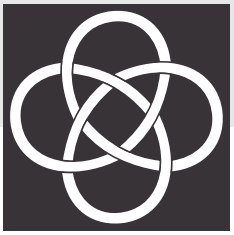
Inter-University Centre for Astronomy and Astrophysics

(An Autonomous Institution of the University Grants Commission)

2011-12

ANNUAL REPORT

24th



IUCAA

Inter-University Centre for Astronomy and Astrophysics

(An Autonomous Institution of the University Grants Commission)

24th ANNUAL REPORT

(April 1, 2011 - March 31, 2012)

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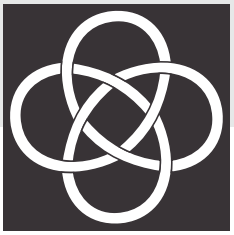

IUCAA

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HIGHLIGHTS OF 2011- 2012

This annual report covers the activities of IUCAA during its twenty-fourth year, April 2011-March 2012.

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), 11 post-doctoral fellows and 29 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 magnetic fields, observational cosmology and extragalactic astronomy, high energy astrophysics, quasars, active galactic nuclei and absorption systems, stars and interstellar medium, solar physics and instrumentation. These research activities are summarised in pages 21 - 45. The publications of the IUCAA members, numbering to about 80 in the current year are listed in pages 46 - 49. IUCAA members also take part in pedagogical activities like lectures, seminars, popularisation of science, etc., the details of which are given in pages 50 - 59 and 84-85 of this report.

The extended academic family of IUCAA consists of about 85 Visiting Associates, who have been active in several different fields of research. Pages 86 - 105 of this report highlight their research contributions. The resulting publications, numbering to about 150 are listed in pages 106 - 112 of this report. A total of about 1635 person-days were spent by Visiting Associates at IUCAA during this year. In addition, IUCAA hosted about 650 visitors from colleges and universities within India and abroad for various conferences, workshops and for academic collaborations. 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. Among the research scholars, three students have successfully defended their theses and obtained Ph.D. degree from the University of Pune during the year 2011 - 2012. Summary of their theses appears in pages 72 - 74.

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 14 such events in IUCAA and 10 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 9000 people visited IUCAA.

The activities carried out by IUCAA were ably supported by the scientific and technical, and administrative staff (28 and 31 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 75 - 79 of this report.

Swara Ravindranath
Editor

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THE COUNCIL AND THE GOVERNING BOARD

THE COUNCIL (As on March 31, 2012)

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VED PRAKASH,
Chairperson (I/c), University Grants Commission, New Delhi.

VICE-PRESIDENT

VED PRAKASH,
Vice-Chairperson, University Grants Commission, New Delhi.

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UGC-DAEF Consortium
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Centre Director,
National Centre
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Pune.

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Physical Research Laboratory,
Ahmedabad.

Chanda Jog,
Indian Institute of Science,
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University Grants Commission,
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T.V. Shivshankara Murthy,
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K. Radhakrishnan,
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Indian Space
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H.P. Singh,
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and Astrophysics,
University of Delhi.

Kandaswamy Subramanian,
IUCAA,
Pune.

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Vice-Chancellor,
Pondicherry University.

MEMBER SECRETARY

Ajit K. Kembhavi,
Director, IUCAA, Pune.

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

K. Ramamurthy Naidu,
Hyderabad.

R. K. Shevgaonkar,
Vice-Chancellor, University of Pune

THE GOVERNING BOARD

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Anil Kakodkar

MEMBERS

P.C. Agrawal

Sanjay Chahande

Mihir K. Chaudhuri

Praveen Chhadah

Swarna Kanti Ghosh

J.N. Goswami

Niloufer Kazmi

Kandaswamy Subramanian

J.A.K. Tareen

MEMBER SECRETARY

Ajit K. Kembhavi,
Director, IUCAA, Pune.

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

K. Ramamurthy Naidu

R.K. Shevgaonkar

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E. Margaret Burbidge,
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Gerard 't Hooft,
Spinoza Institute,
The Netherlands.

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Institute of Astronomy,
University of Cambridge,
UK.

Yash Pal,
Noida.

Govind Swarup,
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National Centre
for Radio Astrophysics,
Pune.

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Mumbai.

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U.S.A.

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Tata Institute of
Fundamental Research,
Mumbai.

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University of Cambridge,
United Kingdom.

Yashwant Gupta,
National Centre for
Radio Astrophysics,
Pune.

Romesh Kaul,
The Institute of
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Chennai.

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

Martin M. Roth,
Astrophysikalisches
Institut Potsdam,
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IUCAA,
Pune.

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(Chairperson, Ex-Officio),
Director,
IUCAA,
Pune.

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IUCAA,
Pune.

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

Sanjeev Dhurandhar,
IUCAA,
Pune.

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,
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THE ACADEMIC PROGRAMMES COMMITTEE

Ajit K. Kembhavi
(Chairperson)

T. Padmanabhan
(Convener)

Sanjeev V. Durandhar
(Retired on 30/11/2011)

Kandaswamy Subramanian

Joydeep Bagchi

Dipankar Bhattacharya

Gulab Chand Dewangan

Ranjan Gupta

Ranjeev Misra

Sanjit Mitra
(Joined on 31/10/2011)

A.N. Ramaprakash

Swara Ravindranath

Varun Sahni

Tarun Souradeep

R. Srianand

Durgesh Kumar Tripathi
(Joined on 05/04/2011)

THE STANDING COMMITTEE FOR ADMINISTRATION

Ajit K. Kembhavi
(Chairperson)

T. Padmanabhan

Sanjeev V. Dhurandhar
(Till 31/08/2011)

Kandaswamy Subramanian
(From 01/09/2011)

Eknath M. Modak
(Member Secretary)

THE FINANCE COMMITTEE

Anil Kakodkar
(Chairperson)

Ajit K. Kembhavi

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Swarna Kanti Ghosh

Niloufer A. Kazmi

T.R. Kem

Kandaswamy Subramanian

Eknath M. Modak
(Non-member Secretary)

MEMBERS OF IUCAA

ACADEMIC

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(Director)

T. Padmanabhan
(Dean, Core Academic Programmes)

Sanjeev V. Dhurandhar
(Dean, Visitor Academic Programmes till 31/08/2011)
(Retired on 30/11/2011)

Kandaswamy Subramanian
(Dean, Visitor Academic Programmes from 01/09/2011)

Joydeep Bagchi

Dipankar Bhattacharya

Gulab Chand Dewangan

Ranjan Gupta

Ranjeev Misra

Sanjit Mitra
(Joined on 31/10/2011)

A.N. Ramaprakash

Swara Ravindranath

Varun Sahni

Tarun Souradeep

R. Srianand

Durgesh Kumar Tripathi
(Joined on 05/04/2011)

EMERITUS PROFESSORS

Jayant V. Narlikar

Naresh K. Dadhich

Shyam N. Tandon

SCIENTIFIC AND TECHNICAL

Prafull S. Barathe

Nirupama U. Bawdekar

Rani S. Bhandare

Santosh S. Bhujbal

Mahesh P. Burse

Shanker B. Chavan
(Resigned on 30/08/2011)

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Hillol K. Das

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(Resigned on 16/12/2011)

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Gajanan B. Gaikwad

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(Joined on 19/05/2011)

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Vilas B. Mestry

Shashikant G. Mirkute

Deepa R. Modi

Vijay Mohan

N. Nageswaran

Arvind Paranjpye
(On lien for 2 yrs from 21/12/2011)

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Chaitanya V. Rajarshi

Hemant Kumar Sahu

Yogesh R. Thakare

ADMINISTRATIVE AND SUPPORT

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(Senior Administrative Officer)

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Vijay P. Barve

Savita K. Dalvi

Rahul S. Gaikwad
(Joined on 01/11/2011)

Sandeep L. Gaikwad

Bhagiram R. Gorkha

Bhimpuri S. Goswami

Ramesh S. Jadhav

Baban B. Jagade
(Retired on 31/12/2011)

Sandip M. Jogalekar

Nilesh D. Kadam

Swati D. Kakade

Santosh N. Khadilkar

Susan B. Kuriakose

Neelima S. Magdum

Manjiri A. Mahabal

Kumar B. Munuswamy

Anil R. Paraste
(Joined on 21/02/2012)

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Rajesh V. Parmar

Mukund S. Sahasrabudhe

Vyankatesh A. Samak

Senith S. Samuel

Balaji V. Sawant

Deepak R. Shinde

Varsha R. Surve

Deepika M. Susainathan

Sadanand R. Tarphe

Shankar K. Waghela

Kalidas P. Wavhal

POST-DOCTORAL FELLOWS

Rizwan Ansari

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Debbijoy Bhattacharya

Ruta Kale

Bibhas Ranjan Majhi

Surajit Paul

Jayanti Prasad

Shalima Puthiyaveettil

Harsha Raichur

Prakash Sarkar

Sanil Unnikrishnan

RESEARCH SCHOLARS

Moumita Aich

Anirban Ain

Maryam Arabsalmani

Hadi Rahmani Bayegi

Pallavi Bhat

Luke Chamandy

Saugata Chatterjee

Sabyasachi Chattopadhyay

Santanu Das

Balaji Dodda

Tuhin Ghosh

Gaurav Goswami

Mohammad Hasan

Charles Jose

Nisha Katyal

Vikram K. Khaire

Sanved V. Kolekar

Nagendra Kumar

Sandeep Kumar

Sibasish Laha

Dipanjan Mukherjee

Suvodip Mukherjee

Sowgat Muzahid

Krishna Mohan Parattu

Mainpal Rajan

Pritesh S. Ranadive

Aditya Rotti

Suprit Singh

Kaustubh P. Vaghmare

TEMPORARY / PROJECT / CONTRACTUAL

Niranjan D. Bangde
Avinash Bhimu Babar
Ganesh Bhat
Neelam Bhujbal
Malathi Deenadayalan
Bharat Gavhane
Arvind Gupta
Santosh B. Jagade
Tejas A. Kale
Chhaya A. Karle
Murli N. Krishnan
A.M. Lande
Maharudra G. Mate
Sharmad D. Navelkar
Dilip Pacharne
Pravin D. Pacharne
Nilesh D. Pokharkar
Ashok N. Rupner
Pratapbhan S. Senger
Sagar C. Shah
Rajendra Shevade
Monali K. Sinare
Garima Singh
Sakya Sinha
Amit R. Sonawane
Sangita W. Thakare
Reji M. Thomas
Kirti Tonpe
Ajay Vibhute

PART-TIME CONSULTANTS

V. Chellathurai
Vidula M. Mhaiskar
N.V. Nagarathanam
Vitthal Savaskar

LONG TERM VISITORS

P.C. Agrawal
Sanjeev V. Dhurandhar
Pushpa Khare

VISITING ASSOCIATES OF IUCAA

Farooq Ahmad	:	Department of Physics, University of Kashmir, Srinagar.
Sk. Saiyad Ali	:	Department of Physics, Jadavpur University, Kolkata.
G. Ambika	:	Department of Physics, Indian Institute of Science Education and Research, Pune.
B.R.S. Babu	:	Department of Physics, University of Calicut, Kozhikode.
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Subenoy Chakraborty	:	Department of Mathematics, Jadavpur University, Kolkata.
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K.P. Harikrishnan	:	Department of Physics, The Cochin College, Kochi.
N. Ibohal	:	Department of Mathematics, University of Manipur, Imphal.
Naseer Iqbal Bhat	:	P.G. Department of Physics, University of Kashmir, Srinagar.
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S.N.A. Jaaffrey	:	Department of Physics, University College of Science, M.L. Sukhadia University, Udaipur.
Joe Jacob	:	Department of Physics, The Newman College, Thodupuzha.
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Kanti Jotania	:	Department of Physics, The M.S. University of Baroda, Vadodara.
Minu Joy	:	Department of Physics, Alphonsa College, Pala.
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Nagendra Kumar	:	Department of Mathematics, M.M.H. College, Ghaziabad.
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Mamta	:	Department of Physics and Electronics, SGTB Khalsa College, Delhi.
Pradip Mukherjee	:	Department of Physics, Barasat Government College, Barasat.
K.K. Nandi	:	Department of Mathematics, North Bengal University, Siliguri.
Archana Pai	:	Department of Physics, Indian Institute of Science Education and Research, Thiruvananthapuram
Sanjay Pandey	:	Department of Mathematics, L.B.S. (P.G.) College, Gonda.
S.K. Pandey	:	Vice-Chancellor, Pt. Ravishankar Shukla University, Raipur.
P.N. Pandita	:	Department of Physics, North Eastern Hill University, Shillong.
K.D. Patil	:	Department of Mathematics, B.D. College of Engineering, Sevagram.

M.K. Patil	:	School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded.
B.C. 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.
S. Rastogi	:	Department of Physics, D.D.U. Gorakhpur University.
C.D. Ravikumar	:	Department of Physics, University of Calicut, Kozhikode.
Saibal Ray	:	Department of Physics, Government College of Engg. and Ceramic Technology, Kolkata.
Biplab Raychaudhuri	:	Department of Physics, Visva Bharati, Santiniketan.
Anirban Saha	:	Department of Physics, West Bengal State University, Barasat.
Sandeep Sahijpal	:	Department of Physics, Panjab University, Chandigarh.
Tarun Deep Saini	:	Department of Physics, Indian Institute of Science, Bengaluru.
Pramoda Kumar Samal	:	Department of Physics, Utkal University, Bhubaneswar.
Sanjay Baburao Sarwe	:	Department of Mathematics, St. Francis De Sales College, Nagpur.
Anjan Ananda Sen	:	Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
Asoke Kumar Sen	:	Department of Physics, Assam University, Silchar.
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.
H.P. Singh	:	Department of Physics and Astrophysics, University of Delhi.
M. Sivakumar	:	School of Physics, University of Hyderabad.
Pranjal Trivedi	:	Department of Physics, Sri Venkateswara College, Delhi.
Paniveni Udayashankar	:	Department of Physics, NIE Institute of Technology, Mysore.
A.A. Usmani	:	Department of Physics, Aligarh Muslim University.

Till July 31, 2011

Somenath Chakrabarty	:	Department of Physics, Visva Bharati, Santiniketan.
Ajay S. Chaudhari	:	School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded.
P.S. Goraya	:	Department of Physics, Punjabi University, Patiala.
E. Saikia	:	Department of Physics, Inderprastha Engineering College, Ghaziabad.

From August 1, 2011

Bijan Kumar Bagchi	:	Department of Applied Mathematics, University of Calcutta, Kolkata.
Shuvendu Chakraborty	:	Department of Mathematics, Seacom Engineering College, Howrah.
Ramesh Chandra	:	Department of Physics, Kumaun University, Nainital.
Surajit Chattopadhyay	:	Department of Computer Application, Pailan College of Management and Technology, Kolkata.
Sudipta Das	:	Department of Physics, Visva Bharati, Santiniketan.
Anoubam S. Devi	:	Department of Physics, Assam University, Silchar.
Sunandan Gangopadhyay	:	Department of Physics, West Bengal State University, Barasat.
Abhinav Gupta	:	Department of Physics, St. Stephen's College, Delhi.
Suresh Kumar	:	Department of Applied Mathematics, Delhi Technological University
B.S. Kushvah	:	Department of Applied Mathematics, Indian School of Mines, Dhanbad.
Soma Mandal	:	Department of Physics, Taki Government College.
Rajib Saha	:	Department of Physics, Indian Institute of Science Education and Research, Bhopal.
B.P. Sarmah	:	Department of Mathematical Sciences, Tezpur University.
Anand Sengupta	:	Department of Physics and Astrophysics, University of Delhi.
H.D. Singh	:	Department of Physical Sciences, Sikkim University, Gangtok.

THE TWENTY-SECOND BATCH OF VISITING ASSOCIATES, WHO WERE SELECTED FOR A TENURE OF THREE YEARS, BEGINNING AUGUST 1, 2011


Bijan Kumar Bagchi


Shuvendu Chakraborty


Ramesh Chandra


Surajit Chattopadhyay


Sudipta Das


Anoubam S. Devi


Sunandan Gangopadhyay


Abhinav Gupta


Suresh Kumar


B.S. Kushvah


Soma Mandal


Rajib Saha


B.P. Sarmah


Anand Sengupta


H.D. Singh

Appointments of the following Visiting Associates from the nineteenth batch were extended for three years : Vasudha Bhatnagar, Gour Bhattacharya, Suresh Chandra, Asis K. Chattopadhyay, Tanuka Chattopadhyay, Rabin Kumar Chhetri, Ujjal Debnath, Jishnu Dey, Mira Dey, Naseer Iqbal Bhat, V.C. Kuriakose, Manzoor A. Malik, Pradip Mukherjee, Sanjay K. Pandey, S.K. Pandey, Kishor Dnyandeo Patil, Ninan Sajeeth Philip, Shantanu Rastogi, Saibal Ray, Sanjay Baburao Sarwe, and T.R. Seshadri.

ORGANIZATIONAL STRUCTURE OF IUCAA'S ACADEMIC PROGRAMMES (FROM AUGUST 1, 2011)

THE DIRECTOR
Ajit K. Kembhavi

- **Dean, Core Academic Programmes** (T. Padmanabhan)
- **Head, Computing Facilities** (Dipankar Bhattacharya)
- **Head, IUCAA Girawali Observatory** (Vijay Mohan)
- **Head, Publications** (Swara Ravindranath)
- **Head, Instrumentation** (A. N. Ramaprakash)
- **Head, Library** (Varun Sahni)
- **Head, Teaching Programmes** (R. Srianand)

- **Dean, Visitor Academic Programmes** (K. Subramanian) (from 01/09/2011) (Sanjeev Dhurandhar) (till 31/08/2011)
- **Head, Public Outreach Programmes** (Gulab C. Dewangan)
- **Head, Scientific Meetings** (Ranjan Gupta)
- **Head, Estate Development and Maintenance** (Ajit Kembhavi)
- **Head, IUCAA Resource Centres** (Ranjeev Misra)
- **Head, Infrastructural Facilities** (Tarun Souradeep)
- **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.

Professor Sanjeev V. Dhurandhar, who has been with IUCAA for about 20 years, was the Dean, Visitor Academic Programmes from September 2009 till August 2011. He retired from service upon superannuation at the end of November 2011. He has had an extremely fruitful research career during which he established himself as one of the leading persons in the world in the domain of gravitational wave data analysis algorithms. He has produced a number of research students and post-doctoral fellows who are now established workers in the field. Professor Dhurandhar continues to be academically associated with IUCAA after his retirement. Dr. Durgesh Tripathi, who specializes in solar astronomy and spectroscopy has joined as an Assistant Professor in April 2011, and Dr. Sanjit Mitra, who specializes in the gravitational waves and cosmic microwave background radiation, has joined as an Assistant Professor in November 2011.

IUCAA faculty members have been engaged in research and development, teaching at the IUCAA graduate school and on various university campuses, thesis supervision and organization of workshops and other meetings. They have produced about 80 research papers in high impact, international and national journals. During the year, IUCAA had 16 faculty members, 29 research scholars and 11 post-doctoral fellows. In addition, there have been several long term senior visitors and emeritus professors.

The 2 m optical and near infrared telescope at IUCAA Girwali Observatory (IGO) had a very good year of observations. About 35% of the successful proposals have originated from the universities and 40% from the various research institutes in the country, with the rest having IUCAA members as principal investigators. The aim has been to try to push the telescope to its limits in observing faint and distant objects. As is described elsewhere in this report, very interesting results have been obtained.

The 11 m 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 2013. 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, and calibration is in progress. IUCAA is also helping to develop a sophisticated proposal management system for ASTROSAT.

A 30 TF parallel computing cluster with 1500 cores, 12 TB RAM and 600 TB storage has been acquired and is expected to be installed and ready for use during the second half of 2012.

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, has been successfully completed. 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 3.6 m Devsthal Optical Telescope. The instrument will be built at IUCAA through collaboration between the two institutions.

There has been a great deal of construction activity at IUCAA, including a new data centre and instrumentation laboratory, a guest house and staff quarters. It is expected that these new buildings will be ready in the last quarter of 2012. Much needed space will then become available to support new activities and additional staff and visitors at IUCAA.

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. IUCAA Nodes for Astronomy and Astrophysics Development (INAAD) have been set up at Tezpur University and Newman College, Thodupuzha, Kerala. Student workshops and other activities are being organized in these new centres. IUCAA now has 85 Visiting Associates from the university sector, many of whom have spent significant period at IUCAA, accompanied by their research students. A number of national and international workshops were conducted at IUCAA during the year covering a number of fields including adaptive optics, solar physics, gravitational waves, the virtual observatory, interstellar dust and cosmology. At the end of the International Virtual Observatory Alliance (IVOA) interoperability meeting, which took place at IUCAA in October 2011, I took over as the Chairman of the IVOA. Special mention should be made here of the International Conference on the Interstellar Dust, Molecules and Chemistry which was highly successful, took place at IUCAA. Professor Shantanu Rastogi of the D. D. U. Gorakhpur University, who is a Visiting Associate of IUCAA, was a coordinator along with Professor Ranjan Gupta of IUCAA.

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 project is now being considered for approval and sites for the giant installation are being surveyed.

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 for the project. 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.

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. Anil Kakodkar for the constant support and encouragement provided to IUCAA and to me personally. Likewise the Council too, and its Chairperson, 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

Congratulations to ...

NARESH DADHICH

for the invitation to take up the newly instituted
M. A. Ansari Chair at the Jamia Millia Islamia, Delhi.
The Chair is hosted in the Centre for Theoretical Physics and its tenure is of 3 years.

SANJEEV DHURANDHAR

for Vaidya-Raychaudhuri Endowment Award, 2012.

ARVIND GUPTA

on being conferred with the **Outstanding Science Teacher Award**
by C.N.R. Rao Education Foundation, Bengaluru

JAYANT NARLIKAR

on being conferred with the

- **Maharashtra Bhushan Award** from the Government of Maharashtra, May 2.
- **Shrimant Malojiraje Smruti Puraskar**
  from the Shrimant Malojiraje Smruti Pratisthan, Phaltan, May 14.
- **DCCIA Pune Award for Excellence - Public Service - 2011**
  from the Deccan Chamber of Commerce, Industries and Agriculture, Pune, September 30.
- **Sri Chandrasekarendra Saraswathi National Eminence Award**
  from the South Indian Education Society (SIES), Mumbai, December 9.
- **Sir Devaprasad Sarvadhikari Medal (2011)**
  for contribution in science from the University of Calcutta, Kolkata, March 22.

T. PADMANABHAN

on being conferred with the **TWAS Prize in Physics** for 2011,
by the Third World Academy of Sciences, Trieste, Italy.

Elected Chairman, Commission 19 (Astrophysics) of International Union of Pure and Applied Physics (2011-2014).

ARVIND PARANJPYE

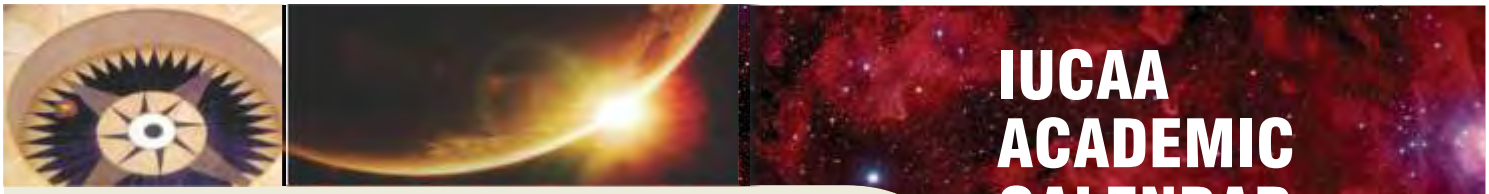
who has joined the Nehru Science Centre, Mumbai,
as the **Director (Planetarium).**

ASHOK RUPNER

on being selected as a **SCIFEST WINNER 2012** for the best Workshop:
Innovative (Toys from Trash) by South Africa's National Science Festival.

DURGESH TRIPATHI

for receiving the **DST Fast Track Scheme Award** for Young Scientist, 2012.



IUCAA ACADEMIC CALENDAR 2011-12

Events at IUCAA - 2011

August 10 - 12
Indo-UK Scientific Seminar: Confronting Particle-Cosmology with Planck and LHC
Coordinators: Tarun Souradeep (tarun@iucaa.ernet.in)
Anupam Mazumdar (a.mazumdar@lancaster.ac.uk)
L. Sriramkumar (sriram@physics.iitm.ac.in)
www.physics.iitm.ac.in/~sriram/indo-uk-meeting

August 22 - 25
Workshop on Astronomy with Adaptive Optics on Moderate-sized Telescopes
Coordinator: A. N. Ramaprakash (anr@iucaa.ernet.in)
Sponsored by: Indo-US Science and Technology Forum

September 5 - 7
Workshop on Physics of the Solar Transition Region and Corona
Coordinator: Durgesh Tripathi (durgesh@iucaa.ernet.in)
www.iucaa.ernet.in/~solar

October 17 - 21
International Virtual Observatory Alliance Interoperability Meeting
Coordinator: Ajit Kembhavi (akk@iucaa.ernet.in)
http://voi.iucaa.ernet.in: 9090/InterOp_2011

November 1 - 2
EGO-IndIGo Meet on Gravitational Waves
Coordinators: Bala Iyer (bri@rri.res.in)
Tarun Souradeep (tarun@iucaa.ernet.in)
www.gw-indigo.org

November 22 - 25
International Conference on Interstellar Dust, Molecules and Chemistry
Coordinators: Shantanu Rastogi (shantanu@iucaa.ernet.in)
Ranjan Gupta (rag@iucaa.ernet.in)
www.iucaa.ernet.in/~idmc2011

December 1 - 11
ICTS School on Cosmology and Gravitational Waves
Coordinators: Subhabrata Majumdar (subha@tifr.res.in)
Tarun Souradeep (tarun@iucaa.ernet.in)
www.icts.res.in/program/details/211

December 20 - 22
ICTS Workshop on Gravitational Wave Astronomy
Coordinators: B. S. Sathyaprakash (b.sathyaprakash@astro.cf.ac.uk)
Tarun Souradeep (tarun@iucaa.ernet.in)
www.icts.res.in/program/details/211

December 26 - January 2, 2012
IUCAA-NCRA Radio Astronomy Winter School (for College & University Students)
Coordinators: Joydeep Bagchi (joydeep@iucaa.ernet.in)
Bhal Chandra Joshi (bcj@ncra.tifr.res.in)
www.ncra.tifr.res.in/~rpl/rplab.html

Events outside IUCAA - 2011

October 17 - 19
Workshop on Teaching and Research with Small Telescopes
at J. E. S. College, Jalna
Coordinators: M. L. Kurtadikar (mukund.kurtadikar@gmail.com / mkurtadikar@yahoo.com)
Ranjan Gupta (rag@iucaa.ernet.in)

October 24 - 26
Workshop on Stellar Astrophysics
at University of Kashmir, Srinagar
Coordinators: Naseer Iqbal (iqbal@iucaa.ernet.in / dr_bhat786@rediffmail.com)
Ranjeev Mishra (rmisra@iucaa.ernet.in)

November 14 - 17
Workshop on Galaxies: Normal and Active
at Swami Ramanand Teerth Marathwada University, Nanded
Coordinators: M.K. Patil (patil@iucaa.ernet.in)
Gulab C. Dewangan (gulabd@iucaa.ernet.in)

Events at IUCAA - 2012

January 9 - 13
Workshop on Photometer Fabrication
Coordinator: Ranjan Gupta (rag@iucaa.ernet.in)

January 23 - 28
Advanced Research Workshop on X-ray Timing
Coordinator: Dipankar Bhattacharya (dipankar@iucaa.ernet.in)
www.iucaa.ernet.in/~astrosat/timingWS2012/

Events Outside IUCAA - 2012

January 23 - 27
Workshop on Gravitational Wave Data Analysis
at Tezpur University
Coordinators:
Bhim Prasad Sarmah (bhim@tezu.ernet.in)
Sanjeev Dhurandhar (sanjeev@iucaa.ernet.in)
www.tezu.ernet.in/wmgwda12

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

IUCAA Annual Events

2011

April 11 - May 20
School Students' Summer Programme

May 6
IUCAA-NCRA Graduate School - Second semester ends

May 9 - June 10
Refresher Course in Astronomy and Astrophysics (for College & University Teachers)

May 9 - June 24
Vacation Students' Programme

August 8
IUCAA - NCRA Graduate School - First semester begins

December 9
IUCAA - NCRA Graduate School - First semester ends

December 29
Foundation Day

2012

January 2
IUCAA-NCRA Graduate School - Second semester begins

February 28
National Science Day

IUCAA Resource Centre Events

July 21 - 22, 2011
Workshop on Astronomy for College Teachers
at Newman College, Thodupuzha
Coordinator: V. C. Kuriakose (vck@cusat.ac.in/vck@iucaa.ernet.in)

October 10 - 13, 2011
Science with Virtual Observatory
at Newman College, Thodupuzha
Coordinator: V. C. Kuriakose (vck@cusat.ac.in/vck@iucaa.ernet.in)

December 21 - 23, 2011
International Workshop on Dark Energy
at CTP, Jamia Millia Islamia, New Delhi
Coordinator: T.R. Seshadri (trs@iucaa.ernet.in/trs@physics.du.ac.in)
http://irc.du.ac.in

Public Outreach Events
Workshop on Astronomy for School Teachers and Science Educators
IUCAA Coordinator: Arvind Paranjpye (arp@iucaa.ernet.in)
www.iucaa.ernet.in/~scipop

November 12 - 14, 2011
at IRC, Raipur
Coordinator: S.K. Pandey (proskp@gmail.com/skp@iucaa.ernet.in)

December 1 - 3, 2011
at IRC, Udaipur
Coordinator: S.N.A. Jaaffrey (sna_jaaffrey@yahoo.co.in)

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E-mail: publ@iucaa.ernet.in • www.iucaa.ernet.in

RESEARCH AT IUCAA

QUANTUM THEORY AND GRAVITY

On static Lovelock black holes

Lovelock generalization of the Einstein's gravity is most interesting, because despite the action being polynomial in Riemann curvature, it has the remarkable feature that the equation of motion still remains second order quasi-linear. The gravitational equation retains its second order character and because of the quasi-linearity, the initial value is well-posed unlike the f(R) gravity theories. However, the Lovelock terms make non-zero contribution in dimension $d > 2n+1$, where n is the order of the polynomial. **Naresh Dadhich** in collaboration with Josep Pons and Kartik Prabhu have found some interesting properties of the static pure Lovelock black holes. In particular, they have identified the universality of the thermodynamical parameters in terms of the event horizon radius as the characterizing property of the pure Lovelock black hole, which is the *n-th* order Lovelock Λ vacuum solution.

It turns out that for the static case, the vacuum equation ultimately turns out to be a first order equation involving an *n-th* order polynomial which could be easily solved. Since *n-th* order case would involve n Lovelock couplings, it was argued by Banados, Teitelboim and Zanelli that for the black hole to be physically meaningful and interesting, all the Lovelock couplings be given in terms of the unique ground state defined by Λ. These were termed dimensionally continued black holes. This corresponded to the *n-th* order algebraic equation being degenerate. There was, however, one undesirable feature that the solution did not go over to the proper Einstein limit for large r. **Dadhich,** Kartik and Pons have overcome this difficulty by taking the polynomial to be derivative degenerate rather than being itself degenerate. This is how they generalize the dimensionally continued black holes, which have the proper Einstein limit for the low energy end. This is what expected as the higher order terms contribution should wean out at large distance.

In this class of derivative degenerate solution, there is an interesting subclass of pure Lovelock black holes with Λ and the *n-th* order coupling alone. It turns out that temperature and entropy always bear the same relation with the event horizon radius for $d = 2n+1, 2(n+2)$ for any n. This universality of thermodynamics is also the characterizing property of the pure Lovelock black hole. It is both necessary and sufficient that thermodynamics is universal in terms of the event horizon radius for the pure Lovelock black hole.

Action principle for the Fluid - Gravity correspondence and emergent gravity

It was shown by Damour decades ago that Einstein's field equations when projected onto a black hole horizon take a form very similar (but not identical) to a Navier-Stokes equation in fluid mechanics (usually called as the Damour-Navier-Stokes equation, or simply DNS equation for short). He showed that the black hole horizon can then be interpreted as a dissipative membrane to which one could attribute fluid like properties. This work later formed the basis for the development of membrane paradigm by several authors to describe black hole physics. More recently, it was shown (T. Padmanabhan 2010) that in a local inertial frame around any event in a spacetime, the Einstein field equations projected onto a null surface become exactly the Navier-Stokes equation with quantities like viscous tensor, momentum density, etc. being related to certain combination of the affine connection Γ^a_{bc} and the normal l^a defining the null surface. Since the dynamics of the geometry of a null surface behaves exactly locally like a viscous fluid, one can ask the question, whether the action for gravity which leads to that geometry can also be written completely in terms of fluid variables such that one can have a corresponding variational principle to obtain the Navier-Stokes equation directly? (One should note that even at the classical level, the action for the Navier-Stokes equation is not known.)

In a recent paper, **Sanved Kolekar** and **T. Padmanabhan** have answered this question by making use of the fact that the field equations of gravity were obtained previously (T. Padmanabhan, et. al. 2008) from an entropy extremisation principle. The procedure involved associating with every null vector in the spacetime an entropy functional S_{grav} and demanding $\delta [S_{grav} + S_{matter}] = 0$ for all null vectors in the spacetime, where S_{matter} is the relevant matter entropy. They have shown that the entropy density functional can be expressed completely in terms of fluid variables defined

above and the entropy of the null surface (horizon) which is one quarter of its area. They have thus obtained a corresponding action for the Damour-Navier-Stokes equation, where the independent variables are now the null vectors and their derivatives. Further, the action is shown to acquire a thermodynamic interpretation in terms of a local entropy density and hence, extremising the action could then be viewed as equivalent to extremising the entropy density of the spacetime in the emergent gravity paradigm. This is demonstrated by considering the spacetime to be completely foliated by null surfaces and expressing the action in terms of the local fluid variables. The rate of change of action is shown to take the form

$$dS_{grav} / dt = - dE + TdS + Pd\,\delta A,$$

where (i) $E = 2\eta\sigma_{ab}\,\sigma^{ba} + \zeta\Phi^2$ is interpreted to be the loss in energy due to viscous dissipation, which leads to the rise in entropy of the spacetime, (ii) TdS denotes the increase in the gravitational entropy proportional to the increase of the area of the horizon, which is due to the familiar information loss processes and (iii) $Pd\delta A$ is the (virtual) work done by the horizon against the pressure P during its area expansion $d\delta A$. They have also shown that the degrees of freedom on the null surface are equivalent to a fluid with an equation of state $PA = TS$ which interestingly, also arises in the context of a spherical shell collapsing to form a horizon.

Two aspects of black hole entropy in Lanczos - Lovelock models of gravity

The first indication of the connection between thermodynamics and gravity came with the work of Bekenstein, who proposed the idea that a black hole should have an entropy that is proportional to the area of its horizon. Work in the last several decades attempted to understand the physical origin of the thermodynamic variables attributed to the horizons concentrating mostly on black hole horizons. In spite of extensive work and different possible suggestions for the source of entropy, it is probably fair to say that we still do not quite understand the physics behind this phenomenon.

One can classify the different approaches to explain black hole entropy by separating them into two broad categories (i) extrinsic origin - from the entropy of matter forming the black hole, entropy of matter fields propagating in the background metric, etc. and (ii) intrinsic origin - microscopic degrees of freedom corresponding to underlying statistical theory of quantum gravity, which are different depending on the approach. Within the context of Einstein's gravity, it is very difficult to discriminate between these two approaches. This is because, in Einstein's theory, entropy of a horizon is proportional to its area, which has a simple geometrical meaning. It is, therefore, very easy to come up with completely different approaches (intrinsic as well as several extrinsic approaches) all of which will lead to $S \alpha A$. On the other hand, the proportionality between horizon entropy and area does not extend to more general class of gravitational theories, in which the entropy is given by a prescription due to Wald, which essentially identifies the horizon entropy with a suitably defined Noether charge. Many of the approaches which correctly reproduces $S \alpha A$ in the context of GR cannot be generalized in a natural fashion to more general class of theories like, for example, Lanczos-Lovelock models. Therefore, the possibility of generalization beyond GR acts as an acid test in discriminating between the different approaches for obtaining the horizon entropy both intrinsic and extrinsic.

In a recent paper, **Sanved Kolekar,** Dawood Kothawala and **T. Padmanabhan** have studied two approaches to black hole entropy, one intrinsic and the other extrinsic, in the general context of Lanczos-Lovelock models of gravity. Both these approaches have been previously shown to reproduce the correct horizon entropy in Einstein's theory. When generalized to Lanczos-Lovelock models, the extrinsic approach fails to give the correct Wald entropy of the theory (though, for a pure m-th order Lanczos-Lovelock model, it is a near miss with the entropy being proportional to Wald entropy), while the intrinsic approach gives exactly the correct result for not only the entropy but even the energy associated with the black hole in Lanczos-Lovelock models!

The two routes to the black hole entropy considered in their work can be described briefly as follows. The most natural extrinsic origin of black hole entropy would be to consider the entropy of the matter which formed the black hole. Indeed, such an approach was taken before where it was shown that when a system consisting of spherically symmetric gravitating shell, or a series of such shells

forming a star, is on the verge of forming a black hole, then its entropy is proportional to the area of the outermost shell, which is same as the area of the horizon it would form at the end of its collapse. Further, the proportionality constant was calculated to be 1/4 making the entropy of the star to be exactly equal to the Bekenstein-Hawking entropy of the black hole. In the first part of the work, this idea is extended to Lanczos-Lovelock models of gravity and to calculate the entropy of a spherically symmetric gravitating star on the verge of forming a black hole. Their analysis shows that the entropy of the system is, in general, *not* equal to the Wald entropy. However, at each order of the Lanczos-Lovelock model, labeled by an index m, with $m=1$ being Einstein's theory, $m=2$ being Gauss-Bonnet, etc., the entropy which they obtain is proportional to Wald entropy of the black hole horizon in the corresponding theory of gravity with the proportionality constant depending on the dimension of spacetime as well as m. So when one considers a Lanczos-Lovelock theory with different orders like, for example, Einstein plus Gauss-Bonnet kind of theories, the overall proportionality breaks down. That is, for a Lanczos-Lovelock theory described by a sum of, say, first m Lanczos-Lovelock terms, the matter entropy of the shell configuration will *not* even be proportional to Wald entropy.

In the second part of their work, an "intrinsic" approach to horizon entropy is considered, which attempts to interpret the black hole entropy as associated with statistical nature of microscopic degrees of freedom of some underlying statistical theory of gravity. One such approach was considered in **T. Padmanabhan** (2002), where a partition function was defined through a Euclideanization of the path integral for Einstein's gravity. Here, the Euclidean action was interpreted to be the effective action for gravity emerging from some unknown quantum theory. It was shown that the form of the partition function allows one to determine the entropy and energy associated with the horizon, which is same as that determined through other approaches. However, the crucial difference between this approach and others is that here one does not use the field equations of gravity in the derivation, thus, allowing us to define an entropy and energy for the horizon even off-shell. In contrast, all the other approaches to entropy rely mainly on the field equations providing us with only a on-shell definition of entropy. Further, they have considered the generalization of this "intrinsic" approach to black hole entropy to Lanczos-Lovelock models. Surprisingly enough, the result generalizes in a nice manner to all the Lanczos-Lovelock models. Their analysis shows that the entropy and energy associated with the horizon off-shell are exactly same as the Wald entropy and energy of a horizon as obtained through other approaches on-shell.

Membrane paradigm and horizon thermodynamics for Lanczos-Lovelock gravity

The event horizon of a black hole is a one way membrane, although its existence is not of much practical relevance to an observer falling freely across it (at least for large black holes). However, the horizon surface serves as a boundary of accessible region to observers who remain static outside the horizon. The so called membrane paradigm of black holes essentially takes the viewpoint that, as far as such static observers are concerned, the black hole horizon can be replaced by a stretched horizon, a membrane, endowed with specific physical properties, which encode the presence of the inaccessible black hole region. Although originally developed to facilitate the easy comprehension of physics in black hole backgrounds for astrophysicists, work over the last decade or so has indicated that physical properties of the membrane such as viscosity, etc. might have a deeper relevance, specifically from the point of view of holographic dualities, which map gravitational systems to non-gravitational systems in one lower dimension.

More recently in **T. Padmanabhan** (2010), and **S. Kolekar** and **T. Padmanabhan** (2011) the membrane paradigm in Einstein gravity was revisited from a view point of the emergent gravity paradigm. It was shown that the Damour-Navier-Stokes equation governing the dynamics of the black hole membrane could be obtained starting from an action, which could be given a thermodynamic interpretation as an entropy production rate when expressed in terms of thermodynamic variables such as temperature, entropy, pressure, etc. of the horizon. Such an approach highlighted the unexplored deeper connection of the membrane paradigm with the horizon thermodynamics. However, a more formal approach would be to establish a correspondence between the thermodynamic variables and the quantities describing the membrane. Indeed one such relation was pointed out before connecting the membrane pressure p_s to the entropy S of the horizon through an

equation of state as $p_s A = ST$, where T is the Hawking temperature and A is the area of the horizon. Further, it was shown that the membrane pressure p_s also has a direct connection with the entropy density s_{shell} of a self-gravitating system of densely packed shells on the verge of forming a black hole. Here, one could question about the robustness of these relations for horizons in general. Hence, the resolution would be to check whether these hold even for higher curvature theories of gravity such as Lanczos-Lovelock theories of gravity. Also, when one is working in Einstein gravity (or Gauss-Bonnet gravity), the geometric structure of the fluid variables such as transport co-efficients of the membrane is not evident. For example, in Einstein's gravity, the shear viscosity η is equal to $1/(16\pi)$, which does not tell anything about its relation with the geometric properties of the horizon such as its relation with the intrinsic curvature of the horizon. To trace their geometric origins, one needs to consider a higher curvature theory of gravity such as Lanczos-Lovelock theories of gravity of an arbitrary order m and then proceed in a more formal general way.

In a recent paper, **Sanved Kolekar** and Dawood Kothawala have generalized the membrane paradigm for black holes to a particular class of higher curvature theories, namely the Lanczos-Lovelock models of gravity. They have considered membranes, which have isotropic tangential stresses (pressure), which is only possible when *all directions, everywhere* within the horizon surface, are equivalent (that is, the horizon surface is maximally symmetric). They have shown that the horizon membrane has a stress tensor whose form analogous to that of a viscous fluid. Such an analogy allows one to read-off the fluid variables in terms of the geometric quantities defining the horizon.

Their analysis highlights two peculiar features namely, (i) the membrane pressure is proportional to the entropy associated with the membrane for a specific m-th order Lanczos-Lovelock model. In particular, they are related by an equation of state of the form $PA = TS$ as in the case of GR and (ii) The shear viscosity co-efficient η and the bulk viscosity co-efficient ζ are related by a ratio as $\zeta = -2\,(D-3)/(D-2)\eta$, which is independent of the Lanczos-Lovelock theory. Also, from the explicit form of the expressions of η, they have shown that the shear viscosity co-efficient η and hence, the bulk viscosity co-efficient ζ are related to the quasi-local energy and Wald entropy s associated with the black hole horizon. Further, the ratio η/s has been calculated for a planar horizon and found to match with that obtained in the context of AdS-CFT correspondence; the difference being the boundary, which is the AdS infinity in the latter case, whereas in the former case, the boundary considered is the stretched horizon. It has been argued that the η/s ratio for the two cases are related by a (RG) flow equation in Einstein's gravity and the result for the membrane paradigm in Lanczos-Lovelock, in conjunction with the AdS-CFT results for Lanczos-Lovelock gravity, does suggest such a possible connection for the planar case.

Black hole spectroscopy

The entropy-area spectrum of a black hole has been a long-standing and challenging problem. Based on the modified tunneling mechanism, **Bibhas Majhi** has obtained the entropy spectrum of a black hole. In Einstein's gravity, he has shown that both entropy and area spectrum are evenly spaced. But in more general theories (like Einstein-Gauss-Bonnet gravity), although the entropy spectrum is equispaced, the corresponding area spectrum is not. In this sense, quantization of entropy is more fundamental than that of area.

This is also discussed from a classical adiabatic invariant quantity. The important advantages in this method is that one does not need any information about the quasi-normal modes of black hole. Also, the method is simple enough to incorporate more general cases.

