IUCAA

INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS

(An Autonomous Institution of the University Grants Commission)

Annual Report

(April 1, 2001 - March 31, 2002)

Editor

T. Padmanabhan
e-mail : **paddy@iucaa.ernet.in**

Design, Typesetting and Layout

Manjiri Mahabal
e-mail : **mam@iucaa.ernet.in**

IUCAA

Postal Address
Post Bag 4, Ganeshkhind, Pune 411 007, India

Location
Meghnad Saha Road, Pune University Campus, Ganeshkhind, Pune 411 007, India

Phone
(91) (20) 569 14 14

Fax
(91) (20) 569 07 60

e-mail
root@iucaa.ernet.in

Universal Resource Locator (URL)
http://www.iucaa.ernet.in/

HIGHLIGHTS OF 2001- 2002

This annual report covers the activities of IUCAA during its fourteenth year, April 2001 -March 2002. The endeavours of IUCAA span different fronts, as outlined in the pages of this Report. Here is a quick summary and highlights.

IUCAA has an academic strength of 15 core faculty members, 9 post-doctoral fellows and 15 Ph.D. students. The core research programmes by these academics span a variety of areas in astronomy and astrophysics. These topics include investigations in quantum and classical gravity, gravitational waves, cosmology and structure formation, cosmic microwave background radiation, extragalactic astronomy, quasar absorption systems, high energy astrophysics, galaxy and interstellar medium, stellar physics, solar physics and instrumentation. These research activities are summarised in pages 15-54. The publications of the IUCAA members, numbering to about 115 in the current year are listed in pages 75-79. IUCAA members also take part in pedagogical activities like lectures, seminars, popularisation of science, etc., the details of which are given in pages 85-95 of this Report.

The extended academic family of IUCAA consists of 84 Visiting Associates, who have been active in several different fields of research. Pages 55-72 of this report highlights their research contributions spanning classical gravity, gravitational waves, gravity in higher dimensions, alternative theories of gravity, quantum cosmology, cosmology and early universe, gamma ray bursts, quasar absorption lines, galactic dynamics, absorption against the CMB, dusty plasma, magnetohydrodynamics, star formation, pulsating stars, neutron stars and quark matter, Sun and solar system, atmospheric and ionospheric physics, observational astronomy, instrumentation, theoretical physics, nonlinear dynamics, Hamiltonian systems, QCD, supersymmetry, atomic physics and solitons. The resulting publications, numbering to about 118 are listed in pages 80-84 of this report.

A total of about 1300 man-days were spent by Visiting Associates at IUCAA during this year. In addition, IUCAA was acting as host to about 520 visitors through the year.

IUCAA conducts its graduate school jointly with the National Centre for Radio Astrophysics, Pune. Among the research scholars, one student has successfully defended his thesis and obtained Ph.D. degree from the University of Pune during the year 2000-2001. Summary of his thesis appears in pages 73-74.

Apart from these activities, IUCAA conducts several workshops, schools and conferences each year, both at IUCAA and at different university campuses. During this year, there were 8 such events in IUCAA and 7 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 this year, several special events were organised. One of the them was the Exhibition titled "100 years o f Nobel prize". It was inaugurated on February 25 and was kept open to public till March 7. The Nehru Science Centre, which made it possible, adopted an innovative approach in displaying the information. The other events comprised of programmes for school students consisting of quiz, essay and drawing competitions, and the Open Day when more than 3000 people visited IUCAA.

These activities were ably supported by the scientific and technical, and administrative staff (19 and 35 in number) who should get the lion's share of the credit for successful running of the programmes of the centre. The scientific staff also looks after the major facilities like library, computer centre and instrumentation lab. A brief update on these facilities is given on pages 108-112 of this report.

IUCAA has plans for a 2-metre new technology telescope for observational research. The telescope is being made under contract with the Particle Physics and Astronomy Research Council of the UK Government. It will be located on a hill near Giravali, about two and half hours drive from IUCAA.

CONTENTS

The Council and the Governing Board

The Council

President

Hari Gautam,
Chairperson,
University Grants Commission, New Delhi.

Vice-President

A.S. Nigavekar,
Vice-Chairperson,
University Grants Commission, New Delhi.

Members

R.P. Bambah, (Chairperson, Governing Board)
1275, Sector 19-B, Chandigarh.

Arvind Bhatnagar,
Emeritus Scientist,
Udaipur Solar Observatory, Udaipur.

M. Bhattacharyya,
Vice-Chancellor,
West Bengal University of Technology, Kolkata.

L. Chaturvedi,
Banaras Hindu University, Varanasi.

S.M. Chitre,
Tata Institute of Fundamental Research, Mumbai.

Ramanath Cowsik,
Director,
Indian Institute of Astrophysics, Bangalore.

G.G. Dandapat,
Officiating Secretary,
University Grants Commission, New Delhi.

S. Gopal (until September 2001)
Vice-Chancellor,
Mangalore University, Mangalore.

B. Hanumaiah (from October 2001)
Vice-Chancellor,
Mangalore University, Mangalore.

A.W. Joshi,
University of Pune, Pune.

K. Kasturirangan,
Secretary to the Government of India,
Department of Space, Bangalore.

S.S. Katiyar,
Vice-Chancellor,
Chhatrapati Shahu Ji Maharaj University, Kanpur.

C.L. Khetrapal,
Sanjay Gandhi Post-Graduate Institute of
Medical Sciences, Lucknow.

A.S. Kolaskar,
Vice-Chancellor,
University of Pune, Pune.

R.A. Mashelkar,
Director General,
Council of Scientific and Industrial Research,
New Delhi.

Sipra Guha-Mukherjee,
Jawaharlal Nehru University, New Delhi.

Rajaram Nityananda,
Centre Director,
National Centre for Radio Astrophysics, Pune.

T. Padmanabhan,
IUCAA, Pune.

K.N. Pathak,
Vice-Chancellor,
Panjab University, Chandigarh.

V.S. Ramamurthy,
Secretary to the Government of India,
Department of Science and Technology, New Delhi.

P. Rama Rao,
Vice-Chancellor,
University of Hyderabad, Hyderabad.

A. Sankara Reddy,
Sri Venkateswara College, New Delhi.

K. Siddappa, (till March 11, 2002)
Vice-Chancellor,
Bangalore University, Bangalore.

M.S. Thimmappa, (from May 2002)
Vice-Chancellor,
Bangalore University, Bangalore.

Member Secretary

J.V. Narlikar,
Director, IUCAA.

The Governing Board

Chairperson

R.P. Bambah

Members

Arvind Bhatnagar
L. Chaturvedi
Ramanath Cowsik
G.G. Dandapat
A.S. Kolaskar
Sipra Guha-Mukherjee
Rajaram Nityananda
T. Padmanabhan
K.N. Pathak
K. Siddappa (till March 11, 2002)
M. S. Thimmappa (from May 2002)

Member Secretary

J.V. Narlikar,
Director, IUCAA.

Honorary Fellows

Geoffrey Burbidge,
University of California,
CASS, USA.

E. Margaret Burbidge,
University of California,
CASS, USA.

R. Hanbury Brown, (deceased January 16, 2002)
Andover, England.

A. Hewish,
University of Cambridge, UK.

Fred Hoyle, (deceased August 20, 2001)
Bournemouth, UK.

Yash Pal,
New Delhi.

A.K. Raychaudhuri,
Kolkata.

Allan Sandage,
The Observatories of Carnegie,
Institute of Washington,
USA.

P.C. Vaidya,
Gujarat University,
Ahmedabad.

Statutory Committees

The Scientific Advisory Committee

K.R. Anantharamaiah, (deceased October 29, 2001)
Raman Research Institute, Bangalore.

S.R. Choudhury,
University of Delhi, Delhi.

E.P.J. van den Heuvel,
University of Amsterdam, The Netherlands.

U. C. Joshi, (from January 9, 2002)
Physical Research Laboratory,
Ahmedabad.

Pushpa Khare,
Utkal University, Bhubaneswar.

N. Mukunda,
Indian Institute of Science, Bangalore.

Rajaram Nityananda,
Centre Director,
National Centre for Radio Astrophysics, Pune.

Alain Omont,
Institut D'Astrophysique de Paris, France.

T.P. Prabhu,
Indian Institute of Astrophysics, Bangalore.

Bernard F. Schutz,
Max-Planck Institute for Gravitation Physics, Germany.

J.V. Narlikar, (Convener)
IUCAA, Pune.

N.K. Dadhich,
IUCAA, Pune.

N. Unnikrishnan Nair,
Vice-Chancellor,
Cochin University of Science and Technology,
Kochi.

Bharat Oza,
Vice-Chancellor,
Bhavnagar University, Gujarat.

R. Ramakrishna Reddy,
Sri Krishnadevaraya University, Anantapur.

Users' Committee

J. V. Narlikar, (Chairperson)
IUCAA, Pune

A.K. Kembhavi, (Convener)
IUCAA, Pune.

A.N. Basu,
Vice-Chancellor,
Jadavpur University, Kolkata.

Somenath Chakrabarty,
Department of Physics,
University of Kalyani, West Bengal.

The Academic Programmes Committee

J. V. Narlikar (Chairperson)
T. Padmanabhan (Convener)
N. K. Dadhich
S. V. Dhurandhar
Ranjan Gupta
A. K. Kembhavi
Varun Sahni
R. Srianand (from September 4, 2001)
S. Sridhar
K. Subramanian (from October 18, 2001)
S. N. Tandon

The Standing Committee for Administration

J.V. Narlikar (Chairman)
T. Sahay (Member Secretary)
A.K. Kembhavi
T. Padmanabhan

The Finance Committee

R.P. Bambah (Chairperson)
L. Chaturvedi (from July 2001)
G. G. Dandapat
R. P. Gangurde (till May, 2001)
J.V. Narlikar
O.P. Nigam
R. Nityananda (from May 2001)
T. Padmanabhan
N. Raghavan (till June 2001)
T. Sahay (Non-Member Secretary)

Members of IUCAA

Academic

J.V. Narlikar (Director)
T. Padmanabhan (Dean, Core Academic Programmes)
A.K. Kembhavi (Dean, Visitor Academic Programmes)
J. Bagchi
N.K. Dadhich
S.V. Dhurandhar
R. Gupta
R. Misra (from November 12, 2001)
A.N. Ramaprakash
S. Raychaudhury (till September 29, 2001)
V. Sahni
Tarun Souradeep
R. Srianand
S. Sridhar
K. Subramanian (from October 18, 2001)
S. N. Tandon

Scientific and Technical

T.D. Agarkar
N.U. Bawdekar
S.S. Bhujbal
M.P. Burse
V. Chellathurai
P.A. Chordia
H.K. Das
S. Engineer
D.V. Gadre (till July 27, 2001)
G.B. Gaikwad
S.U. Ingale
A.A. Kohok
V.B. Mestry
A. Paranjpye
S. K. Pathak
S. Ponrathnam
V.K. Rai
H.K. Sahu
S. Sankara Narayanan

Administrative and Support

T. Sahay (Senior Administrative Officer)
N.V. Abhyankar
V.P. Barve
S.K. Dalvi
S.L. Gaikwad
B.R. Gorkha
B S. Goswami
S.B. Gujar
R.S. Jadhav
B.B. Jagade
S.M. Jogalekar
S.N. Khadilkar
S.B. Kuriakose
N.S. Magdum
M.A. Mahabal
S. G. Mirkute
E.M. Modak
K.B. Munuswamy
K.C. Nair
R.D. Pardeshi
R.V. Parmar
B.R. Rao
M.A. Raskar
M.S. Sahasrabudhe
V.A. Samak
S.S. Samuel
B.V. Sawant
S. Shankar
D.R. Shinde
V. R. Surve
D.M. Susainathan
A.A. Syed
S.R. Tarphe
S.K. Waghole
K.P. Wavhal

Post-Doctoral Fellows

Tapas K. Das
S. Konar
T. Morel (till February 28, 2002)
P. Subramanian
R. Nayak (from July 3, 2001)
A. Thampan (till July 31, 2001)
R.G. Vishwakarma
H. K. Jassal (from December 18, 2001)
S. Sahay (Project Scientist from March 20, 2002)

Research Scholars

A.L. Ahuja
U. Alam
H. Chand (from August 1, 2001)
T. Roy Choudhury
A. Deep
Amir Hajian (from January 28, 2002)
S. Mitra (from August 1, 2001)
A. Pai (till January 2, .2002)
T.D. Saini (till November 13, 2001)
N.B. Sambhus
A. S. Sengupta
S. Shankaranarayanan
J.V. Sheth
P. Singh
Y.G. Wadadekar (till June 30, 2001)

Project and Contractual Appointments

A.P. Chordia
(Computer Centre)

K. James
(Project Officer, ERNET Project)

M. S. Kharade
(Project Officer , ERNET Project)

V. Kulkarni
(Scientific/Technical Assistant-I
Public Outreach Programme)

M. D'sa
(Quasi Steady-State Cosmology Project)

Part time Consultants

I. V. K. Babu (till June 30, 2001)
(Sports)

S. S. Bodas
(Medical Services)

Visiting Members of IUCAA

Visiting Associates

F. Ahmed,
Department of Physics,
Kashmir University, Srinagar.

Z. Ahsan,
Department of Mathematics,
Aligarh Muslim University.

G. Ambika,
Department of Physics,
Maharaja's College, Kochi.

M.N. Anandaram,
Department of Physics,
Bangalore University.

Bindu A. Bambah,
Centre for Advanced Study in Mathematics,
Panjab Unviersity, Chandigarh.

A. Banerjee,
Department of Physics,
Jadavpur University.

N. Banerjee,
Department of Physics,
Jadavpur University.

S.K. Banerjee,
Department of Mathematics,
Mody College of Engineering and
Technology, Lakshmangarh

S.P. Bhatnagar,
Department of Physics,
Bhavnagar University.

Anil Ch. Borah,
Department of Physics,
Assam University, Silchar.

S. Chakrabarty,
Department of Physics,
University of Kalyani.

D.K. Chakraborty,
School of Studies in Physics,
Pt. Ravishankar Shukla University, Raipur.

Subenoy Chakraborty,
Department of Mathematics,
Jadavpur University.

Deepak Chandra,
Department of Physics,,
S.G.T.B. Khalsa College, Delhi.

Suresh Chandra,
School of Physical Sciences,
Swami Ramanand Teerth Marathwada University,
Nanded.

S. Chatterji,
Department of Physics,
New Alipore College.

S. Chaudhuri,
Department of Physics,
Gushkara Mahavidyalaya, Burdwan.

Arnab Rai Choudhuri,
Department of Physics,
Indian Institute of Science, Bangalore.

M.K. Das,
Department of Physics & Electronics,
Sri Venkateswara College, New Delhi.

Jishnu Dey,
Department of Physics,
Maulana Azad College, Kolkata.

Mira Dey,
Department of Physics,
Presidency College, Kolkata.

A.D. Gangal,
Department of Physics,
University of Pune.

P.S. Goraya,
Department of Physics,
Punjabi University, Patiala.

A.K. Goyal,
Department of Physics & Astrophysics,
Hans Raj College, University of Delhi.

P.P. Hallan,
Department of Mathematics,
Zakir Husain College, New Delhi.

S.N. Hasan,
Department of Astronomy,
Osmania University, Hyderabad.

Ng. Ibohal,
Department of Mathematics,
Manipur University, Imphal.

K. Indulekha,
School of Pure and Applied Physics,
Mahatma Gandhi University, Kottayam.

K. N. Iyer,
Department of Physics,
Saurashtra University, Rajkot.

Lalan Kumar Jha,
Department of Physics,
L.N.T. College, Muzaffarpur.

C. Jog,
Department of Physics,
Indian Institute of Science, Bangalore.

M. John,
Department of Physics,
St. Thomas College, Kozhencherri.

K. Jotania,
Physics Division,
Birla Institute of Technology and Science, Pilani.

B.A. Kagali,
Department of Physics,
Bangalore University.

R.S. Kaushal,
Department of Physics & Astrophysics,
University of Delhi.

M. Khan,
Centre for Plasma Studies,
Jadavpur University.

P. Khare,
Department of Physics,
Utkal University, Bhubaneswar.

V.H. Kulkarni,
Department of Physics,
University of Mumbai.

A.C. Kumbharkhane,
School of Physical Sciences,
Swami Ramanand Teerth Marathwada University,
Nanded.

V.C. Kuriakose,
Department of Physics,
Cochin University of Science and Technology, Kochi.

M.L. Kurtadikar,
Department of Physics,
J.E.S. College, Jalna.

D. Lohiya,
Department of Physics & Astrophysics,
University of Delhi.

Usha Malik,
Department of Physics,
Miranda House, Delhi.

A. K. Mittal,
Department of Physics,
University of Allahabad.

Bijan Modak,
Department of Physics,
University of Kalyani.

S. Mukherjee,
Department of Physics,
North Bengal University, Darjeeling.

K.K. Nandi,
Department of Mathematics,
North Bengal University, Darjeeling.

U. Narain,
Astrophysics Research Group,
Meerut College.

S.K. Pandey,
School of Studies in Physics,
Pt. Ravishankar Shukla University, Raipur.

P.N. Pandita,
Department of Physics,
North Eastern Hill University, Shillong.

S.K. Pathak,
Department of Physics,
Christ Church College, Kanpur.

B. C. Paul,
Department of Physics,
North Bengal University, Darjeeling.

S. N. Paul,
Serampore Girls' College,
Kolkata.

Lalan Prasad,
Department of Physics,
M.B. Govt. P.G. College, Nainital.

P. Vivekananda Rao,
Centre of Advanced Study in Astronomy,
Osmania University, Hyderabad.

R. Ramakrishna Reddy,
Department of Physics,
Sri Krishnadevaraya University, Anantapur.
L.M. Saha,
Department of Mathematics,
Zakir Husain College, New Delhi.

Sandeep Sahijpal,
Department of Physics,
Panjab University, Chandigarh

M. Sami,
Department of Physics,
Jamia Millia Islamia, New Delhi

A.K. Sen,
Department of Physics,
Assam University, Silchar.

K. Shanthi,
Academic Staff College,
University of Mumbai

Amitava Sil,
Department of Physics,
St. Joseph's College, Darjeeling.

G.P. Singh,
Department of Mathematics,
Visvesvaraya Regional College of Engineering,
Nagpur.

H.P. Singh,
Department of Physics & Electronics,
Sri Venkateswara College, New Delhi.

L.P. Singh,
Department of Physics,
Utkal University, Bhubaneswar.

S. Singh,
Deshbandhu College, University of Delhi.

Yugindro Singh,
Department of Physics,
Manipur University, Imphal.

P.K. Srivastava,
Department of Physics,
D.A.V. P.G. College, Kanpur.

S.K. Srivastava,
Department of Mathematics,
North Easern Hill University, Shillong.

P. K. Suresh,
School of Physics,
University of Hyderabad
V.O. Thomas,
Department of Mathematics,
M.S. University of Baroda.

R. Tikekar,
Department of Mathematics,
Sardar Patel University, Vallabh Vidyanagar.

...till June 30, 2001

S. Biswas,
Department of Physics,
Unviersity of Kalyani.

S. Chakravarti,
Department of Physics,
Visvabharati, Santiniketan.

D.P. Datta,
Department of Mathematics,
NERIST.

Kalyani Desikan,
M.O.P. Vaishnav College for Women,
Chennai.

Sukanta Dutta,
Department of Physics and Electronics,
S.G.T.B. Khalsa College, Delhi

T. C. Phukon, (deceased October 20, 2001)
Department of Physics,
Gauhati University, Guwahati.

Shantanu Rastogi,
Department of Physics,
Lucknow University.

R. P. Saxena,
Department of Physics and Astrophysics,
University of Delhi.

...from July 1, 2001

B. N. Dwivedi,
Department of Applied Physics,
Institute of Technology, Benaras Hindu University.

S. G. Ghosh,
Department of Mathematics,
S.S.E.S. Amti's Science College, Nagpur.

V. K. Gupta,
Department of Physics and Astrophysics,
University of Delhi.

K.P. Harikrishnan,
Department jof Physics,
The Cochin College, Kochi.

Nagendra Kumar,
Department of Mathematics,
K.G.K. (P.G.) College, Moradabad.

Yogesh Kumar Mathur,
Department of Physics and Astrophysics,
University of Delhi.

Bikram Phookum,
Department of Physics,
St. Stephen's College, Delhi.

Farook Rahaman,
Department of Mathematics,
N.V. College, West Bengal.

M.C. Sabu,
Department of Mathematics,
Christ College, Rajkot.

D.C. Srivastava,
Department of Physics,
D.D.U. Gorakhpur University.

Anisul Ain Usmani,
Department of Physics,
Aligarh Muslim University.

The Twelfth batch of Visiting Associates who were selected for a tenure of three years, beginning July 1, 2001.

B.N. Dwivedi

S. G. Ghosh

Yogesh Kumar Mathuri

Nagendra Kumar

Farook Rahaman

D. C. Srivastava

A.A. Usmani

The photographs of the following Visiting Associates from the twelfth batch are not available: V. K. Gupta, K.P. Harikrishnan, Bikram Phookun and M.C. Sabu

Appointments of the following Associates and Senior Associates from the ninth batch were extended for three years: Farooq Ahmed, G. Ambika, N. Banerjee, S. Chakraborty, S. Chaudhuri, A. Goyal, Chanda Jog, K. Jotania, R.S. Kaushal, V. H. Kulkarni, K. K. Nandi, P. N. Pandita, S. N. Paul, T. C. Phukon (deceased October 20, 2001), H. P. Singh, K. Yugindro Singh and P. K. Srivastava.

Organizational Structure of IUCAA's Academic Programmes

The Director
J.V. Narlikar

Dean, Core Academic Programmes
(T. Padmanabhan)

Head, Post-Doctoral Research
(S.V. Dhurandhar)

Head, Computer Centre
(A.K. Kembhavi)

Head, Library & Documentation
(T. Padmanabhan)

Head, Publications
(T. Padmanabhan)

Head, M.Sc. & Ph.D. Programmes
(S.V. Dhurandhar)

Head, Instrumentation Laboratory
(S.N. Tandon)

Dean, Visitor Academic Programmes
(A.K. Kembhavi)

Head, Associates & Visitors
(A.K. Kembhavi)

Head, Recreation Centre
(S. Sridhar)

Head, Guest Observer Programmes
(Ranjan Gupta)

Head, Workshops & Schools
(Ranjan Gupta)

Head, Public Outreach Programmes
(A.K. Kembhavi)

The Director's Report

During the year 2001-2002, IUCAA suffered the loss of two Honorary Fellows. Professor Fred Hoyle, who had been an Honorary Fellow right from the early days passed away on August 20, 2001 at the age of 86. The institute he set up in Cambridge (the Institute of Theoretical Astronomy) has been one of the ideals for IUCAA to emulate. Professor Fred Hoyle had been a great friend of IUCAA and his visit in 1994 was well cherished and fondly remembered. On January 16, 2002 we lost Professor Hanbury Brown, another friend and well-wisher whom we will greatly miss. He epitomised practical at the same time innovative approach to observational astronomy.

The untimely passing away of Dr. K.R. Anantharamaiah on October 29, 2001 was another blow as in his capacity as a member of the Scientific Advisory Committee, IUCAA was expecting important guidance from him on radio astronomy programmes, especially with the Giant Metrewave Radio Telescope.

I wish to record our special gratefulness to the Scientific Advisory Committee for its very fruitful visit and instructive feedbacks. We are particularly happy to learn that the SAC thinks us mature enough now so that its visits may be spaced at two-year intervals rather than every eighteen months. The intensive work that the SAC puts in every time to assess IUCAA and the constructive suggestions it makes have helped the Centre greatly in its aspirations of excellence.

I also wish to record IUCAA's and my personal thanks to Professor R. P. Bambah whose soothing guidance and wise counsel as Chairperson of the Governing Board have greatly helped us in facing whatever problems that tend to arise in running an institution.

A look at the Awards and Recognitions column will show that the work of IUCAA members, including younger ones is getting recognized and appreciated in the national and international community. Proposals sponsored by IUCAA, whether national ones or for international collaborations, are attracting more and more support. Its guest observing proposals (which enable the university faculty and students to access international facilities) are getting observing times on top class international telescopes.

In this connection, thanks to a collaboration established with the Observatory at Mount Wilson in Southern California, the internet can be used from Pune to run their telescope as part of the programme of using internet for education. Taking advantage of 12.5-13.5 hour time difference between California and India, school children in Pune have experienced the thrill of real time observing so that comets, planets and nebulae have become 'real objects' to them rather than photographs in textbooks.

Although IUCAA has probably the best performance in the number of Ph.Ds produced per faculty member for astronomy institutions in India, the worrying problem remains that it is getting more and more difficult to attract good talent to astronomy. This problem is not limited to astronomy and astrophysics, but extends to other subjects like physics and mathematics also, and is a national concern. The Decadal Vision Discussion conducted by the Astronomical Society of India at IUCAA largely concentrated on this issue. Against this background, there is a general appreciation of IUCAA's efforts in making astronomy and astrophysics popular amongst school children. But viewed against the national backdrop, these efforts are like drops in the ocean.

This year's Foundation Day speaker Professor T.V. Ramakrishnan has drawn attention to this problem in the wider framework of the crisis in higher education. The UGC has proposed ambitious new directions under its Tenth Plan programmes and we hope that the long-awaited rejuvenation of the university system will be soon under way. IUCAA will be anxious to contribute its mite to any such national effort.

At the time of writing this report, Dr. Hari Gautam has retired as Chairperson of the University Grants Commission and has handed over charge to Professor A. S. Nigavekar. We convey our good wishes to Dr. Gautam and look forward to UGC's help and guidance under the new leadership in the days that lie ahead.

Jayant Narlikar
Director

Awards and Distinctions

Naresh Dadhich

Elected member of the Council of International Committee on Gravitation and Relativity.

S. V. Dhurandhar

Elected Fellow of the Indian Academy of Sciences.

Elected Member of the National Academy of Sciences.

J. V. Narlikar

Deshratna Award on the occasion of the Independence Day from the Bharati Think Tank, Bhubaneswar.

Vidnyan Bhushan Samman from the Uttar Pradesh Hindi Sansthan, Lucknow.

Justice M.G. Ranade Award from the Rashtriya Samajik Parishad, Pune.

Jawaharlal Nehru Birth Centenary Award (for the year 2001-2002) from the Indian Science Congress Association, Calcutta.

T. Padmanabhan

Sackler Distinguished Astronomer, Institute of Astronomy, Cambridge, UK.

First Prize winner of the 15th Khwarizmi International Award (for the year 2002), Iranian Research Organization for Science and Technology, Iran.

S. Shankaranarayanan

James Hartle Award (2001) from International Society on General Relativity and Gravitation.

R. G. Vishwakarma

His work "Consequences on variable Λ-models from distant Type Ia supernovae and compact radio sources" (CQG 2001, 18, 1159-1171), has been selected for the "HIGHLIGHTS OF 2000 & 2001" by the journal, Classical and Quantum Gravity.

Calendar of Events

2001

April 16- May 25	**School Students' Summer Programme** at IUCAA
April 27	**IUCAA-NCRA Graduate School** Second semester ends
May 12 -22	**Summer School on Gravity and Field Theory** at St. Thomas College, Kozhencherry
May 14 - June 15	**Refresher Course in A & A for College / University Teachers** at IUCAA
May 21- July 6	**Vacation Students' Programme** at IUCAA
August 13	**IUCAA-NCRA Graduate School** First semester begins
August 27-28	**Brainstorming Session on Liquid Mirror Telescopes: An Indian Perspective** at IUCAA
September 8-10	**Workshop on Fundamentals of Astronomy and Astrophysics** at V.R. College, Nellore
September 24-27	**Workshop on Structure and Dynamics of Galaxies** at Pt. Ravishankar Shukla University, Raipur
October 8-11	**Workshop on Celestial Mechanics and Dynamical Systems** at IUCAA
October 15-19	**Introductory School on Astronomy and Astrophysics** at Rajarshi Shahu College, Latur
October 18-22	**Mini-School on Astronomy and Astrophysics** at H.N.B.G. University, Srinagar-Garhwal
October 29 - November 15	**Workshop on Telescope Making** at IUCAA
November 21-23	**Second Level, IInd Workshop on Astronomical Photometry and Astronomy with Small Telescopes** at IUCAA
November 21-22	**Regional Workshop on General Relativity and Gravitation** at University of Kalyani, Kalyani
December 14	**IUCAA-NCRA Graduate School** First semester ends
December 17-21	**Workshop on Interface of Gravitational and Quantum Realms** at IUCAA
December 29	**Foundation Day**

2002

January 7	**IUCAA-NCRA Graduate School** Second semester begins
January 14-18	**Workshop on Photometric Data Reduction and Analysis** at J.E.S. College, Jalna
February 5 -8	**21st Meeting of the Astronomical Society of India** at IUCAA
February 28	**National Science Day**

ACADEMIC PROGRAMMES

The following description relates to research work carried out at IUCAA by the Core Academic Staff, Post-Doctoral Fellows and Research Scholars. The next section describes the research work carried out by Visiting Associates of IUCAA using the Centre's facilities.

RESEARCH BY RESIDENT MEMBERS

The research described below is grouped area-wise. The name of the concerned IUCAA member appears in italics.

Quantum Theory and Gravity

The unity of horizons

One of the remarkable features of classical gravity is that it can wrap up regions of spacetime, thereby producing surfaces which act as one way membranes. The classic example is that of a Schwarzschild blackhole, which has a compact, observer independent, surface which acts as an event horizon. Another example is the de Sitter universe, which also has a one way membrane though the location of this compact surface depends on the observer. The existence of one-way membranes, however, is not necessarily a feature of gravity or curved spacetime and can be induced even in flat Minkowski spacetime, once we accept the notion of an observer dependent horizon. It is possible to introduce coordinate charts in Minkowski spacetime, such that regions are separated by horizons, a familiar example being the Rindler frame, which has a non-compact surface acting as a coordinate dependent horizon.

The study of quantum field theory (QFT) in these spacetimes suggests a natural way of associating a temperature with the spacetimes which have horizons, irrespective of whether the horizons are observer independent geometrical structures (as in the case of a blackhole) or observer/coordinate dependent (as in the case of de Sitter or Rindler). The operator equations for QFT in the background metric are well defined in these spacetimes; but to make useful predictions, we also need to choose a quantum state for the field. The Schwarzschild, de Sitter and Rindler metrics are symmetric under time reversal and there exists a 'natural' definition of a time symmetric vacuum state in all these cases. Such a vacuum state will appear to be described a thermal density matrix in a subregion $\mathcal{R}$ of spacetime with the horizon as a boundary. The QFT based on such a state will be manifestedly time symmetric and will describe an isolated system in thermal equilibrium in the subregion $\mathcal{R}$. No time asymmetric phenomena like evaporation, outgoing radiation, irreversible changes, etc can take place in this situation.

One would next ask whether one can associate an *entropy* with such spacetimes in a sensible manner, given that the notion of *temperature* arises very naturally. Conventionally, there are two very different ways of defining the entropy, given the notion of temperature: (1) In statistical mechanics, the partition function $Z(\beta)$ of the canonical ensemble of systems with constant temperature β^{-1} is related to the entropy S and energy E by $Z(\beta) \propto \exp(S - \beta E)$. (2) In classical thermodynamics, on the other hand, it is the *change in* the entropy, which can be operationally defined via, $dS = dE/T(E)$. Integrating this equation will lead to the function $S(E)$ except for an additive constant which needs to be determined from additional considerations. Proving the equality of these two concepts was nontrivial and — historically — led to the unification of thermodynamics with mechanics.

Recently, *T. Padmanabhan* has taken a careful look at these issues and has shown that all horizons behave in a similar manner as regards both temperature and entropy. In particular, he has been able to show that it is possible to construct a canonical ensemble of a class of spacetimes with a fixed value for β and evaluate the partition function $Z(\beta)$. For spherically symmetric spacetimes with a horizon at $r = l$, the partition function has the generic form $Z \propto \exp[S - \beta E]$, where $S = (1/4)4\pi l^2$ and $|E| = (l/2)$. This analysis reproduces the conventional result for the blackhole spacetimes and provides a simple and consistent interpretation of entropy and energy for deSitter spacetime, with the latter being given by $E = -(1/2)H^{-1}$. For the Rindler spacetime, the entropy per unit transverse area turns out to be $(1/4)$ while the energy is zero.

Padmanabhan has also shown how to construct radiating states in all these spacetimes such that the thermodynamic approach to entropy can also be realised. It turns out that there is no mathematical distinction between the horizons which arise in the Schwarzschild, de Sitter and Rindler spacetimes. There is no simple way one can associate entropy with blackholes *without* associating entropy with Rindler or de Sitter. It is all or none.

Einstein's equations and thermodynamics of spacetime

Arising from the work described above, *Padmanabhan* has investigated whether there is a deeper connection between thermodynamics of spacetime and gravity. This has led to the development of a general formalism for understanding the thermodynamics of horizons in spherically symmetric spacetimes. The formalism reproduces known results in the case of blackhole spacetimes; but its power lies in being able to handle more general situations like: (i) spacetimes which are not asymptotically flat (like the de Sitter spacetime) and (ii) spacetimes with multiple horizons having different temperatures (like the Schwarzschild-de Sitter spacetime) and provide a consistent interpretation for temperature, entropy and energy. More remarkably, he has been able to show that it is possible to write Einstein's equations for a spherically symmetric spacetime in the form $TdS - dE = PdV$ near *any* horizon of radius a with $S = (1/4)(4\pi a^2), |E| = (a/2)$ and the temperature T determined from the surface gravity at the horizon. The pressure P is provided by the source of the Einstein's equations and dV is the change in the volume when the horizon is displaced infinitesimally. The approach also shows that the de Sitter horizon — like the Schwarzschild horizon — is effectively one dimensional as far as the flow of information is concerned, while the Schwarzschild-de Sitter, Reissner-Nordstrom horizons are not.

It turns out that this work has a bearing on the holographic principle. By reversing some of these arguments it is actually possible to derive the action for Einstein's theory in the bulk by knowing only its properties on the bounding surface. *Padmanabhan* is currently investigating this possibility.

Why do we observe a small but nonzero cosmological constant?

The action for classical gravitational field depends on the speed of light, c, the Newtonian gravitational constant, G and the cosmological constant, Λ. Since it is not possible to produce a dimensionless number from these three constants, their relative values have no meaning and with a suitable choice of units we can set all the three of them to unity if they are nonzero and positive, say. The situation is different in quantum theory which introduces the constant $\hbar$. It is then possible to form the dimensionless number $\Lambda(G\hbar/c^3) \equiv \Lambda L_P^2$ where $L_P \approx 10^{-33}$ cm is the Planck length. If we assume that dimensionless combinations of coupling constants should be of order unity, then the natural value for cosmological constant will be $\Lambda \approx L_P^{-2}$. Current cosmological observations, however, suggest that, the *effective value* value of Λ (which will pick up contributions from all vacuum energy densities of matter fields) has been reduced from the natural value of L_P^{-2} to $L_P^{-2}(L_P H_0)^2$ where H_0 is the current value of the Hubble constant. If these observations are correct, then we need to answer two separate questions: (i) Why does large amount of vacuum energy density remain unobservable by gravitational effects ? (ii) Why does a very tiny part of it appear as observable residue ?

An attractive way of thinking about these questions is the following: Let us assume that the quantum micro structure of spacetime at Planck scale is capable of readjusting itself, soaking up any vacuum energy density which is introduced — like a sponge soaking up water. If this process is fully deterministic and exact, all vacuum energy densities will cease to have macroscopic gravitational effects. However, since this process is inherently quantum gravitational, it is subject to quantum fluctuations at Planck scales. Hence, a tiny part of the vacuum energy will survive the process and will lead to observable effects. *Padmanabhan* has conjectured that the cosmological constant we measure corresponds to this small residual fluctuation which will depend on the volume of the spacetime region that is probed. It is small, in the sense that it has been reduced from L_P^{-2} to $L_P^{-2}(L_P H_0)^2$, which indicates the fact that fluctuations — when measured over a large volume — is small compared to the bulk value. It is the wetness of the sponge we notice, not the water content inside.

To make further progress with such an idea, one needs to know the exact description of spacetime micro structure in a quantum theory of gravity. *Padmanabhan* has succeeded in describing the features of a toy model for the spacetime micro structure which could allow for the bulk vacuum energy densities to be cancelled leaving behind a small residual value of the correct magnitude. Some other models (like the ones based on canonical ensemble for the four volume or quantum fluctuations of the horizon size) lead to an insignificantly small value of $H_0^2(L_P H_0)^n$ with $n = 0.5 - 1$ showing that obtaining the correct order of magnitude for the residual fluctuations in the cosmological constant is a nontrivial task, because of the existence of the small dimensionless number $H_0 L_P$.

Imprint of Planck scale physics on inflationary cosmology

In recent years, there has been a lot of interest in trans-Planckian effects during the cosmological inflation. Inflationary paradigm, originally introduced as a possible solution to a host of cosmological conundrums gives the physical mechanism for producing spectra of density perturbations. Many models of inflation require a period longer than 70 e-foldings to solve the horizon and flatness problems of standard cosmology. In order to obtain the observed density inhomogeneities on the galactic scales, these models of inflation require the modes of vacuum fluctuations at the initial epoch of inflation to be smaller than the Planck length.

It is well known that the spacetime structure at Planck scales is affected by the quantum gravitational effects and it is generally believed that the Planck length acts as a physical cutoff for spacetime intervals. If the quantum theory of gravity has a fundamental length scale, then the low-energy effective quantum field theories should have an imprint of the Planck scale. One of the ways of introducing the fundamental length scale into field theory is by modifying the dispersion relation of the linear field equation.

Sometime back, Robert Brandenberger and Jerome Martin studied the trans-Planckian effects in inflationary cosmology by introducing modified dispersion relations in an *adhoc* manner. They showed that while some hypothesized dispersion relation(s) to quantum field theory yield no change in the power spectrum of the fluctuations, some indicate the cosmological sensitivity to Planck scale physics. However, there have been arguments in the literature that the spectrum of vacuum fluctuations should not be sensitive to the Planck scale physics.

S. Shankaranarayanan has studied the effects of the trans-Planckian dispersion relation on the spectrum of the primordial density perturbations during inflation *without* assuming any specific form of the dispersion relation and allowed the initial state of the field to be arbitrary. He showed that the power spectrum did not *strongly* depend on the dispersion relation and that the form of the dispersion relation did not play a significant role in obtaining the corrections to the scale invariant spectrum. He also showed that the signatures of the deviations from the flat scale-invariant spectrum from the CMBR observations due to quantum gravitational effects *cannot* be differentiated from the standard inflationary scenario with an *arbitrary* initial state.

Classical Gravity

On field of gravitational magnetic charge

The Kerr solution is the unique vacuum solution of axially symmetric stationary spacetime under the assumptions of (i) existence of a regular smooth horizon and (ii) asymptotic flatness. Is either of the two assumptions relaxable? For an isolated body, there will be some radius at which gravitational pull on a test particle becomes irresistable. That means occurrence of a regular horizon cannot possibly be given up.

On the other hand, blackholes can exist in asymptotically non flat spacetimes. In particular, the NUT solution, which is an exact solution of the Einstein vacuum equation, is not asymptotically flat. The NUT parameter could be interpreted as the measure of gravitational magnetic charge. For description of gravitational field of a rotating body having both gravitational electric and magnetic charge, it is therefore pertinent to seek the most general vacuum solution for axially symmetric stationary spacetime without the assumption of asymptotic flatness.

Z.Y. Turakulov and *N. Dadhich* approach this question from different perspective. They argue that any physically meaningful spacetime must have integrable motion; i.e. Hamilton-Jacobi equation for particles and Klein-Gordon equation for scalar field must be separable. On the general axially symmetric spacetime metric, they first impose the conditions of integrability and then seek the most general vacuum solution. The general solution turns out to be the known Kerr-NUT solution which has regular horizon but it is not asymptotically flat.

Their method of obtaining the solution brings forth an interesting duality relation between the electric charge/mass and magnetic charge/NUT parameter. They have in this way obtained a true gravitationally dual spacetime to the Kerr solution. It would describe gravitational field of a rotating NUT (magnetic) charge. This is an interesting solution which (though contained in the Kerr-NUT solution) was not realised as dual of the Kerr solution.

Brane world

Brane world scenario has been inspired by the recent developments in string and M theories. The two most attractive features of this scenario are: (i) the resolution of the mass hierarchy problem in the standard model of particle physics and (ii) the use of curvature of higher dimensional space to confine gravity to the brane, allowing the extra dimensions to be now compact.

Gravity is essentially supposed to be a higher dimensional interaction which manifests as the Einstein theory in usual 4-dimensional spacetime only in low energy limit. The higher dimensional, say 5-D, bulk spacetime hosts the brane as a fixed point, which is the physical 4-D world we live in. All matter fields are on the brane while gravity can propagate in higher dimensions. In the Randall - Sundrum single brane model, bulk is 5-D AdS spacetime and brane is flat. There is Z_2 symmetry in the extra dimension and then bulk's curvature is used to confine gravity on the brane. That means, zero mass gravitons have ground state on the brane and hence remain localized on it. This is the most remarkable feature of this model.

By considering perturbations of AdS bulk metric, it has been shown that for specific values of brane tension and bulk and brane cosmological constants, the wave equation for zero mass graviton does admit normalized solution localized on the brane. This, of course, requires a very fine tuning of the bulk and brane parameters. The question arises: how stable is this confinement? *Parampreet Singh* and *Dadhich* have investigated this question when bulk is described by the Nariai metric which (unlike AdS) is not conformally flat and confinement does not occur. That is, zero mass gravitons do not have ground state on the brane.

This shows that localization of gravity on the brane does not occur for any Λ-vacuum solution for bulk spacetime. It appears that it is quite specific to AdS or to spacetimes that asymptotically approach AdS.

Gravitational collapse

One of the most important questions in GR is the ultimate end product of gravitational collapse. Is it always a blackhole which covers the resulting singularity from outside world or could the singularity be sometimes naked? The statement that the former is the case goes by the name, Cosmic Censorship Conjecture (CCC). A number of examples have indicated that the latter possibility is not ruled out.

It turns out that inhomogeneity in density of collapsing matter could give rise to a naked singularity (NS). In view of recent interest in higher dimensions as well as in brane world, it is pertinent to investigate gravitational collapse in such settings.

S. G. Ghosh and *Dadhich* study collapse of the Vaidya null radiation onto a Minkowski cavity in higher dimensions. As dimensions increase both inhomogeneity and gravity get strengthened. In collapse, they, however, work against each other. It turns out that ultimately gravity has an upper hand. The parameter window in the initial data set leading to NS in 4-D gets partially covered with increase in dimension. Though higher dimension would, therefore, favour BH, the CCC would be fully respected only for a space of infinite dimensions. On the other hand, *Dadhich* and Ghosh study the same situation for collapse on a brane. For this, they first obtain the brane analogue of the Vaidya solution. On the brane, gravity is strengthened because it gets reflected from bulk's curvature back onto the brane as a trace free matter field. It is, therefore, expected that it would, as for higher dimensions, get enhanced and thereby favouring BH against NS. This expectation is borne out by analysis. Here again the parameter window giving rise to NS in 4-D shrinks.

Both these considerations of higher dimensions and brane world refer to high energy end, and in this context BH seemed to be favoured as against NS.

Traversable wormholes

Traversable Lorentzian wormholes gave rise to the exciting possibility of constructing time machine models. It is well known that matter field required to support such an object must necessarily violate the null energy condition. All the work on wormholes suffer from this basic defect.

A generic wormhole spacetime is an adhoc construction in which one prescribes for existence of a throat and non existence of a horizon. *Dadhich*, Sayan Kar, S. Mukherjee and M. Visser have proposed an equation for spherically symmetric spacetime and its general solution gives a Lorentzian wormhole. It is for the first time an equation has been proposed for a wormhole spacetime. Further, this equation has interesting implications for duality. This would also imply vanishing of scalar curvature and hence matter field supporting the wormhole would have to be trace free.

This is the most general electrogravity self dual spacetime containing the Schwarzschild spacetime and it describes a wormhole. Further by transforming the solution into isotropic coordinates, its rich structure in terms of blackholes, wormholes and nakedly singular geometries have been exposed. It may be argued that the Schwarzschild blackhole may not be as isolated and unique as it is believed to be - it is essentially sitting in the midst of a host of traversable wormholes, which are quite exciting objects. The main objection to them is, however, violation of energy conditions. In view of the brane world models, the rigidity about the energy conditions is slowly loosening and hence, it is probably best to keep an open mind on such exotic possibilities.

Of scalar hair, global monopoles and scalar fields

The folklore goes that blackhole has no hair. This is based on the fact that asymptotically flat, axially symmetric, stationary spacetime with horizon admits the unique solution of the vacuum Einstein equation. It is specified by only two parameters, mass and angular momentum of the hole.

If we drop the requirement of asymptotic flatness, it would make way for the additional NUT hair. If we further bring in electrovac in place of vacuum which would generate electric charge as a hair. What happens if we bring in a scalar field? It turns out that only when scalar field is non minimally coupled to curvature, it generates a hair as is the case for dilaton gravity. The hair so generated would be of secondary kind, because it can't live of its own. It can only ride on an other hair like mass or electric charge.

There exists a very useful and fairly general result that existence of scalar hair for a non minimally coupled scalar-tensor theories can actually be inferred by means of a conformal transformation from the one of minimally coupled theory. N. Banerjee, S. Sen and *Dadhich* extend this result to the case in which scalar field is not only minimally coupled but is also self interacting through a potential. Of course, all the previous cases are included as special cases.

Dadhich has defined elctrogravity duality by the interchange of active and passive electric parts of the curvature. This is in fact equivalent to the interchange of Ricci and Einstein tensors. The effective empty space for spherically symmetric spacetime was defined by $\rho = T_{ab}u^a u^b = 0$, $\rho_n = T_{ab}k^a k^b = 0$ where $u^a u_a = 1, k^a k_a = 0$. That is, the absence of energy density for timelike and null particles is good enough to characterize the Schwarzschild solution and thereby empty space, for spherically symmetric spacetime.

Under the electrogravity duality transformation we have: $\rho \to \rho_t = (T_{ab} - 1/2T g_{ab})u^a u^b, \rho_n \to \rho_n$. The dual equation to effective empty space equation would, therefore, be $\rho_t = 0, \rho_n = 0$, which gives the solution of a blackhole with a global monopole charge.

Global monopoles are supposed to be created in phase transition in early universe when global $SO(3)$ symmetry is spontaneously broken into $U(1)$. They are described by triplet scalar fields and they asymptotically produce stresses which agree with the ones produced by the solution of dual (empty space) equation. Global monopole solution is, thus, electrogravity dual of Schwarzschild solution.

The equation $\rho_n = 0$ would imply $T^0_0 = T^1_1$ for radially moving photons while $T^0_0 = T^2_2$ for transversely moving photons. *Dadhich* and Banerjee show that the effective empty space equation $\rho = T^0_0 = 0, \rho_n = T^0_0 = T^2_2$ in the latter case will also give the Schwarzschild solution under the assumption that there is only one independent metric function. In this case, the dual equation, $R^0_0 = 0, R^0_0 = R^2_2$ will yield the solution for minimally coupled scalar field. In this sense, they show that the minimally coupled scalar field is also dual to the Schwarzschild solution.

This shows that there exist more than one electrogravity dual spacetimes to the Schwarzschild solution. Taking null density for radial photons leads to the global monopole spacetime as dual while null density for transverse photons gives minimally coupled scalar field as dual. Of course, both of them would satisfy the zero active gravitational density equation of state, $\rho + \sigma p_i = 0$. That is, the source of duality has zero gravitational mass and hence it does not appear in acceleration but only in tidal acceleration.

Spacetime symmetries

There has been quite a comprehensive body of work on conformal symmetries of spacetime. Despite this, D.B. Lortan, S.D. Maharaj and *Dadhich* have managed to prove a conjecture: For conformal symmetries of inheriting geodesic flows, there can exist no proper conformal Killing vector for perfect fluids except for FRW spacetimes. Further, for a non-homothetic vector field, the propagation of active gravitational density, $(R_{ab}u^a u^b)$, along the integral curves of the symmetry vector is always homogeneous.

Gravitational Waves

The direct detection of gravitational radiation is one of the major challenges in this millenium. The existence of gravitational waves (GW) was predicted by Einstein as early as 1916. In the general theory of relativity, in some ways, GW are similar to electromagnetic waves, in that they travel in vacuum with the universal speed $c \sim 3 \times 10^8$ metres per second and have two polarisation states. But in many crucial ways they differ from electromagnetic waves; while electromagnetic waves are generated by matter on the atomic scale, GW are generated by bulk motions of matter.

Powerful sources of GW of astrophysical origin must be compact and relativistic. Compact objects possess high potential energies which can give rise to relativistic velocities in surrounding matter, thus, producing powerful GW. Even in the best case, the GW are very weak which makes them hard to detect, so much so that, physicists had not seriously considered them for experimental observation or detection till fairly recently.

But thanks to the enormous strides technology has taken in the past few decades and simultaneously the efforts put in by astronomers, the observation of GW has become a serious possibility. At first the sensitivities required to detect GW were believed to be naively optimistic. But subsequent negative results obtained by experimentalists, coupled with the up-to-date and careful estimates of the strengths of the sources obtained from astrophysics and highly focussed R & D for better detection techniques, led to the construction of three large scale and two medium scale laser interferometric detectors. The three large scale detectors comprise of two detectors of the US - the LIGO project with arm lengths of 4 km. - and one detector of the Italian/French collaboration - the VIRGO project with an arm length of 3 km. In the medium scale there are the German-British project - the GEO600 with an arm length of 600 metres - and the Japanese TAMA300 of 300 metres arm length. With funding approval, the Australian AIGO500 project - a 500 metre detector near Perth - is a future possibility.

GW distort spacetime, in that they change the distances between free test masses. For example, a neutron star binary at distance of 100 Mpc will produce a differential length change of $\sim 10^{-17}$ cm, for test masses kept a few kilometres apart, which is the typical length of the arm of a large scale ground-based interferometric detector. These instruments are sensitive in the bandwidth from a few Hz (~ 10 Hz) to a few kHz having the best sensitivity around 500 Hz. In this window, the ground based interferometers will be able to observe inspiraling compact binaries in their last stages before merger, non-axisymmetric rotating neutron stars and supernovae.

However, the lower (floor) limit of few Hz of the band-width of the ground-based detector is a serious limitation to observing GW events. The solution to the above mentioned problem is a detector in space.

The premier instrument in the low frequency band is the Laser Interferometer Space Antenna (LISA). The LISA is a NASA and ESA project and there is good chance of LISA flying as early as 2011. The goal of LISA is to detect and study low frequency astrophysical GW. LISA consists of three space-crafts located 5 million kilometres apart forming an equilateral triangle. Each space-craft houses two lasers and two telescopes each pointing at the two distant space-crafts. Each laser is phased locked either to its companion on the same space-craft or to the incoming light from the laser in the distant space-craft. The light sent out by a laser in one space-craft is received by the telescope on the distant space-craft. This light is then amplified maintaining the phase of the incident light and then sent back to the original space-craft. The phase of this light is then compared with the phase of the outgoing light. The round trip journey defines one arm of the interferometer. Thus, any two arms make up an interferometer. The configuration is, therefore, tantamount to three interferometers which are not fully independent. The space-crafts are maintained drag-free by a complex system of accelerometers and micro-propellers. Each space-craft revolves in its own heliocentric orbit. The centre of the equilateral triangle is located on the ecliptic and lags 20 degrees behind the Earth. The space-crafts rotate in a circle drawn through the vertices of the triangle and the LISA constellation as a whole revolves around the Sun.

Cancelling laser phase noise in LISA

In ground based detectors, the arms are chosen to be of equal length so that the laser light experiences identical delay in each arm of the interferometer. This arrangement precisely cancels the laser frequency/phase noise at the photodetector. This cancellation of noise is crucial, since the raw laser noise exceeds by several orders of magnitude of the other noises in the interferometer. The requisite sensitivity of the instrument can, thus, only be achieved by near exact cancellation of the laser frequency noise. However, in LISA it is impossible to maintain equal distances between space-crafts and the laser frequency noise cannot be cancelled in an obvious manner. Several schemes, some quite elaborate, have been proposed, which combine the recorded data by suitable time-delays corresponding to the three arm,lengths of the giant triangular interferometer. These schemes have been obtained by trial and error, and essentially in a ad-hoc manner.

