Annual Report
of the
Inter-University Centre for Astronomy and Astrophysics

An Autonomous Institution of the University Grants Commission

(April 1, 1993 - March 31, 1994)

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Contents

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University Grants Commission

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Rudraiah Nanjundappa
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Gulbarga University

G.S. Randhawa
Vice-Chancellor
Guru Nanak Dev University

P. Jayarama Reddy
Vice-Chancellor
Sri Venkateswara University
and Scientist Member of UGC

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Mangalore University

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Department of Astronomy
and Space Sciences
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Mehta Research Institute of Mathematics
and Mathematical Physics

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Calcutta University

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IUCAA

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Department of Physics
Roorkee University

Member Secretary J.V. Narlikar
Director, IUCAA

The Governing Body

Chairman	G. Ram Reddy
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Members	Inderjit Khanna
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	S.C. Gupte
	G. Swarup
	R.N. Basu
	M.N. Faruqui
	H.S. Mani
	P. Jayarama Reddy
	M.I. Savadatti
	S.N. Tandon
Member Secretary	J.V. Narlikar

Honorary Fellows

1. S. Chandrasekhar
   University of Chicago, USA

2. W.A. Fowler
   California Institute of Technology, USA

3. R. Hanbury Brown
   Andover, England

4. A. Hewish
   University of Cambridge, U.K.

5. Fred Hoyle
   Bournemouth, U.K.

6. Yash Pal
   New Delhi

7. A.K. Raychaudhuri
   Calcutta

8. A. Salam
   International Centre for Theoretical Physics
   Trieste, Italy

9. P.C. Vaidya
   Gujarat University, Ahmedabad

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Osmania University, Hyderabad

J.R. Bond
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R.D. Cannon
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D. Lynden-Bell
Institute of Astronomy, Cambridge, U.K.

N.C. Mathur
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B.V. Sreekantan
National Institute of Advanced Studies, Bangalore

R.K. Thakur
Ravishankar University, Raipur

J.V. Narlikar (Convener)
IUCAA

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G. Ram Reddy (Chairman)
Y.N. Chaturvedi (Member) (till 7.11.93)
S.K. Khanna (Member) (till 30.4.93)
Inderjit Khanna (Member) (from 8.11.93)
P. Bhatia (Member) (from 1.5.93)
J.V. Narlikar (Member)
T. Sahay (Non-Member Secretary)

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M.N. Desai, Gujarat University
M. Malla Reddy, Osmania University

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K.B. Bhatnagar, Centre for Fundamental
Research in Space Dynamics and
Celestial Mechanics

H.L. Duorah, Gauhati University
S.N. Tandon, IUCAA
N.K. Dadhich, IUCAA (Convener)

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S.V. Dhurandhar
A.K. Kembhavi
T. Padmanabhan
N.C. Rana
S.N. Tandon (Convener)

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T. Sahay (Secretary)

Members of IUCAA

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N.K. Dadhich
S.V. Dhurandhar
R. Gupta
A.K. Kembhavi
T. Padmanabhan
N.C. Rana
V. Sahni
B.S. Sathyaprakash
S.N. Tandon

Scientific Staff

N.U. Bawdekar
R. Chaware
V. Chellathurai
P. Chordia
H.K. Das
M. Deshpande
D. Gadre
G.B. Gaikwad
S.U. Ingale
A.M. Kane
P.A. Malegaonkar
V. Mestry
A. Paranjpye
R. Radhakrishnan

Administrative and Support Staff

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K.M. Abhyankar
N.V. Abhyankar
R. Barke
S.L. Gaikwad
B.R. Gorkha
B.S. Goswami
R.S. Jadhav
B.B. Jagade
M.M. Karnik
S.N. Khadilkar
J.B. Koli
P. Krishnan
M.A. Mahabal
S. Mathew
S. Mirkute
E.M. Modak
K.B. Munuswamy
K.C. Nair
R.D. Pardeshi
N. Pargaonkar
B. Pereira
R. Rao
M.A. Raskar
M.S. Sahasrabudhe
S. Samuel
B.V. Sawant
S. Shankar
D.R. Shinde
D. Surti
V.R. Surve
A. Syed
S.R. Tarphe
T. Varghese

Post-Doctoral Fellows

G.C. Anupama
B. Bhawal
R.K. Gulati
A.K. Sen
M. Seriu
S. Sethi
S. Sinha
M. Valluri

