड्यूल के स्वरूप में तैयार किए जा सकते हैं, और वे "SWAYAM" में उपलब्ध हो सकते हैं, ताकि ग्रामीण और कम विशेषाधिकार प्राप्त छात्रों को लाभान्वित किया जा सके।

(एच) कॉलेज और विश्वविद्यालय के शिक्षकों को विशेष प्रोत्साहन देने की आवश्यकता है जो गुणवत्ता अनुसंधान करते हैं।

(आइ) यदि हमें सभी बड़ी परियोजनाओं को बनाए रखना है तो बड़ी संख्या में शोध छात्रों को तैयार करने के लिए हमें निश्चित रूप से बहुत बडा मानव संसाधन विकास का कार्य करना होगा।

(जे) बीम टाइम के लिए सुविधाओं और विभिन्न अन्य सुविधाओं पर समय बढ़ाने के लिए विशिष्ट अनुरोध थे। यह मात्रा, कार्यक्षमता और रखरखाव में वृद्धि का सवाल था।

(के) यह भावना थी प्रकट हुई कि कॉलेज / विश्वविद्यालय के शिक्षकों को परियोजनाओं के तहत अनुसंधान के लिए धन कम पड रहा था, और इसे ध्यान में रखा जाना चाहिए।

(एल) पुस्तकालयों को एक जगह समेकित किया गया है और यह INFLIBNET में ई–सुविधाएं के स्वरूप में है, जो एक बहुत अच्छे उद्देश्य की पूर्ति करता है।

श्री सोमक रायचौधरी ने माननीय मानव संसाधन विकास मंत्री, उच्च शिक्षा विभाग के सचिव और अध्यक्ष, यूजीसी का इस विचार को शुरू करने के लिए धन्यवाद किया; जिसके फलस्वरूप इस अद्वितीय कार्यक्रम का आयोजन किया गया। रायचौधरी ने सभी चार निदेशकों का भी धन्यवाद किया। वर्ष के सबसे अजीब दिन, प्रतिभागियों को इतने कम समय की सूचना मिलने के बावजूद सभी प्रतिभागियों की उपस्थिति के लिए उन्होंने विशेष आभार प्रकट किया। अंत में, उन्होंने IUCAA में अपनी टीम एवं IUAC और UGC-DE CSR की टीमों का धन्यवाद किया। परदे के पीछे रहकर बड़ी संख्या में जिन लोगों ने परिश्रम किया है, उन्होंने उन सभी को धन्यवाद दिया।

SHODH SHIKSHA SAMEEKSHA

IMPACT OF THE INTER-UNIVERSITY CENTRES OF THE UGC ON RESEARCH AND TEACHING AT INDIAN UNIVERSITIES AND HIGHER EDUCATIONAL INSTITUTIONS

शोध शिक्षा समीक्षा | SHODH SHIKSHA SAMEEKSHA

An event initiated by the MHRD/UGC, named, "Shodh Shiksha Sameeksha", was arranged on Sunday, October 1, 2017, at the Chandrasekhar Auditorium, IUCAA, Pune, to explore the impact of the Inter-University Centres (IUCs) of the UGC on Research and Teaching at Indian Universities and Higher Educational Institutions.

The IUCs involved were:

The Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, The Inter-University Accelerator Centre (IUAC), New Delhi, The UGC-DAE Consortium for Scientific Research (UGC-DAE CSR), Indore, and The Information and Library Network (INFLIBNET) Centre, Gandhinagar.

The event was graced by the presence of Prakash Javadekar, Hon'ble Minister of HRD, Government of India; Virander

S. Chauhan, Chairperson, UGC; and Kewal K. Sharma, Secretary, Department of Higher Education, MHRD, Government of India, and many distinguished academicians.

There were more than 400 participants, primarily consisting of users and potential users of these IUCs, representing more than 120 universities and higher education institutions across the country, and which included about 25 private universities.

The programme started with the felicitation of the special guests and the Directors of the four IUCs. Virander S. Chauhan welcomed the participants and gave a brief address highlighting the motivation behind the meeting, which was to get to know the functioning of the IUCs and discuss how to make their facilities accessible as widely and seamlessly as possible, as well as to bring together current users and those who have not yet used the IUCs for a fruitful exchange.

In his presentation, Jayant V. Narlikar, Founder Director, IUCAA, recounted the tale of IUCAA which was created in 1988, when Yash Pal was the Chairperson of the UGC, in response to the need of the time. Like the other IUCs, IUCAA was established as an autonomous institution whose purpose was to rectify the (then) lack of an organic relationship between research institutes and universities. Narlikar described Yash Pal's many expectations of IUCAA, which included that IUCAA become a world class centre for excellence that provides a quality of academic and experimental environment not easily available to the university community in their own place. Narlikar argued that IUCAA has succeeded in meeting all of these challenges.

Prakash Javadekar gave an engaging address focusing on the need for innovation and research, particularly in the context of contemporary Indian society. He highlighted educational schemes such as Swayam which are benefiting from both technological development as well as partnership with private entities, and are now reaching lakhs of students as well as teachers with high quality educational and training content. Science and technology, Javadekar said, are therefore enriching the educational sector, which in turn will enrich society and make it prosper. In this context and atmosphere, he pointed out, the IUCs play a key developmental role by providing platforms for the University sector to engage in collaborative and innovative research together with scientists.

There were presentations by the four Directors: Somak Raychaudhury, IUCAA, Pune; Dinakar Kanjilal, IUAC, New Delhi; Ajit K. Sinha, UGC-DAE CSR, Indore; and Jagdish Arora, INFLIBNET Centre, Gandhinagar. Each of them gave a report on the facilities available at the respective Centres, and how the university community has been using these.

There were presentations by Dipankar Bhattacharya from IUCAA, on Major Facilities at IUCAA: Present and Future; N. Madhavan from IUAC, on Renaissance in Accelerator based Research and Development; and Vasudeva Siriguri from UGC-DAE CSR, on Research using Mega-Projects by Universities and Institutions in India.

Selected users of three IUCs made presentations: (i) Harinder Pal Singh, from the University of Delhi, presented on IUCAA-Universities Interaction: An Associate's Perspective, (ii)

Prasenjit Sen, from Jawaharlal Nehru University, New Delhi, on Opportunities and User Experiences at the IUAC, and (iii) Shankar I. Patil, from Savitribai Phule Pune University, on UGC-DAE CSR: A User's Perspective.

Kewal K. Sharma addressed the participants and stressed that the educational scenario in India has been expanding in a big way, as regards both institutions of excellence such as IITs, IIMs, scientific institutions, etc. as well as Central and State universities. This meeting, he said, was therefore a very useful opportunity for stock taking. Sharma highlighted several examples of Government initiatives that are currently in place or still being discussed, with the aim of addressing the question: Do adequate facilities exist to nourish the quest of those who are already teaching and those who are potential students? These included ideas for increasing and easing access between universities and scientific laboratories, enabling digital/online education, implementing reforms that give more autonomy to top-ranked universities, incentivising talented students to pursue PhDs in India, facilitating teacher training through schemes such as the Pandit Madan Mohan Malviya Teachers Training Programme and increasing access to higher education across the country in general.

There was a Panel Discussion led by Jagdish Arora, Virander S. Chauhan, Dinakar Kanjilal, Somak Raychaudhury, and Ajit K. Sinha. At the outset, Raychaudhury mentioned that the main and general discussion would be the way, in the future, how the IUCs and UGC could interact with the universities in their research and teaching enhancement. He invited comments from participants who have never used IUC facilities, as well as IUC users who have benefited from their interaction and could suggest what more the IUCs could do.

The salient features (selected) that emerged from this discussion were:

(a) In keeping with Yash Pal's vision, the IUCs serve a very important role providing centralised facilities, which are not easily available to individual universities, but which the university community can visit and use.

(b) All subjects are not covered in these IUCs, and it was suggested to have other such centres for other subjects.

(c) Many were in favour of de-centralising such central facilities. In particular, a need was felt for branching out into regional centres, with not-so-large facilities as local training centres.

(d) Considering the heavy teaching load on most teachers, ideas are needed on how to support a large number of research projects for under-graduate and post-graduate students.

(e) There was emphasis on the colleges and universities in rural India, where good science has been done but where the human resources created have less opportunities.

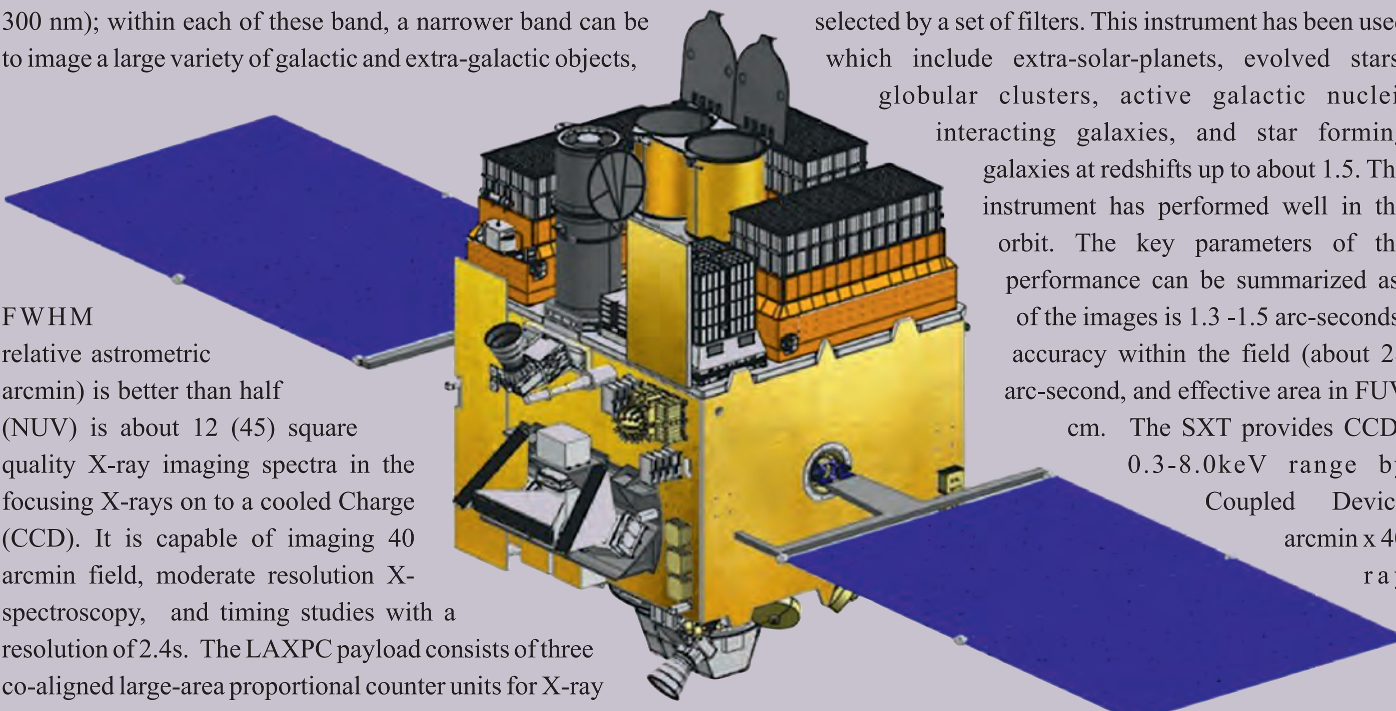
(f) There was a feeling that the funds for research under projects to college/university teachers were shrinking, and this should be taken into consideration.

A summary and report of the discussion would be forwarded to the UGC and the MHRD.

Somak Raychaudhury concluded the meeting with a vote of thanks to the HRD Minister; the Secretary of the Department of Higher Education; the Chairman, UGC, for initiating the idea for this unique event; the IUC Directors; all the participants, who attended at short notice; and the teams at IUCAA, IUAC and UGC-DAE CSR who worked behind the scenes to make the event a success.

ASTROSAT RESEARCH

The Indian multi-wavelength astronomy satellite AstroSat was launched on 28 September 2015, and was placed into a 98 minutes period circular orbit at an altitude of 650km. The co-aligned instruments onboard the AstroSat are: the UV Imaging Telescopes (UVIT), a Soft X-ray focusing Telescope (SXT), the Large Area X-ray Proportional Counters (LAXPC), and a Cadmium-Zinc Telluride Imager (CZTI). UVIT is the long wavelength eye of AstroSat. It is primarily meant for imaging in FUV (130-180 nm) and NUV (200-300 nm); within each of these band, a narrower band can be selected by a set of filters. This instrument has been used to image a large variety of galactic and extra-galactic objects, which include extra-solar-planets, evolved stars, globular clusters, active galactic nuclei, interacting galaxies, and star forming galaxies at redshifts up to about 1.5. The instrument has performed well in the orbit. The key parameters of the performance can be summarized as:



FWHM of the images is 1.3 -1.5 arc-seconds, relative astrometric accuracy within the field (about 28 arcmin) is better than half arc-second, and effective area in FUV (NUV) is about 12 (45) square cm. The SXT provides CCD-quality X-ray imaging spectra in the 0.3-8.0keV range by focusing X-rays on to a cooled Charge Coupled Device (CCD). It is capable of imaging 40 arcmin x 40 arcmin field, moderate resolution X-ray spectroscopy, and timing studies with a resolution of 2.4s. The LAXPC payload consists of three co-aligned large-area proportional counter units for X-ray timing with 10 micro-sec resolution, and spectral studies over the energy range of 3-80 keV. The CZTI is a position sensitive hard X-ray detector consisting of 16,384 semiconductor pixels, it is equipped with a Coded Aperture Mask, and provides spectroscopic/timing measurements in the 20-100 keV region and hard X-ray (above 100 keV) polarization measurement of the brightest cosmic sources. In the last two years and a half, AstroSat has made a number of scientific contributions. A highlight of IUCAA's contribution to AstroSat research is given below.

AstroSat Discovery of Strange Polarisation in the Crab Nebula

(Nature Astronomy publication doi: 10.1038/s41550-017-0293-z)

The AstroSat CZT Imager was used to make the most sensitive measurement so far of the polarisation of hard X-ray emission of the Crab Nebula and Pulsar at 100-380 keV band. The significance of the detection allowed phase-resolved polarimetry at these bands for the first time (see Figure 1). Radiation from the Crab Pulsar is produced by charged particles gyrating around the local magnetic field, and is expected to be polarised in a direction perpendicular to the projection of this magnetic field. The results show that the position angle of the polarisation is primarily aligned with the projection of the pulsar's spin axis on the sky over the entire phase range, strongly suggesting that most of the pulsed emission originates outside the boundary of the pulsar's magnetosphere, where the magnetic field becomes azimuthal and is frozen into the outgoing equatorial wind. This is contrary to the usual belief that the radiation is generated from poloidal magnetic field regions within the magnetosphere. These data also hint a variation of polarisation through the off-pulse region, indicating that a significant fraction of this emission may in fact be associated with the pulsar (S. Vadawale, et al, including **Dipankar Bhattacharya, Ajay Vibhute, Gulab C. Dewangan and Ranjeev Misra**).

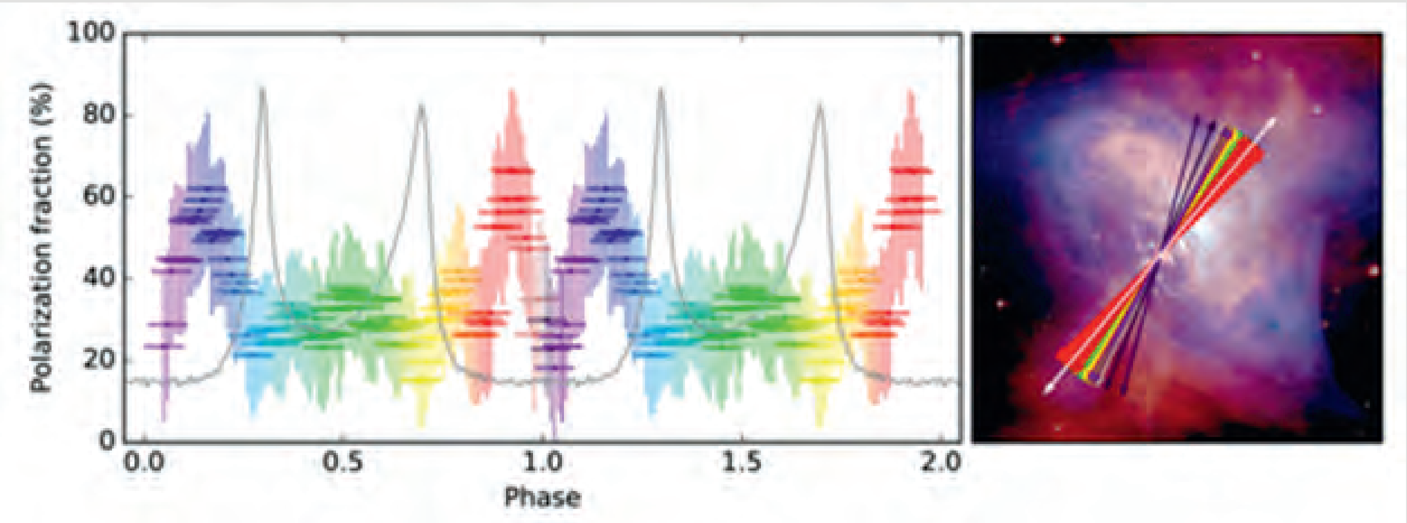


Figure 1. Phase-resolved polarisation measurement of Crab Nebula and the Pulsar with AstroSat/CZTI. **Left panel:** The grey line shows the brightness of the Crab Pulsar as observed by AstroSat CZTI. The horizontal axis (phase) represents time expressed in units of the pulsar's spin period. Phase 0.0 to 1.0 stands for the full rotation cycle of the pulsar. The same result is shown repeated between phase 1.0 and 2.0, for a clear demonstration of the periodic pattern. Coloured bars indicate how strongly polarised the observed radiation is. Sharp variation of polarisation, when the brightness is, low is the surprising discovery by AstroSat. **Right panel:** The angle of X-ray polarisation measured by AstroSat CZTI shown superposed on a composite optical and X-ray image of the Crab Nebula, taken by NASA's Hubble and Chandra telescopes respectively. The white arrow represents the projected spin axis of the pulsar located at the centre of the nebula. Other arrows display the orientation of the observed polarisation. The colour of an arrow indicates the range of phase it belongs to, being equal to that spanned by bars of the corresponding shade in the left panel.

X-ray Binaries with AstroSat/LAXPC

The LAXPC onboard AstroSat is superior to its predecessor on-board the American satellite "Rossi X-ray Timing Experiment (RXTE)" by having a significantly larger area in high energies (> 20 keV) and by having event mode data wherein each photon information is recorded leading to great flexibility in analysis. Combined with the other instruments on board, namely the Soft X-ray telescope (SXT), the Ultra Violet Imaging Telescope (UVIT) and the Cadmium Zinc Telluride Imager (CZTI) makes LAXPC the ideal instrument to unravel the mysteries of rapidly varying bright X-ray sources such as black hole and neutron star systems.

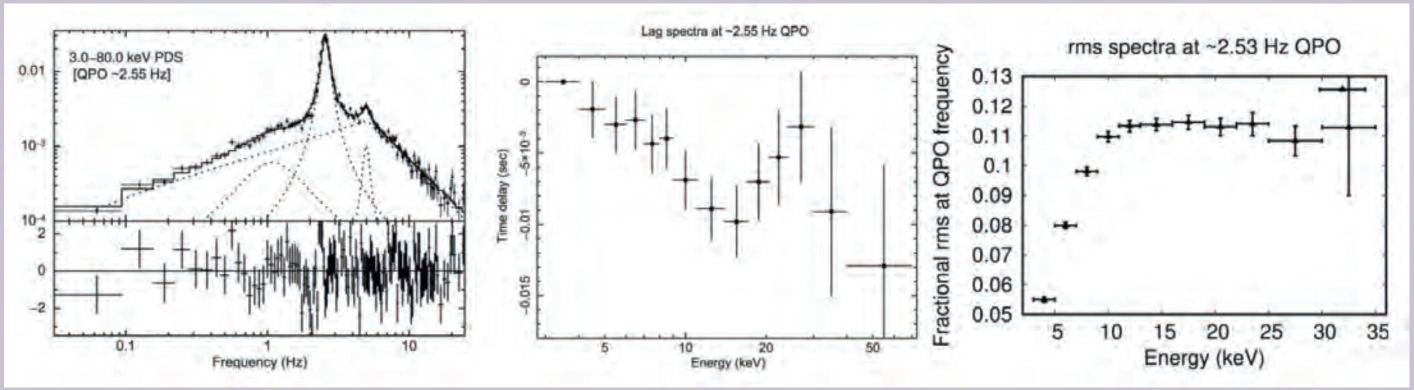


Figure 2: The power spectrum (left) showing the 2.5 Hz QPO for the black hole system GRS 1915+105. The middle and right panels show the time lag and r.m.s. as a function of energy. Results for energy greater than 20 keV were obtained for the first time using AstroSat LAXPC. (Figure taken from Yadav, et al. 2017, ApJ, 833, 27).

Some of the initial sources observed by AstroSat were well known black hole systems, in order to demonstrate AstroSat's capabilities and reveal the rapid variability properties of these sources in hard X-ray energies which had not been seen before. **Ranjeev Misra** and **Mayukh Pahari** as part of the national level LAXPC Science Team, have analysed the complex data from such sources. Data from the well known bright black hole source GRS 1915+105, revealed that the source was on kind of variability state which shows quasi-periodic oscillations (i.e., oscillations which are like but not exactly sinusoidal, QPOs) in the frequency range of 3 to 6 Hz. For these oscillations, they reported the arrival time difference between the very high energy X-ray photons (30 keV) and the lower 5 keV ones. Since higher energy photons are expected to be produced closer to the black hole than low energy ones, such analysis provides unique clues to the geometry of the inner accretion disk and the nature of spacetime near the black hole. **This was the first science result reported by AstroSat and it heralds a new era of X-ray timing studies.**

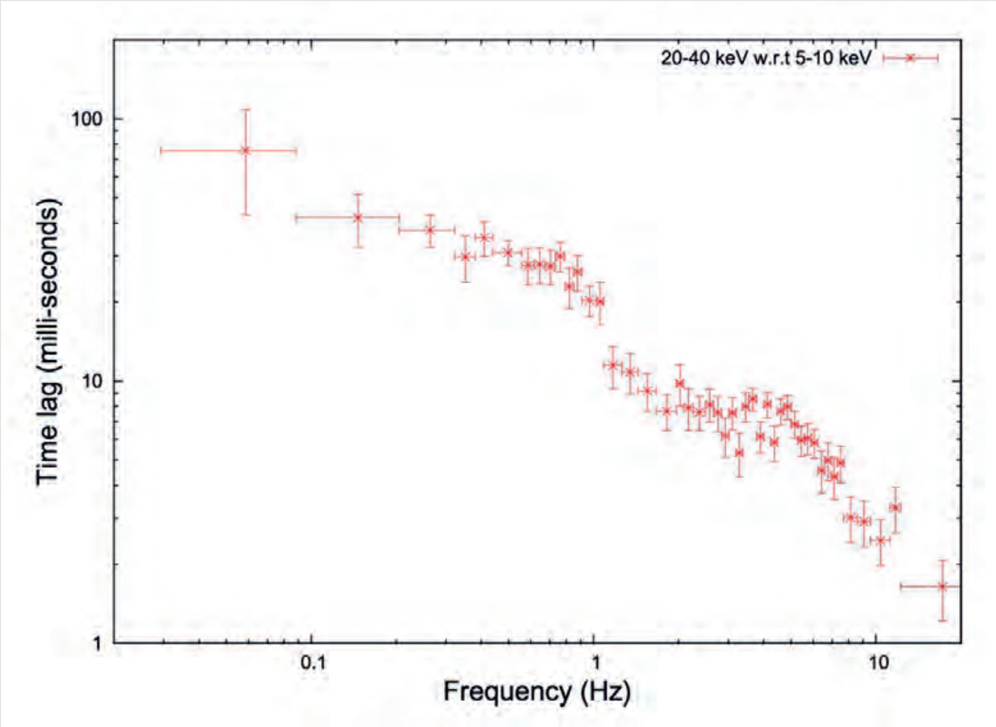


Figure 3: Time lag in milliseconds between photons of 20-40 keV w.r.t. to those of 5-10 keV energies. Such detailed informtion at these high energies was made possible by AstroSat LAXPC. (Figure taken from **Misra**, et al. 2017, ApJ, 835, 195).

This was followed by analysis of another well known black hole system Cygnus X-1. This source does not show quasi-periodic oscillations, but instead its variability is characterized by broad band features. The LAXPC Science Team which included **Ranjeev Misra** and **Mayukh Pahari**, used AstroSat/LAXPC data to study the variability in high energies for the first time. They were able to measure the time difference between different energy photons to a precision level not achieved before. Moreover, using the event mode data, they could create spectra at different fluxes varying on time-scales of 1 second, which was not possible earlier. The spectra at different fluxes showed steepening at higher fluxes which meant that the variability in different energy bands are driven by the low energy photons, i.e., photons from the outer disk.

One of the important capabilities of the LAXPC instrument is the detection of high frequency phenomenon from compact object. **Ranjeev Misra** and other members of the LAXPC team were the first to demonstrate millisecond variability measurement capability of LAXPC by detecting a 830 Hz , Quasi-periodic Oscillations (QPOs) in the time variability of the neutron star system 4U 1728-34. While such QPOs have been detected earlier by RXTE, the novelty here is, its detection above energies of 10 keV, which is due to larger effective area of LAXPC. Neutron stars undergo thermo-nuclear burning on their surfaces which are observed as short 10 second burst. During one of the bursts of 4U 1728-34, a burst oscillation at 363 Hz which is identified with the spin period of the neutron star was detected by LAXPC.

The long term variability capabilities of LAXPC was shown by analysis of the enigmatic X-ray binary Cyg X-3 by the LAXPC team which included **Ranjeev Misra**. Apart from the orbital period 4.8 hrs, a slower oscillation of 36 days was observed. Further more complex variations with harmonics in 100s of seconds time-scales was detected in the observed light curves. More importantly AstroSat observed the source on the onset of a giant radio flare catching the behaviour of the X-ray variation during the event. The source made a state transition and the appearance of an hard power-law tail which was consistent with having the same origin as the radio emission.

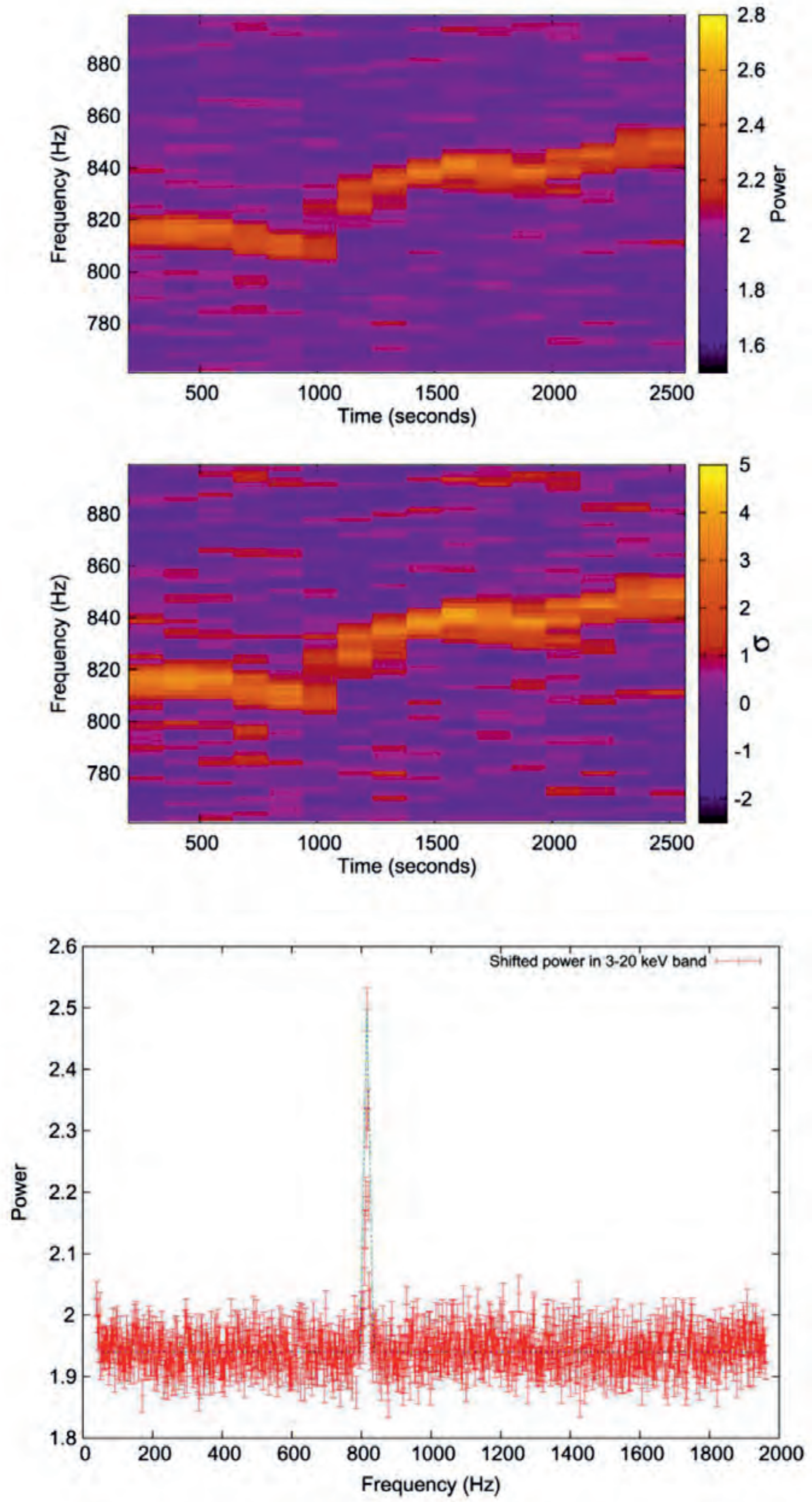


Figure 4: Dynamic power spectra of 4U 1728-34 in the energy range of 3–20 keV (top panel). A drifting kHz QPO whose frequency changes from ~815 Hz to ~850 Hz is clearly visible. The middle panel shows the variation of significance sigma showing that the QPO is significantly detected. The bottom panel shows the co-added power spectra after aligning the QPO frequency. No other features are detected in the 200–2000 Hz. (Figure taken from Verdhan, et al. ApJ 841, 41).

AstroSat/UVIT Reveals Flocculent Spiral in NGC 4571

The late-type spiral galaxy NGC 4571 in the the constellation of Coma Berenices was observed by AstroSat/UVIT in two filters - FUV BaF2 and NUV B4 for 10000 seconds by **Kanak Saha** and **Shyam Tandon**. They have derived true colour images of NGC 4571 that show several knots in blue colour of star forming regions (see Figure 5). These star-forming knots, primarily young stars (as inferred from FUV data), are also visible in the SDSS r band + UVIT colour composite image as shown below. The star-forming clumps are not only confined in the central region but all over the galaxy extending to outskirts. We are currently investigating what is igniting such a wide-scale star formation in the galaxy which is apparently lonely, gas-poor, lying in the outskirts of Virgo Cluster. Although not classified, the UVIT morphology indicates that it is a flocculent spiral.

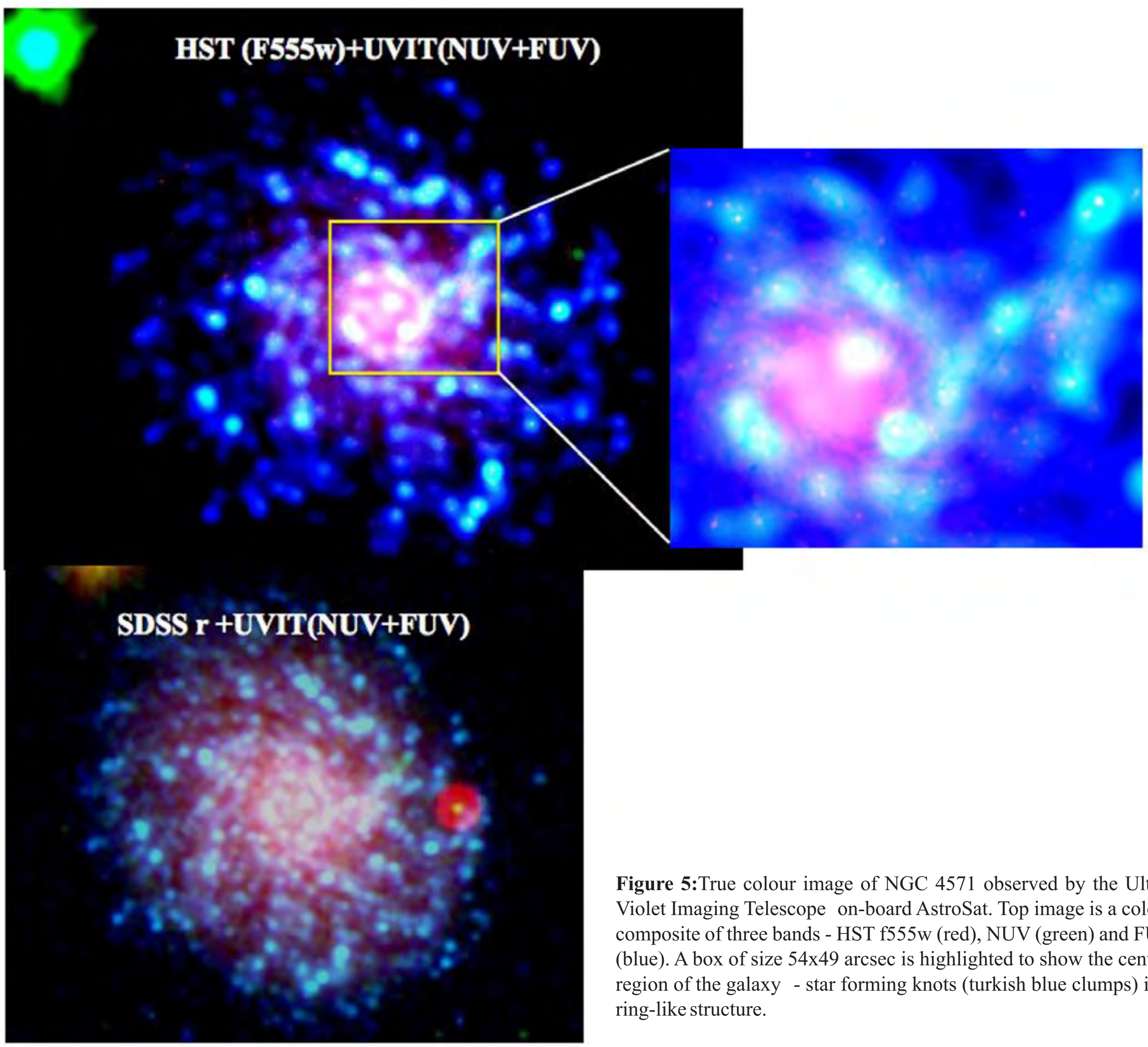


Figure 5: True colour image of NGC 4571 observed by the Ultra-Violet Imaging Telescope on-board AstroSat. Top image is a colour composite of three bands - HST f555w (red), NUV (green) and FUV (blue). A box of size 54x49 arcsec is highlighted to show the central region of the galaxy - star forming knots (turkish blue clumps) in a ring-like structure.

UVIT Finding of Multiple Stellar Populations in NGC 1851

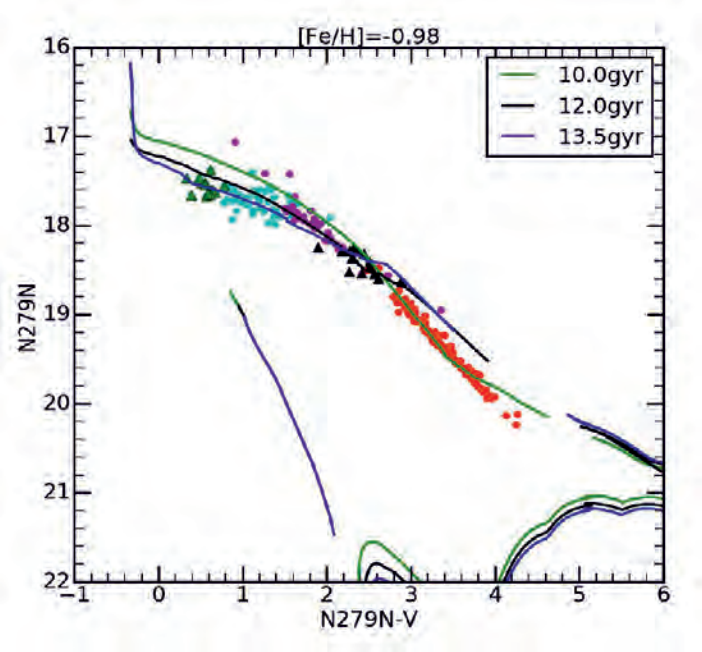


Figure 6: NUV (measured with UVIT)-V Colour Plot for HB Stars of NGC 1851 shows presence of multiple populations with different ages in the range 10 to 13.5 billion years. (Taken from: A. Subramaniam, et al., including **Shyam Tandon** 2017).

UVIT Imaging of Ram-Pressure Stripping in Action: Star Formation in the Stripped Gas of the GASP Jellyfish Galaxy JO201 in Abell 85

Jellyfish galaxies observed in galaxy clusters are subjected to strong ram-pressure effects that strip the gas from the galaxy. The UVIT observation of a jellyfish galaxyJO201, the "UV-brightest cluster galaxy" in Abell 85, has provided high spatial resolution images revealing knots and streams of star formation in the ultraviolet. K. George, et al., including **Shyam Tandon**, 2018 have found star forming knots both in the stripped gas and in the galaxy disk, and measured star formation rates in the individual knots.

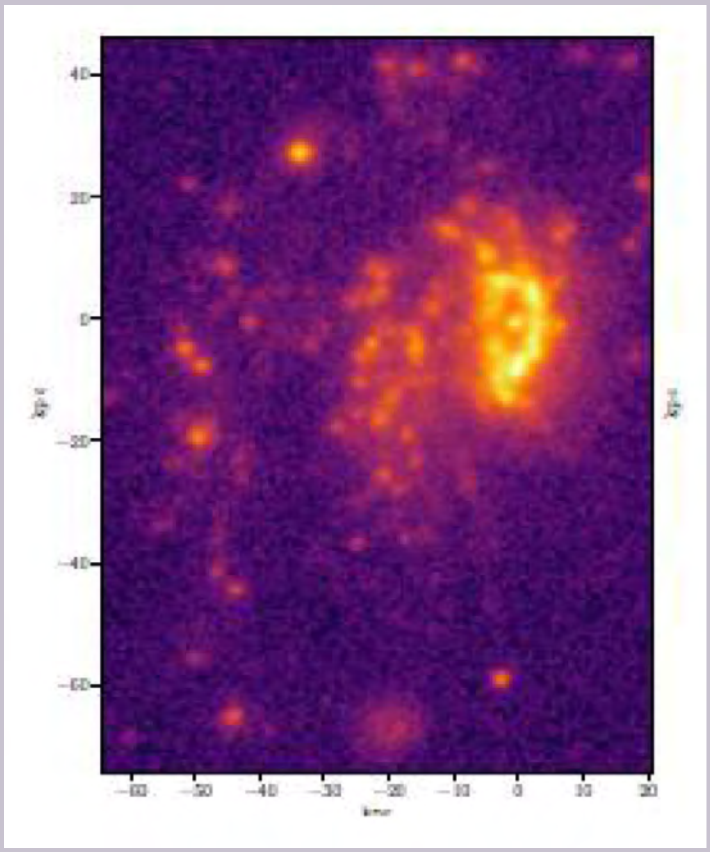


Figure 7: UVIT/NUV image of the GASP jellyifish galaxy JO201 in Abell 85 showing star formation in stripped gas (Taken from K. George, et al 2018).

Multi-wavelength Capability of AstroSat : UV/X-ray Variability of Active Galactic Nuclei

With multiple UVIT broadband filters and three gratings, and 0.3-100 keV X-ray band covered by the X-ray instruments, AstroSat is the de facto multi-wavelength astronomy satellite available today. However, multi-wavelength science requires careful cross-calibration between different instruments. After the calibration of individual instruments, AstroSat's capability for the study of multi-wavelength cosmic sources such as the active galactic nuclei (AGN) is being realised. AstroSat's UV and X-ray instruments cover a significant fraction of the primary continuum emission from radio-quiet AGN. Compared to Swift/UVOT, AstroSat/UVIT covers shorter UV wavelength down to the far UV (1300 Angstrom), and performs simultaneous UV observations in the near and far UV bands. Unlike Swift, AstroSat performs continuous observations, and therefore, is well suited for short-term variability on hours time scales.

AstroSat has observed a number of nearby bright AGN both to study UV/X-ray variability and spectral energy distributions. **Gulab C. Dewangan** and collaborators have been working to bring out the multi-wavelength capability of AstroSat for the study of AGN. They have demonstrated AstroSat's capability to measure time delay between UV and X-ray variations and to measure near UV to X-ray spectral energy distributions. As an example, the results from a four day continuous UVIT and SXT observation performed in July 2016 by **Gulab C. Dewangan, Dipankar Bhattacharya** and A. R. Rao are shown in Figure 8. The UVIT FUV image of NGC 4395 shows the bright active nucleus and the spiral arms of the galaxy. The FUV and NUV light curves of NGC4593 extracted from the nucleus, and the X-ray light curve extracted from the SXT observations are also shown in Figure 8. Clearly, the UV and X-ray emission from the AGN are highly variable and appear correlated. The cross-correlation between the SXT and UVIT FUV light curves of NGC 4593, and the distribution of lags measured based on the technique of flux randomization and random sample selection (FR/RSS) are also shown. This analysis has enabled measurement of soft X-ray-to-far UV lag of 0.475±0.086 days, thus demonstrating AstroSat's multi-wavelength capability to measure such lags.

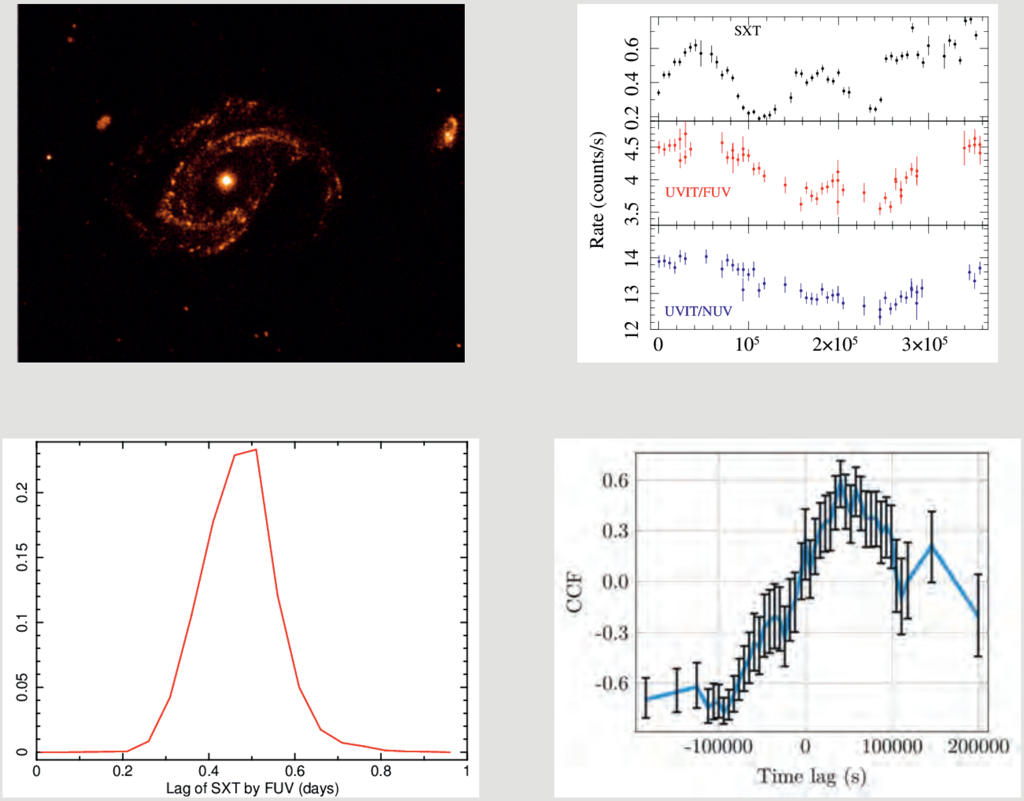


Figure 8: Results of 4-days long AstroSat observations of the active galaxy NGC 4593. **Top left :** UVIT/FUV image of NGC 4593 showing the bright active nucleus and the spiral arms. **Top right:** SXT and UVIT FUV/NUV light curves of the active nucleus in NGC 4593 showing strong variability. **Bottom left:** Cross-correlation function between the FUV and SXT light curves. Positive lag indicates lag of UV variations relative to that of X-rays. **Bottom right:** Distribution of UV lag based on FR/RSS method.

DISCOVERY OF SARASWATI SUPERCLUSTER

Large-scale structures in the Universe are found to be hierarchically assembled, with galaxies, together with associated gas, and dark matter, being clumped in clusters, which are organized with other clusters, smaller groups, filaments, sheets and large empty regions ("voids") in a pattern called the "Cosmic Web" which spans the observable Universe.

Superclusters are the largest coherent structures in the Cosmic Web. A supercluster is a chain of galaxies and galaxy clusters, bound by gravity, often stretching to several hundred times the size of clusters of galaxies, consisting of tens of thousands of galaxies. Recently, **Joydeep Bagchi**, **Somak Raychaudhury**, and **Pratik Dabhade** from IUCAA, and researchers from three other Indian Universities (Shishir Sankhyayan, Prakash Sarkar and Joe Jacob) have identified a previously unknown, extremely large supercluster of galaxies located in the direction of constellation Pisces. This supercluster is the first major discovery of its kind made in India involving Indian Universities. This is one of the largest known structures in the observable Universe, and is at a distance of about 4,000 million light-years (at the redshift, $z \sim 0.28$) away from us. The supercluster is given the name '*Saraswati*' (Figure 9). We named this structure not only after the Indian Goddess of knowledge, music, art, wisdom and nature, but also after the "ever flowing river with many streams"; the ancient *Saraswati* river mentioned in the *Rig'veda*, since the structure projected on the sky has a similar appearance (it might also be mentioned that the Milky Way, the band of stars in the sky that represents the plane of our own Galaxy, is also called "Akashganga" in Indian languages). The newly-discovered *Saraswati* supercluster extends over an enormous scale of 650 million light-years ($\sim$200 Mega parsecs), contains at least 48 individual galaxy clusters and groups and may contain the mass equivalent of over 20 million billion Suns ($\sim 2 \times 10^{16}$ $M_\odot$). When astronomers look far away, they see the Universe as it was long ago, since light takes a while to reach us. The *Saraswati* supercluster is one of the farthest supercluster ever observed, appearing as it was when the Universe was about 10 billion years old.

A major concentration of galaxies, comprising the *Saraswati* supercluster, was identified using the friends-of-friends (FoF) algorithm from the vast spectroscopic galaxy data of the Sloan Digital Sky Survey (SDSS) in the Stripe-82 region. In an FoF algorithm, a linking length (*l*) is chosen for the galaxy distribution. If the separation between two galaxies is less than or equal to *l*, these two galaxies are considered linked and part of the same overdense structure, otherwise not. Defined in this manner the size of a supercluster naturally becomes sensitive to the linking length used to determine it. The *l* for a given galaxy distribution is generally chosen such that maximum number of

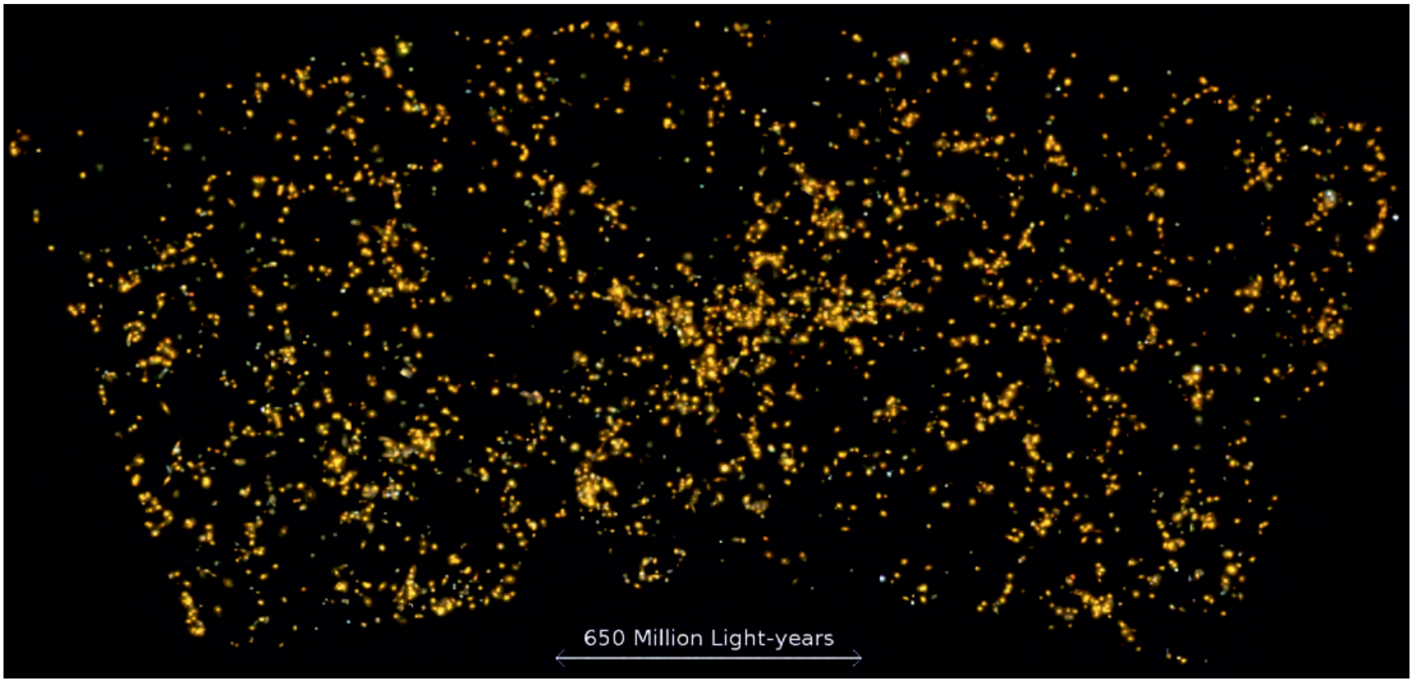


Figure 9: The distribution of galaxies ($\sim$ 3000), from Sloan Digital Sky Survey (SDSS), in and around *Saraswati* supercluster. The wedge shown has $336^\circ \leq R.A. \leq 16^\circ$, $-1.25^\circ \leq Dec. \leq +1.25^\circ$ and $0.23 \leq z \leq 0.33$, which is centered on the *Saraswati* supercluster. It is clearly seen that the density of galaxies is very high in the central region of the image where the supercluster is located. It is surrounded by a cosmic-web of huge voids, filaments and clusters.

overdense structures are obtained given a predetermined limit to the minimum number of galaxies required in an overdense structure.

In the currently accepted cosmological model, clusters of galaxies trace the local extrema in the underlying distribution of matter - both dark and luminous, and since *Saraswati* is particularly a vast and overdense structure of galaxies, some clusters or groups of galaxies should be found at the highest density peaks. Moreover, in the cosmic web overdense regions are surrounded by almost empty voids. For quantifying more objectively, the galaxy distribution in overdense (clusters/groups, filaments) and the underdense (voids) regions of the cosmic web around the *Saraswati* supercluster, we crossmatch the galaxy distribution with the published catalogues of clusters and voids derived from SDSS data, and, indeed, 43 rich clusters or groups (from WHL cluster catalogue) are found in the *Saraswati* supercluster, along with large voids (from Nadathur void catalogue) which surround the supercluster (Figure 10). This shows that the *Saraswati* supercluster is real structure and not just an artifact of the data. Out of the 43 clusters in *Saraswati*, the two most massive ones are the Abell 2631 and ZwCl 2341.1+0000, shown in Figure 11.

The widely-accepted "cold dark matter" cosmological model of the Universe predicts that small structures like galaxies form first, which congregate into larger structures later. Most forms of this model do not predict the existence of structures as large

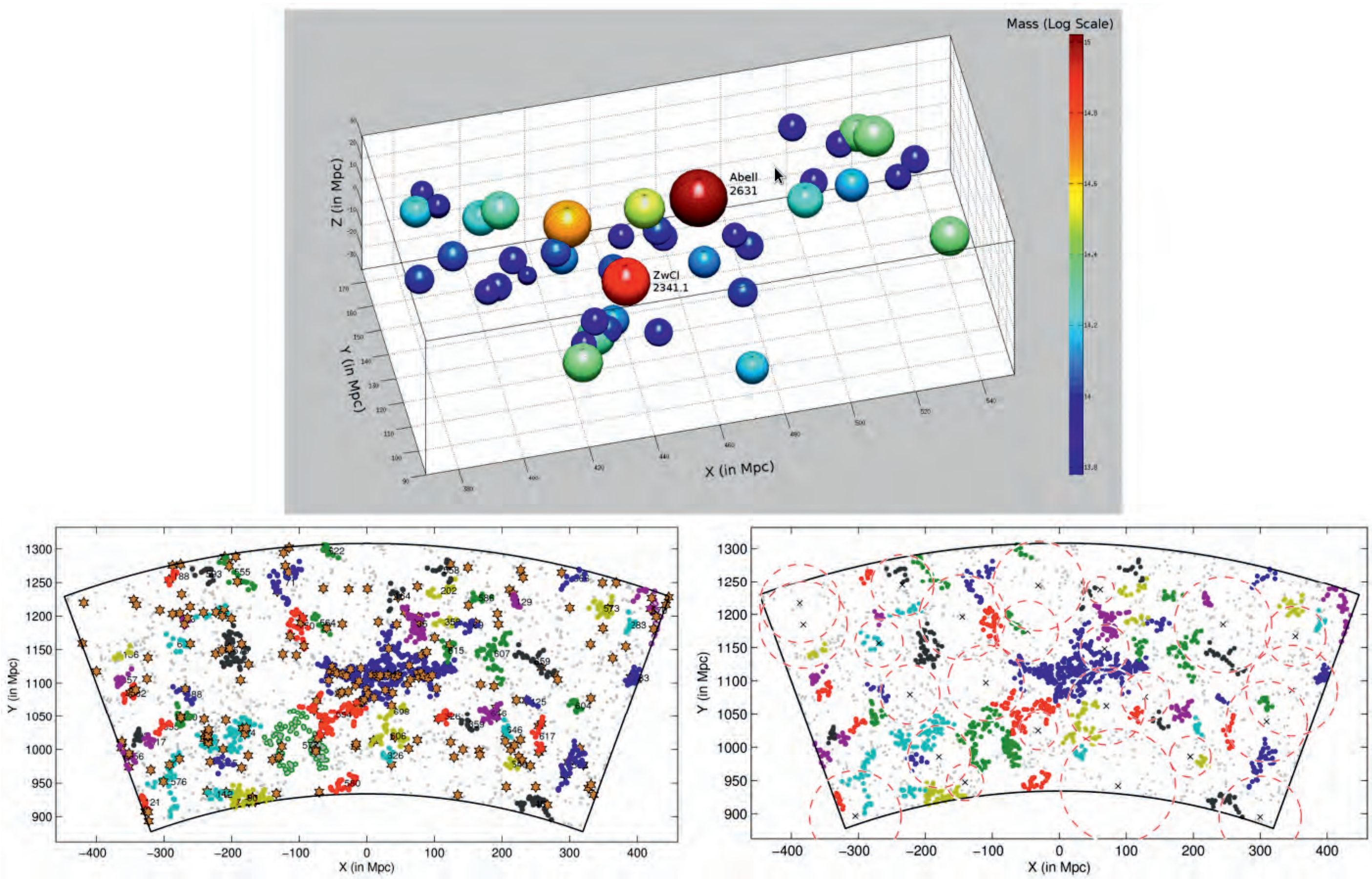


Figure 10: ***Upper panel*** **:** The 3D distribution of the wall-like structure of the *Saraswati* supercluster, mainly comprising 43 known clusters of galaxies, here represented by spheres. The radius of each cluster is proportional to its virial radius. Colours represent the masses of the clusters. ***Lower panels*****:** Overdense structures of galaxies (each dot represents a galaxy) identified in the SDSS galaxy data using Friends-of-Friends algorithm. Different colours indicate various overdense structures. The largest overdensity of galaxies found is *Saraswati,* spanning $\sim$ 200 Mpc across (in blue colour at the centre) with hundreds of galaxies. Gray dots are galaxies that are not part of any overdense structures. ***Lower Left*** **:** Known galaxy clusters/groups from WHL catalogue are shown by stars. A high concentration of clusters near the *Saraswati* supercluster is very clear. ***Lower Right*** **:** Giant Voids identified in the *Saraswati* supercluster region. Red dashed circles are voids in projection, black crosses are void centres, and the radii of circles are equal to the effective radii of voids.

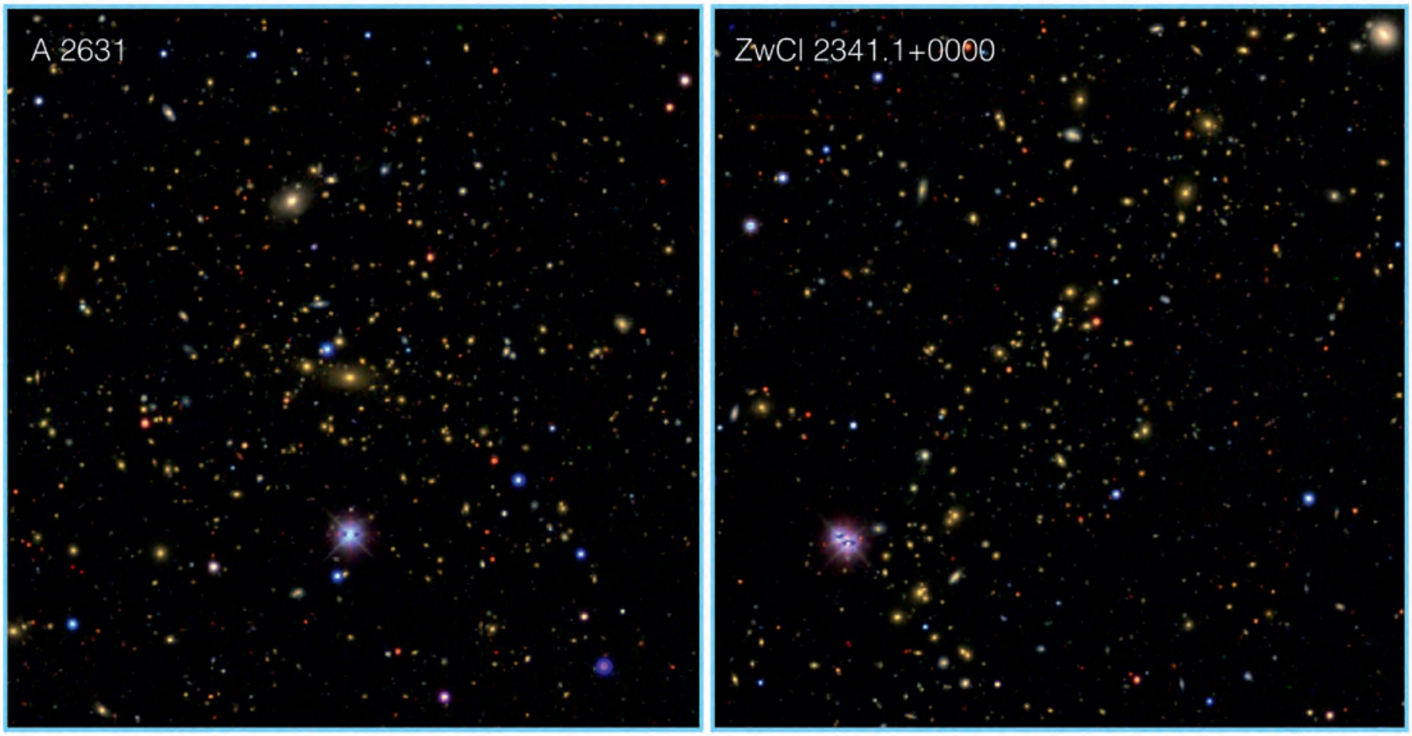


Figure 11: Two of the most massive galaxy clusters of the *Saraswati* supercluster – ***Left*** **:** Abell 2631 and ***Right*** **:** ZwCl 2341.1+0000. These two images are taken from the public Dark Energy Legacy Survey (DECaLS).

as the *Saraswati* within the current age of the Universe. Thus, discovery of this extremely large cosmic structure forces astronomers into re-thinking the popular theories of how the Universe got its current form, starting from a more-or-less uniform distribution of energy after the Big Bang. It is believed that galaxies are formed mostly on the filaments and sheets that are part of the cosmic web, and many of the galaxies travel along these filaments, ending up in the rich clusters, where the crowded environment switches off their star formation and aids in the transformation of galaxies from disky blue spiral galaxies to red elliptical galaxies. Since there is an extensive variation of environment within a supercluster, galaxies travel through these varied environments during their lifetime. To understand their formation and evolution, one needs to identify these superclusters and closely study the effect of their environment on the galaxies. This is a very new research area, and with the aid of new observational facilities, astronomers are now beginning to understand galaxy evolution. The discovery of *Saraswati* will greatly enhance this field of research.

The researchers were very surprised to spot this giant wall-like supercluster of galaxies, clearly visible in a large spectroscopic survey of distant galaxies (the SDSS). This supercluster is clearly embedded in a large network of cosmic filaments traced by clusters and large voids. Previously only a few comparatively large superclusters have been reported, for example, the nearby 'Shapley Concentration' (discovered by **Somak Raychaudhury** in 1989) or the 'Sloan Great Wall' in the nearby Universe, while the *Saraswati* supercluster is far more distant one. Our own galaxy is part of a smaller supercluster called the *Laniakea*. The discovery of *Saraswati* supercluster will help to shed light on the perplexing question; how such extreme large scale, prominent matter-density enhancements had formed billions of years in the past when the mysterious Dark Energy had just started to dominate structure formation? Although the *Saraswati* supercluster is around 650 million light years in one direction, its extent in the transverse direction on the sky is not completely known because of the limited data currently available. It is strongly suspected that *Saraswati* supercluster may have far more extension than what is suggested by the currently available sparse data from the SDSS. This discovery is now being followed up by the original team and their collaborators, involving many more researchers from Indian Universities. In-depth studies are being carried out at optical, radio and X-ray wavelengths, using many international facilities, including Indian telescopes like the Giant Metrewave Radio Telescope (GMRT), at Khodad, near Pune, the Indian AstroSat satellite in space (launched and maintained by ISRO), and at the Southern African Large Telescope, near Cape Town, South Africa, which is partly owned by the Indian Government through IUCAA. In future, vast quantities of optical spectroscopic data of galaxies are planned to be taken with the Anglo-Australian Telescope (AAT) to understand how such enormous structures may have formed in the distant Universe.

The discovery team of *Saraswati*, led by **Joydeep Bagchi**, has been awarded the prestigious year 2018 *New Discovery Award* constituted by the Astronomical Society of India (ASI).

Role of the IUCAA Associateship Programme in this Discovery

One important component of IUCAA's academic activities is the Associateship Programme, under which a faculty member of an Indian university or a post-graduate department in a college can visit IUCAA. They can and often do bring their UG or PG students with them to take part in the collaborative research. This discovery is special because it is a direct product of IUCAA's University Associateship Programme. While three of the authors are from IUCAA, the other three authors are from Indian University sector; IISER (Pune), NIT (Jamshedpur) and one IUCAA Visiting Associate (Newman College, Thodupuzha, Kerala).

IUCAA IN THE NEWS

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The Indian Express, Pune Newsline, Dated 28/09/2017, Page no. 3

2 years into space, Astrosat detects younger stars, records birth of more black holes

ANJALI MARAR
PUNE, SEPTEMBER 27

Astrosat was launched by ISRO on September 28, 2015.

TWO YEARS after its launch, Astrosat — India's first multi-wavelength space-based astronomical observatory — has confirmed the presence of younger stars hidden in globular clusters, which were believed to have housed only old stars.

Launched on September 28, 2015, the satellite began performing full-scale scientific operations in April 2016. The first six months were devoted to performance verification and calibration of all payloads — … these globular clusters, either have an inherent capability sup- … formation of multiple … or could … tor, IUCAA, said, "CZTI is turning out to be one of the world's best instruments in detecting GRBs and its wide field of view has provided an added advantage in … results beyond our ex- … de, the as- … nowledge of … more than six … he launch of … figures have … mprovements … a said, "We have … culate polarisa- … GRBs of the 11 … nts, all of which … ed in the maiden … maining four inci- … concluded to be in … larised category." … mance of UVIT was … sidered to be of high … ds, with image … ons being compared to … gathered by NASA's … Space Telescope and Galex missions.

Raychaudhury said, "The images' resolution was commendable, and it was possible to see some of the galaxies and other celestial objects like never before."

With all the on-board instruments functioning fine, the team has, so far, obtained data sets from 400 varied sources upon completing about 700 pointings into the space. Of these, a few sources were repeatedly observed to have better understanding of their changing behaviour.

Astronomical Society of India (ASI), which is responsible for reaching out to and educating students with activities pertaining to Astrosat, is planning to make all the results and developments available in multiple languages.

Niruj Mohan Ramanujam, ASI member, said, "The aim is to reach out to maximum number of school and college students and make it available for them in as many languages as possible for consumption. Most of our results are updated online."

With Astrosat expected to operate for over five hours sin… its launch, scientists have alrea… held informal talks about … next generation satellite to c… duct astronomy researchers…

Raychaudhury added, "… has extended all its suppo… astronomy community t… velop larger instruments o… scopes, as the space age… now equipped to lift h… payloads."

Times of India, Pune September 02, 2016 Pp.2

AstroSat tracks high energy black hole emission

Pic credit: NASA/CXC/A Hobart

An artist's impression of GRS 1915+105 as would be seen up close to the system which is 40,000 light years away in the constellation Aquila. The disk of accreted material (blue) from the star (red) going towards the black hole and a jet emanating from near it are shown here. AstroSat observed the X-rays coming from this event

TIMES NEWS NETWORK

Pune: AstroSat, India's first satellite dedicated to astronomy, has observed rapid variability of high energy (exceeding 20keV)) X-ray emission from a distant binary system that contains a black hole. This is the first AstroSat result to be declared.

The findings have been reported by a team led by J S Yadav and other scientists from Tata Institute of Fundamental Research, Mumbai, along with astronomers from the Inter-University Centre for Astronomy and Astrophysics (IUCAA), University of Mumbai and Raman Research Institute.

Scientists from IUCAA, Ranjeev Misra and Mayukh Pahari, are members of the scientific team who reported this result. They played a key role in writing the scientific computer codes required to analyse the data which comes from the satellite, tested them and interpreted the results.

Misra said black holes do not emit anything and when matter falls on them, they get heated up and emit radiation which is variable.

"These objects flicker in time space for less than a second. They are extremely small, but very powerful in nature. The emission changes very fast and is extremely close to the black hole. In order to under- … re than ten million degrees celsius and the system can emit X-rays. The total power coming out of these systems is often more than 10,000 times that of the sun. Yet, these systems vary rapidly in time-scales much less than a second.

GRS 1915+105 is one such X-ray binary star system consisting of a regular star and a black hole. For decades astronomers have been observing this object that lies about 40,000 light years in the constellation of Aquila. Among the many peculiar behaviours it shows, its X-ray emission sometimes changes nearly periodically (termed as quasi-periodic oscillations or QPO).

These changes have a timescale of a few hundred milliseconds. Astronomers believe that these oscillations seen in GRS 1915+105 may occur because the inner part of the disk surrounding the black hole wobbles as the spinning black hole drags the space-time fabric around it. This is as predicted by Einstein's general theory of relativity.

Importance for India

Misra said data from AstroSat would be examined by scientists, universities and institutes who had to depend on American, European or Japanese data. "Indian data will be available through this satellite which is a national facility and …

Sakaal Times, Pune September 02, 2016 Pp. 3

Breakthrough in Astrosat for scientists at IUCAA

LAXPC tracks varying X-ray emissions with high energy

ST CORRESPONDENT
reporters@sakaaltimes.conm

ARTISTIC TWIST: An artist's impression of … emanating X-ray …

Pune: Indian astronomers through Astrosat, India's first space-based observatory, have for the first time been able to analyse the gaseous matter emanating from one of the X-ray binary starts, further strengthening the General Theory of Relativity proposed by Albert Einstein.

This was informed by scientists at city-based Inter University State Centre for Astronomy and Astrophysics (IUCAA), one of the many Indian institutions involved in Astrosat mission, launched in September last year.

In the latest study, using observations captured by the onboard Large Area X-ray Proportional Counter (LAXPC) instrument, rapidly varying X-ray emissions with very high energy from binary star named GRS 1915+105 was tracked with its associated black hole.

Indian astronomers have hailed LAXPC's ability to offer very wide range of observation, that lead to such unknown revelations.

Speaking to Sakal Times about this latest findings was senior IUCAA scientist Dipankar Bhattacharya.

"Due to the high sensitivity, we were able to re- …

सकाळ, पुणे सप्टेंबर २, २०१६ पृष्ठांक १, ८

'अॅस्ट्रॉसॅट'ने टिपली कृष्णविवरातील क्ष-किरणे

पुणे, ता. १ : पुण्यातील 'आयुका'चे महत्त्वपूर्ण संशोधनात्मक योगदान असणाऱ्या महत्त्वाकांक्षी अशा भारतीय बनावटीच्या 'अॅस्ट्रॉसॅट' या उपग्रहाच्या ताज्या पाहणीत काही महत्त्वपूर्ण निरीक्षणे नोंदविली गेली आहेत. या निरीक्षणांनुसार कृष्णविवरातून बाहेर पडणाऱ्या आणि उच्च ऊर्जा उत्सर्जित करणाऱ्या क्ष-किरणांच्या (हाय एनर्जी एक्स-रे) उत्सर्जनातील विशिष्ट बदलांची वारंवारता टिपण्यात 'अॅस्ट्रॉसॅट'ला यश आले आहे. या स्वरूपाचा शोध घेण्यात जगभरातील संशोधक गेली अनेक वर्षे गुंतले होते.

'जीआरएस १९१५ + १०५' असे नाव असणाऱ्या बायनरी सिस्टिममधील कृष्णविवरातून उत्सर्जित झालेले हे एक्स-रे आहेत. ज्यात एका ताऱ्यासोबत एक कृष्णविवर एकत्रितपणे अस्तित्वात असते, अशा खगोलीय 'बायनरी सिस्टिम'चा भाग असणाऱ्या आणि पृथ्वीपासून हजारो प्रकाशवर्षे दूर असलेल्या कृष्णविवरातून हे उत्सर्जन होत असल्याचे 'अॅस्ट्रॉसॅट'ला याच आठवड्यात आढळून आले आहे. हे उत्सर्जन एका ठराविक वारंवारतेने होते, असे पहिल्यांदाच दिसून आले आहे. 'लार्ज एरिया एक्स-रे प्रपोर्शनल काउंटर' या उपकरणाचा उपयोग

पान ८ वर »

असे आहे जीआरएस १९१५+१०५ चे रचनाचित्र : निळसर रंग हा ताऱ्यापासून विलग झालेले 'मॅटर' दर्शवितो; तर तांबडा रंग हा तारा दर्शवितो. मध्ये कृष्णविवरातून होणारे ऊर्जाउत्सर्जन दिसेल.

महत्त्व

- महान शास्त्रज्ञ अल्बर्ट आईनस्टाईन यांनी वर्तविलेल्या सापेक्षतावादाच्या सिद्धांताला पुष्टी देणारीच ही घटना आहे. कृष्णविवर स्वत:भोवती फिरण्याच्या गुणधर्मातून हे घडते.
- भारताच्या 'अॅस्ट्रॉसॅट'व्यतिरिक्त एवढी अचूक निरीक्षणे नोंदविण्यास अद्याप जगातील कोणतीही वेधशाळा सक्षम नाही.

कृष्णविवरांचा अभ्यास करणे या नव्या, उपयुक्त शोधामुळे अधिक सोपे होणार आहे. विशेषत: एक्स-रेसारखे किरणोत्सर्जन नक्की कसे होते या अभ्यासातून त्यांच्या मूळ स्रोतांचा आणि त्यात होणाऱ्या बदलांचा अभ्यासही यातून होऊ शकणार आहे. भारताच्या दृष्टीने हा महत्त्वाचा टप्पा आहे.
- प्रा. दीपांकर भट्टाचार्य (संशोधक, आयुका)

17-08-2017 13:17:47

Indian Express, Dated August 12, 2017.Page no. 23

COSMIC INFORMATION

Scientists make breakthrough in dark energy research

EXPRESS NEWS SERVICE
PUNE, AUGUST 11

THE WORK of two physicists, Professor Thanu Padmanabhan at IUCAA, Pune and Dr Hamsa Padmanabhan at ETH, Zurich, (Swiss Federal Institute of Technology), connects and answers two fundamental questions about the cosmos.

An official release issued on Friday by the Inter University Centre for Astro...

Astrophysics, said that they have discovered the correct value for the size of the small fluctuations in the early universe, which later led to the creation of larger structures like galaxies.

The two scientists, in their forthcoming paper to be published in *Physics Letters B*, argue that the very existence, as well as the tiny numerical value of the cosmological constant, can be understood as a direct consequence of the...

There are two tantalising mysteries about our universe — thought to be unconnected with each other — which have intrigued cosmologists for decades. The first one is about the existence of ... called 'dark energ... speeding up the ... the universe at pr...

Current obser... gest that the natu...

Cosmological Constant. But, for this idea to work, the cosmological constant should have a very specific — and enormously tiny — value. Explaining this tiny but non-zero number is ... to be the greatest ...

accessible to an observer in our universe, will be finite, only if the universe undergoes an accelerated phase of expansion later, exactly as we observe.

Thanu and Hamsa Padmanabhan do not postulate ... phase in their ...

8/2/2017 10:02:07 AM

Times of India, Dated 02-08-2017, page no.7

IISER, IUCAA tie-up on G-waves & astronomy

TIMES NEWS NETWORK

Pune: A memorandum of understanding has been signed between the Inter-University Centre for Astronomy and Astrophysics (IUCAA) and Indian ...nstitute of Science Education ...nd Research (IISER), Pune, to ...llaborate on research in gra...ational wave physics, astro...ny and teaching activity.

A Centre for Gravitational ...ics & Astronomy (CGPA) ...een established as part of ...ollaboration where the ...stitutions would share ...h manpower and in...ture resources such la... observational and ...g facilities.

...A's director Somak ...hury and the direc... ...R Krishna Ganesh ... first MoU between ...itutions on July 21 ...entre.

...ent from IUCAA ...U promises to ca... unique opportu... ...phical proximi... ...high expertise ...research insti... ...with the capa... ...ducation and ...n, IISER for ...tual growth ... of gravita... ...stronomy." ...ormalizes ...laboration ...underway between researchers at the two institutions. Undergraduate and postgraduate students from IISER, Pune have been routinely involved in research projects in astronomy and astrophysics at IUCAA.

A number of other IISER students that have worked in areas such as gravitational waves have found placements in top schools around the world. IISER, Pune's faculty is actively participating in the S&T build up for the LIGO-India project led by IUCAA.

IUCAA, among the three lead LIGO-India institutions, is the key science stakeholder of Laser Interferometer Gravitational-Wave Observatory (LIGO)-India and is responsible for science and technology human resource development.

CGPA would provide substantial nucleus required for such an extensive training and human resource building activity, the statement added.

GOAL SETTING

Provide young researchers rigorous training, contributing to human resources development

RESEARCHERS' AGENDA	CORE AREAS
Would create a joint collaborative research and teaching activity	Gravitational wave physics
Expose talented young researchers to exciting scientific challenges in identified focus	Astrophysics of G-wave origin
Share research manpower and infrastructure resources such as laboratory, observational and computing facilities	Precision measurements and technologies
	Electromagnetic follow-up
	Geophysical characterization and cancellation of Newtonian gravity gradient noise
	Big-data science
	Artificial deep learning

Times of India, Pune July 25, 2017 Pp. 6

Why now is indeed the best time to prepare for a career in astronomy

In Eight Years, Astronomers Will Be Using Incredible Technologies

Ashish Shankar

Ajit Kembhavi

Astronomy is a magnificent science.

It's primarily about asking the right questions, about matter light years away from us. It deals with the observation and understanding of the entire Universe and all the cosmic objects in it — planets, stars, galaxies, quasars, black holes. How far are these objects? What is their nature? How did these objects form and how will they evolve as time passes? Has the universe always been around?

These questions have remained with us for thousands of years, since the day we first looked up at the night sky.

Modern astronomers can, of course, go much further into space using cutting-edge telescopes, instruments and imaging technologies. Physics and mathematics too are used to interpret observations.

But how does one become an astronomer? And what are the career opportunities? As a professional astronomer, I'm often asked these questions by students and anxious parents. Everyone wants to go from being merely fascinated by astronomy to building a career in it.

The best way to astronomy is through physics, mathematics and engineering. After Class XII, a student will need to obtain a B.Sc with physics and mathematics amongst the main subjects and then an M.Sc. in physics. After that, one will have to pass entrance exams and interviews to obtain admissions for a PhD in astronomy in one of the national institutes we have. A PhD can also be obtained from certain universities and there are many opportunities abroad too. An important alternative path is to obtain a BE or BTech in any branch of engineering and then appear for competitive exams for admissions in a PhD programme. Research at PhD level can be in a theoretical area of astrophysics or cosmology, which typically requires a strong grasp of physics or mathematics. Research could also involve observations with telescopes or building instruments that can be used on telescopes. And then there are areas which require comprehensive use of computers and the ability to write complex programmes. Astronomy is truly a many-splendored discipline but projects need patience, perseverance and both intellectual and physical stamina. After all, this is a field that measures in light years and investigates objects born billions of years ago.

After the PhD, a young astronomer will typically spend a few years in post-doctoral research following which she or he will be finally ready for appointments as a professor and scientist. This job, which involves research, development and teaching is extremely exciting and intellectually stimulating. One will be presented with opportunities to collaborate with experts from around the world and perhaps the best part is, the expertise developed as an astronomer can be applied to many other areas of science and technology. The skills will allow students to constantly reinvent themselves to seek out new cutting-edge areas for work.

Is Astronomy still relevant? Yes! It is as relevant as it was when Galileo first turned a telescope to the sky to make marvellous discoveries. In fact, we are living in an age which could be described as "astronomically vibrant" because several large projects are taking shape — examples include the Thirty-Meter Telescope in Hawaii and the LIGO-India gravitational observatory that's set to come up in Hingoli, near Nanded.

The projects will be ready in about eight years' time and students who will be finishing high school now will be amongst the first to use these facilities for PhD work. The start of a new, interesting age in astronomy has begun.

