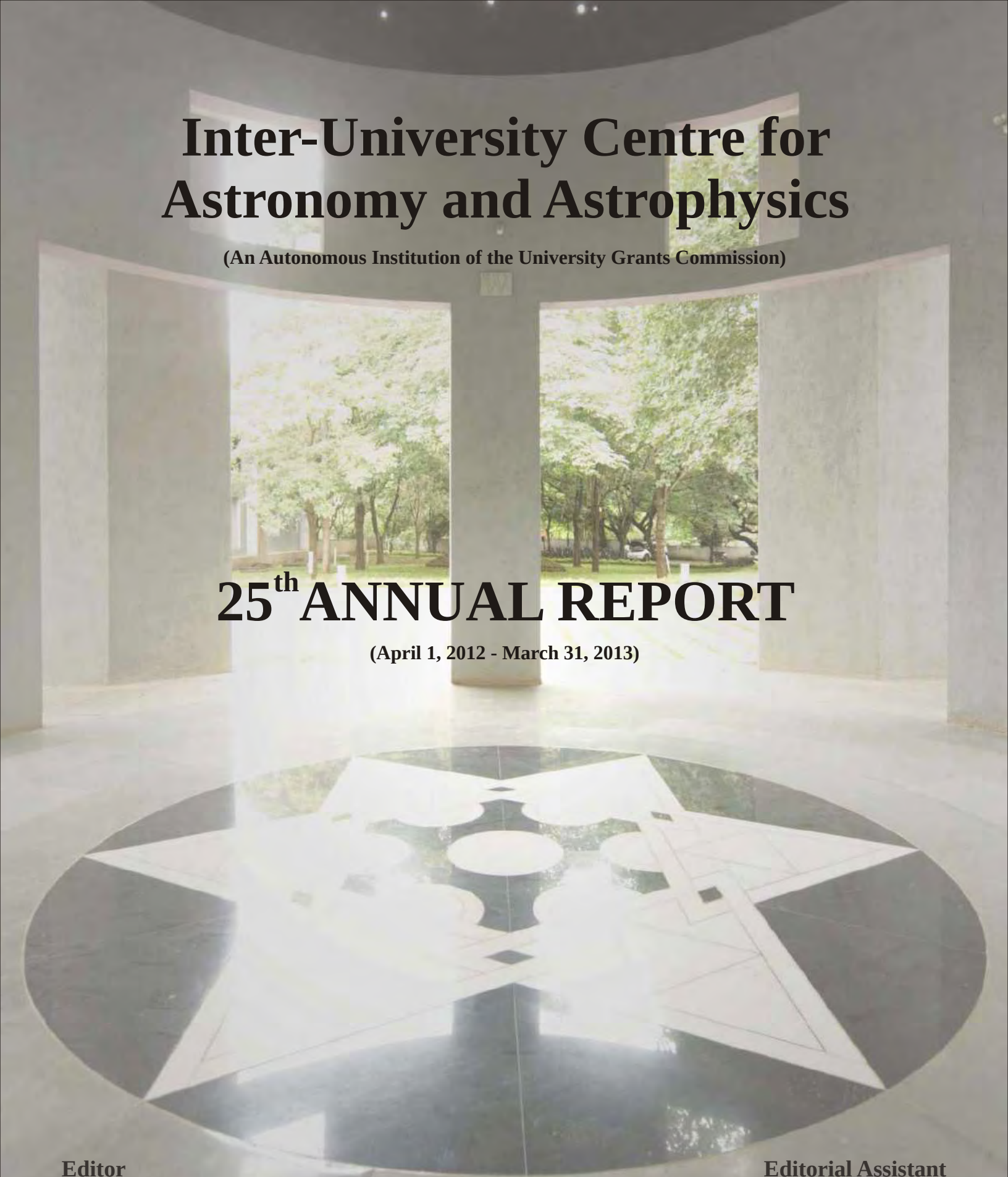
25th Year

IUCAA
ANNUAL REPORT
2012 - 2013

Inter-University Centre for Astronomy and Astrophysics

(An Autonomous Institution of the University Grants Commission)



25th ANNUAL REPORT

(April 1, 2012 - March 31, 2013)

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HIGHLIGHTS OF 2012- 2013

This annual report covers the activities of IUCAA during its twenty-second year, April 2012-March 2013.

The research activities and endeavours of IUCAA span different fronts, and are outlined in the pages of this report. Here, a quick summary and highlights are provided.

IUCAA has an academic strength of 16 core faculty members (academic), 16 post-doctoral fellows and 31 research scholars. The core research programmes by these academics span a variety of areas in astronomy and astrophysics. These topics include quantum theory and gravity, gravitational waves, cosmology and structure formation, cosmic microwave background, cosmic magnetic fields, observational cosmology and extragalactic astronomy, high energy astrophysics, galaxy and the interstellar medium, and solar physics. These research activities are summarised in pages 17 - 49. The publications of the IUCAA members, numbering to about 90 in the current year are listed in pages 50 - 53. IUCAA members also take part in pedagogical activities like lectures, seminars, popularisation of science, etc., the details of which are given in pages 54 - 62 and 80 - 81 of this Report.

The extended academic family of IUCAA consists of about 105 Visiting Associates, who have been active in several different fields of research. Pages 82 - 99 of this report highlight their research contributions. The resulting publications, numbering to about 130 are listed in pages 100 - 105 of this report. A total of about 1635 person-days were spent by Visiting Associates at IUCAA during this year. In addition, IUCAA was acting as host to about 650 visitors through the year. During the current year the Visiting Associates were drawn from 50 universities and colleges from all over India. The visitors to IUCAA came from over 150 institutions, universities and colleges which indicates the extent of participation of the university sector in IUCAA's activities.

IUCAA conducts its graduate school jointly with the National Centre for Radio Astrophysics, Pune. This year one research scholar successfully defended her thesis and obtained Ph.D. degree from the University of Pune during the year 2012 - 2013. Summary of her thesis appears in pages 69 - 70.

Apart from these activities, IUCAA conducts several workshops, schools, and conferences each year, both at IUCAA and at different university/college campuses. During this year, there were 7 such events in IUCAA and 12 were held at other universities/colleges under IUCAA sponsorship.

Another main component of IUCAA's activities is its programme for Science Popularisation. On the National Science Day, several special events were organised, which included a special workshop on making simple spectroscopes. There were posters displayed by the academic members of IUCAA, which elaborated on the research work at IUCAA and topics in the field of astronomy. There were public lectures given by the faculty members and programmes for school students consisting of quiz, essay and drawing competitions. During the Open Day, about 6000 people visited IUCAA.

The activities carried out by IUCAA were ably supported by the scientific and technical, and administrative staff (27 and 32 in number respectively) who should get the lion's share of the credit for the successful running of the programmes of the centre. The scientific staff also looks after the major facilities like library, computer centre, IUCAA Girawali observatory and instrumentation lab. A brief update on these facilities is given on pages 71 - 75 of this Report.

Ajit Kembhavi
Editor

In this year's report

The Council and the Governing Board

THE COUNCIL (As on March 31, 2013)

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Ved Prakash,
Chairperson, University Grants Commission, New Delhi.

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(Chairperson, Governing Board),
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Bhabha Atomic Research Centre,
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Director General,
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University of Pune.

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National Centre for Radio Astrophysics,
Pune.

Jitendra N. Goswami,
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Physical Research Laboratory,
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MEMBER SECRETARY

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Secretary,
University Grants Commissions,
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Indian Institute of Science,
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Indian Institute of Technology,
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M. Basheer Ahmed Khan,
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Parathasarathi Majumdar,
Saha Institute of Nuclear Physics,
Kolkata.

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Rani Durgavati Vishwavidyalaya,
Jabalpur.

T. C. Shivashankara Murthy,
Vice-Chancellor,
Mangalore University.

SPECIAL INVITEE

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University Grants Commission, New Delhi.

K. Radhakrishnan,
Chairman,
Indian Space Research Organization,
Bangalore.

S. V. Raghavan,
Scientific Secretary,
Government of India, New Delhi.

T. Ramasami,
Secretary,
Department of Science and Technology,
New Delhi.

Ramakrishna Ramaswamy,
Vice-Chancellor,
University of Hyderabad.

Amit Roy,
Director,
Inter - University Accelerator Centre,
New Delhi.

Varun Sahni,
IUCAA,
Pune.

Harinder P. Singh,
Department of Physics and
Astrophysics,
University of Delhi.

The following members have served on the Council for part of the year

P. C. Agrawal,
MU-DAE Centre for Excellence in Basic Sciences, Mumbai University Campus, Kalina.

Praveen Chaddah,
Director,
UGC - DAEF Consortium for Scientific Research,
Indore.

Mihir K. Chaudhuri,
Vice-Chancellor,
Tezpur University,
Assam.

Anil Kakodkar,
Chairperson, Governing Board,
DAE Homi Bhabha Chair Professor,
Bhabha Atomic Research Centre,
Mumbai.

Niloufer Kazmi,
Secretary,
University Grants Commission,
New Delhi.

Kandaswamy Subramanian,
IUCAA, Pune.

J. A. K. Tareen,
Vice-Chancellor, Pondicherry University.

THE GOVERNING BOARD (As on March 31, 2013)

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Srikumar Banerjee

MEMBERS

Virander S. Chauhan
Wasudeo N. Gade
Swarna Kanti Ghosh
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Arun Kumar Grover
Akhilesh Gupta
S. V. Raghavan
Ramakrishna Ramaswamy
Amit Roy
Varun Sahni
Ajit Kembhavi (Member Secretary)
Renu Batra (Special Invitee)

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

P. C. Agrawal
Praveen Chaddah
Mihir K. Chaudhuri
Anil Kakodkar
Niloufer Kazmi
Kandaswamy Subramanian
J. A. K. Tareen

HONORARY FELLOWS

E. Margaret Burbidge,
Centre for Astronomy and Space Sciences, University of California, USA.

Russell Cannon,
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E.P.J. van den Heuvel,
Astronomical Institute,
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Antony Hewish,
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UK.

Gerard 't Hooft,
Spinoza Institute,
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Donald Lynden-Bell,
Institute of Astronomy,
University of Cambridge,
UK.

Yash Pal,
Noida.

Govind Swarup,
National Centre for Radio Astrophysics,
Pune.

Statutory Committees

THE SCIENTIFIC ADVISORY COMMITTEE (SAC)

P. C. Agrawal,
MU-DAE Centre for Excellence in BASIC Sciences, Mumbai University Campus, Kalina.

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Deepak Dhar,
Tata Institute of Fundamental Research, Mumbai.

Andrew C. Fabian,
University of Cambridge, U. K.

Yashwant Gupta,
National Centre for Radio Astrophysics, Pune.

Romesh Kaul,
The Institute of Mathematical Sciences, Chennai.

Ajit K. Kembhavi
Director,
IUCAA, Pune.

P. N. Pandita,
North-Eastern Hill University, Shillong.

Martin M. Roth,
Astrophysikalisches Institut Potsdam, Germany.

THE USERS' COMMITTEE

Ajit K. Kembhavi
(Chairperson, Ex-Officio Member),
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IUCAA, Pune.

Dipankar Bhattacharya,
IUCAA, Pune.

Mihir K. Chaudhuri,
Vice-Chancellor, Tezpur University, Assam.

Sarbari Guha,
St. Xavier's College, Kolkata.

M. K. Patil,
Swami Ramanand Teerth Marathwada University, Nanded.

T. Ramachandran,
Vice-Chancellor,
Cochin University of Science and Technology, Kochi.

Indra Vardhan Trivedi,
Vice-Chancellor,
Mohanlal Sukhadia University, Udaipur.

Members of IUCAA

THE ACADEMIC PROGRAMMES COMMITTEE

Ajit K. Kembhavi
(Chairperson)

T. Padmanabhan
(Convener)

Kandaswamy Subramanian

Joydeep Bagchi

Dipankar Bhattacharya

Sukanta Bose

Gulab Chand Dewangan

Tarun Souradeep

Ranjan Gupta

Ranjeev Misra

Sanjit Mitra

A.N. Ramaprakash

Swara Ravindranath

Varun Sahni

R. Srianand

Durgesh Kumar Tripathi

THE STANDING COMMITTEE FOR ADMINISTRATION

Ajit K. Kembhavi
(Chairperson)

T. Padmanabhan

Kandaswamy Subramanian

E.M. Modak
(Member Secretary)

THE FINANCE COMMITTEE

Srikumar Banerjee
(Chairperson)

Ajit K. Kembhavi

Akhilesh Gupta

Upamanya Basu

Swarna Kanti Ghosh

Eknath M. Modak
(Non-member Secretary)

Varun Sahani

ACADEMIC

Ajit K. Kembhavi
(Director)

T. Padmanabhan
(Dean, Core Academic Programmes)

Kandaswamy Subramanian
(Dean, Visitor Academic Programmes)

Joydeep Bagchi

Dipankar Bhattacharya

Sukanta Bose

Gulab Chand Dewangan

Tarun Souradeep

Ranjan Gupta

Ranjeev Misra

Sanjit Mitra

A.N. Ramaprakash

Swara Ravindranath

Varun Sahni

R. Srianand

Durgesh Kumar Tripathi

EMERITUS PROFESSORS

Naresh K. Dadhich

Jayant V. Narlikar

Shyam N. Tandon

Members of IUCAA

SCIENTIFIC AND TECHNICAL

Prafull S. Barathe
Nirupama U. Bawdekar
Rani S. Bhandare
Santosh S. Bhujbal
Mahesh P. Burse
Kalpesh S. Chillal
Pravinkumar A. Chordia
Hillol K. Das
Samir A. Dhurde
Gajanan B. Gaikwad
Sudhakar U. Ingale
Pravin V. Khodade
Abhay A. Kohok
Vilas B. Mestry
Shashikant G. Mirkute
Deepa R. Modi
Vijay Mohan
N. Nageswaran
Nitin D. Ohol
Sarah Ponrathnam
Swapnil M. Prabhudesai
Sujit P. Punnadi
Vijay Kumar Rai
Chaitanya V. Rajarshi
Hemant Kumar Sahu
Yogesh R. Thakare
Arvind Paranjpe

ADMINISTRATIVE AND SUPPORT

Eknath M. Modak
(Senior Administrative Officer)
Niranjan V. Abhyankar
Vijay P. Barve
Savita K. Dalvi
Rahul S. Gaikwad
Sandeep L. Gaikwad
Bhagiram R. Gorkha
Bhimpuri S. Goswami
Ramesh S. Jadhav
Prashant S. Jadhav
Sandip M. Jogalekar
Nilesh D. Kadam
Swati D. Kakade
Santosh N. Khadilkar
Murli N. Krishnan
Susan B. Kuriakose
Neelima S. Magdum
Manjiri A. Mahabal
Kumar B. Munuswamy
Anil R. Paraste
Rajesh D. Pardeshi
Rajesh V. Parmar
Mukund S. Sahasrabudhe
Vyankatesh A. Samak
Senith S. Samuel
Balaji V. Sawant
Deepak R. Shinde
Varsha R. Surve
Deepika M. Susainathan
Shankar K. Waghela
Kalidas P. Wavhal
Sadanand R. Tarphe

POST - DOCTORAL FELLOWS

Varun Bhalerao
Bhaswati Bhattacharyya
Debbijoy Bhattacharya
Vivek M
Bibhas Ranjan Majhi
Sujoy Kumar Modak
Arunava Mukherjee
Surajit Paul
Jayanti Prasad
Shalima Puthiyaveettil
Angel Ruiz
Prakash Sarkar
Nishant Kumar Singh
Srividya Subramanian
Shruti Tripathi
Sanil Unnikrishnan

RESEARCH SCHOLARS

Anirban Ain
Maryam Arabsalmani
Satadru Bag
Hadi Rahmani Bayegi
Pallavi Bhat
Prasanta Bera
Luke Chamandy
Sabyasachi Chattopadhyay
Santanu Das
Rajeshwari Dutta
Balaji Dodda
Bhooshan Gadre
Gaurav Goswami
Charles Jose
Vikram K. Khaire
Sanved V. Kolekar
Nagendra Kumar
Sandeep Kumar
Saurabh Kumar
Sibasish Laha
Dipanjan Mukherjee
Suvodip Mukherjee
Sargam Mulay
Sowgat Muzahid
Hamsa Padmanabhan
Krishnamohan Parattu
Mainpal Rajan
Pritesh S. Ranadive
Aditya Rotti
Suprit Singh
Kaustubh P. Vaghmare

TEMPORARY/ PROJECT/ CONTRACTUAL APPOINTMENTS

Ashish Asgekar
Avinash B. Babar
Niranjan D. Bangde
Neelam Bhujbal
V. Chellathurai
Malathi Deenadayalan
Gaurav S. Datir
Rahul Deokate
Sharad Gaonkar
Bharat Gavhane
Arvind Gupta
Santosh B. Jagade
Bhushan S. Joshi
Tejas A. Kale
Chhaya A. Karle
Murli N. Krishnan
A. M. Lande
Maharudra G. Mate
Vidula M. Mhaiskar
N. V. Nagarathanam
Sharmad D Navelkar
Dilip Pacharne
Pravin D. Pacharne
Jyotirmay Paul
Nilesh D. Pokharkar
Ashok N. Rupner
Vitthal Savaskar
Pratapbhan S. Senger
Sagar C. Shah
Pravin L. Shekade
Monali K. Sinare
Garima Singh
Amit R. Sonawane
Eric Tatulli
Sangita W. Thakare
Reji M. Thomas
Madhukar Togam
Kirti Tonpe
Ajay Vibhute

LONG TERM VISITORS

P. C. Agrawal
Sanjeev V. Dhurandhar
Pushpa Khare
Gopal Krishna

Visiting Associates of IUCAA

Farooq Ahmad	Department of Physics, University of Kashmir, Srinagar
S. K. Saiyad Ali	Department of Physics, Jadavpur University, Kolkata
G. Ambika	Department of Physics, IISER, Pune
Bijan Kumar Bagchi	Department of Applied Mathematics, University of Calcutta, Kolkata
Tanwi Bandyopadhyay	Department of Mathematics, Shri Shikshayatan College, Kolkata
Narayan Banerjee	Department of Physical Sciences, IISER, Kolkata
Shyamal Kumar Banerjee	Department of Mathematics, University of Petroleum and Energy Studies, Dehradun
Vasudha Bhatnagar	Department of Computer Science, University of Delhi.
Gour Bhattacharya	Department of Physics, Presidency University, Kolkata
Pavan Chakraborty	Indian Institute of Information Technology, Allahabad
Shuvendu Chakraborty	Department of Mathematics, Seacom Engineering College, Howrah
Subenoy Chakraborty	Department of Mathematics, Jadavpur University, Kolkata
Ramesh Chandra	Department of Physics, Kumaun University, Nainital
Suresh Chandra	Department of Physics, Lovely Professional University, Punjab
Asis Kumar Chattopadhyay	Department of Statistics, Calcutta University, Kolkata
Surajit Chattopadhyay	Department of Computer Application, Pailan College of Management and Technology, Kolkata
Tanuka Chattopadhyay	Department of Applied Mathematics, Calcutta University, Kolkata
Bhag Chand Chauhan	Department of Physics and Astronomical Sciences, Central University of Himachal Pradesh
Rabin Kumar Chhetri	Department of Physics, Sikkim Government College, Gangtok
Mamta Dahiya	Department of Physics and Electronics, S.G.T.B. Khalsa College, Delhi
Himadri Sekhar Das	Department of Physics, Assam University, Silchar
Sudipta Das	Department of Physics, Visva-Bharati University, Santiniketan
Ujjal Debnath	Department of Mathematics, Bengal Engineering and Science University, Howrah
Anoubam Senorita Devi	Department of Physics, Assam University, Silchar
Jishnu Dey	Department of Physics, Presidency University, Kolkata
Mira Dey	Department of Physics, Presidency University, Kolkata
Anjan Dutta	Department of Physics and Astrophysics, University of Delhi
Sunandan Gangopadhyay	Department of Physics, West Bengal State University, Barasat
Sushant G. Ghosh	Centre for Theoretical Physics, Jamia Millia Islamia, Delhi
Sarbari Guha	Department of Physics, St. Xavier's College, Kolkata
Abhinav Gupta	Department of Physics, St. Stephen's College, Delhi
K. P. Harikrishnan	Department of Physics, The Cochin College, Kochi
K. Indulekha	School of Pure and Applied Physics, Mahatma Gandhi University, Kottayam
Naseer Iqbal Bhat	Department of Physics, University of Kashmir, Srinagar
S.N.A. Jaaffrey	Department of Physics, M. L. Sukhadia University, Udaipur
Joe Jacob	Department of Physics, Newman College, Thodupuzha
Deepak Jain	Department of Physics and Electronics, Deen Dayal Upadhyaya College, New Delhi
Sanjay Jhingan	Centre for Theoretical Physics, Jamia Millia Islamia, Delhi
Kanti Jotania	Department of Physics, The M. S. University of Baroda, Vadodara
Minu Joy	Department of Physics, Alphonsa College, Pala
Md. Mehedi Kalam	Department of Physics, Aliah University, Kolkata
Nagendra Kumar	Department of Mathematics, M.M.H. College, Ghaziabad
Suresh Kumar	Department of Applied Mathematics, Delhi Technological University
V.C. Kuriakose	Department of Physics, Cochin University of Science and Technology, Kochi
Badam Singh Kushvah	Department of Applied Mathematics, Indian School of Mines, Dhanbad
Manzoor A. Malik	Department of Physics, University of Kashmir, Srinagar
Soma Mandal	Department of Physics, Taki Government College
Pradip Mukherjee	Department of Physics, Barasat Government College, Kolkata
Kamal Kanti Nandi	Department of Mathematics, North Bengal University, Siliguri
Archana Pai	Department of Physics, IISER, Thiruvananthapuram
Sanjay P. Pandey	Department of Mathematics, L. B. S. (P. G.) College, Gonda
S. K. Pandey	Pandit Ravishankar Shukla University, Raipur
P. N. Pandita	Department of Physics, North Eastern Hill University, Shillong
Kishor Dnyandeo Patil	Department of Mathematics, B.D. College of Engineering, Sevagram

Madhav K. Patil	School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded
Bikash Chandra Paul	Department of Physics, North Bengal University, Siliguri
Ninan Sajeeth Philip	Department of Physics, St. Thomas College, Kozhencherri
Anirudh Pradhan	Department of Mathematics, Hindu Post-Graduate College, Ghazipur
Farook Rahaman	Department of Mathematics, Jadavpur University, Kolkata
Shantanu Rastogi	Department of Physics, D.D.U. Gorakhpur University, Gorakhpur
C. D. Ravikumar	Department of Physics, University of Calicut, Kozhikode
Saibal Ray	Department of Physics, Government College of Engineering and Ceramic Technology, Kolkata
Biplab Raychaudhuri	Department of Physics, Visva-Bharati University, Santiniketan
Anirban Saha	Department of Physics, West Bengal State University, West Bengal
Rajib Saha	Department of Physics, IISER, Bhopal
Sandeep Sahijpal	Department of Physics, Panjab University, Chandigarh
Tarun Deep Saini	Department of Physics, Indian Institute of Science, Bangalore
Pramoda Kumar Samal	Post-Graduate Department of Physics, Utkal University, Bhubaneshwar
Bhim Prasad Sarmah	Department of Mathematical Sciences, Tezpur University
Sanjay Baburao Sarwe	Department of Mathematics, St. Francis De Sales College, Nagpur
Anjan Ananda Sen	Centre for Theoretical Physics, Jamia Millia Islamia, Delhi
Asoke Kumar Sen	Department of Physics, Assam University, Silchar
Anand Sengupta	Department of Physics, IIT, Gandhinagar, Ahmedabad
T. R. Seshadri	Department of Physics and Astrophysics, University of Delhi
K. Shanthi	Academic Staff College, University of Mumbai
Ranjan Sharma	Department of Physics, P.D. Women's College, Jalpaiguri
Harinder Pal Singh	Department of Physics and Astrophysics, University of Delhi
Hemam Dinesh Singh	Department of Physical Sciences, Sikkim University, Gangtok
Pranjal Trivedi	Department of Physics, Sri Venkateswara College, Delhi
Paniveni Udayashankar	Department of Physics, NIE Institute of Technology, Mysore
Anisul Ain Usmani	Department of Physics, Aligarh Muslim University

Till July 31, 2012

B. R. S. Babu	Department of Physics, University of Calicut, Kozhikode
Surendranath Borah	Dergaon Kamal Dowerah College
Ngangbam Ibohal	Department of Mathematics, Manipur University, Imphal
M. Sivakumar	School of Physics, University of Hyderabad

From August 1, 2012

Gazi Ameen Ahmed	Department of Physics, Tezpur University
Prasad Basu	National Institute of Technology, Barfung, Sikkim
Koushik Chakraborty	Government Training College, Hooghly
Partha Chowdhury	Department of Physics, University of Calcutta, Kolkata
Broja Gopal Dutta	Y.S. Palpara College, Purba - Medinipur
Supriyo Mitra	Department of Earth Sciences, IISER, Kolkata
Soumen Mondal	Department of Physics, Ramakrishna Mission Residential College, Kolkata
Hemwati Nandan	Department of Physics, Gurukula Kangri University, Haridwar
Rajesh Kumble Nayak	Department of Physical Sciences, IISER, Kolkata
Amit Pathak	Department of Physics, Tezpur University, Assam
Somak Raychaudhury	Department of Physics, Presidency University, Kolkata
Sanjay Kumar Sahay	Department of Computer Science and Information System, BITS-Pilani, Goa
Somasri Sen	Department of Physics, Jamia Millia Islamia, Delhi
K. Yugindro Singh	Department of Physics, Manipur University, Imphal
Parijat Thakur	Department of Basic Sciences and Humanities, Guru Ghasidas and Central University, Bilaspur

Visiting Associates of IUCAA

**The Twenty-third Batch (2012) of Visiting Associates,
who were selected for a tenure of three years, beginning August 1, 2012.**

Gazi Ameen Ahmed

Prasad Basu

Koushik Chakraborty

Partha Chowdhury

Broja Gopal Dutta

Supriyo Mitra

Soumen Mondal

Hemwati Nandan

Rajesh Kumble Nayak

Amit Pathak

Somak Raychaudhury

Sanjay Kumar Sahay

Somasri Sen

K. Yugindro Singh

Parijat Thakur

Appointment of the following Visiting Associates from the twentieth batch were extended for three years:
Sk. Saiyad Ali, Shyamal Kumar Banerjee, Anjan Dutta, Sarbari Guha, Joe Jacob, Deepak Jain, Minu Joy, Mamta, Bikash Chandra Paul, Farook Rahaman, C.D. Ravikumar, Sandeep Sahijpal, Asoke Kumar Sen, K. Shanthi, Ranjan Sharma, and Pranjal Trivedi

Organizational Structure of Academic Programmes
(From August 1, 2012)

THE DIRECTOR

Ajit K. Kembhavi

Dean, Core Academic Programmes	T. Padmanabhan
Dean, Visitor Academic Programmes	Kandaswamy Subramanian
Head, Computing Facilities	Dipankar Bhattacharya
Head, Public Outreach Programmes	Durgesh Tripathi
Head, IUCAA Girawali Observatory	Vijay Mohan
Head, Scientific Meetings	Ranjan Gupta
Head, Publications	Swara Ravindranath
Head, Estate Development and Maintenance	Ajit K. Kembhavi
Head, Instrumentation	A. N. Ramaprakash
Head, IUCAA Resource Centres	Ranjeev Misra
Head, Library	Varun Sahni
Head, Infrastructural Facilities	Tarun Souradeep
Head, Teaching Programmes	R. Srianand
Head, Observing Programmes and SALT	R. Srianand

Director's Report

> The period covered by this Annual Report has been fruitful and exciting at IUCAA. A number of projects have been completed and several others have been initiated, new buildings are being constructed, new equipment has arrived, some people have left and others have joined.

Dr. Anil Kakodkar recently completed his second term of three years as Chairperson, Governing Board, IUCAA. His guidance and support have been invaluable to all of us, and we look forward to his sage advice in the future as well. Dr. Srikumar Banerjee, who was Secretary, Department of Atomic Energy and Chairman, Atomic Energy Commission, has been appointed by the UGC as the next Chairperson of our Governing Board. Professor Sukanta Bose, formerly of the Washington State University, joined as a Professor in January 2013. He specialises in gravitational wave astronomy, and will provide valuable support to the LIGO-India project.

IUCAA faculty members have been engaged in research and development, teaching at the IUCAA-NCRA graduate school and on various university campuses, thesis supervision and organization of workshops and other meetings. IUCAA academic members have produced about 75 research papers in high impact, international and national journals. During the year, IUCAA had 16 faculty members, about 30 research students and about 14 post-doctoral fellows. In addition, there have been several long term senior visitors and Emeritus Professors. The work of Professor Tarun Souradeep, Professor Sanjit Mitra, and Mr. Aditya Rotti, who is a graduate student at IUCAA, was widely recognized when the first cosmology results from the European Space Agency – NASA Planck mission were announced.

The 11m Southern African Large Telescope (SALT), of which IUCAA is a part owner, has become available for regular observations from November 2011. Useful spectroscopic data is being obtained by observers from IUCAA and universities, and the analysis of data is in progress. IUCAA members have contributed significantly to the development of hardware and software for ASTROSAT, which is expected to be launched by ISRO during 2014. The development of the Ultra-Violet Imaging Telescope (UVIT) to be carried by ASTROSAT has been completed by Professor Shyam Tandon of IUCAA in the lead. Space flight related tests are now being carried out on the instrument. IUCAA is also helping with calibration of the CZT instrument on ASTROSAT and has helped to develop a sophisticated proposal management system for observations.

A 30 TF parallel computing cluster with 1500 cores, 12 TB RAM and 750 TB storage has been installed and is fully operational. This is one of the faster systems in the country. One third of this facility has been earmarked to set up a proto-type GW data centre in preparation for IUCAA's plans to provide a full fledged tier II datacenter for the international LIGO science collaboration.

The Instrumentation Laboratory at IUCAA has been doing very well in its projects on adaptive optics, focal plane array controllers and optical fibres. A robotic adaptive optics system (ROBO-AO) project for the development of adaptive optics for small and medium telescopes in collaboration with a group at California Institute of Technology, USA, has been successfully completed. A version of this system for the IGO 2m telescope is being built. A new control and monitoring system has been developed in collaboration with the National Centre for Radio Astrophysics and the involvement of Persistent Systems Limited, Pune.

A significant development has been the signing of a memorandum of understanding with ARIES, Nainital, for the development of an integral field spectrograph for the 3.6m Devasthal Optical Telescope. The design of the instrument is under review. It will be built at IUCAA through collaboration between the two institutions.

There has been a good deal of construction activity at IUCAA, including a new and high performance computing data centre and instrumentation laboratory, a new guest house and staff quarters. The computing centre and guest house are fully ready and occupied, and were dedicated by Professor Ved Prakash, Chairperson, UGC on March 14, 2013. The instrumentation laboratory and staff quarters are being furnished and will be ready for occupation in May 2013.

A number of programmes for universities and colleges have been organized at IUCAA, at the six IUCAA Resource Centres (IRCs) at Siliguri, Kolkata, Delhi, Raipur, Udaipur, and Kochi, as well as at other campuses and at the IUCAA Nodes for Astronomy and Astrophysics Development (INAAD) and at the IUCAA University Centres. IUCAA now has 96 visiting associates from the university sector, many of whom spend significant periods at IUCAA, accompanied by their research students. About 25 research students from universities carry out a significant part of their work under the supervision of IUCAA faculty.

A number of national and international workshops were conducted at IUCAA during the year, covering a number of fields of interest to IUCAA. These included an international Thirty Metre Telescope Science meeting, a workshop on Transients and Timing, which was very well attended by astronomers from India and abroad, and a month long X-ray Astronomy School for research students and young faculty from universities and research institutions.

Much progress has been made on the LIGO-India project for the installation of an advanced laser interferometer gravitational wave detector in India, in collaboration with LIGO-USA. The project is being developed with three institutes: IUCAA, the Institute of Plasma Research (IPR), Ahmedabad; and Raja Ramanna Centre for Advanced Technology (RRCAT), Indore having lead roles. Valuable support to the project has also been provided by the IndIGO Consortium. The DAE is preparing a Cabinet Note for final approval of the project. IUCAA is carrying out a survey to identify a site for installing the detector.

The Thirty Metre Telescope (TMT) project, of which IUCAA is a lead institute along with the Indian Institute of Astrophysics (IIA), Bangalore; and ARIES, Nainital, is also making steady progress. IUCAA has been involved in all stages of the project and is actively contributing to the execution of various work packages. These two major projects, of which IUCAA is an integral and important part, when ready, promise to fundamentally change the way astronomy is done in India.

IUCAA, as usual, celebrated the National Science Day on February 28, 2013 by having an open house for the people of Pune and the surrounding region. A number of lectures, demonstrations and question-answer session were organized all through the day, followed by sky observing sessions with small telescopes at night. Various science oriented competitions for school students were organized during the preceding weeks.

Over the year, we have lost two members of the IUCAA family. Ms. Susan Kuriakose, who for long time was my secretary, died in a tragic accident in September 2012. She was known for her hard and efficient work and her friendly, pleasing personality and very helpful nature. The other person who passed away due to a sudden medical complication was Mr. Sadanand Tarphe, who moved to IUCAA from TIFR along with Professor Jayant Narlikar and me in 1989. He was known for his excellent work and organizational abilities, and for long helped to administer the IUCAA Employees Society.

All the exciting work being done at IUCAA has been possible because of the many talents and sincere efforts of its academic, scientific and technical, and administrative staff. I thank all my colleagues for their individual and collective contributions, without which so much success could not have been achieved. I wish to thank the Governing Board and in particular, the Chairperson, Dr. Srikumar Banerjee, for the constant support and encouragement provided to IUCAA and to me personally. Likewise the Council too, and its President, Professor Ved Prakash, have always been very encouraging and supportive. Our work would not have been possible without the help and support provided by the University Grants Commission and its staff and officers.

Ajit Kembhavi
Director

Awards and Recognitions

Congratulations!

Arvind Gupta

On being **conferred with the Dadhichi Puraskar,** by the Education Society, Ambarnath, 2012.

Ajit K. Kembhavi

On being **elected President, Astronomical Society of India**, in 2013.

Jayant V. Narlikar

On being conferred with the **Telesio-Galilei Academy of Science Award and Gold Medal**, U. K.

Kasba Mata Puraskar from the Akhil Kasba Peth Shree Trimurti Navaratra Utsav Samiti, Pune, 2012.

TWAS Regional Office Prize for Scientific Institution Building, 2012.

Jeevan Gaurav Puraskar from the Maharashtra Foundation, U.S.A., 2013.

Jeevansadhana Gaurav Puraskar from the University of Pune, 2013.

Maa Bhagwati Sharada Puraskar from Shree Sharada Prabodhini, Pimpalgaon, 2013.

T. Padmanabhan

On being elected **Fellow of the Third World Academy of Sciences**, Italy, 2012

On being conferred with **Thomson Reuters Research Excellence India Citation Award,** 2012.

On being elected as **Vice-President of Division J on Galaxies and Cosmology of International Astronomical Union,** (2012-2015).

Varun Sahni

On being conferred with **Thomson Reuters Research Excellence India Citation Award**, 2012.

Tarun Souradeep

Elected fellow of International Society on General Relativity and Gravitation, 2013.

Elected Fellow of the Indian Academy of Sciences, Bangalore, 2013.

On being conferred with the **Hari Om Ashram prerit Dr. Vikram Sarabhai Research Award for Space Science**, Physical Research Laboratory, Ahmedabad, 2011.

Inter-University Centre for Astronomy and Astrophysics

ACADEMIC CALENDAR 2012 - 13

Inter-University Centre for Astronomy and Astrophysics
(An autonomous institution of the University Grants Commission)

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EVENTS AT IUCAA

2012

December 10 - 14
TMT Science Meeting
Coordinator: A. N. Ramaprakash (anr@iucaa.ernet.in)

December 17 - 20
Workshop on Galaxies in Absorption
Coordinators: R. Srianand (anand@iucaa.ernet.in)
Pushpa Khare (pak@iucaa.ernet.in)

2013

February 3 - March 2
2nd IUCAA X-Ray Astronomy School
Coordinator: Gulab Dewangan (gulabd@iucaa.ernet.in)

March 4 - 8
International Meeting on Transients and Timing
Coordinator: Ajit Kembhavi (akk@iucaa.ernet.in)

IUCAA RESOURCE CENTRE EVENTS

2012

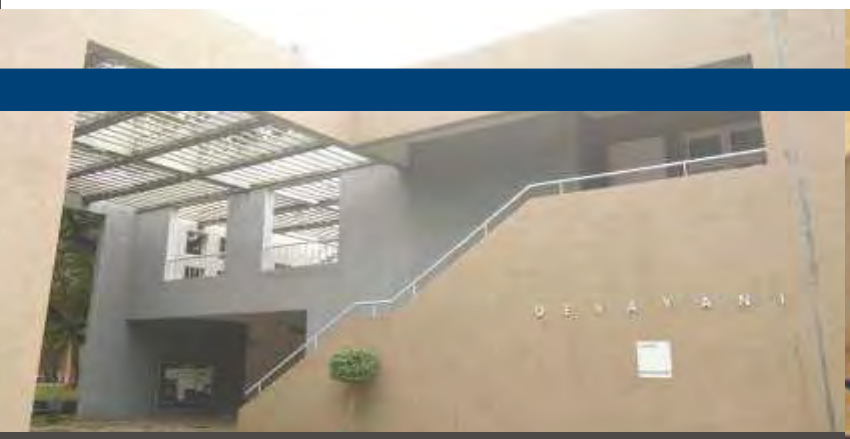
September 6 - 8
INAAD Workshop on Science with Optical Spectra
at St. Thomas College, Kozhencherri
Coordinators : Joe Jacob (drjoephysics@yahoo.co.in)
R. Srianand (anand@iucaa.ernet.in)

September 17-19
Workshop on Advanced Data Analysis Techniques in Astrophysics
at Madhava Observatory, University of Calicut
Coordinators: C. D. Ravikumar (cdravi@gmail.com)
Ranjeev Misra (rmisra@iucaa.ernet.in)

November 5 - 8
Introductory Workshop on Virtual Observatory
at IRC, University of Calcutta
Coordinators : Ajit Kembhavi (akk@iucaa.ernet.in)
Tanuka Chattopadhyay (tanuka@iucaa.ernet.in)

2013

January 28 - February 2
Workshop on Cosmology
at University of Delhi
Coordinators: T. R. Seshadri (trs@iucaa.ernet.in)
Anjan Ananda Sen (aasen@jmi.ac.in)
K. Subramanian (kandu@iucaa.ernet.in)



EVENTS OUTSIDE IUCAA

2012

November 8 - 10
Workshop on Cosmology
at Bangalore University
Coordinators: B.A. Kagali (bakagali@gmail.com)
Sailo Mukherjee (sailom47@rediffmail.com)

November 29 - December 1
IIST - IUCAA Introductory Workshop on Solar Physics
at IIST, Thiruvanathapuram
Coordinators: Anandmayee Tej (anandmayee.tej@gmail.com)
Durgesh Tripathi (durgesh@iucaa.ernet.in)

December 17 - 21
Workshop on Gravitational Wave Data Analysis
at BITS - Pilani, Goa Campus
Coordinators: S. K. Sahay (ssahay@bits-goa.ac.in)
Sanjit Mitra (sanjit@iucaa.ernet.in)

December 19 - 28
Radio Astronomy Winter School
at NCRA, Pune
Coordinators: Joydeep Bagchi (joydeep@iucaa.ernet.in)
B. C. Joshi (bcj@ncra.tifr.res.in)

2013

January 3 - 4
Pulsar Observatory for Students
at NCRA, Pune
Coordinators: Joydeep Bagchi (joydeep@iucaa.ernet.in)
B. C. Joshi (bcj@ncra.tifr.res.in)

January 29 - 31
Introductory School in Astronomy and Astrophysics
at Srikishan Sarda College, Hailakandi
Coordinators: A. K. Das (ashok.dashok.das93@gmail.com)
Ranjan Gupta (rag@iucaa.ernet.in)

February 1 - 3
Introductory Workshop on Solar Physics
at Ramakrishna Mission Vivekanand University, Belur
Coordinators: Abhijit Bandyopadhyay
Partha Chowdhury (partha240@yahoo.co.in)
Durgesh Tripathi (durgesh@iucaa.ernet.in)

February 7 - 9
Workshop on Mathematical Methods and Astronomy
at Indian School of Mines, Dhanbad
Coordinators: Badam Singh Kushvah (bskush@gmail.com)
Ranjan Gupta (rag@iucaa.ernet.in)

IUCAA ANNUAL EVENTS

2012

August 6
IUCAA - NCRA Graduate School, First semester begins

December 7
IUCAA - NCRA Graduate School, First semester ends

December 29
Foundation Day

April 9 - May 18
School Students' Summer Programme at IUCAA

May 4
IUCAA - NCRA Graduate School, Second semester ends

May 7 - June 8
Introductory Summer School in Astronomy and Astrophysics (for College/University students) at IUCAA

May 7 - June 22
Vacation Students' Programme at IUCAA

2013

January 7
IUCAA-NCRA Graduate School, Second semester begins

February 28
National Science Day

For further details contact:
The Dean,
Visitor Academic Programmes
or visit: www.iucaa.ernet.in

Quantum Theory and Gravity

Noether current from the surface term of the gravitational action, horizon Virasoro algebra and entropy

Bibhas Ranjan Majhi with **T. Padmanabhan** has described a simple way of obtaining horizon entropy using the approach based on the Virasoro algebra and central charge. They have shown that the Virasoro algebra defined by the Noether currents corresponding to the *surface term* of gravitational action, for the diffeomorphisms which leave the horizon structure unaltered, has a central extension that directly leads to the horizon entropy. In this approach, there are no ambiguities in the calculation of the central charge. They have explained why this approach is physically well motivated and could provide greater insight into the nature of horizon entropy.