Noether current, horizon Virasoro algebra and entropy

Bibhas Majhi and T. Padmanabhan collaborators have provided a simple and straightforward procedure for defining a Virasoro algebra based on the diffeomorphisms near a null surface in a spacetime and obtained the entropy density of the null surface from its central charge. They have used the off-shell Noether current corresponding to the diffeomorphism invariance of a gravitational Lagrangian L (g_{ab}, R_{abcd}) and defined the Virasoro algebra from its variation. This allows one to identify the central charge and the zero mode eigenvalue using which they have obtained the entropy density of the Killing horizon. This approach works for all Lanczos-Lovelock models and reproduces the

correct Wald entropy. The entire analysis has been done off-shell without using the field equations, and which allows one to define an entropy density for any null surface, which acts as a local Rindler horizon for a particular class of observers.

Complex path: A semi-classical probe of quantum effects

The study of a quantum mechanical system interacting with an externally specified classical background is of importance in several physical contexts. A powerful technique to study external source problems is that of the effective action which captures the quantum effects through a c-number effective action functional of the dynamical variables. In general, the effective action is a complex quantity with its real and imaginary parts being related to vacuum polarization and particle production respectively. In using the effective action to describe the back reaction effects, one usually uses the real part of the effective action and discards the imaginary part, in order to identify the quantum corrections to the classical equations, since in many applications the effect of vacuum polarization dominates over that due to particle production.

It is interesting to ask whether the formalism can be extended to include the effects of imaginary part of the effective action as well since it could, potentially, provide a formal procedure for handling the back reaction due to particle production. The obvious procedure would be to look for the solutions of effective equation of motion, where both the real and imaginary parts are retained. These equations will, in general, be complex rendering the solutions also to be complex. For example, in the elementary context of non-relativistic quantum mechanics, such a solution is the effective average path $X(t; x_2, t_2; x_1, t_1)$ obeying the appropriate boundary conditions at the end points. This function will, in general, be complex and one would presume that its imaginary part will contain some information about the particle production due to the external source.

In their recent paper, **Suprit Singh** and **T. Padmanabhan** have attempted to investigate the properties of this function using simple examples, including that of effective path through the black hole horizon leading to thermal radiation. In their work, they have shown that the effective path in the case of a harmonic oscillator interacting with an external source turns out to be complex, as expected, since the external source can cause transitions in the oscillator, thus, producing particles. The modulus square of the effective path gives the total energy input into the system by the external source due to the production of particles.

In a non-trivial case of the effective path for a system with an inverse square potential, it is found that the modulus square of the effective path increases linearly with time, which allows defining a constant, finite rate, which itself takes a rather curious form in that it contains a `Planck spectrum'. Obviously, in the quantum mechanical example, this result has no physical interpretation, but it is known that the problem of a scalar field in a spacetime with a horizon (in which the near-horizon geometry can be approximated as Rindler geometry) can be mapped to the Schrodinger problem in an inverse square potential. In that context, this can be thought of as rate of production of particles by the horizon and the obtained mathematical result acquires a physical meaning. Thus, the emission of particles by the black hole gets mapped to propagation of particle through the singularity at the origin in the equivalent Schrodinger problem, even though there are no time-dependent sources. The temperature of the black hole is read off from the spectrum to be $T = 1/(4\pi M)$, which is twice the usual temperature associated with black holes (The origin of this extra factor is attributed to using singular coordinates at horizon). Thus, the effective path approach seems to capture the Planck spectrum along with zero-point energy. Clearly, the squared modulus of $X(t)$ does contain information related to the production of particles in a fairly non-trivial setting.

GRAVITATIONAL WAVES

The existence of gravitational waves (GW) is predicted by every theory of gravity which incorporates the special theory of relativity - in particular the general theory of relativity. General relativity is perhaps the simplest theory which generalises special relativity and has passed the observational tests so far with flying colours. The theory accounts for gravitation as the manifestation of the curvature of spacetime. Thus, in general relativity GW are waves in the curvature of spacetime and travel with the

universal speed $c \sim 3 \times 10^5$ km/sec. Although the GW have not been detected so far, their existence has been indirectly established by the decay of the orbit of the binary pulsar PSR 1913+16 - the observed decay being almost exactly being as predicted by general relativity. The Nobel prize for this discovery was given to Hulse and Taylor in the year 1993.

But now the goal is to observe GW directly - and more importantly, use them to probe the universe, an additional probe beyond the electromagnetic ones. Since GW have very different physical properties, it is expected that they will yield new information about the universe hitherto unknown. Several GW observatories have been built, which have achieved initial levels of sensitivity and now the era of advanced detectors, which will have the capability of detecting GW. The current network consists of two detectors of the LIGO project of the US, Virgo of France and Italy, GEO of Germany and UK, and TAMA of Japan. Japan is further building a 3-km armlength detector KAGRA. Following its 20 year old effort on GW data analysis and waveform modelling, India has recently initiated experimental effort in GW. There is a strong and genuine possibility of LIGO setting up its third detector in collaboration with India and located in India, which would enormously increase the efficiency of the network, because this offers almost the longest baseline possible on Earth $\sim$ 39 ms in light travel time.

(i) The cross-correlation search for a hot spot of gravitational waves.

The Virgo cluster of galaxies can be a "hot" source of GW emanating from pulsars in the galaxies. This would be a stochastic source, since the pulsars will have random orientations and other random parameters. The cross-correlation search, which has been successfully applied to map the gravitational wave stochastic background in the sky, and also to target gravitational waves from rotating neutron stars/pulsars, which can be used here for this search. **S. V. Dhurandhar** and the Japanese team consisting of H. Tagoshi, Y. Okada, N. Kanda and H. Takahashi have investigated how the cross-correlation method can be used to target a small region in the sky spanning atmost a few pixels, where a pixel in the sky is determined by the diffraction limit, which is given by the inverse of the detector bandwidth divided by the light travel time between a pair of detectors. Advanced detector pairs among LCGT, LIGO, Virgo, ET, etc. are considered. The results show that sufficient signal to noise can be accumulated with integration times of the order of a year. This analysis could as well be applied to other likely hot spots in the sky and other possible pairs of detectors.

An issue rose as to whether such a hot spot could be visible against the background of stochastic waves - namely the Olber's paradox in the context of GW. N. Majumdar (IISER, Thiruvananthapuram), **S. Mitra** and **Dhurandhar** have shown that assuming typical numbers and the $k = 0$ Friedmann model to obtain an estimate that the Virgo cluster would be about 50 times brighter than the background. A more detailed computation is in progress.

(ii) Vetoes for a coherent search with a network of detectors for inspiraling binaries.

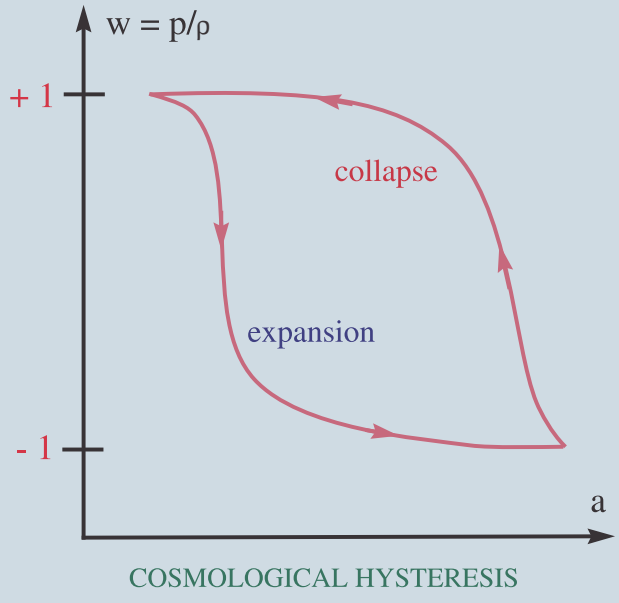
Essentially two strategies currently exist in searching GW sources with a network of detectors: the coherent and the coincident. The coherent strategy involves combining data from different detectors phase coherently, appropriately correcting for time-delays and polarisation phases and obtaining a single statistic for the full network, that is optimized in the maximum likelihood sense. On the other hand, the coincident strategy matches the candidate event lists of individual detectors for consistency of the estimated parameters of the GW signal.

It is, however, assumed without proof that the coincidence strategy acts as a powerful veto for fake events arising from the presence of non-Gaussian noise - the consistency of estimated parameters in an error window acts as a powerful veto. On the other hand in coherent detection, there is no such obvious veto. The main thrust of future work by several IndIGO members is to develop such vetos. The χ^2 statistic seems most promising and the idea is to base the veto on the χ^2 test(s) analogous to the test proposed by Bruce Allen for a single detector. One way is to examine the behaviour of the χ^2 statistic in parameter space close to the candidate event and look for signatures in the neighbourhood of the event. If the event is real - that is, a GW signal is present - then the statistic has a very specific behaviour. This can be used to rule out fake candidate events.

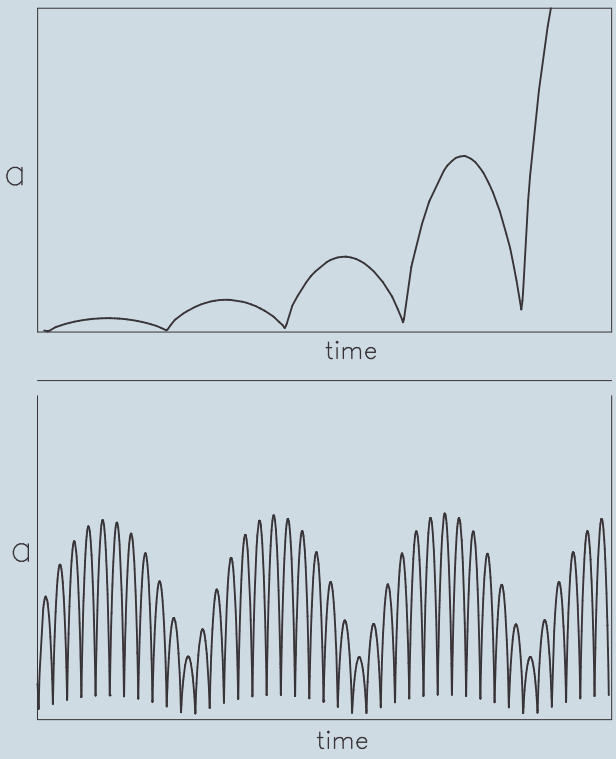
COSMOLOGY AND STRUCTURE FORMATION

Cosmological hysteresis and the cyclic universe

A universe filled with a massive scalar field possesses certain novel features: unlike matter or radiation, the equation of state of the scalar field need not stay the same during the expansion of the universe and its contraction. Consequently, as shown by **Varun Sahni** and Aleksey Toporensky, a universe filled with a homogeneous scalar field exhibits *'Cosmological hysteresis'*. Cosmological hysteresis is caused by the asymmetry in the equation of state during expansion and contraction of the universe. This asymmetry results in the formation of a *hysteresis loop:* $\oint pdV$, whose value can be non-vanishing during each oscillatory cycle. For flat potentials, a negative value of $\oint pdV$ leads to the increase in amplitude of consecutive cycles and to a universe with older and larger successive cycles. Such a universe appears to possess an *arrow of time* even though entropy production is absent, and all of the equations respect time-reversal symmetry! The cosmological flatness problem is, thus, gradually ameliorated. Cosmological hysteresis appears to be widespread and exists for a large class of scalar field potentials and mechanisms for making the universe bounce. For steep potentials, the value of $\oint pdV$ can be positive as well as negative. The expansion factor in this case displays quasi-periodic behaviour, in which successive cycles can be both larger as well as smaller than previous ones. This quasi-regular pattern resembles the phenomenon of *beats* displayed by acoustic systems. Remarkably, the expression relating the increase/decrease in oscillatory cycles to the quantum of hysteresis appears to be *model independent*. The cyclic scenario is extended to spatially anisotropic models and it is shown that the anisotropy density decreases during successive cycles if $\oint pdV$ is negative. This demonstrates that a cyclic universe can, over successive cycles, diminish the amount of anisotropy originally present.



An idealized illustration of cosmological hysteresis; *a(t)* is the expansion factor of the universe and *w* is the equation of state of a homogeneous scalar field present in the universe. The *hysteresis loop* shown above has $\oint pdV < 0$ evaluated over a single expansion-contraction cycle of the universe.



The expansion factor *a(t)* is plotted as a function of cosmic time for a cyclic universe which expands and then contracts. The presence of hysteresis can lead to dramatic behaviour in such a cyclic universe. This is illustrated above for a universe containing a self-interacting scalar field. For flat potentials, the value of the hysteresis loop, $\oint pdV$, (evaluated over one expansion-contraction cycle) is negative, and this causes the amplitude of successive cycles to increase (top panel) so that the universe appears to have an *arrow of time* even though the equations governing cosmological evolution are formally time reversible and there is no entropy production. For moderately steep potentials (bottom panel), the expansion-contraction cycles of the universe display a quasi-periodic pattern reminiscent of *beats* in sound waves. During beats the value of $\oint pdV$ is negative during the first half of the larger (parent) cycle and positive during the second half. For very steep potentials, the hysteresis loop vanishes ($\oint pdV=0$), the phenomenon of *beats* disappears and all cosmic cycles become identical (not shown).

Blast wave formation in the galaxy cluster mergers

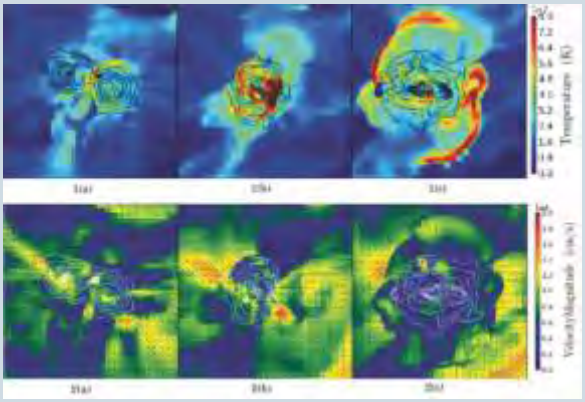
Surajit Paul and his collaborators **Joydeep Bagchi,** Luigi Iapichino and **Prakash Sarkar** have studied about the nature and effect of massive galaxy cluster mergers on the cluster medium. In the hierarchical structure formation framework, clusters are the biggest objects in the universe that may have attained virialisation recently, and at present many clusters are still in the process of growing by accretion and mergers. Aftermath of massive mergers, the most important outcome is the formation of Mpc scale merger shocks. Emergence and evolution of such a big structure in the intra cluster medium (ICM) substantially changes its matter and energy distribution. Here, changes means the change in total energy, fractional energy in thermal and non-thermal regime, spacial and temporal distribution of thermal and non-thermal energy, cosmic rays, magnetic fields, etc.

Due to inherent complexity of such events, numerical simulation becomes very much important to study this phenomena in detail. They have, thus, simulated several such events using ENZO-2.0 hydrodynamic code. The computations were performed using IUCAA HPC. For this cosmological simulation, they have used the cold dark matter cosmology as the cosmological model with parameters from WMAP 5. They have found a striking similarity of expanding inter cluster medium during mergers with the blast wave formation. Results obtained from one of such simulated events are discussed below. Here, two clusters of masses $\sim$ 9.5 x$10^{13}M_{\odot}$ and $\sim$ 6x $10^{13}M_{\odot}$ collided to form a single cluster of mass $\sim$ 1.5 x $10^{14}M_{\odot}$ at redshift as high as z = 0.9.

In this simulation, they have studied a realistic cosmic environment. It is noticed that a supernovae type blast wave emerged after the massive mergers. The blast wave shock when propagated near to or beyond the virial radius of the cluster, its morphology changed depending on whether it meets the void/accretion shocks or the filamentary inflow. These interacting surfaces then act as efficient particle accelerator and magnetic field is magnified due to high compression rate. They are, thus, supposed to produce a significant amount of synchrotron radio emission through which curved shocks are made visible in radio waves. This study, thus, for the first time sheds some light on the formation of curved and nearly symmetric radio emission found in Abell 3376, Abell 3667, CIZA J2242.8+5301, plck g287.0+32.9, etc. clusters.

This crucial feature of mergers is better followed by the evolution of temperature as seen in the figure here. The temperature increase is first driven by compression at the centre of the forming cluster (panel 1(a) to 1(c)), and subsequently, the shock is launched and propagated outwards. The shock front has a roughly spherical or almost an ellipsoid shape.

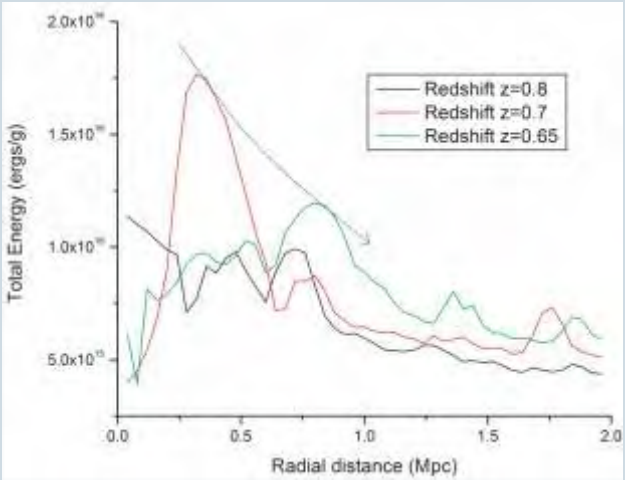
Most important discovery is the expansion of medium after cluster merger is strikingly similar to a blast wave. In the figure panel 2(b), it is clearly seen that the accretion flow in the cluster is totally destroyed and a significant amount of the central material is thrown away radially towards the outskirts. All the velocity arrows are, thus, pointing outwards.



Panel 1(a) to 1(c) shows the evolution of density (contours) during the pre merger and post merger condition. The slices are cut along a plane that passes through the centre of mass. Each panel here is 2.5 Mpc x 2.5 Mpc. Temperature is plotted here as pseudo colour and the values are given on the right side colour bar. Panel 2(a) to 2(c) shows the velocity magnitude of the same region in pseudo colour. The white contours represent the density. Velocity direction of the particles are shown as black vectors.

The radial profile of energy evolution shows almost spheroidal type of energy increment along the radius after the blast wave passes through the medium. It shows an initial increment and slowly loses energy as goes outwards as seen in the figure. The energy falls to its half of the initial value in about 0.6 Gyr.

The shock features quite resembles with the observed radio structures found in merging clusters like Abell 3376, Abell 3667, CIZA J2242.8+5301, etc.



This plot shows the radial variation of total energy of the cluster medium starting from redshift z = 0.80 to z = 0.65 as three different coloured lines. The hand drawn line in deep blue colour shows how the medium loses energy as the shock moves outwards.

Cosmic Microwave Background

The measurements of CMB anisotropy and polarization continue to contribute handsomely to the rapid pace of progress in cosmology. As regularly reported in previous annual reports, **Tarun Souradeep** has maintained, with his students and collaborators, a successful research programme related to the Cosmic Microwave Background (CMB) anisotropy and polarization. Increasingly, more attention is being paid to emerging avenues of fruitful research on subtle cosmic signatures, often referred to as CMB anomalies. **Souradeep, Sanjit Mitra** and IUCAA associate, Rajib Saha, are core-team members of the Planck HFI collaboration.

Statistical isotropy of the CMB sky

The Bipolar Spherical Harmonic (BipoSH) representation has been proposed and established by **Tarun Souradeep** as a robust measure of violation of statistical isotropy in the CMB anisotropy.

The most recent data release by the Wilkinson Microwave Anisotropy Probe (WMAP) team in January 2010 devoted a separate paper to address the CMB anomalies and invoked the bipolar representation of Amir Hajian and **Souradeep** to quantify them. In particular, the WMAP team presented a 9-sigma measurement of non-zero BiPoSH coefficients around modest multipole range of 200-400. **Souradeep** has the responsibility in Planck HFI to quantify SI violation in the data. In the last year, Nidhi Joshi and **Aditya Rotti** have published a derivation of the underlying statistics of BipoSH coefficients. Together with students, **Moumita Aich** and **Rotti, Souradeep** has also explored the possibility that strong features in the projected weak lensing potential could lead to SI violation signal.

Odd parity statistical anisotropy and non-Gaussianity

Measurement of the cosmic microwave background (CMB) bispectrum, or three-point correlation function, has now become one of the principal efforts in early-universe cosmology. Recently, Marc Kamionkowski (Caltech) and **Tarun Souradeep** have shown that there is a parity- odd component of the CMB bispectrum that has been hitherto unexplored. This work has been followed by a number of papers pointing to various possible origins of odd parity bispectra.

More recently, **Souradeep** with Marc Kamionkowski and a Caltech student Laura Book, published a paper on the odd parity BiPoSH coefficients that measure statistical isotropy. In the context of SI break down due to weak lensing, they have shown that the even and odd parity BipoSH relate to gradient and curl parts of photon displacement field. They have provided explicit estimators for the weak lensing field measure through non-zero BiPoSH coefficients.

Non-parametric assessment of the WMAP CMB angular power spectra

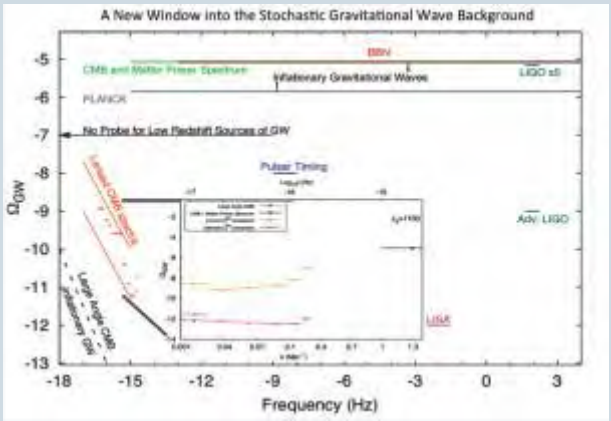
In collaboration with Amir Aghamousa and Mihir Arjunwadkar of the University of Pune, **Tarun Souradeep** has recently published, a comprehensive study of non-parametric estimation of CMB power spectrum from WMAP-7. The best fit angular power spectrum is close to, but not the same, as that obtained in a model fitting. The non-parametric analysis provides an estimate of the peak location and heights with corresponding error balls, independent of theoretical biases. The analysis also reveals sustained improvement in the peak localization in WMAP

data as one includes more years of WMAP data. The analysis also provides a measure of how close the best-fit LCDM model is to the "true" angular power spectrum. WMAP-7 data indicates that there is about 6% chance that the best-fit LCDM model is incorrect. This is a significant improvement from 18% chance based on the WMAP-5 year data.

This analysis is now being extended to include data sets with higher angular resolution such as obtained from the ACBAR, QUad and ACT experiments. Extension to the analysis to polarization data in anticipation of the Planck data is also underway.

Probing stochastic gravitational waves with CMB

Opening a new window to gravitational wave background, graduate student, **Aditya Rotti** and **Tarun Souradeep,** have established upper limits on cosmological and astrophysical gravitational wave (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. Though the effect of lensing due to GW is found to effect all the four CMB power spectra, its effect is most prominently seen in the CMB polarization power spectra. It is shown that for the same rms deflection power, the weak lensing effects on CMB angular power spectra due to GW is more than that due to density perturbations of the large scale structure in the universe. The figure shows the upper limits placed on the GW background from the current upper bounds on CMB B-mode power spectrum. In near future, it will be possible to place more stringent bounds on GW energy density using improved upper limits or detections of the angular power spectra of the B-modes of CMB polarization. The best constraints possible with this probe is indicated in the figure.



Upper limits on CMB B-mode polarization translate to interesting limits on the spectral emergency density of gravitational waves sourced just after recombination (Rotti & Souradeep 2012)

As part of a University of Pune Masters thesis project, Hamsa Padmanabhan, has worked on comparing the effect of the weak lensing arising due to scalar density perturbations and tensor gravitational wave perturbations.

Systematic effects in CMB maps

In this era of high precision CMB measurements, systematic effects are beginning to limit the ability to extract more information. The non-circularity of the experimental beam has become progressively important as CMB experiments strive to attain higher angular resolution and sensitivity. IUCAA graduate student, **Santanu Das** and **Tarun Souradeep** have estimated the effect of non-circular beam profiles of WMAP and Planck on the leakage of power from dipole to quadrupole and octupole anisotropy in CMB measurements. This appears to be a small, but non-negligible effect.

Non-circular beam response function of experiments also leads to SI violation in the CMB maps. **Sanjit Mitra**, Nidhi Joshi, **Das** and **Souradeep** have carried out a detailed study of the SI violation signature of non-circular beam for WMAP and Planck like experiments. An important question here is to assess the role of non-circular beam in the 9-sigma BipoSH signal measured by WMAP team in WMAP-7 year map.

Cosmological parameter estimation

Searching for the 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 in cosmology. Markov Chain Monte Carlo (MCMC) methods, which are stochastic, have been used to find cosmological parameters from the data sets obtained from various Cosmological Microwave Background Radiation

(CMB) experiments (WMAP, etc.). Recently, another stochastic method, named Particle Swarm Optimization (PSO), which is a population based optimization scheme, has become popular for parameter estimation. PSO in some cases of very high dimensionality of parameter space, large number of local minima, etc., performs much better. **Tarun Souradeep** has worked with **Jayanti Prasad**, to implement PSO for cosmological parameter estimation using WMAP data. They have shown that a very simple implementation of PSO, which is easy to parallelize on a cluster system, can provide best fit cosmological parameters in a relatively short time.

COSMIC MAGNETIC FIELDS

Cosmic microwave background trispectrum and primordial magnetic field limits

Primordial magnetic fields will generate non-Gaussian signals in the cosmic microwave background (CMB) as magnetic stresses and the temperature anisotropy they induce depend quadratically on the magnetic field. P. Trivedi, T. R. Seshadri and **K. Subramanian** have computed a new measure of magnetic non-Gaussianity, the CMB trispectrum $T^{l_1 l_2}_{l_3 l_4}$ on large angular scales, sourced via the Sachs-Wolfe effect. The trispectra induced by magnetic energy density and by magnetic scalar anisotropic stress are found to have typical magnitudes of $T^{l_1 l_2}_{l_3 l_4} \approx 5\times10^{-30}$ *and* $T^{l_1 l_2}_{l_3 l_4} \approx 10^{-19}$ respectively. Observational limits on CMB non-Gaussianity from WMAP 7 data allow us to set sub-nanoGauss upper limits of $B_0 < 0.7$ nG on the present value of the primordial cosmic magnetic field. This represents the tightest limit so far on the strength of primordial magnetic fields, on megaparsec scales, better than limits from the CMB bispectrum and all modes in the CMB power spectrum. Thus, the CMB trispectrum is a new and more sensitive probe of primordial magnetic fields on large scales.

The first magnetic fields

In a recent publication by L. M. Widrow, D. Ryu, D. Schleicher, **K. Subramanian,** C. G. Tsagas and R. A. Treumann, the observations of magnetic fields at cosmological redshifts and on cosmological scales are summarized. These observations translate into constraints on the strength, and scale magnetic fields must have during the early stages of galaxy formation in order to seed the galactic dynamo. Mechanisms for the generation of magnetic fields that operate during inflation and subsequent phase transitions such as electroweak symmetry breaking and the quark-hadron phase transition were examined. The implications of strong primordial magnetic fields for the reionization epoch as well as the first generation of stars was discussed in detail. The exotic, early-universe mechanisms are contrasted with astrophysical processes that generate fields after recombination. For example, a Biermann-type battery can operate in a proto-galaxy during the early stages of structure formation. Moreover, magnetic fields either in an early generation of stars or active galactic nuclei can be dispersed into the intergalactic medium.

Current status of turbulent dynamo theory: From large-scale to small-scale dynamos

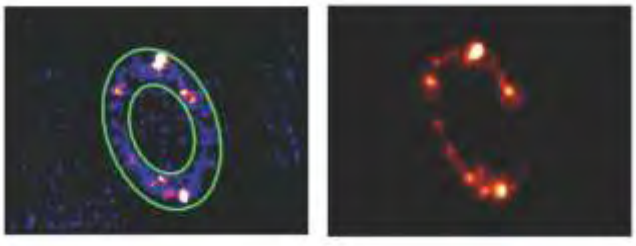
A. Brandenburg, D. Sokoloff and **K. Subramanian** have reviewed several recent advances in turbulent dynamo theory.

High resolution simulations of small-scale and large-scale dynamo action in periodic domains are compared with each other and contrasted with similar results at low magnetic Prandtl numbers. It is argued that all the different cases show similarities at intermediate length scales. On the other hand, in the presence of helicity of the turbulence, power develops on large scales, which is not present in non-helical small-scale turbulent dynamos. At small length scales, differences occur in connection with the dissipation cutoff scales associated with the respective value of the magnetic Prandtl number. These differences are found to be independent of whether or not there is large-scale dynamo action. However, large-scale dynamos in homogeneous systems are shown to suffer from resistive slow-down even at intermediate length scales. The results from simulations are connected to mean field theory and its applications. Recent work on helicity fluxes to alleviate large-scale dynamo quenching, shear dynamos, nonlocal effects and magnetic structures from strong density stratification are highlighted. Several insights which arise from analytic considerations of small-scale dynamos were discussed.

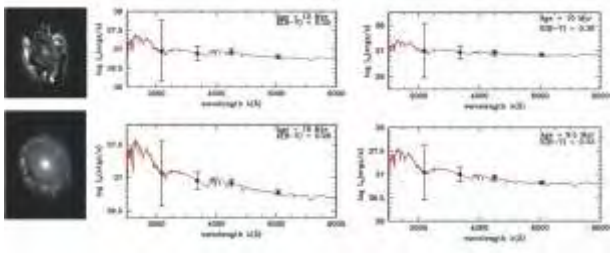
OBSERVATIONAL COSMOLOGY AND EXTRAGALACTIC ASTRONOMY

Star formation in nuclear rings of nearby galaxies

Starbursts are extreme environments, where the bulk of star formation takes place with high efficiency, and they play a major role in galaxy formation and evolution. At high redshifts, intense starbursts are dominant, but these distant systems are often dust-enshrouded. The inferences about their nature and evolution rely on diagnostics available for similar systems at lower redshifts. Local analogues of starbursts are found in the nuclear resonance rings of barred galaxies. The kiloparsec-sized nuclear rings are the result of bar-driven gas inflow toward the inner Lindblad resonance, yeilding a large concentration of gas in a small region surrounding the nucleus. The intense star formation that is triggered in the nuclear rings is a key component in the process of pseudo bulge formation via secular evolution. However, it still remains unknown how star formation propagates in the nuclear ring. While one of the models proposes an azhimuthal propagation and hence a "pearls on a string" scenario, another model predicts that the rings would show a radial age gradient because of outward propagation of old stars. With an aim to test these scenarios, **Swara Ravindranath** and collaborators have used multi-wavelength data of the nearby galaxy NGC 3351 from the optical-to-NIR from the Hubble Space Telescope (HST) archive. In addition, new observations were proposed for, and obtained from Gemini-South 8-m telescope using the TRECS mid-infrared instrument to get the dust emission map. The dust that produces the mid-IR is composed of polycyclic Aromatic Hydrocarbons (PAH), and the emission is powered by the ionizing radiation from massive stars. The PAH emission in NGC 3351 arises from an elliptical ring, which exactly traces the location of the ionized hydrogen which is mapped by the Paschen-α emission seen in the HST/NICMOS images. The ring has inner and outer radius measuring 220 and 398 parsecs respectively. The ring can also be traced at 1.6 microns, comprising of light from older stars, which are also sampled in the optical images, and is fairly circular with the inner radius being just outside the elliptical ring. **Ravindranath** and Marcela Acosta (visiting student from St. Petersburg University, Russia) have carried out photometry of the star clusters located in the position of the nebular and dust emission ring. Single stellar population templates were used to model the spectral energy distribution and estimate average ages of the stars in these regions. The ages of the youngest star clusters that provide the ionizing radiation for the nebular and dust emission, ranges from 8 to 20 Myrs. The nuclear ring shows a wide range in the dust extinction, which causes the patchy appearance of the nuclear ring in the optical wavelengths.



(Left) The Gemini/TRECS 11 micron image of the nuclear ring in the galaxy NGC 3351, which maps the PAH/dust emission. The image shows a 28" x 21" region centered on the galaxy, and has a spatial resolution of 0.3". (Right) Same region showing the continuum-subtracted Paschen- emission line image from HST/F187N, which reveals the nebular emission from the ionized nebular gas.



(Left) The HST/F470W image (top) and the HST/F190N image (bottom) show the nuclear ring as seen in the continuum. The bluer image is affected by light from the young stars and patchy dust extinction. The longer wavelength image is domiated by light from older stars, and the ring is circular and located at larger radius compared to the distribution of younger stars. (Right) The spectral energy distribution (black points) of 4 sample star clusters located in the ring, showing the best-fit stellar population model (red), which is used to infer their ages.

Filamentary infall of cold gas and escape of Lyα and hydrogen ionizing radiation from an interacting high-redshift galaxy

The nature of the main sources that provide ionizing photons for the reionization of hydrogen in the early universe is a subject that is yet unsettled. The emissivity of QSOs appears to drop too rapidly towards higher redshift for them to contribute significantly. In the recent years, there has been a lot of progress in identifying star-forming galaxies as the possible sources of reionization. With the installation of the

WFC3 detector on the HST, such star-forming galaxies have been discovered at redshifts out to z = 8, and few candidates out to z = 10. As the ionizing emissivity inferred for the observed population of galaxies at z ~ 6 – 10 appears to fall short of what is needed to reionize the universe and keep it ionized, faint galaxies are currently the prime contender for driving hydrogen reionization. One of the major impediments to understand the epoch of reionization is the lack of observational constraints on the physical mechanism for the escape of ionizing photons. A large escape fraction of ionizing photons during a merger events is one possibility, which can be observed as these photons will fluorescently illuminate the inflowing cold gas from within the galaxies. Inflow of cold (10^4 K) gas is believed to be the dominant mode by which low-mass galaxies gain most of their baryonic material for star formation, though it has so far eluded direct observational detection. The anticipated fluxes from cold accretion suggest that the prospects of seeing accretion filaments by means of their own Lyα cooling radiation are dim, other than in extremely massive galactic haloes. A filament may be visible, however, if it is illuminated by an external source of ionizing photons, such as QSOs. Those fluorescent detections not directly spatially associated with the QSO are likely to mostly come from low-mass galaxies, the growth of which should be dominated by cold mode accretion.

The team (including **Swara Ravindranath**) lead by Michael Rauch (Carnegie Observatories) published observations of a peculiar Lyα-emitting galaxy at redshift z = 3.344, discovered in a deep, blind spectroscopic survey for faint Lyα emitters with the Magellan II telescope in the Hubble Ultra Deep Field. The galaxy exhibits complex Lyα emission, including an extended, asymmetric component, that is partially suppressed by damped Lyα absorption, and two spatially elongated, narrow emission features. Archival Hubble Space Telescope Advanced Camera for Surveys imaging shows evidence for tidal disruption of the stellar component. This faint galaxy appears to present an unprecedented insight into two fundamental stages in the formation of structure at high redshift: the inflow of gas into ordinary galaxies, and the escape of ionizing radiation into the intergalactic medium. Neutral hydrogen, falling in partly in the form of a narrow filament, appears to emit fluorescent Lyα photons induced by the stellar ionizing flux escaping from the disturbed galaxy. The in-falling material may represent primary cold accretion or an interaction-triggered inflow. The rate of ionizing photons required by the observed Lyα emission is consistent with the rate of photons produced by the observed stellar population, with roughly 50 per cent of ionizing photons escaping from the immediate galaxy and encountering the in-falling gas. While cooling radiation and large-scale shocks can be additional sources for Lyα and ionizing radiation in high-redshift galaxies, the team finds that stellar radiation is likely to be the dominant source of ionizing photons for most faint galaxies. The observational properties of the galaxy lend support to a picture, where galaxy interactions facilitate the escape of both Lyα and ionizing radiation. It is likely that galaxies like the present object may be common at high redshift. This galaxy may, therefore, be a late example of an interacting population of dwarf galaxies that contribute significantly to the reionization of the universe.

The tumultuous formation of the Hubble sequence at z > 1

Understanding the origin of the Hubble sequence of galaxies has remained one of the most outstanding problems in extragalactic astronomy. Massive galaxies in the nearby universe are largely in the form of ellipticals and spirals. This trend continues out to a redshift of unity, which in current cosmology corresponds to a time when the universe was about 40 per cent of its present age. But at larger redshifts, the regular Hubble sequence appears to break down, and galaxies predominantly have irregular and peculiar morphologies. **Swara Ravindranath** and the collaborators led by C. Conselice (University of Nottingham) have used a stellar-mass-selected sample of galaxies at 1 < z < 3 within the Hubble Ultra Deep Field, which have Wide-Field Camera-3 (WFC3) imaging, to study the rest-frame optical morphological and structural distribution of galaxies at this epoch. They have measured how apparent morphologies (disc, elliptical, peculiar) correlate with physical properties, such as quantitative structure and spectral type. One primary result is that apparent morphology does not correlate strongly with stellar populations, nor with galaxy structure at this epoch, suggesting a chaotic formation history for Hubble types at z > 1. By using a local definition of disc and elliptical galaxies based on structure and spectral type, they have found no true ellipticals at z > 2, and a fraction of 3.2 ± 2.3 per cent at 1.5 < z < 2. Local

counterparts of disc galaxies are at a similar level of 7 – 10 per cent, much lower than the 75 per cent fraction at lower redshifts. A comparison of the rest-frame optical morphology from the WFC3 images with the rest-frame ultraviolet view of galaxies from ACS imaging, shows that galaxies imaged with the ACS, which appear peculiar, often contain an 'elliptical'-like morphology in the WFC3. Using simulations, it is shown that this larger fraction of elliptical-like galaxies is partially due to the coarser point spread function of the WFC3, and that the 'elliptical' morphological class very likely includes early-type discs. The merger history analyzed using concentration, asymmetry and clumpiness parameters, show a redshift evolution increasing with redshift, and a peak merger fraction of ~ 30 per cent at $z \sim 2$ for the most massive galaxies with $M > 10^{10} M_{\odot}$ consistent with previous results from the ACS and NICMOS. There is a relatively good agreement between the observed morphological type fractions and the predictions from semi-analytical models. It is likely that galaxies classified visually as peculiar, or peculiar ellipticals, all have similar structural and stellar population properties, suggesting that these galaxies are in a similar formation mode, mostly driven by major mergers.

Spatial clustering of high redshift Lyman break galaxies

A physically motivated model to understand the clustering of high redshift Lyman break galaxies (LBG) has been examined. The model is constrained by fitting the high redshift luminosity functions of these LBGs.

C. Jose, K. Subramanian, R. Srianand and S. Samui have chosen an approach similar to the conventional halo model , where galaxies are assumed to be formed inside dark matter halos. Here, the luminosity of such a galaxy is obtained from a physical model of star formation, which is a function of the mass and redshift of the hosting halo. It is assumed that each halo can host atmost one visible galaxy and hence, they have shown that the prescription of star formation can explain both the luminosity function and clustering at large scales of high redshift LBGs. Further, they have extended the approach by including satellite galaxies harboured in the subhalos inside massive halos. To model the number and luminosity of these satellite galaxies, they have used the conditional mass function. Using this approach, one can also explain the luminosity dependent clustering of LBGs at small angular scales.

Galaxy morphology

One common practice used to describe the morphology of the galaxy quantitatively is to find a suitable combination of analytical profiles that can best describe the distribution of light in the galaxy. To account for the effects of the atmosphere/instruments, it is necessary in this approach to have sufficient knowledge of the Point Spread Function (PSF). The Spitzer Space Telescope takes images in the 3.6 microns waveband, and advantages of preferring these images to employ the above described technique is that these images are relatively free from the effects of dust obscuration, and better represent the underlying dynamical mass content of the galaxy. However, the images taken using the Infra Red Array Camera (IRAC) on Spitzer suffer from several problems. Some of these problems include optical distortions (pixels of the CCD subtending different solid angles onto the sky), inaccurate flat fielding (due to limitations of the design) and most importantly, determination of the PSF (as the data is severely undersampled).

The first two problems can be corrected by co-adding images obtained from dithered observations of the object using a suitable projection scheme along with corrections for optical distortions. The determination of the PSF becomes even more difficult post co-addition of images, since the information of the PSF from different images gets mixed in this process and made even worse due to the data being undersampled. **Kaustubh Vaghmare,** along with Sudhanshu Barway and **Ajit Kembhavi** has found the problems associated with using standard or simulated PSF templates, and explained them as arising from the increase in the Full Width Half Maximum (FWHM) of the PSF due to the co-addition of the images. They have developed a technique involving modification of the simulated PSF template by convolving with a Gaussian, whose properties are determined from bright field stars present in the image. Various scripts have been developed that make the process of photometry of galaxies using Spitzer IRAC images much faster and simpler. The scripts are being employed to study a large sample of lenticular galaxies.

UV and MIR studies of galaxies in the ELAIS-N1 field

The mid-infrared (MIR) emission (3-10 μm) from galaxies is mainly due to three processes, i.e., thermal emission from dust grains heated by stellar radiation, stellar emission, and a power-law component from accreting black holes. The main contributors to the dust emission are continuum emission from very small grains (VSGs) heated by hot massive stars and broad emission features due to polycyclic aromatic hydrocarbons or PAHs. PAHs have broad emission bands at 3.3, 6.2, 7.7, 8.6 and 11.3 μm. They have little absorption at visible wavelengths and need UV photons for excitation.

On the other hand, the emission from VSGs can only be excited by highly luminous UV emitting stars like O-type stars. Therefore, using a combination of the emission from VSGs and PAHs together with the UV emission, it is possible to classify galaxies based on their stellar and dust content. **P. Shalima**, J. Murthy, **Ranjan Gupta**, D. B. Vaidya and **Ranjeev Misra** have used the data from GALEX and Spitzer in order to study and classify 174 galaxies in the ELAIS-N1 field. They have found that the FUV and NUV emission from these galaxies is well-correlated with the PAH emission rather than the 24μ dust emission. This not only shows the dependence of the PAH emission on UV radiation, but also that this UV radiation is mainly from B-type stars or later. They then divided the sample based on the dust model of Li, et al. 2001, which calculates the emission from dust grains exposed to different radiation fields. They have found that in galaxies containing lower radiation fields, the PAH emission is better correlated with the FUV/NUV emission, while as the radiation field increases, the 24 μm emission is better correlated.

Based on these results, they have concluded that most of the galaxies in this sample do not have a high star formation rate and they contain a significant fraction of PAHs. The high radiation field galaxies are those that have a high rate of current star formation and lower 8.0/24 μm flux ratios. This could be an indication that the PAHs are destroyed in these galaxies.

Particle acceleration in giant shock waves arising in collision of massive galaxy clusters

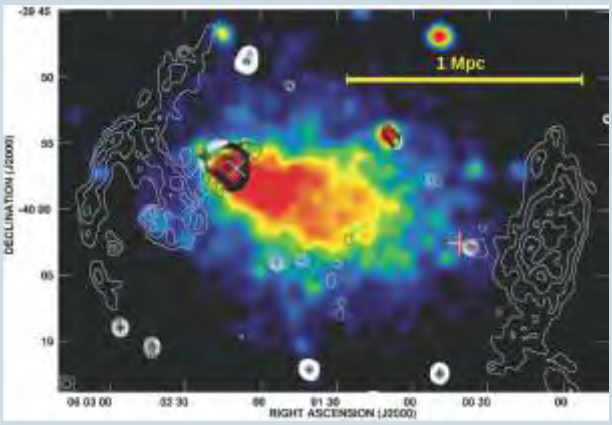
The distribution of galaxies in the universe is marked by giant cosmic voids embedded in a network of galaxy filaments and massive galaxy clusters containing up to thousands of galaxies. This inhomogeneous matter distribution emerged from an extremely smooth initial state created by the Big Bang, with relative density fluctuations of only 10^{-5}. Over billions of years, the initially tiny density variations grew drastically through gravitational attraction of neighbouring matter. Larger and larger structures still form today as a result of the violent merging of galaxies and clusters of galaxies. In addition, there is a continuous accretion flow of gas falling onto galaxy clusters out of the dilute intergalactic medium. Matter falling into the gravitational wells of galaxy clusters can reach velocities of up to a few thousand kilometres per second. When it collides with the hot and ionized gas at a temperature of 10^7 to 10^8 Kelvin within clusters, supersonic shock waves form and heat the in falling gas to similar temperatures. **Joydeep Bagchi** and **Surajit Paul** with collaborators from NCRA/TIFR and Raman Research Institute (RRI) have studied two galaxy clusters undergoing violent mergers with smaller clusters, and obtained strong proof of how the resulting mega parsec scale (about 3.2 million light years) shock waves accelerate subatomic particles close to the speed of light - the largest 'cosmic accelerators' one can imagine.