> We are living in an age that could be described as 'astronomically vibrant' because several large projects are taking shape

Ajit Kembhavi is founder member and a former director of the Inter-University Centre for Astronomy and Astrophysics or IUCAA

TIMES CITY | PUNE

THE TIMES OF INDIA, PUNE
TUESDAY, OCTOBER 17, 2017

4

40 Indians in star collision discovery team

2nd Biggest Find After G-Waves From Black Holes

Ardhra Nair & Swati Shinde Gole | TNN

THE EUREKA MOMENT

The coalescence of two orbiting neutron stars

A computer simulation still of the collision of two black holes, an event detected for the first time ever by LIGO

'Colliding neutrons bolster gravitational wave claim'

All eyes now on LIGO-India detector

IUCAA scientists contributed most to country's share

Telescopes that made a huge difference

Frequency low, but sensitivity high

Missing flashes helped detection

Images from the Himalayan heights

LIGO grasps third gravitational wave

Times News Network

Pune: The Laser Interferometer Gravitational-wave Observatory (LIGO) detected a gravitational wave for the third time on January 4. Indian and other scientists found that the data gives more insights on how two black holes were spinning when they merged and resulted in a gravitational wave strong enough to be detected and its concurrence with the Einstein's Theory of Relativity.

FURTHER INSIGHTS

The third event was produced by the merger of two black holes, 31 and 19 times as massive as the Sun, respectively, forming a larger black hole of about 49 solar masses.

The data suggests that at least one of the black holes in the binary system might have been spinning in a direction that is not completely aligned with the orbital rotation of the pair... on how these binaries have formed," an official ... from Inter-University Centre for Astronomy and Astrophysics (IUCAA) said.

IUCAA scientist Sanjit Mitra said, "By looking at how the merged black hole was spinning and studying the signature of the resultant G-wave, we understood that at least one of the black holes was spinning unlike the other and unlike the resultant black hole."

It is in concurrence with Einstein's theory of relativity, he added. "G-waves are massless and hence do not undergo dispersion, a phenomena of waves travelling at different speeds based on their wavelengths. We are studying it further to understand if there is a breakpoint where G-waves do not concur with Einstein's theory of relativity," Mitra added.

IUCAA's statement also added that the Cadmium Zinc Telluride Imager (CZTI) on AstroSat conducted the most sensitive search for short duration X-ray flashes associated with G-wave detection, but did not find anything.

"When an optical source potentially related to the LIGO event was discovered, the CZTI team joined hands with the international GROWTH collaboration to study it. This India-led study proved that the optical source was not related to this event," the official release said.

PUNE Newsline

The Indian EXPRESS

WEDNESDAY, OCTOBER 4, 2017

WWW.INDIANEXPRESS.COM, TWITTER.COM/INDIANEXPRESS, FACEBOOK.COM/INDIANEXPRESS, INDIANEXPRESS/APPS

TALK PAGE 4
Tom Petty dies at 66

Nobel only beginning for gravitational astronomy: scientists

Scientists part of international collaboration on Laser Interferometer Gravitational Wave Observatory project, which gets Nobel in physics, say it's a first huge step

ANURADHA MASCARENHAS
PUNE, OCTOBER 3

THE NOBEL prize in physics for three scientists for their contribution in detecting gravitational waves brought cheer at the city-based Inter-University Centre for Astronomy and Astrophysics (IUCAA) whose scientists have been part of the international collaboration on the Laser Interferometer Gravitational Wave Observatory (LIGO) project.

The 2017 Nobel prize in physics ...

Thorne and Barry Barish, all of whom played pioneering role in realising the experiment that confirmed the existence of gravitational waves in 2015, almost exactly 100 years after Albert Einstein had proposed it in his theory of gravitation. More than 1,000 scientists from across the world, including 37 from Indian scientific institutions, were also a part of this collaborative effort.

Prof Sanjeev Dhurandhar, one of the key Indian players associated with the project, said he was extremely satisfied ...

weak signals hidden in noise... It is so wonderful that in my lifetime, the work done towards the discovery of the century has been awarded the Nobel prize. I am ready to die now," Dhurandhar, who led a group at IUCAA that did foundational work on developing data analysis techniques, told *The Indian Express*.

"Today, my students talk in terms of teraflops (unit of computing that represents a trillion floating-point ...

megaflop speed was a big thing. We did not have such high performance computing facilities, so there were huge challenges (when gravitational wave experiments had begun)," he said.

"In the 1980s, when everyone was talking about electromagnetic waves, I focused on gravitational waves which ...

"It is a first huge step. There is a long way to go and while we are eagerly waiting for the construction of LIGO-India, the effort should go on to build new generation detectors," Mitra said.

His colleague Tarun Souradeep said the Nobel prize would inspire ...

were being carried out at the location. The LIGO India observatory is slated to begin scientific operations by 2024.

Somak Raychaudhury, director of IUCAA, said there was a celebratory mood at the institution. ...

Loksatta, September 28, 2017, Pp. 1 & 4

गुरुत्वीय लहरींचा अचूक वेध घेण्यात यश

कृष्णविवरांच्या विलीनीकरणाविषयी नवी माहिती उपलब्ध, सापेक्षतावादाच्या सिद्धांताला पाठबळ

प्रतिनिधी, मुंबई, पुणे

दोन कृष्णविवरांच्या विलीनीकरणाच्या खगोलीय घटनेत निर्माण झालेल्या गुरुत्वीय लहरींचे निरीक्षण लायगो आणि व्हर्गो या शोधक यंत्रांच्या साहाय्याने करण्यात यश आले आहे. एकूण तीन शोधक यंत्रांनी गुरुत्वीय लहरींचे ध्रुवीकरण मोजणे शक्य झाले, त्यामुळे आइनस्टाइनच्या सापेक्षतावादाच्या सिद्धांताला पाठबळ मिळाले आहे.

शोध का?

माणसाला विश्वाच्या निर्मितीबरोबरच विश्वातील अनेक गोष्टींची उकल अद्याप होऊ शकलेली नाही. यासाठी जगभरात सर्वच विज्ञानशाखांमध्ये विविध प्रयोग सुरु आहेत. याच प्रयोगाचा एक भाग म्हणून गुरुत्वलहरींचा आणि त्याच्या स्रोताचा शोध घेतला जात आहे.

नवीन स्रोतापासूनच्या गुरुत्वीय लहरी शोधण्यात आल्याची घटना महत्त्वपूर्ण असून तीन शोधकांच्या (डिटेक्टर्स) माध्यमातून प्रथमच स्रोत ठरवण्यात आल्याने कृष्णविवराच्या स्थानाची अचूकता ३० वर्ग अंश म्हणजे पूर्वीपेक्षा दहा पटीनी अधिक आहे. भारतात जेव्हा लायगो डिटेक्टर यंत्र सुरू होईल, तेव्हा ही अचूकता आणखी दहा पटीनी वाढणार आहे.

– संजीव धुरंधर,
गुरुत्वीय लहरींच्या संशोधनातील ख्यातनाम वैज्ञानिक

त्याचबरोबर कृष्णविवराच्या स्थानाची अचूकता टिपणे शक्य शक्य झाले आहे. हे त्यांच्या प्रयोगाचे वैशिष्ट्य आहे.

या संशोधनात जगभरातील वैज्ञानिकांच्या गटात भारतीय वैज्ञानिकांचेही योगदान मोलाचे आहे. वेगवेगळ्या स्रोतांपासूनच्या गुरुत्वीय लहरी टिपण्याची ही चौथी वेळ आहे.

कृष्णविवरांच्या मिलनातील गुरुत्वीय लहरी टिपण्यात यापूर्वी २०१५ मध्ये अमेरिकेतील लायगो उपकरणांच्या मदतीने दोनदा यश आले होते. आताच्या शोधात सूर्यापेक्षा ३१ व २५ पट वस्तुमानाच्या दोन कृष्णविवरांच्या मिलनाच्या घटनेतून निर्माण झालेल्या गुरुत्वीय लहरी टिपण्यात आल्या. कृष्णविवरे एकमेकात विलीन होण्याची ही घटना १.७ अब्ज प्रकाशवर्षे अंतरावर घडली होती. यातील गुरुत्वीय लहरींची ऊर्जा तीन सूर्यांइतकी होती. विश्वात कृष्णविवरे कशा पद्धतीने विखुरलेली आहेत, याचे ज्ञान यातून होणार

(पान ४ वर)

IUCAA stars in yet another discovery

Scientists met on Monday to discuss the import of a new significant observation

| Aprajita.Vidyarthi
@timesgroup.com

TWEET @ThePuneMirror

Recently, a breakthrough ended in a Nobel Prize in Physics for a team of scientists from the US after the US-based Laser Interferometer Gravitational-Wave Observatory (LIGO) and Europe-based Virgo detector caught on to gravitational waves from the collision of black holes in space.

Work by members of Pune's Inter-University Centre for Astronomy and Astrophysics (IUCAA) was also acknowledged as having contributed to this significant discovery. Now, another discovery has been made, with scientists gathering at the IUCAA campus in the varsity here on Monday to discuss the prospects.

As the global scientific community celebrates the detection of gravitational ...

DHANANJAY HELWADE

The event at IUCAA on Monday to fete the body's newest discovery

We know what part of the sky the earth blocks, so it was easier to detect the location of the object. The Himalayan Chandra telescope followed up all positions where neutrinos were supposed to be detected from, and ruled out this presence. GMRT has followed up that the radio emission has not risen to the level that can be detected. We are now awaiting further results to see what the colli...

yet and will have to wait. In terms of possibilities, we could be looking at a massive neutron star, or it could collapse to a black hole. Future observations will tell us more. What we do know currently is that it is a 2.8 solar mass, which is lighter than any black hole ever observed."

IUCAA professor Sanjeev Dhurandhar said, "Many possible things in space create gravitational waves, like isolated spinning neutron stars and supernova... Anything beyond this will be an exciting surprise for the world." Such mergers are also probably the birthplace of elements heavier than iron, which means gold and platinum might also be formed in the collision of two neutron stars, said the scientists.

Senior professor Tarun Souradeep said, "LIGO India was proposed ... exactly such discoveries. We expect ... bigger detections from that. These ... bers are significant, as gravitational ... detectors have poor eyesight in ... sky coverage. Electromagnetic ...

Nobel laureate: India played a key role in LIGO research

From being fascinated by science fiction movies as a kid, to initiating one (Interstellar), and from reading about astronomy and astrophysics in newspapers and journals to finding gravitational waves (GWs), ***Kip Thorne*** *— who shared the 2017 Nobel prize for physics with Rainer Weiss and Barry C Barish — has done it all. The co-founder of the Laser Interferometer Gravitational Wave Observatory (LIGO), who was in Bengaluru for an award ceremony, spoke to* ***TOI's Chethan Kumar*** *about the future of astrophysics. Excerpts:*

Like many big science projects, there was a time when building LIGO seemed difficult. Did ... opposition?

I began thinking ... from a ...

It was less interesting to do that. What was more interesting was that we were going to do with GWs what Galileo (Galilei) did with electromagnetic waves. Galileo changed the way we learnt about the universe 400 ... ago, and LIGO ... GW astro... have a similar ... at what Galileo ... 400 years, ... calculate what ... going to be a ... discoveries.

... major ... most an... agree?

... absolutely ... three ...

9/29/2017 10:10:59 AM

The Times of Indain. Dated 29/09/2017. P-10

Study by 3 Pune scientists aids LIGO-Virgo detection

Trio's Theory Helped Spot G-Waves

... three scientists — Sanjeev Dhurandhar, ... Bose ... theoretically set the ... for the ... Over the years, ... several tech... The ... carried out by the ... 17 years ago, ... the fourth detection ... Laser Interferometer Gravitational-wave Observatory (LIGO) in America, and ... observatory in Europe.

... Wednesday, LIGO ... announced that the LIGO ... in the US ... the gravitational wave ... from yet another merger ... black hole pair. This time, ... was joined by Virgo. ... Dhurandhar, emeritus professor, IUCAA, said, "In 2000, ... had done a theoretical study with three detectors, where ... to get the maximum ... out of the network ...

EINSTEIN'S THEORY PROVED

- Gravitational waves are described as "ripples" in the space-time fabric. They are caused by some of the most violent processes in the Universe
- The existence of gravitational waves was first predicted by Albert Einstein in 1916. His calculations showed that massive accelerating objects — like black holes orbiting each other — would disrupt space-time in such a way that 'waves' of distorted space would radiate from the source. Moreover, these ripples would travel at the speed of light, carrying with them information about their origins

LATEST DETECTION

- On August 14, scientists made the fourth detection of gravitational waves formed by the collision of two massive black holes
- The signal was recorded by two LIGO observatories in the US and Italy's Virgo
- It is the first joint detection of gravitational waves with the LIGO and Virgo collaborations
- The theory used for the network of detectors was the same as the one attempted by 3 scientists from Pune 17 years ago

Observatory's India work to begin in 2018, land acquisition underway

Swati Shinde Gole @timesgroup.com

Pune: Work on India's Laser Interferometer Gravitational-wave Observatory (LIGO) is set to begin by mid-2018, and land acquisition for the observatory is currently underway. The LIGO-India team is expecting a grand groundbreaking ceremony once the requisite land is acquired, and an approval for conducting ...

Souradeep, meanwhile, added, "Multiple detectors will improve the chances of getting more information. Essentially, detectors work for about 80% of the time. Due to various reasons, one or the other detector is non-operational at some point. Therefore, more detectors running at the same time is important for carrying out the analysis and getting information."

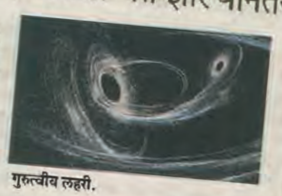
The detector in India will increase the ability and accuracy of localising the gravitational wave sources in the sky. ...

गुरुत्वीय लहरींचा तिसऱ्यांदा पुरावा

'लायगो' वेधशाळा पुन्हा कार्यान्वित झाल्यानंतरचे पहिलेच सिग्नल्स

पुणे, ता. १ : सुमारे दोन वर्षांपूर्वी गुरुत्वीय लहरींचा ऐतिहासिक शोध लावत आणि अल्बर्ट आइन्स्टाईन यांच्या सापेक्षतावादाच्या सिद्धांताला खरे ठरवत अवघ्या जगाचे लक्ष वेधून घेणाऱ्या 'लायगो' वेधशाळेने पुन्हा एक चांगली बातमी दिली आहे. लायगोच्या शोधकयंत्रणेला (डिटेक्टर्स) गुरुत्वीय लहरींच्या अस्तित्वाचे पुरावे पुन्हा एकदा मिळाले असून, गेल्या दोन वर्षांत हे तिसऱ्यांदा घडले आहे. गुरुत्वीय लहरींच्या अस्तित्वाला यामुळे पाठबळ मिळाले असून, गुरुत्वलहरीय खगोलशास्त्राच्या आणि कृष्णविवरांच्या अभ्यासाला यातून मोठी गती मिळणार असल्याचे संकेत शास्त्रज्ञांनी दिले आहेत.

गुरुत्वीय लहरींच्या शोधात लायगो वेधशाळेच्या सोबतीने महत्त्वाची भूमिका पार पाडलेल्या 'आयुका'तील शास्त्रज्ञांनी गुरुवारी या नव्या घडामोडींसंदर्भात माहिती दिली. पृथ्वीपासून सुमारे ३ अब्ज प्रकाशवर्षे दूर असणाऱ्या महाकाय अशा दोन द्विज-कृष्णविवरांच्या महाटकरीतून निर्माण झालेल्या ऊर्जेतून या गुरुत्वीय लहरींची निर्मिती झाल्याचे दिसून आले आहे. लायगो वेधशाळेला ...



गुरुत्वीय लहरी.

विशेष म्हणजे, पहिल्या टप्प्यातील शोधानंतर वेधशाळेचे काम तांत्रिक कारणांसाठी थांबविण्यात आले होते. त्यानंतर दुसऱ्या टप्प्यात वेधशाळा कार्यान्वित झाल्यावर या वर्षी ४ जानेवारी रोजी हा शोध लागला आहे.

काय आहे शोध आणि त्याचे महत्त्व?

सूर्याच्या ३१ पट अधिक वस्तुमानाचे एक कृष्णविवर आणि सूर्याच्या १९ पट अधिक वस्तुमानाचे दुसरे कृष्णविवर यांच्यात ...

ही तर केवळ सुरवात!

या शोधाबद्दल बोलताना आयुकातील शास्त्रज्ञ आणि गुरुत्वीय लहरींच्या शोधात महत्त्वपूर्ण योगदान देणारे प्रा. संजीव धुरंधर म्हणाले, "मूलभूत भौतिकशास्त्राला एक नवी आणि वेगळी दिशा देणारा हा शोध ठरणार आहे. गुरुत्वीय लहरींचा शोध विज्ञान आणि तंत्रज्ञान क्षेत्रातील अनेक नवी दालनं खुली करणार आहे." तर डॉ. संजीत मित्रा म्हणाले, "गुरुत्वीय लहरींच्या अस्तित्वावर शिक्कामोर्तब करतानाच या शोधामुळे लायगो प्रकल्पाची कार्यक्षमताही सिद्ध केली आहे. भारतात लायगोची वेधशाळा सुरू झाल्यावर या शोधाला गती मिळेल."

Gravitational waves: City-based IUCAA to install 3rd LIGO detector

MANASI SARAF JOSHI
reporters@sakaaltimes.com

Pune: The third detector which can detect gravitational waves will be installed by Inter-University Centre for Astronomy and Astrophysics (IUCAA) at LIGO (Laser Interferometer Gravitational-wave Observatory) India site. "This for the first time, India will be directly involved in the research work," said Somak Raychaudhury, Director of IUCAA.

Talking exclusively to Sakal Times, he said, "In LIGO, IUCAA's job was to coordinate research community in the country and to run the project. Americans have built up the third detector for the project. Indian government and the American government have signed a memorandum of understanding (MoU) and according to it, the built detector will be transferred to India."

"We will install this detector at LIGO India site and will also build up an observatory around it. The mirrors and detectors required to build the system will be sent from the LIGO collaborators in the US. And by 2025, it will be functioning, but to make it functional, we have to match up with the technology that Americans would be developing by then. Several researchers from Indian Institute of Science Education and Research, Indian Institutes of Technology (IITs) and various other research institutes will be working on this. We want to develop the technology comparable to it," he said.

ST EXCLUSIVE

"We ... crore fr... Technol... ic Energ... The ... first pre... years ag... ativity ... such as ... orbiting ... from the ... at the sp... verse, ca... about th... able clu... self.

THE LIGO PROJECT

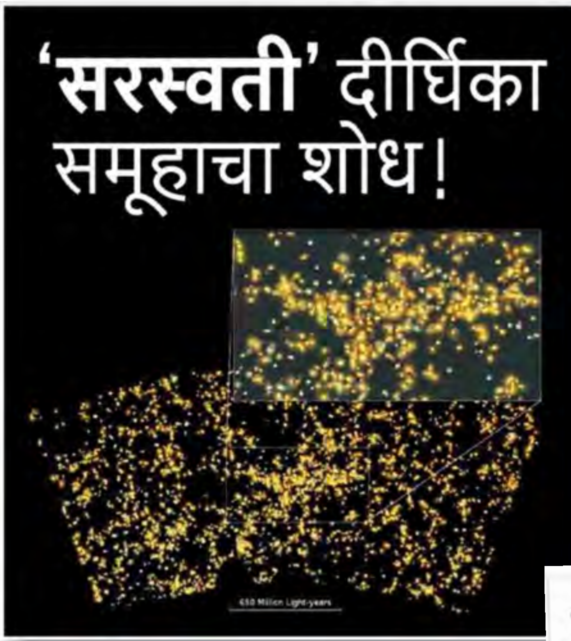
"To encourage astronomy and astrophysics among students across var...

Dr. Harsh Vardhan @drharshvardhan

Follow

The #NobelPrize for #GravitationalWaves should inspire young Science/ Engineering students to join @IndiaDST & @DAEIndia to build #LIGOIndia

12:38 AM - 5 Oct 2017



Maharashtra times, July 14, 2017,Pp.1

आता आकाश 'सरस्वती'

म. टा. प्रतिनिधी, पुणे

रात्रीच्या आकाशात दिसणाऱ्या लाखो ताऱ्यांच्या धूसर पट्ट्याला पुरातन काळापासून 'आकाशगंगा' म्हटले जाते. भारतीय खगोलशास्त्रज्ञांनी आता आकाशातील 'सरस्वती'चाही शोध लावला आहे. आपल्या आकाशगंगेपासून सुमारे चार अब्ज प्रकाशवर्षे दूर असणाऱ्या दीर्घिकांचा (गॅलेक्झी) अतिशय घन असा महासमूह (सुपरक्लस्टर) भारतीय खगोलशास्त्रज्ञांना सापडला असून, शास्त्रज्ञांनी त्याचे नामकरण 'सरस्वती' असे केले आहे.

भारतीय शास्त्रज्ञांनी शोधला दीर्घिकांचा महासमूह

पुण्यातील इंटर युनिव्हर्सिटी सेंटर फॉर ॲस्ट्रोनॉमी ॲंड ॲस्ट्रोफिजिक्सच्या (आयुका) पुढाकाराने केल्या गेलेल्या या संशोधनात पुण्यातील इंडियन इन्स्टिट्यूट ऑफ सायन्स एज्युकेशन ॲंड रिसर्च (आयसर), एनआयटी- जमशेदपूर आणि केरळच्या थोडुपुळा येथील न्यूमन कॉलेजच्या शास्त्रज्ञांचा सहभाग आहे. स्लोन डिजिटल स्काय सर्व्हे (एसडीएसएस) या आंतरराष्ट्रीय सुविधेचा उपयोग करून हे संशोधन करण्यात आले.

मीन राशीत सापडलेल्या सरस्वती या महासमूहात हजारो दीर्घिकांचा सहभाग असणारे ४३ समूह असून, त्यांचे एकत्रित वस्तुमान दोन कोटी अब्ज सूर्यांइतके असावे असा अंदाज आहे. दीर्घिकांच्या या महासमूहाची व्याप्ती ६० कोटी प्रकाशवर्षे इतकी आहे. विश्वाच्या निर्मितीनंतर दहा अब्ज वर्षांनी सरस्वती समूहाची असणारी अवस्था सध्या आपल्याला दिसत आहे असे शास्त्रज्ञांचे म्हणणे आहे. या शोधामुळे विश्वरचनाशास्त्रातील जुन्या संकल्पनांचा खगोलशास्त्रज्ञांना फेरविचार करावा लागणार आहे. प्रख्यात ॲस्ट्रोफिजिकल जर्नल मध्ये हे संशोधन प्रसिद्ध झाले असून, आयुकाच्या प्रा. जॉयदीप बागची यांच्यासह प्रकाश सरकार, शिशिर सांख्यायन, प्रा. सोमक रायचौधरी, जो जेकब आणि प्रतीक दाभाडे यांचा या संशोधनात सहभाग आहे.

'सरस्वती' नामकरण कशामुळे?

सरस्वती ही विद्या, कला, संगीत आणि निसर्गाची प्राचीन देवता असून, ऋग्वेदात सरस्वती या नदीचा उल्लेख झाला आहे. अनेक प्रवाह एकत्र येऊन सतत प्रवाहीत असणाऱ्या या नदीकाठी वेदांची रचना झाली, असे मानले जाते. सरस्वती महासमूहही दीर्घिकांचे अनेक समूह एकत्र येऊन तयार झाला असल्यामुळे त्याचे नामकरण सरस्वती असे करण्यात आल्याचे शास्त्रज्ञांनी शोध निबंधात म्हटले आहे.

Pune scientists discover supercluster 'Saraswati'

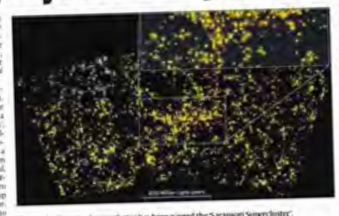
Saraswati supercluster contains over 10,000 galaxies

THE INDIAN EXPRESS, FRIDAY, JULY 14 2017

3 MAHARASHTRA

Indian astrophysicists identify supercluster of galaxies four billion light years away, first time from Indian soil

EXPRESS NEWS SERVICE



The newly discovered supercluster has been named the 'Saraswati Supercluster'.

Indians discover a great wall of galaxies

G.S. MUDUR

New Delhi, July 13: Indian astronomers today reported the discovery of a massive supercluster of galaxies, one of the largest known structures in the universe that they have named Saraswati.

A team of six astronomers from Pune, Jamshedpur and Thodupuzha in Kerala discovered the massive supercluster, which resembles a wall of galaxies spanning over 600 million light years, an unimaginably vast region of the universe.

Massive superclusters are collections of tens of thousands of galaxies bound by gravity and represent the largest distinct structures in the cosmos.

Astronomers had realised more than three decades ago that galaxies are not scattered uniformly across the cosmos but arranged in clusters shaped like bubbles, sheets or walls and linked by filament-shaped structures, a pattern astronomers call the cosmic web.

The first supercluster, the Shapley Concentration, was discovered in 1989 and a second, the Sloan Great Wall, in 2003. The Saraswati is located four billion light years from the Milky Way galaxy.

"We're seeing a structure that had already formed about four billion years ago, or at a time when the universe was about two-thirds of its current age," said Somak Raychaudhury, director of the Inter-University Centre for Astronomy and Astrophysics, Pune, who led the team.

The Saraswati. (PTI)

"This could push astronomers into rethinking about how such large structures form."

Raychaudhury and his colleagues have described their findings in *The Astrophysical Journal*.

According to an estimate by the scientists, the Saraswati supercluster contains the mass equivalent of 20 million billion suns, making it one of the most massive clusters observed.

Raychaudhury had also been a member of the team that had discovered the first supercluster in 1989. He had picked its name, Shapley, after the American astronomer Harlow Shapley who had contributed to mapping the southern hemisphere sky in the 1930s.

"We picked Saraswati for our massive supercluster because we wanted to use an Indian name," Raychaudhury said.

"It's the name of an ancient river, and this supercluster of tens of thousands of galaxies may be imagined as a river of galaxies in the cosmos."

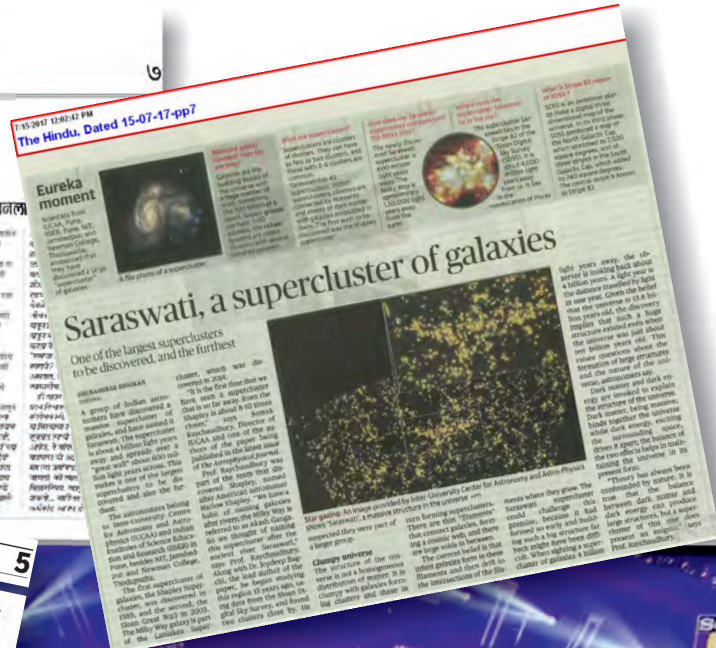
In their search for the supercluster, the astronomers relied on the Sloan Digital Sky Survey, a massive effort led by US astronomers to catalogue stars and galaxies, which has since 1998 documented over 500 million objects.

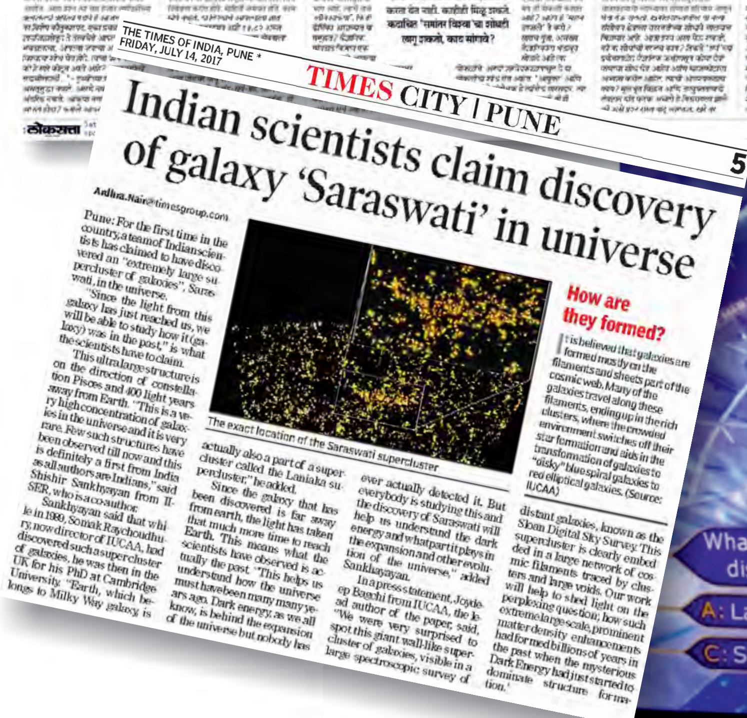
The team used distance data of tens of thousands of galaxies catalogued in the Sloan Digital Sky Survey to create a 3D map of a slice of the cosmic web that revealed a previously unknown wall of galaxies.

"Imagine thousands of galaxies, all more or less huddled together across a wall-like region of space, surrounded by empty space where there is very little matter — that is what a supercluster looks like," Joydeep Bagchi, an astronomer at the Inter-University Centre and lead author of the study, said.

Bagchi and Raychaudhury began their search over a decade ago. Their team-mates in the search were Shishir Sankhyayan, a PhD scholar at the Indian Institute of Science Education and Research, Pune; Pratik Dabade, a research fellow at the Inter-University Centre; Joe Jacob, a physics faculty member at Newman College, Thodupuzha; and Prakash Sarkar, a physics faculty member at the National Institute of Technology, Jamshedpur.


लोकसत्ता
शनिवारचे संपादकीय
‘सरस्वती’चा शोध
पुण्यातील ‘आयुका’ या संस्थेच्या वैज्ञानिकांनी अलीकडेच लावलेला एक खगोलीय शोध अनेक दृष्टीने महत्त्वाचा मानला


7/15/2017 12:02:42 PM
The Hindu, Dated 15-07-17-pp7
Eureka moment
Saraswati, a supercluster of galaxies
One of the largest superclusters to be discovered, and the furthest


THE TIMES OF INDIA, PUNE
FRIDAY, JULY 14, 2017
TIMES CITY | PUNE
5
Indian scientists claim discovery of galaxy 'Saraswati' in universe
The exact location of the Saraswati supercluster
How are they formed?
It is believed that galaxies are formed mostly on the filaments and sheets part of the cosmic web. Many of the galaxies travel along these filaments, ending up in the rich clusters, where the crowded environment switches off their star formation and aids in the transformation of galaxies to "disky" blue spiral galaxies to red elliptical galaxies. (Source: IUCAA)


What was the name given to the supercluster of galaxies, discovered by a team of Indian astronomers in 2017?
A: Lakshmi
B: Parvati
C: Saraswati
D: Durga


Tweet
Dr. Harsh Vardhan
@drharshvardhan
Congratulations to Indian astronomers for discovery of the super-cluster of Galaxies. So aptly named "Saraswati" (cluster of 42 clusters).
14/07/17, 22:35


Vasundhara Raje
Tweets
Tweets & replies
Media
Likes
Vasundhara Raje @Vasundh... · 3d
I congratulate the team of Indian scientists on this rare discovery. #Saraswati
ALL INDIA RADIO @Akashvani...
Indian scientists discover '#Saraswati'- a massive #supercluster of galaxies
Estimated weight: 20 million billion times that of Sun.
31
248
558


Mamata Banerjee
Tweets
Tweets & replies
Media
Likes
Mamata Banerjee @Mamata... · 6h
Replying to @MamataOfficial
"Saraswati" river of galaxies found by team led by Joydeep Bagchi #IUCAAPune & Somak Raychaudhury (Presidency Univ & IUCAA) #BiswaBangla 2/2
Mamata Banerjee @Mamata... · 6h
Congratulations to Indian scientists for discovering #Saraswati Supercluster, largest structure in the Universe, size 60 Cr light years 1/2

UK prof dwells upon microwave background radiation at IUCAA

Sakal Times

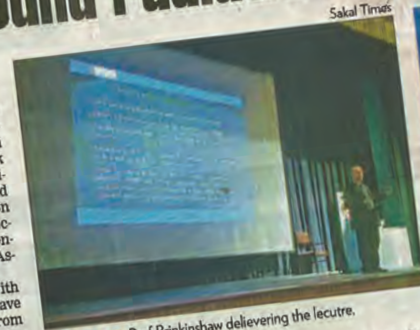
ST CORRESPONDENT
reporters@sakaaltimes.com

...lling the story of ... The micro... ...nd radiation ...", Prof Mark ... from the Uni... ...ristol, UK, held ... spell-bound on ... during his lec... ...r-University Cen... ...stronomy and As... ...s (IUCAA).

...lecture started with ...ory of microwave ...round radiation from ...iginal idea in the 1940s ...e latest easurements ...n satellites in orbit and ...escopes in Antarctica.

Prof Birkinshaw ... In 1964 Bob Wilson ... Arno Penzias were ...ing on a project whe... heard a 'hum' sound ...ing to them from ... They checked out e... ...sibility to find o... it was coming fr... they found out ... the cosmic micro... ground radiatio...

Prof Birkin...



ON STAGE: Prof Brinkinshaw delievering the lecutre.

tion wrote the first paper on how the universe would ex... ...by using a mathemat... ...The CMB is the ...verse.

lending support to the theory of cosmic inflation, which says the universe expanded much faster than the speed of light just a few fractions of a second after ...Bang. Talking about ... he said ...

> The lecture started with the story of microwave background radiation from the original idea in the 1940s to the latest easurements from satellites in orbit and telescopes in Antarctica.

at wavelengths between 0.3 mm and 11.1 mm) spacecraft is busy scanning our skies picking up the light that created the universe after Big Bang. This ancient light travels billions of kilometres to reach us encountering gas, stars and galaxies," he said.

"Neutrinos are one of the fundamental particles which make up the universe and there are only three key neutrinos," Prof Birkin... ...said. Predicting the ... in future, he ...describ...

Nagaland students learn concepts of astronomy

Dimapur, April 7 (EMN): The heavenly bodies and astronomical phenomenon has always fascinated human from pre historical times. Astronomy has developed leaps and bound from simple observation of night sky from naked eye to sending probes to heavenly bodies.

To expose the students of Kohima Science College, Jotsoma (KSCJ) to the field of astronomy and astroph... two-day i... workshop on astronomy and astrophysics was organized on April 5-6. A press release received on Saturday from college authority informed.

The participants for the workshop were Physics faculties from various parts of Nagaland and students of M.Sc. and B.Sc. 6th semester of Physics and Mathematics.

The workshop ... partment of Physics, KSCJ.

The resource persons Prof. Ranjan Gupta, scientist H, IUCAA and Prof. HP Singh, from department of Physics and Astronomy, Delhi University, talked on telescopes and techniques and physical parameters of stars through observations.

... tude systems, distance modulus, mass and luminosity, distance measurement of stars, H-R diagram, stellar evolution, solar system, star and galaxies, basic optics and telescope and some space observations.

Principal of the ...

Introductory workshop on Astronomy and Astrophysics

...ersons, officials and students during the 'Introductory workshop on Astronomy ...ysics' on April 5 and 6 held at Kohima Science College.

..., APRIL 7 ...wo-day 'intro... ...kshop on As... Astrophysics' ...ed at Kohima ...ege, Jotsoma ...il 5 and 6. ...-University ...onomy and ...UCAA) pro... ...rt and re... ...r the work... ...ss release ...e partici... ...hop were ...ies from ...agaland ...I.Sc and ... Physics and Mathematics.

The workshop was co-ordinated by Dr Chetan Kachhara, Assistant Professor, Department of Physics, KSCJ. The resource persons were Prof. Ranjan Gupta, Scientist H, IUCAA and Prof HP Singh, Department of Physics & Astronomy, Delhi University. The inaugural session Chaired by Dr M. Devrani, Head of Physics Department (KSCJ), Dr Lily Sema, Principal (KSCJ) and Dr RC Gupta, PVC, Nagaland University graced the inaugural session with words of encouragement to all the participants.

Prof. Ranjan Gupta and Prof. HP Singh delivered the talks spread over two days on 'Telescopes and Techniques' and 'Physical Parameters of Stars through Observations.' In these talks, the participants were introduced to the concepts in general astronomy: astronomical measurements, magnitude systems, distance modulus, mass and luminosity, distance measurement of stars, H-R diagram, stellar evolution, solar system, star and galaxies, basic optics and telescope and some space observations.

IUCAA sets up dedicated space for science toys

EXPRESS NEWS SERVICE
PUNE, JUNE 8

Arvind Gupta at IUCAA on Friday. *Pavan Khengre*

THE INTER-UNIVERSITY Centre for Astronomy and Astrophysics (IUCAA) has set up a small space called 'Vigyan Tarang', where raw material by toy maker Arvind Gupta have been stocked so people can experiment and create their own toys on science models. Gupta, a Padma Shri who says toys can be used to great advantage in a science class, gave a lecture at IUCAA called 'A journey in education' on Friday.

"It feels great to be back," said Gupta, who has been associated with the public outreach programme at IUCAA for over a decade. From 2004 till 2016, he was coordinating the science toys project, which contributed to the IUCAA's children's science centre. Educators say he made science learning more fun for students.

Samir Dhurde, in-charge of the scientific public outreach programme 'SciPop' at IUCAA, said the original team of Arvind Gupta, Vidula Mhasikar, Ashok Rupner and others, will guide students at the Vigyan Tarang. "Arvind Gupta toys, which are so popular on the internet, will now be displayed at the Vigyaan Tarang. We will stock up raw material here so people can tinker with them, while worksheets on understanding science will be provided," said Dhurde.

While people of all age groups can explore and come up with their version of toys and scientific models at Vigyaan Tarang, volunteers said there would be more freedom in learning science. "We will study whether we can come up with better scientific models and engaging more children in science," said Dhurde. We will also team up with schools, he added.

While Gupta took the opportunity to mingle with members of the Muktangan Vigyan Shodhika — the children's science centre — at IUCAA, he said he would be based in Chennai with his family. "But if things work well, I should be in Pune next year," he said. "Efforts to popularise science have been given a fillip with the government's Atal Tinkering Labs. It is a good opportunity for children and teachers to learn innovation skills and develop ideas — a great initiative that will help children use their hands in the lab to design scientific models," said Gupta.

10/3/2017 9:48:20 AM

Maharashtra Times, Dated 02/10/2017, page 03

संशोधन प्रकल्पांसाठी 'इनोव्हेशन कौन्सिल'

म. टा. प्रतिनिधी, पुणे

'देशातील विद्यार्थ्यांच्या नावीन्यपूर्ण संशोधन प्रकल्पांना वाव देण्यासाठी 'इनोव्हेशन कौन्सिल'ची स्थापना करण्यात आली आहे. या कौन्सिलतर्फे विद्यार्थ्यांचे संशोधन पुढच्या टप्प्यापर्यंत यशस्वी करण्यासाठी मार्गदर्शन करण्यात येईल,' अशी माहिती केंद्रीय मनुष्यबळ विकासमंत्री प्रकाश जावडेकर यांनी रविवारी दिली.

अखिल भारतीय विद्यार्थी परिषदेतर्फे आयोजित केलेल्या 'डिपेक्स' या कार्यक्रमात राज्यातील विविध इंजिनीअरिंग कॉलेजांमधील विद्यार्थ्यांनी नावीन्यपूर्ण संशोधन प्रकल्पांसह सहभाग घेतला होता. यातील उत्तम संशोधन प्रकल्प करणाऱ्या विद्यार्थ्यांशी जावडेकर यांनी संवाद साधून ते प्रकल्प समाजातील समस्या सोडविण्यासाठी उपयोगात आणण्याचे आवाहन केले. अखिल भारतीय तंत्रशिक्षण परिषदेचे (एआयसीटीई) अध्यक्ष डॉ. अनिल सहस्त्रबुद्धे, सावित्रीबाई फुले पुणे विद्यापीठाचे कुलगुरू डॉ. नितीन करमळकर, शासकीय अभियांत्रिकी महाविद्यालयाचे (सीओईपी) संचालक डॉ. बी. बी. आहुजा, अभाविप महाराष्ट्र अध्यक्ष डॉ. प्रशांत साठे, प्रदेश महामंत्री राम सातपुते आदी उपस्थित होते.

जावडेकर म्हणाले, 'देशात विद्यार्थी नावीन्यपूर्ण संशोधन करत आहेत. त्यांची मदत करण्यासाठी केंद्रीय मनुष्यबळ विकास मंत्रालय सर्वतोपरी प्रयत्न करत आहे. त्याअंतर्गत संशोधन प्रकल्पांना प्रत्यक्षात आणण्यासाठी 'इनोव्हेशन कौन्सिल' मदत करणार आहे. प्रकल्पाला पुढच्या टप्प्यावर नेण्यासाठी आणि यशस्वी करण्यासाठी हे कौन्सिल उपयोगी पडणार आहे. या प्रकल्पांचा उपयोग नागरिकांच्या समस्या सोडविण्यात येण्यासाठी मंत्रालय एका यंत्रणेची स्थापना करण्यासाठी प्रयत्नशील आहे. त्यासाठीच निती आयोग, अटल थिंकर टँक आदींची स्थापना करण्यात आली आहे.' दरम्यान, विद्यार्थ्यांनी नावीन्यपूर्ण संशोधन हे वेगळ्या वाटेने आणि विचाराने करण्याची आवश्यकता असल्याचे जावडेकर यांनी सांगितले.

केंद्रीय मंत्री प्रकाश जावडेकर यांची माहिती

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

इनोव्हेशन कौन्सिल काय करणार

- संशोधन प्रकल्पांना वाव देण्यासाठी 'इनोव्हेशन कौन्सिल'
- संशोधन पुढच्या टप्प्यापर्यंत यशस्वी करण्यासाठी कौन्सिल
- संशोधन प्रकल्पांना प्रत्यक्षात आणण्यासाठी 'कौन्सिल' म

'स्मार्ट हॅकेथॉन'ला १६पासून सुरु

देशातील विद्यार्थ्यांच्या कौशल्य विकास व नावीन्यपूर्ण संशोधनाला ... यंदाच्या राष्ट्रीय पातळीवरील 'स्मार्ट हॅकेथॉन' स्पर्धेला येत्या १६ ... होणार आहे. यंदा या स्पर्धेचा शुभारंभ शासकीय अभियांत्रिकी ... (सीओईपी) होणार आहे, अशी माहिती जावडेकर यांनी दिली.

शिक्षकांच्या क्षमतांसाठी तंत्रज्ञान

पुणे : 'एकीकडे देशात विद्यार्थ्यांच्या ज्ञानकक्षा रुंद व्हाव्यात म्हणून तंत्रज्ञानाचा उपयोग मोठ्या प्रमाणावर वाढत असताना, आपण आता शिक्षकांच्या क्षमता विकसित ... यूजीसीच्या इंटर युनिव्हर्सिटी सेंटर्सचा होणारा उपयोग' या विषयावर झालेल्या शोध-शिक्षा-समीक्षा परिषदेत जावडेकर बोलत होते. या वेळी ज्येष्ठ शास्त्रज्ञ ... तयारी आहे.

संशोधनच देशाला समृद्धी कडे नेणार, यात शंका नाही. 'इनोव्हेशन' हेच येत्या काळाचे प्रमुख सूत्र असणार आहे.

विश्वरचनाशास्त्रातील तपस्वी

डॉ. नरेश दधिच

दुर्धर शारीरिक व्याधींवर मात करून इतकं मोठं काम करता येतं, हे दाखवून देणारे स्टीफन हॉकिंग यांचं व्यक्तिमत्त्व हे आगळंवेगळंच होतं. ऐन उमेदीच्या तरुण वयातच त्यांना मोटर न्यूरॉन डिसीज हा दुर्धर आजार झाल्याचं निदान झालं. डॉक्टरांनी ते अल्प अवधीचेच आता सोबती आहेत असं सांगितलं. परंतु हॉकिंग यांनी डॉक्टरांच्या या भाकितावर मात करत मृत्यूला तब्बल ५४ वर्षं झुलवत ठेवलं. त्यांची जीवनेच्छा खरोखरच अलौकिक म्हणावी लागेल. हॉकिंग हे केंब्रिज विद्यापीठात न्यूटनने जे पद भूषवलं होतं त्या ल्युकासियन प्रोफिसरपदाचे मानकरी. त्यांनी आपल्या दुर्धर आजारावर मात करत या पदाची शान कायम राखलीच; त्याचबरोबर विश्वरचनाशास्त्रात पायाभूत स्वरूपाचं संशोधनही त्यांनी केलं. गुरुत्वाकर्षणाचा अभ्यास त्यांनी आइनस्टाईनच्या सापेक्षतावादाच्या सिद्धान्ताआधारे केला, हे त्यांचं वेगळं वैशिष्ट्य. त्यांचं सगळ्यात गाजलेलं संशोधन अर्थातच कृष्णविवरांच्या संदर्भातलं होतं. कृष्णविवर ही खरं तर खूप तप्त वस्तू. त्यातून काहीच बाहेर पडू शकत नाही असं त्याकाळी मानलं जात होतं. पण हॉकिंग यांनी कृष्णविवरातून काही किरण बाहेर पडतात असं अभ्यासाअंती सांगितलं. पुढे हे संशोधन 'हॉकिंग रेडिएशन' नावाने प्रसिद्ध झालं. विश्वाची उत्पत्ती कशी झाली ...

वाटे. कारण ते संगणक यंत्राच्या माध्यमातून संवाद साधत असत. एकदा असेच ते आणि त्यांचे विद्यार्थी पबमध्ये असताना ते मोठ्याने ... काही तरी सांगायचंय.' पण ... हॉकिंग यांनी दुर्धर आजार ... मात करत जीवनाचा आनंद ... वैज्ञानिकांप्रमाणेच ते ... सहभागी होत ... त्यांच्या आड कधी आली ... वैज्ञानिकांप्रमाणेच ... असंच म्हणावं लागेल.

(लेखक ..., आयुका)

... राजेंद्र येवलेकर

THE HINDU

SATURDAY, FEBRUARY 17, 2018

Science should have the last word

As India continues to be hidebound with tradition and rituals, the need for 'scientific temper' is essential as never before

JAYANT V. NARLIKAR

GETTY IMAGES/ISTOCKPHOTO

A few years ago, I was at an international conference in Delhi which dealt with important issues arising from changes brought about by the rapid progress of science and technology. As the meeting progressed, with international experts highlighting the action needed in various areas, I began to feel uncomfortable, much like a diner at a sumptuous buffet searching desperately for that missing ingredient – a pinch of salt. The subject I wanted to hear about but which was being glossed over by the speakers was 'scientific temper'. Ultimately, it was left to me to make a case for it, not only for the scientists but also for the common citizen, whatever his or her occupation.

What is scientific temper? Let me cite a quote from Jawaharlal Nehru's book, *The Discovery of India*: "The impact of science and the modern world have brought a greater appreciation of facts, a more critical faculty, a weighing of evidence, a refusal to accept tradition just because it is tradition..."

He then went on to say: "But even today, it is strange, how we suddenly become overwhelmed by tradition, and the critical faculties of even intelligent men cease to function..." Nehru concludes with the hope that, "Only when we are politically and economically free, will the mind function normally and critically."

No difference

Alas, what has been the outcome? More than seven decades have elapsed since Nehru's deadline of India's independence but where are we *vis-à-vis* scientific temper? We continue to be hidebound with tradition and waste precious time and money in rituals which may have been relevant in earlier times but which have no relevance to modern living.

An interesting sidelight on superstitions has been thrown by Jiří Grygar, a scientist and science communicator from the Czech Republic. He finds that during the Soviet-dominated era, no superstitious ideas were publicly aired as these were feared to be against the state. In the 'free' thinking times that followed the collapse of the Soviet Union, all pent-up superstitions have come up.

Superstitions thrive

Further, there are new superstitions that have their origin in the age of space technology. Towards the end of the last century, I had visited the radio telescope at Arecibo in Puerto Rico. Puerto Rico forms one of the vertices of a rather notorious triangle whose other vertices are at Bermuda and Florida. Known as the Bermuda Triangle, it has generated considerable excitement because of a claim that it formed a region within which mysterious (and possibly malicious) forces were present. A book on the Bermuda Triangle by Charles Berlitz which describes disturbing and unfathomable events makes for fascinating reading. If those accounts were true then the Bermuda Triangle did encompass a sinister region. There have also been accounts of pilots losing their way and their lives, and watches stopping for an appreciable time, which, in short, were events that defied a rational scientific explanation.

A few years later, scientific attempts were made to test the veracity of the Triangle events. Lawrence David Kusche did seminal work in debugging the Triangle stories. His investigations have shown that the stories were either inflated, or did not tell the whole truth, or tinkered with the vital part of the evidence. Thus, one can safely say that there is no tangible evidence to ascribe an alien character to the Bermuda Triangle. Nevertheless as a scientist, whenever I invite questions from an audience of school or college students, the question inevitably pops up: What is the mystery behind all that is going on in the Bermuda Triangle? The questioner is visibly disappointed to learn that there are no black holes or dark energy or powerful aliens hiding there. When I asked my host in Arecibo how the locals react to such questions, he laughed and said that the Bermuda Triangle had long ceased to be a matter of concern. It of course serves the purpose of attracting tourists.

Harmful rays believed to be prevalent during a total solar eclipse keep many of our citizens behind closed doors. I once saw a total solar eclipse while in Zimbabwe. Recalling a previous eclipse in India, I was expecting to be greeted with the sight of empty roads and inhabitants behind closed doors in their houses, as is the case in India.

Nothing happened. Perhaps Zimbabweans were blissfully unaware of the evil rays. But in India, we are good at coming up with antidotes. As a housewife from a well-educated family once explained to me, the food in the fridge is supposed to be destroyed after an eclipse as evil rays will have contaminated it. However, the local priest had a solution which would avoid the food being wasted. His solution, the woman proudly told me, was to smear the fridge with cow dung, which would protect the food.

Here is another example. An executive of a firm had to catch a flight on a certain day but found out later that travelling on that particular day was inauspicious. He was told that the day prior to this was a "good" day. But he had other engagements that day. So what did he do? He stored his bag in his neighbour's house on the earlier day and picked it up while on his way to the airport the following day. By leaving the bag in the neighbour's house he was supposed to have begun his journey the previous "auspicious" day. This trick, known as "keeping prasthan", is sufficient to deceive evil spirits.

From mythology

All these are examples of pseudoscience that grow around superstitions. But there are apparently more serious aspects that have grown around our mythology. Did our Vedic forefathers possess a knowledge of science that was well beyond the level attained by modern science? While references in our Puranas to the Pushpak Viman, Vishwamitra's counter heaven in mid air, and weapons such as the Brahmastra and Indra's Shakti look persuasive, they do not have the details that would stand the test of scientific scrutiny. If such claims are to have standing, their supporters have to give us their technical details. For example, what was the basic mathematical principle that explains how a craft such as the Pushpak is lifted and which propelled it through air? And, if the Brahmastra was a nuclear device, which would indicate a knowledge of nuclear physics, why are there no references to the forces of electricity and magnetism, knowledge of which would be necessary to understanding nuclear physics? In today's modern age, the facility of running tap water and electric lighting is considered the basic minimum for living and forms a part of the manifestos of all political parties. Yet, as the Mahabharata tells us, the Hastinapur palace of Duryodhana or the Indraprastha abode of the Pandavas did not possess this minimal facility.

Recently, there was a claim made in India that the Darwinian theory of evolution is incorrect and should not be taught in schools. In the field of science, the sole criterion for the survival of a theory is that it must explain all observed phenomena in its domain. For the present, Darwin's theory is the best such theory but it is not perfect and leaves many questions unanswered. This is because the origin of life on earth is still unexplained by science. However, till there is a breakthrough on this, or some alternative idea gets scientific support, the Darwinian theory is the only one that should continue to be taught in schools.

In the final analysis, scientific evidence is what should have the last say.

Jayant V. Narlikar is Emeritus Professor, Inter-University Centre for Astronomy and Astrophysics, Pune

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 detection of gravitational waves, reports Swati Shinde Gole.

PUBLIC LECTURES

January 17, 2018

Title :
Two Planets: Challenges of Living and Prospering on Earth and Mars

Speaker :
Professor Frank Shu
(UC San Diego and UC Berkeley)

January 17, 2018

Title :
Ancient Light: The Microwave Background Radiation and Cosmology.

Speaker :
Professor Mark Birkinshaw
(University of Bristol, U.K.,)

February 17, 2018

Title :
The Invisible Universe

Speaker :
Jen Gupta
(University of Portsmouth, UK)

ANNUAL EVENTS AT IUCAA

2017

April 24 - May 26
School Students' Summer Programme and Astronomy Camp

May 15 - June 30
Vacation Students' Programme

December 18 - 26
IUCAA - NCRA Radio Astronomy Winter School

December 29
Foundation Day

2018

February 28
National Science Day

EVENTS AT IUCAA

EVENTS AT IUCAA

2017

May 8 - 12
Executive Committee (EC - 99) Meeting of the IAU

May 15 - 16
Meeting on LIGO - India: The Road Ahead (LITRA - IV)
(Funded by Navajbai Ratan Tata Trust, Mumbai)

May 15 - June 15
Refresher Course in Astronomy and Astrophysics
(for College and University Teachers)

July 25 - August 1
Teachers' Workshop on Astronomy in School Textbooks

July 31 - August 8
Third Indo-French Astronomy School on Spectroscopy and Polarimetry
(Jointly with Centre de Recherche Astrophysique de Lyon, France)

August 30 - September 1
Meeting on Plasma Universe and its Structure Formation

September 11 - 15
Young Astronomers' Meet - 2017

September 21 - 23
Third BRICS Workshop on Astronomy Infrastructure and Instrumentation
(Funded by the Department of Science and Technology, Government of India)

September 23
Third BRICS Astronomy Working Group Meeting
(Funded by the Department of Science and Technology, Government of India)

October 1
Shodh Shiksha Sameeksha
(Impact of the Inter-University Centres of the UGC on Research and Teaching at Indian Universities and Higher Educational Institutions)

October 9 - 11
International Workshop on Post-Planck Cosmology: Enigma, Challenges and Visions

October 30
Workshop on Visualising Textbook Astronomy
(Organised by Sakal NIR, in collaboration with IISER - Pune)

November 8 - 10
PuLastya Science Festival - 2017

November 13 - 26
Workshop on AstroSat Data Analysis

November 16
Advanced Programming Techniques in MATLAB, and Big Data and Machine Learning using MATLAB

December 6
Workshop on Intel Parallel Studio XE

December 12 - 14
International Workshop on QSO Absorption Lines
(Jointly with the University of Chicago Centre at New Delhi)

December 18 - 21
International Workshop on AstroSat View of AGN Central Engines

2018

January 10 - 11
Indo-Chilean Astronomical Dialogue - I

January 20
Workshop on Astronomy for Development

January 22 - 24
International Meeting on Galaxy Evolution and Dynamical Structure (GEDS - 2018)

February 2
Meeting on AstroSat Observations of X-ray Binaries and AGN

February 11 - 17
Franco - Indian Astronomy School

EVENTS OUTSIDE IUCAA

2017

April 6 - 7
IUCAA Academic Retreat
At: Blue Country Resort, Panchgani, Maharashtra

May 3 - 5
Workshop on AstroSat Data Analysis
At: Tezpur University, Assam

May 6
Workshop on Astronomy and Astrophysics: Recent Trends and Scopes
At: The Assam Kaziranga University, Jorhat

August 8 - 11
Workshop on AstroSat Related Science and Data Aspects
At: ARIES, Nainital

October 5 - 7
North East Meet of Astronomer (NEMA - III)
At: St. Antony's College, Shillong (jointly with Assam Don Bosco University)

November 28 - 30
National Conference on High Energy Emission from AGN - III
At: University of Calicut, Kozhikode

December 1 - 2
Meeting on Research in Astronomy: Opportunities and Challenges - IV
At: WMO Arts and Science College, Muttil, Wayanad

December 14 - 16
Workshop on Multi-wavelength Observations using AstroSat
At: Christ (Deemed to be) University, Bengaluru

December 15 - 19
Workshop on Black Holes: From Classical to Quantum Gravity
At: Indian Institute of Technology, Gandhinagar

2018

January 4 - 6
Workshop on New Avenues of Interface between Astronomy and Engineering
At: Model Engineering College, Trikkakara, Ernakulam.

March 9 - 10
Workshop on Astronomy and Astrophysics
At: National Institute of Technology, Rourkela

AWARDS AND DISTINCTIONS

Joydeep Bagchi and Research Team comprising of Shishir Sankhyayan, Somak Raychaudhury, Prakash Sarkar, Joe Jocab and Pratik Dabhade

The Astronomical Society of India (ASI) year 2018 '*New Discovery Prize'* was awarded to Joydeep Bagchi and the Research team for the discovery of Sarswati Supercluster.

Sanjeev Dhurandhar

Majha Sanman Award by ABP News Network Pvt. Ltd. on July 28, 2017.

TMC award for excellence (*Pune Gaurav*) on October 16, 2017, by Top Management Consortium, Pune

Senior Scientist Platinum Jubilee Fellowship awarded in January 2018, by NASc., Allahabad.

Arvind Gupta

Padma Shri 2018 by the Government of India

Girjesh Gupta

Parvez Guzdar Young Scientist Award 2017 instituted by the Institute for Plasma Research (IPR), Bhat, Gandhinagar.

Rutherford Fellowship 2018 tenable at the University of Cambridge by Commonwealth Scholarship Commission.

Sanjit Mitra

Outstanding Faculty Research Award from Careers360.

Jayant V. Narlikar

Lakshmipat Singhania - IIM Lucknow National Leadership Award (2016-17), New Delhi, June 27, 2017, at the hands of the Honourable President of India.

Bharat Asmita Vigyaan Tantragyaan Shreshtha -2018 Award from the MIT World Peace University, Pune, February 3, 2018.

Somak Raychaudhury

Elected as Fellow, National Academy of Sciences

Varun Sahni

Elected Fellow of the Third World Academy of Sciences (TWAS).

Received the *Homi Jehangir Bhabha medal* from the President of the Indian National Science Academy on December 27, 2017.

Tarun Souradeep

Princess of Asturias Award for Scientific and Technical Research 2017 (shared with LIGO Scientific Collaboration), Foundation Principe de Asturias, Spain.

Shyam N. Tandon

Received the Space Science and Applications Award presented by Astronomical Society of India for the success of the UVIT project.

Durgesh Tripathi

Received the Buti Foundation Award - 2017 in the field of Plasma Science and Technology given by the Physical Research Laboratory.

RESEARCH FELLOWSHIPS/GRANTS

Dipankar Bhattacharya

AstroSat Science Support Cell Grant, ISRO, Bengaluru.

Sukanta Bose, Ajit Kembhavi, Sanjit Mitra and Tarun Souradeep

Gravitational Waves Data Centre Grant, Navajbai Ratan Tata Trust, Mumbai.

Girjesh Gupta

INSPIRE Faculty Fellowship, Department of Science and Technology, Government of India.

Neeraj Gupta

Start-up Research Grant, Department of Science and Technology, Government of India.

Research Grant, Indo-French, CFIPRA.

Indo - South Africa Flagship Programme in Astronomy Grant, NRF, South Africa and Department of Science and Technology, Government of India.

Ajit Kembhavi

NKN - NIC Data Diverse Initiative in Astronomy Grant, Ministry of Electronics and Information Technology, Government of India.

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Sanjit Mitra

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The SwarnaJayanti Fellowship, Department of Science and Technology, Government of India.

T. Padmanabhan

J.C. Bose Fellowship, Department of Science and Technology, Government of India.

Aseem Paranjape

Ramanujan Fellowship, Department of Science and Technology, SERB, Government of India.

A.N. Ramaprakash

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Wide Area Linear Optical Polarimeter (WALOP) South Grant, South African Astronomical Observatory, Cape Town.

CIRCE, MIRADAS, Detector Controllers Grant, University of Florida, USA.

Large Binocular Telescope Interferometer Grant, University of Arizona, USA.

RSS - NIR on Southern African Large Telescope Grant, University of Wisconsin, USA.

3 D Polarization Mapping of High Galactic Latitude Sky Grant, Caltech, USA.

A.N. Ramaprakash and Durgesh Tripathi

Solar Ultraviolet Imaging Telescope (SUIT) Grant, ISRO Satellite Centre, Bengaluru.

Durgesh Tripathi

Max-Planck Partner Group Research Grant, Max-Planck Society, Germany, and Department of Science and Technology, Government of India.

Quantum Theory and Gravity

A comment on generalized Schwinger effect

A spatially homogeneous, time-dependent, electric field can induce production of charged particle pairs from the vacuum. When the electric field is homogeneous and time-dependent, the mean number of particle pairs which are produced depends on the strength of the electric field and the coupling constant in a non-analytic manner, showing that this result cannot be obtained from the standard perturbation theory of quantum electrodynamics. When the electric field is time-dependent and vanishes asymptotically, the result may depend on the coupling constant.

T. Padmanabhan and **Rajeev Karthik** have shown that the dependence of particle production on coupling constant is non-analytic for a class of time-dependent electric fields of the form $\mathbf{E} = (E_0 f(\omega t), 0, 0)$, which (i) vanishes asymptotically, (ii) is symmetric under $t \to -t$, and (iii) the vector potential $\mathbf{A} = (-E_0 F(\omega t)/\omega, 0, 0)$ is such that $F(s)$ diverges as a power series as $s \to \infty$. We show that, in the presence of such an electric field, the number of particles $n_{\mathbf{k}}$ produced with a given momentum $\mathbf{k}$ has a non-perturbative factor given by $\exp(-\pi \tilde{\mathcal{C}}_0(m^2 + k_y^2 + k_z^2)/(qE_0))$, where $\tilde{\mathcal{C}}_0$ is the coefficient of $1/s$ in the expansion of $1/F(s)$ as $s \to \infty$. We also demonstrate that for another class of electric fields, which vary rapidly, the dependence of particle production on coupling constant is analytic.

Switching between normal and inverted oscillator representations in the context of particle production in external fields

Many physical problems involving quantum field theory in an external, homogeneous, time-dependent background can be reduced to the study of harmonic oscillators with time-dependent frequency and mass. These include, for example, the case of (i) scalar field in a Friedmann-Robertson-Walker (FRW) spacetime, and (ii) charged scalar field in a time-dependent electric field (viz., generalized Schwinger effect). However, this reduction of quantum field theory (QFT) to a harmonic oscillator can be performed in several different ways for the same system, leading to either a normal oscillator or an 'inverted' oscillator (i.e., one with imaginary frequency). One can transform from one representation to the other by field redefinitions and the choice of time coordinate. The representation in which the field modes are described by a normal oscillator allows interpretation in terms of particles and the production of the particles, in turn, will contribute to backreaction on the classical source. On the other hand, such an interpretation is not possible when the same system is described by an inverted oscillator. **T. Padmanabhan** and **Rajeev Karthik** have studied the relation between these two representations in detail, both in Heisenberg and Schröodinger picture. They also proposed a simple prescription for backreaction, based on energy conservation, which allows the dynamics to be described consistently in both the representations. The result has implications for several problems involving QFT in external fields, especially to the study of QFT in FRW background.

Cosmology and Structure Formation

Tidal effects and halo assembly bias

Halo assembly bias refers to the dependence of dark halo clustering on halo properties other than halo mass. One such property is halo concentration at large halo masses (galaxy cluster scales); highly concentrated haloes are known to be less clustered than less concentrated haloes of the same mass. This trend is, in fact, predicted by simple analytical excursion set/peaks models as a consequence of basic properties of Gaussian random fields. At *low* halo mass (Milky Way to dwarf galaxy scales), however, simulations show that this trend *inverts*, with high concentration haloes now being *more* clustered than low concentration ones. The primary suspect for this inversion is the tidal environment of low mass haloes; haloes in filaments, in particular, can be subjected to strong tidal anisotropy which can lead to mass truncation at early times. Such tidally influenced early forming objects would naturally occur in highly biased surroundings and have a high clustering amplitude.

Aseem Paranjape, Oliver Hahn and Ravi K. Sheth have explored this effect in detail in N-body simulations. They have identified a variable α, which encodes the anisotropy of the local tidal environment of a halo. They find that (a) this *tidal anisotropy* α cleanly segregates haloes in filaments from those in more isotropic 'node' environments, (b) the overall clustering amplitude of haloes at fixed mass is a strong function of α, and finally (c) α also correlates strongly with the *sign* and *strength* of the assembly bias signal.These results provide a new angle on the role of tidal effects in determining the assembly history of dark matter haloes.

Tidal effects in the clustering of SDSS galaxies

Aseem Paranjape, Oliver Hahn and Ravi K. Sheth have used their new classifier of tidal environment the *tidal anisotropy* α to segregate galaxy populations in SDSS and study their clustering as a function of α. A very interesting question is whether the tidal anisotropy plays any role *over and above that of host halo mass* in determining galaxy properties. Indeed, they find that galaxies in the most anisotropic environments show large-scale 2-point correlation function amplitudes that are factors of ~ 20 higher than those of galaxies in the most isotropic environments. However, a comparison with realistic mock galaxy catalogues reveals that most of this effect can be explained by a simple model in which galaxy properties *only* depend on host halo mass. In other words, the large differences mentioned above are 'inherited' by galaxies from their host haloes. They are currently exploring whether smaller residual differences between the mocks and the SDSS measurements could be indicators of small but as-yet unexplored effects of the tidal environment on galaxy evolution.

Halo models of HI selected galaxies

Neutral hydrogen (HI) in galaxies is a key to understand the star-formation history and galaxy evolution. In this work, **Niladri Paul** and **Aseem Paranjape** have modelled the distribution of neutral hydrogen (HI) in galaxies through a connection to dark matter halos. They use a novel approach to infer the HI-dark matter connection at the massive end ($m_{\rm HI} > 10^{9.8} M_{\odot}$) from radio HI emission surveys, using optical properties of low-redshift galaxies as an intermediary.

In particular, they used a previously calibrated optical HOD (Halo Occupation Distribution) function describing the luminosity- and colour-dependent clustering of SDSS galaxies based on halo mass, and described the HI content using a statistical scaling relation between the optical properties and HI mass. Using this scaling-based halo model, they computed the abundance and clustering properties of HI-selected galaxies and compared those with data from the ALFALFA survey. They applied an MCMC (Markov Chain Monte Carlo)-based statistical analysis to constrain the free parameters related to the scaling relation.

The correlation function and HI mass function as obtained from their best-fit scaling relation is shown in Figure 1. A point to note is that the clustering data of only the two thresholds $\log[m_{\rm HI}/M_{\odot}] > 9.8, 10.2$ were used to constrain our scaling-relation parameters; still this model could predict the clustering for the threshold $\log[m_{\rm HI}/M_{\odot}] > 10.4$ with quite good accuracy as seen from the left panel of this figure. The turn over at the low HI mass end is due to the incompleteness of the optical HOD based on SDSS data used in their scaling relation model. Their model predicted that blue galaxies dominate the HI content for $9.2 < \log[m_{\rm HI}/M_{\odot}] < 10.2$, and in other ranges the trend was reported to be reversed.

Using the best-fit scaling model, they predicted the HI content of galaxies at fixed stellar mass m_* and their model described the data quite well within the scatter of the measurements as seen from the left panel of the Figure 2. The model identified massive HI galaxies primarily with optically

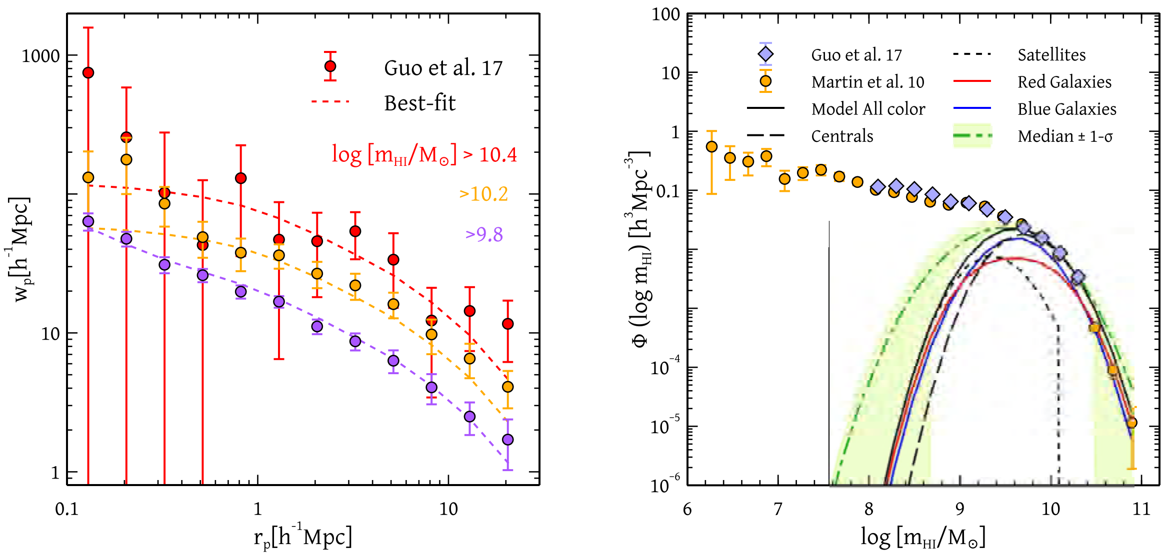


Figure 1: In the left panel, the authors show the projected correlation function of HI galaxies for three thresholds $\log[m_{\rm HI}/M_{\odot}] > 9.8, 10.2$ and 10.4 altogether. The solid circles with error bars represent the measurements from Guo, et al. [2017] using the α-70 data and the dotted curves show their model prediction using the best-fit scaling parameters. The correlation functions are separated by 0.25 dex w.r.t. the middle one. The right panel shows the HI mass function. The orange circles with error bars are measurements from the 40% complete ALFALFA survey [Martin, et al. (2010)] and the purple diamonds with error bars are the measurements from α-70 survey (c.f. Table 1 of Guo, et al. [2017]). The solid black curve shows the mass function computed using their best-fit scaling relation model. The green dot-dashed curve with the error-band shows the median and ± 1 σ error in the HI mass function as obtained from their distribution of parameters in the MCMC chains.

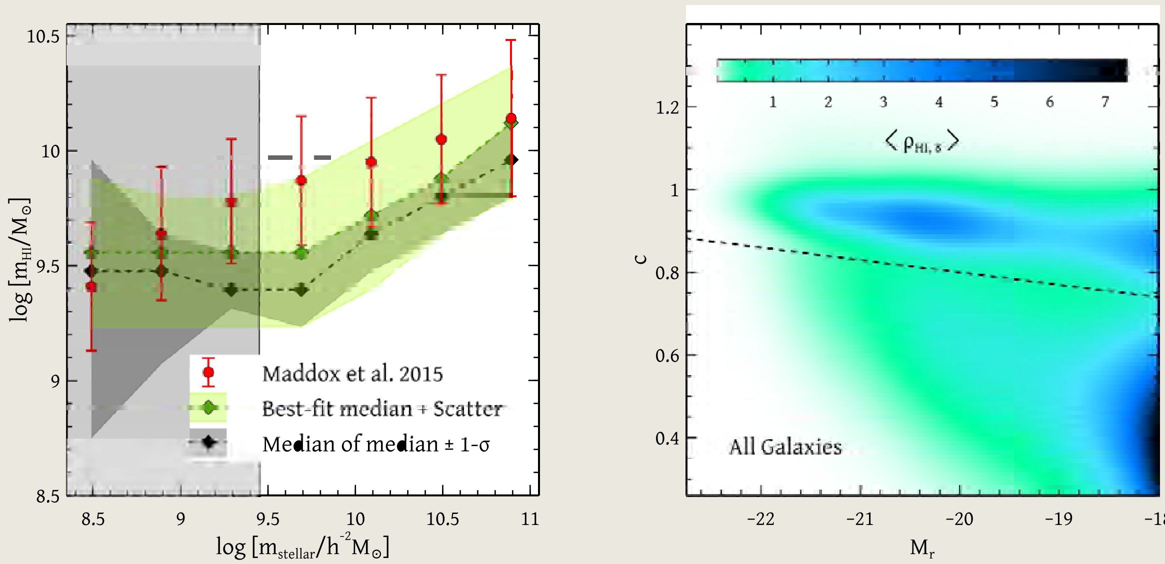


Figure 2: The left panel shows $m_{\rm HI}$ at fixed stellar mass m_* predicted using the best-fit scaling relation, as a function of m_*. The black diamond-shaped points and the dark grey band show the median and scatter respectively computed from the best-fit scaling relation model. The green diamonds and the light green band show the median of the median with $\pm 1\sigma$ uncertainty in this relation as computed from various sets of parameters in their MCMC chains. The light grey shaded area on the left indicates values of m_* that are affected by incompleteness due to the hard luminosity cut $M_r < -18.0$. For comparison, the red points with error bars show the mean and scatter of the measurements from Maddox, et al. [2015] (their Table 1). The right panel shows spatial density of $m_{\rm HI}$ evaluated using the best-fit scaling relation, per unit $c \equiv g - r$ colour, per unit r-band magnitude M_r, as a function of c and M_r. In particular, the colour-bar indicates the value of $\langle \rho_{\rm HI,8} \rangle \equiv \langle m_{\rm HI} | c, M_r \rangle \, p(c|M_r) \phi(M_r) / (10^8 M_\odot h^3 {\rm Mpc}^{-3})$, where $\phi(M_r)$ and $p(c|M_r)$ are the luminosity function and colour distribution at fixed luminosity, respectively. We see that a large fraction of the neutral hydrogen in SDSS galaxies with $M_r < -18$ in their model resides in faint blue galaxies and some amount in red galaxies too. For comparison, the dashed line shows the relation $c = 0.8 - 0.03(M_r + 20)$, which is often used as an empirical separator of red and blue galaxies in optical analyses (see, e.g., Skibba & Sheth [2009]).

faint blue galaxies with also a certain amount in red intermediate bright galaxies too as seen from the right panel of the Figure 2. This prediction was consistent with expectations from galaxy formation models.

Using these results, they also made forecasts for future observations of HI galaxies with upcoming radio telescopes like the SKA, as well as explored the possible synergies between SKA and optical surveys such as Euclid and LSST.

Constraining the halo model parameters with direct measurements from simulations

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 [Zheng, et al. (2016), Guo, et al. (2015)]. 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 ($\sim$ 1Gpc) with huge number of particles ($\sim 3000^3$) 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 ran a single realization of $150h^{-1}$Mpc box, 10 realizations of $300h^{-1}$Mpc boxes and 3 realizations of $600h^{-1}$Mpc boxes each with 1024^3 particles. In this way, effectively they could resolve halos of small masses and also get a substantial number of high mass halos. They are now jointly constraining optical and HI properties of the galaxies along with the satellite red fraction in a single halo model framework with this sophisticated measurements of halo clustering from combined simulation boxes. The work is still in progress.

New tracker models of dark energy

A remarkable property of our Universe is that it appears to be accelerating. Within the context of Einstein's theory of general relativity, cosmic acceleration can arise if at least one of the constituents of the universe violates the strong energy condition, $\rho + 3p \geq 0$. Physical models with this property are frequently referred to as 'dark energy' (DE). Although several models of DE have been advanced in the literature, perhaps the simplest remains Einstein's original idea of the cosmological constant, Λ. As its name suggests, the energy density associated with the cosmological constant, $\frac{\Lambda}{8\pi G}$, and its equation of state, $w = -1$, remain the same at all cosmological epochs. Although $w = -1$ satisfies current observations very well, the non-evolving nature of Λ implies an enormous difference in its density and that in matter or radiation at early times. For instance, $\rho_\Lambda/\rho_r \sim 10^{-58}$ at the time of the electroweak phase transition, at earlier times, this ratio is still smaller.

This 'imbalance' between the non-evolving and small value of Λ on the one hand, and the evolving density in matter/radiation on the other, has fuelled interest in models in which, like matter/radiation, DE also evolves with time. In this context, considerable attention has been focused on models with 'tracker' properties, which enable the present value of the DE density to be reached from a wide range of initial conditions. This class of models appears to alleviate the so-called 'fine-tuning' (or 'initial value') problem which characterizes Λ. A scalar field with the inverse power-law (IPL) potential $V \propto \varphi^{-\alpha}$ ($\alpha > 0$), presents one of the oldest and best studied examples of this class of models. Unfortunately the IPL model cannot account for the large negative values of $w_{\rm DE} \lesssim -0.8$ that seem to be suggested by observations while at the same time preserving a large initial basin of attraction.

Satadru Bag, Swagat Mishra and **Varun Sahni** successfully constructed a new class of DE models based on the α-attractors. A compelling feature of these new models is that they have a very wide basin of attraction which allows the late time asymptote $w = -1$ to be reached from a large class of initial conditions. They have shown how the α-attractors may have an even wider appeal, since they can describe dark energy.

Their dark energy models are based on the following potentials, all of which have interesting tracker properties:

1. The L-model

$$V(\varphi) = V_0 \coth\left(\frac{\lambda\varphi}{m_p}\right). \tag{1}$$

2. The Oscillatory tracker model

$$V(\varphi) = V_0 \cosh\left(\frac{\lambda\varphi}{m_p}\right). \tag{2}$$

3. The Recliner model

$$V(\varphi) = V_0 \left[1 + \exp\left(-\frac{\lambda\varphi}{m_p}\right)\right]. \tag{3}$$

4. The Margarita potential

$$V(\varphi) = V_0 \tanh^2\left(\frac{\lambda_1\varphi}{m_p}\right) \cosh\left(\frac{\lambda_2\varphi}{m_p}\right), \tag{4}$$

where $\lambda_1 \gg \lambda_2$.

It is interesting that all four of the dark energy models introduced above have very different features, which allow for them to be distinguished from each other at late times (see Figure 3).

Focussing on the L-model

$$V(\varphi) = V_0 \coth^p\left(\frac{\lambda\varphi}{m_p}\right), \quad \varphi > 0\,. \tag{5}$$

For small values of the argument, $0 < \frac{\lambda\phi}{m_p} \ll 1$, one finds

$$V \simeq \frac{V_0}{(\lambda\varphi/m_p)^p}, \tag{6}$$

which suggests that the early time behaviour of this model is very similar to that of the IPL model at early times.

$$w_\varphi = \frac{p w_{\rm B} - 2}{p + 2}\,, \tag{7}$$

where $w_{\rm B}$ is the background equation of state of matter/radiation.

The IPL model, (6), therefore has the appealing property that, for large values of $p \gg 1$, its EoS can track the EoS of the dominant matter component in the universe. Unfortunately, it is also well known that, for $\Omega_{0m} \geq 0.2$, the IPL model (6) with $p > 1$ cannot give rise to $w_0 < -0.8$ at the present epoch. This may be viewed as a significant shortfall of this model since observations appear to suggest that the current EoS of dark energy should satisfy $w_0 \leq -0.8$. Of course, this problem can be bypassed if one assumes a smaller value $p < 1$ for the exponent in (6). However, in this case, the initial basin of attraction shrinks considerably, which diminishes the appeal of the IPL model.

This drawback of the IPL model is easily overcome in the L-model, since, for large values of the argument, $\frac{\lambda\phi}{m_p} \gg 1$, the L-model has the asymptotic form

$$V(\varphi) \simeq V_0, \tag{8}$$

indicating that the L-potential flattens and begins to behave like a cosmological constant at late times. Because of this, the present value of the EOS in the L-model can be significantly lower than that in the IPL model (6).