S. Koshti (NBHM Fellow)
D.P.K. Banerjee (till 8.10.93)
A. Kshirsagar (till 14.6.93)

Research Scholars

J.S. Bagla
R. Balasubramanian
V. Chickarmane
D. Duari
T.S. Ghosh
K. Jotania
A. Mahabal
D. Mohanty
D. Munshi

A.N. Ramaprakash
L. Sriramkumar

Project Appointees

Srikumar M. Menon (DST Project)
G. Molakala (ERNET Project)
R. Parui (Project Scientist)
S.K. Pradhan (INDO-US Project)

S. Pitre, C-DAC Project (till 10.7.93)
A. Sohoni, ADC Project (till 1.12.93)
N. Srivastava, Project Scientist (till 3.9.93)

Organizational Structure of IUCAA

IUCAA's project report envisaged an 'eightfold way' for IUCAA's academic activities. To systematise them, the following organizational structure was created as from August 1, 1992, with the persons in charge mentioned in brackets underneath.

The Director
(J.V. Narlikar)

Chairman, Core Programmes
(S.N. Tandon)

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

Head, Computer Centre
(A.K. Kembhavi)

Head, Library and Documentation
(A.K. Kembhavi)

Head, Publications
(T. Padmanabhan)

Head, M.Sc. and Ph.D. Programmes
(T. Padmanabhan)

Head, Instrumentation Laboratory
(S.N. Tandon)

Chairman, Visitor Programmes
(N.K. Dadhich)

Head, Associateship Programmes
(N.K. Dadhich)

Head, Workshops and Schools
(S.V. Dhurandhar)

Head, Guest Observer Programmes
(A.K. Kembhavi)

Head, Science Popularization and Amateur Astronomy
(N.C. Rana)

Awards and Distinctions

S.V. Dhurandhar

Data analysis consultant to the Australian Interferometric Gravitational Wave Observatory project (AIGO).

T.S. Ghosh

Ravi Kumar Bhalla Award - 1994, Indian Physics Association.

J.V. Narlikar

M.P. Birla Award for Astronomy, 1993, Calcutta.

Elected as Fellow of the Third World Academy of Sciences.

T. Padmanabhan

Elected as Fellow of National Academy of Sciences, Allahabad.

M. Seriu

3rd Prize in the Silver Jubilee Essay Competition of Indian Association for General Relativity and Gravitation.

Honda Memorial Fellowship, Japan Association for Mathematical Sciences.

Director's Report

Having completed five years on December 29, 1993, IUCAA now enters the phase of consolidation. This is when it has to demonstrate that it is fulfilling the purpose for which it was created. This report highlights a few facts which make me optimistic about the future.

During 1993-94, IUCAA successfully hosted the first major international meeting : the sixth Asian Pacific Regional Meeting (APRM) of the International Astronomical Union (IAU). All its facilities including the newly built auditorium were put to full use and some 300 delegates including about a hundred from abroad greatly appreciated the academic event. The meeting was held from August 16 to August 20 and it is a tribute to all agencies and persons concerned that the auditorium was made fully usable just in time – with two days to spare. Our neighbours from across the road, the National Centre for Radio Astrophysics, were the co-hosts for the APRM and provided valuable academic support for making up a highly worthwhile scientific programme.

Other international meets on the campus were the 20th International School for Young Astronomers of the IAU, and the first Indo-US Workshop on Active Galactic Nuclei and Quasars. The latter is the first in a series of three workshops, approved under the US-India Fund for a collaborative project between IUCAA and the Harvard Smithsonian Center for Astrophysics, Cambridge. The project also provides for exchanges of scientists between India and the USA.

IUCAA has begun a collaboration in the area of gravitational radiation with French scientists under the umbrella of the Indo-French Centre for the Promotion of Advanced Research. A collaboration with the Australian scientific community in the same field is already going on. It is also proposed to hold joint schools in astrophysics with the Chinese astronomy community.

This year saw the naming of two campus roads after Meghnad Saha and Vainu Bappu, two distinguished astronomers from India. Appropriately it was the Meghnad Saha birth centenary year. Dr. S.C. Gupte, Vice-Chancellor of the University of Poona, unveiled the nameplates on this occasion.

We were particularly happy that Sir Fred Hoyle, one of our Honorary Fellows visited us for two weeks in February. He gave a public lecture, a lecture at the Silver Jubilee Conference of the Indian Association for General Relativity and Gravitation and a lecture to school students.

The last of these was part of IUCAA's monthly lectures/lecture demonstrations for school students. Held on second Saturday of the month, these lectures attract overwhelming response from Pune schools, with the 500-seater auditorium jam-packed. Last summer sixty seven school students participated in one-week projects at IUCAA, again an activity that was successful enough to be repeated in the summer of 1994.