(i) With GMRT low frequency observations at 150 MHz of the galaxy cluster PLCK G287.0+32.9, they have discovered the first signatures of a double shock front in the shape of giant, luminous radio emitting arcs (radio relics) located at about 6 million light years from the collision centre (figure, top panel). This galaxy cluster is exceptionally hot ($>10^8$ Kelvin) and massive containing $>10^{15}$ times the mass of the Sun. The faint radio waves are likely to be generated by charged particles accelerated in shock waves near to the speed of light, and gyrating across weak magnetic lines of force. No previous galaxy cluster has ever been observed to show such giant shock fronts, which have reached so far away from the cluster centre in the extremely dilute intergalactic medium.

(ii) In the second cluster called Abell 3376, their GMRT radio observations at 327 MHz showed energetic shock

waves creating similar looking ring-like double radio arcs, but located closer to the centre of cluster. Moreover, the X-ray image shows a spectacular, bullet-shaped region of X-rays coming from gas heated to 60 million Kelvin (figure , lower panel). The bullet shape of hot gas results from the supersonic collision of two or more smaller galaxy clusters.

These important and surprising observations provide a direct insight into the fluid dynamics of cosmic structure formation. They also give a foretaste of the 'radio glow' of the cosmic large-scale structure, which one hopes to discern with the next generation radio telescopes such as the Low Frequency Array (LOFAR), the Long Wavelength Array (LWA), and the Square Kilometer Array (SKA).



The three upper panels show the GMRT 150 MHz radio image of galaxy cluster PLCK G287.0+32.9 (left panel in red colour) with the giant shock fronts (radio relics) marked as RN (north) and RS (south). The green contours in this panel and in the next central panel are X-ray intensity contours from the XMM-Newton telescope data showing the distribution of extremely hot gas in the cluster. The right most panel shows the same X-ray emission as a colour image. In central panel an optical image of the cluster is shown, taken from the IUCAA Girawali Observatory Telescope observations. The lower panel shows in colour the 'bullet' shaped X-ray emission from hot gas in the merging galaxy cluster Abell 3376 from ROSAT satellite observations. The radio emission coming from a pair of ring-like giant shock fronts is shown in white intensity contours, which is mapped by GMRT at 327 MHz frequency. The '+' and 'X' mark the locations of two massive galaxy clusters undergoing a merger.

HIGH ENERGY ASTROPHYSICS

NGC1365 hosts a unique active galactic nucleus with remarkable X-ray variability that has been interpreted to arise due to a changing partial covering absorber as opposed to the general behaviour of steepening primary spectrum with increasing flux observed in many Seyfert galaxies. The variable partial covering absorption on short-time scales as the origin of X-ray spectral variability is drastic change in the understanding of X-ray variability of AGNs. Hence, a critical analysis of the X-ray observations is required. **Gulab Dewangan** has studied the nature of X-ray variability of NGC1365 by performing broadband X-ray spectroscopy, time-resolved and difference spectroscopy, flux and hardness ratio variability and cross-correlation analysis using a long Suzaku observation. The soft X-ray emission below 2 keV is not variable and consists of diffuse thermal emission, scattered and line emission from photoionized gas by the central source. The broadband X-ray spectrum above 2 keV is well described by primary X-ray emission consisting of a hard power-law, Compton reflection, narrow and broad iron K lines, and modified by a fully covering intrinsic neutral absorber. The broadband spectral data, though consistent with the presence of but do not statistically require the partial covering absorber. The primary X-ray emission is highly variable. Strong positive correlations between the 6 - 10 keV and 10 - 70 keV bands, the hardness ratio variations, spectral variation as inferred from time-resolved spectroscopy and the difference spectrum, all imply that the variability of NGC1365 is similar to that observed from other Seyfert galaxies, i.e., spectral steepening with flux, and not due to short-term variations in the absorption column. The time resolved and difference spectra also suggest variations in the broad iron Kα line and narrow absorption lines near 7 keV from highly ionized iron.

The rapid variability of X-ray binaries

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 **Misra** have been developing a scheme and numerical code, which is 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.

Mid-infrared and X-ray luminosity correlations of X-ray point sources in NGC 1399

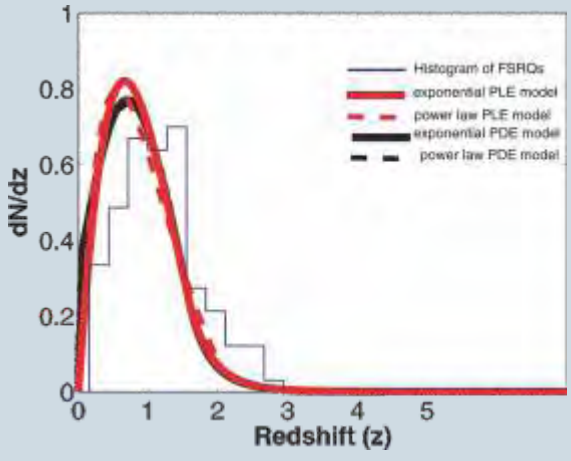
It is known that the infrared and X-ray luminosities of Active Galactic Nuclei (AGN) are correlated with $L_{IR} \sim L_X$. Moreover, the infrared flux ratio between the 5.8 and 3.6 micron bands is a good distinguishing characteristic of AGN or AGN-like behaviour. On the other hand, galactic X-ray binaries (GXB) are under-luminous in the infrared with $L_{IR} << L_X$. Since ultra-luminous X-ray sources in nearby galaxies may be an intermediate class between AGN and GXB, it is interesting to study if their IR properties indicate which kind of objects they resemble. **P. Shalima,** V. Jithesh, K. Jeena, **R. Misra, S. Ravindranath, G. C. Dewangan,** C. D. Ravikumar and B. R. S. Babu have analysed the Spitzer/IRAC images at 3.6μm and 5.8μm to identify mid-infrared counterparts of the X-ray sources in NGC 1399. They considered the 35 bright X-ray sources for which the X-ray counts are high enough to perform reliable spectral modelling and estimate the X-ray luminosities. They have found that 16 of them are detected as point sources in the infrared. They have used the mid-infrared colours of these infrared point sources to classify them into AGN-like and non-AGN-like sources. For 8 sources that have AGN-like (5.8/3.6) colours, the X-ray luminosities correlate well with the mid-infrared luminosities as is the case for AGN in the figure here. On the other hand, the X-ray and MIR luminosities of the remaining sources do not show any correlation in the figures here.

They have also calculated the optical g-z colours, to show that the bright X-ray sources with IR counterparts are typically blue in optical colour. This is in contrast to typical X-ray sources, without IR counterparts, which have predominantly red optical counterparts.

If they are not strongly contaminated by background AGN, this result extends the IR-X-ray luminosity correlation down to $L_X \sim 10^{39}$ergs/s. In summary, their study of the mid-IR counterparts of X-ray sources shows that there are two categories of bright X-ray sources, one where the MIR luminosity correlates with the X-ray like AGN, and the other like galactic X-ray binaries, where the IR luminosities are much smaller than their X-ray luminosities. This indicates that there is a difference in the environment of these two sources, i.e., one which has a dusty environment, other being devoid of dust. They have highlighted the need for IR or optical spectra of these sources to distinguish background AGN and unveil the effect of the X-ray emission on the different environments of these systems.

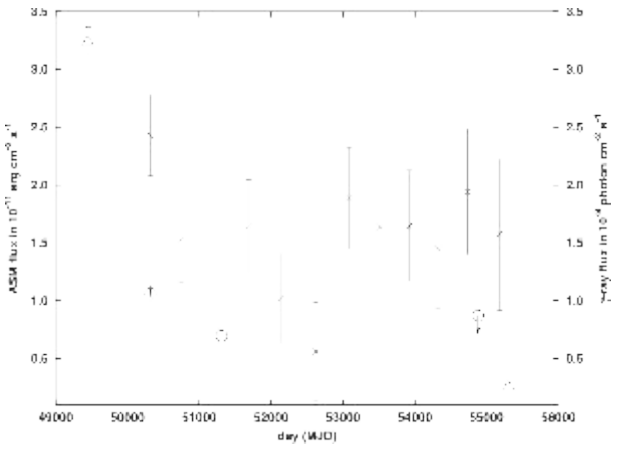
Contribution of blazars to the EGRB

The origin of extragalactic γ-ray background (EGRB) is one of the fundamental unsolved problems in astrophysics. EGRB can arise from some diffuse processes like black hole evaporation, large scale structure formation, matter-antimatter annihilation, etc. Alternatively, due to the limited instrument sensitivity, unresolved γ-ray sources could contribute significantly to the observed EGRB. Majority of the Fermi and EGRET detected identified sources are blazars. So, they are expected to be a significant contributors to the EGRB, for which, needs to construct their luminosity functions. Using the first Fermi catalog, **Debbijoy Bhattacharya** and his collaborators (M. Errando, R. Mukherjee, M. Bottcher, P. Sreekumar, **R. Misra** and P. Coppi) have investigated the luminosity function, and nature of evolution of flat spectrum radio quasars (FSRQs) and BL Lacs separately in γ -rays. They have considered both pure luminosity evolution (PLE) and pure density evolution (PDE) models for FSRQs. Both power law and exponential evolution functions have been considered. The



~ 1 year averaged RXTE-ASM lightcurve (crosses) of PKS 0528+134. The open circles and the upper limit represent RXTE-PCA observations. The triangle represents the γ-ray flux averaged over EGRET and Fermi observations. The scale for gamma-ray fluxes are given in the right side of the figure. MJD 49000 and MJD 56000 correspond to 13th January 1993 and 14th March 2012 respectively.

luminosity function is considered to be of a broken power law form and the parameters are found using likelihood analysis. From this analysis, it is not possible to strongly conclude on the true evolution model. The figure above suggests that PDE model explains observations marginally better than that of PLE model. In contrast to earlier works of determination of luminosity function from γ-ray observations, they have derived that the luminosity function is well constrained.



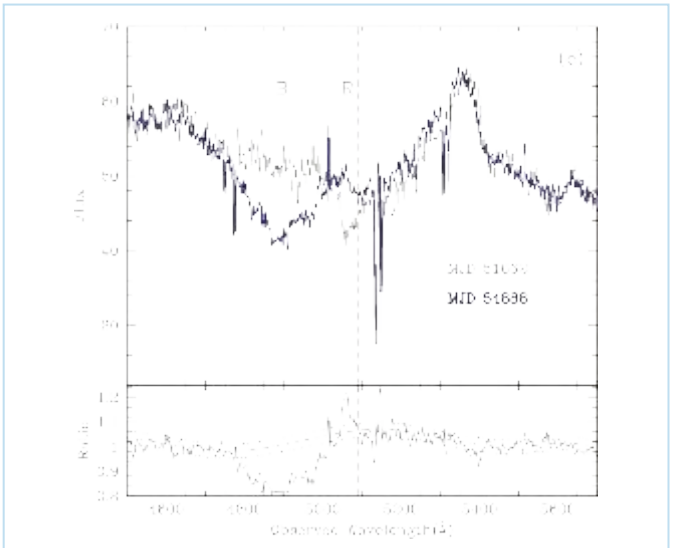
Distribution of FSRQs with redshift. Histogram shows the Fermi observed distribution. The red curves represent PLE models. The black curves represent PDE models. Solid and dash curves are exponential and power law models respectively.

Further, **Bhattacharya, Misra**, A.R. Rao and Sreekumar have examined the long term (~ 10 years) γ-ray variability of blazars observed by EGRET and FERMI, and have found that six sources exhibit flux variation by more than an order of magnitude. Two of these sources (PKS 0528+134 and PKS 1622-29) have been monitored in X-rays by the RXTE, *All Sky Monitor* (ASM). While the ratios of the average γ-ray fluxes between EGRET and Fermi observations are 12.6 ± 1.5 and 16.7± 2.2, respectively, the ASM data show no significant variation. The fractional root mean square (rms) variability amplitude F_{var} of the ASM light curves are **< 0.38 and 0.44 ± 0.07.** The absence of any strong X-ray variability is further supported by pointed RXTE and other satellite observations. The figure above shows the X-ray and γ -ray flux variations of PKS 0528+134 from EGRET to Fermi era. The X-ray emission from such FSRQs is believed to be due to synchrotron self Compton, while the γ-rays originate from the inverse Comptonization of the external soft photons from an accretion disk and/or broad line region. They have argued that in this scenario, the only explanation for the uncorrelated variability is that there has been an order of magnitude decrease in the external soft photons, while the jet parameters remained more or less constant. This result indicates that perhaps the accretion and jet processes are not tightly coupled in these sources.

QUASARS, ACTIVE GALACTIC NUCLEI AND ABSORPTION SYSTEMS

Dynamically evolving Mg II broad absorption line flow

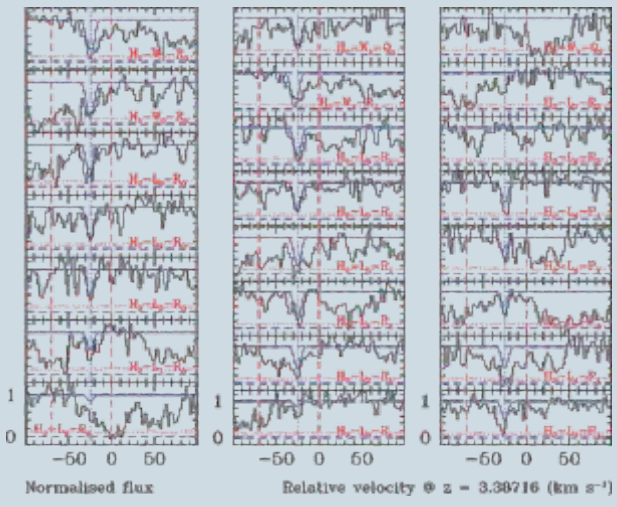
It is widely believed that the kinetic energy output from quasars through the outflows are as important as their radiative output. They are believed to play an important role in regulating the growth of supermassive black holes, and star formation in the host galaxies. In addition, outflows influence the enrichment of the surrounding intergalactic medium. Therefore, it is important to understand the origin and evolution of QSO outflows. Large-scale outflows manifest itself in the form of broad absorption lines (BALs) in QSO spectra. BAL QSOs comprise of up to 40 per cent of the total QSO population. The correct explanation for the



Comparison of IGO spectrum of J1333+0012 (blue) obtained in the year 2008 with the SDSS spectrum (in black) obtained in the year 2000. R and B are two identified outflowing components. R component that was seen in the SDSS spectrum completely disappeared in the IGO spectrum. The B component that was not seen in the SDSS spectrum emerged in our IGO spectrum. Bottom panel of the figure shows the ratio between the two epoch spectra to demonstrate the change in the optical depth.

observed incidence of BAL QSOs is still a subject of debate between the orientational and evolutionary models.

Line variability studies of BAL QSOs are useful for understanding the physical conditions and dynamics of the gas close to the central engine. The time variability of C IV and Si IV absorption is reported in several cases. Such a variability could be related either to variations in the ionization state or to the covering factor of the absorbing gas. However, the most interesting cases are the ones, where the flow emerges afresh or shows strong dynamical evolution (i.e., variation in the absorption profile and signatures of acceleration). These studies attribute the observed dynamical evolution to multiple streaming wind moving across the line of sight. Detecting an emerging Mg~II flow will be very interesting, as Mg~II BALs are considered to be a possible manifestation of a QSOs efforts to expel a thick shroud of gas and dust.



Voigt profile fits to H_2 Lyman and Werner band absorption lines in the $z_{abs} = 3.3868$ DLA system towards J0203+1134 (PKS~0201+113). The zero of the velocity scale is defined at $z = 3.38716$. The two vertical lines at $\upsilon = 0$ and -68 km s^{-1} show the locations of two 21-cm absorption components reported by Kanekar, et al. 2007. The vertical dotted line indicates the location of H_2 absorption. In each panel, the error spectrum with dotted curves, is shown.

M. Vivek, **R. Srianand,** A. Mahabal and V. C. Kuriakose have reported a dynamically evolving low-ionization broad absorption line (BAL) flow in the QSO SDSS J133356.02+001229.1 (at $z_{em} \sim 0.9197$; see fig in next page). These observations are part of an ongoing monitoring of low-ionization BAL QSOs with the 2-m telescope at IUCAA Girawali Observatory (IGO). The broad Mg II absorption with an ejection velocity of 1.7×10^4 km s^{-1}, found in the Sloan Digital Sky Survey (SDSS) spectra, has disappeared completely in their IGO spectra. They have found an emerging new component at an ejection velocity of 2.8×10^4 km s^{-1}. This is the first reported case of emerging Mg~II outflows. During their monitoring period, the emerged component has shown strong evolution, both in its velocity width and optical depth and nearly disappeared in the latest IGO observations. Acceleration of a low-velocity component seen in SDSS spectrum to a higher velocity is unlikely, as the Mg II column densities are always observed to be higher for the new component. They have argued that the observed variations may not be related to ionization changes and are consistent with absorption produced by multistreaming flow transiting across the line of sight. They have reported a possible connection between flux variation of the QSO and N(Mg II) of the newly emerged component. This could mean that the ejection being triggered by changes in the accretion disc or dust reddening due to the outflowing gas.

Search for cold gas in z > 2 damped Lyα systems: 21-cm and H_2 absorption

The galactic interstellar medium (ISM) has a multiphase structure with neutral hydrogen being distributed between the cold neutral (CNM), warm neutral (WNM) and warm ionized (WIM) media. A large fraction of the gas is also found in diffuse, translucent and dense molecular clouds. Newly formed stars are associated with these dense molecular clouds and strongly influence the physical state of the rest of the gas in different forms through radiative and mechanical inputs. The physical conditions in the multiphase ISM depend on the ultraviolet (UV) background radiation field, metallicities, dust content, and the density of cosmic rays. In addition, the filling factor of the different phases depends sensitively on the supernova rate. Therefore, detecting and studying the multiphase ISM in external galaxies has great importance for the understanding of galaxy evolution. Damped Lymanα systems (DLAs) are the highest HI column density absorbers seen in QSO spectra, with N(H I) $\geq 2 \times 10^{20}$ cm^{-2}. These absorbers trace the bulk of the neutral hydrogen at $2 \leq z \leq 3$ and have long been identified as revealing the ISM of the high redshift precursors of present day galaxies. Detection of 21-cm absorption in DLAs is the best way to estimate the CNM fraction of LAs, as it is sensitive to both N(H I) and the thermal state of the gas. This is why it is important to search for 21-cm absorption in DLAs over a wide redshift range.

R. Srianand and his collaborators (Neeraj Gupta (ASTRON), Patrick Petitjean (IAP), Pasquier Noterdaeme (IAP), Chris Salter (Arecibo Observatory) and D. J. Saikia (NCRA)) have reported the results of a systematic Green Bank Telescope (GBT) and Giant Metrewave Radio Telescope (GMRT) survey for 21-cm absorption in a sample of 10 damped Lyman α systems (DLAs) at $2 \leq z_{abs} \leq 3.4$. Analysis of L-band very long baseline array (VLBA) images of the background QSOs were also presented. These milliarcsec images were used to address the gas covering factor related issues. They have detected 21-cm absorption in only one DLA (at $z_{abs} = 3.1745$ towards J1337+3152). Thus, the detection rate of 21-cm absorption is 10 per cent when no limit on the integrated optical depth $\tau(v)\,dv$ is imposed and 13 per cent for a 3σ limit of 0.4 km s^{-1}. Combining their data with the data from the literature (a sample of 28 DLAs) and assuming the measured core fraction at milliarcsecond scale to represent the gas covering factor, they have found that the H I gas in DLAs at $z \geq 2$ is predominantly constituted by a warm neutral medium. The detection rate of 21-cm absorption seems to be higher for systems with higher N(H I) or metallicity. However, no clear correlation is found between the integrated 21-cm optical depth (or the spin temperature, T_s) and either N(H I), metallicity or velocity spread of the low-ionization species.

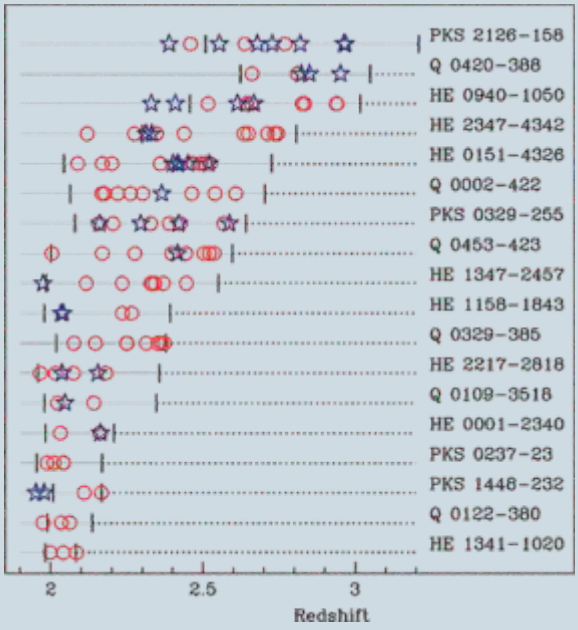
There are 13 DLAs in **Srianand** et al's sample, for which high-resolution optical spectra covering the expected wavelength range of H_2 absorption are available. Using these data, they have reported the detection of H_2 molecules in the $z_{abs} = 3.3871$ 21-cm absorber towards J0203+1134 (see the fig in earlier page). In eight cases, neither H_2 (with molecular fraction $f_{H2} \leq 10^{-6}$) nor 21-cm absorption (with $T_s / f_c \geq 700$ K) is detected. The lack of 21-cm and H_2 absorption in these systems can be explained if most of the H I in these DLAs originates from low-density high-temperature gas. In one case, they have a DLA with 21-cm absorption not showing H_2 absorption. In two cases, both species are detected but do not originate from the same velocity component. In the remaining two cases, 21-cm absorption is not detected despite the presence of H_2 with evidence for the presence of cold gas. All these are consistent with the idea that the H_2 components seen in DLAs are compact (with sizes of ≤ 15 per cent) and contain only a small fraction (i.e., typically ≤ 10 per cent) of the total N(H I) measured in the DLAs. This implies that the molecular fractions f_{H2} reported from the H_2 surveys should be considered as conservative lower limits for the H_2 components.

A high-resolution study of intergalactic OVI absorbers at z ~ 2.3

The study of low-density intergalactic medium (IGM) is extremely important because it forms the primary reservoir of baryons throughout the cosmic ages. These baryons get accumulated into galaxies in the process of structure formation. The heavy elements produced in galaxies got transported to the IGM by means of outflows driven by supernovae or tidal interactions. Thus, the IGM enrichment history provides useful constraints on the star formation history and contribution of various feedback mechanisms at different epochs. The tenuous IGM is detectable in the form of Ly α and heavy element absorption lines in the QSO spectra. Hence, the observations of Ly α and metal lines are crucial to understand the interaction between galaxies and the surrounding IGM.

Given the low metallicity, the direct detection of metals in the underdense regions, which occupy most of the volume of the universe at any given epoch, is beyond the reach of the present day large telescopes. Statistical methods like pixel analysis are used instead. They have shown that metals must be present even in the underdense regions. However, the fractional volume occupied by the metals is still unknown. Under photoionization by UV background, the O VI absorption is generally produced from regions of low density having high ionization parameter. In addition, the high cosmic abundance of oxygen makes O VI a good tracer of metal enrichment in the low density IGM. Hydrodynamical simulations suggest that a considerable amount of baryons could reside in the warm-hot phase of the IGM (called WHIM with $T \sim 10^5$-10^7 K) and this fraction evolves with redshift. Highly ionized species of oxygen such as O VI, O VII and O VIII can be useful probes of the WHIM. In the optical regime, O VI is the best species to probe relatively cooler phase (i.e. , $T \sim 3 \times 10^5$ K) of the WHIM, because the ionization fraction of O VI has its maximum around this temperature in the case of collisional ionization. Thus, a detailed analysis of a large sample of O VI is very important to understand the physical conditions and processes that maintain them in the IGM at high redshifts.

Sowgat Muzahid and **Srianand** togther with Patrick Petitjean and Jacqueline Bergeron of IAP, Paris, have presented a detailed study of the largest sample of intervening O VI systems in the redshift range $1.9 \leq z \leq 3.1$ detected in high-resolution (R ~ 45000) spectra of 18 bright



Schematic diagram showing the positions of the absorbers in redshift space along the lines of sight of the QSOs in the sample. The (red) circles indicate the redshifts of O VI systems, whereas (blue) stars indicate the redshift of C IV systems, where there are upper limits on N(O VI). The left and right vertical lines are the minimum and maximum redshifts along each line of sight. The horizontal dotted lines are just to guide the reader's eye.

quasi-stellar objects (see fig in the next page) observed with Very Large Telescope/Ultraviolet and Visible Echelle Spectrograph (VLT/UVES). Based on Voigt profile and apparent optical depth analysis they have found that (i) the Doppler parameters of the O VI absorption are usually broader than those of C IV, (ii) the column density distribution of O VI is steeper than that of C IV, (iii) line spread (iv) of the O VI and X IV is strongly correlated (at 5.3 σ level) with δv (O VI) being systematically larger than δv (C IV) and (v) δv (O VI) and δv (C IV) are also correlated (at > 5 σ level) with their respective column densities and with N(H I) (at 3 and 4.5σ, respectively). The median column densities of H I, O VI and C IV are found to be higher when low ions are present. N(C IV) and N(H I) are strongly correlated (at 4.3 σ level).

However, no significant correlation is found between N(O VI) and N(H I). These findings favour the idea that C IV and O VI absorption originate from different phases of a correlated structure, and systems with large velocity spread is probably associated with overdense regions.

The velocity offset between optical depth weighted redshifts of C IV and O VI absorption is found to be in the range $0 \leq |\ \Delta v(\text{O VI - C IV})| < 48$ kms^{-1} with a median value of 8 kms^{-1}. They do not find any evidence for the ratios N(O VI)/N(H I), N(O VI)/N(C IV) and N(C IV)/N(H I) to evolve with z over the redshift range considered in their study. However, a lack of systems with high N(O VI)/N(H I) ratio (i.e., ≥ 0.5 dex) for $z \geq 2.5$ is noticeable. Similar trend is also seen for the N(C IV)/N(H I) ratio.

Muzahid et al., have compared the properties of O VI systems in their high-z sample with that of low-redshift ($z < 0.5$) samples from the literature and found that (i) the O VI components at low z are systematically wider than at high z with an enhanced non-thermal contribution to their b parameter, (ii) the slope of the column density distribution functions for high and low *z* is consistent, (iii) the range in gas temperature estimated from a subsample of well-aligned absorbers is similar at both high and low *z* and (iv) $\Omega_{\rm OVI} = (1.0 \pm 0.2) \times 10^{7}$ for N(O VI) > $10^{13.7}$ cm^{2}, estimated in our high-z sample, is very similar to low-z estimations.

Warm absorber properties of Seyfert galaxies

Sibasish Laha, Gulab Dewangan, Guainazzi and **Ajit Kembhavi** have studied a sample of Seyfert galaxies to bring out a consistent picture of the warm absorber properties. Warm absorbers are partially ionised gas clouds found near the central active engine of AGNs and along the line of sight to the central engine. They leave their absorption signatures mainly in the soft X-rays. The sample consisted of 31 sources. The data was obtained for all the sources from the XMM-Newton satellite. The preliminary results show that 50% of the galaxies in the sample have warm absorbers. The absorbers have varied ionization parameters and column densities. A detailed correlation study of the warm absorber parameters and the continuum parameters is underway.

Further **Laha, Dewangan,** and **Kembhavi** have studied two Seyfert galaxies : ESO198-G24 and ESO511-G030 to ascertain the origin of soft-excess in the X-ray spectra. They have found that for either of the sources a Comptonisation model gives a better explanation than a reflection model, indicating that the soft-excess is a primary emission rather than a reprocessed emission.

Laha, Dewangan, Susmita Chakravorty and **Kembhavi** have made a case study on the soft X-ray excess and its effect on warm absorbers with a bright Seyfert 1 galaxy IRAS13349+2438. They have found that the warm

absorber models developed using CLOUDY are highly dependant on the input continuum shape. They have shown how different continua result in different ionization structure and hence, different warm absorber properties even for the same observed data. They conclude that it is important to use realistic continuum shape that includes soft X-ray excess and the big blue bump in order to derive physical parameters of warm absorbers from the observed data. They also conclude that use of generic continuum based on X-ray to optical index, $\alpha_{ox,}$ may lead to erroneous results.

Stability of accretion disks

The standard thin accretion disk model has been successfully used to explain the soft X-ray spectra of galactic black hole systems and perhaps the UV emission of Active Galactic Nuclei. However, radiation pressure dominated disks are known to be viscously unstable and should produce large amplitude oscillations that are typically not observed. Instead, these sources exhibit stochastic variability, which may naturally arise due to viscous fluctuations in a turbulent disk. Agneiska Januik and **Ranjeev Misra** have shown using numerical simulations that these aperiodic viscous fluctuations can stabilize the inner radiation pressure dominated disks. This could be the answer to a forty year old problem in accretion disk theory.

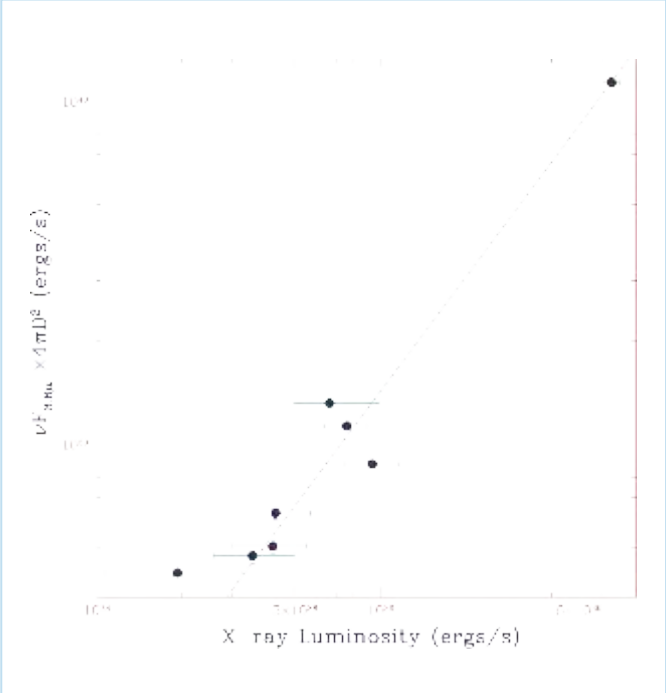
STARS AND INTERSTELLAR MEDIUM

Galaxy and interstellar medium analytical fits to interstellar extinction curves

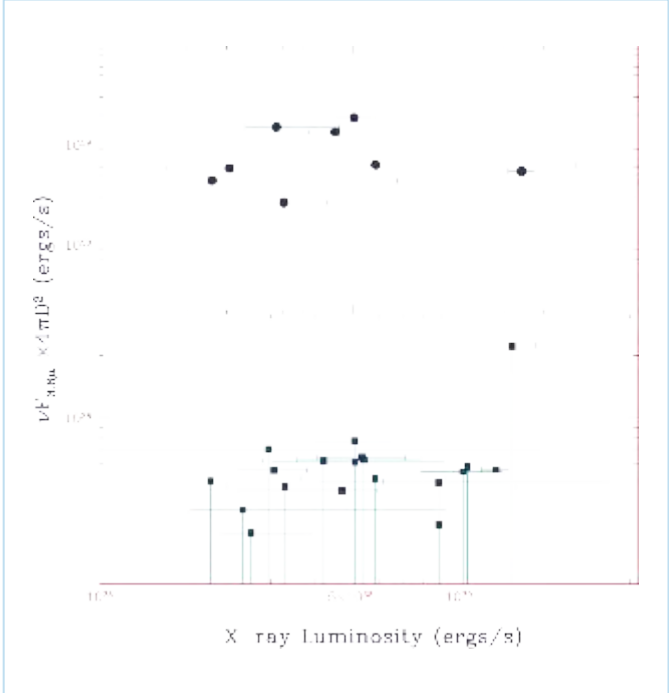
On completion of the second year of the ISRO-RESPOND project entitled: "Developing analytic formulas for extinction spectra of the major interstellar dust components", Ashim Roy, Subodh K. Sharma and **Ranjan Gupta** have developed analytical formulas for PAHs, and the Figure shows a plot of ionic and neutral PAH's absorption efficiencies.

Composite dust grains and circumstellar IR emissions

In continuation of the work on modeling of circumstellar dust around stars, D.B. Vaidya and **Ranjan Gupta** have carried out an extensive statistics of about 700 IRAS objects, which are known to have the 10μm silicate emission feature. Different sets of dust grain models with silicate as host and

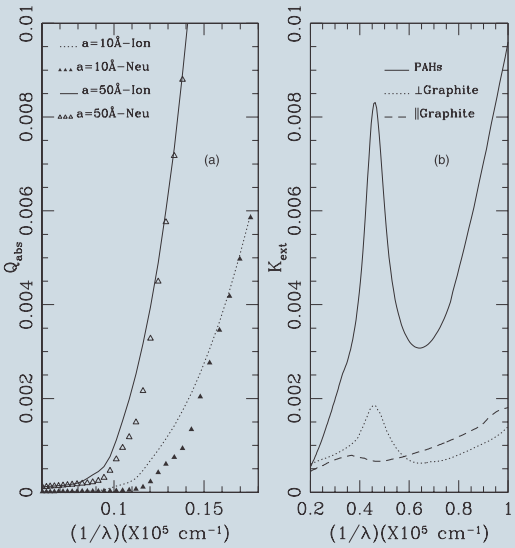


IR(3.6μ) v/s X-ray luminosities for sources in NGC 1399 with positive (log ($F_{5.8}/F_{3.6}$)) AGN-like ratios. The correlation co-efficient is 0.91 (prob = 0.002). Excluding the most luminous object at 3.6mm, the correlation co-efficient becomes 0.86 (prob = 0.01). From Shalima et al. 2012 (submitted to MNRAS)



IR(3.6μ) v/s X-ray luminosities for sources in NGC 1399 with negative (log($F_{5.8}/F_{3.6}$)) ratios (above) and the 3-s upper limits for the locations without IR counterparts (below). The correlation co-efficient is 0.29 (prob = 0.49). From Shalima et al. 2012 (submitted to MNRAS)

graphite or vacuum as inclusions were fitted to the IRAS data, and the analysis shows the following important conclusions:



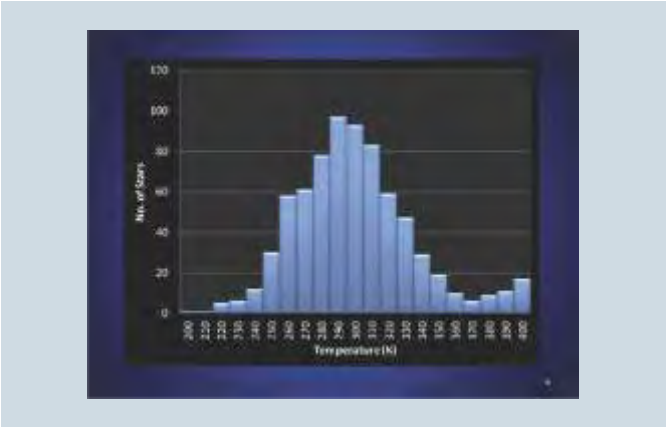
Analytical fits in the UV and FUV region using PAHs.

(I) The composite grain model with number of dipoles N=14440, axial ratio 2.0, and graphite inclusions provides the best fit for infrared flux observed from dust shells around most of the O rich AGB stars. (ii) The composite grain models give dust temperatures range 280-300^0 K, which fit with most of the observed IRAS-LRS curves. It is also comparable to the dust temperature range 200-300^0 K as suggested by Bowey and Adamson (2001); and 200-400^0 K as suggested by Voshchinnikov and Henning (2008).

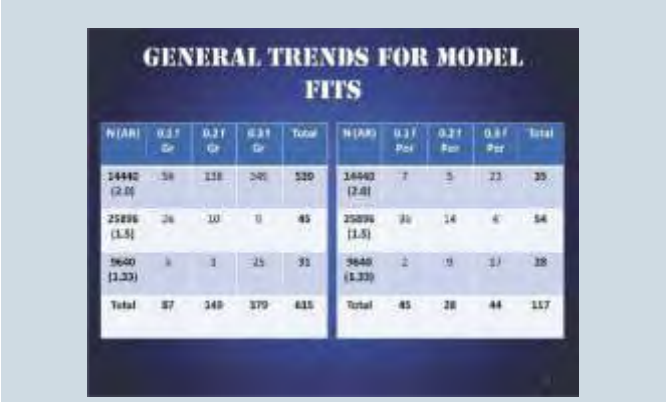
Figures here show the statistics on the model fits; dust temperature estimates and flux ratio R = Flux (18μ) /Flux(10μ).

Polar accretion on strongly magnetized neutron stars

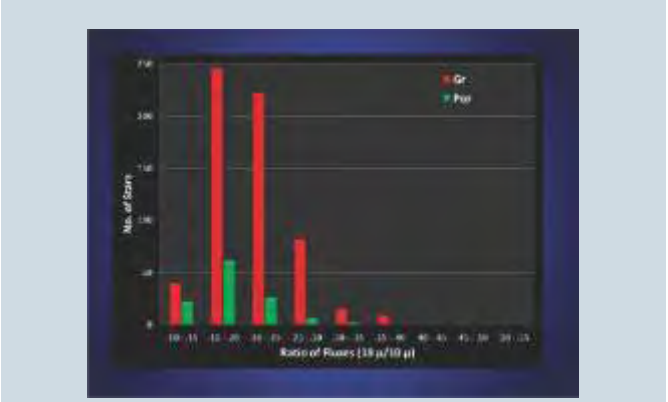
D. Bhattacharya, Dipanjan Mukherjee (Ph.D. Student) and Andrea Mignone (University of Torino, Italy) have been exploring the stability of magnetically confined accretion mound at neutron star polar caps. 2D MHD perturbation calculations using the PLUTO code show magnetic Rayleigh-Taylor instabilities setting in addition of mass to mounds exceeding a threshold height that is a function of



Dust Temperature Estimates



Inclusion Fractions and Axial Ratio of Grain Shape



Flux Ratios for Graphite and Porous Inclusions separately

the original dipole field strength. This demonstrates that the mound mass cannot exceed about 10^{-12} solar mass for a polar dipole field strength of $\sim 10^{12}$G. This limits the amount of gravitational radiation generated from such neutron stars, and also the diamagnetic screening of the magnetic field.

Search for millisecond pulsations from Fermi LAT unassociated sources

Bhaswati Bhattacharyya and her collaborators (Jayanta Roy, Yashwant Gupta and **Dipankar Bhattacharya**) have been continuing the project of search for millisecond pulsars at the positions of Fermi LAT unassociated sources using the GMRT, and have discovered three new pulsars in addition to the three pulsars discovered in the last year. Discovery of these six exotic millisecond pulsars (MSPs) - PSR J1207-5050 (isolated), PSR J1544+4937 (in very tight binary orbit with very low-mass companion, orbital period shortest among Fermi MSPs, a black widow candidate), PSR J1646-2142 (in a binary system, and displays a considerable profile evolution between 325 and 610 MHz), PSR J1828+0625 (a MSP offset by 25' from the best known Fermi position, also in a binary system and with a narrow pulse profile - a potential International Pulsar Timing Array (IPTA) candidate), PSR J1124-36 (a in-beam 5.5 ms MSP different from the known Fermi MSP, J1124-3653) and PSR J1536-49 (with a pulse profile of more than 300 degrees, widest among all MSP known) is pushing the boundaries of the known parameter space of millisecond pulsar. The aid of new efficient High Performance Computing back-end receiver at the GMRT (developed by Jayanta Roy, et al. in 2010) and the powerful computing facility at the IUCAA, made the discoveries of such exotic millisecond pulsars possible.

Being a multi-element interferometer GMRT provides an unique opportunity of imaging the field-of-view, which helped them to localize the position of the pulsar candidate with the aid of multiple phased array beam formation using the GSB baseband data. Using this technique, they have minimized the positional uncertainty of PSR J1544+4937. For localization of other MSPs, they have used MSP gating correlator (Jayanta Roy, et al. 2012), which is an excellent tool to improve the noise statistics in order to increase the detection significance many fold towards a pulsed signal. The MSP gating correlator employs a bank of coherent dedisperser modules running in parallel on all the voltage streams prior to the folding on the visibility plane. The new multi-beam phased array search technique is able to look for pulsations much more efficiently over a larger solid angle.

Further, they have been following up these newly discovered MSPs with the GMRT for detailed timing study, which will allow to detect the gamma-ray light curves. The comparative study of the radio and gamma-ray light curves can provide a much broader window to probe the pulsar magnetosphere. Regular timing of the black widow pulsar J1544+4937 and simultaneous dual frequency study of the pulsar before and after eclipse will help to understand the system. The GMRT discoveries yield a 3.08 ms MSP (PSR J1536-49), whose duty cycle is "widest" among the all known MSPs. Even though there are excess of orthogonal rotators in disk MSP population, this kind of aligned rotators among spun-up disk MSPs has not been emphasized well. Pulsar's surface magnetic field evolution follows the changes in the core magnetic field configuration and as the core flux is squeezed to the spin axis during spin-up, the model predicts much smaller polar cap area with much higher polar cap magnetic field for this aligned MSP.

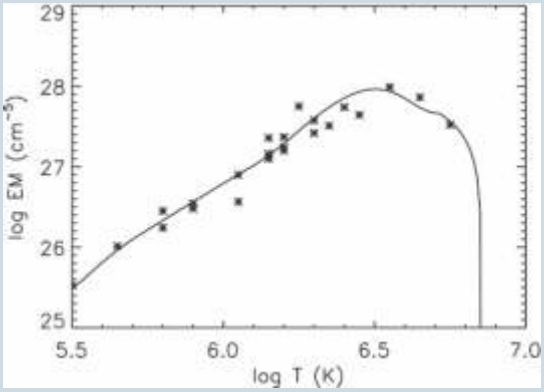
Being the first galactic millisecond pulsars discovered at the GMRT, these discoveries are very important scientific achievement from India, and the individual MSPs also expected to have huge impact on understanding of pulsar astrophysics. Discovery of such gamma-ray selected MSPs is of great value, not only to enhance the MSP population that can contribute to the International Pulsar Timing Array designed to study the gravitational wave background, but also to provide much broader window for probing the pulsar magnetosphere and emission mechanism. With the increased population of MSPs, the number of MSPs in special evolutionary phases would also increase and hence, will allow a more detailed study of the evolutionary processes leading to MSP formation.

SOLAR PHYSICS

Emission measure distribution and heating of solar active region cores

The problem of heating and maintaining the structures in the upper solar atmosphere, such as transition region and corona, has been considered to be one of the most challenging issues in astrophysics. There have been tremendous developments in observations and theory in the past few decades. However, a definitive solution remains elusive.

The discovery that loop structures are one of the basic building blocks of the solar corona has simplified the problem to a great deal. This is basically because of the inherent characteristics of the corona, which are such that there is no cross field conduction due to very high electric conductivity. The large-scale 1 MK loops and fan-like loops (which appear at the periphery of active regions) are seen clearly in observations recorded using the Transition Region and Coronal Explorer 171 Å passband. Their properties appear to be consistent with impulsive heating models. However, the 3 - 5 MK loops in the core of the active regions



Theoretical EM curve predicted by nanoflare heating model (solid line) and averaged observed emission measure (asterisks) for different regions in active region core.

are difficult to isolate even with the present-day observatories. Hence, it is more difficult to measure the physical plasma parameters along these hot core loops and to compare those properties with simulated results.

Faced with the likelihood of unresolved structures, one must look to other ways of distinguishing between steady and impulsive heating. Investigating the distribution of plasma with temperature, as quantified in the emission measure distribution, EM (T), is one of the promising approaches. Using data from the Extreme-ultraviolet Imaging Spectrometer aboard Hinode, **Durgesh Tripathi,** James A. Klimchuk and Helen E. Mason have studied the coronal plasma in the core of two active regions, namely AR 10961 and AR 10980. Concentrating on the area between opposite polarity moss, they have found emission measure distributions, having an approximate power-law form EM proportional to $T^{2.4}$ from log $T = 5.50$ up to a peak at log $T = 6.55$. They have shown that the observations compare very favourably with a simple model of nanoflare-heated loop strands, which also appear to be consistent with more sophisticated nanoflare models.

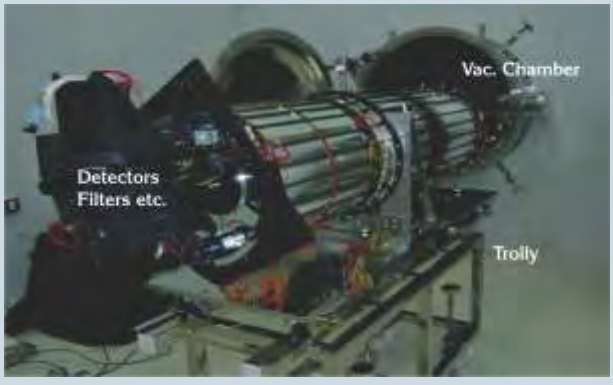
INSTRUMENTATION

Ultra Violet Imaging Telescope (UVIT)

Ultra Violet Imaging Telescope (UVIT) is one of the 5 instruments to go on the first Indian astronomy satellite ASTROSAT; the other 4 instruments are X-ray telescopes. UVIT consists of two telescopes, each of aperture 380 mm. The two telescopes make images in a field of ~ 28' with a resolution of < 1.8", simultaneously in three channels: 1300 - 1800 A, 2000 - 3000 A, and 3200 - 5300 A. UVIT is being developed through a collaboration of several Indian institutions: IIA, ISRO, IUCAA, and TIFR, and Canadian Space Agency. **Shyam Tandon** has been coordinating this development as Programme Manager for the project.