This is illustrated in Figure 4, which shows the evolution of $w_\varphi(z) = p_\varphi/\rho_\varphi$, in the L-potential $V = V_0 \coth^p \varphi/m_p$ and in the IPL potential $V = V_0 \left(\frac{m_p}{\varphi}\right)^p$. Note that both potentials have precisely two free parameters: V_0 and p. From this figure, one finds that for the L-model with $V \sim \coth^6 \phi$,

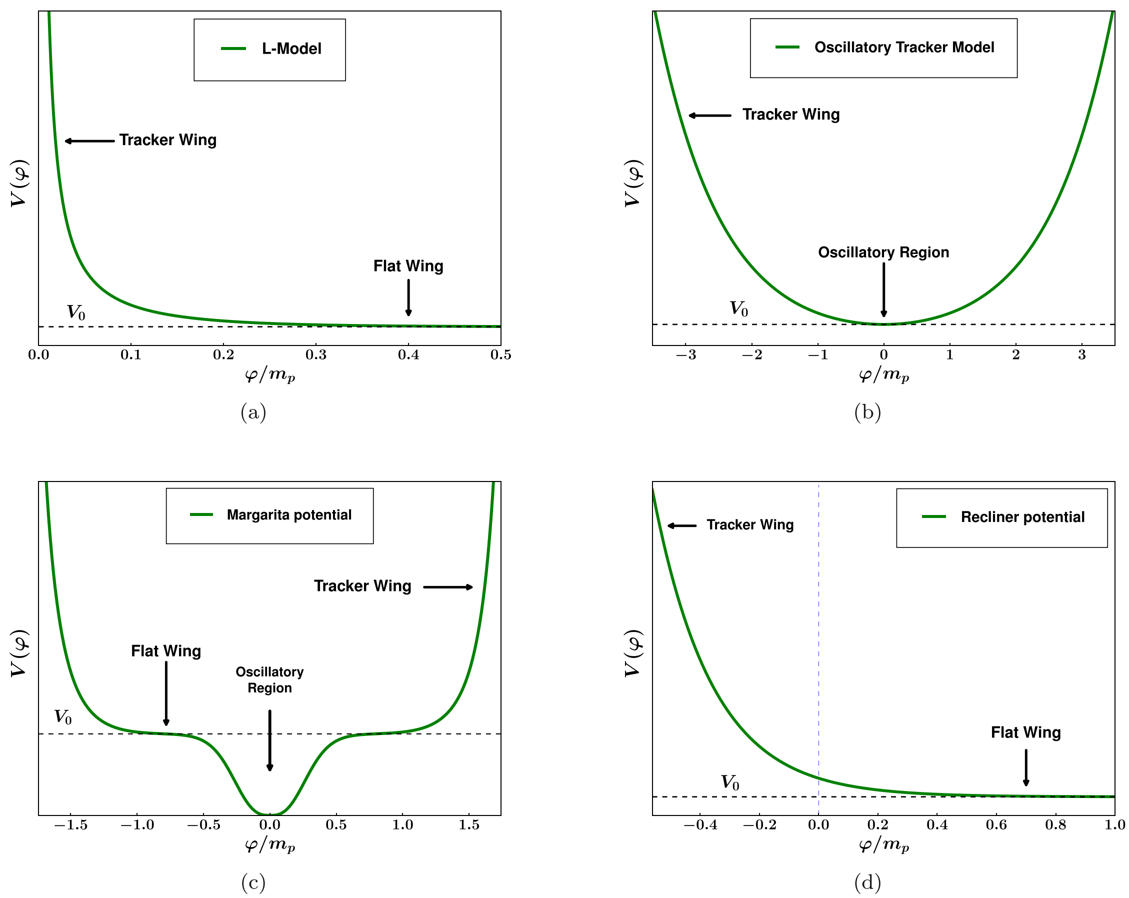


Figure 3: Potentials corresponding to different tracker models of dark energy are schematically displayed. Clockwise from the upper left: The L-model (1), the Oscillatory tracker model (2), the Recliner model (3) and the Margarita potential (4).

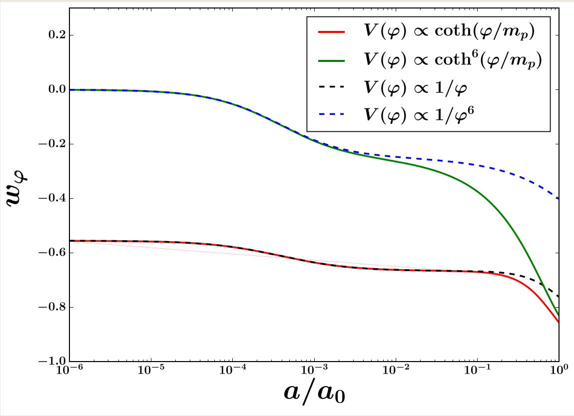


Figure 4: This figure illustrates that the L-model (5) possesses early time tracking features similar to that of the IPL (6). However, at late times, w_φ in the L-model falls significantly below w_φ in the IPL model.

the current value of w_φ can be as low as $w_\varphi \sim -0.8$, which is considerably lower than the corresponding value $w_\varphi \sim -0.4$ for $V \sim \phi^{-6}$. In other words, for identical values of p, the late-time value of w_φ in the L-model (5) is *significantly lower* than that in the IPL model (6).

Figure 5 shows the phase-space trajectories of the equation of state $\{w_\varphi, w'_\varphi\}$ starting from the matter dominated epoch. Here,

$$w'_\varphi = \frac{dw_\varphi}{d\ln a} \equiv \frac{\dot{w}_\varphi}{H}. \tag{9}$$

Note that all trajectories approach the ΛCDM limit ($w_\varphi = -1, w'_\varphi = 0$) at late times. The present epoch is marked by a circle on each trajectory. Comparing the L-model (5) with the IPL potential (6), one finds that the current EoS in the former is always more negative than that in the latter.

Initial conditions for inflation

Since its inception in the early 1980s, the inflationary scenario has emerged as a popular paradigm for describing the physics of the very early Universe. A major reason for the success of the inflationary scenario is that, in tandem with explaining many observational features of our Universe – including its homogeneity, isotropy and spatial flatness, it can also account for the existence of galaxies, via the mechanism of tiny initial (quantum) fluctuations, which are subsequently amplified through gravitational instability.

An important issue that needs to be addressed by a successful model of inflation is whether the universe can inflate starting from a sufficiently large class of initial conditions. **Swagat Mishra, Varun Sahni** and Alexey Toporensky address this question for a large class of inflationary models. These models include (i) large field models such as Higgs inflation and Starobinsky inflation, (ii) small field models including chaotic inflation, monodromy inflation, etc.

It would undoubtedly be interesting if inflation could be realized within the context of the Standard Model (SM) of particle physics. Since the SM has only a single scalar degree of freedom, namely the Higgs field, one can ask whether the Higgs field (11) can source inflation. Unfortunately, the self-interaction coupling of the Higgs field, λ in (11), is far too large to be consistent with the small amplitude of scalar fluctuations observed by the cosmic microwave background.

This situation can, however, be remedied if the Higgs couples non-minimally to gravity. The resultant inflationary model provides a good fit to observations.

The action for a scalar field ϕ which couples non-minimally to gravity (i.e., in the Jordan frame) is given by:

$$S_J = \int d^4x\sqrt{-g}\left[f(\phi)R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - U(\phi)\right], \tag{10}$$

where R is the Ricci scalar and $g_{\mu\nu}$ is the metric in the Jordan frame. The potential for the SM Higgs field is given by:

$$U(\phi) = \frac{\lambda}{4}\left(\phi^2 - \sigma^2\right)^2, \tag{11}$$

where σ is the vacuum expectation value of the Higgs field, $\sigma = 246\,GeV = 1.1 \times 10^{-16} m_p$ and the Higgs coupling constant has the value, $\lambda = 0.1$. Furthermore, $f(\phi) = \frac{1}{2}(m^2 + \xi\phi^2)$, where m is a

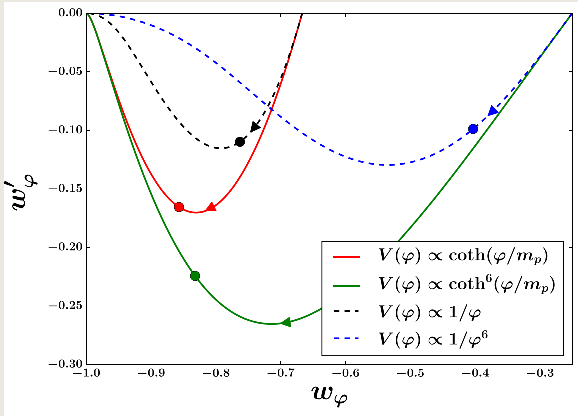


Figure 5: Phase space $\{w_\varphi, w'_\varphi\}$ trajectories for potentials (5) and (6) starting from the matter dominated epoch. The filled circles on each trajectory represents the present epoch with $\Omega_{0m} = 0.3$. One finds that in the far future, the EoS in all models approaches the ΛCDM value of $w_\varphi = -1, w'_\varphi = 0$. This figure demonstrates that with increasing values of p, the current value of w_φ increases while w'_φ decreases. Note that, for identical values of p, the current values of w_φ, w'_φ are much lower in the L model relative to the IPL potential $V \propto \varphi^{-p}$.

mass parameter given by $m^2 = m_p^2 - \xi\sigma^2$, ξ being the non-minimal coupling constant whose value, $\xi = 1.62 \times 10^4$ agrees with observations.

We now transfer to the Einstein frame by means of the following conformal transformation of the metric:

$$g_{\mu\nu} \longrightarrow \hat{g}_{\mu\nu} = \Omega^2 g_{\mu\nu}, \tag{12}$$

where the conformal factor is given by

$$\Omega^2 = \frac{2}{m_p^2} f(\phi) = 1 + \frac{\xi\phi^2}{m_p^2} . \tag{13}$$

The authors study the generality of Higgs inflation in the Einstein frame by plotting the phase-space diagram for the Higgs potential in the Einstein frame, shown in Figure 6. This allows one to determine the region of initial conditions, which lead to adequate inflation with $N_e \geq 60$ efoldings. The results are shown in Figure 7 and a zoomed-in view is presented in Figure 8.

One finds that the phase-space diagram for Higgs inflation has very interesting properties. The asymptotically flat arms result in robust inflation as expected. However, it is also possible to obtain adequate inflation if the inflaton commences from $\chi \simeq 0$. This is because the scalar field is able to climb up the flat wings of $V(\chi)$. This property is illustrated in Figure 7 by lines originating in the central region, which are slanted and hence, can converge to the slow-roll inflationary separatrics resulting in adequate inflation. This feature is not shared by chaotic inflation, where one cannot obtain adequate inflation by starting from the origin (provided the initial energy scale is not too large, i.e., $H_i < m_p$).

This does not, however, imply that all possible initial conditions lead to adequate inflation in the Higgs scenario. As shown in Figure 6, there is a small region of initial field values denoted by $|\chi_A| < |\chi_i| < |\chi_B|$, which does not lead to adequate inflation if χ_i and $\dot{\chi}_i$ have opposite signs (dashed red lines). By contrast, the solid blue lines in the same figure show the region of χ_i that results in adequate inflation *independently of the direction* of the initial velocity $\dot{\chi}_i$. The dependence of χ_A and χ_B on the initial energy scale is shown in Table 1 (also see Figure 6). Note the surprising fact that the value of $\chi_B - \chi_A$ remains *virtually unchanged* as H_i increases.

The results of Figures 7, 8 and 6 demonstrate that there is a region lying close to the origin of $V(\chi)$, namely $\chi_i \in (-\chi_A, \chi_A)$, where one gets ad-

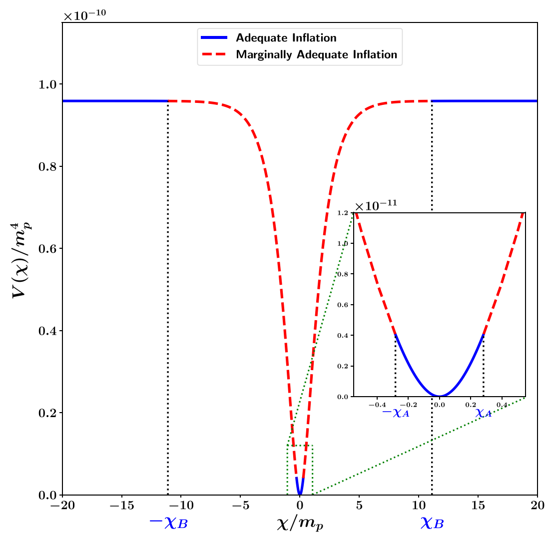


Figure 6: Shows the initial field values, χ_i, which either lead to adequate inflation (solid blue lines) or partially adequate inflation (dashed red lines). The region corresponding to $\chi_i \in [-\chi_B, -\chi_A] \cup [\chi_A, \chi_B]$ (dashed red) leads to partially adequate inflation. Initial field values originating in this region result in inadequate inflation only when $\dot{\chi}_i$ is directed towards decreasing values of $V(\chi)$. The alternative case, with $\dot{\chi}_i$ directed towards increasing $V(\chi)$, leads to adequate inflation for the same subset $\chi_i \in [-\chi_B, -\chi_A] \cup [\chi_A, \chi_B]$. This figure is shown for an initial energy scale, $H_i = 3 \times 10^{-3} m_p$. The precise values of χ_A and χ_B depend on the initial energy scale H_i as shown in Table 1. Note that only a small portion of the full potential is shown in this figure.

H_i (in m_p)	χ_A (in m_p)	χ_B (in m_p)	$\chi_B - \chi_A$ (in m_p)
3×10^{-3}	0.28	11.11	10.83
3×10^{-2}	2.16	12.99	10.83
3×10^{-1}	4.04	14.87	10.83

Table 1: Dependence of χ_A and χ_B on the initial energy scale H_i for Higgs inflation (also see figure 6).

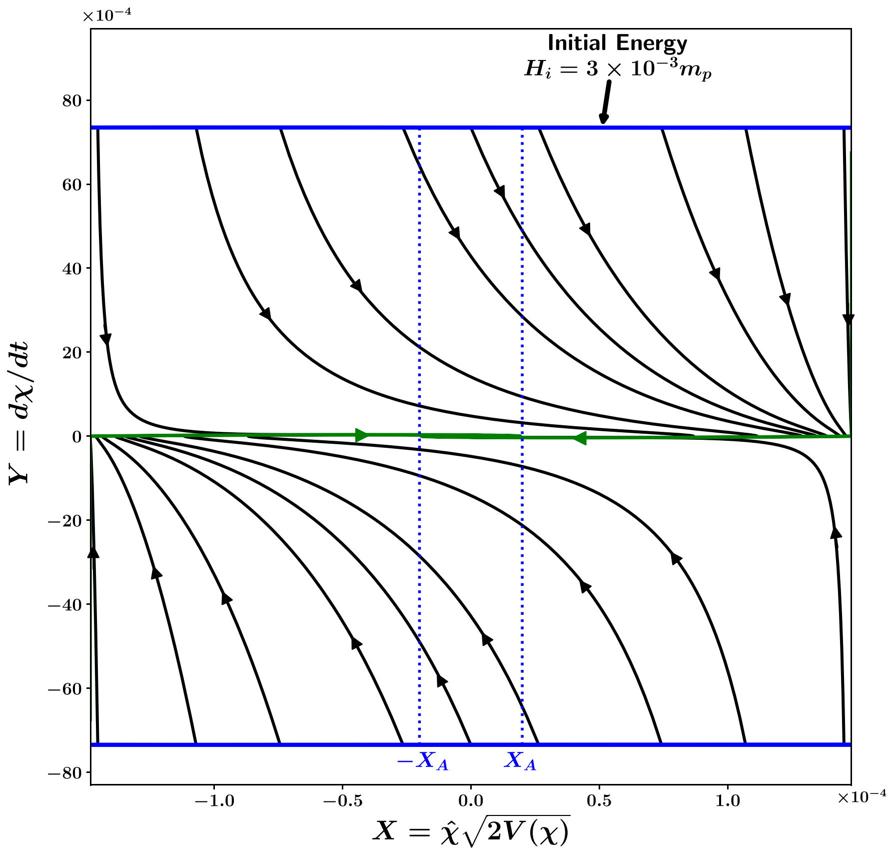


Figure 7: This figure shows the phase-space of Higgs inflation in the Einstein frame. $Y = d\chi/dt$ is plotted against $X = \hat{\chi}\sqrt{2V(\chi)}$ for the initial energy scale, $H_i = 3 \times 10^{-3} m_p$. ($\hat{\chi} = \frac{\chi}{|\chi|}$ is the sign of field χ.) One sees that commencing from a fixed initial energy (shown by the blue boundary lines), most solutions rapidly converge towards the two inflationary separatrices (horizontal green lines) corresponding to slow-roll inflation. We, therefore, find that inflation for the Higgs potential is remarkably general and can commence from a very wide class of initial conditions. Note that trajectories lying close to the origin, i.e., within the vertical band marked by $(-X_A, X_A)$, are *strongly curved*. This property allows them to converge to the inflationary separatrices giving rise to adequate inflation with $N_e \geq 60$. It is interesting that the Higgs scenario displays adequate inflation over a slightly larger range of initial conditions when compared with chaotic inflation.

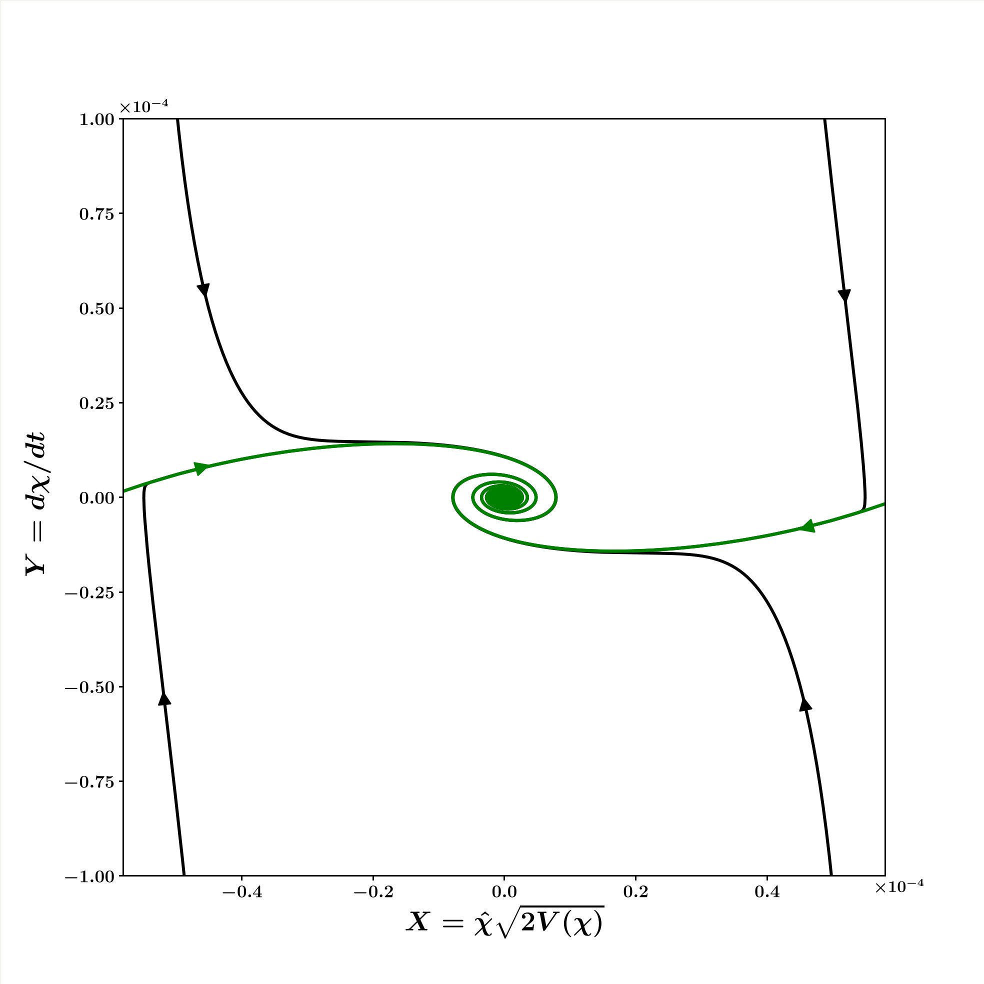


Figure 8: A zoomed-in view of the central region in figure 7. We see that most trajectories (associated with different initial conditions) initially converge towards the horizontal slow-roll inflationary separatrics (green lines) before spiralling in towards the centre. (The spiral reflects oscillations of the inflaton about the minimum of its potential.)

equate inflation regardless of the direction of $\dot{\chi}_i$. One might note that this feature is absent in the power law family of potentials. **Swagat Mishra**, **Varun Sahni** and Alexey Toporensky, therefore, conclude that a wide range of initial conditions can generate adequate inflation in the Higgs case.

A similar analysis has also been carried out for: Chaotic inflation, Starobinsky inflation, Monodromy inflation and non-canonical inflation.

A morphological analysis of the epoch of reionization

It is widely believed that, following the cosmological recombination of hydrogen at $z \simeq 1089$, the universe reionized at the much lower redshift of $z \sim 10$. Our current knowledge about this epoch of reionization (EoR) is guided so far by three main observations. Measurements of the Thomson scattering optical depth of CMB photons from free electrons, observations of the Lyman-α absorption spectra of the high-redshift quasars and the luminosity function and clustering properties of Lyman-α emitters. These observations, when taken together, suggest that the EoR probably extended over a wide redshift range, $6 \lesssim z \lesssim 15$. Although, the precise physical mechanism responsible for cosmological reionization is not known, it is widely believed that early sources of energetic photons contributing to reionization may have come from an early generation of stars (population III objects), galaxies and quasars.

Observation of the redshifted 21 cm signal from neutral hydrogen (HI) provides an excellent means of studying the EoR and the preceding 'dark ages'. Considerable efforts are presently underway to detect the EoR 21 cm signal using ongoing and upcoming radio interferometric experiments. The importance of a precise determination of the EoR, and the associated geometry and dynamics of neutral (HI) and ionized (HII) hydrogen regions, cannot be overstated. Such an advance would open a new window into the physics of the early Universe, shedding light on important issues including the physics of structure formation, the nature of feedback from the first collapsed objects, the nature of dark matter and perhaps even dark energy.

Satadru Bag, **Varun Sahni**, Rajesh Mondal, Prakash Sarkar and Somnath Bharadwaj explore this vibrant reionization landscape using percolation analysis, the Minkowski functionals and the Shapefinders.

They consider a number of HI density fields with neutral fraction ranging between $x_{HI} \in (0.1 - 1.0)$, where the lower limit, $x_{HI} = 0.1$, corresponds to the redshift $z \approx 7$, and the upper limit $x_{HI} = 1$ corresponds to high redshifts (before reionization was initiated). They study the fully ionized regions within the HI density field having $\rho_{HI} = 0$. Side by side, they also consider the complementary region with $\rho_{HI} > 0$,and refer to it as the neutral segment. They define the individual regions, in both segments separately, as the connected grid points of same type (ionized or neutral) using the friends-of-friends (FoF) algorithm compatible with the periodic boundary condition.

In percolation analysis, a key role is played by two quantities:

(1) The 'largest cluster statistics' (LCS), defined for the ionized or the neutral segment as:

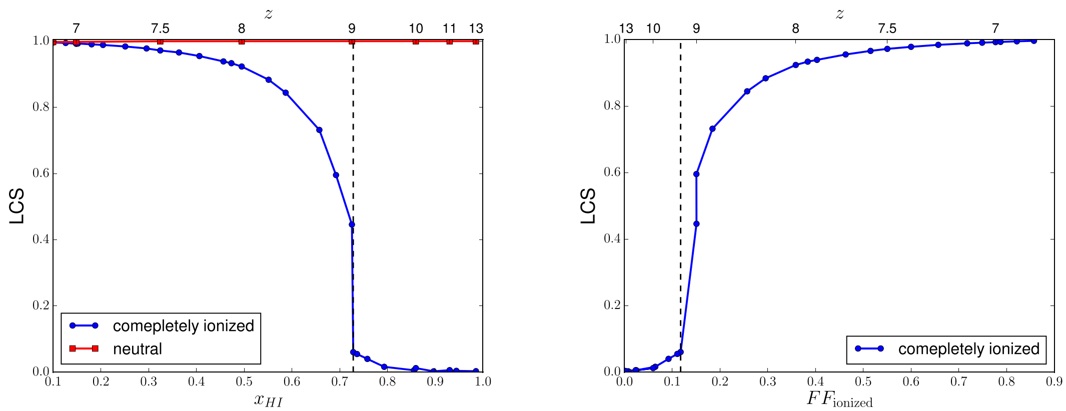
$$\mathrm{LCS} = \frac{\text{volume of the largest neutral orionized region}}{\text{total volume of all the neutral or ionized regions}}, \tag{14}$$

is the fraction of the volume (ionized or neutral) filled by the largest region. (2) The filling factor FF, which is defined for the ionized or the neutral segment as:

$$FF = \frac{\text{total volume of all the neutral or ionized regions}}{\text{volume of the simulation box}} \tag{15}$$

The left panel of Figure 9 shows the LCS vs the neutral fraction (x_{HI}) for both the neutral (red) and ionized (blue) segments. The right panel plots LCS vs the FF_{ionized} for the ionized segment only.

As reionization progresses, the ionized segment grows in size and so does the largest ionized region. Soon the largest ionized region becomes so large that it stretches from one face of the simulation box to the opposite face. (Note that due to periodic boundary conditions, such a region is formally infinite in size.) This is referred to as the 'percolation transition'. During the percolation transition, the



(a)

(b)

Figure 9: **(a)** Largest Cluster Statistics (LCS) of the ionized regions (with $\rho_{HI} = 0$) and the neutral regions (with $\rho_{HI} > 0$) are plotted against the neutral fraction x_{HI}. The corresponding redshift is shown along the top x-axis. The largest neutral region is percolating in the entire range of study, $7 \lesssim z \lesssim 13$. On the other hand, for the ionized regions, the percolation transition takes place at $x_{HI} \approx 0.728$, which roughly corresponds to $z \approx 9$, and is shown by the vertical black dashed line. During the percolation transition the LCS undergoes a sharp rise. (b) The LCS for the ionized regions is plotted against the (ionized) filling factor, FF_{ionized}. The largest ionized region starts to percolate at $FF_{\text{ionized}} \approx 0.12$ and during the percolation transition LCS increases very steeply as well. We note that the filling factor, FF_{ionized}, is essentially the same as the volume weighted ionization fraction.

LCS increases sharply when plotted against x_{HI} or FF_{ionized}, as shown in Figure 9(a) and 9(b). Indeed, the percolation transition itself can be identified through this abrupt rise in LCS. One finds that the ionized regions percolate for $z \lesssim 9$ (or equivalently $x_{HI} \lesssim 0.728$, $FF_{\text{ionized}} \gtrsim 0.12$). These critical thresholds at percolation appear to be quite stable for simulations with different resolutions

They study the shapes of the ionized regions at different redshifts (various stages of reionization) using Shapefinders, which are derived from the 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):

$$C = \frac{1}{2}\oint (\kappa_1 + \kappa_2)\, dS \ , \tag{16}$$

(iv) Integrated Gaussian curvature or Euler characteristic:

$$\chi = \frac{1}{2\pi}\oint (\kappa_1 \kappa_2) dS \ . \tag{17}$$

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:

- Thickness: $T = 3V/S$,
- Breadth: $B = S/C$,
- 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, the authors determine the morphology of an ionized region by means of the following dimensionless quantities, which characterize its planarity and filamentarity:

$$\text{Planarity} : P = \frac{B - T}{B + T} \ , \qquad \text{Filamentarity} : \ F = \frac{L - B}{L + B}. \tag{18}$$

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, $0 \leq P, \mathrm{and} F \leq 1$.

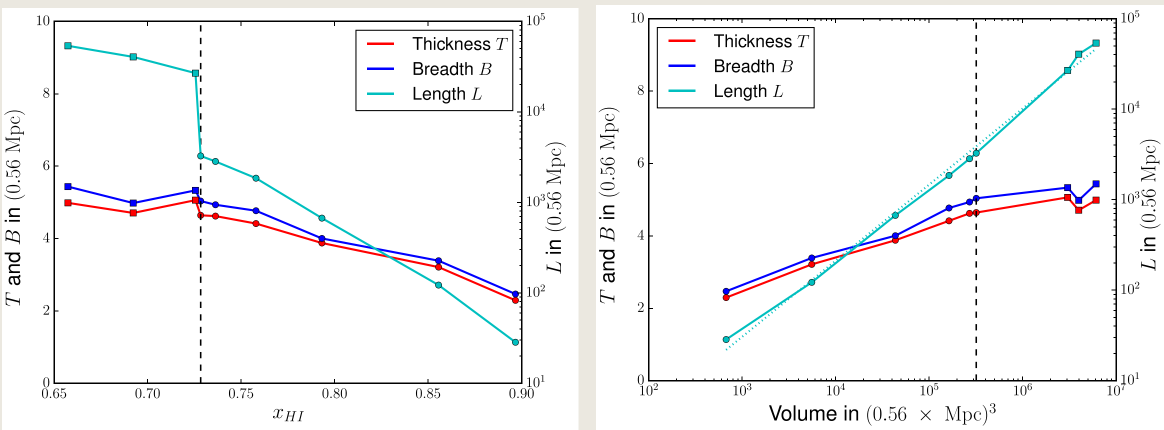
In the simulations, the largest ionized region evolves in such a manner that two of its Shapefinders 'thickness' T and 'breadth' B, increase slowly as reionization proceeds. By contrast, the third Shapefinder, 'length' L, increases steeply as reionization proceeds (see Figure 10(a)) and increases sharply by nearly an order of magnitude at the percolation transition. During the percolation transition, the largest ionized region abruptly grows only in 'length' while the 'cross-section', estimated by $T \times B$, does not change much. One might note that $L \sim 10^3 B$ near the percolation transition. Equation (18), implies that the largest ionized region is highly filamentary, with 'filamentarity' $F \sim \mathcal{O}(1)$, near percolation. In Figure 10(b), the Shapefinders of the largest ionized region are plotted against the region's volume as the latter grows in the vicinity of the percolation transition. The authors conclude that the largest ionized region possesses a characteristic cross-section ($\sim$ 7 Mpc^2), which remains almost constant across the percolation transition, while its length grows rapidly near percolation.

As illustrated in Figure 11, the 'filamentarity' F of the largest ionized region increases reaching almost unity near the percolation transition, while the 'planarity' P is quite low and does not vary much. Therefore, the largest ionized regions become highly filamentary at the onset of percolation. The genus of the largest ionized region, plotted along the right y-axis in Figure 11, also increases as reionization proceeds. This implies that as reionization proceeds the largest ionized region acquires an increasingly complex topology with many filamentary branches and sub-branches joining it, and several tunnels passing through it.

Non-Gaussianity in Loop Quantum Cosmology

The inflationary paradigm provides an efficient mechanism to generate primordial perturbations, which act as seeds for the formation of large scale structure. Despite the many successes of this paradigm, inflationary scenario is incomplete due to the initial big bang singularity. In Loop Quantum Cosmology (LQC), the big bang singularity is replaced by a bounce caused by quantum gravitational effects. Over the past decade, a research programme has been dedicated to analyze the possibility of extending inflationary scenario into the quantum regime. A quantum gravity extension of the inflationary scenario has been worked out at linear order in perturbations and the power spectra arising from such a scenario has been investigated. It was found that quantum gravitational effects leave imprints on the scalar and tensor power spectra at scales comparable to the curvature scale at the bounce. In this work , I. Agullo, B. Bolliet and **V. Sreenath** extended the phenomenology of LQC to second order in perturbations. The motivation was twofold: (i) since LQC predicts a cosmic bounce that takes place at the Planck scale, the second-order contributions could be large enough to jeopardize the validity of the perturbative expansion on which previous results rest, and (ii) the upper bounds on primordial non-Gaussianity obtained by the Planck Collaboration could play a significant role on explorations of the LQC phenomenology.

Primary findings of this work can be summarized as follows: (i) The non-Gaussianity, as characterized using $f_{\rm NL}(k_1, k_2, k_3)$, which is a dimensionless ratio of scalar bi-spectrum to the square of power spectrum, produced by the LQC bounce is strongly scale dependent. The bounce introduces a new scale, determined by the Ricci spacetime curvature scalar at the bounce, $R_{\rm B}$, which can be written as, $k_{\rm LQC} \equiv a_{\rm B}\sqrt{R_{\rm B}/6}$. Fourier modes with comoving wave-numbers, $k \gg k_{\rm LQC}$ are not affected by the bounce, and their primordial non-Gaussianity originate entirely from the inflationary phase and are small ($f_{\rm NL} \sim 10^{-2}$). On the contrary, for Fourier modes $k \lesssim k_{\rm LQC}$, the bounce contributes significantly to their non-Gaussianity. For those modes, the $f_{\rm NL}$ is enhanced ($f_{\rm NL} \sim 10^3$) and is highly oscillatory (see Figure 12). We have provided an analytical argument to understand the enhancement observed in our numerical computations, and concluded that it is given by $|f_{\rm NL}(k_1, k_2, k_3)| \propto e^{-\alpha\,(k_1+k_2+k_3)/k_{\rm LQC}}$, with $\alpha \approx 0.65$. (ii) The con-



(a) (b)

Figure 10: **(a)** The volume, area and the integrated mean curvature of the largest ionized region grow in such a way that if one computes their ratios, the two Shapefinders – thickness and breadth – do not rise much while the third Shapefinder – length (plotted along right y-axis) – increases rapidly near the percolation transition. Note that, in this work all the values of Shapefinders are shown in comoving scale. For the largest ionized region, one always obtains $T \approx B \ll L$ in the figures. Near the percolation transition, at $x_{HI} \approx 0.728$, $L \sim 10^3 B$. **(b)** The Shapefinders of the largest ionized region are plotted against the region's volume as the latter grows during reionization near percolation. The percolation transition is shown by the vertical dashed line in both the panels. The thickness and breadth increase very slowly with volume while length increases almost as power law. The slope of the best fit straight line to $\log L$ vs $\log V$ curve, shown by the dotted cyan line, is very close to unity; $m_L = 0.841$. Hence, the length of the largest ionized region increases almost linearly with volume in the vicinity of percolation while the cross-section, estimated by $T \times B$, does not vary much. Therefore, both the panels show that the largest ionized region possesses a characteristic cross-section of ~ 7 Mpc^2 during its rapid growth near the percolation. Note the enormous difference between T, B on the one hand and L on the other, there is no real intersection of L, B, T, as apparently suggested by the figures.

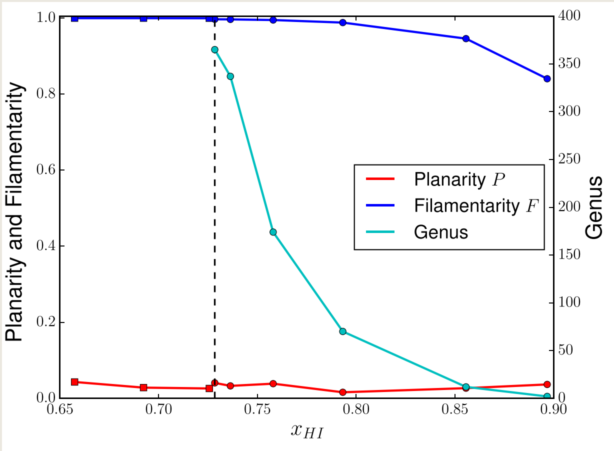


Figure 11: The 'planarity' (P), 'filamentarity' (F) and genus of the largest ionized region are shown as a function of the neutral fraction (x_{HI}) in the vicinity of the percolation transition. The filamentarity of the largest ionized region rises to almost unity during percolation but the planarity remains quite small. The genus of the largest ionized region also increases as the region grows. Therefore, the largest ionized region becomes very filamentary, and more tunnels pass through the largest ionized region as the latter grows rapidly at the onset of percolation. Note that we do not show the genus value of the largest ionized region after percolation ($x_{HI} < 0.728$), due to uncontrollable errors which arise because of periodic boundary condition.

straints on non-Gaussianity are arrived at for various shapes of the function, $f_{\rm NL}(k_1, k_2, k_3)$. We find that the non-Gaussianity generated in LQC peaks in the squeezed-flattened limit (see Figure 12). By analyzing the shape of $f_{\rm NL}$ and comparing it with the Planck constraints, we could arrive at conservative constraints on the model parameters. (iii) Even though there is a large enhancement in non-Gaussianity, we find that the higher-order correction to the power spectrum is small and hence, the perturbation theory is valid.

Gravitational Waves

Unified χ^2 discriminators

The noise in an interferometric detector is neither Gaussian nor stationary, and is contaminated by noise which can come from the detector itself or the environment. Matched filtering, the commonly employed technique for extracting known signals from noise, is by itself not sufficient to distinguish the signal from the noise. Often these noise features or glitches have large power and even if their match may be small with the template bank, they produce detectable triggers. Additional vetoing techniques are required to discriminate the noise from the signal. The test designed by Bruce Allen (traditional) does just this. It splits the broadband data into several smaller bands and checks for consistency between the power expected from the signal in the subband with the observed power in that subband.

But this is not the only type of discriminator that can be constructed. Here, **Sanjeev V. Dhurandhar**, **Sunil Chaudhary** and **Sukanta Bose** propose a unified theory of discrimintors. From a general point of view, it is shown that a wide variety of such discriminators can be constructed and thus, it may be possible to carry out various types of optimisations in arriving at a discriminator, which performs best for a given family of glitches. A constructive procedure is proposed, which can be applied best to modelled glitches. The goal is to implement this idea for the sine-Gaussian glitches, which are ubiquitous in the data.

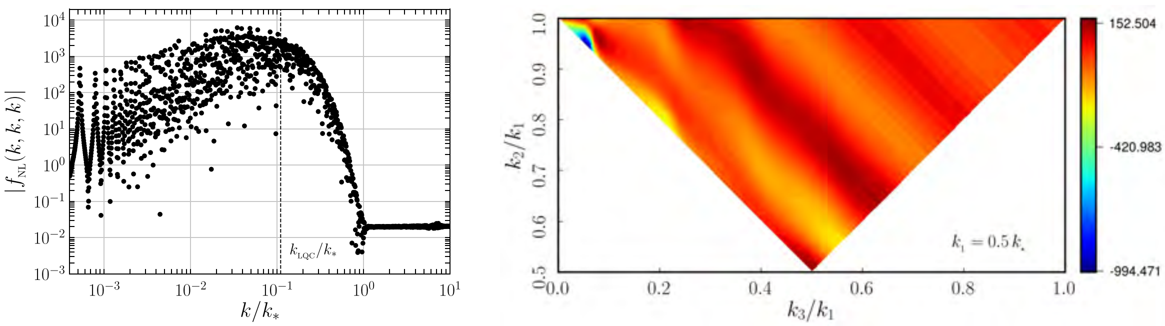


Figure 12: The figure illustrates the behaviour of non-Gaussianity, characterized using the dimensionless quantity $f_{\rm NL}(k_1, k_2, k_3)$, generated in LQC. In the left panel, $|f_{\rm NL}(k_1, k_2, k_3)|$ has been plotted in the equilateral limit ($k_1 = k_2 = k_3 = k$) as a function of k/k_*, where k_* is the pivot scale. As is evident, for $k \gg k_{\rm LQC}$, the Fourier modes are not affected by the curvature at the bounce and hence, primordial non-Gaussianity originate entirely from the inflationary phase and are small. However, for infrared modes, $k \lesssim k_{\rm LQC}$, the $f_{\rm NL}$ is enhanced and is oscillatory. The panel on the right illustrates the shape of $f_{\rm NL}(k_1, k_2, k_3)$. It can be seen that the value of $|f_{\rm NL}|$ peaks near the top-left corner which corresponds to the squeezed-flattened limit ($k_3 << k_1 \simeq k_2$ and $k_3 + k_2 \simeq k_1$).

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 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 we assume a Bianchi tpye I model for its description. We compute its signature waveform and assume masses, distances analogous to the events detected by aLIGO and aVirgo. By matched filtering, the signal we 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. We, 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.

Marginalizing the likelihood function for modelled gravitational wave searches

Matched filtering is a commonly used technique in gravitational wave searches for signals from compact binary systems and from rapidly rotating neutron stars. A common issue in these searches is dealing with four extrinsic parameters which do not affect the phase evolution of the system: the overall amplitude, initial phase, and two angles determining the overall orientation of the system. The F-statistic maximizes the likelihood function analytically over these parameters, while the B-statistic marginalizes over them. The B-statistic, while potentially more powerful and capable of incorporating astrophysical priors, is not as widely used because of the computational difficulty of performing the marginalization. Here, this difficulty is addressed and it is shown by **Sanjeev Dhurandhar**, B. Krishnan and J. Willis how the marginalization can be done analytically by combining the four parameters into a set of complex amplitudes. These results are applicable to both transient non-precessing binary coalescence events, and to long lived signals from rapidly rotating neutron stars.

Prediction of surface wave velocities with historical seismic data.

Nikhil Mukund and his collaborators revisit the problem of estimating seismic surface wave amplitude for early warning systems at LIGO like interferometers. In their earlier work, they had developed an analytic expression for the expected ground motion, taking into account the magnitude, depth, and distance of the earthquake. Although, the above model accurately makes predictions within a factor of five, they needed the accuracy to be within a factor of two to make decisions related to switching control configurations at the site. In this work, parameters related directional dependence of the fault rupture and its moment tensor parameters are utilized to increase the prediction accuracy. They make use of Gaussian Process Regression (GPR) to generate probabilistic estimates of ground motion along with their associated confidence intervals based on data recorded at LIGO Livingston and Hanford observatories during the period 2015-2017.

Information retrieval and recommendation system for astronomical observatories

Nikhil Mukund and his collaborators present a machine-learning-based information retrieval system for astronomical observatories that tries to address user-defined queries related to an instrument. In the modern instrumentation scenario where heterogeneous systems and talents are simultaneously at work, the ability to supply researchers with the right information helps to speed up the tasks for detector operation, maintenance, and upgradation. The proposed method analyzes existing documented efforts at the site to intelligently group related information to a query and to present it online to the user. The user in response can probe the suggested content and explore previously developed solutions or probable ways to address the present situation optimally. They demonstrate natural language-processing-backed knowledge re-discovery by making use of the open source logbook data from the Laser Interferometric Gravitational-Wave Observatory (LIGO). They implement and test a web application that incorporates the above idea for LIGO Livingston, LIGO Hanford, and Virgo observatories.

Transient classification in LIGO data using difference boosting neural network

Detection of short duration gravitational waves (GW) in LIGO data requires reliable identification and removal of noise transients produced by a variety of non-astrophysical sources. Noise transients present in the data reduces the reliability of a GW detection by increasing its false alarm probability. Thus, detection and classification of transients in data from gravitational wave detectors are crucial for efficient searches for true astrophysical events and identification of noise sources. **Nikhil Mukund**, **Sheelu Abraham**, Shivaraj Kandhasamy, **Sanjit Mitra** and Sajeeth Philip developed a hybrid method for classification of short duration transients seen in gravitational wave data, using both supervised and unsupervised machine learning techniques. To train the classifiers, we use the relative wavelet energy and the corresponding entropy obtained by applying one-dimensional wavelet decomposition on the data. The prediction accuracy of the trained classifier on nine simulated classes of gravitational wave transients and also LIGO's sixth science run hardware injections are reported. Targeted searches for a couple of known classes of non-astrophysical signals in the first observational run of advanced LIGO data are also presented. The ability to accurately identify transient classes using minimal training samples makes the proposed method a useful tool for LIGO detector characterization as well as searches for short duration gravitational wave signals. (see Figure 13).

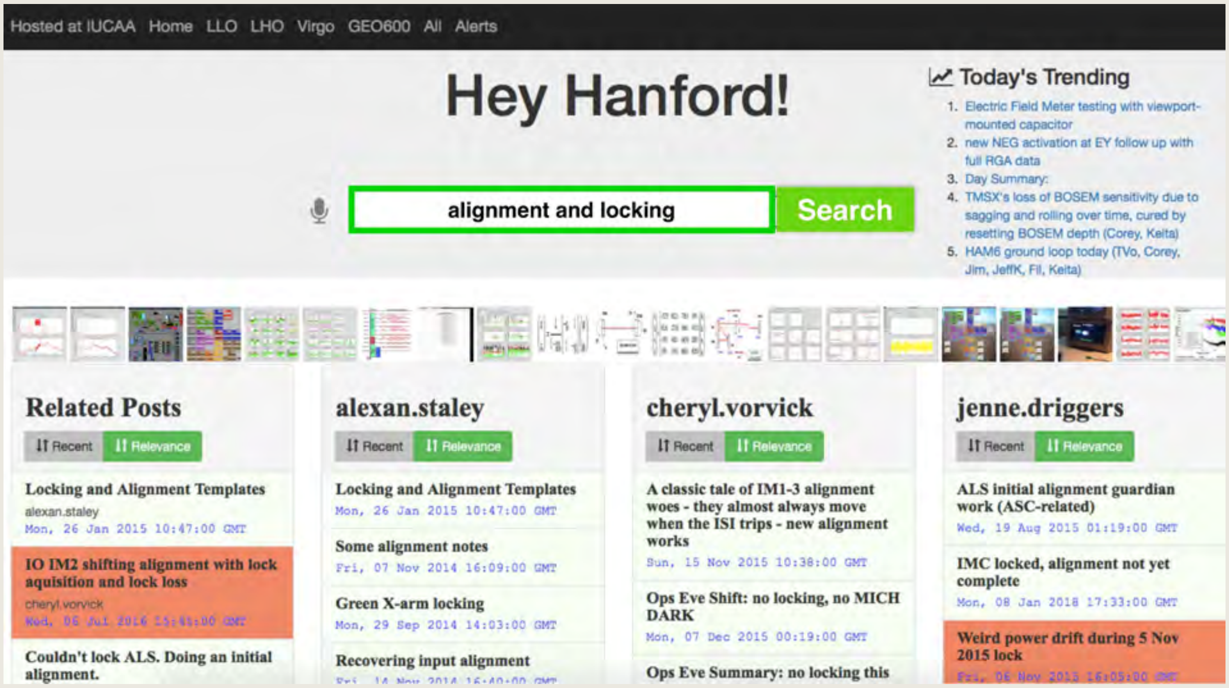


Figure 13: Screenshot of the HeyLIGO (**heyligo.gw.iucaa.in**) interface. The application makes use of natural language processing and semantic learning to intelligently retrieve information about the GW detector from the instrument logbooks that have been maintained for more than a decade. It is routinely used by the LIGO commissioners and site engineers to quickly find solutions to day-to-day commissioning related challenges.

Cosmic Magnetic Fields

Faraday rotation signatures of fluctuation dynamos in young galaxies

Observations of Faraday rotation through high-redshift galaxies have revealed that they host coherent magnetic fields that are of comparable strengths to those observed in nearby galaxies. These fields could be generated by fluctuation dynamos. Sharanya Sur, Pallavi Bhat and **Kandaswamy Subramanian** use idealized numerical simulations of such dynamos in forced compressible turbulence up to rms Mach number of 2.4 to probe the resulting rotation measure (RM) and the degree of coherence of the magnetic field. They obtain rms values of RM at dynamo saturation of the order of 45 - 55 per cent of the value expected in a model, where fields are assumed to be coherent on the forcing scale of turbulence. They show that the dominant contribution to the RM in subsonic, and transonic cases comes from the general sea of volume filling fields, rather than from the rarer structures. However, in the supersonic case, strong field regions as well as moderately overdense regions contribute significantly. Our results can account for the observed RMs in young galaxies.

Challenges in inflationary magnetogenesis

Models of inflationary magnetogenesis with a coupling to the electromagnetic action of the form $f^2 F_{\mu\nu} F^{\mu\nu}$, are known to suffer from several problems. These include the strong coupling problem, the backreaction problem and also strong constraints due to the Schwinger effect. Ramkishor Sharma, Sandhya Jagannathan, T. R. Seshadri and

Kandaswamy Subramanian propose a model which resolves all these issues. In this model, the coupling function, f, grows during inflation and transits to a decaying phase post-inflation. This evolutionary behaviour is chosen so as to avoid the problem of strong coupling. By assuming a suitable power-law form of the coupling function, they can also neglect backreaction effects during inflation. To avoid backreaction post-inflation, they find that the reheating temperature is restricted to be below about 1.7×10^4 GeV. The magnetic energy spectrum is predicted to be non-helical and generically blue. The estimated present day magnetic field strength and the corresponding coherence length taking reheating at the QCD epoch (150 MeV) are 1.4×10^{-12} G and 6.1×10^{-4} Mpc, respectively. This is obtained after taking account of non-linear processing over and above the flux-freezing evolution after reheating. If they consider also the possibility of a non-helical inverse transfer, as indicated in direct numerical simulations, the coherence length and the magnetic field strength are even larger. In all cases mentioned above, the magnetic fields generated in these models satisfy the γ-ray bound below a certain reheating temperature.

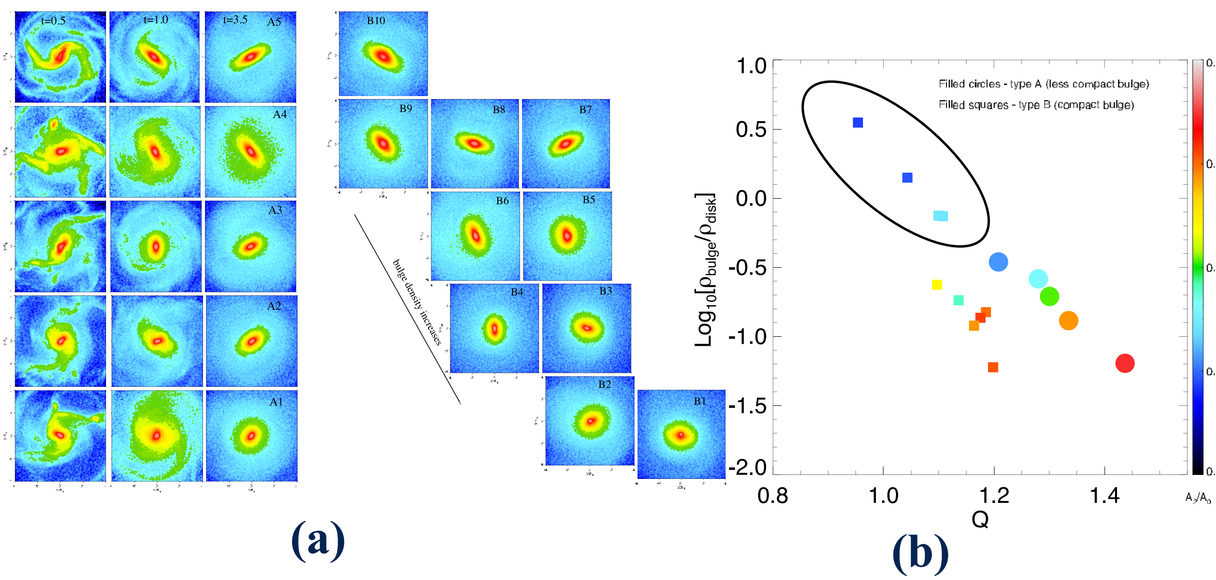
Generation of helical magnetic field in a viable scenario of inflationary magnetogenesis

Ramkishor Sharma, **Kandaswamy Subramanian** and T. R. Seshadri study the generation of helical magnetic fields in a model of inflationary magnetogenesis, which is free from the strong coupling and backreaction problems. To generate helical magnetic fields, they add an $f^2 F_{\mu\nu}\tilde{F}^{\mu\nu}$ term to the Lagrangian of the Ratra model. The strong coupling and backreaction problems are avoided if we take a particular behaviour of coupling function f, in which f increases during inflation and decreases post-inflation to reheating. The generated magnetic field is fully helical and has a blue spectrum, $d\rho_B/d\ln k \propto k^4$. This spectrum is obtained when coupling function, $f \propto a^2$ during inflation. The scale of reheating in our model has to be lower than 4000 GeV to avoid backreaction post-inflation. The generated magnetic field spectrum satisfies the γ-ray bound for all the possible scales of reheating. The comoving magnetic field strength and its correlation length are about 4×10^{-11} G and 70 kpc respectively, if reheating takes place at 100 GeV. For reheating at the QCD scales of 150 MeV, the field strength increases to about a nano gauss, with coherence scale of 0.6 Mpc.

Observational Cosmology and Extragalactic Astronomy

Why some galaxies are not barred?

Kanak Saha uses N-body simulations as a primary tool to investigate bar formation in galaxies. A cold, otherwise smooth and featureless, disk becomes readily unstable to bar formation within a few hundred million years. Amongst the simulation community, bar formation has turnout to be a spontaneous phenomenon. If that is the case, all galaxies should have been barred by now. Of course, one can make the disk stable against bar formation by raising its velocity dispersion to a very high value and/or by adding a rigid potential such as due to dark matter halo. The first one is not the right initial condition,as disk must start cold (stars are born cold) and for the second, dark matter halo potential (being live) are now known to interact with disk stars via resonances - which in turn promote bar formation. **Kanak Saha** and Bruce Elmegreen propose a solution to this half-a-century old issue. They show that a cold disk with a compact bulge having high inner Lindblad resonance (ILR) can prevent bar formation. In the presence of a compact bulge, the feedback loop needed for the swing amplification is cut off from the disk. Secondly, during the early phases of evolution, the spiral grew strongly and breaks down due to non-linear effect - producing stellar clumps on sub-galactic scale. These clumps in-spiral to the central region, heat the disk to a high degree and leads to sudden loss of angular momentum. These combined effects are likely to be instrumental behind some galaxies being not barred (see Figure 14).



Simulated galaxies (marked by A and B Series) and their time evolution. As one goes from upper to lower panel, only the bulge density increases. Model A1, B1, and B3 clearly end up with no bar. These simulations are one of the first realistic models that successfully avoided making a bar despite having a cooler disk to start with.

All models according to Toomre Q (explored in this study) should have made a bar. However, even a cold disk avoided making a bar when the bulge density became greater or equal to the disk density in the central region. This demonstrates how the initial bulge density might affect the formation of bar in the galactic disk.

Figure 14:

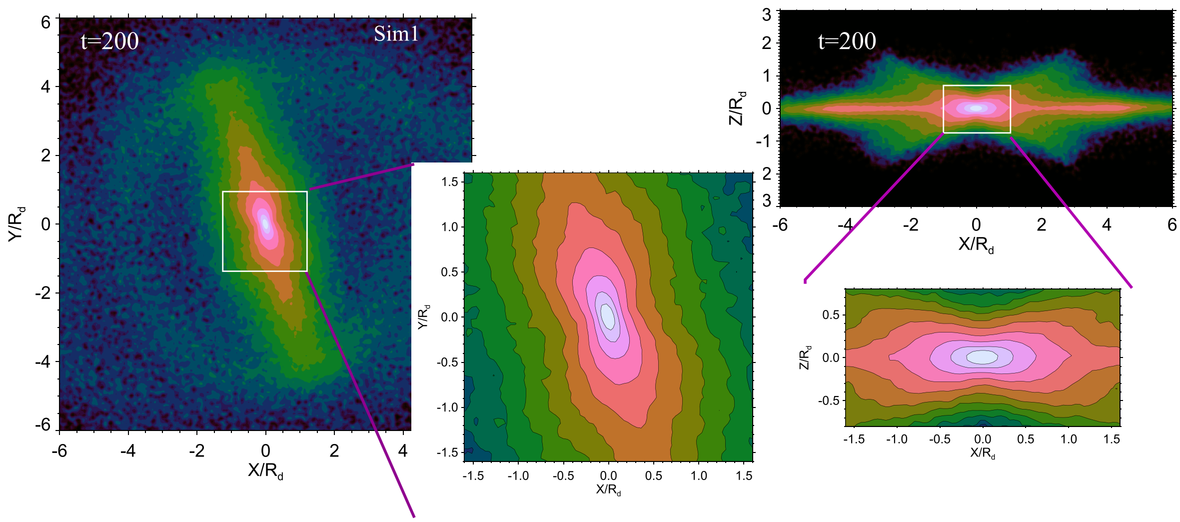


Figure 15: Face-on and edge-on projection of the simulated images at the end of 10 billion years. In face-on projection, we call them pinched bulge

Pinched and peanut bulges in spiral galaxies

A good fraction of galaxies display peanut-shaped structures (including our Milky Way) when viewed in edge-on projection. It is an established fact that peanut-shaped structures are associated with bars, and they are basically a result of the buckling instability of the bar in the vertical direction. Thats why a majority of them show just bar or lens when viewed face-on but peanut is preferentially seen only in edge-on projection. However, there are a number of galaxies, e.g., IC5240, which show peanut-like features even in near-face-on projection, associated with a ring at the end of the bar. **Kanak Saha**, Alister Graham and Isabel Rodriguez-Herranz have created a set of simulated models, which when evolved for a few Gyr produced such peanut like structures even in face-on projection (see Figure 15). They suspect that some bars might not go unstable only in the vertical direction, but also in the planar direction. Detailed orbital study is needed to shed further light on understanding such features.

Detection of bars in galaxies using a deep convolutional neural network

A non-axisymmetric bar-like structure often occurs in galaxies with disks, including spiral and lenticular galaxies. Bars play an essential role in the secular evolution of galaxies, channelling stars and gas from the disc to the inner regions of galaxies. It is, therefore, necessary to estimate how often bars occur in galaxies of different type, and how their properties are related to other morphological properties of galaxies and their environment. Bars have so far been discovered mostly in local galaxies, through inspection of galaxy images by human domain experts. But such an approach is impractical when samples become very large, bars are not prominent, or distant galaxies are to be inspected. To address this problem, **Sheelu Abraham**, Arun Kumar Aniyan, **Ajit Kembhavi**, Ninan Sajeeth Philip and **Kaustubh Vaghmare** have developed an efficient and automated method for the detection of bar-like structures in optical images of galaxies using a deep convolutional neural network (CNN). The significance of this method is that the CNN is capable of extracting features associated with various classes of images without the aid of human domain experts, thus, making it more consistent even when learning is done using large volumes of data with diverse examples.

In this study, we use a sample of 9346 galaxies in the redshift range 0.009 - 0.2 from the Sloan Digital Sky Survey, which has 3864 barred galaxies, the rest being unbarred. We reach a top precision of 94 per cent in identifying bars in galaxies using the trained network. This accuracy matches the accuracy reached by human experts on the same data without additional information about the images. Since deep CNN can be scaled to handle large volumes of data, the method is expected to have great relevance in an era where astronomy data is rapidly increasing in terms of volume, variety, volatility and velocity along with other V's that characterize big data. With the trained model, we have constructed a catalogue of barred galaxies from SDSS and made it available online (http://ddi.iucaa.in/barClassifier). The web interface for the trained network is available for the public and allows the user to upload multiple images. Once the user uploads the images and submits a request, the images are classified on the server and a table is output to the user containing a preview thumbnail, the name of the image file, a flag indicating whether the galaxy is barred or not and the probability associated with the same. The user can download the result table in ASCII format.

Classical bulges in S0 galaxies: Being low mass is complicated

The formation and evolution of S0 galaxies is further complicated by the fact that they have bulges of two types: Classical and pseudo. In a recent study about classical bulges in lenticular (S0) galaxies, **Sheelu Abraham**, Sudhanshu Barway, Yogesh Wadadekar and **Ajit Kembhavi** have showed that classical bulges in high mass S0s have properties similar to elliptical galaxies, while those in low-mass S0s have more complex properties, which point to a different formation history. They have derived the structural parameters for 305 S0 galaxies and studied the correlations of different structural parameters using bulge-disk-bar decompositions on SDSS DR7 r-band images. A combination of bulge Srsic index, and the location of the galaxy bulge on the Kormendy diagram is used to separate the bulge into two types - classical and pseudo. Using multi-band photometry, they use SED fitting techniques to estimate the masses of the sample galaxies, and divide the sample galaxies into high-mass and low-mass subsets. While the bulges of the high-mass S0 galaxies follow the same scaling relations as ellipticals, the bulges of low mass S0 galaxies show greater scatter, and the host galaxies come with mixed stellar populations and a high fraction shows evidence of recent star formation. The bulges of high-mass S0s are likely to have formed in the same manner as ellipticals, while the bulges of low-mass S0s appear to share the properties of classical and pseudo-bulges, with more than one process contributing to their origin.

Radio properties and feedback implications of galaxy groups in the local Universe

From an optically selected, statistically complete sample of 53 nearby groups (CLoGS), observed at both radio (GMRT) and X-ray (Chandra and XMM-Newton) frequencies, **Konstantinos Kolokythas**, et al. have found a high radio detection rate of 92% (24 of 26 BGEs) at either 235, 610 and 1400 MHz, with the majority of the BGEs exhibiting low radio powers between $10^{21} - 10^{23}$W/Hz with only three radio sources in the sample being characterized as radio loud ($P235MHz > 10^{24}$ W/Hz - NGC 4261, NGC 193 and NGC 5044). In agreement with previous studies, e.g., Dunn, et al. 2010, we confirm the trend suggesting that nearly all dominant galaxies in groups or clusters are hosting a central radio source. The radio sources in the sample cover a large spatial scale spanning from 3 to 80 kpc with a variety of morphologies extending for about 4 orders of magnitude in power, from $\sim 10^{21}$ W/Hz (NGC 5982), to $\sim 6 \times 10^{24} W/Hz (NGC\ 4261)$. The majority of the systems has a point-like radio morphology 14/26 ($\sim$ 53%) with 6/26 groups ($\sim$ 3%) hosting a small/large scale jet with the remaining 4/26 groups (15%) hosting diffuse sources. Comparing the X-ray environment in which the BGEs reside with their radio emission, they find a distinction between central radio sources in X-ray bright and faint groups. All but one of the jet sources are found in X-ray bright cool-core systems, confirming that the X-ray bright groups or clusters are the preferred environment for radio jets to appear even down to the lower mass range covered by this sample. On the other hand, all galaxies that lack radio emission are found in X-ray faint systems. Low power radio point sources are common in both environments.

Considering the energetics of the radio jet sources, we find mechanical power values typical for galaxy groups, in the range $\sim 10^{41} - 10^{43}$ with our systems being in good agreement with other group-central sources (e.g., Birzan, et al. 2008, O'Sullivan, et al. 2011). We find that small scale jet systems are able to balance cooling in the central region of the group provided that the AGN continuously injects energy, in agreement with Panagoulia, et al. 2014, whereas the mechanical power output of the two large scale systems in our sample (NGC 193 and NGC 4261) appears to exceed to the cooling X-ray luminosity of their environment by a factor of ~ 100. This suggests that while in some groups thermal regulation can be achieved by a relatively gentle, 'bubbling', feedback mode, considerably more violent AGN outbursts can take place, which may effectively shut down the central engine for long periods.

Cosmic Microwave Background

Bayesian estimation of cosmic hemispherical asymmetry

The Bipolar Spherical Harmonic (BipoSH) representation proposed a decade back is now well established by the cosmology community as the most robust and natural measure of violation of statistical isotropy (SI) in the CMB anisotropy. One of the most intriguing and highlighted results from Planck is a cosmic hemispherical asymmetry (CHA) in the CMB temperature skymap challenging the fundamental cosmological principle is established through our BipoSH analysis at about 3σ significance. The excess of power in one hemisphere of CMB is compared to the other. CHA is modelled as dipole modulation of statistical isotropic CMB sky. Dipole modulated CMB temperature anisotropy field in the direction of the dipole in the sky and the amplitude, A, of the dipole. Under this model, looking for the signature of CHA then reduces to estimating these parameters.

Tarun Souradeep and team have continued its work on BipoSH analysis on the Planck temperature data, employing a Bayesian analysis developed by the group reported in previous years. In the past year, IUCAA graduate students **Shabbir Shaikh**, Suvodip Mukherjee, Santanu Das and **Tarun Souradeep** collaborated with Ben Wandelt to apply the new Bayesian assessment of statistical isotropy violation to the Planck map. Hamiltonian Monte Carlo method is used to sample the likelihood distribution of these parameters, allowing the efficient sampling of the multi-dimensional joint probability distribution. The application to observe Planck sky maps required very careful work of including many of the finer details of instrumental effects and artefacts of the real observations that could influence the robustness of a definitive statement. Figures 16 and 17 show the preliminary results of the distribution of the dipole amplitude and its direction. The team also plans to extend the study to the polarisation measurements when the final maps are released by the Planck collaboration.

Effect of early universe assumptions on the cosmological inferences

The remarkable progress in Cosmic Microwave Background (CMB) studies over the past decade has led to the era of precision cosmology in striking agreement with the LCDM model. However, it is important to bear in mind that the estimation of cosmological parameters is based on an assumed form of the primordial power spectrum (typically, power-law). In the light of tensions in estimation of cosmological parameters from other observations, 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. Karthik Prabhu worked for his fi-

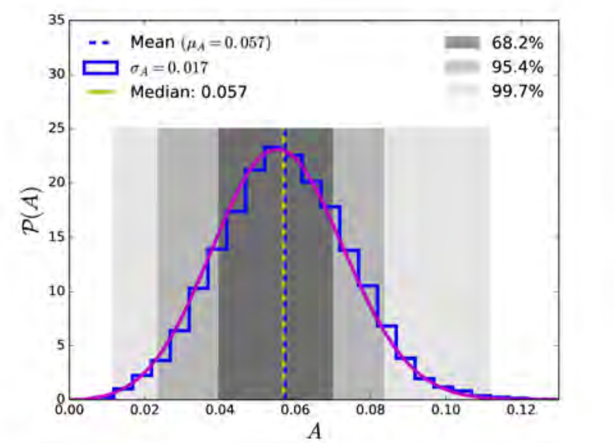


Figure 16: It shows the normalised probability distribution of A for the Planck CMB map. Shaded regions mark the 68%, 95% and 99.7% areas under the probability distribution. The dashed blue line denotes the mean of the distribution.

nal year Masters' thesis under **Tarun Souradeep** on implementing an estimation of the cosmological parameters after deconvolving a 'smoothed' primordial power spectrum at any point of the cosmological parameter space. The exercise clearly shows that there are interesting dependence of cosmological parameters obtained assuming the specific power law form of the primordial power spectrum. Further work to account for subtle effects, such as, the weak lensing of CMB, is underway.

Minimising foreground emission in CMB maps

Tarun Souradeep collaborated with former IUCAA associate, Rajib Saha and his students on an improved technique for the minimisation of diffuse foreground emission that contaminates the Cosmic Microwave Background (CMB) maps using a new multi-phase iterative internal-linear-combination (ILC) approach in harmonic space. The new ILC method nullifies a foreground leakage signal that is otherwise inevitably present in the old and usual harmonic space iterative ILC method.

Weak lensing of the CMB

Weak lensing of CMB due to large scale structure is an important signal in the CMB maps that provides information on late universe and structure formation. Robust estimation of the weak lensing signal and correcting for the same (delensing) to uncover the primordial signal are areas of active research in the field. **Rajorshi Chanda**, Suvodip Mukherjee and **Tarun Souradeep** have developed a formalism to estimate the effects of weak lensing of CMB as statistical isotropy violation using the BipoSH formalism. The implementation of this compute intensive method in an efficient code is currently underway.

CMB-Bharat: Proposal for an India led CMB space mission

In the past, there has emerged a unique window of opportunity to achieve the goal of an Indian CMB space mission in joint international collaboration. Most of the cosmological signals in the temperature fluctuations have been measured and harvested by the two space-based CMB missions, viz., WMAP from NASA, and Planck Surveyor from ESA. How-

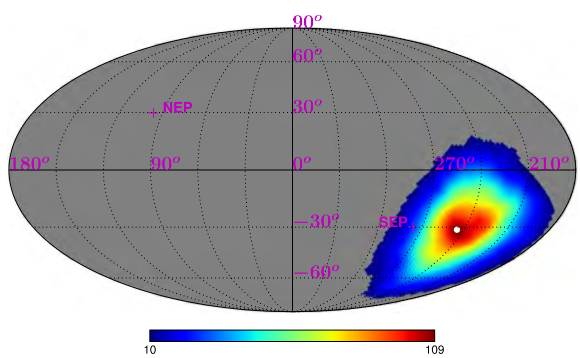


Figure 17: It shows the frequency distribution of the dipole direction for the corresponding map in the galactic coordinate system. White dot represents the maximum likelihood direction for the dipolar modulation, having galactic coordinates $(l, b) = (245^o, -32^o)$, which is substantially distinct from the South Ecliptic Pole or other known special directions

ever, nearly 90% of the information regarding the CMB polarisation and spectral information (which has been virtually unmeasured since COBE) remain to be gleaned by a future CMB mission. Such a 4th generation CMB space mission promises a balanced profile of returns that range from potentially pathbreaking scientific discovery, advancement of related technology to high value science and priceless astrophysical data legacy. There is well established expertise across several institutions in India to garner the science from a CMB imaging and spectroscopy mission to provide considerable returns in terms of enhancing the Indian presence on the frontiers of cosmology and astrophysics. At a meeting titled, "Assessing the prospects for frontier CMB space experiments from India" held at the Indian Space Research Organisation (ISRO) HQ, Bengaluru, during January 8-9, 2018, an Indian Cosmology Consortium, CMB-Bharat, was formed to harness this unique opportunity to carry out frontier research in cosmology with a CMB space mission from India. In response to the 'Announcement of Opportunity (AO) for future Astronomy mission' by the ISRO, CMB-Bharat consortium, with **Tarun Souradeep** as the proposal lead, has submitted a multifaceted frontier science and astronomy mission to map the sky temperature, linear polarization (60-1000 GHz) and spectrum ($\sim$ 30-3000 GHz) of the background radiation with unprecedented sensitivity, accuracy and angular resolution.

High Energy Astrophysics

X-ray/UV connection in Seyferts

The optical/UV continuum emission from radio-quiet active galactic nuclei is thought to be the direct result of the accretion of material onto the central supermassive black holes. However, the origin of the short-term variations in the optical/UV continuum emission is not well understood. To address this issue, **Pramod Pawar**, **Gulab C. Dewangan**, I. E. Papadakis, M. K. Patil and **Ajit K. Kembhavi** studied the relationship between the UV and X-ray variability of the narrow-line

Seyfert 1 galaxy 1H 0707-495. Using a year-long Swift monitoring and four long XMM-Newton observations, they performed cross-correlation analyses of the UV and X-ray light curves, on both long and short time-scales. They also performed time-resolved X-ray spectroscopy on 1-2 ks scale, and studied the relationship between the UV emission and the X-ray spectral components - soft X-ray excess and a power law. They found that the UV and X-ray variations anti-correlate on short, and possibly on long time-scales as well. These results rule out reprocessing as the dominant mechanism for the short-term UV variability. The X-ray spectral shape and the UV flux are not correlated positively. This suggests that the observed UV emission is unlikely to be the seed photons for the thermal Comptonization. The presence of a strong correlation between the continuum flux and the soft-excess temperature implies that the soft excess is most likely the reprocessed X-ray emission in the inner accretion disc. Strong X-ray heating of the innermost regions in the disc, due to gravitational light bending, appears to be an important effect in 1H 0707-495, giving rise to a significant fraction of the soft excess as reprocessed thermal emission.

Energy-dependent X-ray variability of Ark 120

Labani Mallick, **Gulab C. Dewangan**, I. M. Mchardy, and **Mayukh Pahari** performed a detailed spectral-timing study using a long 486 ks XMM-Newton observation of the bare Seyfert 1 galaxy Ark 120 performed in 2014. Ark120 showed alternating diminution and increment in the 0.3-10 keV X-ray flux over four consecutive XMM-Newton orbits in 2014. Mallick, et al. studied the energy-dependent variability of Ark 120 through broad-band X-ray spectroscopy, fractional root-mean-squared (rms) spectral modelling, hardness-intensity diagram and flux-flux analysis. The X-ray (0.3 - 10 keV) spectra are found to be well described by a thermally Comptonized primary continuum with two (blurred and distant) reflection components and an optically thick, warm Comptonization component for the soft X-ray excess emission below $a^{1/4}$ 2 keV. During the first and third observations, the fractional X-ray variability amplitude decreased with energy, while for second and fourth observations, X-ray variability spectra are found to be inverted-crescent and crescent shaped, respectively. The rms variability spectra are well modelled by two constant reflection components, a soft excess component with variable luminosity and a variable intrinsic continuum with the normalization and spectral slope being correlated. The spectral softening of the source with both the soft excess and UV luminosities favours Comptonization models, where the soft excess and primary X-ray emission are produced through Compton up-scattering of the UV and UV/soft X-ray seed photons in the putative warm and hot coronae, respectively. These analyses imply that the observed energy-dependent variability of Ark 120 is most likely due to variations in the spectral shape and luminosity of the hot corona and to variations in the luminosity of the warm corona, both of which are driven by variations in the seed photon flux.

NuSTAR view of Cygnus X-2

Aditya Mondal, **Gulab C, Dewangan**, **Mayukh Pahari** and B. Raychaudhuri studied the NuSTAR observation of the Z-type neutron star low-mass X-ray binary Cygnus X-2 performed on January 7, 2015. During this observation, the source exhibited a sudden decrease in count rate (dips) and stronger variability in 3 - 79 keV X-ray light curve. The hardness-intensity diagram showed 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 3-45 keV luminosity of about < 38 erg/s. 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 Kalpha emission line, which is nearly symmetric at the higher flux and asymmetric when the flux is reduced by a factor of about 2. The relativistic reflection model predicts the inner radius of the accretion disc to be about 30 - 73 km for the non-dip state and 24 - 32 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 $< 8e9$ Gauss at the magnetic poles which is consistent with other estimates.

Long-term spectral variability of the ultraluminous X-ray source Holmberg IX X–1

Ultra-luminous X-ray sources (ULXs) are luminous X-ray emitting objects found in off-nuclear regions of nearby galaxies with apparent luminosities in the range $10^{39} - 10^{41}$ erg s^{-1}. ULXs are variable in nature and their spectral and temporal variability studies will help us to understand the geometry and physical processes in these systems, which can provide constraints on the nature of ULXs. **V. Jithesh**, **Ranjeev Misra** and Zhongxiang Wang have investigated the long-term spectral variability in the ULX source Holmberg IX X–1 by analysing the data from 8 *Suzaku* and 13 *XMM-Newton* observations conducted between 2001 and 2015. They performed a detailed spectral modelling for all spectra with simple and complex physical models to understand the variability of the source. Among them, a disk-plus-thermal-Comptonization model well explained the observed spectra, and they studied the correlations between the X-ray luminosity (L_X) and the spectral parameters. A statistically significant positive correlation between L_X and the photon index (Γ) has been observed for the source in the low luminosities, while at the high luminosities of $> 2 \times 10^{40}$ erg s^{-1}, the source becomes marginally hard, which results in a change in the slope of the $\Gamma - L_X$ correlation (see Figure 18). Interestingly, the optical depth of the source also exhibits a similar variability pattern, as the source appears to be optically very thick ($\tau \sim 12$) above the luminosity 2×10^{40} erg s^{-1}. The observed correlations can be explained on the basis of the disk-corona model, where the corona covers the inner part of the disk. In the disk-corona model, the $\Gamma - L_X$ correlation can be explained as being due to the process of the thermal Comptonization of the variable seed photons from the accretion disk by the hot corona. Their study revealed the complex variability behaviour of Holmberg IX X–1, and the variability mechanism is likely related to the geometry of the X-ray-emitting regions.

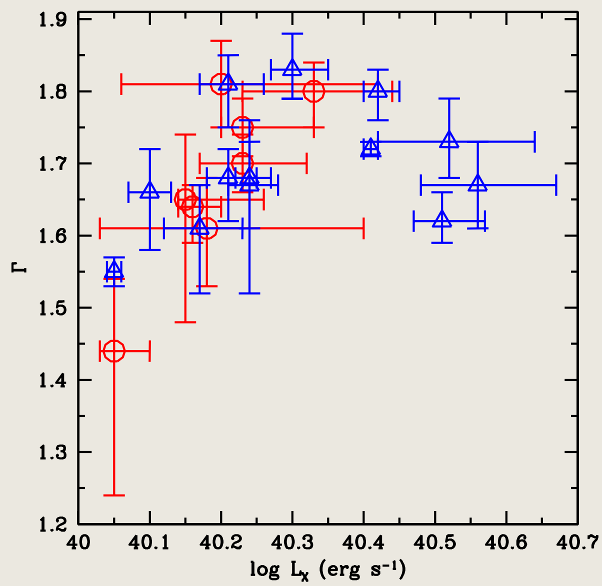


Figure 18: $\Gamma - L_X$ correlation for Ho IX X–1 obtained from the disk-plus-thermal-Comptonization model. The red open circles and blue triangles represent the *Suzaku* and *XMM-Newton* spectra, respectively.

High energy properties of the flat spectrum radio quasar 4C ∼ 50.11

Blazars are radio-loud active galactic nuclei (AGNs) with relativistic jets pointing towards the Earth. The emission from a jet dominates the broad-band spectral energy distribution (SED) from radio to γ-rays energies due to the Doppler beaming effect. Detailed studies of blazars in the high energy bands and their variability studies are essential in understanding the broadband properties and radiation mechanism of the jet.

V. Jithesh, Jianeng Zhou, Chen Liang and Zhongxiang Wang have studied the γ-ray and X-ray properties of the flat spectrum radio Quasar (FSRQ) $4C \sim 50.11$ using the *Fermi*-LAT, *Swift*-XRT and *NuSTAR* data. The *Fermi*-LAT data indicate that this source is in an active state since 2013 July. During this active period, the source's emission appeared harder in γ-rays, with the flux having increased by more than a factor of three. The source exhibits two distinct flares in the active state and the source variability is as short as several hours. The *Swift*-XRT observations conducted during 2007–2015 showed that the source intensity was varied by a factor of 3 at X-ray energies, and in the 2015 *Swift*-XRT observation, the source intensity reached the maximum value of ~ 0.08 count s^{-1}. However, they do find any evidence of X-ray flux or spectral changes related to the γ-ray activity. The broad-band X-ray spectrum obtained with *Swift*-XRT and *NuSTAR* is well described by a broken power law model, with an extremely flat spectrum ($\Gamma_1 \sim 0.1$) below the break energy, $E_{\rm break} \sim 2.1$ keV, and $\Gamma_2 \sim 1.5$ above the break energy. The spectral flattening below ~ 3 keV is likely due to the low energy cut-off in the energy distribution of the photon-emitting electron population. They also constructed broad-band SED of the source using the *Fermi*-LAT, *Swift*-XRT and *NuSTAR* along with the available archival data in the radio and optical bands. The resulted SED in both the active and quiescent states was modelled with the standard blazar emission model: one zone synchrotron plus inverse Comptonization model, and derived the properties of the emission region. This study suggests that the X-ray and γ-ray emission from the jet is mainly due to the inverse-Compton scattering process, with the seed photons provided from the broad line region, and the jet is estimated to be larger than the accretion power if the jet is mainly composed of electron-proton pairs.

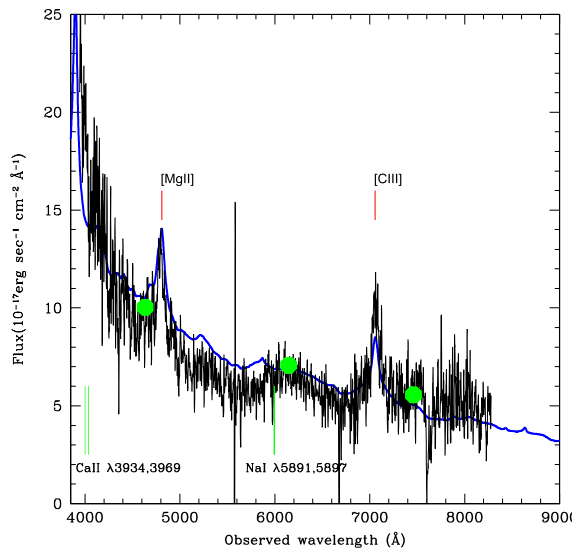


Figure 19: IUCAA Girawali Observatory spectrum of the quasar J1243+4043. The SDSS composite spectrum of quasars at $z \sim 1.5$ is overlaid in blue.