All this, of course, is one facet of IUCAA's human resource development programme in astronomy and astrophysics at all levels. This annual report gives an account of the schools and workshops and other pedagogical activities, while Figure 1 illustrates their year-by-year distribution.

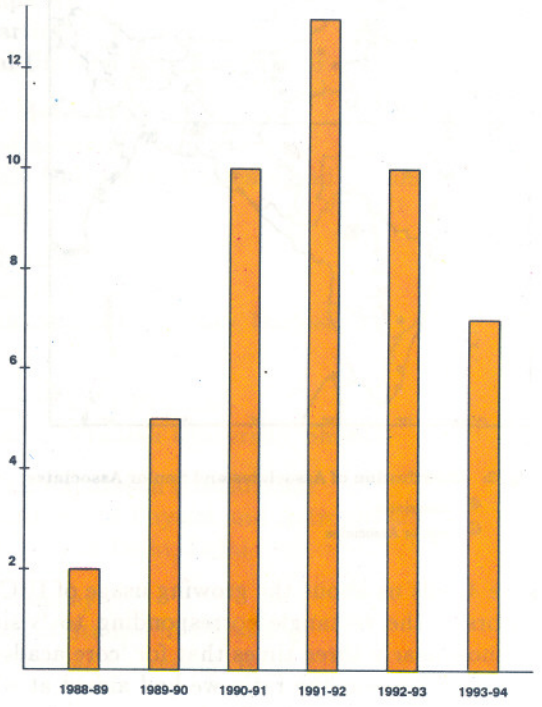

Fig. 1: Workshops, Schools and Regional meetings

The purpose of the initial period was to introduce IUCAA to university and college academics in the country. Now the general regional meetings have given way to well focussed schools and workshops. The map of the country in Figure 2 shows the countrywide off-campus meetings conducted by IUCAA.

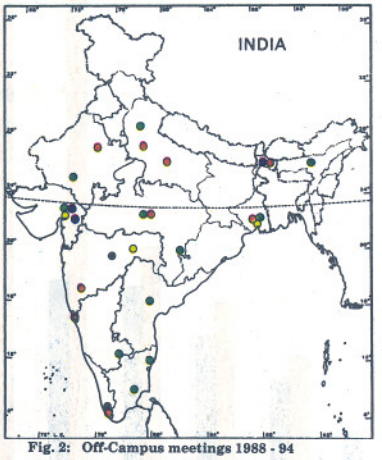

Fig. 2: Off-Campus meetings 1988 - 94

- Regional Discussion Meetings
- Workshops/Schools
- Conferences
- Lectures
- Amateur Astronomers' Meet
- Regional Schools on Introductory Astronomy

Likewise, Figure 3 depicts the countrywide distribution of our associates and senior associates.

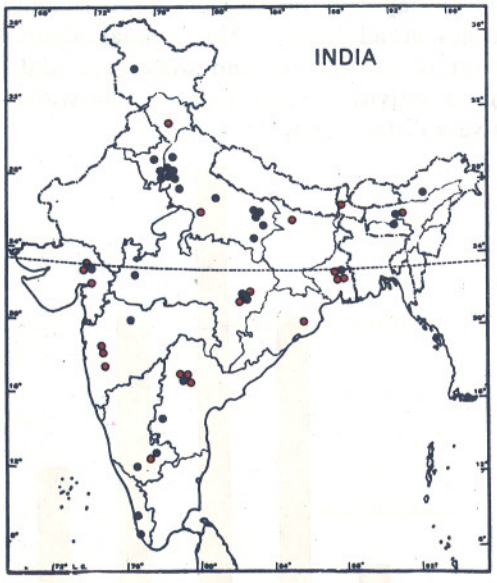

Fig. 3: Distribution of Associates and Senior Associates

- Associates
- Senior Associates

Figure 4 tells us about the growing usage of IUCAA by visitors... the rectangle corresponding to 'visitor-days' is now nearly three times that for 'core academic staff -days'. This was the ratio we had aimed at while IUCAA was being conceptualized.