Critical Design Review of the payload, based on the tests done on the engineering model, was held in July 2011. After this review, assembly of the flight telescopes began. The telescope for near ultraviolet (2000 to 3000 A) and visible (3200 to 5500 A) has been assembled. The assembled telescope has given images, for a collimated beam, with FWHM of < 1.4" which meet the requirement of spatial resolution. A photograph of the telescope is shown below. The telescope for far ultraviolet (1300 to 1800 A) channel is being assembled now. It is expected that the payload would be delivered to ISRO for further tests and integration with the satellite in June 2012.

NUV/VIS Tel. being introduced in vacuum chamber



PUBLICATIONS BY IUCAA ACADEMIC MEMBERS

(A) JOURNALS

Ruta Kale, K.S. Dwarakanath, **Joydeep Bagchi, Surajit Paul** (2011) *Double relics in the outskirts of A3376: Accretion flows meet merger shocks?,* A & A, **32,** 533.

Joydeep Bagchi, S.K. Sirothia, Norbert Werner, Mahadev B. Pandge, Nimisha G. Kantharia, C.H. Ishwara-Chandra, Gopal-Krishna, **Surajit Paul** and Santosh Joshi (2011) *Discovery of the first giant double radio relic in a galaxy cluster found in the Planck Sunyaev-Zel'dovich Cluster Survey: PLCK G287.0+32.9,* ApJ Lett., **736,** L8.

G. Giovannini, L. Feretti, M. Girardi, F. Govoni, M. Murgia, V. Vacca and **J. Bagchi** (2011) *A giant radio halo in the low luminosity X-ray cluster Abell 523",* A & A, **530,** L5.

D. Mukherjee and **D. Bhattacharya** (2012) *A phase-dependent view of cyclotron lines from model accretion mounds on neutron stars,* MNRAS, **420,**720.

D. Bhattacharya (2011) *Beyond the Chandrasekhar limit: The structure and formation of compact stars,* Pramana, **77,** 29.

Radouane Gannouji, Hemwati Nandan and **Naresh Dadhich** (2011) *FLRW cosmology in Weyl-integrable spacetime,* Cosmology and Astroparticle Physics, **11,** 051.

Naresh Dadhich (2011) *On the measure of spacetime and gravity,* Int. J. Mod. Phys., **D20,** 2739.

Naresh Dadhich and Joseph M. Pons (2011) *Consistent Levi Civita truncation uniquely characterizes the Lovelock Lagrangians,* Phys Lett **B705**, 139.

Naresh Dadhich (2011) *On the enigmatic L - a true constant of spacetime,* Pramana, **77,** 433.

S. Tripathi, **R. Misra, G.C. Dewangan** and S. Rastogi *Discovery of soft time lags in the X-ray emission of Mrk 1040',* ApJ Lett., **736,** 37.

V.R. Marthi, J.N. Chengalur, Y. Gupta, **G.C. Dewangan** and **D. Bhattacharya** (2011) *The central point source in G76.9+1.0,* MNRAS, **416,** 2560.

N.V. Voshchinnikov, Th. Henning, M.S. Prokopjeva and **H.K. Das** (2012) *Interstellar polarization and grain alignment: The role of iron and silicon,* A & A, **541,** A52.

S.V. Dhurandhar (2011) *Gravitational wave astronomy: Astronomy of the 21st century,* Bull. Astr. Soc. Ind., **39,** 181.

S.V. Dhurandhar, H. Tagoshi, Y. Okada, N. Kanda and H. Takahashi (2011) *The cross-correlation search for a hot spot of gravitational waves,* Phys. Rev. **D84,** 083007.

S.V. Dhurandhar, H. Mukhopadhyay, H. Tagoshi and N. Kanda (2011) *Coherent versus coincident detection of gravitational wave signals from compact inspiraling binaries,* Int. J. Mod. Phys. **D 20,** 2051.

Nisha Katyal, Ranjan Gupta and D.B. Vaidya (2011) *Interstellar grains: Effect of inclusions on extinction,* Earth, Planets and Space, **63,**1.

R. Gupta and D.B. Vaidya (2011) *Interstellar dust grains,* Journal of Cosmology, **16,** 6661.

D. Deb, A. K. Sen, H. S. Das and **R. Gupta** (2011) *The photometric study of light scattering from the surface of alumina powder and interpretations by Hapke formula,* Advances in Space Research, **48,** 1274.

C. Bhattacharjee Deb, H. S. Das, A. K. Sen and **R. Gupta** (2011) *Modelling laboratory data of bidirectional reflectance of a Regolith surface containing alumina,* Astronomical Society of Australia, **28,** 261.

Ashim K. Roy, Subodh K. Sharma, **Ranjan Gupta** and Pritesh Ranadive (2012) *Analytic formulas for frequency and size dependence of absorption and scattering efficiencies of astronomical polycyclic aromatic hydrocarbons,* JQSRT, **113,** 624.

Sheelu Abraham, Ninan Sajeeth Philip, **Ajit Kembhavi,** Yogesh G. Wadadekar and Rita Sinha (2012), *A photometric catalogue of quasar and other point sources in the Sloan Digital Sky Survey,* MNRAS, **419**, 80.

Harsha Raichur, Ranjeev Misra and **Gulab Dewangan** (2011) *Broad-band spectral analysis of Aql X-1,* MNRAS, **416,** 2637.

Bibhas Ranjan Majhi and Elias C. Vagenas (2011) *Black hole spectroscopy via adiabatic invariance,* Phys. Lett., **B 701,** 623.

Bibhas Ranjan Majhi and T. Padmanabhan (2012) *Noether current, horizon Virasoro algebra and entropy,* Phys. Rev. **D 85,** 084040.

K.P. Harikrishnan, **R. Misra,** and G. Ambika (2012) *Revisiting the box counting algorithm for the correlation dimension analysis of hyperchaotic time series,* CNSNS, **17**, 263.

J. Abadie, ..., **Sanjit Mitra,** ... et al. (2011) (LIGO Scientific Collaboration, Virgo Collaboration), *Directional limits on persistent gravitational waves using LIGO S5 science data,* Phys. Rev. Lett., **107**, 261102.

A. Abergel, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), *Planck early results. XXV. Thermal dust in nearby molecular clouds,* A&A, **A25**, 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XXIII. The first all-sky survey of galactic cold clumps, A&A, **A23,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XXII. The submillimetre properties of a sample of galactic cold clumps, A&A, **A22,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XX. New light on anomalous microwave emission from spinning dust grains, A&A, **A20,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XVIII. The power spectrum of cosmic infrared background anisotropies, A&A, **A18,** 536.

J. Aatrokoski, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XV. Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources, A&A, **A15,** 536.

N. Aghanim, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XII. Cluster Sunyaev-Zeldovich optical scaling relations, A&A, **A12,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. XI. Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations, A&A, **A11**, 536.

N. Aghanim, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. X. Statistical analysis of Sunyaev-Zeldovich scaling relations for X-ray galaxy clusters, A&A, **A10,** 536.

N. Aghanim, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. IX. XMM-Newton follow-up for validation of Planck cluster candidates, A&A, **A9,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. VIII. The all-sky early Sunyaev-Zeldovich cluster sample, A&A, **A8,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. VII. The early release compact source catalogue, A&A, **A7,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck HFI Core Team), Planck early results. VI. The high frequency instrument data processing, A&A, **A6,** 536.

A. Zacchei, ..., **Sanjit Mitra,** ..., et al. (2011) Planck early results. V. The low frequency instrument data processing, A&A, **A5,** 536.

A. Mennella, ... **Sanjit Mitra,** ..., et al. (2011) Planck early results. III. First assessment of the low frequency instrument in-flight performance, A&A, **A3,** 536.

P. A. R. Ade, ..., **Sanjit Mitra,** ..., et al. (2011) (Planck Collaboration), Planck early results. I. The Planck mission, A&A, **A1,** 536.

J.V. Narlikar (2011) *Mach's principle, Resonance,* April, 310.

J.V. Narlikar (2011) *What a student can learn from the Saha equation,* Physics Teacher, **53,** 1-2, 107.

Alexandre Yale and **T. Padmanabhan** (2011) *Structure of Lanczos-Lovelock Lagrangians in critical dimensions,* Gen. Rel. Grav., 43, 1549.

T. Roy Choudhury and **T. Padmanabhan** (2011) *Reply to comment on Quasinormal modes in Schwarzschild-de Sitter spacetime: A simple derivation of the level spacing of the frequencies* Phys. Rev., **D 83,** 108502.

T. Padmanabhan (2011) *Lessons from classical gravity about the quantum structure of spacetime,* J. Phys. Conf. Ser., **306,** 012001.

Hamsa Padmanabhan and **T. Padmanabhan** (2011) *Non-relativistic limit of quantum field theory in inertial and non-inertial frames and the Principle of Equivalence,* Phys. Rev., **D 84,** 085018.

T. Padmanabhan (2011) *Some aspects of field equations in generalised theories of gravity,* Phys. Rev., **D 84,** 124041.

T. Padmanabhan (2011) *The hydrodynamics of the atoms of spacetime: Gravitational field equation is Navier-Stokes equation,* Int. Jour. Mod. Phys., **D 20** 2817.

Sanved Kolekar and **T. Padmanabhan** (2012) Action *principle for the fluid-gravity correspondence and emergent gravity,* Phys. Rev., **D 85,** 024004.

Suprit Singh and **T. Padmanabhan** (2012) *Complex effective path: A semi-classical probe of quantum effects,* Phys. Rev., **D 85,** 025011.

Sanved Kolekar, Dawood Kothawala and **T. Padmanabhan** (2012) *Two aspects of black hole entropy in Lanczos-Lovelock models of gravity,* Phys. Rev., **D 85,** 064031.

Krishna Mohan Parattu and Akin Wingerter (2011) *Tribimaximal mixing from small groups,* Phys. Rev., **D 84,** 013011.

A.N. Ramaprakash and M. K. Srivastava, et al. (2011) *Design and development of an optical-fibre-based Integral Field Unit (IFU) on the IUCAA 2-m telescope,* MNRAS, **418,** 1127.

M. Rauch, G.D. Becker, M.G. Haehnelt, J-R. Gauthier, **S. Ravindranath** and W.L.W. Sargent (2011) *Filamentary infall of cold gas and escape of Lya and hydrogen ionizing radiation from an interacting high redshift galaxy,* MNRAS, **418,** 1115.

A.M. Koekemoer, et al. with **S. Ravindranath** (2011) CANDELS: *The cosmic assembly near-infrared Deep Extragalactic Legacy Survey - The Hubble space telescope observations, imaging data products, and mosaics,* ApJS, **197**, 36.

N.A. Grogin, et al. with **S. Ravindranath** (2011) CANDELS: *The cosmic assembly near-infrared Deep Extragalactic Legacy Survey,* ApJS, **197,** 35.

C.J. Conselice, A.F.L. Bluck, **S. Ravindranath,** A. Mortlock, A.M. Koekemoer, F. Buitrago, R. Grützbauch and S.J. Penny (2011) *The tumultuous formation of the Hubble sequence at z >1 examined with HST/Wide-Field Camera 3 observations of the Hubble Ultra Deep Field,* MNRAS, **417,** 2770.

H. Rahmani, R. Srianand, P. Noterdaeme and P. Petitjean (2012) *The Lyman-α emission of high-z damped Lyman-α systems, A high-resolution study of intergalactic O VI absorbers at z ~ 2.3,* MNRAS, **421,** 446.

R. Srianand, N. Gupta, P. Petitjean, P. Noterdaeme, C. Ledoux, C.H. Salter and D.J. Saikia (2012) *Search for cold gas in z > 2 damped Lyα systems: 21-cm and H_2 absorption,* MNRAS, **421,** 651.

M. Vivek, **R. Srianand,** A. Mahabal and V.C. Kuriakose (2012) *Dynamically evolving Mg II broad absorption line flow in SDSS J133356.02+001229.1* MNRAS Lett., **421,** 107

P. Noterdaeme, P. Laursen, P. Petitjean, S.D. Vergani, M.J. Maureira, C. Ledoux, J.P.U. Fynbo, S. Lopez and **R. Srianand** (2012) *Discovery of a compact gas-rich damped **Lyman-Î± galaxy at z** = 2.2: evidence of a starburst-driven outflow,* A & A, **540,** 63.

Jayanti Prasad and **Tarun Souradeep** (2012) *Cosmological parameter estimation using Particle Swarm Optimization,* Phys. Rev., **D 85,** 123008.

Nidhi Joshi, **Aditya Rotti** and **Tarun Souradeep** (2012) *Statistics of bipolar representation of CMB maps,* Phys. Rev., **D 85,** 043004.

Amir Aghamousa, Mihir Arjunwadkar and **Tarun Souradeep** (2012) *Evolution of the CMB power spectrum across WMAP data releases: A nonparametric analysis,* ApJ, **745,** 114.

Laura G. Book, Marc Kamionkowski and **Tarun Souradeep** (2012) *Odd-parity bipolar spherical harmonics,* Phys. Rev. , **D 85,** 023010.

Arman Shafieloo and **Tarun Souradeep** (2011) *Assumptions of the primordial spectrum and cosmological parameter estimation,* New J. Phys., **13,** 103024.

Tarun Souradeep (2011) *Early universe with CMB polarization,* Bull. Astron. Soc. India, **39,** 163.

C. Jose, S. Samui, **K. Subramanian** and **R. Srianand** (2011) *Weighing neutrinos using high redshift galaxy luminosity functions,* Phys. Rev., **D 83,** 123518.

L. M. Widrow, D. Ryu, D. Schleicher, **K. Subramanian,** C. Tsagas and R. A. Treumann (2012) *The first magnetic fields,* Space Science Reviews, **166,** 37.

Pranjal Trivedi, T.R. Seshadri and **Kandaswamy Subramanian** (2012) *Cosmic microwave background trispectrum and primordial magnetic fields,* Phys. Rev. Lett., **108**, 231301.

D. Tripathi, J.A. Klimchuk, H.E. Mason (2011) *Emission measure distribution and heating of two active region cores,* ApJ, **740,** 111.

(B) PROCEEDINGS

D. Bhattacharya (2011) *Evolutionary processes in neutron star binaries,* AIP Conference proceedings of Astrophysics of Neutron Stars - 2010, **1379,** 31.

A.J. Castro-Tirado, M. Bremer, J-M Winters, et al. 14 authors including **D. Bhattacharya** (2011) *Millimetre observations of gamma-ray bursts,* AIP Conference proceedings of Gamma Ray Bursts - 2010, **1358,** 109.

Debbijoy Bhattacharya, M. Errando, R. Mukherjee, M. Bottcher, P. Sreekumar, **R. Misra** and P. Coppi (2011) *Contributions from radio-loud AGNs to the extragalactic gamma-ray background (EGRB),* The 3rd Fermi Symposium 2011.

V.R. Marthi, J.N. Chengalur, Y. Gupta, **G.C. Dewangan** and **D. Bhattacharya** (2011) *The central point source in G76.9+1.0,* J. Astrophys. Astron, **32,** 451.

Akin Wingerter and **Krishnamohan Parattu** (2011) *A scan for models of neutrino mixing from non-Abelian discrete symmetries,* Contribution to the proceedings of the 2011 Europhysics Conference on High Energy Physics-HEP, July 21-27, 2011, Grenoble, France.

Tuhin Subhra Konar and **Surajit Paul** (2012) On polynomials of the form $\sum_{r=0}^{\infty} \frac{n^r x^{1+nr}}{\prod_{p=0}^{r}(1+pn)}$, $\forall x$ **AND** $\forall n \in \mathbf{Z}^+$; IJPMS, **3,** No. 1.

A.N. Ramaprakash and R.L. Reed et al. (2011) *Robo-AO, The first autonomous laser guide star adaptive optics system for small telescopes,* Bull. of AAS, **43,** 157.

Tarun Souradeep, *Early universe with CMB polarization, Invited contribution, fluid flows to black holes : A tribute to S Chandrasekhar on his birth centenary, Saikia,* D J (ed.) and Trimble, Virginia (ed.), World Scientific Publishing Company, USA, 2011, 312, ISBN-13: 978-9814374767

(C) BOOKS (AUTHORED/EDITED)

J.V. Narlikar (2012) *Char Nagaratale Maze Vishwa (My universe of four cities)* (in Marathi), Mouj Prakashan Griha, Mumbai.

J.V. Narlikar (2012) *Anokha Antariksh (The remarkable space)* (in Hindi), Chhatisgarh Rajya Hindi Granth Academy, Raipur.

J.V. Narlikar (2012) *From black clouds to black holes (Third Edition),* World Scientific Publishing Co. Pte. Ltd., Singapore.

PEDAGOGICAL ACTIVITIES

(a) IUCAA-NCRA Graduate School Lectures

Dipankar Bhattacharya : Quantum and Statistical Mechanics II (14 lectures) (October – December 2011)

Gulab Dewangan : Extragalactic Astronomy II (14 lectures) (March – May 2012)

Sanjeev Dhurandhar : Methods of Mathematical Physics I (21 lectures) (August – September 2011)

Ajit Kembhavi : Electrodynamics and Radiative Processes II (14 lectures) (October – December 2011)

Pushpa Khare : Methods of Mathematical Physics II (14 lectures) (October – December 2011)

T. Padmanabhan : Quantum and Statistical Mechanics I (14 lectures) (August – September 2011)

A.N. Ramaprakash : Astronomical Techniques I (14 lectures) (January – February 2012)

Swara Ravindranath : Introduction to Astronomy and Astrophysics I (14 lectures) (August – September 2011)

R. Srianand : Galaxies : Structure, Dynamics and Evolution (21 lectures) (January – February 2012)

Tarun Souradeep : Extragalactic Astronomy I (21 Lectures) (January – March 2012)

Durgesh Tripathi : Electrodynamics and Radiative Processes I (14 lectures) (August – September 2011)

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

Ranjan Gupta : Laboratory course (Theory 10 lectures) and related to observational astronomy of (10 laboratory and night experiments).

J.V. Narlikar : Astronomy and Astrophysics – II

T. Padmanabhan : Quantum Mechanics [Quantum Field Theory], January-April 2012

(c) University of Pune, M.Sc. (Statistics) Lectures

Ajit Kembhavi : Linear Regression in Astronomy, June 2011

(d) Supervision of Projects

Joydeep Bagchi : Shishir Sankhyayan (IISER, Pune) *Uncovering a giant cosmic galactic structure from SDSS data* (Part I: October 2011 - December 2011) (Part II: January 2012 - March 2012)

Dipankar Bhattacharya : Ajay Vibhute (Pune University M.Sc. in Scientific Computing) *Scanning sky monitoring and source identification*

Gulab Dewangan : Sibasish Laha (Ph. D. project - Informal association) *Warm absorption and emission from Seyfert 1 galaxies*

	Mainpal Rajan (graduate school project) *X-ray emission from 1H0419-477 partial covering absorption or disk reflection.*
	Pramod Pawar (Second year Ph. D. student with M. K. Patil at SRTM University Nanded): *X-ray study of active galactic nuclei*
	Shah Alam (First year Ph. D. student at Jamia Millia Islamia under Sanjay Jinghan): Co-guide for Ph. D. thesis on *Black hole binaries*
	Conducted two month long (15 September - 15 November, 2011) informal course on *X-ray astronomy techniques* for three students Mainpal Rajan (IUCAA), Shah Alam (Jamia Millia Islamia), and Pramod Pawar (SRTM, Nanded) and a postdoc visitor Rezi Thomas
Sanjeev Dhurandhar	: Swetha Bhagwat (IISER, Pune) *General relativity and gravitational waves*
Ranjan Gupta	: Rajeshwari Dutta (University of Pune, M.Sc. Project) *Infrared emission properties of circumstellar dust* (September 2011 - May 2012)
Ajit Kembhavi	: Kamalika Nath, IIT, Kanpur, (Indian Academy of Sciences- Summer Fellowship), May- June 2011, *Galaxy surface photometry*
	Essna Ghose (Fergusson College, Pune) August-February 2012, *Application of virtual observatory tools*
J.V. Narlikar	: School Students' Summer Programme (2011) *Foucault pendulum*
	: Vacation Students' Programme (2011) *Observational tests of cosmological models*
Surajit Paul	: Sowgata Chowdhury, B.Tech. student, Tezpur Central University (Assam), *Understanding the particle acceleration theories and different radiation mechanisms in astrophysics* (December 2011 - January 2012)
A. N. Ramaprakash	: Prashant Pathak (IISER, Thiruvananthapuram) *Near-IR controller testing* Anamay Kane (Vishwakarma Institute of Information Technology, Pune) *Embedded Tip-Tilt Controller For Astronomical Imaging*
Swara Ravindranath	: Marcela Morillo Acosta (St. Petersburg University, Russia, Master's thesis project), *Study of star formation in the nuclear ring of NGC 3351*
	Venkat Punjabi (University of Pune, Masters project), *Evolution of galaxy merger fraction at redshifts $z < 2$*
	Laura Green (University of California, Riverside), *Nature of MIPS sources in the Great Observatories Origins Deep Survey*
Tarun Souradeep	: M.Sc. Thesis by Hamsa Padmanabhan (University of Pune) *A comparison of CMB lensing efficiency of gravitational waves and large scale structure* (January – May 2012)
R. Srianand	: Vikram Khaire (IUCAA-NCRA graduate school 2011) *Metagalactic UV radiation*
	Independent 4 months projects for three students from IIST, Thiruvananthapuram
	Long term project for 6 students from IISER, Pune
	Sneha Shashidhara (Fergusson College, Pune) TYBSc project
	Two months project as a part of Indian Academy of Sciences - Summer Fellowship

Kandaswamy Subramanian : Suyog Jadhav for the Indian Academy of Science Summer fellowship, *Turbulent dynamos*

Durgesh Tripathi : VSP project of Adil Amin *Spectroscopic diagnostics of astrophysical plasma*

Kaustubh Vaghmare : Co-supervised a project titled *Surface photometry of galaxies* by Kamalika Nath, from IIT, Kanpur, IASc - Summer Fellowship under Ajit Kembhavi

Co-supervised a project titled *Applications of virtual observatory tools* by Essna Ghose, from Fergusson College, Pune. This was her B.Sc. Final year project done under Ajit Kembhavi.

(e) Supervision of Ph.D. Thesis

Ajit Kembhavi : Co-guide to Vinu, V., (Ph.D., M.G. University, Kottayam), *Optical data analysis*: Guide: K. Indulekha.

T. Padmanabhan : Dawood Kothawala, *Semiclassical gravity and thermodynamics of horizons.*

A.N. Ramaprakash : Mudit Kumar Srivastava, *Design and development of an optical fibra based Integral Field Unit (IFU) for area spectroscopy on IUCAA 2m telescope.*

Tarun Souradeep : Tuhin Ghosh, *Galactic and cosmological signals in the microwave background anisotropy and polarization*

(f) Articles in Physics

T. Padmanabhan : *The Copernican Revolution*, Resonance, **16**, 304, 2011.

Logarithms, Resonance, **16**, 446, 2011.

The Pathos of Planets, Resonance, **16**, 582, 2011.

The Galilean World, Resonance, **16**, 663, 2011.

The Affairs of the Heart, Resonance, **16**, 770, 2011.

The Invisible Weight, Resonance, **16**, 854, 2011.

Geometry Without Figures, Resonance, **16**, 950, 2011.

The Questions of Life, Resonance, **16**, 1039, 2011.

Measuring the Heavens, Resonance, **17**, 6, 2012.

Calculus is Developed in Kerala, Resonance, **17**, 106, 2012.

All Was Light - 1, Resonance, **17**, 230, 2012.

TALKS BY IUCAA ACADEMIC MEMBERS AT IUCAA AND OTHER INSTITUTIONS

(A) SEMINARS, COLLOQUIA AND LECTURES

Debbijoy Bhattacharya

Long Term X-ray and Gamma-ray Variability of Flat Spectrum Radio Quasars, Advanced Research Workshop on X-ray Timing, IUCAA, January 23-28, 2012.

Long Term Variability of Blazars, Workshop on AGN Science and the Developments on CZT imager on ASTROSAT, TIFR, Mumbai, January 11-13, 2012.

Dipankar Bhattacharya

High Performance Computing in Astronomy, CRL Colloquium, September 29, 2011.

Observational Evidence of Relativity in and Around Compact Stars, ICGC-2011, Goa, December 16, 2011.

Techniques of Astrosat CZT Imager Data Analysis, Advanced Research Workshop on X-ray Timing, IUCAA, January 24, 2012.

Polar Accretion Mounds on Accreting Neutron Stars, HMXB Team Meeting, ISSI, Berne, March 13, 2012.

Naresh Dadhich

Why Einstein [Had I been born in 1844!]?, Mohan Lal Sukhadia University, Udaipur, May 2, 2011.

Gravity (2 lectures), Refresher Course in Astronomy and Astrophysics for College/University Teachers and Vacation Students' Programme, IUCAA, June 8-9, 2011.

Gravity in 5 Dimensions, Uzbekistan National University, September 15, 2011.

Gulab Dewangan

X-ray Spectral Variability of NGC~1365: Intrinsic or Absorption Variability, International Conference on From the Dolomites to the Event Horizon: Sledging Down the Black Hole Potential Well, Sexten, Italy, July 10-17, 2011.

Compton Reflection and Complext Absorption in Active Galactic Nuclei, Workshop on High Energy Astrophysics, HRI, Allahabad, February 18, 2012.

Detection of Binary Supermassive Black Holes, IUCAA-Caltech Workshop on Astronomy with Adaptive Optics on Moderate-sized Telescopes Adaptive Optics, IUCAA, August 22-25, 2011.

X-ray astronomy techniques, Workshop on Galaxies: Normal and Active, SRTM University, Nanded, November 14-17, 2011.

X-ray Emission from Active Galactic Nuclei (2 lectures), Workshop on Galaxies: Normal and Active, SRTM University, Nanded, November 14-17, 2011.

X-ray Data Analysis Sessions, Workshop on Galaxies : Normal and Active, SRTM University, Nanded, November 14-17, 2011.

Sanjeev Dhurandhar

IndIGO: Data Centre at IUCAA, EGO-IndIGO Meeting, IUCAA, October 31 - November 2, 2011.

Astronomy of the 21st Century: Gravitational Wave Astronomy, Vaidya-Raychaudhuri Endowment Award Lecture, St. Xavier's College, Kolkata, November 15, 2011.

Gravitational Wave Astronomy: Astronomy of the 21st Century, Cochin University of Science and Technology, Kochi, July 19, 2011.

The Global Search for Gravitational Waves, IISER, Thiruvananthapuram, July 21, 2011.

Astronomy of the 21st Century: Gravitational Wave Astronomy, IISER, Pune, September 14, 2011.

Ranjan Gupta

ANN Based Effective Temperatures of G-K Dwarf Stars from VBT Spectroscopic Data and Current Developments, Workshop on Commemorating 25 years of the Vainu Bappu Telescope, IIA, Bangalore, August 10-12, 2011.

Modeling Silicate Emission Features in Circumstellar Dust, at International Conference on Interstellar Dust, Molecules and Chemistry IUCAA, November 22-25, 2011.

Stellar Spectroscopy from Indian Telescopes - An Overview, International Workshop on Stellar Spectral Libraries, University of Delhi, December 5-9, 2011.

Dust Modeling of Circumstellar Shells, Pulkova Observatory, St. Petersburg, Russia, December 13, 2011.

Interstellar Molecules and Dust, National Workshop on Astrochemistry, Birla Planetarium, Jaipur, December 22-24, 2011.

Upcoming Large Astronomical Telescopes, Workshop on Photometer Fabrication, IUCAA, January 9-13, 2012.

Circumstellar Dust and its modeling, National Seminar on Dusts in Astrophysics, Assam University, Silchar, January 31 – February 2, 2012.

Developing Analytic Formulas for Extinction Spectra of the Major Interstellar Dust Components, ISRO RESPOND Project Presentation, PRL, Ahmedabad, February 28, 2012.

NIR Silicate Features and Statistics from IRAS Data, CPS, Kobe University, Kobe, Japan, March 14, 2012.

Ajit Kembhavi

The Virtual Observatory and Astronomy Education in India, International Virtual Observatory Alliance Interoperability Workshop, Naples, Italy, May 19, 2011.

The IUCAA Story, Springer Asian Library Advisory Board Meeting, Seoul, July 12, 2011.

Astronomy with the Virtual Observatory, 11th Asia-Pacific Regional IAU Meeting (APRIM 2011), The Empress Convention Centre, Chiang Mai, Thailand, July 26, 2011.

Early Observation of Early Type Galaxies with the VBT and Some Consequences, Indian Institute of Astrophysics, Bangalore, August 10, 2011.

Astronomy with Cutting-Edge ICT: From Transients in the Sky to Data Over the Continents, Keynote Address, Asia-Pacific Advanced Network 32rd Meeting, India Habitat Centre, New Delhi, August 23, 2011.

From Stars to White Dwarfs and Beyond-with S. Chandrasekhar, Karnatak University, Dharwad, September 19, 2011.

Virtual Observatories: Tools and Applications, (JSPS-DST Asia Academic Seminar) CPS 8th Intl. School of Planetary Sciences: Challenges in Astronomy: Observational Advances, Minamiawaji Royal Hotel, Japan, September 28, 2011.

Stars in our Galaxy, Workshop on Stellar Astrophysics, University of Kashmir, Srinagar, October 24, 2011.

Galaxies and Active Galactic Nuclei – I, Workshop on Galaxies: Normal and Active, SRTM University, Nanded, November 14, 2011.

Galaxies and Active Galactic Nuclei – II, Workshop on Galaxies: Normal and Active, SRTM University, Nanded, November 14, 2011.

From Kepler to Kepler – A Journey Over Four Centuries, Kusum Sabhagraha, Nanded, November 14, 2011.

Virtual Observatories, International Workshop on Stellar Spectral Libraries, University of Delhi, December 6, 2011.

Two Mega Projects for Indian Astronomers: The Thirty Metre Telescope and the LIGO-Gravitational Wave Detector, BITS, Pilani, Goa, February 3, 2012.

Extra Solar Planets – New Worlds in the Galaxy, VJTI, Mumbai, February 4, 2012.

Two Mega Projects in Astronomy: The Thirty Metre Telescope and the Advanced LIGO Gravitational Wave Detector, XVII National Space Science Symposium, S. V. University, Tirupati, February 14, 2012.

Mega Projects in Astronomy, IWAMA – 2012, Pt. Ravishankar Shukla University, Raipur, February 19, 2012.

Thirty Metre Telescope: An Astronomy Mega Project for India, Science Day, National Chemical Laboratory, Pune, February 28, 2012.

Great Optical Telescopes, Science Day, IUCAA, February 28, 2012.

The Detection of Gravitational Waves- A New Experiment for India, IISER, Mohali, March 13, 2012.

Thirty Metre Telescope, Nehru Planetarium, New Delhi, March 25, 2012.

Bibhas Ranjan Majhi

Statistical Origin of Gravity, International Conference on Modern Perspectives of Cosmology and Gravitation (COSGRAV 12), Indian Statistical Institute, Kolkata, February 7-11, 2012.

Ranjeev Misra

Rapid X-ray Variability of Black Hole Systems, IISc, Bangalore, July 2011.

Advanced Statistical Techniques, 99th National Science Congress, Bhubaneswar, January 2012.

Advanced Timing Techniques, Advanced Research Workshop on X-ray Timing, IUCAA, January 2012.

Stability of Radiation Pressure Dominated Accretion Disks, ASTROSAT Symposium, HRI, Allahabad, February 2012.

Multi-wavelength Study of ULX, International Conference on Astronomy and Cosmology, Kathmandu, Nepal, March 2012.

Sanjit Mitra

Radiometric Searches for Gravitational Waves Using a Network of Laser Interferometric Detectors, EGO-IndIGO Meeting, IUCAA, November 2, 2011.

Probing a Stochastic Gravitational Wave Background Using a Network of Laser Interferometric Detectors, 7th ICGC, Goa, December 15, 2011.

US-India Virtual Institute Opportunity for GW and CMB Analysis with main focus on IndIGO Activities, HiPC NSF-DST Workshop, Bangalore, December 21, 2011.

Probing a Stochastic Gravitational Wave Background Using a Network of Laser Interferometric Detectors, Workshop on Gravitational Waves, IUCAA, December 22, 2011.

Generation of Gravitational Waves, Gravitational Waves Data Analysis course, IISER, Pune, February 11, 2012.

Jayant Narlikar

Chance and Accident in Astronomy, Indian Institute of Astrophysics, Bangalore, August 11, 2011.

Redshifts and the Hypothesis of Variable Particle Masses, San Marino Workshop on Astrophysics and Cosmology for Matter and Antimatter, San Marino, September 4, 2011.

Harnessing New Technologies in Aid of Higher Education, Foundation for Liberal and Management Education, Pune, October 1, 2011.

Facts and Speculations in Cosmology, Harish-Chandra Research Institute, Allahabad, December 2, 2011.

ICGC – 87 as I See Today, International Conference on Gravitation and Cosmology, Goa, December 15, 2011.

Communicating Science, International Conference for Celebration of 60th Anniversary of UNESCO Kalinga Prize for Popularisation of Science, Kalinga Institute of Industrial Technology, Bhubaneswar, January 4, 2012.

How Nelson Won the Battle of Trafalgar … and Other Issues, National Institute of Science Education and Research, Bhubaneswar, January 6, 2012.

How Well Do We Know Our Universe?, Indian Institute of Technology Madras, Chennai, February 3, 2012.

How Well Do We Know Our Universe?, International Conference on Modern Perspectives of Cosmology and Gravitation (COSGRAV 12), Indian Statistical Institute, Kolkata, February 10, 2012.

T. Padmanabhan

Gravity from an Emergent Perspective, Spanish Relativity Meeting ERE, Madrid, Spain, September 2, 2011.

Gravity as Thermodynamics: Towards the Microscopic Origin of Geometry, SISSA, Trieste, Italy, September 2011.

Gravity: An Emergent Phenomenon, Mini Session on Gravity as an Emergent Phenomena, ICGC-2011, Goa, December 15, 2011.

Gravity: An Emergent Phenomenon, School of Physical Sciences, Jawaharlal Nehru University, April 4, 2011.

Fluid Mechanics of Spacetime, IISER, Pune, December 21, 2011.

Issues on Education, Sinhgad Institute of Management, Pune, April 9, 2011.

Story of the Calendar, National Institute of Oceanography, Goa, December 14, 2011.

Enigma of Gravity, Prof. Subrahmanyan Chandrasekhar Lecture Series, Nehru Planetarium, Mumbai, March 11, 2012.

Krishna Mohan Parattu

Models of Neutrino Mixing: An Algorithmic Approach, Centre for High Energy Physics, Indian Institute of Science, Bangalore, August 08, 2011.

Surajit Paul

Revealing the Mystery of Ringlike Radio-relic Formation Around Some Galaxy Clusters, International Conference on Modern Perspectives of Cosmology and Gravitation (COSGRAV-12), ISI, Kolkata, February 7-11, 2012.

Blast Wave Formation in Galaxy Cluster Mergers and its Role in Shaping the Cluster Morphology and Controlling the Energy Distribution, Sydney Institute for Astronomy, University of Sydney, Australia, November 18, 2011.

Emergence of Blast Wave in Galaxy-Cluster Mergers and it's Effects on ICM, IISER, Pune, March 09, 2012.

A.N. Ramaprakash

IUCAA Instrumentation and Thirty Metre Telescope Project, IUCAA Internal Meeting, Panchgani, April 21, 2011.

Modern Astronomical Telescopes, Astronomy Olympiad Lecture, HBCSE, Mumbai, May 14, 2011.

New Realms in On-sky Efficiency, APRIM 2011, Chiang Mai, Thailand, July 28, 2011.

Astrotechnology! Why Not?, IRDE, Dehradun, October 9, 2011.

Motivation for AO in Astronomy, Robo-AO Science Meeting, IUCAA, August 22, 2011.

Robo-AO plans in India, Robo-AO Science Meeting, IUCAA, August 23, 2011.

IUCAA Facilities, IIST, Thiruvananthapuram, January 15, 2012.

Swara Ravindranath

Mapping the Ionized Gas in Star-forming Galaxies, Commemorating 25 years of Vainu Bappu Telescope, Indian Institute of Astrophysics, Bangalore, August 2011.

Star Formation in Circumnuclear Regions of Galaxies, Conference on Recent Advances in Star Formation: Observations and Theory, Indian Institute of Astrophysics, Bangalore, June 2011.

Clumps in Star-forming Galaxies at High Redshifts and Their Evolution, 219th AAS Meeting: Special Session on CANDELS, Austin, Texas, USA, January 2012.

Giant Clumps in Star-forming Galaxies at High Redshifts, University of California, Riverside, California, USA, January 2012.

Varun Sahni

Dark Matter, Dark Energy and the Cosmic Web, International Conference on Theoretical and Applied Physics, IIT Kharagpur, December 1-3, 2011.

Reconstructing Dark Energy, Brazilian Physics Meeting, Foz de Iguazu, Brazil, June 5-10, 2011.

The Cosmic Web, Dark Energy and the Legacy of Ya.B. Zeldovich, Observatorio Nacional, Rio de Janeiro, Brazil, June 2011.

Dark Energy, International Conference on Gravitation and Cosmology, Goa, December 14-19, 2011.

Tarun Souradeep

Statistical Isotropy of the CMB as Test of the Cosmological Principle, International Cosmology Meeting, COSGRAV 2012, ISI, Kolkata, February 10, 2012.

IndIGO Status, (Introducing LIGO-India Possibility to International GW Community), Amaldi Meeting on GW, Cardiff.

LIGO-India, Planning Commission, RRI, Bangalore, May 28, 2011.

LIGO-India, BARC Group, HBCSE, Mumbai, August 19, 2011.

LIGO-India, Mega-Science Committee of Planning Commission, Delhi, November 21, 2011.

Status of LIGO-India, Special Mini-Session, ICGC, Goa, December 14-19, 2011.

LIGO-India Site Search, Government of Karnataka, Bangalore, January 27, 2012.

Cosmo-Genesis Scripted in Pristine Cosmic Glows, IISER, Kolkata, November 11, 2011.

LIGO-India: An Indian Adventure in Gravitational Wave Astronomy, IISER, Bhopal, 2011.

IndIGO: An update, ICCGF, IISER, Mohali, November 6, 2011.

LIGO-India: An Indian Adventure in Gravitational Wave Astronomy, Astro-Club, IISER, Mohali, November 6, 2011.

Modeling Our Cosmos, Centre for Modeling and Simulation, University of Pune, September 13, 2011.

Measuring Cosmo-Dynamics, DST SERC School on Nonlinear Dynamics, IISER, Pune, December 24, 2011.

R. Srianand

A Quest for Cold Gas at High-z, Astron, Netherlands, September 2011.

Cosmology and Fundamental Physics using QSO Absorption Lines, APRIM 2011, Thailand, July 2011.

MeerKAT Absorption Line Survey, an invited talk given in LADUMA Meeting, Capetown (via Skype), January 2012.

Dust and Molecules at High-z, International Conference on Interstellar Dust, Molecules and Chemistry, IUCAA, November 2011.

Probing the Fundamental Physics Using IGM, UKZN, April 2011.

Kandaswamy Subramanian

Primordial Magnetic Fields: Origins and Constraints, Particle Physics and Cosmology 2011, CERN, Geneva, June 2011.

Primordial Magnetic Fields: Origins and Constraints, Indo-UK Meeting, IUCAA, August 2011.

Magnetizing the Universe, IIT, Kanpur, August 2011.

Cosmological and Other Constraints on Neutrino Masses, Indian Conference on Cosmolgy and Galaxy Formation, IISER, Mohali, November 2011.

Turbulent Dynamos in Astrophysics: Problems and Prospects, 6th Korean Astrophysics Workshop on Astrophysical Turbulence, South Korea, November 2011.

Durgesh Tripathi

Introduction to the Sun (2 lectures), Vacation Students' Programme and Refresher Course on Astronomy and Astrophysics (for College / University teachers), May-June 2011.

Large Amplitude Oscillation in Prominences, BUKS 2011, Mallorca, June 27-29, 2011.

Differential Emission Measure in Moss and Inter-moss Regions and Heating of Active Region Cores, Fifth Coronal Loops Workshop, Mallorca, June 29-July 2, 2011.

Heating of Solar Active Regions, Indian Institute of Astrophysics, Bangalore, July 21, 2011.

Heating of Active Region Cores, Workshop on Physics of the Solar Transition Region and Corona, IUCAA, September 5-7, 2011.

Plasma Diagnostics of Solar Active Regions, Max-Planck-Institute for Solar System Research, Katlenburg-Lindau, Germany, October 2011.

CME Studies with Aditya, Meeting on Science with Planned and Upcoming Solar Facilities in the Country, IIA, Bangalore, November 2-3, 2011.

EUV Spectroscopy of Solar Transition Region and Corona, Solar Radio Workshop, NCRA-TIFR, Pune, November 23-25, 2011.

The Sun: Space Observations (2 lectures) (Special Lecture Series in Physics), Gulbarga University, March 28, 2012.

(B) LECTURE COURSES

Dipankar Bhattacharya

Fluids in Astrophysics (4 lectures), Vacation Students' Programme, IUCAA, May 13-19, 2011.

Compact Objects (4 lectures), Winter School on High Energy Astrophysics: Accretion onto Compact Objects, HRI, Allahabad, February 13-15, 2012.

X-ray Binaries (4 lectures), Winter School on High Energy Astrophysics: Accretion onto Compact Objects, HRI, Allahabad, February 16-18, 2012.

Gulab Dewangan

X-ray Astronomy and Active Galactic Nuclei (4 lectures), VSP/Refresher Course, IUCAA, May-June 2011.

Sanjeev Dhurandhar

Blackholes and Gravitational Waves (3 lectures), Refresher Course and VSP, IUCAA May-June 2011.

General Relativity, Black Holes and Gravitational Waves (4 lectures) (to the postgraduate and Ph. D. students), Kashmir University, Srinagar, May 1-7, 2011.

Ranjan Gupta

Stellar Spectra (2 lectures) and *Interstellar Dust* (3 lectures), Refresher Course in Astronomy and Astrophysics for College/University Teachers and Vacation Student's Programme, IUCAA, May 31 and June 1-2, 2011.

Importance of Small Telescopes in Indian Context - An Overview of Such Telescopes in Use in the Past Two Decades Since Inception of IUCAA; Optical Telescopes and Detectors; Astronomical Photometry and New Telescopes of this Century (4 lectures), Workshop on Teaching and Research Using Small Telescopes, JES College, Jalna, October 17-19, 2011.

Stellar Spectroscopy; Circumstellar Dust and New Telescopes (3 talks), Workshop on Stellar Astrophysics, University of Kashmir, Srinagar, October 24-26, 2011.

Advance Meteorology, Observational Astronomy (5 lectures), Central Training Institute, IMD, Pune, January 2-6, 2012.

Telescopes and Their Mounts; Star Magnitude and its Motion and Atmospheric Effect (3 lectures), Astronomy Refresher Course for Positional Astronomical Centre, Kolkata, February 9-10, 2012.

Ajit Kembhavi

Radiative Processes (5 lectures), Refresher Course in Astronomy and Astrophysics for College/University Teachers and Vacation Students' Programme, IUCAA, May 09-12 and June 8, 2011.

Ranjeev Misra

Accretion Processes in Astrophysics (4 lectures), VSP/Refresher Course, IUCAA, May 2011.

Radiative Processes in Astrophysics (3 lectures), Workshop on Stellar Astrophysics, Kashmir University, Srinagar, October 2011.

Radiative Processes in Astrophysics (3 lectures), Workshop on Galaxies and AGN, SRTM University, Nanded, November 2011.

Accretion Disks and Spectral Modeling (2 lectures), ASTROSAT Workshop, IIST, Thiruvananthapuram, January 2012.

Accretion Processes in Astrophysics (3 lectures), Workshop on Compact Objects, HRI, Allahabad, February 2012.

Sanjit Mitra

Overview and Detectors of Gravitational Waves (2 lectures), Gravitational Wave Data Analysis workshop, Tezpur University, January 23-27, 2012.