Phase transition and scaling behaviour of topological charged black holes in Hořava-Lifshitz gravity

Gravity can be thought as an emergent phenomenon and it has a nice "thermodynamic" structure. In this context, it is then possible to study the thermodynamics without knowing the details of the underlying microscopic degrees of freedom. Here, based on the ordinary thermodynamics, **Majhi** with Dibakar Roychowdhury has investigated the phase transition of the static, spherically symmetric charged black hole solution with arbitrary scalar curvature $2k$ in Hořava-Lifshitz gravity at the Lifshitz point $z = 3$. The analysis is done using the *canonical ensemble* frame work; i.e., the charge is kept fixed. They have found that (a) for both $k = 0$ and $k = 1$, there is no phase transition, (b) while $k = -1$ case exhibits the second order phase transition within the *physical region* of the black hole. The critical point of second order phase transition is obtained by the divergence of the heat capacity at constant charge. Near the critical point, they have found the various critical exponents. It is also observed that the critical exponents satisfy the usual thermodynamic scaling laws.

Gravitational anomalies and entropy

A derivation of entropy from the expressions for two dimensional gravitation anomalies is given by **Majhi**. Starting from the near horizon anomalous energy-momentum tensors corresponding to particular anomalies, the Virasoro algebra with central extension is obtained. The central charge is identified by comparing with the standard form of the algebra. Then the conserved charge in the ground state is computed. Finally, using the Cardy formula, the entropy is obtained. Here, both the vector and Chiral theories are discussed.

Thermality and heat content of horizons from infinitesimal coordinate transformations

Thermal properties of a static horizon (like the entropy S, heat content TS, etc.), can be obtained either from the surface term of the Einstein-Hilbert action or by evaluating the Noether charge, corresponding to the diffeomorphisms generated by the timelike Killing vector field. **Majhi** with **Padmanabhan** has shown that, for a wide class of geometries, the same results can be obtained using the vector field, which produces an infinitesimal coordinate transformation between two physically relevant reference frames, viz., the freely falling frame near the horizon and the static, accelerated frame. In particular, the infinitesimal coordinate transformation from inertial coordinates to uniformly accelerated frame can be used to obtain the heat content and entropy of the Rindler horizon. This result offers insight into understanding the observer dependent degrees of freedom, which contribute to the entropy of null surfaces.

The Structure of the gravitational action and its relation with horizon thermodynamics and emergent gravity paradigm

If gravity is an emergent phenomenon, as suggested by several recent results, then the structure of the action principle for gravity should encode this fact. With this motivation, **Majhi** with **Krishnamohan Parattu**, and **Padmanabhan** has studied several features of the Einstein-Hilbert action and established direct connections with horizon thermodynamics. They have begun by introducing the concept of holographically conjugate variables (HCVs) in terms of which the surface term in the action has a specific relationship with the bulk term. In addition to g_{ab} and its conjugate momentum $\sqrt{-g}M^{cab}$, this procedure allows them to (re)discover and motivate strongly the use of $f^{ab} = \sqrt{-g}g^{ab}$ and its conjugate momentum N^c_{ab}. The gravitational action can then be interpreted as a momentum space action for these variables. They have also shown that many expressions in classical gravity simplify considerably in this approach. For example, the field equations can be written in a form analogous to Hamilton's equations for a suitable Hamiltonian if these variables are used. More importantly, the variation of the surface term, evaluated on any null surface, which acts as a local Rindler horizon can be given a direct thermodynamic interpretation. The term involving the variation of the dynamical variable leads to $T\delta S$, while the term involving the variation of the conjugate momentum leads to $S\delta T$. They have found this correspondence only for the choice of variables $(g_{ab}, \sqrt{-g}M^{cab})$ or (f^{ab}, N^c_{ab}). They use this result to provide a direct thermodynamical interpretation of the boundary condition in the action principle, when it is formulated in a spacetime region bounded by the null surfaces. They analyse these features from several different perspectives and provide a detailed description, which offers insights about the nature of classical gravity and emergent paradigm.

Quantum field theory in de Sitter and quasi-de Sitter spacetimes revisited

It is possible to associate temperatures with the non-extremal horizons of a large class of spherically symmetric spacetimes using periodicity in the Euclidean sector, and this procedure works for the de Sitter spacetime as well. But when the cosmological spacetime is not exactly de Sitter, no static coordinate system will exist. Many of the techniques used to define the vacuum states in exactly de Sitter spacetimes will be inapplicable when there is no de Sitter symmetry. In their recent work, **Suprit Singh**, Chandrima Ganguly, and **Padmanabhan** have examined closely several aspects of quantum field theory in de Sitter spacetime *delineating the properties*, which arise from the symmetry of de Sitter spacetime from those which are of more general nature.

Unlike, e.g., the black hole spacetimes, the de Sitter spacetime also allows a description in Friedmann coordinates. This raises the question of whether the thermality of the de Sitter horizon can be obtained, *working entirely* in the Friedmann coordinates. The study looks at several aspects of this issue for de Sitter and approximately de Sitter spacetimes, in the Friedmann coordinates. The different choices for the vacuum states – the Bunch-Davies and co-moving vacuum states, behaviour of the mode functions and the detector response are studied in both (1+1) and (1+3) dimensions. It turns out that both these vacuum states are identical in (1+1) dimensions, and have thermal character with temperature $H/2\pi$. The situation in (1+3) dimensions is quite different. The co-moving vacuum state and the Bunch-Davies vacuum state do not coincide. Also, the mixing coefficients *do not* have a pure thermal character (and are modified by an extra frequency dependent factor) in the case of Bunch-Davies vacuum. The result for the case of co-moving vacuum is more complicated and involves an interference term containing $\sqrt{N(N+1)}$ factor, which is reminiscent of the fluctuations in the occupation numbers of massless thermal radiation.

Comparing the states defined using Friedmann coordinate system with those defined using the static coordinate system show that the Bunch-Davies vacuum appears to be a thermal state for static observers, both in (1+1) and (1+3) dimensions. On the other hand, the co-moving vacuum in (1+3) dimension, defined in Friedmann coordinates, does not have a simple thermal interpretation in the static coordinates.

Finally, the work also describes a general procedure for studying quantum field theory in spacetimes, which are *approximately* de Sitter, and as an example, derives the corrections to thermal spectrum due to the presence of pressure-free matter.

New perspectives on Hawking radiation

Hawking famously predicted that the gravitational collapse of a (say, spherically symmetric) matter distribution of mass M will be perceived by observers at future infinity in the form of a stationary, outgoing, thermal flux of massless particles with temperature $T_H = (8\pi M)^{-1}$. Like most general-relativistic effects, this 'Hawking phenomenon' is *a priori* observer-dependent and *it is not immediately clear what other, non-asymptotic observers with detectors would measure.* Would they record anything near the horizon? Also does a near-horizon geodesic detector record a non-zero temperature that cannot be explained away by a time-varying gravitational potential?

In their study, Matteo Smerlak, and **Singh** have tried to shed light on these questions by reconsidering the response of geodesic Unruh - DeWitt (UDW) detectors during and after gravitational collapse based on the notion of 'effective temperature'. When applied to *geodesic* trajectories, this formalism yields surprising results:

- In spite of the fact that these trajectories are not accelerated, the temperature perceived on circular orbits is always higher than that on static trajectories at the same distance from the hole - it actually diverges on the photon sphere.
- In the near-horizon region, a freely-falling detector couples to both the outgoing *and* the incoming modes of the field, to which it associates two different quasi-temperatures, depending on its energy and angular momentum. Both can be arbitrarily high (though in different regimes: for fast and slow moving detectors respectively). This singular behaviour of Hawking radiation in the $E \to 0$ limit is confirmed by a flux computation.
- While the thermality of outgoing modes relative to near-horizon geodesic observers can be traced back to the spacetime curvature, this is not the case for incoming modes: These appear thermal (both in terms of UDW response functions and of fluxes) to infallers also in spacetimes with flat horizons.

In a nutshell: Far from a no-particle vacuum, a detector dropped with zero velocity from near the horizon will perceive intense Hawking radiation coming from infinity, i.e., from the sky.

Solution to the cosmological constant problem

Observations indicate that our Universe is characterized by three distinct phases of evolution, (i) an early inflationary phase, driven possibly by a scalar field, (ii) a late-time accelerating phase, dominated by dark energy and, (iii) a transient phase in between, dominated by radiation and matter. The late-time accelerated phase of expansion of our Universe can be consistently modelled in terms of a cosmological constant Λ, provided its value is extremely small: $\Lambda L_P^2 \approx 3.4 \times 10^{-122}$, where $L_P \equiv (G\hbar/c^3)^{1/2}$ is the Planck length. However, no fundamental principle has been suggested in the literature to explain this extremely small value of ΛL_P^2. Understanding this issue from first principles is considered very important in theoretical physics today.

In a recent paper, **Padmanabhan**, and **Hamsa Padmanabhan** have described an approach,

which is powerful enough to tackle the cosmological constant problem. They have shown that the value of ΛL_P^2 can be understood in terms of a new dimensionless parameter N_c (called the "Cosmic Mode Index" or CosMIn for short), which counts the number of modes inside a Hubble volume that cross the Hubble radius during the radiation and matter dominated phases, that is, from the end of inflation until the beginning of the accelerating phase. Theoretical considerations, related to the holographic evolution of the universe, suggest that the natural value for N_c is of the order of 4π, i.e., $N_c \approx 4\pi\mu$, with μ being of the order unity. This postulate allows one to determine the numerical value of ΛL_P^2.

In a purely radiation dominated universe with Planck scale inflation, **Padmanabhan** has shown earlier that the above postulate of $N_c \approx 4\pi\mu$ leads to the result: $\Lambda L_P^2 = (3/4)\exp(24\pi^2\mu)$, which reproduces the observed value of ΛL_P^2 when $\mu \approx 1.18$. In the real universe, they have shown that this result gets modified to $\Lambda L_P^2 = C\beta^{-2}\exp(24\pi^2\mu)$, where C depends on n_γ/n_m, the ratio between the number densities of photons and matter, and the parameter β depends on the energy scale of inflation, E_{inf}. Further, for realistic values of $n_\gamma/n_m \approx 4.3 \times 10^{10}$ and a standard GUTs inflationary energy scale, $E_{inf} \approx 10^{15}$ GeV, the postulate $N_c = 4\pi$ leads to the correct, observed value of the cosmological constant!

The cosmological constant problem is, thus, solved by actually determining its numerical value in terms of other parameters. In the paradigm introduced above, the postulate $N_c = 4\pi$ acts as the connecting thread leading to a unified view of cosmic evolution, linking together the parameters of Planck scale physics, the inflationary era, the matter sector properties and the late-time acceleration. This provides a truly holistic approach to the study of cosmology, which has not been attempted in the literature before.

Observational Cosmology and Extragalactic Astronomy

S0 galaxies exhibit a central bulge and an extended disk with no spiral arms while features such as bars, rings, etc. can be present. Even though their original position on the Hubble tuning fork suggests them to be a transition class between spirals and ellipticals, recent literature suggests that they comprise sub-populations with vastly different properties and hence, formation histories. The central component of these and other late galaxies, i.e., the bulges themselves are known to occur in two major flavours. The bulges, believed to have formed through violent processes, such as a major mergers, are referred to as "classical bulges" , while those believed to have formed through secular processes, are called "pseudobulges". It is important to understand S0 galaxies and their bulges for a clearer understanding of galaxy formation and evolution.

Sudhanshu Barway, Yogesh Wadadekar, **Kaustubh Vaghmare and Ajit Kembhavi** have used multiwavelength data from GALEX (Galaxy Evolution EXplorer), SDSS (Sloan Digital Sky Survey), 2MASS (Two Micron All Sky Survey), and WISE (Wide-field Infrared Survey Explorer) for a sample of 246 S0 galaxies to study their star formation histories. They have found that most of the bright S0s (defined as having an absolute K-band Vega magnitude brighter than -24.5) can be explained as having a formation history involving a single burst of star formation (aka Simple Stellar Population), while many of the faint S0s cannot, implying a more complex formation history. They have further discovered the differences in star formation histories and nature of dominant stellar populations as a function of the environment in which the galaxy resides.

In **Vaghmare,** Barway, and **Kembhavi** have used two-dimensional decomposition technique on 3.6 micron imaging data, taken using the Infrared Array Camera on the Spitzer Space Telescope, to derive structural parameters of the bulge, disk and the bar (if present) for a sample of 185 S0 galaxies. They have used the position of the bulge on the Kormendy diagram and the Sersic index to classify

bulges into "classical" and "pseudo" bulges, and found that the disks of pseudobulge hosting S0s are significantly different from those of the classical bulge hosting S0s. The disks have a smaller scale length, lower central surface brightness, and a lower luminosity. Further, pseudobulges are more likely to be hosted by faint S0 galaxies than by bright. These results can be interpreted as either a possible dichotomy of the population of all disks in the Universe with smaller and fainter disks "preferring" to host pseudobulges or as processes forming pseudobulges having an impact on the disk properties.

Gravitational Waves

Effect of sine-Gaussian glitches on searches of binary coalescence

T. Dal Canton, S. Bhagwat, **Sanjeev Dhurandhar**, and A. Lundgren have investigated the effect of an important class of glitches occurring in the detector data on matched filter searches of gravitational waves (GW) from coalescing compact binaries in the advanced detector era. The glitches modelled as sine-Gaussians, can produce triggers with significant time-delays and thus, have important bearing on the veto procedures. Approximate analytical estimates of the trigger SNR and time of arrival are obtained as a function of the parameters describing the sine-Gaussian and the inspiral waveform. The analytical predictions are validated through simple numerical simulations performed by filtering noiseless sine-Gaussians with the inspiral matched filter. The approximations complement each other to fully cover the parameter space of the sine-Gaussian and the inspiral.

The Olber's paradox and anisotropic stochastic gravitational waves

The goal of this work is to estimate stochastic GW background coming from cosmological distances, and to estimate how strong this background is compared with the foreground sources such as the Virgo cluster hotspot. A crude computation has already been carried out, but a detailed estimate based on the spectral profile of the known pulsar distribution is the final goal of this project. As a by-product, the quadrupole formula must be rederived in the cosmological context. (This investigation is based on a question raised by Bruce Allen during one of the recent LSC meetings). This work has been carried out by Nairwita Mazumder, **S. Mitra**, and **Dhurandhar**.

Revisiting the two body problem in GR

An approximate solution to the classical GR problem of binary black holes or neutron stars is most desirable in the context for the search of GW. Although, there have been several earlier approaches to the problem, B. Krishnan, and **Dhurandhar** would like to approach this problem by looking at general relativity as a field theory. Currently, preliminary studies of the methods are being carried out.

Observation of GW will not only be an important test of general relativity, but promises a whole new window of astronomy. Direct detection of GW is expected by the end of this decade by an international network of advanced (second generation) laser interferometric detectors. Presently, a significant amount of effort is being spent in the GW research community in developing pipelines to efficiently search for signals in noisy data. Compact Binary Coalescence (CBC) events are expected to be the most promising sources for the first detection, because their phases can be modelled to a very high accuracy, so that matched filtering technique can be used to search for them. GW astronomy, however, promises to probe a much wider range of known and (so far) unknown sources, where the phases of the sources (in most of the cases) cannot be modelled. Stochastic GW background is one of such sources, which is created by unresolved astrophysical sources in the anisotropic nearby universe, and a weaker isotropic component is also expected from the early universe.

A localised SGWB source vs. Confusion noise: Olber's paradox

Mazumder, **Mitra**, and **Dhurandhar** have showed that a targeted search for a localised source of a stochastic GW background (SGWB) in the nearby universe can be highly efficient as compared to the statistically isotropic background created by the rest of the universe. This problem is similar to solving the Olber's paradox in electromagnetic astronomy, but more complicated as the detection efficiency strongly depends on the integrated spectra. We have computed the combined spectrum of the mean isotropic background by integrating over different redshifts and showed that a localised source, like the Virgo cluster, is orders of magnitude more "bright" than the isotropic component. This provides a major motivation for performing a directed search for SGWB.

Reconstruction of an anisotropic SGWB

SGWB is anisotropic, because it is dominated by the nearby universe. The LIGO-Virgo Scientific Collaboration has published upper-limits on the anisotropic background for each of the recent science runs. Reconstruction of the true background from the observed maps is still a challenge. Swetha Bhagwat, **Jayanti Prasad**, and **Mitra** have demonstrated that inclusion of prior knowledge of the spatial and spectral features of sources of a SGWB can vastly improve the reconstruction of the true background. This work involves Bayesian image reconstruction and maximum likelihood analysis techniques. The Figure 1 shows that even blind (not very specific) priors can increase the quality of reconstruction as compared to the case without any prior. This also indicates that it may be possible to put stronger constraints on anisotropic backgrounds of astrophysical interest using more specific priors.

Cosmology and Structure Formation

Can a marginally open universe amplify magnetic fields ?

In a series of recent papers, it was claimed that large-scale magnetic fields generated during inflation in a spatially open universe could remain astrophysically significant at the present time, since they experienced superadiabatic amplification specific to an open universe. Yuri Shtanov, and **Varun Sahni** have reexamined this assertion and shown that, on the contrary, large-scale magnetic fields in a realistic open universe decay in much the same manner as they would in a spatially flat universe. Consequently, their amplitude today is extremely small ($B_0 < 10^{-59}$ G), and is unlikely to be of astrophysical significance.

A new null diagnostic customized for reconstructing the properties of dark energy from BAO data

Baryon Acoustic Oscillations (BAO) provide an important standard ruler, which can be used to probe the recent expansion history of our Universe. Arman Shafieloo, Alexei Starobinsky, and **Sahni** have shown how a simple extension of the Om diagnostic, called Om3, can combine standard ruler information from BAO with standard candle information from type Ia supernovae (SNIa) to yield a powerful and novel null diagnostic of the cosmological constant hypothesis. A unique feature of Om3 is that it requires minimal cosmological assumptions, since its determination does not rely upon prior knowledge of either the current value of the matter density and the Hubble constant, or the distance to the last scattering surface. Observational uncertainties in these quantities, therefore, do not affect the reconstruction of Om3. Furthermore, as shown by Shafieloo, Starobinsky, and **Sahni**, the value of $Om3$ in a ΛCDM cosmology stays fixed at $Om3 = 1$, whereas $Om3 \neq 1$ in models in which dark energy evolves. This allows $Om3$ to be used as

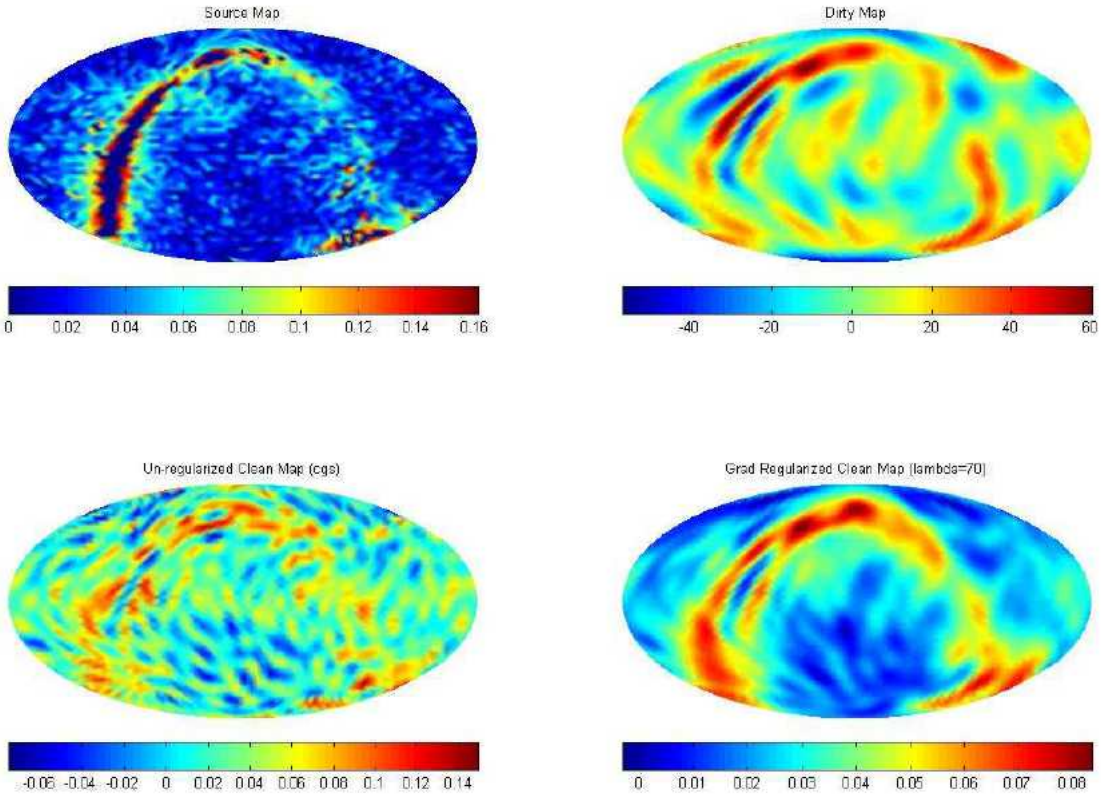


Figure 1: Efficient reconstruction of SGWB sky maps using minimal priors has been illustrated here. GW signal from a toy input sky (top-left) has been injected in data from two different detectors, from which a "dirty" sky map (top-right) was made using the radiometer algorithm. The dirty map was first deconvolved using Conjugate Gradient method to get a clean map (bottom-left) and the same step was repeated using a gradient regularisation method (bottom-right). Clearly, the gradient regulation method, which imposes a blind prior (not specific to the injected map), yields a less noisy and more positive reconstruction (see the colour-bar) than the one without any priors.

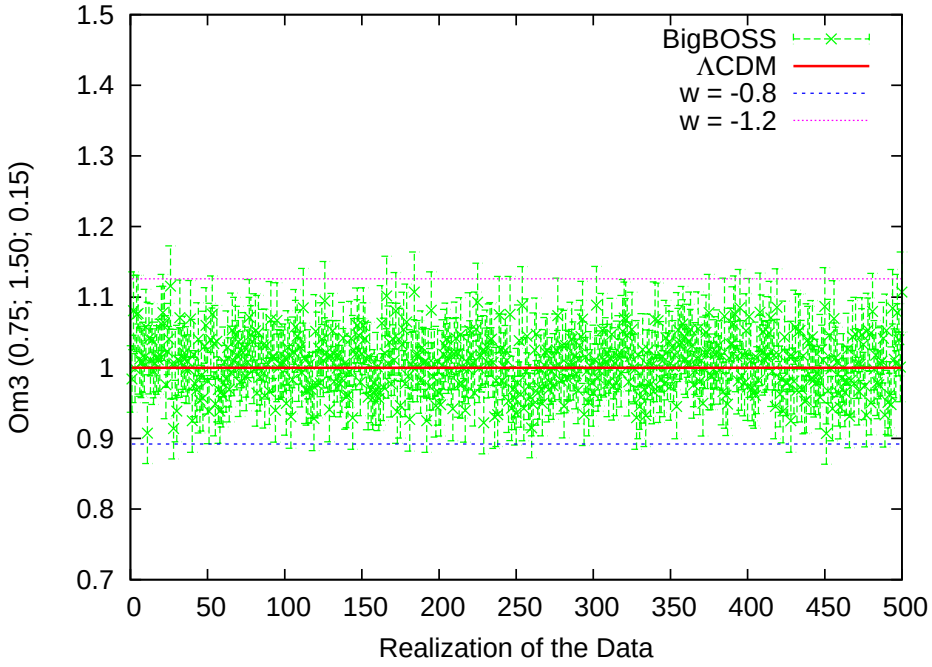


Figure 2: $Om3$ derived using simulated realizations of the BigBOSS experiment assuming a fiducial ΛCDM cosmology. Horizontal lines represent different dark energy models with (top-down) $w = -0.8$, $w = -1.0$, $w = -1.2$. $\Omega_{0m} = 0.27$ is assumed for all models. Note that the value of $Om3$ in a ΛCDM cosmology stays pegged at $Om3 = 1$, whereas $Om3 \neq 1$ in other dark energy models. This property of $Om3$ can be used as a *null test* of the cosmological constant hypothesis.

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They have reconstructed Om3 using the Union 2.1 SNIa data set and BAO data from SDSS, WiggleZ and 6dFGS. Their results are consistent with dark energy being the cosmological constant. Also they have shown that how Om and Om3 can be used to obtain accurate model independent constraints on the properties of dark energy from future data sets such as BigBOSS; (see Figure 2).

Refining inflation using non-canonical scalars

Sanil Unnikrishnan, Alexei Toporensky, and **Sahni** have revisited the inflationary scenario within the framework of scalar field models, possessing a non-canonical kinetic term with the Lagrangian:

$$\mathcal{L}(X,\phi) = X\left(\frac{X}{M^4}\right)^{\alpha-1} - V(\phi). :$$

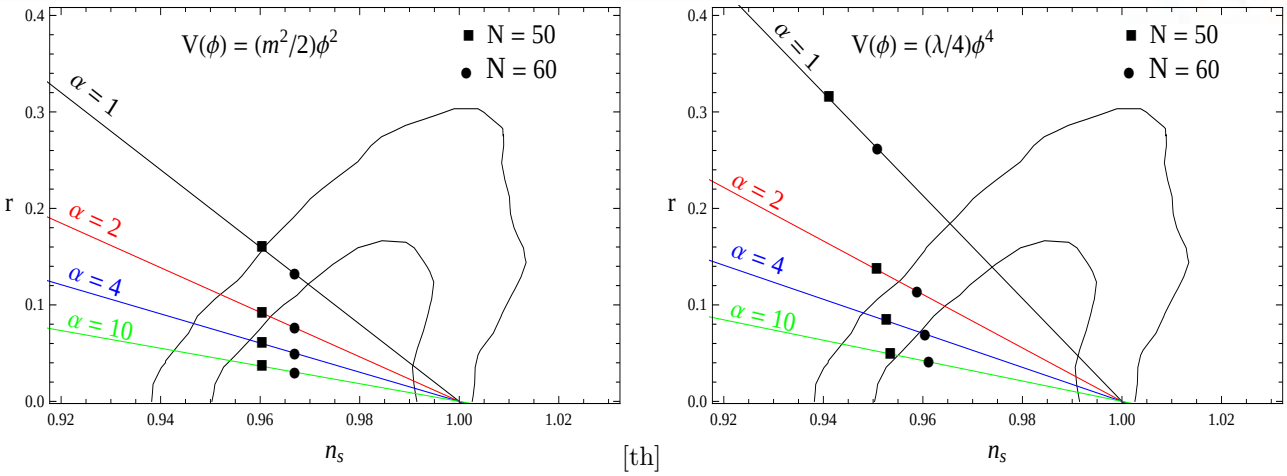
They have obtained closed form solutions for all essential quantities associated with chaotic inflation including slow roll parameters, scalar and tensor power spectra, spectral indices, the tensor-to-scalar ratio, etc. They have also examined the Hamilton-Jacobi equation and demonstrated the existence of an inflationary attractor. One of the highlights of this study is that non-canonical scalars *significantly improve the viability of inflationary models*. They have accomplished this by *decreasing the tensor-to-scalar ratio* while simultaneously increasing the value of the scalar spectral index, thereby, redeeming the models which are incompatible with the cosmic microwave background (CMB) in their canonical version (See Figure 3). For instance, the non-canonical version of the chaotic inflationary potential, $V(\phi) \sim \lambda\phi^4$, is found to agree with observations for values of λ as large as unity! The exponential potential can also provide a reasonable fit to CMB observations. A surprising result of this study is that *steep potentials* (such as $V \propto \phi^{-n}$) usually associated with dark energy, can drive inflation in the non-canonical setting. Interestingly, non-canonical scalars violate the consistency relation $r = -8n_T$, which emerges as a *smoking gun* test for this class of models.

Clustering evolution of Lyman-α emitters

A physically motivated semi-analytic model to understand the clustering of high redshift Lyman Alpha Emitters (LAEs) has been constructed. **C. Jose, R. Srianand,** and **K. Subramanian** have shown that the model parameters constrained by the observed luminosity function, can be used to predict large scale bias and angular correlation function of LAEs. These predictions are shown to reproduce the observations remarkably well. The average masses of dark matter halos hosting LAEs of a given threshold narrow band magnitude are shown to be smaller than that of Lyman Break Galaxies (LBGs) of similar threshold continuum magnitude by a factor about 10. This results in a smaller clustering strength of LAEs compared to LBGs. Nevertheless, this model predictions suggest that both LAEs and LBGs belong to the same parent galaxy population with narrow band technique having greater effectiveness in picking up galaxies with low UV luminosity. It is shown that the lack of evidence of one halo term in the observed LAE angular correlation functions can be attributed to sub-Poisson distribution of LAEs in dark matter halos.

Cosmic Microwave Background

The successful research programme related to the Cosmic Microwave Background (CMB) anisotropy and polarisation at IUCAA maintained by **Tarun Souradeep** has been significantly strengthened by **Sanjit Mitra**, who has joined the IUCAA faculty recently. The prime highlight of the past year has been the contribution from IUCAA to the first Planck cosmology results. Increasingly, more attention is being paid to emerging avenues of fruitful research on subtle cosmic signatures, often referred to as 'CMB anomalies'. The IUCAA team's work using BipoSH representation has provided strong support for the intriguing hemispherical anomaly



[th]

Figure 3: The spectral index $n_{_S}$, and the tensor-to-scalar ratio r, are shown for different values of the parameter α in (), for chaotic inflation sourced by the $m^2\phi^2$ potential (left) and the $\lambda\phi^4$ potential (right). The inner and outer contours correspond to 1σ and 2σ confidence limits obtained using WMAP7, BAO and HST data. $\alpha = 1$ corresponds to canonical scalars, which are ruled out for the $\lambda\phi^4$ model. Increasing α leads to an increase in $n_{_S}$ and a decrease in r, resulting in a marked improvement of fit for the $\lambda\phi^4$ model. N denotes the number of e-folds to the pivot scale at $k = 0.002\,\mathrm{Mpc}^{-1}$.

highlighted in the Planck cosmology results announced on March 21, 2013.

Statistical isotropy of the Planck CMB sky

The Bipolar Spherical Harmonic (BipoSH) representation proposed a decade back has been steadily established in the cosmology community as the most robust and natural measure of violation of statistical isotropy (SI) in the CMB anisotropy. The core team consisted of **Souradeep**, **Mitra**, and the graduate student **Aditya Rotti** One of most intriguing and highlighted results from Planck is a hemispherical asymmetry in the CMB sky challenging the fundamental cosmological principle, which is established through our BipoSH analysis at close to 4σ significance even using only 15 months of the total 30 months of data acquired by the mission [arXiv:1303.5083]. Figure 4 shows the excess power in BipoSH L = 1 measured in low resolution Planck data obtained in four independent methods. The figure also shows the dipole in the reconstructed modulation map, which represents the fluctuations in the red direction, and are about 7% higher than that in blue direction.The IUCAA team plans to continue its participation in the Planck collaboration of the BipoSH analysis on remaining Planck data and also extend their study to the polarisation measurements, both to be announced in 2014.

Apart from SI violation of primordial origin, weak lensing of CMB due the large scale structures (LSS) in the distribution of matter along the path of the photons generates measurable non-zero BipoSH coefficients. With Marc Kamionkowski at Caltech, his student Laura Book, **Souradeep** has shown that the BipoSH coefficients of CMB directly measure projected gravitational potential of LSS. Further, they show that weak lensing due to a stochastic gravitational wave background would also lead to non-zero BipoSH, but of a different (odd) parity as compared to LSS (even parity). As part of his ongoing Ph.D. work at IUCAA, **Rotti** has also established that the methods of detecting CMB weak lensing are very similar to that obtained from BipoSH formalism.

Systematic effects in CMB measurements due to non-circular beams statistical isotropy violation

Systematic effects in the CMB observations can also lead to SI violation signal. In the hunt for a truly cosmic, possibly primordial, SI violation signal, it is important to identify, measure and correct for other effects that contaminate these measures. Wilkinson Microwave Anisotropy Probe (WMAP) team invoked the BipoSH representation of Amir Hajian, and **Souradeep**, and found a strong 9σ measurement of non-zero BiPoSH coefficients in the 7 year data release. BipoSH measures can reveal very subtle uncorrected systematic effects. The team at IUCAA, building on the many years of work on modelling the inevitable non-circular distortions in the response beam of CMB experiments of **Mitra**, and **Souradeep**, a challenging team effort involving students Nidhi Joshi, **Santanu Das**, and **Rotti** have shown that the above 9σ effect arises due to percent level non-circular beam distortions of WMAP experimental beams. In particular, overcoming very significant computational challenges, **Das**has developed an entire pipeline and carried out full blown simulations of the CMB sky scanned by non-circular beams. Joshi has developed the BipoSH representation of CMB maps measured with general non-circular beam response functions. Figure **??** shows the excellent recovery of the WMAP-7 BipoSH anomaly in simulated maps that include the non-circular beam WMAP beams.

Accounting for asymmetric beams in Planck results

Precision cosmology and astrophysics with high resolution low noise experiments like Planck can be achieved in practice only if all the systematic effects have been taken into account. Asymmetric instrumental beams can seed significant systematic errors in both cosmology and foreground astrophysics analyses on data from CMB experiments. **Mitra**, with collaborators Luca Pagano (University of Rome), Graca Rocha, and Krzysztof Górski (Jet Propulsion Lab, Caltech) has developed and implemented a pixel space method to account for asymmetric beams in Planck data. The data products and simulations generated by this pipeline have been used in almost every key Planck analysis, e.g., angular power spectrum estimation, point source flux estimation and component separation.

It may be recalled that in 2004, a group from IUCAA (**Mitra**, Anand Sengupta, and **Souradeep**) was the first to point out that non-circular distortion of WMAP beams has measurable effect on the measured angular power spectrum. Although, this was acknowledged by WMAP team in their subsequent data release, the non-zero BipoSH detection at such high significance implied that the beam distortion effect had not been adequately addressed in 7 year release. In the final 9 year data release, the WMAP team do account for beam distortion and also provide maps that do not carry measurable level remnants from beam distortions. The absence of the same effect in Planck maps has been established and reported in the recent Planck cosmology results from the efforts of the IUCAA group. More detailed assessment through BipoSH of possible systematic effects the Planck maps is underway.

Non-parametric assessment of WMAP CMB angular power spectrum and cosmological parameters

In collaboration with Amir Aghamousa, and Mihir Arjunwadkar of the University of Pune, **Souradeep** carried out a comprehensive, non-parametric estimation of CMB power spectrum from WMAP-7 has been recently published in ApJ [2012]. The best fit C_ℓ is close to, but not the same, as that obtained in a model fitting. The non-parametric analysis provides a space of C_ℓ curves that lie within the 95% CL ball in space of functions around the best fit curve. They then have developed an innovative sampling scheme that allowed a mapping of these non-parametric curves to the space of cosmological parameters. A recent preprint [arXiv:1211.2585] presents these results contrasting this map to the standard model dependent cosmological parameter estimation within the ΛCDM model. The work also shows the im-

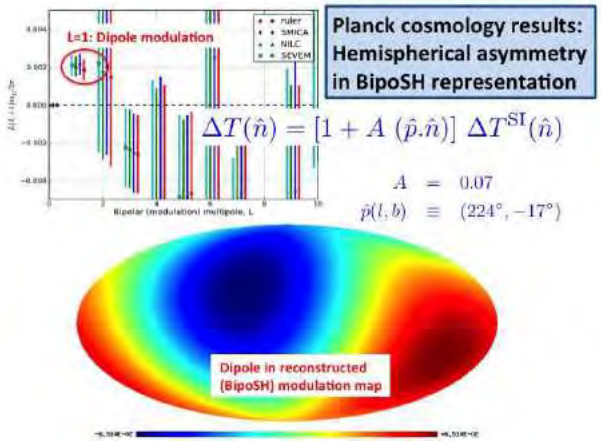


Figure 4: Hemispherical asymmetry in the power distribution in low resolution Planck maps was also captured in BipoSH representation pioneered from IUCAA. Recent (March 21 2013) Planck cosmology results are presented as a collage [Planck 2013 results. XXIII. Isotropy and statistics of the CMB arXiv:1303.5083].

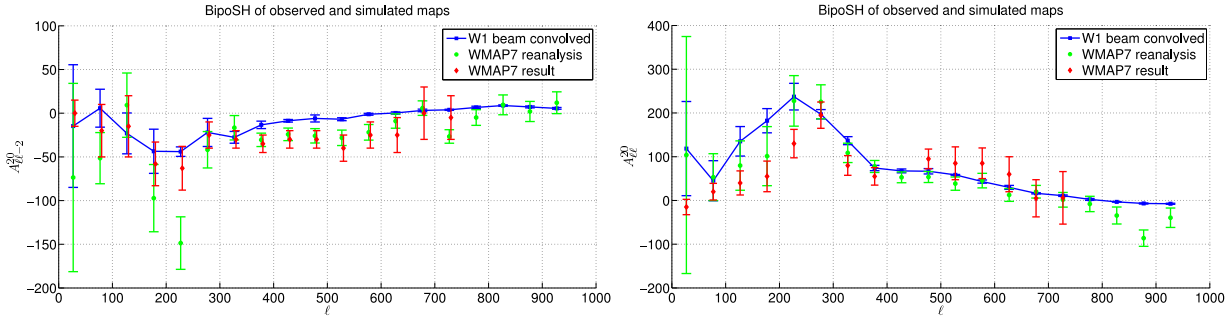


Figure 5: Panels demonstrate that systematic effects of asymmetric beams caused the strong violation of statistical isotropy detected in WMAP-7 maps. The plots show Bipolar Spherical Harmonics (BipoSH) coefficients $A^{20}_{\ell\ell}$ (left) and $A^{20}_{\ell\ell+2}$ (right) measured by WMAP (red), and those obtained from simulations at IUCAA (green) that permit convolving CMB maps with asymmetric (WMAP W1) beam (blue). BipoSH from simulations match the observed BipoSH fairly well.

portance of priors from non-CMB observations in narrowing down parameter estimation even in the WMAP data.

In another work, a forecast study for the Planck CMB measurements [arXiv: 1303.5143] points to immense promise of Planck data set even for a non-parametric analysis.

Early universe from CMB

In the past year, with former IUCAA student Arman Shafieloo, and Dhiraj Hazra, **Souradeep** has continued their work to asses the impact on cosmological parameter estimation of allowing for a free form primordial power spectrum (PPS). A few years back, Shafieloo, and **Souradeep** had shown that meaningful estimation of cosmological parameters is possible even when the PPS is allowed full freedom to vary. In a recent preprint [arXiv:1303.4143], a revised and updated deconvolution scheme that allows identification of free form PPS that has very high likelihood to the measured CMB angular power spectrum. This allows sampling the function space of PPS, which would contribute most to a 'marginalization' over PPS degree of freedom. A recent preprint [arXiv:1303.5336] demonstrates WMAP-9 data, which can rule out a universe without cosmological constant at over 4σ even when granted full freedom to the form of PPS.

New window on gravitational wave using weak lensing of CMB

Opening a new window to gravitational wave background, **Rotti**, and **Souradeep**, have established upper limits on cosmological and astrophysical GW backgrounds from the current experimental upper bounds on the CMB B-polarization measurements. The analysis is based on weak lensing of CMB anisotropy and polarization by large scale stochastic GW background. **Hamsa Padmanabhan** has worked on understanding the difference between weak lensing of CMB by scalar and tensor perturbations.

Cosmological parameter estimation

Finding a set of cosmological parameters consistent with the available observational data sets is a computationally challenging task, mainly due to high dimensionality of the parameter space and large volume of data. Traditionally, Markov Chain Monte Carlo (MCMC) methods, which are stochastic methods, have been used to find cosmological parameters from the data sets obtained from various CMB radiation experiments (WMAP, etc.). Recently, some groups have shown that another stochastic method, named Particle Swarm Optimization (PSO), which is a population based optimization scheme, also can be used for parameter estimation, and in some cases of very high dimensionality of parameter space, large number of local minima, etc. perform much better. **Jayanti Prasad**, and **Souradeep** have demonstrated the use of PSO for cosmological parameter estimation, using WMAP data. A simple implementation of PSO is shown to provide best fit cosmological parameters in a relatively short time for large dimensional problems.

In a parallel development, **Das** has developed an adaptive MCMC method that allows significantly more rapid convergence than widely used MCMC algorithm called CosmoMC. Since, this directly competes with a very well established method used in the community, very careful and detailed understanding of the results prior to publication is underway.