Revealing H I gas in emission and absorption on pc to kpc scales in a galaxy at z ∼ 0.017

Recently, **Neeraj Gupta** and **Raghunathan Srianand** with their collaborators presented a detailed study of the quasar-galaxy pair: J1243+4043-UGC 07904. The sight line of the background quasar ($z_q = 1.5266$) passes through a region of the galaxy ($z_g = 0.0169$) at an impact parameter of 6.9 kpc with high metallicity ($0.5Z_0$) and negligible dust extinction. The redshift of the quasar was measured using the 2-m optical telescope at IUCAA Girawali Observatory (IGO) (see Figure 19).

For this comprehensive study of the quasar-galaxy pair, the authors used radio data from the Giant Metrewave Radio Telescope (GMRT), the Westerbork Synthesis Radio Telescope (WSRT), and the global-VLBI array, consisting of the Very Long Baseline Array (VLBA) and the European VLBI Network (EVN) to map the large scale HI 21 cm emission from the QGP and the associated galaxy group, and detect 21 cm absorption towards the background quasar at arcsecond and mass scales.

For typical cold neutral medium (CNM) temperatures in the Milky Way, the 21 cm absorber detected in this galaxy can be classified as a damped Lyα absorber (DLA). The inferred harmonic mean spin temperature of the gas is $\sim$ 400K and for a simple two-phase medium, the CNM fraction is $f_{CNM} = 0.27$. This is remarkably consistent with the CNM fraction observed in the galaxy. Using VLBI measurements, the authors show that the size of CNM absorbing clouds associated with the foreground galaxy is > 5 pc and they may be part of cold gas structures that extend beyond ~ 35 pc.

Interestingly, the rotation measure of quasar J1243+4043 is higher than any other source in samples of quasars with high-z DLAs. However, the authors do not find any detectable differences in rotation measures and polarization fraction of sight lines with or without high-z ($z \geq 2$) DLAs or low-z ($z \leq 0.3$) 21 cm absorbers. Finally, the foreground galaxy UGC 07904 is also part of a galaxy group. They serendipitously detect HI 21 cm emis-

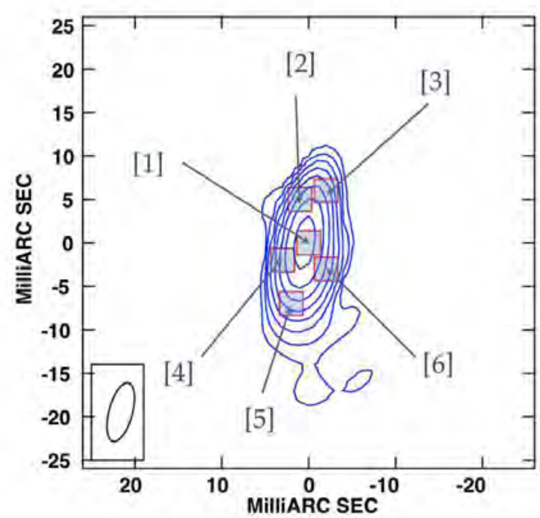


Figure 20: The global VLBI image and HI 21 cm absorption spectrum of the quasar

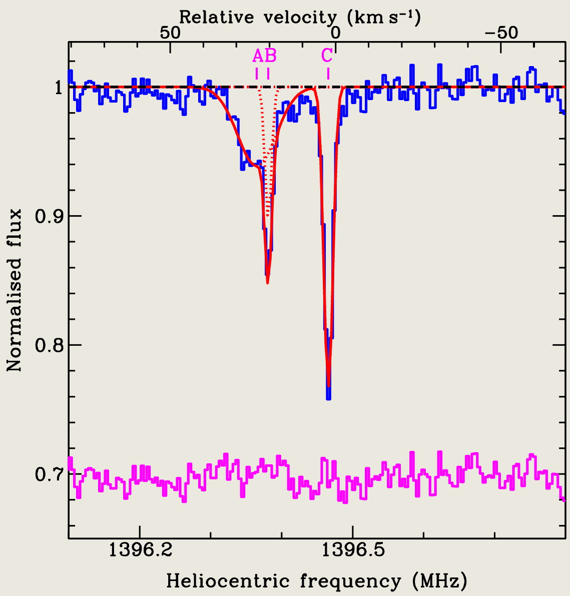


Figure 21: The WSRT radio continuum (blue) and total HI-column density contours (red) overlaid on the mosaiced SDSS r-band image. The HI-column density contour levels are $410^{19}(1, 1.5, 2, 4, 6, 8, 16)cm^2$. The radio continuum contour levels are 12^n mJy beam^1 (where n = 0,1,2,3,..). The synthesized beam is 30.70"13.9"ith P.A. 31^0. This corresponds to 10.54.7 kpc^2 at the z_g . The QGP J1243+4043 is at *top-right corner*. The group members are labelled.

sion from four members of the group, and an ~ 80 kpc long H I bridge connecting two of the other members. The latter, together with the properties of the group members, suggests that the group is a highly interactive environment. (see Figures 20 and 21).

Thanks to large surveys from Square Kilometer Array (SKA) pathfinders and precursors (e.g., the MeerKAT Absorption Line Survey led by **Neeraj Gupta** and **Raghunathan Srianand**; http://mals.iucaa.in/), the number of absorption line systems, especially sight lines through dusty ISM, at radio wavelengths is expected to dramatically increase over the next few years. Detailed HI 21 cm emission and absorption studies over multiple angular scales as presented here will be needed to extract the wealth of information on the neutral ISM in galaxies. Such studies will be routinely possible with SKA-VLBI and the low frequency component of ngVLA.

Efficient cold outflows driven by cosmic rays in high-redshift galaxies and their global effects on the IGM

Saumyadip Samui, **Kandaswamy Subramanian** and **Raghunathan Srianand** present semi-analytical models of galactic outflows in high-redshift galaxies driven by both hot thermal gas and non-thermal cosmic rays. Thermal pressure alone may not sustain a large-scale outflow in low-mass galaxies (i.e., $M \sim 10^8 M_\odot$), in the presence of supernovae feedback with large mass loading. They show that inclusion of cosmic ray pressure allows outflow solutions even in these galaxies. In massive galaxies for the same energy efficiency, cosmic ray-driven winds can propagate to larger distances compared to pure thermally driven winds. On an average, gas in the cosmic ray-driven winds has a lower temperature, which could aid detecting it through absorption lines in the spectra of background sources. Using the constrained semi-analytical models of galaxy formation (that explains the observed ultraviolet luminosity functions of galaxies), they study the influence of cosmic ray-driven winds on the properties of the intergalactic medium (IGM) at different redshifts. In particular, they study the volume filling factor, average metallicity, cosmic ray and magnetic field energy densities for models invoking atomic cooled and molecular cooled haloes. They show that the cosmic rays in the IGM could have enough energy that can be transferred to the thermal gas in presence of magnetic fields to influence the thermal history of the IGM. The significant volume filling and resulting strength of IGM magnetic fields can also account for recent γ-ray observations of blazars.

AstroSat Mission

Results from AstroSat

The first Indian multi-wavelength satellite, AstroSat was successfully launched on September 28, 2015. Since then, AstroSat has been observing many astrophysical objects and collecting unprecedented data. The Large Area X-ray Proportional Counter (LAXPC) is superior to its predecessor on-board the American satellite "Rossi X-ray timing Experiment (RXTE)" by having a significantly larger area in high energies ($> 20keV$) and by having event mode data, wherein each photon information is recorded leading to great flexibility in analysis. Combined with the other instruments on board, namely, the Soft X-ray Telescope (SXT), the Ultra Violet Imaging Telescope (UVIT) and the Cadmium Zinc Telluride Imager (CZTI) LAXPC makes the ideal instrument to unravel the mysteries of rapidly varying bright X-ray sources such as black hole and neutron star systems.

Ranjeev Misra is a member of the LAXPC instrument team and has contributed towards the calibration and software development of the instrument. He has developed user friendly software to do basic analysis such as spectrum, lightcurve and background extraction as well as high level ones, such as frequency and energy dependent power spectra and time-lag computation, and to do flux resolved spectroscopy.

One of the important capabilities of the LAXPC instrument is the detection of high frequency phenomenon from compact object. **Ranjeev Misra** and other members of the LAXPC team were the first to demonstrate millisecond variability measurement capability of LAXPC by detecting a 830 Hz, Quasi-periodic Oscilations (QPOs) in the time variability of the neutron star system 4U 1728-34. While such QPOs have been detected earlier by RXTE, the novelty here is its detection above energies of 10 keV, which is due to larger effective area of LAXPC. Neutron stars undergo thermo-nuclear burning on their surfaces, which are observed as short 10 second burst. During one of the bursts of 4U 1728-34, a burst oscilation at 363 Hz, which is identified with the spin period of the neutron star was detected by LAXPC.

The long term variability capabilities of LAXPC was shown by analysis of the enigmatic X-ray binary Cyg X-3 by the LAXPC team which included **Ranjeev Misra**. Apart from the orbital period of 4.8 hrs, a slower oscillation of 36 days was observed. Further more, complex variations with harmonics in 100s of seconds time-scales were detected in the observed light curves. More importantly, AstroSat observed the source on the onset of a giant radio flare catching the behaviour of the X-ray variation during the event. The source made a state transition and the appearance of an hard power-law tail, which was consistent with having the same origin as the radio emission.

The AstroSat CZT Imager

The AstroSat CZT Imager was used to make the most sensitive measurement so far of the polarisation of hard X-ray emission of the Crab nebula and pulsar at 100 - 380 ke band. The significance of the detection allowed phase-resolved polarimetry at these bands for the first time. Radiation from the Crab pulsar is produced by charged particles gyrating around the local magnetic field, and is expected to be polarised in a direction perpendicular to the projection of this magnetic field. The results show that the position angle of the polarisation is primarily aligned with the projection of the pulsars spin axis on the sky over the entire phase range, strongly suggesting that most of the pulsed emission originates outside the boundary of the pulsars magnetosphere, where the magnetic field becomes azimuthal and is frozen into the outgoing equatorial wind. This is contrary to the usual belief that the radiation is generated from poloidal magnetic field regions within the magnetosphere. These data also hint a variation of polarisation through the off-pulse region, indicating that a significant fraction of this emission may in fact be associated with the pulsar. This work has been done by S. Vadawale, **Dipankar Bhattacharya**, **Ajay Vibhute**, **Gulab C. Dewangan**, **Ranjeev Misra**, et al..

White Dwarfs

Some strongly magnetised white dwarfs exhibit a fast (about 1 Hertz) near-periodic variation of intensity (quasi-periodic oscillations) of optical radiation generated by accretion of matter from a binary companion. These objects also emit X-rays, but surprisingly the quasi-periodic oscillations have not been observed in X-ray bands. A detailed investigation of this radiation process was made via Magnetohydrodynamic simulations of the accretion shock and column. The results display a complex interplay of Cyclotron emission and Bremsstrahlung emission processes that drives the shock instability and also serves to limit the amplitude of X-ray intensity variations This work has been done by **Prasanta Bera** and **Dipankar Bhattacharya**.

LIGO gravitational wave trigger

An optical transient found soon after the LIGO gravitational wave trigger of January 4, 2017 raised the possibility that it may be an optical counterpart of the event. However, AstroSat CZTI observations demonstrated that this was in fact an unrelated Gamma Ray Burst event that occurred 21 hours after the gravitational wave trigger This work has been done by Varun Bhalerao, Mansi Kasliwal, **Dipankar Bhattacharya**, **Vidushi Sharma** and **Ajay Vibhute**.

Interstellar Medium and Planetary Studies

The effect of porosity of dust particles on polarization and colour with special reference to comets

Cosmic dust particles are mostly responsible for polarization of light that we observe from astrophysical objects. They also lead to colour-extinction, thermal re-emission and other scattering related phenomena. Micrometric dust particles are often made of smaller constituent (nanometric grains). They are characterized by their size (average radius), chemical composition and morphology (including porosity). In the present work, **Ranjan Gupta** and collaborators address the question of the role of dust particle porosity on light polarization and colour, using Discrete Dipole Approximation (DDA) light scattering code. To this purpose, they develop an algorithm to generate dust particles of arbitrary values of porosity. In brief, starting from a compact spherical ensemble of dipoles, randomly the dipoles are removed one by one, such that the remaining dipoles remain connected within their neighbours, and stop the removal process when the desired porosity is obtained. Then they compute and study the optical properties of the porous dust particle.The main objective of this work is to develop a tool to generate dust particles with an arbitrary value of porosity and to study the effect of porosity on their light scattering properties. As a possible application, they simulate cometary polarization and colour values, which grossly match with the observed ones for the comet 1P/Halley, leaving scope for future work.

The main conclusions of this study are:

A new generic algorithm able to generate realistic porous aggregates with tunable porosity and tunable dust particle size distribution has been developed. We focused on porous spheres, but generalization of the process to other shapes (e.g., porous ellipsoids) is straightforward.

Using the DDSCAT light scattering code, we showed that such porous dust particles can generate meaningful polarization values for comets, and hence, provide a tool to study in a systematic way the effect of dust particle porosity on cometary light scattering phenomenon, such as polarization, *colour*, etc.

From the analysis of the simulated polarization curves, we find that with the increase in porosity (from 0% to 50%), both the maximum and minimum polarization values change in a non-monotonic way. Indeed, the negative polarization branch becomes deeper with the increase in porosity and then again it becomes shallower. This phenomenon is true for both the wavelengths $\lambda = 0.485\mu m$ and $0.684\mu m$ and with the three values of power law index $\alpha = 1.8$, 2.8 and 3.8 considered here.

More specifically, we have successfully generated polarization values, which match grossly with the observed polarization data for comet Halley. In the first step, this was done for porous pyroxene, to study the effect of porosity on polarization and compare with Effective Medium Theory (EMT).

It has been found that the model of connected dipoles does not produce appreciably different values of polarization as compared to EMT.

Then, taking a more realistic composite model (pyroxene + organic), we make comparison with the observed cometary polarization. It appears that the matching with the observed polarization data of comet Halley (at wavelength $0.485\mu m$) is better with f = 40% porosity and $\alpha = 2.8$ size distribution power law index, though we should adjust the pyroxene to organic ratio to get a better fit.

A sequel work is planned to find the optimum values of the two parameters f, and α and also pyroxene to organic ratio for the composite model which realize the least square fitting to the observed data.

On the other hand, the simulated cometary *colour* values show only weak dependence on the porosity values or on the scattering angles with the noticeable exception of the domain around the back-scattering direction. At the porosity f = 40% and power law index $\alpha = 2.8$, the simulated *colour* value $C \sim -0.6$ (for pyroxene and composite model) does not seem to match well with the average observed *colour* value reported earlier by Kolokolova, et al., which is ~ -0.024. This discrepancy may come from the underestimation of the upper limit of the dust particle radius or from the size dependence of single dust particle *albedo*.

Generally, the simulated *colour* values solely appear to be dependent on the power law index of dust particle size distribution function. Thus, the dust colour depends on dust particle size and this finding confirms a trend reported by Kolokolova, et al. [Icarus, **126** (2) (1997), 351] earlier.

We have also calculated the *colour* slope values for the two dust particle models, as this parameter is often referred in literature.

At last, we showed that the EMT can only be used qualitatively to understand the various features in the polarization or colour behaviours. If quantitative achievement is required, more detailed theory has to be used, such as the DDA method applied to porous particles as generated by the algorithm.

In Figure 22, we provide the plots for the simulated polarization curves with (α, f) fixed at (2.8, 40%) for pyroxene and for the (pyroxene + organics) composite model at 0.485m. For making this plot, the wavelength $0.485\mu m$ was chosen as highest number of observational data points exist corresponding to this wavelength. We clearly see that the observed data points lie between the two curves corresponding to pyroxene and (pyroxene + organics).

Solar Astrophysics

Direct observations of different sunspot waves

Durgesh Tripathi and collaborators have studied the coupling of solar atmosphere through magnetohydrodynamic waves and oscillations associated with sunspots at different heights in the solar atmosphere. Here, we have primarily focused on characterising chromospheric umbral flashes, umbral waves and coronal waves in a sunspot observed in the active region *AR 11133*. This active region was observed on December 11, 2010, by using all the nine filters of Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Obser-

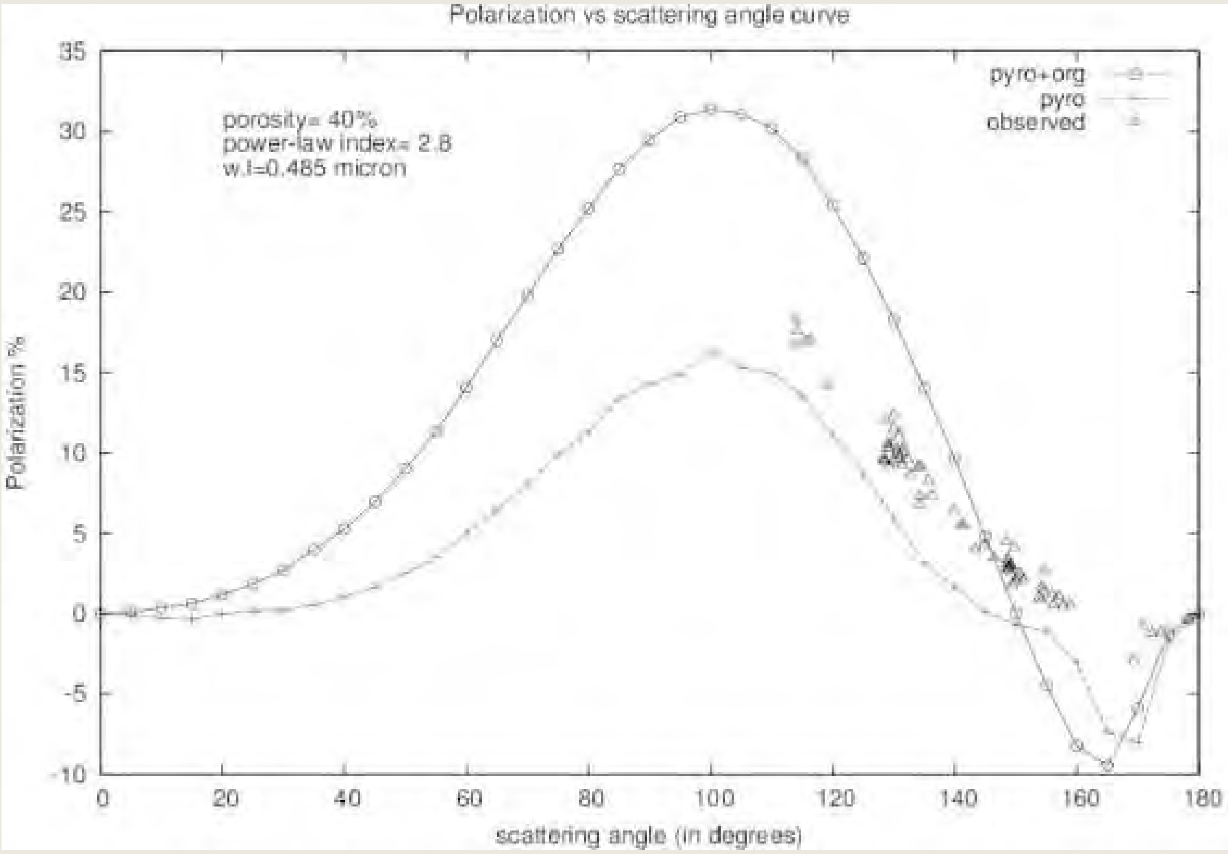


Figure 22: Variations of the simulated polarization versus the scattering angle for the two compositions pyroxene and (pyroxene + organic), with (α, f) values fixed at (2.8, 40%), at wavelength 0.485 μm. The observed polarization values of comet Halley at same wavelength are shown along with.

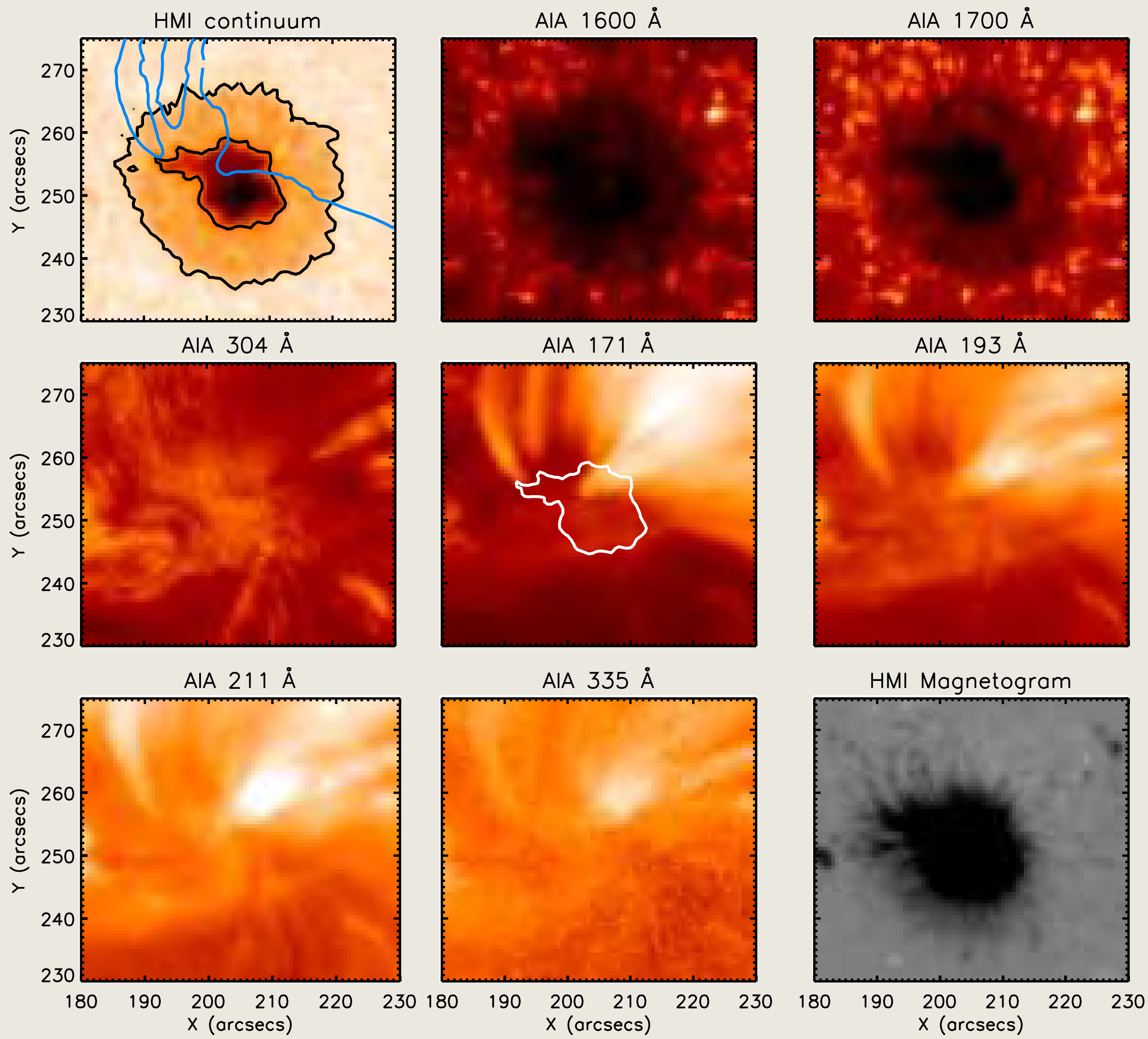


Figure 23: The sunspot in photosphere and associated active region in upper layers of the solar atmosphere observed using different passbands filers of AIA. The umbral and penumbral boundaries are located with the inner and outer contours in the top left panel (HMI continuum). The blue contours in top left panel show the locations of fan loops observed in coronal. The bottom right panel displays the magnetic field structure.

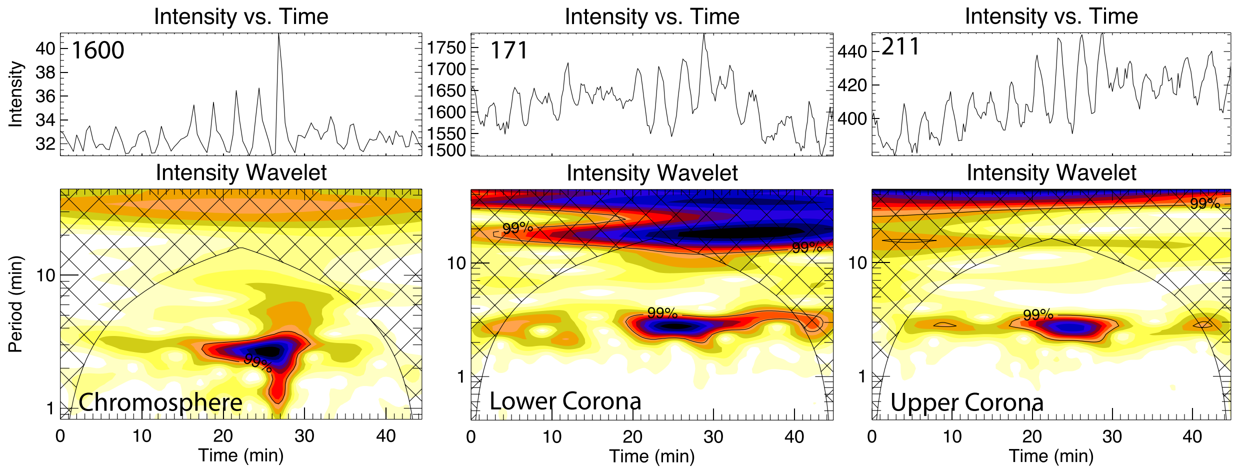


Figure 24: Wavelet analysis results for the intensity light curves obtained in the chromosphere (left, 1600 Å), lower corona (middle, 171 Å) and upper corona (right, 211 Å). In each set, the top panels show the variation of measured intensity with time, which starts around 9:30 UT. The bottom left panels show the computed wavelet power spectrum (blue shaded represents high power density).

vatory (SDO) (see Figure 23). We have used the data taken during 09:30:00 to 10:15:00 UT. The analysis of time-distance maps as well as the original light curves reveal the simultaneous presence of different sunspot waves and oscillations. Most importantly, it shows that the amplitudes of different sunspot waves observed at different atmospheric layers change in synchronization with the light curves obtained from the umbral flash region. These demonstrate that the propagation of other sunspot waves (umbral and coronal waves) are influenced by chromospheric umbral flash oscillations. We also observe almost co-temporal growth of oscillations with a period of 2.8 minute for all the sunspot waves at similar times as the occurrence of the umbral flashes from Wavelet analysis (see Figure 24). This study provides the first observational evidence showing the influence of sunspot oscillations within the umbra on other sunspot waves extending up to the corona from results obtained from original light curves.

PUBLICATIONS BY IUCAA MEMBERS

(a) JOURNALS

1. **Sheelu Abraham,** A. K. Aniyan, **Ajit K. Kembhavi,** Ninan Sajeeth Philip and **Kaustubh Vaghmare** (2018) *Detection of bars in galaxies using a deep convolutional neural network*, MNRAS, **477,** 894.

2. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Search for gravitational waves from Scorpius X-1 in the first advanced LIGO observing run with a hidden Markov model*, PhRvD, **95,** 122003.

3. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Search for intermediate mass black hole binaries in the first observing run of advanced LIGO*, PhRvD, **96,** 022001.

4. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Search for high-energy neutrinos from gravitational wave event GW151226 and candidate LVT151012 with ANTARES and Ice Cube,* PhRvD, **96,** 022005.

5. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *All-sky search for periodic gravitational waves in the O1 LIGO data,* PhRvD, **96,** 062002.

6. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *First low-frequency Einstein@Home all-sky search for continuous gravitational waves in Advanced LIGO data,* PhRvD, **96,** 122004.

7. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *First narrow-band search for continuous gravitational waves from known pulsars in advanced detector data*, PhRvD, **96,** 122006.

8. B. P. Abbott, ... , **Anirban Ain, Dipankar Bhattacharya, Sukanta Bose, Gulab Dewangan, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh, Ajay Vibhute,** et al. (2017) *Multi-messenger observations of a binary neutron star merger*, ApJL, **848,** L12.

9. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *Gravitational waves and gamma-rays from a binary neutron star merger: GW170817 and GRB 170817A*, ApJL, **848,** L13.

10. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *Search for high-energy neutrinos from binary neutron star merger GW170817 with ANTARES, Ice Cube, and the Pierre Auger Observatory*, ApJL, **850,** L35.

11. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *Estimating the contribution of dynamical ejecta in the Kilonova associated with GW170817*, ApJL, **850,** L39.

12. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *On the progenitor of binary neutron star merger GW170817*, ApJL, **850,** L40.

13. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Javed Rana Sk, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *Search for post-merger gravitational waves from the remnant of the binary neutron star merger GW170817*, ApJL, **851,** L16.

14. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh**, et al. (2017) *GW170608: Observation of a 19 solar-mass binary black hole coalescence*, ApJL, **851,** L35.

15. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *First search for gravitational waves from known pulsars with advanced LIGO,* ApJ, **839,** 12.

16. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Search for gravitational waves associated with gamma-ray bursts during the first advanced LIGO observing run and implications for the origin of GRB 150906B*, ApJ, **841,** 89.

17. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Upper limits on gravitational waves from Scorpius X-1 from a model-based cross-correlation search in advanced LIGO data*, ApJ, **847,** 47.

18. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Erratum: First search for gravitational waves from known pulsars with advanced LIGO* (2017, ApJ, **839**, 12), ApJ, **851,** 71.

19. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *VizieR Online Data Catalog: Gravitational waves search from known PSR with LIGO*, yCat, (VizieR Online Data Catalog) **183**.

20. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose,** Shantanu Desai, **Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *A gravitational wave standard siren measurement of the Hubble constant,* Natur, **551,** 85.

21. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Effects of waveform model systematics on the interpretation of GW150914*, CQGra, **34,** 104002.

22. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *Search for continuous gravitational waves from neutron stars in globular cluster NGC 6544*, PhRv, **95,** 082005.

23. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2017) *GW170104: Observation of a 50-solar-mass binary black hole coalescence at redshift 0.2,* PhRvL, **118,** 221101.

24. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *GW170814: A three-detector observation of gravitational waves from a binary black hole coalescence,* PhRvL **119,** 141101.

25. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *GW170817: Observation of gravitational waves from a binary neutron star inspiral*, PhRvL, **119,** 161101.

26. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2018) *First search for non-tensorial gravitational waves from known pulsars*, PhRvL, **120,** 031104.

27. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2018) *GW170817: Implications for the stochastic gravitational-wave background from compact binary coalescences*, PhRvL **120,** 091101.

28. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2018) *All-sky search for long-duration gravitational wave transients in the first advanced LIGO observing run*, CQGra, **35,** 065009.

29. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose, Sanjeev Dhurandhar, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep,** et al. (2018*) Effects of data quality vetoes on a search for compact binary coalescences in advanced LIGO's first observing run*, CQGra, **35,** 065010.

30. **Satadru Bag,** Rajesh Mondal, Prakash Sarkar, Somnath Bharadwaj**, Varun Sahni** (2018) *The shape and size distribution of HII regions near the percolation transition,* MNRAS, **477,** 1984.

31. R. Monteiro-Oliveira, G.B. Lima Neto, E.S. Cypriano, R.E.G. Machado, ... , **Joydeep Bagchi** (2017) *Weak lensing and spectroscopic analysis of the nearby dissociative merging galaxy cluster Abell 3376*, MNRAS, **468,** 4566.

32. K. G. Biju, **Joydeep Bagchi,** ... , **Pratik Dabhade, Samir Dhurde, Sheelu Abraham**, Joe Jacob, Madhav K. Patil, Mahadev Pandge, et al. (2017) *`Zwicky's Nonet': A compact merging ensemble of nine galaxies and 4C 35.06, a peculiar radio galaxy with dancing radio jets*, MNRAS, **471,** 617.

33. **Joydeep Bagchi,** Shishir Sankhyayan, ... , **Somak Raychaudhury**, Joe Jacob, and **Pratik Dabhade** (2017) *Saraswati: An extremely massive ~200 mega-parsec scale supercluster,* ApJ, **844,** 25.

34. **Prasanta Bera** and **Dipankar Bhattacharya** (2018) *Quasi-periodic oscillations from post-shock accretion column of polars*, MNRAS, **474,** 1629.

35. **Yash Bhargava,** A.R. Rao, K.P. Singh, ... , **Gulab C. Dewangan, Dipankar Bhattacharya,** et al. (2017) *A precise measurement of the orbital period parameters of cygnus X-3*, ApJ, **849,** 141.

36. A. R. Rao, M.H. Patil, **Yash Bhargava,** Rakesh Khanna, ... , **Dipankar Bhattacharya,** et al. (2017*) Charged particle monitor on the Astrosat mission,* JApA, **38,** 33.

37. M. M. Kasliwal, E. Nakar, L.P. Singer, D.L. Kaplan, ... , **Dipankar Bhattacharya**, et al. (2017) *Illuminating gravitational waves: A concordant picture of photons from a neutron star merger*, Sci, **358,** 1559.

38. M. L. Middleton, P. Casella, Poshak Gandhi, E. Bozzo, ... , **Dipankar Bhattacharya,** et al. (2017) *Paving the way to simultaneous multi-wavelength astronomy*, New AR, **79,** 26.

39. Varun Bhalerao, M.M. Kasliwal, **Dipankar Bhattacharya,** A. Corsi, ... , **Ajay Vibhute,** et al. (2017) A tale of two transients: GW 170104 and GRB 170105A, ApJ, **845,** 152.

40. Varun Bhalerao, **Dipankar Bhattacharya, Ajay Vibhute**, P. Pawar, A.R. Rao, et al. (2017) *The cadmium zinc telluride imager on AstroSat*, JApA, **38,** 31.

41. M. C. Ramadevi, B.T. Ravishankar, N. Sitaramamurthy, G. Meena, ... , **Dipankar Bhattacharya,** et al. (2017) *Early in-orbit performance of scanning sky monitor onboard AstroSat*, JApA, **38,** 32.

42. **Dipankar Bhattacharya** (2017) *Observing compact stars with AstroSat*, JApA, **38,** 51.

43. M. C. Ramadevi, S. Seetha, **Dipankar Bhattacharya,** B.T. Ravishankar, N. Sitaramamurthy, et al. (2017) *Scanning sky monitor (SSM) onboard AstroSat*, ExA, **44,** 11.

44. S. Vadawale, ... , **Dipankar Bhattacharya**, **Ajay Vibhute**, **Gulab C. Dewangan, Ranjeev Misra,** et al. (2018) *Phase-resolved x-ray polarimetry of the crab pulsar with the AstroSat CZT imager,* NatAs, **2,** 50.

45. **Sukanta Bose**, Debasish Dey, Sudarshana Banerjee, Gufran Ahmad, Sourav Mandal, et al. (2017) *Blue and violet defect levels mediated absorption hot spots in tapered ZnO nanorods toward improved photocatalytic activity*, JMatS, **52,** 12818.

46. Jayasree Roy Sharma, Suchismita Mitra, Hemanta Ghosh, Gourab Das, **Sukanta Bose**, et al. (2018) *Growth of KOH etched AZO nanorods and investigation of its back scattering effect in thin film a-Si solar cell*, PhyB, **530,** 147.

47. **Sukanta Bose**, **Kabir Chakravarti**, Luciano Rezzolla, B. S. Sathyaprakash and Kentaro Takami (2018) *Neutron-star radius from a population of binary neutron star mergers*, PhRvL, **120,** 031102.

48. **Pratik Dabhade**, ... , **Joydeep Bagchi**, Mamta Pandey-Pommier, Shishir Sankhyayan and **Somak Raychaudhury** (2017) *Discovery of giant radio galaxies from NVSS: Radio and infrared properties*, MNRAS, **469,** 2886.

49. **Naresh Dadhich** and Sumanta Chakraborty (2017) *Buchdahl compactness limit for a pure Lovelock static fluid star*, PhRvD, **95,** 064059.

50. **Naresh Dadhich,** Alfred Molina and Josep M. Pons (2017) *Generalized Gödel universes in higher dimensions and pure Lovelock gravity*, PhRvD, **96,** 084058.

51. Sumanta Chakraborty and **Naresh Dadhich** (2018) *1/r potential in higher dimensions*, EPJC, **78,** 81.

52. Main Pal, **Gulab C. Dewangan**, S. D. Connolly and **Ranjeev Misra** (2017) *Correlated x-ray/ultraviolet/optical variability and the nature of accretion disc in the bare Seyfert 1 galaxy Fairall 9*, MNRAS, **466,** 1777.

53. Nibedita Kalita, Alok C. Gupta, Paul J. Wiita, **Gulab C. Dewangan** and Kalpana Duorah (2017) *Origin of x-rays in the low state of the FSRQ 3C 273: Evidence of inverse Compton emission*, MNRAS, **469,** 3824.

54. Alok C. Gupta, Arun Mangalam, Paul J. Wiita, Pankaj Kushwaha, ... , **Gulab C. Dewangan**, et al. (2017) *A peculiar multi-wavelength flare in the blazar 3C 454,* MNRAS, **472,** 788.

55. Pramod Karbhari Pawar, **Gulab C. Dewangan,** ... , Madhav K. Patil, Main Pal, A**jit K. Kembhavi** (2017) *Complex UV/X-ray variability of 1H 0707-495*, MNRAS, **472,** 2823.

56. K. P. Singh, G.C. Stewart, N.J. Westergaard, S. Chandra, ... , **Gulab C. Dewangan**, et al. (2017) *Soft X-ray focusing telescope aboard AstroSat: Design, characteristics and performance*, JApA, **38,** 29.

57. Main Pal, **Gulab C. Dewangan, Ajit K. Kembhavi, Ranjeev Misra** and Sachindra Naik (2018) *Complex optical/UV and x-ray variability of the Seyfert 1 galaxy 1H 0419-577*, MNRAS, **473,** 3584.

58. Aditya S. Mondal, **Gulab C. Dewangan, Mayukh Pahari** and B. Raychaudhuri (2018) *NuSTAR view of the Z-type neutron star low-mass x-ray binary Cygnus x-2*, MNRAS, **474,** 2064.

59. Aru Beri, Biswajit Paul and **Gulab C. Dewangan** (2018) *Changes in the pulse phase dependence of X-ray emission lines in 4U 1626-67 with a torque reversal*, MNRAS, **475**, 999.

60. T. A. Callister, J. B. Kanner, T. J. Massinger, **Sanjeev Dhurandhar** and A. J. Weinstein (2017) *Observing gravitational waves with a single detector*, CQGr, **34,** 155007.

61. **Sanjeev Dhurandhar** and B. S. Sathyaprakash (2017) *Cosmic sirens: Discovery of gravitational waves and their impact on astrophysics and fundamental physics*, CSci, **113,** 663.

62. **Sanjeev Dhurandhar,** Anuradha Gupta, **Bhooshan Gadre** and **Sukanta Bose** (2017) *A unified approach to χ2 discriminators for searches of gravitational waves from compact binary coalescences*, PhRvD, **96,** 103018.

63. **Prakash Gaikwad,** Vikram Khaire, Tirthankar Roy Choudhury and **Raghunathan Srianand** (2017) *Intergalactic Lyman continuum photon budget in the past 5 billion years*, MNRAS, **466,** 838.

64. **Prakash Gaikwad, Raghunathan Srianand,** Tirthankar Roy Choudhury and Vikram Khaire (2017) VoIgt profile Parameter Estimation Routine (viper): H I photoionization rate at z < 0.5, MNRAS, **467,** 3172.

65. **Prakash Gaikwad,** Tirthankar Roy Choudhury, **Raghunathan Srianand** and Vikram Khaire (2018) *Efficient adiabatic hydrodynamical simulations of the high-redshift intergalactic medium*, MNRAS, **474,** 2233.

66. Aishawnnya Sharma, **Girjesh Gupta**, **Durgesh Tripathi**, V. Kashyap and Amit Pathak (2017) *Direct observations of different sunspot waves influenced by umbral flashes*, ApJ, **850,** 206.

67. **Neeraj Gupta, Raghunathan Srianand**, J. S. Farnes, Y. Pidopryhora, M. Vivek, et al. (2018) *Revealing H I gas in emission and absorption on pc to kpc scales in a galaxy at z ~ 0.017*, MNRAS, **476,** 2432.

68. J.-K. Krogager, **Neeraj Gupta**, ... , **Raghunathan Srianand**, Patrick Petitjean, F. Combes, et al. (2018) *MALS-NOT: Identifying radio-bright quasars for the MeerKAT absorption line survey*, ApJS, **235,** 10.

69. Asoke K. Sen, R. Botet, R. Vilaplana, Naznin R.Choudhury and **Ranjan Gupta** (2017) *The effect of porosity of dust particles on polarization and colour with special reference to comets*, JQSRT, **198,** 164.

70. R. Basak, **Shabnam Iyyani,** V. Chand, T. Chattopadhyay, **Dipankar Bhattacharya,** et al. (2017) *Surprise in simplicity: An unusual spectral evolution of a single pulse GRB 151006A,* MNRAS, **472,** 891.

71. **V. Jithesh**, **Ranjeev Misra** and Zhongxiang Wang (2017*) Long-term spectral variability of the ultra-luminous X-ray source Holmberg IX-XI*, ApJ, **849,** 121.

72. J. Zhou, **V. Jithesh**, L. Chen and Z. Wang (2018) *High energy properties of the flat spectrum radio quasar 4C 50.11*, RAA, **18,** 6.

73. **Ravi Joshi, Raghunathan Srianand,** Patrick Petitjean and Pasquier Noterdaeme (2017) *[O II] nebular emission from Mg II absorbers: Star formation associated with the absorbing gas.* MNRAS, **471,** 1910.

74. Sapna Mishra, Hum Chand, Gopal-Krishna and **Ravi Joshi** (2018) *Revisiting the incidence of Mg II absorbers along the blazar sightlines,* **87,** 325.

75. Ewan O'Sullivan, Trevor J. Ponman, **Konstantinos Kolokythas, Somak Raychaudhury,** Arif Babul, et al. (2017) *The complete local volume groups sample – I Sample selection and x-ray properties of the high-richness subsample,* MNRAS, **472,** 1482.

76. Ewan O'Sullivan, **Konstantinos Kolokythas,** Nimisha Kantharia, **Somak Raychaudhury,** Laurence David, et al. (2018) *The origin of the X-ray, radio and H I structures in the NGC 5903 galaxy group*, MNRAS, **473,** 5248.

77. **Labani Mallick, Gulab C. Dewangan,** I. M. McHardy and **Mayukh Pahari** (2017) *Energy-dependent variability of the bare Seyfert 1 galaxy Ark 120*, MNRAS, **472,** 174.

78. Jai Verdhan Chauhan, J. S. Yadav, **Ranjeev Misra,** P. C. Agrawal, H. M. Antia, … , et al. (2017) *AstroSat/LAXPC detection of milli-second phenomena in 4U 1728-34,* ApJ, **841,** 41.

79. Pankaj Kushwaha, Atreyee Sinha, **Ranjeev Misra,** K.P. Singh and E.M. de Gouveia Dal Pino (2017) *Gamma-ray flux distribution and nonlinear behaviour of four LAT bright AGNs*, ApJ, **849,** 138.

80. Harmita Gaur, Liang Chen, **Ranjeev Misra**, Sunder Sahayanathan, ... , **Gulab C. Dewangan** (2017) *The hard X-ray emission of the blazar PKS 2155-304*, ApJ, **850,** 209.

81. K. P. Harikrishnan, **Ranjeev Misra** and G. Ambika (2017) *Is a hyper-chaotic attractor superposition of two multi-fractals?*, CSF, **103,** 450.

82. Rinku Jacob, K. P. Harikrishnan, **Ranjeev Misra** and G. Ambika (2017) *Recurrence network measures for hypothesis testing using surrogate data: Application to black hole light curves*, CNSNS, **54,** 84.

83. Zahir Shah, Sunder Sahayanathan, ... , Pankaj Kushwaha, **Ranjeev Misra**, Naseer Iqbal (2017) *Clues on high-energy emission mechanism from blazar 3C 454.3 during 2015 August flare*, MNRAS, **470,** 3283.

84. **Ranjeev Misra**, A. Bora and **Gulab C. Dewangan** (2017) *Estimation of error on the cross-correlation, phase and time lag between evenly sampled light curves,* A&C, **23,** 83.

85. K.P. Harikrishnan, Rinku Jacob, **Ranjeev Misra** and G. Ambika (2017) *Determining the minimum embedding dimension for state space reconstruction through recurrence netwroks,* Ind. Acad. Sci. Conf. Series, **1,** 1 [doi.10.29195/iascs.01.01.0004].

86. K.P. Harikrishnan, Rinku Jacob, **Ranjeev Misra** and G. Ambika (2017) *Weighted recurrence networks from chaotic time series,* Chao. Model. Sim., **4,** 433.

87. Priya Bharali, Sunder Sahayanathan, **Ranjeev Misra** and Kalyanee Boruah (2017) *Broadening of the thermal component of the prompt GRB emission due to rapid temperature evolution*, NewA, **55,** 22.

88. Naveel Ahmad, **Ranjeev Misra**, Naseer Iqbal, Bari Maqbool and Mubashir Hamid (2018) *Modelling the response of a standard accretion disc to stochastic viscous fluctuations,* NewA, **58,** 84.

89. Rupjyoti Gogoi, P. Shalima and **Ranjeev Misra** (2018) *The distribution of infrared point sources in nearby elliptical galaxies*, NewA, **59,** 21.

90. Sunder Sahayanathan, Atreyee Sinha and **Ranjeev Misra** (2018) Broadband spectral fitting of blazars using XSPEC, RAA, **18,** 35.

91. Kalyani Bagri, **Ranjeev Misra, Anjali Rao,** J.S. Yadac and S.K. Pandey (2018) *Systematic analysis of low/hard state RXTE spectra of GX 339-4 to constrain the geometry of the system* [arXiv: 180202462].

92. **Nikhil Mukund, Sheelu Abraham**, Shivaraj Kandhasamy, **Sanjit Mitra** and Ninan Sajeeth Philip (2017) *Transient classification in LIGO data using difference boosting neural network,* PhRvD, **95,** 104059.

93. **Nikhil Mukund**, **Sheelu Abraham**, ... , **Sanjit Mitra**, Ninan Sajeeth Philip, **Kaustubh Vaghmare,** et al. (2018*) An information retrieval and recommendation system for astronomical observatories*, ApJS, **235,** 22.

94. S. Biscans, J. Warner, R. Mittleman, C. Buchanan, ... , **Nikhil Mukund,** et al. (2018) *Control strategy to limit duty cycle impact of earthquakes on the LIGO gravitational wave detectors,* CQGr, **35,** 055004.

95. **Jayant V. Narlikar** (2018) *The evolution of modern cosmology as seen through a personal walk across six decades*, EPJH, 1 (Online).

96. **T. Padmanabhan** (2017) *Do we really understand the cosmos?,* CRPhy, **18,** 275.

97. **T. Padmanabhan** (2017**)** *The atoms of spacetime and the cosmological constant,* JPCS, **880,** 012008.

98. **T. Padmanabhan** and Hamsa Padmanabhan (2017) *Cosmic information, the cosmological constant and the amplitude of primordial perturbations*, PhLB, **773,** 81.

99. Sumanta Chakraborty, Krishnamohan Parattu and **T. Padmanabhan** (2017**)** *A novel derivation of the boundary term for the action in Lanczos-Lovelock,* GReGr*,* **49,** 121.

100. **T. Padmanabhan** and Hamsa Padmanabhan (2017) *Quantum gravity at Hubble scales determines the cosmological constant and the amplitude of primordial perturbations*, IJMPD**, 26,** 1743002.

101. Sourav Bhattacharya, Sumanta Chakraborty and **T. Padmanabhan** (2017) *Entropy of a box of gas in an external gravitational field - revisited*, PhRvD, **96,** 084030.

102. **T. Padmanabhan** (2018) *Demystifying the constancy of the Ermakov-Lewis invariant for a time-dependent oscillator,* MPLA, **33,** 1830005.

103. **Mayukh Pahari,** I. M. McHardy, **Labani Mallick, Gulab C. Dewangan,** and **Ranjeev Misra** (2017) *Detection of the high-energy cut-off from the Seyfert 1.5 galaxy NGC 5273*, MNRAS, **470,** 3239.

104. H. M. Antia, J.S. Yadav, P.C. Agrawal, … , **Mayukh Pahari, Ranjeev Misra,** et al (2017) *Calibration of the large area X-ray proportional counter (LAXPC) instrument on board AstroSat*, ApJS, **231,** 10.

105. **Mayukh Pahari,** H.M. Antia, Y.S. Yadav, Jai Verdhan Chauhan, …, **Ranjeev Misra**, et al. (2017) *X-ray timing analysis of Cyg X-3 using AstroSat/LAXPC: Detection of milli-hertz quasi-periodic oscillations during the flaring hard x-ray state*, ApJ, **849,** 16.

106. **Mayukh Pahari,** Y.S. Yadav, Jai Verdhan Chauhan, Divya Rawat, **Ranjeev Misra**, et al. (2018) *Extensive broadband X-ray monitoring during the formation of a giant radio jet base in Cyg X-3 with AstroSat*, ApJ, **853,** L11.

107. **Isha Pahwa** and **Aseem Paranjape** (2017) *Analytical halo model of galactic conformity*, MNRAS, **470,** 1298.

108. **Aseem Paranjape** and Nikhil Padmanabhan (2017) *Halo assembly bias from separate universe simulations*, MNRAS, **468,** 2984.

109. Emanuele Castorina, **Aseem Paranjape** and Ravi K. Sheth (2017) *Constraints on halo formation from cross-correlations with correlated variables*, MNRAS, **468,** 3813.

110. Manasi Dhuria, Gaurav Goswami and **Jayanti Prasad** (2017) *Extra-natural inflation redux,* PhRvD, **96,** 083529.

111. Richa Arya, Arnab Dasgupta, Gaurav Goswami, **Jayanti Prasad** and Raghavan Rangarajana (2018) *Revisiting CMB constraints on warm inflation*, JCAP, **2,** 43.

112. G. Schellenberger, Jan M. Vrtilek, Laurence P. David, Ewan O. Sullivan, ... , **Somak Raychaudhury** (2017) *NGC741 - Mergers and AGN feedback on a galaxy group scale,* ApJ, **845,** 84.

113. Asif Iqbal, Ruta Kale, … , Mahadev B. Pandge, Manzoor A. Malik, **Somak Raychaudhury,** et al. (2017) *Active galactic nucleus feedback with the square kilometre array and implications for cluster physics and cosmology*, JApA, **38,** 68.

114. **Sonali Sachdeva, Kanak Saha** and Harinder Pal Singh (2017) *Growth of bulges in disk galaxies since z ~1*, ApJ, **840,** 79.

115. **Kanak Saha,** Alister Graham and Isabel Rodríguez-Herranz (2018) *Building the peanut: Simulations and observations of peanut-shaped structures and ansae in face-on disk galaxies*, ApJ, **852,** 133.

116. Vipin Sudevan, Pavan K. Aluri, Suresh Kumar Yadav, Rajib Saha and **Tarun Souradeep** (2017) *Improved diffuse foreground subtraction with the ILC method: CMB map and angular powers spectrum using Planck and WMAP observations,* ApJ, **842,** 62.

117. Mussadiq H. Qureshi, Asif Iqbal, Manzoor A. Malik and **Tarun Souradeep** (2017) *Low-l power suppression in punctuated inflation*, JCAP, **4,** 13.

118. **Tarun Souradeep**, Sendhil Raja, Ziauddin Khan, C. S. Unnikrishnan and Bala Iyer (2017) *LIGO-India: A unique adventure in Indian science,* CSci, **113,** 578.

119. Amel Durakovic, Paul Hunt, Suvodip Mukherjee, Subir Sarkar and **Tarun Souradeep** (2018) *Reconstruction of a direction-dependent primordial power spectrum from Planck CMB data,* JCAP, **2,** 12.

120. Ivan Agullo, Boris Bolliet and **V. Sreenath** (2018) *Non-Gaussianity in loop quantum cosmology*, PhRvD, **97,** 066021.

121. S. A. Balashev, Pasquier Noterdaeme, Hadi Rahmani, V. V. Klimenko, ... and **Raghunathan Srianand** (2017) *CO-dark molecular gas at high redshift: Very large H_2 content and high pressure in a low-metallicity damped Lyman alpha system*, MNRAS, **470,** 2890.

122. P. Kumar, Gopal-Krishna, C. S. Stalin, Hum Chand, **Raghunathan Srianand,** et al, (2017) *Multi-epoch intra-night optical monitoring of eight radio-quiet BL Lac candidates,* MNRAS, **471,** 606.

123. Ning-Xiano Zhang, W.N. Brandt, N.S. Ahmed, P.B. Hall, ... and **Raghunathan Srianand** (2017) *X-ray insights into the nature of quasars with redshifted broad absorption lines*, ApJ, **839,** 101.

124. Sowgat Muzahid, Jane Charlton, Daisuke Nagai, Joop Schaye and **Raghunathan Srianand** (2017) *Discovery of an H I-rich gas reservoir in the outskirts of SZ-effect-selected clusters*, ApJ, **846,** L8.

125. Hum Chand, Suvendu Rakshit, Priyanka Jalan, Vineet Ojha, **Raghunathan Srianand,** et al. (2018) *Probing the central engine and environment of AGN using ARIES 1.3 m and 3.6 m telescopes,* BSRSL, **87,** 291.

126. Parveen Kumar, Hum Chand, Gopal-Krishna, **Raghunathan Srianand,** C.S. Stalin, et al. (2018) *Spectroscopic and polarimetric study of radio-quiet weak emission line quasars,* **87,** 316.

127. Priyanka Jalan, Hum Chand and **Raghunathan Srianand** (2018) *Transverse and longitudinal proximity effect,* **87,** 330.

128. Aditya K. Aiyer, **Kandaswamy Subramanian** and Pallavi Bhat (2017) *Passive scalar mixing and decay at finite correlation times in the Batchelor regime*, JFM, **824,** 785.

129. Charles Jose, Carlton M. Baugh, Cedric G. Lacey and **Kandaswamy Subramanian** (2017*) Understanding the non-linear clustering of high redshift galaxies*, MNRAS, **469,** 4428.

130. Pallavi Bhat, F. Ebrahimi, E. G. Blackman and **Kandaswamy Subramanian (**2017) *Magneto-rotational instability can sustain turbulence from tangled small-scale fields*, MNRAS, **472,** 2569.

131. Sharanya Sur, Pallavi Bhat and **Kandaswamy Subramanian** (2018) *Faraday rotation signatures of fluctuation dynamos in young galaxies*, MNRAS, **475,** L72.

132. Saumyadip Samui, **Kandaswamy Subramanian** and **Raghunathan Srianand** (2018) *Efficient cold outflows driven by cosmic rays in high redshift galaxies and their global effects on the IGM*, MNRAS, **476,** 1680.

133. Ramkishor Sharma, Sandhya Jagannathan, T.R. Seshadri, **Kandaswamy Subramanian** (2017) *Challenges in inflationary magnetogenesis: Constraints from strong coupling, backreaction and the Schwinger effect*, PhRvD, **96,** 083511.

134. Ramkishor Sharma, **Kandaswamy Subramanian** and T.R. Seshadri (2018) *Generation of helical magnetic field in a viable scenario of inflationary magnetogenesis,* PhRvD, **97,** 083503.

135. **Shyam N. Tandon**, Annapurni Subramaniam, V. Girish, J. Postma, K. Sankarasubramanian, et al. (2017) *In-orbit calibrations of the ultraviolet imaging telescope*, AJ, **154,** 128.

136. **Shyam. N. Tandon**, S. K. Ghosh, J.B. Hutchings, S. Stalin and A. Subramaniam (2017)*Ultraviolet imaging telescope on AstroSat,* CSci, **1**13, 583.

137. **Shyam N. Tandon**, J.B. Hutchins, Swarna K. Ghosh, A. Subramaniam, G. Koshy, et al. (2017) *In-orbit performance of UVIT and first results*, JApA, **38,** 28.

138. **Durgesh Tripathi, A. N. Ramaprakash**, **Aafaque Raza Khan,** ... , **Avyarthana Ghosh, Pravin Chordia,** Dibyendu Nandi, **Chaitanya Rajarshi,** et al. (2017) *The solar ultraviolet imaging telescope on board Aditya-L1*, CSci, **113,** 616.

(b) PROCEEDINGS

1. **Neeraj Gupta, Raghunathan Srianand, Dipankar Bhattacharya,** ... , **Ajit K. Kembhavi**, et al. (2017) *The MeerKAT Absorption Line Survey (MALS)*, Procds. of Science, "MeerKAT Science: On the Pathway to the SKA", Stellenbosch, May 25 - 27, 2016.

2. Matt J. Jarvis, ... , **Neeraj Gupta**, et al. (2017) *The MeerKAT International GHz Tiered Extragalactic Exploration (MIGHTEE) Survey,* Procds. of Science, "MeerKAT Science: On the Pathway to the SKA", Stellenbosch, May 25 - 27, 2016.

3. **Labani Mallick** and **Gulab** C. **Dewangan** (2017) *Large-amplitude X-ray variability and the accretion disc/corona connection in the Seyfert 1 galaxy PG 1404+226,* The X-ray Universe 2017, **136**.

4. **Jayant V. Narlikar** (2017) *Chip Arp (1927-2013)*, The Galileo of Palomar: Essay in Memory of Halton Arp, Eds. Christopher C. Fulton and Martin Kokus (Apeiron, Montreal), 1.

5. Jean-Claude Pecker, **Jayant V. Narlikar**, François Ochsenbin and Chandra Wickramasinghe (2017) *The local contribution to the microwave background radiation*, The Galileo of Palomar: Essay in Memory of Halton Arp, Eds. Christopher C. Fulton and Martin Kokus (Apeiron, Montreal), 1.

6. **Jayant V. Narlikar**, Ram G. Vishwakarma, Shyamal K. Banerjee, P.K. Das and Christopher C. Fulton (2017) *An empirical approach to periodic redshifts*, The Galileo of Palomar : Essay in Memory of Halton Arp, Eds. Christopher C. Fulton and Martin Kokus (Apeiron, Montreal), 1.

7. **Jayant V. Narlikar** (2017) *Relativistic paths: A Feynman problem*, Gravity and the Quantum: Fundamental Theories of Physics, Eds. Jasjit S. Bagla and Sunu Engineer (Springer), 317.

8. **Jayant V. Narlikar** (2018) *Gravitational waves from mini-creation events*, The Physical Universe, Eds. Sanjay M. Wagh, Sunil D. Maharaj and Gayoung Chon (Central India Research Institute, Nagpur), 119.

9. **Chaitanya V. Rajarshi, A.N. Ramaprakash, Pravin Khodade, Siddharth Maharana,** et al. (2017) *RoboPol: A single exposure optical linear polarimeter,* Procds. Intl. Topical Meeting on Applied and Adaptive Optics (INTOPMAA-17), 111.

10. Jan M. Vrtilek, Gerrit Schellenberger, Laurence P. David, Ewan O'Sullivan, ... , **Somak Raychaudhury** (2017) *An abundance of phenomena: Mergers, AGN feedback, radio galaxies, sloshing and filaments in the NGC 741 group,* American Astron. Soc., HEAD Meeting, No. 16, id. 105.02.

11. Gerrit Schellenberger, Jan M. Vrtilek, Laurence P. David, Ewan O'Sullivan, ... , **Somak Raychaudhury** (2017) *NGC 741 - Mergers and AGN feedback on galaxy groups scale,* Procds. Conf. X-ray Universe, Rome, Italy, June 6 - 9, 2017, Ed. J.-U. Ness and Migliari.

(c) TELEGRAMS AND CIRCULARS

1. M.C. Ramadevi, B.T. Ravishankar, Abhilash R. Sarwade, S. Vaishali, ... , **Dipankar Bhattacharya**, et al. (2017) *SSM on AstroSat detects neutron star X-ray transient, Aql X-1 in its outburst,* ATel, No. 10452.

2. A. Anumarlapudi, E. Aarthy, B. Arvind, Varun Bhalerao, **Dipankar Bhattacharya**, et al. (2018) *FRB180301: AstroSat CZTI upper limits,* ATel, No. 11413.

3. A. Anumarlapudi, E. Aarthy, B. Arvind, Varun Bhalerao, **Dipankar Bhattacharya,** et al. (2018) *FRB180311: AstroSat CZTI upper limits and correction to FRB180301 upper limits,* ATel, No. 11417.

4. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170402A: AstroSat CZTI detection,* GCN Circular, No. 21006.

5. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170510A: AstroSat CZTI (Veto) detection,* GCN Circular, No. 21093.

6. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170511A: AstroSat CZTI detection,* GCN Circular, No. 21163.

7. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 170529A: AstroSat CZTI detection,* GCN Circular, No. 21205.

8. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 170607B: AstroSat CZTI detection,* GCN Circular, No. 21232.

9. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170614A: AstroSat CZTI detection,* GCN Circular, No. 21256.

10. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) GRB 170705A: AstroSat CZTI detection, GCN Circular, No. 21327.

11. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170712A: AstroSat CZTI detection,* GCN Circular, No. 21339.

12. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 170702A: AstroSat CZTI detection,* GCN Circular, No. 21348.

13. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 170726A: AstroSat CZTI detection,* GCN Circular, No. 21397.

14. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170805A: AstroSat CZTI detection,* GCN Circular, No. 21502.

15. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170822A: AstroSat CZTI detection,* GCN Circular, No. 21702.

16. Varun Bhalerao, **Vidushi Sharma, Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170830A: AstroSat CZTI detection,* GCN Circular, No. 21773.

17. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 170906A: AstroSat CZTI (Veto) detection,* GCN Circular, No. 21856.

18. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 170921B: AstroSat CZTI detection,* GCN Circular, No. 21922.

19. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171010A: AstroSat CZTI detection,* GCN Circular, No. 21990.

20. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171103A: AstroSat CZTI detection,* GCN Circular, No. 22103.

21. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171120A: AstroSat CZTI detection,* GCN Circular, No. 22143.

22. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171119A: AstroSat CZTI detection,* GCN Circular, No. 22163.

23. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171124A: AstroSat CZTI detection,* GCN Circular, No. 22168.

24. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 171126A: AstroSat CZTI detection,* GCN Circular, No. 22176.

25. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 180103A: AstroSat CZTI detection,* GCN Circular, No. 22310.

26. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171223A: AstroSat CZTI detection,* GCN Circular, No. 22312.

27. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 171227A: AstroSat CZTI detection,* GCN Circular, No. 22313.

28. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 180113A: AstroSat CZTI detection,* GCN Circular, No. 22363.

29. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 180113B: AstroSat CZTI detection,* GCN Circular, No. 22364.

30. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 180120A: AstroSat CZTI detection,* GCN Circular, No. 22370.

31. Y. Sharma, **Vidushi Sharma,** B. Arvind, Varun Bhalerao, **Dipankar Bhattacharya,** et al. (2017) GRB *180112A: AstroSat CZTI detection,* GCN Circular, No. 22421.

32. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao, and S. Vadawale (2017) *GRB 180218A: AstroSat CZTI detection,* GCN Circular, No. 22441.

33. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 180305A: AstroSat CZTI detection,* GCN Circular, No. 22476.

34. **Vidushi Sharma, Dipankar Bhattacharya,** Varun Bhalerao, A.R. Rao and S. Vadawale (2017) *GRB 180314A: AstroSat CZTI detection,* GCN Circular, No. 22515.

35. **Vidushi Sharma,** Varun Bhalerao, **Dipankar Bhattacharya,** A.R. Rao and S. Vadawale (2017) *GRB 180325A: AstroSat CZTI detection*, GCN Circular, No. 22557.

(d) POPULAR ARTICLES

Jayant V. Narlikar

TV sets in the cosmos?, The Asian Age, April 14, 2017.

Help those in need, but avoid quotas, The Asian Age, July 4, 2017.

When scientists are irrational, The Asian Age, July 20, 2017.

There's nothing absolute about time, The Asian Age, September 28, 2017.

Time and its unidirectional flow, The Asian Age, December 12, 2017.

Time is money: Why must we waste it?, The Asian Age, January 31, 2018.

Science should have the last word, The Hindu, February 17, 2018.

Mazi kalpak Aai (in Marathi) (My imaginative mother), Mazi Aai, 25, 2017.

Tisrya peedhiche aatmakathan (in Marathi) (A self account by the third generation), Tisrya Peedhiche Aatmakathan, 101, 2017.

Aani surya hasla! (in Marathi) (And the Sun laughed), Pune Pratishthan, Diwali Issue, 9, 2017.

Khagolshastra ani vaidnyanik paddhati (in Marathi) (Astronomy and the scientific method), Aahuti, Diwali Issue, 17, 2017.

Ek prerak phone call (in Marathi) (A phone call that prompted action), Chaturang, Loksatta, January 13, 2018.

Aapan aahot kuthlya shatkat? (in Marathi) (In what century are we living?), Sakal, March 17, 2018.

Dheyasakta Stephen (In Marathi) (Stephen Hawking: A motivated scientist), Lokrang, Loksatta, March 18, 2018.

Pratik Dabhade

Large sample of giant radio galaxies discovered, Oxford University Press blog (MNRAS journal) https://blog.oup.com/2017/07/giant-radio-galaxies-discovered

(a) IUCAA – NCRA GRADUATE SCHOOL

Sukanta Bose

Electrodynamics and Radiative Processes II (14 lectures) (October - December 2017).

Gulab C. Dewangan

Extragalactic Astronomy II (14 lectures) (March - May 2018).

T. Padmanabhan

Quantum and Statistical Mechanics I (21 lectures) (August - September 2017).

Aseem Paranjape

Methods of Mathematical Physics I (14 lectures) (August - September 2017).

Somak Raychaudhury

Astronomical Techniques I (14 lectures) (January - February 2018)

Raghunathan Srianand

Introduction to Astronomy and Astrophysics I (14 lectures) (August - September 2017).

Tarun Souradeep

Methods of Mathematical Physics II (14 lectures) (October - December 2017).

Durgesh Tripathi

Introduction to Astronomy and Astrophysics II (14 lectures) (October - December 2017).

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

Joydeep Bagchi

Astronomy and Astrophysics Laboratory Course.

Dipankar Bhattacharya

Astronomy and Astrophysics I (22 lectures).

Ranjan Gupta

Astronomy and Astrophysics Laboratory Course (Theory 10 lectures), and related to Observational Astronomy (10 laboratory and night experiments).

Kandaswamy Subramanian: Astronomy and Astrophysics II (18 lectures).

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

Gulab C. Dewangan

Title: *X-ray Spectral Variability of Active Galactic Nuclei*
Student: Main Pal (IUCAA)

Raghunathan Srianand

Title: *Multi-wavelength Spectroscopic Study of Cold Gas in External Galaxies*
Student: Rajeshwari Dutta (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 Bala (IUCAA).

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

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

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

Sukanta Bose

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

Title: *Improving the Detection Efficiency and Parameter Estimation of Neutron Star Binaries through Better GW Modelling.*
Student: Kabir Chakravarti (IUCAA).

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

Title: Space Time Mapping.
Student: Sayak Datta (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 (IUCAA).

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

Gulab C. Dewangan

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

Title: *Multiwavelength Observations of Accretion Disks in Active Galactic Nuclei.*
Student: Pranoti Panchbhai (IUCAA).

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

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

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 Gadre (IUCAA).

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

Aseem 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: Sujata Ramakrishnan (IUCAA).

A.N. Ramaprakash

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

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: *The Emergent Scenario and Other Investigations in Relativistic Cosmology.*
Student: Satadru Bag (IUCAA).

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

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

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

(e) SUPERVISION OF PROJECTS

Md. Shah Alam

Chaitrali Mulay (Savitribai Phule Pune University) *AstroSat reduction techniques,* Vacation Students' Programme, IUCAA.

Joydeep Bagchi and **Pratik Dabhade**

Mary Bosco (St. Joseph's College, Tiruchirappalli, Tamil Nadu) *Identification of giant radio galaxies*.

Anupama Mohanan (Government College, Madappally, Kerala) *Search and analysis of radio galaxies in deep high-frequency radio survey*.

Shreelakshmi M. (Government College, Madappally, Kerala) *Search and analysis of radio galaxies in GMRT low-frequency radio survey.*

Sagar Sethi (Savitribai Phule Pune University) *Exploring the fundamental plane of black hole activity in nearby galaxies*.

Dipankar Bhattacharya

Hrishikesh Shetgaonkar (BITS, Pilani) *Energy dependence of pulsed emission from the Crab,* Vacation Students' Programme, IUCAA.

Sukanta Bose

Abhishek Das (NISER, Bhubaneswar) *Effect of viscosity on non-linear tides in coalescing neutron star binaries,* Vacation Students' Programme, IUCAA.

Tathagata Ghosh (IIT, Kanpur) *Exploring some piecewise polytropic equations of state for neutron stars,* Vacation Students' Programme, IUCAA.

Gulab C. Dewangan

Swapnesh Khade (Savitribai Phule Pune University) *Characterisation of the soft X-ray telescope CCD on AstroSat.*

Pranoti Panchbhai (IUCAA) *Characterizing spectral capabilities of SXT and LAXPC with observation of NGC 4051.*

Girjesh Gupta

Isha Sharma (Fergusson College, Pune) *Propagation of magneto-hydrodynamic waves in the solar corona.*

V. Jithesh

Anjana C. (Government College, Madappally, Kerala) *Broadband X-ray spectral study of ultra-luminous x-ray source M81 X-6 (Ongoing*).

Ajit K. Kembhavi

Madhavi Pachauri (Central University of Rajasthan, Bandarsindri) *Binary orbit and evolution of X-ray binaries,* Vacation Students' Programme, IUCAA.

Akshay Kulkarni (Government College of Engineering, Pune) *Study of binary systems and evolution of X-ray binaries,* Vacation Students' Programme, IUCAA.

Konstantinos Kolokythas

Angaluri Kshitija (Fergusson College, Pune) *The properties of background radio sources in the NGC 924 and NGC2563 fields.*

Nikhil Mukund

Akhil Punia (Vellore Institute of Technology) *Novel strategies for transient detection using Arduino based hardware*.

Khabbab Zakaria (Jadavpur University) *Acoustic noise cancellation in table top Michelson interferometer.*

Urvish Markhad (MIT College of Engineering, Pune) *Adaptive noise cancellation using FPGA*.

Aseem Paranjape

Sindhu Sravya (IIT-Madras, Chennai) *Spherical collapse model,* Vacation Students' Programme, IUCAA.

Niladri Paul

S. Abhinav (BITS, Pilani) *Estimation of cosmological parameters from supernovae-Ia data using the Markov Chain Monte Carlo technique* (jointly supervised with **Aseem Paranjape**).

Somak Raychaudhury

Rwitika Chatterjee (IIST, Thiruvananthapuram), and Lekshmi Thulasidharan (Central University of Tamil Nadu, Thiruvarur) *Probing the dark matter halo of the Milky Way,* Vacation Students' Programme, IUCAA.

Kanak Saha

Suvadip Mandal, (IISER, Kolkata) *Vertical density distribution of NGC 4565 and NGC 7814 observed through Spitzer.*

Sudip Das (IIT, Kanpur) *Morphology of galaxies: Modeling the structures,* Vacation Students' Programme, IUCAA.

Mahathi Chavali (Manipal Institute of Technology, Mangalore), *Photometry of faint galaxies in SDSS Stripe 82 data,* Vacation Students' Programme, IUCAA.

Abhinav Kumar (BITS, Pilani) *Deriving potential using N-body snapshots*.

Tarun Souradeep

Karthik Prabhu (IISER, Pune) *Reconstruction of primordial power spectrum from CMB*.

Raghunathan Srianand

Sunil Simha (IIT - Madras, Chennai) *Origin of Mg II absorbers.*

Jayadev Pradeep (IIST, Thiruvananthapuram) *Statistical estimation of the metallicity of intergalactic medium at low redshifts by spectral stacking of quasar absorption spectra ,* Vacation Students' Programme, IUCAA.

Gitika Shukla (IUCAA) *Diffuse Lyman-α emission around quasars*.

Soumak Maitra (IUCAA) *Spatial correlations in the Lyman-A Forest*.

Niladri Paul (IUCAA) *Halo models for Mg II absorbers*.

Kandaswamy Subramanian

Vaishak Prasad (IUCAA) *Large scale magnetic fields and the turbulent dynamo*.

Rishabh Jain (BITS, Pilani) *Study of winds in the interstellar medium*.

Gaayatri Chandrasekharan, (IISER, Thiruvananthapuram), Indian Academy of Sciences project student, *Smooth cosmology and structure formation* .

Sanaa Agarwal, (BITS, Pilani) *Magnetic reconnection,* Vacation Students' Programme, IUCAA.

A.C. Radhika (IISER, Pune) *Magnetohydrodynamics and its applications*.

Ananya Mohopatra, (NISER, Bhubaneswar) *Magnetohydrodynamics*.

Jishnu Suresh

Mahith Madhanakumar (Cochin University of Science and Technology, Kochi) *Some aspects of general theory of relativity,* Vacation Students' Programme, IUCAA.

Durgesh Tripathi

Nived V. N. (IISER, Pune) *Coronal holes and quiet Sun in transition region*.

Shilpi Buniya (IISER, Pune) *Sources of coronal mass ejections*.

(f) SEMINARS, COLLOQUIA AND LECTURES

Sheelu Abraham

Application of convolutional neural network for the detection of bar structure in optical images of galaxies, Astro-Informatics Conference, Cape Town, South Africa, November 8, 2017.

Detection of barred galaxies with convolutional neural network, galaxy evolution and dynamical structures, International Meeting on Galaxy Evolution and Dynamical Structure (GEDS - 2018), IUCAA, January 22, 2018.

Dipankar Bhattacharya

Crab with AstroSat CZTI, IUCAA Academic Retreat, Panchgani, April 6, 2017.

Accretion columns on magnetic compact stars, Workshop on Cataclysmic Variables, South African Astronomical Observatory, Cape Town, South Africa, April 11, 2017 (Invited).

AstroSat: India's space observatory, Homi Bhabha Centre for Science Education, Mumbai, May 8, 2017.

*Multi-wavelength observations with AstroSat*t, 29th Meeting of the IAGRG, IIT, Guwahati, May 18, 2017 (Invited).

Polarization of gamma ray burst prompt emission, Recent Trends in Compact Star Research Workshop, IIST, Thiruvananthapuram, June 6, 2017 (Invited).

Hard X-ray polarization of gamma ray bursts, Gamma Ray Bursts, NCRA, Pune, July 4, 2017 (Invited).

GRB afterglows with hard spectrum, Gamma Ray Bursts, NCRA, July 5, 2017 (Invited).

IUCAA: Data challenge and plans 2017-2022, Workshop on AstroSat Related Science and Data Aspects, IUCAA, August 11, 2017.

The first binary pulsars and what they told us about binary evolution, IAU Symposium 337 – Pulsar Astrophysics: The Next 50 Years, Jodrell Bank, UK, September 4, 2017 (Invited).

Space borne multi-wavelength observatory AstroSat, Young Astronomers' Meet, IUCAA, September 12, 2017 (Invited).

AstroSat, 3rd BRICS Workshop on Astronomy Infrastructure and Instrumentation, IUCAA, September 21, 2017 (Invited).

Polarisation of gamma ray bursts with AstroSat, Workshop on Two Years of AstroSat, ISRO, Bengaluru, September 27, 2017.

Major facilities at IUCAA: Present and future, Shodh Shiksha Sameeksha, IUCAA, October 1, 2017.

Views on future Astronomy missions, Brainstorming Session on Vision and Explorations in Planetary Sciences in the Decades 2020-2060, PRL, Ahmedabad, November 10, 2017 (Invited).

Implications of GW and GRB observations for the equation of state for neutron stars and merger rates, GW- GRB Detection, IISER, Mohali, December 1, 2017 (By remote presentation, Invited).

AstroSat CZT Imager, International Workshop on AstroSat View of AGN Central Engines, IUCAA, December 21, 2017 (Invited).

Polarised high energy emission from the Crab pulsar, Workshop on Neutron Stars, BITS-Pilani, Hyderabad, January 7, 2018 (Invited).

Space Astronomy in India, Indo-Chilean Astronomical Dialogue - I, IUCAA, January 11, 2018 (Invited).

Science with AstroSat, International Meeting on Galaxy Evolution and Dynamical Structure (GEDS - 2018), IUCAA, January 23, 2018 (Invited).

Polarimetry of gamma ray bursts, International Conference on Advances in Astroparticle Physics and Cosmology, SINP, Kolkata, March 6, 2018 (Invited).

Science with AstroSat, IISER, Kolkata, March 7, 2018 (Colloquium).

Cyclotron resonance in astrophysics, Ramakrishna Mission Vidyapeeth University, Belur, March 8, 2018 (Colloquium).

ISRO call for future Astronomy missions, Team Meeting on Understanding Multi-wavelength Rapid Variability: Accretion and Jet Ejection in Compact Objects, ISSI, Beijing, March 21, 2018 (Invited).

Gulab C. Dewangan

X-ray/UV connections in AGN and the role of AstroSat, Workshop on Recent Trends in Compact Star Research, IIST, Thiruvananthapuram, June 6, 2017 (Invited).

UV/X-ray connections in Seyferts, UVIT Science Meeting, IIA, Bengaluru, July 6, 2017 (Invited).

X-ray/UV connection and the nature of accretion disks in Seyferts, The Power of X-ray Spectroscopy, Poland, Warsaw, September 6 - 8, 2017.

AstroSat and AGN science, Astronomy Seminar, Department of Physics, University of Crete, Greece, September 14, 2017 (Invited).

Performence and calibration of soft x-ray telescope onboard AstroSat, and *AstroSat Proposal Processing System and AstroSat Science Support Cell,* Two Years of AstroSat Meeting, ISRO, Bengaluru, September 27, 2017 (Invited).

AstroSat study of Seyferts, International Workshop on AstroSat View of AGN Central Engines, IUCAA, December 18 - 21, 2017.

X-ray astronomy, Radio Astronomy Winter School, NCRA, Pune, December 21, 2016.

Probing UV/X-ray connection in Seyferts with AstroSat, Meeting on AstroSat Observations of X-ray Binaries and Active Galactic Nuclei, IUCAA, February 2, 2018.

AstroSat study of UV/X-ray connection in radio-quiet AGN, International Conference on Advances in Astroparticle Physics and Cosmology, SINP, Kolkata, March 6, 2018 (Invited).

AstroSat proposals on x-ray binaries, Team Meeting on Understanding Multi-wavelength Rapid Variability: Accretion and Jet Ejection in Compact Objects, International Space Science Institute, Beijing, China, March 19 - 23, 2018.

Sanjeev Dhurandhar

Gravitational wave detection, Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students Programme, IUCAA, May 26, 2017.

Commutative algebra in gravitational wave data analysis, International Conference on Algebra and Analysis, Department of Mathematics, Savitribai Phule Pune University, December 21, 2017 (Invited).

Nobel prize in physics - 2017: Gravitational waves, SERB School on Non-linear Dynamics, Department of Mathematics, Savitribai Phule Pune University, January 8, 2018 (Invited).