The salient achievement of the work (under the IFCPAR programme) by *S. V. Dhurandhar*, *R. Nayak* and J-Y. Vinet consists of providing a *systematic method* based on algebraic-geometry, which not only reproduces the previously obtained data combinations but guarantees *all* the data combinations that cancel the laser frequency noise. The data combinations consist of the six suitably delayed data streams, the delays being integer multiples of the light travel times between space-crafts, which can be conveniently expressed in terms of polynomials in the three delay operators corresponding to the light travel time along the three arms. The laser noise cancellation condition puts three constraints on the six polynomials of the delay operators corresponding to the six data streams. The problem, therefore, consists of finding six tuples of polynomials which satisfy the laser frequency noise cancellation constraints. These polynomial tuples form a module, called in the literature, the *module of syzygies*.

There exist standard methods for obtaining the module of syzygies. By that we mean, methods for obtaining the generators of the module so that the linear combinations of the generators generate the entire module. The procedure first consists of obtaining a Groebner basis for the ideal generated by the coefficients appearing in the constraints. This ideal is in the polynomial ring in the three delay operators. From the Groebner basis, there is a standard way to obtain a generating set for the required module. The method gives seven generators for the module, all of which are not independent. Out of these, four generators suffice to generate the required module. Alternatively, a generating set for the module can be obtained by using the software Macaulay 2.

The importance of obtaining more data combinations is evident: they provide the necessary redundancy - different data combinations produce different transfer functions for GW and so specific data combinations could be optimal for given astrophysical source parameters in the sense of maximising signal-to-noise (SNR), detection probability, improving parameter estimates, etc. This result has several potential applications. It may be possible to combine the data in a coherent way so as to make LISA more directional. Also, if the data combinations corresponding to the generators of the module can be constructed on the spacecraft, it would save enormously in the transfer of data to Earth, because (a) the band-width would be drastically reduced, and (b) data corresponding to just four generators compared to the six data streams, has to be sent down to Earth.

One interesting GW source is the primordial stochastic background. Here one must distinguish between the instrumental noise and the GW 'noise'. In order to accomplish this, one needs a data combination that is insensitive to GW. The previous work lists one such combination - the Sagnac combination - which cancels the GW at the second order in frequency. *Nayak, Dhurandhar* and Vinet have been able to find a submodule on two generators which accomplishes the same. Also one combination has been found which cancels GW to third order. These results will be useful in searching for the primordial background of GW.

The extended hierarchical search for inspiraling binaries

In 1991 B. S. Sathyaprakash and *S. V. Dhurandhar* had presented a procedure for detecting inspiraling binaries with matched filtering techniques. A one step search algorithm was employed with very closely spaced templates in the parameter space. While performing a fine search of the parameter space, this approach entails a large computational cost. S. D. Mohanty and *Dhurandhar* had proposed a rigorous formalism involving a *two step* search where, the data is searched in two stages. In the first (trigger) stage of the algorithm, a coarse set of templates is used along with a low threshold. The first stage crossings are then followed up by a more fine search in the neighbourhood of the crossings. The cost saving factor for the post-Newtonian templates is about 30 over the one step search.

The hierarchical search of Mohanty was performed over the two masses of the binary. For the past year or so, *Sengupta* and *Dhurandhar* and A. Lazzarini and T. Prince from Caltech have been extending the hierarchy to a third parameter: the time-of-arrival. This work forms part of the Ligo Science Collaboration (LSC) tasks (IUCAA joined the LSC in August 2000). The strategy is based on the fact that the inspiraling binary GW signal (the chirp signal) contains most of its power at low frequencies. The power in the chirp signal falls of as $f^{-7/3}$. Because of this, the chirp signal can be cut-off at quarter of the usual upper cut-off frequency without losing too much signal power. The data is then sampled at the reduced Nyquist frequency, saving the computational cost of the FFTs in the triggering stage by about the same factor. The cost saving factor ideally rises to about 130 over the flat search.

However, in the realistic situation, where one assumes a mass range for the parameter space, the search templates must lie within the boundaries specified by the mass range. It turns out that the parameter space in the masses is essentially 1-dimensional for most of the mass range, which results in bringing down the gain factor. Also, there are other effects such as rotation of the templates towards the high mass end. The final outcome of the boundary and rotation effects is to bring down the cost gain factor over a flat search to about 65 for the LIGO noise curve.

Future work involves validation of the extended search algorithm and generating a code to LIGO specifications within the LAL and LDAS environments.

Network analysis

In view of the upcoming network of detectors, the data analysis problem of extracting signals using a network of interferometric detectors is of major importance to the gravitational wave community. It is one of the tasks in the IUCAA-LSC collaboration.

In the past, a sizable amount of research has been done on the problem of detecting gravitational waves using a single detector. However, very little work has been devoted towards developing techniques which analyse data from a network. Searching for burst signals using a network is important because of (i) its superior sensitivity, as compared to a single detector (ii) extracting more and accurate information about the source, such as its location in the sky etc. and (iii) discriminating against non-Gaussian noise events which plague the detector.

There are basically two approaches to the problem: coincident and coherent extraction of the signal from a network of detectors.

The coincidence approach involves separately filtering the signal in each detector, applying two separate thresholds corresponding to each detector and preparing two event lists determined by the crossings. The event lists are then matched. If the estimated parameters for the events lie in a reasonable neighbourhood in the parameter space of signals, a detection is registered.

A. Pai, S. Bose and *Dhurandhar* have formulated a coherent search strategy based on the maximum likelihood methods, which optimally extracts the inspiraling binary signal from the network data. Coherent extraction crucially uses the phase information and combines it optimally. Further, using clever analytical maximisations, the strategy substantially cuts down on the computational cost. The strategy is analogous to the aperture synthesis used by radio astronomers.

A single likelihood ratio is deduced for the entire network, which is now a function of eight parameters of the signal, namely, the distance to the binary, the initial phase, the polarisation angle, the inclination angle of the orbit, the time-of-arrival at a fiducial detector, the direction angles to the source and the chirp time which depends on the masses of the stars. The formalism developed allows for the analytic maximisation over the first four parameters mentioned above and moreover the Fast Fourier Transform (FFT) can be applied to maximise over the time-of-arrival. The analytic maximisation and the FFT allow not only the continuous scanning of the parameter space over the first five parameters but also save enormously on the computational costs. For the rest of the parameters, a bank of templates is needed. The number of templates for a hypothetical network of three detectors widely spaced around the globe is about 10^9 for the post-Newtonian (upto 2.5 order in the PN expansion parameter v^2/c^2) waveform, where the search is carried for binary masses greater than one solar mass (the number of templates is sensitive only to the lower limit of the mass range). This number may be deemed to be typical for the real network, say, of the two LIGO detectors and the VIRGO detector. If the mass limit is lowered to 0.5 solar mass, then the number of templates increases by an order of magnitude. It is clear from these numbers that an hierarchical strategy needs to be formulated in order to bring down the cost of the search.

In the near future LIGO, GEO and TAMA are planning coincidence runs. Both the coherent and coincidence search strategies could be tested on the data and then compared.

Continuous wave sources:

Continuous wave (CW) sources pose one of the most computationally intensive problems in GW data analysis. A rapidly rotating asymmetrical neutron star is a source of continuous gravitational waves. For the known pulsars in our galaxy, the maximum gravitational wave amplitude can be estimated from the spindown luminosity, which turns out to be three or four orders of magnitude below the broadband sensitivity of the detectors. A long integration time typically of the order of a few months or years is needed to build up sufficient signal power before it can stand above the noise. The long integration time in turn implies that Earth's motion around itself, the sun and the moon is important and modulates the signal, introducing Doppler shifts which depend on the direction to the source. If one desires to coherently extract the signal, the detection problem is complicated by the Doppler effect which must be first corrected for. For instance, a monochromatic signal with a frequency of 1 kHz from an isolated source can spread into a million Fourier bins if no Doppler correction is applied. About 10^{13} corrections must be applied to the data to search a monochromatic source over the entire sky. The problem is made worse, if the intrinsic frequency of the source changes, say due to spin down, or because the source itself accelerates, for instance, if it is a part of a binary system. Thus, coherent extraction of the signal whose direction and frequency is unknown is impossibly computationally expensive.

However, targeted searches are computationally viable, for example, if the direction to the source is known. *Dhurandhar* and A. Vecchio from AEI, Max Planck, Potsdam, Germany, considered targeted searches for known radio pulsars. For most pulsars, radio observations place tight error bars on some of the parameters. This considerably reduces the volume of the parameter space to be searched over and the cost reduces dramatically. Using the data from the Princeton catalogue for pulsars in binaries, they have made a detailed analysis. For the pulsars that have been discovered long ago, the parameters, such as say, the orbital period, are known very accurately and a search with just a few filters is sufficient. However, for the recently discovered pulsars, the error bars are not very tight and thus the number of filters needed goes up to $\sim 10^{10}$.

Targeted searches could also be used for

LMXBs. Several such systems would be detectable by LIGO operating in the "enhanced" configuration (LIGO II), if the detector sensitivity is tuned, through narrow-banding, around the emission frequency. In particular, Sco X-1, the most luminous X-ray source in the sky, possibly is marginally detectable by "initial" LIGO and GEO600 (the latter in narrow-band configuration), where an integration time of approximately 2 years would be required.

Cosmology and Structure Formation

Tachyonic field as dark matter

The most conservative explanation of the current cosmological observations will require two components of dark matter: (a) First one is a dust component with the equation of state $p = 0$ contributing $\Omega_m \approx 0.35$. This component clusters gravitationally at small scales and will be able to explain observations from galactic to super-cluster scales. (b) The second one is a negative pressure component with equation of state like $p = w\rho$ with $-1 < w < -0.5$ contributing about $\Omega_V \approx 0.65$. There is some leeway in the (p/ρ) of the second component but it is certain that p is negative and (p/ρ) is of order unity. Cosmological constant will provide $w = -1$, while several other candidates based on scalar fields with potentials will provide different values for w in the acceptable range. By and large, component (b) is noticed only in the large scale expansion and it does not cluster gravitationally to a significant extent.

Neither of the components (a) and (b) has laboratory evidence for their existence directly or indirectly. In this sense, cosmology requires invoking the tooth fairy twice to explain the current observations. It would be nice if a candidate could be found which can explain the observations at both small and large scales (so that the tooth fairy needs to be invoked only once). The standard cold dark matter model of the eighties belongs to this class but – unfortunately – cannot explain the observations. It is obvious from the description in the first paragraph, that any such (single) candidate must have the capacity of leading to different equations of state at different scales and making a transition from $p = 0$ at small scales to $p = -\rho$ (say) at large scales. Normal particles (that is, one-particle-excitations of standard quantum field theory) like wimps will usually lead to the equation of state $p = 0$ at all scales. On the other hand, homogeneous field configurations in scalar field models will behave like dark energy with negative pressure and cannot cluster effectively at small scales.

T. Padmanabhan and *T. Roy Choudhury* are currently investigating the possibility of whether a recently proposed candidate — a rolling tachyon arising from string theory — can explain dark matter observations *at both small and large scales.*

The structure of this scalar field can be understood by a simple analogy from special relativity. A relativistic particle with (one dimensional) position $q(t)$ and mass m is described by the Lagrangian $L = -m\sqrt{1-\dot{q}^2}$. It has the energy $E = m/\sqrt{1-\dot{q}^2}$ and momentum $p = m\dot{q}/\sqrt{1-\dot{q}^2}$, which are related by $E^2 = p^2 + m^2$. As is well known, this allows the possibility of having massless particles with finite energy for which $E^2 = p^2$. This is achieved by taking the limit of $m \to 0$ and $\dot{q} \to 1$, while keeping the ratio in $E = m/\sqrt{1-\dot{q}^2}$ finite. The momentum acquires a life of its own, unconnected with the velocity $\dot{q}$, and the energy is expressed in terms of the momentum (rather than in terms of $\dot{q}$) in the Hamiltonian formulation. We can now construct a field theory by upgrading $q(t)$ to a field ϕ. Relativistic invariance now requires ϕ to depend on both space and time and $\dot{q}^2$ to be replaced by $\partial_i\phi\partial^i\phi$. It is also possible now to treat the mass parameter m as a function of ϕ, say, $V(\phi)$ thereby obtaining a field theoretic Lagrangian. The Hamiltonian structure of this theory is algebraically very similar to the special relativistic example we started with. In particular, the theory allows solutions in which, keeping the energy (density) finite. Such solutions will have finite momentum density (analogous to a massless particle with finite momentum p) and energy density. Since the solutions can now depend on both space and time (unlike the special relativistic example in which q depended only on time), the momentum density can be an arbitrary function of the spatial coordinate. This provides a rich gamut of possibilities in the context of cosmology.

Their model can explain dark matter at different scales and predicts a relation between the ratio $r = \rho_V/\rho_{\rm DM}$ of the energy densities of the two dark components and expansion rate n of the universe (with $a(t) \propto t^n$) in the form $n = (2/3)(1+r)$. For $r \approx 2$, we get $n \approx 2$ which is consistent with observations.

An oscillating universe

Kanekar, *V. Sahni* and Shtanov have developed a new model for an oscillating universe in which the expansion-contraction cycles are powered by the energy of a scalar field.

The idea of a cyclical oscillating universe – one that is continuously reborn from the ashes of a previous existence – finds expression in the philosophical and cultural beliefs of many ancient civilizations. Within the framework of modern relativistic cosmology, oscillating models (analytically continued through the big bang singularity) arise naturally as exact solutions of the Einstein field equations for a spatially closed universe consisting of a perfect fluid. Since, all expansion-contraction cycles in such models are identical, one might feel that an oscillating universe containing an infinite number of cycles would be infinitely old, somewhat resembling, on the average, a steady-state model. Dissipative processes leading to entropy growth, however, change this picture radically.

As originally demonstrated by Tolman (1934), the growth of entropy increases the total volume of the universe at the maximum of each expansion cycle; this observation has several important consequences, some of which are summarised below.

(i) Tolman strongly felt that the possibility of thermodynamically recycling the universe would have a "liberalizing action on our general thermodynamic thinking" since it would dispel the notion that "the principles of thermodynamics necessarily require a universe which was created at a finite time in the past and which is fated for stagnation and death in the future". Thus, the oscillating universe was seen to present a credible alternative to the idea of the thermodynamic heat death postulated by nineteenth century physicists and popular in this century as well. (The latter may still be possible in a flat/open universe.)

(ii) The increase in entropy from cycle to cycle suggests that an oscillating universe could not have had an infinitely long total duration since, given the present (finite) value of its total entropy and postulating that the entropy increase from cycle to cycle is finite, one is led to conclude that the number of cycles preceding the present one is also finite. An oscillating universe cannot, therefore, be infinitely old and must have been created, perhaps quantum mechanically, at some point in the past. Since the total mass (energy) of a closed universe is zero, its creation from the vacuum does not violate any known laws of conservation and is, therefore, possible, in principle.

(iii) An important consequence of an oscillating universe with an increasing expansion maximum at every cycle, is that the horizon and flatness problems are gradually ameliorated as the universe grows older, larger and flatter during each successive expansion cycle. The oscillating universe may, thus, present a credible alternative to the inflationary scenario in this respect.

In a radical departure from most previous work on oscillating models in which entropy production associated with dissipative processes led to the growth of the expansion maximum of each cycle, Kanekar, *Sahni* and Shtanov constructed a mechanism which leads to increasing oscillatory cycles *without* entropy production. In their model, the presence of a massive scalar field (in a closed FRW universe) gives rise to growing expansion cycles, the increase in expansion amplitude being related to the work done by/on the scalar field during the expansion/contraction of the universe. (The presence of other matter fields, in addition to the scalar field, does not affect these conclusions, as long as interactions between such fields and the scalar are sufficiently weak.)

To see how this mechanism works, consider first how the presence of a bulk viscosity affects cosmological expansion.

The presence of a bulk viscosity ζ results in a modification of the cosmological fluid pressure P to $P = P_0 - 3\zeta H$. Here, P_0 is the equilibrium pressure and $H = \dot{a}/a$ is the Hubble parameter. (An example of bulk viscosity is provided by a fluid in which energy is easily exchanged between translational and rotational/internal degrees of freedom, an example being a gas of rough spheres.) From the above relation, one finds that, during expansion, $H > 0$ and $P < P_0$, whereas, during collapse, $H < 0$ and $P > P_0$. This asymmetry during the expanding and contracting phases results in the growth of both energy and entropy, in the words of Tolman (1934) "if the pressure tends to be greater during a compression than during a previous expansion, as would be expected with a lag behind equilibrium conditions, an element of fluid can return to its original volume with increased energy and hence, also with increased entropy". The increase in energy makes the amplitude of successive expansion cycles larger enabling the universe to spend "a greater and greater proportion of its period in a condition of lower density ... even though a return to higher densities would always occur".

Although, Tolman linked the asymmetry in pressure during expansion and collapse to the production of entropy, Kanekar, *Sahni* and Shtanov showed that such an asymmetry also arises for non-dissipative Lagrangians such as those describing a massive scalar field in a FRW spacetime. In this case, the asymmetry in pressure leads to a significant increase in scalar field energy and results in increasing the maximum volume of the oscillating universe.

The motion of the scalar field arises in response to the dual action of the accelerating force $dV/d\phi$ and the damping term $3H\dot{\phi}$. In the chaotic inflationary scenario $V \propto \phi^n$ $(n = 2, 4)$, for sufficiently large values $\phi \gtrsim m_{Pl}$, the damping caused by the expansion of the universe $(H > 0)$ settles the scalar field into a 'slow-roll' regime during which $\frac{1}{2}\dot{\phi}^2 \ll V$ and $P \simeq -\rho$. Since, the equation of

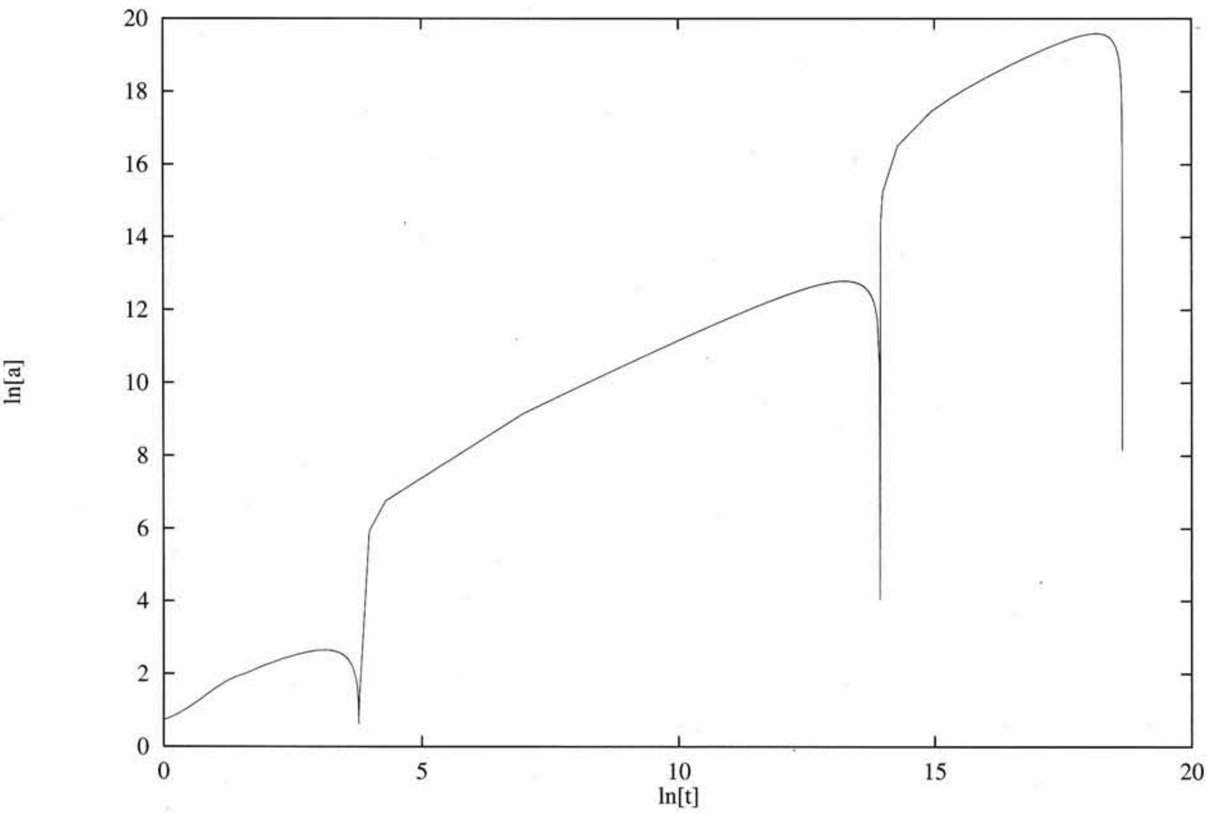


Figure 1: The expansion factor for an oscillating universe containing a scalar field. Note the monotonic increase in successive expansion maxima (plotted on the logarithmic scale).

state of the scalar field mimics that of the cosmological constant, the expansion of the universe is inflationary, $a \propto \exp \int H(t)dt$. Exactly the reverse situation arises when the universe contracts. In this case, $H < 0$ and the term $3H\dot{\phi}$ now accelerates the motion of ϕ instead of damping it, as it did during expansion. As a result, the kinetic energy of the scalar field is now much larger than its potential energy $\frac{1}{2}\dot{\phi}^2 \gg V$ and it follows that the resulting equation of state is $P = \rho$ (sometimes called the equation of state of 'stiff' matter). Consequently, the scalar field in a closed universe satisfies two generic regimes: $P \simeq -\rho$ (expansion $H > 0$)$P \simeq \rho$ (collapse $H < 0$).

For polynomial potentials, $V \propto \phi^n$, these two regimes are separated by an epoch during which the scalar field oscillates about its minimum value while its equation of state mimics that of dust: $\langle P \rangle = 0$ ($n = 2$), or radiation: $\langle P \rangle = \langle \rho \rangle / 3$ ($n = 4$). (The time average is taken over many oscillations of the field.) It is interesting that the quantity P/ρ, when plotted as a function of the expansion factor, resembles a hysteresis curve. The area enclosed by the curve is related to the work done by/on the scalar field during the expansion/contraction of the universe $\delta W = \oint PdV$. If one postulates that the universe 'bounces' during contraction, then one can expect the 'work done' δW during a given expansion cycle to be converted into 'expansion energy', resulting in the growth in amplitude of each successive expansion cycle (see Figure 1).

The increase in the expansion maximum between two successive cycles is related to the work done. (The increase in energy δE is brought about at the expense of the gravitational field energy, since the total energy of a closed universe is identically zero.)

The growth in the maximum expansion amplitude can, therefore, be achieved without any recourse to an entropy generating mechanism. In fact, viewed formally, the field equations are non-dissipative and time-reversible; one, therefore, arrives at the following important conclusion: *time-asymmetry in the evolution of a closed universe can be achieved even with time-reversible field equations* ! These results have important consequences for the inflationary universe scenario since, even in the worst case scenario in which the curvature term dominates causing the universe to collapse prematurely without inflating, subsequent cycles will ensure that the value of the scalar field increases at the commencement of each expansion cycle, until the value of ϕ and $V(\phi)$ become large enough for inflation to occur. Thus, even if the universe did not inflate the first time around, it will eventually do so, due to the growing amplitude of ϕ and $V(\phi)$ at the commencement of each new expansion cycle. The results of Kanekar, *Sahni* and Shtanov, therefore, show that inflation in closed models is remarkably robust, provided the universe bounces when it reaches a high density. An oscillating universe has other important cosmological implications: (i) the possibility that relic scalar fields might play the role of dark matter or dark energy in the universe is very tempting; (ii) relics of an earlier expansion epoch such as gravity waves may be measurable today and could provide a useful test of these models.

Braneworld inflationary cosmology and relic gravity waves

The last two decades have seen considerable effort being devoted to the construction of fundamental theories of nature in more than three spatial dimensions. In such models, the four dimensional Planck scale $M_4 \equiv G^{-1/2} = 1.2 \times 10^{19}$ GeV is related to its fundamental value $M_{\rm f}$ by $M_4^2 = M_{\rm f}^{2+n}\mathcal{R}^n$ where n is the number of extra dimensions. In the original Kaluza-Klein picture, the extra dimensions were compact and microscopic $R \sim 10^{-33}$ cm, hence unobservable. However, it was soon realized that a theory in which one or more of the extra dimensions is macroscopic ($R \sim 1$ mm) has several interesting features. For instance, a model in which two of the extra dimensions extend up to a millimeter has the considerable advantage of decreasing the fundamental Planck scale to electroweak scales $M_{\rm f} \sim 1$ TeV $\ll M_4$ thereby alleviating, the hierarchy problem associated with particle physics. A further development of these ideas led to a scenario in which our universe is a three dimensional domain wall (brane) embedded in an infinite four dimensional space (bulk). The metric describing the full 4+1 dimensional spacetime is non-factorizable and the small value of the true five dimensional Planck mass is related to its large effective four dimensional value by the extremely large warp of five dimensional space. Since, gravity and matter fields remain confined to the brane, the presence of the extra (bulk) dimension does not affect Newton's law which remains inverse square.

Extending previous work, *Sahni*, M. Sami and *T. Souradeep* have shown that the prospects of inflation in such a scenario improve due to the presence of an additional quadratic density term in the Einstein equations. This new term substantially increases the damping experienced by a scalar field as it rolls down its potential. As a result, the class of potentials which lead to inflation increases and includes potentials which are normally too steep to be associated with inflation such as $V(\phi) \propto \phi^{-\alpha}, \alpha \geq 1$.

The importance of steep potentials is linked to the recent discovery that the universe may be accelerating, fuelled by a form of 'dark energy' having substantial negative pressure. Although a cosmological constant provides us with a convenient form of dark energy, formidable fine tuning problems afflict the latter and this has led to the exploration of alternatives. Scalar fields with steep potentials (dubbed 'quintessence') provide an attractive phenomenological model for dark energy since, a large class of initial conditions can be funneled into a common 'tracker-like' evolutionary trajectory at late times. Tracker models such as $V(\phi) \propto \phi^{-\alpha}$ significantly ameliorate the fine tuning problem faced by a cosmological constant and have been used to describe the current evolution of the universe. *Sahni*, Sami and *Souradeep* have demonstrated that, for a suitable choice of parameter values, scalar fields with steep potentials can successfully play the dual role of being the inflation at early times and dark energy (quintessence) at late times giving rise to a successful model of '*Quintessential Inflation*' (see Figure 2(a)).

The spectrum of relic gravity waves is an important observational imprint of brane-inflation. The quantum mechanical creation of gravitons from the vacuum is an important generic feature of expanding cosmological models. In models characterised by an early inflationary epoch, the relic gravity wave amplitude is related to the Hubble parameter during inflation while its spectrum depends upon both the inflationary and post-inflationary equation of state. *Sahni*, Sami and *Souradeep* show that the gravity wave amplitude in braneworld models is considerably enhanced over that in standard inflation. In inflationary models with steep potentials, the immediate aftermath of braneworld inflation is characterised by a 'kinetic regime' during which the inflation has the 'stiff' equation of state $p \simeq \rho$. The presence of the kinetic regime leads to a 'blue' spectrum for gravity waves, on scales smaller than the comoving horizon scale at the commencement of the radiative regime. This is a typical signature of 'Quintessential Inflation'.

Sahni, Sami and *Souradeep* show that in the case of inflationary models with steep potentials, the relic gravity wave background is an extremely potent probe which can be used both to rule out models as well to (indirectly) confirm the reality of extra dimensions (see Figure 2(b)).

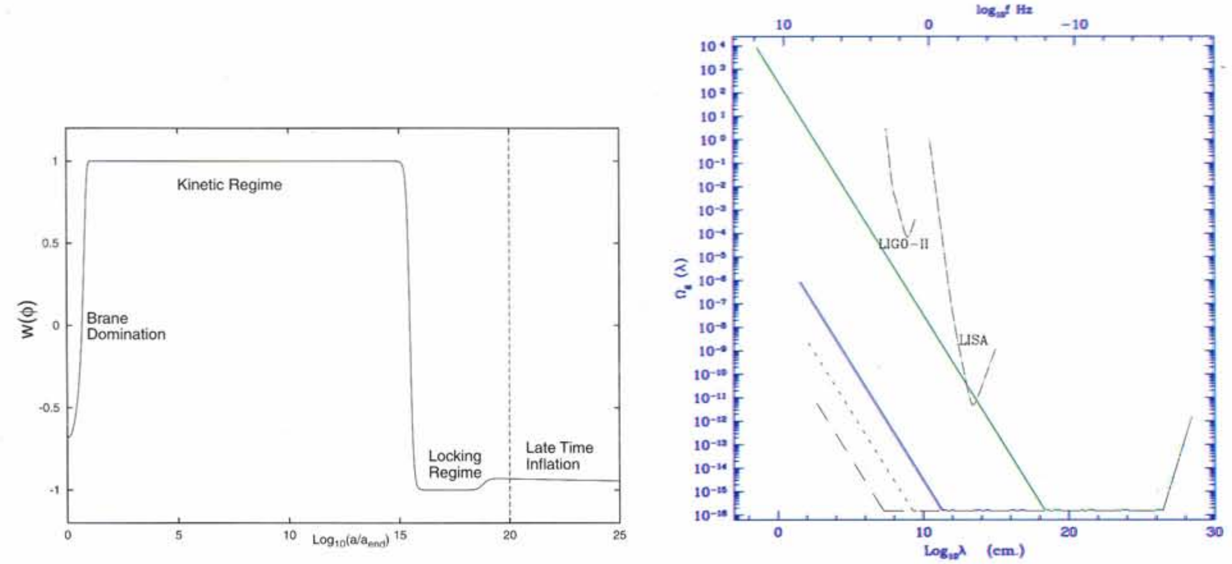


Figure 2: **(2a)** Post-inflationary evolution of the equation of state $w(\phi) = P(\phi)/\rho(\phi)$ for quintessential-inflation. The evolution of $w(\phi)$ follows four distinct stages: (i) *Post-inflationary stage.* Diminishing post-inflationary brane effects cause the equation of state in the ϕ-field to gradually increase from $w(\phi) \simeq -2/3$ to $w(\phi) \simeq 1$. (ii) *The kinetic regime.* During this regime, the kinetic energy of the scalar field exceeds its potential energy leading to $w(\phi) \simeq 1$. (iii) *Locking.* During the radiative regime, the energy density in the scalar field overshoots the energy density in radiation, resulting in an extensive period during which the scalar field equation of state locks to $w(\phi) \simeq -1$. The scalar field during this regime behaves like an effective cosmological constant since its energy density ρ_ϕ does not change appreciably with time. (iv) *Late time inflation.* During the late matter dominated regime, the ratio of the scalar field density to that in matter grows until the scalar field dominates the energy density of the universe. This leads to the current epoch of accelerated expansion ('late time inflation') during which $w(\phi) \leq -0.9$. The vertical dashed line corresponds to the present epoch. **(2b)** The COBE-normalized gravity wave spectrum is shown for a model of braneworld inflation. The dark solid line, dotted, and short dashed line correspond to three values of the post-inflationary reheating temperature: $T_{\rm rh} \simeq 2 \times 10^7$ GeV, 2×10^9 GeV, 2×10^{11} GeV respectively. The gravity wave background for the exponential potential is shown as the gray solid line. In this model reheating is caused by particles created quantum mechanically during inflation, resulting in a low temperature at the commencement of the radiative stage $T_{\rm eq} \sim 0.1$ GeV. The large gravity wave energy density predicted by this model appears to be in serious conflict with primordial nucleosynthesis constraints. The GW spectra assume the present value of the Hubble constant $H_0 = 70$km/s/Mpc. The chained lines marked LISA and LIGO-II are the expected sensitivity curves of the proposed Laser Interferometer Space Antenna and second phase of the Laser Interferometric gravity wave observatory. More details can be found in *Phys. Rev. D.* **65** 023518 [gr-qc/0105121].

Cosmology in higher dimensions

Recently, several people have studied cosmological solutions of models which assume that the universe has more than four dimensions. One assumes that matter fields are confined to a four-dimensional brane embedded in a D=4+n dimensional spacetime, while gravity can propagate in all the D dimensions. Randall and Sundrum (RS) proposed a five-dimensional model based on a non-factorisable geometry. The "warp" factor, which scales the four dimensional spacetime with respect to the extra dimension, is a rapidly changing function of the extra dimension. The first RS model consists of two, four dimensional branes which are defects in a five dimensional anti-de,Sitter background. One of the branes is a positive tension 'Planck' brane and the other is the brane on which standard model particles are confined, which has a negative tension and is called the 'TeV' brane. A variant of this higher dimensional scenario is the one brane world, in which the Planck brane is taken to infinity and one has a four-dimensional brane embedded in a five-dimensional anti-de Sitter bulk. *H. K. Jassal* has studied cosmological solutions in the five dimensional, two brane Randall-Sundrum brane scenario. The radius of the compact extra dimension is taken to be time dependent. The four dimensional reduced action is obtained by integrating over the extra dimension. It is shown that the cosmology consistent with the two brane Randall-Sundrum model is a power law expansion of the universe, with scale factor growing as $t^{1/2}$. The two branes tend to move towards each other with time. This result is consistent with earlier work on D-branes which states that brane anti-brane system is an unstable one.

Topology of the large scale structure

In recent years, there has been a revival of interest in the morphological approach to describe the large scale structure of the universe. Since, morphology involves both the geometrical as well as the topological description of an ensemble, it holds the promise of providing a complete quantification scheme for point processes such as those encountered in N-body simulations of structure formation and redshift surveys of galaxies. The Minkowski Functionals (hereafter MFs), which quantify the morphology of an ensemble, are sensitive to the extent of gravitational clustering in a system and hence, they can be used (together with derived statistics like Shapefinders) to differentiate between rival models of structure formation as well as to make a comparison between the simulation based mock redshift surveys and the observed large scale structure of the universe through existing quasi-two dimensional galaxy catalogues (e.g., the Las Campanas Redshift Survey(LCRS)) as well as ongoing fully three dimensional redshift surveys (2 degree Field (2dF) survey, Sloan Digital Sky Survey (SDSS), etc.).

Jatush Sheth and *Varun Sahni* have adopted the morphological approach to study the large scale structure of the universe. In this context *Sheth* has developed a software (described in the earlier annual report) to calculate the geometric MF (volume, area and integrated mean curvature) of the 3-dimensional point processes by modelling triangulated polyhedral surfaces for clusters and superclusters of galaxies. An important recent extension of the code allows it to compute the genus of the surfaces as well, thereby complimenting geometrical information with the topology and completing the morphological description of excursion sets defined at a given threshold of density. The genus of a compact surface describes whether a surface is simply, or multiply connected. Thus, the genus value of a sphere (and its deformations) is zero, while a torus has a genus of one, a krendel has a genus of two, etc. In more general terms, the genus equals the number of handles(or voids, as they are commonly referred to in the community) in excess of the number of isolated underdense regions (holes). A sponge-like surface consisting of many handles in excess of holes, will as a rule, have a large genus number.

The genus of a closed and continuous triangulated surface is

$$G_s = 1 - \frac{\chi}{2} = 1 - \frac{N_T - N_E + N_V}{2},$$

where χ is the Euler characteristic, N_T is the number of triangles on the surface, N_E is the number of edges which take part in making these triangles and N_V is the total number of vertices on the surface.

While the performance of one of the geometric MFs, the integrated mean curvature, is still being critically assessed, the rest of the three MFs have been found to be estimated with a remarkable accuracy. As a followup, *Sheth and Sahni* have studied the morphology of N-body simulations performed by the VIRGO Consortium of Europe, with specific attention being given to the topology of these samples. Since the topology of the large scale structure is a very widely studied statistic, a large body of confirmation checks and new results were anticipated while carrying out such an exercise.

The VIRGO Consortium has carried out a suite of high-resolution, 17 million particle, N-body simulations that sample volumes large enough to give clustering statistics with unprecedented accuracy. The focus is on a set of four cosmological models; a flat model with the matter density $\Omega_0 = 0.3$ (the ΛCDM model), an open model with $\Omega_0 = 0.3$ (the OCDM model), and two models with the total density $\Omega = 1$, one with the standard CDM power spectrum (the SCDM model) and the other with the same power spectrum as the $\Omega_o = 0.3$ models (the tilted CDM or τCDM model). In all cases, the amplitude of the primordial fluctuations is set so that the models reproduce the observed abundance of rich galaxy clusters at $z = 0$. The box-size in all the cases is 239.5 h^{-1}Mpc. All simulations have been carried out on a 256^3 grid.

The above simulations have been analysed at the present epoch (z=0). Further, the evolution of morphology with redshift is also studied for three of the above four models (excluding OCDM). All samples were studied on a 128^3 grid, with a smoothing scale of 2 h^{-1}Mpc, which was found to be small enough to retain a large number of small scale features. The aim was to check against the form for the genus curve predicted by the Gaussian random phase hypothesis encoded in the initial conditions of the N-body simulations.

Sheth and Sahni estimated the topology of the samples by employing two techniques; the one which is based on the estimation of the deficit angles on a grid, for which the code was developed in mid 80s and is available on the web, and the other based on the triangulation scheme which leads to the calculation of all the three geometric MFs in addition to the topological MF(Genus). The former method works directly with the grid. It computes the topology of the density field at a given level of density by operating on a grid on which the overdense sites are mapped to 1s and the underdense sites are mapped to 0s. The deficit angle has a geometric meaning. It measures the amount of curvature concentrated in a local neighbourhood of the isodensity surface. Since the faces and edges of pixels of a grid do not contribute to the curvature, all the contribution to the curvature is concentrated in the vertices of the grid. The deficit angle from a given locality is calculated by sum-

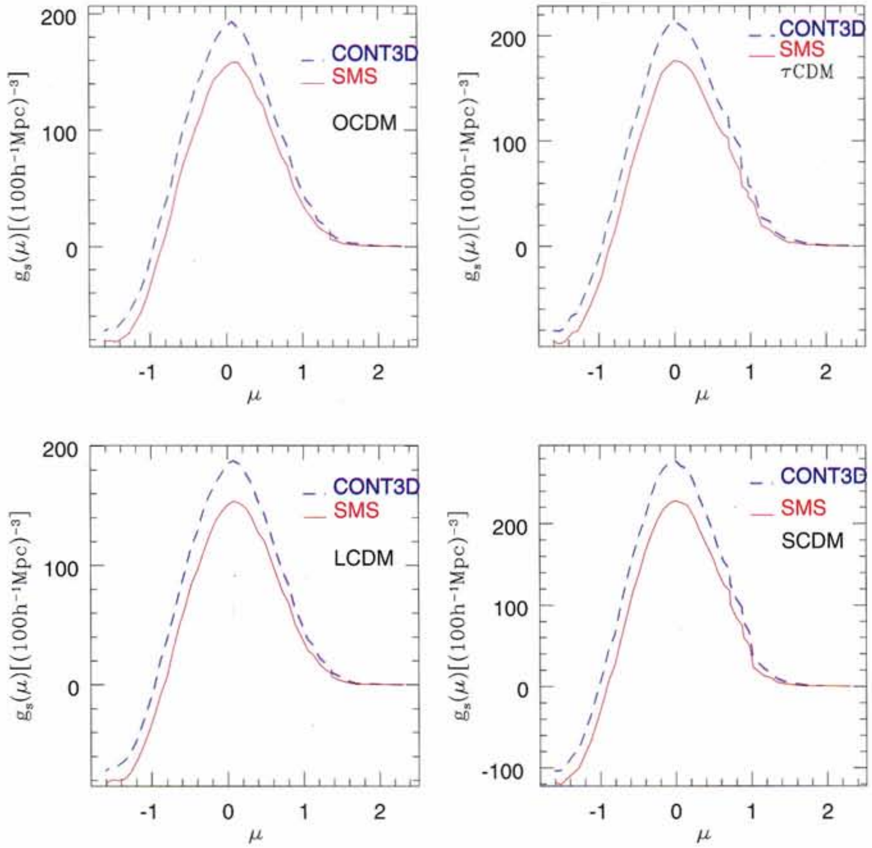


Figure 3: Comparision of the genus estimation from deficit angles and triangulation . The genus has been normalized to a volume of $10^6(h^{-1}pc)^3$. The dimensionless parameter μ is related to the overdense volume fraction and is commonly used to label the density-levels

ming over the angles which all pairs of grid-edges converging to a given vertex make with each other and finally deducting the total angle from 2π; the result being the measure of the curvature of the surface. This exercise is repeated for all the overdense (underdense) vertices while estimating topology of the clusters (voids). The total deficit angle D is the sum over contribution from all the vertices. Genus G_s is related to D by the relation $G_s = 1 - D$. Both codes were used to determine the topology of the individual clusters. The contribution from all the clusters was finally summed up to obtain the cumulative topology of the sample at a given level of density threshold. The results are summarised in (see Figure (3)) which shows the evolution of genus as the density level is scanned from its maximum (positive extreme of μ) to minimum (negative extreme of μ), due to both the methods for all four models.

Both the curves are similar in shape and form. They start from zero value at high μ, because at very high levels of density, the clusters are smaller in size and are simply connected (genus is zero). As the density-level is progressively lowered, the clusters become multiply connected, with the voids through them evolving in number as well as linear extent. This explains a rapid increase in the total genus. The voids through the clusters are highest around the mean density (for a Gaussian random field, the voids are highest in number *exactly* at the mean density). In fact, around this level of density, the matter as well as voids both percolate through the system. The mean density refers to $\mu = 0$. As density level lowers down further, overdense regions start surrounding the original voids. Thus, getting closed from either end, the voids turn into holes. Thus, the genus falls off steadily, indicating a rise in the number of holes as against the number of voids. The large negative genus at negative extremes of μ is explained by this effect. The shape and form of the curves conform to the Guassian random phase hypothesis with a modulation resulting from clustering. For a given cosmological model, both the methods show a slight shift towards the right from the mean density level ($\mu = 0$)(A shift towards right implies that the corresponding density field has a tendency to form more bubbles (isolated underdense regions)

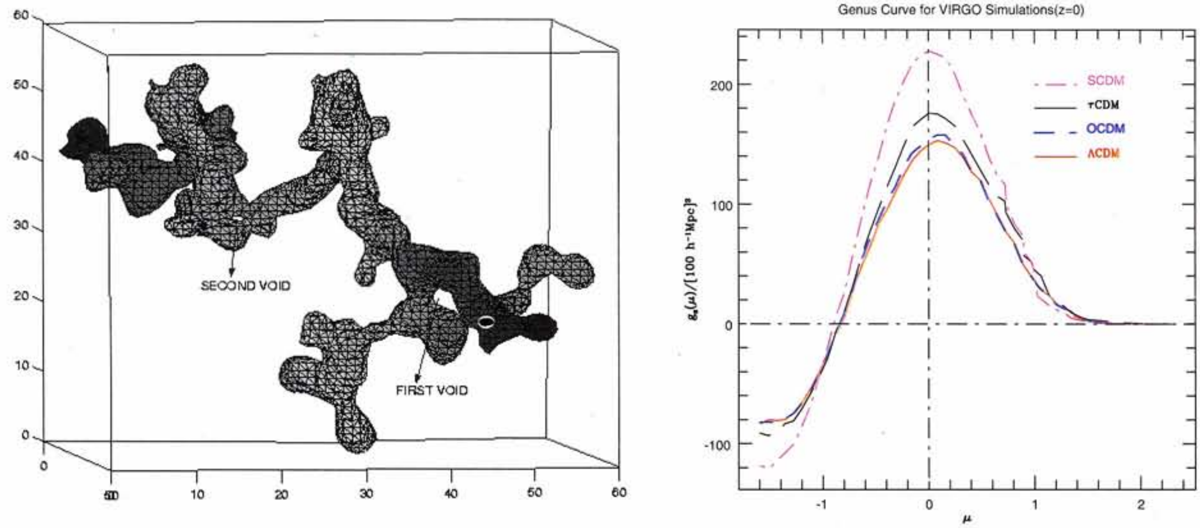


Figure 4: (a) Two voids/handles of a supercluster are visible. The scale of the figure is in Mpc Genus Curves for the four VIRGO simulations at the present epoch. The symbols have usual meaning. The values of genus refer to the triangulation scheme. (b) Genus Curves for the four VIRGO simulations at the present epoch. The symbols have usual meaning. The values of genus refer to the triangulation scheme

than isolated clusters. Hence, this is termed as the bubble shift). Thus, both the techniques identify a qualitatively similar topology for all the N-body simulations. The fact that the peak of the Genus Curve occurs at the same density threshold implies that both the methods identify the same density-level as being the most 'sponge-like'. However, the triangulation scheme always results in *smaller* genus number than the scheme based on the deficit angle estimation. (see Figure (4a)) shows a supercluster which exhibits two handles. Thus, its genus should be 2. This is in line with the estimates of the triangulation scheme. The deficit angle scheme on the other hand estimates its genus to be 6. Thus, the triangulation scheme developed by us is more reliable than a scheme based on the deficit angle approximation.

It turns out that the gravitational clustering leads to decrease in the amplitude of the genus curve. Thus, studying the relative amplitude of various genus curves is an important quantitative test which can be used to calibrate the amount of clustering as well as to compare various cosmological models. Figure (see Figure (4b)) shows the topology of all the four cosmological models at z=0. As shown in the figure, the ΛCDM has the lowest amplitude GC, and it shows the highest amount of bubble shift. The relatively low peak implies that the voids in the large structures are larger in extent and fewer in number. The GC for OCDM closely follows ΛCDM, and the two models are barely discernible. These two models are followed by τCDM and SCDM models. Of the four models, SCDM shows the highest amplitude. This implies that at a given threshold of density, the SCDM exhibits larger number of voids/holes which are smaller in size and relatively more disconnected because of the lesser amount of gravitational clustering. As we move towards ΛCDM, the clustering is more, which leads to large scale connections between the holes through longer voids, which obviously leads to a drop in the amplitude of the genus curve. The degeneracy between ΛCDM and OCDM can be broken if one includes information from recent observations of degree scale anisotropies in the cosmic microwave background which indicate that open models are ruled out to a high degree of confidence. Thus, the genus curve can distinguish between ΛCDM, τCDM and SCDM and is likely to be a useful diagnostic of large scale structure.

Figure (5) shows how the topology of the ΛCDM model evolves as the system progresses from an initially less clumpy and more homogeneous matter distribution at z = 3 to a more clumpy and inhomogeneous matter distribution at z = 0. It is to be noted that in the course of this evolution, the amplitude of the genus curve steadily drops and the peak undergoes a bubble shift.

The remaining three Minkowski functionals add to the discriminatory power already established for GC and they are being critically analysed for all four models at present.

Large scale cosmological structures: magnetic fields, cosmic rays and high energy processes

Recent advances in observational cosmology have revealed that the large-scale distribution of galaxies in the universe has a honeycomb-like structure,

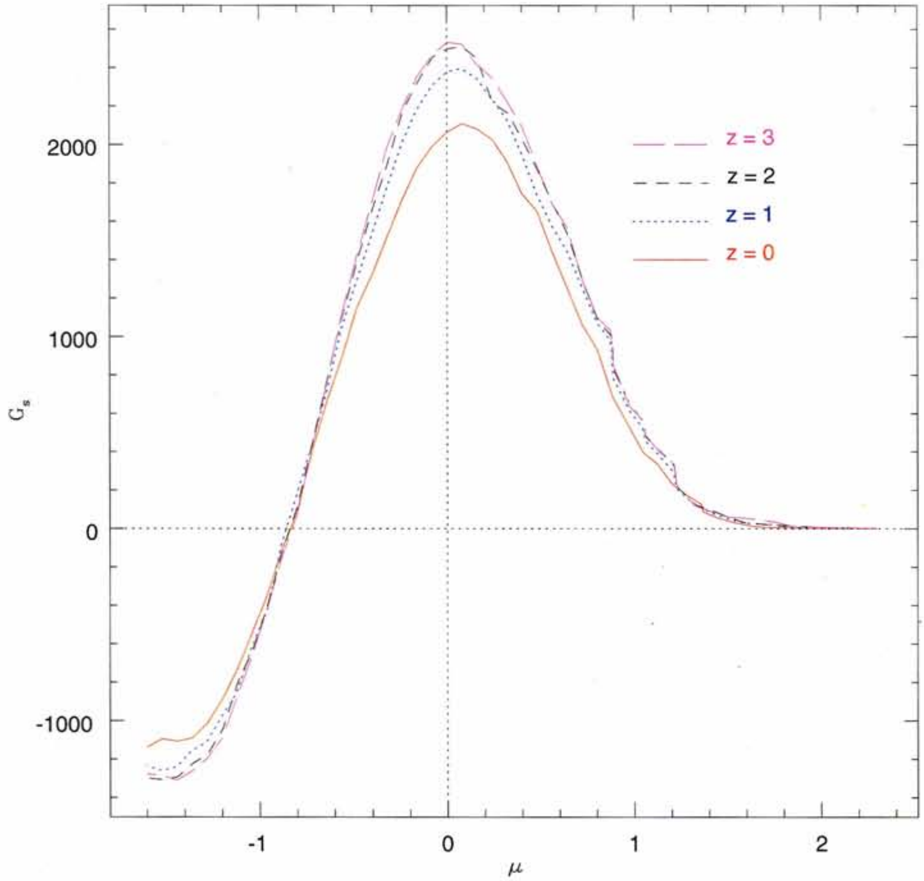
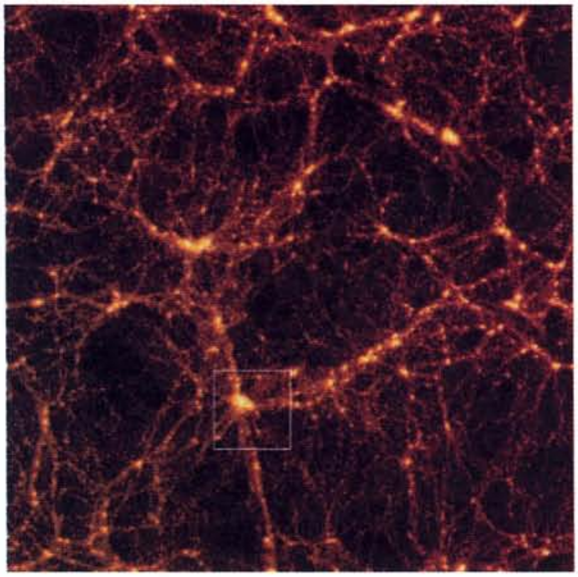


Figure 5: Genus Curves for the ΛCDM simulations at four epochs(z=3,2,1,0). The symbols have usual meaning. The values of genus refer to the triangulation scheme.

where the principal morphological elements are interconnected networks of large filaments and sheets of galaxies surrounding huge volumes almost devoid of galaxies (the 'voids'). This striking large-scale picture of the Universe has been obtained by the large redshift surveys, such as the 'Las Campanas' and the '2df' galaxy redshift surveys. The origin of galaxies and other large-scale structures in the universe remains an outstanding cosmological enigma. The enduring quest has been to understand how such diverse structures are formed in the universe which was so smooth and homogeneous at early times. Clusters of galaxies, which are known to be the most massive and largest virialized mass aggregates, are believed to have formed through the hierarchical process of gravitational collapse of smaller mass components. In this process, the merger and collision of smaller groups and clusters take place mainly along the axes of large filaments of galaxies of length of a few Mpc to up to 100 Mpc. This 'cosmic-web' of filaments and sheets is seen in almost all computer simulations [such as one shown in Figure 6 (left)], even though the simulations cannot yet reveal the details of gas-dynamics that occur during the formation of these structures.