Cosmic Magnetic Fields

Galactic spiral patterns and dynamo action: A new twist on magnetic arms

The theory of mean-field galactic dynamos is generalized by allowing for temporal non-locality in the mean electromotive force (emf). This arises in random flows due to a finite response time of the mean emf to changes in the mean magnetic field and small-scale turbulence, and leads to the telegraph equation for the mean field. The resulting dynamo model also includes the non-linear dy-

namo effects arising from magnetic helicity balance. Within this framework, coherent large-scale magnetic spiral arms superimposed on the dominant axially symmetric magnetic structure are considered. A non-axisymmetric forcing of the mean-field dynamo by a spiral pattern (either stationary or transient) is invoked, with the aim of explaining the phenomenon of magnetic arms. For a stationary dynamo forcing by a rigidly rotating material spiral, **L. Chamandy, K. Subramanian**, and A. Shukurov have found corotating non-axisymmetric magnetic modes enslaved to the axisymmetric modes and strongly peaked around the corotation radius. For a forcing by transient material arms wound up by the galactic differential rotation, the magnetic spiral is able to adjust to the winding, so that it resembles the material spiral at all times. There are profound effects associated with the temporal non-locality, i.e., finite 'dynamo relaxation time'. For the case of a rigidly rotating spiral, a finite relaxation time causes each magnetic arm to mostly lag the corresponding material arm with respect to the rotation. For a transient material spiral that winds up, the finite dynamo relaxation time leads to a large, negative (in the sense of the rotation) phase shift between the magnetic and material arms, similar to that observed in NGC 6946 and other galaxies. They have confirmed that sufficiently strong random seed fields can lead to global reversals of the regular field along the radius whose long-term survival depends on specific features of a given galaxy.

Galactic spiral patterns and dynamo action: Asymptotic solutions

The exploration of mean-field galactic dynamos affected by a galactic spiral pattern, begun using numerical simulations, was continued with an asymptotic solution. Good qualitative agreement is obtained between the asymptotic solution and numerical solutions for a global, rigidly rotating material spiral. At all galactocentric distances except for the co-rotation radius, **Chamandy, Subramanian**, and Shukurov have found that magnetic arms displaced in azimuth from the α-arms, so that the ridges of magnetic field strength are more tightly wound than the α-arms. Moreover, the effect of a finite dynamo relaxation time τ (related to the turbulence correlation time) is to phase-shift the magnetic arms in the direction opposite to the galactic rotation even at the co-rotation radius. This mechanism can be used to explain the phase shifts between magnetic and material arms observed in some spiral galaxies.

Mean-field dynamo action in renovating shearing flows

Mean-field dynamo action in renovating shear flows was studied. Previous results obtained when shear was absent were generalized to the case with shear. The question of whether the mean magnetic field can grow in the presence of shear and non-helical turbulence, as seen in numerical simulations, was examined. It is shown in a general manner that, if the motions are strictly non-helical, then such mean-field dynamo action is not possible. This result is not limited to low (fluid or magnetic) Reynolds numbers nor does it use any closure approximation; it only assumes that the flow renovates itself after each time interval τ. Specifying to a particular form of the renovating flow with helicity, the standard dispersion relation of the $\alpha^2\Omega$ dynamo was recovered, in the small τ or large wavelength limit. Thus, mean-fields grow even in the presence of rapidly growing fluctuations, surprisingly, in a manner predicted by the standard quasi-linear closure, even though such a closure is not strictly justified. The work of **S. Kolekar**, **Subramanian**, and S. Sridhar also suggests the possibility of obtaining mean-field dynamo growth in the presence of helicity fluctuations, although having a coherent helicity will be more efficient.

On the resilience of helical magnetic fields to turbulent diffusion and the astrophysical implications

E. Blackman, and **Subramanian** believe that the extent to which large-scale magnetic fields are susceptible to turbulent diffusion is important for interpreting the need for in situ large-scale dynamos

in astrophysics, and for observationally inferring field strengths compared to kinetic energy. By solving coupled evolution equations for magnetic energy and magnetic helicity in a system initialized with isotropic turbulence and an arbitrarily helical large-scale field, the decay rate of the latter was quantified, for a bounded or periodic system. The magnetic energy associated with the non-helical large-scale field decays at least as fast as the kinematically estimated turbulent diffusion rate, but the decay rate of the helical part depends on whether the ratio of its magnetic energy to the turbulent kinetic energy exceeds a critical value given by $M_{1,c} = (k_1/k_2)^2$, where k_1 and k_2 are the wavenumbers of the large and forcing scales. Turbulently diffusing helical fields to small scales while conserving magnetic helicity requires a rapid increase in total magnetic energy. As such, only when the helical field is subcritical, can it so diffuse? When supercritical, it decays slowly, at a rate determined by microphysical dissipation even in the presence of macroscopic turbulence. In effect, turbulent diffusion of such a large-scale helical field produces small-scale helicity whose amplification abates further turbulent diffusion.

Two curious implications are: (i)Standard arguments supporting the need for in situ large-scale dynamos based on the otherwise rapid turbulent diffusion of large-scale fields require re-thinking, since only the large-scale non-helical field is so diffused in a closed system. Boundary terms could, however, provide potential pathways for rapid change of the large-scale helical field, and (ii) Since $M_{1,c} \ll 1$ for $k_1 \ll k_2$, the presence of long-lived ordered large-scale helical fields as in extragalactic jets do not guarantee that the magnetic field dominates the kinetic energy.

Fluctuation dynamos and their Faraday rotation signatures

Turbulence is ubiquitous in many astrophysical systems, like galaxies, galaxy clusters and possibly even the IGM filaments. Fluctuation dynamo (FD) action in such turbulent systems is studied, focusing on one observational signature; the Faraday rotation measure (RM) from background radio sources seen through the magnetic field generated by such a dynamo. The FD is simulated in periodic boxes up to resolutions of 512^3, with varying fluid and magnetic Reynolds numbers, and the resulting random RMs are measured. **P. Bhat**, and **Subramanian** have shown that even though the magnetic field generated is intermittent, it still allows for contributions to the RM to be significant. When the dynamo saturates, it is of order 40% - 50% of the value expected in a model, where fields of strength B_{rms} uniformly fill cells of the largest turbulent eddy, but are randomly oriented from one cell to another. This level of RM dispersion obtained across different values of magnetic Reynolds number and Prandtl number has been explored. The random RMs are also used to probe the structure of the generated fields to distinguish the contribution from intense and diffuse field regions. Strong field regions (say, with $B > 2B_{rms}$) are shown to contribute only of order 15% - 20% to the RM. Thus, rare structures do not dominate the RM; rather the general 'sea' of volume filling fluctuating fields are the dominant contributors. The magnetic integral scale, L_{int}, which is directly related to the RM dispersion, is also shown to increase in all the runs, as Lorentz forces become important to saturate the dynamo. It appears that due to the ordering effect of the Lorentz forces, L_{int} of the saturated field tends to a modest fraction, 1/2 - 1/3 of the integral scale of the velocity field, for all the runs. These results are then applied to discuss the RM signatures of FD generated fields in young galaxies, galaxy clusters and intergalactic filaments.

Observational Cosmology and Extragalactic Astronomy

Understanding formation and evolution of baryonic structures in the universe, galaxies and intergalactic medium, is one of the main topics of present day physical cosmology. In order to address the issue, one needs to answer questions such as how star-formation proceeds, what is the resultant metal production and how it is related to the UV radi-

ation field and molecular content of the gas. Absorption lines seen in the spectra of high-redshift quasars are very sensitive tracers of the gas whatever its location is, either dense regions as disks of galaxies or diffuse intergalactic clouds. This is, therefore, a unique tool is necessary to tackle the above mentioned problems. Besides, analysis of specific absorption lines can be used as a probe for studying the time evolution of cosmic microwave background radiation and dimensionless fundamental physical constants. In the last academic year, **R. Srianand**,and his collaborators have addressed some of these issues using an unbiased sample of high resolution quasar spectra taken with the Very Large Telescope and GMRT. The main results from their study are summarized below.

Diffuse interstellar bands in external galaxies:

Srianand, **Hadi Rahmani**, and their collaborators (Neeraj Gupta, Patrick Petitjean, Pasquier Noterdaeme and Emmanuel Momjian) have presented a detailed study of the QSO-galaxy pair [SDSS J163956.35+112758.7 (zq = 0.993) and SDSS J163956.38+112802.1 (zg = 0.079)], based on observations carried out using the Giant Metrewave Radio Telescope (GMRT), the Very Large Baseline Array (VLBA), the Sloan Digital Sky Survey and the ESO New Technology Telescope. They have shown that the interstellar medium of the galaxy probed by the QSO line of sight has near-solar metallicity [12+log(O/H) = 8.47± 0.25] and dust extinction [E(B - V) = 0.83 ± 0.11] typical of what is usually seen in translucent clouds. They have reported the detection of absorption in the λ 6284 diffuse interstellar band (DIB) with a rest equivalent width of 1.45 ± 0.20 A. The GMRT spectrum shows a strong 21-cm absorption at the redshift of the galaxy with an integrated optical depth of 15.70 ± 0.13 km s^{-1}. Follow-up VLBA observations show that the background radio source is resolved into three components with a maximum projected separation of 89 pc at the redshift of the galaxy. One of these components is too weak to provide useful 21-cm H I information. The integrated HI optical depth towards the other two components is higher than that measured in the GMRT spectrum and differ by a factor 2. By comparing the GMRT and VLBA spectra, they have shown the presence of structures in the 21-cm optical depth on parsec scales. They have discussed the implications of such structures for the spin-temperature measurements in high-z damped Lyman-α systems. The analysis presented suggests that this QSO-galaxy pair is an ideal target for studying the DIBs and molecular species using future observations in optical and radio wavebands.

A new population of associated absorbers

Sowgat Muzahid, Srianand, and their collaborators (Blair Savage, Anand Narayanan and Nahum Arav) have presented a sample of new population of associated absorbers, detected through Ne VIII$\lambda\lambda$770, 780 absorption, in HST/COS spectra of intermediate redshift ($0.45 < z < 1.21$) quasars (QSOs). Their sample comprised of a total of 12 associated Ne VIII systems detected towards 8 lines of sight (none of them is radio bright). The incidence rate of these absorbers is found to be 40%. Majority of the Ne VIII systems at small ejection velocities (vej) shows complete coverage of the background source, but systems with higher vej show lower covering fractions (i.e., $f_c \sim 0.8$) and systematically higher values of N(Ne VIII). They have detected Mg X$\lambda\lambda$609, 624 absorption in 7 out of the 8 Ne VIII systems, where the expected wavelength range is covered by their spectra, and is free of any strong blending. They have reported the detections of Na IX$\lambda\lambda$681,694 absorption, for the first time, in three highest ejection velocity (e.g., $V_{ej} \geq$ 7000 kms^1) systems in their sample. All these systems show very high N(Ne VIII) (i.e.,$> 10^{15.6}$ cm^2), high ionization parameter (i.e., log U = 0.5), high metallicity (i.e., Z = Z$_\odot$), and ionization potential dependent f_c values. The observed column density ratios of different ions are reproduced by multiphase photoionization (PI) and/or collisional ionization (CI) equilibrium models. While solar abundance ratios are adequate in CIE, enhancement of Na relative to Mg is required in PI models to ex-

plain their observations. The column density ratios of highly ionized species (i.e., O VI, Ne VIII, Mg X, etc.) show a very narrow spread. Moreover, the measured N(Ne VIII)/N(O VI) ratio in the associated absorbers is similar to what is seen in the intervening absorbers. All these suggest a narrow range of ionization parameter in the case of photoionization or a narrow temperature range (i.e., T = 105.9 ± 0.1 K) in the case of CIE models. The present data does not distinguish between these two alternatives. However, detection of absorption line variability with repeat HST/COS observations will allow one to (i) distinguish between these alternatives, (ii) establish the location of the absorbing gas, and (iii) understand the mechanism that provides stability to the multiphase medium. These are important for understanding the contribution of associated Ne VIII absorbers to the AGN feedback.

He II optical depth and ultraviolet escape fraction of galaxies

Vikram Khaire and **Srianand** have developed a code to calculate inter-galactic UV background, taking into account the emission from QSOs and galaxies and opacity of the IGM. Using this code, they have studied the effect that H I ionizing photons escaping from high-redshift (high-z) galaxies, have on the He II ionizing ultraviolet background (UVB) radiation. While these photons do not directly interact with He II ions, it has been shown that they can play an important role, through radiative transport, in modifying the shape of the He II ionizing part of the UVB spectrum. Within the observed range of UV escape from galaxies, they have shown that the rapid increase in the He II Ly-α effective optical depth at $z \sim 2.7$ can naturally be explained by radiative transport effects. Therefore, the relationship between a well-measured He II Ly-α effective optical depth and the redshift in the post-He II reionization era can be used to place additional constraints on the redshift evolution of UV escape from high-z galaxies. The study also suggests that the escape fraction of H I ionizing photons from galaxies has an important role in the fluctuations of the He II ionizing UVB.

Search for cold gas in strong Mg II absorbers at $0.5 < z < 1.5$

Srianand, Muzahid, and their collaborators (Neeraj Gupta, Pasquier Noterdaeme, Patrick Petitjean and Jacqueline Bergeron) have reported four new detections of 21-cm absorption from a systematic search in a sample of 17 strong (rest equivalent width, W_r(Mg IIλ 2796)$\geq 1A$) intervening Mg II absorbers at $0.5 < z_{abs} < 1.5$. They have also presented 20-cm milliarcsecond scale maps of 40 quasars having 42 intervening strong Mg II absorbers, for which they have searched for 21-cm absorption. These maps are used to understand the dependence of 21-cm detection rate on the radio morphology of the background quasar and address the issues related to the covering factor of absorbing gas. Combining 21-cm absorption measurements for 50 strong Mg II systems from their surveys with the measurements from literature, they have obtained a sample of 85 strong Mg II absorbers at $0.5 < z_{abs} < 1$ and $1.1 < z_{abs} < 1.5$. They have presented a detailed analysis of this 21-cm absorption sample, taking into account the effect of the varying 21-cm optical depth sensitivity and covering factor associated with the different quasar sight lines, and it is found that the 21-cm detection rate is higher towards the quasars with flat or inverted spectral index at cm wavelengths. About 70% of 21-cm detections are towards the quasars with linear size, LS < 100 pc. The 21-cm absorption lines having velocity widths, ΔV >100 km s^{-1} are mainly seen towards the quasars with extended radio morphology at arcsecond scales. However, they have not found any correlation between the integrated 21-cm optical depth, $\int \tau dv$, or the width of 21-cm absorption line, ΔV, with the LS measured from the milliarcsecond scale images. All these can be understood if the absorbing gas is patchy with a typical correlation length of ∼30 - 100 pc. They have confirmed their previous finding that the 21-cm detection rate for a given optical depth threshold can be increased by up to a factor 2 by imposing the following additional constraints: Mg II doublet ratio < 1.1, W(Mg II)/W(Fe II) < 1.47 and W(Mg I)/W(Mg ii)> 0.27. This suggests that the proba-

bility of detecting 21-cm absorption is higher in the systems with high N(H I). They have shown that within the measurement uncertainty, the 21-cm detection rate in strong Mg II systems is constant over $0.5 < z_{abs} < 1.5$, i.e., over ∼30% of the total age of universe. They show that the detection rate can be underestimated by up to a factor 2 if 21-cm optical depths are not corrected for the partial coverage estimated using milliarcsecond scale maps. Since stellar feedback processes are expected to diminish the filling factor of cold neutral medium over $0.5 < z < 1$, this lack of evolution in the 21-cm detection rate in strong Mg II absorbers is intriguing. Large blind surveys of 21-cm absorption lines with the upcoming Square Kilometre Array pathfinders will provide a complete view of the evolution of cold gas in galaxies and shed light on the nature of Mg II systems and DLAs, and their relationship with stellar feedback processes.

Probing the time variability of five Fe low broad absorption-line quasars

M. Vivek, Srianand, Vijay Mohan, and their collaborators (Patrick Petitjean, Pasaquier Noterdaeme and Ashish Mahabal) have studied the time variability of five Fe low-ionization broad absorption line (FeLoBAL) QSOs using repeated spectroscopic observations with the 2 m telescope at IUCAA Girawali Observatory (IGO), spanning an interval of up to 10 years. They have reported a dramatic variation in the Al III and Fe III fine-structure lines in the spectra of SDSS J221511.93-004549.9 (zem∼ 1.478). However, there is no such strong variability shown by the C IV absorption. This source is known to be unusual with (i) the continuum emission dominated by Fe emission lines, (ii) Fe III absorption being stronger than Fe II, and (iii) the apparent ratio of Fe III UV 48 to Fe III UV 34 absorption suggesting an inverted population ratio. This is the first reported detection of time variability in the Fe III fine-structure lines in QSO spectra. There is a strong reduction in the absorption strength of these lines between 2000 and 2008. Using the template-fitting techniques, they have shown that the apparent inversion of the strength of ultraviolet lines could be related to the complex spectral energy distribution of this QSO. The observed variability can be related to a change in the ionization state of the gas or due to the transverse motion of this absorbing gas. The shortest variability time-scale of Al III line gives a lower limit on the electron density of the absorbing gas as $n_e >= 1.1 \times 10^4$ cm^{-3}. The remaining four FeLoBALs do not show any changes beyond the measurement uncertainties either in optical depth or in the velocity structure. They have presented the long-term photometric light curve for all the sources. Among them, only SDSS J221511.93-004549.9 shows significant ($\geq$ 0.2 mag) variability.

Clumpy structures and violent instability in high-redshift star-forming disks

Clumpy galaxies are a unique population at high redshifts. They host individual star-forming clumps that are orders of magnitude more massive and denser compared to the starbursts seen in the local Universe. Whether these clumps are embedded in an underlying disk with significant rotation or not, is unclear as yet. However, their kinematics clearly reveal that these are dispersion-dominated systems. One of the major challenges is to understand how the clumpy galaxies have evolved into the relatively smooth bulge and disk structures seen in the present-day galaxies. Theoretically, the massive clumps seen at high redshifts are thought to be the result of violent disk instability in the gas-rich, turbulent galaxy disks. Their dynamical evolution happens on timescales much shorter compared to secular processes. Recently, lot of progress has been made using hydrodynamical simulations to understand the formation and evolution of clumps on spatial scales comparable to the observational data. The basic picture involves fragmentation, clump formation, and their migration to the central regions, resulting in the formation of a bulge component if the clumps manage to survive disruption.

S. Ravindranath, and collaborators have used the Hubble Space Telescope images of the GOODS-ERS field, taken with the ACS and WFC3 instru-

ments, to identify the actively star-forming galaxies at $2.5 < z < 3.5$, using the Lyman-break technique, and photometric redshift method. They have developed a clump-finder algorithm that defines the location of the clumps by identifying the regional maxima. The optical-to-NIR photometry of the clumps is used to study the properties, and estimate clump masses and ages. Using an unprecedented large sample of clumps, they have investigated the scenario of clump migration and coalescence. The individual clumps contribute about 40% to the total UV luminosity, but only 20% of the stellar mass. The more massive clumps are found to be redder, and are also located at smaller radial distance, compared to the less massive clumps. This trend is consistent with the clump migration theory. Some of the clumps are massive enough to be the progenitors of present-day bulges. However, the observed correlation between the clump mass and clump colour, and also the trend with radial distance can be expected if there is self-enrichment of the clumps, and an inside-out propagation of star-formation in the disk. The scenario of clump evolution and its relation to bulge-formation is still far from conclusive, and more accurate age-dating of the clumps will be required to confirm the currently favoured theory.

The bivariate size-luminosity relation for Lyman-break galaxies

Both the galaxy size distribution and the galaxy luminosity function evolve with redshift. This evolution is interesting, as it can provide insights into the initial conditions (e.g., the angular momentum distribution) and environmental effects on galaxy evolution. To date, most of the studies have focussed on these two distributions separately. In disk formation models, the scale size of a disk galaxy is determined by the angular momentum acquired via tidal torques, prior to the collapse of the halo. The angular momentum, expressed as a spin parameter, has a log-normal distribution. Therefore, in these models, the size distribution is also expected to have a similar form. The luminosity function for the galaxy populations is well-described by the Schechter function. However, the two distributions are linked, because galaxy size correlates with the luminosity. Also, the detection and measurement process depend on the surface-brightness, which is a function of both. The bivariate luminosity-size function is a simple parametric form that combines both of these functional forms, and has been studied for the case of local disk galaxies, and for SDSS galaxies.

K. H. Huang, H.C. Ferguson, and **Ravindranath** have extended the study of the bivariate size-luminosity distribution to Lyman-Break Galaxies (LBGs) selected at redshifts, z = 4 - 5 from the GOODS and HUDF fields. Using the GOODS ACS data, they have isolated a sample of 523 B-band and 161 V-band dropouts. This is an unprecedented large sample of star-forming galaxies at $z > 3$, and allows for the first time to explore the bi-variate luminosity-size function at high redshifts. The size-luminosity relation is modelled as a combination of log-normal distribution in size and Schechter function in luminosity. They have performed extensive Monte Carlo simulations to quantify the dropout-selection completeness, measurement biases, uncertainties in two-dimensional size, and magnitude bins. The transfer kernel that incorporates the biases and uncertainties are used to transform the theoretical size-luminosity distribution to derive the expected distribution, which can then be compared to the observed data. Using a maximum likelihood estimator, they have found that the Schechter function parameters for the high-z galaxy sample are consistent with the values in the literature, but the size distributions are wider than expected from the angular momentum distribution of the underlying dark matter halos. The slope of the size-luminosity relation is found to be similar to what is observed for the local disk galaxies, but considerably shallower than local early-type galaxies.

H-α survey of nearby dwarf galaxies

A survey programme to map the H-alpha emission in galaxies belonging to the local volume, with distance $D < 10Mpc$ was initiated in 2004, with the 6-m telescope at the Special Astrophysical Observatory in Russia. This survey completeness exceeds

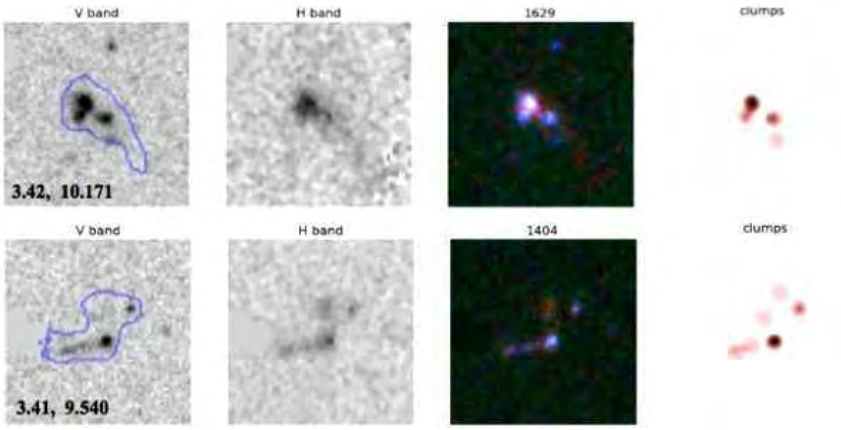


Figure 6: Clumpy galaxies at $z > 3$ along with their individual clumps identified from the rest-frame UV image. The two numbers on the left panel indicate the photometric redshift, and the logarithm of stellar mass (in solar mass units) for the host galaxy.

90 percent in the northern hemisphere. Recently, S. Kaisin, I. Karachentsev, and **Ravindranath** have used the 2 m telescope at IUCAA Girwali Observatory to extend the survey to southern sky. The new data provides H-alpha luminosity and star formation rates for 30 additional galaxies, for which these measurements are not available in the literature. The evolution of galaxies is analyzed using a 'past-future' diagram, which takes into account the total gas mass, and the star formation rate through the use of dimensionless parameters that are defined to be distance-independent. Most of the local bulgeless spiral galaxies and irregular dwarfs lie in the region of the diagnostic diagram, which corresponds to a midpoint of their continuously star-forming phase of evolution. Some of the Blue Compact Dwarf Galaxies (BCDGs) show parameters typical of multiple-burst episodes (see Figure 7).

X-rays from Active Galactic Nuclei

Active Galactic Nuclei (AGNs) exhibit complex X-ray spectra. Seyfert 1 galaxies generally show three primary components: power-law continuum, soft X-ray excess below 2 keV and Compton reflection including the broad FeK-alpha line. Variability of these components provide important information regarding the central engines of AGNs. **Mainpal Rajan**, and **G. C. Dewangan** have performed a detailed broadband X-ray spectral variability study of a Seyfert 1 galaxy 1H0419–577 based on two Suzaku observations (July 2007 and January 2010) and the two latest XMM-Newton observations (May 2010). All the observations show soft X-ray excess emission below 2 keV, and both the Suzaku observations show a hard X-ray excess emission above 10 keV when compared to a powerlaw. They have tested three physical models: a complex partial covering absorption model, a blurred Compton reflection model, and an intrinsic accretion disk emission model. Among these, the blurred Compton reflection model provided statistically the best-fit to all the four observations. 1H0419-577 showed remarkable X-ray spectral variability. The soft X-ray excess and the power-law both became weaker in January 2010 as well as in May 2010. A moderately broad iron line, detected in July 2007, was absent in the January 2010 observation. Correlated variability of the soft X-ray excess and the iron K-alpha line strongly suggest reflection origin for both the components. However, such spectral variability cannot be explained by the light bending model alone and requires changes in

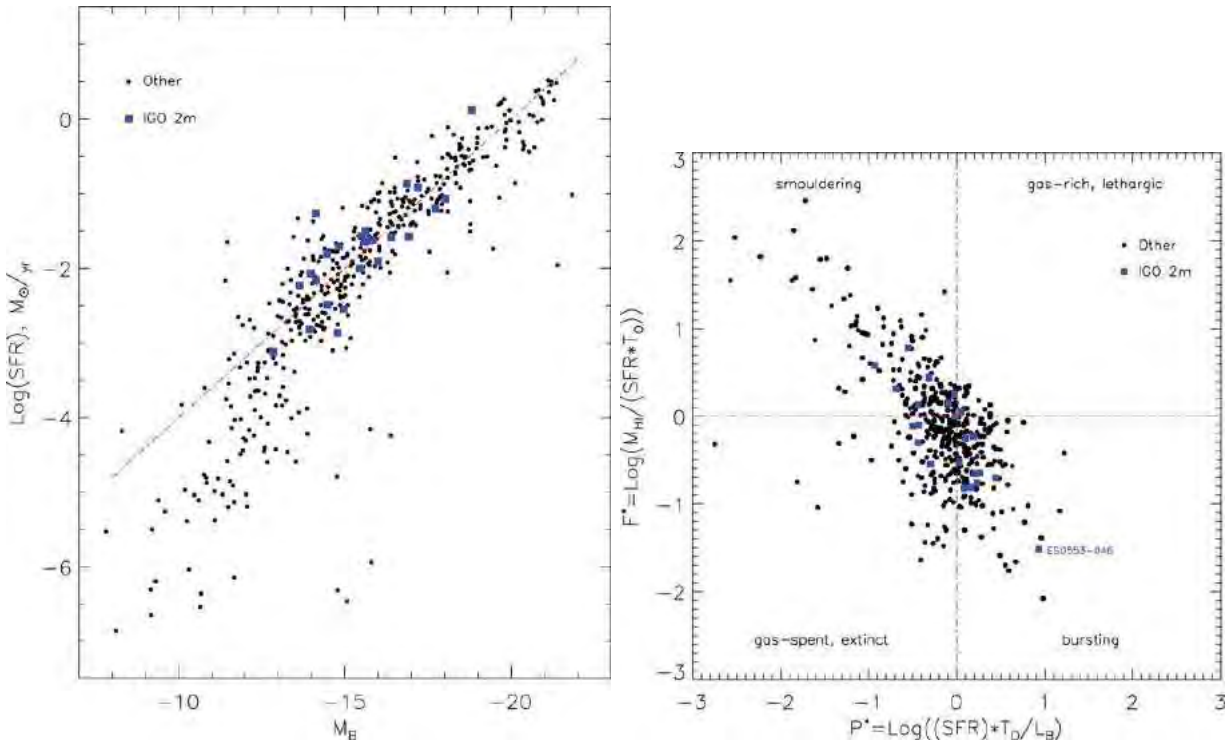


Figure 7: **Figure (left)**: The distribution of galaxies from the H-alpha survey of the nearby dwarf galaxies, in the absolute magnitude versus star formation rate diagram. The blue points represent new data contributed from the IUCAA Girawali Observatory. [From S.Kaisin, I. Karachentsev, and S. Ravindranath (2012).] **Figure (right)**: The diagnostic 'past-future' diagram, which shows the nature of star-formation and phase of evolution of local star-forming galaxies. The dimensionless parameters that are plotted are defined to be distance-independent. [From S. Kaisin, I. Karachentsev, and S. Ravindranath (2012).

]

the accretion disk/corona geometry possibly arising from changes in the accretion rate.

Hyperluminous Infrared Galaxies

Hyperluminous infrared galaxies (HLIRG) are the most luminous persistent objects in the Universe. They exhibit extremely high star formation rates, and most of them seem to harbour an active galactic nucleus (AGN). They are unique laboratories for investigating the most extreme star formation and its connection to super-massive black hole growth. The relative AGN and starburst (SB) contributions to the total output in these objects are still debated. **Angel Ruiz** et al. aim to disentangle the AGN and SB emission of a sample of thirteen HLIRG.

They have studied the MIR low-resolution spectra of a sample of thirteen HLIRG obtained with the Infrared Spectrograph on board Spitzer. The 5 - 8 μm range is an optimal window for detecting AGN activity even in a heavily obscured environment. They performed an SB/AGN decomposition of the continuum using templates, which has been successfully applied for ULIRG in previous works. The MIR spectra of all sources is largely dominated by AGN emission. By converting the 6 μm luminosity into IR luminosity, they found that $\sim 80\%$ of the sample shows an IR output dominated by the AGN emission. However, the SB activity is significant in all sources (mean SB contribution is 30%), showing star formation rates $\sim 300 - 3000$ solar masses per year. With X-ray and MIR data, they have estimated the dust covering factor (CF) of these HLIRG, and found that a significant fraction presents a CF consistent with unity. Along with the high X-ray absorption shown by these sources, this suggests that large amounts of dust and gas enshroud the nucleus of these HLIRG, as also observed in ULIRG. Our results agree with previous studies of the IR SED of HLIRG using radiative transfer models, and they find a strong evidence that all HLIRG harbour an AGN. Moreover, this work provides further support for the idea that AGN and SB are both crucial to understanding the properties of HLIRG. Their study of the CF supports the hypothesis that HLIRG can be divided into two different populations.

X-ray and optical observations of Seyfert galaxies

The fundamental idea behind the standard Unified Model is that type 1 and type 2 active galactic nuclei (AGN) have no intrinsic physical differences, their classification being instead determined by the presence or absence of absorbing material along the line of sight to the object. This scenario has been extremely successful, although some additional ingredients are needed in order to take into account all the observational evidence (see Bianchi, Maiolino and Risaliti (2012) for a review). Among the failed expectations of the Unification Model is the lack of broad optical lines in the polarized spectra of about half of the brightest Seyfert 2 (Sy2) galaxies, even when high-quality spectropolarimetric data are available.

Ruiz et al. present the results of a campaign of simultaneous X-ray and optical observations of 'true' Sy2 galaxies candidates, i.e., AGN without a broad-line region (BLR). Out of the initial sample composed of eight sources, one object, IC 1631, was found to be a mis-classified starburst galaxy, another, Q2130-431, does show broad optical lines, while other two, IRAS 01428-0404 and NGC 4698, are very likely absorbed by Compton-thick gas along the line of sight. Therefore, these four sources are not unabsorbed Sy2 as previously suggested in the literature. On the other hand, they confirm that NGC 3147, NGC 3660 and Q2131-427 belong to the class of true Sy2 galaxies, since they do not show any evidence for a broad component of the optical lines nor for obscuration in their X-ray spectra. These three sources have low accretion rates (Lbol/LEdd ≤ 0.01), in agreement with theoretical models which predict that the BLR disappears below a critical value of Lbol/LEdd. The last source, Mrk 273x, would represent an exception even of these accretion-dependent versions of the Unification Models, due to its high X-ray luminosity and accretion rate, and no evidence for obscuration. However, its optical classification as a Sy2 is only based on the absence of a broad com-

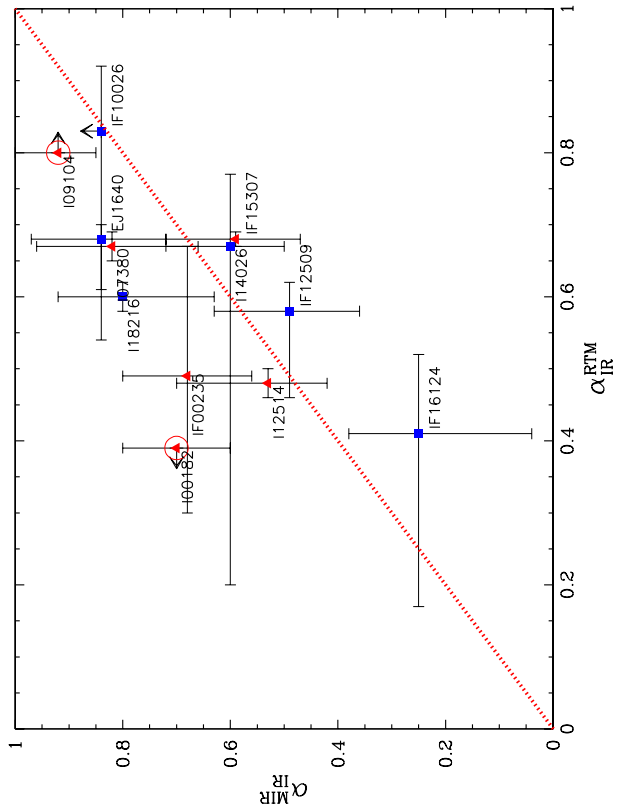


Figure 8: Comparison of the AGN contribution to the IR luminosity estimated through MIR spectral decomposition and through radiative transfer models (RTM, Rowan-Robinson 2000, Farrah, et al. 2002, Verma, et al 2002). The blue squares are type 1 AGN and the red triangles are type 2 AGN and SB. The IR luminosity of seven out of ten HLIRG is dominated by AGN emission. However, the SB contribution is also significant for all sources, spanning from $\sim$ 20% to 70%, with a mean contribution of $\sim$ 30%.

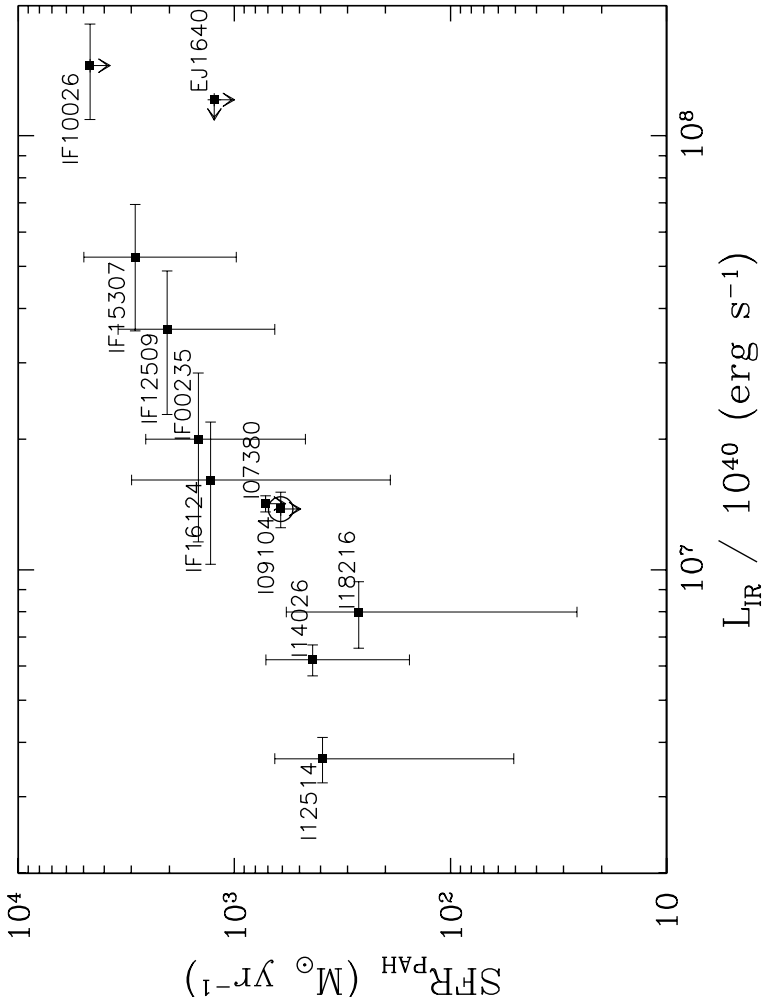


Figure 9: Star formation rate (SFR) estimated using the polycyclic aromatic hydrocarbon (PAH) emission at 7.7 μm versus total IR luminosities. Despite most sources being AGN-dominated objects, we still found high star-forming activity, with SFR $\sim$ 300 3000 solar masses per year.

ponent of $H\beta$, due to the lack of optical spectra encompassing the Hα band.]

High Energy Astrophysics

The X-ray spectra of some neutron star systems are dominated by thermal Comptonization. These sources also exhibit kilo-Hertz quasi-periodic oscillations (KHz QPO), which are expected to give insight into their general relativistic nature. **Nagendra Kumar**, and **Ranjeev Misra** have been developing a scheme and numerical code, which based on thermal Comptonization will predict the r.m.s. and time lag of KHz QPO as a function of energy. This will provide an understanding of the nature of the radiative process that drives the QPO and the compact geometry of the source.

Mayukh Parekh, **Misra**, A. Mukherjee, J. S. Yadav, and S. K. Pandey have been studying the low frequency oscillations of the enigmatic source GRS 1915+105, and found that the difference between the peak and low flux spectra can be fitted with a simple single component disk model. This indicates that the oscillations are due to appearance of a disk component. They have developed an efficient code to compute time lags between different energy bands and have applied it to the low frequency oscillations of this source.

V. Agrawal, **Misra**, and Mayukh Parekh have been studying the spectra of several neutron star systems using Suzaku observations and earlier RXTE observations. While RXTE provides good time resolution, Suzaku provides unprecedented broad band coverage. They have constrained the high energy roll over for some sources and obtained spectral fitting of the time evolving systems.

Debbijoy Bhattacharyya, **Misra**, P. Sreekumar, and A. R. Rao have studied the long term gamma-ray variability of a subclass of blazars, called flat spectrum radio quasars (FSRQ) using EGRET and Fermi fluxes. They have discovered that there are six sources, which have varied by more than an order of magnitude, but for two of them, the X-ray fluxes are the same. This implies that the accretion disk flux has increased, but the jet parameters have remained the same.

Accretion onto neutron stars

Observations suggest that the accretion of mass onto a neutron star from a binary companion leads, over a long period, to the reduction in the strength of the magnetic field of the neutron star. Among the possible causes of this, one suggestion has been that the magnetic field may get buried under the incoming matter as it spreads over the neutron star's surface. Material accreting on a strongly magnetized neutron star is guided by the field onto the magnetic poles, where it piles up into a magnetically confined mound. Eventually, as the weight of this mound increases, material would flow over the rest of the surface. This can lead to field burial, unless plasma instabilities disrupt this process. **D. Bhattacharya, Dipanjan Mukherjee**, and Andrea Mignone have taken up a quantitative study of the stability of the magnetically confined accretion mound at neutron star polar caps. Having earlier investigated axisymmetric instabilities in two dimensions, the work was now extended to three-dimensional Magneto Hydrodynamic (MHD) perturbation calculations using the PLUTO code. These simulations show that once the mass of a mound exceeds $\sim 10^{-13}$ solar mass in a 10^{12} G field, pressure driven MHD instabilities are rapidly generated. Numerous radial finger-like channels develop all over the rim, of alternating higher and lower magnetic field strength. Matter accumulates in the low-field valleys and then leak out of magnetic confinement. No sign of burial of the field was seen in these simulations, suggesting that the reason for the secular reduction of the field strength may have to be sought elsewhere.

Ultra-luminous X-ray sources (ULXs)

These are the brightest off-nuclear, compact X-ray sources in nearby galaxies. Their observed X-ray luminosity exceed the Eddington limit of stellar mass black holes sometimes by large factors. The nature of the ULXs continues to remain an enigma, since their dynamical mass measurements have not been possible. X-ray spectroscopy and variability are the main tools that can unravel the nature of ULXs. While we know the spectral shape and vari-

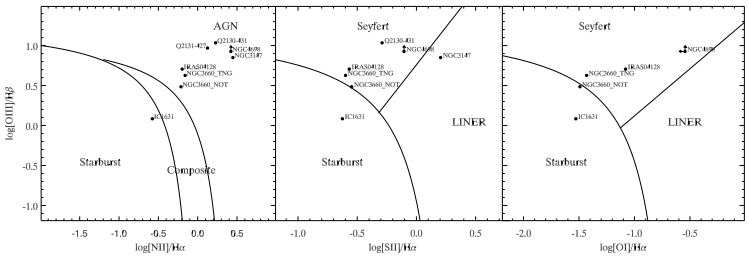


Figure 10: Optical line diagnostic diagrams (line flux ratios) from the analysis of the optical spectra of our campaign. Arrows indicate upper/lower limits. Classifications are done as in Kewley, et al. (2006), and references therein.

Name	L	M_{BH}	L_{bol}/L_{Edd}
(1)	(2)	(3)	(4)
NGC 3147	0.3–0.7	20–62	4×10^{-5}–3×10^{-4}
NGC 3660	1–2	0.68–2.1	4×10^{-3}–2×10^{-2}
Q2131−427	20–30	77	2–3×10^{-3}

Notes. Col. (1) Name of the source. (2) Bolometric luminosity range in 10^{43} erg s^{-1} (see the text for details on the adopted methods for this estimate). (3) BH mass range in 10^7 $M_\odot$ (see the text for the appropriate references). (4) Eddington ratio range.