Girjesh Gupta

Role of waves and small-scale transients in the heating of solar corona, IPR, Gandhinagar, May 4, 2017.

Solar physics, Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, June 15, 2017.

Role of MHD waves in the heating of solar atmosphere, Udaipur Solar Observatory, June 21, 2017.

Role of magneto-hydrodynamic (MHD) waves in the heating of solar coronal plasma, Plasma Science Society of India, Annual Conference, Gandhinagar, November 7 - 10, 2017.

Observations and modelling of heating and cooling of a coronal loop associated with active region transient brightenings, Dynamic Sun II, Siem Reap, Angkor Wat, Cambodia, February 12 - 16, 2018.

Neeraj Gupta

Infrared colour selected sample of quasars for MALS, SALT Science Meeting, Poland, June 9, 2017.

An update from the uGMRT and MeerKAT absorption line surveys, International Workshop on HI Absorption, ASTRON, Dwingeloo, Netherlands, June 15, 2017.

Exploring radio sky using polarization, 3rd Indo-French Astronomy School on Spectroscopy and Polarimetry, IUCAA, August 4, 2017.

Lectures on spectral line analysis in radio astronomy, Radio Astronomy School, NCRA, Pune, August 30, 2017.

The MeerKAT absorption line survey, SKA Data Science Workshop, Cape Town, South Africa, November 22, 2017.

Evolution of cold gas in galaxies: The MeerKAT absorption line survey, International Workshop on QSO Absorption Lines, IUCAA, December 14, 2017.

HI studies of galaxies, and *ARTIP: Automated radio telescope imaging pipeline*, Franco-Indian Astronomy School, IUCAA, February 16, 2018.

Ranjan Gupta

Optical facilities of IUCAA (IGO + SALT + Guest Observing Programme), IUCAA Academic Retreat, Panchgani, April 7, 2017.

Archeo-astronomy in Indian context, Astro-Archeology Meeting, NIAS, Bengaluru, May 12, 2017.

Polarimetry basics and spectroscopy and modelling of polarimetric observations, 3rd Indo-French Astronomy School on Spectroscopy and Polarimetry, IUCAA, July 31 to August 8, 2017.

Optical astronomy programme, *IUCAA and Mega Projects in Astronomy – India Participation*, S.N. Bose National Centre for Basic Sciences, Kolkata, and IERCOO, Sitapur, Paschim, Medinapur, West Bengal, November 6, 2017.

V. Jithesh

High energy properties of the flat spectrum radio quasar 4C 50.11, 3rd National Conference on High Energy Emission from Active Galactic Nuclei, University of Calicut, Kozhikode, November 30, 2017 (Invited).

Long-term spectral variability of the ultra-luminous x-ray source Holmberg IX X-1, Regional Astronomy Meeting-IV, WMO Arts and Science College, Muttil, Wayanad, December 1, 2017.

Konstantinos Kolokythas

GMRT observations and AGN feedback implications of brightest group galaxies in the local Universe, Astrophysics Seminar, Department of Physics, Leiden University, January 10, 2017.

Low frequency GMRT radio observations of brightest group galaxies in the local Universe, Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS), National Observatory of Athens, December 15, 2017 (Invited).

Ranjeev Misra

AstroSat, Workshop on AstroSat Data Analysis, Tezpur University, May 2017.

AstroSat: A new era for rapid x-ray timing, Workshop on Astronomy and Astrophysics: Recent Trends and Scopes, Assam Kaziranga University, Jorhat, May 2017.

AstroSat, Workshop on AstroSat Related Science and Data Aspects, ARIES, Nainital, August 2017.

AstroSat, Workshop on AstroSat Data Analysis, IUCAA, November 2017.

AstroSat, Workshop on Multi-wavelength Observations using AstroSat, Christ University, Bengaluru, December 2017.

LAXPC background, International Workshop on AstroSat View of AGN Central Engines, IUCAA, December 2017.

AstroSat and black holes, Workshop on Introductory Astronomy, NIIT, Rourkela, March 2018.

Nikhil Mukund

Updates on Lockloss monitoring and prediction, Amaldi'12 Meeting Pasadena, California, July 10, 2017; and LIGO Virgo Collaboration Meeting, Pasadena, California, March 20, 2018.

Jayant V. Narlikar

Hoyle's theories and ideas about gravity, Conference on Recent Developments in Gravity, Drakensburg, South Africa, April 14, 2017.

Saha equation and the dawn of astrophysics, University of KwaZulu-Natal, South Africa, April 20, 2017.

The quasi-steady state cosmology (QSSC), National Institute for Theoretical Physics, South Africa, April 21, 2017.

Logical thinking, 16th INSPIRE Internship Camp, Pt. Ravishankar Shukla University, Raipur, August 24, 2017.

Logical reasoning in science, Bose Institute, Kolkata, November 23, 2017.

Ancient Indian science in a historical context, Meeting on History of Indian Science, Bose Institute, Kolkata, November 24, 2017.

How well do we know our universe?, IIT -Madras, Chennai, September 25, 2017; and IISER, Kolkata, November 25, 2017

Gravitational waves from mini-creation events, International Conference on the Physical Universe, Nagpur, February 27, 2018.

Searches for extraterrestrial life, BITS - Pilani, Hyderabad, March 16, 2018.

T. Padmanabhan

Einstein's legacy: The first and the next 100 years of GR, Research Scholars Day - 2017, IIT-Madras, Chennai, April 5, 2017 (Key note lecture).

Action principles for GR, IIT-Madras, Chennai, April 6, 2017.

The cosmos, Department of Physics, Cochin University of Science and Technology, Kochi, January 10, 2018.

The quantum - classical connection, Newman College, Thodupuzha, January 11, 2018 (Professor K.S. Tomy Endowment Lecture).

Aseem Paranjape

Halo assembly bias: The role of local tides, Workshop on Non-linear Universe, Smartno, Slovenia, July 16 -22, 2017.

DLA environments, International Workshop on QSO Absorption Lines, IUCAA, December 12 -14, 2017.

The assembly of halos and galaxies, 36th Annual Meeting of the Astronomical Society of India, Osmania University, Hyderabad. February 5 - 9, 2018 (Plenary talk).

Dark matter and galaxies, Joint Astro and Particle Physics Meeting, IISER, Pune, February 25, 2018 (Invited).

Niladri Paul

An order statistics approach to the halo model for galaxies, Workshop in the School on Open Problems in Cosmology, International Centre for Theoretical Physics, South American Institute for Fundamental Research, Sao Paulo, Brazil, July 17 - 28, 2017.

Halo model of HI galaxies and their scaling relations, 36th Annual Meeting of the Astronomical Society of India, Osmania University, Hyderabad, February 5 - 9, 2018.

Halo model of HI galaxies and their scaling relations, Introductory School on Galaxy Formation, NISER, Bhubaneswar, March 13 - 16, 2018.

A. N. Ramaprakash

IUCAA instrumentation facilities, Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, June 15, 2017.

Somak Raychaudhury

Introduction to galaxies, Indian Astronomy Olympiad Training Camp, April 29, 2017.

The Milky Way's closest friend, Nehru Planetarium, Mumbai, July 1, 2017 (Public talk).

Finding black holes, Fifth Annual Fr. A. Verstraeten Memorial Lecture, St. Xavier's College, Kolkata, September 15, 2017.

The dark side of the Universe, St. Xavier's Collegiate School, Kolkata, September 15, 2017.

Astronomy in India, 3rd BRICS Workshop on Astronomical Infrastructure and Instrumentation, IUCAA, September 21, 2017.

Large-scale structures in the local Universe, International Workshop on Post-Planck Cosmology: Enigma, Challenges and Visions, IUCAA, October 12, 2017.

Astronomy and astrophysics: The early Indian story in Kolkata, INSA Symposium on the Birth of Modern Science in India, Bose Institute, Kolkata, October 14, 2017.

Large-scale structures in the Universe, Maharashtra Vidnyan Parishad, Mumbai, October 27, 2017 (Public talk).

AGN feedback in groups of galaxies, University of the Western Cape, Cape Town, South Africa, November 13, 2017.

Our place in space, Children's Science Meet, Annual Meeting of the National Academy of Sciences in India, Pune, December 10, 2017 (Public talk).

Global projects in astrophysics for India, Annual Meeting of the Indian National Science Academy, IISER, Pune, December 27, 2017.

Astronomy and astrophysics in India, Indo-Chilean Astronomical Dialogue - I, IUCAA, January 10, 2018 (Inaugural talk).

The essential toolkit for black hole hunters, DPS Day, IISER, Kolkata, January 13, 2018.

Galaxy evolution on the outskirts of clusters, International Meeting on Galaxy Evolution and Dynamical Structures, IUCAA, January 22, 2018.

The evolution of galaxies and their environment, Franco-Indian Astronomy School, IUCAA, February 14, 2018.

Einstein's outrageous legacy: Cosmic illusions and gravitational waves, Pune Science Film Festival, National Film Archives, Pune, March 2, 2018 (Public talk).

Astronomy in India: Technological Challenges, Extentia, Pune, March 30, 2018.

Kanak Saha

*Could there be a low-mass classical bulge in the Milky Wa*y, Korean Institute of Advanced Study, South Korea, April 6, 2017 (Invited).

Long-lived spiral structure in galaxies, Korean Astronomical Society Meeting (Spring), April 14, 2017 (Invited).

Galactic spiral structure revisited, IUCAA, August 3, 2017 (Colloquium).

Pinched and peanut bulges in spiral galaxies, International Meeting on Galaxy Evolution and Dynamical Structure (GEDS - 2018), IUCAA, January 23, 2018.

Varun Sahni

Homi Jehangir Bhabha Award Lecture, Annual Meeting of the Indian National Science Academy, IISER, Pune, December 27, 2017.

Tarun Souradeep

Robust but enigmatic post-Planck cosmos, APC, Paris, France, July 3, 2017 (Colloquium), Penn State University, USA, June 16, 2017, and Seoul National University, South Korea April 11, 2017 (Colloquium).

LIGO-India: Beyond discovery of GW, AAPPS-DPS - 2017, Chengdu, China, September 18 - 23, 2017, TEGRAW, IAP, Paris, June 27, 2017 (Colloquium), and KAS-2017, Changwon, South Korea, April 13, 2017 (Invited).

Space-time murmurs and a nation roused, 29th Meeting of the IAGRG, The Era of Gravitational Waves, IIT, Guwahati, May 18, 2017 (Presidential address).

Statistical isotropy of the cosmos from Planck, CRAL, Lyon, France, June 30, 2017.

Questioning the cosmological principle, IISER, Pune, August 7, 2017.

Testing cosmic statistical isotropy, CCA, New York, USA, November 9, 2017 (Group seminar).

LIGO-India: Beyond discovery into gravitational-wave astronomy, Centre for Excellence in Basic Sciences, Mumbai, November 14, 2017 (Colloquium).

Status of Cosmic Microwave Background: Importance, achievements and promise, Assessing the Prospects for Frontier CMB Space Experiments from India, ISRO, Bengaluru, January 8 - 9, 2018 (Opening talk).

Testing cosmic statistical isotropy, Department of Astronomy and Astrophysics, TIFR Mumbai, January 16, 2018 (Colloquium).

Fourier analysis in cosmology, The Intertwining Strands in Physics and Mathematics: Fourier Analysis, IISER, Pune, January 23, 2018.

Status of CMB and the promise of an Indian collaborative space mission, CGPA-IFTHEP Astro-Particle Physics Meet, IISER, Pune, February 25, 2018.

CMB-Bharat: Case for an India led CMB space mission, LEOS, Bengaluru, March 5, 2018 (Colloquium).

LIGO-India: Beyond discovery of GW, KIPAC, Stanford University, March 20, 2018 (Tea talk).

Status of LIGO-India, LVC Meeting, Sonoma State University, March 21, 2018.

V. Sreenath

Primordial non-Gaussianity in loop quantum cosmology, International Workshop on Post-Planck Cosmology: Enigma, Challenges and Visions, IUCAA, October 9 – 12, 2017.

Raghunathan Srianand

Galaxy Mg II absorber connections, Meeting on Plasma Universe and its Structure Formation, IUCAA, August 30, 2017 (Invited).

A white paper on high resolution spectrograph for TMT, TMT Forum, Mysuru, November 7 - 9, 2017.

[OII] nebular emission from Mg ii absorbers, International Workshop on QSO Absorption Lines, IUCAA, December 12 -14, 2017 (Invited).

Gas flows in low-z AGNs, International Workshop on AstroSat View of AGN Central Engines, IUCAA, December 18 - 21, 2017 (Invited).

Optical astronomy, Indo-Chilean Astronomical Dialogue - I, IUCAA, January 10 -11, 2018.

AGN Jets in the TMT era, Annual Meeting of the Astronomical Society of India, IISER, Pune, December 27, 2018 (Invited).

Kandaswamy Subramanian

A unified large/small scale helical dynamo, Newcastle University, UK, June 2017.

Passive scalar mixing and decay at finite correlation times, Meeting on Plasma Universe and its Structure Formation, IUCAA, August 30 - September 1, 2017.

Primordial magnetic fields, International Workshop on Post-Planck Cosmology: Enigma, Challenges and Visions, IUCAA, October 9 - 11, 2017.

Magnetizing the universe, Presidency University, Kolkata, November 2017 (Colloquium).

Faraday rotation from fluctuation dynamos in MGII systems, International Workshop on QSO Absorption Lines, IUCAA, December 12 - 14, 2017.

Turbulence and magnetic fields beyond light years, turbulence from angstroms to light years, ICTS-TIFR, Bengaluru, January 2018.

A unified large/small scale helical dynamo in stars and galaxies, Conference on Plasma Simulations, IISc, Bengaluru, January 2018.

Magnetic fields in the Universe, Workshop on Solar-Stellar Magnetism, Jaipur, February 2018.

Tutorial on high energy astrophysics, IISER, Kolkata, March 7, 2018.

Kaustubh Vaghmare

Astronomy software, Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, June 8, 2017.

(g) LECTURE COURSES

Joydeep Bagchi

21-cm physics (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June 2017.

Dipankar Bhattacharya

Radiative processes (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May 23 - 25, 2017.

Topics in plasma astrophysics (2 lectures) IISER, Pune, October 6 and 10, 2017.

Sukanta Bose

General relativity and black holes (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June 2017.

Gulab C. Dewangan

Stellar structure, X-ray astronomy and active galactic nuclei (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June 2017.

Sanjeev Dhurandhar

Group representation theory in gravitational wave data analysis (4 lectures) Conference on Black Holes: From Classical to Quantum Gravity, IIT, Gandhinagar, December 15 -17, 2017.

Geometry and symmetry in gravitational wave data analysis (16 lectures) Topical Course, IUCAA, January - March 2018.

Samir Dhurde

Public outreach in science and astronomy, and science toys (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May- June, 2017.

Neeraj Gupta

Inter-stellar medium/radio astronomy (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Ranjan Gupta

Astronomical photometry and spectroscopy (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Basics of astronomy (4 lectures) Advance Meteorological Training Course (Batch 178) for Naval Officers and IMD Recruits, IMD - CTI, Pune, January 29 -30, 2018.

Ranjeev Misra

Accretion disks (2 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Sanjeet Mitra

Gravitational waves (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

T. Padmanabhan

Actions in quantum and classical theories (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Action in physics (4 lectures) IISER, Mohali, September 8 -12, 2017.

Assem Paranjape

Cosmology with large scale structure (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Basic cosmology and growth of structure (3 lectures) Workshop on Galaxy Formation, NISER, Bhubaneswar, March 13 - 16, 2018.

Somak Raychaudhury

Galaxies and clusters (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Kanak Saha

Galaxy dynamics (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Galaxy evolution and dynamics from *reionization to large scale structure: A multi-wavelength approach* (2 lectures), Franco-Indian Astronomy School, IUCAA, February 12, 2018.

Varun Sahni

Dark matter and dark energy (2 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Tarun Souradeep

Cosmology (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Raghunathan Srianand

Introduction to SALT + TMT (4 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Observational probes of galaxy formation (4 lectures) Introductory School on Galaxy Formation, NISER, Bhubaneswar, March 13 - 16, 2018.

Kandaswamy Subramanian

Fluids and plasmas in astrophysics (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Galactic magnetic fields, (4 lectures) Nordita Master Class 2017, Hillerod, Denmark, August 2017.

Baryonic physics and galaxy formation (2 lectures) Introductory School on Galaxy Formation, NISER, Bhubaneswar, March 13 - 16, 2018.

Shyam Tandon

Astronomical instrumentation/AstroSat (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

Dhrugesh Tripathi

The Sun (3 lectures) Refresher Course in Astronomy and Astrophysics (for College and University Teachers), and Vacation Students' Programme, IUCAA, May - June, 2017.

(h) POPULAR/PUBLIC LECTURES

Joydeep Bagchi

Sarasvati in the sky, Vishwakarama Institute of Technology, Pune , September 9, 2017.

The Sarswati Supercluster, IUCAA, November 10, 2017.

Sanjeev Dhurandhar

Detection of gravitational waves: Discovery of the century, Rotary Club, Pune, April 6, 2017.

Nobel prize in physics - 2017 goes to gravitational waves, IIT-BHU, Varanasi, November 12, 2017; CEBS, Kalina, Mumbai University, November 18, 2017; IIT, Ropar, November 23, 2017; National Centre for Cell Science, S.P. Pune University Campus, December 4, 2017; and Akashmitra Astronomy Club, Deccan Gymkhana, Pune, December 10, 2017.

Nobel prize in physics - 2017: Gravitational waves - Einstein's messengers, Science Day, IUCAA, February 28, 2018; and Government College of Engineering, Awasari, Manchar, March 27, 2018.

Konstantinos Kolokythas

A historical journey in ancient Greek astronomy and philosophy, Nehru Planetarium, Mumbai, September 8, 2017.

Jayant V. Narlikar

Searches for extra-terrestrial life, Durban University of Technology, South Africa, April 26, 2017; and Infosys, Pune, September 5, 2017.

Convocation address, Savitribai Phule Pune University, June 30, 2017.

Collisions in space, 2nd Saturday Lecture Demonstration, IUCAA, July 8, 2017.

Antaralatil takri (Collisions in space) (in Marathi), 2nd Saturday Lecture Demonstration, IUCAA, July 8, 2017.

Analytical reasoning, Zeal Polytechnic, Pune, September 22, 2017.

Vedh antaralacha (A view of the sky) (in Marathi), Vivekanand Vyakhyanmala, Vidyarthi Utkarsh Mandal, Mumbai, November 30, 2017.

Recent discovery of gravitational waves, Vikhe Patil Memorial School, Pune, December 11, 2017.

Convocation address, D.D.U. Gorakhpur University, December 19, 2017.

How well do we know our universe?, Somaiya Vidyavihar, Mumbai, January 18, 2018; College of Engineering, Pune, February 5, 2018; International Conference on The Physical Universe, Nagpur, February 25, 2018; and India International Centre, Astha Bharati, New Delhi, March 31, 2018 .

Your experience as an author, Cummins College of Engineering for Women, February 16, 2018.

Shodh paragrahavaril jeevshrusticha (Searches for extraterrestrial life) (in Marathi), Someshwar College of Engineering, March 23, 2018 .

T. Padmanabhan

Einstein's gravity: Past, present and future, Jamia Millia Islamia, New Delhi, August 30, 2017.

The story of the calendar, Kerala State Science and Technology Museum, Thiruvananthapuram, December 6, 2017.

The cosmos, Vijyoshi Camp, IISc, Bengaluru, December 8, 2017.

Aseem Paranjape

The Hitchhiker's guide to the cosmic, Presidency University, Kolkata, January 2018.

Raghunathan Srianand

Dark probes of observable universe, IUCAA, December 12, 2017.

Tarun Souradeep

LIGO-India: Beyond discovery into gravitational-wave astronomy, XIth SERC School, NISER, Bhubaneswar, November 16, 2017; and IIT, Ropar, August 18, 2017.

(i) RADIO/ TV PROGRAMMES

Jayant V. Narlikar

National programme of talks, All India Radio, Pune, March 13, 2018.

Somak Raychaudhury

Eureka with Professor Somak Raychaudhury (Interview), Rajya Sabha TV, April 10, 2017 (https://youtu.be/If701Yp_I0Q).

Tarun Souradeep

Radioscope: National Science Magazine, Interview on LIGO-India, All India Radio, May 12, 2017.

Cosmos with Professor Narlikar, Interviewed Professor Jayant Narlikar, DTH/Rajdhani TV, March 13, 2018.

REFRESHER COURSE IN ASTRONOMY AND ASTROPHYSICS

The biennial Refresher Course in Astronomy and Astrophysics for College and University Teachers was held during May 15 to June 15, 2017 at IUCAA. The faculty coordinator for the refresher course was Aseem Paranjape.
(For details, see Khagol, No. 111, July 2017)

VACATION STUDENTS' PROGRAMME

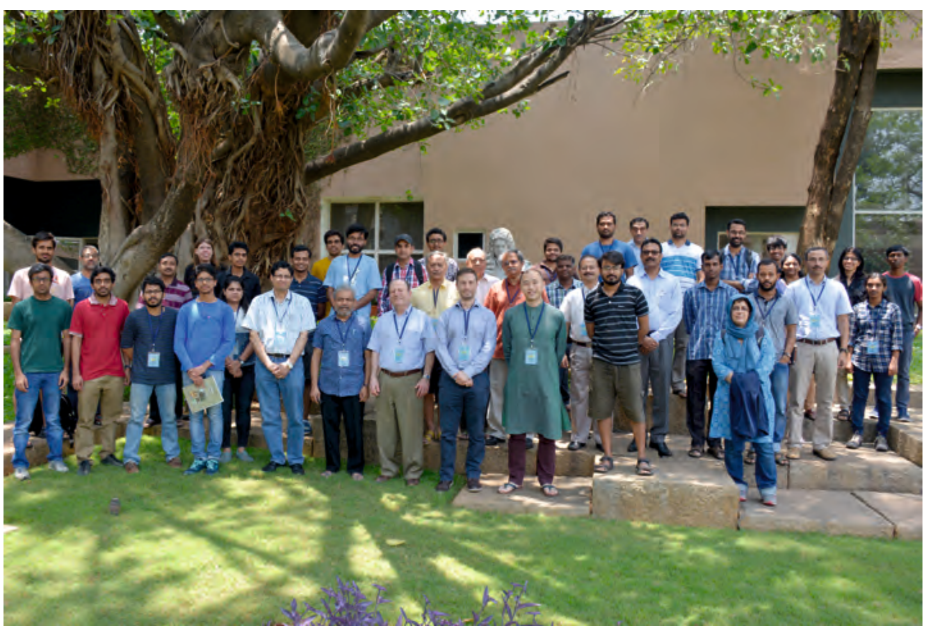
The annual Vacation Students' Programme (VSP) was held during May 15 to June 30, 2017 at IUCAA. R. Srianand was the faculty coordinator of this programme.
(For details, see Khagol, No. 111, July 2017)

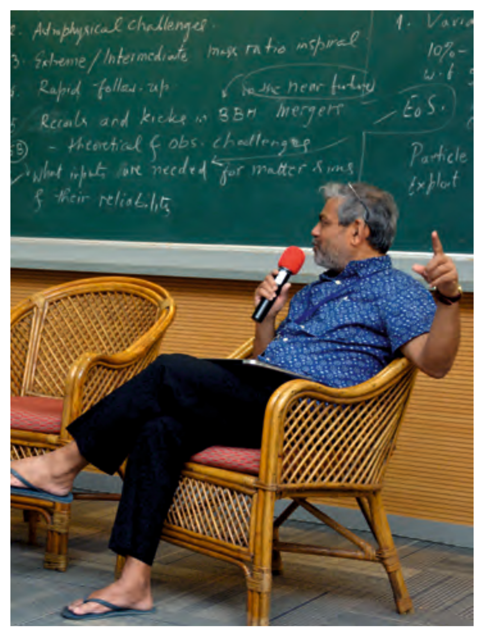
IAU-EC99@IUCAA

The Executive Committee of the International Astronomical Union (IAU) had its 99th annual meeting at IUCAA during May 8 - 12, 2017. The meeting was coordinated by Ajit Kembhavi from IUCAA and Vice-President of IAU.
(For details, see Khagol, No. 111, July 2017)

MEETING ON LIGO - INDIA: THE ROAD AHEAD (LITRA - III)

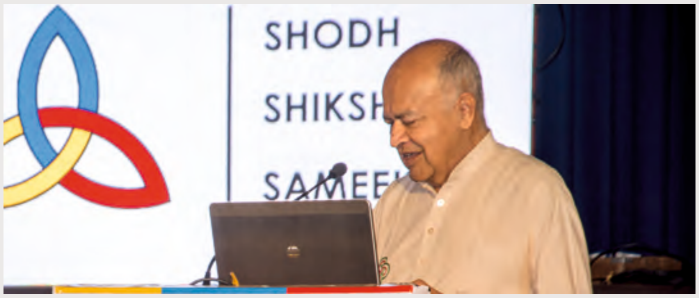
MEETING ON LIGO - INDIA: THE ROAD AHEAD (LITRA - IV)





The fourth meeting in the "LIGO-India: The Road Ahead" (LITRA) series was held at IUCAA, during May 15 -16, 2017. From IUCAA, Sukanta Bose, Sanjeev Dhurandhar, Ajit Kembhavi, Sanjit Mitra, Somak Raychaudhury, and Tarun Souradeep were involved as panelists or organizers.
(For details, see Khagol, No. 111, July 2017)

SHODH SHIKSHA SAMEEKSHA

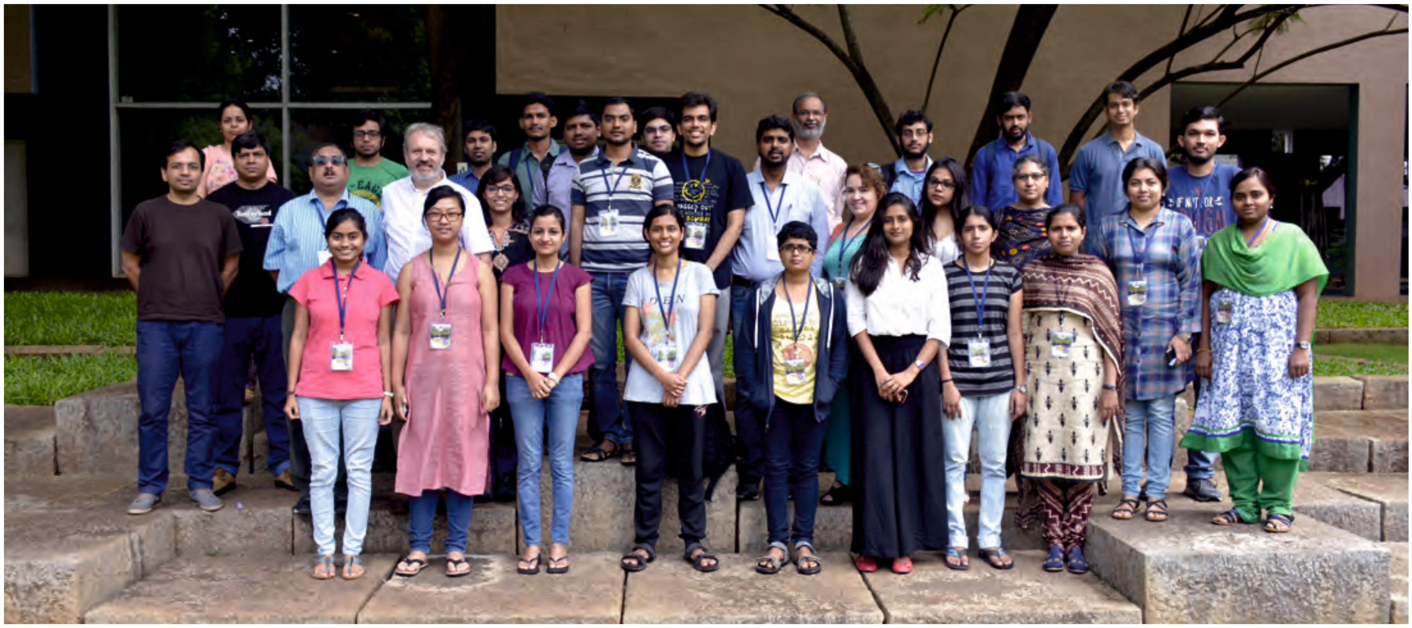


An event initiated by the MHRD/UGC, named, "Shodh Shiksha Sameeksha", was arranged on Sunday, October 1, 2017, at the Chandrasekhar Auditorium, IUCAA. The Inter-University Centres, IUCAA, IUAC, and UGC-DAE CSR have worked behind the scenes make the event success.
(For details, see Khagol, No. 112, October 2017)

MEETING ON PLASMA UNIVERSE AND ITS STRUCTURE FORMATION

A Meeting on Plasma Universe and its Structure Formation was held during August 30 - September 1, 2017 at IUCAA. The meeting was coordinated by Saumyadip Samui (Presidency University, Kolkata) and R. Srianand (IUCAA).
(For details, see Khagol, No. 112, October 2017)

THIRD INDO-FRENCH ASTRONOMY SCHOOL ON SPECTROSCOPY AND POLARIMETRY



Third Indo-French Astronomy School on Spectroscopy and Polarimetry was organized jointly by Centre de Recherche Astrophysique de Lyon (CRAL, CNRS UMR5574, UCBL) and IUCAA, during July 31 - August 8, 2017 at IUCAA. The joint coordinators of this school were Ranjan Gupta and Philippe Prugniel.
(For details, see Khagol, No. 112, October 2017)

THIRD BRICS WORKSHOP ON ASTRONOMY INFRASTRUCTURE AND INSTRUMENTATION

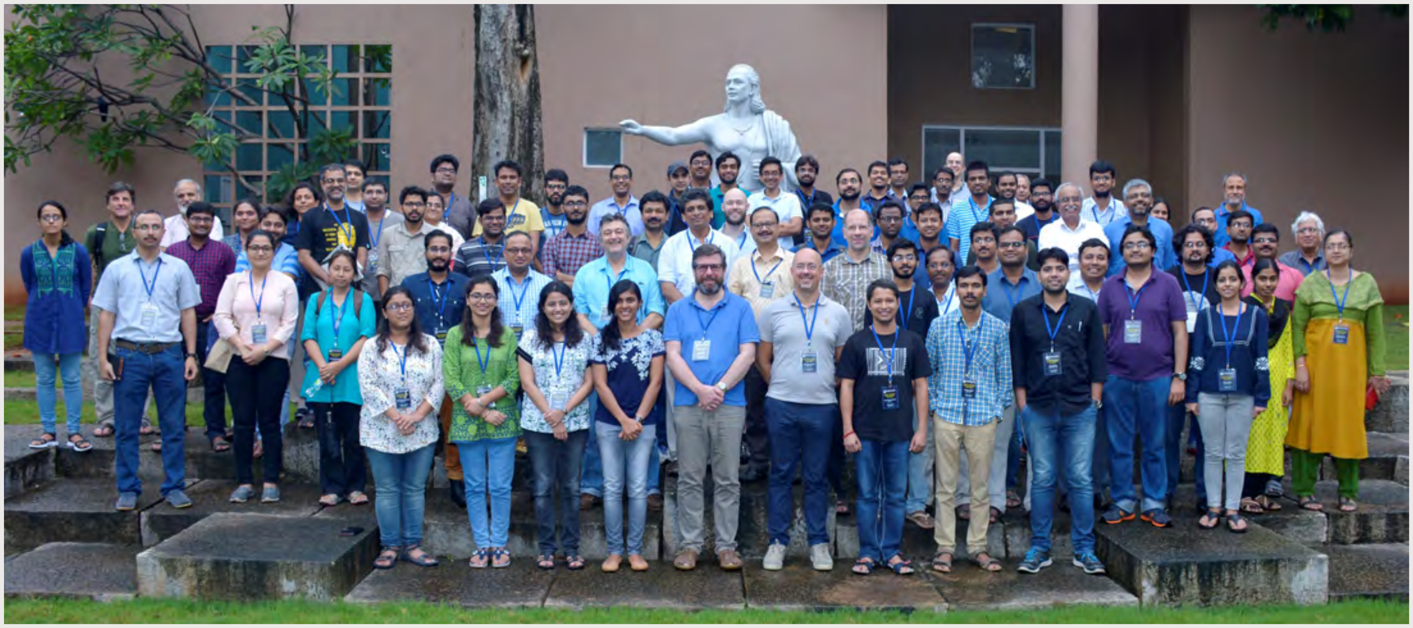
The Third BRICS Workshop on Astronomy Infrastructure and Instrumentation was held at IUCAA, during September 21 - 23, 2017. The workshop was coordinated by Ranjan Gupta from IUCAA along with Harinder Pal Singh from the University of Delhi.

(For details, see Khagol, No. 112, October 2017)

THE 29TH FOUNDATION DAY LECTURE

The 29th Foundation Day Lecture was delivered on Friday, December 29, 2017 at IUCAA. The lecture was delivered by Professor Partha P. Majumder.
(For details, see Khagol, No. 113, January 2018)

INTERNATIONAL WORKSHOP ON POST-PLANCK COSMOLOGY: ENIGMA, CHALLENGES AND VISIONS



An International Workshop on 'Post-Planck Cosmology: Enigma, Challenges and Vision' was conducted at IUCAA during October 9 - 11, 2017. The workshop was co-organised by Suvodip Mukherjee (Centre for Computational Astrophysics, New York) and Tarun Souradeep and Sanjit Mitra (IUCAA).
(For details, see Khagol, No. 113, January 2018)

INTERNATIONAL WORKSHOP ON AstroSat VIEW OF AGN CENTRAL ENGINES

An International Workshop on AstroSat View of AGN Central Engines was organised at IUCAA during December 18 - 21, 2017. Gulab C. Dewangan was the coordinator.
(For details, see Khagol, No. 113, January 2018)

INTERNATIONAL WORKSHOP ON QSO ABSORPTION LINES

A three-day International Workshop on QSO Absorption Lines was held at IUCAA during December 12 -14, 2017. The workshop was coordinated by Neeraj Gupta, Raghunathan Srianand, Hsiao-Wen Chen and Donald York. (For details, see Khagol, No. 113, January 2018)

IUCAA-NCRA RADIO ASTRONOMY WINTER SCHOOL

The 10th Radio Astronomy Winter School (RAWSC) jointly by IUCAA and NCRA was organized during December 18 - 26, 2017 at IUCAA. Neeraj Gupta (IUCAA) and Subhashis Roy (NCRA) were the coordinators.
(For details, see Khagol, No. 113, January 2018)

WORKSHOP ON AstroSat DATA ANALYSIS

The ISRO sponsored workshop on AstroSat Data Analysis was held at IUCAA during November 13-26, 2017.
(For details, see Khagol, No. 113, January 2018)

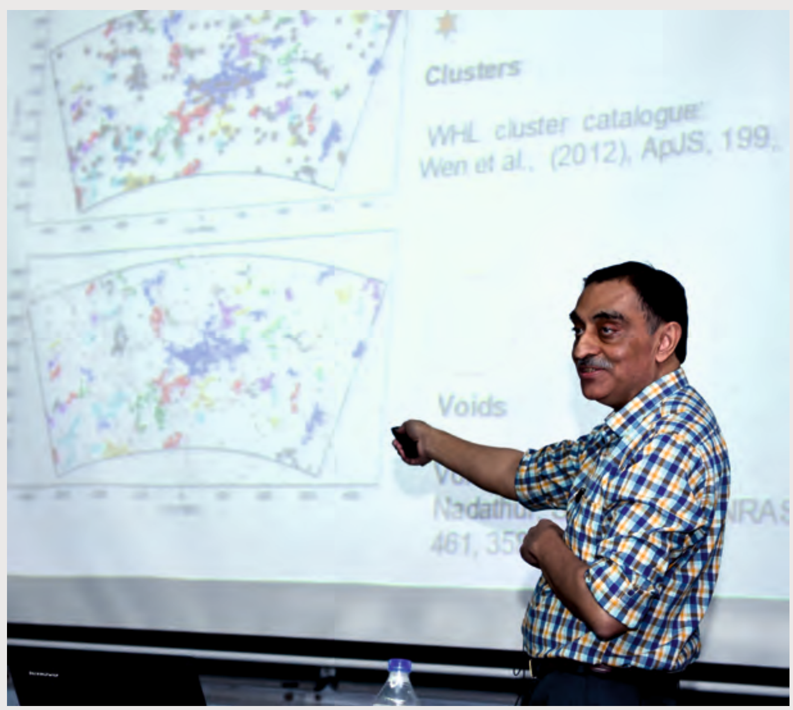
INTERNATIONAL MEETING ON GALAXY EVOLUTION AND DYNAMICAL STRUCTURES

An International Meeting on Galaxy Evolution and Dynamical Structures (GEDS) was held during January 22 - 24, 2018 at IUCAA. The meeting was jointly supported by the Indian Institute of Science, Bengaluru and IUCAA.
(For details, see Khagol, No. 114, April 2018)

INDO-CHILEAN ASTRONOMICAL DIALOGUE - I

The First Indo-Chilean Astronomical Dialogue was organized at IUCAA, during January 10 - 11, 2018. Ranjan Gupta (IUCAA) was the coordinator.
(For details, see Khagol, No. 114, April 2018)

FRANCO-INDIAN ASTRONOMY SCHOOL



Under the auspices of Indo-French Centre for the Promotion of Advanced Research (IFCPAR/CEFIPRA), a Franco-Indian Astronomy school was organised at IUCAA during February 11 - 17, 2018. Joydeep Bagchi and Mamta Pandey-Pommier were the coordinators of the school.
(For details, see Khagol, No. 114, April 2018)

IUCAA-NCRA GRADUATE SCHOOL

Ph.D. Programme

During the year of this report, two IUCAA Research Scholars have defended their Ph.D. theses, namely: **Rajeshwari Dutta** (Guide: R. Srianand), and **Main Pal** (Guide: Gulab Dewangan). Their Ph.D. degrees have been awarded by the Jawaharlal Nehru University, New Delhi. The synopses of their theses are given below:

Rajeshwari Dutta

MULTI-WAVELENGTH SPECTROSCOPIC STUDY OF COLD GAS IN EXTERNAL GALAXIES

The doctoral research is focused on understanding the properties of the cold gas phase of the interstellar/circumgalactic medium of galaxies. We have been using the tool of quasar absorption line spectroscopy to probe gas in and around galaxies. As part of the thesis, we have carried out surveys of H I 21-cm absorption in : (i) $z < 0.4$ quasar-galaxy-pairs (QGPs) (Dutta, et al. 2017, MNRAS, **465**, 588); and (ii) $0.3 < z < 1.5$ strong Mg II systems (Dutta et al. 2017, MNRAS, **465**, 4249; Dutta, et al. 2017, **468**, 1029). In addition, we have conducted in-depth multi-wavelength studies of two individual absorption line systems (Dutta, et al. 2015, MNRAS, **448**, 3718; Dutta, et al. 2016, MNRAS, **456**, 4209). The main results from the thesis are highlighted below:

(a) Distribution of cold H I gas around $z < 0.4$ galaxies

With a view to map the distribution of high neutral hydrogen column density (N(H I) $\geq 10^{19}$ cm^{-2}) cold ($T \sim$ few 100 K) gas around galaxies, we have carried out a systematic search of H I 21-cm absorption in a sample of 55 at $z < 0.4$ galaxies towards radio sources at impact paramters, $b \sim$ 0−35 kpc. The H I 21-cm absorption searches were carried out using $\sim$ 400 hrs of Giant Metrewave Radio Telescope (GMRT), Karl G. Jansky Very Large Array (VLA) and Westerbork Radio Synthesis Telescope (WSRT) observations. The optical properties of the galaxies were obtained using long-slit spectroscopic observations with the Southern African Large Telescope (SALT), and images and fibre spectra from the Sloan Digital Sky Survey (SDSS). In the statistical sample of 40 quasar-galaxy-pairs or QGPs, probed by 45 sightlines, we have found seven H I 21-cm absorption detections. The measurements from the survey have increased the existing number of sensitive H I 21-cm optical depth measurements at low-z by more than a factor of three and the number of H I 21-cm detections from QGPs by a factor of two.

Combining the H I 21-cm measurements with those present in literature with similar sensitivity, as well as with optical properties of the galaxies, we have studied the radial and azimuthal profiles of H I 21-cm absorption around low-z galaxies, and quantified the covering factor of H I 21-cm absorbers as a function of various physical parameters. The main results from this study are: (i) The strength

($\int \tau dv$) and covering factor (C_{21}) of H I 21-cm absorbers decreases, albeit slowly, with increasing impact parameter. There is a weak anti-correlation (rank correlation coefficient = -0.20 at 2.42σ level) between $\int \tau dv$ and b. C_{21} decreases from $0.24^{+0.12}_{-0.08}$ at $b \leq 15$ kpc to $0.06^{+0.09}_{-0.04}$ at $b = 15{-}35$ kpc. $\int \tau dv$ and C_{21} show similar declining trend with radial distance along the galaxy's major axis and distances scaled with the effective H I radius. (ii) There is tentative indication that most of the H I 21-cm absorbers could be co-planar with the extended H I discs. $\int \tau dv$ and C_{21} are higher when the radio sightline passes near the galaxy's major axis. (iii) $\int \tau dv$ and C_{21} do not depend significantly on the host galaxy properties, i.e., luminosity, stellar mass, colour, surface star formation rate density. Hence, the distribution of H I 21-cm absorbers seems to be more sensitive to geometrical parameters than physical parameters related to the star formation in galaxies. (iv) The relative strength of Ca II and Na I absorption in the SDSS spectra of the quasars suggest that the most of the H I 21-cm absorbers are not likely to arise in the dusty star-forming disks. (v) The detection rate of H I 21-cm absorption in the galaxy-selected QGP sample is four times less than that in damped Lyman-α systems (DLAs; $N(\text{H I}) \geq 2 \times 10^{20}\ \text{cm}^{-2}$) at $z < 1$, which indicates towards *small sizes (parsec to sub-parsec scale) and patchy distribution of cold gas clouds around low-z galaxies.* Our results suggest that about $\sim$ 30% of the H I gas around galaxies contributes to the DLA population, and $\sim$ 60% of the DLAs have cold gas that can produce detectable H I 21-cm absorption.

(b) Parsec to kiloparsec-scale structures in the H I gas around low-z galaxies

As part of the efforts to study the cold H I gas around low-z galaxies, we have observed parsec- and kiloparsec-scale structures in the H I gas around two low-z galaxies. The results from the multi-wavelength studies of these two systems are summarized below:

Using Lyman $-$ α and molecular H_2 absorption detected in the Hubble Space Telescope $-$ Cosmic Origins Spectrograph (HST$-$COS) spectrum, and metal absorption detected in the Very Large Telescope $-$ Ultraviolet Echelle Spectrograph (VLT$-$UVES) spectrum towards PKS 0439$-$433, we have carried out a detailed analysis of cold parsec-scale gas at $b \sim 8$ kpc from a $z = 0.1$ star-forming galaxy. Using Very Large Baseline Array (VLBA) 1.4 GHz continuum emission from the radio source and H I 21-cm absorption, we have constrained the size of the molecular gas to be $\lesssim$100 pc. The inferred physical and chemical conditions from our photoionization modelling suggest that the gas may be tracing a recent metal-rich outflow from the host galaxy.

Next, the GMRT H I 21-cm absorption and emission observations and Keck High Resolution Echelle Spectrometer (HIRES) optical spectra have revealed kpc to sub-kpc-scale structures in the H I gas associated with the $z = 0.02$ spiral galaxy, UGC 00439. Using H I 21-cm absorption towards different components of the extended background radio source, and Ca II and Na I absorption towards the optical quasar, we find a factor of $\sim$7 variation in the H I 21-cm optical depth over a $\sim$7 kpc region at $b \sim 25$ kpc from UGC 00439. The absorption is most likely tracing clumpy cold gas corotating with the galaxy. The absorption could also be tracing gas that is stripped out of the H I disc of the galaxy due to tidal interactions with two neighbouring galaxies at $\sim$150 kpc.

(c) Search for cold H I gas in strong Mg II systems at $0.3 < z < 1.5$

Strong Mg II absorbers (rest equivalent width of Mg II λ2796, $W_{\text{Mg II}} > 1$ Å) are believed to trace gas with high $N(\text{H I})$ (Rao, et al. 2006, ApJ, **636**, 610). Using Mg II systems at $z < 1.65$ and at $z \sim 2$, where simultaneous measurements of N(H I) and $W_{\rm Mg\,II}$ are possible (Rao, et al. 2006; Noterdaeme, et al. 2012, A&A, **547**, L1; Zhu and Menard 2013, ApJ, **770**, 130), we have found that strong Mg II absorbers with W(Fe II λ2600) ($W_{\rm Fe\,II}$) > 1 Å have $\sim 50 - 60\%$ probability of being DLAs. Hence, we have carried out a survey of H I 21-cm absorption in 16 strong Fe II systems with $W_{\rm Fe\,II} \geq 1$Å at $0.5 < z < 1.5$ selected from SDSS DR-12, using 110 hrs of GMRT and Green Bank Telescope (GBT). The survey has resulted in six new H I 21-cm absorption detections, increasing the known number of detections in strong Mg II systems at this redshift range by $\sim 50\%$, and demonstrating that a selection technique based on Fe II absorption strength can increase the probability of detecting high N(H I) cold gas by a factor of ~ 2.

The main results from this survey are: (i) The H I 21-cm detection rate increases with $W_{\rm Fe\,II}$, being four times higher in systems with $W_{\rm Fe\,II} \geq 1$ Å compared to in systems with $W_{\rm Fe\,II} < 1$ Å. (ii) The incidence of H I 21-cm absorption in strong Fe II systems remains constant over $0.5 < z < 1.5$ within the uncertainties. However, the incidence of H I 21-cm absorption in DLAs is found to increase from $z \sim 3$ to $z < 1.5$, which may indicate towards an increasing filling factor of cold gas in DLAs with time. (iii) The systems which give rise to H I 21-cm absorption tend to cause more reddening due to dust in the spectrum of the background quasar, as well as produce stronger metal absorption on average. (iv) The velocity widths of intervening H I 21-cm absorption lines show an increasing trend (significant at 3.8σ) with redshift at $z < 3.5$, which may be due to the H I 21-cm absorbers being probed by more massive galaxy halos at high-z.

Next, thanks to the SDSS-Baryon Oscillation Spectroscopic Survey (BOSS), a large number of quasar spectra are available, which can be searched for Mg II absorption at $z < 0.5$, where identification of host galaxies is relatively easier. We have carried out a survey of H I 21-cm absorption in eleven strong Mg II systems at $0.3 < z < 0.5$ selected from SDSS DR-12, using 108 hrs of GMRT. This survey has resulted in two H I 21-cm absorption detections. The lack of H I 21-cm absorption in the other nine Mg II systems could be because they are arising from sub-DLAs, from which we do not have sufficient optical depth sensitivity to detect cold ~100 K gas. By comparing with H I 21-cm searches in strong Mg II systems at $0.5 < z < 1.5$ from the literature, we do not find any significant evolution in the incidence and number density per unit redshift of H I 21-cm absorbers in strong Mg II systems at $0.3 < z < 1.5$.

The results from the H I 21-cm absorption surveys along with the detailed studies of individual absorption line systems will be crucial to interpret the data from upcoming blind H I 21-cm absorption line surveys using the Square Kilometer Array pathfinders. To gain further insight into the metal, dust, molecular content and host galaxy properties of cold gas, the surveys will be followed up with optical, ultraviolet and sub-millimetre spectroscopy and imaging.

Main Pal

X-RAY SPECTRAL VARIABILITY OF ACTIVE GALACTIC NUCLEI

Active Galactic Nuclei (AGN) are the most luminous objects in the Universe emitting continuously over almost the entire electromagnetic spectrum from radio to hard X-rays. The bolometric luminosity is found typically in the range of $10^{40} - 10^{47}$ erg s^{-1}, and this huge luminosity is normally attributed to the accretion of material onto a supermassive black hole (SMBH) sitting at the centre of an active galaxy. The X-ray emission in the $0.1-100$ keV band is the most emission from AGN, almost all AGN are X-ray loud. The observed X-rays provide not only a significant fraction of the total luminosity but also exhibit rapid variability on timescale as short as an hour, which is comparable to the size of the innermost stable orbit around a 10^8 $M_\odot$ black hole. This makes X-ray emission from AGN as the best means currently available to probe the extreme physical conditions in the immediate environments of SMBHs directly.

The spectral energy distribution of type 1 AGN such as Seyfert 1 galaxies can have the following main spectral components in the X-ray to UV/optical bands: (a) Soft X-ray excess below ~ 2 keV, (b) Fe-Kα line near 6 keV and Compton reflection hump in the $10-50$ keV band, (c) Power-law emission with high energy cut-off, and (d) Big blue bump (BBB) emission peaking near 0.01 keV. These spectral components are thought to arise from physically distinct regions in the AGN central engine. For example, the power-law emission is thought to be originated through inverse Compton scattering of seed photons in a hot plasma (~ 100 keV). The UV/optical emission is considered to arise from different parts of the accretion disc and acts as the seed photon for the Comptonization. The different spectral components arising from physically distinct regions are expected to vary differently. Therefore, variability of different spectral components and relationship between them can help to probe central engine and its surroundings.

We have analyzed a total of 178 observations of three Seyfert 1 galaxies 1H 0419–577, II Zw 177 and Fairall 9, performed with `XMM-Newton`, `Suzaku` and `Swift`. We begin with the ambiguity related to hard excess in the 15 – 50 keV band. Turner, et al. (2009) studied *Suzaku* observation of Seyfert 1 galaxy 1H 0419–577. They claimed that the high energy hump in the 10–50 keV band could be explained by a Compton thick partial covering (covering fraction $\sim 70\%$) absorption near the central source. Using the same observation, Walton, et al. (2010) reported that the hump could be interpreted as a result of Compton back-scattering from optically thick material such as distant putative torus or accretion disc. To investigate further, we studied broadband X-ray spectral variability of this AGN in detail using two *Suzaku* and two *XMM-Newton* observations. All observations showed strong soft X-ray excess below 2 keV, and moderate Fe-Kα line near 6 keV. Both *Suzaku* observations exhibited hard excess in the 10 – 50 keV band. We fitted broadband X-ray emission using viable models such as partially covering ionized absorption, reflection from partially ionized accretion disc and Comptonized intrinsic disc model. We found that the blurred reflection model describes the 0.6 – 50 keV band including soft excess statistically in a better way compared to other two models. The spectral variability of two *Suzaku* observations showed the correlation between soft excess flux and Fe-K line flux. This correlation suggests the reflection origin of these components. However, the simple light bending model is unable to describe the observed power-law flux and reflected emission flux, which vary in a similar way in the broad X-ray band. In the framework of reflection model, the extended corona can explain variable and correlated power-law emission and soft excess flux. Possibly the changes in the geometry of disc/corona is playing an important role due to the variation in accretion rate.

We further studied the interplay between the disc and the hot corona using six simultaneous observations in UV/Optical and X-ray bands performed with X̂MM-Newton. The UV/Optical emission is found to be variable on days to years timescales in Seyfert 1 galaxies. The origin of UV/Optical variability and its relationship with X-ray variability is not clearly understood. We have performed a detailed broadband UV/Optical to X-ray spectral variability of the Seyfert 1 galaxy 1H 0419–577 using six *XMM-Newton* observations during 2002 – 2003. These observations covered a large amplitude variability event, in which the soft X-ray $(0.3-2$ keV) count rate increased by a factor of ~ 4 in six months. The X-ray spectra during the varibility are well described by a model consisting of a primary power-law, blurred and distant reflection. The $2-10$ keV power-law flux varied by a factor ~ 7, while the $0.3-2$ keV soft X-ray excess flux derived from the blurred reflection component varied by a factor of ~ 2 only. The variability event was also observed in the optical and UV bands but the variability amplitudes were only at $6-10\%$ level. The variations in the optical and UV bands appear to follow the variations in the X-ray band with a lag of $\sim$ three months. During the rising phase, the optical bands appear to lag behind the UV band but during the declining phase, the optical bands appear to lead the UV band. Such behaviour is not expected in the reprocessing models where optical/UV emission is the result of reprocessing of X-ray emission in the accretion disc. The delayed contribution of the broad emission lines in the UV band or the changes in the accretion disc/corona geometry combined with X-ray reprocessing may give rise to the observed behaviour of the variations in the optical, UV and X-ray bands.

Furthermore, many type 1 AGN show soft X-ray excess below ~ 2 keV. The origin of this component has remained a problem since its discovery in 1985 by Singh, et al. This issue can be addressed by those sources which show strong soft X-ray excess over the power-law emission. II Zw 177 is one such narrow line Seyfert 1 galaxy. We performed a long *XMM-Newton* observation of this source, and studied the spectral variability on short and long timescales using our long ~ 130 ks observation in 2012 and an earlier ~ 13 ks observation in 2001. This object showed strong soft excess below 2 keV in both the datasets. We used a number of spectral models such as the complex partially ionized absorption, blurred reflection from partially ionized accretion disc and intrinsic Comptonized disc emission. We found that both the blurred reflection and the intrinsic Comptonized disc model explain the soft excess equally well. Also, soft excess was slightly stronger in 2001 observation. This is due to slightly higher observed accretion rate. The time-resolved spectroscopy of long 2012 observation suggests that the soft excess and power-law are strongly correlated with similar fractional variability amplitude. This is unlikely to be explained by the simple light bending model. However, this can be explained in the framework of reflection model if the X-ray source is in radially extended form. Furthermore, the UV emission is uncorrelated to any of the X-ray spectral component. The UV emission shows a secular decline, and this may be associated to the changes in the accretion flow.

Moreover, we continue the research to invesigate the nature of accretion disc through the UV/optical variability and its relationship with the X-ray emission. We studied the simultaneous X-ray to UV/optical emission using nearly two years *Swift* monitoring of a bare Seyfert 1 galaxy Fairall 9. The observed variations in the X-ray to UV/optical emission are strongly correlated with each other. The strong correlation suggests a driving mechanism related to a mix of intrinsic disc variations on approximately one-year timescales and reprocessing of X-rays on shorter timescales. The cross-correlation study shows that the UV/optical emission lag behind the X-ray emission. The observed lags ($\tau \propto \lambda^{1.36\pm0.13}$) are consistent with the $\tau \propto \lambda^{4/3}$ prediction for X-ray reprocessing in a standard accretion disc model. However, the lags are also consistent with a simple linear model. The observed lags imply that the variations in the UV/optical emission may be caused by X-ray reprocessing. The predicted lags from the standard accretion disc with X-ray reprocessing are lower than the observed lags. The lag spectrum reveals that the regions of the UV emission, for example, in UVW2 band, seem to be distributed in the range $r/R_S \sim 400$ in the vicinity of the supermassive black hole.

Data Driven Initiatives in Astronomy and Biology

This project is funded by the National Knowledge Network (NKN), under the ministry of Electronics and Information Technology of the Government of India to enable exploration of solutions for big data management, archiving and serving in the fields of Astronomy and Biology. The emphasis is to try and explore / adapt data management solutions for data arising in these two highly data intensive fields.

As a part of this project, the team at IUCAA helped the Kodaikanal Solar Observatory (KSO) to construct a highly modern and sophisticated data search and download facility at http://kso.iiap.res.in/ and it makes available a very valuable set of data collected by this observatory over a period of more than 100 years (since 1904). In order to further enhance the visibility of the data, a low level web service compliant with the Virtual Solar Observatory (VSO) standards has also been created. This service will be integrated soon into the VSO, allowing serendipitious discovery of digitized data set being served through the above link. The site was launched in February 2018 at the IAU symposium on Long Term Solar Datasets concluded recently at Jaipur, Rajasthan.

The team at IUCAA has also deployed the metadata archive at the AstroSat CZTI Payload Operation Centre (POC) located at IUCAA. This service keeps track of processing parameters of all the Level 1 and Level 2 data processing happening at the centre, and presents a web interface to enable quick querying of all available data as well as to package and deliver the data to the analyst working at the POC.

IUCAA High Performance Computing Data Centre.

The service has been demonstrated to experts from several other such centres and has received a positive reception. The system will likely service as a model that other existing as well as future data centres may adopt.

Under this project, a 120 TB storage facility was also setup at IUCAA. Part of this facility has been used to host the large catalogue services known as Vizier created by the CDS. The server also hosts an event management system specially created for the Scipop team at IUCAA to enable management of requests for popular talks to be delivered in the city and across India. This system was recently deployed and is expected to play an important role in helping the Scipop team to handle coordination between IUCAA and target institutes where popular talks and lectures will be delivered. The server also hosts a web interface to a neural network capable of classifying galaxies into barred and unbarred morphological types (this network was developed by **Sheelu Abraham**, et al.)

Assistance was also provided by the team at IUCAA to the Regional Centre of Biotechnology in constructing a data archive for their upcoming large datasets. Work is underway to find economical solutions to design petabyte scale data centres for the three major data intensive disciplines of Astronomy, Biology and Earth Sciences. Future plans also include a data resources management system for the instrumentation lab as well as data management and natural language mining interfaces for the IAU Office of Astronomy for Development (OAD).

IUCAA High Performance Computing clusters Perseus (left two racks) and Sarathi

TMT Telescope Control System

The Thirty Meter Telescope (TMT), a segmented mirror telescope with a 30-metar filled aperture, will be the world's most advanced ground-based telescope operating at optical and infrared wavelengths. An international consortium of institutions in the USA, Canada, China, Japan and India is building the telescope. About 70% of India's contribution to the construction of TMT will be in-kind. India's work share consists of both hardware and software. In software, India-TMT is responsible for delivering the Observatory Software (OSW) and Telescope Control System (TCS).

The TCS is responsible for the coordination and control of various telescope subsystems. India-TMT is responsible for taking TCS through various project phases, i.e., (1) the Preliminary design (2) the Final design (3) the Code and Test (4) the Integration and Test, and finally, (5) the Assembly, Integration and Verification at the telescope site.

IUCAA, on behalf of India-TMT, is responsible for delivering the TCS to the TMT International Observatory (TIO). In April 2016, the contract for the first phase of the project was awarded to Oaces - Honeywell Automation India Limited.

In December 2016, the TCS team that consisted of engineers and scientists from Honeywell, IUCAA and TMT Project Office successfully completed the first phase of the project. As part of this phase, the TCS team successfully delivered (1) Design of the Hardware Control Daemon (HCD) that interfaces between the TCS and the Mount Control System (MCS) of the telescope, (2) MCS

TMT TCS team including members from Honeywell, IUCAA and TMT Project Office.

simulator, (3) Design document for the interface between TCS and the telescope Enclosure, and (4) A plan for all the subsequent project phases.

Based on the successful completion of first phase, IUCAA on behalf of India-TMT contractually engaged Honeywell for the full Preliminary Design (PD) phase. The work on PD phase started in July 2017. It consists of the following key aspects of the design: (1) System engineering, (2) Design and prototyping of various subsystem interfaces, (3) Safety, (4) Reliability, (5) Operations, (6) Management, and (7) A complete plan for the Final Design phase.

The objective of PD phase is to deliver a sufficiently detailed design to demonstrate that (i) design and interface requirements are met, (ii) all significant design choices are met, (iii) enabling technologies are developed, and (iv) major risks are retired. The work is progressing well and is scheduled to be completed in mid-2019 with a detailed review at TMT Project Office, Pasadena. The successful completion of this phase is a crucial milestone towards delivering the full preliminary design of the TCS, which is arguably the most complex software system of the telescope.

Computing Centre

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

The hardware and devices currently managed by the computing facility include 315 servers and desktops, 72 laptop computers, 83 printers and scanners, two large High Performance Computing systems and 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 WiFi devices is over 800.

IUCAA provides e-mail services to its members and associates, and the total number of accounts being nearly 500. IUCAA has its own registered domain name as “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.

In the year 2017- 2018, emphasis was given to implementation of:

1) Purpose built backup appliance (PBBA), which was arrived on March 24, 2017, in the form of Dell-EMC Data-Domain 6800, the back-end backup storage and Net-worker (backup management software). The PBBA has been configured to backup various important physical and virtual servers/services like IUCAA web server, email server, VMware clients, LIGO web server and user filesystems.

2) The file server NetApp FAS 2020 was implemented in April 2011. The old file server, i.e., NetApp FAS 2020 was replaced by new NetApp FAS 8020 with the higher capacity, better redundency and low power, cooling requirement.

3) PaperCut, a print, scan and copy management software has been setup. This allows to assign user based print quota, secure (pin based) printing, and print tracking. New Multi-Function Printers (MFP) have been procured and configured through PaperCut. The use of PaperCut has resulted in 30% paper saving in a year.

4) Effort has continued to improve the WiFi connectivity within the IUCAA campus. In November 2017, 9 outdoor Access Points (Aps) ZF7762 were replaced with T301s APs and T610s. Also 25 indoor Access Points ZF 7343 were replaced with R510.

The new WiFi network adheres to 802.11ac Wave 2, the newest version of the Wi-Fi standard, which is built on first-generation 802.11ac technology, and delivers faster data rates and has the ability to communicate with four different clients simultaneously, instead of one at a time.

During this year, 15 Dell Optiplex 5050 desktops (Small Form Factor), 8 Multi-Function Printers and 23 laptops (HP Probook 450 G3, HP 250G6 Notebook, HP Probook 440 G5, Mac-book pro) were acquired for the academic community, visitors and administrative officers. The LAN (Local Area Network) has been extended to new areas as per requirement.

The Computer Centre continues to provide technical support to visitors, project students, IUCAA associates as well as visitors from the universities and institutions within India and abroad.

The Computing Facility employs 6 personnel, who carry out the day-to-day functions that include:

1. Architecting overall IT solution/technologies required for IUCAA and present it to Computer Users' committee for their consensus.
2. Framing policy documents and finalizing them in consultation with the Computer Users' committee members.
3. Drawing up specification for the RFP (Request for Proposal) tender document for IUCAA IT requirement to be purchased and oversee all purchase related procedure and follow up.
4. Maintenance of IT hardware in the campus including servers, desktops, mobile computing equipment, printers, etc.
5. Maintaining Zimbra email servers, and their day-to-day administration.
6. Configuration and maintenance of mirror sites hosted at IUCAA.
7. Configuration and management of data backups.
8. Design, management and administration of network topology and firewall rules.
9. Administration of Ruckus wireless network covering the office as well as residential campus.
10. Configuration of Wi-Fi support to devices such as laptops, mobile devices for end users.
11. Day to day administration of VMware infrastructure and various servers catering to administration such as AD, etc.
13. Maintenance of Video Conferencing equipment and end user support.
15. Comprehensive inventory management, asset management and tracking.
16. Procurement of SSL certificates and software for all the relevant webservers at IUCAA.
17. Management and software development for iOAS (integrated Office Automation System), Tally, and TDS pack.
18. Designing web portals for various online applications.
19. End user service support to administrative staff, academic members, visitors and associates.
20. Infrastructure, management and coding support to IT intensive projects such as Big Data, AstroSat, LIGO, etc.
20. Procurement, installation and periodic upgradation of mathematical software such as Matlab, IDL, Mathematica meant for general IUCAA users and cluster users.
21. Hardware maintenance and general system administration of clusters in IUCAA in coordination with OEM.
22. Assisting estate department with datacentre management.

High Performance Computing

The High Performance Computing facility houses some of the major IT assets of IUCAA. The services for general users are provided through the 1504 core 30 Teraflop HPC system "Perseus", which also has a 750 Terabyte storage attached to it. The cluster was available for general use with Load Sharing Facility (LSF) as the job scheduler. The Perseus cluster was 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 Backgound Evolution, Fluid Mechanics, Magnetohydrodynamics, Plasma Physics and the 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.

Staff of the Computing Facility at IUCAA Datacentre. The High Performance Computing clusters are seen in the background.

Chiller plant assembly for IUCAA Data Centre

Power conditioning room for IUCAA Data Centre with UPS, battery banks and control panels

Library

In the period under review, the library added 56 books along with the major eBook resources listed below:

1. Cambridge University Press (177 titles)
2. Springer Physics and Astronomy collection 2018
3. World Scientific eBooks (33 titles)

In addition to the library subscriptions, access to the following e-resources was made available courtesy **e-ShodhSindhu: Consortium for Higher Education Electronic Resources**, an initiative by MHRD, Government of India being executed by INFLIBNET Centre.

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

The ongoing initiatives undertaken by the library are listed below.

1. Off campus access to e-resources subscribed by the IUCAA library has been extended to IUCAA Associates using IUCAA LDAP authentication. The EZproxy Access and Authentication software facilitated this access.

2. The library supplied 153 full-text article requests and obtained 03 books against interlibrary loan for requests received from 55 academics (including students). The IUCAA library lent out 07 books on interlibrary loan to other institutions and universities.

3. The library has deployed the Plex Media Server software for enabling streaming of HD videos of recorded lectures available with the library over the internet.

4. The archival content of Khagol (Quarterly Bulletin) and Annual Report has been made available using Open Journal System (OJS). The library undertook the up-gradation of OJS along with the migration of the content on the new server. Further, to give an enhanced look to the content, the 'Flipping Book 'utility software has been implemented.

The library was temporarily functioning from Akashganga Housing Colony since January 2017 on account of major refurbishment. Following completion of the renovation activity, the library began functioning from the ground floor area from May 2018.

Radio Physics Lab

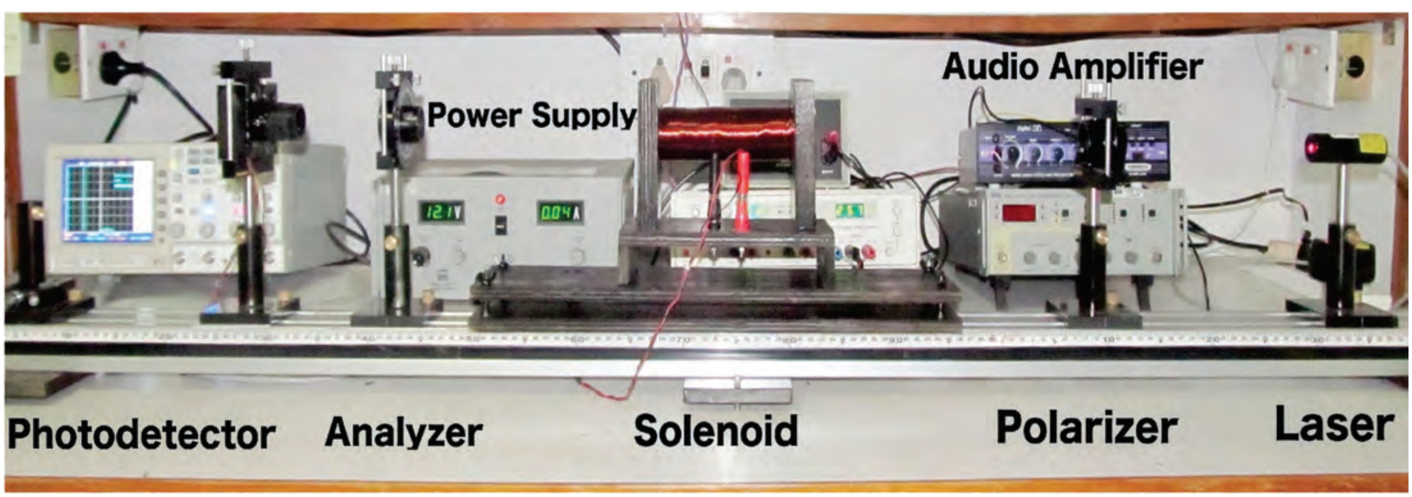
Radio Physics Lab (RPL) is a unique facility at IUCAA, where students from physics and engineering background can explore their skills and learn Astronomy and Astrophysics. Our aim has been to design and demonstrate important experiments related to Radio Astronomy in an innovative way for scientific purpose and for educating students, enthusiasts and 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 undergraduate 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 students are pursuing PhD in astronomy and related areas and many are currently active in research field in some form or the other. Following are the details of experiments and activities carried out by RPL.

Experiments

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



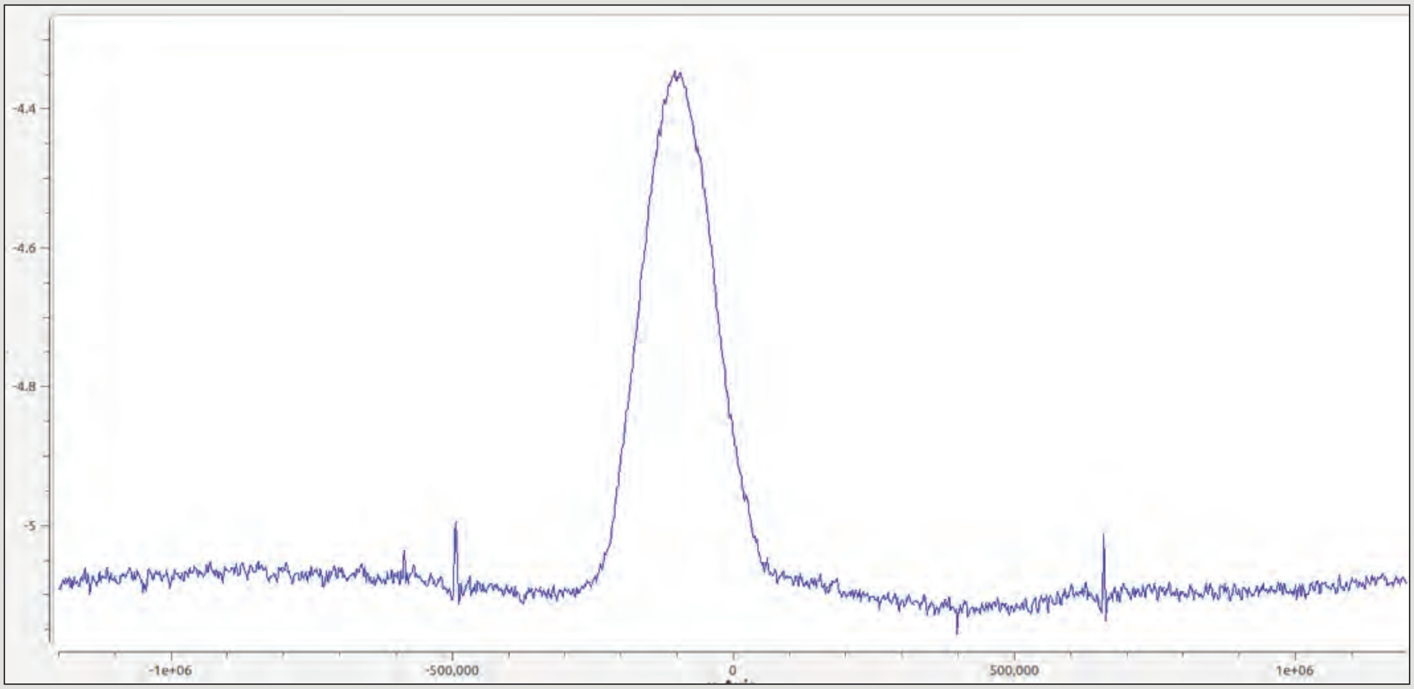
The laser will act as a carrier and the audio is given as a modulating signal to the solenoid, the audio signal modulated in the presence of Faraday material (TGG) and demodulated by converting polarization modulation into intensity modulation at the photo detector. The power requirement is very low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

Horn Antenna for 21cm Hydrogen Line

The 21cm 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 very crucial in the field of Radio Astronomy. A horn antenna was designed for detecting this 21cm 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 21cm 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.

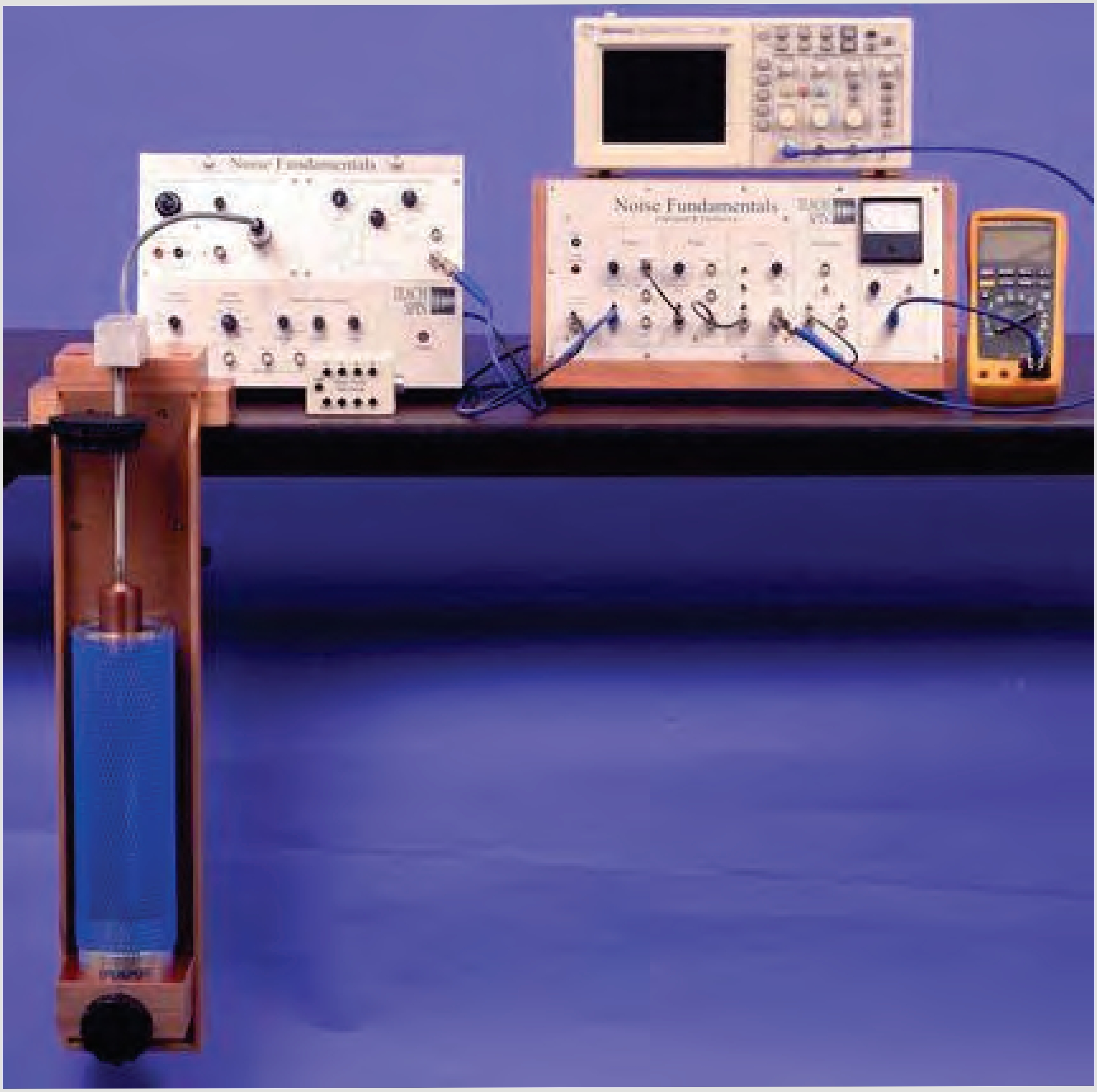
The horn has enabled us to study Hydrogen line profiles from the galaxy. The spiral structure of the galaxy can be estimated. It has also made it possible to estimate the rotation curve of the galaxy.

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 radios, 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 will be used in MSc practical in radio astronomy as well as in Radio Astronomy Winter Schools.



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 parameter of noise like temperature, bandwidth and other parameters.



Cosmic Ray Muon Detector

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 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, M.Sc Astronomy and Astrophysics specialization course as well in Radio Astronomy Winter School.

Other Experiments

Many small experiments are done in the lab. Noise figure measurement of radio frequency amplifiers. Solar observations are taken at 10 GHz with a satellite TV dish antenna. This is a low cost and easily available radio telescope set up. Antenna radiation pattern measurement.

Science Day

Science day is an important event in IUCAA. It is the time of the year when IUCAA is open to general public all day long and the staff here exhibits and explains the experiments and activities which are conducted in IUCAA. The Radio Physics Lab has been demonstrating and explaining various astronomy related experiments over the years. This year, in addition to the horn, 3m parabolic radio telescope, ASRT and Muon detector we presented the recently discovered Saraswati Supercluster LED model, which was made by RPL project students. This supercluster was discovered in this very own 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 general public and different types of radio telescopes working on different types of bands around the world were also displayed. The volunteers representing RPL were from VIT and D.Y. Patil College, Pune.

Shishir Sankhyayan and **Jameer Manur** gave the public talks on Saraswati Supercluster and biggest telescopes in the world respectively. The talks were given in such a manner which would be understood by general public.

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 (as seen here) to make students aware of the career opportunities in the field of astronomy. They also educate them with the latest developments in this field.

The RPL has 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 in India like the GMRT (which is one of the world's largest radio telescope). All these material will be freely available on our RPL website (www.iucaa.in/~rpl) and youtube channel. RPL has also launched pages on the social media like facebook, twitter and youtube for propagation of radio astronomy in India. On National Science Day we exhibit many posters and working models based on astronomy, and radio astronomy where general public can understand it very easily.

Science Exhibition

Fergusson College, Pune had hosted its annual science exhibition in August 2017, was inaugurated by **Joydeep Bagchi**. The PRL team interacted with the students and cleared their several doubts and guided them with their projects.

Public Talks

Joydeep Bagchi and team have given talks on their recent discovery, Saraswati Supercluster, in Vishwakarma Institute of Technology (VIT, Pune), and IUCAA, Pune.

Awards

1. New discovery award: **Joydeep Bagchi** and his team of scientists and students were awarded the ***NEW DISCOVERY AWARD*** at ASI for the discovery of Saraswati Supercluster.

2. Best poster award 2018:

   Extragalactic Astronomy: **Pratik Dabhade** for the poster **"Giant Radio Galaxies from LOFAR Two Metre Sky Survey"**

3. Best poster award 2017:

   Instrumentation: **Ashish Mhaske** for the poster **"Horn Antenna and Software Defined Radio for Detecting 21 cm Hydrogen Line"**.

M.Sc. Practicals

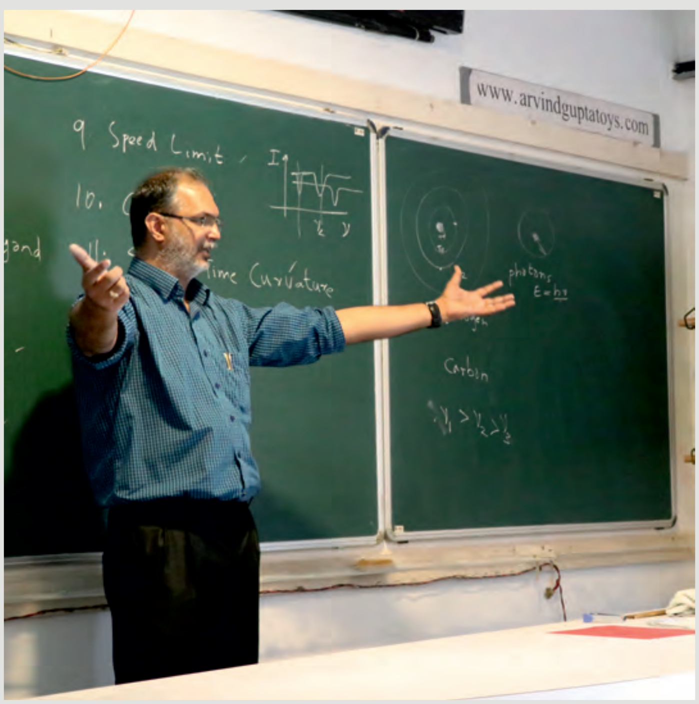
M.Sc. students are supposed to perform experiments as a part of curriculum. The students have to appear for practical exam to complete their course. Some of these experiments are conducted in Radio Physics Lab. Every year 3 to 4 experiments are performed by the students under RPL. These have been a great success and will continue to be so under our the guidance. Some of the experiments are antenna radiation pattern measurement, detection of 21 cm hydrogen line, Faraday rotation and noise fundamentals.