An important role in the structure-formation process is played by the large-scale shocks that form as the primordial density fluctuations become non-linear and the accretion flows of inter-galactic matter (IGM) on collapsing structures become supersonic. These shocks are likely to be responsible for heating of most of the diffuse intergalactic medium up to $10^5 - 10^7$K. Given their large sizes and long lifetimes, these shocks have also been proposed to be the ideal sites for the acceleration of very high energy cosmic-rays (high-energy charged particles and photons of unknown origin) up to $10^{18} - 10^{19}$ eV. It is believed that such particles, which have the highest energy known, are somehow created in the extra-galactic universe within a horizon of 300 million light years. In addition, it has been recently pointed out that the cosmic-ray ions accelerated at intergalactic shocks could accumulate in the formed structures, storing a significant fraction of the total energy there. Exploration of such ideas through



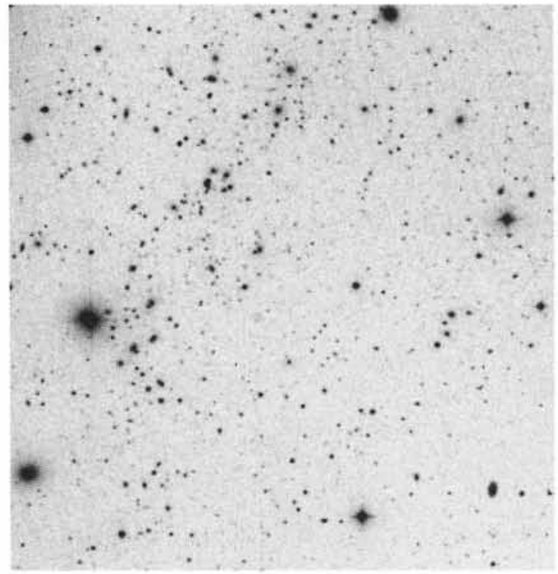


Figure 6: **[Left]**: Slice from a N-body computer simulation showing the projected mass distribution in a Λ+CDM model Universe at $z = 0$ (courtesey of the VIRGO Consortium). The length on each side is about $100h^{-1}$ Mpc. The region inside the white square shows a typical merging filamentary protocluster similar to ZwCl 2341.1+0000 shown on the right panel. **[Right]**: A CCD R-band wide-field (12×12 arcmin) image of the merging proto-cluster ZwCl 2341.1+0000 at z ≈ 0.3 (photometric). About $4\,h_{50}^{-1}$ Mpc long main filament of galaxies and several other Mpc size sub-filaments can be seen to the east and north-east of the main structure. The north and east are oriented to the top and left.

direct observations is very important because even after close to a century since cosmic-rays were discovered by Victor Hess in 1912, we do not know how and where they are accelerated.

In order for particles to be accelerated, magnetic fields have to be present at the site of shock waves. The origin of magnetic field and its evolution in cosmic bodies is one of the least understood of all astrophysical problems. Magnetic fields appear ubiquitous - wherever modern methods allow for their detection. Planets and stars, the diffuse gas in galaxies, and the hot and teneous gas in clusters, all appear to be magnetized by different degrees. Amongst the largest systems, the magnetic field strength in galactic disks is estimated to be about $1 - 10\ \mu$ G, and the clusters of galaxies appear to have fields of order $0.1 - 10\ \mu$G. In recent years, with the advent of fast supercomputers, the MHD evolution of magnetic fields, along with the baryonic and dark matter components, could be followed since very early cosmic epochs. These simulations show that the present day fields can reach strengths of order $10^{-9} - 10^{-7}$ G in large scale ($\sim 10 - 100$ Mpc) web-like network of filaments and sheets. The magnetic field in structures of dimension like clusters (~ 1 Mpc), is obtained to be about $10^{-7} - 10^{-6}$ G. Beyond the scale of great clusters, the magnitude of magnetic fields and even their existence are virtually unknown, but speculations on the strength of magnetic fields in IGM range from 10^{-7}G to 10^{-12}G. To check for the validity of these ideas, it is not only required to detect and estimate the field strengths in largest scale cosmic structures, but also to determine by observations, how much of it correlates with baryonic matter in these structures.

Recently, *J. Bagchi* and his collaborators (T.A. Ensslin, F. Miniati, C.S. Stalin, M. Singh , S. Raychaudhury & N. B. Humeshkar) have reported new evidence for cosmological scale magnetic fields and high energy particles in a large-scale filamentary structure of faint galaxies: ZwCl 2341.1+0000. They have made concentrated efforts to understand the astrophysics of this structure in various wave bands and have carried out large-scale numerical simulations. To explore the nature of optical structure of galaxies underlying this formation, they had earlier made multiband (V, R, I), deep CCD observations with the UPSO (Nainital, India) 1-m telescope. They discovered that morphologically ZwCl 2341.1+0000 is a long S-shaped main filament of galaxies extending over 12 arcmin of angular scale ($\sim 4h_{50}^{-1}$ Mpc), and branching structures of several Mpc-scale galaxy sub-filaments mainly to the east and north-east of the main chain [see Figure 6 (right)]. Associated with this large formation of galaxies, they also discovered a large radio structure - using the interferometric data from VLA (Very Large Array) at 20 and 90 cm wavelengths [see Figure 7 (right)]. The radio emission is found to be quite diffuse in morphology and the generating process is almost certain to be the synchrotron

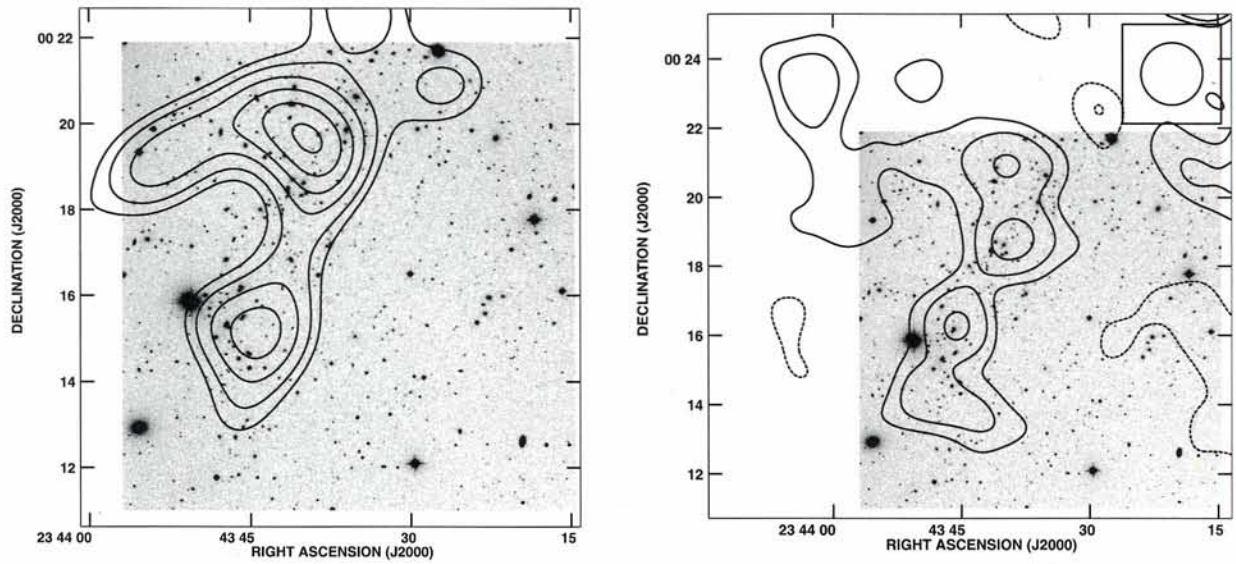


Figure 7: **[Left]**: The ROSAT map in the region of ZwCl 2341.1+0000, from the ROSAT (PSPC) All-sky survey archival data. Data in the 0.5-2.0 keV energy range is shown after smoothening the original data with a Gaussian of σ of about 1 arcminute. The X-ray contours at the levels (4,5,6,7,8,9) $\times\ 5 \times 10^{-3}$ counts/s, i.e., in multiples of the r.m.s. noise level of 5×10^{-3} counts/s, are shown superposed on the CCD image in R-filter. **[Right]**: Diffuse radio emission in the region of proto-cluster ZwCl 2341.1+0000 mapped by VLA at 327 MHz at 1.8 arcmin resolution (beam shown at the upper-right corner). The contour levels are at 2.5 mJy/beam $\times$ [-6.4,-3.2,-1.6,1.6,3.2,6.4,12.8,25.6], i.e., multiples of noise rms of 2.5 mJy/beam. The radio contours are shown superposed on the R-band CCD image. The radio emission is complex in morphology and roughly aligned with the main galaxy filament, but also extended further to NE of it. The end-to-end size of the radio structure is about 12 arcmin or 4 h_{50}^{-1} Mpc. More details can be found in Bagchi et al., New Astronomy, 7(5), pp.249, (2002).

emission of relativistic electrons/positrons accelerated in a magnetic field. The most likely origin of these particles is in the shock waves which occur during the structure formation process.

The estimated redshift, both from the colour-magnitude (C-M) and the colour-colour plots of galaxies, is $z = 0.30 \pm 0.05$, further supported by spectroscopy of several galaxies in the SDSS survey at a mean $z = 0.27$. On the 3-colour C-M diagrams for several hundred galaxies, they have identified the characteristic linear sequences of early type E/S0 galaxies. This is an excellent indicator of existence of a large-scale structure as a random projection of field galaxies can not generate the red C-M sequence which is characteristic of clusters. The estimated linear size of the radio and the optical structures is at least $4 - 6\,h_{50}^{-1}$ Mpc, thus making it comparable to or larger than some of the largest known radio structures in the universe (e.g., 3C236, NVSS 2146+82, HE 1127-1304). From the 'minimum energy' condition, they have estimated that the magnetic field strength in the IGM of this filament could be $\approx 0.3 - 1.5\mu$G; a remarkably strong field for a structure so large. The numerical simulation results obtained by them also suggest fields of the same order. *Their reported radio detection is the first evidence of cosmic-ray particle acceleration taking place at cosmic shocks in a magnetized inter-galactic medium over super-cluster scales of* $\sim 5\,h_{50}^{-1}$ *Mpc.*

Recently *Bagchi*, et al. have obtained evidence of extended hot gas in ZwCl 2341.1+0000 from ROSAT all sky survey (RASS) data. The X-ray data shows a peculiar non-relaxed morphology of two major X-ray clumps in a region about 2.5 Mpc across the filament of galaxies [see Figure 7(left)]. To the east of the main filament of galaxies, an extended X-ray filament/plume of ~ 3 arcmin (900 h_{50}^{-1} kpc) size, detected at the $4 - 6\ \sigma$ level, is possibly present at the location where several smaller filaments branch off the main filament. The RASS detection is not very strong, but a total flux of 3×10^{-13} erg s^{-1} cm^{-2} and an X-ray luminosity of 1.3×10^{44} erg s^{-1} is detected at 3σ level. They have submitted observing proposals for investigating in detail the X-ray emission with the CHANDRA and XMM-Newton observatories.

A large-scale numerical simulation of cosmic structure formation is carried out by *Bagchi* and collaborators at the Max-Planck-Institut fur Astrophysik, Garching, Germany. The simulation not only included the gravitational interactions, but also the acceleration of cosmic-ray electrons (CREs) at cosmological shocks and magnetic field evolution. An Eulerian, grid based Total-Variation-Diminishing hydro + N-body cosmology code was used. A commonly favoured Λ + cold dark matter cosmology model was used with the following parameters: total mass density $\Omega_m = 0.3$, vacuum energy density $\Omega_\Lambda = 1 - \Omega_m = 0.7$,

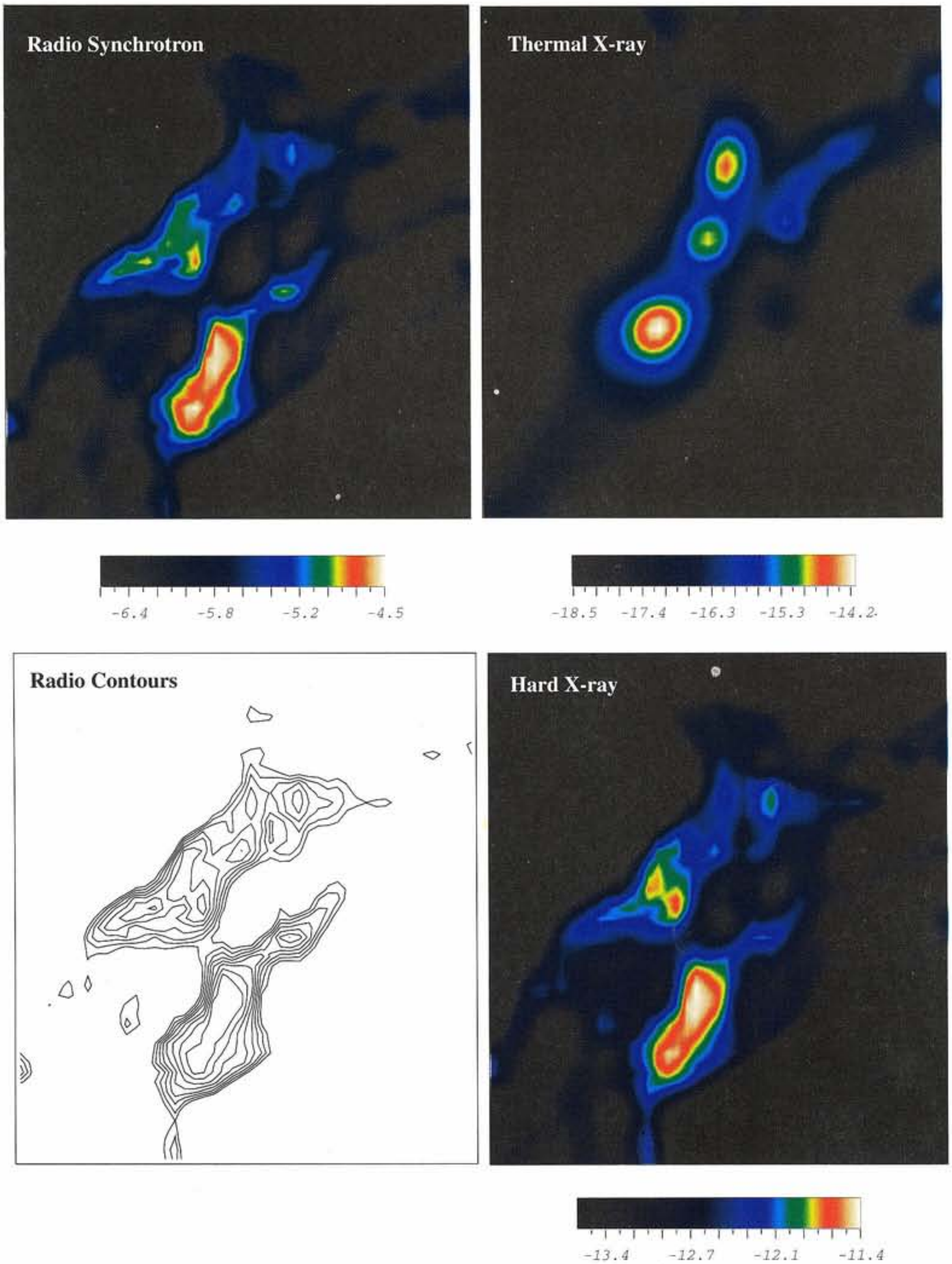


Figure 8: Images from hydro + N-body structure formation simulation. Each panel is a 2-D projection $\approx$ 10 Mpc $\times$ 10 Mpc in size showing the appearance of a forming structure at the redshift z=0.3. To better compare with the observational radio images, the value of radiation emissions integrated along line of sight in synthetic images have been averaged over 3×3 pixels (i.e., $\approx 1' \times 1'$). **[Top left]**: Radio emission map at 1.4 GHz. The log of the flux density is shown in units of '$R_{e/p}^{-1}$ Jy pxl^{-1}'. **[Bottom left]**: The iso-contours of the radio emission at 1.4 GHz, ranging from $10^{-5.8}$ to $10^{-4.6}$ and separated by constant factor of $10^{0.15}$. **[Top right]**: X-rays from thermal bremsstrahlung in the energy range 0.5-2.0 keV. The log of the flux is shown in units of 'erg s^{-1} cm^{-2} pxl^{-1}'. **[Bottom right]**: Inverse Compton hard X-ray emission at 50 keV. The log of the monochromatic flux is shown in units '$R_{e/p}^{-1} 10^{-23}$ erg s^{-1} cm^{-2} Hz^{-1} pxl^{-1}'. In these radio or X-ray units, 1 pxl is about 0.34×0.34 arcmin^2. The factor $R_{e/p}$ is the ratio of number of cosmic-ray electrons to protons at relativistic energies, on which the non-thermal radiation flux is dependent.

baryonic mass fraction $\Omega_b = 0.04$ and $H_0 = 67\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. The initial density perturbations were distributed as a Gaussian random field with a power spectrum characterized by a spectral index $n = 1$ and "cluster" normalization $\sigma_8 = 0.9$. The dark matter component is described by 128^3 particles, whereas the gas component is evolved on a grid of 256^3 cells. The magnetic field is treated as a passive quantity, in the sense that its dynamical role on the fluid behaviour is completely neglected. The CRE treatment includes the effects of diffusive shock acceleration, plus adiabatic, radiative and Coulomb losses. Both protons and electrons are injected at the shocks from the thermal plasma using an established model (by means of the numerical code COSMOCR developed by F. Miniati, MPA). The simulation data allow to compute various quantities directly related to the observations of ZwCl 2341.1+0000. These are the synchrotron emission from the simulated relativistic electrons and magnetic field distribution. They also obtained maps of inverse Compton hard X-rays (HXR) at 50 keV (from the same relativistic electrons responsible for the radio emission) and of X-ray emission in the 0.5-2 keV band from thermal Bremsstrahlung of the collapsed structures (see Figure 8) shows a portion of size 10×10 Mpc^2 comoving, corresponding to the same structure seen in radio and X-rays).

A principal conclusion obtained from the numerical simulation results is that the diffusive shocks in large scale structures can produce the power-law momentum distribution function and the power-law radio frequency spectrum for the accelerated electrons as observed. The simulation results are also in good accord with the synchrotron and X-ray thermal bremstrahlung radiation fluxes observed from ZwCl 2341.1+0000.

Consequences on various dark energy candidates from the recently observed type Ia supernova 1997ff

R. G. Vishwakarma has examined the status of various *dark energy*-models in light of the recently observed SN 1997ff at $z \approx 1.7$. The modified data still fit a pure cosmological constant Λ or a quintessence with an equation of state similar to that of Λ. The kinematical Λ-models- $\Lambda \sim a^{-2}$ and $\Lambda \sim H^2$- also fit the data reasonably well and require less *dark energy* density than is required by the constant Λ-model. However, the model $\Lambda \sim a^{-2}$ with low energy density becomes unphysical as it cannot accommodate higher redshift objects.

He has also examined an alternative explanation of the data, viz., the absorption by the intervening whisker-like dust and find that the quasi-steady state model and the FRW model $\Omega_{m0} = 0.33$, *without any dark energy* also fit the data reasonably well.

Vishwakarma has calculated the age of the universe in these models and find that, in the models with a constant Λ, the expansion age is uncomfortably close to the age of the globular clusters. *Quintessence*-models give even lower age. The kinematical Λ-models (especially the model $\Lambda \sim H^2$), give remarkably large age of the universe.

Growth of clustering in a generic context

Observations show that the two point correlation function of the distribution of galaxies is an approximate power law over a range of scales. It is possible to model non-linear gravitational clustering by a scaling ansatz and show that such a power law behaviour is expected in a spatial and temporal interval for scale invariant initial conditions. This result arises from the fact that Newtonian gravitational dynamics in a $\Omega = 1$ universe does not have any preferred scale which is of interest to cosmology.

There are, however, alternate (and less popular) models for galaxy formation in which the process is addressed without invoking gravitational instability explicitly. It has been claimed in QSSC, based on numerical simulations, that these models also lead to power law correlation functions for galaxy distribution. Since the "rule" used for creating galaxies in this model is simple and explicit, it is indeed possible to analyze this process completely analytically. *T. Padmanabhan* has provided such an analysis recently and has shown that the model is intrinsically unstable. However, the galaxies produced by this rule *will* exhibit a power law correlation function for a range of intermediate time scales.

The fact that the above result can be obtained for a model which does not involve gravity explicitly (for example, neither Newtonian gravitational constant nor the fact that gravitational force varies as a power law is used in the "rule" mentioned above), suggests that results of the above kind could be quite general. In fact, there exists several physical phenomena in nature which are described by power law correlations. More often than not, such a correlation function seem to arise in a manner which does not depend critically on the details of the underlying dynamical model. It would be interesting to see whether one can provide a mathematical model with a minimal set of assumptions which can reproduce the power law correlation. *Padmanabhan* has identified one such minimal set of assumptions and shown that models based on these assumptions will have a generic behaviour.

Padmanabhan showed that a class of such models are exactly solvable — in the discrete as well as continuum limit — and can represent several physical situations as varied from the formation of galaxies in some cosmological models to growth of bacterial cultures. This class of models, in general, has no steady state solution and evolve unstably as $t \to \infty$ for generic initial conditions. They can, however, exhibit (unstable) power law correlation function in the continuum limit, for an intermediate range of times and length scales.

Alternative cosmologies

Jayant Narlikar and *T. Padmanabhan* coauthored an article for the Annual Reviews in Astronomy and Astrophysics (2001) entitled Standard Cosmology and Alternatives: A critical appraisal, in which they reviewed the achievements and shortcomings of standard cosmology and also discussed what is required form any alternative cosmology like the quasi-steady state cosmology (QSSC) to offer a credible competition to the standard model. Currently the main alternative to the standard model is offered by the QSSC. The QSSC has the universe undergoing a long term (1000 Gyr) exponential expansion superposed with short term (50 Gyr) oscillation. Each oscillation is driven by new matter created at the minimum scale epoch (which is non-singular). The article brings out the possible distinguishing tests that will tell if the universe is as per the standard model or the QSSC. It also stresses the requirement of more detailed work in the QSSC on structure formation, cosmic microwave background (CMBR), and other issues on which the standard model has progressed considerably.

In this spirit, *Narlikar, T. Souradeep, R.G. Vishwakarma, Amir Hajian* and Geoffrey Burbidge are engaged in modelling the inhomogeneities of the CMBR in the quasi-steady state cosmology. The model assumes that the CMBR is generated in the QSSC by thermalization of relic starlight from previous generations of stars. The latest contribution to this background will show slight excesses in the neighbourhood of rich clusters of galaxies observed at the time of the last minimum of the oscillation. Power spectrum of the expected variations across the globe is being worked out for comparison with observations.

Narlikar, Vishwakarma and Burbidge are also reviewing the claim for an accelerating universe and a positive cosmological constant (Λ). In this context, the advantages and disadvantages of having a non-zero Λ in the standard model are discussed and an alternative is offered in the framework of the QSSC for the data on magnitude redshift relation for distant extragalactic Type Ia supernovae. In this alternative, the dust in the form of metallic whiskers, (whose existence was invoked in order to thermalize relic starlight and convert it to CMBR) is suggested as the dimming agent which make the distant supernovae fainter than the usual inverse-square distance effect. It is pointed out in favour of the overall scenario that the whisker density required for both the thermalization process and the supernova dimming effect is the same within observational uncertainties.

Vishwakarma has studied the problem of reducing the value of Λ by 108 orders of magnitude from the time of inflation to the present epoch, by introducing models of its variation under various assumptions. He has compared the performance of these different models in the cosmological tests like the angular size - redshift relation for ultracompact radio sources, the magnitude redshift relation for Type Ia supernovae, etc.

Cosmic Microwave Background

The primordial nature of the microwave background photons makes the cosmic microwave background (CMB) observations an extremely valuable cosmological probe. The CMB anisotropy in a Gaussian model is completely specified by its angular two point correlation function. These anisotropies encode an immense wealth of information on the model of cosmology and formation of the observed large scale structure. The observational success in measuring CMB anisotropy over a range of angular scales has set off an intense interplay between theory and observation in the past few years.

Measuring the CMB angular power spectrum

Most theoretical models predict statistically isotropic fluctuations, where the anisotropy can then be characterized solely in terms of an angular power spectrum $\mathcal{C}_\ell$ in the space of spherical harmonic multipole, ℓ. The immediate and primary objective of CMB observations is to estimate $\mathcal{C}_\ell$. There are now well over one hundred band power estimates of CMB anisotropy by a number of experiments probing various regions of ℓ space.

In continuation of his collaboration with S. Podariu, J. R. Gott, B. Ratra and M. Vogeley, *T. Souradeep* has included recent data into their weighted mean and median statistics techniques to combine individual CMB anisotropy detections, and determine binned, multipole-space, CMB anisotropy power spectra. This model independent combination of current data reveals a peak in resultant power spectra, however, whether a significant second and third peak exist in the binned data, it is still unclear. This issue is being currently addressed with detailed peak fitting techniques.

With the Python-V team, *Souradeep* has analyzed their data using covariance matrices corrected for non-circularity and sky curvature and computed the band power estimates of the power spectrum using the full modulated data set. These band power estimates agree with the band powers derived from an optimal map. The band power estimates for the CMB anisotropy measured by Python-V team has been submitted for publication.

Souradeep and Ratra are also computing exact likelihood estimate over a grid of theoretical models given the Python-V data. The size of the data set with over 5000 effective pixels makes a full blown likelihood analysis a computational challenge. *Souradeep*, Ratra and P. Mukherjee are also engaged in the reanalysis of the more recent MAT data set.

Statistical isotropy of the CMB sky:

It is possible to conceive that the anisotropy cosmic microwave background violates statistical isotropy, i.e., the covariance of temperature fluctuations in two directions does not depend solely on the separation of the two directions. This could happens in case the universe has non-trivial global topology on scales not far beyond the horizon scale but can arise due to less exotic reasons such as non-uniform coverage and residuals from foreground removal, etc.

Souradeep and *Amir Hajian* are working on measures for detecting general deviations from statistical isotropy in observed CMB maps. In the absence of statistical isotropy, the angular power spectrum cannot be used to make simulated maps. Hence, *Hajian* and *Souradeep* have developed and implemented a fast method for simulating CMB anisotropy maps using the correlation function of the underlying theory and experimental noise. This approach to simulating CMB sky can be applied in all cases where statistical isotropy is violated. The simulated maps has allowed them to estimate the efficacy of the measures of statistical anisotropy. The measures have been successfully tested on simulated full sky maps for detecting non-trivial topology of the universe.

In the absence of statistical isotropy, it is important to compute the CMB correlation function and not the angular power spectrum. *Atul Deep* and *Souradeep* developed a numerical code for obtaining the angular correlation of CMB anisotropy in terms of the spatial correlations of source functions. The code uses the source terms numerically computed by publicly available softwares CMBfast and COSMICS. The code works for flat cosmological models and can be readily extended to non-flat cosmology in the future. Combining this with regularized method of images developed by Bond, S. Pogosyan and *Souradeep*, a code for computing the CMB anisotropy predictions in any multiply connected universe is being envisaged.

For CMB measurements made with a circular beam, the covariance of temperature fluctuations in two directions is statistically isotropic, For a generic experimental scan pattern, non-circular beam would lead to violation of statistical isotropy. Consequently, the cosmic variance of $\mathcal{C}_\ell$ is enhanced. Also, a bias is introduced in the standard estimator of $\mathcal{C}_\ell$. Using the formalism developed by *Souradeep* and Ratra for handling CMB experiments with non-circular beam, *Anand Shankar Sengupta* and *Souradeep* have studied the effect of a non-circular beam for partial sky coverage and scan patterns that rotate the beam on the estimation of angular power spectrum of CMB anisotropy.

Constraining early universe scenarios using cosmological observations

Cosmological parameters estimated from CMB anisotropy assume a spectrum (or a limited class of spectra) of initial perturbations. *Souradeep* has worked with project students V. Gopisankararao and Arman Shafeiloo on the complementary problem of estimating the initial power spectrum from angular power spectrum of CMB given a (class of) cosmological models. Here, the cosmological parameters are constrained using cosmological observations independent of initial condition for perturbations. Two techniques were investigated for tackling this inverse problem. A direct method which does not impose positivity of the power spectrum and a deconvolution algorithm method that ensures positivity but is iterative. The latter has proved to be very efficient and useful. As part of his M.Sc. thesis, Shafeiloo has computed the initial power spectra that map very disparate cosmological models to the same CMB angular power spectrum. Present band power data is not good enough to give any meaningful constraint on a general initial power spectrum. CMB data in the near future combined with improvement in independent estimation of cosmological parameters may yield interesting broken scale invariant spectra. Such spectra can then be connected to the details of early universe physics, such as the inflation potential.

Estimation of cosmic microwave power spectrum

A. Sengupta and *T. Souradeep* reviewed the basic sources of CMB anisotropies and the statistical issues of CMB power spectrum (C_ℓ) estimation (like anisotropic CMB sky, detector noise, etc.) In particular, based on an earlier formalism due to

Souradeep and Ratra (2001), they studied the effect of anisotropic beam on the C_ℓ estimates. Current CMB anisotropy data is of significantly higher quality than the data that was available just a few years ago. Consequently, an accurate estimation of angular power spectrum must now account for effects that were ignored for earlier experiments such as the non-circularity of the beam. This was the main motivation behind the work.

They showed that the isotropized estimator of the angular power spectrum remains unbiased if an anisotropic beam is used. Further, the estimate depends only on the isotropic component of the beam. This is a new result and the expressions obtained are general, and can be used for arbitrary beam profiles. They used these expressions for the specific case of the Python-V experiment beam and also showed that the expression for cosmic variance of estimated power spectrum is identical to that obtained by using only the isotropic component of the beam.

Extragalactic Astronomy

Emission processes in radio galaxy hotspots

Prasad Subramanian and GopalKrishna have been working on emission processes in radio galaxy hotspots. Using published data, they have concluded that it is not necessary to resort to the commonly invoked concept of electron reacceleration at shocks in hotspots in order to explain the observed emission from the hotspots. They found that the observed optical/near-IR synchrotron emission of the hotspots can be explained even if the radiating relativistic electrons are accelerated exclusively within the nuclear region, provided the energy losses incurred by the electrons during their transport down the jet are dominated by inverse compton upscatterings of the cosmic microwave background (CMBR) photons. Under these circumstance, they found that in situ reacceleration of relativistic electrons inside the hotspots or lobes is not mandated by their reported optical/near-infrared detections.

Recent Chandra observations have demonstrated that there are significant discrepancies between the spectral slopes of synchrotron radiation at radio wavelengths and X-ray inverse Compton emission from hotspots. Furthermore, if one invokes a uniform magnetic field in hotspots, the electron population that is responsible for producing the observed X-ray emission would produce significantly more radiation at radio wavelengths than is observed. To overcome this, some authors propose that the X-ray radiation is produced by a low energy population of electrons that is distinct from the population that produces the synchrotron radiation at radio wavelengths. There is considerable observational evidence for filamentary magnetic fields in hotspots. *Subramanian* and Krishna are investigating the possibility that synchrotron and inverse compton radiation from a single population of electrons in such a filamentary magnetic field can explain all the observed characteristics of emission from the hotspots. There would then be no need to appeal to a second, hitherto unobserved population of electrons in order to explain the multiwavelength observations.

Dynamical modelling of the stellar nucleus of M31

The Andromeda galaxy (M31) is believed to possess a centrally located supermassive black hole (SMBH), of mass $3.3 \times 10^7 M_\odot$, which is about ten times more massive than the SMBH in our Galactic Centre. The balloon–borne Stratoscope II telescope first discerned the remarkable nucleus of M31. Subsequently, observations from ground, as well as, space based telescopes revealed a lopsided nucleus, with two peaks in the brightness distribution. One peak is very close to the centre, and the other – which appears brighter in optical bands – is offset by about half a second of arc (which is about one and half parsecs). A luminous centre is, in itself, not surprising, but the off–centered peak raised awkward dynamical questions. Early ideas that it could be a separate cluster of stars or even a massive object with a stellar cloak, ran into difficulties. Shouldn't dynamical friction from the dense, stellar environment cause the object to spiral into the centre ? A key insight was offered in 1995 by Tremaine: the entire nucleus could be an eccentric disc of stars in orbit about the SMBH. He presented a kinematical model, in which stars populated (nearly) Keplerian orbits, whose apoapsides were aligned, thus producing a peak in the density of stars. This model seemed to be in reasonable agreement with the then available photometry and kinematics. Subsequently, there have been attempts to construct truly dynamical models – i.e. those that included the self–gravity of the stars, through N–body s,imulations and the construction of approximate distributions. However, these models are based on plausible guesses, not directly on data, whose quality has improved significantly.

Niranjan Sambhus and *S. Sridhar* have constructed stellar dynamical model of the eccentric disc. They use Hubble Space Telescope photom-

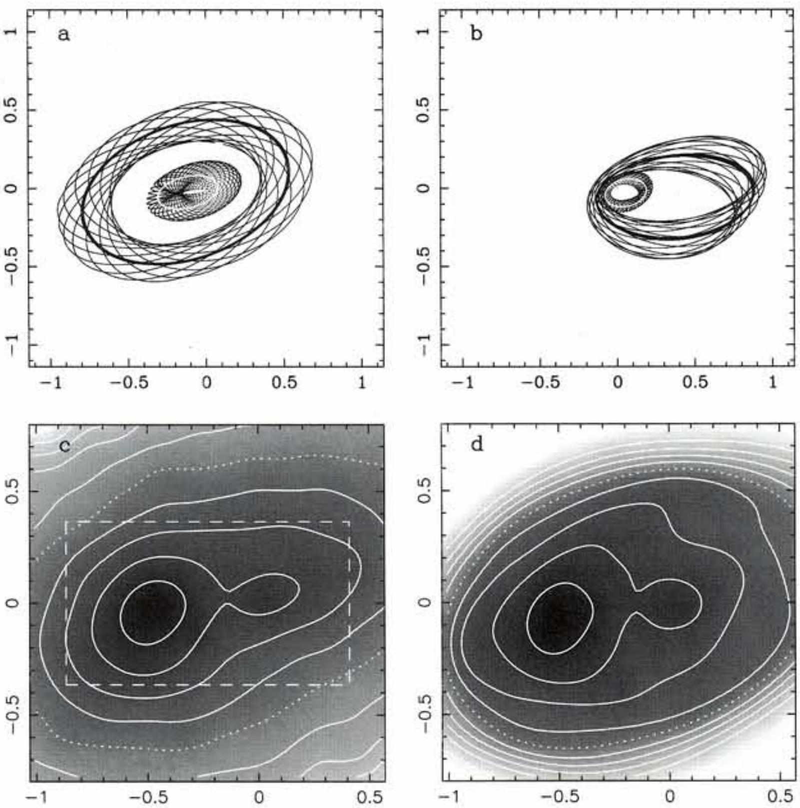


Figure 9: Orbits in the rotating frame and photometric fits. The axes in all panels are sky positions. (a) and (b) show prograde and retrograde loop orbits, respectively, as seen on the sky, for $\Omega = 16\,\mathrm{km\ s^{-1}\ \ pc^{-1}}$; the parent (resonant) orbits are overdrawn as the solid curves. The photometry in (c) is from Lauer 1998, smoothed with a Gaussian beam of FWHM = 0."17. The (bulge–subtracted) light in the region enclosed by the dashed box was employed in a Schwarzschild–type iterative method. (d) is the model disk, including the bulge. The dotted lines in both (c) and (d) have magnitude equal to 14.5, and successive isocontours differ by 0.25 magnitudes. The brightness is displayed in the "negative" mode, to better emphasize the distribution.

etry, to derive the surface density distribution of a (model) razor–thin disc in the disc plane. The (stellar) self-gravitational potential was then calculated, and approximated by a high–order polynomial function of the cartesian coordinates in the disc plane. To this, they add the gravitational potential of the SMBH. They also assume that the pattern of the stellar disc, and the SMBH are in steady rotation, at a rate that is to be determined. Orbits of test particles are integrated numerically in the rotating frame, for a range of pattern speeds (Ω). Of the many families of orbits, they select two – the prograde and retrograde loop orbits – to build a library of orbits (see Figure(9)). Each orbit belonging to the library consists of a set of test particle positions and velocities, the positions on the orbit chosen so as to make the mass density along the orbit approximately time independent (in the rotating frame). All the test particles on a given orbit may be assumed to have the same mass, which is the unknown quantity of interest. The masses are determined, by iteratively invoking consistency between model and photometry (in a central rectangle shown in Figure (10), using the Richardson–Lucy algorithm. The results of a convergent iteration are shown in Figure (10). They also compute two dimensional maps of the mean line–of–sight velocities and line–of–sight velocity dispersions, and compared with recent Integral–Field Spectroscopic data. It should be noted that the best-fit photometric model also provides the best–fit kinematic maps.

Their numerical dynamical models are self-consistent, in the sense that the observed light distribution, used to compute the disc potential and the orbit families, is well reproduced by populating orbits with non-negative masses. A feature unique to the models is the presence of stars moving in counter–rotating streams. The mass in these stars is equivalent to that of a globular cluster, and they speculate that an infall of such a cluster, on retrograde orbit might have excited lopsided instabil-

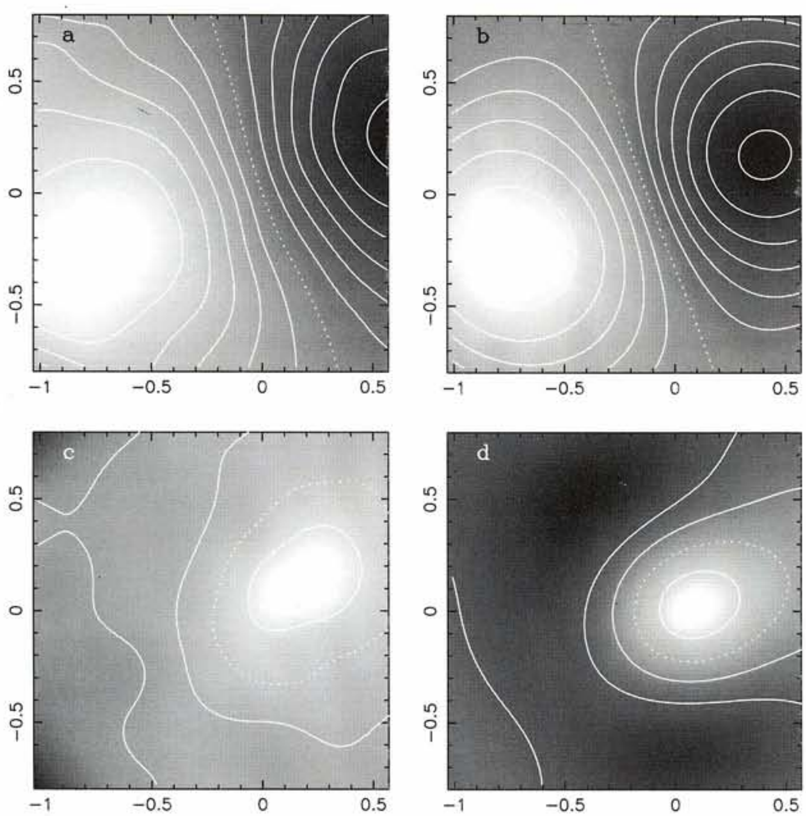


Figure 10: Comparison of the $\Omega = 16\,\mathrm{km\ s^{-1}\ pc^{-1}}$ model with kinematic maps. The axes in all panels are sky positions. (a) and (c) are maps of mean line–of–sight velocity, and velocity dispersion, respectively, taken from the "M8" data of Bacon 2001; (b) and (d) are predictions of the model, including a constant bulge velocity dispersion of $150\,\mathrm{km\ s^{-1}}$, and smoothed with a Gaussian beam of FWHM = 0."5. In (a) and (b), the dotted line is the zero–velocity curve, and successive isocontours are in steps of $25\,\mathrm{km\ s^{-1}}$; positive (negative) velocities are in light (dark) shades. The dotted line in(c) and (d) corresponds to velocity dispersion of $200\,\mathrm{km\ s^{-1}}$, successive isocontours are in steps of $25\,\mathrm{km\ s^{-1}}$, and lighter shades indicate higher values.

ity in an originally axisymmetric stellar disc. This speculation is motivated by recent investigations of instabilities in counter–rotating, nearly Keplerian stellar discs.

Galaxy surface photometry

A programme of observing bright nearby galaxies, with a view to determining structural parameters which define their large scale morphology, is being carried out at IUCAA by *Ajit Kembhavi* in collaboration with several persons over a number of years. An important result from this programme, obtained in collaboration with Habib Khosroshahi and *Yogesh Wadadekar* of IUCAA, and Bahram Mobasher of the Space Telescope Science Institute, Baltimore, has been the demonstration of the existence of the photometric plane, which is the locus defined by the central surface brightness, effective radius and the Sersic parameter of elliptical galaxies (which describes the shape of the intensity profile). The locus is found to be a relatively thin plane, and even the bulges of early type spiral galaxies are found to lie on the same plane as the ellipticals. The photometric plane is related to the fundamental plane of galaxies, but unlike the latter it does not require spectroscopic data, which is more difficult to obtain than just the direct imaging data required for the former.

The fact that elliptical galaxies and the bulges of early type galaxies share a single plane points to overall structural similarities between these objects, and possibly a common formation process. There are indications that the bulges of late type galaxies lie away from the plane, and that the even those objects which share a single plane lie on different sectors of it depending possibly on the luminous mass in the galaxy, and also the environment. With a view to examining these possibilities in detail, *Kembhavi*, in collaboration with Ravi Kumar of Cochin University, and Bahram Mobasher, is analyzing a large sample of galaxies from several clusters of galaxies, which have been observed in near infrared bands. The distribution of parameters obtained has confirmed the equation of the photometric plane originally obtained from a smaller sample, and is being analyzed to compare the properties of different subsamples. It is very important to see whether the plane also exists at higher redshifts. The weak signal and small number of pixels available for galaxies at redshifts greater than about 0.5 make it difficult to obtain accurate values for the morphological parameters, and some analogue of the Sersic parameter, like a concentration index, has to be used. Work related to these issues is in progress using images of clusters at a redshift of about 0.5.

Lenticular galaxies have a bulge, as well as a disk, with the luminosity of the disk being comparable to, or less than, the luminosity of the bulge. The disk is often difficult to spot, and while it can have a bar, no spiral arms are seen. *Kembhavi*, in collaboration with Sudhanshu Barway and S. K. Pandey of Ravishankar University, Raipur, and Divakar Mayya of INAOE, Mexico, has observed a sample of about 40 lenticular galaxies, at optical and near infrared wavelengths, using 2m class telescopes in Mexico. Accurate decomposition of the bulge and disk components in lenticulars is difficult, because there is no region within the observed limits where just one of the components dominates, and results from the present sample, obtained using a sophisticated two dimensional code, are providing some of the first ever homogeneous results in this direction. The multiband data is also being analyzed to examine the colours of the stellar population in the galaxies, and the extent and distribution of dust.

Quasar Absorption Systems

HD Molecular lines in an absorption system at redshift z = 2.3377

In the framework of standard big-bang cosmology, the light element abundances uniquely fix the baryon density. Indeed, the relative abundance of deuterium, [D]/[H], formed during Big Bang nucleosynthesis is one of the key parameters of contemporary cosmology, because it is the most sensitive indicator of the baryon density in the universe. High redshift QSO spectra are very useful for measuring the primordial [D]/[H] value at very early epoch. Until now, only absorption lines produced by atomic lines of D I and H I have been used for measuring the deuterium abundance. However various observational difficulties such as continuum placement uncertainty, saturation in the Lyman series lines of H I, contamination by intervening Lyman alpha absorption lines, makes the [D]/[H] measurement based on atomic transitions very uncertain. However, the above difficulties do not arise if one measures the relative abundances of molecules [HD]/H_2 since the appropriate wavelengths differ considerably. However molecular lines are very rare and are detected only in hand full of high redshift, high column density absorption systems (called Damped Lyman alpha systems). *R. Srianand* in collaboration with Varshalovich, Ivanchi, Petitjean and Ledoux has reported the first detection of HD molecular absorption at high redshift in an z_{abs}=2.3377 absorption system toward PKS 1232+082. The column densities of the HD molecules in J = 0 and J = 1 levels are 1-3$\times10^{14}$ cm^{-2} and 4-8$\times10^{13}$ cm^{-2} respectively. The excitation temperature measured between these two levels are, T_{ext} = 70$\pm$7 K. A detail analysis of [HD]/H_2 is carried out at present with a very high signal to noise echelle spectra obtained with UVES (Ultraviolet Visible Echelle Spectrograph) on VLT (Very Large Telescope).

Molecular hydrogen at z=1.973 toward Q0013-004: Dust depletion pattern in damped Lyman-alpha systems

The amount of dust present at high redshift has important consequences on the physics of the gas. In addition, dust directly affects our view of the high redshift universe through extinction. Therefore, the presence of dust in damped Lyman alpha (hereafter, DLA) systems, that contain most of the neutral hydrogen in the universe, can have significant consequences. Although, the presence of dust in DLA systems has been claimed very early (Pei, et al. 1991), the issue has remained controversial. Indeed, Lu, et al. (1996) have questioned the idea that the over abundance of Zn compared to Cr or Fe observed in DLA systems (e.g. Pettini, et al. 1997) is due to selective depletion into dust-grains and have argued that the overall metallicity pattern is indicative of Type II supernovae enrichment. In the recent years several studies have shown that both effects, dust-depletion and peculiar nucleosynthesis history, should be invoked to explain the abundance pattern (Vladilo 1998, Prochaska & Wolfe 1999, Ledoux et al. 2001). However the lack of statistics and the wide variety of objects that can give rise to DLAs, namely dwarf galaxies (Centurión et al. 2000), large disks (Prochaska & Wolfe 1997, Hou et al. 2001), galactic building blobs (Haehnelt et al. 1998, Ledoux et al. 1998) etc., with, for each of these objects, its own history, prevent us to have a clear picture of the nature of DLAs. Nevertheless, all studies conclude that the dust content of DLA systems is small. However, it is possible that the current sample of DLAs is biased against high-metallicity and dusty systems. Indeed, Boissé et al. (1998) have noticed that there is a lack of systems with large

N(H I) and large metallicity. Very recent investigation of an homogeneous sample of radio-selected quasars shows that the dust-induced bias cannot lead to underestimate the H I mass in DLA systems by a large factor (Ellison et al. 2001). However even a factor of two could change our understanding of DLA systems.

An obvious way to search for DLAs with large amounts of dust is to select those where molecules are detected. However, it may not be so simple as it has been shown that the presence of H_2 is not only related to the dust-to-metal ratio but is mostly dependent on the physical conditions of the gas. First of all, H_2 is detected when the particle density is large (Petitjean et al. 2000, Ledoux et al. 2001b). In any case, the system at $z_{\rm abs} = 1.973$ toward Q 0013−004 is a good target as very strong molecular absorptions have been identified by Ge & Bechtold (1997, see also Ge et al. 1997).

Srianand with Petitjean and Ledoux has presented the first direct evidence for large depletion of iron and silicon into dust in a high redshift DLA system. The depletion, [Fe/Zn] = −1.92, [Fe/S] = −1.86, [Si/Zn] = −1.01, [Si/S] = −0.95, is similar to what is observed in cold gas of the Galactic disk. This is observed in one of the weakest components of the $z_{\rm abs} = 1.973$, $\log N(\rm H\ I) = 20.8$, system toward Q 0013−004. Molecular hydrogen is detected in this metal rich ([Zn/H] > -0.54) component with $\log N(\rm H_2) \sim 16.5$. Dust extinction due to this component is negligible owing to small total H I column density, $\log N(\rm H\ I) \leq 19.6$. This observation supports the possibility that current samples of DLA systems might be biased against the presence of cold and dusty gas along the line of sight.

The global metallicities of this peculiar DLA system in which O I and C II are spread over $\sim$1050 km s^{-1} are [P/H] = −0.59, [Zn/H] = −0.70 and [S/H] = −0.71 relative to solar. The abundance ratios seen in different velocity components span a wide range. The clear correlation between [Fe/S] and [Si/S] in different components indicates that the abundance pattern is due to dust-depletion. The overall molecular fraction is in the range $-2.7 < \log f < -0.6$, which is the highest value found for DLA systems. H_2 is detected in four components at −625, −475, 0 and 80 km s^{-1} relative to the strongest component at $z_{\rm abs} = 1.97296$.

The presence of H_2 is closely related to the physical conditions in the gas: high particle density and low temperature. Excitation of high J levels varies largely from one component to the other suggesting that the UV radiation field is highly inhomogeneous through the system. Gas pressure, estimated from C I absorptions, is larger than what is observed in the ISM of our galaxy. In addition, the ionization state of most of the gas, especially in the component at $z_{\rm abs} = 1.96912$, is consistent with a soft radiation field. This is probably a consequence of star-formation activity in the vicinity of the absorbing gas. Molecular CO is not detected ($\log N(\rm CO)/N(\rm H\ I) < -8$) and HD could be present at $z_{\rm abs} = 1.97380$.

A collimated flow driven by radiative pressure toward the quasar Q 1511+091

High velocity outflows from quasars are revealed by the absorption signatures they produce in the spectrum of the quasar. Clues on the nature and origin of these flows are important for our understanding of the dynamics of gas in the central regions of the Active Galactic Nuclei (AGNs) but also of the metal enrichment of the intergalactic space. Line radiation pressure has often been suggested to be an important process in driving these outflows, however no convincing evidence has been given so far. *Srianand*, Petitjean and Ledoux have reported the detection of a highly structured flow, toward Q1511+091, where the velocity separation between distinct components are similar to O VI, N V and C IV doublet splittings with some of the profiles matching perfectly. This strongly favours the idea that the absorbing clumps originate at similar physical location and are driven by radiative acceleration due to resonance lines. The complex absorption can be understood if the flow is highly collimated so that the different optically thick clouds are aligned and cover the same region of the background source. The fact that the clouds cover only part of the small continuum source implies that the flow is located very close to the continuum source. We believe that this system is the first clear evidence of the existence of disk winds in AGNs. [see Figure (11)]

Modelling of damped Lyman-alpha systems

The Damped Lyman-α systems (DLA) are identified with the lines having highest column densities in a typical observed absorption spectrum of a distant quasar. These high column density systems are important in understanding the baryonic structure formation (like formation of galaxies), because they contain fair amount of the neutral hydrogen in the universe at high redshifts. *T. Roy Choudhury* and *T. Padmanabhan* have developed a simple analytical model for estimating the fraction ($\Omega_{\rm gas}$) of matter in gaseous form within the collapsed dark matter (DM) haloes. The model is developed using (i) the Press-Schechter formalism to estimate

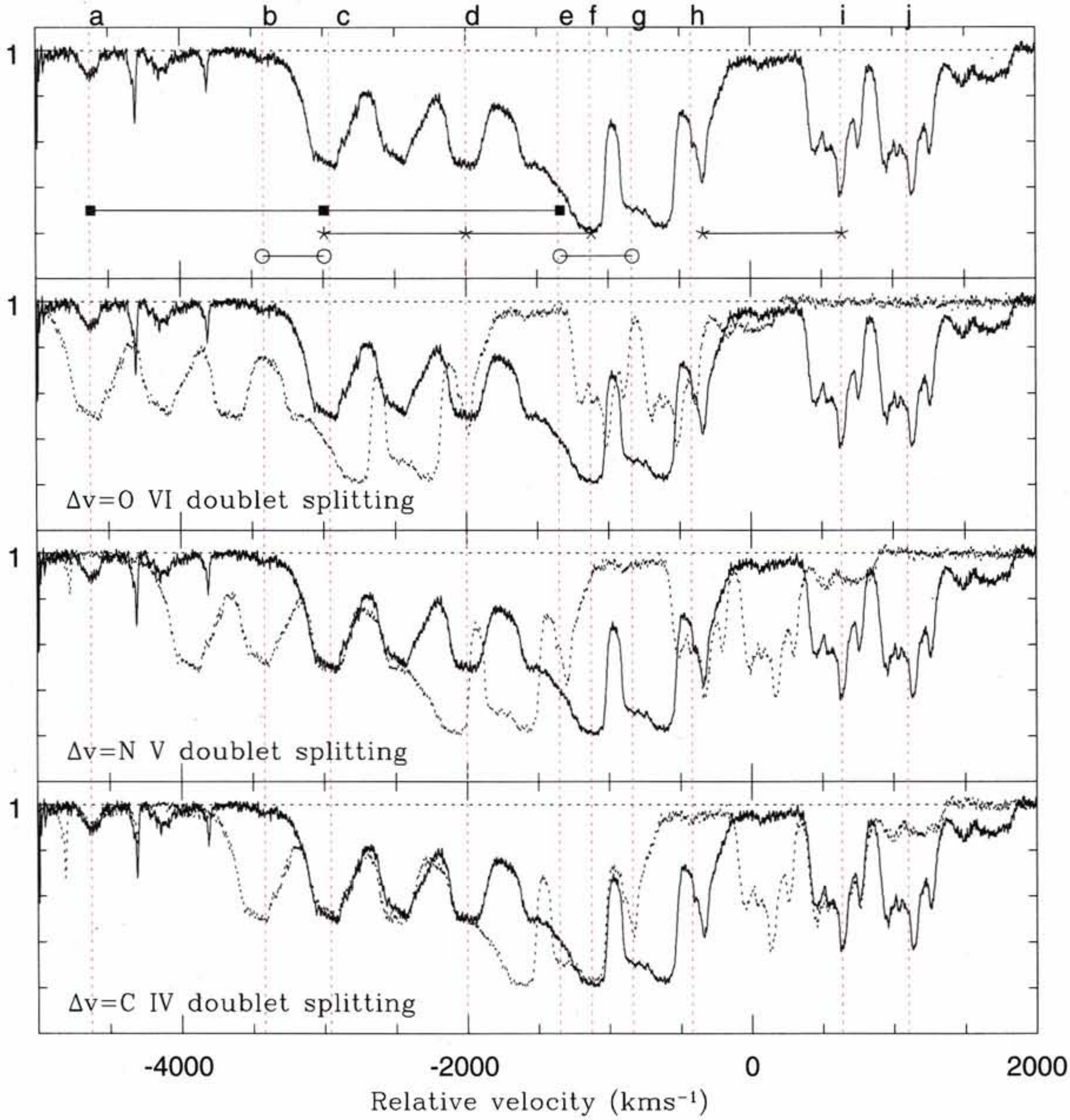


Figure 11: The profile of the C IV absorption seen toward Q1511+070 (top panel and solid line in other panels). The same profile, but shifted by different velocity separations, is overplotted as a dotted line in the other panels (respectively O VI, N V and C IV from top to bottom). In the top most panel, different velocity components are marked that are separated by C IV (circle), N V (star) and O VI (filled square) doublet splittings. The vertical dotted lines mark the position of various distinct component identified in the flow.

the fraction of baryons in DM haloes, and (ii) the observational estimates of the star formation rate at different redshifts. The prediction for $\Omega_{\rm gas}$ from the model is in broad agreement with the observed abundance of the damped Lyα systems. Furthermore, it can be used for estimating the circular velocities of the collapsed haloes at different redshifts, which could be compared with future observations.