Jayant Narlikar

Cosmology (5 lectures), Centre for Excellence in Basic Sciences, Mumbai, April 4-9, 2011.

Introduction to Cosmology (4 lectures), Refresher Course in Astronomy and Astrophysics for College/University Teachers and Vacation Students' Programme, IUCAA, May 13-19, 2011.

Laws of Motion (3 lectures), Motivational Bridge Course, Deogiri College, Aurangabad, June 18 – 19, 2011.

T. Padmanabhan

Special and General Relativity (4 lectures), Refresher Course in Astronomy and Astrophysics for College/University teachers and Vacation Students' Programme, IUCAA, May 2011.

A.N. Ramaprakash

Telescopes and Instrumentation, VSP and Refresher Course, IUCAA, May 30-June 2, 2011.

Swara Ravindranath

Galaxies (4 lectures), Refresher Course in Astronomy and Astrophysics/Vacation Students' Programme, IUCAA, May 2011.

Star Formation and Stellar Evolution (3 lectures), Workshop on Stellar Physics, University of Kashmir, Srinagar, October 2011.

Tarun Souradeep

Cosmology with CMB and LSS (3 lectures), IUCAA School on Gravitation and Astrophysics, Jamia Milia Islamia, Delhi, May 15-17, 2011.

VSP and Refresher Course, IUCAA, May 2011.

R. Srianand

Introduction to Astronomy (5 lectures), VSP and Refresher Course, IUCAA, May-June 2011.

Introduction to Spectroscopy (3 lectures), Workshop on Galaxies and AGN, SRTM University, Nanded, November 2011.

Kandaswamy Subramanian

Magnetohydrodynamics (3 lectures), Refresher Course/VSP, IUCAA, May 2011.

Structure Formation in the Universe (2 lectures), Refresher Course/VSP, IUCAA, May 2011.

SCIENTIFIC MEETINGS AND OTHER EVENTS AT IUCAA

The Refresher Course in Astronomy and Astrophysics
for college and university teachers was held during May 9 – June 10, 2011.
The Refresher Course was coordinated by T. Padmanabhan and R. Srianand.

[For details see Khagol, Issue No 87, July 2011]

The Vacation Students' Programme (VSP)
was also simultaneously conducted during May 9 – June 24, 2011.
The VSP was coordinated by K. Subramanian.

[For details see Khagol , Issue No 87, July 2011]

INDO-UK SCIENTIFIC SEMINAR







Seminar titled
Confronting Particle-Cosmology with Planck and LHC
was conducted during August 10-12, 2011. The seminar was coordinated by Anupam Mazumdar, Tarun Souradeep and L. Sriramkumar.

[For details see Khagol , Issue No 88, October 2011]

A NATIONAL WORKSHOP ON PHYSICS OF THE SOLAR TRANSITION REGION AND CORONA

It was conducted jointly with IISER, Pune, during September 5-7, 2011. The workshop was coordinated by Durgesh Tripathi.

[For details see Khagol , Issue No 88, October 2011]

WORKSHOP ON ASTRONOMY WITH ADADPTIVE OPTICS ON MODERATE-SIZED TELESCOPES

This workshop was conducted during August 22-25, 2011. It was coordinated by A.N. Ramaprakash and C. Baranec.

[For details see Khagol , Issue No 88, October 2011]

SANJEEV FEST

to celebrate and felicitate Sanjeev Dhurandhar was conducted on December 20, 2011

ICTS WORKSHOP ON GRAVITATIONAL WAVE ASTRONOMY

DECEMBER 20-22, 2011

The fest was coordinated by Tarun Souradeep and the ICTS workshop was jointly coordinated by B.S. Sathyaprakash, Bala Iyer and Tarun Souradeep.

[For details see Khagol, Issue No. 89, January 2012]

THE 20TH INTERNATIONAL VIRTUAL OBSERVATORY ALLIANCE INTEROPERABILITY MEETING

It was conducted during October 17-21, 2011. The meeting was jointly hosted with Persistent Systems Ltd., Pune, who are the co-investigators in the Virtual Observatory India Project.

[For details see Khagol, Issue No. 89, January 2012]

EGO-IndIGO Meet on Gravitational Waves

This meeting was conducted during November 1-2, 2011. The scientific organization was coordinated by Federico Ferrini (EGO), and Bala Iyer and Tarun Souradeep (IndIGO). The local organization was coordinated by Tarun Souradeep (IUCAA), and Lidia Szpyrkowicz (Scientific Attache, Italian Embassy, New Delhi).

[For details see Khagol, Issue No. 89, January 2012]

INTERNATIONAL CONFERENCE ON INTERSTELLAR DUST, MOLECULES AND CHEMISTRY

It was conducted during November 22-25, 2011. The conference was coordinated by Shantanu Rastogi from D.D.U. Gorakhpur University and Ranjan Gupta.

[For details see Khagol, Issue No. 89, January 2012]

ICTS SCHOOL ON COSMOLOGY AND GRAVITATIONAL WAVES

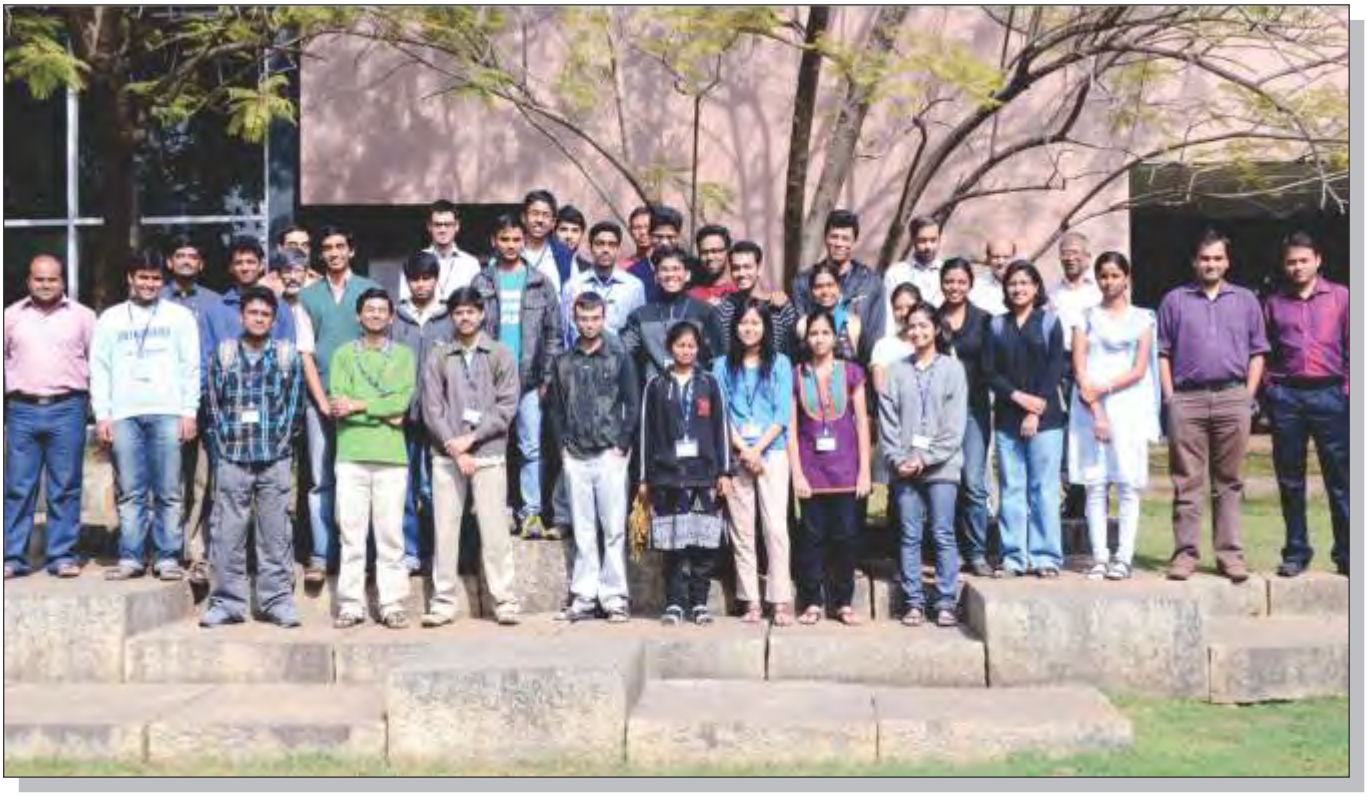




It was conducted during December 1-11, 2011. The coordinators of the meeting were Subhabrata Majumdar (TIFR), Sanjit Mitra and Tarun Souradeep from IUCAA.

[For details see Khagol, Issue No. 89, January 2012]

IUCAA-NCRA RADIO ASTRONOMY WINTER SCHOOL



It was conducted by the IUCAA-NCRA Radio Physics Laboratory during December 26, 2011 – January 2, 2012 at the IUCAA and NCRA/TIFR campuses.
The School was coordinated by Joydeep Bagchi (IUCAA) and Bhal Chandra Joshi (NCRA/TIFR)

[For details see Khagol, Issue No. 89, January 2012]

THE 23RD IUCAA FOUNDATION DAY

[December 29, 2011]

**The 23rd IUCAA Foundation Day lecture titled,
"Energy, Environment And Sustainable Development"
was delivered by Srikumar Banerjee, Chariman, Atomic Energy Commission,
and Secretary, Department of Atomic Energy, Government of India**

[For details please refer to Khagol, Issue No. 89, January 2012. Soft copy available at http://ojs.iucaa.ernet.in]

The 23rd IUCAA Foundation Day lecture, titled Energy, Environment, and Sustainable Development, was delivered by Srikumar Banerjee, Chairman, Atomic Energy Commission and Secretary, Department of Atomic Energy, Goverment of India. He pointed out that sustainable energy source is among the foremost challenges being faced by all developing countries. He highlighted the growth in Indian technology, and improvement in living standards, and emphasized on the energy generation rate that would be required to meet the aspirations of the Indian people in the future. The use of coal, natural gas, and other carbon-based energy sources, are believed to increase the fraction of greenhouse gases and enhance global warming and ozone depletion. Banerjee briefly described the non-carbon-based alternatives, such as solar, wind, and nuclear energy sources. Using various arguments, he proposed that nuclear energy generation is the possible sustainable solution to make up for the large deficit between the required power generation, and what could be achieved by continuing with the current energy generation methods. He explained about the Indian Nuclear Energy Programme, the technology of nuclear energy generation, nuclear fuel used, and the various nuclear reactors that are operational in the country. Also Banerjee discussed the cost effectiveness and viability of nuclear energy source, and touched upon the risks and precautions regarding the nuclear programme.

WORKSHOP ON PHOTOMETER FABRICATION

It was conducted at Muktangan Science Centre, IUCAA during January 9-13, 2012. Ranjan Gupta was the coordinator of the workshop.

[For details see Khagol, Issue No. 90, April 2012]

ADVANCED RESEARCH WORKSHOP ON X-RAY TIMING





It was conducted during January 23-28, 2012.
The workshop was coordinated by Dipankar Bhattacharya.

[For details see Khagol, Issue No. 90, April 2012]

THE IUCAA - NCRA GRADUATE SCHOOL

Ph.D. Programme

Three IUCAA Research Scholars, Tuhin Ghosh (Guide: Tarun Souradeep) Dawood Kothawala (Guide: T. Padmanabhan) and Mudit Kumar Srivastava (Guide: A.N. Ramaprakash), have defended their Ph.D. thesis submitted to the University of Pune during the year of this report.

(i) **Tuhin Ghosh**

Title of the thesis :

Galactic and Cosmological Signals in the Microwave Background Anisotropy and Polarization

Abstract :

The understanding of foreground emissions has emerged as an important topic of research in Cosmology with CMB anisotropy and polarization. Foregrounds here, refer to all astrophysical emission processes that contaminate the cosmic signal in the observational frequency bands of the primordial CMB signal. These include a diffuse component that arises in the galactic interstellar medium due to synchrotron, free-free, thermal dust, spinning dust emission and compact component such as extragalactic `point' sources as well as Sunyaev-Zel'dovich effect in clusters of galaxies. The level at which various foreground components contribute to CMB observations depends both on the observational frequency and the angular scale. The removal of foregrounds is critical for obtaining accurate CMB temperature anisotropy and polarization power spectra for cosmology. Furthermore, the study of individual foreground emission components would reveal interesting information about the structure, composition and astrophysical phenomenon in our galaxy.

In the thesis, the key attribute of foreground emission in microwave band -- spectral behaviour, morphology and statistical distribution has been studied. The spectral properties of different foreground emission processes is studied in detail using the WMAP seven year data. He had demonstrated the evidence of spinning dust emission arise from distinct environment in the interstellar medium from the WMAP data. The spectral shape of synchrotron emission encodes information about the cosmic ray electron energy distribution and the magnetic field distribution in the galaxy. The morphological distribution of total foreground emission maps is obtained at WMAP frequency resolution. These foreground maps are useful for the study of galactic science at large angular scales and also for identification of compact extragalactic sources. He has obtained the combined foreground power spectrum from WMAP data alone in a model independent manner that evades uncertainties in the astrophysics of foreground modeling. Foregrounds emissions are non-stationary signal like “natural” images and follow a non-Gaussian statistics in pixel (sky) space. The thesis has explored the statistical characterisation of foreground in needlet (spherical wavelet) basis, which has been increasingly used in processing natural images. In case of foregrounds, it is found that the conditional distribution of needlet coefficients at two needlet scales follows a highly non-Gaussian statistics with extended tails. The dependence of needlet coefficient between two scales is a key distinguishing feature of statistical properties of foregrounds from the Gaussian CMB signal that can be exploited in improved component separation methods.

The main goal of the thesis is an early exploration to understand various properties of foreground emissions given the high resolution and high sensitivity CMB observations. Such studies form the base from which it would be possible to extract exquisite information about the galaxy from upcoming data, e.g. the Planck Surveyor mission. The methods and results obtained in this thesis are expected to be important for the ongoing efforts to cleanly extract the cosmological CMB signal to higher accuracy from future data.

(ii) **Dawood Kothawala**

Title of the thesis :

Semiclassical Gravity and Thermodynamics of Horizons

Abstract :

One of the most remarkable results to have come out from semiclassical gravity is the intriguing fact that black holes radiate due to quantum effects, and have temperature and entropy. This perhaps provides the most important clue to understand better some key aspects of quantum gravity, and begs the question: How does gravity know about thermodynamics? The thesis addresses this question by showing that dynamical equations of gravity themselves possess a thermodynamic structure, and can be written in the form TdS - dE=PdV, the first law of thermodynamics, near a horizon. He has explored this relationship (first noted by Padmanabhan) further, generalize it to a considerable extent, and in the process uncover several intriguing mathematical features responsible for its origin. From a broader viewpoint, the results support the point of view that gravitational dynamics may be an emergent phenomenon.

Another clue from semiclassical gravity he has explored is the existence of a minimal spacetime length, and its implications. Various independent lines of thought have indicated that Planck length sets a lower bound on all spacetime intervals, and this can provide a potential cure for ultraviolet (UV) divergences of quantum field theory (QFT), while at the same time regulating the singularities in solutions of general relativity. In this thesis, he has used the so called principle of path-integral duality to study Planck scale effects on propagators in spacetimes of constant curvature. The thesis has also speculated on implications of minimal length for small scale structure of spacetime.

iii) **Mudit Kumar Srivastava**

Title of the thesis :

Design and Development of an Optical Fibre based Integral Field Unit (IFU) for Area Spectroscopy on IUCAA 2m Telescope

Abstract :

Area Spectroscopy or *Integral Field Spectroscopy (IFS)* has a relatively short history in the context of astronomical research. IFS is a powerful tool for astronomical spectroscopic observations that provides spectra of individual spatial elements over a 2-dimensional (2-D) area of the sky. The application of IFS to astrophysical studies can overcome many of the limitations posed by the classical long slit or multi slit spectroscopy. The IFS technique is also a very powerful tool in the study of the formation and evolution of galaxies, their intrinsic shape, orbital structure, internal dynamics, the dynamical importance of the central black hole, etc.

The demand to obtain simultaneous spectra over a 2-D field of view in a single observing run led towards the development of *Integral Field Units (IFUs),* which are to be used in association with a spectrograph to yield simultaneous spectral measurement of a sky area. However, an approach based on using optical fibres and lenslet together offers certain advantages over the others given the flexibility of optical fibres and a uniform fill factor of the lenslet array.

A lenslet-fibre based IFU has been developed for IUCAA Faint Object Spectrometer and Camera (IFOSC), the main back-end instrument on IUCAA 2m f/10 telescope at Girawali (near Pune). IFOSC has working wavelength range from 3500 – 8500Å and the field of view is 11.5 arc-minutes x 11.5 arc-minutes. It has an input plate scale of 10.*3arc – second/mm* and employ a 2K x 2K thinned E2V CCD with 13.5m a side pixels. This Fibre based IFU for IFOSC : FIFUI has been designed with these input

parameters. FIFUI is developed to provide a 2-D interface to IFOSC. Due to existing setup at the IUCAA telescope, the opto-mechanical design of FIFUI is highly coupled to the mechanical setup, including IFOSC and a calibration unit.

FIFUI optics is preliminary designed in three parts: (1) Fore-Optics (2) Lenslet-Fiber Unit, and (3) the Output Optics. The primary job of the fore-optics is to provide the necessary magnification in a '*telecentric way*' so that maximum light coupling would be achieved between the lenslets and the fibres. The *lenslet-fibre unit* is used to sample the magnified image and to transport the light from the magnified image plane to the spectrograph. The output optics is used to couple this fibre slit to IFOSC through the existing calibration unit. And is designed to provide a magnification of 2.5 in a *telecentric way* so as to match the input f/number of the spectrograph.

The mechanical parts of FIFUI have been designed in the IUCAA laboratory and manufactured by local manufacturers. The fibre bundle, to reformat 2-D field of view in to 1-D slit, has been fabricated in the laboratory. The lenslet array has also been fabricated in the laboratory using individual lenslets on the input end of the fibre bundle. After a series of laboratory tests FIFUI was finally assembled and commissioned on the IUCAA telescope.

Ultra Luminous Infrared Galaxies (ULIRGs) are found to be suitable candidates for science verification programme of FIFUI. Most of these objects are merging systems having double nuclei and complex kinematics in the central regions. FIFUI observations of a ULIRGs (Mrk231) is presented in the thesis. IFS data reduction is a complex process and includes (a) identification of the positions of the spectra on the detector, (b) determination and subtraction of scattered light, (c) extraction of each individual spectrum, (d) dispersion correction, (e) fibre to fibre response correction, (f) flux calibration, and (g) subtraction of sky emission.

IFS has revolutionized the modern astronomical research with all major observatories now either having or constructing these instruments. Various techniques required for the realization of fibre based IFUs have been developed. These techniques would have wide applications in the future IFS instrumentation for several upcoming astronomical facilities not only in India but also around the world.

This thesis describes the research work carried out to develop an *Fibre based Integral Field Unit (IFU) for IFOSC : FIFUI* on IUCAA 2m telescope. This includes different aspects of IFU development like optical and opto-mechanical design, fabrication, assembly and testing in the laboratory, its electro-mechanical controls, commissioning on the telescope and data reduction and analysis.

FACILITIES AT IUCAA

(i) Computing Facility

The IUCAA computer centre has always been known for its world class computing facility and its use of latest computer technology and applications.

In April 2011, in order to pave way for the ongoing construction work adjacent to ERNET NOC, it had to be shifted to cabin 1 of computing facility. This was a major work undertaken by the computing facility since the ISPS (Internet Service Providers) namely BSNL, Tata Communication, and Reliance Communication had to relocate their respective MUX to reroute their fibre cables. Apart from that, various allied network equipment such as high end CISCO routers and switches and ERNET servers, etc. were moved to the new location.

In late September 2011, ISS 3500 storage from SGI having 64 Terabytes raw disk capacity, was procured for backup purposes. In November 2011, FAS 2020 storage from Netapp was upgraded to include an additional enclosure. This has not only boosted the performance of the storage as the number of disks available became more but made both the controllers accessible to offer high availability.

The Ruckus WiFi topology at the residential campus, was redesigned to offer multiple VLANs based on the logical user groups and to improve overall performance. In August 2011, this was extended to office premises, so that mobility could be achieved everywhere in the campus. In February 2012, the length of poles were increased in places where the signal strength was found to be low and a few more access points were also added to boost the overall signal strength.

In December 2011, ERNET (Educational Research NETwork) intranet links connecting Bangalore and Mumbai, were migrated to NKN (National Knowledge Network) backbone successfully with the introduction of a router from NKN.

In January 2012, a new router from NKN was incorporated in IUCAA's network to announce its newly registered domain "iucaa.in" to the world.

The major part of last year was spent in identifying the required 30 TF HPC (High Performance Computing) hardware and the corresponding Data Centre to house it. The new HPC facility is expected to be commissioned shortly.

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

(ii) Library and Publications

During this year, the library has added 195 books and 400 bound volumes of journals taking the total collection to 24,247. One hundred forty three books were added to the collection of the Muktangan Vidnyan Shodhika (MVS) library. The details of various activities undertaken by the library during this period are described below :

E-Books: The IUCAA library has acquired e-books in physics and astronomy accessible on (http://www.iucaa.ernet.in/~library/eBooks.html), as **Cambridge University Press : 183 e-books, and Oxford Scholarship Online books (78 titles) under three sub-groups :**

(a) History of Physics, Particle Physics
(b) Astrophysics/Cosmology and Theoretical
(c) Computational and Statistical Physics.

At present, access to the above-mentioned e-books has been extended to the IUCAA Resource Centres at Kochi, Delhi, Kolkata.

Open Journal System: The library has undertaken the digitization of Khagol (IUCAA quarterly bulletin) and the IUCAA Annual Report, as follows:

Khagol: Issue Nos. 1 (January 1990) to 86 (April 2011) and IUCAA Annual Report: 1988-89 to 2010-11.

The contents are accessible at URL http://ojs.iucaa.ernet.in/index.php/khagol/issue/archive

Institutional Archive using DSpace (http://202.141.155.12:8080/jspui/) : The IUCAA library has set up its institutional repository using DSpace, which is an open source repository software package for creating repositories on delivering digital content to end users, and providing a full set of tools for managing and preserving the content within the application. The IUCAA institutional archive consists of the following documents:

- Conference/ Workshop – Oral Presentations
- IUCAA Academic Calendar
- IUCAA Preprints
- National Science Day Posters
- Newspaper Clippings
- Research Publications

Tulsient Network Assisted Storage (NAS) Server : The library has mirrored the following content, which can be accessed through the NAS Server:

- Book CDROMs
- Science Popularization Videos
- NASA Videos
- World Telescopes_80

Recorded lectures delivered by T. Padmanabhan are available at http://www.iucaa.ernet.in/~archives/TP/index.html , which are accessible on a userid and password basis.

Library Trainee Programme : Four library trainees were selected from fresh library science graduates for a period of one year (April 2011- March 2012). The trainee programme aims to impart in-depth and practical knowledge of traditional and electronic resources along with exposure to a range of library activities, from processing library materials, addressing circulation desk queries, shelving, and journal to providing reference service to users. The trainees were involved in the tasks related to the Institutional Archives using DSpace as well as the procedure for digitisation of issues of Khagol and the IUCAA Annual Report.

Under the UGC-INFONET programme, the IUCAA library receives access to the following e-resources: (a) American Institute of Physics (18 titles), (b) American Physical Society (10 titles), (c) Emerald Database (29 titles), (d) IndianJournals.com, (e) Institute of Physics, (f) ISID, (g) JCCC Database (Journal Custom Content for Consortia, an e-journal gateway for universities and colleges), (h) Science Direct (1036 titles), (i) Springer Link (1389 titles), (j) Taylor and Francis (1173 titles), and (k) Web of Science (1 citation database).

(iii) Instrumentation Laboratory

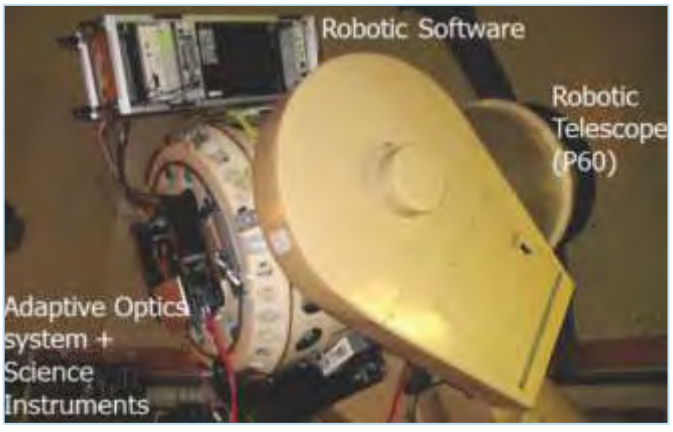
Robo-AO (a low cost, robotic, queue-scheduled adaptive optics (AO) system for telescopes with 1-3m diameter apertures) have been commissioned on the Palomar 60 inch telecope (see figure). An overwhelming list of proposals was received for the science demonstration run scheduled to be carried out in the second half of 2012. As an extension of this collaborative project, IUCAA is now building a HAWAII detector (procured by Caltech), based near-IR arm for Robo-AO. Also, optical and mechanical design work has started for a second version of the instrument, which will be used on the IUCAA 2 m telescope.

An upgraded version of IUCAA SIDECAR Drive Electronics Card (ISDEC) has been developed in the laboratory. This system is designed to better withstand the harsh environments of an observatory, and has the ability to work at temperatures as low as -40^{0}C. The new ISDEC version has been delivered to University of Wisconsin, Madison to be integrated into the Robert Stobie Spectrograph (RSS-NIR), which is being built there for the 11 m Southern African Large Telescope (SALT). Another ISDEC system has been delivered to the University of Florida for being integrated into the Canarias InfraRed Camera Experiment (CIRCE) instrument being built there for the 10.4 m Gran Telescopio Canarias (GTC) on La Palma.

The IUCAA SIDECAR Drive Electronics Card V2, which are designed toindustrial standards and can operate at temperatures as low as -40^{0}C.

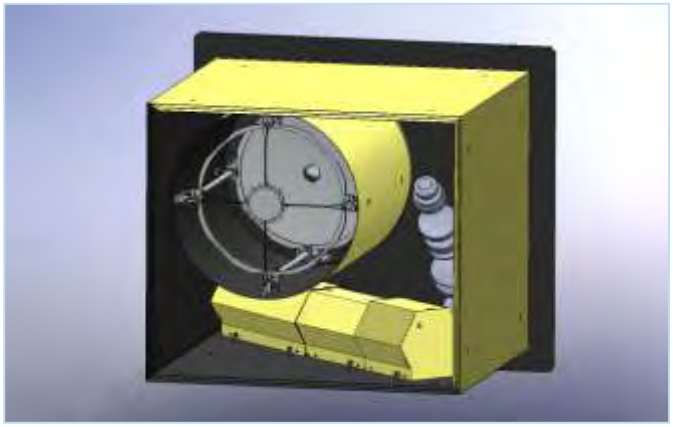
A version of the ISDEC system will be used for implementing special readout modes with HAWAII detectors that are to be used for the On-Instrument Wavefront Sensors (OIWFS) of the upcoming Thirty Metre Telescope (TMT).

As part of a collaboration with the Tata Institute of Fundamental Research (TIFR), Mumbai, the optical design for the laboratory model of the InfraRed Spectroscopic Imaging Survey (IRSIS) satellite has been completed. The mechanical components are currently being designed. Special near-IR optical fibres have been procured by TIFR to be used in the integral field unit of the spectrograph. These fibres are being tested to understand their properties like focal ratio degradation.

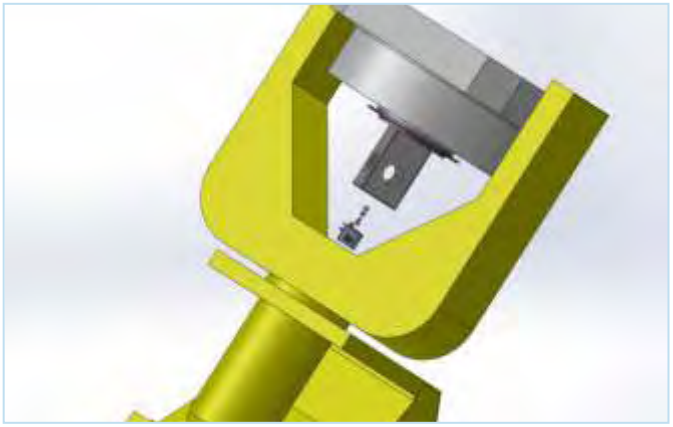


Robo-AO system mounted on the Palomar 60 inch telescope.

A new collaboration has been set up with California Institute of Technology, Max Planck Institute for Radio Astronomy, University of Crete and the Nicolaus Copernicus University, to carry out a three year comprehensive survey of a carefully selected sample of blazars. This survey, to be conducted from the Skinakas Observatory 1.3 m telescope, will monitor the blazars for optical linear polarization variability. This data will be supplemented by observations ranging from x-rays to radio that will be obtained from other observatories. IUCAA's role in the collaboration is to design, build, deliver and commission the polarimeter that will carry out the survey.



An initial SolidWorks model of the InfraRed Imaging Spectroscopic Satellite (IRSIS) satellite.



An initial opto-mechanical design of the RoboPOI instrument as mounted on the Skinakas Observatory 1.3 m telescope.

(iv) IUCAA Girawali Observatory (IGO)

During this year, the telescope operations were smooth and productive. The primary mirror of the telescope was aluminised in December 2011 after a gap of about 2 years. Observations could be made on 160 nights. IGO Time Allocation Committee had allotted time to 39 proposals, out of which 17 proposals were from universities. During 2011-12, 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 the Osmania University, Hyderabad.

(v) Virtual Observatory India – Phase II

The second year of VOI-Phase II has been dedicated to revamp VOIndia's flagship products, namely VOPlot and VOStat. The aim of doing this was to keep up with new IVOA standards, take advantage of advances in hardware technologies, augment capabilities and improve user experience. Several brainstorming sessions were held with participation from developers, users and domain experts to come up with ideas for these upgrades and as a result of the discussions, a work plan was evolved to complete these within a year.

VOPlot, a data visualization tool, has been redesigned with new functionality and user interface. Data manipulation and data visualization functionalities have been decoupled, with a single "launcher" panel for loading files and viewing metadata, and plots appearing in independent panels, making it easier to compare multiple plots side by side and take maximum advantage of new generation displays with high resolutions. Visualization of large datasets, which earlier required the data to be preprocessed (VOMegaplot) in order to make the loading times practical, is now possible in VOPlot without any preprocessing. The loading mechanisms were revised to make them efficient and faster. This has also been made possible due to recent advances in machine configurations, with PCs having higher amounts of memory and multiple processors inbuilt. Users also have better control over the cosmetic properties of the plot, allowing them to do customization to their liking for publishing their results.

VOStat, a statistical analysis tool, has a new interface that has been designed with the aim of reducing the number of steps the user has to perform to get results. Examples and help links regarding the statistical tests are embedded in locations where they have maximum relevance.

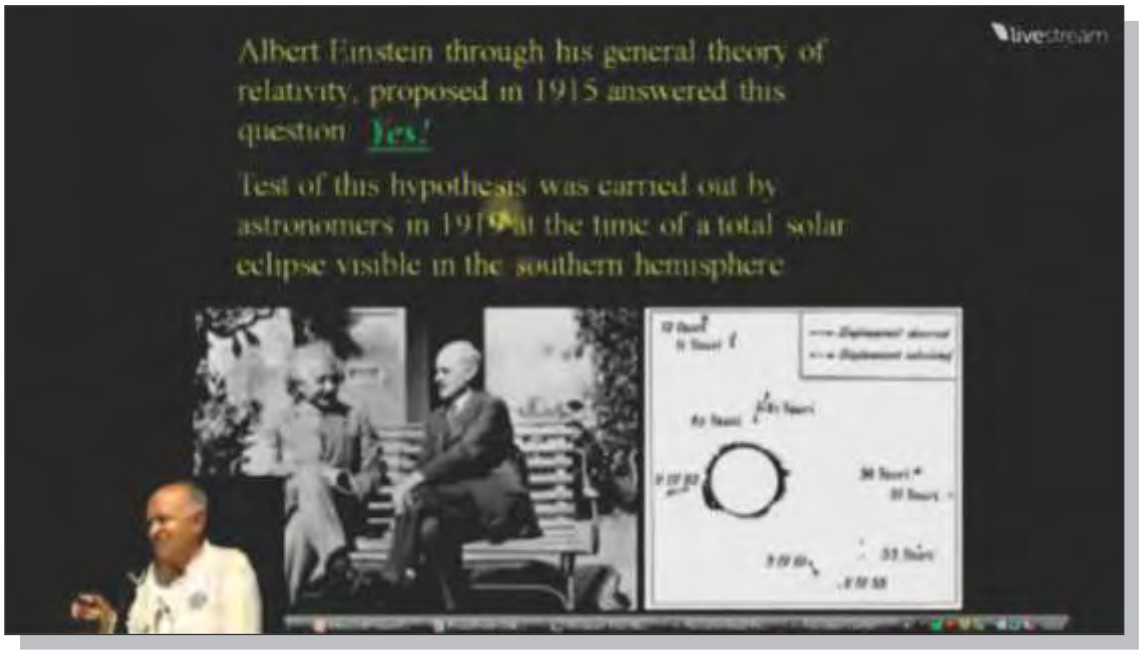
Researchers and students from the statistics domain have been involved in the development process, and they have contributed by introducing a list of new tests and their associated documentation. The output has been refined and adequately labeled and formatted to make it easy to grasp and be used further.

In addition to improvements to existing tools, several new projects have also been taken up for development. VOIMachine, a machine learning tool is well underway and close to release. This tool will allow users to upload datasets to a server that hosts the machine learning tools and use it to train them and use them for analysis of fresh data. As an example, VOIMachine contains a Baysian classifier that can be trained to classify celestial bodies into different subtypes based on their properties. A feasibility study was done to determine if we could create a framework for making spectral libraries VO compatible. As a result of this study, it was possible to develop a database and query interface with value adding VO functionality for the Near Infra-Red Library (NIRLIB) hosted on the VO-India site. This framework can be applied to any spectral library and it is planned to offer it to other similar libraries hosted around the world.

The 20th International Virtual Observatory Alliance Interoperability meeting was held from October 17 to 21 at IUCAA. The IVOA holds two Interoperability Workshops each year in different IVOA member countries, typically in May and October. These meetings are opportunities for the IVOA Groups and Committees to have face-to-face discussions. New technical developments and their scientific applications was the agenda of the InterOp meeting. There were two plenary sessions; one each at the beginning and end of the workshop; with all participants attending. Most of the sessions were held in parallel by various Working Groups (WG) and Interest Groups (IG) such as Applications, VOTable, VOEvent, Data Model, Query Language, Registry, to name a few. About 80 participants from 12 countries attended the meeting.

Other Public Outreach Activities included a Microsoft World Wide Telescope (WWT) presentation and workshop during the tech fest "Quark 2012" at the Birla Institute of Technology and Science (BITS), Goa. Students from all across the country were in attendance for this workshop, where hands-on sessions for them to experience the features of WWT were conducted. The VO presentations at the Annual Science Day celebration and the VSP/SSP programmes were very well received by participants.

PUBLIC OUTREACH ACTIVITIES



IUCAA Public Outreach Programme Lectures – Live webcasts
Jayant Narlikar delivered the first lecture on July 9, 2011
(the background is the slide that was projected, and the speaker in the inset).

[For details see Khagol, Issue No 88, October 2011]

A special session for hearing impaired students from the C.R. Ranganathan Residential School was conducted at IUCAA by Samir Dhurde and Milind Sathe, Hon. Gen. Secretary, Maharashtra Sports Council of the Deaf.

[For details see Khagol, Issue No 88, October 2011]


K.S.V.S. Narasimhan (3rd from left), Visitor to IUCAA, visited schools in Ambegaon Taluka and made a generous donation to encourage the students. He also visited four schools at Awasari, Gavdewadi, Kalamb, and Chas and interacted with the students and teachers.

[For details see Khagol, Issue No 88, October 2011]

Tabasum Bhat, from Kashmir University visited Pandharinath Secondary and Higher Secondary School, Pokhri, and gave a brief introduction about how she became an astronomer and talked about her work.

[For details see Khagol, Issue No 88, October 2011]



The annual **School Students' Summer Programme** was conducted at IUCAA during April 11 – May 20, 2011.

[For details see Khagol , Issue No 87, July 2011]

IUCAA organized a public outreach programme for 120 students from the National Service Scheme (NSS) on December 26, 2011.

[For details see Khagol, Issue No 89, January 2012]

National Children Science Congress, 2011 :
Durgesh Tripathi and Samir Dhurde from IUCAA participated in a Video Conferencing Activity for the National Children Science Congress, 2011 held in Jaipur.
[For details see Khagol, Issue No 89, January 2012]

The National Science Day was celebrated on February 25 and February 28, 2012 at IUCAA.

[For details see Khagol, Issue No 90, April 2012]

HIGHLIGHTS

Gulab Dewangan and Samir Dhurde attended the first stakeholders workshop of the IAU Office of Astronomy for Development (OAD) held during 12 - 14 December 2012 at the SAAO in Cape Town.
Joe Jacob from Cochin IRC was also present.
They represented IUCAA amongst the participants from 28 different countries.
The outreach work of IUCAA was presented and India-centric astronomy-for-development activities were suggested.
Inputs were given towards planning the activities of the OAD and their implementation strategy.
Future collaborations between IUCAA and OAD for large scale outreach were also discussed.

POPULAR TALKS

Dipankar Bhattacharya

The Lure of Astronomy, Astronomy Workshop, National Council of Science Museums, September 20, 2011.

Naresh Dadhich

Science and Society, Deccan Education Society's Sangli Regional Office, Sangli, August 9, 2011.

Einstein for Everyone, Samarkand State University, Uzbekistan, September 10, 2011.

Einstein for Everyone, Institute of Nuclear Physics, Uzbekistan, September 13, 2011.

Einstein for Everyone, Stellenbosch Institute for Advanced Study, Stellenbosch, South Africa, November 13, 2011.

Gulab Dewangan

Exploring the Universe at X-rays (in English and Hindi), Second Saturday Lecture at IUCAA, August 13, 2011.

IUCAA Public Outreach Programme, OAD Workshop, Cape Town, South Africa, December 13, 2011.

Sanjeev Dhurandhar

The Story of Gravity, Srinagar, Kashmir, May 6, 2011.

Ajit Kembhavi

Giant Telescopes for the New Generation, Sikkim Science Centre, Gangtok, April 27, 2011.

From Stars to White Dwarfs and Beyond with Chandrasekhar (as part of the Professor Subramanyan Chandrasekhar Lecture Series), Nehru Planetarium, Mumbai, August 27, 2011.

Worlds Beyond the Solar System, University of Kashmir, Srinagar, October 24, 2011.

From Kepler to Kepler – A Journey Over Four Centuries (in Marathi), K. A. Thakar Memorial Lecture, Vivekanand College, Samarth Nagar, Aurangabad, November 15, 2011.

The Mega Projects for Indian Astronomers: The Thirty Metre Telescope and the LIGO Gravitational Wave Detector, Public Astronomical Observatory, Panjim, Goa, February 2, 2012.

Ranjeev Misra

Black Holes in the Universe, St. Xavier's College, Kathmandu, Nepal, March 2012.

Black Holes in the Universe, SHIATS University, Allahabad, February 2012.

Black Holes in the Universe, Alphonsa College, Pala, January 2012.

Black Holes in the Universe, Workshop on Optical Astronomy, Newman College, Thodupuzha, January 2012.

Sanjit Mitra

Observational Astronomy and Gravitational Waves, INSPIRE lecture for school students, IIIT, Pune, February 13, 2012.

Jayant Narlikar

Cambridge University: My Alma Mater, Indian Council of Social Science Research – Western Regional Centre, Mumbai, April 8, 2011.

The Message of Science Fiction, Seminar on Science Fiction and Its Prospect, Department of English, Deogiri College, Aurangabad, April 12, 2011.

The Excitement of Study in Science, Pt. Ravishankar Shukla University, Raipur, April 15, 2011.

The Search for Micro-Life in the Earth's Atmosphere, Pt. Ravishankar Shukla University, Raipur, April 16, 2011.

Why Study Astronomy?, Aditya Birla Public School, Rawan, Raipur, April 18, 2011.

Why Study Astronomy?, Civic Centre, Bhilai, April 19, 2011.

Prithivibaher Sukshamajeevancha Shodh (The Search for Micro-life in the Earth's Atmosphere) (in Marathi), Bharatiya Vidya Bhavan, Pune, April 28, 2011.

Illusion in Space, DST sponsored INSPIRE Camp, Shri Mata Vaishno Devi University, Katra, Jammu, May 28, 2011.

Prithvi ke Vayumandal Mein Sukshmajeevonki Kohj (The Search for Micro-life in the Earth's atmosphere) (in Hindi), C-DOT, New Delhi, June 3, 2011.

Antaralatil Drushtibrahm (Cosmic Illusion) (in Marathi and Englilsh), 2nd Saturday Lecture Programme, IUCAA, July 9, 2011.

Searches for Micro-organisms in Space (in Hindi), Mahakoshal Vigyan Parishad, Jabalpur, September 17, 2011.

Unusual Aspects of Our Solar System (in Hindi), Mahakoshal Vigyan Parishad, Jabalpur, September 17, 2011.

Building Scientific Institutions, National Institute of Advanced Studies, Bangalore, August 12, 2011.

The Importance of Innovations, Tata Motors, Pune, August 19, 2011.

Vishwat Jeevshristicha Shodh (Searches for Extraterrestrial Life) (in Marathi), organized by Senior Air-Indian's Forum, Swamikrupa Hall, Pune, September 25, 2011.

Marathi Vidyankatha Sahitya (Marathi Science Fiction Literature) (in Marathi), Smt. Kasturbai Walchand College, Sangli, September 26, 2011.

The Role of Science Fiction in Science Popularisation, organized by Vigyan Prasar, New Delhi, Regional Workshop on Science Broadcasting, Film and Television Institute of India, Pune, November 16, 2011.

Cosmic Illusions, Poorna Pragna High School, Mumbai, December 22, 2011.

Taryanchi Jeevangatha (The Biography of Stars) (in Marathi), Nagar Vachanalaya, Kankavli, January 21, 2012.

Vishwat Jeevshristicha Shodh (Searches for Extraterrestrial Life) (in Marathi), Nagar Vachanalaya, Kankavli, January 22, 2012.

Vidnyan ani Adhyatma (Science and Spirituality) (in Marathi), North Maharashtra University, Jalgaon, January 27, 2012.

Vidnyan ani Adhyatma (Science and Spirituality) (in Marathi), Jaihind College, Dhule, January 27, 2012.

From Black Clouds to Black Holes, Naval College of Engineering, INS Shivaji, Lonavala, February 17, 2012.

Khagolshastratil Suras ani Chamatkarik Goshti (Amusing and Strange Tales from Astronomy) (in Marathi), organized by Modern High School, Warje, Pune, Yashwantrao Chavan Auditorium, Pune, March 17, 2012.

Antaralatil Drushtibrahm (Cosmic Illusion) (in Marathi), Lokmanya Mahavidyalaya, Warora, March 30, 2012.

Antaralatil Drushtibrahm (Cosmic Illusion) (in Marathi), Raman Science Centre and Planetarium, Nagpur, March 31, 2012.

T. Padmanabhan

Aspects of Gravity, DST-INSPIRE Programme, University of Kerala, Thiruvananthapuram, May 2, 2011.

Many Faces of Gravity, 4th Science Conclave: A Congregation of Nobel Laureates, Indian Institute of Information Technology, Allahabad, November 29-30, 2011.

Surajit Paul

Evolution of Large Scale Structures, Radio Astronomy Winter School, IUCAA/NCRA, Pune, December 28, 2011.

Kandaswamy Subramanian

Magnetizing the Universe, IISER, Mohali, November 2011.

Kaustubh Vaghmare

A Career in Astronomy and Astrophysics, Dnyan Prabodhini Institute of Psychometry, Hatke Career Series, November 2011.

RADIO / TV PROGRAMMES

Kaustubh Vaghmare : Guest appearance on Arvind Paranjpye's programme of *Akaash Darshan* on AIR, April 2011.