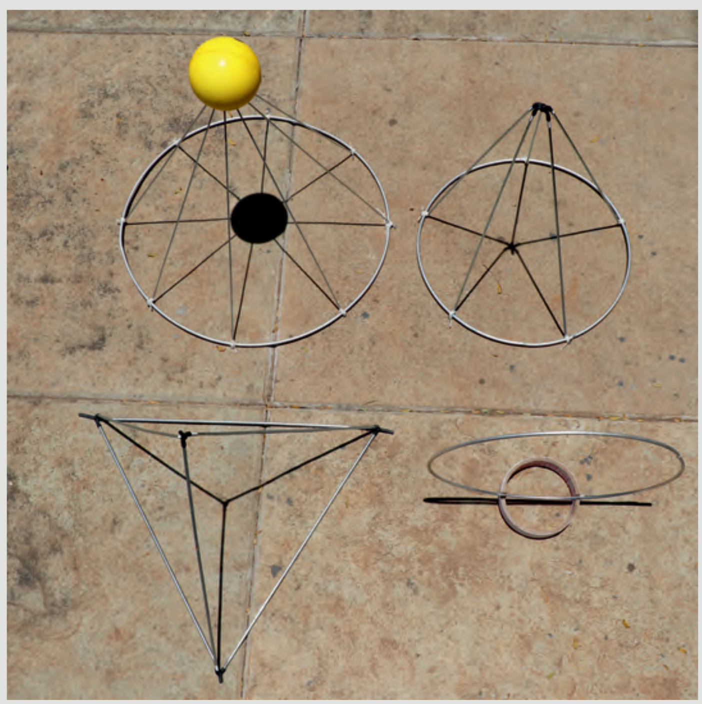
Radio Astronomy Winter School

Radio Astronomy Winter School (RAWS) has been organized every year, jointly by IUCAA and NCRA. The school is largely meant for undergraduate students in science, pursuing B.Sc. (Physics / Electronics /Astronomy), and Engineering (B.E./ B.Tech.). 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 school exposes the participants to Astronomy in general, and Radio Astronomy in particular. The school has been immensely popular, and so far seven such schools have been organized since 2008. The experiments are conducted by Radio Physics Lab (RPL). The hands-on experiments included (1) Observations of Sun with the 4 m telescope to determine the antenna power pattern, (2) Observations of HI 21 cm line to neutral hydrogen from the Galaxy, and (3) 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 10th workshop, one of the pioneers of radio astronomy Govind Swarup attended the school and gave his insights, and interacted with the students.

SCHOOL STUDENTS' SUMMER PROGRAMME AND ASTRONOMY CAMP





The annual School Students' Summer Programme and Astronomy Camp was held during April 24 to May 26, 2017. Students were also given an opportunity to interact with IUCAA faculty members. Somak Raychaudhury, Durgesh Tripathi, Aseem Paranjape, Sanjit Mitra and A. N. Ramaprakash spent some of their valuable times to answer the questions of the students in a friendly manner.
(For details, see Khagol, No. 111, July 2017)

TEACHERS' WORKSHOP ON ASTRONOMY IN SCHOOL TEXTBOOKS

Teachers' Workshop on Astronomy in School Textbooks was conducted during July 25 - August 1, 2017, for secondary school teachers from Akanksha Foundation.
(For details, see Khagol, No. 112, October 2017)

OTHER REGULAR EVENTS

MoU ON A RURAL ASTRONOMY POPULARISATION PROGRAMME

A Memorandum of Understanding was signed between a non-profit organisation Agricultural Development Trust (ADT), Baramati and IUCAA on September 13, 2017.
(For details, see Khagol, No. 112, October 2017)

WORKSHOP ON VISUALISING TEXTBOOK ASTRONOMY

The workshop on Visualising Textbook Astronomy was conducted on October 30, 2017, for secondary school teachers from Kendriya Vidyalayas at Regional Training Centre, Khadki Cantonment Board. The workshop was organised by Sakal NIE in collaboration with IISER, Pune, and IUCAA.
(For details, see Khagol, No. 113, January 2018)

INTERNATIONAL OBSERVE THE MOON NIGHT

Every year, International Observe the Moon Night (InOMN) is celebrated in the month of September or October by Astronomers Without Borders. This year, InOMN was celebrated worldwide on October 30, 2017.
(For details, see Khagol, No. 113, January 2018)

PuLastya SCIENCE FESTIVAL

To commemorate the birth anniversary of Late Shri Pu La Deshpande, November 8, the PuLastya Science festival was organised during Nobember 8 - 10, 2017 at IUCAA.
(For details, see Khagol, No. 113, January 2018)

THIRTY METRE TELESCOPE WORKFORCE, EDUCATION, PUBLIC OUTREACH AND COMMUNICATIONS MEETING

The annual meeting of the Thirty Metre Telescope Workforce, Education, Public Outreach and Communications (TMT WEPOC) board took place in Bengaluru, and was hosted by the IIA, during November 2 - 5, 2017. Samir Dhurde (IUCAA) was the organiser for this meeting.

(For details, see Khagol, No. 113, January 2018)

UNOOSA WORKSHOP

As part of the Outreach Programme in IUCAA, Samir Dhurde attended the United Nations/Italy Workshop on the Open Universe initiative in Vienna, Austria, during November 20 - 22, 2017.
(For details, see Khagol, No. 113, January 2018)

SOLAR OUTREACH PROGRAMME

As a part of the Solar Outreach Programme, Helen Mason (University of Cambridge) along with **Durgesh Tripathi** (IUCAA) interacted with school students during November 28 - 30, 2017.
(For details, see Khagol, No. 113, January 2018)

REGULAR EVENTS

During 2017 - 18, the IUCAA Outreach personnel have conducted: 26 Science Toys Workshops, 22 Basic Astronomy Workshops, and 22 Campus Visits, with reach to about 4,000 people. Further, the Mobile Planetarium has reached to 47 schools, in which about 7,000 students have witnessed the planetarium shows.

SECOND SATURDAY LECTURES / DEMONSTRATIONS

June 8, 2017:
Jayant V. Narlikar (IUCAA), on Collisions in space.

August 12, 2017:
Avyarthana Ghosh (IUCAA), on Story of a star.

September 9, 2017:
Sudha Rajamani, and Chaitanya Mungi (IISER, Pune), on Life on Earth: How did it come about?

December 16, 2017:
Shrikant Pawar (NCCS-MCC, Pune), on Wonders of microbiology.

January 13, 2018:
Samir Dhurde (IUCAA), on The Moon.

February 10, 2018:
Shantipal Ohol (Government College of Engineering, Pune), on Robotics.

SPECIAL ACADEMIC VISIT

A group of faculty members and staff inclined towards academic writing from CEIAR - TISS, Mumbai visited IUCAA Science Centre on January 18, 2018. Samir Dhurde shared information about IUCAA Science Outreach Programme and how does a digital medium helps in this.

WORKSHOP ON ASTRONOMY FOR DEVELOPMENT

A one day workshop on Astronomy for Development was held at IUCAA on January 20, 2018 with invited participants from astronomy, education and social sciences. The workshop was organized by IUCAA and Astronomical Society of India's Public Outreach Education Committee together with the IAU Office of Astronomy for Development.
(For details, see Khagol, No. 114, April 2018)

TOTAL LUNAR ECLIPSE

On January 31, 2018 there was a triple bonanza for astronomy enthusiasts. The total lunar eclipse that occurred on the second full moon of the month (i.e., on a "blue moon") and close to the supermoon position.

(For details, see Khagol, No. 114, April 2018)

NATIONAL SCIENCE DAY

The celebrations of National Science Day 2018 attracted numerous groups of students that came in from around Pune and from other parts of Maharashtra.
(For details, see Khagol, No. 114, April 2018)

EQUINOX EVENT

On the occasion of Vernal Equinox on March 21, Shivom Gupta coordinated an event for school students.
(For details, see Khagol, No. 114, April 2018)

EDUSAT NETWORK NATIONAL ORIENTATION PROGRAMME

Sonal Thorve participated in this orientation cum training workshop organised by Vigyan Prasar in Chennai during March 6 - 8, 2018. She presented the status report of the IUCAA satellite interactive terminal.

(For details, see Khagol, No. 114, April 2018)

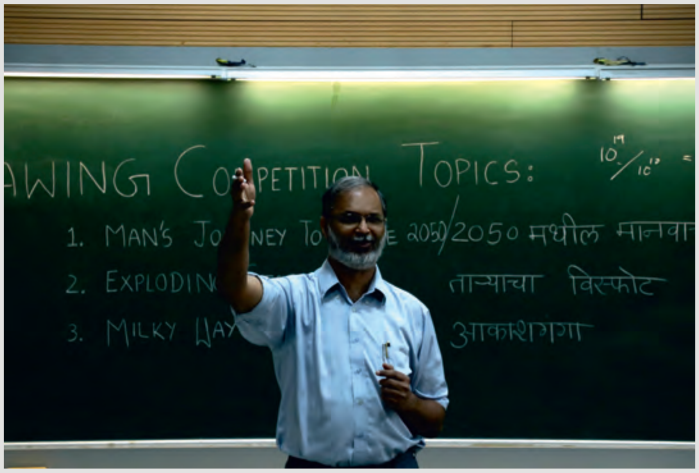
ZERO SHADOW DAY - SOUTH REGION WORKSHOP AT PONDICHERRY

Sonal Thorve was a resource person at the workshop organised by Tamil Nadu Science Forum and ASI POEC. She was part of a session on role play in astronomy education.
(For details, see Khagol, No. 114, April 2018)

ASTRONOMY LECTURE AT MUKTANGAN EXPLORATORY

As a part of summer camps organised by Muktangan Exploratory, an introductory lecture on Astronomy was delivered by Shivom Gupta. About 50 school children attended and enjoyed the session.
(For details, see Khagol, No. 114, April 2018)

SCIENCE TOYS DEMONSTRATION, SKY-WATCHING AT HEMALKASA AND ANANDWAN



Members of IUCAA Public Outreach team visited social projects - Lok Biradari Prakalp (for the development of tribal people), Hemalkasa, Dist. Gadchiroli, and Anandwan (a community rehabilitation centre for leprosy patients and the disabled from downtrodden sections of society), Dist. Chandrapur, Maharashtra.
(For details, see Khagol, No. 114, April 2018)


Andromeda Galaxy

LIGO-INDIA EDUCATION AND PUBLIC OUTREACH

The LIGO-India EPO (LIEPO) effort was formally launched in February 2018 and has been now hosted at IUCAA. Several activities have been started by the associated team. It has an online presence on Facebook and twitter as well (@LIGOIndia).
(For details, see Khagol, No. 114, April 2018)

CAP 2018 CONFERENCE

Samir Dhurde secured a grant to travel to Fukuoka, Japan to be part of the IAU's Communicating Astronomy with Public conference during March 23 - 29, 2018.
(For details, see Khagol, No. 114, April 2018)

PUBLIC LECTURES

May 11, 2017:
Ewine F. van Dishoek (Leiden Observatory, The Netherlands), on Building stars, planets and the ingredients of life in space.

November 8, 2017:
Durgesh Tripathi (IUCAA), on The star in our "backyard".

November 9, 2017:
Sukanta Bose (IUCAA), on Gravitational waves: What have we learned in the first two years of Advanced LIGO?

November 10, 2017:
Joydeep Bagchi (IUCAA), on A supercluster named "Saraswati".

December 19, 2017:
Frank Shu (University of California at Berkeley and San Diego, USA), on Two planets: Challenges of living and prospering on Earth and Mars.

January 17, 2018:
Mark Birkinshaw (University of Bristol, UK), on Ancient light: The microwave background radiation and cosmology.

February 17, 2018:
Jen Gupta (University of Portsmouth, UK), on The invisible Universe.

WORKSHOP ON AstroSat DATA ANALYSIS

The Workshop on AstroSat Data Analysis was organized by the Department of Physics, Tezpur University, during May 3 - 5, 2017.
(For details, see Khagol, No. 111, July 2017)

WORKSHOP ON ASTRONOMY AND ASTROPHYSICS: RECENT TRENDS AND SCOPES

The one day workshop, held at the Department of Physics, Assam Kaziranga University, Jorhat, was organized jointly with IUCAA on May 6, 2017.
(For details, see Khagol, No. 111, July 2017)

NORTH EAST MEET OF ASTRONOMERS (NEMA - III)

The meeting of North East Astronomers, jointly organized by Assam Don Bosco University (ADBU), Guwahati, and IUCAA, was held at St. Anthony's College, Shillong, during October 5 - 7, 2017.
(For details, see Khagol, No. 113, January 2018)

WORKSHOP ON MULTI-WAVELENGTH OBSERVATIONS USING AstroSat

The workshop on Multi-wavelength Observations using AstroSat was conducted at the Department of Physics and Electronics, Christ University, Bengaluru, during December 14 - 16, 2017.
(For details, see Khagol, No. 113, January 2018)

WORKSHOP ON BLACKHOLES: FROM CLASSICAL TO QUANTUM GRAVITY

A workshop titled, Blackholes: From Classical to Quantum Gravity was held in honour of the eminent relativist Professor C.V. Vishveshwara, at IIT, Gandhinagar's campus by the Sabarmati, during December 15 - 19, 2017.
(For details, see Khagol, No. 113, January 2018)

MEETING ON RESEARCH IN ASTRONOMY: OPPORTUNITIES AND CHALLENGES

The south regional astronomers meeting on Research in Astronomy: Opportunities and Challenges was conducted at the Department of Physics. WMO Arts and Science College, Muttil, Wayanad, Kerala, during December 1 - 2, 2017. (For details, see Khagol, No. 113, January 2018)

NATIONAL CONFERENCE ON HIGH ENERGY EMISSION FROM AGN-III

The 3rd National Conference on High Energy Emission from Active Galactic Nuclei was conducted during November 28 - 30, 2017, at the University of Calicut, Kozhikode. (For details, see Khagol, No. 114, April 2018)

RESEARCH BY VISITING ASSOCIATES

Sk. Saiyad Ali

Validating a novel angular power spectrum estimator using simulated low frequency radio-interferometric data

The "Tapered Gridded Estimator" (TGE) is a novel way to directly estimate the angular power spectrum from radio-interferometric visibility data that reduces the computation by efficiently gridding the data, consistently removes the noise bias, and suppresses the foreground contamination to a large extent by tapering the primary beam response through an appropriate convolution in the visibility domain. Here, we demonstrate the effectiveness of TGE in recovering the diffuse emission power spectrum through numerical simulations. We present details of the simulation used to generate low frequency visibility data for sky model with extragalactic compact radio sources and diffuse Galactic synchrotron emission. We then use different imaging strategies to identify the most effective option of point source subtraction and to study the underlying diffuse emission. Finally, we apply TGE to the residual data to measure the angular power spectrum, and assess the impact of incomplete point source subtraction in recovering the input power spectrum (C_ℓ) of the synchrotron emission. This estimator is found to successfully recover the C_ℓ of input model from the residual visibility data for the angular scale $\ell \leq 2\times10^4$ ($\theta \gtrsim 1$ arcmin). These results are relevant for measuring the diffuse emission like the Galactic synchrotron emission. It is also an important step towards characterizing and removing both diffuse and compact foreground emission in order to detect the redshifted 21cm signal from the Epoch of Reionization. This work has been done in collaboration with Samir Choudhuri, Nirupam Roy, Somnath Bharadwaj, Abhik Ghosh and Prasun Dutta.

The angular power spectrum measurement of the galactic synchrotron emission in two fields of the TGSS survey

Characterizing the diffuse Galactic synchrotron emission at arcminute angular scales is needed to reliably remove foregrounds in cosmological 21-cm measurement. The study of this emission is also interesting in its own right. Here, we quantify the fluctuations of the diffuse Galactic synchrotron emission using visibility data for two of the fields observed by the TIFR GMRT Sky Survey (TGSS). We have used the 2D Tapered Gridded Estimator (TGE) to estimate the angular power spectrum (C_ℓ) from the visibilities. We find that the sky signal, after subtracting the point sources, is likely dominated by the diffuse Galactic synchrotron radiation across the angular multipole range $240 \leq \ell \lesssim 500$. For the first data, we present a power law fit, $C_\ell = A \times \left(\frac{1000}{l}\right)^\beta$, to the measured C_ℓ over this ℓ range. We find that (A, β) have values $(356 \pm 109\ \text{mK}^2, 2.8 \pm 0.3)$ for the first data set. Assuming the residual contribution is negligible at lower multipole for the second data set, we fit the same power law and find the values of (A, β) are $(54\pm26\ \text{mK}^2, 2.2\pm0.4)$. However, in this case, there is indication of a significant contribution from the residuals, and hence, we only get an upper limit of diffuse Galactic synchrotron emission power spectrum. While the slopes are both consistent with earlier measurements, one of the fields appears to have an amplitude which is considerably smaller compared to similar measurements in other parts of the sky. This work has been done in collaboration with Samir Choudhuri, Somnath Bharadwaj, Nirupam Roy, H.T. Intema and Abhik Ghosh.

G. Ambika and K.P. Harikrishnan

Detecting abnormality in heart dynamics from multifractal analysis of ECG signals

The characterization of heart dynamics with a view to distinguish abnormal from normal behaviour is an interesting topic in clinical sciences. Here, we present an analysis of the electro-cardiogram (ECG) signals from several healthy and unhealthy subjects using the framework of dynamical systems approach to multifractal analysis. The analysis differs from the conventional non-linear analysis, in which the information contained in the amplitude variations of the signal is being extracted and quantified. The results, thus obtained, reveal that the attractor underlying the dynamics of the heart has multifractal structure and the variations in the resultant multifractal spectra can clearly separate healthy subjects from unhealthy ones. We use supervised machine learning approach to build a model that predicts the group label of a new subject with very high accuracy on the basis of the multifractal parameters. By comparing the computed indices in the multifractal spectra with that of beat replicated data from the same ECG, we show that how each ECG can be checked for variations within itself. The increased variability observed in the measures for the unhealthy cases can be a clinically meaningful index for detecting the abnormal dynamics of the heart. This work has been done in collaboration with Snehal M. Shekatkar and Yamini Kotriwar.

Is a hyperchaotic attractor superposition of two multifractals?

In the context of chaotic dynamical systems with exponential divergence of nearby trajectories in phase space, hyperchaos is defined as a state where there is divergence or stretching in at least two directions during the evolution of the system. Hence, the detection and characterization of a hyperchaotic attractor is usually done using the spectrum of Lyapunov Exponents (LEs) that measure this rate of divergence along each direction. Though hyperchaos arise in different dynamical situations and find several practical applications, a proper understanding of the geometric structure of a hyperchaotic attractor still remains an unsolved problem. In this work, we present strong numerical evidence to suggest that the geometric structure of a hyperchaotic attractor can be characterized using a multifractal spectrum with two superimposed components. In other words, apart from developing an extra positive LE, there is also a structural change as a chaotic attractor makes a transition to the hyperchaotic phase and the attractor changes from a simple multifractal to a dual multifractal, equivalent to two inter-mingled multifractals. We argue that a cross-over behaviour in the scaling region for computing the correlation dimension is a manifestation of such a structure. In order to support this claim, we present an illustrative example of a synthetically generated set of points in the unit interval (a Cantor set with a variable iteration scheme) displaying dual multifractal spectrum. Our results are also used to develop a general scheme to generate both hyperchaotic as well as high dimensional chaotic attractors by coupling two low dimensional chaotic attractors and tuning a time scale parameter. This work has been done in collaboration with Ranjeev Misra.

Arunima Banerjee

Evolution of late-type galaxies in a cluster environment: Effects of high-speed multiple encounters with early-type galaxies

Late-type galaxies falling into a cluster would evolve being influenced by the interactions with both the cluster and the nearby cluster member galaxies. Most numerical studies, however, tend to focus on the effects of the former with little work done on those of the latter. We, thus, perform a numerical study on the evolution of a late-type galaxy interacting with neighbouring early-type galaxies at high speed, using hydrodynamic simulations. Based on the information obtained from the Coma cluster, we set up the simulations for the case where a Milky Way-like late-type galaxy experiences six consecutive collisions with twice as massive early-type galaxies having hot gas in their halos at the closest approach distances of 15 - 65 kpc/h at the relative velocities of 1500 - 1600 km/s. The simulations show that the evolution of the late-type galaxy can be significantly affected by the accumulated effects of the high-speed multiple collisions with the early-type galaxies, such as on cold gas content and star formation activity of the late-type galaxy, particularly through the hydrodynamic interactions between cold disk and hot gas halos. We find that the late-type galaxy can lose most of its cold gas after the six collisions and have more star formation activity during the collisions. By comparing our simulation results with those of galaxy-cluster interactions, we claim that the role of the galaxy-galaxy interactions on the evolution of late-type galaxies in clusters could be comparable with that of the galaxy-cluster interactions, depending on the dynamical history. This work has been done in collaboration with Jeong-Sun Hwang, Changbom Park and Ho Seong Hwang.

Origin of low surface brightness galaxies: A dynamical study

Low Surface Brightness Galaxies (LSBs), inspite of being gas rich, have low star formation rates and are, therefore, low surface brightness in nature. We calculate QRW, the 2-component disc stability parameter as proposed by Romeo and Wiegert, as a function of galactocentric radius R for a sample of five LSBs, for which mass models, as obtained from HI 21cm radio-synthesis observations and R-band photometry, were available in the literature. We find that the median value of Q_{RW}^{min} , the minimum of QRW over R, lies between 2.6 and 3.1 for our sample LSBs, which is higher than the median value of 1.8 ± 0.3 for Q_{RW}^{min} for a sample of high surface brightness galaxies (HSBs) as obtained in earlier studies. This clearly shows that LSBs have more stable discs than HSBs, which could explain their low star formation rates, and possibly, their low surface brightness nature. Interestingly, the calculated values of QRW decrease only slightly (median $Q_{RW}^{min} \sim$ 2.3-3.0 if the discs were taken to respond to the gravitational potential of the dark matter halo only, but reduce by a factor of 2∼3 (median $Q_{RW}^{min} \sim$ 0.7 - 1.5) if they respond to their self-gravity alone. This implies that the dark matter halo is crucial in regulating disc stability in LSBs, which may have important implications for models of galaxy formation and evolution. This work has been done in collaboration with Prerak Garg.

Debbijoy Bhattacharya

Unusual long-term low-activity states of EGRET blazars in the Fermi era

We examine the long-term (∼ 10 years) γ-ray variability of blazars observed by EGRET and Fermi, and find that 10 EGRET-detected flat spectrum radio quasars (FSRQs) were not present in any of the Fermi catalogue (during the first four years of Fermi observation). Six of these 10 EGRET sources show possible Fermi counterparts based on overlap with error circles given in 3^{rd} Fermi catalogue. A seventh EGRET source is positionally consistent with a newly discovered Fermi source from our analysis. Unlike the high luminosity state exhibited during 1991 to 1995, our analysis using seven years of Fermi data showed that five of these were at its low luminosity state in the GeV band. This result indicates that FSRQs exhibit a long-term quiescent state (more than 7 years). In addition, 37 new γ-ray sources are also detected during the course of this analysis. On the basis of AGN being the most dominant source class in γ-rays, many of these new sources could be associated with AGN and may exhibit long-term variabilities in γ-rays. This work has been done in collaboration with Krishna Mohana A., Sanna Gulati, Subir Bhattacharyya, Nilay Bhatt, P. Sreekumar et al.

The uncorrelated multiwavelength variability of 3C 279 and its implications on blazar zone

By analyzing the time series of RXTE/PCA data, the non-linear variabilities of compact sources have been repeatedly established. Depending on the variation in temporal classes, compact sources exhibit different non-linear features. Sometimes they show low correlation/fractal dimension, but in other classes or intervals of time they exhibit stochastic nature. This could be because the accretion flow around a compact object is a non-linear general relativistic system involving magnetohydrodynamics. However, the more conventional way of addressing a compact source is the analysis of its spectral state. Therefore, the question arises: What is the connection of non-linearity to the underlying spectral properties of the flow when the non-linear properties are related to the associated transport mechanisms describing the geometry of the flow? The present work is aimed at addressing this question. Based on the connection between observed spectral and non-linear (time series) properties of two X-ray binaries: GRS 1915+105 and Sco X-1, we attempt to diagnose the underlying accretion modes of the sources in terms of known accretion classes, namely, Keplerian disc, slim disc, advection dominated accretion flow (ADAF) and general advective accretion flow (GAAF). We explore the possible transition of the sources from one accretion mode to others with time. We further argue that the accretion rate must play an important role in transition between these modes. This work has been done in collaboration with Oluwashina Adegoke Prasun Dhang, Banibrata Mukhopadhyay and M. C. Ramadevi.

Ritabrata Biswas

Fate of an accretion disc around a black hole when both the viscosity and dark energy are effecting

This work deals with the viscous accretion flow of modified Chaplygin gas towards a black hole as the central gravitating object. Modified Chaplygin gas is a particular type of dark energy model, which mimics the radiation era to phantom era depending on the different values of its parameters. We compare the dark energy accretion with the flow of adiabatic gas. An accretion disc flow around a black hole is an example of a transonic flow. To make the model, we consider three components of Navier Stokes' equation, the equation of continuity and the Modified Chaplygin gas's equation of state. As a transonic flow passes through the sonic point, the velocity gradient being apparently singular there, gives rise to two flow branches: One infalling the accretion and the other outgoing the wind. We show that the wind curve is stronger and wind speed reaches to that of light at a finite distance from the black hole when dark energy is considered. Besides, if we increase the viscosity, accretion disc is being shortened in radius. These two processes acting together deviates much from adiabatic accretion case. It shows a weakening process for the accretion procedure by the works of viscous system influenced angular momentum transport and the repulsive force of the Modified Chaplygin gas together. This work has been done in collaboration with Sandip Dutta.

Thermodynamic studies of different black holes with modifications of entropy

In recent years, the thermodynamic properties of black holes are topics of interests. We investigate the thermodynamic properties like surface gravity and Hawking temperature on event horizon of regular black holes viz., Hayward Class and asymptotically AdS (Anti-de Sitter) black holes. We also analyze the thermodynamic volume and naive geometric volume of asymptotically AdS black holes and show that the entropy of these black holes is simply the ratio of the naive geometric volume to thermodynamic volume. We plot the different graphs and interpret them physically. We derive the Cosmic-Censorship Inequality for both type of black holes. Moreover, we calculate *the thermal heat capacity* of aforesaid black holes and study their stabilities in different regimes. Finally, we compute the logarithmic correction to the entropy for both the black holes considering the quantum fluctuations around the thermal equilibrium and study the corresponding thermodynamics. This work has been done in collaboration with Amritendu Haldar.

Subenoy Chakraborty

Emergent scenario in first and second order non-equilibrium thermodynamics and stability analysis

First and second order non-equilibrium thermodynamics are studied in the context of particle creation mechanism for homogeneous and isotropic FLRW model and a general formulation of the emergent scenario is investigated. Finally, the stability of the non-equilibrium thermodynamics is examined. This work has been done in collaboration with Sourav Halder and Pritikana Bhandari.

A new stability criterion for general cylindrical thin-shell wormholes

The work deals with a detailed study of the stability criteria for general static cylindrical thin-shell wormhole.The stability analysis is done under perturbations preserving the symmetry for two definitions of the throat of the wormhole separately. Finally, the stability conditions are discussed both geometrically and physically.

Nand Kumar Chakradhari

Anomalous extinction towards type Ia supernova SN 2004ab in NGC 5054

Supernovae (SNe) are very energetic stellar explosions producing $\sim 10^{51}$ ergs of kinetic energy, $\sim 10^{49}$–10^{50} ergs of energy in the form of radiation and very high luminosities of the order of $\sim 10^{41}$–10^{44} ergs s^{-1}. Recent studies have suggested that the values of total to selective extinction ratio (R_V), in the direction of SNe Ia in a few host galaxies are lower than its canonical value of 3.1 (used for Milky Way). We presented another case of anomalous extinction behaviour of a highly reddened type Ia supernova SN 2004ab in NGC 5054. Optical photometric and spectroscopic observations of SN 2004ab were carried out using the Himalaya Faint Object Spectrograph Camera (HFOSC) attached to the 2-metre Himalayan Chandra Telescope (HCT), IAO-IIA, Hanle, India. The photometric monitoring began on February 24, 2004 and continued until June 22, 2004 in Bessell's B, V, R and I filters. Spectroscopic observations were carried out at 11 occassions during February 24 to May 5. Spectra in the wavelength range 3500 – 9250 at a spectral resolution of ~ 7Å, were obtained with

HFOSC. The total reddening of SN 2004ab is estimated as $E(B-V) = 1.70 \pm 0.05$ mag. The host galaxy NGC 5054 is found to exhibit very low value of $R_V = 1.41 \pm 0.06$ in the direction of SN 2004ab. The intrinsic decline rate parameter, $\Delta m_{15}(B)_{\rm true}$ is 1.27 ± 0.05, and B-band absolute magnitude at maximum $M_B^{\rm max}$ is -19.31 ± 0.25 mag. Peak bolometric luminosity is derived as $\log L_{\rm bol}^{\rm max} = 43.10 \pm 0.07$ erg s^{-1}. The mass of ^{56}Ni synthesized in the explosion of SN 2004ab is estimated as $M_{\rm Ni} = 0.47 \pm 0.06$ $M_\odot$. The photospheric velocity measured from absorption minimum of Si II λ6355 line shows a velocity gradient of $\dot{v} = 90$ km s^{-1} d^{-1}, indicating that SN 2004ab is a member of the high velocity gradient (HVG) subgroup. The ratio of strength of Si II λ5972 and λ6355 absorption lines, $\mathcal{R}$(Si II) is estimated as 0.37, while their pseudo equivalent widths suggest that SN 2004ab belongs to broad line (BL) type subgroup. Though, SN 2004ab is a highly reddened supernova, its absolute luminosity, after correcting for extinction using non-standard extinction law, is similar to a normal SN Ia and follows the empirical luminosity decline rate relation. This work has been done in collaboration with G. C. Anupama, Devendra Kumar Sahu and Tushar P. Prabhu.

Exploring the optical behaviour of a type Iax supernova SN 2014dt

We present optical photometric (up to ∼ 410 d since B_{max}) and spectroscopic (up to ∼ 157 d since B_{max}) observations of a type Iax supernova (SN) 2014dt located in M61. SN 2014dt is one of the brightest and closest (D ∼ 20 Mpc) discovered type Iax SN. It best matches the light-curve evolution of SN 2005hk and reaches a peak magnitude of $M_B \sim -18.13 \pm 0.04$ mag with $\triangle m_{15} \sim 1.35 \pm 0.06$ mag. The early spectra of SN 2014dt are similar to other Type Iax SNe, whereas the nebular spectrum at 157 d is dominated by narrow emission features with less blending as compared to SNe 2008ge and 2012Z. The ejecta velocities are between 5000 and 1000km s^{-1}, which also confirms the low-energy budget of type Iax SN 2014dt compared to normal type Ia SNe. Using the peak bolometric luminosity of SN 2005hk, we estimate the ^{56}Ni mass of ∼ 0.14 $M_\odot$. The striking similarity between SN 2014dt and SN 2005hk implies that a comparable amount of ^{56}Ni would have been synthesized in the explosion of SN 2014dt. This work was carried out in collaboration with Mridweeka Singh, Kuntal Misra, Devendra Kumar Sahu, Raya Dastidar, Anjasha Gangopadhyay, et al.

Ramesh Chandra

Two-step filament eruption during 14 - 15 March 2015

The filament was located in NOAA AR 12297 and associated with a halo Coronal Mass Ejection (CME). We use observations from the Atmospheric Imaging Assembly (AIA) and Heliospheric Magnetic Imager (HMI) instruments onboard the Solar Dynamics Observatory (SDO), and from the Solar and Heliospheric Observatory (SOHO) Large Angle and Spectrometric Coronagraph (LASCO). We also use Hα data from the Global Oscillation Network Group (GONG) telescope and the Kanzelhoehe Solar Observatory. The filament shows a first step eruption on 14 March 2015 and it stops its rise at a projected altitude ≈ 125 Mm on the solar disk. It remains at this height for ≈ 12 hrs. Finally, it erupts on 15 March 2015 and produces a halo CME. We also find jet activity in the active region during both days, which could help the filament destabilization and eruption. The decay index is calculated to understand this two-step eruption. The eruption could be due to the presence of successive instability-stability-instability zones as the filament is rising. This work has been done in collaoration with B. Filippov, R. Joshi and B. Schmieder.

Slippage of jets explained by the magnetic topology of NOAA active region 12035

We present the investigation of 11 recurring solar jets that originated from two different sites (site 1 and site 2) close to each other ≈ 11 Mm in NOAA active region (AR) 12035 during 15 - 16 April 2014. The jets were observed by the Atmospheric Imaging Assembly (AIA) telescope on board the Solar Dynamics Observatory (SDO) satellite. Two jets were observed by the telescope of the Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, India, in Hα. On 15 April, flux emergence is strong in site 1, while on 16 April, flux emergence and cancellation mechanisms are involved in both sites. The jets of both sites have parallel trajectories and move to the south with a speed between 100 and 360 km s^{-1}. The jets of site 2 occurred during the second day have a tendency to move toward the jets of site 1 and merge with them. We conjecture that the slippage of the jets could be explained by the complex topology of the region, which included a few low-altitude null points and many quasi-separatrix layers (QSLs), which could intersect with one another. This work has been done in collaoration with R. Joshi, B. Schmieder, G. Aulanier, F.P. Zuccarello and W. Uddin.

Suresh Chandra

Suggestion for the detection of TiO_2 in interstellar medium

Since all the carbon in oxygen-rich stars is locked into carbon monoxide (CO), how the formation of dust takes place in their environment is a matter of great interest. Being a refractory species, the titanium dioxide (TiO_2) is thought to play important role in the dust-condensation sequence. The TiO_2 is detected in the environment of red supergiant VY Canis Majoris through sub-millimetre wavelengths. All these lines are between the levels lying at high energies, for which large kinetic temperature in the region is required. Based on the detailed study of transfer of radiation, we propose for the identification of TiO_2 through its transitions between low lying levels. Using spectroscopic data, we have calculated energies of 100 rotational levels of para-TiO_2 (up to 82 cm^{-1}) and the Einstein A-coefficients for radiative transitions between the levels. These Einstein A-coefficients along with the scaled values of collisional rate coefficients, we have solved a set of 100 statistical equilibrium equations coupled with 436 equations of radiative transfer. We have found 9 transitions having anomalous absorption and 6 transitions showing emission features. These transitions may help in identification of TiO_2 in a cosmic object. This work has been done in collaoration with Mohit Kumar Sharma and Monika Sharma.

Temperature dependence of collisional rate coefficients for rotational transitions: A-type asymmetric top molecules

On realizing that the rate coefficients for rotational transitions in the H_2CS, H_2CO, H_2CC, H_2CSi, due to collisions with He atom, under the IOS approximation, increase with the increase of kinetic temperature, we have looked analytically for 9 transitions in a-type asymmetric top molecules, because the results of Green, *et al.* (1978) for H_2CO do not increase for all the transitions, though they also are calculated under the IOS approximation. We tried to understand the source of discrepancy, but could not succeed. Data for other three molecules (H_2CS, H_2CC, H_2CSi) are not available in the literature. Since our investigation is analytical, there is no reason not to believe our results. This work has been done in collaoration with Mohit Kumar Sharma and Monika Sharma.

Ayan Chatterjee

Entropy of black holes in $\mathcal{N} = 2$ supergravity

Using the formalism of isolated horizons, we construct space of solutions of asymptotically flat extremal black holes in $\mathcal{N}= 2$ pure supergravity in 4 dimensions. We prove that the laws of black hole mechanics hold for these as well. Further, restricting to constant area phase space, we show that the spherical horizons admit a Chern-Simons theory. Standard way of quantizing this topological theory and counting states confirms that entropy is indeed proportional to the area of horizon.

Asis K. Chattopadhyay and Tanuka Chattopadhyay

Two phase formation of massive elliptical galaxies: Study through cross correlation including spatial effect

The present work investigates the formation and evolution of several components of the nearby massive early-type galaxies (ETGs) through CCF, using the spatial parameters right ascension (RA) and declination (DEC), and intrinsic parameters mass (M_*) and size. We study the CCF between each of these three components of nearby massive ETGs and the ETGs in the high redshift range, $0.5 < z \leqslant 2.7$. It is found that the innermost components of nearby ETGs are highly correlated with ETGs in the redshift range, $2 < z \leqslant 2.7$, known as 'red nuggets'. The intermediate and the outermost parts have moderate correlations with ETGs in the redshift range, $0.5 < z \leqslant 2.7$. The quantitative measures are highly consistent with the two phase formation scenario of nearby massive ETGs, as suggested by various authors, and resolve the conflict raised in a previous work (De, Chattopadhyay and

Chattopadhyay 2014) suggesting other possibilities for the formation of the outermost part. This improvement is expected due to inclusion of the spatial effects in addition to the other parameters in the study. This work has been done in collaboration with Soumita Modak.

Unsupervised classification of eclipsing binary light curves through k-medoids clustering

An automatic unsupervised classification of 1318 light curves of variable stars, including eclipsing binaries along with some possible pulsating stars, has been performed using k-medoids clustering method. This separates the stars according to their geometrical configuration in a more scientific way compared to the subjective traditional classification scheme. The light curves in the Galaxy, subjectively grouped in four categories (EA, EB, EW, PUL) in Miller, et al. (2010), have been found to consist of two optimum groups containing primarily eclipsing binaries corresponding to bright, massive systems and fainter, less massive systems. Our technique has been assessed in terms of clustering accuracy measure the Average Silhouette Width, which shows the resulting clustering pattern is quite good. This work has been done in collaboration with Soumita Modak.

Surajit Chattopadhyay

A study on the bouncing behaviour of modified Chaplygin gas in presence of bulk viscosity and its consequences in the modified gravity framework

The present work reports a study on the bouncing behaviour of the viscous modified Chaplygin gas (MCG) in Einstein as well as modified gravity framework. For a bouncing scale factor proposed by Cai, et al. (Class. Quantum Grav. **28**, 215011 (2011)), we have studied the cosmology of MCG in presence of bulk viscosity. In Einstein gravity framework, we have studied the equation of state parameter and it has been found to cross $-1/3$, indicating the end of the early accelerated expansion and it has also been observed that for flat FRW universe, the presence of bulk viscosity induces the crossing of phantom boundary. Role of the model parameters of the MCG has also been investigated before and after the bounce. A Hubble flow dynamics has been carried out and it was revealed that MCG is capable of realizing inflationary phase as well as an exit from inflation. A $f(T)$ gravitational paradigm has also been considered, where the MCG density has been reconstructed in the presence of bulk viscosity. Role of σ the bouncing scale factor, describing how fast the bounce takes place, has also been studied in this framework.

Viewing the cosmological consequences of modified holographic dark energy in various interaction scenarios

We consider the interaction between modified holographic dark energy and pressureless dark matter for three different choices of scale factor, namely logamediate, intermediate and emergent. Two different interaction terms have been considered. In one case, the interaction has been taken proportional to the dark energy density and in the other case, it has been taken proportional to the matter density. In the case of $Q = 3H\delta\rho_x$, we have observed that there is a crossing of phantom boundary, and the equation of state parameter has been observed to behave like quintessense. The influence of various parameters in the scale factors has also been observed. Also, an exit from phantom phase has been observed for the choice of scale factor in the emergent form. Considering the interaction term Q to be proportional to the matter density for logamediate scale factor, the w_x has been found to behave like quintessence, i.e., > -1. For emergent scale factor in this interaction scenario, the model has been found to lead to an w_x parameter lying in the region ≤ -1. Therefore, in general, it has been found that $Q = 3H\delta\rho_x$ is more suitable than $Q = 3H\delta\rho_m$ in creating a model having w_x parameter crossing the phantom boundary. This work has been done in collaboration with Sthiti Chakrabarti.

Himadri Sekhar Das

The study of correlation among different scattering parameters in an aggregate dust model

We study the light scattering properties of aggregate particles in a wide range of complex refractive indices ($m = n + ik$, where $1.4 \leq n \leq 2.0$, $0.001 \leq k \leq 1.0$) and wavelengths ($0.45 \leq \lambda \leq 1.25 \mu m$) to investigate the correlation among different parameters, e.g., the positive polarization maximum ($P_{\max}$), the amplitude of the negative polarization ($P_{\min}$), geometric albedo (A), (n, k) and λ. Numerical computations are performed by the Superposition T-matrix code with Ballistic Cluster–Cluster Aggregate (BCCA) particles of 128 monomers and Ballistic Aggregates (BA) particles of 512 monomers, where monomer's radius of aggregates is considered to be 0.1 μm. At a fixed value of k, $P_{\max}$ and n are correlated via a *quadratic regression* equation and this nature is observed at all wavelengths. Further, $P_{\max}$ and k are found to be related via a polynomial regression equation when n is taken to be fixed. The degree of the equation depends on the wavelength, and higher the wavelength lower is the degree. We find that A and $P_{\max}$ are correlated via a *cubic regression* at $\lambda = 0.45\mu m$, whereas this correlation is *quadratic* at higher wavelengths. We notice that $|P_{\min}|$ increases with the decrease of $P_{\max}$ and a strong linear correlation between them is observed when n is fixed at some value and k is changed from higher to lower value. Further, at a fix value of k, $P_{\min}$ and $P_{\max}$ can be fitted well via a *quartic regression* equation when n is changed from higher to lower value. We also find that $P_{\max}$ increases with λ and they are correlated via a *quartic regression*. This work has been done in collaboration with A. M. Mazarbhuiya.

Study of light scattering properties of dust aggregates with a wide variation of porosity

We study the light scattering properties of moderately large dust aggregates ($0.8\mu m \leq R \leq 2.0\mu m$) with a wide variation of porosity ($\mathcal{P}$) from 0.57 to 0.98. The computations are performed using the Superposition T-matrix code with BAM2 cluster ($\mathcal{P} \sim 0.57$ - 0.64), BAM1 cluster ($\mathcal{P} \sim 0.74$), BA or BPCA cluster ($\mathcal{P} \sim 0.85$ - 0.87) and BCCA cluster ($\mathcal{P} \sim 0.98$). The simulations are executed at two wavelengths $0.45\mu m$ and $0.65\mu m$ with highly absorbing particles (organic refractory) as well as with low absorbing particles (amorphous silicates) to understand the photopolarimetric behaviour (phase function, polarization, and colour) of dust aggregates. The effect of aggregate size parameter (X) on the light scattering properties of aggregates (BA and BAM2) having different porosities is explored in this study. We find that the positive polarization maximum (P_{max}), the amplitude of the negative polarization (P_{min}) and phase function at the exact backscattering direction ($S_{11}(180°)$) are correlated with the porosity of aggregates. Compact aggregates show deeper negative polarization as compared to porous aggregates when the characteristic radius (R) of the aggregates are considered to be the same. Further, lower porosity aggregates show higher $S_{11}(180°)$ and vice versa. When $\mathcal{P}$ is increased in a range from 0.64 to 0.98, both $S_{11}(180°)$ and P_{min} decrease linearly, whereas P_{max} increases linearly. We also find that the porosity of the aggregates plays a crucial role in determining the polarimetric colour for high absorbing organic refractories. The compact clusters (BAM1 and BAM2) show the negative polarimetric colour, whereas BA clusters show almost positive polarimetric colour at all values of scattering angle. We have also made some comparisons of our simulated results with PROGRA^2 experimental results. This work has been done in collaboration with P. Deb Roy and P. Halder.

Sudipta Das

A parametric reconstruction of the deceleration parameter

The present work is based on a parametric reconstruction of the deceleration parameter $q(z)$ in a model for the spatially flat FRW universe filled with dark energy and non-relativistic matter. In cosmology, the parametric reconstruction technique deals with an attempt to build up a model by choosing some specific evolution scenario for a cosmological parameter and then estimate the values of the parameters with the help of different observational datasets. In this work, we have proposed a logarithmic parametrization of $q(z)$ to probe the evolution history of the universe. Using the type Ia supernova (SNIa), baryon acoustic oscillation (BAO) and the cosmic microwave background (CMB) datasets, the constraints on the arbitrary model parameters q_0 and q_1 are obtained (within 1σ and 2σ confidence limits) by χ^2-minimization technique. We have then reconstructed the deceleration parameter, the total EoS parameter ω_{tot}, the jerk parameter, and have compared the reconstructed results of $q(z)$ with other well-known parametrizations of $q(z)$. We have also shown that two model selection criteria (namely, Akaike and Bayesian) provide the clear indication that the reconstructed model is well consistent with other popular models. This work has been done in collaboration with Abdulla Al Mamon.

Ujjal Debnath

Dynamical system analysis of interacting Hessence dark energy in $f(T)$ gravity

We have analysed the critical points due to autonomous system. The resulting autonomous system is non-linear. So, we have approached via the theory of non-linear dynamical system. We have used the theory of non-linear dynamical system developed till date. This approach gives totally different stable solutions, in contrast to what the linear analysis would have predicted. We have discussed the stability analysis in details due to exponential potential through computational method in tabular form and analyzed the evolution of the universe. Some plots are drawn to investigate the behaviour of the system (this plotting technique is different from usual phase plot, and devised by the authors). Interestingly, the analysis shows the universe may resemble the 'cosmological constant' like evolution (i.e., ΛCDM model is a subset of the solution set). Also, all the fixed points of our model are able to avoid Big Rip singularity. This work has been done in collaboration with Jyotirmay Das Mandal.

Analysis of interacting entropy-corrected holographic and new agegraphic dark energies

We have assumed the flat FRW model of the Universe filled with dark matter and dark energy where they are interacting. For dark energy model, we have considered the entropy-corrected HDE (ECHDE) and the entropy-corrected NADE (ECNADE). For entropy-corrected models, we have assumed logarithmic correction and power law correction. For ECHDE model, length scale L is assumed to be Hubble horizon and future event horizon. The ω_{de}-ω'_{de} analysis for the different horizons are discussed. This work has been done in collaboration with Chayan Ranjit.

Shantanu Desai

GW170817 falsifies dark matter emulators

On August 17, 2017, the LIGO interferometers detected the gravitational wave (GW) signal (GW170817) from the coalescence of binary neutron stars. This signal was also simultaneously seen throughout the electromagnetic (EM) spectrum from radio waves to gamma-rays. We point out that this simultaneous detection of GW and EM signals rules out a class of modified gravity theories, termed "dark matter emulators", which dispense with the need for dark matter by making ordinary matter couple to a different metric from that of GW. We discuss other kinds of modified gravity theories which dispense with the need for dark matter and are still viable. This simultaneous observation also provides the first observational test of Einstein's Weak Equivalence Principle (WEP) between gravitons and photons. We estimate the Shapiro time delay due to the gravitational potential of the total dark matter distribution along the line of sight (complementary to the calculation in arXiv:1710.05834 to be about 400 days). Using this estimate for the Shapiro delay and from the time difference of 1.7 seconds between the GW signal and gamma-rays, we can constrain violations of WEP using the parameterized post-Newtonian (PPN) parameter γ, and is given by $|\gamma_{\rm GW} - \gamma_{\rm EM}| < 9.8 \times 10^{-8}$. This work has been done in collaboration with S. Boran, E.O. Kahya, and R.P. Woodard.

Limit on graviton mass from galaxy cluster Abell 1689

To date, the only limit on graviton mass using galaxy clusters was obtained by Goldhaber and Nieto in 1974, using the fact that the orbits of galaxy clusters are bound and closed, and extend up to 580 kpc. It is known that only a Newtonian potential gives rise to such stable bound orbits, and a limit on the graviton mass $m_g < 1.1 \times 10^{-29}$ eV was obtained (PRD **9**, 1119, 1974). Recently, it has been shown that one can obtain closed bound orbits for Yukawa potential (arXiv:1705.02444), thus, invalidating the main *ansatz* used in Goldhaber and Nieto (1974) to obtain the graviton mass bound. In order to obtain a revised estimate using galaxy clusters, we use dynamical mass models of the Abell 1689 (A1689) galaxy cluster to check their compatibility with a Yukawa gravitational potential. We use the mass models for the gas, dark matter, and galaxies for A1689 from arXiv:1703.10219 and arXiv:1610.01543, who used this cluster to test various alternate gravity theories, which dispense with the need for dark matter. We quantify the deviations in the acceleration profile using these mass models assuming a Yukawa potential and that obtained assuming a Newtonian potential by calculating the χ^2 residuals between the two profiles. Our estimated bound on the graviton mass (m_g) is thereby given by, $m_g < 1.37 \times 10^{-29}$ eV or in terms of the graviton Compton wavelength, $\lambda_g > 9.1 \times 10^{19}$ km at 90% confidence level.

S. Dev

Neutrino mass matrices with three or four vanishing cofactors and non-diagonal charged lepton sector

We investigate the texture structures of lepton mass matrices with four (five) non-zero elements in the charged lepton mass matrix and three (four) vanishing cofactors in the neutrino mass matrix. Using weak basis transformations, all possible textures for three and four vanishing cofactors in M_ν are grouped into seven classes, and predictions for the unknown parameters−such as the Dirac $CP-$violating phase and the effective Majorana mass−for the phenomenologically allowed textures are obtained. We also illustrate how such texture structures can be realized using discrete Abelian flavour symmetries. This work has been done in collaboration with Desh Raj and Radha Raman Gautam.

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 was 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 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 P. Sarathi Pal and Sandip K. Chakrabarti.

Inclination effects and time variability properties of black hole transients

We study time variability properties of black hole transients densely monitored by the RXTE instruments. We systematically study the time/phase lag at QPO frequency. We find hard lag, integrated over Quasi Periodic Oscillation (QPO) frequency for the low inclination source (such as GX 339-4). The hard lag monotonically decrease and become negative (i.e., soft lag happens) close to 3.0 Hz for the high inclination sources (e.g., XTE J1550-564). Thus we find two different behaviours for the high inclination and the low inclination systems. We also find that the evolution properties of low-frequency quasi-periodic oscillations (QPOs) do not depend on the orbital inclination though the amplitude of low-frequency quasi-periodic oscillations (QPOs) depends on the orbital inclination. We conclude these evolutions could be due to the systematic movement of the Comptonizing region itself confirming the propagatory shock oscillation model. This work has been done in collaboration with Sandip P. Chakrabarti.

Jibitesh Dutta

Cosmological dynamics of mimetic gravity

We present a detailed investigation of the dynamical behaviour of mimetic gravity with a general potential for the mimetic scalar field. Performing a phase-space and stability analysis, we show that the scenario at hand can successfully describe the thermal history of the universe, namely the successive sequence of radiation, matter, and dark-energy eras. Additionally, at late times, the universe can either approach a de, Sitter solution, or a scaling accelerated attractor, where the dark-matter and dark-energy density parameters are of the same order, thus, offering an alleviation of the cosmic coincidence problem. Applying the general analysis to various specific potential choices, including the power-law and the exponential ones, we show that mimetic gravity can be brought into good agreement with the observed behaviour of the universe. Moreover, with an inverse square potential, we find that mimetic gravity offers an appealing unified cosmological scenario, where both dark energy and dark matter are characterized by a single scalar field, and the cosmic coincidence problem is alleviated. This work has been done in collaboration with W. Khyllep, E. N. Saridakis, N. Tamanini and S. Vagnozzi.

Dark energy with a gradient coupling to the dark matter fluid: Cosmological dynamics and structure formation

We consider scalar field models of dark energy interacting with dark matter through a coupling proportional to the contraction of the four-derivative of the scalar field with the four-velocity of the dark matter fluid. The coupling is realized at the Lagrangian level employing the formalism of scalar-fluid theories, which use a consistent Lagrangian approach for relativistic fluid to describe dark matter. This framework produces fully covariant field equations, from which, we can derive unequivocal cosmological equations at both background and linear perturbations levels. The background evolution is analyzed in detail by applying dynamical systems techniques, which allow us to find the complete asymptotic behaviour of the universe given any set of model parameters and initial conditions. Furthermore, we study linear cosmological perturbations investigating the growth of cosmic structures within the quasi-static approximation. We find that these interacting dark energy models give rise to interesting phenomenological dynamics, including late-time transitions from dark matter to dark energy domination, matter and accelerated scaling solutions and dynamical crossing of the phantom barrier. Moreover, we obtain possible deviations from standard CDM behaviour at the linear perturbations level, which have an impact on the dynamics of structure formation and might provide characteristic observational signatures. This work has been done in collaboration with W. Khyllep and N. Tamanini.

Sukanta Dutta

Spin-$0^{\pm}$ portal induced dark matter

Standard model (SM) spin-zero singlets are constrained through their di-Bosonic decay channels via an effective coupling induced by a vector-like quark (VLQ) loop at the LHC for $\sqrt{s} = 13$ TeV. These spin-zero resonances are then considered as portals for scalar, vector or Fermionic dark matter particle interactions with SM gauge Bosons. We find that the model is validated with respect to the observations from LHC data and cosmology, indirect and direct detection experiments for an appreciable range of scalar, vector and Fermionic DM masses greater than 300 GeV and VLQ masses $\geq$ 400 GeV, corresponding to the three choice of portal masses 270 GeV, 500 GeV and 750 GeV respectively. This work has been done in collaboration with Ashok Goyal and Lalit Kumar Saini.

Signals of Leptophilic dark matter at the ILC

Adopting a model independent approach, we constrained the various effective interactions of Leptophilic DM particles with the visible world from the WMAP and Planck data. The thermally averaged indirect DM annihilation cross section and the DM-electron direct-detection cross section for such a DM candidate are observed to be consistent with the respective experimental data. We study the production of cosmologically allowed Leptophilic DM in association with Z ($Z \to f\bar{f}$), $f \equiv q$, e^-, μ^- at the ILC. We perform the χ^2 analysis and compute the 99% C.L. acceptance contours in the m_χ and Λ plane from the two-dimensional differential distributions of various kinematic observables obtained after employing parton showering and hadronisation to the simulated data. We observe that the dominant hadronic channel provides the best kinematic reach of 2.62 TeV ($m_\chi = 25$ GeV), which further improves to ~ 3 TeV for polarised beams at $\sqrt{s} = 1$ TeV and an integrated luminosity of 1 ab^{-1}. This work has been done in collaboration with Divya Sachdeva and Bharti Rawat.

Sunandan Gangopadhyay

Scalar-metric quantum cosmology with Chaplygin gas and perfect fluid

In this work we consider the flat FRW cosmology with a scalar field coupled with the metric along with generalized Chaplygin gas and perfect fluid comprising the matter sector. We use the Schutz's formalism to deal with the generalized Chaplygin gas sector. The full theory is then quantized canonically using the Wheeler-DeWitt Hamiltonian formalism. We then solve the WD equation with appropriate boundary conditions. Then by defining a proper completeness relation for the self-adjointness of the WD equation, we arrive at the wave packet for the universe. It is observed that the peak in the probability density gets affected due to both fluids in the matter sector, namely, the Chaplygin gas and perfect fluid. This work has been done in collaboration with Saumya Ghosh and Prasanta K. Panigrahi.

Non-commutative effects on holographic superconductors with power Maxwell electrodynamics

The matching method is employed to analytically investigate the properties of holographic superconductors in higher dimensions in the framework of power Maxwell electrodynamics taking into account the effects of spacetime non-commutativity. The relationship between the critical temperature and the charge density, and the value of the condensation operator are obtained first. The Meissner like effect is then studied. The analysis indicates that larger values of the non-commutative parameter and the parameter q appearing in the power Maxwell theory make the condensate difficult to form. The critical magnetic field, however, increases with increase in the non-commutative parameter θ. This work has been done in collaboration with Suchetana Pal.

Sushant Ghosh

Lovelock black holes surrounded by quintessence

Lovelock gravity, consisting of the dimensionally continued Euler densities, is a natural generalization of general relativity to higher dimensions such that equations of motion are still second order, and the theory is free of ghosts. A scalar field with a positive potential that yields an accelerating universe has been termed quintessence. We present exact black hole solutions in D-dimensional Lovelock gravity surrounded by quintessence matter and also perform a detailed thermodynamical study. Further, we find that the mass, entropy and temperature of the black hole are corrected due to the quintessence background. In particular, we find that a phase transition occurs with a divergence of the heat capacity at the critical horizon radius, and that specific heat becomes positive for $r_h < r_c$, allowing the black hole to become thermodynamically stable. This work has been done in collaboration with Sunil D. Maharaj, Dharmanand Baboolal and Tae-Hun Lee.

Non-commutative geometry inspired Einstein-Gauss-Bonnet black holes

Low energy limits of a string theory suggests that the gravity action should include quadratic and higher-order curvature terms, in the form of dimensionally continued Gauss-Bonnet densities. Einstein-Gauss-Bonnet is a natural extension of the general relativity to higher dimensions, in which the first and second-order terms correspond, respectively, to general relativity and Einstein-Gauss-Bonnet gravity. We obtain five-dimensional ($5D$) black hole solutions, inspired by a non-commutative geometry, with a static spherically symmetric, Gaussian mass distribution as a source both in the general relativity and Einstein-Gauss-Bonnet gravity cases, and we also analyze their thermodynamical properties. Owing to the non-commutative corrected black hole, the thermodynamic quantities have also been modified, and phase transition is shown to be achievable. The phase transitions for the thermodynamic stability, in both the theories, are characterized by a discontinuity in the specific heat at $r_+ = r_C$, with the stable (unstable) branch for $r < (>)\ r_C$. The metric of the non-commutative inspired black holes smoothly goes over to the Boulware-Deser solution at large distance. The work has been appended with a calculation of black hole mass using holographic renormalization.

Gaurav Goswami

Revisiting CMB constraints on warm inflation

We revisit the constraints that Planck 2015 temperature, polarization and lensing data impose on the parameters of warm inflation. To this end, we study warm inflation driven by a single scalar field with a quartic self interaction potential in the weak dissipative regime. We analyse the effect of the parameters of warm inflation, namely, the inflaton self coupling λ and the inflaton dissipation parameter Q_P on the CMB angular power spectrum. We constrain λ and Q_P for 50 and 60 number of e-foldings with the full Planck 2015 data (TT, TE, EE + lowP and lensing) by performing a Markov-Chain Monte Carlo analysis using the publicly available code `CosmoMC`, and obtain the joint as well as marginalized distributions of those parameters. We present our results in the form of mean and 68 % confidence limits on the parameters and also highlight the degeneracy between λ and Q_P. From this analysis, we show how warm inflation parameters can be well constrained using the Planck 2015 data. This work has been done in collaboration with Richa Arya, Arnab Dasgupta, Jayanti Prasad and Raghavan Rangarajan.

Extranatural inflation redux

The success of a given inflationary model crucially depends upon two features: Its predictions for observables such as those of the Cosmic Microwave Background (CMB) and its insensitivity to the unknown ultraviolet (UV) physics such as quantum gravitational effects. Extranatural inflation is a well motivated scenario which is insensitive to UV physics by construction. In this five dimensional model, the fifth dimension is compactified on a circle and the zero mode of the fifth component of a bulk $U(1)$ gauge field acts as the inflaton. In this work, we study simple variations of the minimal extranatural inflation model in order to improve its CMB predictions while retaining its numerous merits. We find that it is possible to obtain CMB predictions identical to those of, e.g., $\mathcal{R}+\mathcal{R}^2$ Starobinsky model of inflation and show that this can be done in the most minimal way by having two additional light Fermionic species in the bulk, with the same $U(1)$ charges. We then find the constraints that CMB observations impose on the parameters of the model. This work has been done in collaboration with Mansi Dhuria and Jayanti Prasad.

Umananda Dev Goswami

A simulation study on a few parameters of Cherenkov photons in extensive air showers of different primaries incident at various zenith angles over a high altitude observation level

We have studied the distribution patterns of lateral density, arrival time and angular position of Cherenkov photons generated in Extensive Air Showers (EASs) initiated by γ-ray, proton and iron primaries incident with various energies and at various zenith angles. This work is the extension of our earlier work to cover a wide energy range of ground based γ-ray astronomy with a wide range of zenith angles ($\leq 40°$) of primary particles, as well as the extension to study the angular distribution patterns of Cherenkov photons in EASs. Importantly, such study gives an insight on the nature of γ-ray and hadronic showers in general. In this work, the CORSIKA 6.990 simulation code is used for generation of EASs. Similarly, this study also revealed that the lateral density and arrival time distributions of Cherenkov photons vary almost in accordance with the functions: $\rho_{ch}(r) = \rho_0\ e^{-\beta r}$ and $t_{ch}(r) = t_0 e^{\Gamma/r^\lambda}$ respectively, by taking different values of the parameters of functions for the type, energy and zenith angle of the primary particle. The distribution of Cherenkov photon's angular positions with respect to shower axis shows distinctive features depending on the primary type, its energy and the zenith angle. As a whole, this distribution pattern for the iron primary is noticeably different from those for γ-ray and proton primaries. The value of the angular position at which the maximum number of Cherenkov photons are concentrated, increases with increase in energy of vertically incident primary, but for inclined primary it lies within a small value ($\leq 1°$) for almost all energies and primary types. No significant difference in the results obtained by using the high energy hadronic interaction models, viz., QGSJETII and EPOS, has been observed. This work has been done in collaboration with G.S. Das and P. Hazarika.

Shivappa B. Gudennavar

Alternate models to dark energy

One of the unresolved questions currently in cosmology is that of the non-linear accelerated expansion of the universe. This has been attributed to the so called dark energy (DE). The accelerated expansion of the universe is deduced from measurements of type Ia supernovae. Here, we propose alternate models to account for the type Ia supernovae measurements without invoking dark energy. This work has been done in collaboration with Kenath Arun, A. Prasad and C. Sivaram.

Investigating the in-flight performance of the UVIT payload on AstroSat

We have studied the performance of the Ultraviolet Imaging Telescope (UVIT) payload on AstroSat and derived a calibration of the far-ultraviolet (FUV) and near-ultraviolet (NUV) instruments on board. We find that the sensitivity of both the FUV and NUV channels is as expected from ground calibrations, with the FUV effective area about 35 per cent and the NUV effective area about the same as that of GALEX. The point spread function of the instrument is on the order of $1.2 - 1.6$". We have found that pixel-to-pixel variations in the sensitivity are less than 10 per cent with spacecraft motion compensating for most of the flat-field variations. We derived a distortion correction but recommend that it be applied post-processing as part of an astrometric solution. This work has been done in collaboration with P. T. Rahna, Jayant Murthy, Margarita Safonova, Firoza Sutaria and S. G. Bubbly.

Priya Hasan

Optical and near-infrared photometric study of NGC 6724

BVRI CCD photometry for the poorly studied open star cluster NGC 6724 has been carried out down to a limiting magnitude of V $\sim$ 20 mag. The stars of the cluster have been observed using the Newtonian focus (f/4.84) of the 74-inch Telescope of Kottamia Astronomical Observatory in Egypt. Also, the 2MASS - JHK system are used to confirm the results we obtained. The main photometric parameters have been estimated for the present object; the diameter is found to be 6 arcmin, the distance is 1530$\pm$60 pc from the Sun, and the age is 900$\pm$50 Myr. The optical reddening E(B-V) = 0.65 mag, while the infrared one E(J-H) = 0.20 mag. The slope of the mass function distribution and the relaxation time estimations conclude that the cluster NGC 6724 is dynamically relaxed. This work has been done in collaboration with Reda Bendary, Ashraf Tadross, Anas Osmanvand and Ahmed Essam.

Spectroscopic study of NGC 281 west

NGC 281 is a complex region of star formation at 2.8 kpc. This 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 photoevaporation driven molecular core compression. To get a complete census of the young stellar population, we use observations from Chandra ACIS 100 ksec coupled with data from 2MASS and Spitzer. The Master X-ray catalogue 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 NH/AK to be 1.93 $\pm$ 0.47 x 1022 cm^{-2} mag^{-1} for this region. In this work, 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.

Naseer Bhat Iqbal

Modeling the response of a standard accretion disc to stochastic viscous uctuations

The observed variability of X-ray binaries over a wide range of time-scales can be understood in the framework of a stochastic propagation model, where viscous fluctuations at different radii induce accretion rate variability that propagate inwards to the X-ray producing region. The scenario successfully explains the power spectra, the linear rms-flux relation as well as the time-lag between different energy photons. The predictions of this model have been obtained using approximate analytical solutions or empirically motivated models, which take into account the effect of these propagating variability on the radiative process of complex accretion flows. Here, we study the variation of the accretion rate due to such viscous fluctuations using a hydro-dynamical code for the standard geometrically thin, gas pressure dominated α-disc with a zero torque boundary condition. Our results confirm earlier findings that the time-lag between a perturbation and the resultant inner accretion rate variation depends on the frequency (or time-period) of the perturbation. Here, we have quantified that the time-lag $t_{lag} \propto f^{-0.54}$, for time-periods less than the viscous time-scale of the perturbation radius and is nearly constant otherwise. This, coupled with radiative process would produce the observed frequency dependent time-lag between different energy bands. We also confirm that if there are random Gaussian fluctuations of the α-parameter at different radii, the resultant inner accretion rate has a power spectrum which is a power-law. This work has been done in collaboration with Naveel Ahmad, Ranjeev Misra, Bari Maqbool and Mubashir Hamid.

Clues on high energy emission mechanism from blazar 3C454.3 during 2015 August solar flare

We perform a detailed spectral study of a recent flaring activity from the Flat Spectrum Radio Quasar (FSRQ), 3C 454.3, observed simultaneously in optical, UV, X-ray and γ-ray energies during 16 to 28 August 2015. The source reached its peak γ-ray flux of (1.9 ± 0.2) x 10^{-05} ph cm$^{-2}s^{-1}$ on 22 August. The time averaged broadband spectral energy distribution (SED) is obtained for three time periods, namely flaring state; covering the peak γ-ray flux, post flaring state; immediately following the peak flare and quiescent state separated from the flaring event and following the post flaring state. The SED corresponding to the flaring state is investigated using different emission models involving synchrotron, synchrotron self Compton (SSC) and external Compton (EC) mechanisms. The study suggests that the X-ray and γ-ray emissions from 3C 454.3 cannot be attributed to a single emission mechanism and instead, one needs to consider both SSC and EC mechanisms. Moreover, the target photon energy responsible for the EC process corresponds to an equivalent temperature of 564 K, suggesting that the flare location lies beyond the broad line emitting region of the FSRQ. The SED fitting of the other two flux states further supports these inferences. This work has been done in collaboration with Zahir Shah, Sunder Sahayanathan, Nijil Mankuzhiyil, Pankaj Kushwaha and Ranjeev Misra.

Deepak Jain

Probing the cosmic distance duality relation using time delay lenses

The construction of the cosmic distance-duality relation (CDDR) has been widely studied. However, its consistency with various new observables remains a topic of interest. We present a new way to constrain the CDDR η(z)using different dynamic and geometric properties of strong gravitational lenses (SGL) along with SNe Ia observations. We use a sample of 102 SGL with the measurement of corresponding velocity dispersion σ_0 and Einstein radius θ_E. In addition, we also use a dataset of 12 two image lensing systems containing the measure of time delay $\triangle t$ between source images. Jointly these two datasets give us the angular diameter distance DA$_{of}$ of the lens. Further, for luminosity distance, we use the 740 observations from JLA compilation of SNe Ia. To study the combined behaviour of these datasets, we use a model independent method, Gaussian Process (GP). We also check the efficiency of GP by applying it on simulated datasets, which are generated in a phenomenological way by using realistic cosmological error bars. Finally, we conclude that the combined bounds from the SGL and SNe Ia observation do not favour any deviation of CDDR and are in concordance with the standard value (η=1) within 2σ confidence level, which further strengthens the theoretical acceptance of CDDR. This work has been done in collaboration with Akshay Rana, Shobit Mahajan, Amitabha Mukherjee and R. F. L. Holanda.

Cosmic transparency and acceleration

In this work, by considering an absorption probability independent of photon wavelength, we show that current type Ia supernovae (SNe Ia) and gamma-ray burst (GRBs) observations plus high-redshift measurements of the cosmic microwave background (CMB) radiation temperature support cosmic acceleration regardless of the transparent-universe assumption. Two flat scenarios are considered in our analyses: the $\wedge$CDM model and a kinematic model. We consider where τ(z)=2ln(1+z)$^{\epsilon}$, where τ(z)denotes the opacity between an observer at z=0 and a source at z. This choice is equivalent to deforming the cosmic distance duality relation as $D_L D_A^{-1}$ =(1+z)$^{2+\epsilon}$ and, if the absorption probability is independent of photon wavelength, the CMB temperature evolution law is T_{CMB}(z)=T_0(1+z)$^{1+2\epsilon/3}$ By marginalizing on the ϵ parameter, our analysis rules out a decelerating universe at 99.99 % C.L. for all scenarios considered. Interestingly, by considering only SNe Ia and GRBs observations, we obtain that a decelerated universe indicated by $\Omega_\wedge \leq 0.33$ and $q_0 > -0$ is ruled out around 1.5σ C.L. and 2σ C.L., respectively, regardless of the transparent-universe assumption. This work has been done in collaboration with R. F. L. Holanda and S. H. Pereira.

Md. Mehedi Kalam

Neutron stars: A relativistic study

We study the inner structure of a neutron star from a theoretical point of view and the outcome results are compared with observed data. We propose a stiff equation of state relating pressure with matter density. From our study, we calculate mass (M), compactness (u) and surface redshift (Zs) for two binary millisecond pulsars, namely PSR J16142230 and PSR J1903+327, and four X-ray binaries, namely Cen X-3, SMC X-1, Vela X-1 and Her X-1, and compare them with recent observational data. Finally, we examine the stability for such a type of theoretical structure.This work has been done in collaboration with Sk. Monowar Hossein and Sajahan Molla.

Analytical model of massive Pulsar J0348+0432

In this work, we propose a model for the Pulsar J0348+0432 (Antoniadis, et al. in Science 340:1233232, 2013) in a compact relativistic binary. Here, we investigate the physical properties by using the Finch and Skea (Class. Quantum Gravity 4:467, 1989) metric. Using our model, we evaluate central density (ρ_0), surface density (ρ_b), central pressure (p_0), surface redshift (Z_s) and probable radius of the above mentioned compact object, which is very much consistent with reported data. We also obtain a possible equation of state (EoS) of the pulsar which is physically acceptable. This work has been done in collaboration with M. Abdul Kayum Jafry, Sajahan Molla and Rabiul Islam.

Nandita Lahkar Kalita

Abundances of La^{138} and Ta^{180} through $\mathcal{V}$-nucleosynthesis in 20 $M_\odot$ type II supernova progenitor, guided by stellar models for seeds

Yields of nature's rarest isotopes La^{138} and Ta^{180} are calculated by neutrino processes in the Ne-shell of density $\rho \approx 10^4$ g/cc in a type II supernova (SN II) progenitor of mass $20M_\odot$. Two extended sets of neutrino temperature -$T_{\mathcal{V}_e}$ = 3, 4, 5, 6 MeV and $T_{\mathcal{V}(\frac{\mu}{\tau})}$ = 4, 6, 8, 10, 12 MeV respectively for charged and neutral current processes are taken. Solar mass fractions of the seeds La^{139}, Ta^{181}, Ba^{138} and Hf^{180} are taken for calculation. They are assumed to be produced in some *s*-processing events of earlier generation massive seed stars with average interior density range (ρ) $\approx 10^3$ - 10^6 g/cc. The abundances of these two elements are calculated relative to O^{16}, and are found to be sensitive to the neutrino temperature. For neutral current processes with the neutron emission branching ratio, b_n = 3.81 x 10^{-4} and b_n = 9.61 x 10^{-1}, the relative abundances of La^{138} lie in the ranges 4.48 x 10^{-14} - 2.94 x 10^{-13} and 1.13 x 10^{-10} - 7.43 x 10^{-10} respectively. Similarly, the relative abundances of Ta^{180} lie in the ranges 1.80 x 10^{-15} - 1.17 x 10^{-14} and 4.53 x 10^{-12} - 2.96 x 10^{-11} respectively for the lower and higher values of the neutron emission branching ratio. For charged current processes, the relative abundances of La^{138} and Ta^{180} are found to be in the ranges 1.38 x 10^{-9} - 7.62 x 10^{-9} and 2.09 x 10^{-11} - 1.10 x 10^{-10} respectively. Parametrized by density of the seed stars, the yields are found to be consistent with recent supernova simulation results throughout the range of neutrino temperatures. La^{138} and Ta^{180} are found to be efficiently produced in charged current interaction. This work has been done in collaboration with Sanjeev Kalita, H.L. Duorah and Kalpana Duorah.

Sanjeev Kalita

An unnoticed significance of the Chandrasekhar mass limit

Simultaneous occurrence of the three fundamental constants G, $\hbar$ and c and hence, the role of Planck mass in the Chandrasekhar mass limit is critically examined in the light of cosmology, by incorporating the cosmological constant through vacuum fluctuation at Planck scale and the holographic principle. A new interpretation of the cosmological constant problem is also put forward.

Gravitational theories near the galactic center

Upcoming Extremely Large Telescopes (ELTs) are promising probes of gravity in or near the galactic centre (GC). Effects of alternative theories of gravity, namely the Brans-Dicke theory (BDT) and f(R) gravity are studied near the GC black hole by calculating departure from general relativity (GR) in periastron advance of the S-stars and light deflection. For these estimations, black hole spin parameter is taken in the range 0.1 - 2.0 and quadrupole moments are taken in the ranges 10^{-6} - 2.0. Periastron advance been calculated for hypothetical S-stars with orbital period, $1/5^{th}$ of S0 - 2 and eccentricity e = 0.8. The difference in periastron advance between BDT and GR lies in the range 10^{-3} - 2.3 microarcseconds/yr even for large departure from GR. The difference in periastron advance between quadrupoles 10^{-6} and 2.0 lies in the range 0.268 - 0.281 microarcseconds/yr. These ranges are not only outside the astrometric capability of the ELTs, but are also contaminated by stellar perturbations. Parameter degeneracy among black hole spin, quadrupole and Brans-Dicke is discussed. For black hole S-star distances, 100 AU and 50 AU, the difference in light deflection between BDT and GR lies in the range 10^{-5} - 10^{-1} microarcseconds, making it difficult to distinguish them. From the relation between scalaron mass in f(R) gravity and calculated shift of deflection, it is found that the scalaron mass in the range, 10^{-18} - 10^{-17} eV can form stable 'dark cloud' near the black hole. Scalarons with 10^{-21} eV are found to bring the deflection shift close to astrometric range of the ELTs. Prospects for these scalarons in the tests of gravity are discussed.

Laxman Katkar

Einstein-Cartan relativity in 2-dimensional non-Riemannian space

We have introduced two real null vector formalism, here after referred to as a dyad formalism. This facilitates the computational complexity and will serve as an instructional tool to simplify mathematics. The results are derived by two different methods; one based on the dyad formalism and the other based on the techniques of differential forms introduced by the author by introducing a new derivative operator d* defined with respect to the asymmetric connections. Both the methods serve as an 'amazingly useful' technique to reduce the complexity of mathematics. We have proved that the Einstein tensor vanishes identically, yet the Riemann curvature of the non-Riemannian 2-space is influenced by the torsion. This work has been done in collaboration with D. R. Phadatare.

Ram Kishor

Normalization of Hamiltonian and non-linear stability of the triangular equilibrium points in non-resonance case with perturbations

For the study of non-linear stability of a dynamical system, normalized Hamiltonian of the system is very important to discuss the dynamics in the vicinity of invariant objects. In general, it represents a non-linear approximation to the dynamics, which is very helpful to obtain the information as regards a realistic solution of the problem. In the present study, normalization of the Hamiltonian and analysis of non-linear stability in non-resonance case, in the Chermnykh-like problem under the influence of perturbations in the form of radiation pressure, oblateness, and a disc is performed. Initially, quadratic part of the Hamiltonian is normalized in the neighbourhood of triangular equilibrium point and then higher order normalization is performed by computing the fourth order normalized Hamiltonian with the help of Lie transforms. In non-resonance case, non-linear stability of the system is discussed using the Arnold-Moser theorem. Again, the effects of radiation pressure, oblateness and the presence of the disc are analyzed separately and it is observed that in the absence as well as presence of perturbation parameters, triangular equilibrium point is unstable in the non-linear sense within the stability range $0 < \mu < \mu_1 = \bar{\mu_c}$ due to failure of the Arnold-Moser theorem. However, perturbation parameters affect the values of μ at which $D_4 = 0$, significantly. This study may help to analyze more generalized cases of the problem in the presence of some other types of perturbations such as P-R drag and solar wind drag. The results are limited to the regular symmetric disc but it can be extended in the future. This work has been done in collaboration with Badam Singh Kushvah.

Nagendra Kumar

Effect of time dependent background temperature on slow waves in viscous coronal plasma

Solar observations made by SUMER on board SOHO have shown that solar atmosphere is composed of numerous magnetic structures and is dynamic in nature. These structures support a wide range of magnetohydrodynamic waves. We study the effect of varying background temperature on small amplitude oscillations interpreted in terms of slow magnetohydrodynamic waves in solar coronal structures like prominences and coronal loops. We consider two damping mechanisms radiation and viscosity to study the behaviour of slow MHD waves. We solve the MHD equations numerically to examine the effects of radiation and viscosity on velocity amplitude. It is found that amplitude of perturbed velocity decreases in case of increasing background temperature, whereas the perturbed velocity amplitude increases in case of decaying background temperature. This work has been done in collaboration with Anil Kumar.

Suresh Kumar

Echo of interactions in the dark sector

We investigate the observational constraints on an interacting vacuum energy scenario with two different neutrino schemes (with and without a sterile neutrino) using the most recent data from CMB temperature and polarization anisotropy, baryon acoustic oscillations (BAO), type Ia supernovae from JLA sample and structure growth inferred from cluster counts. We find that inclusion of the galaxy clusters data with the minimal data combination CMB + BAO + JLA suggests an interaction in the dark sector, implying the decay of dark matter particles into dark energy, since the constraints obtained by including the galaxy clusters data yield a non-null and negative coupling parameter between the dark components at 99% confidence level. We deduce that the current tensions on the parameters H_0 and σ_8 can be alleviated within the framework of the interacting as well as non-interacting vacuum energy models with sterile neutrinos. This work has been done in collaboration with Rafael C. Nunes.