Figure 11: Table 1: Main properties of the three true type 2 Sy2s confirmed in this study.

ability properties below 10 keV based on Chandra and XMM-Newton observations of ULXs, the X-ray emission above 10 keV is not known due to the lack of sensitive hard X-ray observations with good spatial resolution. **G. C. Dewangan**, V. Jithesh, **Misra**, and C. D. Ravikumar have studied the broadband X-ray spectral study of two ultraluminous X-ray sources (ULXs), M81 X-6 and Holmberg IX X-1 based on Suzaku and XMM Newton observations. They have performed joint broadband spectral analysis of the brightest sources in the field, i.e., the two ULXs and the active galactic nucleus (AGN) in M81, and demonstrated that the X-ray spectra of the ULXs cut off at energies above 3 keV with negligible contribution at high energies in the Suzaku HXD/PIN band. These results show that there is not an additional high energy power-law component contributing significantly to the X-ray emission. The spectral form of the two ULXs are very different from those of galactic black hole X-ray binaries (BHBs) or AGNs. This implies that the ULXs are neither simply scaled-up versions of stellar mass BHBs or scaled-down versions of AGNs.

Galaxy and Interstellar Medium

Analytical fits to interstellar extinction curves

On completion of the third year of the ISRO-RESPOND project titled "Developing analytic formulas for extinction spectra of the major interstellar dust components", Ashim Roy, Subodh K. Sharma, **Ranjan Gupta**, and **Pritesh Randive** have now developed analytical formulae for three galaxies, viz., Milky Way, LMC and SMC. This process could be now extended to other galaxies as well. Attempts are also on to provide analytical formulae for interstellar polarization.

The following figures show the effect of variation of number of silicates to graphites on extinction, and compare the extinction efficiencies of ultra-small silicates with Draine's data.

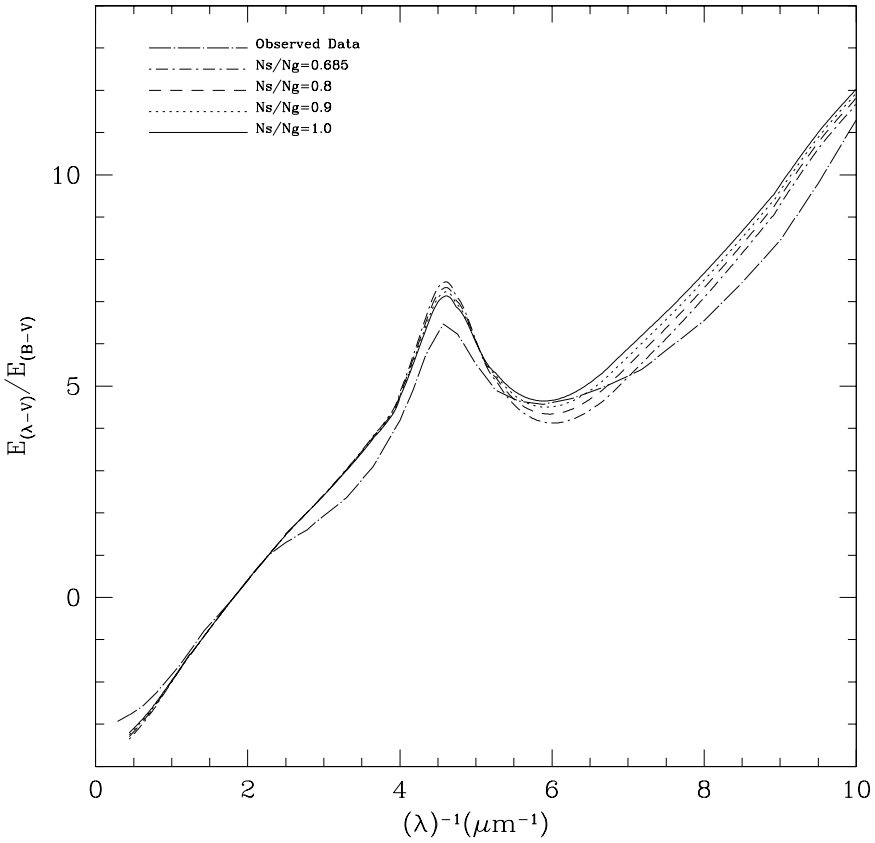


Figure 12: The effect of variation of the number of silicates to the number of graphites(Ns/Ng) on the extinction.

Composite dust grains and circumstellar IR emissions

The work by D.B. Vaidya, **Ranjan Gupta**, and **Rajeshwari Dutta** on the study of circumstellar dust around 700 IRAS objects has now progressed further, and the two figures below show the best fit dust model curves to the IRAS 10μ silicate feature using silicate with graphite inclusions and vacuum inclusions. The estimated dust temperatures agree well with those published in the literature.

Figures show the statistics on the model fits and dust temperature estimates.

Dust properties from GALEX observations of a UV halo around Spica

GALEX has detected ultraviolet halos extending as far as 5° around four bright stars (Murthy, et al. (2011)). These halos are produced by scattering of star light by dust grains in thin foreground clouds that are not physically associated with the star. Assuming a simple model consisting of a single layer of dust in front of the star, Murthy, et al. have been able to model these halo intensities and constrain the value of the phase function asymmetry factor g of the scattering grains in the FUV and NUV. However, due to the uncertainty in the dust geometry, they could not constrain the albedo. **P. Shalima**, Jayant Murthy, and **Ranjan Gupta** have tried to constrain the optical constants and dust geometry by modelling the UV halo of Spica. Since the halo emission is not symmetric, they have modelled the northern and southern parts of the halo seperately.

Figure 15 shows a best-fit albedo of 0.26±0.03 and g of 0.58±0.11 in the FUV for the northern parts of Spica. The corresponding limits on the distance and optical depth (τ) of the dust sheet are 3.65±1.05 pc and 0.047±0.006 respectively (see 16). In the NUV, they have constrained the optical constants albedo and g to 0.62±0.02 and 0.585±0.025 respectively. The distance and τ derived are 6.35±0.95 pc and 0.017±0.002.

By comparing the model intensities with the observed values (shown in Figure 3-chk with Shalima), it can be seen that the model explains the observed intensities reasonably well for the northern parts. The derived optical constants are in agreement with the theoretical predictions for typical Milky Way dust grains (Draine (2003)) at these wavelengths.

However, owing to a complicated dust distribution to the south of Spica, they were unable to uniquely constrain the dust parameters in that region. Nevertheless, by assuming the optical constants of the northern region and assuming a denser medium, they were able to constrain the distance of the scattering dust layer to 9.5±1.5 pc and the corresponding τ to 0.04±0.01 from the FUV intensities and 6.75±4.25 pc and 0.01±0.005 from the NUV intensities.

Solar Physics

Heating of the solar corona

The problem of heating of solar corona is considered to be one of the most challenging tasks in astrophysics. Solar active regions are the brightest long-lived regions on the Sun and present an ideal target of opportunity for studying the coronal heating problem. Active regions are comprised of a diffuse component and a variety of discrete structures, including fan loops, warm loops, and hot core loops. The fan loops (only the legs are visible) are large structures observed at the edges of active regions, which are characterised by cool emission ($< 1MK$). The warm loops are clearly defined at around 1MK, and the hot loops are seen in higher temperatures emission ∼(3MK). Therefore, in order to obtain a comprehensive view of coronal heating, it is mandatory to understand the heating mechanism(s) for different structures in active regions. For example, are warm loops heated in the same way as fan loops and hot loops? or, what are the heating mechanisms involved in diffuse component of the corona?

Durgesh Tipathi et al. have shown earlier that the observed plasma properties of warm loops such as density, temperature and plasma flow structures are consistent with those predicted by low fre-

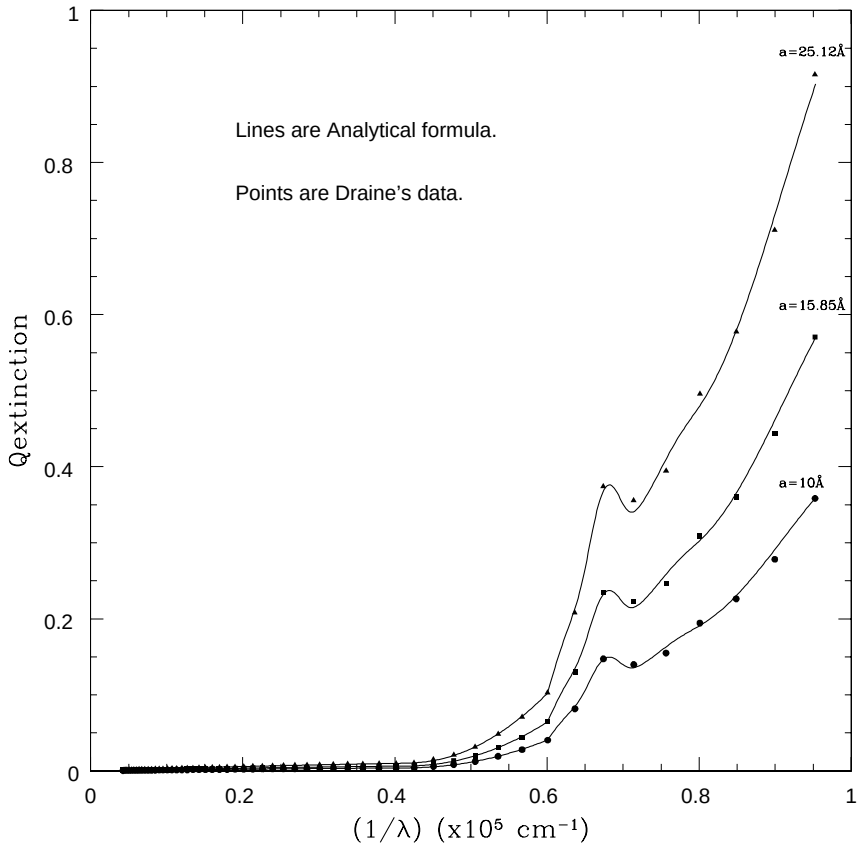


Figure 13: Comparison of extinction efficiencies of Ultrasmall Silicates by analytical formula with Draine's data. For a=10, 15.85 and 25.12 A .

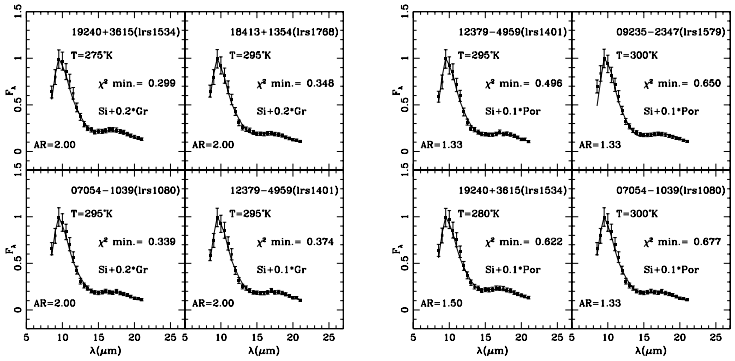


Figure 14: The best fit with graphite inclusions and Porous (Voids) inclusions respectively

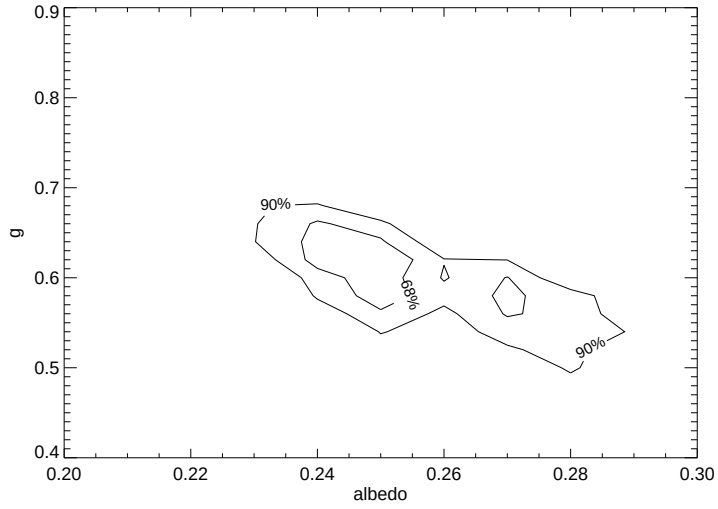


Figure 15: 68% and 90% contour plot of the albedo and g of the dust cloud in the FUV for the Northern regions (P. Shalima, J. Murthy, and R. Gupta, 2013, EPS.

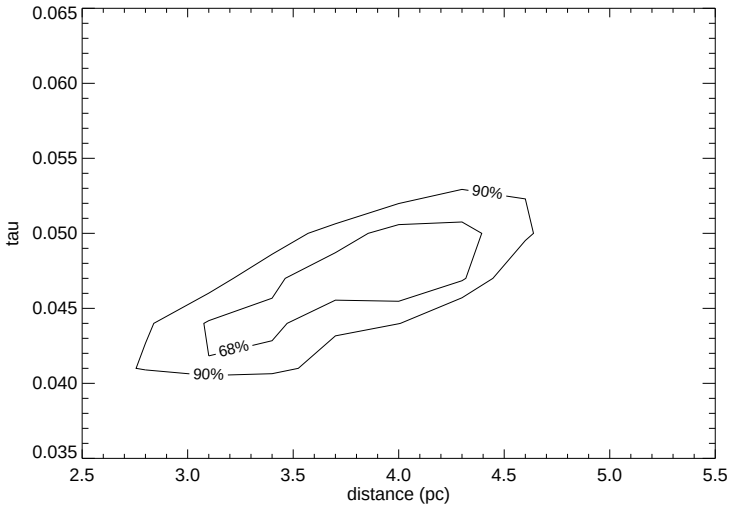


Figure 16: 68% and 90% contour plot of the distance and optical depth of the dust cloud in the FUV for the northern regions (P. Shalima, J. Murthy, and R. Gupta, 2013, EPS.)

quency nano-flare heating model (impulsive heating model). Similar results were obtained by other authors. However, recently they have detected a few warm loops in an active region, which do not appear to be consistent with low frequency nano-flares heating model. For example, a theoretically simulated warm loop shows high velocity (100 km/s) upflows at higher temperatures (5 - 6$\sim$ MK) and plasma condensation at lower temperatures $\sim$ (1MK). Although, the loops have consistent temperature and density structure with impulsive heating model, they show up flows of plasma at temperature of about 1 MK. This is exactly opposite to what has been observed and understood so far. This needs to be explained by theoretical modelling and possesses a challenge to coronal heating theories.

In addition to studying the heating of warm loops, they have also studied the emission and plasma flow structures in core of active regions. With the present day instrumentation, the warm loop structures can be spatially resolved. Therefore, it is easier to determine the basic physical properties of warm loops and compare their properties with theoretically predicted ones. However, it is almost impossible to disentangle one specific hot loop seen in the core of the active regions. Therefore, they have relied on plasma properties, which do not demand spatial structure to be resolved. These techniques are based on emission measure and Doppler shift analysis. They have used these two techniques in core of active regions and found that the heating in the core could also be explained by low frequency nano-flare model, making it consistent with warm loops.

Determination of magnetic field in solar prominences

Observations by the Hinode satellite show, in great detail, the dynamics of rising plumes, dark in chromospheric lines, in quiescent prominences that propagate from large $\sim$ (10 Mm) bubbles that form at the base of the prominences. These plumes present a very interesting opportunity to study Magneto Hydrodynamic (MHD) phenomena in quiescent prominences, but obstacles still remain. One of the biggest issues is that of the magnetic field strength, which is not easily measurable in prominences. **Tirpathi** et al. have invented a method

that may be used to determine a prominence's plasma beta when rising plumes are observed. Using the classic fluid dynamic solution for flow around a circular cylinder with an MHD correction, the compression of the prominence material can be estimated. This has been successfully confirmed through simulations; application to a prominence gave an estimate of the plasma beta as beta = 0.47 +/- 0.079 to 1.13 +/- 0.080 for the range of gamma = 1.4 - 1.7. Using this method, it may be possible to estimate the plasma beta of observed prominences, therefore, helping the understanding of a prominence's dynamics in terms of MHD phenomena.

Discovery of sausage pinch instability in solar corona

With the increasing capabilities of instruments to observe the Sun's atmosphere at sub-arcsecond spatial resolutions with a temporal resolution of few seconds, different kinds of plasma instabilities such as kink instability, torous instability, magnetic Rayleigh Taylor instability, etc. have been observed. However, there have been no observation of sausage-pinch instability in solar atmosphere, although, it has been theoretically predicted. Theoretically, it has been established that this instability evolves in cylindrical flux tubes. In a perfectly symmetric flux tube, the inward directed Lorentz force is balanced with the pressure gradient. However, if the flux tube is not a perfect cylindrical plasma column, it becomes unstable at the locations where the confining field is concave and the longitudinal field is less dominant over azimuthal component. This leads to an instability known as sausage-pinch instability. On the locations where the plasma column is pinched, it can be stabilised against the sausage instability, where longitudinal field is significantly dominant over azimuthal component.

Since, almost all the structures in solar transition region and corona can be approximated as cylindrical flux-tubes, which may or may not be homogeneous, solar atmosphere provides unique laboratory to observe this instability. In addition, it may play a pivotal role in plasma ejections from solar atmosphere. With unprecedented observations being provided by the Atmospheric Imaging Assembly (AIA), aboard the Solar Dynamics Observatory (SDO), they have detected evidences for sausage-pinch instability. **Tripathi**, et al. have identified the first observational evidence of evolution of sausage-pinch instability in an active region during a prominence eruption. Further, they have identified a magnetic flux tube, which shows curvatures on its surface with variable cross-sections, as well as enhanced brightness on a $\sim$ 20 - 40 s timescales. The flux-tube smoothed out within the next $\sim$ 30 - 70 s. These curved locations on the flux tube exhibit a radial outward enhancement of the surface of about 1-2 Mm (factor of 2 larger than the original thickness of the flux tube) from the axis of the flux tube. These observational findings provide strong evidence in favour of sausage-pinch instability.

Publications by the IUCAA Academic Members

(A) Journals

1. **D. Mukherjee**, **D. Bhattacharya**, and A. Mignone (2013) *MHD instabilities in accretion mounds - I. 2D axisymmetric simulations*, MNRAS, **430**, 1976.

2. L. Resmi, et al. (16 authors including **D. Bhattacharya)** (2012) *Comprehensive multiwavelength modelling of the afterglow of GRB 050525A*, MNRAS, **427**, 288.

3. **Naresh Dadhich**, Josep M. Pons, and Kartik Prabhu (2012) *Thermodynamical universality of the Lovelock black holes*, Gen. Rel. Grav., **44** , 2595.

4. **Naresh Dadhich**, Josep M. Pons, and Kartik Prabhu (2013) *On the static Lovelock black holes*, Gen. Rel. Grav., **45**, 1131.

5. **S. V. Dhurandhar**, W. T. Ni and G. Wang (2013) *Numerical simulation of time-delay interferometry for LISA: The case of a single interferometer*, Advan. in Space Res., **51**, 198.

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72. Sudhanshu Barway, Yogesh Wadadekar, **Kaustubh Vaghmare**, and **Ajit Kembhavi**, *Luminosity-dependent star formation history of S0 galaxies: Evidence from GALEX-SDSS-2MASS-WISE colours,* MNRAS, **432**, 430.

(B) Proceedings

1. P. Kretschmar, et al.(20 authors including **D. Bhattacharya**) (2012) *Understanding the Last Mile - Physics of the Accretion Column*, Proceedings of IAU Symposium 290.

2. P. S. Ray, et al (32 authors including **D. Bhattacharya**) (2012) *Radio searches of Fermi LAT sources and blind search pulsars: The Fermi Pulsar Search Consortium*, Fermi Symposium proceedings - eConf C110509.

3. **Naresh Dadhich** (2012) *The gravitational equation in higher dimensions,* Proceedings of the Conference, Relativity and Gravitation: 100 years after Einstein in Prague.

4. **J. V. Narlikar** (2012) *A static universe (Un univers statique!), Un autre cosmos?*, Eds. Thomas Lepeltier, Jean-Marc Bonnet-Bidaud, (Vuibert), **45**.

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6. **J. V. Narlikar** (2012) *Quasars in the life of astronomers : Alternative views and ideas*, Fifty Years of Quasars, Eds. Mauro D'Onofrio, Paola Marziani and Jack W. Sulentic, (Springer), **73**.

7. **J. V. Narlikar** (2012) *Some conceptual problems in GR*, Journal of the Tensor Society, 6, 2, **47**.

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10. D. K. Ojha, …, **A. N. Ramaprakash**, …, et al. (2012) *First light observations with TIFR Near Infrared Imaging Camera (TIRCAM-II)*, ASI Conf. Series, 4, **189**.

11. C. Baranec, …, **A. N. Ramaprakash**,…, et al. (2012) *Robo-AO:Autonomous and replicable laser-adaptive-optics and science system*, SPIE Proc. Adaptive Optics Systems III, 8447, **11**.

12. R. Riddle, …, **A. N. Ramaprakash**,…, et al. (2012) ***The** Robo-AO software: Fully autonomous operation of a laser guide star adaptive optics and science system,* SPIE Proc. Adaptive Optics Systems III, 8447, **9**.

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14. S. P. Tendulkar, …, **A. N. Ramaprakash**,…, et al. (2013) *Robo-AO: Performance and characterization at Palomar Observatory*, Proc. of AAS Meeting, AAS, **221**, 305.03.

15. N. M. Law, ..., **A. N. Ramaprakash**,…, et al. (2013) *Robotic transit follow-up: adaptive optics imaging of thousands of stars*, Proc. of AAS Meeting, AAS, **221**, 334.06.

16. C. Baranec, ..., **A. N. Ramaprakash**,..., et al. (2013) *Bringing the visible universe into focus with Robo - AO*, J. Vis. Exp., **72**, e50021.

17. Sudhanshu Barway, Yogesh Wadadekar, **Kaustubh Vaghmare**, and **Ajit Kembhavi** (2012) *Clues from star-formation histories: Does the formation scenario of S0 galaxies depend on their luminosities?*, Proceedings of the IAU, **292**, pp. 153.

Pedagogical

(a) IUCAA-NCRA Graduate School Lectures

Dipankar Bhattacharya	:	*Introduction to Astronomy and Astrophysics I*	(14 lectures)	(August - October 2012)
Gulab Dewangan	:	*Extragalactic Astronomy - II*	(14 lectures)	(March - May 2013)
Ajit Kembhavi	:	*Electrodynamics and Radiative Processes II*	(14 lectures)	(October - December 2012)
T. Padmanabhan	:	*Quantum and Statistical Mechanics I*	(14 lectures)	(August - October 2012)
A. N. Ramaprakash	:	*Astronomical Techniques I*	(14 lectures)	(January - March 2013)
Swara Ravindranath	:	*Galaxies, Structure, Dynamics and Evolution*	(14 lectures)	(January - March 2013)
Tarun Souradeep	:	*Extragalactic Astronomy I*	(14 lectures)	(January - March 2013)
Durgesh Tripathi	:	*Electrodynamics and Radiative Processes I*	(14 lectures)	(August - October 2012)

(b) University of Pune, M.Sc. (Physics and, Space Science) Lectures

Ranjan Gupta : Laboratory Course (Theory 10 lectures) *Related to Observational Astronomy* (10 laboratory and night experiments)
Sanjit Mitra : *General Relativity* (Astronomy and Astrophysics II)
J. V. Narlikar : Astronomy and Astrophysics II

(c) Supervision of Projects

Dipankar Bhattacharya

- Sambit Panda (Academy SRFP), *Magnetic field strengths of accreting neutron stars.*
- Amrtya Jyoti Saha (Academy SRFP), *Gravitational light bending near neutron stars.*
- R. Sughan Harrish (IUCAA VSP), *Estimating magnetic fields of X-ray binaries.*

Gulab Dewangan

- Sharda Joganand (SRTM University, Nanded) (VSP), *Broad iron line from neutron star low mass X-ray binaries.*
- Avinash Ashok Aher (IIT, Mumbai), Summer School, *X-ray Astronomy.*
- Sonali Kadam (SRTM University, Nanded), Summer School, *X-ray Astronomy.*
- Thanmayalaxmi D. (Mangalore University), Summer School, *X-ray Astronomy.*
- Payaswini Sakia (A post - M. Sc. student under a European programme for three months) *Suzaku observation of 3C120.*

Sanjeev Dhurandhar

- Swetha Bhagwat(IISER, Pune) *General relativity and gravitational waves* (along with Sanjit Mitra).

Ajit Kembhavi

- Madhura Parikh, *IASC - INSA - NASI Summer Research Fellowship*, May - June 2012.
- Tanvi Gujarati, *Probing rotating black holes - the X-ray iron line*, VSP, May 2012.
- Arpita Saha, *Probing rotating black holes - the X-ray iron line*, VSP, May 2012.

Sanjit Mitra

- Rakesh Lakshman (IIST, Thiruvananthapuram, M. Sc.) *Gravitational waves.*

- Prathamesh Dalvi (BITS Pilani, Goa Campus, M. Sc.) *Efficient analysis of the data from laser interferometric gravitational wave detectors to probe an anisotropic stochastic gravitational wave background.*
- Swetha Bhagwat (IISER, Pune, M.Sc.), *Data analysis techniques in gravitational wave astronomy.*
- Anirban Ain (IUCAA - NCRA Graduate School), *Stochastic gravitational waves from local anisotropies in the universe.*
- Nikhil Menon (VSP) *Adaptive noise cancellation in gravitational wave detectors.*
- Masroor C. P., Tanmayee Gupte and Zainab Hakim (Summer school project), *Gravitational Waves.*

T. Padmanabhan

- Andreas Finke (University of Heidelberg, Germany), *Accelerated frames in curved spacetime,* September 1 – October 31, 2012.
- Hui-Yiing Chang (Vanderbilt University, USA), *Statistical mechanics of gravitating systems*, (Under APS - IUSSTF Physics Student Visitation Program) February 1- March 15, 2013.
- Chandrima Ganguly ((IIT, Hyderabad) (VSP) *Particle creation in the expanding universe*, May - June 2012.
- Ramit Kumar Dey, (IIT, Madras) (VSP) *Particle creation in the expanding universe*, May - June 2012.

A. N. Ramaprakash

- Aafaque Khan (MANIT, Bhopal) : *Adaptive optics in astronomy.*
- Pallavi Dilip (IISER, Pune) : *Structure functions, power spectral density and zernike polynomials.*
- Rakesh Lakshman : *Statistics of polarization measurements in astronomy.*
- Shantanu Agarwal, Siddireddy Prasanna Kumar (IIT, Mumbai) - NIUS 9 : *New techniques for wavefront reconstruction and correction.*
- S. Chattopadhyay (IUCAA - NCRA Graduate School): *Performance characterization of ISDEC+SIDECAR driven HAWAII ROIC for TMT OIWFS.*
- R. Goenka (IIST, Thiruvananthapuram) : *Integration and testing of a novel polarimeter.*

Tarun Souradeep

- G. Abhinav (IIST, Thiruvananthapuram), B.Tech. final year by (January - April 2013) *Measurement of statistical isotropy of CMB anisotropy.*
- Rakesh Laxman (IIST, Thiruvananthapuram) B.Tech. final year by (January -April 2013) *Gravitational waves.*

R. Srianand

- IUCAA School Students' Summer Programme (2012)3 students
- 1 TYBSc student from Fergusson college
- A 2 month project as a part of summer programme of Indian Academy of Sciences summer programme

Durgesh Tripathi

- Samir Salunkhe (Pune University, M. Sc.) (September 2012 --).
- Juie Shetye (University College, London) (January - March 2013).
- Moosa Ali (IIST, Thiruananthapuram) (January - April 2013).

(d) Supervision of Ph. D. Thesis (other than IUCAA)

Gulab Dewangan

- Shah Alam (Jamia Millia Islamia, New Delhi, Co-guide for on going thesis project), X-ray emission from black hole X-ray binaries.
- Pramod Pawar (SRTM University, Nanded, informal association with his thesis), Optical-X-ray variability of AGN.

(e) Tutorial Assistantship

Gulab Dewangan

- X-ray data analysis at the 2nd X-ray Astronomy School.

(f) Supervision of Ph.D. Thesis (IUCAA)

Tarun Souradeep

- Moumita Aich, Key observational issues in the cosmic microwave background.

Pedagogical Articles

T. Padmanabhan

- Series called "The Dawn of Science", dealing about the history of science.
- All Was Light - II, Resonance, 17, 324, 2012.
- The Quest for Power, Resonance, 17, 436, 2012.
- Chemistry Comes of Age, Resonance, 17, 532, 2012.

Talks

By IUCAA Academic Members at IUCAA and other Institutions

(A) Seminars, Colloquia and Lectures

Dipankar Bhattacharya

Neutron Stars: Equation of State and Magnetic Fields, Indo-South Africa symposium, University of Kwazulu Natal, Durban, April 12, 2012.

Evolutionary Processes in Accreting Neutron Stars: the role of Magnetic Fields (via Skype), Neutron Star Magnetic Field workshop, University of Amsterdam, June 15, 2012.

Astrosat, Associate Fest, IUCAA, June 25, 2012.

Studies of Accreting Neutron Stars with Astrosat, 39th COSPAR Scientific Assembly, Mysore, July 18, 2012.

Cyclotron Lines in Accretion Powered Pulsars, 39th COSPAR Scientific Assembly, Mysore, July 21, 2012.

ASTROSAT: A forthcoming Indian Astronomy Mission, IAU Symposium 290, IAU XXVIII General Assembly, Beijing, August 24, 2012.

High Energy Magnetospheric Emission from Neutron Stars, Workshop on Neutron Stars: Inside and Outside, Saha Institute of Nuclear Physics, Kolkata, October 19, 2012.

Computational Astrophysics, International Conference on Metacomputing, Bhuvaneshwar, December 7, 2012.

Compact Objects and Astrosat, TMT Science Meeting, IUCAA, December 11, 2012.

Indian Astronomy Initiatives: Space Astronomy, International Conference on Transients and Timing, IUCAA, March 4, 2013.

Naresh Dadhich

Gravity (2 lectures) Introductory Summer School in Astronomy and Astrophysics and Vacation Students Programme, IUCAA, Pune, May 2012.

The gravitational equation in higher dimensions, Conference, Relativity and Gravitation: 100 years after Einstein in Prague, June 25-28, 2012.

Why Einstein (Had I been born in 1844!)? Palestinian International Conference on Mathematics and Physics, Hebron, July 15-18, 2012.

Gravity in higher dimensions, Inaugural Workshop of the Institute of Fundamental Studies, Phitasnulok, Thailand, July 20-22, 2012.

Gravitational equation in higher dimensions, Indian Institute of Technology Madras, Chennai, January 31, 2013.

Einstein's gravity, a pedagogical lecture, Indian Institute of Technology Madras, Chennai, February1, 2013.

Relativity for everyone, IISER, Bhopal, March 12 & NISER, Bhubaneswar, April 15, 2013.

Einstein is Newton with space curved, Institute of Physics, Bhubaneswar, April 16, 2013.

Gulab Dewangan

X-ray Spectral Variability of Seyfert Galaxies, 39th COSPAR Scientific Assembly, Mysore, July 14 - 22 , 2012.

Probing Black-hole Environment with X-ray Binaries, RESPOND meeting, Physical Research Laboratory, Ahmedabad, February 9, 2013.

Astrosat Proposal Processing System - Development and testing, ASTROSAT Ground Segment Critical Design Review meeting, ISAC, Bangalore, January 29, 2013.

How to write an X-ray Observing Proposal, X-ray View of Cosmos - Conference on Observation X-ray Astronomy, Physical Research Laboratory, Ahmedabad, April 23 - 25, 2012.

S. V. Dhurandhar

The Indian Initiative in Gravitational Observations (IndIGO), Osaka university, Osaka, Japan, March 13, 2012.

The IndIGO Project, Albert Einstein Institute, Hannover, Germany, April 25, 2012.

Ranjan Gupta

Dust and Interstellar Medium, Universityof Toledo, Toledo, USA, June 17, 2012.

Star formation studies in our Galaxy, South Africa - India joint Workshop on Ground Based Astronomy, SAAO, Cape Town, South Africa, August 6, 2012.

Interstellar and Circumstellar Dust and its Modeling, University of Kwazulu - Natal, Durban, South Africa, August 10, 2012.

Observational Astronomy, Hamirpur College, Hamirpur, HP, October 14, 2012.

Astronomical Spectroscopy and Photometry, Srikishan Sarda College, Hailakandi, Assam, Introductory School in Astronomy and Astrophysics, January 30, 2013.

Astronomical Photometry:Spectroscopy and Instrumentation, Mathematical Methods and Astronomy workshop, ISM Dhanbad, February 7 - 8, 2013.

New Telescopes, Science Day School Teachers event, February 16, 2013.

Telescopes of this Century, DST-INSPIRE Programme, University of Rajasthan, Jaipur, February 21, 2013.

Ajit Kembhavi

Observing General Relativistic Effects in Black Hole Systems: The Iron Line, INAAD Workshop on Black Hole Astrophysics, Fergusson College, Pune, September 5, 2012.

Supermassive Black Holes and Iron Emission Line, INAAD Workshop on Science with Optical Spectra, Mar Athanasions College for Advanced Studies (MACFAST), Thiruvalla, September 8, 2013.

Fundamental Planes, Introductory Workshop on Virtual Observatory, Calcutta University, December 5, 2012.

Introduction to Quasars, Introductory Workshop on Virtual Observatory, Calcutta University, December 5, 2012.

Virtual Observatories, Indian Institute of Sciences, Bangalore, January 18, 2013.

Introduction to High Energy Astrophysics, 2nd X-ray Astronomy School, IUCAA, February 4, 2013.

Radiation Processes in High Energy Astrophysics (3 lectures), 2nd X-ray Astronomy School, IUCAA, February 5 - 6, 2013.

Great Telescopes, North Bengal University, Darjeeling, Siliguri, March 24, 2013.

The X-ray Iron Line as a Probe of Black Holes Spin, Workshop on X-ray Astronomy at Department of Physics, North Bengal University, Darjeeling, Siliguri, March 24, 2013.

Overview of Indian Astronomy Initiatives, Transients and Timing Meeting, IUCAA, March 4, 2013.

The LIGO - India Project: Gravitational Wave Astronomy from India, V. V. Narlikar Memorial Lecture, Jamia Millia Islamia, New Delhi, March 19, 2013.

LIGO: A Giant Gravitational Wave Detector for India, MACFAST, Thiruvalla, September 7, 2012.

Bulges in Lenticular Galaxies, CPS, Kobe University, Japan, February 13, 2013.

The LIGO - India Project, Government Arts College, Thiruvananthapuram, February 21, 2013.

Bibhas Ranjan Majhi

Noether Charge, **Virasoro Algebra and Horizon Entropy**, S.N. Bose National Centre for Basic Sciences, Kolkata, March 28, 2013.

Ranjeev Misra

Radiative Processes in Astrophysics (2 lectures), INAAD Introductory Workshop on Astronomy, Sikkhim Govt. College, Gangtok, March 2013.

Radiative Processes in Astrophysics (2 lectures), Workshop on X-ray Astronomy, North Bengal University, Siliguri, March 2013.

Radiation Pressure Instability in Standard Accretion Disks, COSPAR General Assembly, Mysore, July 2012.

Sanjit Mitra

Opportunities for future collaboration in experiment and data exploitation, Cardiff University, UK, February 21, 2013.

CMB Data Analysis and Cosmological Constraints (2 lectures), IRC workshop, Delhi University, January 31 - February 01, 2013.

Introduction to Gravitational Wave Astronomy, Radio Astronomy Winter School, NCRA, December 27, 2012.

Introduction to Gravitational Waves and Hands-on Sessions, BITS-IUCAA Workshop on Gravitational-wave Data Analysis, BITS-Pilani Goa campus, December 17 - 21,2012.

Gravitational Waves from Black Hole Mergers, Fergusson College, September 5, 2012.

Introduction to Gravitational Waves (2 lectures and demonstrations), Introductory summer school on astronomy and astrophysics, IUCAA, 2012.

Talks

By IUCAA Academic Members at IUCAA and other Institutions

Jayant Narlikar

Why Study Astronomy?, Introductory Summer School in Astronomy and Astrophysics and Vacation Students Programme, IUCAA, Pune, May 7, 2012.

Analytical Thinking, Introductory Summer School in Astronomy and Astrophysics and Vacation Students Programme, IUCAA, Pune, May 11, 2012.

Highlights of an Alternative Cosmology, Torun Centre for Astronomy, Nicolaus Cloernicus University, Torun, Poland, May 28, 2012.

The Case for an Alternative Cosmology, Polish Academy of Arts and Sciences, Cracow, Poland, June 1, 2012.

Cosmology from 1962 to 2012, General Relativity and Gravitation - 50 years after Jabłonna, Banach Mathematical Center, Warsaw, Poland, June 4 , 2012.

How Well Do We Know Our Universe?, 4th Byurakan International Summer School for Young Astronomers, Byurakan Astrophysical Laboratory, Armenia, September 18, 2012.

Some Cosmological Puzzles, 4th Byurakan International Summer School for Young Astronomers, Byurakan Astrophysical Laboratory, Armenia, September 19, 2012.

How Well Do We Know Our Universe?, Indian Institute of Science Education and Research, Thiruvanathapuram, September, 2012.

Analytical Thinking, Indian Institute of Science Education and Research, Thiruvanathapuram, September , 2012.

Some Cosmological Puzzles (2 lectures), Indian Institute of Science Education and Research, Thiruvanathapuram, September , 2012.

Building New Institutions: Challenges and Rewards, TWAS Regional Office Prize lecture, Jawaharlal Nehru Centre for Advanced Scientific Research, November 16, 2012.

Analytical Reasoning, Indian Institute of Information Technology, Allahabad, December 8, 2012.

How Well Do We Know Our Universe?, Indian Institute of Information Technology, Allahabad, December 8, 2012.

Searches for life in the Universe, Indian Institute of Information Technology, Allahabad, December 10, 2012.

How well do we know our universe?, University of Lucknow, Lucknow, December 14, 2012.

Why Study Astronomy?, Fergusson College, Pune, January 4, 2013.

Why Study Astronomy?, a talk delivered during the Two Day National Seminar on Recent Developments and Measurement Techniques in Astronomy and Astrophysics, Sahajiraje Mahavidyalaya, Khatav, January 17, 2013.

The Role of Teaching and Research in the University System, Kerala Science Congress, Thiruvananthapuram, January 30, 2013.

Analytical Reasoning, High Energy Materials Research Laboratory, Pune, March 16, 2013.

T. Padmanabhan

Matters of Gravity, The Sixth International School on Field Theory and Gravitation, Rio de Janeiro, Brazil, April 23 - 24, 2012.

Secret Life of Spacetime, Institut d'Astrophysique, Paris, April 27, 2012.

Secret Life of Spacetime, ICTS, Bangalore, June 19, 2012.

Future Directions of Research in Quantum Gravity/ Cosmology, Department of Physics, University of Pune, April 13, 2012.

Secret Life of Spacetime, Observatorio Nacional, Rio de Janeiro, April 25, 2012.

Lessons from Classical Gravity about the Quantum Structure Spacetime, ICTS, Bangalore, June 19, 2012.

Matters of Gravity, IIT, Chennai, October 10, 2012.

Matters of Gravity, IISc., Bangalore, October 12, 2012.

An Emergent Perspective of Cosmology, ASI Meeting, Trivandrum, February 22, 2013.

Gravity, University College, Trivandrum, February 22, 2013.

Universe: Status and Prospects (Public lecture), Kerala State Science and Technology Museum, February 23, 2013.

Krishna Mohan Parattu

Neutrino Mixing and Discrete Groups, LPSC Grenoble Journal Club, France, October 28, 2012.

A Minimal Model of Neutrino Flavour, GDR Terascale@Paris, November 5, 2012.

A Minimal Model of Neutrino Flavour, LPSC Grenoble Journal Club, France, November 9, 2012

Swara Ravindranath

Deep UV Imaging Surveys with the Hubble Space Telescope, 39th COSPAR Scientific Assembly, Mysore, July 2012.

Science with the Integral Field Spectrograph on Devasthal Optical Telescope, Devasthal Optical Telescope Integral Field Spectrograph (DOTIFS) design review, Aryabhatta Research Institute for Observational Sciences, Nainital, October 2012.

Clumpy Structures and Violent Disk Instability at Early Epochs of Galaxy Formation, Seminar, Indian Institute of Science, Bangalore, November 2012.

Galaxy Formation and Evolution - Seeking New Frontiers with TMT Capabilities, TMT Science workshop, IUCAA, December 2012.

CANDELS: Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey, 30th meeting of Astronomical Society of India, IISER, Thiruvananthapuram, February 2013.

Clump Structures and Violent Disk Instability at Early Epochs of Galaxy Formation, Colloquium at the National Centre for Radio Astronomy, Pune, March 2013.

Tarun Souradeep

Revealing Beam Systematics in WMAP-7, IIT, Kanpur, December 28 , 2012.

LIGO-India Status: An Indian (ad)venture in GW Astronomy, LIGO Lab Seminar, Caltech, December 18, 2012.

Revealing Beam Systematics in WMAP-7, LIGO Labs, MIT, November 25, 2012.

Fundamental Tests of Cosmology, SPS Seminar, Jawaharlal Nehru University, Delhi, August 9, 2012.

Fundamental tests with CMB Anisotropy and Polarisation, Acceptance talk for Vikram Sarabhai Research Award, Physical Research Lab., Ahmedabad, August 10, 2012.

Expected CMB results from the Planck Surveyor Satellite, Intl. Meeting ASTROD-5, RRI, Bangalore, July 11-13, 2012.