RESEARCH BY VISITING ASSOCIATES OF IUCAA

S.Saiyad Ali

Observational cosmology

Saiyad Ali, in collaboration with Somnath Bharadwaj, Abhik Ghosh and Jayaram N. Chengalur, has developed and improved the foreground removal in GMRT 610 MHz observations towards detecting redshifted 21-cm tomography from z = 1 32. Foreground removal is a challenge for 21-cm tomography of the high redshift universe. The statistics used is the two visibility correlation function or equivalently the multi-frequency angular power spectrum $C_l(?í)$ The earlier measurement of $C_l(?í)$ has revealed the presence of oscillatory patterns along, which turned out to be a severe impediment for foreground removal. Using the same data, it is possible to considerably reduce these oscillations by suppressing the sidelobe response of the primary antenna elements. For the first three angular multipoles l = 1405, 1602 and 1876, this sidelobe suppression along with a low order polynomial fitting completely results in residuals of ($\leq$ 0 02 mK²), consistent with the noise at the 3ó level. Since the polynomial fitting is done after estimation of the power spectrum, it can be ensured that the estimation of the HI signal is not biased. The chances of removing a part of HI signal along with the foregrounds are also minimal. They have considered $\overline{x}_{HI}b$ as a free parameter, and performed a likelihood analysis using their observational data to place an upper limit on it. The corresponding 99% upper limit on the HI signal is $\overline{x}_{HI}b \leq 2.9$, where $\overline{x}_{HI}$ is the mean neutral fraction and b is the bias.

They have done another work, with Jayanti Prasad, where they have characterized diffuse galactic synchrotron emission for redshifted 21-cm radiation at 150 MHz. The observational data was taken from GMRT. The diffuse galactic emission is revealed after the point sources are subtracted out from the uv plane at 20 mJy level. They have found that $C_l \alpha\, l^{-2.34}$ for $253 \leq l \leq 800$, which is characteristic of the galactic synchrotron radiation measured at higher frequencies and larger angular scales. The estimated fluctuations in the galactic synchrotron emission is $\sqrt{l(l+1)\,Cl/2\pi} \simeq 10$ K at l = 800 (è > 10'). The measured $C_l \simeq 103mk^2$ is dominated by the residual point sources and artifacts at smaller angular scales where $l > 800$.

Tanwi Bandyopadhyay and Ujjal Debnath

A study of generalized second law of thermodynamics in magnetic universe in the light of non-linear electrodynamics

The Einstein field equations for non-flat FRW model have been considered when the universe is filled with the matter and magnetic field only. They have discussed the validity of the generalized second law of thermodynamics of the magnetic universe bounded by Hubble, apparent particle and event horizons using Gibbs' law and the first law of thermodynamics for interacting and non-interacting scenarios. It has been shown that the GSL is always satisfied for Hubble, apparent and particle horizons but for event horizon, the GSL is violated initially and satisfied at late stage of the universe.

Shuvendu Chakraborty

Brans-Dicke theory in an anisotropic model with a viscous fluid

Shuvendu Chakraborty has considerd anisotropic models of the universe in the presence of a Brans–Dicke (BD) scalar field ö, a causal viscous fluid and a barotropic fluid has been considered. It has been shown that, irrespective of the fluid, the causality theory provides a late-time acceleration of the universe. If deceleration occurs in a radial direction and acceleration in the transverse direction, then the anisotropic universe will accelerate for a particular condition in a power-law representation of the scale factors.

Dilaton dark energy model in f(R), f(T) and Horava-Lifshitz gravities

He has considered the dilaton dark energy model in Weyl-scaled induced gravitational theory in presence of barotropic fluid. It is to be noted that the dilaton field behaves as a quintessence. Further, he has discussed the

role of dilaton dark energy in modified gravity theories, namely f (R), f (T) and Horava-Lifshitz gravities and analyzed the behaviour of the dilaton field and the corresponding potential in respect to these modified gravity theories instead of Einstein's gravity. In particular forms of f (R) and f (T) gravities, it is shown that the potentials always increase with the dilaton fields. But in Horava-Lifshitz gravity, it has been seen that the potential always decreases as dilation field increases.

Subenoy Chakraborty

Interacting three fluid systems and thermodynamics of the universe bounded by the event horizon

The thermodynamics of the universe bounded by the event horizon is considered with matter in the form of interacting three fluid systems, namely, dark energy, dark matter and radiation. The variation of entropy of the surface of the horizon is obtained from unified first law, while matter entropy variation is calculated from the Gibbs' law. Then validity of the generalized second law of thermodynamics is examined. Subenoy Chakraborty in collaboration with his graduate students (Nairwita Mazumder and Ritabrata Biswas) has considered the universe as inhomogeneous spherically symmetric Lemaitre-Tolman-Bondi model, and has analyzed the thermodynamics of this model of the universe. The trapping horizon is calculated and is found to coincide with the apparent horizon. The Einstein field equations are shown to be equivalent with the unified first law of thermodynamics. Finally, assuming the first law of thermodynamics, validity of the generalised second law of thermodynamics is examined at the apparent horizon for the perfect fluid and at the event horizon for holographic dark energy.

Ramesh Chandra

Observations of multiple surges associated with magnetic activities in AR10484 on 25 October 2003

A multiwavelength study of recurrent surges observed in H-alpha, UV (SOHO/EIT) and Radio (Learmonth, Australia) from the super-active region NOAA 10484 on 25 October 2003 has been done. Several bright structures visible in H-alpha and UV corresponding to subflares are also observed at the base of each surge. Type III bursts are triggered and RHESSI X-ray sources are evident with surge activity. The major surge consists of the bunches of ejective paths forming a fan-shape region with an angular size of (~ 65 degree) during its maximum phase. The ejection speed reaches upto ~ 200 km/s. The SOHO/MDI magnetograms reveal that a large dipole emerges east side of the active region on 18-20 October 2003, a few days before the surges. On October 25, 2003, the major sunspots were surrounded by "moat regions" with moving magnetic features (MMFs). Parasitic fragmented positive polarities were pushed by the ambient dispersion motion of the MMFs and annihilated with negative polarities at the borders of the moat region of the following spot to produce flares and surges. A topology analysis of the global Sun using PFSS shows that the fan structures visible in the EIT 171 A images follow magnetic field lines connecting the present AR to a preceding AR in the South East. Radio observations of type III bursts indicate that they are coincident with the surges, suggesting that magnetic reconnection is the driver mechanism. The magnetic energy released by reconnection is transformed into plasma heating and provides the kinetic energy for the ejections. A lack of a radio signature in the high corona suggests that the surges are confined to follow the closed field lines in the fans. It is concluded that these cool surges may have some local heating effects in the closed loops, but probably play a minor role in global coronal heating and the surge material does not escape to the solar wind. This work was done in collaboration with W. Uddin, B. Schmieder, A.K. Srivastava, P. Kumar and S. Bisht.

Actors of the main activity in large complex centres during the 23 solar cycle maximum

During the maximum of solar cycle 23, large active regions had a long life, spanning several solar rotations, and produced large numbers of X-class flares and CMEs, some of them associated to magnetic clouds (MCs). This is the case for the Halloween active regions in 2003. The most geoeffective MC of the cycle (Dst = - 457) had its source during the disk passage of one of these active regions (NOAA 10501) on 18 November 2003. Such an activity was presumably due to continuous emerging magnetic flux that was observed during this passage. Moreover, the region exhibited a complex topology with multiple domains of different magnetic helicities. The complexity was observed

to reach such unprecedented levels that a detailed multi-wavelength analysis was necessary to precisely identify the solar sources of CMEs and MCs. Magnetic clouds are identified using in situ measurements and interplanetary scintillation (IPS) data. Results from these two different sets of data are also compared. This work was done in collaboration with B. Schmieder, P. Démoulin, E. Pariat, T. Török, G. Molodij, C.H. Mandrini; S. Dasso, W. Uddin, P. Kumar, P.K. Manoharan, P. Venkatakrishnan and N. Srivastava.

Suresh Chandra

Suggestion for the search of H_2CC in cool cosmic objects

The transition 1_{11}-1_{10} at 4.829 GHz of formaldehyde (H_2CO) was the first one showing the anomalous absorption, i.e., the absorption against the cosmic microwave background. Anomalous absorption is an unusual phenomena. Structure of H_2CC is very similar to that of H_2CO and H_2CS. Both H_2CO and H_2CS have already been identified in a number of cosmic objects. Though H_2CC is not yet identified in the cosmic objects, it has proposed that H_2CC may be identified in cool cosmic objects through its transition 1_{11}-1_{10} at 4.85 GHz in anomalous absorption.

Intermediate magnetoacoustic waves

For understanding the problem of solar coronal heating, role of fast-mode and slow-mode magnetoacoustic waves has been discussed from time to time by using the dispersion relation $\omega(k) = 0$. Porter, et al. (1994), Kumar, et al. (2006), Pandey and Dwivedi (2007) and Chandra et al. (2010) have derived a dispersion relation as a polynomial in ω and discussed the fast-mode and slow-mode magnetoacoustic waves. Pekunlu, et al. (2002) have derived a dispersion relation as a polynomial in k and discussed about the fast-mode and slow-mode magnetoacoustic waves.

When Suresh Chandra expressed the said dispersion relation in ω, as a polynomial in k, he obtained intermediate waves, besides the fast-mode and slow-mode waves. In the present investigation, he has discussed the effects of density, magnetic field, temperature and the angle of propagation on the intermediate waves. However, he could not yet assign the physical significance of the intermediate waves.

Asis Kumar Chattopadhyay

Independent Component Analysis for dimension reduction classification: Hough transform and CASH algorithm

Classification of galaxies has been carried out by using two recently developed methods, viz. Independent Component Analysis (ICA) with K-means clustering and Clustering in Arbitrary Subspace based on Hough Transform (CASH) for different data sets. The first two sets consist of dwarf galaxies and their globular clusters whose distributions are non Gaussian in nature. The third one is a larger one containing a wider range of galaxies consisting of dwarfs to giants in 56 clusters of galaxies. Morphological classification of galaxies are subjective in nature, and as a result could not properly explain the formation mechanism and other related issues under the influence of different correlated variables through a proper scientific approach. Hence, objective classification by using the above mentioned methods are preferred to overcome the loopholes. This work was done in collaboration with Tanuka Chattyopadhyay, Tuli De and Saptarshi Mondal.

Surajit Chattopadhyay

Generalized Ricci dark energy in Horava-Lifshitz gravity

Surajit Chattopadhyay has considered the generalized Ricci dark energy in the Horava-Lifshitz gravity, and has reconstructed Hubble's parameter in terms of fractional densities, and viewed the equation-of-state parameter in this situation. Also, he has examined the behaviour of the deceleration parameter and investigated the nature of the statefinder diagnostics. The equation-of-state parameter has exhibited quintom-like behaviour, and from the plot of the deceleration parameter, he has observed a transition from decelerating to accelerating phase of the universe.

Surajit Chattopadhyay and Ujjal Debnath

Emergent universe in the Chameleon, f(R) and f(T) gravity theories

They have considered an emergent universe in generalized gravity theories like the Chameleon, f(R) and f(T) gravities, and reconstructed the potential of the chameleon field

under the emergent scenario of the universe and observed its increasing nature with the evolution of the universe. It has been found that in the emergent universe scenario, the equation-of-state parameter behaves like quintessence in the case of f(R) gravity, and like phantom in the case of f(T) gravity.

Tanuka Chattopadhyay

Uncovering the formation of ultra-compact dwarf galaxies by multivariate statistical analysis

Tanuka Chattopadhyay, in collaboration with S. Margarita (of Special Astrophysical Observatory, Russian Academy of Sciences), Emmanuel Davoust (of *IRAP, Universit'e de Toulouse, CNRS),* Tuli Ghosh and Asis Kumar Chattopadhyay (of Department of Statistics, Calcutta University) has studied the properties of a large sample of dynamically hot old stellar systems, from globular clusters to giant ellipticals, which was performed in order to investigate the origin of ultra-compact dwarf galaxies. The data were mostly drawn from Forbes, et al. (2008). They have recalculated some of the effective radii, computed mean surface brightnesses and mass-to-light-ratios, estimated ages and metallicities, for the sample with globular clusters of M31. They have used a multivariate statistical technique (K-Means clustering), together with a new algorithm (Gap Statistics) for finding the optimum number of homogeneous sub-groups in the sample, using a total of six parameters (absolute magnitude, effective radius, virial mass-to-light ratio, stellar mass-to-light ratio and metallicity). It is found that FK1 and FK5 are composed of high- and low-mass elliptical galaxies respectively, and FK3 and FK6 are composed of high-metallicity and low-metallicity objects, respectively, and both include globular clusters and ultra-compact dwarf galaxies. Two very small groups, FK2 and FK4, are composed of Local Group dwarf spheroidals. These six groups differ in their mean masses and virial mass-to-light ratios. The relations between these two parameters are also different for the various groups. The probability density distributions of metallicity for the four groups of galaxies is similar to that of the globular clusters and UCDs. The brightest low-metallicity globular clusters and ultra-compact dwarf galaxies tend to follow the mass-metallicity relation like elliptical galaxies. The objects of FK3 are more metal-rich per unit effective luminosity density than high-mass ellipticals.

Modelling of the initial mass function using the Metropolis Hastings algorithm

Tanuka Chattopadhyay, in collaboration with Asis Kumar Chattopadhyay, and Abisa Sinha, has developed a stochastic model for the hierarchical fragmentation of molecular cloud. Here the number of fragments, time between successive fragmentation steps and mass of a fragment are considered as random variables and fragment masses are generated using Metropolis Hastings algorithm. The resulting mass spectra, computed at different projected distances, taking opacity into consideration, show signature of mass segregation. The critical mass, mass spectrum and mass segregation are consistent with the observations of young massive clusters in our galaxy as well as in external galaxies.

H. S. Das

Modelling the polarization properties of Comet 1P/Halley using a mixture of compact and aggregate particles

H. S. Das, in collaboration with D. Paul, A. Suklabaidya and A. K. Sen, has been studying the polarization properties of comet Halley. Both the *in situ* measurement of Comet 1P/Halley and the *Stardust*-returned samples of Comet Wild 2 showed the presence of a mixture of compact and aggregate particles, with both silicates and organic refractory being in the composition of the cometary dust. Results obtained recently from the *Stardust* mission suggest that the overall ratio of compact to aggregate particles is 65:35 (or 13:7) for Comet 81P/Wild 2. Here, a model is proposed, which considers cometary dust as a mixture of compact and aggregate particles, with a composition of silicate and organic. They have considered compact particles as spheroidal particles and aggregates as both ballistic cluster–cluster aggregate (BCCA) and ballistic agglomeration with two migrations (BAM2) aggregate with a certain size distribution. The mixing ratio of compact to

aggregate particles is taken to be 13:7. For modelling Comet 1P/Halley, the power-law size distribution $n(a) \sim a^{-2.6}$, obtained from a re-analysis of the *Giotto* spacecraft data, for both compact and aggregate particles, is used. They have considered a mixture of BAM2 and BCCA aggregates with a lower cut-off size of about 0.20 μm and an upper cut-off of about 1 μm, and a mixture of prolate, spherical and oblate compact particles with an axial ratio (E) of 0.8 – 1.2, where a lower cut-off size of about 0.1 μm and an upper cut-off of about 10 μm.

Using a T-matrix code for polydisperse spheroids ($0.1\,\mu m \leq a \leq 10\,\mu m$) and superposition T-matrix code for aggregates ($0.2\,\mu m \leq a \leq 1\,\mu m$), the average simulated polarization curves are generated, which can best ?t the observed polarization data at the four wavelengths: ë = 0.365, 0.485, 0.670 and 0.684 μm. The suitable mixing percentages of aggregates obtained from the present modelling are 50 per cent BAM2 and 50 per cent BCCA particles, and the silicate-to-organic mixing percentages are 78 per cent silicate and 22 per cent organic, in terms of volume. The present model successfully reproduces the observed polarization data, especially the negative branch, for Comet 1P/Halley at the above four wavelengths, more effectively as compared to other work done in the past. It is found that among the aggregates, the BAM2 aggregate plays a major role in deciding the cross-over angle and depth of the negative polarization branch.

Modelling laboratory data of bidirectional reflectance of a Regolith surface containing alumina

Bidirectional reflectance of a surface is defined as the ratio of the scattered radiation at the detector to the incident irradiance as a function of geometry. Accurate knowledge of the bidirectional reflection function or layers composed of discrete, randomly positioned scattering particles is essential for many remote sensing, engineering, and biophysical applications, as well as for different areas of astrophysics. Computations of bidirectional reflection functions for plane parallel particulate layers are usually reduced to solving the radiative transfer equation by the existing techniques. In this work, the laboratory data on bidirectional reflectance versus phase angle for two sample sizes of alumina, 0.3 and 1 mm, for the He–Ne laser at wavelengths of 632.8 nm (red) and 543.5 nm (green) has been presented. The nature of the phase curves of the asteroids depends on the parameters like particle size, composition, porosity, roughness, etc. The data are analyzed, which are being generated using a single scattering phase function, that is, Mie theory of treating particles as a compact sphere. The well-known Hapke formula, along with different particle phase functions, such as Mie and Henyey–Greenstein, have been used to model the laboratory data obtained at the asteroid laboratory of Assam University. This work has been done in collaboration with C. Bhattacharjee, D. Deb, A. K. Sen and R. Gupta.

Ujjal Debnath

Thermodynamics in quasi-spherical Szekeres spacetime

It has been considered that the universe is the inhomogeneous (n+2) dimensional quasi-spherical Szekeres spacetime model. Now consider the universe as a thermodynamical system with the horizon surface as a boundary of the system. To study the generalized second law (GSL) of thermodynamics through the universe, it was assumed that the trapped surface was the apparent horizon. Next the validity of the GSL of thermodynamics on the apparent horizon was examined by two approaches: (i) using the first law of thermodynamics on the apparent horizon and (ii) without using the first law. In the first approach, the horizon entropy has been calculated by the first law. In the second approach, first the surface gravity and temperature on the apparent horizon were calculated and then horizon entropy has been found from area formula. The variation of internal entropy has been found by Gibb's law. Using these two approaches separately, the conditions for validity of GSL in (n+2) dimensional quasi-spherical Szekeres model have been investigated.

Holographic dark energy interacting with two fluids and validity of generalized second law of thermodynamics

Ujjal Debnath has considered a cosmological model of holographic dark energy interacting with dark matter and another unknown component of dark energy of the universe. Now assume two interaction terms Q and Q' in order to include the scenario in which the mutual interaction

between the two principal components (i.e., holographic dark energy and dark matter) of the universe, which leads to some loss in other forms of cosmic constituents. The model is valid for any sign of Q and Q' . If $Q < Q'$, then part of the dark energy density decays into dark matter and the rest in the other unknown energy density component. But if $Q > Q'$, then dark matter energy receives from dark energy and from the unknown component of dark energy. Observation suggests that dark energy decays into dark matter. Here, one has presented a general prescription of a cosmological model of dark energy, which imposes mutual interaction between holographic dark energy, dark matter and another fluid. The equation of state for the holographic dark energy density has been obtained, which is interacting with dark matter and other unknown component of dark energy. Using first law of thermodynamics, the entropies for holographic dark energy, dark matter and other component of dark energy was obtained, when holographic dark energy is interacting with two fluids (i.e., dark matter and other component of dark energy). Also the entropy at the horizon when the radius (L) of the event horizon measured on the sphere of the horizon was found. The GSL of thermodynamics at the present time for the universe enveloped by this horizon was investigated. Finally, validity of GSL which implies some bounds on deceleration parameter q was obtained.

Jishnu Dey

Quasi-periodic oscillations, stellar masses

The mass of a star, also called as stellar mass (M), determines, at birth, the basic essentials of a stars structure and its future life. According to the Russll-Voget theorem, if one knows the mass of a star and its chemical composition, we can use the laws of physics to determine all of its other properties like its luminosity, radius, temperature and density profiles and how these properties will change in time.There are two ways of determining the stellar mass: (1) direct determination of masses observationally using binary system and (2) inference of stellar masses using models. Now another method using Quasi-Periodic Oscillation (QPO) has been proposed.

Celestial bodies such as stars and black holes have a disk of objects spinning around them known as an accretion disk. The objects could be gases, asteroids, etc. These objects spin inwards towards the centre due to the stars' gravitational pull and radiate a massive amount of energy. QPO is the manner in which X-rays from an astronomical object flicker about certain frequencies. The X-rays are emitted near the inner edge of an accretion disk.

Stars are usually found in pairs, spinning around each other. This is called a binary system. When one of these celestial bodies becomes a neutron star — the remains of a star that exploded and collapsed back into itself to form a small body core of neutrons — it gravitationally pulls matter and objects from its companion star. When the matter falls towards the neutron star, it emits X-rays. The pulses of these X-rays can be recorded in a graph. However, QPO was another type of pulsation that was discovered in 1985 by EXOSAT — a satellite of the European Space Agency (ESA). It was observed that brighter the source was in X-ray, the shorter the QPO. The frequency of QPOs for most sources is very fast — 6 to 10 times a second.

According to Subharthi Ray, et al, (2012), the characteristic frequencies of the kHz QPOs (high frequency QPOs) have two peaks: the lower one (νlow) ranges from a few hundreds of hertz and the upper one (νup) often goes beyond 1kilohertz (kHz).

Ray, et al, have assumed that νlow is caused due to matter thickly clustering the inner edge of the accretion disk and υup is caused due to matter clustering the stable orbit. Researchers previously had derived equations for calculating the radial distances of these clusters of matter. So, by calculating the radial distances (using the data from the frequencies), they could calculate the stellar masses of ten stars. A star's possible range of mass is 0.08 to 150M. One more factor that gets affected by the stellar mass is the life of the star as Tms ~M/L, where Tms = life time of a star, M = the stellar mass and L = the luminosity.

Ray, et al. have data for only ten stars, they hope that in the future, satellites like ASTROSAT, which is to be launched in India in 2012, with advanced X-ray technology would, provide more data. It would help them re-examine their

findings and tell more about how QPOs can be used to estimate the weight of stars.

Mira Dey

Strange quark matter being lower in energy at high density forms a compact star, more compact than neutron star

It is suggested that the mass of four compact stars SAX J1808.4-3658, KS 1731-260, SAX J1750.8-2900 and IGR J17191-2821 can be determined from the difference in the observed kiloHertz quasi periodic oscillations (kHz QPOs). The stellar radius is very close to the marginally stable orbit. It may be noted that the first of these stars was suggested to be a strange star more than a decade back by Li, et al. (1999a) from the unique millisecond X-ray pulsations with an accurate determination of its rotation period. It showed kHz QPOs eight years back and so far it was the only set that has been observed (Wijnands, et al, 2003, M. Mendez, private communication). This is the first time that an estimate of the mass of the star and of three other compact stars (Mendez and Belloni, 2007) in low-mass X-ray binaries using their observed kHz QPOs have been given.

Sunandan Gangopadhyay

Hamiltonian analysis of symmetries in a massive theory of gravity

The generator of Hamiltonian gauge symmetries in a 2+1 dimensional massive theory of gravity, proposed recently, through a systematic off-shell algorithm has been constructed. Using a field dependant map among gauge parameters, it is shown that the symmetries obtained from this generator are on-shell equivalent to the Poincare gauge symmetries. Certain subtle issues concerning the implementation of this map have also been clarified. This work was done in collaboration with R. Banerjee and D. Roy.

Voros product and the Pauli principle at low energies

Using the Voros star product, the status of the two particle correlation function to study the possible extent to which the previously proposed violation of the Pauli principle may impact at low energies has been investigated. The results show interesting features, which are not present in the computations made using the Moyal star product. This work was done in collaboration with A. Saha and F.G. Scholtz.

Sushant Ghosh

Nonstatic charged BTZ-like black holes in N+1 dimensions

Sushant Ghosh has found an exact nonstatic charged BTZ-like solutions, in *(N+1)*-dimensional Einstein gravity in the presence of negative cosmological constant and a nonlinear Maxwell field, defined by powers of the Maxwell invariant, which describes the gravitational collapse of charged null fluid in an anti-de Sitter background. Considering the situation that a charged null fluid injects into the initially an anti-de Sitter spacetime, it is shown that a black hole form a naked singularity, irrespective of spacetime dimensions, from gravitational collapse in accordance with cosmic censorship conjecture. The structure and locations of the apparent horizons of the black holes are also determined. It is interesting to see that, in the static limit, and when *N=2*, one can retrieve *2+1* BTZ black hole solutions.

5D Radiating black holes in Einstein-Yang-Mills-Gauss-Bonnet gravity

He has derived nonstatic spherically symmetric solutions of a null fluid, in five dimensions (5D), to Einstein–Yang–Mills (EYM) equations with the coupling of Gauss–Bonnet (GB) combination of quadratic curvature terms, namely, 5D EYMGB radiating black hole solution. It is shown that, in the limit, it is possible to recover known radiating black hole solutions. The spherically symmetric known 5D static black hole solutions are also retrieved. The effect of the GB term and Yang–Mills (YM) gauge charge on the structure and location of horizons, of the 5D radiating black hole, is also discussed.

Sarbari Guha

A dynamical systems analysis of motion in the bulk with respect to the brane

Sarbari Guha and collaborator (Pinaki Bhattacharya) have investigated the geodesic motion for massive and massless

particles in a five-dimensional bulk using the dynamical systems analysis, where the system is studied with respect to the brane affine parameter. Since all measurements are carried out within the spacetime limit of our four - dimensional universe, such a study is more appropriate for confronting the theoretical results thus obtained, with the actual experimental observations. The authors have discussed the phase portrait for different types of warping function along with the nature of confinement with respect to the hypersurface. They have also studied the system at infinity to obtain the global picture.

Sarbari Guha and Subenoy Chakraborty

Five-dimensional warped product spacetime with time-dependent warp factor and cosmology of the four-dimensional universe

The authors have studied a five-dimensional warped product spacetime with a time-dependent warp factor. This warp factor plays an important role in localizing matter to the four-dimensional hypersurface constituting the observed universe and leads to a geometric interpretation of dynamical dark energy. The five-dimensional field equations are constructed and its solutions are obtained. The nature of modifications produced by this warp factor in the bulk geometry is discussed. It is found that the effective cosmological constant of the four-dimensional universe is a variable quantity monitored by the time-dependent warp factor. The universe is initially decelerated, but subsequently makes a transition to an accelerated phase at later times.

K. P. Harikrishnan

A new computational scheme for the correlation dimension analysis of hyperchaotic time series.

The authors have undertaken the correlation dimension analysis of hyperchaotic time series using the box counting algorithm. It is shown that the conventional box counting scheme is inadequate for the accurate computation of the correlation dimension (D2) of a hyperchaotic attractor and propose a modified scheme, which is automated and gives better convergence of D2 with respect to the number of data points. The scheme is first tested with the time series from standard chaotic systems, pure noise and data added with noise. It is then applied on the time series from three standard hyperchaotic systems for computing D2. This analysis clearly reveals that a second scaling region appears at lower values of box size as the system makes a transition into the hyperchaotic phase. This, in turn, suggests that correlation dimension analysis can also give information regarding chaos – hyperchaos transition. This work was done in collaboration with R. Misra and G. Ambika.

Ng. Ibohal

Hawking's radiation in non-stationary rotating de Sitter background

Hawking's radiation effect of Klein-Gordon scalar field, Dirac particles and Maxwell's electromagnetic in the non-stationary rotating de Sitter cosmological spacetime is investigated by using a method of generalized tortoise coordinate transformation. The locations and the temperature of the cosmological horizons of the non-stationary rotating de Sitter model are derived. It is found that the locations and the temperatures of the rotating cosmological model depend not only on the time but also on the angle. The stress energy regularization techniques are applied to the two dimensional analog of the de Sitter metrics and the calculated stress-energy tensor contains the thermal radiation effect. This work was done in collaboration with T. Ibungochouba.

Non-vacuum conformally flat space-times: Dark energy

A class of exact solutions (stationary and non-stationary) of Einstein's field equations has been proposed. They have found that the spacetime geometries of the solutions are non-vacuum and conformally flat, whose energy momentum tensors possess dark energy with negative pressure and the energy equation of state parameter $w = \frac{-1}{2}$. Also, it has been found that the time-like vector fields of the matter distribution of the solutions are expanding, shearing with acceleration and zero twist. Further, due to the negative pressure, the energy-momentum tensors violate the strong energy conditions leading to the repulsive

gravitational fields of the spacetime geometries. Energy-momentum tensors for the solutions also obey the energy conservation equations. From these physical properties of the matter distribution, the spacetimes have been seen as examples of exact solutions of the Einstein's field equations admitting dark energy with negative pressure. It is to note that the approximate sizes of the masses of the (stationary and non-stationary) solutions are less than (1/2) x 10^{-60} in Bousso's length scale r $>10^{60}$. It is also found that the surface gravities on the horizons are directly proportional to their respective masses. This work has been done in collaboration with Ngangbam Ishwarchandra and K. Yugindro Singh.

K. Indulekha

Timing and spectral studies of the transient X-ray pulsar GX 304-1 during an outburst

The timing and spectral properties of the transient X-ray pulsar GX 304-1 during its recent outburst in 2010 August, using observations carried out with the Proportional Counter Array (PCA) instrument on board the Rossi X-ray Timing Explorer (RXTE) satellite have been presented. The author has detected strong intensity and energy-dependent variations in the pulse profiles during the outburst. The pulse profile showed significant evolution over the outburst. It showed complex structures consisting of a main peak with steps on both sides during the start of the outburst. On some days, a sharp dip-like feature was seen, which disappeared at the end of the outburst when the profile evolved into a sinusoidal shape. At low energies, the pulse profiles appeared complex, consisting of multiple peaks and a narrow minimum. The amplitude of the second brightest peak in low energies decreased with energy, and above 12 keV, the shape of the pulse profile changed to a single broad peak with a dip-like feature. The dip had energy dependence, both in phase and in width. Quasi-periodic oscillations (QPOs) at 0.125 Hz with a harmonic have been detected. The QPO feature had a low rms value of 2.9 per cent and it showed a positive energy dependence up to 40 keV with the rms value increasing to 9 per cent at 40 keV. The QPO frequency decreased from 0.128 to 0.108 Hz in 12 days. During most of the outburst, the 3 - 30 keV spectrum of GX 304-1 can be well fitted with a partial covering power-law model with a high-energy cut-off and iron fluorescent line emission. For a few of the observations carried out during the decay of the outburst, the partial covering absorption component is found to change to single-component absorption. It is also found that the partial covering and high-energy cut-off parameters vary significantly with the pulse phase.

RXTE-PCA observations of 1A 1118-61: Timing and spectral studies during an outburst

The author has reported a detailed timing and spectral analysis of Rossi X-ray Timing Explorer Proportional Counter Array (RXTE-PCA) data obtained from observations during the outburst of a transient X-ray pulsar 1A 1118-61 in 2009 January. The pulse profile showed significant evolution during the outburst and also significant energy dependence - a double-peaked profile up to 10 keV and a single peak at higher energy. It is also detected quasi-periodic oscillations (QPOs) at 0.07 - 0.09 Hz. The rms value of the QPO is 5.2 per cent, and it shows a significant energy dependence with highest rms of 7 per cent at 9 keV. The QPO frequency changed from 0.09 to 0.07 Hz within 10 d. The magnetic field strength calculated using the QPO frequency and the X-ray luminosity is in agreement with the magnetic field strength measured from the energy of the cyclotron absorption feature detected in this source. The 3 - 30 keV energy spectrum over the 2009 outburst of 1A 1118-61 can be well fitted with a partial covering power-law model with a high-energy cut-off and an iron fluorescence line emission. The pulse phase resolved spectral analysis shows that the partial covering and high-energy cut-off model parameters have significant changes with the pulse phase.

Naseer Iqbal

Study of impact materials of Akhnoor meteor crater in Jammu and Kashmir (India)

A sample of Akhnoor meteor crater, which fell on 2nd January 2009 in Jammu District of Jammu and Kashmir, India, has been analyzed for elemental composition by spectroscopic techniques. Concentrations of 17 major, minor and trace elements were determined. The authenticity of the meteorite sample was established by

comparing its composition with those of standard meteorites/chondrite. The classification of the sample has been made by comparing the abundances and concentration ratios of elements with other known meteorites

Thermodynamical model of the universe

The author has analysed the physics of a self gravitating medium in quasi-static equilibrium, using the phenomenological approach of thermodynamics. Gravitational galaxy clustering is statistical, and its origin is dynamical. Hence, the aspects of clustering must be understood in order to arrive at a proper appreciation of the subject of the formation and evolution of the large scale structure of the universe. Long range gravitational forces modify the thermodynamic functions and equations of state. First, the importance of thermodynamics as applicable to the gravitational clustering problem, and the study of various thermodynamic functions like free energy, entropy, pressure, internal energy and others was extended. The various results have interested implications for the study of large scale structure in the universe. They support the view that an easy and simple approach can be made an alternative study, while discussing the central issues of cosmology of large scale structure of universe.

Deepak Jain

Cosmokinetics: A joint analysis of standard candles, rulers and cosmic clocks

The authors have studied the accelerated expansion of the universe by using the kinematic approach. In this context, one parameterizes the deceleration parameter, q(z), in a model independent way. Assuming three simple parameterizations, they have reconstructed q(z), and performed the joint analysis with combination of latest cosmological data consisting of standard candles (Supernovae Union2 sample), standard ruler (CMB/BAO), cosmic clocks (age of passively evolving galaxies) and Hubble (H(z)) data. The results support the accelerated expansion of the universe. This work was done in collaboration with Remya Nair and Sanjay Jhingan.

Observational cosmology and the cosmic distance duality relation

They have studied the validity of cosmic distance duality relation between angular diameter and luminosity distances. To test this duality relation they have used the latest Union2 Supernovae Type Ia (SNe Ia) data for estimating the luminosity distance. The estimation of angular diameter distance comes from the samples of galaxy clusters (real and mock) and FRIIb radio galaxies. The parameterized distance duality relation as a function of redshift in six different ways has ruled out some of the parameterizations significantly. This work was done in collaboration with Remya Nair and Sanjay Jhingan.

Kanti Jotania

A new class of LRS Bianchi type VI_0 universes with free gravitational field and decaying vacuum energy density

A new class of LRS Bianchi type VI_0 cosmological models with free gravitational fields and a variable cosmological term is investigated in presence of perfect fluid as well as bulk viscous fluid. To get the deterministic solution, The authors have imposed the two different conditions over the free gravitational fields. In 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 Ë 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. This work was done in collaboration with Anirudh Pradhan, Shyam Sundar Kumhar and Padmini Yadav.

Dark energy models with anisotropic fluid in Bianchi type-VI_0 spacetime with time dependent deceleration parameter

The authors have presented two dark energy (DE) models with an anisotropic fluid in Bianchi type VI_0 spacetime by considering time dependent deceleration parameter (DP). The equation of state (EoS) for dark energy $\grave{u}$ is found to be time dependent and its existing range for derived models is in good agreement with the recent observations. Under the suitable condition, the anisotropic models approach to

isotropic scenario. They also have found that during the evolution of the universe, the EoS parameter for DE changes from $\grave{u} > -1$ to $\grave{u} = -1$ in first model, whereas from $\grave{u} > -1$to $\grave{u} < -1$ in second model, which is consistent with recent observations. The cosmological constant $\ddot{E}$ 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 type Ia supernovae observations. The cosmic jerk parameter in the derived models is also found to be in good agreement with the recent data of astrophysical observations. The physical and geometric aspects of both the models are also discussed in detail. This work was done in collaboration with Anirudh Pradhan, Rekha Jaiswal and Rajeev Kumar Khare.

Minu Joy

Cosmology and structure formation

Minu Joy has been studying the primordial non-Gaussianity generated by an inflationary model where the potential has a step in the second order derivative with respect to the field. Joy and collaborators have computed the 3-point function of the curvature perturbation for this inflationary model and showed that there would be three more terms which contribute, at order square of slow roll parameters, to the 3-point function, as compared to standard slow roll inflation. These terms affect the scales that exit Hubble horizon around the time the field crosses the feature in the potential. The distinctive feature of this non-Gaussianity is its characteristic ringing behaviour of f_{NL}. It is seen that the oscillations in f_{NL} in this model last for a much longer range of k values, as compared to the previously studied models. In that sense, this model is potentially distinguishable from models with other features in the potential.

Md. Mehedi Kalam

A comparison of Hoøava-Lifshitz gravity and Einstein gravity through thin-shell wormhole construction

The author has constructed a new class of thin-shell wormholes from black holes in Horava–Lifshitz gravity. Particular emphasis is placed on those aspects that allow a comparison of Horava–Lifshitz gravity to Einstein gravity.The former enjoys a number of advantages for small values of the throat radius.

Modeling galactic halos with predominantly quintessential matter

Further, the author has formulated a new model for galactic dark matter by combining an anisotropic pressure field corresponding to normal matter and a quintessence dark energy field having a characteristic parameter $\grave{u}_q$ such that $-1 < \grave{u}_q < -1/3$. Stable stellar orbits together with an attractive gravity exist only if $\grave{u}_q$ is extremely close to -1/3, a result consistent with the special case studied by Guzman, et al. (2003). Less exceptional forms of quintessence dark energy do not yield the desired stable orbits and are, therefore, unsuitable for modeling dark matter.

Nagendra Kumar

Role of equilibrium plasma flow on damping of slow MHD waves

In the solar corona, waves and oscillatory activities are observed with modern imaging and spectral instruments. These oscillations are interpreted as slow magneto-acoustic waves excited impulsively in coronal loops. Nagendra Kumar and collaborators (P. Kumar, A. Kumar and R. Chauhan) have explored the effect of steady plasma flow on the dissipation of slow magneto-acoustic waves in the solar coronal loops permeated by uniform magnetic field. They have investigated the damping of slow waves in the coronal plasma taking into account viscosity and thermal conductivity as dissipative processes. On solving the dispersion relation, it is found that the presence of plasma flow influences the characteristics of wave propagation and dissipation. It has been shown that the time damping of slow waves exhibits varying behaviour depending upon the physical parameters of the loop. The wave energy flux associated with slow magneto-acoustic waves turns out to be of the order of 106 erg cm^{-2} s^{-1} which is high enough to replace the energy lost through optically thin coronal emission and the thermal conduction below to the transition region.

Alfven surface waves in a partially ionized resistive medium

Nagendra Kumar and collaborators (V. Kumar and H. Sikka) have studied the joint effects of viscosity, resistivity and ion-

neutral collisions on Alfvén surface waves propagating along a partially ionized plasma - vacuum interface. Applying boundary conditions at plasma-vacuum interface, they have obtained the dispersion relation for Alfvén surface waves and solved it numerically. For different values of resistivity and neutral gas friction parameters, the variation of real and imaginary parts of wavenumber with viscosity parameter is shown graphically. It is found that two-mode structure of Alfvén surface waves results due to the combined effects of resistivity, viscosity and ion-neutral collisions. These results might be useful for studying the behaviour of Alfvén surface waves in laboratory and space plasmas.

Suresh Kumar

Observational constraints on Hubble constant and deceleration parameter in power-law cosmology

The author has shown that the expansion history of the universe in power-law cosmology essentially depends on two crucial parameters, namely the Hubble constant H_0 and deceleration parameter q. He has found the constraints on these parameters from the latest $H(z)$ and SNe Ia data. At 1ó level, the constraints from $H(z)$ data are obtained as $q=-0.18^{+0.12}_{-0.12}$ and $H_0=68.43^{+2.84}_{-2.80}$ km s^{-1} Mpc^{-1}, while the constraints from the type Ia supernovae (SNe Ia) data are $q = -0.38+0.05-0.05$ and $H_0 = 69.18+0.55-0.54$ km s^{-1} Mpc^{-1}. He has also performed the joint test using $H(z)$ and SNe Ia data, which yields the constraints $q=-0.34^{+0.05}_{-0.05}$ and $H_0 = 68.93^{+0.53}_{-0.52}$ km s^{-1} Mpc^{-1}. The estimates of H_0 are found to be in close agreement with some recent probes carried out in the literature. The analysis reveals that the observational data successfully describe the cosmic acceleration within the framework of power-law cosmology. It is found that the power-law cosmology accommodates well with the $H(z)$ and SNe Ia data. Further, he has tested the power-law cosmology using the primordial nucleosynthesis, which yields $q > 0.72$ and $H_0 < 41.49$ km s^{-1} Mpc^{-1}. These constraints on q and H_0 are found to be inconsistent with the ones derived from the $H(z)$ and SNe Ia data on q and H_0 and that the power-law cosmological models approach the standard cold dark matter (CDM) model as $q \rightarrow -1$. Finally, concluded that despite having several good features, power-law cosmology is not a complete package for the cosmological purposes.

V.C. Kuriakose

Evolution of massive and massless fields around a black hole in Horava gravity

One of the challenges faced by theoretical physicists is to bring GTR in to quantum filed theoretic framework. Recently, Horava (2009) has proposed a power counting renormalizable theory of gravity in 3+1 dimensions inspired from the Lifshtiz model in condensed matter. This model, now known as Horava-Lifshtiz (HL) gravity, assumes an anisotropic scaling between space and time and hence, break-down of Lorentz invariance at short distances. It is important to study the behaviour of black hole solutions under this new theory. Nijo Varghese and V.C. Kuriakose have considered a black hole solution, known as Kehagias-Sfetsos (KS), possessing asymptotically flat spacetime and studied the evolution of massive scalar field and the associated quasinormal modes (QNMs). They have found a noticeable deviation of the evolution behaviour of the massive field in the ring-down region from that of the Schwarzschild black hole case. It is found that massive QNMs in HL theory have a higher oscillation frequency and damping rate than the Schwarzschild case. They have also studied the evolution of electromagnetic and massless Dirac fields using time domain integration method. The aim of these studies is to know whether one can distinguish the HL theory by studying the evolution of fields around black holes in HL theory from GTR. From the present studies, they have found that the QNMs phase has been extended for a longer time in HL theory before the power-law tail begins compared to Schwarzschild situation. The oscillation frequency and the damping time have higher values in HL theory compared to the Schwarzschild case. The late-time decay is found to be independent of the nature of the fields and follows the power-law tail behaviour as in the Schwarzschild case.

Badam Singh Kushvah

Existence of equilibrium points and their linear stability in the generalized photogravitational Chermnykh-like problem with power-law profile

The authors have considered the modified restricted three body problem with power-law density profile of disk, which rotates around the centre of mass of the system with perturbed mean motion. Using analytical and numerical methods, they have found equilibrium points and examined

their linear stability, and have also found the zero velocity surface for the present model. In addition to five equilibrium points, there exists a new equilibrium point on the line joining the two primaries. It is found that L_1 and L_3 are stable for some values of inner and outer radius of the disk, while other collinear points are unstable, but L_4 is conditionally stable for mass ratio less than that of Routh's critical value. Lastly, they have studied the effects of radiation pressure, oblateness and mass of the disk on the motion and stability of equilibrium points. This work was done in collaboration with Ram Kishor and Uday Dolas.

Manzoor A. Malik

Critical phenomena in the cosmological many body problem

Manzoor A. Malik and M. S. Khan have studied the phase transitions occurring in the gravitational clustering of galaxies on the basis of specific heat analysis and Lee-Yang theory. They have found that a first order phase transition occurs, when the galaxies cluster gravitationally from an initial homogenous phase. At the critical temperature Tc, the system breaks the symmetry from homogeneity and there is growth of correlations from linear to non-linear regime. These results are extended to multi-component systems and extended mass galaxies. It is found that there is little effect of extended mass but appreciable effect of the different mass profiles of galaxies in a multi-component system. The phase transition for a multi-component system, dominated by more massive galaxies, occurs at an earlier stage of clustering as compared to a single component system. The results of Lee-Yang theory of phase transitions applied to gravitational clustering of galaxies closely match with those from specific heat analysis.

Spatial galaxy distribution function for a three-component system

Manzoor A. Malik and coworkers (Raja Nisar Ali and Farooq Ahmad) have derived the distribution function and the allied thermodynamic quantities for a system of galaxies with three mass species. A new clustering parameter that inherently takes into account the masses and the number of galaxies of each kind, emerges directly from the calculations. It is shown that the multi-component nature of the system does not significantly effect the overall features of the distribution function.

Soma Mandal

The kilo-second variability of X-ray sources in nearby galaxies

Soma Mandal and her collaborators (Ranjeev Misra and Gulab C. Dewangan) have studied the variability of a sample of *Chandra* detected X-ray sources in nearby galaxies in the time scale $\sim$ 10 ksec. *Chandra* observations of 17 nearby galaxies were analyzed and 166 bright sources with X-ray counts > 100 were chosen for temporal analysis. Fractional root mean square variability amplitudes were estimated for lightcurves binned at $\sim$ 4 ksec and of length $\sim$ 40 ksec. Eight sources, of which three are ultra-luminous X-ray sources (ULX) with unabsorbed L > 10^{39} ergs/sec, were found to be variable at a significance level > 2-sigma. Two of the three variable ULX exhibit secular transitions and have ultra-soft spectra with temperatures < 0.3 keV, while the other is a rapidly varying unique source in NGC 0628.These results seem to indicate that these sources are typically not highly variable in ksec time-scales, except for some ultra-soft one. Among the relatively low luminosity sources (L $\sim$ 10^{38}ergs/sec), apart from an earlier known source in NGC 1569, a source in NGC 2403 was identified, which exhibits persistent high amplitude fluctuations. The variability of the sources in general, do not seem to be correlated with hardness, which indicates that they may not be due to variations in any absorbing material, but instead could reflect inner accretion disk instabilities and/or state transitions.