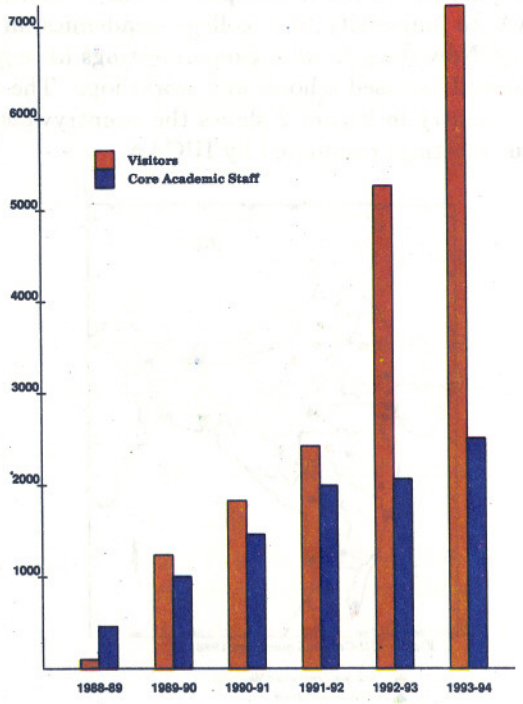

Fig. 4: Visitor man-days in comparison with core academic staff man-days

Figure 5 shows the in-house lecturing activity at Pune which include technical seminars, colloquia, journal club talks and PEP talks.

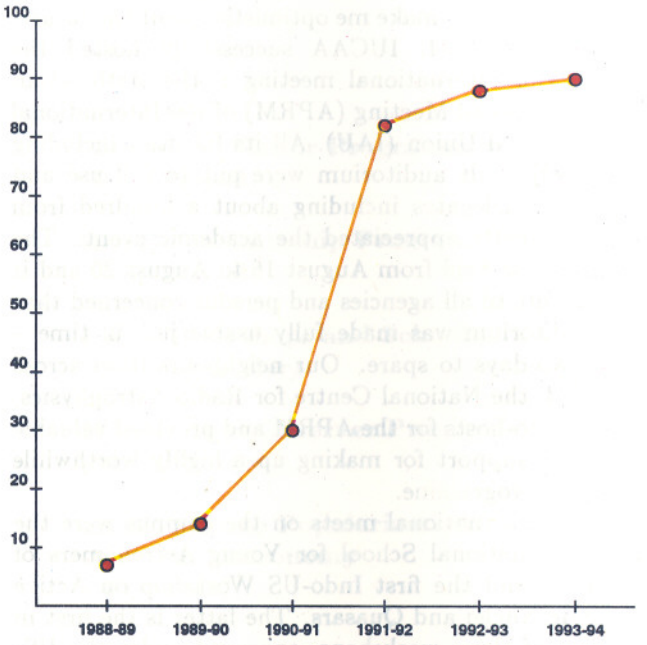

Fig. 5: Seminars, Colloquia, etc. activities

We hope that this activity will further grow as IUCAA's core membership and post-doctoral component increases.

To facilitate interaction between IUCAA and the university community, a national database of workers in astronomy and astrophysics is being prepared. The hope is to add a significant number to this from the existing faculty members of universities and colleges. We also hope that the number of associates and senior associates will touch the hundred-mark in the next five years.

Despite the growth of academic activities of IUCAA and the increase in the number of outside users of its facilities, there has been no corresponding increase in its support staff. This is because of the efficient administration and the excellent cooperation extended by all support staff members which the visitors have frequently remarked on. This occasion provides me an opportunity to record my thanks to all of them.

Finally, I end with a note of appreciation for the help extended to IUCAA from the UGC at all levels, without which the smooth progress reported here would not have been possible.

Jayant Narlikar

Visiting Members of IUCAA

Visiting Professors

Abhay Ashtekar
Centre for Gravitational Physics
and Geometry
Department of Physics
The Pennsylvania State University, USA

C.V. Vishveshwara
Indian Institute of Astrophysics, Bangalore

Senior Associates

S.M. Alladin
Centre for Advanced Study in Astronomy
Osmania University, Hyderabad

R.E. Amritkar
Department of Physics
University of Poona, Pune

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

S.M.R. Ansari (till 30.6.93)
Department of Physics
Aligarh Muslim University, Aligarh

A. Banerjee
Department of Physics
Jadavpur University, Calcutta

S. Banerji
Department of Physics
University of Burdwan, Burdwan

B. Basu
Department of Applied Mathematics
Calcutta University, Calcutta

K.B. Bhatnagar (till 30.6.93)
Department of Mathematics
Zakir Husain College, Delhi

H.L. Duorah
Department of Physics
Gauhati University, Guwahati

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

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

B. Ishwar
Department of Mathematics
Bihar University, Muzaffarpur

G.K. Johri
Department of Physics and Electronics
DAV College, Kanpur

Pushpa Khare
Department of Physics
Utkal University, Bhubaneshwar

A.N. Maheswari (till 30.6.93)
Vice-Chancellor
Cochin University of Science and Technology
Cochin