CMB Weak Lensing Constraints on the Stochastic GW Background, GWPAW-12, Hannover, Germany, June 4-7, 2012.

Testing the Isotropic Cosmos, Colloquium NCRA, Pune, May 28, 2012.

Measuring the Isotropy of the Cosmos, University of Western Cape, Cape Town, South Africa, April 18, 2012.

Challenging the Isotropic Cosmos, CTACC Colloquium, AIMS, Cape town, South Africa, April 13, 2012.

Testing the Cosmological Principal, Colloquium, University of KwaZulu-Natal, Durban, South Africa, April 5, 2012.

R. Srianand

Early Universe Observations with TMT, COSPAR, Mysore.

Physics of IGM, CEFIPRA, Chennai.

MeerKAT Absorption Line Survey, SKA-Bursary, Cape Town.

IGM Physics with TMT, TMT Meeting, IUCAA.

A Seach for 21-cm Absorption at High-z, Galaxies in Absorption Meeting, IUCAA.

Science with SALT, Associates Fest, IUCAA.

Kandaswamy Subramanian

Turbulent Dynamos in Astrophysics: ***Problems and Prospects***, University of Rochester, USA, April 2012.

Turbulent Dynamos in Astrophysics: ***Problems and Prospects***, Center for Environmental and Applied Fluid Mechanics, Johns Hopkins University, USA, May 2012.

CMBR Anisotropies: ***Theory*** (2 lectures), Workshop on Cosmology, University of Delhi, January 2013.

Fluctuation to Mean Field Dynamos, The Search for Coherence, Cosmic Magnetic Fields: Mathematical and Observational Descriptions, Newcastle University, UK, March 2013.

Probing the Universe Using High Redshift Galaxies, Institute of Computational Cosmology Seminar, University of Durham, UK, March 2013.

Durgesh Tripathi

Introduction to the Sun (2 lectures), Introductory Summer School on Astronomy and Astrophysics, IUCAA, May 7 to June

6, 2012

Flows and Waves in Active Regions: An Observational Overview, COSPAR Meeting, Mysore, July 16-22, 2012.

Heating of Active Region Cores, Rocks'n'stars Meeting Goettingen, October 8-11, 2012.

Heating of the Solar Corona, Astrophysics Seminar, DAMTP, Cambridge, October 15, 2012.

Invited Review Talk on Heating of active Region Cores: Steady or Impulsive, International Symposium on Solar Terrestrial Physics, November 6-9, 2012.

Solar Physics (2 lectures), IIST - IUCAA in Introductory Workshop on Solar Physics, Indian Institute of Space Science and Technology, Thiruvananthapuram, November 29 - December 1, 2012.

Our Star: The Sun, National Seminar, Satara, January 17, 2013.

Dynamics and Coupling of Upper Solar Atmosphere, Indo-UK Meeting, Indian Institute of Astrophysics, Bangalore, January 21-23, 2013.

Solar Atmosphere and Spectroscopy (2 lectures), Introductory Workshop on Solar Physics at RKMVU, Belur, West Bengal, February 5-7, 2013.

(B) Lecture Courses

Dipankar Bhattacharya

Fluids in Astrophysics (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 7 - 10, 2012.

High Energy Astrophysics (5 lectures), Winter School on Astronomical Surveys, TIFR, Mumbai, December 12 - 14, 2012.

X-ray Astronomy: Introduction, Imaging, **Compact Objects, Jets and Cyclotron Lines** (6 lectures), 2nd IUCAA X-ray Astronomy School, February 4 - 14, 2013.

Gulab Dewangan

X-ray Astronomy and Active Galactic Nuclei (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May - June 2012.

X-ray Detectors and Telescopes, Data Analysis Techniques (4 lectures), 2nd X-ray Astronomy School, IUCAA, February 4 - March 2, 2013.

X-ray Emission from Active Galactic Nuclei (4 lectures), 2nd X-ray Astronomy School, IUCAA, February 4 - March 2, 2013.

S. V. Dhurandhar

Course on GR and GW (3 lectures), IUCAA School on Gravitational Waves, Tezpur, January 23 - 27, 2012.

Course on GR and GW (3 lectures), IUCAA School on Gravitational Waves, Tezpur, December 17 - 21, 2012.

Course on GR, **Gravitational Waves and the Data Analysis of Gravitational Waves** (5 lectures), IPR, Ahmedabad, January 28 - 31, 2013.

Ranjan Gupta

Stellar Spectroscopy and Spectroscopic Instrumentation (3 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 15 - 17, 2012.

Observational Astronomy Course (5 lectures), IMD-CTI, Pune, January 16 - 17, 2013.

Ajit Kembhavi

Radiation Processes in High Energy Astrophysics (3 lectures), 2nd X-ray Astronomy School, IUCAA, February 5-6, 2013.

Radiative Processes (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

Ranjeev Misra

Radiative Processes in Astrophysics (3 lectures), Workshop on Infra-red Astronomy, Tezpur University, Assam, March 2013.

Radiative and Accretion Processes in Astrophysics (6 lectures), 2nd X-ray Astronomy School, IUCAA, February 2013.

Radiative Processes in Astrophysics (3 lectures), Workshop on Optical Astronomy, Tezpur University, Assam, June 2012.

Accretion Processes in Astrophysics (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 15 - 17, 2012.

By IUCAA Academic Members at IUCAA and other Institutions

Vijay Mohan

Photometry Techniques (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

T. Padmanabhan

Special and General Relativity (3 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

A. N. Ramaprakash

Basic Astronomy, Geometric Optics and Telescopes, Astronomy Olympiad Training Camp, HBCSE, Mumbai, April 2012.

Detectors and Instrumentation (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

Adaptive Optics in Astronomy, NIUS Physics Camp, HBCSE, Mumbai, June, 2012.

Astronomical Instrumentation, WMMA-2013, ISM, Dhanbad, February 2013.

Swara Ravindranath

Galaxies (4 lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May - June, 2011.

Tarun Souradeep

Cosmology (4 Lectures), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

R. Srianand

Introduction to Astronomy, Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

Observational Constraints on Reionization (3 lectures), IUCAA workshop organised in Delhi University.

Spectroscopy Workshop (3 lectures + Demo), Kerala Academy of Sciences.

Introduction to Spectroscopy + ***How to Write Proposals*** (4 lectures), IGO-School, IUCAA.

Kandaswamy Subramanian

Magnetohydrodynamics (3 lectures), Introductory Summer School in Astronomy and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

Cosmic Magnetic Fields (2 lectures) **and Structure formation in the Universe** (1), Introductory Summer School in Astronomy, and Astrophysics, and Vacation Students Programme, IUCAA, May 2012.

IUCAA Associates Fest '12

The very first Associates Fest was organized during June 25-29, 2012. The associateship Programme was initiated by IUCAA to spread astronomy and astrophysics in universities and colleges in the country.

The talks were delivered by Sk. Saiyad Ali, Dipankar Bhattacharya, Mamta Dahiya, Sushant Ghosh, Yashwant Gupta, S. N. A. Jaaffrey, Joe Jacob, Md. Mehedi Kalam, Ajit Kembhavi, Pushpa Khare, V. C. Kuriakose, Vijay Mohan, Sailo Mukherjee, S. K. Pandey, Sajeeth Philip, Anirudh Pradhan, A. N. Ramaprakash, C. D. Ravikumar, Saibal Ray, T. R. Seshadri, H. P. Singh, Tarun Souradeep, R. Srianand, Kandaswamy Subramanian, Prasad Subramanian, and Pranjal Trivedi, and followed by a panel discussion, in which Anil Kakodkar, Chairperson, Governing Board of IUCAA participated.

For details see Khagol, Iusse No. 91 - July 2012.

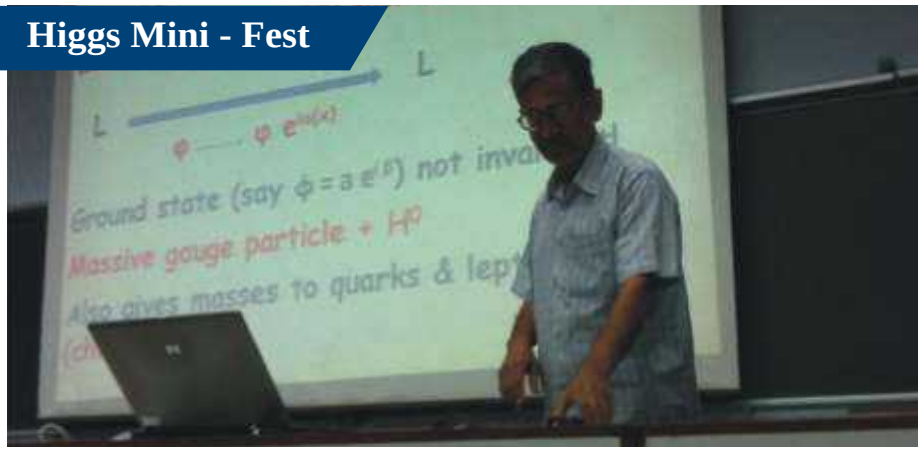
Introductory Summer School on Astronomy and Astrophysics (For College/ University Students)

The Introductory Summer School on Astronomy and Astrophysics, was conducted at IUCAA, during May 7 - June 8, 2012.

24 students from across the country participated in the school. The programme consisted of a series of lectures on a wide range of topics in theoretical and observational astronomy, data analysis, and problem solving sessions.

For details see Khagol, Iusse No. 91 - July 2012 .

Higgs Mini - Fest



In July 2012, scientists in CERN announced the discovery of the Higgs - Boson, a crucial component in the Standard Model of particle physics. Three experts Avinash Khare (IISER, Pune) Rohini Godbole (IISc, Bangalore) and Gobinda Majumder (TIFR, Mumbai) gave talks in front of an overflowing and eager audience.

On October 11, 2012, IUCAA organized a Higgs Mini - Fest to discuss the discovery of the Higgs - Boson, and shed some light on this elusive particle. The mini-fest was co - ordinated by Varun Bhalerao and Ajit Kembhavi, first of its kind at IUCAA was a success.

For details see Khagol, Iusse No. 93 - January 2013.

The Vacation Students' Programme (VSP)

The Vacation Students' Programme (VSP), was held during May 7 - June 22, 2012 for students in their penultimate year of M.Sc. (Physics) or engineering degree course.

The participants attended about 50 lectures, on Astronomy and Astrophysics by the academic members of IUCAA. R. Srianand was the faculty coordinator of this programme.

For details see Khagol, Iusse No. 91 - July 2012.

Thirty Metre Telescope Science and Instrumentation Workshop

A two and a half day Thirty Metre Telescope Science and Instrumentation workshop was held at IUCAA, during December 10-12, 2012, followed by a one day meeting of the Science Advisory Committee of the TMT.

Sixty five astronomers and instrument specialists from the TMT consortium members participated a two panel sessions to discuss (i) Questions of interest to the Indian community, (ii) How to help forge the scientific collaborations with the TMT consortium, and (iii) Action plans to complete the activities of the working groups on polarimetry, time resolved science and astrometry.

For details see Khagol, Iusse No. 93 - January 2013.

Workshop on Galaxies in Absorption

The fourth workshop in the series: "Galaxies in Absorption", was held at IUCAA during December 17 - 20, 2012. A group of people working in this field have been meeting once a year for the past three years.

Participants from across the country, Europe and US attended, and about 25 talks, covering various issues related to the connection between QSO absorbers and galaxies were delivered.

The workshop was coordinated by Pushpa Khare and R. Srianand.

For details see Khagol, Iusse No. 93 - January 2013.

2nd IUCAA X-Ray Astronomy School

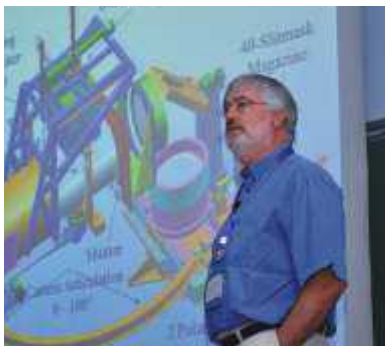
IUCAA conducted a well focused four-week long X - ray Astronomy school during February 4 - March 2, 2013.

The main purpose of the school was to enable Ph. D. students from Indian universities and institutes to gain a good understanding of the X-ray data analysis techniques, and the interpretation of the data.

Twenty participants worked on research projects and 13 scientists from India and abroad delivered around 40 lectures and an additional 10 experienced students and post-doctoral associates helped in conducting the hands-on sessions and interacted with the participants on their projects.

For details see Khagol, Iusse No. 94 - April 2013.

International Meeting on Transients and Timing: A Multi - wavelength Approach



"Transients and Timing: A Multi-wavelength Approach", an international meeting was held at IUCAA during March 4 - 8, 2013.

The meeting had invited review talks and some shorter presentations, covering various aspects of transients, discovered across different wavelengths, their follow-up observations and theoretical studies, detection techniques, quick data dissemination, use of machine learning techniques for their identification and present and forthcoming surveys for the detection of transients and was attended by around 30 eminent scientists from U.S.A, U. K., Germany, The Netherlands, South Africa, Italy and Japan, as well as about 70 scientists from India covering a wide range of expertise. Ph. D. students from Indian universities and institutes showcased their research through posters.

Ed. van den Heuvel (University of Amsterdam) summarized the success of the meeting in the last talk and emphasized the need for more such get-togethers in the light of Indian participation in large international projects.

For details see Khagol, Iusse No. 94 - April 2013.

24th IUCAA FOUNDATION DAY

December 29, 2012.

The 24th IUCAA foundation day lecture was delivered by Professor Ashoke Sen from Harish-Chandra Research Institute, Allahabad, and was titled "Search for a unified theory".

Professor Sen provided an overview of the current status of string theory. He started with a description of our understanding of the elementary particles and their interactions, and how the Standard Model can unify the three (strong, weak, and electromagnetic) of the four fundamental forces and explain most of the experimental data. He then discussed issues, which arise when one tries to include gravity. The standard model is based on the framework of the theory of relativity and quantum mechanics, and gravity will have to be consistent with these two concepts for a unified model to work.

He introduced the idea that string theory may be the avenue where this can be achieved, since gravity appears as a more natural outcome in this formalism, which incorporates relativity and quantum theory. In string theory, the different elementary particles correspond to different vibrational states of a string, where the typical size of a string is about sixteen orders of magnitude smaller than the smallest scales probed by current experiments.

Theoretical consistency of string theory requires working in 9-dimensional space. In order to relate to our experience of 3-dimensional space, one introduces the notion of 'compactification' of space, which he explained using simple analogues. He also used analogues to describe how various versions of string theory are based on the choice of the compact space, but are all really equivalent in the M-theory formalism of the string theory. This formalism is capable of describing different phases of the string theory, and Professor Sen concluded the talk by emphasizing that the real challenge is to determine the phase that corresponds to the observable Universe that we live in.

For details see Khagol, Iusse No. 93 - January 2013.

A Three day INAAD workshop on Science with Optical Spectra

A three day workshop on 'Science with Optical Spectra' was conducted at Mar Athanasios College for Advanced Studies, Tiruvalla (Kerala), during September 6 - 8, 2012.

It was a follow-up of the workshop on 'Optical Astronomy Projects using IRAF', which was held at Newman College, Thodupuzha (Kerala) in January 2012.

Workshop on Cosmology

The Workshop on Cosmology was held at Bangalore University, during November 8 - 10, 2012, inaugurated by K. Siddappa, former Vice-Chancellor of Bangalore University and a renowned nuclear physicist. Siddappa spoke about the importance of holding workshops on current topics and about the good work done by IUCAA in this regard. S. Mukherjee presented an overall review of the activities of IUCAA.

Participants included 30 teachers and 25 post graduate physics students who attended 12 lectures on various topics in cosmology, as finalized by the academic coordinators S. Mukherjee and Sanjay Jhingan in the auditorium of Bangalore University.

An interactive session was held on the last day wherein the participants asked questions to the resource persons.

The participants were given several review articles in cosmology as well as the well known book 'Elements of Cosmology' by Professor Jayant Narlikar.

For details see Khagol, Iusse No. 93 - January 2013.

Ph. D. Program - Moumita Aich

IUCAA Research Scholar, Moumita Aich (Guide: Tarun Souradeep), has defended her thesis submitted to the University of Pune during the year of this report.

Title of the thesis:

Key Observational Issues in the Cosmic Microwave Background

The standard model of cosmology, where the universe began with a "hot big bang", followed by an inflationary epoch – a period of accelerated expansion, forms the foundation of modern cosmology. Observations from cosmic microwave background experiments and various other astrophysical missions, have been successful in matching the predictions of this standard model of cosmology in the most accurate manner. The CMB temperature anisotropy is an overt evidence of the hot big bang model and contains a wealth of information about the physical structure of the universe. Observations from the WMAP satellite experiment of the CMB anisotropy gives an exquisitely accurate reconstruction of the temperature anisotropy angular power spectrum. However, certain anomalies at large angular scales in the CMB measured by WMAP have been suggested as possible evidence of slight deviations from this standard model. Existence of a few data points outside the confidence region in the CMB temperature angular power spectrum, motivates the study of new inflationary dynamics, with a deviation from the standard power law inflationary model.

Certain oscillatory features in the primordial scalar power spectrum are known to provide a better fit to the outliers in the CMB data near the multipole moments of $\ell = 22$ and 40. These features are usually generated by introducing a step in the popular, quadratic potential describing the canonical scalar field. Such a model will be ruled out, if the tensors remain undetected at a level corresponding to a tensor-to-scalar ratio of, say, $r \simeq 0.1$. In addition to the popular quadratic potential, the effects of the step in a small field model and a tachyon model are investigated. With possible applications to future datasets (such as PLANCK) in mind, the tensor power spectrum is evaluated exactly, and its contribution included in the analysis. The models are compared with the WMAP (five as well as seven-year), the QUaD and the ACBAR data. As expected, a step at a particular location and of a suitable magnitude and width is found to improve the fit to the outliers (near $\ell = 22$ and 40) in all these cases. It is discussed that if the tensors are proved to be small (say, $r \lesssim 0.01$), the quadratic potential and the tachyon model will cease to be viable, and more attention will need to be paid to examples such as the small field models.

Amongst the many models of inflation currently available, models that lead to features in the primordial scalar spectrum are becoming increasingly popular, as they are known to provide a better fit to the CMB datasets than the standard power law primordial spectrum. The scope of this work also includes the exact numerical evaluation of the power spectra in the case of axion monodromy model and a canonical scalar field model described by a quadratic potential with a sinusoidal modulation. Both the models produce oscillations in the primordial power spectrum on all scales. However, it is observed that the former provides a considerably better fit to the recent CMB data in comparison to the power law primordial spectrum. To compare with the small scale data, the recent results from the Atacama Cosmology Telescope have been taken into account. Parameter forecasting performed using simulated Planck data for both the models shows that the Planck data may be expected to perform significantly better in constraining the model parameters as compared to current CMB datasets.

Peculiarities in the CMB temperature all-sky maps, where coincidental alignments are observed in random realizations, prompt the study of breakdown of statistical isotropy in the CMB temperature two point correlation function. SI violation of cosmological perturbations is a generic feature of ultra large scale structure of the cosmos and breakdown of global symmetries. The CMB photons free-stream to the present from the surface of last scattering. It is, thus, reasonable to expect statistical isotropy violation in the CMB photon distribution observed now to have originated from SI violation present in baryon-photon fluid at last scattering, in addition to anisotropy of the primordial power spectrum studied earlier in literature.

This motivates the introduction of an anisotropic brightness distribution function $\Delta(\vec{k}, \hat{n}, \tau)$ at the surface of last scattering, that is not simply a function of $|\vec{k}|$ and $\hat{k} \cdot \hat{n}$. In this case, the brightness fluctuations expanded in Bipolar Spherical Harmonic series, can be written in multipole space as $\Delta^{LM}_{\ell_1 \ell_2}(\vec{k}, \tau)$, where $L > 0$ encodes deviations from statistical isotropy. Violation of SI encoded in the observed off-diagonal elements of the harmonic space correlation $\langle a_{\ell m} a^*_{\ell' m'} \rangle$, equivalently, the BipoSH coefficients $A^{LM}_{\ell \ell'}$, are then related to the generalized BipoSH brightness fluctuation terms at present. Statistically, anisotropic fluctuations

at the last scattering surface $\Delta^{LM}_{\ell_1\ell_2}(\vec{k},\tau_s)$ in the free streaming regime evolve to non-zero moments $\Delta^{LM}_{\ell_3\ell_4}(\vec{k},\tau)$ at the current epoch, where τ is the conformal time. It is seen that the terms with given BipoSH multipole, LM, evolve independently. Moreover, similar to the SI case, power at small spherical harmonic (SH) multipoles of $\Delta^{LM}_{\ell_3\ell_4}(k,\tau_s)$ at the last scattering, is transferred to $\Delta^{LM}_{\ell_1\ell_2}(k,\tau)$ at larger SH multipoles. The structural similarity is more apparent in the asymptotic expression for large values of the final SH multipoles. This formalism allows an elegant identification of any SI violation observed today to a possible origin in SI violating physics present in the baryon-photon fluid. This is illustrated for the known result of SI violating angular correlations due to the presence of a homogeneous magnetic field in the baryon-photon fluid.

The problem of initial conditions is one of the weaknesses of the inflationary paradigm. The problem of pre-inflationary homogeneity, however, can be attended to by considering a compact universe, where during the pre-inflationary period there is typically sufficient time for smoothening out primordial fluctuations. Inflationary framework suggests that the relatively homogeneous observable patch of the universe is probably a smaller subset of an extremely inhomogeneous and complicated spatial manifold. This motivates the study of multiply connected cosmic topological spaces, and CMB anisotropy measurements have become an integral tool to address the issue of global topology of the universe from the realm of theoretical possibility to within the grasp of observations. The finite spatial size in compact universe models, imposes an infrared cut-off in the power spectrum of perturbations, which in turn implies a suppression of the power in the CMB anisotropy on angular scales above a characteristic angle related to size of the universe. Another signature determined by the structure of this compact space is the breaking of statistical isotropy in the angular correlations of the CMB anisotropy. SI violation in a flat compact universe, namely, the flat torus model, has been analyzed. The discretization of the perturbation modes in this compact space has been encoded in the non-zero Bipolar coefficients. Detection of such Bipolar coefficients would suggest violation of SI in non-trivial compact spaces.

Facilities @ IUCAA

Computer Centre

The IUCAA Computing Facility continues to provide technology rich work space and facilities to IUCAA members, associates and visitors. The major part of last year was spent in getting the Datacentre ready for housing the new 30 TeraFlop rating cluster named Perseus from M/S Hewlett and Packard. The specifications are as follows:

Persues: 1504 + 24 + 64 cores

Head Node	Two DL380G7, 2x3.06Ghz, Hex Core X5675, 96GB RAM, 2x146GB 10K SAS HDD, QDR IB HCA, RPS, DVD, ROM; RPS.
Utility Node	Two DL580G7, 4x2.0Ghz , 8 core E7-4820, 128GB, 3x146GB 10K SAS, 4x450GB 10k SAS HDD, QDR IB, HCA, 10G Adapter, RPS, DVD ROM; RPS used for running mathematica, IDL, matlab, etc.
Compute Nodes	94 SL230s compute nodes * 2 CPUs * 8 cores = 1504 cores. Each SL230s compute nodes with 2 CPU (2.6GHz), 8 core E5-2670, 128GB memory, 1 x 500GB 7200rpm, SATA disk, QDR IB (RPS at the chassis end)
RAM	94 * 128 GB = 12032 GB = 12 TB.
Storage	1 X DDN SFA10000-X Hardware RAID array with 750 TB usable storage. 50 TB for LIGO data, 150 TB for NFS and 300 TF for parallel filesystem (Luster based) and 250 TB for archival totaling 750 TB.
Interconnect	InfiniBand.
Scheduler/Mgt	Loading Sharing Facility (LSF) with Simple Linux Utility for Resource Management.
Web Portal	Custom made web portal for submission of jobs and resource monitoring, etc. by TCS (Former CRL)

In August 2012, 50 users Linux/MAC/Windows VPN license was procured and implemented so that academic users could use it to connect to IUCAA network securely when they go out of station. This would allow the users to use the internal licensed products such as mathamtica, idl, matlab, etc and to access journals subscribed by the IUCAA library.

In late September 2012, a SGI storage server ISS 3112 with 2*2.0Ghz CPUs, 128GB RAM, 36TB Raw data disks, 2*120GB SSD, dual port 10 Gbit card was installed to serve Catalina Real Time Survey (CRTS) data from IUCAA.

During the first quarter of 2013, single mode and multimode fibre optic cables have been laid in the residential colony for strengthening the WiFi network and to extend wired network to academic members. The wired network was extended to B3 seminar room and the newly constructed Datacentre, Open office and Instrumentation lab during late 2012. In Feb. 2013, wired and wireless network connectivity was made available at the newly constructed guest house.

The Computer Centre continues to offer technical support to project students, IUCAA associates as well as visitors from universities and institutions within India and abroad.

Library and Publications

The IUCAA library is an automated open access library with a total collection of 24,730 volumes comprising of 14,332 books, which include major collections in astronomy and astrophysics, physics, mathematics, computer and electronics, supported by literature in other walks of life, and 10,398 bound volumes of journals. Besides this, the library has been fortunate in receiving rare and valuable books and journal issues from the personal collections of renowned scientists. The library subscribes to 126 journals, in print and online and has acquired e-books in physics and astronomy from reputed publishers viz. Cambridge University Press, Oxford University Press, and recently from Springer. In addition, the library also receives complimentary access to e-journals in astronomy and astrophysics not subscribed by the IUCAA library, courtesy INFLIBNET, Ahmedabad.

The library is equipped with state-of-the-art facilities such as a high-resolution scanner, digital photocopier, user terminals and wifi connectivity, and it serves as the main resource library in Astronomy and Astrophysics in the university sector. It is open all round the year, except on the three national holidays and is extensively used by the in-house users as well as associates, students, amateur astronomers, teachers and visitors coming to IUCAA. Full-text access to the presentations delivered during various schools and conferences held in the institute, posters displayed during the National Science Day, IUCAA Academic Calendar, research papers, newspaper clippings and IUCAA preprints is made available through the IUCAA institutional repository set up using DSpace. Online access to Khagol, the IUCAA Bulletin, and the Annual Report is provided using Open Journals System (OJS). The library provides access to astronomy related CD/DVDs as well as recorded lectures delivered by T. Padmanabhan through the Network Assisted Server (NAS), which are accessible on a username and password basis.

Instrumentation Laboratory

Robo-AO, a low cost, robotic, queue-scheduled adaptive optics (AO) system for small and medium class (primary mirror diameter of 1-3m) telescopes was developed through a collaboration between IUCAA and Caltech, USA. The first version of Robo-AO was offered for science observations from the middle of 2012 on the Palomar 60 inch telescope. Several publications have already resulted from these observations as listed elsewhere in this report. The collaboration is now continuing to work on the development of an infrared arm for the AO system. The optical and optomechanical design of the infrared camera was done at IUCAA and component fabrication has already started. (See fig.1: Near-infrared arm of Robo-AO being designed and developed at IUCAA. This instrument will enhance the capabilities of Robo-AO (visible) which is already in use for scientific observations at the Palomar 60 inch telescope.)

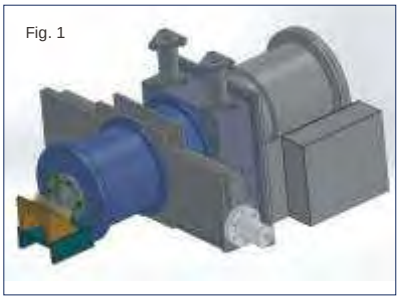
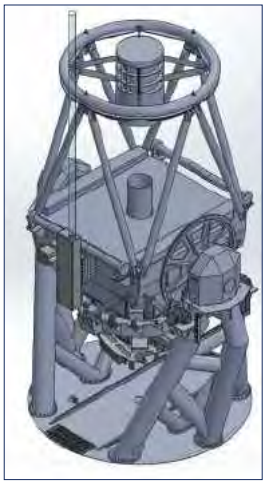


Fig. 1



The infrared arm is expected to be incorporated into Robo-AO later this year. Design of a second version of Robo-AO for the IUCAA telescope is in the final stages with procurement of several of the components already underway. (See fig. 2: Solid Works model of a new version Robo-AO as mounted on the IUCAA 2m telescope at the Girawali Observatory.)

Under two independant MoUs signed with University of Wisconsin-Madison (UW) and Univeristy of Florida (UF), IUCAA laboratory has developed controllers (IUCAA SIDECAR Drive Electronics Controller - ISDEC) for handling the operation and data acquisition from near-IR HAWAII detectors using a special ASIC called SIDECAR. The first of these controllers is now integrated (See fig. 3*) with the near-IR arm of the Robert-Stobie Spectrograph which is being built by UW for the Southern African Large Telescope (SALT). (See fig. 3*: IUCAA SIDECAR Drive Electronics Controller (ISDEC) being integrated into the near-IR test Dewar of the Robert-Stobie spectrograph at the University of Wisconsin.)


Fig. 3

A second controller is used for the Canarias InfraRed Camera Experiment (CIRCE) being built by UF for the 10.4m Gran Telescopio Canarias (GTC) on La Palma. The detailed optical and optomechanical design of the InfraRed Spectroscopic Imaging Survey (IRSIS) instrument has been completed in the IUCAA laboratory as part of a collaboration with the Tata Institute of Fundamental Research (TIFR), Mumbai. Procurement of optical components and fabrication of the optomechanical components are currently underway. The lab model will be assembled at the Hyderabad Balloon Facility of TIFR, and key functional and performance parameters will be demonstrated.

The new browser-based observatory control and monitoring system that was developed through a contract given to Persistent Systems

Ltd., Pune, has been now deployed at the IUCAA Girawali Observatory (IGO). This will replace the in-house built OS-dependent user interface which is currently in use at IGO.

IUCAA has signed an MoU with the Aryabhatta Research Institute of Observational Sciences (ARIES), through which an integral field spectrograph (See fig. 4*: DOTIFS Deployment Assembly) will be built by IUCAA for the 3.6m Devasthal Optical Telescope being set up ARIES near Nainital. IUCAA will get observation time on the telescope in return for developing this instrument. H. Chung, a student from Seoul University and Korea Institute Advanced Study (KIAS) has been working for his Ph. D. thesis as part of this development work.

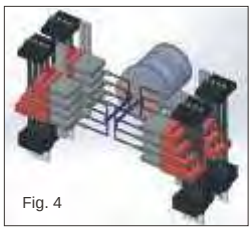


Fig. 4

(See fig. 4*: A model of the IFU deployment mechanism at the focal plane of the 3.6m Devasthal Optical Telescope. The integral field spectrograph being designed and built by IUCAA will offer about 16 independant IFUs that can be deployed over a 10 arcminute field of view. Each IFU will be made of an array of about 144 fibres+microlenses that covers about 12"x12" in the sky.)

IUCAA laboratory has established a collaborative programme with Caltech (USA), MPIfR (Germany), University of Crete (Greece) and NCU (Poland) as part of which a novel, four-channel polarimeter is being designed and developed in the laboratory which will be installed at the Skinakas Observatory (Greece).

The construction of this instrument (see fig. 5*) is in an advanced stage with shipment planned for late April 2013. The collaboration will use the instrument to carry out a comprehensive three year monitoring survey to understand the linear polarization signature in the light emitted by blazars during their quiescent and outburst phases.

(See fig. 5*: RoboPol, a novel four-channel polarimeter being assembled and tested in the laboratory. This instrument will be used at the Skinakas observatory in Greece to cary out a three year survey of optical linear polarization behaviour of blazars.)

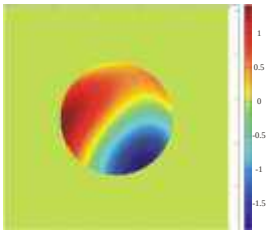


Fig. 6: Early results from a novel approach to measure wavefront errors and a predictive-iterative reconstruction technique that may be useful adaptive optics implementations on future large telescopes. The figure on the left shows the true wavefront error injected. The figure on the right shows that the wavefront reconstructed with our approach is in good agreement with the original one.

E. Tatulli, a Research Associate at IUCAA, worked on developing a detailed model to help understand the impact of effects like photon noise, angular anisotropy etc. under different types of adaptive optics approaches (SLAO, LTAO, MCAO etc.) that are employed in astronomy. The model was then applied to optimize the cost vs. performance parameter space of adaptive optics implementations for small and large astronomical telescopes.

In a related development, work has been in progress in the laboratory to develop new approaches for estimating atmosphere-induced wavefront distortions as well as their realtime compensation with a view for their applications in adaptive optics systems for future large telescopes (see fig. 6*)

As one of the three institutes (ARIES, IIA and IUCAA) leading the national effort to participate in the design and construction of the Thrity Metre Telescope (TMT), IUCAA laboratory personnel are involved in a number of activities related to development of components for the TMT. In addition to overseeing hardware and software components being prototyped through industrial contracts, IUCAA laboratory is working on developing readout schemes for the On-Instrument Wavefront Sensors (OIWFS) for the TMT adaptive optics system (see fig. 7*)

Fig. 7

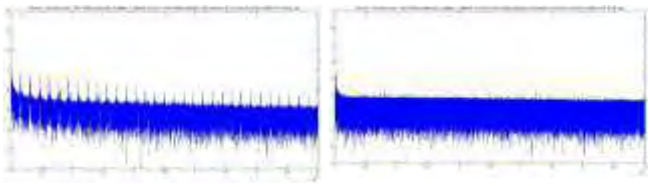


Fig. 7*: Fourier transform analysis which shows the presence of several noise components in the readout of near-IR detectors that may be used for on-instrument wavefront sensing for the TMT. The figure on the right shows the spectrum after the noise components have been removed.

The IUCAA-NCRA Radio Physics Laboratory (RPL)

A Cosmic Ray Muon Detector Experiment

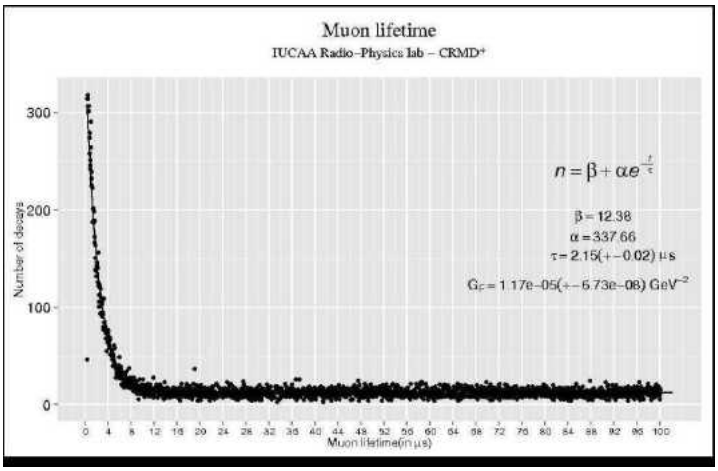
Primary rays are originally produced in various astrophysical processes. They are composed primarily of protons and alpha particles (99%), with a small amount of heavier nuclei (~1%) and an extremely small component of antiprotons and positrons. Cosmic Ray muons

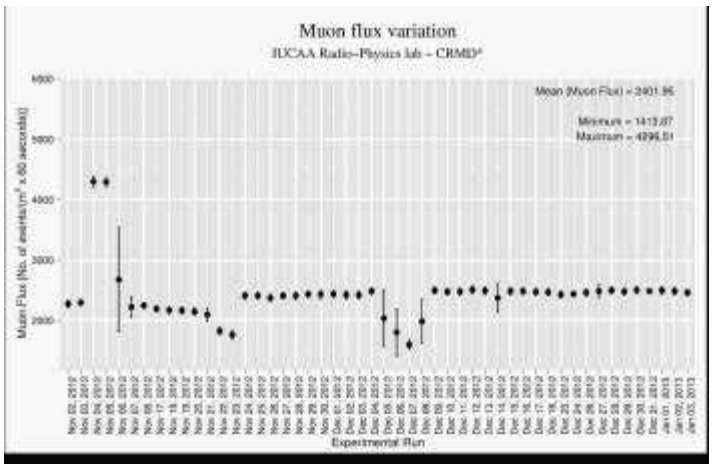
(μ^+ or μ^-) are extremely high energy relativistic secondary particles created in the earth's upper atmosphere via interaction of primary cosmic ray particles with the nuclei of atmospheric gases. Being an unstable particle, the muon decays in about 2.2 μs into an electron, a neutrino and an antineutrino , the process governed by weak interactions (see fig. xx). Measurement of the decay time of muons thus constitutes one of the most important tests of the Standard Model of particle physics.

Recently, components of a cosmic ray muon detector were obtained from Fermilab, USA. The Quarknet Cosmic Ray E-lab is a Fermilab's programme to bridge research with education. Under this initiative they have created a worldwide network of Cosmic Ray muon detectors in schools and colleges, which often indulge in correlation studies on a global scale. IUCAA Radio Physics lab has also joined in this global educational effort. Since October 2010 two university students, Pratic Dabhade and Maduri Gaikwad, with **Joydeep Bagchi** at IUCAA have not only built the entire detector and added it to the global network of Fermilab, but also carried out their own extensive analysis of the muon decay rate and flux data they collected. The IUCAA cosmic ray muon experiment comprises of 4-channel plastic scintillators, photomultiplier tubes, data acquisition board, an accurate GPS time referencing and powerful data analysis software. The students built the detector after studying the parts carefully and gathering all other required materials locally. The detector was subsequently calibrated and added to the global network of muon detectors. The lab has successfully participated in two International Muon Weeks conducted (2012 and 2013) annually by Fermilab. The students carried out a statistical analysis of huge number of muon decay events recorded in coincidence mode.

They have computed the mean lifetime of muons from observations and obtained a value 2.15 (+/- 0.02) μs very close to the best theoretical value of 2.1969811± 0.0000022 μs (see Fig2.xxx). A matching value for the Fermi coupling constant was also obtained from this data. The daily muon flux has been monitored continuously since September 2012 until now. Few sudden huge increment (See fig. xxx) in the muon flux in early November 2012 has been seen and we are currently investigating its cause.

Figures show wrapping the plastic scintillators with foil and black sheets to block all external lights. A blue glow from the bare scintillator can be seen. The assembled expewriment is also shown.





The left panel shows muon lifetime data collected over several months. A least square fit to the muon events versus their lifetime provides the value for the mean muon lifetime from the radioactive decay type curve shown. The right panel shows the muon flux measurement from the same collected over many months.

IUCAA Girawali Observatory (IGO)

Observations at IGO went on well till May 2012 ,until onset of monsoon .After monsoon the observations could have started only in January 2013 ,as there were problems with altitude axis of the telescope .The axis problem was finally solved, but autoguider of the telescope was found to be unoperational .As a result, only those programmes that required short exposures could be undertaken .Efforts to acquire a new auto guider were initiated .The primary mirror was aluminised in October 2012 . During 2012 13 ,based on the observations taken from IGO ,a total of 10 research papers were published .In addition to these, a thesis incorporating major observations done from IGO ,was awarded Ph D .degree by Cochin University of Science and Technology .

Virtual Observatory - India

This is the third year of VOI-Phase II, which is the third generation of the VOI projects hosted at IUCAA in collaboration with Persistent Systems Ltd. (PSL), Pune. The VOI project was started as India's contribution to a global effort to bring about standardization in astronomical data definition formats and astronomy-oriented applications development.

The goal of the project is to facilitate storage of astronomical data, seamless and easy retrieval of the data over the internet, and visualization and analysis of the data using the latest advances in computer hardware and software, while being governed by a set of constantly improved standards and protocols laid down by the International Virtual Observatory Alliance (IVOA). VOI has developed a number of tools to help astronomers in specific aspects of their research, and has constantly improved these tools by releasing new versions regularly.

One recent release by VOI is AstroStat, a tool that allows astronomers to use both simple and sophisticated statistical routines on large datasets. The tool contains routines for visualization, finding the distribution of data points, determining co-relation between entities, etc. AstroStat has a visual interface that is easy to comprehend, and results are presented in a well formatted manner with focus on important output parameters. Help sections explaining all the routines in sufficient details are built in. AstroStat is a significant improvement over a previous similar tool by VOI for statistical analysis. Work has already commenced on the next version of this application, which will focus on adding time series and survival analysis techniques.

In the domain of mobile phone applications, the SALT Android Visibility application has been developed for the Android smart phone operating system for calculating the target visibility from the Southern African Large Telescope (SALT). It provides a graphical representation of the target visibility duration based on provided co-ordinates (right ascension and declination). Visibility graphs can be plotted for individual night visibility or the annual visibility. In addition to target visibility graphs, the application also presents users with additional information related to the sunrise/sunset, moonrise/moonset times and moon phases.

The Catalina Real-Time Transient Survey (CRTS) is a synoptic astronomical exploration that covers thirty three thousand square degrees of the sky in order discover rare and interesting transient phenomena. The survey utilizes data taken by the three dedicated telescopes. VOI is in the process of developing a catalogue and image access service for CRTS data, which will allow users to retrieve archived CRTS images and data. While the catalogues were being served in some form from Caltech, the images will be served for the first time via this application, and several projects will immediately benefit from this ability.

VOI has also contributed to the following meetings and events during this year:

- Two presentations at the International Virtual Observatory Alliance (IVOA) InterOp meeting (Sao Paulo, Brazil - October 20-24, 2012).
- Participated as tutors at the First BRAVO VO school, preceding the InterOp meeting (Sao Paulo, Brazil - October 18-19, 2012).
- Conducted a week long VO workshop, where we provided training on the use of VO tools like Simbad, Aladin, VOPlot, AstroStat etc using lectures and hands-on sessions based on science cases (Kolkata, December 3-7, 2012).
- Microsoft Research's World Wide Telescope demonstration on the occasion of National Science Day (IUCAA, February 28, 2013).