Pradip Mukherjee

Hamiltonian analysis of higher order systems

With Rabin Banerjee and Biswajit Paul, Pradip Mukherjee has studied Hamiltonian analysis of higher order systems in general. An algorithm has been developed to determine the gauge symmetries, which has been applied to both particle and field theoretic models.

P.N. Pandita

Minimal supersymmetric standard model

Supersymmetry (SUSY) is at present a leading candidate for physics beyond the Standard Model (SM). In supersymmetric theories the Higgs sector, so essential for the internal consistency of the SM, is technically natural. Supersymmetry is, however, not an exact symmetry in nature. The precise manner in which SUSY is broken is not

known at present. The necessary SUSY breaking can be introduced through soft supersymmetry breaking terms that do not reintroduce quadratic divergences in the Higgs mass, and thereby do not disturb the stability of the hierarchy between the weak scale and the large~(grand unified or Planck) scale. Such terms can typically arise in supergravity theories, in which local supersymmetry is spontaneously broken in a hidden sector, and is then transmitted to the visible sector via gravitational interactions. A possible implementation of the idea of supersymmetry is the minimal supersymmetric standard model (MSSM), obtained by introducing the supersymmetric partners of the SM states, and introducing an additional Higgs doublet with opposite hypercharge to that of SM Higgs doublet, in order to cancel the gauge anomalies and generate masses for all the Fermions of the Standard Model, with soft supersymmetry breaking terms generated by a suitable supersymmetry breaking mechanism. In order for broken supersymmetry to be effective in protecting the weak scale against large radiative corrections, the supersymmetric partners of the SM particles should have masses of the order of ~ TeV. Their discovery is one of the main goals of present and future accelerators.

Because of underlying gauge invariance and supersymmetry, the Higgs sector of the MSSM is very tightly constrained, and, therefore, is especially interesting. The LEP experimental lower bound on the Standard Model Higgs boson is about 114 GeV. In order for the MSSM to accommodate this result, the top squarks should be heavy. This makes the theory appear as finely tuned. Alternatively, there must be large left-right mixing between scalar top quarks. While such large mixing is possible, it is rather difficult to obtain in specific models and can arise only in special regions in the parameter space. As pointed out by Dine, Seiberg and Thomas, this suggests that there are likely to be additional degrees of freedom in the theory beyond those of the MSSM.

P. N. Pandita, along with his collaborators, has been investigating the implications of dimension five operators involving Higgs chiral superfields, which can help in accommodating the LEP limit on the lightest Higgs mass without fine tuning, 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. They have discussed the effect of these operators for different models of supersymmetry breaking gaugino masses. In addition to the masses of the neutralinos and charginos, it is shown that sum rules involving the masses and squared masses of these particles can be used to study the presence of the dimension five operators in the context of MSSM.

M.K. Patil

Systematic study of X-ray cavities in the brightest galaxy in the Draco constellation NGC 6338

The results based on the systematic analysis of currently available Chandra archive data on the brightest galaxy in the Draco constellation, NGC 6338, in order to investigate the properties of the X-ray cavities have been presented. In the central ~ 6 kpc, at least two, possibly three, X-ray cavities are evident. All these cavities are roughly of ellipsoidal shape and show a decrement in surface brightness of several tens of per cent. In addition to these cavities, a set of X-ray bright filaments are also noticed, which are spatially coincident with the Há filaments over an extent of 15 kpc. The Há emission-line filaments are perpendicular to the X-ray cavities. Spectroscopic analysis of the hot gas in the filaments and cavities reveals that the X-ray filaments are cooler than the gas contained in the cavities. The emission-line ratios and the extended, asymmetric nature of the Há emission-line filaments seen in this system require a harder ionizing source than that produced by star formation and/or young, massive stars. Radio emission maps derived from the analysis of 1.4-GHz Very Large Array Faint Images of the Radio Sky at Twenty-Centimeters survey data failed to show any association of these X-ray cavities with radio jets; however, the cavities are filled by radio emission. The total power of the cavities is 17×10^{42} erg s^{-1} and the ratio of radio luminosity to cavity power is $\sim 10^{-4}$, implying that most of the jet power is mechanical.

Dust extinction and X-ray emission from the starburst galaxy NGC 1482

The author has presented the results based on multi-wavelength imaging observations of the prominent dust lane starburst galaxy NGC 1482 aimed to investigate the extinction properties of dust existing in the extreme environment. (B-V) colour-index map derived for the starburst galaxy NGC 1482 confirms two prominent dust lanes running along its optical major axis and are found to extend up to ~11 kpc. In addition to the main lanes, several filamentary structures of dust originating from the central starburst are also evident. Though, the dust is surrounded by exotic environment, the average extinction curve derived for this target galaxy is compatible with the galactic curve, with $R_v = 3.05$, and imply that the dust grains responsible for

the optical extinction in the target galaxy are not really different than the canonical grains in the Milky Way. The estimate of total dust content of NGC 1482 assuming screening effect of dust is $\sim 2.7 \times 10^5 M_{sun}$, and provide lower limit due to the fact that the method is not sensitive to the intermix component of dust. Comparison of the observed dust in the galaxy with that supplied by the SNe to the ISM, imply that this supply is not sufficient to account for the observed dust and hence, point towards the origin of dust in this galaxy through a merger like event. The multiband imaging analysis reveals a qualitative physical correspondence between the morphologies of the dust and Há emission lines as well as diffuse X-ray emission in this galaxy. Spatially resolved spectral analysis of the hot gas along outflows exhibit a gradient in the temperature. Similar gradient was also noticed in the measured values of metallicity, indicating that the gas in the halo was not yet enriched. High resolution, 2-8 keV Chandra image reveals a pair of point sources in the nuclear region with their luminosities equal to 2.27×10^{39} erg s^{-1} and 9.34×10^{39} erg s^{-1}, and are in excess of the Eddington-limit of 1.5 M_{sun} accreting source. Spectral analysis of these sources exhibit an absorbed-power law with the hydrogen column density higher than that derived from the optical measurements.

B. C. Paul

Classical cosmology

A model of an ever existing universe, which eventually enters into the standard big bang epoch at some stage and consistent with the features known today has been constructed by Mukherjee, Paul and Dadhich (CQG, 2006). The model can be implemented with a composition of normal and exotic matter permitted by the non-linear equation of state (EOS) $p = A\rho - B\sqrt{\rho}$, where ρ represents the energy density and p represents the pressure of the fluid, is considered to obtain a flat emergent universe scenario. Using observational data, they have predicted the range of permissible values for the parameters A and B for a physically viable cosmological model. The permitted values of the parameters are determined by taking into account the H(z)-z data obtained from observations, a model independent BAO peak parameter and CMB shift parameter (WMAP3 data). It is found that although A can be very close to zero, most of the observations favour a small and negative A. As a result, the effective EOS parameter for a class of emergent universe solutions remains negative always. The magnitude μ(z) v/s. Redshift (z) curve obtained in the model with that obtained from the union compilation data has been also considered. According to the analysis, the class of emergent universe solutions considered here is not ruled out by the observations.

Compact objects

B. C. Paul with P. K. Chattopadhyay, S. Karmakar, and R. Tikekar, has studied relativistic strange star with anisotropy. Considering strange matter with equation of state $p=\frac{1}{3}(\rho - 4B)$, where B is Bag parameter, they have analyzed the effect of pressure anisotropy on the Bag parameter for a compact star making use of Vaidya-Tikekar metric. The values of B inside and on surface of the star are determined for different aniosotropic parameter (α). It is found that in the vicinity of the centre of a compact star, B parameter is almost constant. However, away from the center, B varies with the radial distance and finally at the surface B attains a value independent of the anisotropy. It is also noted that for some values of α, B remains constant throughout the star. It is also noted that for a given α and spheriodicity (a), B decreases with an increase in compactness factor (ratio of mass to radius of a star). On the other hand, there exists some models, where B increases with an increase of α for a given spheriodicity parameter(a) and compactness.

Ninan Sajeeth Philip

A photometric catalogue of quasar and other point sources in the Sloan Digital Sky Survey

Ninan Sajeeth Philip and Sheelu Abraham, in collaboration with Ajit Kembhavi, Yogesh G. Wadadekar and Rita Sinha have developed a machine learning tool for the classification of unresolved objects in Sloan Digital Sky Survey (SDSS data release 7) photometric detections. The study has been published in the Monthly Notices of the Royal Astronomical Society (MNRAS) and has produced a catalogue of about 6 million point sources with probable class labels describing their nature (see the figure). They have used a Bayesian algorithm to correlate the spectroscopic class of a subset of unresolved objects from SDSS to its colour in a ten dimensional feature space. This information is used to estimate the Bayesian prior and likelihood for later classifying about 6 million unresolved point sources from SDSS that do not have a spectra. The catalogue has a spectroscopic completeness up to z ~ 2.6 and has a small fraction of objects that are two orders of magnitude fainter than the SDSS spectroscopic limit in the i-band. They have compared their predictions with about 30 different

spectroscopic catalogues and have shown that the predictions agree with more than 95% of the spectroscopic confirmations and that there is no systematic deviation in the predictions at fainter magnitudes, except those due to colour estimation uncertainties. To reduce this effect, they have removed all objects with magnitude uncertainties greater than 0.2 from the final catalogue. They have also shown that the predicted number counts of quasars in their catalogue closely match with theoretical estimates. According to this study, the quasar number density in the SDSS foot print at limiting magnitude g ~ 22 is 116 per square degree for a redshift cut off z ~2.6. It falls to ~54 and ~ 18 per square degree at g ~ 21 and g ~ 20 respectively, and is well in agreement with observations. The research was supported by ISRO Respond project ISRO/RES/2/339/2007-2008 and the publication charges for the MNRAS paper was shared by both IUCAA and NCRA.

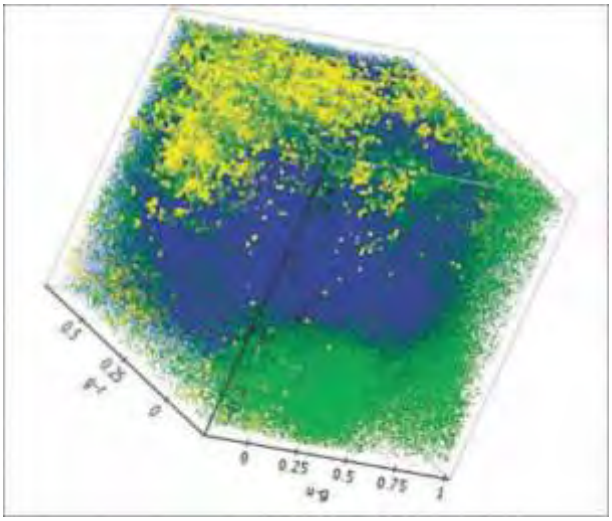


Figure : The 3D colour space distribution (u-g, g-r, r-i) of the six million unresolved objects in the catalogue produced by the current study is shown. The quasars are coloured in blue, galaxies in yellow and stars in green.

Anirudh Pradhan

Anisotropic Bianchi type-I magnetized string cosmological models with decaying vacuum energy density Ë

A spatially homogeneous and anisotropic Bianchi-I cosmological models representing massive strings with magnetic field and decaying vacuum energy density Ë have been studied. The energy-momentum tensor, as formulated by Letelier (1983), has been used to construct massive string cosmological models for which, it is assumed the expansion scalar in the models is proportional to one of the components of shear tensor. The Einstein's field equations have been solved by applying a variation law for generalized Hubble's parameter in Bianchi-I spacetime. The variation law for Hubble's parameter generates two types of solutions for the average scale factor; one is of power-law type and other is of the exponential form. Using these two forms, Einstein's field equations are solved separately that correspond to expanding singular and non-singular models of the universe respectively. The author has made a comparative study of accelerating and decelerating models in the presence of string scenario. The study reveals that massive strings dominate in the decelerating universe, whereas strings dominate in the accelerating universe. The strings eventually disappear from the universe for sufficiently large times, which is in agreement with current astronomical observations. The cosmological constant Ë is found to be a positive decreasing function of time, which is corroborated by results from recent supernovae Ia observations. The physical and geometric properties of the models have been also discussed in detail.

Accelerating dark energy models in Bianchi type-V spacetime

A. Pradhan and H. Amirhashchi have obtained some new exact solutions of Einstein's field equations in a spatially homogeneous and anisotropic Bianchi type-V spacetime with minimally interaction of perfect fluid, and dark energy components have been obtained. To prevail the deterministic solution, has been chosen the scale factor $a(t) = \sqrt{(t^n e^t)}$, which yields a time dependent deceleration parameter (DP), representing a model which generates a transition of the universe from the early decelerating phase to the recent accelerating phase. They have found that for $n \geq 1$, the quintessence model is reproducible with present and expected future evolution of the universe. The other models (for $n < 1$), the phantom scenario has been obsvered. The quintessence as well as phantom models approach to isotropy at late time. For different values of n, it is possible to generate a class of physically viable DE models. The cosmic jerk parameter in the descended model is also found to be in good concordance with the recent data of astrophysical observations under appropriate condition. The physical and geometric

properties of spatially homogeneous and anisotropic cosmological models have been discussed.

Farook Rahaman

The (2+1)-dimensional gravastars

The author in collabration with Saibal Ray, A.A. Usmani, Safiqul Islam has proposed a new model of a *gravastar* in (2+1) anti-de Sitter spacetime. This new three dimensional configuration has three different regions with different equations of state: [I] Interior: $0 < r < r_1$, $\rho = -p$; [II] Shell: $r_1 < r < r_2$, $\rho = p$; [III] Exterior: $r_2 < r$, $\rho = p = 0$. The outer region of this gravastar corresponds to the exterior (2+1) anti-de Sitter spacetime, popularly known as the BTZ spacetime. Like BTZ model, Ë is taken to be negative, which at the junction turns out to be positive as required by stability of gravastar and mathematical consistency. After investigating the Interior, Shell and Exterior spacetimes he has highlighted different physical features in terms of length and energy, entropy, and junction conditions of the spherical distribution. It is shown that the present model of charge-free gravastar in connection to the exterior (2+1) anti-de Sitter spacetime or the BTZ spacetime is non-singular.

Saibal Ray

R. G. Chandra: A self-taught sky watcher and his contributions in observational astronomy

Radha Gobinda Chandra was a self-taught astronomer of a remote village of Indian subcontinent. By virtue of his sheer perseverance, determinism and love for sky watching, he achieved so much dexterity in observational astronomy that his observational results (mainly related to variable stars) were highly valued by famous astronomers of Europe and USA. A detailed account of the life and works of R. G. Chandra has been presented, which reveals his role, as an amateur astronomer, in the development of astronomy. This work was done in collaboration with S.N. Biswas and U. Mukhopadhyay.

A comparison of Hořava-Lifshitz gravity and Einstein gravity through thin-shell wormhole construction

The authors have constructed a new class of thin-shell wormholes from black holes in Hořava–Lifshitz gravity. Particular emphasis is placed on those aspects that allow a comparison of Hořava–Lifshitz gravity to Einstein gravity. The former enjoys a number of advantages for small values of the throat radius. This work was done in collaboration with F. Rahaman, P.K.F. Kuhfittig, M. Kalam and A.A. Usmani.

Pramoda K. Samal

Effect of foregrounds on the cosmic microwave background radiation multipole alignment

The authors have analysed the effect of foregrounds on the observed alignment of the cosmic microwave background radiation (CMBR) quadrupole and octopole. The alignment between these multipoles is studied by using a symmetry-based approach, which assigns a principal eigenvector (PEV) or an axis with each multipole. The alignment between these multipoles and its significance using the internal linear combination (ILC) 5- and 7-yr maps has been determined. The internal power spectrum estimation (IPSE) procedure on the corresponding Wilkinson Microwave Anisotropy Probe data sets has been applied to assess its significance. The effect of foreground cleaning is studied in detail within the framework of the IPSE method, both analytically and numerically. By using simulated CMBR data, including foregrounds and detector noise, it is possible to study how the PEVs of the simulated pure CMB maps differ from those of the corresponding clean maps. It is found that, in general, the shift in the PEVs is relatively small and in random directions. Because of the random nature of the shift, it is concluded that the residual foregrounds can only lead to misalignment rather than cause alignment of multipoles. It is found that the results in this case are identical to those obtained by simple analytic estimates or by using simulated pure CMB maps. This work was done in collaboration with Pavan K. Aluri, Pankaj Jain and John P. Ralston.

Asoke Kumar Sen

Laboratory astrophysics programme at Assam University

With a laser source and a CCD detector on the two arms of a goniometer, a bidirectional reflection (scattering) experiment has been set up at Assam University, Silchar.

Synthetic Regolith surfaces (as analogues for asteroid surfaces) are illuminated and reflection properties of different sample materials are studied.

The author has performed laboratory based photometry of the light scattered from the surfaces of powdered alumina (Al2O3) at various tilt angles of the sample and at large phase angles, with the particles having diameter 0.3 micron . The wavelength of observation was 632.8 nm. These data have been fitted by a surface scattering model originally suggested by Hapke. Instead of using empirical Henyey–Greenstein phase function to fix the values of albedo and phase function to be used within Hapke formula, he has used Mie theory for the same. This approach helped us to determine the single particle properties such as particle diameter and complex refractive index from surface scattering phase curve alone. Mie theory depends only on the size parameter X(=2p(radius/wavelength)) and complex refractive index (n, k) of the material. Since the absorption coefficient (k) for alumina is known, the best fit to the experimental data has been obtained by least square technique.

Model for cometary grains : Combination of compact and aggregate

Both the in situ measurement of Comet 1P/ Halley and the Stardust-returned samples of Comet Wild 2 showed the presence of a mixture of compact and aggregate particles, with both silicates and organic refractory being in the composition of the cometary dust. Results obtained recently from the Stardust mission suggest that the overall ratio of compact to aggregate particles is 65:35 (or 13:7) for Comet 81P/Wild 2. Here, Asoke Kumar Sen has proposed a model that considers cometary dust as a mixture of compact and aggregate particles, with a composition of silicate and organic. He has considered compact particles as spheroidal particles and aggregates as both ballistic cluster–cluster aggregate (BCCA) and ballistic agglomeration with two migrations (BAM2) aggregate with a certain size distribution. The mixing ratio of compact to aggregate particles is taken to be 13:7. For modelling Comet 1P/Halley, the power-law size distribution $n(a) \sim a^{-2.6}$, obtained from a re-analysis of the Giotto spacecraft data, for both compact and aggregate particles, is used. He has considered a mixture of BAM2 and BCCA aggregates with a lower cut-off size of about 0.20 ì m and an upper cut-off of about 1 µm. Further, a mixture of prolate, spherical and oblate compact particles with an axial ratio (E) of 0.8 – 1.2, where a lower cut-off size of about 0.1 ì m and an upper cut-off of about 10ì m are considered.

Ranjan Sharma

A class of interior solutions corresponding to a (2+1) dimensional asymptotically anti-de Sitter spacetime

R. Sharma along with F. Rahaman and I. Karar, have shown that the lower dimensional gravity has the potential of providing non-trivial and valuable insight into some of the conceptual issues arising in four dimensional relativistic gravitational analyses. Consequently, the asymptotically anti-de Sitter (2+1) dimensional spacetime described by Banados, Teitelboim and Zanelli (BTZ), which admits a black hole solution, has become a source of fascination in recent years. By suitably choosing the form of the mass function m(r), they have obtained a new class of solutions representing the interior spacetime of a star corresponding to the exterior (2+1) dimensional asymptotically anti-de Sitter BTZ spacetime. The class of solutions obtained has been found to be regular at the centre satisfying all the physical requirements of a realistic star. In the model, a thin ring of matter content with negative energy density was found to be essential for continuity of the affine parameters across the boundary of the star. The solution may find its applications in the analysis of gravitational collapse in lower dimensions.

Relativistic stars undergoing non-adiabatic radiative collapse under different initial conditions

R. Sharma and R. Tikekar have examined the role of spacetime geometry in the non-adiabatic collapse of a star dissipating energy in the form of radial heat flow, studying its evolution under different initial conditions. The collapse of a star filled with a homogeneous perfect fluid has been compared with that of a star filled with inhomogeneous imperfect fluid under anisotropic pressure. Both the configurations are spherically symmetric, however, in the latter case, the physical space t = constant of the configurations endowed with spheroidal or pseudo-spheroidal geometry, has been assumed to be inhomogeneous in nature. It has been observed that as long as the collapse is shear-free, its evolution depends only on the mass and size of the star at the onset of collapse. The

collapse rate of stars having identical initial masses and radii have been found to be independent of the geometry of their interior physical spacetimes. Since the geometry of the physical space of a star in equilibrium is related with the composition of the interior matter of the star, this implies that stellar configurations having identical initial masses and radii irrespective of their compositions, after loss of equilibrium, will take same time to become black holes.

Harinder P. Singh

Overshooting above a stellar type convection zone

As compressible convection has inherent up/down asymmetry, overshooting above and below a convection zone behaves differently. In downward overshooting, the narrow down-flow columns dynamically play an important role. The work done in collaboration with colleagues at the University of Science and Technology discusses the results of a set of numerical experiments that investigate the problem of overshooting above a convection zone. Particle tracing and colour advection are used to follow the mixing process. The overshoot region above a convection zone is found to contain multiple counter cell layers.

Physical parameters of eclipsing binary stars from the ASAS-3 database

Eclipsing binaries are important astronomical targets for determining the physical parameters of component stars and an independent direct method of measuring the radii of stars. In this work done with Sukanata Deb, the author has presented a detailed light curve analysis of publicly available V band observations of 62 binary stars, mostly contact binaries, obtained by the All Sky Automated Survey (ASAS)-3 project between 2000 and 2009. The periods, ephemeris and the Fourier parameters were re-determined from the phased light curves, which were then used for preliminary classification of the stars. The phased light curves were further analysed with the aid of the Wilson-Devinney code in order to obtain various geometrical and physical parameters of these binaries. The spectroscopic mass ratios as determined from the radial velocity measurements available in the literature were used as one of the inputs to the light curve modelling. Thus, reliable estimates of parameters of these binaries were obtained with combined photometric and spectroscopic data and error estimates were made using the heuristic scan method. Out of 62 stars in the sample, photometric analysis of 39 stars are presented for the first time using the ASAS photometry and precise spectroscopic mass ratios. From the analysis, the stars were classified as 54 contact binaries, 6 semi-detached binaries, and 2 detached binaries.

Pranjal Trivedi

Cosmic microwave background trispectrum and primordial magnetic fields

A new probe of cosmic magnetic fields, the trispectrum, has been calculated that improves the knowledge about magnetic fields on large scales in the universe.

Magnetic fields are observed in galaxies and clusters of galaxies and recent *Fermi/LAT* observations also hint at cosmic magnetic fields being present throughout the universe. However, the origin of such cosmic magnetic fields is a puzzle. An interesting possibility is that such magnetic fields are of primordial origin, formed in the early universe. A key to understanding their origin may lie in studying how they alter the fluctuations of the cosmic microwave background (CMB). In particular, the intrinsically non-linear magnetic effects will introduce a new kind of non-Gaussianity in the CMB fluctuations.

Pranjal Trivedi along with collaborators T. R. Seshadri and Kandaswamy Subramanian has calculated a new effect, the magnetic CMB trispectrum. The trispectrum, or the four-point correlation in harmonic space, is a measure of non-Gaussian fluctuations in the CMB radiation. It is found that magnetic fields can produce a significant amount of trispectrum in the CMB. In fact, the trispectrum turns out to be a more sensitive probe of magnetic fields than the CMB bispectrum (three-point correlation) studied by this group and other researchers recently. The latest WMAP7 observational limits on CMB non-Gaussianity are compared to the magnetic scalar trispectrum predictions. The strongest constraints (known so far), thus, emerge on cosmic magnetic fields, placing their strength below or about one nano Gauss at present, on megaparsec scales.

These first trispectrum results improve upon all previous probes of large-scale magnetic fields by a factor of two or three. The trispectrum, thus, emerges as a new and powerful probe of primordial magnetism using the CMB.

Paniveni Udayashankar

Solar convection and solar supergranulation

The author 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 is obtained according to the relation $P \propto A^{D/2}$, where 'A' is the area and 'P' is the perimeter of the supergranular cells. There is 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.

Observations of the solar photosphere through high resolution instruments have long indicated that the surface of the Sun in not a tranquil, featureless surface, but is beset with a granular appearance. These cellular velocity patterns are a visible manifestation of sub-photospheric convection currents, which contribute substantially to the outward transport of energy from the deeper layers, thus, maintaining the energy balance of the Sun as a whole.

Convection is the chief mode of transport in the outer layers of all cool stars such as the Sun. Convection zone of thickness 30% of the solar radius lies in the sub-photospheric layers of the Sun. Here the opacity is so large that heat flux transport is mainly by convection rather than by photon diffusion. Convection is revealed on four scales. On the scale of 1000 km, it is granulation and on the scale of 30000 km, it is supergranulation. Mesogranulation represents 8 - 10 arcsec scale of convection.The largest reported manifestations of convection in the Sun are 'Giant Cells'or 'Giant Granules', on a typical length scale of about 10^8 m.

The standard solar model has reached remarkable accuracy. It is, thus, natural to extend the interest in the Sun to other stars. The profiles of spectral lines are related to several properties of the star such as gravity, opacity, etc. By comparing the theoretically computed spectra and the observed ones, it is possible to infer values of these properties in the star and assess the discrepancies between the model and the star.

Anisul Ain Usmani

Charged gravastars admitting conformal motion

A. A. Usmani in collaboration with F. Rahaman, Saibal Ray, K.K. Nandi, Peter K.F. Kuhfittig, Sk.A. Rakib and Z. Hasan.has proposed a new model of a gravastar admitting conformal motion. While retaining the framework of the Mazur–Mottola model, the gravastar is assumed to be internally charged, with an exterior defined by a Reissner–Nordström, instead of a Schwarzschild line element. The solutions, obtained by exploiting an assumed conformal Killing vector, involve (i) the interior region, (ii) the shell, and (iii) the exterior region of the sphere. Of these three cases, the first one is of primary interest, since the total gravitational mass here turns out to be an electromagnetic mass under some specific conditions. This suggests that the interior de Sitter vacuum of a charged gravastar is essentially an electromagnetic mass model that must generate gravitational mass, which provides a stable configuration by balancing the repulsive pressure arising from charge with its attractive gravity to avert a singularity. Therefore, the present one, like the Mazur–Mottola model, results in the construction of a compact astrophysical object, as an alternative to a black hole. They have also analyzed various other aspects, such as the stress energy tensor in the thin shell and the entropy of the system.

PUBLICATIONS BY VISITING ASSOCIATES OF IUCAA

(A) JOURNALS

A. Ghosh, S. Bharadwaj, **S.S. Ali** and J.N. Chengalur (2011) *Improved foreground removal in GMRT 610 MHz observations towards redshifted 21-cm tomography,* MNRAS, **418**, 2584.

G. Ambika and R.E. Amritkar (2011) *Synchronizing time delay systems using variable delay in coupling,* Chaos, Solitons and Fractals, **44**, 1035.

V. Resmi, **G. Ambika** and R.E. Amritkar (2011) *General mechanism for amplitude death in coupled systems,* Phys. Rev., **E 84**, 046212.

G. Ambika and R.E. Amritkar (2011) *Delay or anticipatory synchronization in one way coupled systems using variable delay with reset,* Pramana (J. Phys), **77**, 891.

A. Cavaglia, A. Fring and **B. Bagchi** (2011) *PT symmetry breaking in complex nonlinear wave equation and their deformations,* J. Phys., **A44**, 325201.

B. Bagchi and C. Quesne (2011) *Comment on supersymmetry, PT symmetry and spectral bifurcation,* Annals of Phys., **326**, 534.

Tanwi Bandyopadhyay (2011) *Modified holographic dark energy and phantom behaviour of Randall-Sundrum brane,* Int. J. Th. Phys., **50**, 3284.

Tanwi Bandyopadhyay and **Ujjal Debnath** (2011) *A study of generalized second law of thermodynamics in magnetic universe in the light of non-linear electrodynamics,* Phys., Lett., B **704**, 95.

S. Chakraborty and **U. Debnath** (2011) *Brans-Dicke theory in an anisotropic model with a viscous fluid,* Gravitation and Cosmology, **17(3)**, 280.

S. Maity, **S. Chakraborty** and **U. Debnath** (2011) *Correspondence between electro-magnetic field and other dark energies in non-linear electrodynamics,* Int. J. Mod. Phys., **D 20(12)**, 2337.

P.B. Khatua, **S. Chakraborty** *and* ***U. Debnath*** *(2011) Dilaton dark energy model in f(R), f(T) and Horava-Lifshitz gravities,* Int. J. Th. Phys., **51(2)**, 405.

S. Chakraborty *and* ***U. Debnath*** *(2012) The effects of tachyonic and phantom fields in the intermediate and logamediate scenarios of the anisotropic universe,* Int. J. Th. Phys., **51(4)**, 1224.

S. Chakraborty *and* ***U. Debnath*** *(2012) Role of Chameleon field in presence of variable modified Chaplygin gas in brans-dicke theory,* Can. J. Phys., **90(2)**, 131.

N. Mazumder, R. Biswas and **Subenoy Chakraborty** (2011) *Interacting three fluid system and thermodynamics of the universe bounded by the event horizon,* Gen. Rel. Grav., **43**,1337.

J. Dutta and **Subenoy Chakraborty** (2011) *Generalized law of thermodynamics for interacting dark energy in the DGP braneworld,* Int. J. Th. Phys., **50**,2383.

R. Biswas, N. Mazumder and **Subenoy Chakraborty** (2011) *Lemaitre-Tolman-Bondi model of the universe and hawking radiation of a dynamical horizon,* Int. J. Th. Phys., **51**,101.

Subenoy Chakraborty, N. Mazumder and R. Biswas (2011) *Cosmological evolution across phantom crossing and the nature of the horizon,* Astrophys. and Space Science, **334**,183.

N. Mazumder, R. Biswas and **Subenoy Chakraborty** (2011) *Thermodynamics of Lemaitre-Tolman-Bondi model,* Gen. Rel. Grav., **43**,1287.

S. Chakraborty and **Subenoy Chakraborty** (2011) *Trajectory around a spherically symmetric non-rotating black hole,* Can. J. Phys., **89**, 689.

S. Mukherji, R. Biswas, N. Mazumder and **Subenoy Chakraborty** (2012) *How does inflation depend upon the nature of fluids filling up the universe in brane world scenario,* Astrophys. and Space Science, **337**, 425.

Subenoy Chakraborty, R. Biswas and N. Mazumder (2011) *Unified first law and some comments,* Nuovo Cim., B **125**,1209.

W. Uddin, B. Schmieder, **R. Chandra,** A.K. Srivastava, P. Kumar and S. Bisht (2012) *Observations of multiple surges associated with magnetic activities in AR10484 on 25 October 2003,* Ap. J., **752**, 1.

B. Schmieder, P. Démoulin, E. Pariat, T. Török, G. Molodij, C.H. Mandrini, S. Dasso, **R. Chandra,** W. Uddin, P. Kumar, P.K. Manoharan, P. Venkatakrishnan and N. Srivastava (2011) *Actors of the main activity in large complex centres during the 23 solar cycle maximum,* Adv. Space Res., **47**, 2081.

R. Chandra, B. Schmieder, C.H. Mandrini, P. Démoulin, E. Pariat, T. Török, G. Aulanier, W. Uddin and M.G. Linton (2011) *Study of solar flares and filament interaction in NOAA 10501 on 20 November 2003,* Bull. Astron. Soc. India, Conference Series, **2**, 323.

Suresh Chandra, Amit Kumar, B.K. Kumthekar and M.K. Sharma (2011) *Suggestion for the search of H_2CC in cool cosmic objects*, New Astronomy, **16**, 152.

Suresh Chandra and B.K. Kumthekar (2011) *Intermediate magnetoacoustic waves,* Rom. Astron. J., **21**, 47.

Tanuka Chattopadhyay, Asis Kumar Chattopadhyay and Abisa Sinha (2011) *Modeling of the initial mass function using the Metropolis-Hastings algorithm,* Ap. J., **736(2),** 152.

Arindam Gupta, Sabyasachi Bhattacharya and **Asis Kumar Chattopadhyay** (2012) *Exploring new models for population prediction in detecting demographic phase change for sparse census data,* Comm. Statistics, Theory and Methods, **41,** 1171.

Tanuka Chattopadhyay, M Sharina, E. Davoust, Tuli De and **Asis Kumar Chattopadhyay** (2012) *Uncovering the formation of ultra-compact dwarf galaxies by multivariate statistical analysis,* Ap. J., **750(2)**,91.

Saptarshi Mondal, Bharat Warule and **Tanuka Chattopadhyay** (2011) *Fundamental plane for galaxy data with measuremental error,* CSA Bulletin, **62**, 277.

Surajit Chattopadhyay (2011) *Interacting Ricci dark energy and its statefinder description*, Euro. Phys. J. Plus, **126**, 130.

Surajit Chattopadhyay and **Ujjal Debnath** (2011) *Role of generalized Ricci dark energy on Chameleon field in the emergent universe*, Can. J. Phys., **89**, 941.

Ujjal Debnath and **Surajit Chattopadhyay** (2011) *Generalized second law of thermodynamics in emergent universe*, Int. J. Th. Phys., **50**, 3415.

Surajit Chattopadhyay and **Ujjal Debnath** (2011) *Emergent universe in the Chameleon, f(R) and f(T) gravity theories*, Int. J. Mod. Phys., D **20**, 1135.

Surajit Chattopadhyay, Deepak Jhajharia and Goutami Chattopadhyay (2011) *Trend estimation and univariate forecast of the sunspot numbers: Development and comparison of ARMA, ARIMA and Autoregressive Neural Network models*, Comptes Rendus Geoscience, **343**, 433.

Surajit Chattopadhyay, Goutami Chattopadhyay (2011) *The possible association between summer monsoon rainfall in India and sunspot numbers,* International Journal of Remote Sensing, **32,** 3, 891.

Surajit Chattopadhyay (2012) *Generalized Ricci dark energy in Horava-Lifshitz gravity*, Euro. Phys. J. Plus, **127**, 16.

Ujjal Debnath, **Surajit Chattopadhyay**, Ibrar Hussain, Mubasher Jamil and Ratbay Myrzakulov (2012) *Generalized second law of thermodynamics for FRW cosmology with power-law entropy correction,* Euro. Phys. J. C - Particles and Fields, **72**, 1875.

Chayan Ranjit and **Surajit Chattopadhyay** (2012) *Study of tachyonic field and its statefinder diagnostics in various scenarios of the anisotropic universe*, Can. J. Phys., **90**, 97.

Ujjal Debnath, Mubasher Jamil and **Surajit Chattopadhyay** (2012) *Fractional action cosmology: emergent, logamediate, intermediate, power law scenarios of the universe and generalized second law of thermodynamics*, Int. J. Th. Phys., **51**, 812.

Rahul Ghosh, **Surajit Chattopadhyay** and **Ujjal Debnath** (2012) *A dark energy model with generalized uncertainty principle in the emergent, intermediate and logamediate scenarios of the universe*, Int. J. Th. Phys., **51**, 589.

Arundhati Das, **Surajit Chattopadhyay** and **Ujjal Debnath** (2012) *Validity of the generalized second law of thermodynamics in the logamediate and intermediate scenarios of the universe*, Found. Phys., **42**, 266.

Zoltan Batiz and **Bhag C. Chauhan** (2011) *Green's function formalism of holography with arbitrary mass, spin, and dimensionality,* Physics: Optics, **1109**., 4996.

Bhag C. Chauhan (2012) *Historical dating of Karsog Shiv Temple.* Itihaas Diwakar, **4,** 4.

H. S. Das, D. Paul, A. Suklabaidya and **A. K. Sen** (**2011**) *Modelling the polarization properties of Comet 1P/Halley using a mixture of compact and aggregate particles*, MNRAS, **416**, 94.

C. Bhattacharjee, D. Deb, **H. S. Das**, **A. K. Sen** and R. Gupta (**2011**) *Modelling of laboratory data of bi-directional reflectance of Regolith surface containing alumina*, Pub. Astron. Soc. Aus., **28**, 261.

D. Deb, **A. K. Sen**, **H. S. Das** and R. Gupta (**2011**) *The photometric study of light scattering from the surface of alumina powder and interpretations by Hapke formula*, Adv. Space Res., **48**, 1274.

A.K. Singha and **U. Debnath** (2011) *Accelerating universe in Brans-Dicke theory in presence of Chaplygin gas,* Int. J. Th. Phys., **50**, 1536.

M. Jamil and **U. Debnath** (2011) *FRW cosmology with variable G and Λ,* Int. J. Th. Phys., **50**, 1602.

M. Jamil and **U. Debnath** (2011) *Interacting modified Chaplygin gas on loop quantum cosmology,* Astrophys. and Space Sci., **333**, 3.

U. Debnath (2011) *Thermodynamics in quasi-spherical Szekeres spacetime,* Europhys. Lett., **94**, 29001.

U. Debnath and S. Chakraborty (2011) *Emergent universe with exotic matter in brane world scenario,* Int. J. Th. Phys., **50**, 2892.

S. Bhattacharya and **U. Debnath** (2011) *Thermodynamical laws in Horava-Lifshitz gravity,* Int. J. Mod. Phys., D, **20**, 1191.

M.U. Farooq, M. Jamil and **U. Debnath** (2011) *Dynamics of interacting phantom and quintessence dark energies,* Astrophys. and Space Sci., **334**, 243.

S. Chattopadhyay and **U. Debnath** (2011) *Interaction between tachyon and Hessence (or Hantom) dark energies,* Int. J. Th. Phys., **50**, 3166.

S. Bhattacharya and **U. Debnath** (2011) *Brans-Dicke theory and thermo-dynamical laws on apparent and event horizons,* Can. J. Phys., **89**, 883.

U. Debnath and M. Jamil (2011) *Correspondence between DBI-essence and modified Chaplygin gas and the generalized second law of thermodynamics,* Astrophys. and Space Sci., **335**, 545.

P. Rudra, R. Biswas and **U. Debnath** (2011) *Gravitational collapse in generalized vaidya spacetime for Lovelock gravity theory,* Astrophys. and Space Sci., **335**, 505.

U. Debnath, (2011) *Modified Chaplygin gas with variable G and Λ,* Chinese Phys. Lett., **28**, 119801.

S. Bhattacharya and **U. Debnath** (2012) *Thermodynamics of modified Chaplygin gas and tachyonic field,* Int. J. Th. Phys., **51**, 565.

S. Bhattacharya and **U. Debnath** (2012) *Study of Thermodynamics in generalized holographic and Ricci dark energy models,* Int. J. Th. Phys., **51**, 577.

J. Dutta and **U. Debnath** (2012) *Reconstruction of potentials as well as dynamics of scalar fields in DGP braneworld model,* Int. J. Th. Phys., **51**, 639.

U. Debnath (2012) *Holographic dark energy interacting with two fluids and validity of generalized second law of thermodynamics,* Astrophys. and Space Sci., **337**, 503.

J. Bhadra and **U. Debnath** (2012) *Dynamical system analysis of interacting variable modified Chaplygin gas model in FRW universe,* Euro. Phys. J. Plus, **127**, 1.

P.B. Khatua and **U. Debnath** (2012) *Statefinder description in generalized holographic and Ricci dark energy models,* Int. J. Th. Phys., **51**, 1155.

J. Bhadra and **U. Debnath** (2012) *Accretion of new variable modified Chaplygin gas and generalized cosmic Chaplygin gas onto Schwarzschild and Kerr-Newman black holes,* Euro. Phys. J., C **72**, 1912.

Taparati Gangopadhyay, Xiang-Dong Li, Subharthi Ray, **Mira Dey** and **Jishnu Dey** (2012) *kHz QPOs in LMXBs, relations between different frequencies and compactness of stars,* New Astron., **17**, 43.

Subharthi Ray, Taparati Gangopadhyay, **Mira Dey** and **Jishnu Dey** (2011) *Estimate of stellar masses from their QPO frequencies,* Pramana, **77**, 1.

R. Banerjee and **Sunandan Gangopadhyay** (2011) *Komar energy and Smarr formula for noncommutative Schwarzschild black hole,* Gen. Rel. Grav., **43**, 3201.

R. Banerjee, **Sunandan Gangopadhyay** and D. Roy (2011) *Hamiltonian analysis of symmetries in a massive theory of gravity,* JHEP, **1110**, 121.

Sunandan Gangopadhyay and D. Roychowdhury (2012) *Voros product, noncommutative inspired Reissner-Nordstrom black hole and corrected area law,* Int. J. Mod. Phys., **A27**, 1250041.

Sunandan Gangopadhyay, R. N. Deb and F. G. Scholtz (2012) *Statistical interparticle potential on noncommutative space*, Europhys. Lett., **97**, 21001.

Sushant G. Ghosh (2012) *Nonstatic charged BTZ-like black holes in N+1 dimensions,* Int. J. Mod. Phys., **D21**, 1250022.

Sushant G. Ghosh (2011) *5D Radiating black holes in Einstein-Yang-Mills-Gauss-Bonnet gravity,* Phys. Lett., **B704**, 5.

Pinaki Bhattacharya and **Sarbari Guha** (2012) *A dynamical systems analysis of motion in the bulk with respect to the brane***,** Physica Scripta, **85**, 025001.

Sarbari Guha and **Subenoy Chakraborty** (2012) *Five-dimensional warped product spacetime with time-dependent warp factor and cosmology of the four-dimensional universe,* Int. J. Th. Phys., **51**, 55.

Ng. Ibohal and T. Ibungochouba (2011) *Hawking's radiation in non-stationary rotating de Sitter background,* Astrophy. Space Sci., **333**, 175.

Ng. Ibohal, Ngangbam Ishwarchandra and K. Yugindro Singh (2011) *Non-vacuum conformally flat spacetimes: Dark energy,* Astrophys. and Space Sci., **335**, 581.

Jincy Devasia, Marykutty James, Biswajit Paul and **Kavila Indulekha** (2011) *RXTE-PCA observations of 1A 1118-61: Timing and spectral studies during an outburst,* MNRAS, **414**, 1023.

Jincy Devasia, Marykutty James, Biswajit Paul and **Kavila Indulekha** (2011) *Timing and spectral studies of the transient X-ray pulsar GX 304-1 during an outburst,* MNRAS, **417**, 348.

R. Rakhi, **K. Indulekha** and **Minu Joy** (2011) *Dark energy and tracker solution ALFOMINE,* Int. J. Part A (Sciences), **1 (1)**, 49.

Naseer Iqbal, A. Ajaz, M. Tabasum and V. Manyak (2011) *Study of impact materials of Akhnoor Meteor Crator in Jammu and Kashmir (India),* Natural Science, **3(6)**, 426.

S. Aniket, B. Ajaz, V. Manyak, **N. Iqbal** and M. Tabasum (2011) *Indian record for Keplers supernova: An evidence from Kashmir Valley,* Astron. Nachr. AN, **332**, 655.

Naseer Iqbal, M.K. Shafi, M. Tabasum and S. Ibrahim (2012) *Thermodynamical model of universe,* Electronic J. of Th. Phys., **9(26)**, 283.

R. Nair, **S. Jhingan** and **Deepak Jain** (2011) *Observational cosmology and the cosmic distance duality relation,* J. Cos. Astropart. Phys., **05**, 023.

R. Nair, **S. Jhingan** and **Deepak Jain** (2012) *Cosmokinetics: A joint analysis of standard candles, rulers and cosmic clocks*, J. Cos. Astropart. Phys., **01**, 018.

Anirudh Pradhan, Shyam Sundar Kumhar, Padmini Yadav and **Kanti Jotania** (2012) *A new class of LRS Bianchi type VI_0 universe with free gravitational field and decaying energy density,* Int. J. Math. Engg. Sci., **1**, 2.

A. Pradhan, R. Jaiswal, **K. Jotania** and R.K. Khare (2012) *Bianchi type VI_0 dark energy models with time dependent deceleration parameter,* Astrophys. and Space Sci., **337**, 401413.

Farook Rahaman, P.K.F. Kuhfittig, **M. Kalam**, **A.A. Usmani** and **Saibal Ray** (2011) *A comparison of Hoøava-Lifshitz gravity and Einstein gravity through thin-shell wormhole construction,* Class. Quan. Grav., **28**, 5021.

F. Rahaman, Peter K.F. Kuhfittig, K. Chakraborty, **M. Kalam** and D. Hossain (2011) *Modeling galactic halos with predominantly quintessential matter,* Int. J. Th. Phys., **50,** 2655.