S. Mukherjee
Department of Physics
North Bengal University, Darjeeling

B.K. Pal
Department of Physics
Himachal Pradesh University, Shimla

N. Panchapakesan (till 30.6.93)
Department of Physics and Astrophysics
University of Delhi, Delhi

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

L.K. Patel
Department of Mathematics
Gujarat University, Ahmedabad

L. Radhakrishna
Department of Mathematics
Shivaji University, Kolhapur

K. Sankara Sastry
Centre for Advanced Study in Astronomy
Osmania University, Hyderabad

S.G. Tagare
School of Mathematical and CIS
University of Hyderabad, Hyderabad

R.K. Thakur
School of Studies in Physics
Ravishankar University, Raipur

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

V.R. Venugopal (till 30.6.93)
School of Physics
Madurai Kamaraj University, Madurai

S.D. Verma
Department of Physics and Space Sciences
Gujarat University, Ahmedabad

Associates

F. Ahmad
Department of Physics
University of Kashmir, Srinagar

G.M. Ballabh (till 30.6.93)
Department of Astronomy
Osmania University, Hyderabad

S.H. Behere
Department of Physics
Marathwada University, Aurangabad

Kalyani Boruah
Department of Physics
Gauhati University, Guwahati

S. Chakrabarty
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University of Kalyani, Kalyani

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Sri Venkateswara College, New Delhi

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University of Delhi, Delhi

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Department of Mathematics
NERIST, Arunachal Pradesh

B.N. Dwivedi (till 30.6.93)
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Banaras Hindu University, Varanasi

K. Indulekha
Department of Physics
Mahatma Gandhi University, Kottayam

K.N. Iyer (till 30.6.93)
Department of Physics
Saurashtra University, Rajkot

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

Z.H. Khan
Department of Physics
Jamia Millia Islamia, New Delhi

S. Mahajan (till 30.6.93)
Department of Physics,
St. Stephen's College, Delhi

Man Mohan
Department of Physics
Kirori Mal College, Delhi

C. Mukku
School of Mathematics and CIS
University of Hyderabad, Hyderabad

Udit Narain
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Meerut College, Meerut

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Department of Physics
University of Kerala, Trivandrum

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University of Gorakhpur, Gorakhpur

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Department of Physics
U.N. Post Graduate College, Deoria

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Sri Krishnadevaraya University, Anantapur

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Lucknow University, Lucknow

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Department of Physics
Kurukshetra University, Kurukshetra

T. Singh
Department of Applied Mathematics
Banaras Hindu University, Varanasi

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

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

A.C. Balachandra Swamy
Department of Physics and Electronics
Saradavilas College, Mysore

D.B. Vaidya
Department of Physics
Gujarat College, Ahmedabad

Visiting Fellows

V.I. Korchagin
Institute of Physics
Rostov-on-Don
Russia

S.V. Chervon
Department of Physics and
Mathematics
The Branch of Moscow University
in Ulyanovsk, Russia

Short Term Visitors

T.K. Menon
Department of Geophysics and
Astronomy
University of British Columbia,
Vancouver, Canada

Calendar of Events

May 3 - June 12	Summer Programme for School Students
May 10 - 28	First Refresher Course in Astronomy and Astrophysics for College and University Teachers
May 31 - June 4	Miniworkshop on Gravity Waves
June 1 - July 15	Vacation Students Programme
June 28 - July 6	Minischool on Numerical Relativity
August 16	IUCAA-NCRA Graduate School First Semester begins
August 16 - 20	VI-IAU Asian Pacific Regional Meeting on Astronomy
August 22 - 23	Secondary School Teachers' Meet (IAU Working Group for the Worldwide Development of Astronomy)
August 23 - 25	Miniworkshop on Cataclysmic Variables
August 28 - 29	Formation of National Confederation of Indian Amateur Astronomers
September 10 - 11	Marathi Science Writers' Meet
November 1 - 6	Workshop on Making Your Own Planetarium
December 6 - 18	Indo-US Workshop on Active Galactic Nuclei and Quasars
December 6 - 20	Introductory School on Astronomy for IIT Students
December 23	Naming of Campus Roads
December 24	IUCAA–NCRA Graduate School First Semester ends
December 29	Fifth Foundation Day
January 3 - 21	XX-IAU International School for Young Astronomers
January 5	Launch of Phase IV - Staff Housing and Recreation Centre
January 17	IUCAA - NCRA Graduate School Second Semester begins
January 21 - 22	Fourth All India Amateur Astronomers' Meet
February 14 - 18	IAGRG Silver Jubilee Conference
February 21 - 25	Workshop on Astroparticle Physics (Co-sponsored by S.N. Bose Centre for Basic Sciences, Calcutta)
February 28	National Science Day