Public Outreach Higlights

MVS Solar - System Themed Landscape

A themed landscaping has been carried out outside the MVS Exploratorium with concrete spheres and soil mounds representing planets. Children can get information about scales and other details of the planets and can even climb or play around them for fun. A small planetarium is being set up under the "Jupiter Mound".

Spark Talks

IUCAA has been providing support for a series of talks by the voluntary group, InnoVidya. Started in January 2013, the talks, aimed at college students, are conducted on 3rd Saturdays at IUCAA. The speakers were Mathai Joseph, Paul Ratnasamy and Sohan Modak.

Transit of Venus Awareness and Observations

IUCAA was able to motivate people to understand and watch the Transit of Venus event on June 6, 2012. There was a great response from the general public despite rain. About 2000 students and members of the public were made aware of this event and also given resources to tell others about it. These included Ball-Mirror Sun projectors, Solar Eclipse goggles and handouts about the transit. A public talk too was arranged on this topic. The volunteers from amateur astronomy groups helped us to conduct the proceedings. Many TV news channels covered this efforts.

Pune Amateur Astronomers' Meet

A meeting for the City's Amateur Astronomers was held at IUCAA on November 25, 2012, with efforts made to unify the activities of all the groups and to attract more interested individuals. Special action groups were set up during this, with many amateurs volunteering to conduct the activities.

A book exhibition was also held with the help of IUCAA Library staff to make the amateur community aware of the good literature available.

Public Outreach Higlights

School Students' Summer Programme and Astronomy Camp

IUCAA Public Outreach group has conducted the regular School Students' Summer Programme as well as an Astronomy Camp from April 11 to May 20, 2012. One hundred and sixty students of class VIII/ IX/ X participated in this programme, who were nominated by their schools.

The highlight of the Camp was the newly developed content to give an overview of Astronomer's tools to school students, while getting them to try out what they study in school. Topics covered ranged from simple geometry and statistics to optics and spectroscopy.

The students used the Samrat Yantra to study Trigonometry, as well as the Celestial Motions of the Sun. They were able to understand the scales of the solar system by finding the ratio of the distances of the Planets to the Sun. They were also introduced to the basics of aeromodelling and flight. Star maps were distributed, and sky watching practice sessions were held for all the students on Friday evenings.

The programme was coordinated by **Samir Dhurde**.

For details see Khagol, Iusse No. 91 - July 2013.

Astronomy Outreach by IUCAA

From July 2012, over 200 shows have been very successfully run by many enthusiastic school teachers and volunteers trained at IUCAA. More than 6000 students, in places as far as Sangamner, in Ahmednagar District of Maharashtra, have been exposed to the wonders of the night sky through Mobile Planetarium Programmes of IUCAA astronomy outreach.

A special evening course for amateur Astronomers was arranged during August to December 2012 at the Muktangan Vidnyan Shodhika by **Samir Dhurde**. The aim was to give experienced amateurs an exposure to advanced methods like photoelectric photometry and CCD imaging.

For details see Khagol, Iusse No. 92 - October 2013.

National Science Day Celebrations '12

The National Science Day - 2013 was celebrated with great enthusiasm and efficiency by IUCAA members and visitors. The occasion saw a great response, and around ten thousand people were estimated to have been to IUCAA during the celebrations on 3 different days.

On February 10, twenty one schools participated in the Science quiz, Essay writing, Story writing and Drawing competitions at New English School, Landewadi conducted by IUCAA and organised by the Public Outreach personnel, Vikram Khaire and IUCAA Girawali Observatory staff, Nilesh Pokharkar along with others. On February 16, sixty six schools in Pune participated in another set of inter-school Drawing, Essay, Poetry and Science quiz competitions. The winning students from Pune and Landewadi, received their prizes from Ranjeev Misra. On the National Science Day, February 28, IUCAA, Pune campus was opened to the general public and various programmes were arranged.

This year, special pandals were set up in the Science Park. The Science toys group was responsible for explaining the various experiments developed at the Muktangan Vidnyan Shodhika (MVS), IUCAA, to the crowd.

For details see Khagol, Iusse No. 94 - April 2013.

National Science Day Celebrations

Modern Genesis and the Limits of Cosmic Knowledge

IUCAA hosted the Third Chandra Lecture titled "Modern Genesis and the Limits of Cosmic Knowledge" by Sandra Faber on December 11, 2012 in the Chandrasekhar Auditorium.

Faber is a Professor of Astronomy and Astrophysics at the University of California, and works at the Lick Observatory.

The lecture focused on the effect of the remarkable progress made by astronomers in understanding how galaxies form in our expanding Universe.

For details see Khagol, Iusse No. 93 - January 2013.

Popular Talks

By IUCAA Academic Members at IUCAA and other Institutions

Sanjeev Dhurandhar

The March of Gravity from Newton to Einstein, Jalna Education Society College, Jalna, Vigyan Prasar programme of the DST, August 31, 2012.

Ajit Kembhavi

Our Universe: From Planets to Galaxies, INSPIRE Internship Programme, School of Biotechnology, KIIT University, Bhubaneswar, April 26, 2012.

A Gravitational Wave Detector for India, JVP Astronomy Course, Tilak Smarak Mandir, Pune, May 7, 2012.

LIGO-A Giant Gravitational Wave Detector for India, The Bangalore Science Forum, Bangalore, July 21, 2012.

Our Universe, DST-INSPIRE lecture at G.S. College, Belgaum, November 22, 2012.

Our Universe, INSPIRE lecture at Department of Geology, University of Pune, December 13, 2012.

The Universe and Us, (2 lectures) INSPIRE Science and Astronomy Camp at Birbhum Institute of Engineering and Technology, Suri, Birbhum, January 6-7, 2013.

LIGO-India: A Giant Detector for Gravitational Waves, Rotary Club of Poona Downtown, Pune, August 2, 2012.

Space, BNCA College of Architecture, Pune, February 11, 2013.

Great Optical Telescopes, Science Day, IUCAA, February 28, 2013.

The IUCAA Story, CPS, Kobe University, Japan, February13, 2013.

Ranjev Misra

Black Holes in the Universe, National Workshop in Astronomy, Mednipur College, West Bengal, February 2013.

Black Holes in the Universe, Winter School on Radio Astronomy, NCRA, Pune, December 2012.

Black Holes in the Universe, Workshop on Astronomy, S. B. College, Kerala, December 2012.

Black Holes in the Universe, Providence College, Kozikode, Kerala, October 2012.

Black Holes in the Universe, CUSAT, Kochi, Kerala, December 2012.

Sanjit Mitra

Introduction to Gravitational Wave Astronomy, Shahajiraje Mahavidyalaya, Khatav, January 17, 2013.

Overview of GW Astronomy, Vigyan Prasar to celebrate "Legacy in Science: S. Chandrasekhar, and Srinivasa Ramanujan, Satara, August 6, 2012.

First Light of the Universe: CMB, JyotirVidya Parisanstha (JVP), Pune, June 21, 2012.

Observational Astronomy and Gravitational Waves, INSPIRE program, IIIT, Pune, May 23, 2012.

J. V. Narlikar

Meghnad Saha and the Dawn of Astrophysics, 50th Meghnand Saha Memorial Lecture, Saha Institute of Nuclear Physics, Kolkata, April 5

Cosmic Perspectives on Human Existence, 16th Dr Sarvepalli Radhakrishnan Memorial Lecture under the auspices of the Institute of Advanced Study, Shimla, University of Mumbai, Mumbai, April 10

Searches for Life in the Universe, a lecture organized by the AASTRONOMICA Club, N. M. V. Girls' High School, Pune, April 29

The Three Investigations of the Universe - Mathematics, Physics and Astronomy, 2nd Saturday Lecture Programme, IUCAA, July 14

Brahmandache Teen Anveshak - Ganit, Bhuatikshastra Ani Khagolshastra, (The three investigations of the universe - Mathematics, Physics and Astronomy) (in Marathi), 2nd Saturday Lecture Programme, IUCAA, July 14.

Sanskrit Madhun Mala Milnara Anand, (My enjoyment through Sanskrit literature) (in Marathi), a lecture delivered on the occasion of Sanskrit Day, Sahakar Sadan, Pune, August 1.

Facts and Speculations in Cosmology, Infosys Ltd., Pune, October 11.

Analytical Thinking in Mathematics, Army Public School Kirkee, Pune, November 30.

Bharatiya Vishwavidyalayonki Ki Prachin Parampara, (Ancient tradition of Indian universities) (in Hindi), Banaras Hindu University, Varanasi, December 6.

Tools for Popularising Science and the Scientific Temper, Vigyan Parishad Prayag, Allahabad, December 13.

Searches for Extraterrestrial Life, Lucknow, December 15.

Logical Thinking, C.N. Vidyavihar, Ahmedabad, December 22.

Antaralatil Jeevjantu, (Microbes in space) (in Marathi), Bapurao Deshmukh College of Engineering, Wardha, January 11.

Khagolvidnyan Ka Shikave?, (Why study astronomy?) (in Marathi), Shri Shivaji Education Society, Amravati, January 12.

Popular Talks

By IUCAA Academic Members at IUCAA and other Institutions

Searches for Extraterrestrial Life, a lecture to the students from the D. Y. Patil International School, Mumbai, IUCAA, January 15.

Khagolvidnyan ka shikave? (Why study astronomy?) (in Marathi), a lecture organized by the Jeshtha Nagarik Samajik Pratisthan, Warje, January 20.

Cosmic Illusions, Nehru Planetarium, New Delhi, February 13.

Space Research, Vidyapeeth High School, Kolhapur, February 16.

Science and Society: A Two-way Interaction, N. L. Dalmia Memorial Lecture, Mumbai, February 22.

Khagolshastratil Suras Ani Chamatkarik Goshti, (Amusing and strange tales from astronomy) (in Marathi), Panchavati Utkarsh Seva Sanastha, Pune, February 28.

T. Padmanabhan

Gravity and Cosmos, Sahyadri School, Rajgurunagar, Krishnamurti Foundation India, August 25, 2012.

Fundamental Interactions of Nature, Shri Shivaji Junior College, Lonar, December 10, 2012.

Tarun Souradeep

Cosmic Microwave Glow of Cosmogenesis, KVPY camp, IISER Pune, May 24, 2012.

Unraveling Our Universe, Public talk, JVP, Pune, May 12, 2012.

Radio/ TV Programmes

J. V. Narlikar

Sanvad (in Marathi), All India Radio, July 22, 2012.

Sk. Saiyad Ali

Characterization of foregrounds for redshifted 21-cm HI signal: GMRT 150 MHz Observations

Foreground removal is a major challenge for detecting the redshifted 21-cm neutral hydrogen (HI) signal from the epoch of reionization. Saiyad Ali in collaboration with Somnath Bharadwaj, Abhik Ghosh, Jayaram N. Chengalur, and Jayanti Prasad has characterized the statistical properties of the foreground in four different fields of view using GMRT 150 MHz data. The statistics they use is the two visibility correlation function or equivalently, the multi-frequency angular power spectrum $C_\ell(\Delta\nu)$. The measured multi-frequency angular power spectrum is found to have values in the range 10^4 mK^2 to 2×10^2 mK^2 across $700 \leq \ell \leq 2 \times 10^2$ and $\Delta\nu \leq 2.5$ MHz, which is consistent with model predictions, where point sources are the most dominant foreground component. The measured $C_\ell(\Delta\nu)$ does not show a smooth $\Delta\nu$ dependence and this poses a severe difficulty for foreground removal using polynomial fitting.

The observational data was used to assess point source subtraction. Considering the brightest source ($\sim$ 1 Jy) in each field, they find that the residual artefacts are less than 1.5% in the FIELD I. Considering all the sources in the fields, they find that the bulk of the image is free of artefacts, which being localized to the vicinity of the brightest sources. They have used the FIELD I, which has a rms noise of 1.3 mJy/Beam, to study the properties of the radio source population to a limiting flux of 9 mJy. The differential source count is well fitted with a single power law of slope -1.6. They find that there is no evidence for flattening of the source counts towards lower flux densities as observed in deep radio surveys at higher frequencies, suggesting that source population is dominated by the classical radio-loud Active Galactic Nucleus (AGN).

The diffuse galactic emission is revealed after the point sources are subtracted out from the FIELD I . They find that $C_\ell \propto \ell^{-2.34}$ for $253 \leq \ell \leq 800$, which is characteristic of the galactic synchrotron radiation measured at higher frequencies and larger angular scales. They estimate the fluctuations in the galactic synchrotron emission to be $\sqrt{(\ell\,(\ell+1)\,C_\ell/2\pi)} \simeq 10$K at $\ell = 800$ ($\theta > 10$ arcmin). The measured C_ℓ is dominated by the residual point sources and artefacts at smaller angular scales where $C_\ell \sim 10^2$ mK^2 for $\ell > 800$.

Ambika G.

Amplitude death in complex networks induced by environment

V. Resmi, G. Ambika, R. E. Amritkar, and G. Rangarajan have presented a mechanism for amplitude death in coupled non-linear dynamical systems on a complex network having interactions with a common environment like external system. They have developed a general stability analysis that is valid for any network topology, and obtain the threshold values of coupling constants for the onset of amplitude death. An important outcome of our study is a universal relation between the critical coupling strength and the largest non-zero eigenvalue of the coupling matrix. Our results are fully supported by the detailed numerical analysis for different network topologies.

Evolving networks with bimodal degree distribution

Networks with bimodal degree distribution are most robust to targeted and random attacks. G. Ambika in collaboration with Abhijeet R. Sonawane, A. Bhattacharyay and M. S. Santhanam has presented a model for constructing a network with bimodal degree distribution. The procedure adopted is to add nodes to the network with a probability p and delete the links between nodes with probability $(1 - p)$. They have introduced an additional constraint in the process through an immunity score, which controls the dynamics of the growth process based on the feedback value of the last few time steps. This results in bimodal nature for the degree distribution. They have studied the standard quantities, which characterize the networks, like average path length and clustering coefficient in the context of our growth process, and have shown that the resultant network is in the small world family. It is interesting to note that bimodality in degree distribution is an emergent phenomenon.

Tanwi Bandyopadhyay

Thermodynamics of Gauss-Bonnet brane with modified Chaplygin gas

Tanwi Bandyopadhyay discusses the generalized second law of thermodynamics (GSLT) in the braneworld scenario with induced gravity and curvature correction terms. To explain the present acceleration of the universe, a dark energy component has been chosen on the 3-brane in the form of Modified Chaplygin Gas, together with a

perfect fluid as the dark matter and she shows that the GSLT is valid on the apparent horizon in late time.

Shuvendu Chakraborty

Observational constraints of modified Chaplygin gas in loop quantum cosmology

Shuvendu Chakraborty in collaboration with Ujjal Debnath, and C. Ranjit has considered the FRW universe in loop quantum cosmology (LQC) model, filled with the dark matter (perfect fluid with negligible pressure) and the modified Chaplygin gas (MCG) type dark energy. They have presented the Hubble parameter in terms of the observable parameters Ω_{m0}, Ω_{x0} and H_0 with the redshift and the other parameters like A, B, C, and α. From the Stern data set (12 points), they have obtained the bounds of the arbitrary parameters by minimizing the χ^2-test. The best fit values of the parameters are obtained by 66 %, 90 % and 99 % confidence levels. Next, due to joint analysis with BAO and CMB observations, they have also obtained the bounds of the parameters (B, C) by fixing some other parameters α and A. From the best fit of the distance modulus μ (z) for our theoretical MCG model in LQC, they concluded that the model is in agreement with the Union2 sample data.

Variable G correction for dark energy model in higher dimensional cosmology

Shuvendu Chakraborty, Ujjal Debnath, and M. Jamil have considered N(= 4 + d)-dimensional Einstein field equations, in which 4-dimensional spacetime is described by a Friedmann–Robertson–Walker metric and that of the extra d-dimensions by an Euclidean metric. They have calculated the corrections to statefinder parameters due to variable gravitational constant G in higher dimensional cosmology. They have considered two special cases: whether dark energy and dark matter interact or not. In a universe, where the gravitational constant is dynamic, the variable G-correction to statefinder parameters is inevitable. The statefinder parameters are also obtained for generalized Chaplygin gas including the effect of the variation of G correction.

Subenoy Chakraborty

Is thermodynamics of the universe bounded by event horizon a Bekenstein system?

Subenoy Chakraborty has studied the validity of the first law of thermodynamics for the homogeneous and isotropic FRW model of the universe bounded by event horizon. For the matter field, he has chosen perfect fluid with constant equation of state or holographic dark energy model with event horizon as the IR cut off. The key point is the appropriate choice of the temperature on the event horizon. Instead of choosing the temperature on the event horizon in analogy with that on the apparent horizon, he has started from the very definition of the Hawking temperature in terms of the surface gravity, and evaluated the temperature on the event horizon. This temperature is termed by him as modified Hawking temperature, which coincides with the usual Hawking temperature on the apparent horizon. He has also shown the equivalence of the Einstein field equations and the first law of thermodynamics on the event horizon. Finally, he has concluded that universe bounded by the event horizon may be a Bekenstein system.

A redefinition of Hawking temperature on the event horizon: Thermodynamical equilibrium

Subenoy Chakraborty, in collaboration with his Ph.D. student Subhajit Saha has investigated the validity of the generalized second law of thermodynamics and thermodynamical equilibrium using the recently introduced modified Hawking temperature on the event horizon. They have considered FRW universe and examined the generalized second law of thermodynamics and thermodynamical equilibrium with three examples. They have concluded that from the thermodynamic viewpoint, the universe bounded by the event horizon is more realistic than that by the apparent horizon at least for some examples.

Suresh Chandra

Importance of collisional rates for anomalous absorption in H_2CO molecule

Formaldehyde (H_2CO) is the first organic molecule identified in a number of galactic and extragalactic radio sources through its transition 1_{10} - 1_{11} at 4.830 GHz in absorption. Later on, this transition was found in anomalous absorption. In some cosmic objects, this transition, however, was found in emission and even as a maser radiation.

Since the transition 1_{10} - 1_{11} of ortho-H_2CO is considered as a unique probe of high density gas at low temperature, the study of H_2CO has always been of great importance for astrophysicists as well as for spectroscopists. In view of the availability of better input data required for such investigation, it is worth

while to investigate again about the radiations from ortho-H_2CO.

In the present study, M. Sharma, M.K. Sharma, and Suresh Chandra have investigated anomalous absorption of 1_{10} - 1_{11}, 2_{11} - 2_{12} and 3_{12} - 3_{13} transitions of ortho-H_2CO. The present results are more reliable as compared to those obtained earlier.

Study of possible new ring molecules in cosmic objects

Suresh Chandra, et al. have theoretically investigated a number of cyclic molecules of four kinds: XC_2H_2, XC_2H_4, XC_2, and HXC_2, where X can be C, N, O, Na, Mg, Al, Si, P, S, and Ca, which might be present in interstellar and/or circumstellar space, and calculated their structural and physical data within the rigid rotor harmonic oscillator approximation with the help of a density functional theoretic approach, employing the gradient corrected exchange correlation hybrid functional B3LYP (B^3 Lee, Yang, and Parr) and an extended basis set. At the chosen level of theory, the cyclic geometry was fully optimized for every molecular system. A subsequent frequency analysis shows that the structures are indeed energetically stable configurations. For each of these molecules, they have obtained the energies of atomization D_{at}, the experimentally observable quantities D_0, harmonic vibrational frequencies, infrared absorption coefficients, molecular rotational constants, and electric dipole moments. Finally, the radiative transition probabilities (Einstein A-coefficients) for pure rotational transitions are obtained.

Asis Kumar Chattopadhyay

Independent component analysis for the objective classification of globular clusters of the galaxy NGC 5128

Asis Kumar Chattopadhyay in collaboration with Saptarshi Mondala, and Tanuka Chattopadhyay has shown that Independent Component Analysis (ICA) is closely related to Principal Component Analysis (PCA) and factor analysis. Whereas, ICA finds a set of source data that are mutually independent, PCA finds a set of data that are mutually uncorrelated. The assumption that data from different physical processes are uncorrelated does not always imply the reverse case that uncorrelated data are coming from different physical processes. This is because, lack of correlation is a weaker property than independence.

In the present case, an objective classification of the globular clusters (GCs) of NGC 5128 has been carried out. Components responsible for significant variation have been obtained through both PCA, and ICA, and the classification has been done by K-means clustering. The set of observable parameters includes structural parameters, spectroscopically determined Lick indices and radial velocities from the literature.

They have proposed that GCs of NGC 5128 consist of two groups. One group originated in the original cluster formation event that coincided with the formation of the elliptical galaxy, and the other group emerged from an accreted spiral galaxy. This is unlike the previous result (Chattopadhyay, et al., 2009), which accounts for a third group originating from the accretion of tidally stripped dwarf galaxies.

Surajit Chattopadhyay

Reconstruction of f(T) gravity from the holographic dark energy

Among the different candidates to play the role of dark energy (DE), modified gravity has emerged as offering a possible unification of dark matter (DM) and DE. The present work has been carried out by Surajit Chattopadhyay, and Antonio Pasqua of the University of Trieste. The purpose is to develop a reconstruction scheme for the modified gravity with *f*(*T*) action using holographic energy density. In the framework of the said modified gravity, they have considered the equation of state of the holographic DE (HDE) density given by $\rho_\Lambda = 3c^2 M_p^{\ 2} R_h^{\ -2}$, where R_h represents the future event horizon and *c* is a constant. The scale factor is chosen in power-law form as $a(t) = a_0(t_s - t)^n$. Subsequently, they have developed a reconstruction scheme for modified gravity with *f*(*T*) action.
In this way, they have got a modified gravity action consistent with the HDE scenario. Finally, the stability of the two reconstructed *f*(*T*) models is examined by means of the squared speed of sound.

A study on the modified holographic Ricci dark energy in logarithmic f(T) gravity

Surajit Chattopadhyay, and Antonio Pasqua of the University of Trieste have studied and investigated the behaviour of a recently proposed model of energy density of DE, that is MHRDE, interacting with pressureless DM under the modified gravity model dubbed as logarithmic *f*(*T*) gravity.

The interaction term between DE and DM they have considered has the form $Q = 3H\gamma\rho_m$, where γ is an interaction parameter whose strength is still under debate. They have investigated the behaviour of someb of the important physical quantities, such as the torsion *T*, the Hubble parameter *H*, the EoS parameter ω_{DE}, the energy density of DE ρ_{DE}, and the energy density contribution due to torsion ρ_T as functions of the redshift, *z*.

They have found that the torsion *T*, increases with the redshift *z*, the Hubble parameter *H*, which shows an increasing behaviour as the universe evolves, the EoS parameter ω_{DE}, is always greater than –1, which indicates a quintessence-like behaviour, and the energy densities, ρ_{DE} and ρ_T, both increase going from higher to lower redshifts. This leads us to conclude that: (i) the energy density of DE is increasing with the evolution of the universe when it is interacting with pressureless DM, and (ii) the density contribution due to torsion ρ_T is increasing with the evolution of the universe.

Tanuka Chattopadhyay

A six-parameter space to describe galaxy diversification

The diversification of galaxies is caused by transforming events such as accretion, interaction, or mergers. These explain the formation and evolution of galaxies, which can now be described by many observables. Multivariate analyses are the obvious tools to tackle the available datasets and understand the differences between different kinds of objects. However, depending on the method used, redundancies, incompatibilities, or subjective choices of the parameters can diminish the usefulness of these analyses.

Didier Fraix-Burnet, Tanuka Chattopadhyay, Asis Kumar Chattopadhyay, Emmanuel Davoust, and Mark Thuillard have studied a sample of 424 early-type galaxies described by 25 parameters, 10 of which are Lick indices, to identify the most discriminant parameters, and construct an evolutionary classification of these objects. Four independent statistical methods are used to investigate the discriminant properties of the observables and the partitioning of the 424 galaxies: principal component analysis, K-means cluster analysis, minimum contradiction analysis, and Cladistics. The methods agree in terms of six parameters: central velocity dispersion, disc-to-bulge ratio, effective surface brightness, metallicity, and the line indices NaD and OIII. The partitioning found using these six parameters, when projected onto the fundamental plane, looks very similar to the partitioning obtained previously for a totally different sample and based only on the parameters of the fundamental plane. Two additional groups are identified here, and they are able to provide some more constraints on the assembly history of galaxies within each group thanks to the larger number of parameters. They have also identified another "fundamental plane" with the absolute *K* magnitude, the linear diameter, and the Lick index Hβ and confirmed that the Mg b vs. velocity dispersion correlation is very probably an evolutionary correlation, in addition to several other scaling relations. Finally, they have obtained a classification of galaxies that is based on the transforming processes, which are at the origin of the different groups. By taking into account that the galaxies are evolving into complex objects, and using appropriate tools, they are able to derive an *explanatory* classification of galaxies, based on the physical causes of the diverse properties of galaxies, as opposed to the *descriptive* classifications that are quite common in astrophysics.

Multivariate study of dynamically hot stellar systems: Clues to the origin of ultra compact and ultra faint dwarfs

A multivariate classification has been performed for a large sample of dynamically hot stellar systems comprising globular clusters to giant ellipticals, in quest of the formation theory of ultra compact dwarf galaxies (UCDs). For this, K-means cluster analysis is carried out together with the optimum criterion (Sugar, et al., 2003) with respect to three parameters, logarithm of stellar mass, logarithm of effective radius and stellar mass to light ratio. The present data set has been taken from Misgeld and Hilker (2011). Tanuka Chattopadhyay in collaboration with Pradip Karmakar has found five groups MK1–MK5. These are predominated by giant ellipticals (gEs), faint dwarf ellipticals (dEs), globular clusters (GCs), massive compact objects (UCDs, and nuclei of dE, Ns), and bright dwarf ellipticals respectively. Almost all UCDs are found either in MK3 or MK4. The fraction is roughly 50%–50% between MK3 and MK4. Comparable fraction of UCDs share properties either with normal GCs or with nuclei of dE, N. This adds a quantitative constraint to the long discussed hypothesis that UCDs may be formed either as massive globular clusters or have an origin similar to

nuclei of dwarf galaxies. They have finally found that for our clustering test in mass-size-stellar M/L ratios, ultra faint dwarf galaxies are attributed to globular cluster group (MK3) and not to the dwarf galaxy group (MK2). This highlights that there is no clear cut morphological distinction between extended star clusters and ultra faint dwarfs. These groups are highly consistent with the groups found in a previous classification for a smaller sample and completely different set of parameters.

Partha Chowdhury

Heliospheric modulation of galactic cosmic rays during solar cycle 23

Galactic cosmic rays (GCRs) encounter an outward-moving solar wind with cyclic magnetic-field fluctuation and turbulence. This causes convection and diffusion in the heliosphere. The GCR counts from the ground-based neutron monitor stations show intensity changes that are anti-correlated with the sunspot numbers with lag of a few months. GCRs experience various types of modulation from different solar activity features, and influence space weather and the terrestrial climate. In this work, Partha Chowdhury, K. Kudela and B.N. Dwivedi investigated certain aspects of the GCR modulation at low cut-off rigidity ($Rc \approx 1$ GV) in relation to some solar and geomagnetic indices for the entire solar cycle 23 (1996 – 2008). Further they have studied the GCR modulation during the ascending phase of cycle 23 including its maximum (1996 – 2002) and the descending phase including its minimum (2003 – 2008). It is found that during the descending phase, the GCR recoveries are much faster than those of the solar parameters with negative time-lag. The results are discussed in the light of modulation models, including drift effects and previous results.

A study of the hemispheric asymmetry of sunspot area during solar cycles 23 and 24

Solar activity indices vary over the Sun's disk, and various activity parameters are not considered to be symmetric between the northern and southern hemispheres of the Sun. The north–south asymmetry of different solar indices provides an important clue to understanding sub-photospheric dynamics and solar dynamo action, especially with regard to nonlinear dynamo models. In the present work, Partha Chowdhury, D. P. Choudhary, and Sanjay Gosain have studied the statistical significance of the north–south asymmetry of sunspot areas for the complete solar cycle 23 (1996–2008) and rising branch of cycle 24 (first 45 months). The preferred hemisphere in each year of cycles 23 and 24 has been identified by calculating the probability of hemispheric distribution of sunspot areas. The statistically significant intermediate-term periodicities of the north–south asymmetry of sunspot area data have also been investigated using Lomb–Scargle and wavelet techniques. A number of short and mid-term periods including the best known Rieger one (150–160 days) are detected in cycle 23 and near Rieger-type periods during cycle 24, and most of them are found to be time variable. They have presented their results and discuss their possible explanations with the help of theoretical models.

Mamta Dahiya

Constraining unparticles from top physics at TeVatron

The study of the top quark production and related discrepancies at TeVatron and LHC might hold key to new physics beyond standard model (SM). Both CDF and D0 collaborations have consistently measured values of t tbar production cross-sections through various decay channels, and they are all consistent with the theoretical predictions at NNLO level. On the other hand, the top quark forward-backward asymmetry is observed to be significantly larger than what the SM predicts. The recent measurements of this asymmetry at CDF obtains parton level asymmetry to be 0.296 ± 0.067 for invariant mass $m_{tt} > 450$ GeV with 8.7 fb^{-1} of data in contrast to the NLO QCD prediction of 0.100. If this asymmetry is true, it should indicate the presence of new physics.

Mamta Dahiya in collaboration with Sukanta Dutta and Rashidul Islam has studied and analyzed the recent observations of the top pair production at TeVatron through flavour conserving and flavour violating channels *via* vector and tensor unparticles. The theory of unparticles as a conformally invariant sector that is weakly coupled to the SM particles was proposed by Georgi, which was motivated by Banks-Zaks theory. This assumes the existence of a hidden sector with non-trivial infrared fixed point (e.g., Banks-Zaks type) that interacts with the SM through the exchange of messenger field with a large mass M. In the present work, unparticle sector is considered with the possibility of being a colour singlet or octet and the modified unparticle propagator is used to investigate the contribution of them to the observed forward-backward asymmetry in top pair production and the spin correlation at TeVatron. They have also studied the impact of the flavour violating couplings of unparticles to the third generation quarks on (a)

pair production of same sign tops/antitops at TeVatron, and (b) the partial top decay width for Γ_U ($t \rightarrow u\ U$). They have found that a large region of parameter space is consistent with the measurements of t tbar production cross-section, asymmetry and spin correlation coefficient at TeVatron, and observe that the top decay width measurement constrains the flavour violating coupling of vector unparticles more severely than the same sign top/antitop production at TeVatron. They have also predicted the best point-set in the model parameter space for specific choices of scaling dimension d_U corresponding to χ^2_{min} evaluated using the m spectrum of asymmetry ttbar from the data set of Run II of TeVatron at the integrated luminosity 8.7 fb^{-1}. The χ^2 analysis is performed with two independent parameters of the theory, namely, scaling dimension d_U and coupling for a given unparticle energy scale Λ_U. Their results and analysis are consistent even with unparticle theories having broken scale invariance as long as the infrared cut-off scale is much less than the top pair production threshold.

H. S. Das

Imaging polarimetry of the Bok globule CB56

The measurement of polarization of the background stars in the region of Bok globules is important to study the magnetic field geometry and dust grain characteristics in the globule. These parameters are important for the formation and evolution of dark clouds. H. S. Das in collaboration with D. Paul, and A. K. Sen has made polarimetric observations of Bok globule CB56 in the R-filter from the 2-metre telescope at IUCAA Girawali Observatory (IGO). The observations were carried out on 2011 March 4th and 5th. The CCD images obtained from the instrument (IFOSC) were analyzed, to produce the polarization map of the Bok globule CB56.

Sudipta Das

Can neutrino viscosity drive the late time cosmic acceleration?

In this work Sudipta Das, and Narayan Banerjee have considered a well known sector of matter, namely the neutrino distribution, as a candidate for the dark energy The motivation comes from particle physics, where it is considered that neutrinos are normally in the sector, which 'feels' the existence of dark energy, and cannot really solve the problem by itself, i.e., without a quintessence potential. In the present work, they treat the neutrinos completely classically, and show that bulk viscous stresses in the distribution can indeed do the trick. The advantage of the neutrinos is that they are real objects, the method of detection being quite well conceived. They employ a two-component non-interacting matter sector, one is the normal cold dark matter and the other being a neutrino distribution. The latter is endowed with bulk viscosity, which produces a negative stress. It is shown that a very simple accelerated model can be constructed from this. It has been shown that a sufficient bulk viscous stress in the neutrino distribution can potentially serve the purpose of a dark energy. This does not require any ill-motivated scalar potential or an otherwise unwarranted modification of general relativity. Although, the neutrino viscosity can, in fact, give a wide range of accelerating models, they have only discussed the effective Λ CDM model. But some other examples have also been mentioned, which leaves a possibility of finding many other solutions, which are favoured from the consideration of stability as well as that of observational bounds.

Ujjal Debnath

Dynamical study of DBI-essence in loop quantum cosmology and braneworld model

Jhumpa Bhadra, and Ujjal Debnath have studied homogeneous isotropic FRW model having dynamical dark energy DBI-essence with scalar field. Existence of cosmological scaling solutions restricts the Lagrangian of the scalar field ϕ. Choosing $p = X\,G\left(X\,e^{\lambda\phi}\right)$, where $X = -\frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi$ with G is any function of $X\,e^{\lambda\phi}$ and defining some suitable transformations, we have constructed the dynamical system in different gravity: (i) Loop Quantum Cosmology (LQC), (ii) DGP BraneWorld, and (iii) RS-II Brane World. They have investigated stability of this dynamical system around the critical point for three gravity models and investigated the scalar field dominated attractor solution in support of accelerated universe. Roles of physical parameters have also been analyzed during accelerating phase of the universe.

Broja Gopal Dutta

The evolution of time lag variability associated with quasi-periodic oscillations in galactic black hole sources

The complex behaviour of Fourier phase lags associated to quasi-Periodic oscillations is one of the most important observational effects of galactic black hole sources. This temporal property can diagnose the dynamics of accretion flow around the black holes. GX 339-4 is one of the best studied X-ray transient galactic black hole candidates over a wide range of wavelengths. Broja Gopal Dutta, Tomaso Belloni (INAF-Osservatorio Astronomico di Brera, Italy), and Sara Motta (Universitá dell'Insubria, Como, Italy) have analyzed RXTE/PCA data of the black hole source GX 339-4 for the 2002/2003, 2004, 2007 and 2010 outbursts and XTE J1550-564 for the 1998 outburst. They have measured the average time/phase lags between soft (2-5 keV) and hard (5-13 keV) photons at the QPO centroid frequency with a width equal to the FWHM of the QPO peak. They have found positive time lags for GX 339-4 for all the outbursts, which indicate that the hard photons lag the soft one. The evolution of time lag is correlated with the QPO frequency for all the outbursts and suggests towards a common evolution scenario of black hole transients GX 339-4 through their outbursts. But this behaviour is remarkably opposite to what they observed in XTE J1550-564 and GRS 1915+105. The smoothness of the variation of phase lag/time lag at QPO frequency with time over a period of weeks directly supports the view that it is due to the drifting of the Comptonizing region.

Sarbari Guha and Subenoy Chakraborty

Particle motion in the field of a five-dimensional charged black hole

Sarbari Guha, and Subenoy Chakraborty, with their student (Pinaki Bhattacharya) have investigated the geodesics of neutral particles near a five-dimensional charged black hole using a comparative approach. The effective potential method is used to determine the location of the horizons, and to study radial and circular trajectories. This also helps one to analyze the stability of radial and circular orbits. The radii of the innermost stable circular orbits was determined and it was found that although the circular orbits of massive particles may have up to eight possible values of specific radius, the photons will only have two distinct values for the specific radii of circular trajectories. Finally, the dynamical systems analysis is used to determine the critical points and the nature of the trajectories for the time like and null geodesics.

Sarbari Guha

Geodesic motions near a five-dimensional Reissner–Nordström anti-de Sitter black hole

Sarbari Guha, and Pinaki Bhattacharya have studied the geodesics of neutral particles near a non-rotating, charged five-dimensional Reissner-Nordström anti-de Sitter black hole using the effective potential analysis and the dynamical systems analysis. The effective potential analysis is used to determine the location of the horizon, and to study radial and circular trajectories. The dynamical systems method is used to determine the stability and the fixed points of the phase trajectories.

Naseer Iqbal

Correlation functions for extended mass galaxy clusters

The phenomenon of clustering of galaxies on the basis of correlation functions in an expanding universe is studied by using equation of state, taking gravitational interaction between galaxies of extended nature into consideration. The partial differential equation for the extended mass structures of a two-point correlation function developed earlier by Iqbal, Ahmad and Khan (2006) is studied on the basis of assigned boundary conditions. The solution for the correlation function for extended structures satisfies the basic boundary conditions, which seem to be sufficient for understanding the phenomena, and provides a new insight into the gravitational clustering problem for extended mass structures. This work has been done by Naseer Iqbal in collaboration with A. Naveel, H. Mubashir, and M. Tabasum.

Indulekha K.

The role of gas dynamical friction in embedded clusters

Gas dynamical friction has been considered before as a mechanism for contracting embedded stellar clusters, by dissipating their energy. This would locally raise the SFE, which might then allow bound clusters to form. Noticing that dynamical friction is inherently capable of producing mass segregation, Indulekha K. has made a general analysis of some of the details and implications of such a scenario, vis-a-vis observations, for low SFEs. Making analytical approximations, she has obtained a boundary value for the density of a star forming clump of given mass, such that, stellar clusters born in clumps which have densities higher than this, could emerge bound after

gas loss. For a clump of given mass and density, a critical mass such that, sub-condensations with larger masses than this could suffer significant segregation within the clump.

Azad Sreedharan and Indulekha K. have looked at the SFR and the location in the UV -Optical Colour - Colour space, of the BCD galaxies of the local volume. They have found that the mean SFR is lower than that obtained for larger samples comprising galaxies from distances that are larger, and the location in the CCM diagram is different from that of normal galaxies as well as local dwarfs. This could have implications for the use of the CCM diagram in determining photometric redshifts. They are exploring this sample further.

Gas dynamical friction on prestellar clumps and open clusters

Stars are seen to form in a clustered mode within molecular clouds in galaxies. While most of these clusters emerge as unbound associations, after the system loses gas due to momentum input from the stars that are born, a few percent of them emerge bound as open clusters. Since only less than ten percent of the mass of a cloud gets converted to stars, the formation of open clusters has been a puzzle. Observations have shown that some clusters can show significant mass segregation at a dynamically young age itself. Also, the brown dwarf stars associated with a cluster are seen distributed in a wider region compared to the core. Here, K. Indulekha, K. Ambili, and C.J. Jog have examined whether gas dynamical friction, operating on pre-stellar objects in the embedded phase, holds the key to solving some of the puzzles associated with open clusters.

Deepak Jain

An interacting model for the cosmological dark sector

Deepak Jain along with F. E. M. Costa, and J.S. Alcaniz discusses the new cosmological interacting model of vacuum decay. In this scenario, the attenuated dilution of cold dark matter is described by an arbitrary function of scale factor, f(a). They have studied the thermodynamic behaviour of this decaying vacuum model. Using SNe Ia and CMB/BAO data, they have obtained constraints on the interacting function.

Cosmic distance duality and cosmic transparency

Deepak Jain along with Sanjay Jhingan, and Remya Nair has studied the validity of cosmic distance duality relation (DD). The DD relation relates the angular diameter distance and the luminosity distance. In this work, they have explored the possibility of violation of DD relation due to violation of photon number conservation. Assuming that there is some photon absorption in the universe, they have found that the parameter, which characterizes the absorption is negative. It implies that supernovae are brighter than expected from BAO measurement.

Kanti Jotania

Anisotropic Bianchi type-I massive string cosmological models in general relativity

A new class of LRS Bianchi type VI0 cosmological models with free gravitational fields, and a variable cosmological term is investigated in the presence of perfect fluid as well as bulk viscous fluid. To get the deterministic solution, Kanti Jotania in collaboration with Anirudh Pradhan, and Shyam Sundar Kumhar has imposed the two different conditions over the free gravitational fields.

In the first case they have considered the free gravitational field as magnetic type, whereas in second case, `gravitational wrench' of unit `pitch' is supposed to be present in free gravitational field. The viscosity coefficient of bulk viscous fluid is assumed to be a power function of mass density. The effect of bulk viscous fluid distribution in the universe is compared with perfect fluid model. The cosmological constant is found to be a positive decreasing function of time, which is corroborated by results from recent observations. The physical and geometric aspects of the models are discussed.

Finch-Skea star in (2+1) dimensions

The Bañados, et al. solution corresponding to the exterior spacetime of a black hole in *(*2 + 1*)* dimensions has been found to be very useful to understand various aspects relating to the gravitational field of a black hole. Ayan Banerjee, Farook Rahaman, Kanti Jotania, Ranjan Sharma, and Indrani Karar have presented here a class of interior solutions corresponding to the BTZ exterior by making use of a model presented by Finch and Skea, which was earlier found to be relevant for the description realistic stars in *(*3+1*)* dimensions. They have shown physical viability of the model in lower dimensions as well.

Mehedi Kalam

Central density dependent anisotropic compact stars

Stars can be treated as self-gravitating fluid. In this connection, Mehedi Kalam, Farook Rahaman, Sk. M. Hossein, and Saibal Ray have proposed a model for an anisotropic star under the relativistic framework of Krori-Barua spacetime. It is shown that the solutions are regular and singularity free. The uniqueness of the model is that the interior physical properties of the star solely depend on the central density of the matter distribution.