High Energy Astrophysics

Gamma-ray bursts - Where are the missing afterglows?

Last year, it was reported that K. George and *A. N. Ramaprakash* were investigating possible reasons for not detecting afterglows in the case of a large number of well-localized gamma-ray bursts. They compiled a subsample of bursts based on the following three criteria. (a) The bursts had associated X-ray afterglows which were well-localized with positional errors less than 3 arcminutes. (b) Quick follow-up deep searches were undertaken in optical and near-infrared wavelengths to identify afterglows at other wavelengths, but none were found. (c) X-ray observations were carried out on at least two well separated epochs in the 2-10keV band which is almost unaffected by extinction.

The most accepted models for gamma-ray burst afterglows predict a flux evolution given by $F_\nu = \nu^{-\alpha}t^{-\beta}$ above a threshold frequency with α and β related through the power law index p of the shock-accelerated electron energy distribution. The exact nature of the relation between α and β depends on the particular evolutionary stage, which the afterglow is passing through at any time. The temporal flux decay index of the X-ray afterglow obtained from (c) above, allows one to estimate β and then in turn α for the burst. Using this they estimate the expected flux from the afterglow when the deep searches were undertaken at a particular waveband. The amount of extinction in the restframe of the afterglow, that would be required to render it fainter than the sensitivity limits of the search are then determined. George and *Ramaprakash* find that in the case of the five bursts they studied, the non-detection of optical afterglows can be explained by line of sight ultraviolet extinction by dust typical to star forming galaxies.

Shock formation in blackhole accretion and related phenomena

It is generally argued that, in order to satisfy the inner boundary conditions imposed by the event horizon, accretion onto black holes exhibit transonic properties in general, which further indicates that formation of shock waves are possible in astrophysical fluid flows onto galactic and extragalactic blackholes. One also expects that shock formation in blackhole accretion might be a general phenomena, because shock waves in rotating and non-rotating flows are convincingly able to provide an important and efficient mechanism for conversion of significant amount of the gravitational energy (available from deep potential wells created by these massive compact accretors) into radiation by randomizing the directed infall motion of the accreting fluid. Hence shocks possibly play an important role in governing the overall dynamical and radiative processes taking place in accreting plasma. Thus the study of steady, stationary shock waves produced in blackhole accretion has acquired a very important status in recent years and it is expected that shocks may be an important ingredient in an accreting blackhole system in general. *Tapas K. Das* and collaborators are currently engaged in studying the following aspects of shock formation in accretion flow around blackholes.

(a) Non-self-similar, multi-transonic disc structure, shock dynamics and accretion powered cosmic jets

Hot, dense and exo-entropic post-shock regions in advective accretion disks are used as a powerful tool in understanding the spectral properties of BH candidates and in theoretically explaining a number of diverse phenomena, including millisecond variability in the X-ray emission from LMXBs and the generation mechanism for high frequency QPOs in general, high energy emission from central engines of AGNs, formation of heavier elements in BH accretion discs via non-explosive nucleosynthesis, formation and dynamics of accretion powered galactic and extragalactic jets, quiescent states of X-ray novae systems and outflow induced low luminosity of our galactic centre. Rigorous investigation of some of the shock related phenomena is extremely difficult (sometimes, completely impossible) to study using full general relativistic framework. Hence one is expected to always rely on pseudo-general relativistic blackhole potentials because of the ease of handling them.

Tapas K. Das provides a generalized modeling which for the first time, *all* available pseudo-Schwarzschild potentials are exhaustively used to investigate the possibility of shock formation in hydrodynamic, invicid, blackhole accretion discs. It is shown that a significant region of parameter space spanned by important accretion parameters allows shock formation for flow in *all* potentials used in this work. This leads to the conclusion that the standing shocks are essential ingredients in accretion discs around non-rotating blackholes in general.

Using a complete general relativistic framework, equations governing multi-transonic blackhole accretion and wind are also formulated and solved in the Schwarzschild metric. Shock solutions for accretion flow in various pseudo potentials are then compared with such general relativistic solutions to identify which potential is the best approximation of Schwarzschild space-time as far as the question of shock formation in black hole accretion discs is concerned. It was also shown that, as the shock forms at a particular radial distance, it is clear that self-similar solutions should *not* be invoked while studying real physical BH accretion and related phenomena. It is sometimes argued that a non-standing oscillating shock may modulate the disc spectrum in order to explain the dwarf novae outburst or Quasi Periodic Oscillation

(QPO) of the black hole candidates. In this context, the region of parameter space found by *Das*, for which three sonic points are formed in accretion but still no steady, standing shock is found, can be considered as quite an important zone because such regions can provide the relevant parameters responsible for such physical processes.

In an ongoing work, *Das* and *Sanjit Mitra* show that for the specific region of parameter space (spanned by the energy, angular momentum, accretion rate and the polytropic index of the advective flow) which allows shock formation, always there is a possibility of emergence of shock generated, accretion powered, collimated, cosmic jets; thus for the first time, the accretion phenomena and jet formation for galactic and extra galactic sources was self-consistently and non-self similarly coupled for *all* pseudo-general relativistic blackhole potentials. Work is also in progress where such jet formation is studied using full general relativistic framework.

(b) Analytical calculation of QPO frequencies of the galactic microquasars

In an ongoing work, *Das*, along with A. R. Rao and Santosh Vadawala of Tata Institute of Fundamental Research, India, proposes that the disc-outflow model by *Das* & S. Chakrabarti, could be a robust tool for establishing a theoretical connection between QPO and the formation of galactic relativistic jets. The QPO is argued to be produced due to large amplitude oscillation of weak and strong shock formed in CENBOL situated very close to the event horizon of stellar mass black hole sitting at the dynamical centre of the microquasars. *Das*, Rao and Vadawala show that the related mass ejection takes place from this CENBOL region which is in fair agreement with the observational evidence of the disappearance of inner accretion disc during the emission of radio flares from galactic micro-quasar candidate GRS1915+105. They have been able to compute the range of QPO frequencies (in terms of only three accretion parameters) and obtained a theoretical correlation of QPO frequencies with the loss rate which is able to systematically explain the recently observed correlation of QPO frequencies with the radio and thermal flux.

(c) Radio luminosity and the mass of the central blackholes in Active Galactic Nuclei

A good number of papers are available in the literature which *observationally* calculate the radio luminosity L_{Rad} of AGNs as well as the mass of the blackhole M_{BH} situated at their dynamical centres. In an ongoing project, *Das*, along with Amri Wandel of Racah Institute of Physics, the Hebrew University of Jerusalem,. Israel, and with Luis. C. Ho of the Centre for Astrophysics (CfA), Harvard (also, the Observatories of the Carnegie Institution of Washington), attempts to provide a *theoretical* correlation between the M_{BH} and L_{Rad} via the correlation between M_{BH} and the baryonic load of AGN jets; and to test their calculations with the existing observational results.

Dynamics of general relativistic blackhole accretion

(a) Spherically symmetric, transonic black hole accretion

Tapas K. Das has formulated and solved the equations governing general relativistic, spherically symmetric, hydrodynamic accretion and the corresponding 'self-wind' of polytropic fluid onto blackholes in Schwarzschild metric to investigate some of the transonic properties of the flow in terms of fundamental accretion parameters. For the first time, behaviour of some flow variables in the close vicinity of the event horizon are studied as a function of specific energy and polytropic index of the flow. A significantly important new model was constructed which allows real physical transonic solution *even for* $\gamma < 4/3$ or $\gamma > 5/3$, where γ is the polytropic index of the flow.

(b) Advective, multi-transonic accretion discs

Although, the general relativistic accretion disc structure around a non-rotating, weakly magnetized compact objects is an well addressed problem in the literature, it is fair to say that any self-consistent solution has yet appeared which can handle the global structure of multi-transonic, hydrodynamic blackhole accretion which may contain steady, standing Rankine-Hugoniot shock waves (RHSWs). Using complete general relativistic framework, *Das* and *Sanjit Mitra* investigates the dynamics of rotating, advective, multi-transonic blackhole accretion which essentially involves the analytical formulation and analytical and numerical solutions of equations governing radiative-hydrodynamics in Schwarzschild metric for a set of specific boundary condition. The possibility of RHSW formation in such flows is being investigated as well. They are able to numerically solve a set of non-linearly coupled differential flow equations to calculate the exact value of a number of dynamical and thermodynamic flow variables to the extreme close vicinity of the event horizon; in some sense such solutions seem to be extremely important, because it is expected to theoretically predict the dynamical behaviour of accreting material in its final state of motion, i.e., when the flow disappears through the event horizon.

(c) Viscous transonic accretion in Kerr metric and the Bardeen-Petterson effect

Due to the non-spherical symmetry of the gravitational field in Kerr spacetime,the dragging of inertial frames (The Lense-Thirring effect) produces significant structural changes of a non-equatorial accretion disc around a spinning black hole. Introduction of viscous torques of the accreting material leads to another very important phenomenon, the Bardeen-Petterson effect (BPe). In an ongoing project, *Das*, along with John Papaloizou and Richard Nelson of the Department of Mathematics, Astronomy Unit, Queen Mary and Westfield College, University of London, studies some aspects of BPe for full general relativistic viscous transonic accretion onto a Kerr blackhole. For this purpose, they try to formulate and solve the set of equations governing the flow of non-magnetized viscous fluid in Boyer-Lindquist co-ordinate. After introducing a suitable perturbation, they attempt to linearize the resulting equations to study various aspects of disc oscillation and BPe.

The blackhole-bulge relation in AGNs

In a recent work (Wandel, A. 2002, ApJ, 565, 762), a very tight correlation between bulge luminosity of AGNs and the size of the broad line region (BLR) has been reported. Wandel concludes such correlation to be a non-trivial one, as it relates two independent observables: on the one hand the bulge luminosity, a global galactic property on a kpc-scale, and on the other hand, the BLR size (measured by reverberation mapping or luminosity scaling), on a few light-days scale. It may be reflecting the BH-bulge relation, but the correlation being much stronger than the BH-bulge relation supports the case that this new relation is more fundamental. In an ongoing project, *Tapas K. Das* and Amri Wandel are engaged in constructing theoretical model of accretion in galactic scale, which might be able to explain this phenomenological correlation. In another related project, *Das* and Wandel try to measure the galaxy light concentration for a number of Seyfert galaxies (for which the mass of the central blackhole is an well-estimated quantity) to investigate the correlation among the light concentration and M_{BH}.

Stability of radiation pressure dominated discs

Radiation pressure dominated thin accretion disks around blackholes are known to be both thermally and secularly unstable. However, observations of blackhole systems, in the soft state, indicate that such disks indeed exist and are stable. *R. Misra* and R. E. Taam have studied the effect of an optically thick dissipative corona on the stability of the underlying radiation pressure dominated disk. They found that the presence of such a dissipative corona, stabilizes the disk for a factor of four larger accretion rates. Thus, such disks are an attractive explanation for the origin of the soft spectral component observed in blackhole X-ray binary systems.

Neutron star systems and QPO

Neutron star systems often exhibit quasi-periodic oscillations (QPO) in kilohertz frequencies. The time lag between the high and low energy photons in the QPO, can be used to constrain the size and geometry of the QPO producing mechanisms. *R. Misra* and R. E. Taam have obtained the time lag as a function of energy for four neutron star systems. They find that the inferred size of all four systems is the same (around 10 km). This and the variation of time lag with energy seems to indicate that the QPO producing mechanism is the inner accretion disk rather than the boundary layer.

Galaxy and Interstellar Medium

Simultaneous multifrequency pulsar observations

The conducting interstellar medium in the galaxy disperses electromagnetic waves travelling through it. The highly periodic pulses emitted at radio wavelengths by pulsars are affected by this dispersion so that the lower frequency components of a broad band pulse arrive later than the higher frequency components. This broadening in time of the radio pulses has to be corrected for in constructing accurate pulse profiles and measuring arrival times. The dispersion can be put to good use in studying the properties of the interstellar medium, since the observed time delay over a small frequency interval is related in a simple manner to the pulsar dispersion measure (DM), which is the product of the average electron density along the line of sight to the pulsar and the distance to it. Dispersion measures are most accurately measured by the simultaneous multifrequency observation of the radio pulses, and the Giant Metrewave Radio Telescope (GMRT) of the National Centre for radio Astrophysics (NCRA), Pune, has a unique capability for such measurements. A project for multifrequency observations of a number of pulsars over an extended period of time is being carried out by *Ajit Kembhavi* and *Amrit Lal Ahuja*, in collaboration with Yashwant Gupta and Vasant Kulkarni of

NCRA. Gupta is the originator of this key project.

Simultaneous observations made at two frequencies provide very accurate estimates of the dispersion measures. The accuracy here is limited only by the signal-to-noise ratio of the data at the two frequencies, and accuracies of one part in 10^4 to a few parts in 10^5 have been obtained for observations of some bright pulsars with the GMRT. With such accuracy, it is possible to study fluctuations in the value of DM over time. This provides a direct estimate of the spectrum of fluctuations in electron density, which proves to be a very useful input in the study of the physics of the interstellar medium. The multifrequency observations can be used as powerful tools in interstellar scintillation studies and in tracking the frequency dependence of parabolic arcs that are seen in the secondary spectra of some pulsars. The simultaneous observation of the pulses over a range of frequency can also provide understanding of the mechanism of pulse generation and the distribution and location of pulse emission regions.

As a part of this project, about a dozen pulsars have been observed simultaneously at two frequencies, 243 and 325 MHz or 243 and 610 MHz, with the GMRT once every two weeks over a total period of about a year. For most of the pulsars, the mean value, over several epochs, of the DM measurements agrees quite well with the cataloged values, while for the rest, the mean value has been found to be significantly different. Significant temporal variations have been detected for several pulsars, over timescales of weeks to months. These variations will be very useful in probing the large scale density fluctuations in the ionized part of the interstellar medium.

Galactic magnetic fields

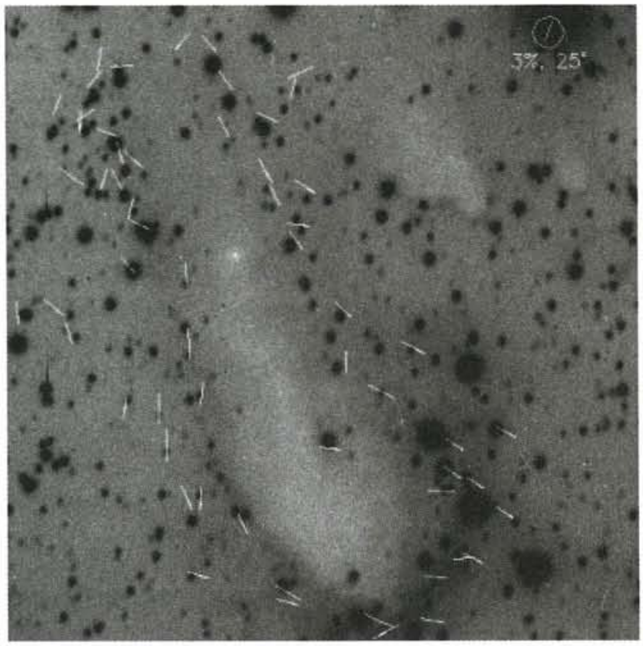
Magnetic fields in spiral galaxies are of order a few micro Gauss and are ordered on scales of several kilo parsecs. The origin of such ordered fields remains a challenging problem. One possibility is the dynamo amplification of a weak but non-zero seed magnetic field. The galactic dynamo works due to the combined action of galactic shear and helical turbulence. However galactic turbulence also leads to the generation of magnetic noise (fields correlated on the scale of the turbulence of about 100 parsecs). There is the potential danger that Lorentz forces due to rapidly growing small-scale fields will lead to the saturation of the large-scale dynamo before it can produce the observed large-scale fields. *K. Subramanian* is trying to understand the details of the saturation of both small and large scale fields and the strength of resulting large-scale galactic fields.

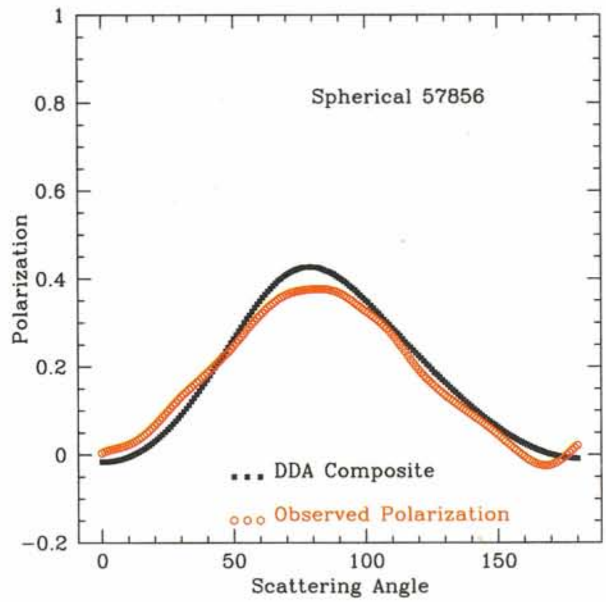
First, corrections to the dynamo coefficients, due to the growing small-scale magnetic fields, have been re-derived, using the quasi-linear approximation. Earlier work had claimed that the alpha-effect (which depends on the helicity of the turbulence and helps to generate poloidal from toridal fields in galaxies) is reduced by the growth of small-scale current helicity. But, the turbulent diffusion is not affected. The work by *Subramanian* shows that this is not true; even in the quasi-linear regime, the effect of Lorentz forces is to generate additional diffusion, but now in the form of hyper-diffusion. This hyper-diffusion may not be as crucial as the decrease of alpha-effect for mean-field dynamo saturation, but it is likely to be important for the saturation of the small-scale dynamo.

It had been shown earlier by him (and others), that the major difficulty associated with large-scale field generation arises due to constraints imposed by magnetic helicity conservation. One can ask what is the minimal strength of large-scale magnetic fields, which can be generated, inspite of strict magnetic helicity conservation? A general upper limit implied by helicity conservation, and a more model dependent limit using the quasi-linear model of dynamo saturation, has been derived. It is found that the large-scale dynamo saturates due to alpha-effect suppression, when the mean field energy density is of order a few percent of the turbulent energy density, depending on the parameters of the galactic dynamo.

Magnetic fields near cometary globule S131-37

Cometary globules are small, dusty molecular clouds associated with HII regions and are found near star forming regions in our Galaxy. It is believed that their survival in the hostile ambient medium depends on magnetic confinement of the surrounding ionized plasma. In this model, the magnetic field lines are expected to be aligned along the tail of the globule, thus delaying diffusion of ionizing particles across. *U. Alam* and *A. N. Ramaprakash* studied linear polarization of field stars shining through the edges of the cometary globule S131-37 in the Galactic HII region IC 1396. Since, the polarization is due to starlight scattered by magnetically aligned dust grains, the polarization vectors trace the magnetic field lines in the vicinity of the cloud. The predominant alignment of polarization vectors along the tail of the globule, as seen in their results are in good support of the magnetic confinement model. (see Figure 12) The data for this study was obtained by S. R. Kulkarni with the Palomar 200 inch telescope using an improvised polarimeter arrangement of the COSMIC





instrument.

Interstellar dust and extinction by composite porous grains

In continuation of the ongoing research on modeling of interstellar dust grains, *Ranjan Gupta* (in collaboration with D.B. Vaidya and J.B. Dobbie and P. Chylek), is planning further work on obtaining the polarization curves for Comet Halley in the near-IR K-band of 2.2μm by using the composite grain models that they have developed.

Figure 13 shows the observed polarization curve (Brooke, T.Y., et. al., A & A, 187, 621B, 1987) and its fitting with these corresponding models. The spherical grain has 57856 host graphite dipoles with 13 inclusions of 912 silicate dipoles. The corresponding model fitting curve in Figure 13 uses grains of sizes between 0.05 to 0.5 μ with a power law distribution of power index -2.5 .

The non-spherical grain has 14440 host silicate dipoles with 11 inclusions of 224 graphite dipoles. The corresponding model fitting curve in Figure 13 uses grains of sizes between 0.02 to 1.0 μ with a

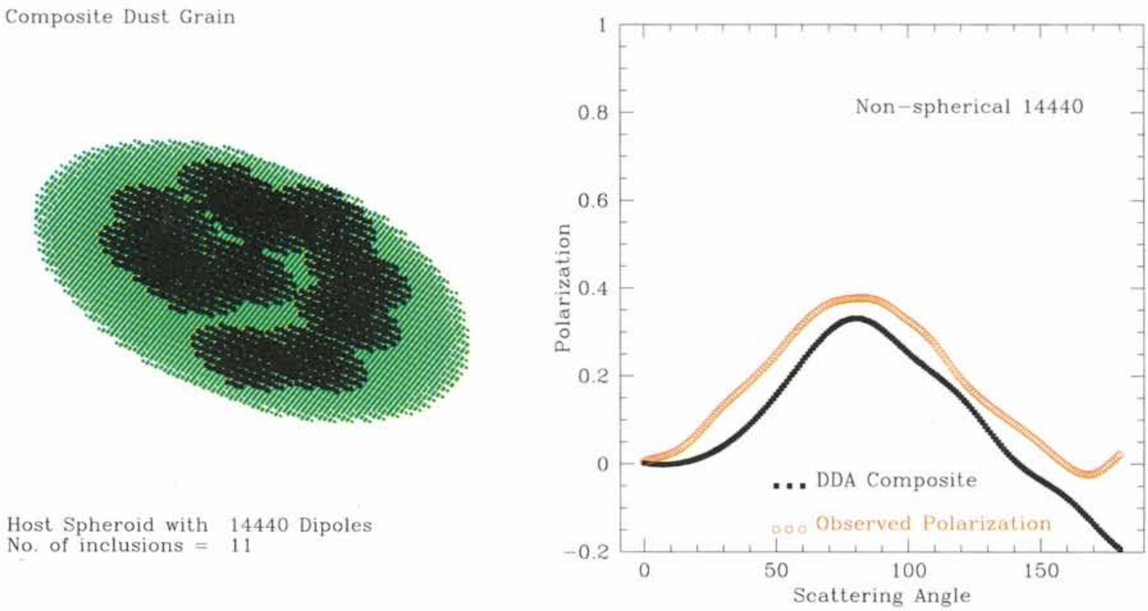


Figure 13: **The Figure 12 on page 48 (top) is a Polarization vector map of the field stars shining through the dust near the cometary globule S131-37. North is downwards, East is to the left. The Figure 13 on page 48 bottom left is a 3-D view for spherical (57856) dust grain and bottom right is the corresponding observed Polarization curve in K-band. On page 49 left is a 3D view for non-spherical (14440) dust grain and right is the corresponding observed Polarization curve in K-band**

power law distribution of power index -4.0 .

ISRO sponsored balloon experiment on panspermia

Theories of panspermia are rapidly coming into vogue, with the possibility of the transfer of viable bacterial cells from one planetary abode to another being generally accepted as inevitable. The panspermia models of Hoyle and Wickramasinghe require the transfer of viable bacterial cells from interstellar dust to comets and back into interplanetary and interstellar space. In such a cycle, a viable fraction of as little as 10-18 at the inception of a newly formed comet/planet system suffices for cometary panspermia to dominate over competing processes for the origin and transfer of life. The well-attested survival attributes of microbes under extreme conditions, which have recently been discovered, gives credence to the panspermia hypothesis. The prediction of the theory that comets bring microbes onto the Earth at the present time is testable if aseptic collections of stratospheric air above the tropopause can be obtained.

To test this hypothesis and out of a general interest to probe the possibility of existence of life at heights in the range of 20-40 km, a recent collection of this kind was obtained from a cryosampler taken up to a height of 41 km by a balloon. Microbiological analysis of the samples recovered by the biologists at Cardiff, UK shows the existence of viable cells at 41km, falling to Earth at the rate of a few tonnes per day over the entire globe. Some of these cells have been cultured in the laboratory at Sheffield, UK and found to include microorganisms that are not too different from related species on the Earth. This investigation is still in progress. The experiment with *J. V. Narlikar* as the Principal Investigator, is supported by ISRO and involves a multi-institutional collaboration.

Stellar Physics

Spectroscopic observations

A DST-NSF Indo-US proposal entitled 'A Comprehensive Digital Library of Stellar Spectra' on collaboration with *Ranjan Gupta,* H.P. Singh (Delhi University) and Jim Rose (University of N. Carolina, USA) and his team has been approved and in October 2001 the first visit to NOAO, Tucson was carried out to essentially work out a procedure to stitch each of the individual spectra of about 1200 stars from the KPNO observations. The procedure is based on the fitting of continuum for various spectro-luminosity types by using the recent library of Pickles. Figure 14 shows the example of three such spectra. Further refinement of this procedure is in progress.

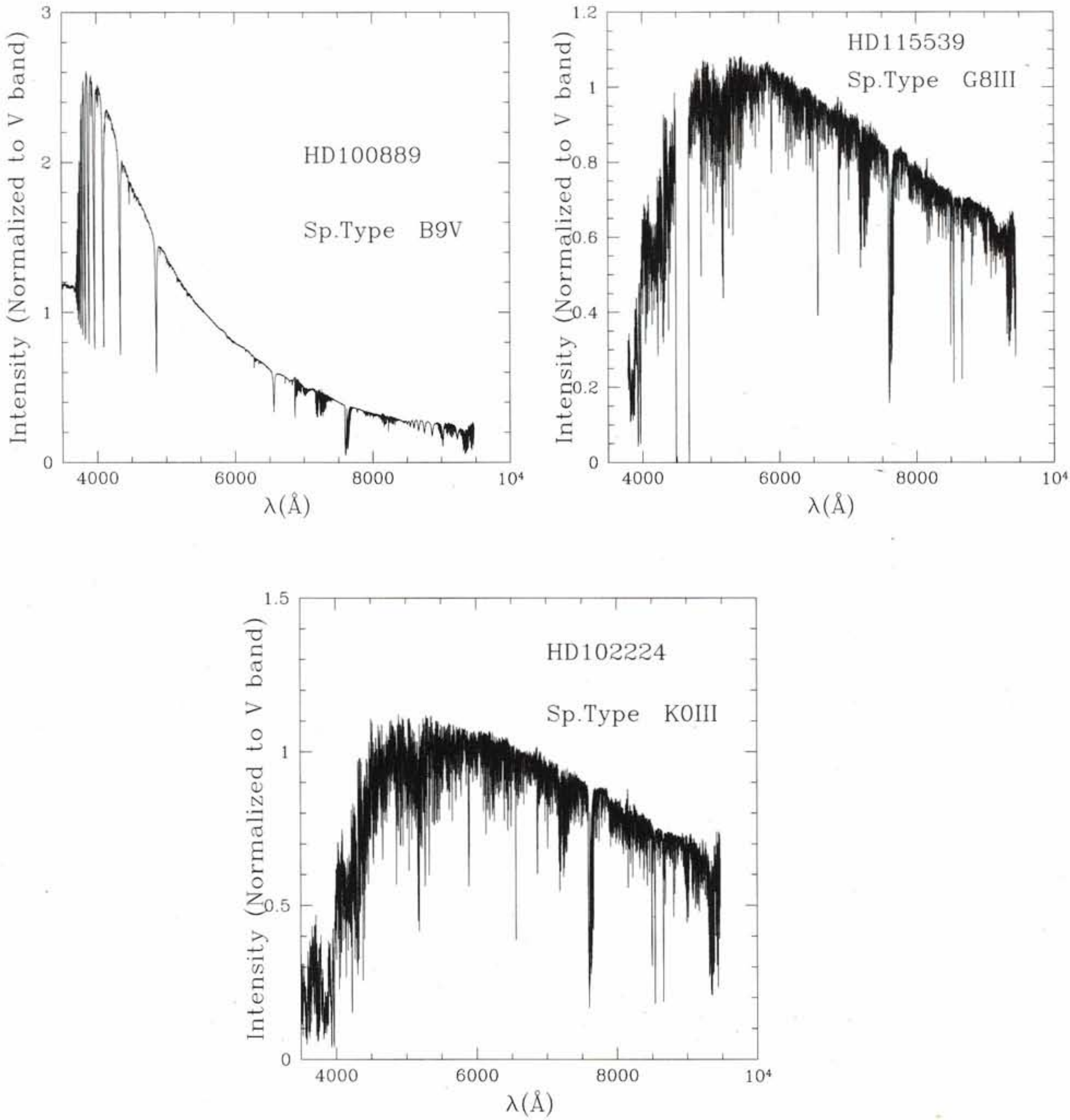


Figure 14: Example of a B-type, G-type and a K-type Coude Feed, KPNO spectra normalized to V band and processed by using Pickles library continuum. The spectral resolution is about 1 Å .

Star-galaxy classification with neural networks

The star-galaxy classification problem addresses the task of labelling objects in an image either as stars or as galaxies. Bright galaxies at low redshift are markedly different from stars, which in optical and near infrared images appear as point sources spread out by the point spread function (psf). The extent and shape of the psf itself depends upon the location of the observatory, the conditions prevailing at the time of the observation and the telescope optics. Galaxies at high redshift have low surface brightness and small angular sizes, and at the faint limits of a survey, it can become difficult and time consuming task to reliably separate and distinguish between the images of stars and galaxies. Traditionally such classification, when it is needed, has been carried out by human experts with intuitive skills and experience. Such an approach is, of course, no longer feasible, given the vast quantities of data, which are being generated by large surveys, and the need to bring objectivity into the classification. It is, therefore, necessary to develop tools for quick and reliable automated classification of data, and artificial neural networks have been found to be very useful in this respect.

Ajit Kembhavi, in collaboration with Sajith Philip of St. Thomas College, Kozhancherri, and *Yogesh Wadadekar* of IAP, Paris, has applied a new artificial neural networks, known as the difference boosting neural network (DBNN) developed by Philip and Babu Joseph, to the problem of star-galaxy classification. The DBNN uses a Bayesian classification algorithm, which is computationally less intensive than the similar procedures, and has significantly higher speed and flexibility during training as well as classification. These attributes can be critically important in addressing data from very extensive surveys, which have been carried out over varying observational conditions, and which can, therefore, require retraining for different sectors of the survey.

The training set for the classifier was constructed from the R band image of the new NOAO Deep Wide Field Survey (NDWFS), which has been obtained using the MOSAIC-I CCD camera on the KPNO 4m Mayall telescope, and is publicly available. The DBNN was trained using several hundred objects from the survey, which were visually classified into stars and galaxies. The trained network was then used to classify several large samples of objects from the same survey, using three parameters which were determined to be the optimum ones for the purpose through extensive experimentation. The accuracy in classification, reached by the trained network, was checked using independent visual classification, as well as automated classification made using SExtractor, which is a standard routine used in classification and photometry. It was found that the DBNN reaches an accuracy of about 98 percent, which is at least as good as the accuracy reached by SExtractor. But the DBNN has very significant advantages in speed in training as well as classification, which will be very valuable in addressing large data sets which require retraining. The DBNN can be applied to a variety of classification problems in astronomy as well as other fields, and several of the possible applications are under investigation.

Solar Physics

Source regions of solar coronal mass ejections

Prasad Subramanian and K. P. Dere (Naval Research Laboratory, Washington, DC) have recently concluded an extensive study of the source regions and initiation mechanisms of coronal mass ejections (CMEs). They use data from the Large Angle Spectroscopic Coronograph (LASCO), the Extreme Ultraviolet Imaging Telescope (EIT) and the Michelson Doppler Imager (MDI) instruments aboard the Solar and Heliospheric Observatory (SOHO) spacecraft, together with H-alpha data from various ground-based instruments. From a dataset of 32 well observed CMEs, with source regions on the solar disk over a period of 2 years during the last solar minimum, they find that 41% of these CMEs are associated with active regions without any evidence for erupting prominences. 44% of these CMEs involve eruptions of prominences embedded in active regions, while 15% of these CMEs are associated with eruptions of prominences outside active regions. This has led to a shift in the widely held previous perception that CMEs are almost entirely associated with prominence eruptions.

Solar observations with the Giant Metrewave Radio Telescope

Prasad Subramanian, S. Ananthakrishnan and A. Pramesh Rao (NCRA-TIFR) and Monique Pick (Observatoire de Paris, Meudon) have been observing the solar corona with the GMRT and the Nancay radioheliograph in France over the last year. These preliminary metre wavelength observations have yielded snapshots of type 1 radio noise storms with impressive spatial resolution. Type 1 noise storms are believed to be initiated by Langmuir waves excited by loss cone instabilities in electrons streaming along closed magnetic loops. The Langmuir waves coalesce with low frequency waves such as ion-acoustic or lower hybrid waves to produce observable electromagnetic emission. The high resolution snapshot maps from the GMRT yield more detailed information about the locations and motion of noise storm sources and their polarization than was hitherto available. They are being used to effectively constrain models of generation, scattering (angular broadening) and depolarization of type 1 noise storms. These continuing observations also offer the possibility of serendipituous observations of flares and coronal mass ejections (CMEs). Together with the wealth of readily available multiwavelength data from satellites and ground-based instruments, it is possible to gain crucial insights into the initiation mechanisms of flares and CMEs.

Coronal electron density models from total brightness measurements

Models of electron density in the solar corona have traditionally been derived using polarization brightness measurements of the Thomson scattered

Near-IR PICNIC Imager (NIPI) Optical Layout

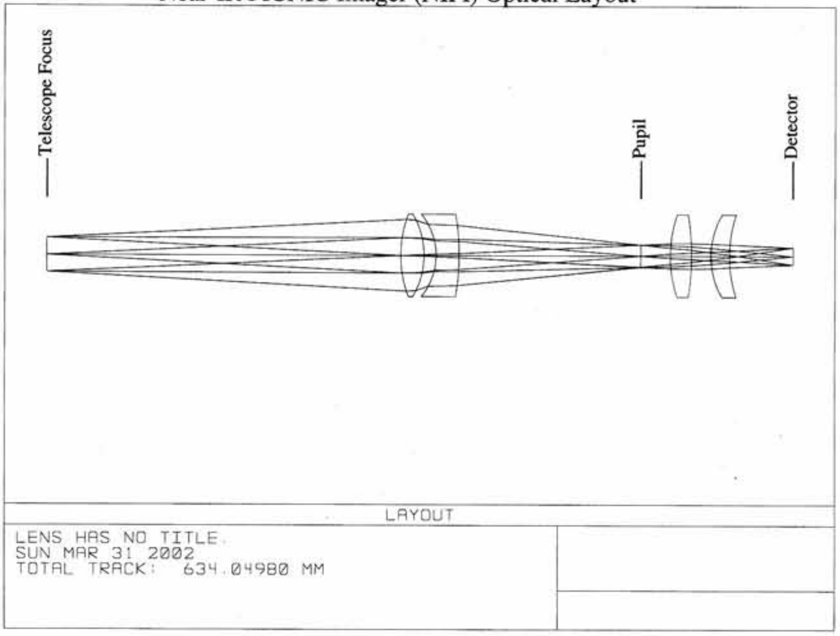


Figure 15: Optical layout of NIPI. The focal plane of the telescope is reimaged onto the PICNIC detector with a image scale reduction by a factor of 2.

light from coronal electrons. Polarization brightness measurements are mostly used in ground-based observations of eclipses. The derivations use variations of an inversion method, first proposed by van de Hulst (1950). Modern space-based coronographs such as the LASCO routinely obtain highly accurate white light total brightness images. The high quality of these data nullify the advantages of polarization brightness measurements. Hayes, Vourlidas and Howard (2001) have implemented a numerical method of inverting the electron density from these total brightness measurements, thus enhancing their scientific return. *Prasad Subramanian* and Bhalchandra Pujari, an undergraduate student from Wadia College, Pune, have obtained an analytical solution for electron density inverted from total brightness measurements. This solution is the analog of van de Hulst's (1950) result for total brightness measurements. It will significantly speed up Hayes, et al's (2001) numerical implementation of coronal density from LASCO white light observations. They are also working with Vourlidas on subtracting contributions from the Fraunhofer (F) corona to the white light observations from the C2 and C3 coronographs of LASCO. This work is also expected to be of considerable use in processing coronograph data from the forthcoming Solar-Terrestrial Relations Observatory (STEREO).

Instrumentation

Imager spectrograph for IUCAA telescope (IFOSC)

This instrument, along with a calibration box, has been developed for imaging and low/medium resolution spectroscopic observations with the forthcoming IUCAA 2 metre telescope in the visible band. The instrument uses lenses and grisms, and has a field of view of about 11 arcmin square; more details about it can be found in the last year's report.

A procedure (based on the commercial technology of fabricating electronics printed circuit boards) has been developed by *Abhay Kohok* and *Hillol Das* to make multislit masks, with a positional accuracy of about 0.01 mm, i.e., 0.1 arcsec equivalent, for multiobject spectroscopy.

An accessory has been developed by Parmita Barai, *Das, Kohok*, and *Shyam Tandon* to measure wavefront aberrations in the telescope's beam. The hardware consists of a Hartmann mask placed at the pupil plane (between the collimator and the camera lenses) and a convex lens immediately behind it – the lens separates images of holes in the mask on the CCD. Images of the mask are taken with the telescope beam and with a reference beam generated in the calibration box. An analysis of the relative positions of the centroids (of holes in the mask) in the two images are analysed to derive the

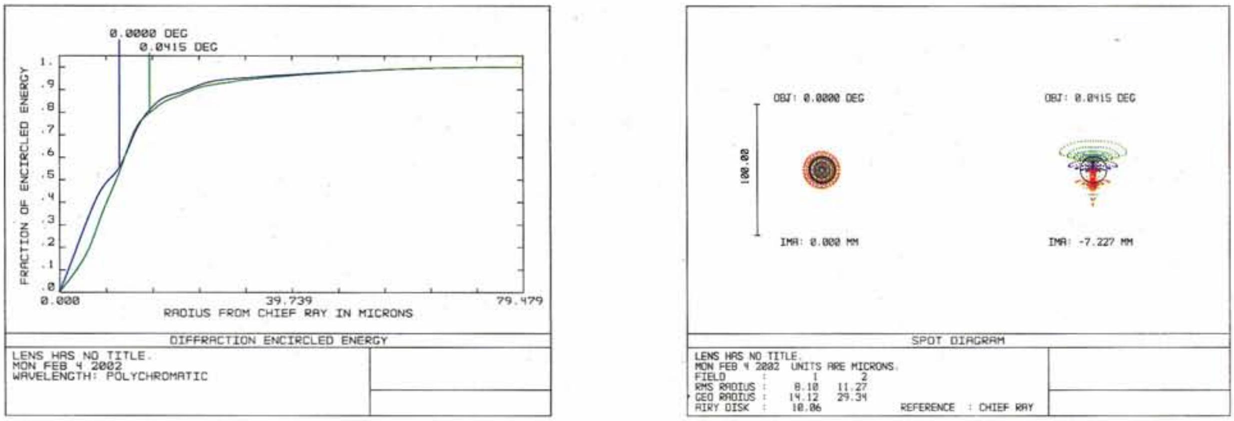


Figure 16: (a) The encircled energy as a function of distance from chief ray. The two curves are for on-axis (0°.0) and full-field (0°.0415) point objects. (b) The polychromatic spot diagrams for on-axis (0°.0) and full-field (0°.0415) point objects. These are for the entire H-band.

aberrations.

In order to be able to do spectropolarimetric and photopolarimetric observations an accessory is being developed by *Das* and *Tandon.* It involves introducing a rotating half wave plate modulator between the aperture plane and the collimator, and a Wollaston prism analyser near the pupil plane between the collimator and the camera. A slit mask is used in the aperture plane to ensure that ordinary and extraordinary images from neighbouring fields do not overlap. A set of four images taken with four different rotational positions of the modulator (at 0 deg., 22.5 deg., 45 deg., and 67.5 deg. respectively) can be used to derive the Stoke's parameters; this set of four images provides enough redundancy so that effects of flat-fielding and variations in atmospheric extinction can be divided out.

Near-Infrared PICNIC imager (NIPI)

The work which was reported last year on building a near-IR camera for the IUCAA telescope has made further progress. Reimagaing optics has been designed by *Atul Deep*, *A. N. Ramaprakash* and *S. N. Tandon*, which reduces the image scale at the telescope focal plane to one that matches the detector pixel scale and typical seeing expected at the site in the near-IR wavebands.

This design uses two $CaF_2 - SiO_2$ achromatic (see Figure) doublets to achieve focal reduction by a factor of two. At this reduction, the camera will have a field of view of about 2.5 arcminutes. PICNIC detector pixels are 40 x 40 microns in size. The optics is capable of enclosing within one pixel, more than 85% of the light within each waveband, from a point source anywhere in the field. (see Figure 16)

Assuming typical observing conditions (seeing, sky brightness, etc.) and detector characteristics, the camera is expected to reach detection sensitivity limits of J=21.6, H=20.2 and K=19.1, in 15 minutes, for a signal to noise ratio of 5. In order to achieve these limits, particularly in the K band, the optics will have to be cooled to about -50^0C so that the thermal background will no longer be the dominant noise source. Design work has started for making a cryogenic dewar which will house the optics and the detector. The PICNIC chip will be kept in contact with the liquid nitrogen can inside the dewar. Heat shields inside the dewar will provide a minimum radiation background environment around the optics.

Work on building the data-acquisition system for the camera is underway now. Some of the electronic cards which form the detector controller has been populated by *P. Chordia* and the same are undergoing laboratory tests currently. Finalising the design of the remaining parts of the electronic system will be the next stage, followed by building and testing these components. A configurable software package which will handle both CCD and near-IR controllers is being developed and tested.

CCD Controller System

IUCAA's CCD controller system has been undergoing constant upgradation in order to keep up with improvements in technology and changes in trends.

At present, two major upgradation efforts are underway. The first one is to replace the old ISA-bus based data-acquisition system with a new PCI-bus based one so that the recent improvements in PC architecture can be effectively exploited. This work which started over a year ago is now approaching completion. The engineering first light with the new system connected to an EEV CCD dewar was achieved on March 22, 2002. *A. N. Ramaprakash, S. N. Tandon, D. V. Gadre,* R. K. Singh (NCRA) and *S. Engineer* are involved in this effort.

The second upgradation involves implementing two of the electronic cards (the command processor and the waveform generator) with new Field Programmable Gate Array (FPGA) based circuits which will replace the earlier Digital Signal Processor (DSP) circuits. FPGAs are Very Large Scale Integrated (VLSI) chips, which can be configured for different applications through software programming. For instance, in the FPGA-based CCD controller, one card is configured to be the command processor and another identical one as the waveform generator. This system is undergoing final tests in the laboratory currently. *M. P. Burse, Tandon, Chordia* and *Ramaprakash* are involved in this work along with two project students, V. Soni and D. Kulkarni.

(II) RESEARCH BY VISITING ASSOCIATES

Classical Gravity

Zafar Ahsan

It is known that the Riemann curvature tensor can be decomposed in terms of the Weyl conformal tensor, the Ricci tensor and the metric tensor. This decomposition involves certain irreducible tensors. In empty spacetime, the pure gravitational radiation field is described by the Weyl conformal tensor. However, when gravitational waves propagate through matter, the Weyl tensor is still pertinent. In 1962, C. Lanczos thought that the Weyl tensor can also be derivable from a simpler tensor field, and this can indeed be done through the covariant differentiation of a tensor field. This tensor field is now known as Lanczos potential. Zafar Ahsan has carried out the following work in the context of the Lanczos potential.

(i) Using the methods of general observers, a study of this potential has been made. The kinematical quantities, such as, expansion, shear and twist, etc. and the equations satisfied by them have been translated into the language of spin coefficient formalism of Newman-Penrose and the Lanczos potentials for the perfect fluid spacetimes have been obtained in terms of the spin coefficients. A structural link between the Lanczos scalars and the spin coefficients has been established and the Lanczos potential for the Godel solution has been obtained. The compacted spin coefficient versions of the Weyl-Lanczos equations and the Lanczos differential gauge conditions have been obtained and a potential for a Petrov type D spacetime has been found. The results are then used to obtain the Lanczos potential for a Kerr blackhole and it is seen that the Lanczos potential can be expressed in terms of the Coulomb component of the gravitational field and the mass parameter of the Kerr blackhole.

(ii) It is known that the spin coefficient formalism due to Newman-Penrose can successfully be used in treating many problems of general relativity. An extension to this formalism is due to Geroch, Held and Penrose (abbreviated as GHP-formalism). This formalism is more concise and efficient than the widely known NP-formalism. Using GHP-formalism, the non-null electromagnetic fields have been studied. A study of the propagation equations for the shear, twist and the expansion of the null congruences has been made and the conditions under which the coupling of expansion and twist are obtained. The behaviour of the modified Lie derivative operator on the electromagnetic bivector, Ricci tensor and metric tensor has also been studied.

(iii) Corresponding to a null tetrad $\{l^a, n^a, m^a, \bar{m}^a\}$ and a Lorentz transformation, it is known that there are six transformation laws (a) null rotation about l^a (b) null rotation which leaves the direction of l^a and n^a unchanged, but rotate m^a (and $\bar{m}^a$) in m^a - $\bar{m}^a$ plane (c) null rotation about n^a (d) reflection in l^a - n^a plane (e) reflection in m^a - $\bar{m}^a$ plane and (f) improper complex Lorentz transformation. The effects of these transformation laws on the scalars describing the gravitational field have been examined using the GHP formalism. Some of the applications of these transformation laws have also been mentioned.

S.G. Ghosh

Cosmic Censorship Conjecture (ÇCC) remains one of the most important unresolved issues in classical general relativity. According to CCC, the singularities that appear in gravitational collapse are always surrounded by an event horizon, i.e., singularities are not naked. In this context, one question, which could naturally arise, is, what happens in higher dimensions (HD), which are currently being considered in view of their relevance for string theory and other field theories? Would the examples of naked singularity in 4D go over to HD or not? S. G. Ghosh and N. Dadhich have employed the Vaidya null radiation collapse scenario to study this effect and their investigation shows that qualitatively the situation remains similar with monotonic shrinkage of naked singularity window with increase in dimensions. As D increases, two opposing effects set in, one increase in inhomogeneity and the other strengthening of gravitational field. The former would favour naked singularity while the latter blackhole. It turns out that in the final analysis it is the latter that has an upper hand and leads to shrinkage of the naked singularity window.

Similar situation arises in the HD Tolman-Bondi case as well, which was shown by S. G. Ghosh in collaboration with A Beesham. Ghosh, in collaboration with Beesham and R. V. Sarayakar, has constructed non-self similar models in HD case.

Dadhich and Ghosh have obtained the analogue of Vaidya's solution on the brane for studying the collapse of null fluid onto a flat Minkowski cavity on the brane. Since the back-reaction of the bulk onto the brane is supposed to strengthen gravity on the brane, it would favour formation of blackhole as against naked singularity. That is, the parameter window in the initial data set giving rise to naked singularity in the 4D Vaidya case would now get partially covered.

Ng. Ibohal

(a) Ng. Ibohal has discussed an application of Newman-Janis algorithm in spherical symmetric metrics with the mass function M(u,r) and the charge e(u,r). After the transformation of the metric via this algorithm, these two functions M(u,r) and e(u,r) might be of the three variables (u, r,), With these functions of three variables, all the Newman-Penrose (NP) spin coefficients, the Ricci as well as the Weyl scalars have been calculated and presented here in NP formalism in general. From these NP quantities, a class of rotating solutions of Einstein's field equations could be generated. These so-generated solutions include (a) the rotating Kerr-Newman (known), (b) the rotating Vaidya solution, (c) rotating Vaidya-Bonnor solution, (d) rotating Husain's solution, (e) rotating Wang-Wu solutions. It is found that the technique of Wang and Wu is so powerful to generate solutions, that the rotating Vaidya solution obtained here could be combined smoothly with the rotating Kerr-Newman solution to generate rotating Kerr-Newman-Vaidya solution, and similarly, rotating Kerr-Newman-Vaidya-Bonnor solution of the field equations. Thus, it suggests that the rotating Kerr-Newman-Vaidya and Kerr-Newman-Vaidya-Bonnor solutions could be written in Kerr-Schild form, showing the extension of Xanthopoulos's theorem on the rotating Kerr-Newman background.

(b) The variable-charged non-rotating Reis rotating Kerr-Newman blackholes have also been considered by Ng. Ibohal. Such a variable charge e with respect to the polar coordinate r in the field equations is referred as an electrical radiation of the blackhole". It is shown that every electrical radiation e(r) of the non-rotating blackhole leads to a reduction of its mass M by some quantity. If one considers such electrical radiation to take place continuously one after another for a long time, then a continuous reduction of the mass may take place in the blackhole body and the original mass of the blackhole may be exhausted completely. At that stage, the gravity of the blackhole may depend only on the electromagnetic field, not on the mass. Just after the complete exhaustion of the mass, if the next radiation continues, there may be a formation of a new mass of the blackhole. It appears that this new mass of the blackhole would never decrease, but might increase gradually as the radiation continues forever. A similar investigation is also discussed in the case of variable charged rotating Kerr-Newman blackhole. Thus, it has been shown the incorporation of Hawking's evaporation of radiating blackholes in the form of spacetime metrics in relativistic viewpoint that every electrical radiation of variable-charge non-rotating as well as rotating blackholes may produce a change in the mass of the body without affecting the Maxwell scalar.

R. Tikekar

The introduction of the time dependence in the static fluid solutions of Einstein's field equations has been already shown to lead to physically viable models of spherical universe without any big bang type singularity. These models include those, which describe ever-existing universe filled with perfect fluid in the presence of heat flux. The universes of these models either witness a transition from state of contraction to that of ever expansion or oscillate between two regular states. Using this procedure, R. Tikekar has obtained a spherical inhomogeneous cosmological model from an isotropic, spherical static fluid metric, which describes a universe filled with a perfect fluid in the presence of heat flux and contains RW universe as a particular case. The metric with appropriate choice of the parameters can as well be used to discuss collapse of a fluid distribution accompanied with heat flux. Relativistic models of stellar structures can be described both analytically as well as by adopting numerical procedures, but all these models do not stand the test of physical reality. An ansatz prescribing specific geometries for the 3-dimensional physical space is already shown to be highly instructive in developing easily tractable equilibrium models describing interiors of super dense stars and their subsequent collapse in the presence of heat flux. A new three-parameter family of interior solutions of Einstein's equations describing spherical static perfect fluid interior that can be smoothly joined with Schwarzschild exterior has been obtained by prescribing 3-hyperboloidal geometry for the physical space of the interior. A general three-parameter solution of the Einstein's equations with unisotropic matter on the background of spheroidal spacetimes is obtained jointly with B.C.Paul. The nature of the core-envelope models of compact fluid spheres with anisotropy in core region, based on this three-parameter family of solutions is being examined. These models are observed to accommodate density variation of high degree and admit a subclass for which both radial and tangential pressure vanish at the boundary. This subclass of solutions is shown to be useful in constructing easily tractable models of compact stars with anisotropies in their central regions.