Lectures at IUCAA

Colloquia

G. Baskaran: *Why is high temperature superconductivity so interesting?*, April 12

C.W. Misner: *Beyond stars and galaxies - do we live in a false vacuum?*, June 21

J.G. Negi: *South Indian earthquakes*, October 27

Antony Hewish: *Imaging interplanetary weather patterns*, November 17

V. Krishnamurthy: *Counting techniques of Polya*, December 21

Leon Mestel: *Tom Cowling and the early days of stellar structure*, March 10

Seminars

J.S. Vaishya: *Wolf effect - its possible implications in optical measurements*, April 7

Y.D. Mayya: *Star formation in giant extragalactic HII regions*, April 13

Jayant Murthy: *Voyager observations of dust scattering in the far ultraviolet*, April 20

Toivo Jaakkola: *Equilibrium cosmology*, April 21

K. Srinivasa Rao: *Quantum theory of angular momentum – selected topics*, April 26

N. Panchapakesan: *Constraint on Higgs mass from electroweak baryogenesis*, May 18

S.D. Joglekar: *Superspace formulation of gauge theories*, June 7

N.T. Bishop: *Horizons of two black holes*, June 30

N.T. Bishop: *Is superluminal travel a theoretical possibility?*, July 1

R. Ramachandran: *Spin manifolds and the standard particle physics model*, July 2

Himadri Gupta: *Wavelet transform of coalescing binary chirp signal*, July 15

J.L. Osborne: *Observational TeV gamma ray astronomy*, July 29

Surya Narayan Nayak: *Signature of CP violation in astrophysics and cosmology*, August 2

J.S. Bagla: *Frozen potential approximation*, August 10

E. Regos: *The real value of Ω_0 and the biasing factor*, August 26

Judith Perry: *Activity in galactic nuclei : New theoretical insights*, September 1

A. Starobinsky: *Late time asymptote of gravitational instability in the Burgers equation*, September 7

Ashok Goyal: *Soliton stars*, September 28

Subhash Karbelkar: *Summing up a path in statistical optics*, September 30

Poorvi Vora: *Set theoretic constrained reconstruction*, October 8

J. Batt: *The initial value problem of stellar dynamics*, October 14

J. Batt: *(Linear) stability of stationary models of stellar dynamics and plasma physics*, October 15

Biplab Bhawal: *Nobel Prize 1993 : Hulse–Taylor binary pulsar*, October 20

Masafumi Seriu: *On the smallness of the cosmological constant*, October 21

B.S. Sathyaprakash: *Gravitational wave tails and their detection*, October 28

J. Maharana: *Noncompact symmetries in string theory*, November 18

Sir Fred Hoyle: *(Video Seminar) Microwave background and the quasi steady state cosmology*, December 1

Dipak Munshi: *Non-linear approximations to gravitational instability : A comparison in weakly non-linear regime*, December 3

R. Bhatia: *Current trends in astronomical telescopes and instruments*, December 10

Daksh Lohiya: *Gravity balls*, December 30 and 31

J.P. Ostriker: *Gravitational lensing : The clue to understanding large scale cosmic structures*, January 12

Sucheta Koshti: *Classical and quantum dynamics of the Faraday lines of force*, January 13

Janaki Balakrishnan: *Effective action for quantum fields*, January 21

D. Sugimoto: *Terraflops project dedicated to the many body problems*, January 27

Peter Coles: *The case for an open universe*, February 4

S.V. Chervon: *Exact solutions in cosmological inflation*, February 10

Nils Andersson: *Phase-integral approach to quasi normal modes*, March 1

B.C. Bhatt: *Studies in galactic star clusters*, March 3

Suketu Bhavsar: *Filaments, sheets and voids in the universe - The challenge and quantifying visual structure*, March 4