Anisotropic compact stars with variable cosmological constant

Now a days, the small value of the cosmological constant and its ability to accelerate the expansion of the universe is of great interest. Mehedi Kalam, and his collaborators S.M. Hossein, Farook Rahaman, J. Naskar, and Saibal Ray have studied the possibility of forming of anisotropic compact stars from dark energy (cosmological constant) by taking the analytical solution of Krori and Barua metric. They have taken the radial dependence cosmological constant, and checked all the regularity conditions, TOV equations, stability, and surface redshift of the compact stars, and concluded that their model is very much compatible to it.

Nagendra Kumar

Surface Waves along the Martian Ionopause

Observational findings indicate that wave-like structures and instabilities arise at the Martian ionopause. Nagendra Kumar and collaborators (P. Chmielewski and K. Murawski) have studied the behaviour of surface waves propagating along the ionopause of the planet Mars and derived the onset criteria for unstable Kelvin-Helmholtz modes, and negative energy waves at the Martian ionopause. Growth rate of unstable Kelvin-Helmholtz mode decreases with wavelength. The backward propagating waves became negative energy waves for the ionosheath velocity higher than critical velocity. It is found that short wavelength surface waves propagating along the Martian ionopause are less dispersive than long waves.

Density structure and analysis of an active region observed with EUV imaging spectrometer on Hinode

The Extreme Ultraviolet Imaging Spectrometer (EIS) on Hinode observes solar corona and upper transition region emission lines in the wavelength ranges 170 – 210 Å and 250 – 290 Å. EIS produces high resolution spectra that can be combined via rasters into monochromatic images of solar structures, such as active regions. Nagendra Kumara and collaborators (P. Kumar, B. Singh, and R. Chauhan) have adopted a set of object oriented IDL routines that enables to search, download and analyse solar data from the EUV imaging spectrometer on-board Hinode. Using spectral observations performed over an active region on October 14, 2011 with the EIS spectrometer on Hinode, they have studied the density structure at different temperatures. To analyze the density structure, they have compared density ratios of a series of iron lines and Mg lines observed by the Hinode/EUV Imaging Spectrometer. It is found that the electron density in the observed active region (AR 11314) varies from $10^{8.5}$ -10^{12} cm^{-3}. The highest densities are found in bright, and compact areas. Maps of intensities, velocities, and electron densities derived from these observations are presented and discussed. The density distribution and plasma temperature within solar active region, illustrate the power of EIS and Solarsoft IDL for solar plasma diagnostics. These powerful spectroscopic diagnostics will allow identification and characterization of magnetic reconnection and wave propagation processes in the upper solar atmosphere.

Suresh Kumar

Bianchi type-II models in the presence of perfect fluid and dark energy

Spatially homogeneous but totally anisotropic and non-flat Bianchi type II cosmological model has been studied in general relativity in the presence of two minimally interacting fluids; a perfect fluid as the matter fluid, and a hypothetical anisotropic fluid as the dark energy fluid. The Einstein's field equations have been solved by applying two kinematical ansatze, which have assumed the variation law for the mean Hubble parameter that yields a constant value of deceleration parameter, and one of the components of the shear tensor has been considered proportional to the mean Hubble parameter. Suresh Kumar, and Ozgur Akarsu have particularly dwelled on the accelerating models with non-divergent expansion anisotropy as the universe evolves. Yielding anisotropic pressure, the fluid they consider in the context of dark energy, can produce results that can be produced in the presence of isotropic fluid in accordance with the Lambda CDM cosmology. However, the derived model gives additional opportunities by being able to allow kinematics that cannot be produced in the presence of fluids that

yield only isotropic pressure. They have obtained well behaving cases, where the anisotropy of the expansion and the anisotropy of the fluid converge to finite values (including zero) in the late universe. They have also showed that although the metric they have considered is totally anisotropic, the anisotropy of the dark energy is constrained to be axially symmetric, as long as the overall energy momentum tensor possesses zero shear stress.

V.C. Kuriakose

Late-time tails of fields around Schwarzschild black hole surrounded by quintessence

Black holes are among the simplest objects in the universe as they can be fully described by merely three quantities, viz., mass, charge and angular momentum. The evolution of perturbations in the black hole spacetimes involves three stages, the first one is an initial response, determined by the particular form of the original wave field followed by a region dominated by damped oscillation of the field, called quasi-normal modes (QNMs), which depend entirely on the background black hole spacetimes. The QNMs play an important role in almost all astrophysical processes involving black holes, and the spectra of QNMs are expected to be detected by the future gravitational wave detectors. At late-times, the QNMs are suppressed by the so called *tail* form of decay. This comprises the last stage of evolution, and is an interesting topic of study, since it reveals the actual physical mechanism, by which a perturbed black hole sheds its hairs. Assuming a quintessence model of dark energy as the cause for the observed accelerated expansion of the universe, Nijo Varghese and Kuriakose have studied the evolution of scalar, electromagnetic and gravitational fields around spherically symmetric black hole surrounded by quintessence with special interest on the late-time behaviour. It is known that for a field with spin s, any radiative multipole ($l \geq s$) gets radiated away completely, in the late stage of collapse and that at late times, the field dies out with a power-law tail. They have found that as the value of the quintessential parameter decreases, the late-time decay of $l = 0$ mode of scalar field gives up the power-law form of decay, relaxing to a constant residual field, and for large values of the quintessence parameter, the $l > s$ modes of scalar, electromagnetic and gravitational perturbations, still show a power-law decay, having a slower decay rate than the corresponding Schwarzschild case. As the value of quintessence parameter decreases, the power-law decay gives way to an exponential decay.

Thermodynamics and spectroscopy of Schwarzschild black hole surrounded by quintessence

R. Tharanath and V.C. Kuriakose have investigated the effect of quintessence on the thermodynamic and spectroscopic properties of Schwarzschild black hole. They have derived the expressions for mass, density of quintessence, temperature and heat capacity of the black hole surrounded by quintessence in terms of its entropy. Since entropy is the crucial factor, which comes in the spectroscopic analysis, they could define the variations of the above given parameters in terms of entropy. And in the mass-entropy graph, the idea of area law is justified. They have studied the variation of quintessence density parameter with respect to entropy and found that density decreases with entropy. Heat capacity of the black hole shows a discontinuity, which implies that the black hole may undergo a phase transition.

Badam Singh Kushvah

Periodic orbits in the generalized photogravitational Chermnykh-like problem with power-law profile

The orbits about Lagrangian equilibrium points are important for scientific investigations. Since, a number of space missions have been completed and some are being proposed by various space agencies. In the light of this, Badam Singh Kushvah in collaboration with Ram Kishor has considered a more realistic model in which a disk, with power-law density profile, is rotating around the common centre of mass of the system. Then, they have analyzed the periodic motion in the neighbourhood of Lagrangian equilibrium points for the value of mass parameter $0 < \mu \leq 12$. Periodic orbits of the infinitesimal mass in the vicinity of equilibrium are studied analytically and numerically. In spite of the periodic orbits, they have found some other kind of orbits like hyperbolic, asymptotic, etc. The effects of radiation factor as well as oblateness coefficients on the motion of infinitesimal mass in the neighbourhood of equilibrium points are also examined. The stability criteria of the orbits is examined with the help of Poincaré surfaces of section (PSS), and found that stability regions depend on the Jacobi constant as well as other parameters.

Equilibrium points and zero velocity surfaces in the restricted four-body problem with solar wind drag

Badam Singh Kushvah in collaboration with Reena Kumari has analyzed the motion of an infinitesimal mass in the restricted four-body problem with solar

wind drag. It is assumed that the forces which govern the motion are mutual gravitational attractions of the primaries, radiation pressure and solar wind drag. They have derived the equations of motion and found the Jacobi integral, zero velocity surfaces, and particular solutions of the system. It is found that three collinear points are real when the radiation factor $0 < \beta < 0.1$, whereas only one real point is obtained when $0.125 < \beta < 0.2$. The stability property of the system is examined with the help of Poincaré surface of section (PSS) and Lyapunov characteristic exponents (LCEs). It is found that in the presence of drag forces, LCE is negative for a specific initial condition, and hence, the corresponding trajectory is regular whereas the regular islands in the PSS are expanded.

Manzoor A. Malik

Thermodynamic fluctuations as a probe for the study of gravitational galaxy clustering

Manzoor A. Malik, Farooq Ahmad, and Hameeda derived the physical form of the clustering parameter (a measure of gravitational clustering) on rigorous mathematical grounds from two approaches. One result is a direct consequence of the solution of a differential equation and the other follows from the calculation of thermodynamic metric elements using Riemannian geometric approach. Both these approaches lead to the same physical form of the clustering parameter as hypothesized in the gravitational quasi-equilibrium distribution (GQED) theory. These results lend a strong support to GQED theory, wherein the physical form of the clustering parameter is hypothesized. The results are consistent with the inferences drawn from the statistical mechanical description of gravitational galaxy clustering, studied as a cosmological many-body problem.

Soumen Mondal

The origin of the most probable 3:2 twin-peak quasi-periodic oscillations (QPOs) frequency ratio in the micro-quasars

Soumen Mondal, and C. S. Choi have noticed that within a few gravitational radii, where the X-ray emission originates, the perturbations in the accretion disk may excite high frequency quasi-periodic oscillations (QPOs). The vertical and the radial disk oscillations frequencies, due to the perturbation, exhibit a 3:2 twin-peak ratio, which is most commonly detected in the X-ray fluxes in many Galactic Micro-quasars. The high frequency QPOs happen most likely if the oscillations occur very close to the centre. They have further noticed that the perturbations originate in the neighbourhood of the shock transition or from a discontinuity in the disk, and could be the possible mechanism to excite the high frequency QPOs. The shocks are more probable in the X-ray emission region, and may form very close to the horizon, particularly, when the black hole spin is very high. Studying the shock locations as a function of the black hole spin in a fully general relativistic inviscid transonic accretion flows, they have calculated the disk oscillation frequencies and their ratios in that perturbed orbit. Further, from the spin dependence, they have estimated the `most probable spin interval' in the micro-quasars by considering the *1/M* scaling hypothesis in high frequency QPOs. Finally, they have found the spin (*a*) interval, which lies for *XTE 1550 - 564*, at $a \sim (0.89 - 0.99)$, for the *GRO 1655 - 40*, at $a \sim (0.96 - 0.99)$, and for the *GRS 1915+105*, at $a \sim (0.74 – 0.999)$. The uncertainty in the mass analysis corresponds to the above spin intervals.

P. N. Pandita

Neutralino and Chargino masses and related sum rules beyond MSSM

K. Huitu, P. N. Pandita, and Paavo Tiitola have studied the implications of dimension five operators involving Higgs chiral superfields for the masses of neutralinos and charginos in the minimal supersymmetric standard model (MSSM). These operators can arise from additional interactions beyond those of MSSM involving new degrees of freedom at or above the TeV scale. In addition to the masses of the neutralinos and charginos, they have studied the sum rules involving the masses and squared masses of these particles for different gaugino mass patterns in the presence of dimension five operators. They have derived a relation for the higgsino mixing mass parameter and tan beta.

Radiative production of lightest neutralinos in electron - positron collisions in supersymmetric Grand Unified Models

P. N. Pandita, and Monalisa Patra have studied the production of the lightest neutralinos in the radiative process $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0\gamma$ in supersymmetric models with grand unification. They have considered a model, wherein the standard model gauge group $SU(3)_c \times SU(2)_L \times U(1)_Y$ is unified into the grand unified gauge groups *SU(5)*, or *SO(10)*. Further, they have studied this process at energies that may be

accessible at a future International Linear Collider and compared and contrasted the dependence of the signal cross section on the grand unified gauge group, and different representations, into which the standard model gauge group is unified. In addition, a detailed study of the background to the signal process corning from the standard model radiative neutrino production $e^-e^- \to \nu\bar{\nu}\gamma$, as well as from the radiative production of the scalar partners of the neutrinos (sneutrinos) $e^-e^- \to \tilde{\nu}\tilde{\nu}^*\gamma$. The latter can be a major supersymmetric background to the radiative production of neutralinos when the sneutrinos decay invisibly. It is likely that the radiative production of the lightest neutralinos may be a viable channel to study supersymmetric partners of the standard model particles at the first stage of an International Linear Collider, where heavier sparticles may be too heavy to be produced in pairs.

M.K. Patil

Investigation of X-ray cavities in the cooling flow system Abell 1991

M.K. Patil, M.B. Pandge, N.D. Vagshette, and S.S. Sonkamble have presented results based on the systematic analysis of *Chandra* archive data on the X-ray bright Abell Richness class-I type cluster Abell 1991 with an objective to investigate properties of the X-ray cavities hosted by this system. The unsharp masked image as well as 2-d β model subtracted residual image of Abell 1991 reveals a pair of X-ray cavities and a region of excess emission in the central ~12 kpc region. Both the cavities are of ellipsoidal shape and exhibit an order of magnitude deficiency in the X-ray surface brightness compared to that in the undisturbed regions. Spectral analysis of X-ray photons extracted from the cavities lead to the temperature values equal to $1.77^{+0.19}_{-0.12}$ keV for N-cavity and $1.53^{+0.05}_{-0.06}$ keV for S-cavity, while that for the excess X-ray emission region is found to be equal to $2.06^{+0.12}_{-0.07}$ keV. Radial temperature profile derived for Abell 1991 reveals a positive temperature gradient, reaching to a maximum of 2.63 keV at ~76 kpc and then declines in outward direction. 0.5–2.0 keV soft band image of the central 15" region of Abell 1991 reveals relatively cooler three different knots like features that are about 10" off the Xray peak of the cluster. Total power of the cavities is found to be equal to $\sim 8.64\times10^{43}$ erg s−1, while the X-ray luminosity within the cooling radius is found to be 6.04×10^{43} erg s−1, comparison of which implies that the mechanical energy released by the central AGN outburst is sufficient to balance the radiative loss.

Spectral properties of XRBs in dusty early-type galaxies

M.K. Patil in collaboration with N.D. Vagshette and M.B. Pandge has presented spectral properties of a total of 996 discrete X-ray sources resolved in a sample of 23 dusty early-type galaxies selected from different environments. The combined X-ray luminosity function of all the 996 sources within the optical D25 of the sample galaxies is well described by a broken power law with a break at 2.71 x 10^{38} erg s^{-1} and is close to the Eddington limit for a 1.4M○sun neutron star. Out of the 996, about 63% of the sources have their X-ray luminosities in the range between few x 10^{37} to 2.0 x 10^{39} erg s^{-1} and are like normal LMXBs; about 15–20% with luminosities < few x 10^{37} erg s^{-1} are either super-soft or very-soft sources; while the remaining represents ULXs, HMXBs or unrelated heavily absorbed harder sources. More XRBs have been detected in the galaxies from isolated regions, while those from rich groups and clusters host very few sources. The X-ray colour-colour plot for these sources has enabled us to classify them as SNRs, LMXBs, HMXBs and heavily absorbed AGNs. The composite X-ray spectra of the resolved sources within D25 region of each of the galaxies are best represented by a power law with the average photon spectral index close to 1.65. The contribution of the resolved sources to the total X-ray luminosity of their host is found to vary greatly, in the sense that, in galaxies like NGC 3379, the XRB contribution is about 81%, while for NGC 5846, it is only 2%. A correlation has been evidenced between the cumulative X-ray luminosity of the resolved sources against the star formation rate and the Ks band luminosity of the target galaxies indicating their primordial origin.

B. C. Paul

Relativistic models of a class of compact objects

Considering Vaidya-Tikekar metric, a class of relativistic solutions of the Einstein-Maxwell equations for a charged static fluid sphere has been obtained. The physical 3-space (t = constant) here is described by pseudo-spheroidal geometry. The relativistic solution for the theory is used to obtain models for charged compact objects, thereafter a qualitative analysis of the physical aspects of compact objects has been done. The dependence of some of the properties of a superdense star on the parameters of the three geometry is explored. Rumi

Deb, B. C. Paul and R. Tikekar have found that the spheroidicity parameter (λ), plays an important role for determining the properties of a compact object. A non-linear equation of state is required to describe a charged compact object with pseudo-spheroidal geometry, which they have shown for known masses of compact objects. They also have noted that the size of a static compact charged star is more than that of a static compact star without charge.

Modified Chaplygin gas in Horava-Lifshitz gravity and constraints on its B –parameter

Cosmological models are explored in the Horava-Lifshitz gravity by considering modified Chaplygin gas. Observational constraints on the EoS parameters are obtained using H(z) - z (OHD) data, BAO peak parameter and CMB data. This work has been carried out by B. C. Paul in collaboration with P. Thakur and A. Saha.

Ninan Sajeeth Philip

Surveying the variable universe

N.S Philip along with his research students Sheelu Abrahama, and Arun Kumar have been trying to develop automated tools for the identification and classification of variable sources detected by the CRTS (Catalina Real-time Transient Survey) in collaboration with Ashish Mahabal and his colleagues at Caltech. With support from the IUSSTF, a joint research centre ClassACT has been set up for this purpose with Ajit Kembhavi as the Indian PI and Ashish Mahabal as the US PI. A software Annotator module was developed and is now available in the CRTS website with the name 'DBNN annotator'. This annotator is capable of predicting the probable nature of a newly identified variable source based on inputs gathered from previous observations and other surveys. It can also be used to generate alerts for immediate follow up observation of interesting events such as a supernova that faints off very fast.

The CRTS continuously photograph the sky and search for objects that vary their magnitudes between observations. Objects that vary in magnitude beyond a certain threshold generates an alert and various annotators search existing survey database to gather available information about the object in that region of the sky. This information goes as input to the DBNN annotator. For example, if the transient is detected near a galaxy, it is likely to be a supernova or if there exist radio or x-ray detections in the same region, it could be some other source. Detecting the exact nature of the object based on this type of inputs is non-trivial and the DBNN annotator has the ability to learn as it encounter new objects with the help of a real-time learning algorithm. The algorithm works as follows: When a prediction is made by the annotator, some follow-up work is done and the nature of the object is confirmed. If the confirmed nature is different from the prediction, the annotator will try to learn how to differentiate similar objects without increasing the overall error in its predictions. There is always a limiting accuracy by which such qualitative inputs can make reliable predictions.

The CRTS, because it is continuously surveying the sky, also generates the light-curves of all the objects they detect. The nature of the light-curves can give quantitative information about the nature of the object. The group is presently working on methods to convert the information content in light-curves into numbers that can be used by the DBNN annotator for more reliable classification of the variable sources. Sheelu Abraham, and Arun Kumar will be visiting Caltech from June 2013 to develop tools for the light-curve based classification of CRTS detections.

Anirudh Pradhan

Accelerating dark energy models with anisotropic fluid in Bianchi type-VI0 spacetime

Motivated by the increasing evidence for the need of a geometry that resembles Bianchi morphology to explain the observed anisotropy in the WMAP data, Anirudh Pradhan has revealed some features of Bianchi type - VI0 universes in the presence of a fluid that has an anisotropic equation of state (EoS) parameter in general relativity. He has presented two accelerating dark energy (DE) models with an anisotropic fluid in Bianchi type - VI0 spacetime. To ensure a deterministic solution, he has chosen the scale factor a(t) = √(tnet), which yields a time-dependent deceleration parameter, representing a class of models, which generates a transition of the universe from the early decelerating phase to the recent accelerating phase. Under suitable conditions, the anisotropic models approach an isotropic scenario. The EoS for DE, ω is found to be time-dependent and its existing range for derived models is in good agreement with data from recent observations of type Ia supernovae (SNe Ia), SNe Ia data combined with cosmic microwave background (CMB) anisotropy and galaxy clustering statistics, as well as the latest combination of cosmological data sets coming from CMB anisotropies, luminosity distances of high redshift SNe Ia and galaxy clustering. For different values of n, we can generate

a class of physically viable DE models. The cosmological constant is found to be a positive decreasing function of time and it approaches a small positive value at late time (i.e., the present epoch), which is corroborated by results from recent SN Ia observations. He also has observed that the solutions are stable. The physical and geometric aspects of both models are also discussed in detail.

Interacting two-fluid viscous dark energy models in non-flat universe

Anirudh Pradhan in collaboration with H. Amirhashchi, and H. Zainuddin has studied the evolution of the dark energy parameter within the scope of a spatially non-flat and isotropic Friedmann-Robertson-Walker model filled with barotropic fluid and bulk viscous stresses. They have obtained cosmological solutions that do not have a Big Rip singularity, and concluded that in both non-interacting and interacting cases, the non-flat open universe crosses the phantom region. They have found that during the evolution of the universe, the equation of state for dark energy, ω_D changes from ω_{eff} $D > -1$ to ω_{eff} $D < -1$, which is consistent with recent observations.

Farook Rahaman

Anisotropic universe models in f(T) gravity

Farook Rahaman in collaboration with M.E. Rodrigues, M.J.S. Houndjo and D. Saez-Gomez has investigated the cosmological reconstruction in anisotropic universe for both homogeneous and inhomogeneous content of the universe. Special attention is attached to three interesting cases: Bianchi type-I, Bianchi type-III, and Kantowski-Sachs metrics. The de Sitter, power-law and general exponential solutions are assumed for the scale factor in each spatial direction and the corresponding cosmological models are reconstructed. Moreover, for the general exponential solutions, from which the de Sitter and power-law solutions may be obtained, they have obtained models, which reproduce the early universe, assumed as the inflation, and the late time accelerated expanding universe. The models obtained for the late time universe are consistent with a known result in literature, where a power-law type correction in T is added to a power-law type of f(T) for guaranteeing the avoidance of the Big Rip and the Big Freeze.

Quark matter as dark matter in modelling galactic halo

Considering the flat rotation curves as input, and treating the matter content in the galactic halo region as quark matter, Farook Rahaman, P.K.F. Kuhfittig, R. Amin, G. Mandal, Saibal Ray, and N. Islam have found out a background spacetime metric for the region of the galactic halo. They have obtained fairly general conditions that ensure that gravity in the halo region is attractive. They also have investigated the stability of circular orbits, along with a different role for quark matter. Bag-model quark matter meeting these conditions, therefore, provides a suitable model for dark matter.

Shantanu Rastogi

Combined experimental and theoretical study on the infrared spectroscopy of PAH derivatives 2- and 9-vinylanthracene

A. Maurya, Shantanu Rastogi, G. Rouillé, F. Huisken, and Th. Henning have proposed to evaluate the contribution of polycyclic aromatic hydrocarbon (PAH) molecules that carry side groups to the mid-infrared emission spectra. Within this framework, the IR absorption spectra of 2-vinylanthracene (2-VA) and 9-vinylanthracene (9-VA) were measured in Ar matrices at 12 K and in CsI and polyethylene pellets at room temperature. The laboratory spectra were analyzed with the support of simulations based on the density functional theory. For each PAH molecule, eight IR spectra were computed by combining the B3LYP functional with as many different basis sets, namely, 4-31G, 4-31G(d), 6-31G, 6-311G, 6-31G(d), 6-31G(d,p), 6-31+G(d,p), and 6-31++G(d,p). The comparison of the theoretical spectra with the laboratory data allowed us to determine the most suitable combinations for modelling the IR spectra of neutral PAH molecules that carry a vinyl side group. It was concluded from the examples of 2- and 9-VA that the optimum basis set is 6-31G, unless a steric interaction has to be taken into account, in which case the optimum basis set is 6-31G(d). Thus, in the presence of such an interaction, the use of d-type polarization functions is recommended. They have discussed the possibility for neutral vinyl-substituted PAHs to contribute to the mid-infrared emission spectra and found that their specific features do not match with the mid-infrared aromatic emission bands.

Modelling anomalous/non-CCM extinction using nanodiamonds

R.K. Rai, and Shantanu Rastogi have reported that the modelling of extinction along anomalous/non-Cardelli, Clayton and Mathis sightlines, which are

characterized by a broad 217.5-nm bump and steep far-ultraviolet (FUV) rise. The extinction along these sightlines, namely HD 210121, HD 204827, HD 29647, and HD 62542, is difficult to reproduce using standard silicate and graphite grains. A very good match with the observed extinction is obtained by considering a nano-diamond component as part of the carbonaceous matter. Most of these sightlines are rich in carbon and are invariably backed by a young hot stellar object. Nano-diamond is taken as a core within amorphous carbon and graphite. These core-mantle particles, taken as additional components along with graphite and silicates, lead to a reduction in the silicate requirement. The abundance of carbonaceous matter is not affected, as a very small fraction of nano-diamond is required. Extinction along sightlines that show steep FUV is also reported, demonstrating the importance of the nano-diamond component in all such region

C. D. Ravikumar

Long term optical variability of X-ray point sources in early type galaxies

C. D. Ravikumar, and V. Jithesh along with their collaborators (Ranjeev Misra, Swara Ravindranath, Gulab C Dewangan, Shalima P, Jeena. K, and B. R. S. Babu), have studied the long term optical variability of bright X-ray sources in four nearby elliptical galaxies with Chandra Advanced CCD Imaging Spectrometer array (ACIS-S) and Hubble Space Telescope (HST) Advanced Camera for Surveys observations. Out of the 46 bright (with X-ray counts greater than 60) sources that are in the common field of view of the Chandra and HST observations, 34 of them have potential optical counterparts, while the rest of them are optically dark. They also have found that four of the X-ray sources (three in NGC 1399 and one in NGC 1427) have variable optical counterparts at a high significance level. The X-ray luminosities of these source are ¡- 10^{38} ergs/s and are also variable on similar time-scales. For all the four sources, the ratio of fluxes in 5.8 to 3.6 micron is larger than 0.63, indicating that they do have AGN-like IR spectra. For one source, the change in optical magnitude is > 0.3, which is one of the highest reported for this class of X-ray sources. The optical variability implies that the optical emission is associated with the X-ray source itself rather than being part of the integrated light from a host globular cluster.

Saibal Ray

Searching for higher-dimensional wormholes with non-commutative geometry

Non-commutative geometry, an offshoot of string theory, replaces point like structures with smeared objects and has recently been extended to higher dimensions. The purpose is to obtain wormhole solutions with this extended non-commutative geometry as a background. It is found through this investigation that wormhole solutions exist in the usual four, as well as in five dimensions, but they do not exist in higher-dimensional spacetimes. Saibal Ray has carried out this work in collaboration with F. Rahaman, P.K.F. Kuhfittig, and S. Islam.

Does accelerating universe permit varying speed of light?

Saibal Ray in collaboration with P. P. Ghosh and U. Mukhopadhyay has investigated the possible variation of c in the context of the present accelerating universe as discovered through SN Ia observations, and shown that variability of c is not permitted under the variable Λ models.

Anirban Saha

Quantum mechanics of a charged particle in a background magnetic field interacting with linearized gravitational waves

Sunandan Gangopadhyay, and Anirban Saha have considered the dynamics of a charged particle interacting with background electromagnetic field under the influence of linearized gravitational waves in the long wave-length and low-velocity limit. The system is quantized and the Hamiltonian is then solved by using standard algebraic iterative methods. The solution is in conformity with the classical analysis and shows the possibility of tuning the frequency by changing the magnetic field to set up resonance.

Asoke Kumar Sen

Imaging polarimetry of the Bok globule CB56

The measurement of polarization of the background stars in the region of Bok globules is important to study the magnetic field geometry and dust grain characteristics in the globule. These parameters are important for the formation and evolution of dark clouds. Polarimetric observations of Bok globule

CB56 were made in the R-filter from the 2-metre telescope at IUCAA Girawali Observatory (IGO).

The observations were carried out on 4 - 5 March 2011. The CCD images obtained from the instrument (IFOSC) were analyzed, to produce the polarization map which has indicated that the magnetic field is more or less unidirectional and nearly parallel to the long axis of the cloud, and has the same direction as the local interstellar magnetic field. This work has been carried out by Asoke Kumar Sen in collaboration with D. Paul, and H. S. Das.

Dust in Comet 103P/Hartley 2 coma during EPOXI mission

The Deep Impact spacecraft flew by Comet 103P/Hartley 2 on 4 November 2010 (EPOXI mission). In situ observations are complemented by a systematic ground and space-based observation campaign. With these objectives, the comet was observed from 2 m IUCAA Girawali telescope and 0.8 m HP observatory in France during October – November 2010, under an Indo-French collaborative project (funded by CEFIPRA). Imaging polarimetry was used to emphasize different dust regions in the coma and follow their evolution over a period including the EPOXI fly-by. On the intensity images, the coma was found to be asymmetric with an important tailward feature. Jets in the sunward direction were observed to present an extension that depended on the nucleus phase. The azimuthal integrated intensity presented a nominal radial decrease for optocentric distances larger than a few hundred kilometers. Through cometary continuum narrow band filters, the aperture polarization decreased with the optocentric distance. On the polarization maps, the short sunward jets were more polarized than other parts of the coma, and the intensity variations were explained by large slow moving particles in the inner coma, and possibly by their fragmentation into smaller particles, under ice sublimation processes.

The decrease of linear polarization with increasing optocentric distance was correlated with intensity variations and may be induced by the same physical process. The optical behaviour of 103P/Hartley 2 was finally compared to those of other Jupiter-family comets such as Comet 9P/Tempel 1 impacted by the Deep Impact projectile in 2005 and Comet 67P/Churyumov– Gerasimenko, target of the Rosetta mission (2014–2015), since the polarimetric properties of both comets had been monitored remotely in the recent past. This work has been carried out by Asoke Kumar Sen in collaboration with E. Hadamcik, A.C. Levasseur-Regourd, R. Gupta, J. Lasue, and R. Botet.

T. R. Seshadri

Inflation in higher dimensional Gauss-Bonnet cosmology

A variety of inflationary models, without the need for an onflaton field, have been obtained with a higher dimensional action with a Gauss-Bonnet term. The scale factor for the hidden dimension(s) is not constrained to be the same as that of the visible ones. The phase space has been shown to have a rich structure. The stable and unstable solutions have been studied.

For a number of classes of solutions, the scale factor swiftly approaches an exponential form. Even for a modest compression of the hidden space, sufficient inflation is obtained for sufficiently large number of extra dimensions.

This work has been carried out by T.R. Seshadri in collaboration with Isha Pahwa, and Debakyoti Choudhury.

Thawing versus tracker behaviour: observational evidence

Using the generalized Chaplygin gas (GCG) parametrization for the dark energy equation of state (EoS), the evidence for thawing and trackking models have been studied. T.R. Seshadri in collaboration with Shruti Thakur, Akhilesh Nautiyal, and Anjan A. Sen have shown that the data from SN+H(z) + Lookback does not favour either tracker or thawer classes.

However, if one includes data from GR+WMAP-7, the thawer class of models are favoured as long as one assumes the dark energy to be a smooth component. If dark energy perturbations are considered, both tracker and thawer types of models are equally favoured by the data.

Ranjan Sharma

Spacetime inhomogeneity, anisotropy and gravitational collapse

Ranjan Sharma in collaboration with Ramesh Tikekar has investigated the evolution of non-adiabatic collapse of a shear-free spherically symmetric stellar configuration with anisotropic stresses accompanied with radial heat flux. The collapse begins from a

curvature singularity with infinite mass and size on an inhomogeneous spacetime background. The collapse is found to proceed without formation of an event horizon to singularity when the collapsing configuration radiates all its mass energy. The impact of inhomogeneity on various parameters of the collapsing stellar configuration is examined in some specific spacetime backgrounds.

Collapse of a relativistic self-gravitating star with radial heat flux: Impact of anisotropic stresses

Ranjan Sharma in collaboration with Shyam Das has developed a simple model for a self-gravitating spherically symmetric relativistic star, which begins to collapse from an initially static configuration by dissipating energy in the form of radial heat flow. They have utilized the model to show explicitly how local anisotropy effects the collapse rate and thermal behaviour of gravitationally evolving systems.

K. Yugindro Singh

Hawking radiation of Kerr-de Sitter black holes using Hamilton-Jacobi method

Hawking radiation of Kerr-de Sitter black hole has been investigated using Hamilton-Jacobi method. When the well-behaved Painleve coordinate system and Eddington coordinate are used, they get the correct result of Bekenstein-Hawking entropy before and after radiation, but a direct computation will lead to a wrong result via Hamilton-Jacobi method. Our results show that the tunneling probability is related to the change of Berkenstein-Hawking entropy, and the derived emission spectrum deviates from the pure thermal, but it is consistent with underlying unitary theory. This work has been done by K. Yugindro Singh in collaboration with T. Ibungochouba Singh, and I. Ablu Meitei.

Parijat Thakur

Possible transit timing variations of TrES-3 planetary system

Parijat Thakur and his collaborators (Ing-Guey Jiang, Li-Chin Yeh, Yu-Ting Wu, Ping-Chien, Yi-Ling Lin, Hong-Yu Chen, Juei-Hwa Hu, Zhao Sun, and Jianghui Ji) have been working in the field of photometric follow-up of the stars during the transits of their close-in extra-solar planets. As the signal of transit timing variations (TTVs) in the extra-solar planetary systems could imply the existence of additional unseen planets, the main goal of their study is to investigate the transit timing variations (TTVs). Since the TrES-3 planetary system attracts much attention due to its strong transit signal *(0.0291 mag)* and short orbital period *(P=1.30619 days)*, they have considered this planetary system to examine the possible transit timing variation. The five runs of transit observations of TrES-3 system were successfully completed in *R* band between May and June 2010, using *the 0.8-m telescope at Tenagra Observatory in Arizona, USA*. The images were calibrated using standard procedures within *IRAF*, such as trimming, bias and dark subtractions and flat fielding division. In order to plot the TrES-3 light curve for each transit events, the differential photometry was performed. Together with eight light curves from Sozzetti, et al. (2009), nine light curves from Gibson, et al. (2009), and one light curve from Colon, et al. (2010), twenty three light curves in total, which cover an overall time scale of 911 epochs, have been analyzed through the Transit Analysis Package (TAP) described by Gazak, et al. (2012). The orbital parameters of TrES-3 system were determined and possible transit timing variations (TTVs) were also investigated. As a null TTV model fits the data with reduced $\chi^2 = 1.52$, their results agree with previous work that TTVs might not exist in the TrES-3 system. However, Lomb's normalized periodogram was also used to search for possible transit timing variation in the data, which suggests that a one-frequency oscillating TTV model, giving a fit with a reduced $\chi^2 = 0.93$, does possess a statistically higher possibility than the one with null TTVs. It is, therefore, concluded that future high-precision observations and dynamical simulations for the TrES-3 system will lead to fruitful scientific results.

Effect of bar strength and sound speed on gas fueling in barred galaxies

Parijat Thakur and his collaborators (Ing-Guey Jiang, and H.B. Ann) have been working to understand the formation mechanism of nuclear spirals in barred galaxies. In this regards, it is worth mentioning here that all the symmetric two-armed nuclear spirals are most frequently observed in active galaxies where bars and supermassive black holes (*SMBHs)* are expected to be present. Moreover, it was also proposed that nuclear spirals in barred galaxies may be related to fueling of *AGN* activity. These suggest that there should be some correlation between nuclear spiral, bar strength and *AGN* fueling. It is, therefore, important to examine the choices of bar strength and gas sound speed for which nuclear spirals can provide enough fueling to power the *AGN*. With this goal in mind, the particle-mesh smoothed particle hydrodynamics (PMSPH) simulations was performed

to study the response of the central kiloparsec region of a gaseous disk to the imposition of non axisymmetric bar potentials. The PMSPH code developed by Fux (1999, 2001) was used here. The model galaxies are composed of the three stellar components (disk, bulge and bar) and two dark ones (supermassive black hole and halo) whose gravitational potentials are assumed to be invariant in time in the frame corotating with the bar. In this project, the effect of the bar strength and gas sound speed on the formation of nuclear spirals, as well as on the gas fueling in barred galaxies was examined. It has been found that the strong nuclear spirals are formed in the models with moderately strong bars, whose innermost parts reach close to the galactic centre to provide enough fuel for the AGN when the gas sound speed $c_s = 15$ km s^{-1}. On the other hand, the weak bar models having $c_s = 15$ km s^{-1} show the formation of the weak nuclear spirals, whose innermost parts cannot reach close to the galactic centre to fuel the AGN. However, it was also noticed that in the high sound speed medium ($c_s = 20$ km s^{-1}), the nuclear spirals formed in the weak bar models, as well as in the moderately strong bar models can provide the fuel to power the nearby AGN.

Dr. Paniveni Udayashankar

Solar energy utilities

Paniveni Udayashankar has studied the complexity of supergranular cells using the intensity patterns obtained from the Kodaikanal Solar Observatory during the 23rd solar cycle. The data consists of visually identified supergranular cells, from which a fractal dimension D for supergranulation has been obtained according to the relation $P \alpha A^{D/2}$, where 'A is the area, and 'P' is the perimeter of the supergranular cells. She has found a difference in the fractal dimension between the active and quiet region cells in the ascending phase, during the peak and in the descending phase, which is conjectured to be due to the magnetic activity level.

A. A. Usmani

The (2+1)-dimensional charged gravastars

This is the continuation and generalization of our earlier work on gravastar in (2+1) anti-de Sitter spacetime to (2+1)-dimensional solution of charged gravastar. Morphologically, this gravastar contains three regions, namely: (i) charged interior, (ii) charged shell, and (iii) electrovacuum exterior. They have studied different characteristics in terms of length and energy, entropy, and junction conditions of the spherical charged distribution. It has been shown that the present model of charged gravastar is non-singular, and represents itself an alternative of black hole. This work has been done by A.A. Usmani in collaboration with Farook Rahaman, Saibal Ray, and Safiqul Islam.

Galactic rotation curves inspired by a non-commutative geometry background

A.A. Usmani with his collaborators F. Rahaman, Peter K.F. Kuhfittig, K. Chakraborty, and Saibal Ray has discussed the observed flat rotation curves of galaxies in the context of non-commutative geometry. The energy density of such a geometry is diffused throughout a region due to the uncertainty encoded in the coordinate commutator. This intrinsic property appears to be sufficient for producing stable circular orbits, as well as attractive gravity, without the need for dark matter.

Oscillatory universe, dark energy equation of state and general relativity

The concept of oscillatory universe appears to be realistic and buried in the dynamic dark energy equation of state. A.A. Usmani in collaboration with Partha Pratim Ghosh, Saibal Ray, and Utpal Mukhopadhyay has explored its evolutionary history under the frame work of general relativity. They have observed that oscillations do not go unnoticed with such an equation of state, and that their effects persist later on in cosmic evolution. The `classical' general relativity seems to retain the past history of oscillatory universe in the form of increasing scale factor as the classical thermodynamics retains this history in the form of increasing cosmological entropy.

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By Visiting Associates

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Supervision of Ph. D. Thesis

Nagendra Kumar Thesis titled "*Waves and oscillations in the interior and corona of the Sun*", by **Anil Kumar** submitted to MJP Rohilkhand University, Bareilly.

M. K. Patil Thesis titled "*X-ray properties of early-type galaxies*", by **Nilkanth D. Vagshette** submitted to S.R.T.M. University, Nanded, Maharashtra.

Anirudh Pradhan (2012) Thesis titled "*A study on early universe with variabe gravitational and cosmological terms*", by **Ajay Kumar Singh**, submitted to V. B. S. Purvanchal University, Jaunpur.

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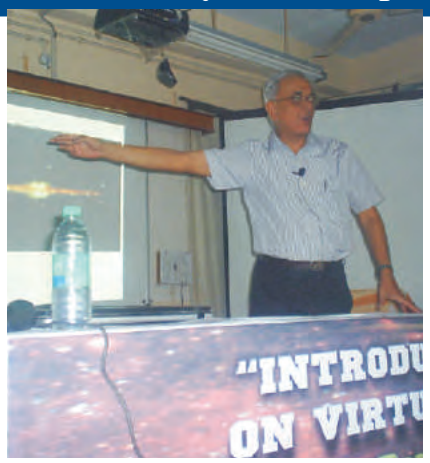
Introductory Workshop on Virtual Observatory



An Introductory Workshop on Virtual Observatory was held in the Department of Applied Mathematics, Calcutta University, during December 3-7, 2012, in collaboration with IUCAA Resource Centre (IRC), Kolkata.

Ajit Kembhavi, Asis Kumar Chattopadhyay, Tanuka Chattopadhyay, Sajeeth Philip, Shruti Tripathi, Sharmad Navelkar, M. Vivek, Tejas Kale, Ajay Bibhuti, Tushar Agarwal, and Saptarshi Mondal, delivered lectures as well as conducted lab sessions during the workshop. About forty five persons participated in the workshop.

The perspective of this workshop was (i) to train M.Sc. students on how to work with VO, so that they could pursue their M.Sc. based project dissertations using VO in future. (ii) Enable young faculty members to introduce VO, for their students in their respective universities. Ph. D. students have also benefitted from this workshop. Ajit Kembhavi and Tanuka Chattopadhyay were the coordinators of the workshop

For details see Khagol, Iusse No. 93 - January 2013.

BITS-IUCAA Workshop on Gravitational Wave Data Analysis

The Birla Institute of Technology and Science (BITS), Pilani, Goa Campus, and IUCAA, jointly organised a national level workshop on Gravitational Wave Data Analysis at the BITS-Pilani K. K. Birla Goa Campus, during December 17 - 21, 2012. The workshop was inaugurated by K. E. Raman, Acting Director, BITS, Pilani, K.K. Birla Goa Campus.

In total, 61 participants from all the corners of the country participated. The main topics covered in the lecture sessions were the basics of General Theory of Relativity, Gravitational Waves, their sources and detectors, and basics of GW Data Analysis.