Sarbeswar Chaudhuri

Astrophysical objects are surrounded by matter and they might be influenced by external gravitational as well as electromagnetic fields. So in order to describe the behaviour of these objects faithfully, one has to take into account the effects of these fields on a test body. For this purpose, S. Chaudhuri constructed some stationary axisymmetric solutions of vacuum Einstein field equations using the Soliton Technique of Belinskii and Zakharov. Some of the solutions are well behaved at spatial infinity and reproduce some already known solutions. Some static magnetovac solutions were generated by Chaudhuri using the transformation techniques developed by Das-Chaudhuri and Gutsunaev-Manko. The generated solutions are asymptotically flat and some of them reduce to the Schwarzschild form in the static limit in the absence of magnetic field. Chaudhuri is also in search of discovering new transformation techniques to generate new solutions of Einstein and Einstein-Maxwell field equations as well as to establish correlation between different solution generating techniques. Recently, Chaudhuri started investigation on the exterior gravitational field of a thin disk around a blackhole. For simplicity, both the disk and blackhole are assumed to be static. A static disk is interpreted in the literature as the rotation and counterrotation of equal number of particles so that the total angular momentum of the system is zero. The solutions show some peculiar behaviour. The disk energy density is found to be negative in some localized region of space which is in violation of the weak energy condition. It is also found that under certain restrictions on the parameters the velocity of the counterrotating disk particles assumes tachyonic speed.

M.C. Sabu

Using the Vaidya-Tikekar metric, gravitational collapse of stars for spherically symmetric fluid distribution with heat flux in the interior has been studied by M.C. Sabu. In collaboration with V O Thomas, spheroidal as well as pseudo spheroidal spacetimes have been studied by considering one parameter (K) as time dependent. The same method has been used to obtain exact solution for anisotropic fluid distribution together with heat flux.

Gravitational Waves

D. C. Srivastava

The first generation of laser interferometers and bar detectors will start collecting data very soon. The majority of the experimental searches are focused on the detection of burst and *chirp* signals. However, the interest in the data analysis for continuous gravitational wave (CGW) signals is growing. A prime example of sources of this type is a spinning neutron star. The detection of GW signals has its own problems, not the least of which is the sheer volume of data analysis. Each detector produces a single data stream that may contain many kinds of signals. Detectors don't point, but rather sweep their broad quadrupolar beam pattern across the sky as the Earth moves. Accordingly, the data analysis algorithms need to accommodate signals from any arbitrary location of its source. Further, the output data has broad band noise and the signal is to be extracted out of it. For this, one has to enhance signal-to-noise ratio (SNR). This is achieved by analyzing long observation time data. However, in a long duration data set, the monochromatic signal gets Doppler modulated due to (i) orbital motions of Earth around Sun and (ii) spin of Earth.

D.C. Srivastava with his research student S. K. Sahay, has studied, in a sequel of IUCAA preprints, the Fourier Transform analysis of a CGW (IUCAA-52/01, IUCAA-53/01 and IUCAA-54/01).

In the first preprint, they have analysed the one day observation time data set of a detector at an arbitrary location. In view of the fact that the data output at the detector is available in discrete form, the analytical FT is not very convenient and one normally employs the FFT. They have made a comparative study of the resolution of anlytical FT and FFT. It is found that the drop in amplitude due to FM and AM are about 56% and 18%, respectively whereas, for the complete response it is about 74%.

They find that the maximum power due to AM is associated with $f+2f_{rot}$. The drop of the amplitude in complete response is considered to be severe both due to AM and FM as the relevant frequency ranges lie in the same region.

In the second preprint, they have generalised their results for data set of (i) one year observation time and (ii) arbitrary observation time. They have outlined how their results can be applied to investigate the pulsar spin down and N-component signal source. It is found that the AM and FM result into a large number of side bands about the signal frequency f_o. Consequently, the maximum power lies in the frequency $f + 2f_{rot}$ with amplitude reduction by 74% to what one would have expected due to increased data interval [f_{rot} represents Earth's rotational frequency].

In the third preprint, they have applied their results to study the problem of all sky search for CWG sources. They have made an analysis of the number of templates required for matched filter analysis as applicable to these sources. They have investigated the matching of two signals corresponding to different source location (θ, ϕ). It has been found that two different templates values in source location each in θ_T and ϕ_T have same *fittingfactor*(FF). Hence, the computation burden will be reduced by a factor of four. They have also computed the number of templates required assuming the noise power spectral density to be flat. It is observed that higher FF requires exponentially increasing large number of templates. They have noticed marked symmetries in all sky search in both θ and ϕ space for one day observation time. It has been found that any FF corresponds to two values each in θ_T and ϕ_T. This reduces the computation burden by a factor of four. However, it is not clear whether this symmetry property can be established analytically as well. The source location, because of this symmetry is uncertain and some other analysis is to be adopted to remove this uncertainity.

Gravity in Higher Dimensions

Farook Rahaman

Solution of Einstein's field equation in higher dimensional spacetime are believed to be of physical relevance possibly at the extremely early times before the universe underwent the compactification transitions. Farook Rahaman has studied the topological defects, particularly monopole and domain wall in higher dimensional spacetime. He has obtained a class of non-static solutions around global monopole in higher dimensional spacetime. We have also considered spherical domain wall in higher dimension and have examined its gravitational field by the motion of a test particle. He has also investigated the behaviour of the test particles around changed Ads blackhole and charged Duonic blackholes.

S.K. Srivastava

S. K. Srivastava has proposed that, at high energy level, the Ricci scalar behaves in dual manner (i) like a geometrical field as well as (ii) like a matter field. Particles, representing matter aspect of the Ricci scalar are called riccions. Recently, he has obtained riccions from higher-dimensional higher-derivative gravity. The higher - dimensional spacetime contains D-dimensional sphere as a compact manifold. It is found that, after compactification, the resulting theory, is one-loop multiplicatively renormalizable. It is interesting to note that results indicate fractal spacetime above 3.05×10^{16} GeV. Phase transition also takes place at this energy scale, showing de-coupling of gravity from other interactions. Using the dual role of the Ricci scalar, he had derived inhomogeneous cosmological models of the early universe in true and false vacuum states. The essential feature of these models is capability of these to exhibit gravitational effect of compact objects also in an expanding universe. In another work, he has demonstrated production of spinless and spin - particles in these models. It is suggested that the latter universe emerged as a back - reaction of these produced particles. According to the emerging cosmological scenario, it is interesting to note that the universe started from a big-bang like scenario with the initial temperature 2×10^{18} GeV and attained steady state spontaneously around the age of the universe 6.48×10^9 years.

M. Sami

Theories with extra dimensions have interesting cosmological consequences. In particular, the prospects of inflation in these scenarios improve due to the presence of an additional quadratic density term in the Einstein equations. It is remarkable that extra dimensional effects allow a scalar field with steep potentials to play the dual role of the inflaton as well as the dark energy (quintessence). However, the models of 'quintessential inflation' also generate a relic gravity background, which can be several orders of magnitudes larger than in conventional models. In the case of inflationary models with steep potentials, the relic gravity background is an extremely potent probe which can be used both to rule out the models as well as to (indirectly) confirm the reality of extra dimensions.

One of the important questions is whether the large extra dimensions in the early universe leads to directly observable consequences today? Forthcoming observations of microwave background anisotropies may be used to test the brane world ideology. The situation in brane world cosmology with regard to the perturbations is very different from the traditional Kaluza-Klein theories in which, the internal and external fluctuations decouple due to the factorizable nature of the underlying geometry. The matter fields confined to the brane are expected to get exited in the early universe and as a result the cosmological background is highly inhomogeneous in the bulk. Hence the perturbations of the brane are effected by the nonlinear distortions of the cosmological background in the extra dimensions.

In this context, M. Sami is addressing the following problems : (1). The study of the behaviour of cosmological perturbations in brane world cosmology, in general, and in unified models of inflation and quintessence (in collaboration with V. Sahni) in particular. (2). The issues of cosmological perturbations in the bouncing universe with and without brane worlds. (3). The study of perturbations in view of the closed system of equations on the brane (studied by Y. Shtanov). (4) Perturbations of the brane cosmological models, and study the stability of inflationary stage, and more generally of FRW model as well.

Alternative Theories of Gravity

Farook Rahaman

In last few decades, there has been considerable interest in alternative theory of gravitation. The most important among them being scalar tensor theories by Lyra (Math,Z 54,52 (1951)) and Brans-Dicke (Phys.Rev. 124,925 (1961)). Farook Rahaman has studied domain wall and cosmic string based on Lyra geometry . He has also studied a higher dimensional cosmological model in Lyra geometry, and the gravitational field of a higher dimensional global monopole and cosmic strings in Brans-Dicke theory.

Quantum Cosmology

Subenoy Chakraborty

In quantum cosmology, which is still a challenging issue, the primary object is to evaluate the wave function of the universe. S. Chakraborty has evaluated the wave function of the universe by metric formulation and by using Ashtekar's new variables. He has formulated canonical quantization (Wheeler-DeWitt equation) and path integral approach with non-minimally coupling scalar tensor theory. Also, he has calculated quantum Bohmian trajectories, and has found some solutions which are not possible classically.

He has also investigated cosmic no-hair conjecture for homogeneous anisotropic Bianchi models, with B.C. Paul. He has taken a scalar field with arbitrary potential and has obtained both exponential and power-law inflation. The late time behaviour depends largely on the constant additive term in the potential and the universe becomes isotropic and matter free.

B.C. Paul

B.C. Paul has found gravitational instantons in higher derivative theories which are useful for describing two physical situations : (i) creation of a universe with a pair of primordial blackholes (PBH) and (ii) creation of an open universe. Considering a gravitational action polynomial in Ricci scalar (R) (upto cubic terms), the above scenario are studied. In the first case, he makes use of standard non-singular instanton, while the second process has been described by a singular Hawking Turok (HT) instanton. For the open universe, creation problem in the framework of the higher derivative theories, the parameters needed for the occurrence of the HT instanton are found to be highly constrained. This work was done in collaboration with S. Mukherjee and R. Tavakol. The probability for quantum creation of an inflationary universe with a pair of PBH was evaluated in the higher derivative theories up to cubic terms in R. It was found that it was suppressed when the coefficient of the cubic term has a lower bound determined by the coefficient of square term in the action. This work was done with A. Saha.

P.K. Suresh

One could believe that quantum effects of matter fields played a significant role in the dynamics of the early universe. But, to study the quantum effects in a particular cosmological model, both metric and matter fields are to be treated quantum mechanically. At present, no consistent quantum theory of gravity is available. Therefore, quantum effects, in a specific cosmological model , can be studied in terms semiclassical theory of gravity, in which the background metric can be considered as classical and matter field as quantum mechanical. P.K. Suresh has considered a homogeneous massive scalar field (inflaton) minimally coupled to the spatially flat Friedmann-Robertson-Walkar metric, in semiclassical theory of gravity. The oscillatory phase of the inflaton after inflation is studied, in terms of coherent and squeezed state formalisms of quantum optics. The approximate leading solution of the semiclassical Einstein equation is obtained for coherent and squeezed vacuum states and are found to obey the same power-law expansion as that of the classical Einstein equation. The energy density of the scalar field is computed in thermal squeezed and thermal coherent state formalisms and the validity of the semiclassical theory examined, by using a dimensional quantity. The density fluctuations in thermal squeezed state are found very large and, therefore, the theory may not be valid in this formalism, but it is consistent in thermal coherent state formalism.

Cosmology and Early Universe

A. Banerjee

The massless scalar dilaton field appears in the low energy limit of the string theory. The deformation of the topological blackhole in the presence of a dilaton field with Liouville type dilaton potential was previously discussed by others. A. Banerjee has extended his study to a subclass of locally rotationally symmetric Bianchi I universe in the presence of a Liouville type dilatonic potential, where this field interacts with the electromagnetic field coupled with gravity. In the models constructed point like singularities appear at the beginning and have in course of time big crunch at finite epoch unlike the corresponding case of vacuum Kasner universe, where the proper volume increases indefinitely with time.

A few spherically symmetric bounded fluid models with radial heat flow are constructed. They match with Vaidya's radiating metric at their boundaries and are either expanding or collapsing in course of time. The fluid in each case has regular density and pressure both being positive and falling in the radially outward direction upto the boundary, but contains singularity. These models may be of relevance to compact astrophysical objects. The causal heat flow equation is discussed in the context of a special case of Maiti's metric, which of course, reduces to the FRW model of non-zero spatial curvature when the heat flow vanishes. The truncated causal heat flow equation admits inflationary solution, which may be of some relevance to the realistic cosmological evolution subject to certain limitations.

B.C. Paul

A class of new cosmological solutions of the gravitational field equation in the Randall-Sundrum model for an anisotropic brane with Bianchi type I geometry and with perfect fluid have been obtained by B.C. Paul. The matter is described by a scalar field. The solutions admit an inflationary era and at a later stage anisotropy washes out. Two cosmological models in the brane scenario are found : (i) begins with singularity and (ii) without singularity. In the first case, the approach of singularity is faster than that in GTR.

Cosmic no-hair theorem for anisotropic Bianchi models which admit an inflationary solution with a scalar field have been studied by B.C. Paul in collaboration with S. Chakraborty . It is found that the form of the potential does not affect the evolution in the inflationary era while the late time behaviour is controlled by a constant additive factor in the potential for the inflation field.

Moncy John

Observations of the apparent magnitude-redshift relation for Type IA supernovae and the angular size-redshift relation for ultracompact radio sources are two important datasets used to discriminate between cosmological models. While the standard practice in model comparison problems is to use the long run relative frequency approach to statistics, Moncy V. John and J.V. Narlikar used Bayesian probability to compare two different cosmological models. When compared to the frequentist goodness of fittest of models, which judges the relative merits of the models using the lowest value of χ^2 (even when it is obtained by some fine tuning or by having more parameters), the present approach has the advantage that it evaluates the overall performance of the models under consideration.

The models they analyzed were the standard model with matter and a non-zero cosmological constant and a new coasting model with matter and a time-varying cosmological constant and having vanishing gravitational charge. The Bayesian model comparison helps them to conclude that the existing apparent magnitude or angular size-redshift data alone are not very discriminating about these cosmological models.

V.C. Kuriakose

The formation of structures in the universe is still an unsolved problem. Minu Joy and V.C. Kuriakose have explored the role of scalar field in cosmological evolution. They have considered a massive scalar field coupled arbitrarily to gravitational background. The stress energy tensor is evaluated and using this, the energy density and pressure associated with the density perturbation in a Robertson-Walker universe are determined. From these results expressions for Jeans mass and Jeans length are calculated.

D. Lohiya

Daksh Lohiya has demonstrated that a Freidman-Robertson-Walker cosmology with a linear evolving scale factor can be dynamically realized, not only in a large class of scalar tensor theories that dynamically sort out the cosmological constant problem, but also in standard general relativity with proper initial conditions. If one interprets Einstein's theory as a microscopic theory of gravity, a proper averaging procedure must be specified for any application to a large system - in particular to the whole universe. A linear evolution of the scale factor results from natural averaging procedures. Such an evolution has also been demonstrated by

Lohiya and Mittal, for a fractal universe. The concordance of linear scaling with the Hubble diagram, the age of the universe, nucleosynthesis and lensing statistics have been established by Lohiya.

Ashok Kumar Mittal

During the last decade some investigators, led by Pietronero have gathered impressive evidence to argue that the universe does not become homogeneous up to the largest scales observed. Although, this claim is not undisputed, it is now generally accepted that at least up to scales of order 100 Mpc the distribution of galaxies is indeed a fractal. There is no generally acceptable structure formation scenario to explain this distribution within the framework of the standard big bang cosmologies. Mandelbrot had proposed replacing the Cosmological Principle by the Conditional Cosmological Principle. According to this principle, a fractal universe is not homogeneous in the conventional sense of uniform number density; it is homogeneous in the sense that the same fractal scaling behavior is observed from any galaxy. Mittal has proposed a model fractal universe that assumes a fractal distribution on a space-like surface as given a priori, and examines the consequences that follow from the General Theory of Relativity and the Copernican Principle. Although the Conditional Cosmological Principle was proposed about two decades ago, this model probably presents the first ansatz that provides a concrete application of the Conditional Cosmological Principle. Peebles has observed that the geometrical picture of a fractal universe is elegant, but since it has not been translated into a physical model we cannot discuss some of the precision cosmological tests. The model proposed here may be regarded as an idealized fractal model, around which more realistic physical models may be built, that can provide observational tests to settle the fractal vs homogeneous debate.

Gamma Ray Bursts

K. Shanthi

Gamma Ray Bursts (GRB) continue to confound astrophysicists even today. While the nature of the Burst (GRB) progenitors is still to be completely settled, it now appears that at least some bursts originate in explosions of very massive stars, or at least occur in or near the regions of massive star formations. K. Shanthi and C. L. Bhat have studied the GRB bulk properties, like time duration, photon spectra, fluence and peak flux and have reaffirmed their dicotomic nature in the duration-hardness plane. They found that while one group of events (Population I) displayed shorter duration and harder spectra, the larger group of events displayed longer duration and softer spectra (Population II). Then they examined the two populations for signatures of anisotropy and inhomogeneity. It was found that while both the populations displayed isotropy, a subclass of events in Population II showed a pronounced departure from a Euclidian distribution and deviated strongly from the -3/2 slope (homogeneous distribution). The rest of the events on the other hand were found to show very little deviation from a Euclidian distribution and fit a simple cosmological model implying a fairly homogeneous source distribution for this majority class of GRB. The subclass, which deviates strongly, could possibly be a different class of objects experiencing strong evolutionary effects.

Quasar Absorption Lines

Pushpa Khare

Pushpa Khare has proposed a three component model consisting of minihalos and galactic halos with embedded thin discs for absorbers producing all the observed classes of intervening quasar absorption line systems. It was shown that this model, based on CDM cosmology, can explain most of the observed statistical distributions of various types of absorption systems. Use of the Schechter luminosity function for absorbers, on the other hand, was found to be consistent with the observations only if the number of galaxies was larger in the past and reduced with time due to mergers. A strong chemical evolution in the halos of galaxies seems to be indicated by the observed properties of CIV lines.

Galactic Dynamics

C.J. Jog

C.J. Jog with C.A. Narayan from IISc has studied the galactic disk as a gravitationally coupled, three-component system consisting of stars, interstellar atomic gas and molecular gas, and the self-consistent vertical distribution of these have been obtained. It is shown that the self-gravity of the gas is crucially important in deciding the scale-heights of all the three components. This approach physically explains the long-standing puzzle (Oort 1962) of the nearly-constant scale-height of atomic hydrogen gas as observed in the inner galaxy.

C. J. Jog, with A. Chitre from IISc has considered an optically selected sample of 27 disturbed galaxies. For these, the K_s - band images from the

2MASS archival public-domain database are analyzed to obtain their radial luminosity profiles. Half the sample studied shows an elliptical-like profile, this is expected theoretically from mergers of equal-mass galaxies. Surprisingly, the other half of the sample shows an exponential disk behaviour which we propose arises due to a minor merger of unequal-mass galaxies, and suggest that the dynamics of this new parameter range should be checked by future N-body simulations.

Bikram Phookun

Bikram Phookun has been looking at the way that deviations from axisymmetry in the gravitational potentials of spiral galaxies are manifested in their velocity fields and their gas distributions. In particular, he has examined the morphological and kinematic asymmetries in the 21-cm radio data on a sample of spiral galaxies, and attempted to estimate the lopsidedness in their gravitational potentials. He finds some evidence for lopsidedness of the order of less than 10 per cent in the gravitational potentials of these galaxies.

Elliptical Galaxies

D.K. Chakraborty

D.K. Chakraborty and his students Parijat Thakur and Mousumi Das have studied the projected properties of triaxial versions of modified Hubble, and γ-models of Dehnen (1993). Apparent ellipticities at small and at large radii are found to be correlated and the correlation patterns are seem to carry the signature of the intrinsic axial ratios. Intrinsic shapes of test galaxies, using these correlations and the techniques of Bayesian statistics were found to be satisfactory. Further, refinements in these mass models have also been made by adding 4^{th} order spherical harmonics terms, to the existing models. Numerical distribution function for a specific case of γ-model was also studied.

Interstellar Matter

A.C. Kumbharkhane

The space between stars in the galaxy is filled with gas containing hydrogen, helium, oxygen, carbon, calcium, and many other elements and dust grains. Hydrogen is the most abundant species in the galaxy-both in the ISM and in stars. In a thermal plasma when the electrons and ions interact, they may pass close enough to each other that the electron gets bound to the ion in excited state, losing some of its energy. The recombination electron cascades down towards the ground state giving rise to narrow-band line radiation. The lines which are radiated as the electrons cascade down the energy levels are known as Recombination Lines. The lines emitted at Radio wavelenght are called Radio Recombination line (RRLs). These lines are emitted from ionized material, so they offer a way to study the physical properties of thermal gas in H II region, planetary nebulae and ionised low density interstellar matter. A.C. Kumbharkhane is engaged in a programme to observe the recombination line emission from H II regions and the associated photo-dissociated region using the Giant Meter Radio Telescope (GMRT) in the L band, in collaboration with Nimisha Kantharia, NCRA, Pune.

Absorption against the CMB

Suresh Chandra

Observation of an interstellar line in absorption against the Cosmic Microwave Background is an unusual phenomenon. For positive optical depth (which is an usual situation for most of the lines), observation of an interstellar line in absorption against the cosmic background, obviously, implies the excitation temperature of the line to be less than 2.7 K, which is the CMB temperature. Up to now, only two lines have been found in absorption against the CMB. The first one is the 1_{10} - 1_{11} transition of formaldehyde (H_2CO) at 4.831 GHz, which was found in absorption in several directions. However, in some cases, it has been seen in emission, and even as a maser line. The second line found in absorption against the CMB, in a large number of cosmic objects, is the 2_{20} - 2_{11} transition of cyclopropenylidene (C_3H_2) at 21.587 Ghz. However, in the planetary nebula NGC 7027, it is found in emission.

Chandra along with W.H. Kegel (Germany) is working on the absorption against the CMB. Their proposal is that in asymmetric top molecules, when the levels with $J = 3$ are above the levels with $J = 2$, and the collisional deexcitations are negligible in comparison to the radiative ones, the two transitions $2_{20} - 2_{21}$ and $2_{20} - 2_{11}$ show the anomalous absorption. Chandra and his collaborators have done calculations for C_3H_2, C_2H_4O and C_3H_4 molecules and have predicted that the molecule C_3H_4 may be identified through its transition $2_{20} - 2_{21}$ at 3.67218 GHz in cosmic objects having low density and low kinetic temperature.

Dusty Plasma

Manoranjan Khan

Manoranjan Khan worked in the area of dusty plasma with charge fluctuation, wave induced magnetized plasma and dope plasma. Khan studied in collaboration with M.R. Gupta, S. Sarkar and S. Ghosh the characteristics of small amplitude dust acoustic wave propagation and solved K-dV equation in a dusty plasma, having grain charge fluctuation with application in Saturn's F, G and E rings. They studied nonlinear characteristics of dust acoustic waves in magnetized dusty plasma having dust charge variation. An interesting phenomena of shock wave generation in dusty plasma having charge variation have been exhaustively studied in both non-adiabatic and adiabatic dust charge variation by K-dV Burger equation. They in collaboration with M. Debnath, studied the effect of non-adiabaticity of dust charge variation on dust acoustic waves and shock wave generation. In collaboration with Sarkar, P. Mukhopadhyay, J. Ortner, M. Steinberg, W. Ebeling (Humbolt University, Germany), he studied the evolution of induced axial magnetization in a two component magnetized plasma. In collaboration with B. Chakraborty, Sarkar, R. Bhattacharyya, S. Mondal, A.M. Basu, he studied the Landau damping of ion acoustic waves in a dope plasma.

Magnetohydrodynamics

Nagendra Kumar

In astrophysical plasmas, there are several physical situations where the plasma medium can be appropriately described by the model consisting of two components; a cosmic ray fluid and a magnetospheric plasma. N. Kumar in collaboration with H. Sikka has studied the propagation of surface waves at the interface. The medium on one side of the interface is field free and the other side is a two component thermal and suprathermal (cosmic) plasma. Unlike the single component plasma, a new mode called suprathermal mode is obtained, besides the usual magnetosonic modes. Observations lead to the conclusion that the suprathermal mode travels with the greater pace than that of fast and slow magnetosonic modes.

Kumar and Meenakshi Yadav have studied the stability of molecular cloud using local linear instability analysis of self gravitating partially ionized, warm magnetized plasma in the presence of turbulence. The study is done taking generalized equation of state when the frictional force caused due to the ion-neutral collisions is ignorable. The magnetosonic waves obtained here propagate with faster speed than the waves propagating in the absence of turbulence.

Star Formation

K. Indulekha

K. Indulekha has been studying some of the energy loss mechanisms for protostars and cores in a star forming cloud. The aim is to determine some of the characteristics of stellar clusters that would form from such clouds. The analytical results indicate that two main processes act in tandem, towards producing clusters with some of the key characteristics observed. A numerical investigation, has been undertaken.

Negative refractive index materials have been fabricated recently. Indulekha has studied theoretically the reflection statistics of light passing through such media with random scatterers and absorbers/amplifiers.

Sandeep Sahijpal

There is a general consensus that the solar system was formed around 4.6 billion years ago as a result of gravitational collapse of the proto-solar molecular cloud. Nonetheless, the physico-chemical processes involved in the formation of the solar system still remain debatable. In particular, the hypothesis (based on some experiments on radio nuclides) that a nearby supernova explosion triggered the formation has to be verified as it defines the initial conditions for the system. S. Sahijpal has been involved in carrying out a comprehensive diagnostic study on the contributions of stable as well as radio nuclides from a core collapse supernova to the proto-solar molecular cloud in order to quantitatively understand the hypothesis.

Pulsating Stars

G. Ambika

It has been established in the case of a few irregular and semi-irregular variables that the irregularities in the light intensities are chaotic in origin due to the inherent non-linearities in the underlying dynamics. G Ambika in collaboration with A K Kembhavi and Janet A Mattei of AAVSO, Massachusetts, analysed one such typical star viz. SXHer using time series analysis that emphasize aspects of non-linear dynamics. SXHer is an SRd type super giant with an average period of 102 days. The data covers the period from JD 2437596-2450777 and the preliminary analysis is done using TS program developed by AAVSO. The first 20 most prominent peaks are identified and used to compute a multiperiodic fit to the data. The difference of the fit with the data is obtained as the residual which is subjected to the same analysis again. Every time new peak structures are seen, indicating more complex behaviour than multiperiodicity. However, there is considerable power in the fundamental period of 102 days and its first overtone at 51 days. The multi-periodic fit is used to generate the missing data and the data thus obtained with 5000 values at equal intervals of 1 day is used for calculating the correlation and the corresponding dimension value D2 as 3.1- 3.5 for an embedding dimension 6. The data obtained after one whitening is used to make a 5000 point data set with ar-modelling with a polynomial of degree 10. The correlation function of this data is seen to drop to zero at a delay time of 7. So also the mutual information has its first minimum at 7. With this delay, the method of false nearest neighbours gives the minimum embedding dimension as 6. For this delay and dimension, using singular value decomposition (svd) technique, filtering is done and the phase space is reconstructed. The results are clearly indicative of deterministic and low dimensional chaos in the system. The latter part of the analysis is done using the TISEAN algorithm.

In collaboration with M Takeuti of Tohoku University, Sendai, Japan, G. Ambika has continued the analysis in an entirely different type of variable viz. CYAquaris. This is a short period white dwarf with radial and non-radial modes. With a wide range of amplitudes, it is doubly periodic with ratio = 0.667. The data taken from the IAU archives of unpublished variable star photometry, 3503 entries covering JD 2447392.75 - 397.96. An attempt has been made to reconstruct its phase space using delay -embeddding techniques. The svd filtering is done, followed by the method of false nearest neighbours for differing delay times. It is found that for a delay of 11, the fraction of nearest neighbours drops to zero at embedding dimension of 17. Using this, the svd is repeated to get the filtered time series and the phase is reconstructed. The dimension calculations in this case gives the value of D2 as 2.26-2.32 with an embedding dimension of 17. Using Takens theorem, this would mean, the phase space dimension for the underlying system is 8. The fact that the attractor dimension is much smaller and this indicates that the other modes are highly dissipative in nature.

Neutron Stars and Quark Matter

Somenath Chakrabarty

To conclude strongly that the quark matter core is absolutely forbidden in a magnetized neutron star, Somenath Chakrabarty along with his Ph.D. student, Sutapa Ghosh has studied the chemical evolution of nascent quark matter in presence of moderately strong magnetic field. The assumed field strength at the core region is slightly greater than 4.4×10^{13}Gauss, which is the quantum mechanical limit to populated the Landau levels for electrons only. This is also not too high to achieve at the core region. In this physical scenarion, a first order phase transition to quark matter is also allowed. They have noticed from the chemical evolution study of nascent quark matter that a β-equilibrium scenarion is impossible in presence of moderately strong magnetic field at the core, the electron density becomes negative at some stage of evolution. Since, a non-equilibrium static system is physically impossible, They have concluded from this and earlier work that quark matter is absolutely impossible at the core of a neutron star, if the magnetic field exceeds the quantum limit for electrons, as mentioned above.

Chakrabarty along with his two Ph.D. students Sutapa Ghosh and Sanchayita Ghosh and Asoke Goyal from Delhi University and his student Kanupriya Goswami have completed some work on the evaluation of electrical conductivity of dense charged stellar matter at the core of a magnetar. They have used relativistic version of Boltzman equation and made relaxation time approximation. They have calculated the relaxation time from the scattering of charged particles at the core region (electrons and protons) and also by neutrons by field theoretic method. In their calculations, they have used the modified form of Diarc spinors for the charged particles in the presence of quantizing strong magnetic field and used S-matrix method and evaluated traces of the products of γ-matrices to obtain the rates of the processes. Then using the formula $1/\tau_{eff} = um_i 1/\tau_i$, to obtain the effective rate of the scattering processes. The inverse of which is the relaxation time. They have studied the variation of electrical conductivity with magnetic field strength relevant for the core of magnetars.

It was shown by Chakrabarty and Ghosh that in the presence of strong quantizing magnetic field, the shear viscosity coefficient of electron gas at the core of a neutron star vanishes identically if only the zeroth Landau levels are occupied. In this calculation also they have followed the same technique as mention in the evaluation of electrical conductivity. They have also noticed that the electrical conductivity of electron gas under such physical condition remains finite (finite resistivity). Therefore, the bahaviour of electron gas under such extreme condition is to some extent exotic- super fluid but not super-conductor, which is really surprising.

Chakrabarty and his Ph.D. student Nandini Nag have completed some work related to the equation of state of neutron star crustal matter in the presence of strong quantizing magnetic field. They have solved Thomas-Fermi-Dirac equation in the presence of strong quantizing magnetic field. Such equation was solved for the first time in the presence of strong quantizing magnetic field. They have noticed that the singularity in the solution of Thomas-Fermi-Dirac equation is completely removed in the presence of strong magnetic field. They are now extending this work for the relativistic case.

Deepak Chandra

Knowledge of neutrino transport in supernovae cores, in neutron stars and in collapsing stars is an essential prerequisite for an understanding of a host of phenomenon like pulsar kicks etc. Deepak Chandra along with Ashok Goyal and Kanupriya Goswami have studied the neutrino interaction rates in hot matter at high densities in the presence of uniform magnetic field. Neutrino cross-section involving both the charged current absorption and neutral current scattering reactions on baryons and leptons have been studied. They have in particular considered the interesting case when the magnetic field is strong enough to completely polarise the protons and electrons in supernovae and neutron stars. They found that the opacity in such a situation is considerably modified and the cross-section develops anisotropy. This has implications for explaining observed pulsar kicks.

Deepak Chandra along with Meenu Dahiya and Ashok Goyal has also studied the properties of strange quark matter (SQM) in the context of Nambu-Jona-Lasinio model by introducing additional interaction terms in the Lagrangian, in particular, vector interactions, which are known to be important in dense matter. They have studied the phase transition at large densities and temperatures and investigated the properties of the mixed phase. This mixed phase may exist in the core of neutron stars. This has consequences for the neutron star structure.

Chandra and Goyal have been studying the effects of QCD and hadronic interactions on the dynamics of the deconfinement phase transition for QGP and Hadron Resonance Gas. It turns out that the exponential factor in the nucleation rate equation is of less relevance than the prefactor, unlike the case in the early universe, where it is the exponent that dominates the nucleation rate.

Arnab Rai Choudhuri

The evolution of magnetic fields of neutron stars - There is observational evidence that the magnetic field of a neutron star decreases substantially if the neutron star spends time in a binary system and accretes matter from its binary companion. The details of how this happens are not understood. One possibility is that the accreting matter buries the magnetic field of the neutron star under it. Arnab Rai Choudhuri, in collaboration with Sushan Konar, has used a code developed for the Solar dynamo problem to address the issue. They were able to show through a 2D simulation that accreting matter can indeed screen a magnetic field underneath it. They also found that this was an inherently 2D problem and arguments based on crude 1D models (which was all that existed before the present work) could be quite misleading.

Mira Dey

Mira Dey is continuing to investigate the astrophysical observations in the context of strange quark star which could be denser than 15 times the normal nuclear matter at the centre. At low enough density, however, matter can be treated as point baryons. Such matter consisting of nucleons and isobars at low temperature and low density has also been studied using path integral technique non-perturbatively.

Ashok Goyal

Ashok Goyal with his collaborators Deepak Chandra and Meenu Dahiya continues his studies of symmetry structure and phase transitions in the external enviorenment of high temperature, density, magnetic field, external gravity, etc. in the context of early Universe and compact star cores. Possibility of formation of quark nuggets in the early Universe and their survival till the present epoch and identification with recently observed dark objects (MACHOS) in our galactic halo to account for dark matter component in the universe is investigated.

In the context of neutron stars, the effect of strong magnetic field on neutrino emissivity, equation of state, neutrino transport, bulk viscosity, radial oscillations, etc. have been studied in collaboration with V.K. Gupta, J.D. Anand, S. Singh. D. Chandra, V. Tuli and K. Goswami.

In the light of recent estimates of the mass and radius of newly observed compact objects exhibiting quasi periodic oscillations (QPO) in low mass X-ray binaries hinting at the exciting possibility of their being identified with strange stars, Goyal, Chandra and Dahiya are looking at the possibility of forming stable strange stars in the frame work of quark dynamics modeled by Nambu-Jona-Lasinio. The NJL model with the presently agreed values of parameters to fit low energy hadron phenomenology precludes the existence of strange matter being the true ground state of matter.

With Sukanta Dutta and Poonam Mehta, Goyal is investigating the possibility offered by the muon storage ring in the proposed neutrino factory to provide intense neutrino beam to explore the physics beyond the standard model, in particular to test theories with lepto-quarks and theories with large extra dimensions.

Sun and the Solar system

B.N. Dwivedi

Physics and diagnostics of the solar X-rays and ultraviolet emission processes, and coronal heating mechanisms were investigated by B.N. Dwivedi.

Udit Narain

U. Narain and his co-workers have been working on mechanisms responsible for maintaining the million degree temperature of the outer atmosphere, namely corona. Various mechanisms, e.g., heating by acoustic, magnetoacoustic and Alfven waves and by magnetic fields and currents via magnetic re- connection and transients such as nano-, micro- and flares have been proposed which are quite important. They have studied the dissipation of shear Alfven waves in closed (loop-like) magnetic fields by considering heating in several layers around the axis of the cylindrical magnetic flux-tube and have obtained encouraging results. At present they are investigating the heating of solar corona by nano/micro-flares, which is one of the important mechanisms proposed so far. Here, the corona contains a large number of regions called current sheets in which the electric current is very high, consequently a small resistivity produces large heating, which is proportional to the square of the current.

Lalan Prasad

Lalan Prasad has studied the heating of coronal loops by linear resonant Alfven waves excited by the footpoints motions in the photosphere. The analysis of single layer heating is extended to multilayer heating in semiempirical treatment.

P.P. Hallan

The location and stability of equilibrium points in Robe*s* circular restricted three body problem have been studied by P.P. Hallan when (i) there are perturbations in the coriolis and centrifugal forces and the density parameter has arbitrary value and (ii) one of the primaries is an oblate spheroid . For certain values of the parameters, there are (a) two equilibrium points on the line joining the centre of the first primary and the second primary (b) two triangular equilibrium points and (c) infinite number of circular equilibrium points. It is proved that circular and triangular equilibrium points are unstable and when the parameters occurring in the problem satisfy certain inequalities, the equilibrium points of the type (a) are stable.

N. Hasan

The work done by N. Hasan is as follows :

(a) Various aspects of the photogravitational restricted three body problem have been studied; such as new class of periodic solutions and their stability.

(b) A parabolic encounter of a single mass with a circular binary has been studied in direct and retrograde orbits. Hasan obtained expressions for energy, angular momentum and eccentricity from pertubation theory. The results have been compared with Spitzer's impulsive approximation and solutions of Huang and Valtonen (1987, MNRAS 229, 383).

(c) The study of the three body scattering problem has been extended to study the induced merger in a binary galaxy by a single perturbing galaxy in a parabolic orbit. The analytic work was completed with n-body simulations to investigate the implications of such encounters for inducing rapid mergers of the binary and for formation of close triple systems. The numerical integration was performed by adopting the tree code of Joshua Barnes and Piet Hut.

Atmospheric and Ionospheric Physics

K.N. Iyer

During the year, K.N. Iyer has continued his study of ionospheric plasma irregularities causing the phenomenon of Equatorial Spread F (ESF) that manifests as range spreading of post sunset equatorial ionogram traces, as well as scintillations of trans-ionospheric VHF and GHz signals from satellites. Data of this phenomenon recorded at Trivandrum and Rajkot using VHF transmissions from geostationary satellites, at different locations in Brazil using the L1 band (1.575GHz) GPS signals, and ionosondes from India and Brazil are used in a comprehensive study of the elusive problem of its generation and dynamics. A new VHF radar at magnetic equatorial location, So Luis in Brazil, is also used to map the Range-Time-Intensity distribution of the plasma irregularities. An empirical model, based on cubic splines, of the scintillation occurrence in India is developed.

V.H. Kulkarni

Whistler mode wave instabilities, due to temperature anisotropic or loss cone distribution of electrons are the main source for Very Low Frequency Emission activities in the magnetosphere. The field-aligned currents have been extensively observed and studied. The dominant characteristics are that (a) there are large-scale field aligned currents of dimensions > 50 kms and (b) there are small-scale currents whose dimensions less than 50 kms. The former is carried mainly by warm electrons of energy of 100s ev and latter consist mainly of high energy electrons of few 10s kev. It is seen by V.H. Kulkarni that these field-aligned currents can reduce the strength of VLF activity. Our studies show that the field aligned currents can absorb the VLF waves those are generated by the temperature anisotropy. Thus it can provide a useful source of energy for the high-energy electrons, which carry the type (b) currents. Moreover, the currents (a) can easily assist in converting energy in the temperature anisotropy to field aligned currents by decreasing the resonant velocity.

The ionospheric plasma, supported by magnetic field, has an equilibrium density gradient suitable for growth of wave perturbations by mechanism of Rayleigh-Taylor instability [RT]. This instability is responsible for formation of equatorial bubbles, which are being studied extensively by incoherent backscatter radars, rockets, satellites and ground based CCD all sky imaging cameras. The presence of charged dust grains do change the RT, and reduce the range of unstable wave numbers. This is very useful when analyzing the effect of dust grains introduced by meteors on the RT. Another important factor that could affect the formation of irregularities is the loss of electrons and ions either due to recombination or due to attachment. In a recent work, it has been reported that the recombination losses has no effect on the RT. Kulkarni reanalyzed this aspect and shown that the attachment has a significant effect on the RT, which supports previous conjectures. We see that loss of electrons due to attachment leads to damping unstable perturbations. The wave activity seems to be reduced. It is the density gradient to decide the unstable wavelengths.

S.K. Pathak

S.K. Pathak has worked on atmospheric particulates and their role in the tropospheric aerosol formation. This involves the study of atmospheric aerosols and particulate matter, microphysics of clouds, cloud condensation, homogeneous and heterogeneous nucleation, kinetics of soot oxidation, preparation of laboratory soot samples for chemical characterization, etc. The aerosols are important not only in air chemistry but in determining visibility, atmospheric radiation and the formation of cloud particles and so the climate change. Early studies of atmospheric chemistry emphasize trace gases and homogeneous gas-phase reactions. However, in the latter part of the twentieth century, increasing attention has been given to atmospheric aerosols, chemical reactions on aerosol surfaces and role of clouds. Aerosols play an important role in atmospheric electricity, air chemistry, radiative transfer and clouds and precipitation processes, thereby, affecting the chemistry of natural atmosphere and the phenomenon of global climate change. The specific work is on cloud condensation, investigating nucleation probabilities to elucidate the mechanism of formation of cloud particles. These studies play a very important role in understanding the atmospheric chemistry dynamics and thereby related to the phenomenon of global climate and climate change.

Pathak has also been involved developing modules on the problem of ozone depletion in the stratosphere during his visit to MIT, USA. Two research projects, entitled "Dynamics of trace chemical species associated with ozone involving nitrogen and halogen oxides for understanding the general kinetics of ozone layer depletion mechanisms using synchrotron radiation," and "Experimental Investigations of the chemistry of atmospheric particulates," have been successfully completed in collaboration with the University College London and Daresbury Synchrotron Laboratory, Warrington, UK and Massachusetts Institute of Technology (MIT), USA. These studies on the spectroscopy and collision dynamics of ozone depletion compounds and atmospheric sink compounds have established an important finding that photolysis of ozone depletion compounds in shorter wavelength region also play a dominant role in ozone depletion, which has largely been underestimated, in global models. In particular, the distribution of ozone and other trace gases in the atmosphere is governed by the complex interaction of dynamical, chemical and radiative processes. These processes determine both the absorbed solar flux and radiative transfer. The importance of ozone radiation absorption in the atmosphere and the general kinetics of the stratospheric ozone depletion mechanisms have been studied through extensive laboratory studies and this has been concluded that our knowledge of both the spectroscopy and the photodissociation of trace molecules in the troposphere and in the stratosphere needs to be enhanced. In order to understand the problem of ozone destruction by ClOx and NOx compounds, and especially the role of ice surfaces, the photolysis of such species by UV radiation must be understood in detail.

R. Ramakrishna Reddy

R. Ramakrishna Reddy has made surface measurements of trace gases like CO and NOx at Anantapur, which is a drought prone area situated in the semi-arid zone. Measurements of CO and NOx are made for the period July 2000 to August 2001. NOx and CO show diurnal variations opposite to that of urban site. During the course of their observations for this period the daytime concentration of CO varies between 200 and 1200 ppbv and that of NOx varies between 3 and 20 ppbv. Diurnal variations in CO and NOx are mainly due to local emissions, boundary layer processes and local wind pattern. It is observed that NOx concentration is maximum during the seasons autumn and winter, where as it is minimum in summer. Similarly, CO concentration levels are high during the seasons autumn and summer and low in winter season. The variations of NOx and CO are correlated with the atmospheric and wind parameters. The atmospheric gases at the rural site like Anantapur (14.62N, 77.65E) which is situated in drought prone area, are dominated by the wind patterns. The total surface reaching solar radiation at Anantapur is found to be maximum (20,000 KW/m2) during the month of April of every calendar year.

Observational Astronomy

V.C. Kuriakose

In collaboration with A. K. Kembhavi (IUCAA) and C.D. Ravikumar V.C.Kuriakose is studying the formation of bulges and disks in galaxies. A qualitative evaluation of various formation scenarios requires accurate extraction of global parameters that describe the luminosity and density distribution of the bulge and as well as the disk. Correlations among global photometric parameters can be used to differentiate among different scenarios. They have already finished the decomposition of some 36 galaxies in two nearby clusters (A2199 and A2634). They are now trying to get correlations among different global parameters over relatively high redshifts.

S.K. Pandey

S.K. Pandey, in collaboration with A.K. Kembhavi, M.K. Patil and D.K. Sahu has carried out a detailed study of wavelength dependent properties of dust in four early-type galaxies: NGC1172, NGC1439, NGC2672 (all ellipticals of type E1) and NGC3489 (lenticular of type SO) as a part of an on-going programme of studying dust and its physical connection to other forms of interstellar matter in a large sample of early-type galaxies. Color-index maps(e.g.,(B-V)) were generated to examine dust distribution and its morphology as well as to estimate color-excess in dusty regions of the galaxies. For studying wavelength dependence of extinction properties of dust, extinction maps were generated and used to compute the ratio of total extinction at a given wavelength to selective extinction for each galaxy. In general, the extinction curves of sample galaxies are found to run parallel to that of Milky Way in the visible as well as in near-IR regions. This in turn implies that dust extinction properties in these galaxies are quite similar to those of our galaxy, as has been found for other early-type galaxies studied so far. The values of R_v, the ratio of total extinction in visual band to selective extinction, however, are not significantly different from that for Milky Way, except for NGC1439, in which case its value turns out to be lower than the canonical Galactic value of 3.1. The analysis was based on imaging observations of these galaxies in optical broad bands(BVRI) from the State Observatory, Nainital as well as in near-IR bands from the Near-IR Observatory of Physical research Laboratory at Mt. Abu.

S.K. Pandey, in collaboration with Padmakar Parihar and Sudhanshu Barway, has carried out an investigation of the long-term photometric variation for a sample of well observed chromospherically active stars to explore the possibility of detecting activity cycle akin to the sunspot cycle. A traditional starspot model was used to model the observed light curves and spot parameters were extracted. A variety of activity tracers were applied to the data set to search for a periodicity in the stellar activity. The analysis reveals the presence of activity cycles in most of the stars with periods ranging from few years to over few decades. Differential photometric observations of well known as well as suspected Chromospherically Active Stars (CAS) were carried out in BVRI bands using 16" Meade telescope equipped with SSP-3A photometer at IUCAA during Nov. - Dec., 2001. Preliminary analysis of the data on classical RS CVn shows significant changes in the shape of the light curve and amplitude of the light variation in most of these stars when compared with their corresponding data for the past years. Detailed analysis of the data in the frame work of star-spot models to examine short-term variation in their light curves is in progress. For suspected CAS spectroscopic observations are needed to confirm whether they indeed belong to the class of CAS.

Lalan Prasad

Lalan Prasad is engaged in observational work in collaboration with Wahab Uddin, Astronomer, State Observatory, Nainital. They have observed a post-flare loop system in Hydrogen alpha on the west limb on 27 Nov. 1996. The post-flare loops were associated with long duration X-ray flare of importance class - B9. They have studied the evolution of post-flare loop system which display complex fan like structure with multi bright loop tops in H-alpha as well as in X-ray/ Yohkoh and SOHO observations.

P. Vivekananda Rao

All the light curves available in the literature on UV Piscium spread over several years (15 years) were analysed by P. Vivekananda Rao to determine long term behaviour of the spot characteristics on this system. In order to find out whether late type binaries with spots would be useful in solidifying the radiative surface flux and temperature scale, several of these were studied and their fluxes and temperatures were determined from the analysis of their light curves. The results of this work indicate that once the spot effects are removed, the derived fluxes fit the theoretical curves quite well. An online data acquisition software developed by him for recording the photometric data is working satisfactorily.

Results of the analysis done on the eclipsing binary FZ Orionis has been accepted for publication in the Astronomy and Astrophysics Journal.

K.Y. Singh

The nature of the compact object in the X-ray binary system of Cygnus X-3 is not yet clearly understood. There are various arguments in the literature supporting the compact object as a massive blackhole whereas, some authors believe the primary companion as a neutron star. An interesting way to probe the nature of this system is to investigate the arrival time history of the 4.8 hr orbital modulation in the X-ray light curve. K. Y. Singh in collaboration with TIFR, Mumbai has studied the evolution of the orbit of Cygnus X-3 by measurements of the arrival times of the minima of the light curves using the data from the Indian X-ray Astronomy Experiment (IXAE) and the archival data from ROSAT, ASCA, BeppoSAX and RXTE. The study suggests that the orbital decay due to mass loss from the companion star to be most probable mechanism for the non-linear nature of the arrival time of the 4.8 hr binary modulation in the X-ray light curve of Cygnus X-3. Most likely, the compact star in this system has an accretion disk with an extended corona.

Instrumentation

M.N. Anandaram & B.A. Kagali

The APT telescope built at IUCAA has been transported to a roof top observatory of the Department of Physics, Bangalore University. Installation of the telescope is in progress.

S.P. Bhatnagar

S.P. Bhatnagar along with Umesh Dodia is using 14" Automated Photoelectric Telescope (developed at IUCAA) for photometric studies of variables. The control software for APT is being ported to windows environment using Visual C++. The IUCAA photometer being used for the photometry, lacked a previewer flip-mirror system. A flip mirror system is developed which fits between the photometer and the telescope. Thus, the existing beam splitter arrangement of the IUCAA photometer can be used along with CCD guider. The same flip mirror system could also be used with the night sky photometer of IUCAA.

He has taken up a search and study of variables from the list of Hipparcos suspected variables. Two suspected variables namely IN Hya and TV Uma are under observation.

M.L. Kurtadikar

A 12" Meade LX200, obtained with support from the DST, telescope and optec SSP-3A photometer has been installed by M..L. Kurtadikar and his group at J.E.S. College, Jalna. Calibration of the photometer has been in progress at IUCAA and in Jalna. A CCD has been assembled with help from S.K. Popalghat and Vinu P.

Theoretical Physics

L.P. Singh

L.P. Singh, in collaboration with A. Datta and E.A. Paschos, has looked at the possibility of CPT symmetry breakdown through its contribution to the width difference among the Bd and Bs states. The present data are not sufficiently restrictive to simultaneously constrain width difference and CP and CPT violating parameters. Singh in collboration with D. Gangopadhyaya has found that Bariola-Vilenkin type topological monopole solutions can be generated in a spacetime dependent Lagrangian formalism by invoking certain general characteristics of the spacetime dependent function at asymptotic values of the spacetime coordinates.

J. Dey

Application of QCD models to terrestial and stellar observations is an interesting subject. Jishnu Dey has been working on it for a long time.

P.N. Pandita

Supersymmetry is at present the only framework in which the Higgs sector of the Standard Model (SM) is natural. Since in nature there are no supersymmetric particles with the same mass as ordinary particles, supersymmetry must be a broken symmetry at low energies. At present, there are several models of supersymmetry breaking. This includes the gravity-mediated supersymmetry breaking, the gauge mediated suersymemtry breaking, and the anomaly mediated supersymmetry breaking models. The soft supersymmetry breaking terms in the above breaking mechanisms have contributions originating from the super-Weyl anomaly via loop effects. If the gravity and gauge mediation are somehow suppressed, the anomaly mediated contributions can dominate, as may happen, *e.g.,* in brane models. If this happens, then this mechanism of supersymmetry breaking is referred to as anomaly mediated supersymmetry breaking (AMSB).

P. N. Pandita, together with K. Huitu and J. Laamanen has made a detailed analysis of the superparticle spectrum in AMSB models in which supersymmetry breaking terms are induced by super-Weyl anomaly. We have investigated the minimal anomaly mediated supersymmetry breaking models, gaugino assisted supersymmetry breaking models, as well as models with additional residual non-decoupling D-term contributions due to an extra U(1) gauge symmetry at high energy scale. We have derived some rules for the sparticle masses in these models, which can help in differentiating between them. We have also obtained the sparticle spectrum numerically, and compared and contrasted the results so obtained for the different types of AMSB models.

Usha Malik

From a study aimed at re-deriving some of the known results in the field of superconductivity in the temperature-dependent approach to dynamics as espoused by Malik, Pande and Varma, to a study of some theoretical aspects of superconductivity perse has been a natural step for Usha Malik. This is a challenging field since even ninety years after the discovery of the phenomenon - and despite the successes of the BCS theory - no theory is yet available of high-Tc superconductors. Usha Malik's efforts in this direction were concerned with obtaining new exact solutions of a model that was originally given in the context of solitons and showing that these solutions possess features akin to Abrikosov's classic solution of the Ginzburg-Landau equations of superconductivity. More recently, she also obtained new exact solutions of the historic sine-Gordon equation and drawn attention to their possible use in superconductivity, in collaboration with G.P. Malik.