K. Rajendran: *Computer simulation of trajectory of a charged particle in cusped magnetic fields*, March 23

V. Chickarmane: *Laser interferometric gravitational wave detectors using dual recycling and squeezed light*, March 24

Public Lecture

Sir Fred Hoyle : *The origins of civilization and cultures*, February 8

PEP Talks

C.V. Vishveshwara (IIA): *GR and GYRO*

G. Baskaran (IMSc): *Physics in lower dimensions*

S.N. Tandon: *Balloon-borne astronomy*

K. Srinivasa Rao (IMSc): *Life and work of Srinivasa Ramanujan*

N. Dadhich: *Some lanes and bylanes in relativity*

R. Sinha (NCRA): *Galactic centre*

Biplab Bhawal: *Accelerated observers*

J.V. Narlikar: *The many faces of Mach*

Deshdeep Sahdev (IIT, Kanpur): *Higher dimensional Cosmology : A particle physics viewpoint*

Pramesh Rao (NCRA): *Improving angular resolution using 'seeing'*

T. Padmanabhan: *Quantum cosmology without tears*

B.S. Sathyaprakash: *Lagrange perturbation theory and gravitational radiation reaction*

S.K. Sethi: *Inflation for everyone*

A. Kembhavi: *The binary pulsar and its brothers and sisters*

K.P. Singh (TIFR): *A discussion on X-ray astronomy*

T.P. Prabhu (IIA): *Measurements in astronomy*

Ramana Athreya (NCRA): *Extragalactic radio sources*

S.D. Mohanty: *Supersymmetric quantum mechanics*

G. Burbidge (University of California, San Diego): *Quasar redshifts : Some idle thoughts*

P. Coles (Queen Mary's and Westfield College): *Probability in cosmology*

U. Yagnik (IIT, Bombay): *Solitons in physics*

S. Bhavsar (University of Kentucky): *Surprising uses of statistics*

IDG (Informal Discussion Group) Meetings

Y. Gupta (NCRA): *Improved distance scale for pulsars*

A.K. Sen: *An imaging polarimeter for observational astronomy*

R. Athreya (NCRA): *Alignment effect in high redshift galaxies*

N. Gupte (University of Poona, Dept. of Physics): *An index for mutual correlations*

N.C. Rana: *Relation between the monsoon and the Earth's angular momentum*

B.S. Sathyaprakash: *Signal recycling in gravitational wave interferometric detector*

J. Bagchi (NCRA): *Probing dark matter in clusters using gravitational lenses*

N. Dadhich: *Singularity-free cosmological models*

A.D. Gangal (University of Poona, Dept. of Physics): *Levy walk and strange kinetics*

Gopal Krishna (NCRA): *Correlations and riddles*

K. Ashwathnarayan (NCRA): *Beyond the Zeldovich approximation*

J.V. Narlikar: *Radio source count in oscillatory cosmology*

S.V. Dhurandhar: *The last three minutes*

R. Subrahmanyan (NCRA): *Another Eta Carinae*

V. Korchagin: *Large scale vortices in disk galaxies : Theory and reality*

A.P. Rao (NCRA): *Dynamic spectra of interstellar scintillation*

R. Gulati: *Stellar populations*

R. Sinha (NCRA): *Galactic centre annihilator*

T. Padmanabhan: *Quasi linear regime of density growth : A comparison of various approaches*

C.R. Subrahmanya (NCRA): *Non-isoplanatic ionosphere and low frequency imaging*

P. Gothoskar (NCRA): *Radio observations toward an Einstein ring*

R. Gupta: *Stellar spectral classification : Qualitative and quantitative*

K. Subramanian (NCRA): *Possible detection of MACHOs and its implications*

B. Phookun (NCRA): *The optical jet of quasar 3C 273*

V. Sahni: *Reconstructing the cosmological density field*

B. Bhawal: *Orbits of planets around PSR 1257+12*

S. Nair (NCRA): *More evidence for the 'missing' odd image in gravitational lensing?*

S. Ananthakrishnan (NCRA): *Ionospheric scintillation and location of GMRT*

M. Valluri: *Elliptical galaxies as merger remnants*

M.R. Sankararaman (NCRA): *Time and frequency standards*

S. Sethi: *Merger of dark matter halos in Press-Schecter formalism*

V. Chickarmane: *Thermal noise in laser interferometric gravitational wave detectors*

R.K. Singh (NCRA): *The trajectories of cosmic rays (10 - 100 MeV) in geomagnetosphere*

M. Seriu: *A note on the arrow of time*

S.N. Tandon: *Tip-tilt error in "Laser guide star adaptive telescopes"*

T.S. Ghosh: *CMBR anisotropy in an open universe*

V.K. Kapahi (NCRA): *A possible local counterpart to the excess population of faint blue galaxies*

D. Duari: *QSO absorption systems: The intervening galaxies hypothesis*

C.H. Ishwara Chandra (NCRA): *Relic radio emission in 3C 388*

G.C. Anupama: *The Seyfert Galaxy : NGC 7172*

S. Upreti (NCRA) : *Observations with Pulsar receiver: Some results*

Lecture Series

C.V. Vishveshwara, IIA, Bangalore: *Spacetime symmetries*, March-April (4 lectures).