K. G. Arun (Chennai Mathematical Institute), Patrick Dasgupta (Delhi University), Sanjeev Dhurandhar (IUCAA), T. K. Jha (BITS-Pilani, Goa Campus), Rajesh Nayak (IISER-Kolkata), S. K. Sahay (BITS-Pilani Goa Campus), Anand Sengupta (IIT-Gandhinagar), and C. S. Unnikrishnan (TIFR, Mumbai) were some of the experts, who delivered the lectures.

S.K. Sahay (BITS-Pilani, Goa Campus) and Sanjit Mitra (IUCAA) coordinated the workshop. The organisers were delighted with the students' responses and their enthusiasm towards Gravitational Waves.

For details see Khagol, Iusse No. 93 - January 2013.

Workshop on Mathematical Methods and Astronomy (WMMA 2013)

The Workshop on Mathematical Methods and Astronomy (WMMA 2013) was organized by the Department of Applied Mathematics, Indian School of Mines (ISM), Dhanbad, and sponsored by IUCAA. The workshop was inaugurated by D. C. Panigrahi.

In the workshop, there were 15 lectures. The number of participants and resource persons were 35 and 9 respectively. Some of the main topics covered were Astronomical Photometry, Astronomical instrumentation, Astronomical spectroscopy, TMT and its upcoming opportunities, Interstellar dust, Astrophysical dust and molecules, Stellar Evolution and nucleosynthesis, Astronomical polarimetry, Homotopy and its applications, and Unsolved restricted three body problem. This workshop was coordinated by Ranjan Gupta and Badam Singh Kushvah.

For details see Khagol, Iusse No. 93 - January 2013.

Introductory Workshop on Solar Physics

Ramakrishna Mission Vivekanda University (RKMVU), Belur Math, West Bengal and IUCAA, jointly organized an Introductory Workshop on Solar Physics during February 5 - 7, 2013.

The workshop was hosted at RKMVU, Belur Math Campus, and was funded by IUCAA. The aim of the workshop was to motivate B.Sc./ B.Tech./ M.Sc./ Ph.D. students to pursue studies/ research in the field of solar physics. The programme of the workshop consisted of 12 lectures by six speakers, who were experts in the field. A total of 42 students participated in the workshop from different universities, colleges, and institutes all over the country.

The workshop was coordinated by Abhijit Bandyopadhyay (RKMVU), Partha Chowdhuri (Calcutta University), and Durgesh Tripathi (IUCAA).

For details see Khagol, Iusse No. 94 - April 2013.

Workshop on Cosmology

A workshop on Cosmology titled "Present Observational Constraints on Cosmological Parameters" was held at IUCAA Resource Centre, University of Delhi during January 28 - February 1, 2013.

There were about 15 talks by 6 speakers. The talks were focused on the areas of Cosmic reioinization, Large-scale structures, Cosmic microwave background radiation, and Late time acceleration of the universe. The talks were followed by extensive discussions.

There were about 60 participants and more than half of them were from outside Delhi. Most of the participants were students and some post-doctoral fellows.

The coordinators were T. R. Seshadri (University of Delhi), Anjan A. Sen (Jamia Millia Islamia), and K. Subramanian (IUCAA).

For details see Khagol, Iusse No. 94 - April 2013.

Department of Physics
Cochin University of Science and Technology, Kochi.

Coordinator: V C Kuriakose
Jt. Coordinator: Ramesh Babu T

Data Centre

The Data Centre is being now used by M.Sc. and M. Phil. students for doing projects, and research students for their research studies twelve B.Sc. students from neighbouring colleges and Institutes carried out their summer projects using the facilities available at the Data Centre.

Research

The thrust areas of research are: Physics of black holes, Extended theories of gravity, Observational astronomy, Bose-Einstein condensation and quantum optics. Twelve research students are now doing research in these areas.

Workshops and Meetings

1. Seminar on Challenges in Astrophysics and Cosmology at S. B. College, Changanacherry.
In collaboration with the Department of Physics, S B College, Changanacherry, the IRC has organized a two day seminar during December 18-19,2012. There were about 90 participants including, PG students, research scholars, undergraduate students and teachers. The resource persons Ranjeev Misra (IUCAA), K Indulekh (M.G. University.) C D Ravikumar (Calicut University.) and V C Kuriakose (IRC). Jose Mathew of S B College was the local organizer of the seminar.

2. Workshop on Advanced Data Analysis Techniques in Astrophysics at University of Calicut.
The Department of Physics, University of Calicut, in association with IRC has organized a workshop on Advanced Data Analysis Techniques in Astrophysics during October 10-13, 2012 at the Madhava Observatory, University of Calicut. Over 100 participants attended the workshop, including M Sc students of the department. The lectures were given in topics like Basics of linux, Planetary science, Solar physics and High energy astrophysics. The Resource persons were Ranjeev Misra (IUCAA), K Sankar Subramaniam (IIA), Ninan Sajeeth Philip (St. Thomas College, Kozhencherry), . Dhanya M.P (VSSC), Sreejith P(ISAC), Vinu Vikram (University of Pennsylvania), A .M . Vinodkumar (Calicut University) and C D Ravikumar (Calicut University) . Afternoon sessions were devoted to hands on experience, and introduced different astronomical tools to them. These sessions were conducted by research scholars , V Jithesh, A U Preetha, Dhanya Joseph, and M Nikesh of the department. C D Ravikumar was the coordinator of the workshop.

Participants of the Workshop on Advanced Data Analysis Technique in Astrophysics held at Calicut University

3. Workshop on Fourier Transforms in Astrophysics at Mahatma Gandhi University, Kottayam.
In association with IRC, School of Pure and Applied Physics, M G University organized this workshop during February 13 -15, 2013. About thirty participants (the beginning researchers/M.Sc /B.E./ M.Tech students / college teachers) from various colleges and institutions in Kerala attended the lectures and very actively worked through the laboratory sessions. The resource persons were Udaya Shankar (RRI), Rakesh Kumar Singh (IIST-Thiruvananthapuram) , and Ajith Parameswaran (ICTS, Bengaluru), Ninan Sajeeth Philip (St. Thomas College, Kozhencherri), Joe Jacob (Newman College, Thodupuzha), K Indulekha (M G University) and V C Kuriakose(IRC). K Indulekha and A S Padmanabhan (M G University) were the local organizers of the workshop.

Publications

a) In refereed journals

1. Thermodynamics and spectroscopy of Schwarzschild black hole surrounded by Quintessence, R Tharanath, and V C Kuriakose, Mod. Phys. Lett. A, 28, 1350003 (2013)

2. Probing late-time tails of fields around Schwarzschild black hole surrounded by quintessence, Nijo Varghese and V C Kuriakose, Gen. Rel. Grav., 45:189–201 (2013)

3. Probing the time variability of five Fe low broad absorption line quasars, M Vivek, R Srianand, P Petitjean, P Noterdaeme, V Mohan, A Mahabel and V C Kuriakose, MNRAS, 423, 2879 (2012)

4. Gravitational waves from f(R) theory and its detection using spherical antenna, P Prasia, and V C Kuriakose J. Phys.: Conf. Ser. 405 012019(2012)

b) Oral/poster presentations in Conferences

1. Light beam propagation through photorefractive materials, V C Kuriakose, 37th Symposium of Optical Society of India, Pondicherry, January . 23-25, 2013

2. Duration of Star Formation in Young Open Clusters, B Bhavya, Annapurni Subramaniam and V. C. Kuriakose, 30th Meeting of Astronomical Society of India, Feb. 21-23, 2013, Trivandrum.

3. Thermodynamics and spectroscopy of Schwarzschild black hole surrounded by quintessence, R Tharanath and V C Kuriakose, 27th Meeting of IAGRG, March 7-9, 2013, Srinagar(Garwal)

4. Fermionic perturbations around Schwarzschild-de Sitter black hole, Nijo Varghese and V. C. Kuriakose, 27th Meeting of IAGRG, March 7-9, 2013, Srinagar(Garwal)

5. UV Instability and Asymptotic Quasinormal Modes in Lovelock – AdS Model C B Prasobh and V C Kuriakose, 27th Meeting of IAGRG, March 7-9, 2013, Srinagar(Garwal)

Seminars and Colloquia

IRC Seminar

i) V C Kuriakose: Higgs - Boson (August 10, 2012)
ii) Ranjeev Misra(IUCAA) : Black holes in the universe (December 17, 2012)
iii) Ishwara Chandra C. H (NCRA, Pune): Giant Metrewave Radio Telescope - Scientific and technological milestone in Indian science (March 1, 2013)

Lectures given by the Co ordinator:

1. S B College, Changnacherry, Higgs boson (August 9, 2012)
2. University of Calicut, Accelerating Universe (August 23, 2012)
3. Pt. Ravishankar Shukla University, Raipur, Patterns of Symmetry Breaking in the very early Universe (September 5, 2012)
4. Farook College, Feroke, Understanding the Universe (September 26, 2012)
5. Academic Staff College, University of Calicut : Introduction to General Theory of Relativity (February 12, 2013)
6. INCULCATE Programme, M. G University, Introduction to Astronomy and Astrophysics. (February 24, 2013).

Public Out - Reach Programme

Physics: Scope awareness programme for School Children:

Department of Physics, CUSAT, has organized a workshop for school students during April 23 – 28, 2012, in collaboration with the IRC, Kochi. These students were given training in assembling small telescopes and they assembled their own telescopes. There were also lectures on Astronomy and Astrophysics and related topics. In addition there were lectures on other topics in physics, and the students were given training on doing experiments, and they were given opportunity to visit different research laboratories in the department. There were 30 students from different schools in Kerala.

Lectures, telescope making and sky watching programmes at Schools

We have visited the following schools and colleges and conducted telescope making and sky watching programmes for the benefit of the students.

1.St. Francis Assisi Teacher Training Institute, Arthunkal, April 17, 2012
2.Navy Children School, Ernakulam, October 19, 2012
3.Sree Sarada Vidyalaya, Kalady, November 25, 2012
4.S B College, Changanacherry, December 18, 2012

The programme consisted of lectures in general Astronomy, introduction of stellarium software, small telescope making and sky watching. This programme was conducted in Malayalam.
The research scholars of the Astronomy and Astrophysics group, Nijo Varghese, R Tharanath, Saneesh Sebastian, B Bhavya, P Prasia, and Jishnu Suresh rendered valuable services in making the public out-reach programme and other activities of the IRC a great success.

Department of Physics and Astrophysics, University of Delhi

Coordinator: T. R. Seshadri

Jt. Coordinator: H. P. Singh

Conferences/ Workshops

The workshop on ***Present Observational Constraints on Cosmological Parameters*** was organized by the IUCAA Resource Centre, University of Delhi during January 28- February1, 2013.

Organizers: Anjan Ananda Sen (Jamia Millia Islamia), T R Seshadri, (University of Delhi) and K. Subramanian (IUCAA)

Journal Club Talks

1. Aspects of the Zel'dovich-Sunyaev mechanism (J.Bernstein and S.Dodelson) by **Bidisha Bandyopadhyay**

2. How exactly did the universe become neutral. (astro-ph 9912182) by **Sampurnanand**

3. Particle decay and 21-cm absorption from first minihaloes (arXiv : 1205.1204v1) by **Bidisha Bandyopadhyay**

4. Mimicry of dark energy from back-reaction- Realisation and loopholes by **Sourav Sur**

Seminars

1. DBI Galileon and the Late time acceleration of the universe by **Sampurnamand.**

2. Studying the diffuse ionized gas in the milky way by **Ashish Asgekar**, (ASTRON, Netherlands.

3. Probing the epoch of reionization through radio-interferometric observations of neutral hydrogen by **Suman Majumdar** (IIT Kharagpur).

4. Astronomy with VO by **Ninan Sajeeth Phillip** (St. Thomas College, Kozhencherri, Kerala.).

5. Neutron star astrophysics : New challenges by **Sushan Konar** (NCRA , Pune).

Lecture Series

1. General introduction to intergalactic medium by **Srianand**, (IUCAA)
2. Observables that constrain the reionization by **Srianand**, (IUCAA)
3. Probes of Reionization (3 lectures) by **Shiv. K Sethi**, (RRI, Bangalore)

Department of Statistics, Calcutta University, Kolkata

Coordinator: Asis Chattopadhyay
Jt. Coordinator: Narayan Banerjee

Research Areas

The principal areas of interest in IRC Kolkata are astrophysics and related data analysis. Research scholars and faculty members are very much involved in the use of statistical techniques and computer programme for the appropriate analysis of astronomical data. They are also trying to develop new statistical techniques appropriate for the analysis. Theoretical research work related to theory of general relativity, and cosmology is also going on. The following project works have been carried out by the post graduate students of different universities at this centre:

a) Classification of globular clusters of NGC 5128 through Independent Component Analysis, at the Department of Statistics, Calcutta University.Supervised by: Asis Chattopadhyay and Tanuka Chattopadhyay.

b) Study of broad absorption lines of quasars , at the Department of Applied mathematics, Calcutta University. Supervised by: Tanuka Chattopadhyay.

c) Carbon stars as active star formation tracers in LMC , at the Department of Applied Mathematics, Calcutta University. Supervised by: Tanuka Chattopadhyay.

d) Classification between starburst galaxies and AGN, at the Department of Applied Mathematics, Calcutta University. Supervised by: Tanuka Chattopadhyay.

e) Proper motion of Barnard star, Classification between starburst galaxies and AGN, at the Department of Applied Mathematics, Calcutta University. Supervised by: Tanuka Chattopadhyay

f) BH mass estimates at the centres of massive galaxies, at the Department of Physics, West Bengal State University, Barasat. Supervised by: Tanuka Chattopadhya.

g) Study of star formation history for a Salperter type initial mass function, at the Department of Physics, West Bengal State University, Barasat. Supervised by: Tanuka Chattopadhya.

Workshops and Meetings Organized

Workshop on Virtual Observatory (VO)

An introductory Workshop on Virtual Observatory was held at the Department of Applied Mathematics, Calcutta University, during December 3-7, 2012, in collaboration with IUCAA Resource Centre (IRC), Kolkata.

Virtual Observatory (VO) is a collection of data archives and software tools, using which various types of astronomical research can be conducted with the help of internet. This is analogous to a real observatory, where telescopes are used for data collection. VO, however, stores data from the observations made through various telescopes all over the world. The advantage of VO is that users from various regions all over the world can simultaneously access data easily without going through painstaking task of observations. At the same time, terabytes of data can be stored in VO at a time, which can be used for various studies simultaneously.

The perspective of this workshop was (i) to train M.Sc. students on how to work with VO, so that they could pursue their M.Sc. based project dissertations using VO in future. (ii) Enable young faculty members to introduce VO for their students in their respective universities. Ph.D. students also benefitted from this workshop.

In the inaugural session, Susmita Sarkar, Head, Department of Applied Mathematics, CU, welcomed the participants. Uma Basu, senior faculty member, Department of Applied Mathematics, presided over the session and Asis Kumar Chattopadhyay, Coordinator of IRC, Kolkata, outlined on the perspective of the workshop. Suma Debsarma conveyed vote of thanks.

The speakers there were Ajit Kembhavi, Asis Kumar Chattopadhyay, Tanuka Chattopadhyay, Sajeeth Philip, Shruti Tripathi, Sharmad Navelkar, M. Vivek, Tejas Kale, Ajay Bibhuti, Tushar Agarwal and Saptarshi Mondal. There were a number of lab sessions to demonstrate the use of VO India packages during the workshop.

About forty five persons participated in the workshop. Ajit Kembhavi and Tanuka Chattopadhyay were the coordinators of the workshop.

List Of Publications / Posters

1. Probability distributions of number of children and maternal age at various order births using age-specific fertility rates by birth order, Samba Siva Rao Pasupuleti , and Asis Kumar Chattopadhyay, **Sankhya series** B,2013

2. Independent component analysis for the objective classification of globular clusters of the galaxy NGC 5128, Asis Kumar Chattopadhyay, Saptarshi Mondal, and Tanuka Chattopadhyay , **Computational Statistics and data analysis**, 2013, 57, 17.

3. A six-parameter space to describe galaxy diversification D. Fraix-Burnet, T. Chattopadhyay, Asis. Kr. Chattopadhyay, E. Davoust, and M. Thuillard **A & A**, 2012,545, A80.

4. Multivariate study of dynamically hot stellar systems: Clues to the origin of ultra compact and ultra faint dwarfs Tanuka Chattopadhyay , and Pradip Karmakar, **New. Astron**, 2013, 22,22.

Seminars and Colloquia

1. Sun in multi-wavelength by **Rajmal Jain** , August 25,2012 at the Physical Research Laboratory , Ahmedabad

2. Lipschitz connections in metric spaces by Dharmanand Baboolal, December 26,2012 at the School of Mathematical Sciences , University of KwaZulu-Natal, South Africa

School of Studies in Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur

Coordinator: S. K. Pandey
R. C. Agrawal

Highlights

3.5 m Astrophysics Observatory (Dome) and Mobile planetarium have been successfully installed. They are the main sources of attraction and curiosity during the various astronomical activities. S.K. Pandey has been reappointed as a Vice-Chancellor. This is first case of reappointment of VC in the history of Raipur University. Nand Kumar Chakradhari has received the prestigious Chhattisgarh Young Scientist award 2013.

Research

D. K. Chakraborty and his research students have continued their work on the projected properties of a family of triaxial mass models. They have extended their work on the mass models with central cusp to investigate the effect of the inclusion of high order residuals on intrinsic shapes of elliptical galaxies. S. K. Pandey continued the collaborative research programme with A. K. Kembhavi, on multiwavelength photometric study of dusty early-type galaxies, which constitutes the thesis work of Samridhi Kulkarni.

The programme of studying faint outermost regions of the early-type galaxies from the Large Format Camera (LFC) field was continued during the year. Investigation was done whether inner and outer parts of the early-type galaxies are different. Merger history of sample galaxies was speculated by comparing our results with the properties of isophotal shapes of merger remnants reported in the literature, obtained from N-body simulations. This is a collaborative research programme involving A. K. Kembhavi, Russell Cannon, and Ashish Mshabal, and the work constitutes thesis work of Laxmikant Chaware.

Sheetal Sahu, research student of S. K. Pandey has started working on the project "Multiwavelength study of a sample of radio loud elliptical galaxies" and is using the 2 m telescope at IUCAA Girawali Observatory for the observations. Amit Tamrakar and Mahendra Verma, two new research students have joined S.K. Pandey. Research work entitled "Observational studies of type Ia supernovae" is being carried out by N.K. Chakradhari, and S.K. Pandey in collaboration with G.C. Anupama and D.K. Sahu, IIA, Bangalore. Chakradhari has been also involved in the research work on short period variability in chemically peculiar stars in collaboration with S. Joshi, ARIES, Nainital.

To strengthen the research activities, department has signed an MoU with ARIES, Nainital. A number of Scientists V C Kuriakose (CUST, Cochin), Gulab Dewangan (IUCAA), H.M. Antia, S.K. Ghosh, R.K. Manchanda (TIFR, Mumbai), S.K. Satheesh (IISc, Bangalore), Sunetra Giridhar, D. K. Sahu (IIA, Bangalore), M.K. Patil (SRTM, Nanded), Sudhanshu Barway (SAAO, South Africa), have visited the department, delivered popular lectures and interacted with the students.

The faculty members, and research scholars in the university as well as visitors from other universities/colleges in this region have made use of the facilities (data centre, library, etc.) provided by IUCAA at the centre to strengthen their research activities.

Workshops and Meetings

A three days workshop on "Transit of Venus and Day time Astronomy" was organized in collaboration with SCERT, Raipur and Chhattisgarh Vigyan Sabha with the help of Vigyan Prasar, New Delhi at SCERT, Raipur during May18-20, 2012.

List of Publications/ Poster

1. S. Joshi, E. Semenko, P. Martinez, M. Sachkov, Y.C. Joshi, S. Seetha, **N. K. Chakradhari**, D. L. Mary, V. Girish, and B. N. Ashoka (2012) A spectroscopic analysis of the chemically peculiar star HD 207561, MNRAS. 424.2002J.

2. N.D. Vagshette, M.B. Pandge, **S. K. Pandey, M. K. Patil** (2012) Dust extinction and X-ray emission from the starburst galaxy NGC 1482, New A. 17.524V.

3. S. P. Deshmukh, B. T. Tate, N. D. Vagshette, **S. K. Pandey, M. K. Patil** (2012) Multiwavelength view of ISM in the merger remnant Fornax A galaxy, arXiv1207.4324D.

4. Mayukh Pahari, Sudip Bhattacharyya, J. S. Yadav, S. K. Pandey (2012) Evidence of two unique variability classes from IGR J17091-3624, MNRAS.422L..87P.

5. N.D. Vagshette, S. K Pandey, M K Patil (2012) Environment dependent spatial correspondence between the dust, ionized gas and hot gas in some early-type galaxies; SRTMU's Research Journal of Science; 1(2), 1-13 (ISSN: 2277-8594).

Poster

1. Study of ionized gas in E/SO galaxies with dust, Samridhi Kulkarni , Laxmikant Chaware , N. K. Chakradhari , D. K. Sahu and S. K. Pandey, presented at 30th Scientific Meeting of Astronomical Society of India (ASI-2013) held during February 20-22, 2013 at IISER-IIST-IRC, Thiruvananthapuram, Kerala.

2. Spectral studies of some E/SO galaxies using the SDSS DR7 data, Amit Kumar Tamrakar, L. K. Chaware, S. K. Pandey, N. K. Chakradhari and Sheetal Sahu, presented at 30th Scientific Meeting of Astronomical Society of India (ASI-2013) held during February 20-22, 2013 at IISER-IIST-IRC, as above.

3. Spectrophotometric study of some Radio-loud early type galaxies, Sheetal K. Sahu, Laxmikant Chawre, S.K. Pandey, Samridhi kulkarni, N K Chakradhari,Dr. AK Diwakar, Amit Tamrakar, presented at 30th Scientific Meeting of Astronomical Society of India (ASI-2013) held during February 20-22, 2013 at IISER-IIST-IRC, as above.

Seminars and Colloquia

1. The patterns of symmetry breaking in the very early universe by V. C. Kuriakose, September 2012, SoS in Physics and Astrophysics, Pt. R. S. University, Raipur.

2. Wonderful World of Dead stars by R. K. Manchanda, August 2012, Raipur, SoS in Physics and Astrophysics, Pt. R. S. University, Raipur.

3. Black Carbon Aerosols: The Absorbing Phenomena by S. K. Satheesh, August 2012, SoS in Physics and Astrophysics, Pt. R. S. University, Raipur.

4. Active Galactic Nuclei by Gulab Dewangan, May 2012, SoS in Physics and Astrophysics, Pt. R. S. University, Raipur.

Activities And Public Outreach Programmes

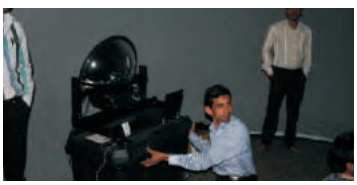
1. Regularly organized Planetarium Shows, sky watching programmes and telescope demonstrations at various places for school/ college students, teachers and public.

2. Arrangements were made to witness the "Transit of Venus" on June 6, 2012. Various activities were carried out before and after the Transit of Venus.

3. Activities were done during the INSPIRE summer and winter camps.

4. Lunar Occultation Programme on March 19, 2013.

5. Introduction to galaxies and Lab Sessions on Galaxy Surface Photometry was conducted by Laxmi Kant Chaware at the workshop on Astrophysical Observation and Data Analysis during 5-7, June, 2012 conducted at Tezpur University, Assam.



Popular Lectures

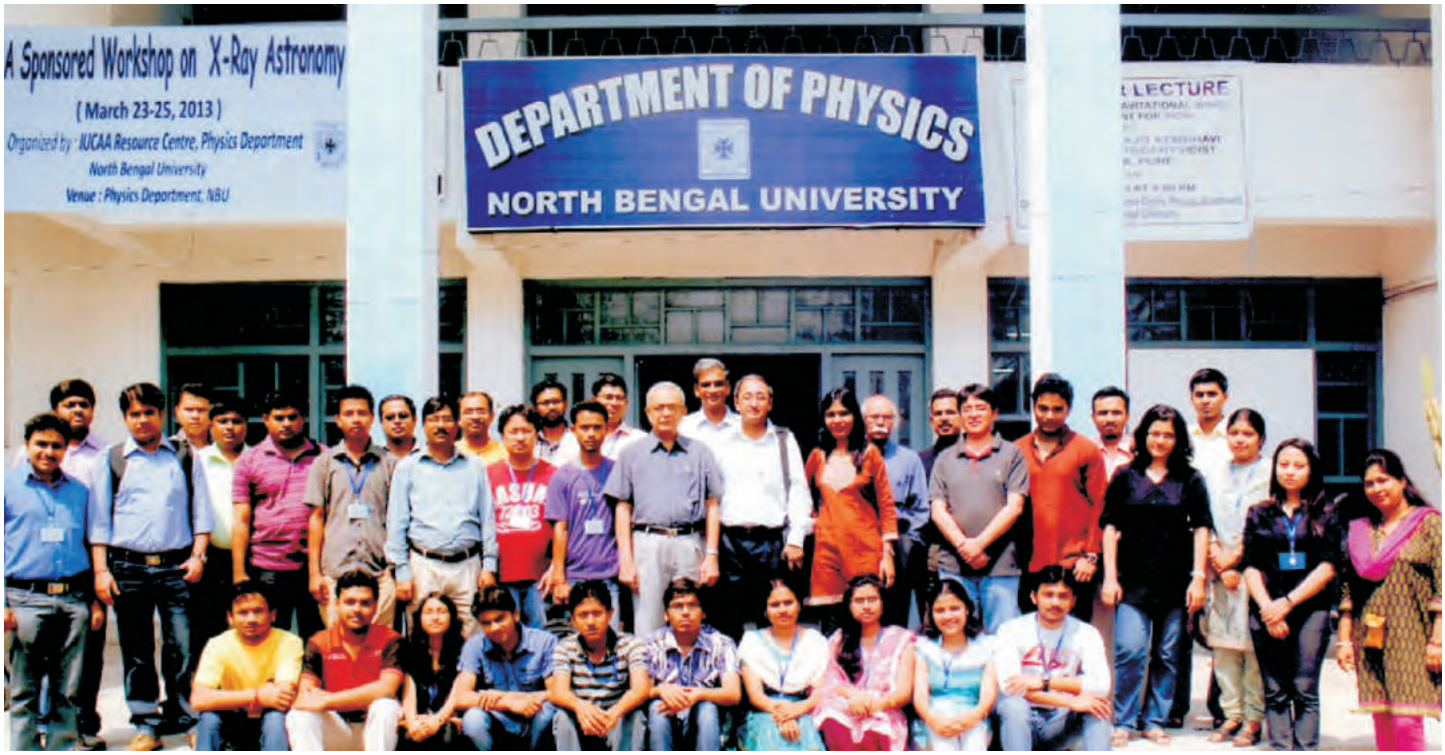
1. N.K.Chakradhari
   a. Career in astronomy and astrophysics , Govt J.R.Dani Girls Higher Sec.School,Raipur, March 30,2013.

2. S.K.Pandey
   a. *A glimpse of the Universe*, SCERT , Raipur : Workshop on Transit of Venus ,May 18-20,2012.
   b. *Teaching and research in A&A at the university*, Associate Fest, IUCAA, May 29, 2012.
   c. *The story of our Universe*, lecture given at Saraswati Shishu Mandir, Jamgaon(R) , May 30, 2012.
   d. *A fresh view of the Universe*, INSPIRE camp, PRSU, Raipur, May 31, 2012.
   e. *Amazing world of Astronomy*, lecture given at Rungta College of Engg. & Technology, August 25, 2012.
   f. *A fresh view of the Universe*, lecture given at GM College, Sambalpur, Odisha, September 29, 2012.
   g. *How well do we know our Universe?*, Govt. Chhattisgarh College, Raipurn (National Workshop on Mathematics) January 17, 2013.
   h. *Our Universe as we know now*, lecture given at ASC, March 15, 2013.
   I. An interview on AIR-Vigyan Lok, on *Akash Ganga kyon sikud rahi hai*, April 2, 2012.
   j. An interview on AIR-Vigyan Lok, on *Bharat ka Mangal Abhiyan* (India's Mars Mission), August 20, 2012.
   k. An interview on AIR-Vigyan Lok, on *Antariksh me sthapit prayogshalayen* (Laboratories in Space).

North Bengal University, Siliguri

Coordinator: B. C. Paul

Jt. Coordinator: A. Bhadra



Research Area

Cosmology, Compact objects, Foundations of relativity, Data analysis of X-ray sources and pulsars, and Non-linear Dynamics

Workshops and Meetings

Workshop on X-Ray Astronomy (March 23-25, 2013) : Thirty research scholars and young teachers from different colleges and universities attended. In the first half of the day theory on X-ray Astronomy were discussed and in the second half hands on training on data analysis have been arranged. Eleven PG students of the department participated the entire programme with great enthusiasm. S. Mukherjee gave the keynote address. The speakers were A. K. Kembhavi, R. Misra, A. K. Chattopadhyay, and B.C. Paul. In one of the slot S, Mandal, T. Sarkar and P. Pradhan talked on the research work they were doing in X-ray astronomy.

List of Publications / Posters

1. A. Palit, and D. P. Datta, (2012) On the determination of limit cycles in Lienard systems, Bull. Cal. Math. Soc., 24(1), 152.

2. D. P. Datta, S. Raut, and A. Roychoudhuri (2012) Diffusion on a class of fractal sets, Int. J. App. Math & Stat, 30 (6), 37-50.

3. Continuous rescaling symmetry and emergence of complex structures, D P Datta, Bull. Cal.Math. Soc, 104(5), 2012, 445-454.

4. Selecting gamma-ray showers from hadronic background using lateral shower age of EAS, R. K. Dey and A. Bhadra, Astropart. Phys. 44, 68-75(2013)

5. Comment on Impact of a Global Quadratic Potential on Galactic Rotation Curves, Kamal. K. Nandi,and Arunava Bhadra, Phys. Rev.

Letts. 109, 079001 (2012)

6. Influence of microscopic particle interaction models on the flux of atmospheric antiprotons, A. Bhadra, Biplab Bijay, Sanjay K. Ghosh, et al , Astropart. Phys., 35, 277(2012)

7. Scaling behaviour of lateral distribution of electrons in EAS, R.K Dey, A. Bhadra, and J. N. Capdevielle, J. Phys. G.: Nucl. Part. Phys 39, 085201 (2012)

8. Relativistic solution for a class of static compact charged star in pseudo spheroidal space-time , P. K. Chattopadhyay, R. Deb and B. C. Paul, Int. J. Mod. Phys. D 21, 1250071 (2012).

9. Relativistic Models of a Class of compact objects - R. Deb, B. C. Paul and R. Tikekar, Pramana- J. of Phys. 79, 211 (2012)

10. Modified Chaplygin Gas in Horava-Lifshitz gravity and constraints on its B parameter i. B. C. Paul, P. Thakur, and A. Saha , Phys. Rev. D 85, 024039 (2012)

11. Relativistic anisotropic strange stars in pseudo spheroidal space-time – B C Paul and P. K. Chattopadhyay (11th APRIM, 2011 NARIT Conference Series, Vol . 1 (2012) (to be published)

12. Relativistic strange stars with anisotropy and B-parameter in Pseudo-spheroidal spacetime- P. K. Chattopahyay and B. C. Paul (Neutron Stars and Pulsars : Challenges and Opportunities after 80 years, Procee. IAU symposium No. 291 (2012) (to be published)

Seminars and Colloquia

1. String theory and the quest for quantum space-time : Rajesh Gopakumar , Harish Chandra Research Institute, Allahabad (31.5.2012)

2. Universal thermodynamics : Lograithmic correction : S. Chakraborty, Jadavpur University (22.1.2013)

Public Outreach Programmes

1. Popular Lecture : A. K. Kembhavi ,May 23, 2013. About one hundred interested persons attended the lecture in the IRC, Physics Department, NBU.

2. Past and Present of Indian Astronomy : talk delivered by Dr. B. C. Paul at North Bengal Science Centre, Matigara on Feb 28, 2013 (Participants are mostly High school students).

Visitors

P. Majumdar (SINP, Kolkata)

R. Deb (Sikkim)

P. Thakur (Alipurduar College)

P. K. Chattopadhyay (Alipurduar College)

Mira Dey (Kolkata)

Jishnu Dey (Kolkata)

Rajesh Gopakumar (Harish Chandra Research Institute)

S. Chakraborty (Jadavpur University)

D. Dasgupta (Kolkata)

Pragati Pradhan (Darjeeling)

B. G. Dutta (Palpara College)

Robin Chhetri (Sikkim)

Ritesh Ghosh (Visva Bharati)

Ritabrata Biswas (BESU, Shibpur)

A. S. Mondal (Visva Bharati)

S. Sarkar(Visva Bharati)

Anuj Bal (Jadavpur University)

S. Khangebam (Manipur University)

R. B. Singh (Manipur University)

H. Gogoi (Assam University)

M. Gohain (Assam University)

R. Sharma (P. D. Women's College, Jalpaiguri)

Biswajit Paul (RRI, Bangaluru)

A. K. Kembhavi (IUCAA)

R. Misra (IUCAA)

P. Shalima (IUCAA)

S. Mukherjee (Kolkata)

A. Chattopadhyay (Calcutta University)

S. Mandal (Taki Govt. College)

INAAD, Newman College, Thodupuzha, Kerala

Workshops and Meetings

a .) Science with Optical Spectra

As a follow up of workshop on 'Optical astronomy projects using IRAF, a three day workshop on 'Science with Optical Spectra' was conducted at Mar Athanasios College For Advanced Studies (MACFAST), Tiruvalla , Kerala from 6-8 September 2012. In addition to 15 undergraduate students from the previous workshop, 15 research scholars from different universities also participated in this workshop. A pre-workshop session was held on 5th of September at Newman College to refresh the participants on the spectral reduction procedures that were taught during the January workshop. The theory sessions were handled by Prof. R.Srianand and Prof. Pushpa Khare from IUCAA. It was supported with hands-on sessions led by Vivek. M, Biju K.G, Sheelu Abraham and Arunkumar. Participants used SDSS spectra of about a dozen galaxies to estimate star formation rates, black hole mass, galaxy rotational velocities and the mass of the galaxies. A parallel 'day with an astronomer' session on "understanding the universe" for school students was conducted on 7th of September by Prof. Pushpa in which over 500 students participated.

A public Lecture by Professor Ajit Kembhavi on 7th evening to about 300 elite participants which included leading medical doctors, researchers and teachers from the region marked the ceremonial climax of the workshop. The talk highlighted the major Indian Astronomy research projects and collaborations such as the TMT, SALT and LIGO with special emphasis to the importance of the "LIGO- India" project. Prof. R. Srianand. Prof. V.C.Kuriakose and Dr. Joe Jacob were the coordinators.

b.) Radio Astronomy Meeting I

This advanced five day Radio Astronomy meeting that was held from February 24-28, 2013 at Mar Athanasios College For Advanced Studies (MACFAST), Tiruvalla , Kerala. The meeting was devoted to discussions on the basic theory and methods of Radio Astronomy data acquisition and processing. Prof Rajaram Nityananda (NCRA) and Prof. Iswar Chandra (NCRA) were the resource persons. The participants of the meeting analysed low frequency radio data of a galaxy cluster under the able guidance of Prof. Iswar Chandra.

The Radio Macfast (an FM radio station operated from the campus) broadcasted two interviews each of twenty minutes duration of Prof. Rajaram and Prof. Ishwar on 25th and 27th. During the ''Meet an Astronomer'' programme conducted on 27th in connection with the meeting, Prof. Iswar talked to the Post-graduate students of Computer Applications of the college regarding the new developments in the field of Radio Astronomy and the opportunities for students of engineering stream in it. He also delivered the National Science Day Lecture at St. Thomas College, Kozhencherry, on the 28th of February. Dr. Joe Jacob and Dr. Sajeeth Ninan Philip were the co-ordinators of the meeting.

c.) Radio astronomy Meeting II

A follow up of the first radio astronomy meeting was conducted at St. Thomas College, Kozhencherry from 8-10 May 2013. During the program 7 research scholars from the region continued the analysis and the discussions on the low frequency radio data from GMRT. They also interacted with ten post-graduate students of the college in which they discussed fundamentals in Radio astronomy, so as to motivate them to take up projects in the topic for their PG course. Dr. Joe Jacob and Dr. Sajeeth Ninan Philip were the co-ordinators of the meeting.

Department of Physics, Mohanlal Sukhadia University, Udaipur

Coordinator: S. N. A. Jaaffrey
Jt. Coordinator: G. S. Rathore

IUCAA Resource Centre (IRC), Udaipur was established in 2009 after signing an MoU by the Mohanlal Sukhadia University, Udaipur and Inter-University Centre of Astronomy and Astrophysics, Pune. The main motive of an IRC is to enhance the facilities to the teachers and students of colleges and universities of that region, involving the younger generation, who are pursuing research in Astronomy and Astrophysics, and in other related areas. The IRC would focus on activities to popularize Astronomy and Astrophysics among students and the general public.To keep up the objectives at first priority, IRC Udaipur organized the following activities at various point of times of the year:

Workshops and Meetings

Orientation Workshop on Transit of Venus

The Transit of Venus took place on June 06, 2012; it was the second in the pair of the transit occurred on June 08, 2004. One alive today would not be alive to watch the next pair of Venus, which would take place during 2117 and 2125. Therefore, the Transit of Venus 2012 was a life time opportunity for everyone on the earth. This workshop was for three day held during April 26-28,2012. There had been the hands on practice and lectures for 50 participants from Rajasthan, Gujarat and M. P. Amitabh Pandey, A .Ambastha , S. Chatterjee, Arvind Paranjape, Sachin delivered talks on various topics during the workshop.

The IRC at Mohanlal Sukhadia University, Udaipur had invited to **P. C. Agrawal** (Chair Professor of ISRO & Principal Director of ASTROSAT Mission) as the Chief Guest and **I. V. Trivedi** Hon'ble Vice-Chancellor M.L.S University, presided the inaugural function **S. N. A. Jaaffrey, G. S. Rathore, B.L.Ahuja**, and **M. Bhattnagar** chaired as Coordinator, cordinator of IRC, Udaipur, Head of the Department of Physics, and Dean of University College of Science, Udaipur respectively. The workshop was sponsored by Vigyan Prasar and co-ordinated by G.S.Rathore.

P. C. Agrawal addressing at Inaugural function.

Demonstration of Solar System by Dr. Amitabh Pandey.

Watching Sun-spots and Solar flares with S. N. A. Jaaffrey and Hon'ble V. C., MLSU, I. V. Trivedi.

(b.) Workshop on Radio Interferometry

The IRC at Mohanlal Sukhadia University, organized a Workshop on Radio Interferometry during May 16 – 17 , 2012 under the sponsorship of IUCAA. College/school students were invited to attend the inaugural function. The Chief Guest of inaugural function was **I.V. Trivedi**, Hon'ble Vice-Chancellor, M.L.S University and was presided by **M. Bhattnagar**, Dean and Chairman, Faculty of Science, M.L.S.University. Special Guest was **R. Ramesh**, Director, G. Radio Observatory, IIAP, Bangalore. This workshop was conducted at the Amanatra comfort Hotel, Udaipur.

S. N. A. Jaaffrey addressing on Radio Astrophysics: Significance of Research at Radio Wavelength.

Ramesh discussing on Radio Observations of Sun.

Balance Sheet

The Bombay Public Trust Act, 1950. Schedule VIII [Vide Rule (1)]

Name of the Trust : INTER-UNIVERSITY CENTRE FOR ASTRONOMY & ASTROPHYSICS

Address: Post Bag-4,Ganeshkhind, Pune-7. Registration No. :F-5366 (PUNE) dated 27.1.1989.

BALANCE SHEET AS AT 31ST MARCH 2013

Sr No.	FUNDS & LIABILITIES	Schedule No.	31.03.2013 Rs.
1	Trust Fund / Corpus	6	4,33,97,948
2	Grant-In-Aid from UGC	7	1,23,26,94,279
3	Other Project Grants	8	3,43,08,819
4	Projects and Other Payable (Net)	9	91,42,760
5	Current Liabilities	10 & 10A	3,35,71,665
6	Income and Expenditure a/c	14	(4,65,17,881)
	Total		1,30,65,97,590

Sr No.	ASSETS & PROPERTIES	Schedule No.	31.03.2013 Rs.
1	Fixed Assets (At cost)	11	1,04,05,79,236
2	Investments / Deposits	12	22,45,89,851
3	Project & Other Receivables (net)	13	36,70,714
4	Current Assets -	13	
	a) Cash, Bank balances & Revenue Stamps		5,77,377
	b) Loans and Advances	13A	1,43,93,388
	c) Deposits		23,17,016
	d) Prepaid Expenses		45,61,051
	e) Advance to Suppliers	13B	1,59,08,957
	Total		1,30,65,97,590

For Inter-University Centre for Astronomy & Astrophysics

N. V. Abhyankar
Admn.Officer (Accounts)

E.M.Modak
(Sr.Admn.Officer)

Prof. A.K.Kembhavi
(Director / Trustee)

As per Report of even date
For A.H.Joshi & Co.
Chartered Accountants
FRN- 112396W

S.A.Joshi
(Partner)
Membership No.037772

A.H. Joshi & Co. PUNE-30. Chartered Accountants

Place : Pune
Date : 05.08.2013.

Chairperson
Governing Board

IUCAA, Post Bag 4, Ganeshkhind, Pune 411 007, India
Phone : (91) (20) 2560 4100 | **Fax** : (91) (20) 2560 4699
e-mail : publ@iucaa.ernet.in | **website** : www.iucaa.ernet.in