Nonlinear Dynamics

G. Ambika

The chaotic behaviour in a few dynamical systems is analysed from the point of view of dynamical systems theory by G. Ambika together with her students. The case of the Froude pendulum with cubic and linear damping terms is subjected to analytic search procedures for loss of stability and onset of chaos. Approximate solutions are obtained using harmonic balance followed by reduction to Matheu equation for stability analysis.

In the context of unimodal and bimodal nonlinear maps, the critical exponents associated with the scaling of generalized fractal dimensions during the transition from order to chaos are calculated numerically. The behaviour of Lyapunov exponents in the cross over region are also studied for a complete characterization.

An extensive numerical analysis of the phenomenon of stochastic resonance (SR) in bimodal maps with bistability is done in the presence of both noise and chaos. By coupling it with a similar system, it is shown that coupling can enhance SR and result in optimum performance.

In a coupled map lattice (CML) formed with the logistic map and nearest neighbour coupling and periodic boundary condition, we analysed the formation of Cantor set like fractal structures during the onset of coherent collective modes. The dependence of the fractal dimension in the size of the lattice and the coupling coefficient are studied.

V.C. Kuriakose

Electromagnetic wave propagation through optical fibres is a topic of current interest to both theoretical and experimental physicists. Ganapathy and V.C. Kuriakose have studied soliton propagation through birefringent optical fibres wherein wave propagation is described by coupled nonlinear Schrodinger equations. In the present study, they have considered the effects due to fibre loss and chirping of the pulse as it advances through the fibre. They have found that the amplitude of the pulse decreases while the width of the pulse increases in such a way that the pulse area being kept constant. This implies that soliton nature of the pulse is maintained as the pulse advances through the fibre. They have also obtained the conditions for the occurrence of polarisation modulational instability in optical fibres where higher order dispersion is important. Vinoj and Kuriakose have studied the propagation of solitons through nonuniform fibres and obtained the conditions for maintaining the soliton properties. They have also considered a possibility of compression of pulses as the pulses advance through the fibres. Shaju and Kuriakose have studied fluxon dynamics in non-uniform Josephson junctions. Here, they have assumed a non-uniform geometry for the junction and found that these types of junctions can be used as rectifiers.

R.S. Kaushal

In view of the fact that the theoretical understanding of several newly discovered phenomena in physics, biology and engineering now requires a study of momentum- and/or time-dependent as well as complex Hamiltonian systems, the classical and quantum aspects of such systems are investigated by R.S. Kaushal and his coworkers. In the classical domain, while the methods are developed and used to construct the dynamical invariants of a momentum- and/or time-dependent systems in two dimensions, the quantum mechanics of a complex Hamiltonian system in one dimension, H(x,p), is investigated by way of considering an extended complex phase space characterized by $x = x_1 + ip_2, p = p_1 + ix_2$. While the applications of the former class of systems are possible to some electrical circuits and in the experiments pertaining to the testing of Bell's Inequality, the cases of the power, singular and exponential potentials are studied within the frame work of the latter.

Ashok Kumar Mittal

Palmer introduced constant (forcing) terms in the Lorenz equations to put forward a paradigmatic model for discussing long-range monsoon predictability. In this model, the 'forcing' terms correspond to the tropical Pacific sea surface temperature anomaly and the two branches of the Lorenz attractor correspond to the two regimes of active and weak spells of the monsoon. A.K. Mittal explored the bifurcation structure of this forced Lorenz model in special cases that are amenable to simplified mathematical analysis. He has also studied the shift in the probability distribution function between the two branches of the Lorenz attractor when constant forcing terms are introduced. The goal is to quantify this shift in terms of system parameters. It is found that on introduction of forcing, the Lorenz map, which is a cusp in the absence of forcing, splits into a double cusp. This split is explained in terms of invariant manifolds of the dynamical system, obtained in the neighborhood of fixed points. The techniques for obtaining invariant measures for one-dimensional maps are known. It is hoped to extend these techniques to the double-cusp, which is not a single valued map. This work was done in collaboration with Mitaxi Mehta and S. Dwivedi.

Atomic Physics

L.K. Jha

Absolute cross sections for electron impact single and multiple ionization of atoms/ions from the ground and excited states are of considerable importance in many fields of research ranging from controlled nuclear fusion to astrophysics. The theoretical calculations of double ionization cross section are particularly important because contributions from different physical processes can be separately estimated. Due to non-availability of the sophisticated theoretical calculations of double ionization cross sections in the literature, the calculations have been carried out in the double binary encounter model using Hartree-Fock (HF) distributions for the target electrons throughout the calculations. L.K. Jha has been working on electron impact double ionization cross sections for Titanium (plus) ion. The calculations of electron impact single and double ionization cross sections for gallium carried out have been properly interpreted in light of experimental results. In this case interesting facts have emerged and it has been shown that ionization of 3d shell contributions partly to single ionization and partly to double ionization. The calculation of electron impact double ionization cross sections for C+, N+, O+ and Ne+ have been successfully completed by incorporating the focusing action of the target ion on the incident electron. Contributions of ionization-autoionization have also been included in the calculations. The results so obtained show satisfactory agreement with experimental data except at low incident energies.

M.L. Kurtadikar

Collision-induced rates for Interstellar Cyanopolyynes colliding with molecular Hyerogen were theoretically calculated by M.L. Kurtadikar using the Effective Straight-line Trajectory (EST) approach developed by Kurtadikar and Mehrotra. Calculation for the collision induced rotational excitation cross-sections for these systems with atomic hydrogen were also done.

S.N. Paul

The dust grains immersed in ambient plasma get charged due to collision with various charged particles such as electrons. The presence of charged dust grains give rise to new kind of modes called dust modes . Dusty plasma is important for the study of the structure of planetary rings, star formation, environmental problems. S.N. Paul has theoretically studied the propagation of both low and high frequency waves in dusty plasma to find the characteristics of dust acoustic wave propagating through the plasma. Dispersion relation of the wave deduced is a generalization of that obtained by found that nonlinear localization of high frequency electromagnetic field in such plasma generates magnetic field. The magnetic field is seen to depend on the temperature of electrons and positrons and also on their equilibrium density ratio. In a bounded system, the propagation of acoustic waves in dusty plasma is found to be more interesting. Sagdeev potential is found to be positive and inverted profile, which predicts that solitary wave does not exist in such plasma.

(III) IUCAA-NCRA GRADUATE SCHOOL

One IUCAA research scholar, Yogesh Wadadekar, has defended his Ph.D. thesis titled "Optical Studies of VLA FIRST Survey Radio Sources ", to the University of Pune during the year of this Report. The abstract of the same is given below :

Optical Studies of VLA FIRST Survey Radio Sources

Yogesh Wadadekar

This thesis is about the properties of the optical counterparts of the sources detected by the VLA FIRST (Faint Images of the Radio Sky at Twenty centimeters) radio survey.

The National Radio Astronomy Observatory (NRAO), USA, is undertaking a dedicated effort to produce a deep high-resolution survey of 25% of the celestial sphere at 1400 MHz. The FIRST survey currently being carried out by the Very Large Array (VLA) telescope is providing astronomers with high quality data with high sensitivity (1 mJy), good resolution (1 arc second) and large sky coverage (over 6000 square degrees already, eventually 10000 square degrees). The FIRST survey represents a 50-fold improvement in sensitivity, resolution and positional accuracy over previous large area radio surveys. The first half of the survey has been completed and the data have been publicly released. The FIRST catalog already lists over 560,000 radio sources with flux densities greater than 1 mjy at 20 cm. The surface density of radio sources is roughly 90 per square degree.

In this thesis, we have adopted three distinct strategies for obtaining the optical counterparts of FIRST sources: (1) by cross correlation of the FIRST source catalog with catalogs of active galaxies and quasars, (2) by cross correlation of the FIRST catalog with an optical catalog from a complete photographic survey (DPOSS) and (3) by obtaining deep CCD images of a small portion of the FIRST survey area.

We begin the thesis by presenting an overview of major radio and optical surveys, focusing on the new surveys that are currently underway. We also list the various classes of objects that form the optical counterparts of extragalactic radio sources and summarize the unified orientation based scheme for understanding their phenomenology.

We then present an extensive analysis of radio emission from distant quasars and relatively nearby active galaxies, where the radio information was obtained from the FIRST survey. We report on *new* radio detections of 69 quasars and 206 active galaxies. We present several statistical correlations between the radio and optical properties of these objects and examine the implications of these to quasar evolution. In particular, we examine the bimodal distribution of radio luminosity in quasars. Our work with the FIRST survey allows us to measure the distribution of radio to optical flux ratios over a wide range from a single large but inhomogeneous sample.

Our second approach involves matching FIRST source positions with an unbiased, complete optical source catalog constructed from 3 plates from the DPOSS survey. We have obtained optical counterparts for over 2100 radio sources. As before, we examine the correlations between optical and radio properties. We construct a candidate list of over 250 quasars using selection criteria based on radio flux and optical colours.

The third approach is to obtain deep CCD images of a small area of the sky to allow optical identification, photometry and morphological classification of optical counterparts of a statistically significant number of FIRST sources. We have obtained data on 9 deep fields using a wide field CCD imager on the 2.5 m Dupont telescope at the Las Campanas Observatory in Chile. We have obtained photometric and morphological information on about 40 faint identifications, some of which are as faint as $m_v = 24$.

We have also developed a sophisticated two dimensional bulge disk decomposition software. This software called *fitgal* and our cross identification code have been described in the Appendix.

We end the thesis with a summary of the new results reported, and discuss the new lines of investigation that have been suggested by the present work.

This thesis is largely based on work reported in the following publications.

- **Y. Wadadekar**, B. Robbason & A. Kembhavi, *Two-dimensional galaxy image decomposition*, AJ, 117, 1219 (1999).

- **Y. Wadadekar** & A. Kembhavi, *A study of quasar radio emission from the VLA FIRST Survey*, AJ, 118, 1435 (1999).

- A. Kembhavi, **Y. Wadadekar** & R. Misra, *The appearance of AGN host galaxies at moderate redshifts*, Proceedings X Rencontres de Blois "The Birth of Galaxies", eds. B. Guiderdoni et al., Editions Frontiere (in press).

- A. Kembhavi, R. Misra & **Y. Wadadekar**, *The appearance of AGN host galaxies at moderate redshifts*, ApJ, (submitted).

- **Y. Wadadekar** & A. Kembhavi, *A study of radio emission from AGN using the VLA FIRST Survey*, AJ, (to be submitted).

- **Y. Wadadekar**, A. Kembhavi & P. McCarthy, *Faint radio sources from the VLA FIRST survey I. Optical identifications*, AJ, (to be submitted).

My other publications are:

- H. Khosroshahi, **Y. Wadadekar** & A. Kembhavi, *Correlations among global photometric properties of disk galaxies*, ApJ, 533, 162 (2000).

- H. Khosroshahi, **Y. Wadadekar**, A. Kembhavi & B. Mobasher, *An infrared photometric plane for ellipticals and early type disk galaxies*, ApJ, 531, L103 (2000)

Guide: Ajit Kembhavi, IUCAA

(IV) PUBLICATIONS

by IUCAA Academic Staff

The publications are arranged alphabetically by the name of the IUCAA staff member, which is highlighted in the list of authors. When a paper is co-authored by an IUCAA staff member and a Visiting Associate of IUCAA, the name of the latter is displayed in italics.

(a) Journals

Bagchi J., Ensslin T.A., Miniati F., Stalin C.S., SIngh M., Raychaudhuri S., Humeshkar N.B. (2002) Evidence for shock acceleration and intergalactic magnetic fields in a large-scale filament of galaxies ZWCl 2341.1+0000, New Astronomy, Vol. 7(5), (2002), 249.

Lortan, D. B., S.D. Maharaj and **N. K. Dadhich** (2001) Inheriting geodesic flows, Pramana **56**, 715.

Banerjee, N., S. Sen and **N. Dadhich** (2001) On the detection of scalar hair, Mod. Phys. Lett. **A16**, 1223.

Dadhich, N. and *N Banerjee* (2001) Global monopoles and scalar fields as the electrogravity dual of Schwarzschild spacetime, Mod. Phys. Lett. **A16**, 1193.

Ghosh S. G. and **N Dadhich** (2001) On naked singularities in higher dimensional Vaidya spacetimes, Phys. Rev. **D64**, 04750.

Dadhich, N. and *S.G. Ghosh* (2001) Gravitational collapse of null fluid on the brane, Phys. Lett. **B518**, 1.

Turakulov, Z. Y. and **N. Dadhich** (2001) A stationary vacuum solution dual to the Kerr solution, Mod. Phys. Lett. **A16**, 1959.

Dadhich, N. and S. Kar, *S. Mukherjee* and M. Visser (2002) R=0 spacetimes and Lorentzian wormholes, Phys. Rev. **D65**, 064004.

Das, Tapas, K. (2002) On some transonic aspects of general relativistic spherical accretion onto a Schwarzschild
black hole, MNRAS, **330**, 563.

Sarkar, A., and **Das, Tapas K.** (2002) One parameter solution of spherically symmetric accretion in various pseudo-Schwarzschild Potentials, Int. Jour. Mod. Phys. D, **11**, 427.

Das, Tapas K. (2001) Accretion powered spherical wind in general relativity, A & A, **376**, 697.

Das, Tapas K. (2001) On the Formation of Accretion-powered Galactic and Extra-galactic Jets, Astrophysics and Space Science, 276, 267.

Das, Tapas K. and Sarkar, A. (2001) Pseudo-Schwarzschild description of transonic spherical accretion onto compact objects, A & A, **374**, 1150.

S. V. Dhurandhar and A. Vecchio (2001) Searching for continuous gravitational wave sources in binary systems, Phys. Rev. **D 63**, 12200.

A. Pai, S. V. Dhurandhar and S. Bose (2001) A data-analysis strategy for detecting gravitational wave signals from inspiraling compact binaries with a network of laser-interferometric detectors, Phys. Rev. **D 64**, 042004.

Gupta, Ranjan (2001) Small/automated telescope and background instrumentation, BASI, **29** 471.

Vaidya, D. B., **Ranjan Gupta**, J.S. Dobbie and P. Chylek (2001) Interstellar Extinction by Composite Grember, A & A, **375**, 584.

Pandey, S.K., D. K. Sahu, **A. K. Kembhavi** and P. J. McCarthy (2001) Optical and near-IR imaging of dusty ellipticals, BASI, **29**, 449.

Patil, M.K., *S. K. Pandey*, **A. K. Kembhavi** and Mahendra Singh (2001) Dust in an extragalactic environment; the case of NGC 2907, BASI, **29**, 453.

Kaushik Bhattacharya, Avijit K. Ganguly and **Sushan Konar** (2002) Effective neutrino photon interaction in a magnetized medium, Phys. Rev. **D 65**, 013007.

T. M. Tauris and **S. Konar** (2001) Torque decay in the pulsar (P, P) diagram A & A 376, 543.

Lin, D. J., **R. Misra** and R. E. Taam (2001) Hydrodynamical winds from two-temperature plasma in X-ray binaries, MNRAS, **324**, 319.

Misra, R. and R. E. Taam (2001) The influence of hydrodynamical winds on hot accretion disk solutions, ApJ, **553,** 978.

Bhattacharyya, S. , **R. Misra** and **A. V. Thampan** (2001) General relativistic spectra of accretion disks around rotating neutron stars, ApJ, **550**, 841.

Narlikar, J.V. (2001) The quasi-steady state cosmology, Acta Scientiarum, **22**, 5, 1241.

Narlikar, J.V. and **T. Padmanabhan** (2001) Standard cosmology and alternatives: A critical appraisal, Ann. Rev. Astron. & Astrophys., **39**, 1, 211.

Narlikar, J.V. and Saroja Bhate (2001) Search for ancient Indian records of the sighting of supernovae, Current Science, **81**, 6, 701

Narlikar, J. V. and Saroja Bhate (2001) Search for ancient Indian records of the sighting of supernovae, Indian Journal of History of Science, **36**, 3-4, 171.

John, Moncy V. and **J.V. Narlikar** (2002) Comparison of cosmological models using Bayesian theory, Phy. Rev. **D 65**, 043506-1.

Narlikar, J.V. , **R.G. Vishwakarma**, *S.K. Banerjee*, P.K. Das and H.C. Arp (2002) Dynamics of ejection from galaxies and the variable mass hypothesis, Int. Jour. Mod. Phys. **D 11**, 2, 245.

Kanekar, Nissim and **T. Padmanabhan** (2001) The effects of anti-correlation on gravitational clustering MNRAS, **324**, 988.

Padmanabhan, **T**. and Shiv Sethi (2001) Constraints on ω, ω and *h* from MAXIMA and BOOMERANG Ap.J, **555**, 125-129.

Choudhury, T. R., **R. Srianand** and **T. Padmanabhan** (2001) Semianalytic approach to understanding the distribution of neutral hydrogen in the universe: Comparison of simulations with observations Ap.J. **559** 29.

Sriramkumar, L. and **T. Padmanabhan** (2002) Probes of vacuum structure of quantum fields in classical backgrounds, Int. Jour. Mod. Phys., **D11**, 1.

Hwang, J., **T. Padmanabhan**, O. Lahav and H. Noh (2002) On the {1/ 3} factor in the CMB Sachs-Wolfe effect Phys. Rev. **D**., **65**, 043005-5.

P. Singh and **N Dadhich** (2001) The field equation from Newton's law of motion and absence of magnetic monopole, Int. J. Mod. Phys. **A16**, 1237.

P. Singh and **N. Dadhich** (2001) Non-conformally flat bulk spacetime and the 3-brane world, Phys. Lett. **B511**, 291.

Kanekar, Nissim, **Varun Sahni** and Yuri Shtanov (2001) Recycling the universe using scalar fields Phys. Rev. D. **63**, 083520 .

Sahni, Varun, M. Sami and **Tarun Souradeep** (2002) Relic gravity waves from braneworld inflation Phys. Rev. **D. 65** 023518.

Souradeep, Tarun and Bharat Ratra (2001), Window function for non-circular beam CMB anisotropy experiment, Ap. J., **560**, 28.

Podariu Silviu, **Tarun Souradeep**, J. Richard Gott III, Bharat Ratra and Michael S. Vogeley (2001), Binned cosmic microwave background anisotropy power spectra: Peak location, Ap.J., **559**, 9.

Srianand, R and P. Petitjean (2001) A near-solar metallicity damped Lyman-alpha system toward the BAL quasar Tol 1037-2703, A & A **373**, 816.

Varshalovich, D. A., Ivanchik A.V., Petitjean P., **R. Srianand** and C. Ledoux (2001), HD Molecular lines in an absorption system at redshift z=2.3377, Ast. L, **27**, 683

Petitjean, P., **R. Srianand** and C. Ledoux (2002) Molecular hydrogen at z_{abs} = 1.973 toward Q 0013-004: dust depletion pattern in damped Lyman alpha systems, MNRAS, **332**, 383.

Subramanian, Prasad and K.P. Dere, (2001) Source regions of coronal mass ejections, Ap.J., vol. **561**, 372.

Gopal-Krishna, **Prasad Subramanian**, P. Wiita and P.A. Becker (2001) Are the hotspots of radio galaxies the sites of in-situ acceleration of relativistic particles? A &A, **377**, 827.

Manoharan, P. K., M. Tokumaru, M. Pick, **P. Subramanian**, F.M. Ipavich, K. Schenk, M.L. Kaiser, R.P. Lepping and A. Vourlidas (2001) Coronal mass ejection of 2000 July 14 flare event: Imaging from near-Sun to Earth environment,
ApJ, **559**, 1180-1189.

Becker, P. A., **P. Subramanian** and D. Kazanas (2001) Relativistic outflows from advection-dominated accretion disks around blackholes, Ap.J., **552**, 209.

S. K. Ghosh, B. Mookerjea, T. N. Rengarajan, **S. N . Tandon**, and R. P. Verma (2001) Far infrared mapping of three galactic star forming regions, BASI, **29**, 335.

S. K. Ghosh, B. Mookerjea, T. N. Rengarajan, **S. N. Tandon** and R. P. Verma (2001) Far Infrared Mapping of Three Galactic Star Forming Regions: W3(OH), S209& S187, Journal of Astrophysics and Astronomy, **22**, 173.

Vishwakarma, R.G.(2001)Study of the magnitude-redshift relation for type Ia supernovae in a model resulting from a Ricci-symmetry, Gen. Rel. Grav., **33**, 1973.

Vishwakarma, R.G.(2002) Consequences for some dark energy candidates from the Type Ia supernova SN 1997ff, MNRAS, **331**, 776.

(b) Proceedings

R. Gupta and D.B. Vaidya (2001) *Modeling of interstellar dust grains* ASP Conf. Series, 223, 1238.[The Eleventh Cambridge Workshop on Cool Stars, Stellar Systems and Sun — Challenges for the New Millenium, October 4-8, Tenerife, Spain. Editors: R.J. Garcia-Lopez, R. Rebolo & M.R. Zapatero Osorio.]

B. Biswal, *Harinder P. Singh*, **Ranjan Gupta** (2002) *Predicting dynamics through artificial neural networks* 149. [Automated Data Analysis in Astronomy, Editors: Ranjan Gupta, H. P. Singh, C. Bailer-Jones 2002, Narosa Publishing]

Philip, Ninan Sajeeth, Joseph, K. Babu, **Ajit Kembhavi**, and Yogesh Wadadekar (2002) *Bayesian approach for star-galaxy classification*, [Automated Data Analysis in Astronomy, Eds. Ranjan Gupta, H.P. Singh, C.A.L. Bailer-Jones (Narosa, New Delhi] 125.

J. V. Narlikar (2001) *Action at a distance in electrodynamics and inertia*, [Instantaneous Action at a Distance in Modern Physica : 'Pro' and 'Contra', Eds. A. Chubykalo, V. Pope and R. Smirnov-Rueda, Nova Science Publishers] 19 .

J. V. Narlikar (2002) *The evolution of alternative cosmologies*, [Historical Development of Modern Cosmology, Eds. V.J. Martinez, V. Trimble and M.J. Pons-Borderia (Astronomical Society of the Pacific Conference Series] 175.

(c) Books Authored / Edited

(i) Books Authored

Ranjan Gupta, *H. P. Singh*, C. Bailer-Jones (2002), *Automated Data Analysis in Astronomy,* (Narosa Publishing, New Delhi.)

Narlikar, J.V. (2001) [co-author : M. J. Narlikar] *Fun and Fundamentals of Mathematics*, (Universities Press (India) Ltd., Hyderabad)

- (2002) *Introduction to cosmology* (3rd Edition), (Cambridge University Press, Cambridge)

- (2002) [in Marathi] *Antaral ani vidnyan*, (Navachaitanya Prakashan, Mumbai)

Padmanabhan,T. (2001) *Course of Theoretical Astrophysics - Vol II: Stars and Stellar Systems,* (Cambridge University Press, Cambridge)

Padmanabhan, T. (2002) *The Story of Physics* [a comic strip with figures contributed by Keith Francis and Avinash Deshpande, based on the author's ideas] (both in Hindi and English), [Vigyan Prasar, New Delhi]

(d) Book Reviews

Narlikar, J.V. (2001) An astro-trilogy, A review of three books: (i) Indian Mathematics and Astronomy: Some Landmarks, (ii) Indian Astronomy, An Introduction and (iii) Astrology: Believe it or not? by S. Balachandra Rao, Current Science, 81, 2, 215.

(e) Popular articles

Dadhich, Naresh (2001) A Historical Challenge: Will US Take it?, (Deccan Herald, October 3)

- (2001) Science: Vital Role for Social Values, (Deccan Herald, November 13)

- (2001) Science: Challenge and Opportunity, (Deccan Herald, November 14)

Narlikar, J.V. (2001) Red stars over China : Science lessons from supernovas, (Times of India, April 21)

- (2001) Star of superstition : UGC has its head in the clouds, (Times of India, May 14)

- (2001) Cosmic puzzles and speculations, (The Earth Has No Corners, Ed. K.L. Nandan, p.185) (Felicitation volume on the 70th Birthday of Dr. Karan Singh)

- (2001) Vedic astrology or jyotirvigyan, (Economic and Political Weekly, June 16)

- (2001) Mere shadow play : Hippos under an eclipsed Sun, (Times of India, July 21)

- (2001) The great rebel : Fred Hoyle's contribution to astronomy, (Times of India, September 4)

- (2001) Fred Hoyle : Scientist of multifaceted talents, (Current Science, 81, 7, 843)

- (2001) Science and religion : Approach towards a synthesis (Creeds of Our Times, (Foundation of Universal Responsibility, Delhi), 267)

- (2001) Astronomy in the millennium, (Souvenir : Mini School on Astronomy & Astrophysics, 10)

- (2001) Half measures : Badly begun is never done, (Times of India, November 29)

- (2001) Vidnyan me kariyar - Mera chunav (in Hindi) [Career in science - My choice], (Srot, November)

- (2001) IUCAA : A new experiment for Indian universities, (Organizations and Strategies in Astronomy II, Ed. A. Heck (Kluwer), 29)

- (2001) Search for extra-terrestrial intelligence (Souvenir,
National Children's Science Congress - 2001, 39)

- (2002) Science and me, (Science And You, (National Book Trust, India) 110),

- (2002) Creativity, Society and Science, (India International Centre Quarterly, 28 (Special Commemorative Volume), 164)

- (2002) Finding the treasure, (SLIMlines, January-February, 1)

- (2002) Knowledge creation : Higher education as primary goal, (Times of India, March 13)

- (2001) Itihaskaro ke liye char saval (in Hindi) [Four questions for historians], (Shaishik Sandarbha, April-May, 43)

- (2001) Ekeesavi sadi me vidnyan (in Hindi) [Science in the twentyfirst century], (Akshar Parva, June)

- (2001) Bhavishya hum rachenge, sitare nahi (in Hindi) [We control our future not the stars], (Navbharat Times, August 22)

- (2001) Ekeesavi sadi me vidnyan (in Hindi) [Science in the twentyfirst century], (Vagarth, September)

- (2001) Ekeesavi sadi me vidnyan (in Hindi) [Science in the twentyfirst century], (Smarika, National Science Exhibition -
2001, 20)

- (2002) Bachhe jawab dhundhane ko tatpar rahe (in Hindi) [It's question time : Children must look for answers], (Harkara, 16)

- (2001) Manala phulavanare Pu.La. : Ek abhivadan (in Marathi) [P.L. who brought joy to our minds], (Tarun Bharat, June 10)

- (2001) Mumbaishimatla anusanhar (in Marathi) [The nuclear devastation of "Bombay-shima"], (Maharashtra Times, August 5)

- (2001) Ekvishave shatak: Swapne ani avhane (in Marathi) [Twenty-first century - Dreams and challenges], (Vidnyanyug, August)

- (2001) 21 June, 2001 che suryagrahan (in Marathi)[Solar eclipse dated June 21, 2001], (Marathi Vidnyan Parishad Patrika, August)

- (2001) Bahurangi pratibhecha vaidnyanik (in Marathi) [Fred Hoyle : Scientist of Multi-Faceted Talents], (Ravivar Sakal, August 26)

- (2001) Bhavishyavedh (in Marathi) [Forecasting], (Amrut, September)

- (2001) Jyotirvidnyan : Vidnyan navhe (in Marathi) [Vedic astrology or jyotirvigyan], (Marathi Vidnyan Parishad - Patrika, Diwali Issue)

- (2001) Dakshin golardhatun pahilele suryagrahan (in Marathi) [Total solar eclipse witnessed from the southern hemisphere], (Gammat Jammat, Diwali Issue)

- (2001) Dhakata bhau (in Marathi) [Younger brother], (Maharashtra Times, Diwali Issue)

- (2001) Jyotish vishyach bhavisha kay asel! (in Marathi) [What will be the future of Jyotish], (Milun Saryajani, Diwali Issue)

- (2001) Dakshin golardhatun pahilele suryagrahan (in Marathi) [Total solar eclipse witnessed from the southern hemisphere], (Dharmabhaskar, Diwali Issue)

- (2001) Vidnyan aani tantradnyan : Aathavan aani shikvan (in Marathi) [Science and technology : Memorable results and lessons], (Tonic, 26)

- (2001) Gelya sahasrakatil vishwasankalpanecha vikas (in Marathi) [The development of cosmology in the last millennium], (Vidnyan Vedh, Marathi Vidnyan Parishad, Barshi, 26)

- (2002) Don paryay (in Marathi) [Two options], (Dharmabhaskar, January)

- (2002) Matrubhashet vidnyan! Einstein te samanya manus!! (in Marathi)[Science in mother tongue - From Einstein to common man], Vishwa Vidnyan, January)

- (2002) Dakshin golardhatun pahilele suryagrahan (in Marathi)[Total solar eclipse witnessed from the southern hemisphere], (Dhyas Vidnyanacha, Marathi Vidnyan Parishad, Kolhapur)

- (2002) Dakshin golardhatun pahilele suryagrahan (in Marathi)[Total solar eclipse witnessed from the southern hemisphere], (Maitra Jeevanche, 9)

- (2002) Prashnotaracha taas : Mulanni shodhak vruti banavavi (in Marathi)[It's question time : Children must look for answers), (Vishwa Vidnyan, February)

- (2002) Vidnyanyug va vidnyansahitya (in Marathi)[The age of science and the literature of science], (Amrutsanchay, 45)

- (2002) Sphurtiche aadarsh : Vaidnyanik karyacha chirkal varasa (in Marathi) [Model of inspirtation : Enduring legacy of scientific works], (Vishwa Vidnyan, March)

- (2002) Phalajyotish aani vidnyan (in Marathi) [Astrology and science), (Dhanurdhari, March)

- (2002) Navya sahasrakachya umbarthyavarun bhavishavedh (in Marathi) [Outlook for the future on the threshold of the new millennium], (Vidyasanvardhan, 1)

- (2002) Pudhalya dashakatil khagolvidnyan aani vishwarachanashastra (in Marathi) [Astronomy and the structure of the universe in the next ten years], (Pursharth, March)

P. Subramanian 3 articles on relativity in Jantar Mantar, childrens' science magazine published by Tamilnadu Science Forum, Mar-May 2001.

(f) Resource Summaries in Khagol

A.N. Ramaprakash (2002) Imaging Through Turbulence with Adaptive Optics, Resource Summary, (Issue No. 50 April).

Tarun Souradeep (2001) Cosmic Microwave Background Radiation (Issue No. 46, April).

PUBLICATIONS

by Visiting Associates

Ahsan, Z., Ahsan, N. and S. Ali (2001) Transformation laws for the gravitational field variables, The Aligarh Bull. Maths. **20**, 54.

Ahsan, Z., Ahsan, N. and S. Ali (2001) Non null electromagnetic fields and compacted spin coefficient formalism in general relativity, Indian J. Physics **75B** (6), 565.

Ahsan, Z., Ahsan, N. and S. Ali (2001) Lanczos potential and tetrad formalisms, Bull. Cal. Math. Soc. **93** No. 5, 407.

Thakur, Parijat and **D.K. Chakraborty** (2001) Correlated projected properties of triaxial mass models implications for their intrinsic shapes, MNRAS, **328**, 330.

Chakraborty, D.K, Das, Mousumi and Parijat Thakur (2001) Intrinsic shape of elliptical galaxy NGC 661, A.S.P. Conf. Ser., **205**, 178.

Thakur, Parijat and **D.K. Chakraborty** (2001) Correlated projected properties of triaxial mass models, BASI, **29**, 443.

Das, Mousumi and **D.K. Chakraborty** (2001) A family of triaxial mass models: Analytical study of its projected properties, BASI, **29**, 439.

Ghosh, Sutapa, Sanchayita, Ghosh, Kanupriya, Goswami, **Chakrabarty, Somenath** and **Ashok Goyal** (2002) Electrical conductivity at the core of a magnetar, Int. Jour. Mod. Phys.,**D11**,1.

Nag, Nandini and **Somenath Chakrabarty** (2002) Thomas-Fermi-Dirac model for low density stellar matter in presence of strong quantizing magnetic field, Int. Jour. Mod. Phys., **D11**, 13.

Chakraborty, S. and **B.C. Paul** (2001) Inflation in bianchi models and cosmic no-hair theorem.Phys.Rev.**D64**, 127502.

Chakraborty, S. (2002) Quantum cosmology in Ashtekar Variables with non-minimally coupling scalar tensor theory, Pramana **58**, 1.

Chakraborty, S. (2001) Vacuum Brans dicke theory and wormholes, Int.J.Mod.Phys.D **10**, 957.

Chakraborty, S. (2001) Vacuum solutions in higher dimension with Brans Dicke theory, Mod. Phys. Lett. **A16**, 1629.

Chakraborty, S. (2001) Quantum cosmology in anisotropic cosmological models with scalar-tensor theories, Int.J.Mod.Phys.**D 10,** 943.

Chakraborty, N.C. and **S. Chakraborty** (2001) Bianchi II,III,VIII & IX bulk viscous cosmological models with variable G and $x\lambda$, Nuovo Cimento **B 116**, 191.

Chakraborty, N.C. and **S.Chakraborty** (2001) String Cosmology with magnetic field in Bianchi V model, Int.J.Mod.Phys. **D 10**, 723.

Chandra, Deepak, Ashok Goyal and Kanupriya Goswami (2002) Neutrino opacity in magnetised hot and dense nuclear matter, Phys. Rev. **D65**, 053003.

Chandra, Suresh and W.H. Kegel (2001) Absorption against the cosmic 2.7 K background, Astron. Astrophys., **367**, 995.

Chandra, Suresh (2001) Dissociation energy of diatomic molecules - comment on the work of Kaur & Mahajan, Pramana, **56**, C585.

Sharma, A.K. and **Suresh Chandra** (2001) About the Dunham coefficients Y_{20} and Y_{11} for diatomic molecules, Can. J. Phys., **79**, 1169.

Sharma, A.K. and **Suresh Chandra** (2001) Suggestions for an interstellar cyclopropene search, Astron. Astrophys., **376**, 333.

Chandra, Suresh and A.K. Sharma (2001) Collisional rates for vib-rotational transitions in diatomic molecules, Astron. Astrophys., **376**, 356.

Sharma, Arvind K., **Chandra, Suresh** and S.H. Behere (2001) Comment on "The calculation of potential curve of $A^1\Sigma^+$ state of ^{7}LiH from experimental data", Ind. J. Phys., **75B**, 477.

Sharma, A.K. and **Suresh Chandra** (2001) Detection of rotational lines of NaSH molecule, Ind. J. Pure and Appl. Phys., **39**, 765.

Chaudhuri, S. and K.C.Das (2001) Odd-soliton solutions to the Einstein equations, Czech. J. Physics, **51 (8)**, 781.

Chaudhuri, S. (2002) On the generation techniques of axially symmetric stationary metrics, Pramana -J. Phys., **58 (3)**, 449.

Chaudhuri, S. and K.C.Das (2002) One-soliton solutions from Laplace's seed, Pramana- J. Phys., **58 (3)**, 465.

Cenni, R., **Dey, J.** and **M. Dey** (2001) Nucleons and Isobars at finite density and temperature, Eur. Phys. J., **A12**, 41.

Curdt, W., Brekke, P., Feldman, U., Wilhelm, K., **Dwivedi, B.N.**, Schuhle, U. and P. Lemaire (2001) The SUMER spectral atlas of solar-disk features, Astron. Astrophys., **375**, 591.

Mohan, A. and **B.N. Dwivedi** (2001) Why is the Sun's corona so hot ? X-rays and ultraviolet emission from the solar atmosphere, Current Science, **81**, 349.

Ghosh, S.G. and R. V. Saraykar (2002) Higher dimensional charged null fluid collapse and cosmic censorship, Int. J Mod. Phys. **D 11,** 237.

Ghosh, S.G. and A. Beesham (2001) Higher dimensional Inhomogeneous dust collapse and cosmic censorship, Phys. Rev. **D 64**, 124005.

Ghosh, S.G., Saraykar, R.V. and A. Beesham (2001) Collapsing shells of radiation in higher dimensional space-time and cosmic censorship, Int. J Mod. Phys. **A 16**, 4481.

Goyal, Ashok , **Gupta, V.K.**,Tuli, V. and Kanupriya Goswami (2001), Nuclear matter in intense magnetic field and weak processes, IJMPA **16**,347.

Goyal, Ashok (2001), Photon neutrino interactions in magnetic field through neutron magnetic moment, Phys.Rev. **D64**, 013005.

Goyal, Ashok and Meenu Dahiya (2001), Chiral symmetry in NJL model in curved space time at finite temperature and density, J.Phys. **G27**, 1827.

Goyal, Ashok, Gupta, V.K., **S. Singh**, Kanupriya Goswami, and J.D. Anand (2001) Bulk viscosity of magnetised neutron star matter, J.Phys. **G27**, 921.

Hallan, P.P. (2001) The existence and stability of equilibrium points in the Robe's restricted three body problem, Journal of Celestial Mechanics and Dynamical Astronomy, **79**, 145.

Hallan, P.P. (2001) Effect of perturbations in coriolis and centrifugal forces on the location and stability of the equilibrium points in the Robe's circular restricted three body problem, Journal of Planetary and Space Science, **49**, 957.

Vats, Hari Om, Som Sharma, R. Oza, **K .N. Iyer,** Chandra, H., Sawant, H.S. and M.R. Deshpande (2001) Interplanetary and terrestrial observations of an earth directed coronal mass ejection, Radio Sci., **36**,1769.

Jadeja A.K., R. M. Jadav, Hari Om Vats and **K.N. Iyer** (2001) Study of travelling ionospheric disturbances using IPS array at Rajkot, Indian J. Radio Space Phys., **30**, 457.

Vats, Hari Om, H.S. Savant, Rupal Oza, **K.N. Iyer** and R. M. Jadhav (2001) Interplanetary scintillation observations for the solar wind disappearance event of May, 1999, J. Geophys. Res.(Space Physics),**106**, 25121.

Jog, C.J., and C.A. Narayan (2001) Vertical Distribution of Galactic Disc Stars and Gas Constrained By A Molecular Cloud Complex, Mon. Not. Roy. Astr. Soc., **327**, 1021.

Jog, C.J., and C.A. Narayan (2001) Vertical Distribution of Galactic Stars and Gas Determined By A Molecular Cloud Complex, Bull. Astr. Soc. India, **29**, 343.

Sivakumar, C., **Moncy V. John** and K. Babu Joseph (2001) Stochastic evolution of cosmological parameters in the early universe, Pramana- J.Phys., **56**, 477.

Kaushal, R.S. and Shalini Gupta (2001) Construction of exact dynamical invariants in coupled oscillator problems, Journal of Physics **A:**Math & Gen, **43**, 9879.

Kaushal, R.S. (2001) On the quantum mechanics of complex hamiltonian systems in one dimension, Journal of Physics **A**: Math & Gen **34**, L709.

Sarkar, Susmita, P. Mukhopadhyay, **Manoranjan Khan,** J. Ortner, M. Steinberg and W. Ebeling (2001) Evolution of induced axial magnetization in a two component magnetized plasma, Phys. Rev **E, 64,** 046401.

Mondal, S., Susmita Sarkar, A.M. Basu, **Manoranjan Khan,** Rajarshi Bhattacharyya and B. Chakraborty (2001) A theory of Landau damping of ion acoustic waves in a dope plasma, Phys. Plasmas, **8**, 713.

Gupta, M.R., Susmita Sarkar, Samiran Ghosh, M. Debnath. and **Manoranjan Khan** (2001) Effect of nonadiabaticity of dust charge variation on dust acoustic waves, Phys. Rev. **E, 63**, 0464061.

Ghosh, Samiran, Susmita Sarkar, **Manoranjan Khan** and M.R. Gupta (2001) Small amplitude nonlinear dust acoustic wave in a magnetized dusty plasma with charge fluctuation, IEEE, TPS, **29**, 409.

Ghosh, Samiran, Susmita Sarkar, **Manoranjan Khan** and M.R. Gupta (2001) Small amplitude nonlinear dust ion acoustic waves in a magnetized dusty plasma with charge variation, Physica Scripta, **63**, 395.

Ghosh, Samiran, Susmita Sarkar, **Manoranjan Khan** and M.R. Gupta (2001) Ion acoustic shock waves in a collisional dusty plasma, Physics Plasmas **8** (12).

Sarkar, Susmita, **Manoranjan Khan,** Samiran Ghosh, and M.R. Gupta (2001) Effect of grain charge fluctuation on dispersion relation of dust acoustic waves in

unmagnetized dusty plasma, Rev. Bull. Cal. Math. Soc., **8** (1&2), 1.

Ghosh, Samiran, T.K. Chaudhuri, S. Sarkar, **Manoranjan Khan,** and M.R. Gupta (2001) Small amplitude nonlinear dust acoustic wave propagation in Saturn's F,G and E rings, Astrophysics & Space Science, **278**, 463.

Das, S., **P. Khare,** A. Samantray (2001), Unified model for quasar absorption lines, Astronomy and Astrophysics, **373**, 843.

Vinoj, M.N., **V. C. Kuriakose** and K. Poreszian (2001) Optical soliton with damping and frequency chirping in fibre media, Chaos, Solitons and Fractals. **12**, 2569.

Ganapathy, R., **V. C. Kuriakose,** and K. Poreszian (2001) Soliton propagation in a birefringent optical fibre with fibre loss and frequency chirping, Opt. Comm.**194**, 299.

Ganapathy, R. and **V. C. Kuriakose** (2001) Polarization modulational instability in a birefringent optical fibre with fourth order dispersion, Pramana J. Phys., **57**, 743.

Vinoj, M.N. and **V. C. Kuriakose** (2001) Nonlinear compression of optical solitons, Pramana J.Phys., **57**, 987.

Lohiya, D., Abha Dev, and M. Sethi (2001) Linear coasting in cosmology and S Ne1a, Phys. Lett. **B504**, 207.

Mittal A. K., Lohiya D. (2001) Conditional cosmological principal and fractal cosmology; Spacetime and substance, **2**, 105.

Malik, Usha and G.P. Malik (2002) A nonlinear model having solutions akin to Abrikosov's mixed state, J. Phys. A: Math. Gen. **35**, 2005.

Mittal, A. K. and T.R. Seshadri (2002) Fractals and the large-scale structure in the universe: Introduction and basic concepts, Resonance, **7**, 6.

Narain, U., P. Agarwal, R.K. Sharma, **L. Prasad,** and **B.N. Dwivedi** (2001) On Solar coronal loop heating by torsional Alfven waves, Solar Phys. 199, 307.

Pandey, K. and **U. Narain** (2001) On solar coronal heating, Bull. Astron. Soc. India, 29, 231.

Pandita, P. N. (2001) Nonminimal supersymmetric standard model with baryon and lepton number violation, Phys. Rev. **D64**, 056002.

Ananthanarayan, B. and **P.N. Pandita** (2002) Reply to comment on infrared fixed point structure in the minimal supersymmetric standard model with baryon and lepton number violation, Phys. Rev. **D65**, 058902.

Paul, B.C., S. Mukherjee, and R. Tavakol (2002) Singular instanton in higher derivative theories, Phys. Rev. **D 65**, 064020.

Paul , B. C. (2001) Inflationary Cosmologies in an anisotropic brane world, Physical Review **D 64**, 124001.

Paul, B.C. (2001) On the mass of a uniform density star in Higher Dimensions Classical and Quantum Gravity **18**, 2637.

Paul , B.C. (2001) Viscous cosmologies with extra dimensions, Phys. Rev. **D 64**, 027302.

Paul, B.C. and A. Saha (2002) Probability for primordial black holes in higher derivative theories, Int. J. Mod. Phys. D., 11, No. 4, 493.

Mondal, K.K., A. Roychowdhury, and **S. N. Paul** (2001) On the problem of self-focussing and transversal stability in a magnetized plasma, FIZIKA A (Zagreb),**10**,No 1, 31.

Chakraborty, B., R. Bhattacharyya , R. and **S. N. Paul** (2001) Classical physics of magnetic moment, Indian J. Phys., **75B**, No. 5, 1.

Burman, S., A. Roychowdhury and **S. N. Paul** (2001) Propagation of waves in a multi-component plasma having charged dust particles, Pramana (India), **56** No.6, 785.

Chattopadhyaya, S., S. Bhattacharyya and **S. N. Paul** (2002) On the effect of drift motion and negative ions on solitons and double-layers in plasma, Indian J. Phys., **76B**, No.1, 53.

Mondal, K. K., A. Roychowdhury, and **S. N. Paul** (2002) On the existence of solitary wave in a bounded dusty plasma, Phys. Rev..E. (USA), **65**, 16404.

Uddin, Wahab and **Lalan Prasad** (2001) Dynamical properties of flare loops of 27 Nov. 1996, Bull. Astron. Soc. India **29**, 241.

Rahaman, F. (2001) Global string in Lyra geometry, International Journal of Modern Physics **D 10**,579.

Rahaman, F. and J.Bera (2001) Higher dimensional cosmological model in Lyra geometry, International Journal of Modern Physics **D 10**,729.

Rahaman, F., Chakraborty, S. and M.Kalam (2001) Domain wall in Lyra geometry, International Journal of Modern Physics **D 10**,735.

Chakraborty, S. and **F. Rahaman** (2001) Motion of test particles around charged dyonic blackhole, Bulletin of Calcutta Mathematical Society **93**, 99.

Rahaman, F. and M. Kalam (2001) Charged AdS black hole and test particles, Indian J.Physics **75B**,505.

Rahaman, F., S. Chakraborty and K. Maity (2002) Non static spherically symmetric solution in a higher dimensional spacetime, Indian J.Physics **76B**,311.

Rahaman, F. and M. Kalam (2002) Gravitational field of spherical domain walls in higher dimension, Pramana J.of Phys. **58**,127.

Rahaman, F., S. Chakraborty . and K. Maity (2002) Test particle trajectories near cosmic strings, Pramana J.of Phys. **58**, 113.

Rahaman, F., S. Chakraborty and M. Kalam (2002) Higher dimensional global monopoles in Brans-Dicke theory of gravity, Pramana J. of Phys. **58**,121.

Rahaman, F., S. Chakraborty, K. Maity and M. Kalam (2002) Non static global monopole solution in higher dimensional spaetime, Indian J.Physics **76B**, 65.

Reddy, R.R. (2001) Physico-Chemical parameters of alkali halides using optical electronegativity, Infrared Physics & Technology, **42**, 49.

Reddy, R.R. (2001) Electronic polarizability and Optical basicity properties of oxide glass, Journal of Non-Crystalline Solids, **286**, 169.

Reddy, R.R. (2001) Potential energy curves, dissociation energies and Franck Condon factors of NI and ScI molecules, J. Quan. Spec. Radia. Transfer, **22**, 206.

Reddy, R.R. (2001) Thermo acoustic parameters of rare earth metals and references materials from volume expansivity data at 300 K. Journal of Acoustical Society of India, **29**, 367.

Sami, M. (2001) An exact inflationary solution on the Brane, Gravitation and Cosmology, **7**, 228.

Shanthi, K. and C.L. Bhat (2002) Reclassification of gamma ray bursts based on their brightness distributions, Bull. Astr. Soc. India, **30**, 445.

Shanthi, K., C. L. Kaul, R.K. Kaul, A.K. Tickoo and C.L. Bhat (2002) Gamma ray bursts at high energies: detection ranges and event rates, Bull. Astr. Soc. India, **30**, 429.

Hota, P.K., V. Vijayan, S. N. Senapati and **L.P. Singh** (2001) Use of a 3Mev proton accelerator for trace analysis in cancer, J. Med.Phys **26**,190.

Hota, P.K., Vijayan, V. and **L.P. Singh** (2001) Application of X-ray spectroscopic analysis to human blood samples, Ind.J.Phys **75B**,333.

Singh, N.S., **K.Y. Singh,** S. Naik, B. Paul, P.C. Agrawal, A. R. Rao, S. Seetha and K. Kasturirangan (2001) Observations of X-ray binary Cygnus X-3 by Indian X-ray Astronomy experiment, Bull. Astr, Soc. India, **29**, 351.

Suresh, P.K. (2001) Thermal squeezing and density fluctuations in semiclassical theory of gravity, Mod.Phys.Lett., **A16**, 707.

Suresh, P.K. (2001) Nonclassical state representation of inflaton and power-law expansion in FRW universe, Mod.Phys.Lett.**A16**, 2431.

Suresh, P.K. (2001) Thermal squeezed state representation of scalar field and energy density in semiclassical theory of gravity, Int.J.Thero.Phys. **40**, 2091.

Tikekar, R. and **V.O. Thomas** (2001) A relativistic charged fluid model on pseudo spheroidal spacetime, J.M.S. University of Baroda, **46 & 47**,117.

Other Publications

Ahsan, Zafar (2001) Differential Equations and Their Applications, Prentice-Hall of India, New Delhi (1999) Bestseller of the year 1999-2000. Second Printing, September 2001.

Ahsan, Zafar and M.A. Pathan (2002) Edited: Proc. of 67th Annual Conference of Indian Mathematical Society held at Department of Mathematics, AMU, Aligarh.

Ahsan, Zafar (2001) Lecture Notes on Mathematical Methods, Department of Mathematics, AMU, Aligarh.

Chakraborty, D.K. (2001) Brahamandiki: A text book for M.Sc., Publisher: Madhya Pradesh Hindi Granth Academy.

Chandra, Suresh, Kegel, W.H. and A.K. Sharma (2001) Absorption against the cosmic 2.7 K background - A technique for detection of asymmetric top molecules in cosmic objects, in First Steps in the Origin of Life in the Universe ed. by J. Chela-Flores, T. Owen and F. Raulin , Kluwer Academic Publishers (London) p. 135.

Dwivedi, B.N. and K.J.H. Phillips (2001) Paradox of the Sun's Hot Corona Scientific American, **284**, No. 6, pp. 40.

Dwivedi, B.N., Landi,E. and A. Mohan (2001) in Recent Insights into the Physics of the Sun and Heliosphere, P. Brekke, B. Fleck, and J.B. Gurman (eds.) ASP Conf. Ser. **200**, 356.

Curdt, W., Landi, E., Feldman, U., Innes, D.E., **Dwivedi, B.N**. and K. Wilhelm (2001) in Recent Insights into the Physics of the Sun and Heliosphere, P. Brekke, B. Fleck, and J.B. Gurman (eds.) ASP Conf. Ser. **200**, 260.

Dammasch, I.E., Curdt, W., Kliem, B., **Dwivedi, B.N.** and K. Wilhelm (2001) in Recent Insights into the Physics of the Sun and Heliosphere, P. Brekke, B. Fleck, and J.B. Gurman (eds.) ASP Conf. Ser. **200**, 264.

Jog, C.J. (2001), Book Review of 'Annual Review of Astronomy & Astrophysics, 2000' (eds. G. Burbidge et al.), in Current Science, **80**, No.12, 1596.

Posezian, K. and **V.C. Kuriakose** (2001) Optical Solitons: Theory and Experiments, Indian Academy of Sciences, Bangalore.

Mittal, A.K. (2002) Chaos in the Foundations of Quantum Mechanics, In Quantum Implications, Ed. C. M. Bhandari. Proceedings of the National Seminar on Quantum Implications, Dec 14-15, 2000, organized by Department of Physics & Department of Applied Physics & Technology, University of Allahabad, 84

Prasad, Lalan (2001) Sun's Hot Crown, Lalan Prasad : Science Reporter, 56.

Rao, P. Vivekananda and J. Rukmini (2002) An Online Photometric Data Acquisition and Analysis Facility at Japal-Rangapur Observatory, Automated Data Analysis in Astronomy, 211(Narosa Publising House, Editors: Ranjan Gupta, Harinder Singh and Coryn A. L. Bailer Jones).

Sahijpal, S. (2002) Stable and radiogenic isotopic constraints on the role of core-collapse supernova as a source of short-lived nuclides. Lunar & Planetary Science Conference CD-ROM, Abstract #1095.

Supervision of Thesis

Ashok Goyal and S.R. Choudhury `Supersymmetric effects on flavour changing neutral currents', January 2002, University of Delhi, Ph.D. Thesis of Naven Gaur.