Comparison between the Logotropic and ΛCDM models at the cosmological scale

We perform a detailed comparison between the Logotropic model [P.H. Chavanis, Eur. Phys. J. Plus **130**, 130 (2015)] and the ΛCDM model. These two models behave similarly at large (cosmological) scales up to the present. Differences will appear only in the far future, in about 25 Gyrs, when the Logotropic Universe becomes phantom while the ΛCDM Universe enters in the de, Sitter era. However, the Logotropic model differs from the ΛCDM model at small (galactic) scales, where the latter encounters serious problems. Having a non-vanishing pressure, the Logotropic model can solve the cusp problem and the missing satellite problem of the ΛCDM model. In addition, it leads to dark matter halos with a constant surface density $\Sigma_0 = \rho_0 r_h$, and can explain its observed value $\Sigma_0 = 141\, M_\odot/\mathrm{pc}^2$ without adjustable parameter. This makes the Logotropic model rather unique among all the models attempting to unify dark matter and dark energy. The comparison is facilitated by the fact that these models depend on only two parameters, the Hubble constant, H_0, and the present fraction of dark matter, Ω_{m0}. Using the latest observational data from Planck 2015+Lensing+BAO+JLA+HST, we find that the best fit values of H_0 and Ω_{m0} are $H_0 = 68.30\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $\Omega_{\mathrm{m0}} = 0.3014$ for the Logotropic model, and $H_0 = 68.02\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $\Omega_{\mathrm{m0}} = 0.3049$ for the ΛCDM model. The difference between the two models is at the per cent level. As a result, the Logotropic model competes with the ΛCDM model at large scales and solves its problems at small scales. It may, therefore, represent a viable alternative to the ΛCDM model. Our study provides an explicit example of a theoretically motivated model that is almost indistinguishable from the ΛCDM model at the present time while having a completely different (phantom) evolution in the future. We analytically derive the statefinders of the Logotropic model for all values of the Logotropic constant B. We show that the parameter s_0 is directly related to this constant since $s_0 = -B/(B+1)$ independently of any other parameter like H_0 or Ω_{m0}. For the predicted value of $B = 3.53 \times 10^{-3}$, we obtain $(q_0, r_0, s_0) = (-0.5516, 1.011, -0.003518)$ instead of $(q_0, r_0, s_0) = (-0.5427, 1, 0)$ for the ΛCDM model corresponding to $B = 0$. This work has been done in collaboration with Pierre-Henri Chavanis.

Badam Singh Kushvah

Secular effect of Sun oblateness on the orbital parameters of Mars and Jupiter

In this work, we considered the Mars-Jupiter system to study the behaviour of Near Earth Asteroids (NEAs) as most of the NEAs originate in the main asteroid belt located between Mars and Jupiter. The materials obtained from NEAs are very useful for space industrialisation. The variations in orbital parameters, such as eccentricity, inclination, longitude of pericenter and longitude of ascending node of Mars and Jupiter were investigated for a time span of 200,000 years centered on J2000 (January 2000) using secular perturbation theory. We studied the effect of Sun oblateness on orbital parameters of Mars and Jupiter. Moreover, we determined the orbital parameters for asteroids moving under the perturbation effect of Mars and Jupiter by using a secular solution of Mars-Jupiter system.This work has been done in collaboration with Avaneesh Vaishwar and Devi Prasad Mishra.

Yarkovsky effect and solar radiation pressure on the orbital dynamics of the asteroid (101955) Bennu

In this work, the orbital perturbation of near-Earth asteroid Bennu due to Yarkovsky effect and solar radiation pressure (SRP) is studied. The physical model of the astroid Bennu is used to compute Yarkovsky acceleration. The basic equation of motion is written in perturbed two body problem to show the variations in orbital elements and change in position of Bennu. The change in semi-major axis due to perturbation of Yarkovsky effect is obtained. In the presence of Yarkovsky effect, the semi-major axis decreases by 348 m over one period. The magnitude of Yarkovsky force and solar radiation pressure force is computed. We find that the maximum magnitude of Yarkovsky force and solar radiation pressure force as 0.09 N and 1.16 N, respectively, at the perihelion. It is also found that Yarkovsky effect shifts the position of Bennu up to 185.2 km over 12 years of period. The change of position of Bennu due to combined effect of Yarkovsky force and solar radiation pressure is 172.35 km. This study shows that the solar radiation pressure has a much smaller effect on the orbit of Bennu than Yarkovsky effect. This work has been done in collaboration with S.N. Deo.

Smriti Mahajan

Galaxy And Mass Assembly (GAMA): Blue spheroids within 87 Mpc

In this work, we test if nearby blue spheroid (BSph) galaxies may become the progenitors of star-forming spiral galaxies or passively evolving elliptical galaxies. Our sample comprises 428 galaxies of various morphologies in the redshift range $0.002 < z < 0.02$ (8-87 Mpc) with panchromatic data from the Galaxy And Mass Assembly survey. We find that BSph galaxies are structurally (mean effective surface brightness, effective radius) very similar to their passively evolving red counterparts. However, their star formation and other properties such as colour, age, and metallicity are more like star-forming spirals than spheroids (ellipticals and lenticulars). We show that BSph galaxies are statistically distinguishable from other spheroids as well as spirals in the multi-dimensional space mapped by luminosity-weighted age, metallicity, dust mass, and specific star formation rate. We use H_I data to reveal that some of the BSphs are (further) developing their discs, hence their blue colours. They may eventually become spiral galaxies - if sufficient gas accretion occurs - or more likely fade into low-mass red galaxies. This work has been done in collaboration with Michael J Drinkwater, S Driver, A. M. Hopkins, Alister W Graham, S. Brough, et al.

Galaxy And Mass assembly (GAMA): Formation and growth of elliptical galaxies in the group environment

There are many proposed mechanisms driving the morphological transformation of disc galaxies to elliptical galaxies. In this work, we determine if the observed transformation in low-mass groups can be explained by the merger histories of galaxies. We measured the group mass-morphology relation for groups from the Galaxy And Mass Assembly group catalogue with masses from 10^{11} to $10^{15} M_\odot$. Contrary to previous studies, the fraction of elliptical galaxies in our more complete group sample increases significantly with group mass across the full range of group mass. The elliptical fraction increases at a rate of 0.163 ± 0.012 per dex of group mass for groups more massive than $10^{12.5} M_{\odot}$. If we allow for uncertainties in the observed group masses, our results are consistent with a continuous increase in elliptical fraction from group masses as low as $10^{11} M_{\odot}$. We tested if this observed relation is consistent with the merger activity using a gadget-2 dark matter simulation of the galaxy groups. We specified that a simulated galaxy would be transformed to an elliptical morphology either if it experienced a major merger or if its cumulative mass gained from minor mergers exceeded 30 per cent of its final mass. We then calculated a group mass-morphology relation for the simulations. The position and slope of the simulated relation were consistent with the observational relation, with a gradient of 0.184 ± 0.010 per dex of group mass. These results demonstrate a strong correlation between the frequency of merger events and disc-to-elliptical galaxy transformation in galaxy group environments. This work has been done in collaboration with Simon Deeley, Michael J. Drinkwater, Daniel Cunnama, Joss Bland-Hawthorn, Sarah Brough, et al.

Manzoor A. Malik

AGN feedback with the Square Kilometer Array (SKA) and implications for cluster physics and cosmology

AGN feedback is regarded as an important non-gravitational process in galaxy clusters, providing useful constraints on large-scale structure formation. It modifies the structure and energetics of the intra-cluster medium (ICM) and hence, its understanding is crucially needed in order to use clusters as high precision cosmological probes. In this context, particularly keeping in mind the upcoming high quality radio data expected from radio surveys like SKA with its higher sensitivity, high spatial and spectral resolutions, we review our current understanding of AGN feedback, its cosmological implications and the impact that SKA can have in revolutionizing our understanding of AGN feedback in large-scale structures. Recent developments regarding the AGN outbursts and its possible contribution to excess entropy in the hot atmospheres of groups and clusters, its correlation with the feedback energy in ICM, quenching of cooling flows and the possible connection between cool core clusters and radio mini-halos, are discussed. We describe current major issues regarding modeling of AGN feedback and its impact on the surrounding medium. With regard to the future of AGN feedback studies, we examine the possible breakthroughs that can be expected from SKA observations. In the context of cluster cosmology, for example, we point out the importance of SKA observations for cluster mass calibration by noting that most of $z > 1$ clusters discovered by eROSITA X-ray mission can be expected to be followed up through a 1000 hour SKA-1 mid programme. Moreover, approximately 1000 radio mini halos and ~ 2500 radio halos at $z < 0.6$ can be potentially detected by SKA1 and SKA2 and used as tracers of galaxy clusters and determination of cluster selection function. This work has been done in collaboration with Asif Iqbal, Ruta Kale, Subhabrata Majumdar, Biman B. Nath, Mahadev Pandge, et al.

Excess entropy and energy feedback from within cluster cores up to r_{200}

We estimate the non-gravitational entropy injection profiles, $\Delta K(m_g)$, and resulting non-gravitational energy feedback profiles, $\Delta E(m_g)$, of the intra-cluster medium (ICM) for a sample of 17 clusters using the joint data sets of Planck SZ pressure profiles and ROSAT X-Ray observations. The clusters are chosen such that all observed profiles span a large radial range from $0.2\, r_{500}$ (i.e., from inside the cluster cores) up to r_{200}. The feedback profiles are estimated by comparing the observed entropy, at fixed gas mass shells, with theoretical entropy profiles predicted from non-radiative (i.e., without feedback) hydrodynamic simulations. We include non-thermal pressure and gas clumping in our estimates of the feedback profiles since they become important at larger radii, typically beyond r_{500}. The inclusion of non-thermal pressure and clumping results in changing the estimates for r_{500} and r_{200} by 10-20%. We show that neglect of clumping leads to an under-estimation of $\Delta K \approx 300$ keV cm^2 at r_{500} and $\Delta K \approx 1100$ keV cm^2 at r_{200}. On the other hand, neglecting non-thermal pressure results in the over-estimation of $\Delta K \approx 100$ keV cm^2 at r_{500} and under-estimation of $\Delta K \approx 450$ keV cm^2 at r_{200}. Combining both in our analysis, we conclusively show that for the sample as a whole, an entropy floor of $\Delta K \gtrsim 300$ is ruled out at $\approx 3\sigma$ throughout the entire radial range and hence, strongly constraining all ICM pre-heating scenarios. For the estimated feedback energy profiles, we find that the neglect of clumping leads to an under-estimation of energy per particle $\Delta E \approx 1$ keV at r_{500} and $\Delta E \approx 1.5$ keV at r_{200}. Similarly, neglect of the non-thermal pressure results in an over-estimation of $\Delta E \approx 0.5$ keV at r_{500} and under-estimation of $\Delta E \approx 0.25$ keV at r_{200}. We find that the average feedback energy per particle of $\Delta E \approx 1$ keV, reminiscent of pre-heating, is also ruled out at more than 3σ beyond r_{500}. Subdividing the sample into cool-core (CC) and non cool-core (NCC) fractions, we find that CC clusters feedback profiles have significantly higher profiles compared to NCC clusters; this can be attributed to the lower values of gas mass fraction of CC compared to NCC clusters. We explore in details the effect of changes in non-thermal pressure modeling as well as the choice of choosing either AMR vs SPH simulations to get the pre-feedback profiles. We also demonstrate that our non-gravitational feedback constraints are robust w.r.t. cluster sample selection, X-Ray analysis procedures and entropy modeling, etc. This study has important implications for the understanding of the ICM physics at cluster outskirts as well as for any plausible energy feedback mechanism over a large cluster radial range. This work has been done in collaboration with Asif Iqbal, Subhabrata Majumdar, Biman B. Nath, Stefano Ettori and Dominique Eckert.

Titus Mathew

Bulk viscous matter and recent acceleration of the universe based on causal viscous theory

The evolution of the bulk viscous matter dominated universe has been analysed using the full causal Israel-Stewart theory for the evolution of bulk viscous pressure in the context of recent acceleration of the universe. The form of bulk viscosity is taken as, $\xi = \alpha\rho^{1/2}$. We obtained analytical solutions for the Hubble parameter and scale factor of the universe. The model parameters have been computed using the type Ia supernovae observational data. The evolution of the prominent cosmological parameters were obtained. The age of the universe for the best estimated model parameters is found to be less than observational value. The viscous matter behaves like stiff fluid in the early evolutionary phase and then evolves to a negative pressure fluid in the later phase. The equation of state is found to be stabilized with value $\omega > -1$ and thus, the model is not showing any of the phantom behaviour during the evolution. The local as well as the generalized second law of thermodynamics are satisfied in this model, while it was shown by many that the local second law is breaking in the Eckart formalism approach. The statefinder geometric diagnostic shows that the present model is distinct from the standard ΛCDM model of the universe. One of the marked deviation seen in this model compared to a corresponding model using Eckart approach is that in this model, the bulk viscosity decreases with the expansion of the universe, while in Eckart approach, it increases from negative values in the early universe towards positive values. This work has been done in collaboration with N. D. Jerin Mohan and Athira Sasidharan.

Holographic equi-partition and the maximization of entropy

The accelerated expansion of the universe can be interpreted as a tendency to satisfy the holographic equi-partition. It can be expressed by a simple law, $\Delta V = \Delta t \left(N_{surf} - \epsilon N_{bulk}\right)$, where V is the Hubble volume in Plank units, t is the cosmic time in Plank units and $N_{surf/bulk}$ is the degrees of freedom on the horizon/bulk of the universe. We show that this holographic equi-partition law effectively implies the maximization of entropy. In the cosmological context, a system that obeys the holographic equi-partition law behaves as an ordinary macroscopic system that proceeds to an equilibrium state of maximum entropy. We consider the standard ΛCDM model of the universe and have shown that it is consistent with the holographic equi-partition law. Analyzing the entropy evolution, we find that it also proceeds to an equilibrium state of maximum entropy. This work has been done in collaboration with P. B. Krishna.

Irom Ablu Meitei

Quantum gravity effects on Hawking radiation of Schwarzschild-de-Sitter black holes

The correction of Hawking temperature of Schwarzschild-de-Sitter (SdS) black hole is investigated using the generalized Klein-Gordon equation and the generalized Dirac equation by taking the quantum gravity effects into account. We derive the corrected Hawking temperatures for scalar particles and Fermions crossing the event horizon. The quantum gravity effects prevent the rise of temperature in the SdS black hole. Besides correction of Hawking temperature, the Hawking radiation of SdS black hole is also investigated using massive particles tunneling method. By considering self gravitation effect of the emitted particles and the space time background to be dynamical, it is also shown that the tunneling rate is related to the change of Bekenstein-Hawking entropy and small correction $(1 + 2\beta m^2)$. If the energy and angular momentum are taken to be conserved, the derived emission spectrum deviates from the pure thermal spectrum. The result gives a correction to the Hawking radiation and is also in agreement with the result of Parikh and Wilczek. This work has been done in collaboration with T. Ibungochouba Singh and K. Yugindro Singh.

Hameeda Mir

Clustering of galaxies in $f(R)$ gravity

Based on thermodynamics, we discuss the galactic clustering of expanding Universe by assuming the gravitational interaction through the modified Newton's potential given by $f(R)$ gravity. We compute the corrected N-particle partition function analytically. The corrected partition function leads to more exact equations of states of the system. By assuming that system follows quasi-equilibrium, we derive the exact distribution function which exhibits the $f(R)$ correction. Moreover, we evaluate the critical temperature and discuss the stability of the system. We observe the effects of correction of $f(R)$ gravity on the power law behaviour of particle-particle correlation function also. In order to check feasibility of an $f(R)$ gravity approach to the clustering of galaxies, we compare our results with the observational galaxy cluster catalogue. This work has been done in collaboration with Salvatore Capozziello, Mir Faizal, Behnam Pourhassan, Vincenzo Salzano and Sudhaker Upadhyay.

Large distance modification of Newtonian potential and structure formation in Universe

In this work, we study the effects of super-light brane world perturbative modes on structure formation in our Universe. As these modes modify the large distance behaviour of Newtonian potential, they effect the clustering of a system of galaxies. So, we explicitly calculate the clustering of galaxies interacting through such a modified Newtonian potential. We use a suitable approximation for analyzing this system of galaxies, and discuss the validity of such approximations. We observe that such corrections also modify the virial theorem for such a system of galaxies.This work has been done in collaboration with Sudhaker Upadhyay, Mir Faizal, Ahmed F. Ali and Behnam Pourhassan.

Bivudutta Mishra

Two fluid anisotropic dark energy models in a scale invariant theory

Some anisotropic Bianchi V dark energy models are investigated in a scale invariant theory of gravity. We consider two non-interacting fluids such as dark energy and a bulk viscous fluid. Dark energy pressure is considered to be anisotropic in different spatial directions. A dynamically evolving pressure anisotropy is obtained from the models. The models favour phantom behaviour. It is observed that, in presence of dark energy, bulk viscosity has no appreciable effect on the cosmic dynamics. This work has been done in collaboration with S. K. Tripathy and P. K. Sahoo.

Bianchi V string cosmological model with dark energy anisotropy

The role of anisotropic components on the dark energy and the dynamics of the universe 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 work has been done in collaboration with S. K. Tripathy and Pratik P. Ray.

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. This work has been done in collaboration with Samir Mandal.

Pradip Mukherjee

Milne boost from Galilean gauge theory

Physical origin of Milne boost invariance of the Newton-Cartan spacetime is traced to the effect of local Galilean boosts in its metric structure, using Galilean gauge theory. Specifically, we do not require any gauge field to understand Milne boost invariance. This work has been done in collaboration with Rabin Banerjee.

Taming Galileons in curved spacetime

Localising Galileon symmetry along with Poincare symmetry, we have found a version of the Galileon model coupled with curved spacetime, which retains the internal Galileon symmetry in covariant form. Also, the model has second order equations of motion. This work has been done in collaboration with Rabin Banerjee.

Hemwati Nandan and Rashmi Uniyal

Geodesic flows in a charged black hole spacetime with quintessence

We investigate the evolution of timelike geodesic congruences, in the background of a charged black hole spacetime surrounded with quintessence. The Raychaudhuri equations for three kinematical quantities, namely the expansion scalar, shear and rotation along the geodesic flows in such spacetime are obtained and solved numerically. We have also analysed both the weak and the strong energy conditions for focusing of timelike geodesic congruences. The effect of the normalisation constant and equation of state parameter on the evolution of the expansion scalar is discussed, for the congruences with and without an initial shear and rotation. It is observed that there always exists a critical value of the initial expansion, below which, we have focusing with smaller values of the normalisation constant and equation of state parameter. As the corresponding values for both of these parameters are increased, no geodesic focusing is observed. The results obtained are then compared with those of the Reissener-Nordtrom and Schwarzschild black hole spacetimes as well as their de-Sitter black hole analogues accordingly.

Null geodesics and observables around Kerr-Sen black hole

We investigate the geodesic motion in the background of Kerr-Sen black hole arising in the heterotic string theory. The nature of effective potential is discussed in radial as well as latitudinal direction. A special class of spherical photon orbits is obtained along with the expression for the turning point for radial photons. Dependence of photon motion within this class of solution is discussed explicitly in view of the different black hole parameters. We have discussed the allowed regions for geodesic motion of massless test particles in more generalised way by including non-equatorial motion of the photons into the account. The conditions for different types of possible orbits are discussed with specific parameter values along with the corresponding orbit structure. No terminating orbits are possible for photons due to non-zero black hole charge. Observables on the angular plane (viz., bending of light and perihelion precession for massive test particles) are analysed as special cases.

We have also calculated the rotation and mass parameters in terms of the red/blue shifts of the photons in circular and equatorial orbits emitted by the massive test particles which represent stars or other probable sources of photons. This work has been done in collaboration with K.D. Purohit.

Dibyendu Nandi

The Solar Ultraviolet Imaging Telescope on-board Aditya-L1

The Solar Ultraviolet Imaging Telescope (SUIT) is an instrument on-board Aditya-L1 mission of ISRO that will measure and monitor the solar radiation emitted in the near ultraviolet wavelength range (200 - 400 nm). SUIT will simultaneously map the photosphere and chromosphere of the Sun using 11 filters sensitive to different wavelengths and covering different heights in the solar atmosphere and help us to understand the processes involved in the transfer of mass and energy from one layer to the other. SUIT will also allow us to measure and monitor spatially resolved solar spectral irradiance that governs the chemistry of oxygen and ozone in the stratosphere of the Earths atmosphere. This is central to our understanding of Sun-climate relationship. This work has been done in collaboration with Durgesh Tripathi, A. N. Ramaprakash, Aafaque Khan, Avyarthana Ghosh, Subhamoy Chatterjee, et al.

A Sun-to-Earth analysis of magnetic helicity of the 2013 March 17-18 interplanetary coronal mass ejection

We compare the magnetic helicity in the 2013 March 17-18 interplanetary coronal mass ejection (ICME) flux rope at 1 au and in its solar counterpart. The progenitor coronal mass ejection (CME) erupted on 2013 March 15 from NOAA active region 11692 is associated with an M1.1 flare. We derive the source region reconnection flux using the post-eruption arcade (PEA) method that uses the photospheric magnetogram and the area under the PEA. The geometrical properties of the near-Sun flux rope is obtained by forward-modeling of white-light CME observations. Combining the geometrical properties and the reconnection flux, we extract the magnetic properties of the CME flux rope. We derive the magnetic helicity of the flux rope using its magnetic and geometric properties obtained near the Sun and at 1 au. We use a constant α force-free cylindrical flux rope model fit to the in situ observations in order to derive the magnetic and geometric information of the 1 au ICME. We find a good correspondence in both amplitude and sign of the helicity between the ICME and the CME, assuming a semi-circular (half torus) ICME flux rope with a length of π au. We find that about 83 percentage of the total flux rope helicity at 1 au is injected by the magnetic reconnection in the low corona. We discuss the effect of assuming flux rope length in the derived value of the magnetic helicity. This study connecting the helicity of magnetic flux ropes through the Sun-Earth system has important implications for the origin of helicity in the interplanetary medium and the topology of ICME flux ropes at 1 au and hence their space weather consequences. This work has been done in collaboration with Sanchita Pal, Nat Gopalswamy, Sachiko Akiyama, Seiji Yashiro, Pertti Makela, et al.

Rajesh Kumble Nayak

Carter constant and angular momentum

We investigate the Carter-like constant in the case of a particle moving in a non-relativistic dipolar potential. This special case is a missing link between the Carter's constant in stationary and axially symmetric spacetimes (SASS), such as Kerr solution and its possible Newtonian counterpart. We use this system to carry over the definition of angular momentum from the Newtonian mechanics to the relativistic SASS. This work has been done in collaboration with Sajal Mukherjee.

Carter's constant and superintegrability

Carter's constant is a non-trivial conserved quantity in motion of a particle moving in stationary axisymmetric spacetime. In the version of the theorem originally given by Carter, due to the presence of two Killing vectors, the system effectively has two degrees of freedom. We propose an extension to the first version of Carter's theorem to a system having three degrees of freedom to find two functionally independent Carter-like integrals of motion. We further generalize the theorem to a dynamical system with N degrees of freedom. We further study the implications of Carter's constant to superintegrability and present a different approach to probe a superintegrable system. Our formalism gives another viewpoint to a superintegrable system using the simple observation of separable Hamiltonian according to Carter's criteria. We then give some examples by constructing some two-dimensional superintegrable systems based on this idea and also show that all three-dimensional simple classical superintegrable potentials are also Carter separable. This work has been done in collaboration with Payel Mukhopadhyay.

Biswajit Pandey

Does information entropy play a role in the expansion and acceleration of the Universe?

We propose an interpretation of the expansion and acceleration of the Universe from an information theoretic viewpoint. We obtain the time evolution of the configuration entropy of the mass distribution in a static Universe and show that the process of gravitational instability leads to a rapid dissipation of configuration entropy during the growth of the density fluctuations making such a Universe entropically unfavourable. We find that in an expanding Universe, the configuration entropy rate is governed by the expansion rate of the Universe and the growth rate of density fluctuations. The configuration entropy rate becomes smaller but still remains negative in a matter dominated Universe and eventually becomes zero at some future time in a Λ- dominated Universe. The configuration entropy may have a connection to the dark energy and possibly plays a driving role in the current accelerating expansion of the Universe leading to its maximum entropy configuration.

Can anisotropy in the galaxy distribution tell the bias?

We use information entropy to analyze the anisotropy in the mock galaxy catalogues from dark matter distribution and simulated biased galaxy distributions from ΛCDM N-body simulation. We show that one can recover the linear bias parameter of the simulated galaxy distributions by comparing the radial, polar and azimuthal anisotropies in the simulated galaxy distributions with that from the dark matter distribution. This method for determination of the linear bias requires only $O(N)$ operations as compared to $O(N^2)$ or at least $O(N \log N)$ operations required for the methods based on the two-point correlation function and the power spectrum. We apply this method to determine the linear bias parameter for the galaxies in the 2MASS Redshift Survey (2MRS) and find that the 2MRS galaxies in the K_s band have a linear bias of ~ 1.3.

Mahadev Pandge

MACS J0553.4-3342: A young merging galaxy cluster caught through the eyes of Chandra and HST

We present a detailed analysis of a young merging galaxy cluster MACS J0553.4-3342 (z = 0.43) from Chandra X-ray and Hubble Space Telescope archival data. X-ray observations confirm that the X-ray emitting intra-cluster medium (ICM) in this system is among the hottest (average T = 12.1 ± 0.6 keV) and most luminous known. Comparison of X-ray and optical images confirms that this system hosts two merging subclusters SC1 and SC2, separated by a projected distance of about 650 kpc. The subcluster SC2 is newly identified in this work, while another subcluster (SC0), previously thought to be a part of this merging system, is shown to be possibly a foreground object. Apart from two subclusters, we find a tail-like structure in the X-ray image, extending to a projected distance of 1 Mpc, along the north-east direction of the eastern subcluster (SC1). From a surface brightness analysis, we detect two sharp surface brightness edges at 40 (320 kpc) and 80 arcsec (640 kpc) to the east of SC1. The inner edge appears to be associated with a merger-driven cold front, while the outer one is likely to be due to a shock front, the presence of which, ahead of the cold front, makes this dynamically disturbed cluster interesting. Nearly all the early-type galaxies belonging to the two subclusters, including their brightest cluster galaxies, are part of a well-defined red sequence. This work has been done in collaboration with Joydeep Bagchi, S. S. Sonkamble, Viral Parekh, M.K.Patil, Pratik Dabhade, et al.

A hot X-ray filament associated with A3017 galaxy cluster

Recent simulations and observations have shown large scale filaments in the cosmic web connecting nodes, with accreting materials (baryonic and dark matter) flowing through them. Current high sensitivity observations also show that the propagation of shocks through filaments can heat them up, and make filaments visible between two or more galaxy clusters or around massive clusters, based on optical and/or X-ray observations. We are reporting here the special case of the cluster A3017 associated with a hot filament. The temperature of the filament is $3.4^{-0.77}_{+1.30}$ keV and its length is ~ 1 Mpc. We have analysed its archival *Chandra* data and report various properties. We also analysed GMRT 235/610 MHz radio data. Radio observations have revealed symmetric two-sided lobes, which fill cavities in the A3017 cluster core region, associated with central AGN. In the radio map, we also noticed a peculiar linear vertical radio structure in the X-ray filament region which might be associated with a cosmic filament shock. This radio structure could be a radio phoenix or old plasma, where an old relativistic population is re-accelerated by shock propagation. Finally we put an upper limit on the radio luminosity of the filament region. This work has been done in collaboration with Viral Parekh, F. Durret and P. Padmanabh.

P. N. Pandita

Measuring the trilinear neutral Higgs Boson couplings in the MSSM at e^+e^- colliders

We consider the measurement of the trilinear couplings of the neutral Higgs Bosons (H^0, h^0) in the minimal supersymmetric standard model (MSSM) at a high energy e^+e^- linear collider in the light of the discovery of a Higgs Boson at the CERN Large Hadron Collider (LHC). We identify the state observed at the LHC with the lightest CP-even Higgs Boson of the MSSM. We implement this constraint, as well as all the other relevant experimental constraints, on the parameter space of the MSSM in order to study the feasibility of measuring the trilinear couplings of the neutral Higgs Bosons. For the measurement of trilinear couplings, we consider the multiple Higgs production processes. We delineate the regions of MSSM parameter space where the trilinear couplings of the neutral Higgs Bosons could be measured at a high energy electron-positron collider. This work has been done in collaboration with Charanjit K. Khosa.

Amit Pathak

Interstellar dehydrogenated PAH anions: Vibrational spectra

Interstellar polycyclic aromatic hydrocarbon (PAH) molecules exist in diverse forms depending on the local physical environment. Formation of ionized PAHs (anions and cations) is favourable in the extreme conditions of the interstellar medium (ISM). Besides in their pure form, PAHs are also likely to exist in substituted forms; for example, PAHs with functional groups, dehydrogenated PAHs, etc. A dehydrogenated PAH molecule might subsequently form fullerenes in the ISM as a result of ongoing chemical processes. This work presents a density functional theory (DFT) calculation on dehydrogenated PAH anions to explore the infrared emission spectra of these molecules and discuss any possible contribution towards observed IR features in the ISM. The results suggest that dehydrogenated PAH anions might be significantly contributing to the 3.3 μm region. Spectroscopic features unique to dehydrogenated PAH anions are highlighted that may be used for their possible identification in the ISM. A comparison has also been made to see the size effect on spectra of these PAHs. This work has been done in collaboration with Mridusmita Buragohain, Peter J. Sarre and Nand Kishor Gour.

Probing the infrared counterparts of diffuse far-ultraviolet sources in the Galaxy

Recent availability of high quality infrared (IR) data for diffuse regions in the Galaxy and external galaxies have added to our understanding of interstellar dust. A comparison of ultraviolet (UV) and IR observations may be used to estimate absorption, scattering and thermal emission from interstellar dust. In this work, we report IR and UV observations for selective diffuse sources in the Galaxy. Using archival mid-infrared (MIR) and far-infrared (FIR) observations from Spitzer Space Telescope, we look for counterparts of diffuse far-ultraviolet (FUV) sources observed by the Voyager, Far Ultraviolet Spectroscopic Explorer (FUSE) and Galaxy Evolution Explorer (GALEX) telescopes in the Galaxy. IR emission features at 8 m are generally attributed to Polycyclic Aromatic Hydrocarbon (PAH) molecules, while emission at 24 μm are attributed to Very Small Grains (VSGs). The data presented here is unique and our study tries to establish a relation between various dust populations. By studying the FUV-IR correlations separately at low and high latitude locations, we have identified the grain component responsible for the diffuse FUV emission. This work has been done in collaboration with Gautam Saikia, P. Shalima and Rupjyoti Gogoi.

Madhav K. Patil

Complex UV/ X-ray variability of 1H 0707 - 495

We study of the relationship between the UV and X-ray variability of the narrow-line Seyfert 1 galaxy 1H 0707495. Using a year-long Swift monitoring and four long XMM-Newton observations, we perform cross-correlation analyses of the UV and X-ray light curves, on both long and short time-scales. We also perform time-resolved X-ray spectroscopy on 1-2 ks scale, and study the relationship between the UV emission and the X-ray spectral components - soft X-ray excess and a power law. We find that the UV and X-ray variations anti-correlate on short, and possibly on long time-scales as well. Our results rule out reprocessing as the dominant mechanism for the UV variability, as well as the inward propagating fluctuations in the accretion rate. Absence of a positive correlation between the photon index and the UV flux suggests that the observed UV emission is unlikely to be the seed photons for the thermal Comptonization. We find a strong correlation between the continuum flux and the soft-excess temperature, which implies that the soft excess is most likely the reprocessed X-ray emission in the inner accretion disc. Strong X-ray heating of the innermost regions in the disc, due to gravitational light bending, appears to be an important effect in 1H 0707-495, giving rise to a significant fraction of the soft excess as reprocessed thermal emission. We also find indications for a non-static, dynamic X-ray corona, where either the size or height (or both) vary with time. This work has been done in collaboration with P.K.Pawar, Gulab C. Devangan, I.E. Papadakis, Main Pal and Ajit K. Kembhavi.

Multiphase ISM in nearby early type galaxy IC 5063

A multi-wavelength study of a nearby dust lane early-type galaxy IC 5063 is presented. The objectives are to investigate dust extinction properties and the association of interstellar dust with other phases of ISM. The colour-index maps as well as the extinction maps derived from the analysis of deep CCD observations in optical passbands revealed a prominent dust lane along its optical major axis in the inner region. In addition, two more fainter and extended dust patterns are apparent in the colour index map as well as extinction maps. These features are also evident in the smooth model subtracted residual maps. The extinction curve derived for this galaxy revealed that dust grains in it are identical to the canonical grains in the Milky Way with the dust grains little larger than the canonical grains. The total extinction measured in the V band extinction map enabled us to quantify the dust content of this galaxy to be equal to 4.9 x 10^4 M$\odot$, an order of magnitude smaller than that estimated using the IRAS flux densities at 60 and 100 μm. A multiphase ISM study revealed a surprising similarity in the morphologies of the Hα emitting ionized gas distribution and X-ray emitting gas. Systematic analysis of high resolution X-ray observations using Chandra telescope enabled us to detect 18 discrete X-ray sources within optical D_{25} region of IC 5063, out of which 17 sources were separated out as the low mass X-ray binaries and one as the high mass X-ray binary source in the X-ray colour-colour plot. This work has been done in collaboration with Bhagora T. Tate, Anil T. Kyadampure and S. K. Pandey.

Bikash Chandra Paul

Observational constraints on EoS parameters of emergent universe

We investigate emergent universe model using recent observational data of the background as well as the growth tests. The flat emergent universe model obtained by Mukherjee, et al. is permitted with a non-linear equation of state (EoS) (p=Aρ - B$\rho^{\frac{1}{2}}$), where A and B are constants (here, in our analysis A=0 is considered). We carried out analysis considering the Wang-Steinhardt ansatz for growth index (γ) and growth function ($f = \Omega_m^{\gamma}$(a)).The best-fit values of the EoS and growth parameters are determined making use of chi -square minimization technique. Here, we specifically determined the best-fit value and the range of value of the present matter density (Ω_m) and Hubble parameter (H_0). The best-fit values of the EoS parameters are used to study the evolution of the growth function *f*, growth index (γ), state parameter ω and deceleration parameter (q) for different red shift parameter z. The late accelerating phase of the universe in the EU model is accommodated satisfactorily. This work has been done in collaboration with Prasenjit Thakur.

Observational constraints on extended Chaplygin gas cosmologies

We investigate cosmological models with extended Chaplygin gas (ECG) as a candidate for dark energy and determine the equation of state parameters using observed data, namely, observed Hubble data, baryon acoustic oscillation data and cosmic microwave background shift data. Cosmological models are investigated considering cosmic fluid, which is an extension of Chaplygin gas, however, it reduces to modified Chaplygin gas (MCG) and also to generalized Chaplygin gas (GCG) in special cases. It is found that in the case of MCG and GCG, the best-fit values of all the parameters are positive. The distance modulus agrees quite well with the experimental Union2 data. The speed of sound obtained in the model is small, necessary for structure formation. We also determine the observational constraints on the constants of the ECG equation. This work has been done in collaboration with P. Thakur and A. Saha.

Ninan Sajeeth Philip

Transient classification in LIGO data using difference boosting neural network

Detection and classification of transients in data from gravitational wave detectors are crucial for efficient searches for true astrophysical events and identification of noise sources. We present a hybrid method for classification of short duration transients seen in gravitational wave data using both supervised and unsupervised machine learning techniques. To train the classifiers, we use the relative wavelet energy and the corresponding entropy obtained by applying one-dimensional wavelet decomposition on the data. The prediction accuracy of the trained classifier on 9 simulated classes of gravitational wave transients and also LIGO's sixth science run hardware injections are reported. Targeted searches for a couple of known classes of non-astrophysical signals in the first observational run of Advanced LIGO data are also presented. The ability to accurately identify transient classes using minimal training samples makes the proposed method a useful tool for LIGO detector characterization as well as searches for short duration gravitational wave signals. This work has been done in collaboration with Nikhil Mukund, Sheelu Abraham, Shivaraj Kandhasamy and Sanjit Mitra.

An information retrieval and recommendation system for astronomical observatories

We present a machine learning based information retrieval system for astronomical observatories that tries to address user defined queries related to an instrument. In the modern instrumentation scenario where heterogeneous systems and talents are simultaneously at work, the ability to supply with the right information helps speeding up the detector maintenance operations. Enhancing the detector uptime leads to increased coincidence observation and improves the likelihood for the detection of astrophysical signals. Besides, such efforts will efficiently disseminate technical knowledge to a wider audience and will help the ongoing efforts to build upcoming detectors like the LIGO-India, etc. even at the design phase to foresee possible challenges. The proposed method analyses existing documented efforts at the site to intelligently group together related information to a query and to present it on-line to the user. The user in response can further go into interesting links and find already developed solutions or probable ways to address the present situation optimally. A web application that incorporates the above idea has been implemented and tested for LIGO Livingston, LIGO Hanford and Virgo observatories. This work has been done in collaboration with Nikhil Mukund, Saurabh Thakur, Sheelu Abraham, A. K. Aniyan, Sanjit Mitra.

Ananta C. Pradhan

Spectroscopy of Na I and K I atoms embedded in weakly coupled plasma environment

The effect of the plasma environment on the structure and properties of Na I and K I atoms is studied using the Fock-space multi-reference coupled-cluster theory in the relativistic framework. The

Debye-Huckle model is used to account the effect of the plasma environment on the atoms. A significant change in the ionization energies, transition energies, transition probabilities, and oscillator strengths of Na I and K I atoms is seen when they are immersed in plasma. The number of bound states and the binding energies of plasma embedded Na I and K I reduce notably in comparison to the isolated plasma free atoms, and these changes tend the system towards gradual instability. The transition spectra of Na I and K I show red shifts in the presence of plasma screening, whereas the oscillator strengths show the red and blue shifts for the same and different principal quantum number transitions, respectively. Furthermore, the presence of plasma screening causes the suppression of spontaneous transition probabilities of plasma embedded Na I and K I atoms. These results are useful to interpret the spectral lines of astrophysical plasma and to get insights into the physical processes that are operative in the celestial objects. This work has been done in collaboration with Madhulita Das.

Anirudh Pradhan

On the origine of generalized uncertainty principle from compactified M5-brane

In this work, we demonstrate that compactification in M-theory can lead to a deformation of field theory consistent with the generalized uncertainty principle (GUP). We have shown that all Dp-branes can be formed from joining D0-branes. We generalized this model to M-theory and showed that M5-branes could also be obtained from M0-branes. Then, we compactified an M5-brane on two circles by replacing two gauge fields with two scalars. Thus, we were able to calculate the relevant action for M3-branes. We observed that extra derivative terms are produced due to compactification. These higher derivative terms can be expressed in terms of higher order momentum terms in the equation of motion for new scalar fields. These terms can be obtained by modifying the usual uncertainty principle to the GUP. In fact, we have constructed the Heisenberg algebra consistent with this deformation, and explicitly demonstrated it to be the Heisenberg algebra obtained from the GUP. So, we have demonstrated that compactification in M-theory can be used as an motivation for the GUP. This work has been done in collaboration with Alireza Sepehri and Aroonkumar Beesham.

Teleparallel dark energy in a system of D0-brane

A new model which allows a non-minimal coupling between gravity and quintessence in the configuration of teleparallel gravity was recently proposed by Geng, et al. [arXiv:1109.1092v2 [hep-th]], and they named it 'teleparallel dark energy'. Now the main problem which arises is to know what is the source of this dark energy? The answer to this question is given by the authors in M-theory. This type of dark energy may be produced at three stages in our model. First, one six-dimensional universe is formed by combining and expanding D0-branes. We know that this universe-brane is polarized on two circles and the four-dimensional cosmos and two D1-branes are yielded. At third stage, two D1-branes glued to each other and one D2-brane has been formed. This D2-brane connects the universe with another universe, gives its energy to them and causes the production of dark energy. Thus, the D2-brane is unstable and dissolves in our four-dimensional universe and supplies the needed teleparallel dark energy for expansion. These calculations are extended to M-theory and shown that the amount of teleparallel dark energy, which is produced by compactification of universe-branes in M-theory is more than string theory. This work has been done in collaboration with Umesh Kumar Sharma and Alireza Sepehri.

Farook Rahaman

Gravastars in f(R, T) gravity

We propose a unique stellar model under the f(R,T) gravity by using the conjecture of Mazur-Mottola [P. Mazur and E. Mottola, Report number: LA-UR-01-5067., P. Mazur and E. Mottola, Proc. Natl. Acad. Sci. USA 101, 9545 (2004)], which is known as gravastar and a viable alternative to the black hole as available in literature. This gravastar is described by the three different regions, viz., (I) Interior core region, (II) Intermediate thin shell, and (III) Exterior spherical region. The pressure within the interior region is equal to the constant negative matter density which provides a repulsive force over the thin spherical shell. This thin shell is assumed to be formed by a fluid of ultra relativistic plasma and the pressure, which is directly proportional to the matter-energy density according to Zel'dovich's conjecture of stiff fluid [Y.B. Zel'dovich, Mon. Not. R. Astron. Soc. **160**, 1 (1972)], does counter balance the repulsive force exerted by the interior core region. The exterior spherical region is completely vacuum and assumed to be de-Sitter spacetime, which can be described by the Schwarzschild solution. Under this specification, we find out a set of exact and singularity-free solution of the collapsing star, which presents several other physically valid features within the framework of alternative gravity. This work has been done in collaboration with Amit Das, Shounak Ghosh, B.K. Guha, Swapan Das and Saibal Ray.

Cosmic space and Pauli exclusion principle in a system of M0-branes

We show that the Pauli exclusion principle in a system of M0-branes can give rise to the expansion and contraction of the universe which is located on an M3-brane. We start with a system of M0-branes with high symmetry, which join mutually and form pairs of M1-anti-M1-branes. The resulting symmetry breaking creates gauge fields that live on the M1-branes and play the role of graviton tensor modes, which induce an attractive force between the M1 and anti-M1 branes. Consequently, the gauge fields that live on the M1-branes, and the scalar fields which are attached symmetrically to all parts of these branes, decay to Fermions that attach anti-symmetrically to the upper and lower parts of the branes, and hence the Pauli exclusion principle emerges. By closing M1-branes mutually, the curvatures produced by parallel spins will be different from the curvatures produced by anti-parallel spins, and this leads to an inequality between the number of degrees of freedom on the boundary surface and the number of degrees of freedom in the bulk region. This behaviour is inherited in the M3-brane on which the universe is located, and hence, this leads to the emergence of the universe expansion and contraction. In this sense, the Pauli exclusion principle rules the cosmic dynamics. This work has been done in collaboration with Salvatore Capozziello, Emmanuel N. Saridakis, Kazuharu Bamba, Alireza Sepheri, Ahmed Farag, et al.

C. D. Ravikumar

Study of central light concentration in nearby galaxies

We propose a novel technique to estimate the masses of super massive black holes (SMBHs) residing at the centres of massive galaxies in the nearby Universe using simple photometry. Aperture photometry using SEXTRACTOR is employed to determine the central intensity ratio (CIR) at the optical centre of the galaxy image for a sample of 49 nearby galaxies with SMBH mass estimations. We find that the CIR of ellipticals and classical bulges is strongly correlated with SMBH masses, whereas pseudo bulges and ongoing mergers show significant scatter. Also, the CIR of low luminosity AGNs in the sample shows significant connection with the 5 GHz nuclear radio emission, suggesting a stronger link between the former and the SMBH evolution in these galaxies. In addition, it is seen that various structural and dynamical properties of the SMBH host galaxies are correlated with the CIR, making the latter an important parameter in galaxy evolution studies. Finally, we propose the CIR to be an efficient and simple tool, not only to distinguish classical bulges from pseudo bulges but also to estimate the mass of the central SMBH. This work has been done in collaboration with S. Aswathy.

SN 2015bp: Adding to the growing population of transitional type Ia supernovae

Photometric and spectroscopic observations of type Ia supernova 2015bp are presented, spanning $\sim$ -6 to $\sim$ +141 days since B-band maximum. Also presented are unpublished HCT spectra of type Ia iPTF13ebh between 11 to +34 days since B-band maximum. SN 2015bp shows rapidly declining light curves with $\triangle m_{15}(B) = 1.72 \pm 0.04$. The I-band light curve shows a clear secondary maximum and peaks before the B-band maximum, placing SN 2015bp in the transitional category of SNe Ia. The spectral evolution of SN 2015bp resembles other transitional SNe Ia rather than 1991bg-like events. The C II λ6580 feature is detected in both SN 2015bp and iPTF13ebh, though it is present till the epoch of B-band maximum in the case of SN 2015bp. The velocity gradients of Si II λ6355 place SN 2015bp and iPTF13ebh in the FAINT subclass, whereas pseudo-equivalent widths of Si II features place them in the Cool (CL) subclass of SNe Ia.

The bolometric light curve of SN 2015bp indicates that ~ 0.2 $M_\odot$ of ^{56}Ni was synthesized in the explosion, with a total ejected mass of ~ 0.9 $M_\odot$, suggesting a sub-Chandrasekhar mass white dwarf progenitor. This work has been done in collaboration with Shubham Srivastav, G. C. Anupama and D. K. Sahu.

Saibal Ray

Relativistic model for anisotropic strange stars

In this work, we attempt to find a singularity free solution of Einsteins field equations for compact stellar objects, precisely strange (quark) stars, considering Schwarzschild metric as the exterior spacetime. We consider that the stellar object is spherically symmetric, static and anisotropic in nature and follows the density profile given by Mak and Harko (2002) , which satisfies all the physical conditions. To investigate different properties of the ultra-dense strange stars, we have employed the MIT bag model for the quark matter. The investigation displays an interesting feature that the anisotropy of compact stars increases with the radial coordinate and attains its maximum value at the surface, which seems an inherent property for the singularity free anisotropic compact stellar objects. In this connection, we also perform several tests for physical features of the proposed model and show that these are reasonably acceptable within certain range. Further, we find that the model is consistent with the energy conditions, and the compact stellar structure is stable with the validity of the TOV equation and Herrera cracking concept. For the masses below the maximum mass point in mass vs radius curve the typical behaviour achieved within the framework of general relativity. We have calculated the maximum mass and radius of the strange stars for the three finite values of bag constant B_g. This work has been done in collaboration with Debabrata Deb, Sourav Roy Chowdhury, Farook Rahaman and B.K. Guha.

Strange stars in f(R,T) gravity

In this work, we try to present spherically symmetric isotropic strange star model under the framework of f(R,$\mathcal{T}$) theory of gravity. To this end, we consider that the Lagrangian density is an arbitrary linear function of the Ricci scalar R and the trace of the energy momentum tensor $\mathcal{T}$ given as f(R,$\mathcal{T}$)=R+2$\chi\mathcal{T}$. We also assume that the quark matter distribution is governed by the simplest form of the MIT bag model equation of state (EoS) as $p = \frac{1}{3}(\rho$ - 4B), where B is the bag constant. We have obtained an exact solution of the modified form of the Tolman-Oppenheimer-Volkoff (TOV) equation in the framework of f(R,$\mathcal{T}$) gravity theory and studied the dependence of different physical properties, viz., total mass, radius, energy density and pressure on the chosen values of χ. Further, to examine physical acceptability of the proposed stellar model in detail, we conducted different tests, viz. energy conditions, modified TOV equation, mass-radius relation, causality condition, etc. We have precisely explained the effects arising due to the coupling of the matter and geometry on the compact stellar system. For a chosen value of the Bag constant, we have predicted numerical values of different physical parameters in tabular form for the different strange stars. It is found that as the factor χ decreases, the strange star candidates become gradually massive and larger in size with less dense stellar configuration. However, when χ increases, the stars shrink gradually and become less massive to turn into a more compact stellar system. Hence, for $\chi > 0$ the proposed model is suitable to explain the ultra-dense compact stars well within the observational limits, and for $\chi < 0$ case allows to represent the recent massive pulsars and super-Chandrasekhar stars. For $\chi = 0$ we retrieve as usual the standard results of general relativity (GR). This work has been done in collaboration with Debabrata Deb, Farook Rahaman and B.K. Guha.

Prabir Rudra

Vaidya spacetime in massive gravity's rainbow

In this work, we analyze the energy dependent deformation of massive gravity using the formalism of massive gravity's rainbow. So, we use the Vainshtein and the dRGT mechanisms for the energy dependent massive gravity, and thus, analyze a ghost free theory of massive gravity's rainbow. We study the energy dependence of a time-dependent geometry, by analyzing the radiating Vaidya solution in this theory of massive gravity's rainbow. The energy dependent deformation of this Vaidya metric will be performed using suitable rainbow functions. This work has been done in collaboration with Yaghoub Heydarzade, Farhad Darabi, Ahmed Farag Ali and Mir Faizal.

S.K. 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. The results outperform the accuracy obtained without grouping data (79.27%, 2017), Arp, et al. (94%, 2014), Annamalai, et al. (84.29%, 2016), Bahman Rashidi, et al. (82%, 2017)) and Ali Feizollah, et al. (95.5%, 2017). 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.

Categorizing text data using deep learning: A novel approach

With large number of internet users on the web, there is a need to improve the working principle of text classification, which is important and well-studied area of machine learning. Hence, in order to work with the text data and to increase the efficiency of the classifier, choice of quality features is of paramount importance. This study emphasizes two important aspects of text classification: Proposes a new feature selection technique named Combined Cohesion Separation and Silhouette Coefficient (CCSS) to find the feature set, which gathers the crux of the terms in the corpus without deteriorating the outcome in the construction process and then discusses the underlying architecture and importance of deep learning in text classification. To carry out the experimental work, four benchmark datasets are used. The empirical results of the proposed approach using deep learning are more promising compared to the other established classifiers. This work has been done in collaboration with R. K. Roul.

Sandeep Sahijpal

Thermal evolution of the trans-Neptunian objects (TNOs), icy satellites and minor icy planets in the early solar system

Numerical simulations have been performed to understand the early thermal evolution and planetary differentiation of icy bodies. These icy bodies include trans-Neptunian objects, minor icy planets (e.g., Ceres, Pluto); the icy satellites of Jupiter, Saturn, Uranus, and Neptune; and probably the icy-rocky cores of these planets. The decay energy of the radionuclides, ^{26}Al, ^{60}Fe, ^{40}K, ^{235}U, ^{238}U, and ^{232}Th, along with the impact-induced heating during the accretion of icy bodies were taken into account. The sinking of the rock mass fraction in primitive water oceans produced by the substantial melting of ice led to planetary scale differentiation with the formation of a rocky core that is surrounded by a water ocean and an icy crust within the initial tens of millions of years of the solar system. The heat produced due to ^{40}K, ^{235}U, ^{238}U, and ^{232}Th, could have further raised the temperature of the interiors of the icy bodies to the melting point of iron and silicates, thereby, leading to the formation of an iron core. The simulations indicate the presence of an iron core even at the centre of icy bodies with radii $\geq$ 500 km for different ice mass fractions. Numerical simulations for the early thermal evolution and planetary scale differentiation of Mars and Mercury have also been performed. This work has been done in collaboration with G.K Bhatia.

Did ^{26}Al and impact induced-heating differentiate Mercury?

Numerical models dealing with the planetary scale differentiation of Mercury are presented with the shortlived nuclide, ^{26}Al, as the major heat source along with the impact-induced heating during the accretion of planets. These two heat sources are considered to have caused differentiation of Mars, a planet with size comparable to Mercury. The chronological records and the thermal modeling of Mars indicate an early differentiation during the initial $\sim$ 1 million years (Ma) of the formation of the solar system. We theorize that in case Mercury also accreted over an identical time scale, the two heat sources could have differentiated the planets. Although unlike Mars, there is no chronological record of Mercury's differentiation, the proposed mechanism is worth investigation. We demonstrate distinct viable scenarios for a wide range of planetary compositions that could have produced the internal structure of Mercury as deduced by the MESSENGER mission, with a metallic iron (Fe-Ni-FeS) core of radius $\sim$ 2000 km and a silicate mantle thickness of $\sim$ 400 km. The initial compositions were derived from the enstatite and CB (Bencubbin) chondrites that were formed in reducing environments of the early solar system. We have also considered distinct planetary accretion scenarios to understand their influence on thermal processing. The majority of the models would require impact-induced mantle stripping of Mercury by hit and run mechanism with a protoplanet subsequent to its differentiation in order to produce the right size of mantle. However, this can be avoided if we increase the Fe-Ni-FeS contents to $\sim$ 71% by weight. Finally, the models presented here can be used to understand the differentiation of Mercury like exoplanets and the planetary embryos of Venus and Earth. This work has been done in collaboration with G.K Bhatia

Pramoda Kumar Samal

Testing statistical isotropy in cosmic microwave background polarization maps

We apply symmetry based power tensor technique to test conformity of PLANCK polarization maps with statistical isotropy. On a wide range of angular scales (l = 40 - 150), the preliminary analysis detects many statistically anisotropic multipoles in foreground cleaned full sky PLANCK polarization maps, viz., COMMANDER and NILC. We also study the effect of residual foregrounds that may still be present in the galactic plane using both common UPB77 polarization mask, as well as the individual component separation method specific polarization masks. However, some of the statistically anisotropic modes still persist, albeit significantly in NILC map. We further probed the data for any coherent alignments across multipoles in several bins from the chosen multipole range. This work has been done in collaboration with Pranati K. Rath, Srikanta Panda, Debesh D. Mishra and Pavan K. Aluri.

Asoke Kumar Sen

Trajectory of light ray slightly above the equatorial plane in Kerr geometry and its deflection

Deflection angle for a light ray travelling in the equatorial plane of a rotating Kerr mass has been calculated in the past by various investigators. Considering the light ray to be travelling only slightly above the equatorial plane, calculations have been made in the present work for such a rays deflection angle. We calculate deflection angles for the light ray at various heights above the equatorial plane, which are small compared to the impact parameter and derive corresponding analytical expressions for deflection angle. This work has been done in collaboration with Sarani Chakraborty.

Analysis of polarization introduced due to the telescope optics of the Thirty Meter Telescope

An analytical model has been developed to estimate the polarization effects, such as instrumental polarization (IP), crosstalk (CT), and depolarization, due to the optics of the Thirty Meter Telescope. These are estimated for the unvignetted field-of-view and the wavelengths of interest. The model estimates an IP of 1.26% and a CT of 44% at the Nasmyth focus of the telescope at the wavelength of 0.6 μm at field angle zero with the telescope pointing to zenith. Mueller matrices have been estimated for the primary, secondary, and Nasmyth mirrors. It is found that some of the Mueller matrix elements of the primary and secondary mirrors show a fourfold azimuthal antisymmetry, which indicates that the polarization at the Cassegrain focus is negligible. At the inclined Nasmyth mirror, there is no azimuthal antisymmetry in the matrix elements, and this results in non-zero values for IP and CT, which would negatively impact the polarization measurements at the telescope focus. The averaged Mueller matrix is estimated at the Nasmyth focus at different instrument ports and various zenith angles of the telescope. The variation in the Mueller matrix elements for different coatings is also estimated. The impact of this polarization effect on the science case requirements has been discussed. This analysis will help in achieving precise requirements for future instruments with polarimetric capability. This work has been done in collaboration with Ramya Manjunath Anche, G. C. Anupama, Kasiviswanathan Sankarasubramanian and Warren Skidmore.

T. R. Seshadri

Challenges in inflationary magnetogenesis: Constraints from strong coupling, backreaction, and the Schwinger effect

In models of inflationary magnetogenesis, there is a need to break conformal invariance. One of the ways this is done is to introduce a coupling to the electromagnetic action of the form, $f^2 F^{\mu\nu} F_{\mu\nu}$. These are, however, known to suffer from problems, namely, the strong coupling problem, the back reaction problem and also strong constraints due to Schwinger effect. We have proposed a model which resolves all these issues. In this model, f grows during inflation and decays post-inflation. This form of f is chosen so as to avoid the problem of strong coupling. We choose a suitable power law form of the coupling function, so that back reaction effects during inflation can be neglected. To achieve these the reheating temperature is restricted to be below $\approx 1.7 \text{ x } 10^4$ GeV. The magnetic energy spectrum is predicted to be blue. The present day magnetic field strength and the corresponding coherence length taking reheating at the QCD epoch (150 MeV) are found to be $1.4 \text{ x } 10^{-12}$G and 6.1 x 10^{-4} Mpc, respectively, after taking account of non-linear processing over and above the flux freezing evolution after reheating. The magnetic fields generated in these models satisfy the γ-ray bound below a certain reheating temperature. This work has been done in collaboration with Ramkishor Sharma, Sandhya Jagannathan and Kandaswamy Subramanian.

Studying neutral hydrogen structures during the epoch of reionization using fractal dimensions

Generalized fractal dimensions have been used to study the neutral hydrogen distribution (HI) during the epoch of reionization. HI field is generated using a numerical model of ionized bubbles. We find that the HI field displays significant multifractal behaviour and is not consistent with homogeneity at these scales when the mass averaged neutral fraction $x_{HI}^{M} \geq 0.5$. The shape and distribution of ionized regions govern the multifractality. The fractal dimension is very different when the reionization proceeds inside-out compared to when it is outside-in. Thus, the multifractal nature of HI density field at high redshifts can be used to study the nature of reionization. This multifractal nature is driven entirely by the shapes and distribution of the ionized regions. The sensitivity of the fractal dimension to the neutral fraction implies that it can be used for constraining reionization history. We find that the fractal dimension is relatively less sensitive to the value of the minimum mass of ionizing haloes when it is in the range $\sim 10^9$ *to* $10^{10} h^1$ solar mass. This work has been done in collaboration with Bidisha Bandyopadhyay and Tirthankar Roy Choudhury.

Mohit Kumar Sharma

Suggestion for search of cyclopropenone (c-C_3H_2O) in a cosmic object

Following Minimum Energy Principle, out of the three isomers of chemical formula C_3H_2O, the cyclopropenone (c-C_3H_2O) is the most stable and, therefore, may be the most abundant and easily detectable in a cosmic object. The cyclopropenone is detected in Sgr B2(N). Owing to half-spin of each of two hydrogen atoms, the c-C_3H_2O has two distinct ortho and para species. Using the rotational and centrifugal distortion constants along with the electric dipole moment, we have calculated energies of 100 rotational levels of each of the ortho and para species of c-C_3H_2O and the Einstein A-coefficients for radiative transitions between the levels. The values of Einstein A-coefficients along with the scaled values for collisional rate coefficients are used for solving a set of statistical equilibrium equations coupled with the equations of radiative transfer. Brightness temperatures of seven rotational transitions of each of the ortho and para species of c-C_3H_2O are investigated. Out of fourteen transitions, seven are found to show anomalous absorption and the rest seven are found to show emission feature. We find that the transitions $1_{10} - 1_{11}$ (1.544 GHz) may play important role in identification of cyclopropenone in a cosmic object. This work has been done in collaboration with Monika Sharma and Suresh Chandra.

Rotational quenching of H_2CO by molecular hydrogen - Suggestion on the work of Wiesenfeld and Faure

Wiesenfeld and Faure investigated rotational quenching of H_2CO by molecular hydrogen, where they considered 40 rotational levels of o-H_2CO, and 41 rotational levels of p-H_2CO. Data on energies of rotational levels of the molecule are fundamental in the investigation. We have found that the sequence of levels reported by Wiesenfeld and Faure was not as per convention of molecular physics. Their results are also available on the website http://home.strw.leidenuniv.nl/~moldata/datafiles/ph2co-h2.dat, where the collisional transitions are shown even between the levels having equal energies. Data for such transitions should not be there. This work has been done in collaboration with Monika Sharma and Suresh Chandra.

Ranjan Sharma

Anisotropic extension of Finch and Skea stellar model

In this work, the spacetime geometry of Finch and Skea [*Class. Quantum Gravity* **6**:467, 1989] has been utilized to obtain closed-form solutions for a spherically symmetric anisotropic matter distribution. By examining their physical admissibility, it has been shown that the class of solutions can be used as viable models for observed pulsars. In particular, one of the model parameters has been used as an 'anisotropic switch' to examine the impact of anisotropy on the gross physical properties of a stellar configuration. The mass-radius ($M - R$) relationship of the resultant stellar configuration has also been analyzed. This work has been done in collaboration with Shyam Das and S. Thirukkanesh.

Anisotropic generalization of well-known solutions describing relativistic self-gravitating fluid systems: An algorithm

By relaxing the pressure isotropy condition, an algorithm has been developed to generalize a plethora of well-known solutions to Einstein's field equations, describing spherically symmetric relativistic fluid spheres. By suitably fixing the model parameters in this formulation, closed-form solutions have been generated, which might be treated as anisotropic generalization of a large class of solutions describing isotropic fluid spheres. Physical acceptability of the class of solutions has been analyzed. Making use of the current estimates of mass and radius of known pulsars, the effects of anisotropic stress on the gross physical behaviour of a relativistic compact star has been highlighted. This work has been done in collaboration with S. Thirukkanesh, F. C. Ragel and Shyam Das.

Gyan Prakash Singh

Bulk viscous cosmological model in Brans-Dicke theory with new form of time varying deceleration parameter

We have presented FRW cosmological model in the framework of Brans-Dicke theory. This work deals with a new proposed form of deceleration parameter and cosmological constant Λ. The effect of bulk viscosity is also studied in the presence of modified Chaplygin gas equation of state ($p = A\rho - \frac{B}{\rho^n}$). Further, we have discussed the physical behaviours of the models. This work has been done in collaboration with Binaya K. Bishi.

LRS Bianchi type-I cosmological model with constant deceleration parameter in $f(R,T)$ gravity

A spatially homogeneous anisotropic LRS Bianchi type-I cosmological model is studied in $f(R,T)$ gravity with a special form of Hubbles parameter, which leads to constant deceleration parameter. The parameters involved in the considered form of Hubble parameter can be tuned to match, our models with the ΛCDM model. With the present observed value of the deceleration parameter, we have discussed physical and kinematical properties of a specific model. Moreover, we have discussed the cosmological distances for our model.

This work has been done in collaboration with Binaya K. Bishi, S. K. J. Pacif and P. K. Sahoo.

K. Sriram

Possible presence of a third-body in the Kepler K2 variable EPIC 202073314

We report the presence of an unseen third-body companion in a low-mass-ratio deep contact binary system Kepler K2 EPIC 202073314 as seen by the presence of the light time (LITE) effect on the O-C diagram. The system is found to be exhibiting an increasing period trend along with a sinusoidal behaviour of the O-C residuals owing to the LITE variations. The residuals are modelled initially assuming a circular orbit to obtain a third-body orbital period of $\sim$ 9.75 years. We further performed a rigorous analysis by allowing the eccentricity to vary, which led to a third-body orbital period of $\sim$ 8.66 years with $e_3 = 0.51$. We also report the photometric study of this variable. The system is found to have a mass ratio of $\sim$ 0.15 with an inclination of $\sim 77°$. Monte-Carlo simulations were performed to verify the consistency of the obtained photometric solution. The system is considered to be in significant geometrical contact as seen by the high fill-out factor of $\sim$ 57%. Magnetic inactivity of the system is understood in terms of the absence of O'Connell effect and lack of fill-in effect in the Hα spectral line. The dynamical state of the system is discussed in terms of the Hut's stability criteria as the low-mass, and high fill-out factor configuration of the system makes it a promising candidate in the context of stellar mergers. Assuming conservative mass transfer, the system is expected to meet the critical mass ratio of $\sim$ 0.07 - 0.09 in $\sim$10 million years. This work has been done in collaboration with Siddharth Malu, C. S. Choi and P. Vivekananda Rao.

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 between June 2016 and September 2016 using the 2-m Himalayan Chandra Telescope (HCT) at the Indian Astronomical Observatory (Hanle, India). 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 work has been done in collaboration with Vineet Kumar Mannaday, Ing-Guey Jiang, Devendra Kumar Sahu and Swadesh Chand.

Paniveni Udayashankar

Latitudinal dependence of supergranular area and fractal dimension

A dependence of the area of supergranular cells with respect to the latitude is studied, and it is found that the cells are situated symmetrically about the $\pm$ 25° latitude. Fractal dimension of the supergranular cells also shows a marginal latitudinal dependence, variation being in the range 1.6 - 1.7 in the latitudinal limits of $\pm$ 30°. Fractal dimension D for supergranulation is obtained according to the relation $P \propto A^{\frac{D}{2}}$, where A is the area and P is the perimeter of the supergranular cells. A difference in the fractal dimension between the active and quiet region cells is noted, which is conjectured to be due to the magnetic activity level. Supergranular cells are essentially a manifestation of convective phenomena. They can shed light on the physical conditions in the convection zone of the Sun. Moreover, supergranules play a key role in the transport and dispersal of magnetic fields as it is an important step in our quest to understand the solar cycle.

Rotational effects on supergranulation: A survey

Supergranules are large-scale convection cells in the high solar photosphere that are seen at the surface of the Sun as a pattern of horizontal flows. They are approximately 30,000 kilometres in diameter and have a lifespan of about 24 hours. About 5,000 of them are seen at any point of time in the upper photospheric region. A great deal of observational data and theoretical understanding are now available in the field of supergranulation. In this work, we review the literature on the rotational effect of the supergranules and its relation to the solar dynamo model. This work has been done in collaboration with G. M. Sowmya, G. Rajani, M. Yamuna, R. Srikanth and Jagdev Singh.

Anisul Ain Usmani

Matter radii of light proton-rich and neutron-rich nuclei

We extract root-mean-square (rms) radii of a wide range of light proton and neutron rich nuclear isotopes (He $-$ Mg) by studying their interaction cross sections (σ_I) on ^{12}C at intermediate energies within the framework of Glauber model. The calculations involve the nucleon densities obtained from harmonic-oscillator Slater determinants. The matter rms radii so obtained are compared with those available in literature. It is demonstrated that the present description of matter densities can be conveniently used to explain the experimental values of σ_I, and the extracted matter rms radii may be considered as an indication of the presence of halos and skins in proton- and neutron-rich nuclei. This work has been done in collaboration with Subel Ahmed and Z. A. Khan.

Interaction cross sections and matter radii of oxygen isotopes using the Glauber model

Using the Coulomb modified correlation expansion for the Glauber model S matrix, we calculate the interaction cross sections of oxygen isotopes ($^{16-26}O$) on ^{12}C at 1.0 GeV/nucleon. The densities of $^{16-26}O$ are obtained using (i) the Slater determinants consisting of the harmonic oscillator single-partcle wave functions (SDHO), and (ii) the relativistic mean-field approach (RMF). Retaining up to two body density term in the correlation expansion, the calculations are performed employing the free as well as the in-medium nucleon-nucleon (NN) scattering amplitude. The in-medium NN amplitude considers the effects arising due to phase variation, higher momentum transfer components, and Pauli blocking. Our main focus in this work is to reveal how could one make the best use of SDHO densities with reference to the RMF one. The results demonstrate that the SDHO densities, along with the in-medium NN amplitude, are able to provide satisfactory explanation of the experimenatal data. It is found that, except $^{23,24}O$, the predicted SDHO matter rms radii of oxygen isotopes closely agree with those obtained using the RMF densities. However, for $^{23,24}O$, our results require reasonably larger SDHO matter rms radii than the RMF values, thereby, predicting thicker neutron skins in ^{23}O and ^{24}O as compared to RMF ones. In conclusion, the results of the present analysis establish the utility of SDHO densities in predicting fairly reliable estimates of the matter rms radii of neutron-rich nuclei. This work has been done in collaboration with Suhel Ahmad, Shakeb Ahmad and Z. A. Khan.

Deepak Vaid

Superconducting and anti-ferromagnetic phases of spacetime

A correspondence between the SO(5) theory of high-T_c superconductivity and anti-ferromagnetism, put forward by Zhang and collaborators, and a theory of gravity arising from symmetry breaking of a SO (5) gauge field is presented. A physical correspondence between the order parameters of the unified SC/AF theory and the generators of the gravitational gauge connection is conjectured. A preliminary identification of regions of geometry, in solutions of Einstein's equations describing charged-rotating black holes embedded in de-Sitter spacetime, with SC and AF phases, is carried out.

LQG for the bewildered

In this book, we present a pedagogical introduction to the notions underlying the connection formulation of general relativity loop quantum gravity (LQG) with an emphasis on the physical aspects of the framework. We begin by reviewing general relativity and quantum field theory, to emphasise the similarities between them, which establish a foundation to build a theory of quantum gravity. We then explain, in a concise and clear manner, the steps leading from the Einstein-Hilbert action for gravity to the construction of the quantum states of geometry, known as spin-networks, which provide the basis for the kinematical Hilbert space of quantum general relativity. Along the way, we introduce the various associated concepts of tetrads, spin-connection and holonomies, which are a pre-requisite for understanding the LQG formalism. Having provided a minimal introduction to the LQG framework, we discuss its applications to the problems of black hole entropy and of quantum cosmology. A list of the most common criticisms of LQG is presented, which are then tackled one by one in order to convince the reader of the physical viability of the theory. This work has been done in collaboration with Sundance Bilson-Thompson.

Murli Manohar Verma

Dynamics of f(R) gravity models and asymmetry of time

We solve the field equations of modifed gravity for f(R) model in metric formalism. Further, we obtain the fixed points of the dynamical system in phase space analysis, both with and without the effects of radiation. The stability of these points is studied against the perturbations in a smooth spatial background by applying the conditions on the eigenvalues of the matrix obtained in the linearized first-order differential equations. Following this, these fixed points are used for analysing the dynamics of the system during the radiation, matter and acceleration dominated phases of the universe. Certain linear and quadratic forms of f(R) are determined from the geometrical and physical considerations and the behaviour of the scale factor is found for those forms. Further, we also determine the Hubble parameter H(t), the Ricci scalar R, and the scale factor a(t) for these cosmic phases. We show the emergence of an asymmetry of time from the dynamics of the scalar field exclusively owing to the f(R) gravity in the Einstein frame that may lead to an arrow of time at a classical level. This work 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 work has been done in collaboration with Bal Krishna Yadav.

Jaswant K. Yadav

Low-amplitude clustering in low-redshift 21cm intensity maps cross-correlated with 2dF galaxy densities

We report results from 21cm intensity maps acquired from the Parkes radio telescope and cross-correlated with galaxy maps from the $2dF$ galaxy survey. The data span the redshift range $0.057 < z < 0.098$ and cover approximately 1300 $\deg^2$ over two long fields. Cross-correlation is detected at a significance of 5.7σ. The amplitude of the cross-power spectrum is low relative to the expected dark matter power spectrum, assuming a neutral hydrogen (HI) bias and mass density equal to measurements from the ALFALFA survey. The decrement is pronounced and statistically significant at small scales. At $k \sim 1.5$ hMpc^{-1}, the cross-power spectrum is more than a factor of 6 lower than expected, with a significance of 15.3σ. This decrement indicates a lack of clustering of neutral hydrogen, a small correlation coefficient between optical galaxies and HI, or some combination of the two. Separating 2dF into red and blue galaxies, we find that red galaxies are much more weakly correlated with HI on $k \sim 1.5$ hMpc^{-1} scales, suggesting that HI is more associated with blue star-forming galaxies and tends to avoid red galaxies. This work has been done in colloboration with C. J. Anderson, N. J. Luciw, Y.-C. Li, C. Y. Kuo, J. Yadav, et al.

Interactions of galaxies outside clusters and massive groups

We investigate the dependence of physical properties on small and large scale density environment. The galaxy population consists of mainly passively evolving galaxies in comparatively low density regions of Sloan Digital Sky Survey (SDSS). The environment is defined by (i) local density using adaptive smoothing kernel, (ii) projected distance to the nearest neighbour and (iii) the morphology of the nearest neighbour. We report that the impact of interaction on galaxy properties is detectable at least out to the pair separation corresponding to the virial radius of (the neighbour) galaxies in the sample, which is mostly between 210 and 360 h^1kpc. We show that early type fraction are almost ignorant of the background density, and has a very weak density dependence for closed pairs. Star formation activity of a galaxy is found to be crucially dependent on neighbour galaxy morphology. We find star formation activity parameters and structure parameters of galaxies to be independent of the large scale background density. We also exhibit that changing the absolute magnitude of the neighbour galaxies does not affect significantly the star formation activity of those target galaxies, whose morphology and luminosities are fixed. This work has been done in collaboration with Xuelei Chen.

PUBLICATIONS BY VISITING ASSOCIATES

(a) JOURNALS

1. Samir Choudhuri, Nirupam Roy, Somnath Bharadwaj, **Sk. Saiyad Ali**, Abhik Ghosh, et al. (2017) *Validating a novel angular power spectrum estimator using simulated low frequency radio-interferometric data,* NewA, **57,** 94.

2. Samir Choudhuri, Somnath Bharadwaj, **Sk. Saiyad Ali,** Nirupam Roy, Huib T. Intema, et al. (2017) *The angular power spectrum measurement of the galactic synchrotron emission in two fields of the TGSS survey,* MNRAS, **470,** L11.

3. Anjan Kumar Sarkar, Somanth Bharadwaj and **Sk. Saiyad Ali** (2017) *Fisher matrix-based predictions for measuring the z = 3.35 binned 21-cm power spectrum using the Ooty Wide Field Array (OWFA)*, JApA, **38,** 14.

4. G. Kashyap and **G. Ambika** (2017) *Mechanisms for tuning clustering and degree-correlations in directed networks,* J. Complex Networks [https://doi.org/10.1093/comnet/cnx057].

5. Kajari Gupta and **G. Ambika** (2017) *Dynamics of slow and fast systems on complex networks,* Ind. Acad. Sci. Conf. Series, **1,** 1 [doi.10.29195/iasscs.01.01.0003].

6. Sandip V. George and **G. Ambika** (2017) *Non-linearity in data with gaps: Application to ecological and meteorological datasets,* Ind. Acad. Sci. Conf. Series, **1,** 1 [doi.10.29195/iascs.01.01.0002].

7. Prerak Garg and **Arunima Banerjee** (2017) *Origin of low surface brightness galaxies: A dynamical study,* MNRAS, **472,** 166.

8. Jeong-Sun Hwang, Changbom Park, **Arunima Banerjee** and Ho Seong Hwang (2018) *Evolution of late-type galaxies in a cluster environment: Effects of high-speed multiple encounters with early-type galaxies*, ApJ, **856,** 166.

9. **Debbijoy Bhattacharya**, Krishna Mohana, Sanna Gulati, Subir Bhattacharyya, Nilay Bhatt, et al. (2017) *Unusual long-term low-activity states of EGRET blazars in the Fermi era* , MNRAS, **471,** 5008.

10. Oluwashina Adegoke, Prasun Dhang, Banibrata Mukhopadhyay, M.C. Ramadevi and **Debbijoy Bhattacharya** (2018) *Correlating non-linear properties with spectral states of RXTE data: Possible observational evidences for four different accretion modes around compact objects*, MNRAS, **476,** 1581.

11. Sandip Dutta and **Ritabrata Biswas** (2017) *Fate of an accretion disc around a black hole when both the viscosity and dark energy is in effect*, EPJC, **77,** 717.

12. Amritendu Haldar and **Ritabrata Biswas** (2018) *Thermodynamic studies of different black holes with modifications of entropy*, Ap&SS, **363,** 27.

13. **Koushik Chakraborty, Farook Rahaman** and Arkopriya Mallick, (2017) *A relativistic two-fluid model of compact stars*, MPLA, **32,** 1750055.

14. **Subenoy Chakraborty** (2017) *A new stability criterion for general cylindrical thin-shell wormholes*, GReGr, **49,** 47**.**

15. Sujay Kr. Biswas,Wompherdeiki Khyllep, Jibitesh Dutta and **Subenoy Chakraborty** (2017) *Dynamical analysis of an interacting dark energy model in the framework of a particle creation mechanism*, PhRvD, **95,** 103009.

16. Sourav Haldar, Pritikana Bhandari and **Subenoy Chakraborty** (2017) *A thermodynamical analysis of the inhomogeneous FLRW type model: Redefined Bekenstein–Hawking system*, IJGMM, **14,** 11.

17. Sourav Haldar, Sudipto Bhattacharjee and **Subenoy Chakraborty** (2017) *Unified first law and some general prescription: A redefinition of surface gravity*, EPJC, **77,** 604.

18. Subhra Bhattacharya and **Subenoy Chakraborty** (2017) *f® gravity solutions for evolving wormholes*, EPJC, **77,** 558.

19. Sourav Haldar, Pritikana Bhandari and **Subenoy Chakraborty** (2017) *Emergent scenario in first and second order non-equilibrium thermodynamics and stability analysis*, AnPhy, **387,** 203.

20. Pritikana Bhandari, Sourav Haldar and **Subenoy Chakraborty** (2017) *Interacting dark energy model and thermal stability*, EPJC, **77,** 840.

21. Subhra Bhattacharya, Shibaji Halder and **Subenoy Chakraborty** (2017) *Evolving cosmic scenario in modified Chaplygin gas with adiabatic matter creation*, AnPhy, **388,** 443.

22. Santu Mondal, Sourav Dutta, Manjusha Tarafdar and **Subenoy Chakraborty** (2018) *A cosmological study of Einstein–Skyrme model in anisotropic Kantowski–Sachs spacetime using Lie and Noether symmetries*, IJGMM, **15,** 6.

23. **Nand K. Chakradhari**, Devendra K. Sahu, G. C. Anupama and Tushar P. Prabhu (2018) *Highly reddened type Ia supernova SN 2004ab: Another case of anomalous extinction*, MNRAS, **474,** 2502.

24. Mridweeka Singh, Kuntal Misra, Devendra K. Sahu, Raya Dastidar, ... , **Nand K. Chakradhari**, et al. (2018) *Exploring the optical behaviour of a type Iax supernova SN 2014dt*, MNRAS, **474,** 2551.

25. Devendra K. Sahu, G.C. Anupama, **Nand K. Chakradhari,** S. Srivastav, ... , K. Nomoto (2018) *Broad-line type Ic supernova SN 2014ad,* MNRAS, **475,** 2591.

26. **Nand K. Chakradhari** and Santosh Joshi (2018) *The National Cape Survey Project: A search for pulsation in chemically peculiar stars,* BSRSL, **87,** 150.

27. Mridweeka Singh, Kuntal Misra, Devendra K. Sahu, Raya Dastidar, ... , **Nand K. Chakradhari,** et al. (2018) *A peculiar subclass of type Ia supernovae a.k.a. type Iax,* BSRSL, **87,** 340.

28. **Ramesh Chandra**, B. Filippov, R. Joshi and B. Schmieder (2017) *Two step filament eruption during 14 –15 March 2015*, SoPh, **292,** 81.

29. R. Joshi, B. Schmieder, **Ramesh Chandra**, G. Aulanier, F. P. Zuccarello, et al. (2017) *Slippage of jets explained by the magnetic topology of NOAA active region 12035*, SoPh, **292,** 152.

30. F. P. Zuccarello, **Ramesh Chandra**, B. Schmieder, G. Aulanier and R. Joshi (2017) *The transition from eruptive to confined flares in the same active region*, A&A, **601,** A26.

31. M. Luna, Y. Su, B. Schmieder, **Ramesh Chandra** and T.A. Kucera (2017) *Large-amplitude longitudinal oscillations triggered by the merging of two solar filaments: Observations and magnetic field analysis*, ApJ, **850,** 143.

32. Bhuwan Joshi, Julia K. Thalmann, Prabir K. Mitra, **Ramesh Chandra** and Astrid M. Veronig (2017) *Observational and model analysis of a two-ribbon flare possibly induced by a neighboring blowout jet*, ApJ, **851,** 29.

33. Ivan Zhelyazkov, **Ramesh Chandra** and Abhishek K. Srivastava (2017) *Modeling Kelvin–Helmholtz instability in soft X-ray solar jets*, AdAst, 2626495.

34. Aabha Monga, **Ramesh Chandra** and Wahab Uddin (2018) *Photospheric Doppler enhancement and Hα evolution of an X-class flare*, NewA, **62,** 85.

35. Ivan Zhelyazkov, T. V. Zaqarashvili, L. Ofman and **Ramesh Chandra** (2018) *Kelvin-Helmholtz instability in a twisting solar polar coronal hole jet observed by SDO/AIA,* AdSpR, **61,** 628.

36. **Ramesh Chandra**, P.F. Chen, A. Fulara, Abhishek K. Srivastava and Wahab Uddin (2018) *A study of a long duration B9 flare-CME event and associated shock*, AdSpR, **61,** 705.

37. Bima Pande, Seema Pande, **Ramesh Chandra** and Mahesh Chandra Mathpal (2018) *Solar flares, CMEs and solar energetic particle events during solar cycle 24*, AdSpR , **61,**777.

38. **Ayan Chatterjee** (2017) *Entropy of black holes in N = 2 super-gravity,* InJPh, **92,** 927 [https://doi.org/10.1007/s12648-017-1152-6].