N. Kumar, P. Kumar, A. Kumar and R. Chauhan (2011) *Role of equilibrium plasma flow on damping of slow MHD waves,* Indian J. Phys., **85(12)**, 1879.

N. Kumar, V. Kumar and H. Sikka (2012) *Alfven surface waves in partially ionized resistive medium,* App. Mech. Mat., **110-116**, 867.

Suresh Kumar (2012) *Observational constraints on Hubble constant and deceleration parameter in power-law cosmology,* MNRAS. **422**, 2532.

Nijo Varghese and **V.C. Kuriakose** (2011) *Evolution of massive fields around a black hole in Horava gravity,* Gen. Rel. Grav., **43**, 2757.

Nijo Varghese and **V.C. Kuriakose** (2011) *Evolution of electromagnetic and Dirac perturbations around a black hole in Horava gravity,* Mod. Phys. Lett. **A 26**, 1645.

M. Vivek, R. Srianand, A. Mahabal and **V.C. Kuriakose** (2012) *Dynamically evolving Mg II broad absorption line flow in SDSS J133356.02+001229.1,* MNRAS Lett., **421,** 107.

Badam Singh Kushvah, Ram Kishor and Uday Dolas (2012) *Existence of equilibrium points and their linear stability in the generalized photogravitational Chermnykh-like problem with power-law profile,* Astrophys. Space Sci., **337**, 115.

Manzoor A. Malik, Raja Nisar Ali and **Farooq Ahmad** (2011) *Spatial galaxy distribution function for a three-component system*, Astrophys. Space Sci., **336**, Issue 2, 447.

M. S. Khan and **Manzoor A. Malik** (2012) *Critical phenomena in the cosmological many-body problem*, MNRAS, **421**, issue 3, 2629.

Pradip Mukherjee and Biswajit Paul (2012) *Gauge invariances of higher derivative Maxwell-Chern-Simons field theory – A new Hamiltonian approach,* Phys. Rev., **D 85** ,045028.

Rabin Banerjee, **Pradip Mukherjee** and Biswajit Paul (2011) *Gauge symmetry and W-algebra in higher derivative systems,* JHEP, **1108**, 085.

A. Bhattacharya, G M Garipova, A. A Potapov, A. Bhadra, and **K. K. Nandi** (2011) *The Vacuole model revisited: New repulsive terms in the second order deflection of light,* JCAP, 028 (2011).

P.N. Pandita and Chandradew Sharma (2012) *Radiative neutralino production in low energy supersymmetric models. II. The case of beam polarization,* Phys. Rev., **D 85**, 015021.

M.B. Pandge, N.D. Vagshette, L.P. David and **M.K. Patil** (2012) *Systematic study of X-ray cavities in the brightest galaxy in the Draco constellation NGC 6338,* **421**, 808.

N.D. Vagshette, M.B. Pandge, **S.K. Pandey** and **M.K. Patil** (2012) *Dust extinction and X-ray emission from the starburst galaxy NGC 1482,* New Astron., **17**, 524.

S. Ghose, P. Thakur and **B. C. Paul** (2012) *Observational constraints on the model parameters of a class of emergent universe, Mon. Not. Roy. Astron. Soc.,* 421, 20.

B. C. Paul, P. Thakur and A. Saha (2012) *Modified Chaplygin gas in Horava-Lifshitz gravity and constraints on its B parameter,* Phys. Rev., D 85, 024039.

B.C. Paul, P. Chattopadhyay, S. Karmakar and R. Tikekar (2011) *Relativistic strange star with anisotropy, Mod. Phys. Letts., A 26,* 575.

B. C. Paul, S. Ghose and P. Thakur (2011) *Emergent universe from a composition of matter, exotic matter and dark energy, Mon. Not. Roy. Astron. Soc.,* 413, 686.

Sheelu Abraham, **Ninan Sajeeth Philip**, **Ajit Kembhavi**, Yogesh G. Wadadekar and Rita Sinha (2012) *A photometric catalogue of quasar and other point sources in the Sloan Digital Sky Survey,* MNRAS, **419**, 80.

A. Pradhan (2011) *Anisotropic Bianchi type-I magnetized string cosmological models with decaying vacuum energy density Ë*, Com. Th. Phys., **55**, 931.

H. Amirhashchi, H. Zainuddin and **A. Pradhan** (2011) *Magnetized Bianchi type-III string universe with time decaying vacuum energy density Ë,* Int. J. Th. Phys., **50**, 2531.

A. Pradhan, H. Amirhashchi, and B. Saha (2011) *Bianchi type-I anisotropic dark energy models with constant deceleration parameter,* Int. J. Th. Phys., **50**, 2923.

H. Amirhashchi, **A. Pradhan** and H. Zainuddin (2011) *An interacting and non-interacting two-fluid dark energy models in FRW universe with time dependent deceleration parameter,* Int. J. Th. Phys., **50**, 3529.

A. Pradhan and H. Amirhashchi (2011) *Accelerating dark energy models in Bianchi type-V spacetime*, Mod. Phys. Lett., A **26**, 2261.

A. K. Yadav, **A. Pradhan** and A. K. Singh (2012) *Bulk viscous LRS Bianchi-I universe with variable G and Ë,* Astrophys. Space Sci., **337**, 379.

R. C. Gupta, **A. Pradhan** and S. Gupta (2012) *A novel concept for mass as a complex-mass towards wave-particle duality,* Infinite Energy, USA, **17**, 40.

S. Agarwal, R. K. Pandey and **A. Pradhan**, (2012) *Bianchi type-II string cosmological models in normal gauge for Lyra's manifold with constant deceleration parameter*, Ind. J. Phys., **86**, 61.

F. Rahaman, Peter K.F. Kuhfittig, K. Chakraborty, **A. Usmani** and **S. Ray** (2012) *Galactic rotation curves inspired by a noncommutative-geometry background,* Gen. Rel. Grav., **44**, 905.

F. Rahaman and A. Banerjee (2012) *Thin-Shell Wormholes from black holes with dilaton and monopole fields,* Int. J. Th. Phys., **51**, 901.

A.K. Yadav, **F. Rahaman** and **S. Ray** (2011) *Dark energy models with variable equation of state parameter,* Int. J. Th. Phys., **50**, 871.

Saibal Ray, **Farook Rahaman,** Utpal Mukhopadhyay and Ruby Sarkar (2011) *Variable equation of state for generalized dark energy model,* Int. J. Th. Phys., **50**, 2687.

I. Radinschi, **F. Rahaman** and A. Banerjee (2011) *On the energy of Hoøava-Lifshitz black holes,* Int. J. Th. Phys., **50**, 2906.

I. Radinschi, **F. Rahaman** and A. Banerjee (2012) *The energy distribution of Horava-Lifshitz black hole solutions,* Int. J. Th. Phys., **51**, 1425.

R. Sharma, **F. Rahaman** and I. Karar (2011) *A class of interior solutions corresponding to a (2+1)-dimensional asymptotically anti-de Sitter spacetime,* Phys. Lett., B **704**, 1.

F. Rahaman, R. Maulick, A. K. Yadav, **S. Ray** and **R. Sharma** (2012) *Singularity free dark energy star,* Gen. Rel. Grav., **44**, 107.

Farook Rahaman, **Saibal Ray**, **A.A. Usmani** and Safiqul Islam (2012) *The (2+1)-dimensional gravastars,* Phys. Lett., B. **707**, 31.

A.A. Usmani, **Farook Rahaman**, **S. Ray**, K.K. Nandi, Peter K.F. Kuhfittig, Sk. A. Rakib and Z. Hasan (2011) *Charged gravastars admitting conformal motion,* Phys. Lett., B. **701**, 388.

B. Das, P. C. Ray, I. Radinschi, **F. Rahaman** and **Saibal Ray** (2011) *Isotropic cases of static charged fluid spheres in general relativity,* Int. J. Mod. Phys., D **20,** 1675.

S.N. Biswas, U. Mukhopadhyay and **Saibal Ray** (2011) *R. G. Chandra: A self-taught sky watcher and his contributions in observational astronomy,* Ind. J. Hist. Sci., **46**, 483.

P.P. Ghosh, U. Mukhopadhyay and **Saibal Ray** (2012) *Does accelerating universe permit varying speed of light?,* Astrophys. Space Sci., **337,** 509.

Pavan K. Aluri, **Pramoda K. Samal,** Pankaj Jain and John P. Ralston (2011) *Effect of foregrounds on the cosmic microwave background radiation multipole alignment,* MNRAS, **414**, 1032.

E. Hadamcik, A.C. Levasseur-Regourd, J.-B. Renard, J. Lasue and **A.K. Sen** (2011) *Polarimetric observations and laboratory simulations of asteroidal surfaces : The case of 21-Lutetia,* J. Quant. Spectroscopy and Radiative Transfer, **112**, 1881.

H. S. Das and **A. K. Sen** (2011) *Model for cometary grains to explain optical polarization*, J. Quant. Spectroscopy and Radiative Transfer, **112**, 1833.

K. J. Meech, …., **A. K. Sen,** ….. (total 100 authors) (2011) *EPOXI: Comet 103P/Hartley 2 observations from a worldwide campaign,* Ap. J. Lett., **734**, L1.

D. Deb and **A. K. Sen** (2012) *Light scattering from Regolith: Intensity versus particle size behaviour earth, Moon and Planets*, 10.1007/s11038-011-9384-5.

Isha Pahwa, Debajyoti Choudhury, **T.R. Seshadri** (2011) *Late-time acceleration in higher dimensional cosmology* JCAP, Issue **09,** 015.

R. Sharma and R. Tikekar (2012) *Relativistic stars undergoing non-adiabatic radiative collapse under different initial conditions,* Pramana-J. Phys., **1**.

R. Tikekar and **R. Sharma** (2011) *Geometry, equation of state and the collapse of a star,* Mathematics Today, **26**, 105.

Vinita Suyal, Awadhesh Prasad and **H.P. Singh** (2012) *Hysteresis in a solar activity cycle,* Solar Physics, **276**, 407.

Vinita Suyal, Awadhesh Prasad and **H.P. Singh** (2012) *Symbolic analysis of slow solar wind data using rank order statistics,* Planetary and Space Sci., **62(1)**, 55.

M. Sivakumar, E.Harikumar and N.Srinivas (2011) *Kappa deformed Dirac equation,* Mod. Phys. Lett., **A26**, 1103.

M. Sivakumar (2012) *Basics of renormalisation group: Divide and conquer,* J. Phys. Edu., **28**, 9.

Pranjal Trivedi, **T.R. Seshadri** and Kandaswamy Subramanian (2012) *Cosmic microwave background trispectrum and primordial magnetic fields,* Phys. Rev. Lett., **108**, 231301.

(B) PROCEEDINGS

Asis Kr. Chattopadhyay, Tanuka Chattopadhyay, Tuli Ghosh and Saptarshi Mondal (2012) *Independent component analysis for dimension reduction classification: Hough transform and CASH algorithm,* Astrostatistical Challenges for New Astronomy, Springer Series in Astrostatistics, **Ed.** Joseph Hilbe.

N. Kumar and A. Kumar (2011) *Damping and the period ratio $P_1/2P_2$ of non-adiabatic slow mode,* Proc. of the Int. Astrono. Union 273: Physics of Sun and Star Spots, Vol. 6, Symposium S 273, 491.

N. Kumar and A. Kumar (2011) Effect of flow and thermal conduction on the damping of slow MHD waves, Proc. 30th ICPIG Conference held at Queen's University Belfast, Northern Ireland, UK, A4-345.

N.S. Philip, A. Mahabal, S. Abraham, R. Williams, S.G. Djorgovski, A. Drake, C. Donald and M. Graham, *Classification by boosting differences in input vectors,* Proc. Int. Workshop on Spectral Stellar Libraries ,ASI Series , **Eds.** P. Prugniel and H. P. Singh.

R. Sharma (2011) *Dissipative inhomogeneous collapse of an anisotropic star*, Lambert Academic Publishing, Germany, pp. 36-43, 2011, *Proc. of the Conference on Astrophysics and Astro-particle Physics held at the University of North Bengal during 27-28 January 2011*.

Kwing L. Chan, Tao Cai and **H.P. Singh** (2011) *Overshooting above a convection zone. Astrophysical dynamics: From stars to galaxies,* Proc. Int. Astrono. Union, IAU Symposium, **271**, 317.

(C) BOOKS

Surajit Chattopadhyay (2011) *Some dark energy models for accelerated expansion of the universe: Various dark energy candidates, their interactions, correspondence and thermodynamic consequences,* LAP Lambert Academic Publishing, Germany.

Ujjal Debnath (2011) *Cosmological models in Einstein's gravity and gravitational collapse,* Lambert Academic Publishing, Germany.

S.S. De and **F. Rahaman** (2012) *Finsler geometry of hadrons and Lyra geometry: Cosmological aspects,* Lambert Academic Publishing, Germany.

Saibal Ray and U. Mukhopadhyay (2012) *The Accelerating universe: Role of Ë-dark energy*, Lambert Academic Publishing, Germany.

(D) SUPERVISION OF PH. D. THESIS

Suresh Chandra, Thesis titled *"Alfven waves in viscous, resistive medium around the sun",* by ***Bhagvat K. Kumthekar*** submitted to SRTM University, Nanded.

Suresh Chandra, Thesis titled *"Collision rate coeficients for rotational transitions in H_2CS colliding with He atoms",* by *Amit Kumar* submitted to SRTM University, Nanded.

Suresh Chandra, Thesis titled *"Dispersion relations in solar plasma and their utility",* by *Ganpat M. Dak* submitted to SRTM University, Nanded.

Ujjal Debnath, Thesis titled *"Some possible causes for expansion of the universe",* by *Anup Kumar Singha* submitted to Bengal Engineering and Science University, Howrah.

K. Indulekha and **Minu Joy,** Thesis titled *"Modeling of some observational aspects of cosmological evolution",* by *Rakhi R.* submitted to Mahatma Gandhi University, Kottayam.

K. Indulekha and B. Paul, Thesis titled *"Quasi periodic oscillations in transient accretion powered pulsars",* by *Marykutty James* submitted to Mahatma Gandhi University, Kottayam.

N. Iqbal, Thesis titled *"Astronomical significance of terrestrial impacts and their post effects",* by *Ajaz Ahmad Najar* submitted to University of Kashmir, Srinagar.

A. Pradhan, Thesis titled *"A study on the universe – its dynamic and physical behaviour", by Anju Rai, submitted to* V. B. S. Purvanchal University, Jaunpur.

F. Rahaman, Thesis titled *"Theoretical construction of some Lorentzian wormholes and thin shell wormholes",* by *K. A. Rahman* submitted to Jadavpur University, Kolkata.

F. Rahaman, Thesis titled *"Investigation of spacetime of different topological defects in alternative theories of gravity",* by *R. Mondal* submitted to Jadavpur University, Kolkata.

F. Rahaman, Thesis titled *"Some aspects of static charged fluid spheres in general relativity",* by *B. Das* submitted to Jadavpur University, Kolkata.

H.P. Singh, Thesis titled *"Analysis of light curves of some variable stars",* by *Sukanta Deb* submitted to University of Delhi.

(E) AWARDS

Surajit Chattopadhyay, Fast Track Programme for Young Scientists, DST, New Delhi.

The project title: ***Study of the various aspects of interacting dark energy under modified gravity theories***

IUCAA SPONSORED MEETINGS AND EVENTS AT VARIOUS UNIVERSITIES IN INDIA

Workshop on Teaching and Research with Small Telescopes was conducted at J.E.S. College, Jalna during October 17-19, 2011. The workshop was coordinated by Ranjan Gupta and M.L. Kurtadikar.

[For details see Khagol, Issue No. 89, January 2012]

Workshop on Stellar Astrophysics was conducted by the Department of Physics, University of Kashmir during October 24-26, 2011. The workshop was coordinated by Naseer Iqbal from University of Kashmir and Ranjeev Misra from IUCAA.

[For details see Khagol, Issue No. 89, January 2012]

SCHOOL OF PHYSICAL SCIENCE S.R.T.M. UNIVERSITY NANDED.

National Workshop on GALAXIES : NORMAL and ACTIVE 14 Nov 2011

Workshop on Galaxies: Normal and Active was conducted at the School of Physical Sciences of SRTM University, Nanded during November 14-17, 2011. The coordinators of the workshop were M.K. Patil and Gulab C. Dewangan.

[For details see Khagol, Issue No. 89, January 2012]

Workshop on Gravitational Waves Data Analysis was conducted during January 23-27, 2012. It was cosponsored and organized by Department of Mathematical Sciences, Tezpur University
The workshop was coordinated by Sanjit Mitra and Bhim P. Sarmah

[For details see Khagol, Issue No. 90, April 2012]

IUCAA RESOURCE CENTRES (IRCs)

1) 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. 4 M.Sc. students and 6 B.Sc. students from neighbouring colleges carried out their projects using the facilities available at the Data Centre. Twelve Research students working under IUCAA Associates also use the Data Centre facilities for their research work.

Research

The thrust areas of research are: Physics of black holes, Extended theories of gravity, Observational astronomy, Bose-Einstein condensation, and Quantum optics. 12 research students are now doing research in these areas.

Workshops and Meetings

A. Workshop on Astronomy for School Teachers

The workshop on Astronomy for School Teachers was held during November 3-4, 2011at the Department of Physics. This workshop was attended by 17 school teachers. The programme of the workshop consisted of lectures and hands on sessions. The resource persons for the workshop were Arvind Paranjpye (IUCAA) and V. C. Kuriakose(CUSAT). The research scholars of the Astronomy and Astrophysics group led the hands on sessions.

B. Workshop conducted at other places

1. Summer Mini School in Astronomy at Newman College, Thodupuzha

A mini school in Astronomy for undergraduate students was held at Newman College in collaboration with IRC, CUSAT during May 25-27, 2011. The aim of the school was to expose undergraduate students to the interesting and intriguing world of Astronomy. The programme of the school consisted of introductory lectures in Astronomy and hands on training in data analysis. The resource persons of the School were K. Indulekha (M. G. Univ.), C. D. Ravikumar (Calicut Univ.), Ninan Sajeeth Philip(St. Thomas College, Kozhencherry), N. Shaji (Maharaja's College, Ernakulam) and V. C. Kuriakose (CUSAT). Research students, Vivek M. (CUSAT) and Sheelu Abraham (St. Thomas College, Kozhencherry) led hands on training sessions. Joe Jacob was the local organizer of the programme

2. Workshop in Astrophysics and Cosmology at University of Calicut, Kozhikode

In association with IRC, CUSAT, the Department of Physics, University of Calicut organised a workshop in Astronomy and Cosmology for graduate and postgraduate physics students in colleges under the university during September 22-24, 2011. The aim of the workshop was to introduce basic ideas in Astronomy and Cosmology to the students and to give them training in astronomical data acquisition, processing and analysis, so that they may be able to do independent project work as part of their course work. The resource persons of the workshop were, B. R. S. Babu (Calicut Univ.), George Varghese (Calicut Univ.), A. M. Vinodkumar (Calicut Univ.), C. D. Ravikumar (Calicut Univ.), Ninan Sajeeth Philip (St. Thomas College, Kozhencherry), Sini R. (Providence College, Calicut) and V. C. Kuriakos (CUSAT). Research scholars of the Department, Nikesh M., Preetha and Dhanya Joseph led the hands on sessions. There were about 45 participants. C. D. Ravikumar was the local organizer of this workshop.

3. Workshop on Mathematics for (Astro)Physics at M. G. University, Kottayam

School of Pure and Applied Physics, M. G. University in association with the IRC, CUSAT organized this workshop during September 27 to October 1, 2011. The mode was to introduce the theoretical basis and delineation of calculational procedure followed by actual hands on experience using free software. The resource persons of the workshop were N. Mukunda (IISc, Bangalore), Moncy V. John (St. Thomas College, Kozhencherry), Ninan Sajeeth Philip (St. Thomas College, Kozhencherry), K. P. Harikrishnan (The Cochin College, Kochi), M. K. Haris (IISER, TVM) A. S. Padmanabhan (M. G. Univ.), C. Venugopal (M. G. Univ.), S. Antony (M. G. Univ.), K. Indulekha (M. G. Univ.) and V. C. Kuriakose(CUSAT). There were 30 participants for the workshop and K. Indulekha was the local organizer of the workshop.

4. Workshop on Science with Virtual Observatory at Newman College, Thodupuzha

Newman College in collaboration with the IRC, CUSAT conducted a workshop on Science with Virtual Observatory during October 11-13, 2011. The aim of the workshop was to introduce potential young

researchers to the use of Virtual Observatory tools in modern astronomy research. Marco Mollinaro and Massimo Ramella, INAF, Italy, who have many years of experience in popularising VO among the student community in Italy, were the main architects of this workshop. There were 30 participants, and they were selected on all India basis. The workshop had two components, the lecture sessions and the practice sessions. The lecture sessions introduced the participants to the basic scientific concepts and the practice sessions familiarised them with the use of VO tools. Participants were introduced to the basics of software such as STELLARIUM, ALLADIN, TOPCAT, VOPLOT, VOSTAT, SPLAT, and the methodology of their use to specific research problems. Joe Jacob was the local organizer of the programme

Publications

a) In Refereed Journals

1. Dynamically evolving Mg II broad absorption line flow in SDS J133356.02+001229.1, M. Vivek, R. Srianand, A. Mahabal and V. C. Kuriakose, Mon. Not. R. Astron. Soc., **421,** L107 (2012).

2. Evolution of massive fields around a black hole in Horava gravity, Nijo Varghese and V.C. Kuriakose, Gen Rel. Grav., 43, 2757(2011).

3. Evolution of electromagnetic and Dirac perturbations around a black hole in Horava gravity, Nijo Varghese and V.C. Kuriakose, Mod. Phys. Lett., A 26, 1645 (2011) .

4. Effect of gravity on collective excitations of a quasi two-dimensional Bose Einstein condensate in an anharmonic trap, P.D. Anoop and Ramesh Babu Thayyullathil, Com. Th. Phys., 56, 669 (2011).

5. Control of collapse revival phenomenon using a time varying squeezed field, K.V Priyesh, Ramesh Babu Thayyullathil, of Nonlinear Optical Phys. Materials, 20, 2. (2011).

6. Effect of phase shifted frequency modulation on two level atom-field interaction, K.V. Priyesh and Ramesh Babu Thayyullathil , Com. Th. Phys., 57, 468(2012).

b) Poster/Oral Presentations in Conferences

1. Evolution of massive fields around black hole in Horava gravity, Nijo Varghese and V. C. Kuriakose, 7th International Conference on Gravitation and Cosmology, Goa, December 14-19 (2011).

2. Late time tails of massive fields around Schwarzschild black hole surrounded by quintessence, Nijo Varghese and V. C. Kuriakose, International Conference on Modern Perspectives of Cosmology and Gravitation, Kolkata, February 7-12 (2012).

3. Area and entropy spectra of Schwarzschild black hole surrounded by quintessence, R. Tharanath and V. C. Kuriakose, International Conference on Modern Perspectives of Cosmology and Gravitation, Kolkata, February 7-12 (2012).

4. Stability analysis of black holes in Lovelock model in AdS spacetime, C. B. Prasobh and V. C. Kuriakose, International Conference on Modern Perspectives of Cosmology and Gravitation, Kolkata, February 7-12 (2012).

5. Gravitational waves from f(R) theory, P. Prasia and V. C. Kuriakose, International Conference on Modern Perspectives of Cosmology and Gravitation, Kolkata, February 7-12 (2012).

Seminars/Colloquia

1. IRC Colloquia

A colloquium was held on February 18, 2012 at Department of Physics, CUSAT. This was attended by local IUCAA Associates and their students. The talks delivered were :

Young clusters as probes of star formation by B. Bhavya; *A Variational approach to BEC* by Lini Devassy; *Gravitational waves from f(R) theory* by P. Prasia; *Kinematics of open clusters* by K.Indulekha; *Stability and QNMs studies in Lovelock gravity* by C.B. Prasobh; *and Thermodynamic foundations of Q.G* by E.Goplalkrishna Panicker. This was followed by a Discussion session.

2. IRC Seminars

i) Sanjeev Dhurandhar (IUCAA), *The 21st century astronomy: Gravitational wave astronomy,* July 19, 2011.

ii) V. C. Kuriakose, *The accelerating universe,* December 12, 2011.

iii) C. D. Ravikumar (Calicut University), *War of titans: The story of galactic evolution,* December 19, 2011.

V. C. Kuriakose has given the following lectures at other colleges

i) *The accelerating universe,* TKM Arts and Science College, Kollam, November 2, 2011.

ii) *Astronomy - why and how?,* Newman College, Thodupuzha, January 13, 2012.

iii) *Beyond Einstein,* Catholicate College, Pathanamthitta, February 23, 2012.

iv) *Accelerating universe,* Radio Talks in Malayalam, AIR, Trichur, December 11 and 25, 2011.

Public Outreach programmes

i) Telescope making and sky watching for the school students

The Department of Physics, CUSAT, organized a workshop for school students during April 25-30,2011 in collaboration with 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 related topics. In addition to the astronomy programme, there were lectures on other topics in physics and the students were given training on doing some experiments and they were given opportunity to visit different research laboratories in the department. There were 30 students for the programme from different schools in Kerala.

ii) Lectures, telescope making and sky watching programmes at schools

The members of IRC have visited the following Schools and Colleges in villages and conducted telescope making and sky watching programmes for the benefit of the students.

i) M. A. High School, Athani (11-10-2011)

ii) S. R. High School , Ezhupunna (12-10-2011)

iii) Sarang School, Pathiripala (3-12-2011)

iv) Govt. High School, Irinjalakuda(6-1-2012) (Organized by Block Resource Centre, Irinjalakuda)

v) K. E. College, Mannanam (1- 2- 2012). The programme consisted of lectures in general Astronomy, introduction of Stellarium software, small telescope making and sky watching. The programmes were conducted in Malayalam.

iii) Science Day Celebrations

IRC, CUSAT in association with the Department of Physics celebrated the Science Day on March 1, 2012. The programme consisted of a talk on elementary Astronomy, introduction of Stellarium software and sky watching. This programme was attended by the students and faculty members of the Department as well as students from other departments in the university campus.

The research scholars of the Astronomy and Astrophysics group: Nijo Varghese, R. Tharanath, Saneesh Sebastian, M. Vivek, B. Bhavya , and P. Prasia rendered valuable services in making the public out-reach programme and other activities of the centre a great success.

2) Department of Physics and Astrophysics, University of Delhi.

Coordinator T.R. Seshadri

An International Workshop on Dark Energy was jointly organized by IRC, Delhi and CTP, Jamia Millia Islamia during December 20-23, 2011. It consisted of about 50 participants including some from abroad. The talks were held at Jamia Millia Islamia. Several students presented their work.

- A three lecture series on Cosmic Reionization was held at IRC in February-March 2012. The lectures were given by Tirthankar Roy Choudhary. These were followed by long detailed discussions in the subject.
- A colloquium on Neutron Star Astrophysics was given by Sushan Konar on February 29, 2012.
- The facilities at IRC have been used extensively by both PhD and MSc students. The computing facilities and some of the software have been used for the MSc course on Observational Astronomy.
- In addition, regular seminars and journal club meetings have been conducted. There is an active collaboration between IRC and CTP, Jamia Millia Islamia.

3) Department of Statistics, Calcutta University, Kolkata

Coordinator Asis K. Chattopadhyay

Highlights

During this year many students, research scholars and faculty members from different universities and colleges have used the facilities of the IRC, Kolkata. Recently, we have installed the Binary Maker package provided by IUCAA. The centre is very useful for researchers working with large data sets related to different astronomical objects.

Research Areas

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

Project Works : Supervised by Tanuka Chattopadhyay

a. Classification of radio and millisecond pulsars – A multivariate statistical approach, by Shankhanil Dey, Institute of Radiophysics and Electronics, Calcutta University.

b. In search of various properties of binary stars under statistical paradigm, by Tanmoy Ghosh, Department of Physics, W.B. State University, Barasat.

c. H-R diagram of galactic globular clusters, by Keshab Mondal, Department of Physics, W.B. State University, Barasat.

d. Statistical analysis in search for the anisotropies for the observed UHECRs, by Soumavo Ghosh, Department of Applied Mathematics, Calcutta University.

e. Multivariate study of globular clusters classification, by Imran Khan, Department of Applied Mathematics, Calcutta University.

f. An objective classification of stars, by Sukanta Das, Department of Applied Mathematics, Calcutta University.

g. Nature of initial mass function for unresolved stellar populations, by Bidyut Kumar Halder, Department of Applied Mathematics, Calcutta University.

h. Molecular clouds mass function in dark clouds, by Amit Biswas, Department of Physics, W.B. State University, Barasat.

i. Opacity limited fragmentation under dust and molecular hydrogen cooling, by Kiranmoy Mondal, Department of Physics, W.B. State University, Barasat.

Workshops and Meetings

Introductory Workshop on Astronomy and Astrophysics: Theory and Practice, February 18, 2012

It was a one day programme at the Department of Applied Mathematics, Dhanbad School of Mines jointly organized by Society of Applied Mathematics (SAM), Indian School of Mines and IUCAA Resource Centre, Kolkata. There were three technical lectures by Sailajananda Mukherjee, Tanuka Chattopadhyay and Asis Kumar Chattopadhyay. Mukherjee discussed the basic concepts of cosmology, Tanuka Chttopadhyay presented her work on fragmentation of molecular clouds and initial mass function. Asis Kumar Chattopadhyay demonstrated a few applications of statistical tools and techniques for the analysis of astronomical data. Many students, research scholars and faculty members of the Indian School of Mines participated in the programme.

Publications

1. Saptarshi Mondal, Bharat Warule and **Tanuka Chattopadhyay** (2010), *Fundamental planes for galaxy data with measuremental errors,* Calcutta Statistical Association Bulletin, **62(247-248),** 277.

2. **Tanuka Chattopadhyay, Asis Kumar Chattopadhyay** and Abisa Sinha (2011), *Modeling of the initial mass function using the Metropolis-Hastings algorithm,* Ap. J., **736(2),** 152.

3. **Tanuka Chattopadhyay,** M Sharina, E. Davoust , Tuli De and **Asis Kumar Chattopadhyay** (2012), *Uncovering the formation of ultra-compact dwarf galaxies by multivariate statistical analysis,* Ap. J., **750(2),** 91.

4. **Asis Kumar Chattopadhyay, Tanuka Chattopadhyay,** Tuli De and Saptarshi Mondal (2012), *independent component analysis for dimension reduction classification: Hough transform and CASH algorithm,* Astrostatistical Challenges for the New Astronomy (edited by Joseph M Hilbe) Springer.

Seminars and Colloquia

1. *Our nearest star : The Sun,* Dipankar Banerjee , Indian Institute of Astrophysics, Bengaluru, on June 22, 2011.

2. *Multivariate evolutionary analyses in astrophysics,* Didier Fraix-Burnet, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG), France, January 18, 2012.

3. *Classification and dimensionality reduction: The astrophysical context,* Didier Fraix-Burnet, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG), France, January 20, 2012.

4) Department of Physics, North Bengal University, Siliguri

Coordinator B. C. Paul

The new addition Data centre to the IRC is very much useful to the users visiting from different colleges and universities. The research scholars and M. Sc. students of the department also have been using the data centre to complete their project works. IRC, NBU has organized a number of seminars during the year.

Research Areas

Cosmology, Compact Objects, Foundations of Relativity, Data Analysis of X-ray Sources and Pulsars, Non-linear dynamics.

Visitors

R. Tikekar (IUCAA), C. S. Unnikrishnan (TIFR), D. P. Duari (Birla Planetarium, Kolkata), A. Majumdar (SNBNCBS, Kolkata), D. Majumdar (SINP, Kolkata), Shib Shankar Karmakar (Jalpaiguri), S. Mukherjee (Kolkata), N. K. Dadhich (IUCAA), Bhakta Kunwar (Sikkim Govt. College, Gangtok), Parthasarathi Majumdar (SINP), S. Chakraborty (JU), S. Giri (BIT, Kolkata), A. K. Chattopadhya (CU), M. Sanyal (Chakraborty) (SINP, Kolkata), U. Debnath (BESU), Shuvendu Chakrabarty (Seacom Engineering College), Dilip Paul (Islampur College), Subrato Sarkar (Visva Bharati), Aditya Sow Mondal (Visva Bharati), Ritesh Ghosh (Visva Bharati), Arundhuti Raychaudhuri (SMIT, Sikkim), R. Deb (Sikkim), R. Chhetri (Sikkim Govt. College, Gangtok), P. Chattopadhyay (Alipurduar College), P. Thakur (Alipurduar College), P. Pradhan (St. Joseph's College, Darjeeling), S. Mandal (Taki Govt. College, North 24 Parganas), S. Chakraborty (JU), P. S. Debnath (A B N Seal College, Coochbehar), A. Saha (Jalpaiguri Govt. Enginnering College), P. Barman (Raiganj University College), and Pralay Chanda (Narendrapur Ramkrishna Mission Residential College, Kolkata).

Workshops / Meetings organized

1. Recent Advances in Relativity, Cosmology and Astrophysics, during February 28 - March 01, 2011.

2. Workshop on Data Analysis : X-ray Pulsars and Compact Objects, during December 1 - 3, 2011. About 30 participants attended the workshop from different universities, colleges and institutes. Asis Kumar Chattopahyay (CU), S. Mukherjee (Kolkata), B. C. Paul (NBU), Soma Mandal (Taki Govt. College, Kolkata) were the resource persons. Soma Mandal, Samir Sarkar (NBU), A. Mukhopadhyay (NBU), Pragati Pradhan (NBU)and Tamal Sarkar (NBU) conducted the laboratory sessions for the data analysis in the IRC Data Centre.

List of Publications using the facilities of IRC

1. S. Ghose, P. Thakur and **B. C. Paul** (2012) *Observational constraints on the model parameters of a class of emergent universe, Mon. Not. Roy. Astron. Soc.,* 421, 20.

2. **B. C. Paul,** P. Thakur and A. Saha (2012) *Modified Chaplygin gas in Horava-Lifshitz gravity and constraints on its B parameter,* Phys. Rev., D 85, 024039.

3. **B.C. Paul,** P. Chattopadhyay, S. Karmakar and R. Tikekar (2011) *Relativistic strange star with anisotropy, Mod. Phys. Letts., A 26,* 575.

4. **B. C. Paul,** S. Ghose and P. Thakur (2011) *Emergent universe from a composition of matter, exotic matter and dark energy, Mon. Not. Roy. Astron. Soc.,* 413, 686.

5. R. K. Dey, A. Bhadra and J. N. Capdevielle (2011) *Behaviour of the EAS age parameter in the knee energy region,* Proc. ISVHECRI (arXiv:1009.5396).

6. A. Bhattacharya, G M Garipova, A. A Potapov, A. Bhadra, and **K. K. Nandi** (2011) *The Vacuole model revisited: New repulsive terms in the second order deflection of light,* JCAP, 028 (2011).

Seminars / Colloquia organized

1. *Thermal stability of quantum black hole,* by Partha Majumdar, SINP, Kolkata, March 12, 2012.

2. *Dynamical systems in cosmology,* by Subenoy Chakraborty, Jadavpur University, January 25, 2012.

3. *Magnetic semiconductor system,* by Mahua Sanyal (Chakraborty), Calcutta University, November 14, 2011.

Public Outreach Programmes

B. C. Paul delivered a popular talk on *Past and Present of Indian Astronomy* on February 29, 2011 at North Bengal Science Centre, Siliguri.

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

Coordinators S. K. Pandey and R. C. Agrawal

Highlights

A.K. Diwakar has received the Chhattisgarh Young Scientist award 2012 at the Young Scientist Meeting organized by CGCOST at Sarguja University, Ambikapur.

Research Areas

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.

D. K. Chakraborty and his research students 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. Some results were presented at the International Conference on Interstellar Dust, Molecules and Chemistry, November 22-25, 2011 held at IUCAA, as well as at the International Workshop on Advanced Materials and Astrophysics, February 21-22, 2012 held at the School of Studies in Physics and Astrophysics of the University.

The programme of studying faint outermost regions of the early-type galaxies from the Large Format Camera (LFC) field was continued during the year. Investigations whether inner and outer parts of the early-type galaxies are different have been continued. 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, Ashish Mahabal, and the work constitutes thesis work of Laxmikant Chaware.

Sheetal Sahu, research student of S. K. Pandey 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.

Nand Kumar Chakradhari, Lecturer in the department, is actively involved with his research work on supernova and short period variability in chemically peculiar stars.

To strengthen the research activities, department has signed MoU with ARIES, Nainital. A number of scientists, J. V. Narlikar, Mangala Jayant Narlikar, Ajit Kembhavi, (IUCAA), D. K. Sahu (IIA, Bangalore), Sudhanshu Barway (SAAO, South Africa), Nandita Sivastava (Udaypur Solar Observatory), Maheshwar Gopinathan, Indranil Chattopadhyay, (ARIES, Nainital), Robert Nemiroff, (Michigan Tech Univ., USA) have visited the department and interacted with the students.

Workshops and Meetings

International Workshop on Advanced Materials and Astrophysics (IWAMA) was held during February, 19-21, 2012.

List of Publications/Posters

1. Laxmikant Chaware participated in JSPS-DST Seminar and 8th CPS International School, "Recent and Future Advances in Observational Astronomy" held at Kobe, Japan during September 26-30, 2011. Presented a poster entitled "Isophotal shapes of early-type galaxies to very faint levels".

2. Intrinsic shapes of very flat elliptical galaxies, D. K. Chakraborty, A. K. Diwakar, **S. K. Pandey** (2011) MNRAS, **412,** 585C.

3. Dust extinction and X-ray emission from the starburst galaxy NGC 1482, N. D. Vagshette, M. B. Pandge, **S. K. Pandey,** and M. K. Patil (2012), New Astronomy, **17,** 524V.

4. Evidence of two unique variability classes from IGR J17091-3624, Mayukh Pahari, Sudip Bhattacharyya, J. S. Yadav,and **S. K. Pandey** (2012) MNRAS, **422L,** 87P.

5. The orientation of elliptical galaxies, D. K. Chakraborty, and A. K. Diwakar (2011) Astrophys. and Space Sci., **331,** 419C.

6. Search for P-mode pulsations in late-type CP stars, S. Joshi, and N. K. Chakradhari (2011), AOGS, **27,** 219J.

7. Time-resolved photoelectric, photometric and high-resolution spectroscopic data analysis of a luminous Ap star HD 103498, S. Joshi, Y. C. Joshi, O. V. Ezhkova, M. Sachkov, T. Ryabchikova, O. Kochukhov, N. K. Chakradhari, and S. K. Tiwari (2011), mast conf, 330J.

8. Intrinsic shape of very flat elliptical galaxy NGC720, A. K. Diwakar, D. K. Chakraborty, and **S. K. Pandey** (2012), 17th NSSS 2012, held at SVU, Tirupati.

9. Orientation of the two elliptical galaxy: NGC 3379 and NGC7619, A. K. Diwakar, Chhattisgarh Young Scientist Congress, 2012, held at Sarguja University, Ambikapur.

10. Intrinsic shape of elliptical galaxy, A. K. Diwakar, National Conference on Advanced Physics, 2012, Govt. N. Science College, Raipur.

Seminars and Colloquia

1. J.V. Narlikar and Mangala Jayant Narlikar, Excitement of study in science, followed by interaction with MSc/MPhil students, SoS in Physics and Astrophysics, Pt. R.S. Univ., Raipur, 15-04-2011.

2. J.V. Narlikar, The search for micro-life in the earth's atmosphere, Pt. R.S. Univ., Raipur, 16-04-2011.

3. J.V. Narlikar, Why study astronomy?, Aditya Birla Higher Sec. School, Ravan, Balodabazar, 18-04-2011.

4. Mangala Jayant Narlikar, Mathematics without calculation, Aditya Birla Higher Sec. School, Ravan, Balodabazar, 18-04-2011.

5. J.V. Narlikar and Mangala Jayant Narlikar, Live interaction through Edusat Network : Astronomy and Mathematics, SCERT, Raipur, 19-04-2011.

6. J.V. Narlikar and Mangala Jayant Narlikar, Astronomy and Mathematics, Civic Center, Bhilai, 19-04-2011.


पद्म विभूषण प्रोफेसर जयंत विष्णु नार्लीकर

Public Outreach Programmes

Celebration of Total Lunar Eclipse on 10 December 2011 was held at Supela, Bhilai.

Astronomical lecture, telescope demonstration and sky watching programmes were held at :

- SCERT/BEd College, Raipur; Sector 8, Bhilai; Pahandore, Bhilai; during 29th March – 01st April 2012.
- Rakhi, Naya Raipur, December 13, 2011.
- Uparwara, Naya Raipur, December 14, 2011.
- INSPIRE Summer Camp, Pt. R.S. Univ., Raipur during 06-10th June, 2011.
- Sector 2, Bhilai, May 09, 2011.
- Hudko, Bhilai, May 12, 2011.
- Indus World School, Sejbahar, Raipur,April 18, 2011.
- Some of the popular lectures in Astronomy delivered by S. K. Pandey include :

1. *"The Dynamic Universe"*, at Hindol College, Odisha, January 22, 2012.
2. *"Nucleosynthesis in Stars"*, at Bhilai Mahila Mahavidyalaya, Bhilainagar, February 6, 2012.
3. *"A Glimpse of the Universe"* at Sarguja University, Ambikapur (Youing Scientists Meet-2012), March 1, 2012.
4. *"Astronomy with Small Optical Telescope"* at Nehru Planetarium, New Delhi, March 4, 2012.
5. *"The Expanding Universe : is it accelerating?"* at Sambalpur University, March 09, 2012.
6. *"A Fresh View of the Universe : 20th Century Milestones and Challenges for the 21st Century in Astronomy"*, at the National Conference on Advances in Physics, Govt. Science College, Raipur, March 15, 2012.

6) Department of Physics, Mohanlal Sukhadia University, Udaipur.

Coordinator S.N.A. Jaaffrey

IUCAA Resource Centre (IRC) has organized a series of extension lectures on Astronomy and Astrophysics, and Japanese Space X-ray Laboratory "Suzaku", during September 24 – 26, 2011. S. Naik from the Physical Research Laboratory, Ahmedabad, delivered the lectures and hands-on training for archival data analysis obtained from "Suraku" to the M.Sc. students and research scholars of the Department of Physics. There were about 40 participants. The main topics covered were: introduction to X-ray binaries, physical properties of accreting disk, introduction to magnetars, magnetars with and without powered accreting disk, and spectral properties of accreting disk around black hole. The hands-on sessions were on Suzaku data downloading from NASA site, and Suzaku data analysis of magnetars.

Also, a Workshop on Astronomy for Science Educators and School Teachers was conducted during December 1 – 3, 2011, to celebrate the Golden Jubilee year of the Mohanlal Sukhadia University. The main resource person was Arvind Paranjpye from IUCAA, and there were a large number of local school teachers and students attending this workshop. The main topics covered were: the birth and death of stars, the sun – day time star, and finger printing the universe – introduction to spectroscopy. There were hands-on sessions to find directions, to measure the circumference of the earth, phases of the moon, and why we see only one side of moon, eclipses and occultation, understanding astronomical telescopes, and reading sky maps. A visit to Udaipur Solar Observatory and Global Oscillation Network Group was arranged.

IUCAA has established a data centre at the IRC, which helps the M.Sc. students of the Department of Physics to complete their project. Also, the research scholars and the faculty members of the department make use of this data centre to the maximum extend.

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 2012

Sr No.	FUNDS & LIABILITIES	Schedule No	31.03.2012 Rs.
1	Trust Fund / Corpus	6	4,02,55,231
2	Grant-In-Aid from UGC	7	111,48,12,079
3	Other Project Grants	8	3,01,10,606
4	Projects and Other Payable(Net)	9	70,50,293
5	Current Liabilities	10 & 10A	1,90,54,841
6	Income and Expenditure a/c	14	(3,99,53,027)
	Total		117,13,30,023

Sr No.	ASSETS & PROPERTIES	Schedule No.	31.03.2012 Rs.
1	Fixed Assets (At cost)	11	82,47,88,593
2	Investments / Deposits	12	19,13,16,733
3	Project & Other Receivables(Net)	13	22,56,174
4	Current Assets -	13	
	a) Cash, Bank balances & Revenue Stamps		4,29,76,842
	b) Loans and Advances	13A	1,04,73,134
	c) Deposits		15,55,061
	d) Prepaid Expenses		54,07,605
	e) Advance to Suppliers	13B	9,25,55,882
	Total		117,13,30,023

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 Kirtane & Pandit
Chartered Accountants
FRN- 105215W

Parag Pansare
(Partner)
Membership No.117309

Chairperson
Governing Board

Place : Pune
Date : 12.07.2012.

IUCAA, Post Bag 4, Ganeshkhind, Pune 411 007, India.
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