(V) PEDAGOGICAL ACTIVITIES

(a) IUCAA-NCRA Graduate school

Naresh Dadhich: Mathematical Methods of Physics-II

S. V. Dhurandhar : Mathematical Methods of Physics -I

A. K. Kembhavi: Introduction to Astronomy and Astrophysics II

J. V. Narlikar: Quantum and Statistical Mechanics II

T. Padmanabhan: Introduction to Astronomy and Astrophysics I

T. Padmanabhan: Aspects of Quantum Field Theory (Topical course)

A. N. Ramaprakash: Astronomical Techniques I - Coherent detection

Varun Sahni : Cosmology

Tarun Souradeep: Power Spectrum Estimation of Cosmic Microwave Anisotropy Spectrum (Topical course)

S. Sridhar: Electrodynamics and Radiative Processes - II

Tutorial Assistanceship

T. Roy Choudhury: Introduction to Astronomy and Astrophysics - I

Harvinder K. Jassal: Astronomical Techniques I

Jatush Sheth : Introduction to Astronomy and Astrophysics - II (Stellar Structure)

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

Ranjan Gupta: Astronomy and Astrophysics I, (40 theory lectures and a set of 10 laboratory and night experiments).

Tarun Souradeep: Astronomy and Astrophysics II : General Relativity and Cosmology (40 lectures)

(c) Supervision of Projects

J. Bagchi

Shri Manu Garg (BHU-IIT) (VSP)
Radio Imaging and Deconvolution

A. K. Kembhavi

Chote Nuangun
Image Processing

Poonam Singh (VSP)
Pulsars and Supernovae

Koushik Dutta (VSP)
Supermassive Blackholes in Galaxies

Sudeep Gandhe, VJTI, Mumbai
Amey Dharurkar, VJTI, Mumbai
Robin Dhamankar, VJTI, Mumbai
Pooja Mishra, VJTI, Mumbai
Gunjan Prakash, VJTI, Mumbai
Application of Data Mining to Astronomy

Sushan Konar

Subinoy Das (IIT, Kanpur) Effective Neutrino *Interactions in a Young Neutron Star* (VSP)

A.N. Ramaprakash

Somaditya Banerjee (VSP)
Gamma-rayBurst AfterglowPolarization

Ujjaini Alam (IUCAA-NCRA Graduate School)
Magnetic Field Near the Cometary Globule S131-37

Koshy George (Mahatma Gandhi University, M.Sc)
Gamma-ray Bursts : Where Are the Missing Afterglows?

H. Kuppuswamy, R. Devale and S. Vahule (College of Engineering, Pune, B. Tech)
Remote Control System for Meade 16inch telescope

A. Nair and S. Aich (AISSMS College of Engineering, Pune, B. Tech.)
Programmable Microstepping, Stepper Motor Controller

Tarun Souradeep

Atul Deep (IUCAA-NCRA Graduate School)
Correlations in the CMB Anisotropy

Anand Sengupta (IUCAA Graduate student)
Cosmic Microwave Power Spectrum Estimate Using Non-circular Beams

Amir Hajian, (visiting student from IASBS, Iran)
Aspects of CMB Power Spectrum

Arman Shafeiloo
(M.Sc. thesis project, University of Pune)
Initial Power Spectrum from CMB Anisotropy data

V. Gopisankararao (VSP-2001)
Primordial perturbations and the Cosmic Microwave Background Anisotropy Spectrum

S. Murali Krishna (IIT, Kharagpur)
Aspects of Cluster Computing

P. Subramanian

C. G. Raghunath, (M.Sc student, IIT Madras)
Radio Galaxy Hotspots

Bhalchandra Pujari, (Project Student, B.Sc. Wadia College, Pune)
I*nversion of Electron Density from Total Brightness Coronograph Measurements.*

S. N. Tandon

Paramita Barai, IIT , Kharagpur
VSP Project/Practical Training for B Tech. course
Analysis of Images for Correcting Telescope Optics

(d) Supervision of thesis

A. K. Kembhavi (Guide)

Yogesh Wadadekar
Optical Studies of VLA FIRST Survey Radio Sources

(e) School Students' Summer Programme

Preamble

The School Students' Summer Programme was held between April 16 and May 25, 2001. Schools in greater Pune were invited to nominate two scientifically motivated students each, and about 150 students from 75 schools participated in this programme. Every week, a new batch of 26 students was invited to work on a project at IUCAA from Monday to Friday. Groups of four to six students were attached to individual guides. This programme had no set syllabus or course guidelines and the students and the guide worked out their schedule for the week.

The sample of topics that the Summer School Students took up for their projects were Foucault's pendulum; lenses, mirrors and prisms; telescopes and microscopes; solar system; Kepler's laws; Doppler effect; Luminosity and temperature; Hubble's Law, Obler's paradox, Achilles and the tortoise; non-Euclidean geometry; combinations; calculus; number system and percolation, etc.

V. Chellathurai, Ranjan Gupta, Vinaya Kulkarni, J. V. Narlikar, T. Padmanabhan, Arvind Paranjpye, Anand Sankar Sengupta, T. Souradeep, Arun V. Thampan, Thierry Morel and R. G. Vishwakarma acted as guides for the students.

(VI) IUCAA COLLOQUIA, SEMINARS, ETC.

(a) Colloquia

Tanmay Vachaspati: *Topological defects in the lab and cosmos*, June 11.

Bharat Ratra: *Is the univese flat or open*?, July 20.

Vijay Pandharipande: *Theory of neutron stars*, August 2.

Spenta R. Wadia: *String theory and the information puzzle of black hole physics*, August 20.

Wasaburo Unno: *Causality and Indra's Net (ENN in Japanese)*, October 9.

Sanjay Jain: *Studying complex networks in biology and the social sciences: some recent approaches and new insights*; November 12.

Kavan U. Ratnatunga: *Gravitational lensing in the HST medium deep survey*, December 12.

A.V. Patki: *Rocket and launch vehicle development at ISRO*, December 19.

Sunil K. Gupta: *Excitement of experiments in cosmic ray astrophysics*, February 11.

(b) Seminars

Zafar Turakulov: *A new amially symmetric stationary vacuum solution*, April 4.

Koshy George: *Gamma ray burst: Where are the missing afterglows*?, June 8.

Ujjaini Alam: *A study of the magnetic field in the cometary globule S. 131-37,* July 12.

Amrit Lal Ahuja: *Processing of dual frequency pulsar data from GMRT to obtain accurate dispersion measure*, July 26

Atul Deep: *Correlations in CMB anisotropy*, July 27

Ashok Ambastha: *Total solar eclipse 2001 from Lusaka, Zambia: USO experiments and preliminary results*, August 21

Ajit Kembhavi: *First light in the universe*, August 23

Parthasarthy Ganguly: *Applying the Bohr Model for hydrogen atoms to interacting atoms*, October 4.

Pawan Kumar: The enigmatic cosmic gamma-ray bursts, October 11.

A.A. Ubachukwu: *Relativistic beaming and orientation effects in high luminosity AGNs and their implications for unification theories and cosmology*, October 18.

Paul Baki: *A geometric representation of the electromagnetic field in Finslerian geometry*, October 25.

Jihad Touma: *Nonlinear Core-Mantle coupling I: Historical background*, November 22.

Jihad Touma: *Nonlinear Core-Mantle coupling II: Consequences of passage through resonance on Earth and Venus*, November 27.

Dave Green: *A power spectrum analysis of neutral hydrogen in the galaxy,* November 29.

Judith Bishop: *Present and future prospects for programming languages*, January 3.

Zoltan Haiman: *Probing the end of the dark gases*, January 24.

James A. Rose: *Multiple merging events in the A3128/A3125 double cluster of galaxies*, January 25.

Menas Kafatos : *Accretion onto blackholes,* February 18.

Sujan Sengupta: *Atmosphere of substellar-mass objects: Brown dwarfs and extra solar giant planets,* March 14.

(c) MAHFIL (Mid-day Astronomy Hour for Interaction and Lunch)

M.N. Anandaram) A.K. Mittal) Prasad Subramanian)	April 18
A.A. Ubachukwu) Paul Baki) Zafar Turakulov)	October 10
Kandaswamy Subramanian) Ranjeev Misra) Dave Green)	November 21
Jihad Touma) Yuri Shtanov) Kavan Ratnatunga)	December 12
C.D. Ravikumar) Rajesh Nayak) Niranjan Sambhus)	March 20

(VII) TALKS AT IUCAA WORKSHOPS OR AT OTHER INSTITUTIONS

(a) Seminars, Colloquia and Lectures

J. Bagchi

Acceleration of cosmic rays at the structure formation shocks, Indo-French meeting , NCRA, (December 6 -11), Pune.

T. Roy Choudhury

Semi analytic modelling of the low density intergalactic medium, Institut d'Astrophysique de Paris, Paris, November.

Naresh Dadhich

General axially symmetric stationary vacuum solution; GR-16, Durban, July

Field theories from relativistic law of motion; GR-16, Durban, July

N. Dadhich, *Non-conformally flat bulk spacetime and the 3-brane world*; GR-16, Durban, July

Why do naked singularity occur?; GR-16, Durban, July

The solution dual to Kerr solution, Field Theoretic Aspects of Gravity - II, Ooty, October 2-10

Gravitational filed of a rotating particle having both gravoelectric and gravomagnetic charge, Workshop on Interface of Gravitational and Quantum Realms- I, IUCAA, Pune, December 16-21

How to make the Schwarzschild field Machian, International workshop on Mach's Principle, IIT, Kharagpur, February 6-8

Subtle is the Gravity
QAU, Islamabad, April 25
University of South Africa, Pretoria, June 25
University of Witwatersand, Johannesburg, June 28
S.N. Bose Centre for Basic Sciences, Kolkata, February 11.

Field equations from the relativistic law of motion
University of Witwatersand, Johannesburg, June 29.
University of Natal, August 18.
Calcutta University, February 12.

General axially symmetric stationary electrovac solution
QAU, Islamabad, April 28.
Jadavpur University

Electromagnetics of gravitation
Institute of Mathematical Sciences, Chennai, October 12.

Tapas K. Das

On the formation of accretion powered galactic and extra-galactic jets, Astronomy Department, Osmania University, Hyderabad, February 22.

Shock formation in blackhole accretion and related phenomena, Astronomy Department, Osmania University, Hyderabad, February 21.

On the formation of accretion powered galactic and extra-galactic jets, (TPSC Lecture), School of Physics, Hyderabad Central University, Hyderabad, January 16.

Accretion and Outflow around massive blacholes, Jadavpur University, Calcutta, December 28.

On the formation of accretion powered extra-galactic radio jets,Indian Institute of Science, Bangalore, November 15.

Accretion and outflows around compact astrophysical objects, School of Physical Sciences, Jawaharlal Nehru University, Delhi, October 19.

The hole, the disc and the jet: A coexisting trio at the centre of active galaxies, Colloquium presented at the School of studies in Physics, Pt. Ravishankar Shukla University, Raipur, July 5.

Blackhole accretion and related outflows, Deparment of Mathematics and Applied Physics (DAMTP), University of Cambridge, UK, June 12.

Some aspects of relativistic outflows, Blacket Laboratory, Imperial College of Science and Technology, UK, May 23.

Accretion processes around blackholes and related phenomena, School of Mathematical Sciences, Astronomy Unit, Queen Mary and Westfield College, University of London, May 18.

Modelling the origin of astrophysical outflows from galactic and extra-galactic sources powered by accreting compact objects, Jadavpur University, April 11.

S. V. Dhurandhar

Gravitational wave astronomy: Recent Advances, 21st meeting of the Astronomical Society of India held at IUCAA, Pune, February 8.

Group talk in Kip Thorne's meeting: *LISA data analysis* *by the algebraic approach,* Physics Department, Caltech, Pasadena, U. S. A., May 24.

The extended hieararchical search for inspiraling compact binaries, Physics Department, Caltech, Pasadena, U. S. A., May 29.

The extended hierarchical search for inspiraling binaries and LISA data analysis, National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan January 24.

Ranjan Gupta

Application of artificial neural networks to stellar spectra and interstellar extinction and its modeling at Physics and Astronomy Department, University of Wisconsin at Oshkosh, Oshkosh, USA, Oct 31 and Nov. 1

IUCAA 2 meter Telescope and its First Light Instrument IFOSC, 21st ASI meeting, IUCAA, February 5-8.

Astronomical instruments for photometry and programmes, IInd Level, 2nd Workshop on Astronomical Photometry, IUCAA, Nov. 21-23.

Ajit Kembhavi

Photometric plane of galaxies, University of California, Los Angeles, USA, April 3.

Galaxy morphology, Caltech, USA, April 4.

The formation of galactic bulges and the photometric plane, Raman Research Institute, Bangalore, June 8.

Derivables of the school system, Egurucool, Delhi, July 2.

Quasar host galaxies, TIFR, Mumbai, September 12.

Galaxies, Pt. Ravishankar Shukla University, Raipur, September 27-30.

The new planets - have discovered new worlds, Tribhuvan University, Kathmandu, Nepal, October 3-4.

The new planets - have discovered new worlds, Indian Association of Physics Teachers, Goa, October 7.

Stellar physics, H.N.B.G. University, Srinagar-Garhwal, October 18-22.

The world of galaxies, Venkatagiri Rajah's College, Nellore, December 11.

The world of blackholes, Venkatagiri Rajah's College, Nellore, December 12.

Image processing with computers, Venkatagiri Rajah's College, Nellore, December 12.

The universe of galaxies, Karnatak University, Dharwad, December 26.

Blackholes in binary stars, Karnatak University, Dharwad, December 26.

The nature of ultra-high frequency-selected flat spectrum radio sources, Indo-French Meeting, NCRA, Pune, December 7.

Stellar Mass Blackholes, North Bengal University, Siliguri, January 11.

The physics of stars, Science College, Siliguri, January 12.

Black holes in Binary x-ray sources, 1st Astrosat Workshop on Pulsar Astrophysics, TIFR, Mumbai, February 12.

Virtual Observatory, Maharshi Karve Stree Shikshan Samstha's Cummins College of Engg., Pune, March 23.

The Virtual Observatory project, TAUVEX workshop, IIA, Bangalore, April 1.

Sushan Konar

Generation and Evolution of magnetic Fields of Neutron Stars - High-Energy Astrophysics Department, Nijmegen University, Nijmegen, The Netherlands, September 28.

Magnetic field evolution of accreting neutron stars - Max-Planck Institute for Astrophysics, Garching, Germany September 27.

Magnetic Fields of Neutron Stars - Astronomy Department, University of Tuebingen, Tuebingen, Germany September 25.

Diamagnetic Screening of Magnetic Fields - AIP, Potsdam, Germany, September 20

Photon propagation in magnetised medium - "5th Workshop on Quantum Field Theory under the Influence of External Conditions", University of Leipzig, Leipzig, Germany, September 11.

Effective charge of neutrinos - Theory Group, Raman Research Institue, Bangalore, July 26.

MHD of accreting neutron stars - Physics Department, Indian Institute of Science, Bangalore, July 23.

J. V. Narlikar

Cosmic illusions Department of Maths, Applied Maths and Astronomy, University of South Africa, Pretoria, South Africa, June 26.

Some conceptual problems in general relativity, Department of Mathematics, University of Witwatersrand, Johannesburg, South Africa, June 28.

Do astronomical observations require new physics? 46th Annual Conference of the South African Institute of Physics , University of Durban, South Africa, July 5.

Do astronomical observations sometimes require new physics? "Current Issues in Theoretical Physics" , Cochin University, Cochin, July 30.

An experiment to look for micro-organisms in the Earth's atmosphere , University of Pune, August 25.

An alternative interpretation of CMBR , Dedication of the Indian Astronomical Observatory at Hanle being organized by the Indian Institute of Astrophysics, IIA Bangalore,) August 30.

Do astronomical observations require new physics?, National Centre for Biological Sciences, Bangalore, August 31.

CMBR in the quasi-steady state cosmology, Insitute of Astronomy, Cambridge, U.K., September 19.

Some conceptual problems in general relativity and cosmology, Queen Mary and Westfield College, University of London, U.K., September 25.

Structure and composition of the milky way, Introductory School on Astronomy and Astrophysics, Rajarshi Shahu Mahavidyalaya, Latur, October 15.

Galaxies and active galactic nuclei Introductory School on Astronomy and Astrophysics, Rajarshi Shahu Mahavidyalaya, Latur, October 15.

The world of telescopes, Workshop on Telescope Making, IUCAA, November 8.

Small scale fluctuations of the CMBR in the quasi-steady state cosmology, Institute for Astronomy, Hawaii, March 6.

Elements of cosmology, Refresher Course, R.P. Gogate College of Arts and Science, Ratnagiri, March 23.

T. Padmanabhan

Statistical mechanics of gravitating systems and gravitational clustering, Institute of Astronomy, Cambridge, May 22.

Conceptual issues in quantum gravity, Department of Physics, University of Portsmouth, UK, May 24.

Energy densities in the universe, Institut D'Astrophysique, Paris, June 14.

Non-linear gravitational clustering, Institut D'Astrophysique, Paris, June 15.

Cosmic inventory of energy densities: Issues and concerns, The XIIIth Rencontres de Blois entitled "Frontiers of the Universe", Blois, June 19.

Combining general relativity and quantum theory: points of conflict and contact, The University of Cape Town Cosmology Conference on the Early Universe and Cosmological Observations: A Critical Review, Cape Town, July 25.

Cosmological constant and dark energy, Center for Philosophy and Foundations of Science, Delhi, August 20.

CMBR: Smoking gun in cosmology, Indian Institute of Astrophysics, Bangalore, November 20.

A new era in cosmology, Indian Space Research Organization, Bangalore, November 27.

Temperature and entropy of spacetimes with horizons, Workshop on the Interface of Gravitational and Quantum Realms, IUCAA, December 18.

Issues related to thermodynamics of horizons, Indo-Russian International Workshop on Integrable Models, Strings and Quantum Gravity, Institute of Mathematical Sciences, Chennai, January 19.

Cosmological constant: Is it for real?, Institute of Mathematical Sciences, Chennai , January 21.

Arvind Paranjpye

Extinction measurement and photometer calibration, Second Level, IInd Workshop on Astronomical Photometry and Astronomy with small Telescopes, IUCAA, November 21.

Occultation observations, Second Level, 2nd Workshop on Astronomical Photometry and Astronomy with small Telescopes, IUCAA, November 22.

A. N. Ramaprakash

Near infrared PICNIC imager (NIPI) for IUCAA telescope, 21st meeting of the ASI, IUCAA, Pune, February 5 -8.

Anand Sengupta

EHS algorithm for detection of gravitational waves from inspiralling compact binaries, 4th E. Amaldi Conference on Gravitational Waves, University of Western Australia, Perth, July 8 - 15.

Gravitational wave search strategies, Symposium on Cosmology and Astrophysics, Jamia Milla Islamia, New Delhi , September.

Varun Sahni

The cosmological constant problem and quintessence, The Early Universe and Cosmological Observations: a Critical Review, Cape Town, South Africa, July.

Dark energy, Moscow State University, Russia, October.

S. Shankaranarayanan

Vanishing of cosmological constant in non-factorizable geometry, GR-16, Durban, S. Africa, July 17.

Method of complex paths and covariance of Hawking radiation, GR-16, Durban, S. Africa, July 20.

Aspects of blackhole physics - Entropy, Field Theoretic Aspects of Gravity - II, Radio Astronomy Centre, Ooty, India, October 8.

P. Singh

Quantum phase shifts in gravity, Department of Physics, University of Delhi, April 12.

Semi-classical States in the context of constrained systems, Field Theoretic Aspects of Gravity FTAG- II, Radio Astronomy Centre, Ooty, October 5.

Tarun Souradeep

Elementary introduction to cosmic topology and the microwave background, American Mathematical Society Meeting, Williamstown, MA, U.S.A., October 13.

Measuring statistical isotropy of the cosmic microwave background, research, American Mathematical Society Meeting, Williamstown, MA, U.S.A., October 14.

Probing cosmic topology with the cosmic microwave background, Department of Physics, CWRU, Cleveland, OH, U.S.A., October 16.

CMB anisotropy experiments with non-circular beam, Canadian Institute for Theoretical Astrophysics, Toronto, Canada, October 29.

Cosmic topology and the cosmic microwave background, Department of Physics, University of Alberta, Edmonton, Canada, October 29.

Early universe physics from precision cosmology, WHEPP-7, Harish Chandra Research Institute, Allahabad January 4.

R. Srianand

Molecules at high redshift, IAP Colloquium, Paris, June 23.

Molecular hydrogen in the Damped Lyman alpha systems, IOA Cambridge, August 16.

Temperature of the CMBR, 21st Meeting of the Astronomical Society of India, IUCAA, February 7.

Science with IUCAA telescope, 21st Meeting of the Astronomical Society of India, IUCAA, February 7.

S. Sridhar

Physical processes in galactic nuclei, Raman Research Institute, Bangalore, April 12

P. Subramanian

Observations of the Sun with the Giant Metrewave Radio Telescope, at 'Probing the Sun with High Resolution', A meeting to celebrate 25 years of the Udaipur Solar Observatory, Udaipur, October 16-19.

Source regions of coronal mass ejections and GMRT observations of the Sun, Indian Institute of Astrophysics, Bangalore, April 4.

S. N. Tandon

Electronic detectors for light, Refresher Course on Experimental Physics, Goa University, November 3.

(b) Lecture Courses

J. Bagchi

Astronomical imaging techniques, IUCAA Refresher Course 2001 (4 lectures) May-June.

Radio astronomy, Introductory School on Astronomy and Astrophysics, Rajarshi Shahu College, Latur, (4 lectures), October 16-19.

Naresh Dadhich

Blackholes and electromagnetics of gravitation, Workshop on String Theory, National Centre for Physics, QAU, Islamabad, 23 April - 5 May (3 lectures).

General relativity, School on General Relativity and Field Theory, Charal Mount, Kozencherry, May (10 lectures).

Gravitation, Shivaji College, Nagpur, Febuary 14 -15 (2 lectures).

Tapas K. Das,

Compact objects and high energy astrophysics, Introductory School on Astronomy and Astrophysics, held at Latur, October 13-16 (5 lectures).

Ranjan Gupta

Observational techniques, Refresher Course in A & A for College and University Teachers, IUCAA May 14 - June 15, (10 lectures)

Astronomical Spectroscopy, Workshop on Fundamentals of A & A at V.R. College, Nellore, September 8-10 (3 lectures).

Astronomical observations, basic concepts, photometry and spectroscopy, Assam University, Silchar, UGC Refresher course, December 18 (2 lectures).

Spectroscopy in astronomy, Workshop on Photometric Data Reduction and Analysis, January 14 - 18 (3 lectures).

Ajit Kembhavi

The Milky Way and other galaxies, UGC Refresher Course, IUCAA, June 4-7 (5 lectures).

*Active Galactic Nucle*i, BARC, Mumbai, July 30-Aug.1 and November 21-22 (6 lectures).

S*tellar photometry*, Workshop on photometric data reduction and analysis, J.E.S. College, Jalna, January 14-15 (3 lectures).

Sushan Konar

Final stages of stellar evolution, School on Astronomy & Astrophysics, H.N.B.G University, Srinagar-Garhwal, October 18 -22 (3 lectures)

J. V. Narlikar

Cosmology, Mumbai University, January 13-25 (15 lectures).

T. Padmanabhan

Cosmology and structure formation, RRI, Bangalore November 12 - December (6 lectures).

Arvind Paranjpye

Astronomical observations for school and college teachers, Workshop on observational astronomy at Chennai Planetarium, Chennai, August 17 - 18 (5 lectures)

Solar system, Introductory School on Astronomy and Astrophysics, Latur, October 15-19 (5 lectures)

Making and teaching - how to make an amateur astronomical telescope, Workshop on Telescope Making, IUCAA, October 29 - November 15 (10 lectures)

A.N. Ramaprakash

An introduction to astronomical techniques, Refresher Course in Astronomy and Astrophysics for College and University Teachers, May 14 - June 15, IUCAA, Pune, (10 lectures)

Coordinates, distances and magnitudes, Introductory School on Astronomy and Astrophysics, Rajarshi Shahu College, Latur, October 15 - 19 (4 lectures)

Tarun Souradeep

Observations and statistics in cosmology, Introductory School on Cosmology, Harish-Chandra Research Institute, Allahabad , December 22 -30 (8 lectures)

Introductory cosmology, group of KVPY scholar school students visiting IUCAA, June, (2 lectures)

R. Srianand

Probing the universe with absorption lines, in Osmania University, Hyderbabad, March 11, (2 lectures)

S. Sridhar

Dynamics of galaxies and their nuclei, Raman Research Institute, Bangalore, April (3 lectures)

(c) Popular Lectures

J. Bagchi

Extrasolar Planets, (a lecture for VSP and Refresher Course participants)

Tapas K. Das

The monster in the middle and his smoking gun: How massive blackholes fuel the cosmic power-houses, IUCAA Science Day, February 28.

Naresh Dadhich

Relavitistic world: A farmer's perspective, Presidency College, Kolkata, February 13 ; Janakibai Bajaj College, Sewagram, February 15.

Science: method and vision,
QAU, Islamabad, April 27.

Ranjan Gupta

Is Shatabdi ki doorbeene (in Hindi) IUCAA Science Day, February 28.

Ajit Kembhavi

Wonders and accidents in space, Shri Shiv Chattrapathi College, Junnar, August 6.

Planets outside the solar system, IUCAA, August 11 (1 lecture each in English and Marathi).

Visions of the universe- from the eye to the computer, IUCAA, August 25.

The new planets, H.N.B.G. University, Srinagar-Garhwal, October 18.

The new planets, Workshop on Photometric Data Reduction and Analysis, J.E.S. College, Jalna, January 14.

Motion of planets, National Institute of Ophthalmology, Pune, March 17.

J. V. Narlikar

Recent developments in cosmology, lecture delivered under the Distinguished Lecture Series 2000-2001 in the Physics Auditorium, Panjab University, Chandigarh, April 9.

Cosmic illusions, lecture organized by the Exploratory at IUCAA, April 21.

Avakashatil dhristibhram (Cosmic illusions) (in Marathi), lecture organized by the Exploratory at IUCAA, May 5.

Anomalous observations in astronomy - special evening talk at the VSRP/VSP 2001 at IUCAA, May 22.

Myths, beliefs and facts in astronomy, public lecture delivered at the University of Natal in Pietermaritzburg, July 12.

Anomalous observations in astronomy, non-technical talk delivered to the Amateur Astronomical Society in Durban, July 12.

The lighter side of gravity, public lecture delivered at the 16th Meeting of the International Society on General Relativity and Gravitation (GR-16), International Convention Centre, Durban, South Africa, July 16.

Cosmic illusions, lecture for the school students at IUCAA, July 21.

Antaralatil drishtibrham (Cosmic illusion) (in Marathi), lecture for the school students at IUCAA, July 21.

The physics-astronomy frontier, lecture for the junior college students at IUCAA, July 28.

Is God left handed, lecture delivered on the occasion of "International Left-Handers Day", organized by the Association of Left Handers, Amphi Theatre, Fergusson College Campus, Pune, August 13.

The search for extra-terrestrial intelligence, Hindustan Lever Research Centre, Bangalore, August 31.

Latest developments in astronomy and astrophysics, National Defence Academy, Pune, September 5.

Life in the universe, public lecture delivered in the Sky Theatre, Nehru Planetarium, Mumbai, September 12.
Prithvi baher Jeevshristicha shodh (The search for extra-terrestrial intelligence) (in Marathi), public lecture delivered at the Rajarshi Shahu Mahavidyalaya, Latur, October 16.

Vidnyanatale rushi-maharshi (Good teachers and scholars in science) (in Marathi), Ramtirthkar Memorial Lecture organized by the ICICI Traning Institute, Pune, December 9.

The contributions of space technology to modern astronomy, Vikram Sarabhai Memorial Lecture, Indian Institute of Management, Ahmedabad, January 3.

The trials and excitement of setting up a scientifc institution, The first TIFR Alumni Association Public lecture delivered at the Tata Institute of Fundamental Research, Mumbai, January 16.

Recent advances in astronomy, an endowment lecture in memory of Smt. Pilloo H. Irani, Gulbarga University, Gulbarga, January 19.

Prithvi palikade Jeevshristicha shodh (The search for extra-terrestrial intelligence) (in Marathi) Late Sahebraoji Buttepatil Memorial Lecture, Rajgurunagar, January 30.

Convocation address delivered at the Netaji Subhas Institute of Technology, New Delhi, February 20.

Current speculations about the origin of the universe , lecture deliverd at the India International Centre, New Delhi in the lecture series "Dimensions of Science" jointly organized by the National Institute of Science, Technology and Development Studies and the India International Centre, February 20.

Exciting developments on the frontiers of cosmology and particle physics, First Abdus Salam Memorial Lecture, Jamia Millia Islamia, New Delhi, February 21.

Challenges and benefits of studying astronomy, Jawaharlal Nehru Birth Centenary Award Lecture, Indian Science Congress Association, Calcutta, March 21.

T. Padmanabhan

New revolution in cosmology, Center for Philosophy and Foundations of Science, Delhi, August 20.

Recent advances in cosmology, Workshop on Telescope Making, IUCAA, Pune, November 5.

Cosmology: A new era, 21st Meeting of the Astronomical Society of India, IUCAA, Pune , February 8.

Arvind Paranjpye

How Foucault showed that the Earth is rotating? Vidya Prathishtan's English Medium School, Baramati, April 4.

Ekvisave Shatak ani Andha-shradha Nirmulan, Maharashtra Andha-Shradha Nirmulan Samiti, Pune Branch, April 10.

Why astrology is not a science? Rotary Club of Pune Ganeshkhind, June 2001.

Khagol Shastra ani andha shradha, AniS, Aurangabad, July 29.

Pruthvi la baherun dhoka, J. E. S. College, Jalna, September 16.

Chanda akash nirikshana cha, C. T. Bora College, Shirur, December 1.

A.N. Ramaprakash

Our beautiful universe through telescopes, Saturday lecture for Junior College Students, IUCAA, December 22.

Engineers in astronomy, Talk and panel discussion at Sinhgad College of Engineering, Pune, February 14.

Work in IUCAA instrumentation laboratory, Talk given to engineers and technicians from VSNL, IUCAA, Pune March 12.

P. Subramanian

The solar corona, Saturday talk for school students, IUCAA, February 26.

S. N. Tandon

Colours of rainbow and cloud, in Hindi and in English, to School Students in Chandrasekhar Auditorium, IUCAA, September 8

R. G. Vishwakarma

Theory of Indian calendars, National Science Day, IUCAA, February 28 .

(d) Radio / TV programmes

S. V. Dhurandhar

Search for gravitation waves, During the Amaldi conference on gravitational waves, 8 - 13 July, in Australia,

Ajit Kembhavi

Search of new planets (Marathi), AIR, Pune, April 26.

J. V. Narlikar

Jimmedar Kaun?, SAB Channel, June 17.

Samorasamor, Mumbai Doordarshan, Sahyadri Channel, August 12.

Paragrahasth Jeevsrushti, All India Radio, January 5.

Arvind Paranjpye

Soorya Grahan June 21, 2001 ka, B.B. C. Hindi service "Gyan Vigyan' Phone-in June 30.

Chandra Grahan Phone in for Zee News, July 5

Aaple Vishwa - Balchitravani, August 1. (three repeat telecasts)

Chandra - Balchitravani, August 2. (three repeat telecasts)
Grahane - Balchitravani, August 15. (three repeat telecasts).

Doosare ghrahon se jeevshrushiti ka aagaman , B.B.C. Hindi service "Gyan Vigyan' Phone-in August 4.

(VIII) SCIENTIFIC MEETINGS

School Students' Summer Programme 2001

Some of the participants of the School Students' Summer Programme 2001

This year's School Students' Summer Programme was held between April 16 and May 25, 2001. Schools in greater Pune were invited to nominate two scientifically motivated students each, and about 150 students from 75 schools participated in this programme. Every week, a new batch of 26 students was invited to work on a project at IUCAA from Monday to Friday. Groups of four to six students were attached to individual guides. This programme has no set syllabus or course guidelines. The students and the guide worked out their schedule for the week.

During the week, the students went through other activities too. They watched scientific films and visited the Science Park. The students also had free access to the IUCAA library. One day of the week was assigned for question and answer session with Ajit Kembhavi.

On the last day for each batch, the students were asked to give an oral presentation of their work, in addition to submitting a written report. This presentation was followed by a send off party. Students were encouraged to avoid bookish phrases and flowery language in their presentations, and to stress scientific facts. Barring a few incidences, presentations were in true scientific spirit. The friendly atmosphere at IUCAA made students bold enough to make constructive criticisms.

Students were also asked for their opinions about the programme. Important suggestions made by them were that the programme for each batch of students should be longer in duration and that debates and group discussions should be included. It was also suggested that similar programmes should be conducted in individual schools for the benefit of larger number of students.

Projects done by the students included Foucault's pendulum; lenses, mirrors and prisms; telescopes and microscopes; solar system; Kepler's laws; Doppler effect; luminosity and temperature; Hubble's law, Olber's paradox, Achilles and the tortoise; non-Euclidean geometry; combinations; calculus; number system and percolation. Most of the students read introductory books on astronomy and other popular science books.

V. Chellathurai, Ranjan Gupta, Vinaya Kulkarni, Jayant V. Narlikar, T. Padmanabhan, Arvind Paranjpye, Anand Sankar Sengupta, T. Souradeep, Arun V. Thampan, Thierry Morel and R.G. Vishwakarma acted as guides for the students.

Vacation Students' Programme (VSP)

The Eleventh Vacation Students' Programme (VSP) was held in IUCAA during May 21-July 6, 2001. Ten students in the penultimate year of their M.Sc. (Physics) and Engineering degree course were selected from over 75 applicants from various Indian universities, IITs and engineering institutes. A number of IUCAA's visiting associates made special efforts to encourage their students to apply and helped the selection procedure by thoughtfully written recommendation letters. Depending on their aptitude and interest, each student chose the research project to work during the programme from a selection offered by the IUCAA faculty members and postdoctoral fellows. The students displayed a lot of enthusiasm and made good use of the IUCAA facilities and resources. They interacted freely with the IUCAA graduate students, postdocs, visitors and faculty members during their stay. The average quality of project work and its presentation was quite good. The students also attended over 40 expository lectures given by members of NCRA, IUCAA (including Visiting Associates of IUCAA) on a broad range of topics in Astronomy and Astrophysics. The lectures included six special evening seminars. The lectures were jointly organised with the Vacation Students' Research Programme (VSRP) of NCRA. During their stay, day trips were also organised to see the IUCAA's 2-meter telescope site and the Giant Meterwave Radio Telescope (GMRT) near Pune. Tarun Souradeep was the faculty coordinator for this programme.

Refresher Course in Astronomy and Astrophysics

Twenty five teachers selected from postgraduate departments of colleges and universities spread all over the country spent five weeks, between May 14 and June 15, 2001 in IUCAA, participating in the Refresher Course in A & A for College/University Teachers. Joydeep Bagchi and A. N. Ramaprakash were the faculty coordinators.

A coherent series of 30 lectures on introductory astronomy and astrophysics, and observational techniques formed the backbone of the course. There were also a number of one or two lecture courses each covering a specific topic of current interest in Astronomy. The lecture sessions were in the forenoons, while the afternoons were used for problem solving sessions, laboratory experiments, demonstrations (CCDs, image processing, accessing data over the internet, etc.), solar observations and video shows (Our Sun, Occultation Observations, etc.). Additionally, the participants were encouraged to attend the evening lectures organised along with the Vacation Students' Programme, on exciting topics in Astronomy. Night sessions were also conducted in which participants, in groups of five or six, were introduced to an equatorial-mount 9 inch telescope and encouraged to practise techniques of aligning, pointing, etc. Attempts to do real sky observations were mostly unsuccessful because of adverse weather conditions preceeding the arrival of monsoon.

An one day trip was arranged on May 26, 2001 to the IUCAA observatory site at Giravali and the Giant Metrewave Radio Telescope site at Narayangaon. Towards the end of the course, feedback forms were distributed and participants were requested to comment on all aspects of their stay including food, accommodation, facilities like library, internet access, etc. From the feedback forms, it was found that the course was successfully conducted to the satisfaction of all participants.

Participants of the Refresher Course in Astronomy and Astrophysics

Workshop on Structure and Dynamics of Galaxies

A workshop on Structure and Dynamics of Galaxies was organised in the School of Studies in Physics, Pt. Ravishankar Shukla University, Raipur during September 24 - 27, 2001, sponsored by IUCAA and the University. Speakers included R. K. Thakur, A. K. Kembhavi, U. C. Joshi, D.K. Sahu, S. N. Hasan, A. K. Sapre, D. K. Chakraborty and S. K. Pandey. In addition to about 15 outstation participants, a large number (30-40) of M.Sc. students from Raipur as well as from Bhilai / Durg and about 10 college / school teachers and students of the Education College also participated in the workshop. There were a series of review lectures covering large scale structure in the universe, classification of galaxies, Milky way and interstellar medium, normal and active galaxies, quasars and AGNs, starburst galaxies, dynamics of galaxies and image processing techniques in astronomy with a view of introducing the subject matter to M.Sc. students and young college/school teachers. Remaining lectures were research oriented and were focussed on specialized topics in structure and dynamics of galaxies. Some participants also gave seminars on their research work. During the course of the workshop, popular lectures of A. K. Kembhavi and U. C. Joshi were also organised at Government College, Durg and Government Education College, Raipur. Professor R. K. Thakur, former head, School of Studies in Physics, Pt. Ravishankar Shukla University was felicitated during the inaugural function of the workshop remembering his dedicated efforts in initiating and strengthening teaching and research in the area of Astronomy and Astrophysice in the University.

A. K. Kembhavi and S. K. Pandey were coordinators of the workshop.

Participants of the Workshop on Structure and Dynamics of Galaxies

Participants of the Liquid Mirror Telescopes: An Indian Perspective

Brainstorming Session on Liquid Mirror Telescopes: An Indian Perspective

A brainstorming session on Liquid Mirror Telescopes (LMT) was held at IUCAA during August 27-28, 2001. The main resource persons for this session were Paul Hickson and Ermanno Borra from Canada, who were the pioneers of this type of telescopes. They covered all aspects of such telesopes in about 10 lectures, which were very informative for the Indian participants. About 25 participants attended this session. There was ample representation from the university sector, i.e., Allahabad University, Delhi University and Bhavnagar University. Several astronomy and upper-atmosphere research institutions like NPL, USO, UPSO, IIA, NCRA, IUCAA and ISRO were also represented and some of them made presentations on how an Indian LMT can be used fruitfully. Towards the end of the session, a working group was formed, which will make a proposal to different funding agencies (including ISRO) for fabricating an Indian LMT.

This activity was initiated by A. K. Gupta from Allahabad University and sponsored by ISRO. A.N. Ramaprakash and Ranjan Gupta from IUCAA were the coordinators of this session.

Introductory School on Astronomy and Astrophysics

The Introductory School on Astronomy and Astrophysics was held at Rajarshi Shahu College, Latur during October 15-19, 2001 and began with a key note address delivered by J.V. Narlikar, Director, IUCAA. P.R. Deshmukh,

Director, Shiv Chhatrapati Shikshan Sanstha to which Rajarshi Shahu College belongs, was in chair and Principal R.L. Kavle was also present at this occasion. In addition to J.V. Narlikar, J. Bagchi and A.N. Ramaprakash (the Coordinators from IUCAA), Tapas K. Das, Arvind Paranjpye, M.K. Patil and A.C. Kumbharkhane have also contributed to the programme. Most of the topics covered were meant for undergraduate level students and some for M.Sc. students. Teachers who attended the school benefitted significantly.

In conjunction with the school, two lectures by J.V. Narlikar and one by Arvind Paranjpye were arranged under the science popularisation programme. These lectures and one interview were well received by the students and citizens of Latur. For the interview with J.V. Narlikar, the questions were collected from the local schools and colleges and there was an overwhelming response from the students and teachers. Arvind Paranjpye conducted a programme of sky watching. There were 85 participants, including local residents.

Participants of the Mini-School on Astronomy and Astrophysics

Mini-School on Astronomy and Astrophysics

A Mini -School on Astronomy and Astrophysics sponsored by IUCAA was organized by the Department of Physics, H.N.B. Garhwal University (HNBGU), Srinagar-Garhwal, Uttaranchal, during October 18-22, 2001. The university had recently introduced astronomy and astrophysics as a compulsory part of its M.Sc. physics course. One of the aims of the school was to provide a short term refresher course to the teachers of the universities/colleges, to enable them to tackle the new course they were beginning to teach. The school also provided an opportunity to M.Sc. physics students as well as research scholars from the region to be introduced to some of the exciting recent developments in the subject. Participants at the school were drawn from Garhwal, Kumaon, Pantnagar, Avadh and Delhi universities. There was a large representation of students and faculty from the host department.

The topics covered at the school included Stellar Structure and Evolution, Neutron Stars and Pulsars, Binary Stars, Solar and Planetary Physics, General Relativity and Physical Cosmology. At least three lectures were delivered by each resource person and summaries of important ideas and recent developments were provided. There was a significant amount of discussion following each lecture and there was close interaction between participants and the lecturers over the period of the school. The speakers/lecturers included Naresh Dadhich (IUCAA), M.K. Das (Sri Venkateswara College, Delhi University), D.C. Joshi (HNBGU), Ajit Kembhavi (IUCAA), Sushan Konar (IUCAA), S.Mukherjee (North Bengal University), Purohit (HNBGU) and L.M. Saha (Zakir Husain College,
Delhi University). Popular level talks on "The New Planets" by Ajit Kembhavi and on "Murmuring Mountains" by A.N. Purohit, Vice Chancellor of HNBGU were also delivered during the school. K.D. Purohit was the coordinator from the host university and Ajit Kembhavi was the coordinator from IUCAA.

Regional Workshop on General Relativity and Gravitation

A Regional Workshop on General Relativity and Gravitation was held in the Department of Physics, University of Kalyani during November 21-22, 2001. There were 35 participants at the workshop, out of which 10 were from universities and colleges from outside the Kalyani region. There were 12 invited speakers. The workshop was inaugurated by the Vice-Chancellor, Kalyani University and the academic session was started with a key note address by A.K. Raychaudhuri.

In the classical gravitation and cosmology section of the workshop, various lecturers spoke about accretion of matter onto blackholes, blackholes no hair theorem, Noether symmetry approach to cosmology, possiblity of inflation with arbitrary initial conditions, formation of voids, and inhomogeneous cosmological models with energy flux. In the quantum gravity and quantum theory of curved space-time section, the speakers talked on instanton solutions in higher dimension in connection with Hawking-Turok instanton, quantization of fourth order gravity theory, preheating and reheating mechanism in early universe through the method of CWKB, unification of the string theory calculations in low energy limit through Sagnac effect.

There was also a talk on future experimental and observational work with the 14" telescope of Assam University, Silchar. All those who attended the workshop, including young research students from the universities actively participated in the discussions following the lectures. Somenath Chakrabarty from the Physics Department of Kalyani University, who is a Visiting Associate of IUCAA, was the Coordinator of the workshop.

Participants of the workshop on Fundamentals of Astronomy and Astrophysics

Workshop on Fundamentals of Astronomy and Astrophysics

A workshop on Fundamentals of Astronomy and Astrophysics was held at V.R. College, Nellore during September 8 - 10, 2001 with the financial support from IUCAA.

The lectures were delivered by Ranjan Gupta (IUCAA), K.S.V.S. Narasimhan (Chennai), H.P. Singh (Delhi University), B.A. Kagali (Bangalore Unviersity), N. Udaya Shankar (Raman Research Institute, Bangalore), S. P. Bagare (Indian Institute of Astrophysics) and R. Ramakrishna Reddy (S.K. University, Anantapur).

A local organizing committee was formed with D. Gopal Krishna Murthy (Principal, V.R. College) as the Chairman. There were about 60 participants, out of which 26 were from outside and the rest were local participants.

The workshop was inaugurated by K. Narayana (Director, SHAR Centre, Department of Space, Sriharikota) on September 8, 2001. He delivered the inaugural address on Astronomy. There were totally fourteen lectures and it was worth noting that besides the selected participants, about 40 others also attended the lectures on all the three days.

All the participants have appreciated the lectures and the way the workshop was conducted. The participants have unanimously suggested to have some demonstration classes during such workshops.

Second Level, 2nd Workshop on Astronomical Photometry and Astronomy

The second level, second workshop on Astronomical Photometry with small Telescopes was conducted at IUCAA during November 21 - 23, 2001. Once again, the aim of the workshop was to get feedback from those participated in the first level workshop in which they made their photometer at IUCAA. Eight participants were invited to attend this workshop and were requested to bring the photometer made by them. Vilas Mestry checked the photometer and one of the photometer required minor adjustment.

S. N. Tandon, Ranjan Gupta, D.B. Vaidya and Arvind Paranjpye gave talks on the issues related to astronomical photometry. Every participant was also invited to present the works carried out by him or her using the photometer. Credible was the effort by Umesh Dhodia from Bhavnagar University, who used the photometer for variable star observations and for estimating the brightness of the night sky. P. Nagaraju from Vijaya College, Bangalore talked about his use of the photometer in the laboratory experiments.

An overnight trip was organized to Wai, a place about 100 k.m. south of Pune for actual observations. On November 23, Ranjan Gupta moderated a discussion on coordinated observing programme. It was agreed by the participants that they would initiate a regular night sky monitoring programme. The workshop was conducted by Ranjan Gupta and Arvind Paranjpye.

Workshop on Interface of Gravitational and Quantum Realms

Participants of the Workshop on Interface of Gravitational and Quantum Realms

A cosy and intimate meeting was organized at IUCAA during December 17-21, 2001 to discuss the current problems in the emerging interface between gravitational and quantum realms. It was a collection of about 30 active workers, drawn from both home and abroad, and the speakers included D.V. Ahluwalia, J. Anandan, N. Dadhich, G. Date, N. Firsova, T.R. Govindarajan, N.D. Haridas, V. Husain, P. Joshi, S. Kar, U. Mohrhoff, S. Mukherjee, T. Padmanabhan, S. Sarkar, L. Sriramkumar, D. Sudarsky, C.S. Unnikrishnan, L. Urrutia, M. Visser and U. Yajnik. The topics covered a wide spectrum including concerns and effects centred on blackholes, cosmology and interplay between gravitational and quantum realms and its astrophysical and experimental consequences; and also the questions of non-locality and particle propagation.The proceedings of the workshop will be published as a special issue of Modern Physics Letters A.

The meeting was conceived by D.V. Ahluwalia and Naresh Dadhich . The format of the meeting was quite informal, where the speaker was asked to chair his own talk and it worked wonderfully. It was also discussion promoting, not only by extensive use of the black board but also with a generous provision of 90 minutes for most talks. The IUCAA kund provided an excellent venue for informal discussions. Participants were very happy and felt quite charged to continue this series with a frequency of about 2 years.

Workshop on Telescope Making

A Workshop on Telescope Making was conducted at IUCAA during October 29 - November 15, 2001. Eighteen teams of two members each participated in this workshop from different parts of India. All the teams made reflecting telescope of 150 mm diameter primary mirror. The optical configuration of the telescopes was Newtonian and the telescopes were mounted on an altazimuth mount. The participants have taken the completed telescopes to their respective organizations.

On October 29th, the workshop started with Jayant Narlikar's brief welcome address. Ajit Kembhavi gave an overview of the workshop and also encouraged the participants to interact with IUCAA faculty and to make best use of the facilities here. In his talk, Ajit Kembhavi told the participants that the telescope that they would be making would become a powerful instrument in taking science to public, which was the need of the day.

Vinaya Kulkarni guided the participants and supervised every stage of making the telescopes. A target was set for every day and it was mandatory for every pair to achieve that goal before calling it 'a day'. Participants followed the instructions and achieved the goal enthusiastically. Tushar Purohit, a local amateur astronomer who made his telescope in IUCAA, helped Vinaya.

The aim of the workshop was not limited to participants making their own telescope; they were expected to go back and conduct similar activity in their own home town. Evening sessions were conducted by Arvind Paranjpye every day to discuss the progress of the day's work and to clarify any doubts in the minds of the participants. During this session, matters related to common errors and their remedies, different approaches to various stages of making the telescopes, etc. were discussed. Arvind Paranjpye also discussed various observing programmes which could be taken up with the telescopes.

After the grinding and polishing was completed, the mirrors were tested (the process called figuring) by observing the Ronchi patterns. Using a modified web camera, the pattern was displayed on a computer screen. The interpretation of the pattern and corrective measures that were to be taken, if required, was explained to all the participants.

During polishing and figuring stages of mirror making, the participants had relatively less workload. They were invited to attend special evening lectures by IUCAA faculty and the speakers were requested to join them for dinner. Talks by T. Padmanabhan, Jayant Narlikar, S. N. Tandon and Ajit Kembhavi were an intellectual treat for the participants. H. K. Das took interactive session for the participants on computer aided optical designing. The participants also visited the Giant Metrewave Radio Telescope site at Khodad.

A few components of the telescope, such as Newtonian secondary and spider, eyepiece and an altazimuth mount were purchased off the shelf from Tejraj and Co. in Mumbai. The participants made their own mirror cells, cut the tubes and mounted all the components to complete the telescope.

All the telescopes were ready on November 13th and all IUCAA members were invited for an evening high tea, where the participants proudly 'showed off' their prized creation.

On November 14th Ajit Kembhavi gave away the participation certificates in a very informal ceremony. On the occasion, he told the participants that now they have made their first telescope; they should think of bigger projects such as putting these telescope on equatorial mounts and adding sidereal drive to it. He also told them that IUCAA would be very happy to help them in every possible manner. Rabin Chetry from Sikkim University expressed gratitude on behalf of the participants and appreciated IUCAA's efforts.

Participants busy in one of the grinding and polishing sessions of the workshop

Workshop on Photometric Data Reduction and Analysis

Participants of workshop on Photometric Data Reduction and Analysis

A small telescope (12" Meade LX200) with SSP-3A automated photometer (OPTEC) has been obtained by J.E.S. College, Jalna, under a DST supported project sanctioned to M. L. Kurtadikar of the college. With a view to use the telescope for observational work effectively, a workshop on Photometric Data Reduction and Analysis was organized at J.E.S. College, Jalna, during January 14-18, 2002, intended mainly for teachers and M.Sc. students. Thirty one teachers, thirty five students and three amateur astronomers/researchers attended the workshop.

Lectures were delivered on Fundamentals of Astronomical Photometry (Ajit Kembhavi, IUCAA), Spectroscopy in Astronomy (Ranjan Gupta, IUCAA), Variable Stars, Light Curves, Observational Projects (S. K. Pandey, Pt. Ravishankar Shukla University, Raipur), Astronomy Basics, Observational Programmes (P. Vivekananda Rao, Osmania University), Using Small Telescopes for Binary Stars and Comets (N. M. Ashok, PRL), Occultations (T. Chandrasekhar, PRL), Physics in Astronomy (Suresh Chandra, SRTM University, Nanded), CCDs in Astronomy (S. K. Popalghat, J.E.S. College, Jalna) and Astronomical Facilities in India (M. L. Kurtadikar, J.E.S. College, Jalna). A Sky Observation Session was conducted by Nandan Phatak and demonstrations were given by P. Vinu, S.K.Popalghat and M.L.Kurtadikar of J.E.S. College.

A popular talk in Marathi by Ajit Kembhavi, 'Navi Srishti Nave Graha', was also arranged for the public of Jalna in the evening of January 14.

Ninth Meeting of the Scientific Advisory Committee of IUCAA

IUCAA is unique amongst Indian institutions in setting up a review-cum-assessment process for itself, right from the beginning. The Scientific Advisory Committee of IUCAA meets every eighteen months for this purpose. Eight distinguished scientists including three from abroad are nominated to the SAC for a period of three years during which the committee meets twice. Each visit lasts for 4-5 days and includes inspection of facilities, presentations of work by the resident academics as well as by a few visiting associates, discussions with associates as well as staff from different categories, meetings with the Director and the Academic Programmes Committee and informal interactions as well. The present SAC members are listed on page 3 of this Report.

The SAC visited IUCAA during January 7 - 12, 2002 and had very intensive series of meetings and as usual came out with a very perceptive and instructive report which will be debated by the Governing Board. IUCAA has found this exercise of great help in keeping its academic and other programmes on rails. It also helps to know (from an external perspective) what one's strengths and weaknesses are. We thank SAC for carrying out a conscientious job and strongly recommend this exercise to other institutions.