39. Soumita Modak, **Tanuka Chattopadhyay** and **Asis Kumar Chattopadhyay** (2017) *Two phase formation of massive elliptical galaxies: Study through cross-correlation including spatial effect,* Ap&SS, **362,** 206.

40. Soumita Modak, **Tanuka Chattopadhyay** and **Asis Kumar Chattopadhyay** (2018) *Unsupervised classification of eclipsing binary light curves through k-medoids clustering* [arXiv:1801.09406].

41. **Surajit Chattopadhyay** (2017) *A study on the bouncing behaviour of modified Chaplygin gas in presence of bulk viscosity and its consequences in the modified gravity framework*, IJGMM, **14,** 1750181.

42. Antonio Pasqua, **Surajit Chattopadhyay**, D. Momeni, M. Raza, R. Myrzakulovc, et al. (2017) *Cosmological reconstruction and Om diagnostic analysis of Einstein-Aether theory*, JCAP, **15,** 1475.

43. Sthiti Chakrabarti and **Surajit Chattopadhyay** (2018) *Viewing the cosmological consequences of modified holographic dark energy in various interaction scenarios*, ZNatA, **73,** 3.

44. **Surajit Chattopadhyay** (2018) *A reconstruction scheme for f(T) gravity and its consequences in the perturbation level*, IJGMM, **15,** 1850025.

45. Antonio Pasqua, **Surajit Chattopadhyay** and Ratbay Myrzakulov (2018) *Consequences of three modified forms of holographic dark energy models in bulk–brane interaction*, CaJPh, **96,** 112.

46. A.M. Mazarbhuiya and **Himadri Sekhar Das** (2017) *The study of correlation among different scattering parameters in an aggregate dust model*, Ap&SS, **362,** 161.

47. P. Deb Roy, Prithish Halder and **Himadri Sekhar Das** (2017) *Study of light scattering properties of dust aggregates with a wide variation of porosity*, Ap&SS ,**362,** 209.

48. Prithish Halder and **Himadri Sekhar Das** (2017) *JaSTA-2: Second version of the Java Superposition T-matrix application*, CoPhC, **221,** 421.

49. Tanuj Kumar Dhar and **Himadri Sekhar Das** (2017) *Correlation among extinction efficiency and other parameters in an aggregate dust model*, RAA, **17,** 118.

50. Jaydeep Paul, Apratim Nag, Karabi Devi and **Himadri Sekhar Das** (2018) *Characteristic features of double layers in rotating, magnetized plasma contaminated with dust grains with varying charges*, JKAS, **72,** 662.

51. Abdulla Al Mamon and **Sudipta Das** (2017) *A parametric reconstruction of the deceleration parameter*, EPJC, **77,** 495.

52. Jyotirmay Das Mandal and **Ujjal Debnath** (2017) *Analysing Hessence intermediate and logamediate universe in loop quantum cosmological background,* IJTP, **56,** 1771.

53. Jyotirmay Das Mandal and **Ujjal Debnath** (2017) *A note on equivalence among various scalar field models of dark energies,* IJTP, **56,** 2413.

54. Jyotirmay Das Mandal and **Ujjal Debnath** (2017) *Dynamical system analysis of interacting Hessence dark energy in (T) gravity*, AdHEP, **2017,** 2864784**,** 1.

55. Chayan Ranjit and **Ujjal Debnath** (2018) *Analysis of interacting entropy-corrected holographic and new agegraphic dark energies*, IJMPD, 27**,** 1.

56. B. P. Abbott, ... , Anirban Ain, Sukanta Bose, **Shantanu Desai,** Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh, et al. (2017) *A gravitational wave standard siren measurement of the Hubble constant,* Natur, **551,** 85.

57. P. Melchior, D. Gruen, T. McClintock, T.N. Varga, … , **Shantanu Desai,** et al. (DES Collaboration) (2017) *Weak-lensing mass calibration of redMaPPer galaxy clusters in Dark Energy Survey science verification data*, MNRAS, **469,** 4899.

58. Y.-C. Pan, R.J. Foley, M. Smith, L. Galbany, …, **Shantanu Desai,** … , et al. (DES Collaboration) (2017) *DES15E2mlf: A spectroscopically confirmed super-luminous supernova that exploded 3.5 Gyr after the big bang*, MNRAS, **470,** 4241.

59. A. Agnello, H. Lin, L. Buckley Geer, T. Treu, … , **Shantanu Desai,** et al. (2017) *Models of the strongly lensed quasar DES J0408−5354*, MNRAS, **472,** 4038.

60. G. M. Bernstein, R. Armstrong, A.A. Plazas, A.R. Walker, … , **Shantanu Desai,** et al. (2017) *Astrometric calibration and performance of the dark energy camera*, PASP, **129,** 074503.

61. G. M. Bernstein, T. M. C. Abbott, **Shantanu Desai,** D. Gruen, R.A. Gruendl, et al. (2017) *Instrumental response model and detrending for the dark energy camera*, PASP, **129,** 114502.

62. B. P. Abbott, ... , **Anirban Ain, Sukanta Bose,** Shantanu Desai, **Sanjeev Dhurandhar, Bhooshan Gadre, Sharad Gaonkar, Sanjit Mitra, Nikhil Mukund, Jayanti Prasad, Tarun Sourdeep, Jishnu Suresh,** et al. (2017) *Multi-messenger observations of a binary neutron star merger*, ApJL, **848,** L12.

63. M. Soares-Santos, D.E. Holz, J. Annis, R. Chornock, … , **Shantanu Desai,** et al. (2017) *The electromagnetic counterpart of the binary neutron star merger LIGO/Virgo GW170817. I. discovery of the optical counterpart using the dark energy camera*, ApJL, **848,** L16.

64. P. S. Cowperthwaite, E. Berger, V.A. Villar, B.D. Metzger, … , **Shantanu Desai,** et al. (2017) *The electromagnetic counterpart of the binary neutron star merger LIGO/Virgo GW170817. II. UV, optical, and near-infrared light curves and comparison to Kilonova models*, ApJL, **848,** L17.

65. A. Palmese, W. Hartley, F. Tarsitano, C. Conselice, … , **Shantanu Desai,** et al. (2017) *Evidence for dynamically driven formation of the GW170817 neutron star binary in NGC 4993*, ApJL, **849,** L34.

66. H. T. Diehl, E.J. Buckley-Geer, K.A. Lindgren, B. Nord, … , **Shantanu Desai,** et al. (DES Collaboration) (2017) *The DES bright arcs survey: Hundreds of candidate strongly lensed galaxy systems from the Dark Energy Survey science verification and year 1 observations*, ApJS, **232**, 15.

67. Shalini Ganguly and **Shantanu Desai** (2017) *Statistical significance of spectral lag transition in GRB 160625B*, APh, **94,** 17.

68. Thomas E. Collett, Elizabeth Buckley-Geer, Huan Lin, David Bacon, … , **Shantanu Desai,** et al. (2017) *Core or cusps: The central dark matter profile of a strong lensing cluster with a bright central image at redshift 1*, ApJ, **843,** 148.

69. J. Prat, C. Sánchez, R. Miquel, J. Kwan, … , **Shantanu Desai,** et al. (2018) *Galaxy bias from galaxy–galaxy lensing in the DES science verification data*, MNRAS, **473,** 1667.

70. T. Schrabback, D. Applegate, J.P. Dietrich, H. Hockstra, … , **Shantanu Desai,** et al. (2018) *Cluster mass calibration at high redshift: HST weak lensing analysis of 13 distant galaxy clusters from the South Pole Telescope Sunyaev–Zel'dovich Survey*, MNRAS, **474,** 2635.

71. M. Klein, J. J. Mohr, **Shantanu Desai,** H. Israel, S. Allam, et al. (DES Collaboration) (2018) *A multi-component matched filter cluster confirmation tool for eROSITA: Initial application to the RASS and DES-SV data sets*, MNRAS, **474,** 3324.

72. C. Chang, A. Pujol, B. Mawdsley, D. Bacon, … , **Shantanu Desai**, et al. (DES Collaboration) (2018) *Dark Energy Survey year 1 results: Curved-sky weak lensing mass map*, MNRAS, **475**, 3165.

73. C.F. Weathers, M. Banerji, P.C. Hewett, C.A. Lemon, ... , **Shantanu Desai,** et al. (2018) UV-luminous, star-forming hosts of z ~2 reddened quasars in the Dark Energy Survey, MNRAS, **475,** 3682.

74. S. Samuroff, S.L. Bridle, J. Zuntz, M.A. Troxel, … , **Shantanu Desai**, et al. (DES Collaboration) (2018) *Dark Energy Survey year 1 results: The impact of galaxy neighbours on weak lensing cosmology with IM3SHAPE*, MNRAS, **475,** 4524.

75. M. Garcia-Fernandez, E. Sanchez, I. Sevilla-Noarbe, E. Suchyta, … , **Shantanu Desai**, et al. (DES Collaboration) (2018) *Weak lensing magnification in the Dark Energy Survey science verification data*, MNRAS, **476,** 1071.

76. S. Bethapudi and **Shantanu Desai** (2018) *Separation of pulsar signals from noise using supervised machine learning algorithms*, A&C, **23,** 15.

77. Ashwani Rajan and **Shantanu Desai** (2018) *Non-Gaussian error distributions of galactic rotation speed measurements*, EPJP, **133,** 107.

78. S. Boran, **Shantanu Desai**, E. O. Kahya and R. P. Woodard (2018) *GW170817 falsifies dark matter emulators*, PhRvD, **97,** 041501.

79. **Shantanu Desai** (2018) *Limit on graviton mass from galaxy cluster Abell 1689*, PhLB, **778,** 325.

80. **Shantanu Desai** and Emre Kahya (2018) *Galactic Shapiro delay to the Crab pulsar and limit on weak equivalence principle violation*, EPJC, **78,** 86.

81. D. Q. Nagasawa, J.L. Marshall, T.S. Li, T.T. Hansen, … , **Shantanu Desai,** et al. (2018) *Chemical abundance analysis of three α-poor, metal-poor stars in the ultra-faint dwarf galaxy horologium I*, ApJ, **852,** 99.

82. M. Smith, M. Sullivan, R.C. Nichol, L. Galbany, … , **Shantanu Desai,** et al. (DES Collaboration) (2018) *Studying the ultraviolet spectrum of the first spectroscopically confirmed supernova at redshift two*, ApJ, **854,** 37.

83. N. Rumbaugh, Yue Shen, Eric Morganson, Xin Liu, … , **Shantanu Desai,** et al. (DES Collaboration) (2018) *Extreme variability quasars from the Sloan Digital Sky Survey and the Dark Energy Survey*, ApJ, **854,** 160.

84. D. L. Burke, E.S. Rykoff, S. Allam, J. Annis, … , **Shantanu Desai,** et al. (DES Collaboration) (2018) *Forward global photometric calibration of the Dark Energy Survey*, AJ, **155,** 41.

85. F. Courbin, V. Bonvin, E. Buckley-Geer, C.D. Fassnacht, … , **Shantanu Desai,** et al. (2018) *COSMOGRAIL: The COSmological MOnitoring of GRAvItational*, *Lenses*, A&A, **609,** A71.

86. **S. Dev,** Desh Raj and Radha Raman Gautam (2017) *Neutrino mass matrices with three or four vanishing cofactors and non-diagonal charged lepton sector*, PhRvD, **96,** 095002.

87. **Jibitesh Dutta,** Wompherdeiki Khyllep and Nicola Tamanini (2017) *Dark energy with a gradient coupling to the dark matter fluid: cosmological dynamics and structure formation*, JCAP, **1801,** 38.

88. Sujay Kr. Biswas, Wompherdeiki Khyllep, **Jibitesh Dutta** and **Subenoy Chakraborty** (2017) *Dynamical analysis of an interacting dark energy model in the framework of a particle creation mechanism*, PhRvD, **95,** 103009.

89. Hmar Zonunmawia, Wompherdeiki Khyllep, Nandan Roy, **Jibitesh Dutta** and Nicola Tamanini (2017) *Extended phase space analysis of interacting dark energy models in loop quantum cosmology*, PhRvD, **96,** 083527**.**

90. **Jibitesh Dutta,** Wompherdeiki Khyllep, Emmanuel N. Saridakis, Nicola Tamanini and Sunny Vagnozzi (2018) *Cosmological dynamics of mimetic gravity*, JCAP, **1802,** 41.

91. **Sukanta Dutta**, Bharti Rawat and Divya Sachdeva (2017) *Signals of leptophilic dark matter at the ILC*, EPJC, **77,** 639.

92. **Sukanta Dutta,** Ashok Goyal and Lalit Kumar Saini (2018) *Spin-$0^{\pm}$ portal induced dark matter*, JHEP, **1802,** 23.

93. Debabrata Ghorai and **Sunandan Gangopadhyay** (2017) *Non-linear effects on the holographic free energy and thermodynamic geometry*, EL, **118,** 31001.

94. Sukanta Bhattacharyya, **Sunandan Gangopadhyay** and **Anirban Saha** (2017) *Quantum mechanics of a particle in an accelerated frame and the equivalence principle,* EL, **120,** 30005.

95. Saurav Das, **Sunandan Gangopadhyay** and Debabrata Ghorai (2017) *Viscosity to entropy density ratio for non-extremal Gauss–Bonnet black holes coupled to Born–Infeld electrodynamics*, EPJC, **77,** 615.

96. Rabin Banerjee, **Sunandan Gangopadhyay** and **Pradip Mukherjee** (2017) *On the question of symmetries in non-relativistic diffeomorphism-invariant theories*, IJMPA, A32, 1750115.

97. Aslam Halder and **Sunandan Gangopadhyay** (2017) *Phase-space non-commutativity and the thermodynamics of the Landau system,* MPLA, **32,** 1750102.

98. Saumya Ghosh and **Sunandan Gangopadhyay** (2017) *Thermodynamics and emergent universe*, MPLA, **32,** 1750089.

99. Subhajit Saha, Saumya Ghosh, and **Sunandan Gangopadhyay** (2017) *Interacting Chaplygin gas revisited*, MPLA, **32,** 1750109.

100. Saumya Ghosh, **Sunandan Gangopadhyay** and Prasanta K. Panigrahi (2018) *Scalar-metric quantum cosmology with Chaplygin gas and perfect fluid*, EPJC,78, 41.

101. Suchetana Pal and **Sunandan Gangopadhyay** (2018) *Non-commutative effects on olographic super-conductors with power Maxwell electrodynamics*, AnPhy, **388,** 472.

102. **Sushant G. Ghosh,** Muhammed Amir and Sunil D. Maharaj (2017) *Quintessence background for 5D Einstein–Gauss–Bonnet black holes*, EPJC, **77,** 530.

103. Rahul Kumar and **Sushant G. Ghosh** (2017) *Accretion onto a non-commutative geometry inspired black hole*, EPJC,**77,** 577.

104. Lunchakorn Tannukij, Pitayuth Wongjun and **Sushant G. Ghosh** (2017) *Black string in dRGT massive gravity*, EPJC, **77,** 846.

105. **Sushant G. Ghosh,** Sunil D. Maharaj, Dharmanand Baboolal and Tae-Hun Lee (2018) *Lovelock black holes surrounded by quintessence*, EPJC, **78,** 90.

106. **Sushant G. Ghosh** (2018) *Non-commutative geometry inspired Einstein–Gauss–Bonnet black holes,* CQGra, **35,** 085008.

107. Gautam Saikia, P. Shalima, **Rupjyoti Gogoi** and **Amit Pathak** (2017) *Probing the infrared counterparts of diffuse far-ultraviolet sources in the galaxy*, P&SS, **149,** 77.

108. **Rupjyoti Gogoi,** P. Shalima and Ranjeev Misra (2018) *The distribution of infrared point sources in nearby elliptical galaxies*, NewA, **59,** 21.

109. Manasi Dhuria, **Gaurav Goswami** and Jayanti Prasad (2017) *Extra-natural inflation redux,* PhRvD, **96,** 083529.

110. Richa Arya, Arnab Dasgupta, **Gaurav Goswami,** Jayanti Prasad and Raghavan Rangarajana (2018) *Revisiting CMB constraints on warm inflation*, JCAP, **2,** 43.

111. G.S. Das, P. Hazarika and **Umananda Dev Goswami** (2018) *A simulation study on few parameters of Cherenkov photons in extensive air showers of different primaries incident at various zenith angles over a high altitude observation level*, APh, **100,** 38.

112. P. T. Rahna, Jayant Murthy, Margarita Safonova, Firoza Sutaria, **Shivappa B. Gudennavar,** et al. (2017) *Investigating the in-flight performance of the UVIT payload on AstroSat*, MNRAS, **471,** 3028.

113. Jayant Murthy, P. T. Rahna, Firoza Sutaria, Margarita Safonova, **Shivappa B. Gudennavar,** et al. (2017) *JUDE: An ultraviolet imaging telescope pipeline*, A&C, **20,** 120.

114. Madhu Kashyap Jagadeesh, **Shivappa B. Gudennavar,** Urmi Doshi and Margarita Safonova (2017) *Indexing of exo-planets in search for potential habitability: Application to Mars-like worlds*, Ap&SS, 362, 146.

115. Kenath Arun, **Shivappa B. Gudennavar** and C Sivaram (2017) *Dark matter, dark energy, and alternate models: A review*, AdSpR, 60, 166.

116. Kenath Arun, **Shivappa B. Gudennavar,** A. Prasad and C. Sivaram (2018) *Alternate models to dark energy*, AdSpR, **61,** 567.

117. Behnam Pourhassan, Sudhaker Upadhyay, **Mir Hameeda** and Mir Faizal (2017) *Clustering of galaxies with dynamical dark energy*, MNRAS, **468,** 3166.

118. **Mir Hameeda**, Sudhaker Upadhyay, Mir Faizal, Ahmed F. Ali and Behnam Pourhassan (2018) *Large distance modification on Newtonian potential and structure formation in universe,* PDU, **19,** 137 [arXiv:1706.01753].

119. Salvatore Capozziello, Mir Faizal, **Mir Hameeda**, Behnam Pourhassan, Vincenzo Salzano, et al. (2018) *Clustering of galaxies with f(R) gravity*, MNRAS, **474,** 2430.

120. **K. P. Harikrishnan,** Ranjeev Misra and **G. Ambika** (2017) *Is a hyper-chaotic attractor superposition of two multi-fractals?*, CSF, **103,** 450.

121. Rinku Jacob, **K. P. Harikrishnan,** Ranjeev Misra and **G. Ambika** (2017) *Recurrence network measures for hypothesis testing using surrogate data: Application to black hole light curves*, CNSNS, **54,** 84.

122. Snehal M. Shekatkar, Yamini Kotriwar, **K.P. Harikrishnan** and **G. Ambika** (2017) *Detecting abnormality in heart dynamics from multi-fractal analysis of ECG signals,* NatSR, **7,** 15127 [doi. 10.1038/s41598-017-15498-z].

123. **K.P. Harikrishnan,** Rinku Jacob, Ranjeev Misra and **G. Ambika** (2017) *Determining the minimum embedding dimension for state space reconstruction through recurrence netwroks,* Ind. Acad. Sci. Conf. Series, **1,** 1 [doi.10.29195/iascs.01.01.0004].

124. **K.P. Harikrishnan,** Rinku Jacob, Ranjeev Misra and **G. Ambika** (2017) *Weighted recurrence networks from chaotic time series,* Chao. Model. Sim., **4,** 433.

125. Reda Bendary, Ashraf Tadross, **Priya Hasan,** Anas Osman, Ahmed Essam (2018) *Optical and near-infrared photometric study of NGC 6724,* RAA, **18,** 1674.

126. **Priya Hasan** (2018) *Spectroscopic study of NGC 281 West,* BSRSL, **87**, 207.

127. Zahir Shah, Sunder Sahayanathan, ... , Pankaj Kushwaha, Ranjeev Misra, **Naseer Iqbal** (2017) *Clues on high-energy emission mechanism from blazar 3C 454.3 during 2015 August flare*, MNRAS, **470,** 3283.

128. Naveel Ahmad, Ranjeev Misra, **Naseer Iqbal,** Bari Maqbool and Mubashir Hamid (2018) *Modelling the response of a standard accretion disc to stochastic viscous fluctuations,* NewA, **58,** 84.

129. Joydeep Bagchi, Shishir Sankhyayan, Prakash Sarkar, Somak Raychaudhury, **Joe Jacob,** and Pratik Dabhade (2017) *Saraswati: An extremely massive ~200 mega-parsec scale supercluster,* ApJ, **844,** 25.

130. K. G. Biju, Joydeep Bagchi, ... , Pratik Dabhade, Samir Dhurde, Sheelu Abraham, **Joe Jacob, Madhav K. Patil, Mahadev Pandge,** et al. (2017) *`Zwicky's Nonet': A compact merging ensemble of nine galaxies and 4C 35.06, a peculiar radio galaxy with dancing radio jets*, MNRAS, **471,** 617.

131. Akshay Rana, **Deepak Jain,** Shobhit Mahajan, Amitabha Mukherjee and R.F.L. Holanda (2017) *Probing the cosmic distance duality relation using time delay lenses*, JCAP, **1707,** 10.

132. R. F. L. Holanda, S. H. Pereira and **Deepak Jain** (2017) *Constraints on a possible evolution of mass density power-law index in strong gravitational lensing from cosmological data*, MNRAS, **471,** 3079.

133. R. F. L. Holanda, S. H. Pereira and **Deepak Jain** (2018) *Cosmic transparency and acceleration*, PhRvD, **97,** 023538.

134. **Charles Jose,** Carlton M. Baugh, Cedric G. Lacey and Kandaswamy Subramanian (2017*) Understanding the non-linear clustering of high redshift galaxies*, MNRAS, **469,** 4428.

135. **Kanti Jotania** (2017) *List of papers published by Professor P.C. Vaidya (compiled in his birth centenary year),* Mathematics Today*,* **33,** 1**.**

136. M. Abdul Kayum Jafry, Sajahan Molla, Rabiul Islam and **Mehedi Kalam** (2017) *Analytical model of massive Pulsar J0348+0432*, Ap&SS, 362, 188.

137. **Mehedi Kalam, Sk. Monowar Hossein** and Sajahan Molla (2018) *Neutron stars: A relativistic study*, RAA, **18,** 25.

138. **Nandita Lahkar Kalita, Sanjeev Kalita,** H. L. Duorah and Kalpana Duorah (2017) *Abundances of La^{138} and Ta^{180} through v-nucleosynthesis in $20M_\odot$ type II supernova progenitor, guided by stellar models for seeds*, JApA, **38,** 8.

139. **Sanjeev Kalita** (2017) *An unnoticed significance of the Chandrasekhar mass limit*, Ap, 60, 422.

140. **Sanjeev Kalita** and A. Barman (2017) *Effect of the Kerr metric on photosperic radius expansion in X- ray burst*, Ap, **60,** 582.

141. **Sanjeev Kalita** (2017) *Revealing new picture of dark matter through test of gravity near the galactic center*, RNAAS, **1,** 27.

142. **Sanjeev Kalita** (2018) *Gravitational theories near the galactic center*, ApJ, **855,** 70.

143. **Laxman N. Katkar** and D. R. Phadatare (2017) *Einstein-Cartan relativity in 2-dimensional non-Riemannian space*, Global J. Pure and App. Maths., **13,** 5945.

144. **Ram Kishor** and **Badam Singh Kushvah** (2017) *Normalization of Hamiltonian and non-linear stability of the triangular equilibrium points in non-resonance case with perturbations*, Ap&SS, **362,** 156.

145. Anil Kumar and **Nagendra Kumar** (2018) *Effect of time dependent background temperature on slow waves in viscous coronal plasma*, Intl. J. Stat. App. Maths., **3,** 178.

146. **Suresh Kumar** and Rafael C. Nunes (2017) *Observational constraints on dark matter–dark energy scattering cross section*, EPJC, **77,** 734.

147. **Suresh Kumar** and Rafael C. Nunes (2017) *Echo of interactions in the dark sector*, PhRvD, **96,** 103511.

148. Pierre-Henri Chavanis and **Suresh Kumar** (2017) *Comparison between the logotropic and ΛCDM models at the cosmological scale*, JCAP, **5,** 18.

149. Ozgur Akarsu, Nihan Katirci and **Suresh Kumar** (2018) *Cosmic acceleration in dust only Universe via energy-momentum powered gravity*, PhRvD**, 97,** 024011.

150. S.N. Deo and **Badam Singh Kushvah** (2017*) Yarkovsky effect and solar radiation pressure on the orbital dynamics of the asteroid (101955) Bennu*, A&C, **20,** 97.

151. Avaneesh Vaishwar, **Badam Singh Kushvah** and Devi Prasad Mishra (2018) *Secular effect of sun oblateness on the orbital parameters of Mars and Jupiter*, FBS, **59,** 4.

152. Simon Deeley, Michael J. Drinkwater, Daniel Cunnama, Joss Bland-Hawthorn, … , **Smriti Mahajan,** et al. (2017) *Galaxy and Mass Assembly (GAMA): Formation and growth of elliptical galaxies in the group environment*, MNRAS, **467,** 3934.

153. M. S. Owers, J.T. Allen, I. Baldry, J.J. Bruant, … , **Smriti Mahajan,** et al. (2017) *The SAMI Galaxy Survey: The cluster redshift survey, target selection and cluster properties*, MNRAS, **468,** 1824.

154. **Smriti Mahajan,** Michael J. Drinkwater, S. Driver, A. M. Hopkins, Alister W. Graham, et al. (2018) *Galaxy and Mass Assembly (GAMA): Blue spheroids within 87 Mpc*, MNRAS, **475,** 788.

155. Asif Iqbal, Subhabrata Majumdar, Biman B. Nath, Stefano Ettori, … , **Manzoor A. Malik** (2017**)** *Excess entropy and energy feedback from within cluster cores up to r_{200}*, MNRAS, **472,** 713.

156. Ajaz Ahmad Dar and **Manzoor A. Malik** (2017) *Gulmarg, Kashmir, India: Potential site for optical astronomical observations*, JApA, **38,** 18.

157. Mussadiq H. Qureshi, Asif Iqbal, **Manzoor A. Malik** and Tarun Souradeep (2017) *Low-l power suppression in punctuated inflation*, JCAP, **4,** 013.

158. N.D. Jerin Mohan, Athira Sasidharan and **Titus K. Mathew** (2017) *Bulk viscous matter and recent acceleration of the universe based on causal viscous theory*, EPJC, **77,** 849.

159. P. B. Krishna and **Titus K. Mathew** (2017) *Holographic equipartition and the maximization of entropy*, PhRvD, **96,** 063513.

160. T. Ibungochouba Singh, **Irom Ablu Meitei** and K. Yugindro Singh (2017) *Quantum gravity effects on Hawking radiation of Schwarzschild-de Sitter black holes*, IJTP, **56,** 11.

161. S. K. Tripathy, **Bivudutta Mishra** and P. K. Sahoo (2017) *Two fluid anisotropic dark energy models in a scale invariant theory*, EPJP, **132,** 388.

162. **Bivudutta Mishra,** S. K. Tripathy and Pratik P. Ray (2018) *Bianchi-V string cosmological model with dark energy anisotropy*, Ap&SS, **363,** 86.

163. **Soumen Mondal** and **Prasad Basu** (2018) *Relativistic accretion and wind flows around rotating black holes*, Intl. J. Engg. Sci. Maths., Special Issue, **7,** 70.

164. Samir Mandal and **Soumen Mondal** (2018) *Spectral properties of the accretion discs around rotating black holes*, JApA, **39,** 19.

165. Rabin Banerjee and **Pradip Mukherjee** (2017) *Taming Galileons in curved spacetime*, CQGra, **34,** 235005.

166. Rabin Banerjee and **Pradip Mukherjee** (2018) *Milne boost from Galilean gauge theory,* PhLB, **778,** 303.

167. Buddhi Vallabh Tripathi, **Hemwati Nandan** and K. D. Purohit (2017) *Global monopole in a broken-symmetric theory of gravitation*, MPLA, **32,** 1750061.

168. Sanchita Pal, Nat Gopalswamy, **Dibyendu Nandi,** Sachiko Akiyama, Seiji Yashiro, et al. (2017) *A sun-to-earth analysis of magnetic helicity of the 2013 March 17 – 18 interplanetary coronal mass ejection*, ApJ, **851,** 2, 123

169. Durgesh Tripathi, A. N. Ramaprakash, Aafaque Raza Khan, ... , Avyarthana Ghosh, Pravin Chordia, **Dibyendu Nandi,** Chaitanya Rajarshi, et al. (2017) *The solar ultraviolet imaging telescope on board Aditya-L1*, CSci, **113,** 616.

170. Dibyendu **Nandi,** Prantika Bhowmik, Anthony R. Yeates, Suman Panda, Rajashik Tarafdar, et al. (2018) *The large-scale coronal structure of the 2017 August 21 great American eclipse: An assessment of solar surface flux transport model enabled predictions and observations*, ApJ, **853,** 1, 72.

171. Sajal Mukherjee and **K. Rajesh Nayak** (2018) *Carter constant and angular momentum*, IJMPD, **27,** 1750180.

172. Payel Mukhopadhyay and, **K. Rajesh Nayak** (2018) *Carter's constant and super-integrability*, IJMPD, **27,** 1850066.

173. **Biswajit Pandey** (2017) *Can anisotropy in the galaxy distribution tell the bias?*, MNRAS, **469,** 1861.

174. **Biswajit Pandey** (2017) *Does information entropy play a role in the expansion and acceleration of the Universe?*, MNRASL, **471,** L77.

175. Sheetal K. Sahu, N. R. Navale, **S. K. Pandey** and **Mahadev B. Pandge** (2017) *Optical imaging and spectral study of FR-I type radio galaxy: CTD 086 (B2 1422+26B)*, Ap&SS, **362,**158.

176. Kalyani Bagri, Ranjeev Misra, Anjali Rao, J.S. Yadac and **S.K. Pandey** (2018) *Systematic analysis of low/hard state RXTE spectra of GX 339-4 to constrain the geometry of the system* [arXiv: 180202462].

177. Bhagorao T. Tate, Anil T. Kyadampure, **S.K. Pandey** and **Madhav K. Patil** (2018) *Multi-phase ISM in nearby early type galaxy IC 5083,* IJAA, **8,** 79.

178. V. Parekh, F. Durret, P. Padmanabh and **Mahadev B. Pandge** (2017) *A hot X-ray filament associated with A3017 galaxy cluster*, MNRAS**, 470,** 3742.

179. **Mahadev B. Pandge,** Joydeep Bagchi, ... , **Madhav K. Patil,** Pratik Dabhade, Somak Raychaudhury and **Joe Jacob,** et al. (2017) *MACS J0553.4−3342: A young merging galaxy cluster caught through the eyes of Chandra and HST*, MNRAS, **472,** 2042.

180. Asif Iqbal, Ruta Kale, … , **Mahadev B. Pandge, Manzoor A. Malik,** Somak Raychaudhury, et al. (2017) *Active galactic nucleus feedback with the square kilometre array and implications for cluster physics and cosmology*, JApA, **38,** 68.

181. Aishawnnya Sharma, Girjesh Gupta, Durgesh Tripathi, V. Kashyap and **Amit Pathak** (2017) *Direct observations of different sunspot waves influenced by umbral flashes*, ApJ, **850,** 206.

182. Mridusmita Buragohain, **Amit Pathak,** Peter Sarre, and Nand Kishor Gour (2018) *Interstellar dehydrogenated PAH anions: Vibrational spectra*, MNRAS, **474,** 4594.

183. P. K. Pawar, Gulab C. Dewangan, ... , Madhav K. Patil**,** Main Pal, Ajit K. Kembhavi (2017) *Complex UV/X-ray variability of 1H 0707-495*, MNRAS, **472,** 2823.

184. P. S. Debnath and **Bikash Chandra Paul** (2017) *Emergent universe model with dissipative effects*, MPLA, 32, 1750216.

185. **Bikash Chandra Paul** and A. S. Majumdar (2018) *Emergent universe with wormholes in massive gravity*, CQGra, **35,** 065001.

186. Nikhil Mukund, Sheelu Abraham, Shivaraj Kandhasamy, Sanjit Mitra and **Ninan Sajeeth Philip** (2017) *Transient classification in LIGO data using difference boosting neural network,* PhRvD, **95,** 104059.

187. Nikhil Mukund, Sheelu Abraham, ... , Sanjit Mitra, **Ninan Sajeeth Philip,** Kaustubh Vaghmare, et al. (2018*) An information retrieval and recommendation system for astronomical observatories*, ApJS, **235,** 22.

188. Sheelu Abraham**,** A. K. Aniyan, Ajit K. Kembhavi**, Ninan Sajeeth Philip** and Kaustubh Vaghmare (2018) *Detection of bars in galaxies using a deep convolutional neural network*, MNRAS, **477,** 894.

189. Madhulita Das and **Ananta C. Pradhan** (2017) *Spectroscopy of Na I and K I atoms embedded in weakly coupled plasma environment*, PhPl, **24,** 112706.

190. Dinesh Chandra Maurya, Rashid Zia and **Anirudh Pradhan** (2017) *Dark energy models in LRS Bianchi type-II space-time in the new perspective of time-dependent deceleration parameter*, IJGMM, **14,** 17500773.

191. Alireza Sepehri, **Anirudh Pradhan**, Richard Pincak, **Farook Rahaman,** A. Beesham et al. (2017) *Birth of the GUP and its effect on the entropy of the Universe in Lie - N - algebra,* IJGMM, **14,** 17501304.

192. Biplab Sarkar and **Anirudh Pradhan** (2017) *Trajectory modulated arc therapy using quasi-continuous couch motion layered on top of volumetric modulated arc therapy in left breast and chest wall irradiation: A feasibility study*, J. Radiotherapy Practice, **16,** 133.

193. Upendra Kumar Giri and **Anirudh Pradhan** (2017) *Establishing inherent uncertainty in the shifts determined by volumetric imaging*, J. Radiotherapy Practice, **16,** 258.

194. Upendra Kumar Giri and **Anirudh Pradhan** (2017) *Inherent uncertainty involved in six-dimensional shift determination in ExacTrac imaging system*, J. Radiotherapy Practice, **16,** 409.

195. Alireza Sepehri, Richard Pincak, **Anirudh Pradhan** and Aroonkumar Beesham (2017) *Emergence of anti-F(R) gravity in type-IV bouncing cosmology as due to M0-brane*, GrCo, 23, 219.

196. Rishi Kumar Tiwari, A. Beesham and **Anirudh Pradhan** (2017) Transit cosmological models with domain walls in *f(R, T*) gravity, GrCo, **23,** 392.

197. Alireza Sepehri, **Anirudh Pradhan** and A. Beesham (2017) *On the origin of generalized uncertainty principle from compactified M5-brane*, MPLA, 32, 1750123.

198. Alireza Sepehri, Umesh Kumar Sharma and **Anirudh Pradhan** (2017) *Holographic diode*, PhLA, 381, 3536.

199. Umesh Kumar Sharma and **Anirudh Pradhan** (2018) Cosmology in modified f(R, T)-gravity theory in a variant Λ(T) scenario-revisited, IJGMM, **15,** 1850014.

200. Salvatore Capozziello, Emmanuel N. Saridakis, Kazuharu Bamba, ... , **Farook Rahaman, Anirudh Pradhan,** et al. (2017) *Cosmic space and Pauli exclusion principle in a system of M0-branes*, IJGMM, **14,** 17500955.

201. Alireza Sepehri, **Farook Rahaman,** Salvatore Capozziello, Ahmed Farag Ali and **Anirudh Pradhan** (2017) *The evolution of Brown–York quasi-local energy as due to evolution of Lovelock gravity in a system of M0-branes*, IJGMM, **14,** 17500992.

202. Ksh. Newton Singh, Piyali Bhar, **Farook Rahaman** and Neeraj Pant (2017) *Effect of electric charge on anisotropic compact stars in conformally symmetric spacetime*, JPhCo, **2,** 015002.

203. Amit Das, Shounak Ghosh, B. K. Guha, ... , **Farook Rahaman** and **Saibal Ray** (2017) *Gravastars in f(R,T) gravity,* PhRvD, **95,** 124011.

204. Piyali Bhar, Ksh. Newton Singh, Nayan Sarkar and **Farook Rahaman** (2017) *A comparative study on generalized model of anisotropic compact star satisfying the Karmarkar condition*, EPJC, **77,** 596.

205. S.K. Maurya, Y.K. Gupta, **Farook Rahaman**, Monsur Rahaman and Ayan Banerjee (2017) *Compact stars with specific mass function*, AnPhy, **385,** 532.

206. **Farook Rahaman,** Sunil D. Maharaj, Iftikar Hossain Sardar and **Koushik Chakraborty** (2017) *Conformally symmetric relativistic star*, MPLA, **32,** 1750053.

207. Ksh. Newton Singh, Piyali Bhar, **Farook Rahaman,** Neeraj Pant and Mansur Rahaman (2017) *Conformally non-flat spacetime representing dense compact objects*, MPLA, **32,** 1750093.

208. Dibyendu Shee, S. Ghosh, **Farook Rahaman,** B. K. Guha and **Saibal Ray** (2017) *Compact star in pseudo-spheroidal spacetime*, Ap&SS, **362,** 114.

209. Irina Radinschi, Theophanes Grammenos, **Farook Rahaman,** Andromahi Spanou, ... , **Surajit Chattopadhyay,** et al. *(2017) Energy-momentum for a charged non-singular black hole solution with a non-linear mass function,* AdHEP, **2017,** 7656389.

210. Kimet Jusufi, **Farook Rahaman** and Ayan Banerjee (2018) *Semi-classical gravitational effects on the gravitational lensing in the spacetime of topological defects*, AnPhy, 389, 219.

211. Faizuddin Ahmed and **Farook Rahaman** (2018) *Gravitational collapse in a cylindrical symmetric vacuum spacetime and the naked singularities,* EPJA, **54,** 52.

212. Nupur Paul, S. S. De and **Farook Rahaman** (2018) *Cosmological solutions and finite time singularities in Finslerian geometry,* MPLA, **33,** 1850046.

213. Alireza Sepehri, Richard Pincak, Michal Hnatic, **Farook Rahaman** and **Anirudh Pradhan** (2018) *Quarkonium in a thermal BIon,* CaJPh, **96,** 127.

214. Debabrata Deb, **Farook Rahaman, Saibal Ray** and B.K. Guha (2018) *Strange stars in f(R, T) gravity*, JCAP, **3,** 44.

215. Reshma Bhaskaran, **C.D. Ravikumar,** Visnuprasad Ashok Kumar, Jojo Panakal John, Bangaru Danalakshmi, et al. (2017) *Inhalation dose and source term studies in a tribal area of Wayanad, Kerala, India*, J. Environ. Public Health, **2017,** 1930787.

216. Reshma Bhaskaran, **C. D. Ravikumar,** A. M. Vinodkumar, I. Vijayalakshmi, Bangaru Danalakshmi, et al. (2017) *Hazard indices and annual effective dose due to terrestrial radioactivity in Northern Kerala, India*, JRNC, **314,** 2171.

217. Shubham Srivastav, G. C. Anupama, Devendra Kumar Sahu and, **C. D. Ravikumar** (2017) *SN 2015bp: Adding to the growing population of transitional Type Ia supernovae*, MNRAS, **466,** 2436.

218. S. Aswathy and **C. D. Ravikumar** (2018) *Study of central light concentration in nearby galaxies*, MNRAS, **477,** 2399.

219. Debabrata Deb, Sourav Roy Chowdhury, **Saibal Ray, Farook Rahaman** and B.K. Guha (2017) *Relativistic model for anisotropic strange stars*, AnPhy, **387,** 239.

220. S. K. Maurya, Y. K. Gupta and **Saibal Ray** (2017) *All spherically symmetric charged anisotropic solutions for compact stars*, EPJC, **77,** 360.

221. Yaghoub Heydarzad, **Prabir Rudra,** Farhad Darabi, Ahmed Farag Ali and Mir Faizal (2017) *Vaidya spacetime in massive gravity's rainbow*, PhLB, **774,** 46.

222. **Anirban Saha, Sunandan Gangopadhyay** and Swarup Saha (2018) *Quantum mechanical systems interacting with different polarizations of gravitational waves in non-commutative phase space*, PhRvD, **97,** 044015.

223. Ashu Sharma and **Sanjay K. Sahay** (2018) *Group-wise classification approach to improve Android malicious apps detection accuracy,* Intl. J. Network Security (in Press).

224. Gurpreet Kaur Bhatia and **Sandeep Sahijpal** (2017) *Thermal evolution of trans-Neptunian objects, icy satellites, and minor icy planets in the early solar system*, M&PS, 52, 2470.

225. Gurpreet Kaur Bhatia and **Sandeep Sahijpal** (2017) *Did ^{26}Al and impact-induced heating differentiate Mercury?*, M&PS, **52,** *295.*

226. Pranati K. Rath, **Pramoda Kumar Samal,** Srikanta Panda, Debesh D. Mishra and Pavan K. Aluri (2018) *Testing statistical isotropy in cosmic microwave background polarization maps,* MNRAS, **475,** 4357.

227. **Saumyadip Samui,** Kandaswamy Subramanian and Raghunathan Srianand (2018) *Efficient cold outflows driven by cosmic rays in high redshift galaxies and their global effects on the IGM*, MNRAS, **476,** 1680.

228. **Asoke K. Sen**, R. Botet, R. Vilaplana, Naznin R. Choudhury and Ranjan Gupta (2017) *The effect of porosity of dust particles on polarization and colour with special reference to comets*, JQSRT, **198,** 164.

229. Sarani Chakraborty and **Asoke K. Sen** (2017) *Effect of gravomagnetism on the trajectory of light ray*, ZNatA, 72, 577.

230. Saswati Roy and **Asoke K. Sen** (2017) *Deflection of light ray due to a charged body using material medium approach*, ZNatA, **72,** 1113.

231. Sarani Chakraborty and **Asoke K. Sen** (2017) *Deflection of light in equatorial plane due to Kerr-Ttaub-Nut body*, SerAJ, 194, 23.

232. Sarani Chakraborty *and* **Asoke K. Sen** (2017) *Trajectory of light ray slightly above the equatorial plane in Kerr geometry and its deflection*, CaJPh, **95,** 1307.

233. Anuj Kumar Dubey, **Asoke K. Sen** and Bijoy Mazumdar (2017) *Gravitational redshift in Kerr-Newman geometry using gravity's rainbow*, Ap&SS, **362**, 204.

234. Ramya Manjunath Anche, **Asoke K. Sen,** G. C. Anupama, Kasiviswanathan Sankarasubramanian and Warren Skidmore (2018) *Analysis of polarization introduced due to the telescope optics of the Thirty Meter Telescope*, JATIS, **4,** 018003 .

235. Debashish Acharya, Bidhan Mohanta, Sanjib Deb and **Asoke K. Sen** (2018) *Theoretical prediction of absorbance spectra considering the particle size distribution using Mie theory and their comparison with the experimental UV–Vis spectra of synthesized nanoparticles*, SpecL, **51**, 139.

236. Bidisha Bandyopadhyay, Tirthankar Roy Choudhury and **T. R. Seshadri** (2017) *Studying neutral hydrogen structures during the epoch of reionization using fractal dimensions*, MNRAS, **466,** 2302.

237. Sunil Malik, Hum Chand and **T.R. Seshadri** (2917) *Effect of intervening Mg II systems on residual rotation measure of background QSOs,* MNRAS [arXiv: 1710.10396] (in Press).

238. Ramkishor Sharma, Sandhya Jagannathan, **T.R. Seshadri,** Kandaswamy Subramanian (2017) *Challenges in inflationary magnetogenesis: Constraints from strong coupling, backreaction and the Schwinger effect*, PhRvD, **96,** 083511.

239. Ramkishor Sharma, Kandaswamy Subramanian and **T.R. Seshadri** (2018) *Generation of helical magnetic field in a viable scenario of inflationary magnetogenesis,* PhRvD, **97,** 083503.

240. **Mohit Kumar Sharma,** Monika Sharma and **Suresh Chandra** (2017) *Temperature dependence of collisional rate coefficients for rotational transitions: A-type asymmetric top molecules*, NewA, **52,** 48.

241. **Mohit Kumar Sharma,** Monika Sharma and **Suresh Chandra** (2017) Suggestion for search of cyclopropenone (c-C3H2O) in a cosmic object, MolAs, **6**, 1.

242. **Mohit Kumar Sharma,** Monika Sharma and **Suresh Chandra** (2017) *Rotational quenching of H_2CO by molecular hydrogen – Suggestion on the work of Wiesenfeld & Faure*, Prama, **88,** 10.

243. **Mohit Kumar Sharma,** Monika Sharma and **Suresh Chandra** (2017) *On partition function in astronomy & astrophysics*, AN, **338**, 125.

244. **Mohit Kumar Sharma,** Monika Sharma, **Suresh Chandra** (2017) Suggestion for the detection of TiO2in interstellar medium, Ap&SS, **362,** 168.

245. **Mohit Kumar Sharma** and **Suresh Chandra** (2017) *Cosmic molecular laboratories*, Phy. Astron. Intl. J., **1,** 13.

246. **Ranjan Sharma,** Shyam Das and S. Thirukkanesh (2017) *Anisotropic extension of Finch and Skea stellar model,* Ap&SS , **362**, 232.

247. Piyali Bhar, Megan Govender and **Ranjan Sharma** (2018) *Anisotropic stars obeying Chaplygin equation of state*, Prama, **90,** 5.

248. K. Komathiraj and **Ranjan Sharma** (2018) *A family of solutions to the Einstein–Maxwell system of equations describing relativistic charged fluid spheres*, Prama, **90**, 68.

249. S. Thirukkanesh, F. C. Ragel, **Ranjan Sharma** and Shyam Das (2018) *Anisotropic generalization of well-known solutions describing relativistic self-gravitating fluid systems: An algorithm*, EPJC, **78,** 31.

250. **Gyan Prakash Singh** and Binaya K. Bishi (2017) *Bianchi type - V domain walls and quark matter cosmological model with cosmological constant Λ in F(R, T) gravity,* IrJST, **41,** 33.

251. **Gyan Prakash Singh** and Binaya K.Bishi (2017) *Bulk viscous cosmological model in Brans-Dicke theory with new form of time varying deceleration parameter*, AdHEP, **2017,** 1390572.

252. Binaya K. Bishi, S. K. J. Pacif, P. K. Sahoo and **Gyan Prakash Singh** (2017) *LRS Bianchi type-I cosmological model with constant deceleration parameter in f(R, T) gravity,* IJGMM, **14,** 1750158.

253. Sonali Sachdeva, Kanak Saha and **Harinder P. Singh** (2017) *Growth of bulges in disk galaxies since z ~1*, ApJ, **840,** 79.

254. Kaushal Sharma, Santosh Joshi and **Harinder P. Singh** (2018) *Low resolution spectroscopic investigation of Am stars using automated method,* BSRSL, **87,** 121.

255. **K. Sriram,** Siddharth Malu, C. S. Choi and P. Vivekananda Rao (2018) *Possible presence of a third body in the Kepler K2 variable EPIC 202073314*, AJ, **155**, 172.

256. **Parijat Thakur,** Vineet Kumar Mannaday, Ing-Guey Jiang, Devendra Kumar Sahu and Swadesh Chand (2018) *Investigating extra-solar planetary system Qatar-1 through transit observations***,** BSRSL, **87,** 132.

257. G.M. Sowmya, G. Rajani, M. Yamuna, **Paniveni Udayshankar,** R. Srikanth, et al. (2017) *Rotational effects on supergranulation - A survey*, Intl. J. Res. Sci. Innov., **4,** 39.

258. **Paniveni Udayashankar** (2018) *Latitudinal dependence of supergranular area and fractal dimension*, Expert Opinion A&A, **2,** 1.

259. **Rashmi Uniyal, Hemwati Nandan** and K. D. Purohit (2018) *Null geodesics and observables around the Kerr–Sen black hole*, CQGra, **35,** 025003.

260. Suhel Ahmad, **Anisul A. Usmani,** Shakeb Ahmad and Z. A. Khan (2017) *Interaction cross sections and matter radii of oxygen isotopes using the Glauber model*, PhRvC, **95,** 054601.

261. Suhel Ahmad, **Anisul A. Usmani** and Z. A. Khan (2017) *Matter radii of light proton-rich and neutron-rich nuclear isotopes*, PhRvC, **96,** 064602.

262. Asloob A. Rather, M. Ikram, **Anisul A. Usmani,** B. Kumar and S. K. Patra (2017) *A study of multi-Λ hypernuclei within spherical relativistic mean-field approach, BrJPh,* **7,** 628.

263. **Deepak Vaid** (2017) *Superconducting and anti-ferromagnetic phases of spacetime*, AdHEP, **2017,** 7935185.

264. **Murli Manohar Verma** (2017) *Observational role of dark matter in f(R) models for structure formation,* IJMP: Conf. Series, Id. 141.

265. **Murli Manohar Verma** (2017) *On a possibility of the gravitational wave detection at the high energy colliders,* IJMP: Conf. Series, **46,** 1860059.

266. Bal Krishna Yadav and **Murli Manohar Verma** (2018) *Cosmological wheel of time: A classical perspective of f(R) gravity*, IJMPD, **27,** 1750183 .

267. **Murli Manohar Verma** and Bal Krishna Yadav (2018) *Dynamics of f(R) gravity models and asymmetry of time*, IJMPD, **27, 1**850002.

268. C.J. Anderson, N.J. Luciw, Y.-C. Li, C.Y. Kuo, **Jaswant K. Yadav,** et al. (2018) *Low-amplitude clustering in low-redshift 21-cm intensity maps cross-correlated with 2dF galaxy densities,* MNRAS, **476,** 3382.

269. **Jaswant K. Yadav** and Xuelei Chen (2018) *Interactions of galaxies outside clusters and massive groups*, JApA, **39,** 31.

(b) PROCEEDINGS

1. G. Kashyap and **G. Ambika** (2017) *Link deletion in directed complex networks*, Dynamics Days, Europe-Szeged, Hungary.

2. Sandip V. George and **G. Ambika** (2017) *Detecting dynamical states of variable stars from their light curves*, Dynamics Days, Europe-Szeged, Hungary.

3. G. Kashyap and **G. Ambika** (2017) *Synapse loss and progression of Alzheimer's disease- A complex networks approach - TTGR* , Tata Review Meeting, CNS IISc.

4. Kajari Gupta and **G. Ambika** (2017) *Interplay of time scales on the dynamics of complex networks*, Complex Networks, Lyon, France.

5. Jayant V. Narlikar, Ram G. Vishwakarma, **Shyamal K. Banerjee,** P.K. Das and Christopher C. Fulton (2017) *An empirical approach to periodic redshifts*, The Galileo of Palomar : Essay in Memory of Halton Arp, Eds. Christopher C. Fulton and Martin Kokus (Apeiron, Montreal), 1.

6. **Broja G. Dutta** and Sandip K. Chakrabarti (2017) *Inclination effects and time variability properties of black hole transients*, Procds. 14^{th} Mar. Gross. Meet., **1,** 1028.

7. P. T. Rahna, Jayant Murthy, Margarita Safonova, Firoza Sutaria, **Shivappa B. Gudennavar** and S. G. Bubbly (2017) *Characterizing the in-flight performance of UVIT instrument and UV properties of a galaxy*, Procds. 36^{th} Meet. Astron. Soc. India, February 5 - 9, 2018, Osmania University, Hyderabad.

8. Gayathri Viswanath, C. S. Stalin, Suvendu Rakshit and **Shivappa B. Gudennavar** (2017) *Estimation of black hole mass of a sample of narrow line Seyfert 1 galaxies*, Procds. 36^{th} Meet. Astron. Soc. India, February 5 - 9, 2018, Osmania University, Hyderabad.

9. Arun Kenath, **Shivappa B. Gudennavar** and C. Sivaram (2017) *Effects of dark matter in star formation and evolution in the early universe,* Procds. Intl. Conf. Post Planck Cos.: Enigma, Challenges and Visions, October 9 - 12, 2017, IUCAA.

10. P. T. Rahna, Jayant Murthy, Margarita Safonova, Firoza Sutaria, **Shivappa B. Gudennavar** and S. G. Bubbly (2017) *Photometric calibration of UVIT instrument using GT and AO observations*, Procds. AstroSat Sci. Meet, September 26 - 27, 2017, ISRO Headquarters, Bengaluru.

11. **Sarbari Guha** and Sukanta Das (2017) *Noether symmetry analysis of FRW model in presence of generalised scalar-gravity interaction,* Intl. Conf. Post-Planck Cosmology: Enigma, Challenges and Visions, October 9 -12, 2017, IUCAA.

12. **Dibyendu Nandi,** A. Valio and P. Petit (Eds.) (2017) *Living around active stars,* Procds. Intl. Astron. Symp., Cambridge University Press, 328

13. Rajendra Kumar Roul and **Sanjay Kumar Sahay** (2017) *Categorizing text data using deep learning: A novel approach,* Advances in Intelligent Systems and Computing, Procds. Intl. Conf. Comp. Intell. Data Mining (in Press).

14. Sanjay Sharma, Rama Krishna and **Sanjay Kumar Sahay** (2017) *Detection of advanced malware by machine learning techniques,* Advances in Intelligent Systems and Computing, Procds. Intl. Conf. Soft Comp.: Th. and Applns. (in Press).

(c) BOOKS

1. **Suresh Chandra** and **Mohit Kumar Sharma** (2018) *Textbook of Optics,* Ane Books Pvt. Ltd., New Delhi, ISBN 978-9386761569.

2. **Deepak Vaid** and Sundance Bilson-Thompson (2017) *LQG for the Bewildered,* Springer Nature, doi: 10.1007/978-3-319-43184-0.

(d) SUPERVISION OF Ph.D. THESES

Asis Kumar Chattopadhyay

Title: *On growth curve analysis and related statistical problems incorporating biological and ecological issues,* University of Calcutta, Kolkata.
Student: Bratati Chakraborty

Himadri Sekhar Das

Title: *Study of optical properties of cosmic dust by numerical simulations and observations,* Assam University, Silchar.
Student: Arindwam Chakraborty

Title: *Comprehensive dust model to describe the polarization properties of comet,* Assam University, Silchar.
Student: Parizath Deb Roy

Title: *Photopolarimetric study of some selected dark clouds,* Assam University, Silchar.
Student: Arup Das

Title: *Photometric and polarimetric studies of some selected dark clouds,* Assam University, Silchar.
Student: Ajoy Barman

Title: *A theoretical study of double layers and sheaths in various plasma configurations,* Assam University, Silchar.
Student: Jaydeep Paul

Ujjal Debnath

Title: *Study of various aspects of dark energy in accelerating universe,* Indian Institute of Engineering Science and Technology, Shibpur.
Student: Sayani Maity

Ujjal Debnath (jointly with **Surajit Chattopadhyay)**

Title: *Exploration of the various aspects of modified gravity approach to the accelerated expansion of the universe,* Indian Institute of Engineering Science and Technology, Shibpur.
Student: Rahul Ghosh

Sarbari Guha

Title: *On some investigations of cosmological solutions and geodesic motions in brane world scenario,* Jadavpur University, Kolkata.
Student: Pinaki Bhattacharya

Naseer Iqbal

Title: *Study of correlated UV and X ray emission from x ray binaries,.* University of Kashmir, Srinagar.
Student: Bari Maqbool

Title: *Spectral time evolution and variability of black hole x ray binaries,* University of Kashmir, Srinagar.
Student: Mubahsir Hamid Mir

Geometry of accretion flow in compact object system, University of Kashmir, Srinagar.
Student: Naveel A. Wani

Manzoor A. Malik (jointly with Subhabrata Majumdar**)**

Title: *Astrophysics and cosmology with Sunyaev-Zel'dovich effect in galaxies, groups and cluster of galaxies,* University of Kashmir, Srinagar.
Student: Asif Iqbal

Soumen Mondal

Title: *Dissipative shocks in relativistic accretion flows around black holes,* Jadavpur University, Kolkata.
Student: Abhijit Kundu

Title: *Modeling gravitational wave signals emitted from binary systems,* Jadavpur University, Kolkata.
Student: Sangita Chatterjee

Farooq Rahaman

Title: *On galactic dark matter, star modelling and wormhole physics,* Jadavpur University, Kolkata.
Student: Mosiur Rahman

Title: *Study of some astrophysical and cosmological phenomena admitting a one parameter group of conformal motion,* Jadavpur University, Kolkata.
Student: Akrapriya Mallick

Title: *Some aspects of cosmological and astrophysical phenomena in Einstein and modified gravity,* Jadavpur University, Kolkata.
Student: Iftikar Hossain Sardar

Saibal Ray

Title: *Studies of compact stars under alternative gravity,* Indian Institute of Science, Engineering and Technology, Shibpur.
Student: Amit Das

Title: *Studies of compact stars under Einstein's general theory of relativity,* Indian Institute of Science, Engineering and Technology, Shibpur.
Student: Dibyendu Shee

(e) AWARDS AND DISTINCTIONS

Shyamal Kumar Banerjee

Best citizen of India gold medal, 2018, for Individual Achievement and National Development by the Global Economic Progress and Research Association, New Delhi, on the occasion of 68th Republic Day Celebration on January 26, 2018 at Chennai.

Asis Kumar Chattopadhyay

Selected a Fellow of West Bengal Academy of Science and Technology (WAST), 2018,

Elected a Member of International Statistical Institute, 2017 - 18.

Ram Kishor

ISCA Best Poster Award, 2018 (Mathematical Sciences including Statistics), 105th Indian Science Congress Association (ISCA), Manipur University, Imphal.

Elected a Sectional Committee Member, 2018 (Mathematical Sciences including Statistics), 105th Indian Science Congress Association (ISCA), Manipur University, Imphal (for one year).

Smriti Mahajan

Selected a Member of the International Science Development Team (ISDT) of the TMT.

Manzoor Malik

Granted funding for his project titled: *X-ray study of galaxy clusters*, (to the tune of Rs. 23.5 Lakh), ISRO (RESPOND), June 2017.

Gyan Prakash Singh

Elected a Council Member of the Indian Mathematical Society, 2017 (for three years).

Department of Statistics, University of Calcutta, Kolkata.

Coordinator: Asis Kumar Chattopadhyay, and Joint Coordinator: Narayan Banerjee

Areas of Research

During the period 2017-18, the main focus of the research work was on Galaxy and star formation rate, Explosion triggered star formation, Thermal instability driven star formation, Distance determination of nearby as well as far off stars, Star formation in the presence of turbulence, Measure of chaos in the presence of SMBH under different halos, and Episodic model of star formation with small scale dissipation. Some large scale simulation studies have also been carried out. Many research scholars and faculty members of different colleges and universities in and around Kolkata are very much involved in the use of mathematical and statistical software as well as development of computer programmes for the appropriate analysis of astronomical data. Theoretical research work related to theory of relativity and cosmology is also going on.

The following project works have been carried out by the post-graduate students:

Supervised by: **Asis K. Chattopadhyay,** Department of Statistics, University of Calcutta, Kolkata.

Title: *Study on formation and evolution galaxy NGC 5128 through globular*
Student: Prasenjit Banerjee.

Supervised by: **Tanuka Chattopadhyay,** Department of Applied Mathematics, University of Calcutta, Kolkata.

Title: *Measuring the diameter of the craters of the Moon using 14 inch Schmidt telescope*
Students: Poulomi Bhattacharya.

Title: *Reproducing H-R diagram using Sky Map Pro-XII*
Student: Debolina Medda.

Title: *Stellar structure solving Lane Emden equation for n=1.2 and 1.1*
Student: Ayan Paul.

Title: *Reproducing BPT diagram using SDSS dr-13 archive*
Student: Firdaus Alam.

Title: *Classification of light curves of variable stars in SMC*
Student: Aritra Roy (IISER, Kolkata).

Workshop

Workshop on Machine Learning for post-graduate students and young researchers, March 15 -17, 2018, at the Department of Statistics, University of Calcutta, Kolkata.

Lectures

Unsupervised Learning, by Swapan Kumar Parui, at the Indian Statistical Institute, Kolkata.

Machine Learning with Python, by Prasenjit Majumder and Gaurav Arora, at Dhirubhai Ambani Institute of Information and Communication Technology, Ahmedabad.

Machine Learning in Information Retrieval, by Mandar Mitra, at the Indian Statistical Institute, Kolkata.

Reinforcement Learning, by Dipti Prasad Mukherjee, at the Indian Statistical Institute, Kolkata.

Introduction to Neural Network and Deep Learning, by Pawan Goyal, at the Indian Institute of Technology, Kharagpur.

Topic Models, by Chiranjib Bhattacharyya, at the Indian Institute of Science, Bengaluru.

Clustering of Galaxies: A Search for Evolution, by Tanuka Chattopadhyay, at the International Conference on New Paradigms in Statistics for Scientific and Industrial Research, Central Glass and Ceramic Research Institute, Jadavpur, Kolkata.

Deep Learning in Astronomy, by Ajit Kembhavi, at the International Conference on New Paradigms in Statistics for Scientific and Industrial Research, Central Glass and Ceramic Research Institute, Jadavpur, Kolkata.

A Strange Star Scenario for Formation of Eccentric Milli-second Pulsar-White Dwarf Binaries, by Jishnu Dey, at the International Conference on New Paradigms in Statistics for Scientific and Industrial Research, Central Glass and Ceramic Research Institute, Jadavpur, Kolkata.

Lectures by the Coordinator of IRC

Fifth IIMA International Conference on Advanced Data Analysis, Business Analytics and Intelligence, at the Indian Institute of Management, Ahmedabad, April 8 - 9, 2017 (Key note address).

Clustering and Dimension Reduction- Ways to Big Data Analysis, at the Department of Computer Science and Engineering, Jadavpur University, Kolkata, May 22 - 29, 2017 (Series of lectures).

National Workshop cum Training Programme on Statistical Tools for Research Data Analysis, at the Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, May 29 -June 09, 2017.

Faculty Development Programme, at the Army Institute of Management, Kolkata , July 24, 29, 31, August 1, 2017.

International Conference on New Paradigms in Statistics for Scientific and Industrial Research, at the Central Glass and Ceramic Research Institute, Kolkata, January 4 - 6, 2018.

Three-day seminar on Statistical Issues in Music and Home Science Researches, at the Department of Home Science, University of Calcutta, Kolkata, February 6 - 8, 2018.

Visitors

Sunil Maharaj, University of KwaZulu-Natal, Durban, South Africa, December 17-23, 2017, and
Ajay Tiwari, University of KwaZulu-Natal, Durban, South Africa, December 17-23, 2017.

Award

Fellow of West Bengal Academy of Science and Technology-2018: Asis Kumar Chattopadhyay

List of Publications

1. Soumita Modak, Tanuka Chattopadhyay and Asis Kumar Chattopadhyay (2017) *Two phase formation of massive elliptical galaxies: study through cross-correlation including spatial effect,* Ap&SS, **362,** 206.

2. Soumita Modak, Tanuka Chattopadhyay and Asis Kumar Chattopadhyay (2018) *Unsupervised classification of eclipsing binary light curves through k-medoids clustering* [arXiv:1801.09406].

School of Studies in Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur.

Coordinators: S. K. Pandey, and R.C. Agrawal

Supervision of Ph.D. Theses (Ongoing)

S.K. Pandey

Title: *Multiband Studies of Radio Loud Elliptical Galaxies from the B2 Sample*
Student: Sheetal Sahu.

Multi-wavelength Isophotal Shape Analysis of Early Type Galaxies
Stusent: Amit Tamrakar.

S.K. Pandey and Sudhanshu Barwey (IIA, Bengaluru)

Title: *Central Region of Lenticular Galaxies*
Student: Mahendra Verma.

S.K. Pandey, Ranjeev Misra (IUCAA) and J.S. Yadav (TIFR, Mumbai)

Title: *Study of Accretion Process and Jets in X-ray Binaries*
Student: Kalyani Bagri

N.K. Chakradhari (Pt. Ravishankar Shukla University, Raipur) has been doing collaborating research work with G.C. Anupama (IIA, Bengaluru) and D.K. Sahu (IIA, Bengaluru) on Supernovae. He is also involved in the study of chemically peculiar (CP) stars, in collaboration with Santosh Joshi (ARIES, Nainital).

Students of M.Sc. IV Semester (Pragati Sahu, Shrutika Tiwari, Jyoti Kaushal, Nitya Pandey, Pooja Sahu, Neeraj Kumar, Shubradeep Majumder and Mayank Dewangan) visited ARIES, Nainital, to carry out their project work.

Eminent Visitors and Lectures

K.P. Singh (IISER, Mohali), on AstroSat and X-ray Astronomy.

Alok Gupta (ARIES, Nainital), on AGN and Blazar.

Jen Gupta (British Council, UK), on The Invisible Universe (Public lecture).

P. Sreekumar (Director, IIA, Bengaluru), on Doing Experiments in Space.

A.S. Kiran Kumar (Chairman, ISRO, Bengaluru), on India in Space.

Ajit Kembhavi (IUCAA), on Exoplanet.

Visitors

Jayant V. Narlikar and Mangala Narlikar (IUCAA).

Ranjan Gupta (IUCAA).

D.K. Sahu (IIA, Bengaluru).

Amitesh Omar (ARIES, Nainital).

M. Gopinathan (IIA, Bengaluru).

Parijat Thakur (Guru Ghasidas Central University, Bilaspur).

Astronomical Activities and Public Outreach Programmes

Various astronomical activities were organized during the INSPIRE summer and winter camps. Planetarium Show, Sky Watching Programme and Telescope Demonstrations were organized time to time at various places. S. K. Pandey and N.K. Chakradhari have delivered lectures in several Schools, Colleges and Public forums, as a part of Science Popularization and Public Outreach Programmes.

Total Lunar Eclipse

The first Lunar Eclipse of year 2018 took place on January 31. During this time, the Moon was closer to the Earth, and apparently bigger in size. Since it was second full Moon in the same month, it was called supper-blue-Moon. A sky gazing programme was held to witness the eclipse at the IUCAA Resource Centre. The event was viewed using 6 inch Newtonian Telescope (provided by IUCAA), 8 inch, and 14 inch Schmidt Cassegrain Telescopes, available at Professor R.K.Thakur Memorial Observatory of the Department. The Moon was already in total eclipse phase, when it was rising. Many people and students had gathered to see the eclipse. Their questions were answered by N.K. Chakradhari, L.K. Chawre, Mahendra Verma and Amit Tamrakar. The event was broadcasted live by many TV Channels. It was also covered in local News Papers.

चांद को देखने ऐसा उत्साह, घंटों खड़े रहे कतार में

इस साल का पहला चंद्रग्रहण बुधवार को माघ पूर्णिमा के अवसर पर दिखाई दिया। वैसे तो हर साल चंद्रग्रहण लगता है, लेकिन 35 सालों के बाद ऐसा संयोग बना जब चंद्रमा तीन रंगों में दिखाई दिया। बुधवार को ब्लू मून, ब्लड मून और सुपर मून का नजारा एक साथ दिखा। राजधानी के अलावा विभिन्न शहरों में अलग-अलग समय में चंद्रग्रहण दिखा। लंबे समय बाद बने चंद्रग्रहण के इस दुर्लभ योग को देखने लोगों में भारी उत्साह दिखा। जिन जगहों मे इसे देखने की विशेष व्यवस्था की गई थी, वहां सैकड़ों की भीड़ जुटी। लोगों ने अपने घरों में भी इस नजारे को खुली आंखों से देखा।

- पं. रविशंकर शुक्ल विश्वविद्यालय में ग्रहण देखने की गई थी विशेष व्यवस्था, छात्रों संग आमजन भी जुटे
- रायपुर में 6:20 से 8:41 तक दिखा ग्रहण
- 28 साल बाद इतना लंबा चंद्रग्रहण, 35 साल बाद दिखा तीन रंग में

रायपुर। रायपुर में 6:20 को दिखाई दिया, जो 8:41 तक रहा। शहर के खगोल वैज्ञानिकों ने बताया, सुपरमून होने के कारण आम दिनों में दिखने वाला चंद्रमा आज काफी चमकीला और बड़े आकार में दिखाई दिया। वहीं दूसरी ओर राजधानी रायपुर में सुबह से मंदिरों के कपाट बंद रहे। जो देर रात तक नहीं खोले गए। पंडितों के अनुसार, धर्मशास्त्र में चंद्रग्रहण के दिन किसी भी शुभ चीज को छूने की मनाही है। इसके अलावा भगवान की मूर्ति को ढंककर रखा जाता है। गर्भवती महिलाओं को भी अधिकर परिवारों में घरों से बाहर नहीं निकलने दिया गया।

शहर में ये रही ग्रहण की स्थिति

रविवि के खगोल एवं भौतिकी विभाग के नंदकुमार चक्रधारी ने बताया, शहर में ग्रहण शाम 4:21 से शुरु हो गया। 5:18 को गहरी छाया पड़ने लगी है। 5:48 को चंद्रग्रहण स्पष्ट रूप दिखने लगा। 6:21 को चंद्रमा पूरी तरह ढंक गया। ढंकने के बावजूद यह तांबे के रंग की तरह दिखाई देने लगा। 7:37 तक पूरी तरह ढंका रहा। इसके बाद यह छाया धीरे-धीरे हटाने लगी। 8:41 को यह हट गया, लेकिन हल्की धुंधली परछाई पड़ती रही। हल्का धुंधलापन 9:38 को पूरी तरह हट गया। इसके साथ ही ग्रहण समाप्त हो गया।

जेएन पांडेय विद्यालय में अंध श्रद्धा निर्मूलन समिति ने छात्रों को टेलीस्कोप द्वारा पृथ्वी की छाया में छुपे चंद्रमा का आवर्धित प्रतिबिम्ब दिखाया।

कैंपस में उमड़ी भीड़

चंद्रग्रहण के मौके पर रविवि के भौतिक विभाग द्वारा वहां के स्टूडेंट्स और आम नागरिकों को दिखाने टेलीस्कोप सहित कई उपकरणों की व्यवस्था की गई। लगाए गए दूरबीन की सहायता से स्टूडेंट्स ने चंद्रमा को करीब से निहारा। छात्रों के साथ ही विश्वविद्यालय के अन्य विभाग के प्रोफेसर्स व आम नागरिकों ने पूरे घटनाक्रम को नजदीक से देखा। अपनी पारी का इंतजार करने छात्रों संग आमजन भी घंटों इंतजार में खड़े रहे। इसके अलावा प्लेनेटेरियम लगाया गया, जिसमें सौर मंडल के बारे में बताया गया। पृथ्वी कैसे बनी, ग्रहों की उत्पति और उनसे जुड़ी तमाम तरह की जानकारी इसके माध्यम से दी गई।

Source : Hitavada 01 Feb 2018

LUNAR ECLIPSE: The Raipur sky witnessed the super blood moon on Wednesday as the Lunar Eclipse was taking place, the distance between of the city skyline widened. The Hitavada Lensmen Manoj Dewangan & Rupesh Yadav captured this eclipse.

Super Blue Moon Lunar Eclipse important from scientific point of view'

Despite myths and superstitions around total Lunar Eclipse, people were seen looking at the sky to witness one of the unique celestial events and busy capturing the image with their mobile phones

■ Staff Reporter
RAIPUR, Jan 31

LUNAR Eclipse on Wednesday was unique from others as it happened at Super Blue Moon. The celestial event remained important from scientific point of view, said Dr N K Chakradhari, School of Studies in Physics & Astrophysics, Pt Ravishankar Shukla University (PRSU), Raipur.

When Moon is nearest to the Earth at full-moon during its elliptical orbits around Earth, it is known as super-moon because at this point moon appears apparently 14% bigger, also its brightness increases by 30 %. But it is difficult to notice this difference in daily life. The first full-moon of the year 2018 was on 2nd January and the second full-moon happened on January 31st.

Hence there were two full-moon this month during moon's nearest approach to earth. This type of full moon is known as super blue moon, Dr Chakradhari said. Lunar eclipse, occurred on Wednesday, is also known as copper blue moon eclipse.

"It was a great opportunity that we were able to see this eclipse from our own city. For Raipur Chhattisgarh, the penumbral (light) shadow of earth started falling on to the moon at 04:21 pm and the dark shadow (umbral) at 05:18, However moon was below horizon during these times. At 05:48 pm the moon rose in the East direction and at 06:21, the moon was completely covered by Earth's shadow," said Dr Chakradhari. Though the moon was in complete shadow it appeared in copper colour. This makes moon attractive to the people. This colour is due to the Earth's atmosphere. The full eclipse was there till 07:37, and after this the umbral/dark shadow started decreasing till 08:41. The effect of light shadow was there till 09:38 and hence moon appeared dull till this time. Arrangements for the students and public were made at Physics and Astrophysics Department of PRSU.

Despite myths and superstitions around total Lunar Eclipse, people were seen looking at the sky to witness one of the unique celestial events and busy capturing the image with their mobile phones. 'Marine Drive' Telibandha Talab witnessed the most crowd, youths in particular, during the Lunar Eclipse and they were seen taking selfie while capturing the lunar eclipse.

Source : Haribhoomi 01 Feb 2018

List of Publications

1. Sheetal K. Sahu, N.R. Navale, S.K. Pandey and Mahadev B. Pandge (2017) *Optical imaging and spectral study of FR-I type radio galaxy: CTD 086 (B2 1422+26B),* Ap&SS, **262,** 158.

2. Nand K. Chakradhari, Devendra K. Sahu, G.C. Anupama and Tushar P. Prabhu (2018) *Highly reddened type Ia supernova SN2004ab: Another case of anomalous extinction*, MNRAS, **474,** 2502.

3. Devendra K. Sahu, G.C. Anupama, Nand K. Chakradhari, S. Srivastav, M. Tanaka, K. Meada and K. Nomoto (2018) *Broad-line type Ic supernova SN 2014ad,* MNRAS, **475,** 2591.

4. Mridweeka Singh, Kuntal Mishra, Devendra K. Sahu, Raya Dastidar, Anjasha Gangopadhyay, Subhash Bose, Shubham Srivastav, G.C. Anupama, Nand K. Chakradhari, Brajesh Kumar, Brijesh Kumar and Shashi B. Pandey (2018) *Exploring the optical behaviour of a type Iax supernova SN 2014dt,* MNRAS, **474,** 2551.

5. Nand K. Chakradhari and Santosh Joshi (2018) *The Nainital Cape Survey Project: A search for pulsation in chemically peculiar stars,* BSRSL, **87,** 150.

6. Mridweeka Singh, Kuntal Misra, Devendra Kumar Sahu, Raya Dastidar, Anjasha Gangopadhyay, Subhash Bose, Shubham Srivastav, G.C. Anupama, Nand K. Chakradhari, Brajesh Kumar, Brijesh Kumar and Shashi B. Pandey (2018) *A peculiar subclass of type Ia supernovae a.k.a. type Iax,* BSRSL, **87,** 340.

7. Kalyani Bagri, Ranjeev Misra, Anjali Rao, J.S. Yadav and S.K. Pandey (2018) *Systematic analysis of low/hard state RXTE spectra of GX 339-4 to constrain the geometry of the system* [arXiv: 180202462].

8. Mayukh Pahari, J.S. Yadav, Jai Verdhan Chauhan, Divya Rawat, Ranjeev Misra, P.C. Agrawal, Sunil Chandra, Kalyani Bagri, Pankaj Jain, R.K. Manchanda, Varsha Chitnis and Sudip Bhattacharyya (2018) *Extensive broadband X-ray monitoring during the formation of a giant radio jet base in Cyg X-3 with AstroSat,* ApJL, **853,** 11.

9. Bhagorao Tukaram Tate, Anil Tejerao Kyadampure, S.K. Pandey and Madhav K. Patil (2018) *Multiphase ISM in nearby early type galaxy IC 5063,* IJAA, **8,** 79.

Department of Physics
North Bengal University, Siliguri.

Coordinator: Bikash Chandra Paul, and Joint Coordinator: Arunava Bhadra

Areas of Research

- Cosmology
- Compact Objects
- Data Analysis of X-Ray Sources and Pulsars
- Non-linear Dynamics

Data Centre

Students, research scholars and faculty members of the university as well as of neighbouring colleges have been using the computing facilities for their academic purpose.

Seminar

Multi-frequency multi-constellation Global Navigation Satellite System (GNSS) signal characterisation, by A. K. Paul, University of Calcutta, Kolkata, November 29, 2017

Visitors

Partha Sarathi Debnath (ABN Seal College, Coochbehar),

Nanba Kumar Mandal (Kolkata),

Ranjan Sharma (P.D. Women's College, Jalpaiguri),

Shyam Das (P.D. Women's College, Jalpaiguri),

Pragati Pradhan (St. Joseph College, Darjeeling),

Pradip Chattopadhyay (Alipurduar College),

Prasenjit Thakur (Alipurduar College),

T. Khaling (Darjeeling), and

Pravat Dangal (St. Xavier's College, Darjeeling).

Ph. D. Thesis

Title: *Pulse profile studies and hard X-ray properties of neutron stars*
Student: Pragati Pradhan
Supervisor: Bikash Chandra Paul

Sri Sayan Kundu, Department of Physics, has done his M.Sc. project, supervised by Bikash Chandra Paul (Jointly with Kanak Saha (IUCAA)).

List of Publications

1. P. S. Debnath and Bikash Chandra Paul (2017) *Emergent universe model with dissipative effects*, MPLA, **32,** 1750216.

2. Prabir Banik and Arunava Bhadra (2017) *Implications of supernova remnant origin model of galactic cosmic rays on gamma rays from young supernova remnants*, PhRvD, **95,** 123014.

3. Bikash Chandra Paul and A.S. Majumdar (2018) *Emergent universe with wormholes in massive gravity*, CQGra, **35,** 065001.

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 2018

Sr No.	FUNDS & LIABILITIES	Schedule No.	31.03.2018 Rs.
1	Trust Fund / Corpus	6	1,46,59,423
2	Grant-In-Aid from UGC	7	1,11,89,44,806
3	Other Earmarked Funds and Project Grants	8	28,04,55,662
4	Projects and Other Payable	9	15,68,43,435
5	Current Liabilities	10 & 10A	18,46,32,825
6	Income and Expenditure a/c	14	(31,35,03,050)
	Total		1,44,20,33,101

Sr No.	ASSETS & PROPERTIES	Schedule No.	31.03.2018 Rs.
1	Fixed Assets	11	63,55,43,475
2	Investments / Deposits	12	54,70,64,225
3	Project & Other Receivables	13	13,13,64,095
4	Current Assets -	13	
	a) Cash, Bank balances & Revenue Stamps		9,94,42,172
	b) Loans and Advances	13A	1,68,73,205
	c) Deposits		23,57,016
	d) Prepaid Expenses		36,64,747
	e) Advance to Suppliers	13B	57,24,166
	Total		1,44,20,33,101

For Inter-University Centre for Astronomy & Astrophysics

As per Report of even date
For Kirtane & Pandit LLP
Chartered Accountants
FRN- 105215W/W100057

M.S.Sahasrabudhe
Admin. Officer (Accounts)

N. V. Abhyankar
(Sr.Admn.Officer)

Parag Pansare
(Partner)
Membership No.117309

KIRTANE & PANDIT LLP FRN 105215W/ W100057 Chartered Accountants

Place : Pune
Date : 25.05.2018

Prof. Somak Raychaudhury
(Director / Trustee)

Chairperson
Governing Board

IUCAA, Post Bag 4, Ganeshkhind, Pune 411 007, India.
Location : Meghnad Saha Road, S. P. Pune University Campus, Ganeshkhind, Pune 411 007, India
Phone : (91) (20) 2560 4100 Fax : (91) (20) 2560 4699
e-mail : publ@iucaa.in
Universal Resource Locator (URL) : http://www.iucaa.in