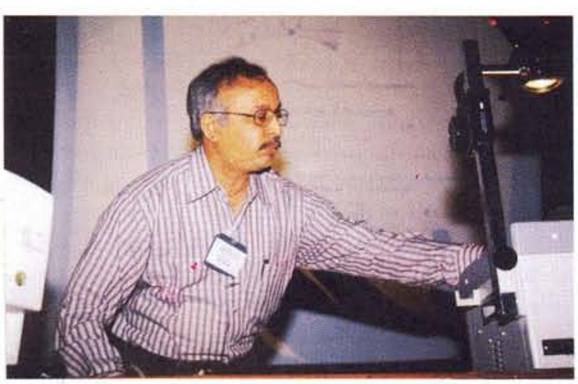
Workshop on Celestial Mechanics and Dynamical Systems

The workshop on Celestial Mechanics and Dynamical systems was conducted during October 8 - 11, 2001 at IUCAA. The idea of holding the above workshop came from Ajit Kembhavi, in view of the recent developments in non-linear dynamics and also celestial mechanics.

About 40 people from within the country and abroad participated in the workshop. W. Unno, M. Takeuti, Y. Tanaka and M. Yuasa from Japan and G.H. Erjee from Iran contributed greatly to the success of the workshop in terms of their own contribution and chairing various sessions of the meeting. W. Unno and M. Takeuti also delivered special lectures. S. M. Alladin, a renowned theoretical astrophysicist and B. Ishwar delivered very useful talks in their respective fields. Several interesting and very useful contributions were made by our young researchers. In fact, the workshop provided a very useful and interactive platform, where our younger colleagues could discuss and present new ideas common to both celestial mechanics and dynamical system theory.

J. V. Narlikar, Director, IUCAA, formally inaugurated the workshop on October 8, 2001 with a brief outline of the significance of this workshop. In all, there were 28 oral and 9 poster presentations. A visit to the IUCAA telescope site was arranged on October 10. In the closing session W. Unno summarised the proceedings of the workshop and it ended with encouraging remarks from Ajit Kembhavi. We thank all the IUCAA faculty and other members of the office, Library, Computer Centre, etc. for providing all the help needed from time to time. The necessary funding was provided by IUCAA, ISRO and CSIR.

The 21st Meeting of the Astronomical Society of India



A lecture session in progress during the ASI

One of the participants putting up a poster during the ASI

The 21st Meeting of the Astronomical Society of India was held during February 5-8, 2002 at IUCAA, Pune. About 180 participants attended the meeting. The scientific programme was rich in texture and had the following components: (a) About seventeen invited plenary talks spread over five sessions dealing with Sun and Solar System, Stars, Our Galaxy, Galaxies and Cosmology, Gravitational Wave Astronomy and High Energy Astrophysics. (b) One day of discussion on the Decadal Vision of Astronomy document, which was being prepared by the panels appointed for this purpose. (c) One session dealing with ASTROSAT and the IUCAA Telescope as well as reports from the activities being carried out at different Observatories. (d) Two public lectures on Cosmology and Lunar Science. In addition, a visit to the IUCAA Telescope and GMRT sites was arranged on February 9.

Financial assistance for this meeting was provided [in addition to funds from IUCAA and ASI] by the following organisations - Council of Scientific and Industrial Research, New Delhi; Department of Science and Technology, New Delhi; Harish Chandra Research Institute, Allahabad; Indian Institute of Astrophysics, Bangalore; Indian Space Research Organisation, Bangalore and Raman Research Institute, Bangalore.

The proceedings of the meeting will be published as a special issue of the Bulletin of Astronomical Society of India.

Public Outreach Programme (2001 - 2002)

IUCAA's Public Outreach Activities are grouped into two parts. Programmes consisting of National Science Day, School Students' Summer Programme and Lecture - Demonstration for secondary, higher secondary and junior college students are annual features. In addition to these, special programmes for general public and amateur astronomers are also organized. The basic information about the regular programme is available on the Public Outreach Programme web site http://www.iucaa.ernet.in/~scipop. What follows here are the highlights of these regular programmes and reports on other activities.

(I) National Science Day

This year National Science Day at IUCAA was celebrated in three parts. An exhibition entitled '100 Years of Nobel Prize' marked the main feature of this year's celebrations, programme for school students and open house.

Programme for school students consisting of competitions (quiz, drawing and essay) was conducted on Saturday, February 23, 2002. C. K. Desai of the Exploratory, Bharatiya Vidya Bhavan, Pune, gave a lecture - demonstration on doing physics experiments. Shyam Tandon initiated a "Dialogue with teachers on experiments in school" for the teachers accompanying the students.

The Exhibition "100 Years of Nobel Prize"

The exhibition entitled '100 Years of Nobel Prize' marked the main feature of this year's celebrations.

This exhibition was inaugurated by I. K. Mukherjee, Director General, National Council of Science Museums, Kolkata on February 25, and was open for the public till March 7. The Nehru Science Centre (NSC), Mumbai, made this exhibition possible. It adopted an innovative approach in the display of information on 734 Nobel Laureates in all the subjects and over a span of 101 years and presented it through panels and index frames. G. A. Rautela, Director, NSC, Mumbai, took personal interest in setting up the exhibition in Pune. Shivaprasad M. Kened, who was the man behind making the exhibition, provided valuable inputs in setting up the exhibition and was present on the day of the inauguration. Rout Mathur of NSC was deputed to interact with visitors. He had help from two volunteers Ashish Kate (Symbiosis College) and Sushrut Bhanushali (M.E.S. Garware College) of the Sky Watchers' Association of Pune.

The exhibition was kept open every day from 11:30 a.m. till 3:00 p.m., exclusively for students and from there onwards till 7:30 p.m., for general public. It was estimated that a total of about 8000 people visited the exhibition.

The Programme for School Students

The programme for the school students consisted of quiz, essay and drawing competitions and lecture demonstrations. Five students each from 82 schools were invited to participate in various competitions. This programme was conducted on Saturday, February 23 and began with Jayant Narlikar giving a brief introduction on the importance of celebrating the National Science Day.

Essay and drawing competitions along with quiz elimination round were held from 9:30 a.m. to 10:30 a.m. During this period Shyam Tandon initiated a "Dialogue with teachers on experiments in school" with the teachers accompanying the students.

A lecture - demonstration was given by C. K. Desai of the Exploratory, Bharatiya Vidya Bhavan, Pune, from 11:30 a.m. to 12:30 p.m. on doing physics experiments.

After the lunch break, at 2:00 p.m., final quiz competition was conducted for the top 5 teams selected after the elimination round. This competition was held on stage in front of an audience. The highlight of this year's quiz competition was some video clippings of experiments that were shown and the contestants were asked to answer questions based on the clips. Shyam Tandon was also present to give expert's comments and to comment on the answers given. Jayant Narlikar gave away the prizes. (Please see below the names of the prize winners.)

Jatush Sheth, Tarun Souradeep, Harvinder Jassal and Amir Hajian judged the entries for drawing competition. The essays were judged by Varun Sahni, Nirupama Bawdekar, Vinaya Kulkarni, Ujjaini Alam, Tapas K. Das and Mangala Narlikar. Anand Sengupta, Anoop Nair, Sanjit Mitra, Hum Chand Verma and Subbashish Aich conducted the quiz competitions. Parampreet Singh and Ujjaini Alam conducted the quiz on stage.

Drawing Competition

1st Prize
Masidwalla Hydershah
Don Bosco High School

2nd Prize
Raj Pravin Tatiya
Crescent High School

Honourable Mention
Punit Patel
Sanghavi K.M High School

Essay Competition (Marathi Medium)

1st Prize
Kakade Ashish Anil
Bharat English School

2nd Prize
No prize was given

Honourable Mention
Ashwini Satish Gaikwad
N.M.V Girls' High School

Rohini Roopchand Lipare
Jain Girls' High School

Essay Competition (English Medium)

1st Prize
No prize was given

2nd Prize
No prize was given

Honourable Mention
Ramchandani Madhu
Jai Hind High School

Moksha Sharma
Kendriya Vidyalaya, Range Hills

Yugal Tiwari
Loyola High School

Quiz Competition

1st Prize
Shyam Jade, Sameer Garg and Sandeep Gangakhedkar
St. Vincent's High School

2nd Prize
Adithya Srinivas Rao, Saurabh Prajulla Chatradeo, and Nipun Avinash Dharmadhikari
Vidya Bhavan High School

3rd Prize
Vinayak Vishnu Ranade, Amod Suhas Jog and Chinmay Vivek Nivargi
Abhinava Vidyalaya English Medium

The other two teams which qualified for the quiz competition were - Rohit Prakash Pandharkar, Mandar Dilip Phatak and Radhika Atul Marathe of Jnana Prabodhini Prashala, and Aditya Akole, Sudeep Pradhan and Kshiteesh Phansalkar of Panditrao Agashe School.

Open Day

This was held in the afternoon of February 28, when more than 3000 visitors came to IUCAA. Lectures, films and displays of R & D at IUCAA were very popular with the public.

(II) Programmes for School Students

Lecture Demonstrations

Since 1993, IUCAA has been organizing lecture demonstration programme for the students of classes VIII to X. This programme has been very popular and success ful. Since 1998, there has also been a similar programme for students of class XI and XII.

At school level, lectures are given separately in English and Marathi. Lectures for the senior students are only in English. During the period of this report, 7400 students attended the programmes.

Lectures for High School Students (Classes VIII - X) [Every speaker delivered lecture in Marathi and then in English]

Jayant V. Narlikar (IUCAA)
Cosmic Illusions, July 21

Ajit Kembahvi (IUCAA)
Planets Outside the Solar System, August 11

S. N. Tandon (IUCAA)
Colours of Rainbow and Clouds, September 8

Arvind Paranjpye (IUCAA)
Sky Watching - A Hobby and A Study, October 13

P. Vidyasagar (Dept. Physics, Pune University)
Know Thy Brain, December 8

For Students of Jr. College (Class XI - XII)

[These lecture were in English only]

Jayant V. Narlikar (IUCAA)
The Physics-Astronomy Frontier, July 28

Ajit Kembhavi
Visions of the Universe - from the Eye to the Computer, August 25

Arvind Paranjpye
Meteors, Comets and Meteor Showers, September 22

Prasad Subramanian (IUCAA)
The Solar Corona, February 16

Special Programme in collaboration with Alliance Francaise de Poona

A special programme of screening of French films describing a few ideas in mathematics for school students was organized on February 2, 2002. Mangala Narlikar introduced the subject matter.

Live viewing of Occultation of Saturn by the Moon

IUCAA helped local amateur astronomers' association / clubs for public viewing of the occultation of Saturn by the Moon on January 24, 2002. With the help of a web camera placed at the focus of a telescope and PC connected to a digital projector large number of people could watch the event live.

Facilities

(I) Computer Centre

The IUCAA Computer Centre continues to offer the state of the art computing facility to the users from IUCAA as well as visitors from the universities and institutions within India and abroad. During 2001-2002, a mirror site of the Astrophysics Data System (ADS) article service was made available at IUCAA. This service provides free and unrestricted access to scanned images of journals, conference proceedings and books in Astronomy. The present size of the data base is about 450 GB. A four node cluster comprising of HP Vectra Intel PIII with 512MB RAM was set up to augment the parallel computing needs of our users. LAM (Local Area Multicomputer) which is an MPI (Message Passing Interface) programming environment and development system for heterogeneous computers has been implemented on this cluster. With LAM, a dedicated cluster can act as one parallel computer solving many compute intensive tasks.The major activity at the Ernet Center at IUCAA was in upgrading the intra ernet bandwidth to have better connectivity within the ernet network. We have two new leased lines of 2 Mb capacity between Pune-Mumbai and Pune-Bangalore. We also have an E1/R2 line and two ISDN lines for our dialup customers. All these WAN connections come from a new telephone public exchange which has been set up within IUCAA campus. We have many new clients this year who have taken up leased line connectivity with Ernet, IUCAA. To manage the gateway link and our clients, we have installed many network monitoring and bandwidth management tools.The IUCAA computer centre continues to extend support to university departments and colleges for configuring networks, obtaining hardware and software.

(II) Library and Publications

The IUCAA library added 227 books and 467 bound volumes during the period under review. The total collection amounts to approximately 17,500. The library caters to the needs of the inhouse academic community, as well as visitors coming to IUCAA.

The IUCAA library is a member of the Forum for Resource Sharing in Astronomy (FORSA), which has been established by astronomy librarians in 1979. The fourth FORSA meeting was held in parallel during the 21st meeting of Astronomical Society of India at the Inter-University Centre for Astronomy and Astrophysics, Pune, during February 5-8, 2002. There were presentations from each participating librarian highlighting the achievements, facilities and services started in the last three years or so. The problems faced by individual libraries and issues related to digitization, consortia formation were also discussed. The members interacted with scientists from the universities to know in what way the FORSA group could additionally address to their needs.

The IUCAA library has recently shifted from the Windows based version of the library software "SLIM" (System for Library Information Management) to the linux based software called "SLIM ++". This is a web based version which incorporates various features in addition to those available in the Windows based version. The library has also acquired a Canon digital photocopier. Its networking as well as remote administration features have enabled the library staff to provide efficient and speedy service to its users.

IUCAA has full-fledged publications department that uses the latest technology and DTP software for preparing the artwork and layout of its publications like the Annual Report, Quarterly bulletin "Khagol", Posters, Academic Calendar, Conference Proceedings, etc.

(III) Instrumentation Laboratory

The laboratory has facilities for the design, construction, and testing of the instruments for optical observations. These facilities are also used by the groups from universities and colleges for developing and testing their instruments.

During this year, a group from J.E.S. College, Jalna fabricated a thermoelectrically cooled CCD camera for their small telescope; this camera is based on a low cost design developed in this laboratory. Hardware of the CCD controllers developed in the laboratory, and reported on in the past years, has been upgraded to be compatible with PCI standard of the PCs and speed of the clocking cards has been increased by a factor four by replacing the Digtal Signal Processing chips with Field Progammable Gate Arrays — this increase in the speed makes these cards suitable for control of near infrared array detectors which operate with short exposures of a few seconds.

(IV) The IUCAA Telescope

As reported in earlier, IUCAA is setting up a 2 m telescope for observations in the optical and near infrared bands. The telescope is being supplied by the Particle Physics and Astronomy Research Council of UK. The telescope has an alt. - azimuth mount, and a f/10 Cassegrain focus. A corrector provides a large field of 40 arcmin. diameter with sub arcsecond images in the optical band, whereas the uncorrected field gives sub arcsec. images up to a radius of 10 arcmin.

After several rounds of delays, the telescope was ready for final performance tests in the factory by the end of March 2002, and the final tests are planned to be done in April. If everything goes well, the telescope is likely to

be shipped in the month of June or July.
The observatory, at a site about 80 km from IUCAA, has two main buildings: a telescope enclosure and a service building. In order to minimise thermal perturbations of the telescope enclosure, ambient air is sucked through it and let out in the service building which is located about 80 metres away. The buildings are ready and the dome has been installed. Control of dome rotation too has been tested to give a satisfactory performance — to reach the desired azimuth within 0.5 degrees.

It is expected that the telescope would be installed soon after the monsoon and would be ready for observations before the end of the year 2002.

A brief description of the instruments being developed for observations with the telescope can be found under the head Instrumentation in section on Research at IUCAA.

(V) Virtual Observatory

Astronomers use vast quantities of data for their research. These data are obtained using many different kinds of telescopes situated on the ground and on satellites in space. Because of the rapid advance in telescope and detector technology, there has been a phenomenal increase in the quantity of data, both from observation of specific objects as well as from surveys which cover entire areas of the study. The data volumes have already reached terabytes and great growth is expected over the coming decade. Because of the large volume of data, and the many different forms in which it is available, the storage and retrieval of data have become difficult tasks. It has also become very challenging for astronomers to use the vast store house of data to produce exciting new scientific discoveries. Projects are being undertaken in the USA and some countries in Europe to efficiently utilize the data through the establishment of a Virtual Observatory.The Virtual Observatory-India (VOI) project seeks to bring together astronomers and software developers, with experience in handling large volumes of data, to contribute substantially to the international VO effort, and to make accessible to astronomers in India and in other countries for developments in the most useful forms. The aim over the next few years will be to (1) Undertake research and development for data search and retrieval; (2) Develop software for equal and efficient use of the data; (3) Enable astronomers and other interested scientists to undertake major scientific projects using the data and (4) Make the technology available for use by other fields, like remote sensing, population studies, bioinformatics, health care, etc. which involve large volumes of data.The project is being undertaken through a collaboration between (1) astronomers and other scientists working in research institutes and university departments and (2) expert computer software developers from the industry. The project will establish a model for collaboration between experts from academic fields and from industry in the area of information technology. A good part of the developmental and scientific work will be done in collaboration with California Institute of Technology and other renowned institutes in the USA. The products which arise from this collaboration will have wide applicability and will enable scientists and technologists all over India to benefit from the rich databases which are being developed all over the world. The project will use Indian scientific and technical expertise to make important contributions to the world wide effort, and establish India as one of the pioneers of virtual science. The Ministry of Information Technology is providing a major part of the funds required for the project. Substantial contribution to the effort, particularly in the form of expert software engineers, is being received from Persistent Systems Pvt. Ltd., Pune. IUCAA will provide infrastructure, expertise, computing facilities and other resources. The investigators in the project from IUCAA are Ajit Kembhavi, Sarah Ponrathnam and J. V. Narlikar and Anand Deshpande, T. M. Vijyaraman and a team of software engineers from Persistent Systems.An important task of the VO will be to establish and implement new standards for creating data files for storage and exchange. This is being done by creating a new standard called the VOTable, which is based on XML. Ajit Kembhavi and Pallavi Kulkarni from IUCAA, in collaboration with T. M. Vijayraman and his team from Persistent Systems are developing tools for converting fits files to the VOTable format and for creating, accessing and visualizing VOTable files.

IUCAA Reference Centres (IRCs)

1. Cochin University of Science and Technology
Report by V.C. Kuriakose (Coordinator)

The library and computer facilities available at IRC are being used by the teachers and students of this department for their research activities. The INTERNET and the online search facilities of 10 AIP journals provided by IUCAA have increased the number of users at IRC . Teachers and students from other universities and neighbouring colleges also visit this centre for reference and computation work. The library and the online search facilities at IRC are also used by M.Sc. students and helped them to do their project work in areas related to Astronomy and Astrophysics.

Areas of Research Work

i) Quantum field theory in curved spacetime: Minu Joy and Kuriakose have studied the nature of phase transitions which might have taken place in the early universe. Using effective potential method they found that Φ^6 model is regularizable in (3+1) Bianchi spacetime and found that this model can be used to explain first order phase transitions. The same model is also studied in (2+1) dimensions and the calculations are extended to study nuclear bubble formations associated with phase transitions. Now they are studying the role of scalar fields in the formation of structures in the universe and the study is in progress.

ii) Observational Astronomy: Research work in this area is done in collaboration with A K. Kembhavi. C. D. Ravikumar and Kuriakose are involved in this study and analysed images of about 50 elliptical galaxies using IRAF and other related packages. One M.Sc. student, Gineesh, did his M.Sc. project work in the same area by simulating images of elliptical galaxies.

iii) *Neural Network*: Extensive studies on neural network and its applications to astrophysical problems have been carried out by Ninan Sajeeth Philip and K. Babu Joseph.

iv) *Nonlinear Dynamics*: This is another area of research. Shaju and Kuriakose are studying fluxon dynamics in Josephson junctions and they have proposed a new geometry for Josephson junctions and using this geometry they are able to show that Josephson junctions can be used as flux flow oscillators, and the study of other aspects of the model is in progress. R.Ganapathy, M.N. Vinoj and Kuriakose are studying optical solitons. Two M.Sc. students have also done their project work in these areas.

v) *High Energy Physics*: Using relativistic quark model, A.P. Jayadev and Ramesh Babu T. are studying meson spectroscopy.

vi) *Chaos*: K.G.Sandhya , T. Manju and M.Sabir are involved in this area of research studies.

Colloquium and Seminars

With a view to achieve more interaction among research workers, IRC organized a one day colloquium on "Early Universe" on April 21, 2001. Research students and faculty members presented their works and this programme was well attended by the research students and teachers working in other disciplines, M.Sc. and M.Phil. students.

The IRC conducts monthly seminars regularly with PG students, research scholars and teachers of various disciplines (both experiment and theory) participating in the seminars. The IRC, therefore, provides a forum for fruitful interactions of research students working in different areas. Seminars were given by
(i) J.V.Narlikar: Do astronomical observations sometime require new Physics;
(ii) P.D. Shaju: Fluxon dynamics in Josephson junctions ;
(iii) P.N.Maya: Type III Solar Radio Bursts;
(iv) R. Renjith: LEBCD in nanostructure and RBS analysis;
(v) V.M. Nandakumaran: Hamiltonian Chaos;
(vi) A.W. Joshi: Our Solar System;
(vii) R.Ganapathy: Soliton propagation through single mode fibres.
All these seminars were attended by teachers, research students, M.Phil. and M.Sc. students.

Visitors

J.V.Narlikar visited this Centre in July 2001. K.Porsezian, Department of Physics, Anna University, Chennai, M. Lakshmanan, Centre for Nonlinear Dynamics Bharathidasan University, Tiruchirappalli also visited this Centre. A.W. Joshi , University of Pune visited this Centre while he was visiting this Department under TPSC programme.

2. Pt. Ravishankar Shukla University, Raipur
Report by S.K. Pandey (Coordinator)

The facilities (Internet, library, etc) provided by IUCAA at the centre have proved to be extremely useful for the faculty members, and research scholars in the University in keeping their research activities alive. The INTERNET facility that has been provided by IUCAA at the centre is used extensively by the researchers here in browsing through important websites around the globe that helps them in scanning/downloading the articles of their research interest. Electronic subscription to some of the journals that has been made available to the centre are used by the researchers in updating their research profile. It is expected that soon they will have access to some other journals too. Some of the important activities of the centre are listed below.

Research activities : D. K. Chakraborty and his research students continued their work on the projected properties of a family of mass models, which are triaxial generalizations of the modified Hubble model, to gain further insight into the structure and dynamics of elliptical galaxies. Research activities of A K Sapre and his group were mainly focussed in the study of QSO-galaxy pairs to examine whether these pairs are physically associated or not. S. K. Pandey along with his students was involved in (a) studying properties of dust in extragalactic environment to examine the nature, origin and evolution of dust in early-type galaxies, and (b) photometric monitoring of chromospherically active stars using small telescopes to investigate short term as well as long term variations of activity in them in the framework star-spot models.

Workshop/Conference organized: A workshop on "Structure and Dynamics of Galaxies" was organized in the School of Studies in Physics during Sept. 27-30, 2001. The workshop was sponsored by IUCAA and the University. The details are given on page 98.

Visitors to the centre: Teachers and students from local schools occasionally visit the centre to make use of the IRC facilities for preparation of Science Posters/models/ lectures, etc. Tapas Das from IUCAA, visited the centre during August 2001 and delivered a series of lectures in the department. A few college lecturers, R. S. Singh from Govt. College, Utai (Durg), A Jadhav from Govt. College Neemuch and Priyanka Pandey from Girls' College, Ambikapur) also visited the centre and had discussion with S. K. Pandey to pursue research work in Astronomy and Astrophysics.

Seminars/lectures : M.Sc. students of the department make use of the IRC facilities for the preparation/ presentation of weekly seminars organized in the department. In addition to this, following lectures were organized during the year. D. K. Chakraborty gave a popular lecture on *Cosmology* at Govt. School Mana, Raipur, July, 2001. Tapas Das gave a series of two lectures on *Accretion Disks around Black Holes*, August 2 and 3, 2001. R. K. Thakur gave a seminar on : *Special Theory of Relativity Revisited*, August 10,2001. D. K. Chakraborty gave a seminar on *Cosmological Models* at Department of Mathematics, Pt. Ravishankar Shukla University, Raipur, July, 2001. A. K. Kembhavi gave a popular lecture on *New Planets: the new Worlds at last* at Govt. Science College, Durg, Sept 28, 2001. U. C. Joshi gave a popular lecture on *Our Universe* at Govt Science College, Durg, Sept. 28, 2001. A. K. Kembhavi gave a popular lecture on *Black Holes: how can we see them*? at Govt. College of Education, Raipur, Sept. 29, 2001.

Project work in Astronomy : Seven students from M. Sc. (final) of the Department used IRC facilities(INTERNET and library)) in carrying out their project work, as a part of their course work, in Observational Astronomy using the observing facility in the Department.

Sky gazing programme : Students of the department, students from local Schools/Colleges as well as general public visit the department during nights when M. Sc. students start their observational programme, to have a view of surface features of the Moon, Jupiter and its moons, Saturn and its rings through the telescope that the department has. M. Sc. students of the department also enjoyed having a view of sunspots using our 6" telescope fitted with solar filters.

Books:

Cosmology : A text book for M.Sc. (in Hindi), Madhya Pradesh Hindi Granth Academy, 2001. (Author : D. K. Chakraborty)

3. North Bengal University, West Bengal
Report by S. Mukherjee (Coordinator)

During the year 2001-2002, the IRC in North Bengal University showed enhanced overall development. The centre provided some essential research facilities and also an opportunity for collaboration among college and university teachers, including some visitors from universities abroad. An electronic library, giving access to some selected journals, became operational in September 2001. This led to a spurt in research activities which are outlined below.:

(a) Lectures/Seminars/Workshop, etc. : Apart from group discussions and lectures by visiting scientists, the IRC organized, in collaboration with the Physics Department of North Bengal University, a National Workshop on "Conceptual Issues in Relativity , Cosmology and Astrophysics" during May 28 - 30, 2001, in which 35 scientists from different parts of the country participated.

(b) Research Work: The research work covered a number of fields in the area of Astrophysics, Relativity and Cosmology. These are outlined below:

i) **Astrophysics:** Considerable work has been done on various aspects of compact stars (like Her X-1 and SAX J 1808.4-3658) by S. Mukherjee, R. Sharma, J. Dey and M. Dey. The problem of radiative collapse has also been studied by S. Mukherjee, R. Sharma and T. K. Dey in collaboration with a group of scientists from Natal University, South Africa.

ii) **Gravitational Instantons and Wormholes:** The problems studied include creation of open universe (S. Mukherjee, B. C. Paul and R. Tavakol) and possibilities of a special type of traversable wormholes (N. K. Dadhich, S. Kar, S. Mukherjee and M. Visser).

iii) **Brane World:** Inflationary cosmologies in an anisotropic brane world has been studied by B. C. Paul.

iv) **Cosmological Models:** The problems studied include (a) various aspects of Brans-Dicke theory (K. K. Nandi, A. K. Bhadra, T. B. Nayak, P. M. Alsing and J. C. Evans), (b) Bianchi Models (B. C. Paul and S. Chakrabarty) and (c) Viscous Cosmologies (B. C. Paul).

v) **Black Hole :** Some problems of primordial blackholes have been studied by B. C. Paul, A. Saha and S. Chakrabarty. The behavior of tidal forces on the horizon of some spherically symmetric static black hole solutions in scalar tensor theories have been investigated by A. Bhadra, K. K. Nandi and others.

vi) **Gamma Ray Astronomy :** Gamma ray flux to be observed at Earth from the proposed single source (supernova remnant) and the knee structure of primary cosmic ray spectrum have been studied by A. Bhadra.

vii) **Cosmic Rays :** Experimental as well as theoretical study on the correlation among the different air shower parameters have been made and the physical significance of some parameters are discussed. High-energy interaction parameters in the forward region (inaccessible in the present colliders experiments) are estimated from cosmic ray data by A. Bhadra and R. K. Dey.

viii)**Sagnac Effect :** Some aspects of Sagnac effect are studied by S. K. Ghosal, Biplab Raychadhuri, K. K. Nandi and A. Bhadra.

Publications: The research papers published by IUCAA associates through these programmes are listed under the section 'Publication by Visiting Associates'.

The Thirteenth IUCAA Foundation Day Lecture

The Present Crisis in Higher Education in India, and Some Ways Out

T. V. Ramakrishnan
Department of Physics
Indian Institute of Science
Bangalore, India

Introduction:

I am very thankful to Professor Jayant Narlikar for inviting me to talk on this occasion. I thought a discussion of the state of higher education ending in some suggestions on what one could do to help realize our potential may be of greater value than a specialized lecture.

In this talk, I will start by mentioning some expectations from higher education and research. Against this background, it is clear that our system is seriously dysfunctional, both in terms of quality and quantity, especially the former. I try to highlight this with some examples and statistics both for India and for other countries. I then go into reasons for this. Some of these, such as lack of sufficient support or investment, are well known. Others such as the peculiarly fragmented nature of our higher education/research system, are not clearly recognized. Finally, I suggest some solutions. A few can be implemented easily.

1. What do we expect from higher education?

We have many expectations from education. To start with the personal, education (at all levels) can help transform, open up one's mind, increase its awareness and capabilities, and add valuable skills. This classical view emphasizes the conviction that the quality of the individual mind (trained, developed, augmented with specialized skills, etc) is central. As a society, we expect that the value higher education adds to each of us can be used for general prosperity. No society that has restricted or low quality higher education is prosperous as a whole. In a country with widespread higher education, the level of public discourse can be high and its affairs are conducted with greater deliberation. Higher education can be a great force for social transformation and empowerment, and many social reformers recognizing this, have been pioneers in higher education. For many of our large national problems, e.g.. unavailability of water for drinking and for other uses, fatal and debilitating diseases, floods, sustainable practices, one needs a mixture of appropriate scientific/technological solutions and broad, active participation by knowledgeable individuals and groups backed by political will. Higher education has an important role here. We expect that higher education, through its spirit of enquiry and scholarship is a means of transmitting and creating culture, especially for an ancient land and a diverse society such as ours, and in the prevalent world atmosphere.

Finally, the most immediate expectation from higher education and research is that it will enable us not just to survive but flourish as a large nation in the present day world, where the traffic of goods and services across countries is growing explosively. Unless what we do or make is world class, this traffic will remain one way. The value of primary products continues to decline; what is crucial is the value added by human invention and intellect. Widespread quality education, basic and applied research of the best kind, efficient and innovative manufacturing powered by these and a national will are not just desirable; they are essential.

2. The Crisis in Quality and Quantity

a. Quality:

These and other expectations are not being fulfilled because our system of higher education and research is poor in quality except for a very few small pockets. In relation to the future we can have because of our background and size, not enough people have the advantage of good higher education, specially of certain kinds. Our system of higher education and research is highly fragmented and very poorly supported. I shall first expand on the fact of poor quality, because it seems to me the most crucial but poorly recognized contributor to the crisis. I will then discuss the size of our higher education activity, comparing it with UK and China to get an idea of the possible correlations between numbers, their distribution in various subjects and economic well being.

Everyone feels deep inside that the quality of education is its most distinguishing characteristic (and it is not in conflict with its being useful!). In the words of Teshoo Lama the wise Tibetan Buddhist monk in Kipling's novel 'Kim', "Education of greatest value if of best quality. Otherwise no earthly use". The quality of most of our higher education is extremely poor and so, thus, it is of no earthly use. With a few exceptions our education in colleges and universities is generally antianalytical, prescriptive and descriptive. A simple way of seeing this is to compare the BSc textbook and the question paper of a typical Indian University (say Bangalore) in Botany or in Physics with the corresponding textbooks and question papers which a student of the same age would work with in an average US university (say Kansas State). Our typical Botany text book presents generally undigested facts. The physics book flatly describes phenomena and theoretical results, occasionally enlivened by numericals. Some teachers may suggest and students may use more analytical and 'live' textbooks; but the examination still emphasizes regurgitation and substitution. This is specially tragic in an age where facts and even information are readily available. The process of refining facts into information and then to knowledge and understanding, which is the very essence of real higher education, is hardly encountered. The state of laboratories is an insult to the experimental nature of science. Subjects are not taught as living growing activities.

Another way of seeing the same thing is to look for depth in higher education. A very few institutions have good syllabi, appropriate text books and teaching, and an analytically oriented examination system. (The number in any subject is of order ten or less). Then there is the vast majority of others which are by and large similar to each other, but all at roughly the other end of the educational spectrum. Contrast this with say the USA where in Harvard (one of the very best) and Nebraska (one of the hundred or so average universities) the books, the course content, the examination system in terms of what is examined and how, are almost the same. Harvard has better researchers and 'brighter' students, but at both places the value sought to be added to the students is comparable. We have an educational caste system in which a very small fraction (1-2% !) is privileged to have an experience which should be available to at least 30-40% of the students if not all. This is also true of engineering undergraduate education, though not to the same extreme degree.

An indication of the crisis in quality is the fact that only 5% of the fifty thousand or so students who appear for the CSIR-NET examination every year after MSc (prerequisite for a PhD scholarship for research in the sciences) are successful. This is disturbing, considering that the NET is essentially an MSc level examination, not especially convoluted (unlike say the IIT-JEE examination). A related fact is the difficulty a handful of science research institutions (in different subjects) have in selecting out of the very large pool of MSc's those whom they consider suitable for research. The ratio is about 1:50 or 1:100!

In many institutions of higher education, there is plain cheating of the students. For example, in response to the great popular demand for education in biotechnology, several universities and colleges have started MSc courses in this subject (this refers to non DBT supported courses). An institution or programme in this area typically has one or two teachers and hardly any labs. A few guest lecturers fill in the gaps. The students are sent out with a degree after two years. This practice is increasingly common even for established courses. In many places; teachers are regularly engaged by the hour. A worse fate awaits those who have done their MSc (or BSc) and would like to work in bioinformatics. Many private ventures promise to make you profitably employable in a few weeks to a few months. They generally have no infrastructure or teachers, and rely heavily on guest lecturers.

Another striking indication is the proliferation of foreign degree granting institutions in India. Some function either in the 'sandwich' mode, i.e., a part of the instruction is given here by a private educational body (under guidelines from the collaborating foreign institution) and the remainder by the foreign institution. In other cases, the mode can be called scouting or internet. Students are willing to pay sizeable amounts for this; the convenient 'craze for foreign' explanation implies an ingrained belief in the superiority of foreign education. More defendably, there is a generally justified faith that the standards of instruction, the content, the methods of evaluation, etc. are as they should be. (Though one may legitimately have doubts about this for some of the foreign institutions involved; also if the standards are too high, viz. MS in computer science of the University of Illinois, there are not enough takers).

The IT revolution is a tribute to our innate skills and ingenuity in finding low cost educational solutions. It is also an indication that quality education and high value added research/development are rare. The large majority of young people involved have learnt on the job, and from private institutions, and through their abilities and efforts have created many jobs and an international presence. The fact that the IT earnings of Israel and India are about the same makes one wonder as to how things could be if our quality of education and research in this field were to be uniformly as good as that of Israel, so that most of our young people had advantages equal to their abilities.

At the research level, there is a variety of institutions, such as primarily or exclusively research institutes, some universities, CSIR laboratories, and research centres which are part of government departments. There is a wide sprinkling of ability and of commitment under difficult conditions and some institutions or groups or individuals are of high international standards. However, the overall picture is that the quality whether indicated by the peaks or by the average is lower than that of many industrialized countries with a (numerically) smaller workforce. (Compared below are the science education statistics for India and UK). In several areas, there is hardly any strength. Even the output is small. Most of the research is incremental or derivative. While these statements are by and large subjective, except perhaps in my own field of specialization, there are ways of quantifying them. These are in terms of citations, number of papers published, etc. We see then that in many traditionally high strength research areas, eg., physics or chemistry, there has been a decline in the fraction of science contributed to from India (eg., citations or number of papers) with time. In case of China for example, the slope is opposite; the fractional contribution is growing. At present, India has probably among the strongest research profiles in third world countries, but there are clear trends, from the relative decline of research in several areas, and from the rapid growth in other countries that this situation is changing rapidly. In science except for biology, and in most areas of humanities, there seems to be a real difficulty in recruiting young faculty of quality.

The quality of scholarship in the humanities is a major cause for concern. For example, in the Journal of Indian Philosophy (Holland), a highly respected journal in the field, several issues pass by without an article by a scholar working in India, and this in Indian Philosophy!

Table I

Breakup of undergraduate students in India and the UK, by discipline. (Data are for the late 90's).

Country	India	UK	China
Total Population	10^9	5×10^8	1.25×10^9
Discipline:- (numbers in lakhs)			
Engineering	3.43	2.60	-
Medicine and Allied	1.40	2.36 (nursing:1.22)	-
Agriculture and Forestry	0.45	0.14	-
Education	1.13	1.31	-
Veterinary Science	0.10	0.04	-
Other professional	2.80	--	-
Arts (Humanities)	27.9	4.8	-
Science	11.4	1.8	-
Commerce	12.02	--	
Total	51.3	18.6	110.0*
*(10% of school students)			

*** For China only the total figures are available.**

b. Quantity:

Let me now turn to the situation in terms of numbers. For this, I have collected together, in Table I, the number of undergraduates in differ fields from India and the UK. For China, I could get only the total figure. We have, compared to the UK a much smaller fraction (1/60) of people studying beyond high school. (The fraction is smaller than what one might expect). China, a more appropriate country to compare, has more than twice the Indian number of college students. What is even more noteworthy is the Chinese plan for the future (not in the table). In 2005, the goal is to have 90% of Chinese children complete Junior high school, and about the same fraction of these to finish senior high school. About 15% of them are expected to enter college every year; about 75 lakhs! The distribution of student numbers in Table I is quite revealing. In spite of the large increase in the number of professional colleges in India, the overwhelming fraction of our undergraduates are in the humanities and sciences (54% and 22% respectively). We notice that in the UK, the percentages are much less (25% and 10% respectively). For engineering, medicine and allied professions, and education the percentages in India are 7,3 and 2 while in the UK they are 15, 13, and 7 respectively. The first comparison reinforces the fact that quality is all important; it far outweighs any advantages in percentages or even numbers. Conversely, our human resources at the college level are mostly (75%) wasted! The second set of comparisons, for professional subjects, indicates the shape of things to come if India moves into the global village; professional education will grow greatly. In several parts of the country where professional education has expanded and attracts a very large number of students (e.g., Karnataka) there is a precipitous fall in not just the quality of students opting for the sciences (with a few exceptions) but also the number. Many college departments in physics and chemistry are being shut down or merged. Considering the fact mentioned above that the number of science and arts students is extremely large, such pruning is inevitable. It is also a clear signal that quality improvement in these subjects is the only way out.

3. Some Causes:

a. Inadequate Investment in Education

Perhaps the first thought that comes to mind is the cumulative effect of inadequate investment by the country in education at all levels. After independence, there was a major growth in the number of universities and colleges, as well as schools. This investment is largely public (universities and research institutions are overwhelmingly established and supported by central and state governments) while in colleges (including specially professional colleges) and schools, a large and increasing fraction owes to private initiative. Much of the education and research network we have is from this sustained effort. We should remember that all this was done over nearly three decades, as a part of modern nation building, before industrialization. This is nearly opposite in order with respect to other developing countries (e.g., South Korea, Malaysia) in which large scale industrialization came first, and serious concern with quality higher education and research is more recent. However, amount of the support and commitment have proved insufficient in the present global context. This begins to show at the school level; in Karnataka only about 23% of the students appearing for the high school examination pass it. One can ask: how did they come up to high school, if 77% could not complete class X? The poor state of schools to which most of our children go (90% of the state expenditure on schools goes towards salaries), at one end and the emphasis on memorization and marks as against experimentation, observation, thinking, imagination, problem solving, the building of skills and interest means that our human resources are not developed. Support for education continues to be bad at the college and university level, with the exception of a few per cent of the students. While the infrastructure of education has grown in the last fifty years, the investment is very low. With 240 universities, the University Grants Commission had a budget of about Rs. 1000 cr. in the year 2000 of which about 70% is accounted for by salaries. The annual budget of the Indian Institute of Science, a research institute with 300 faculty members and 1300 students, is about Rs. 100 cr.. Banaras Hindu University, with 1100 faculty members, 15,000 students and 125 departments, and undergraduates, postgraduates and research students, spends about Rs. 137 crores a year. While unthinking comparisons without accounting for factors such as state government support for universities, the higher level of expenses in a purely research institution, etc. can be misleading, the stark inadequacy of our support for higher education cannot be missed. Perhaps in the pre-globalization period, which was also when this infrastructure was being put in place, quality perhaps did not matter much, and the people coming out of this system could be employed. But now, it is an absolute necessity for our future that the education of the young, of a good fraction of the young, be of world class. This commitment to large scale quality education at all levels as a national necessity, to the role of the government as the major force in developing the intellectual infrastructure of the country, and consequent financial investment are not clearly visible.

At the level of research and development, our commitment in well defined programmes such as of ISRO and DAE is fruitful; there are many signal achievements. In several areas of basic sciences, such as molecular biology and biotechnology, and experimental astronomy there is considerable support. However, in many major fields of great research interest and applications significance, eg. condensed matter and modern materials science (including both physics and chemistry) the funding is subcritical by almost an order of magnitude. For example, the SERC of the DST has budget of about Rs. 60 crores for 'free' basic research in the entire country in all areas of science and technology. This is small; the consequences are that few major facilities or challenging, cutting edge experimental programmes are possible in universities and other institutions for which the DST is the main source of support. Over a period of time, people learn to live with this. The tragic decline in experimental physical science of the highest quality in India owes much to lack of support of the right size at the right time (it is also due to the absence of much physics based technology). There are of course a few great survivors, but for a country of our size, with its head start in science, this is not enough. In a number of frontier areas, there are no practitioners. This is perhaps inevitable, given the realities of support. In this connection, the recent national initiative on nanoscience and nanotechnology if pursued with vigour looks promising.

b. The Trivarna of Colleges, Universities and Institutes:-

A major cause of the unhealthy state of higher education and research in our country is its unique structure. It consists of three nearly disconnected parts; colleges for undergraduate teaching, universities which with time have become essentially homes for postgraduate education, and institutes which generally have no teaching but only research. We have become used to this somewhat hierarchical and definitely unhealthy pattern as a norm. This institutional caste system runs counter to hundreds of years of academic reality all over the world, starting from, say, Nalanda. It has been the common experience that the intellectual growth of young people coming out of school takes place best in an atmosphere where all higher knowledge is at home, so that the student is exposed to a wide, bright world where knowledge is being created and where the teachers are participants process of creation. The range and depth of skills it is possible to acquire is much wider. Compared to this, a college can be a dead end, an extension of school; of course inspiring if the right teacher or facilities are there. Similarly, the flow of a large number of young people with their interest, questions, and vitality is a strong factor in the liveliness of research. It is not that most undergraduates go on to do research. Even in a university like Cambridge, the percentage is less than twenty, but it is more so that the eighty percent out grow intellectually and in their skills in a stimulating atmosphere.

If we look at our situation against this background, we see that there has been a phase separation, so that higher education as a whole suffers. Undergraduate students are intellectually malnourished and limited being confined to colleges. The universities are truncated and demoralized, increasingly bereft of their natural function. Research institutes have proliferated, and are generally well supported so one expects them to be flourishing. However, the fact is that many of them have very few students in relation to their capacity. For example, the TIFR, Mumbai has about 250 or more faculty and about 130 students. In most research universities abroad, the ratio of faculty to research students is 1:3 or 1:4. One consequence is that in many areas research cannot be effectively pursued, given the facilities and scientific manpower. Also, most of the institutes are small; this along with their isolation and meagre number of research students (which is of course strongly influenced by job prospects) contributes to a hothouse atmosphere, and reduces productivity. This is probably one of the worst ways of investing in non corporate research in the long run. Most countries have found that it is much more fruitful to directly support university scientists, or to strongly link an institute (if it is necessary to have one separately) to a university through physical location and/or through scientists being associated as faculty members. The latter is the case with the CNRS, the great French chain of national research laboratories.

4. Some solutions:

a. World class undergraduate education:

I outline below some suggestions on how the problems of quality higher education could be tackled. The malaise is national, deep rooted and widespread, and my suggestions are quite limited. Of course, there is first the all important necessity of recognizing that there is a problem.

Even if the problem is recognized the difficulty of initiating and implementing changes is compounded by the fact that education is a state subject. The UGC, for example, has made model syllabi (undergraduate and postgraduate) which are not generally followed. Using good syllabi to develop essential abilities, skills, and knowledge is hard. I do not know if the NAAC, the national accreditation body, can be persuaded to accredit courses only if certain norms of testing, etc. are met (My impression is that it does not have such powers).

Supposing there is a shared commitment that our students will be academically comparable to those, in, say China, UK or USA at the same age, there is a simple way to know in detail what it is. The contents of hundreds of university courses (lecture notes, the problem sets, examinations, etc.) are available on the world wide web. We should have several centres in the country where these courses (if relevant, e.g., not in Indian economics) are adapted to our needs, rewritten as necessary and redistributed widely. Original course material is even more welcome; the main idea is to have many sources of actual classroom lectures, homework, experiments and equipment, of world quality. This could be a very major activity, and takes on open university like tones. If at all the programme is to work, massive and continuous retraining of teachers is a must; strong encouragement of good teaching as an activity of national importance is needed.

The undergraduate programme needs to be made more attractive and useful. One way is to remove the inflexibility (fixed for ever choice of most subjects and papers) in the present degree courses, and enable the student to choose a wide variety of them (e.g., a biology student takes economics and Indian history) within a recognizable orientation. This flexibility should extend to engineering and professional courses as well.

A four year BSc/BA programme with the first three years providing a strong intellectual/laboratory foundation, and the fourth year focusing on one skill area of value or research project should make the graduates much more employable. The idea would be to make such a course intrinsically professional; the four year BSc or BA should be comparable to a good B.Tech. in terms of strength in fundamentals and skills, and employability. It is possible that colleges and departments under threat of closure may decide to develop such as pattern of education. Entrance to such programmes could also be via statewide or national tests. In China, where undergraduate education is a sharply felt reality, partly because of the cultural revolution, from the 90's a massive participatory effort is underway "and the aim that by the end of this century and early next century nearly a hundred new talents training patterns (?) and almost a thousand set of new teaching materials will come into being is realized. The National Teaching Achievements Awards organized and implemented by the former SedC all together offered 422 awards. The national comparison of computer-aided teaching software research was carried out in 1995 and 1997 respectively and a bunch of systematic teaching software has sprung up". The Chinese programme is inspiring in its forthrightness, pragmatism and steadiness of purpose.

The changes indicated above can be implemented within the existing college/university system. The additional expenses involved in modernizing the laboratories, retraining of teachers, new learning material, etc. may not exceed a few hundred crores per year. This is a feasible sum for the state to invest in if there is a will. The main difficulty will be inertia and of implementing it on a large scale. Even a small number of autonomous colleges breaking away completely from the familiar path, and clear headedly aiming for global quality, can catalyse the transformation.

b. Research Institution Clusters Starting Undergraduate Education:

The second suggestion is that existing research institutions get together in groups and start undergraduate/ postgraduate education in a way that does not compromise their intensity and quality of research. For example in Pune, Professor Govind Swarup has been working for many years towards and an institution realizing an undergraduate science programme in which Pune University, NCL, IUCAA, NCRA, other scientific institutions and industry, participate. I believe similar institutions are possible in half a dozen places, e.g., Bangalore, Chennai, Ahmedabad, Mumbai, Kolkata, Hyderabad, Lucknow. The most important fact is that each of these (and other) places have the ability to run such a programme, and with distinction. The question is whether they would be willing to. The reluctance may simply be due to habit, both individual and administrative. More seriously, many scientists may justifiably feel that their research will suffer. The participation in teaching should be such that this does not happen. The stimulation of many young people, and more concretely, their active participation in research projects, will help in research. Additional infrastructural facilities, new faculty, new research centres, etc. should form part of the new effort.

The advantages of this development for the students are obvious. They will learn in an excellent, diverse research environment. The quality and reputation of the institutions, and the nature of the programme will attract many very good students. I believe that the number of students in each place should not be too small; say 200 or so per year per centre. It should not be aimed at producing scientists; there is an unconscious (or conscious) habit many of us have of working towards cloning our types. It must be explicitly recognized that 75 to 80% of the graduates will not go on to become PhD's. This is really the strength of such a programme; it gives to the wider society a number of highly capable young people whose mind and skills have been deepened and broadened and who have first hand experience of the frontiers of knowledge. They will contribute in unexpected ways. The subjects taught should cover a wide specturm, from engineering and science to humanities and the arts. Most practically, these could be physically separate centres with the research institutions adjunct to them. I believe also that if imaginatively conceived and executed, with many centres, major financial support from many private sources (e.g., the Indian diaspora) will be available. It probably represents the best immediate, though limited scale, solution to the problem of quality undergraduate education.

The most natural, but in our context perhaps most difficult solution is for the universities to become themselves. This means reintroducing undergraduate education, professional (technical and medical) education included. It also means that new research centres should be located in campuses, and be connected with them organically. The inbuilt advantages a university can offer for undergraduate education, especially if it is to offer students choices, are obvious. The extra expenses will be less than those for setting up a new undergraduate college.

If we think that we have a strong future as a nation with much traditional knowledge and wisdom to enrich ourselves and the world with, in a regime in which modern scientific knowledge and its consequences are essential, we will empower a large segment of our young in the way needed. Our present pattern of higher education adds little value to most of them; this is not a shortcoming of their intelligence or commitment, but much more of our inertia. We have the human and economic capabilities to refashion our system of higher education and research and to help create a great future for all of us. If we believe that, we will act.

ACRONYMS

ACIGA	:	Australian Consortium for Interferometric Gravitational Astronomy
AIGO 500	:	Australian International Gravitational Observatory
AGN	:	Active Galactic Nuclei
BARC	:	Bhabha Atomic Research Centre
BCS	:	Bardeen, Cooper, Schrieffer Theory
BH	:	Black Hole
BHU	:	Banares Hindu University
CASA	:	Centre for Advanced Study in Astronomy
CASS	:	Centre for Astrophysics and Space Sciences
CASPEC	:	Cassegrain Spectrograph
CBI	:	Cosmic Background Imager
CCD	:	Charge Coupled Device
CERN	:	Centre Europeen pour la Recherche Nucleaire
CFA	:	The Centre for Astrophysics (Redshift Survey)
CIRI	:	Central India Research Institute
CMB	:	Cosmic Microwave Background
COBE	:	Cosmic Background Explorer
CSIO	:	Central Science Instruments Organisation
CSIR	:	Council for Scientific and Industrial Research
CWKB	:	Complex Wentzel-Kramers-Brillouin
DD	:	Door Darshan
DSY	:	Department of Science and Technology
EFOSC	:	ESO Faint Object Spectrograph and Camera
ERNET	:	Educational Research Network
ESO	:	European Southern Observatory
ESPEO	:	Ecole Superieure des Procedes Electroniques at Optiques
FRW	:	Friedmann - Robertson - Walker
GMRT	:	Giant Metrewave Radio Telescope
GR	:	General Relativity
HRI	:	Harish Chandra Research Institute of Mathematics and Mathematical Physics
IACS	:	Indian Assocaition for Cultivation of Science
IAGRG	:	Indian Association for General Relativity and Gravitation
IAP	:	Instittue of Astrophysics
IASBS	:	Instittute for Advanced Studies in Basic Sciences
IAU	:	International Astronomy Union
ICGC	:	International Conference on Gravitational and Cosmology
IGM	:	Inter galactic Medium
IIA	:	Indian Institute of Astrophysics
IISc	:	Indian Institute of Science
IIT	:	Indian Institute of Technology
IOA	:	Institute of Astronomy
IRAS	:	Infra-Red Astronomy Satellite
JSPS	:	Japan Society for the Promotion of Science
ISO	:	Infrared Space Observatory
ISRO	:	Indian Space Research Organisation
LIGO	:	Laser Interferometric Gravitational Wave Observatory
LISA	:	Laser Interferometric Space Antenna
LMXB	:	Low Mass X-ray Binaries
MACHOS	:	Massive Compact Halo Objects
NCRA	:	National Centre for Radio Astrophysics
NERIST	:	North Eastern Regional Institute of Science and Technology
NIV	:	National Institute of Virology
NS	:	Naked Singularities
PRL	:	Physical Research Laboratory
QCD	:	Quantum Chromo Dynamics
QED	:	Quantum Electrodynamics

QSO	:	Quasi Stellar Object
QSSC	:	Quasi - Steady State Cosmology
RAC	:	Radio Astronomy Centre
RHIC	:	Relativistic Heavy Ion Collider
RRI	:	Raman Research Institute
SNR	:	Signal to Noise Ratio, Supernova Remnant
TIFR	:	Tata Institute of Fundamental Research
UPSO	:	Uttar Pradesh State Observatory
USO	:	Udaipur Solar Observatory
UVES	:	UV-Visual Echelle Spectrograph
VECC	:	Variable Energy Cyclotron Centre
VJTI	:	Veermata Jijabai Technological Institute
VLT	:	Very large telescope
VSP	:	Vacation Students' Programme
VST	:	Very Large-Survey Telescope
WKB	:	Wentzel-Kramers-Brillouin