A. Starobinsky, Landau Institute for Theoretical Physics, Moscow: *Cosmology and quantum field theory in curved spacetime*, August–September (6 lectures).

Academic Programmes

(I) RESEARCH AT IUCAA

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 associates of IUCAA using the Centre's facilities.

Quantum Gravity and Cosmology

Fluctuation - dissipation theorem and semiclassical gravity: An important question in cosmology is whether one can understand the observed large scale homogeneity and isotropy of the universe as a consequence of dynamical processes occurring over the history of the universe rather than attributing them to special initial conditions.

Studies of quantum fields in homogeneous but anisotropic universes have revealed that one of the most effective mechanisms of dissipating anisotropy which is present initially is through the back reaction of particle pairs produced in the very early universe.

It is tempting to see whether this dissipative process can be understood in the broader framework of a "fluctuation–dissipation theorem". This theorem provides a very general relation between the dissipation in the dynamics of a system and the fluctuations in the heat bath to which it is coupled. Existence of such general relations proves to be quite useful in guiding the development of models of complex physical systems in statistical mechanics and thermodynamics and they find applications in a wide variety of phenomena ranging from Brownian motion to black holes. However, such investigations have usually been confined to near equilibrium situations. It is important to understand the fluctuation-dissipation relation in the context of quantum fields in a cosmological spacetime, where the background geometry is time dependent, particles are produced and equilibrium conditions do not necessarily hold.

With this motivation, Bei-Lok Hu and *Sukanya Sinha* have analyzed this question in the model problem of a quantum scalar field in an anisotropic (Bianchi-I) universe. It was found that a generalized fluctuation-dissipation relation does exist in such a situation and the dissipation of anisotropy during the expansion of the universe can be understood as a manifestation of this relation, with particle production contributing to both noise and dissipation. The semiclassical backreaction equation now appears in the form of an Einstein-Langevin equation. The stochastic contribution appearing as a coloured noise term in the above equation modifies the results of earlier studies on anisotropy dissipation.

Hu and *Sinha* later applied the same formalism

to the question of the validity of the minisuperspace approximation in quantum cosmology. In quantized minisuperspace models, only the homogeneous mode of the geometry is quantized and all the inhomogenous modes are ignored. It is important to assess under what conditions, if any, minisuperspace quantum cosmology gives a reasonable approximation to the full theory. They have studied a model of a self interacting ($\lambda\Phi^4$) scalar field in a FRW background where the homogeneous mode of the scalar field and the scale factor of the universe constitute the minisuperspace and the truncated modes are represented by the inhomogeneous modes of Φ . It can be shown that the effect of these truncated modes on the minisuperspace sector appear as noise and dissipation as in the previous case, and the minisuperspace approximation is valid only when these terms are small. They are at present investigating how this "geometrodynamic noise", arising out of information loss from the truncated modes can be used to define gravitational entropy in a cosmological context.

For the description of phenomena in the early universe, the following scheme is often used: One provides an approximate description of the dynamical system by paying attention only to a few degrees of freedom, treating the remaining modes as an environment. To understand the decoherence of the universe, i.e., the emergence of the classical properties from the quantum universe, such a treatment is even essential. *Masafumi Seriu* has investigated one of such schemes called the memory function method, which has been first introduced by H.Mori in the context of statistical physics. The memory function method is a powerful tool for splitting a total system into the sub-system and the environment and then obtaining the Langevin-type equation. Although it is an elegant, well-defined scheme, its relation to the other standard scheme, e.g. the influence functional method is not clear and non-trivial. As a starting point, *Seriu* has generalized this method to the case when an external potential force exists along with the environmental noise. This generalization is indispensable for the application to cosmology. It has been shown that the external force produces a new, non-local, term in addition to the usual friction term and that it also destroys the time-homogeneity in the fluctuation-dissipation relation.

Any reasonable formulation of quantum gravity should lead to Einstein's equations in the semiclassical limit. *Seriu* has taken the causality condition of semiclassical limit as a guiding principle in developing a formalism for quantum cosmology. He showed that an almost unique formulation satisfying this requirement is obtained by using the Lorentzian path-integral in the "in-in" form. By the investigation of the stationary-phase approximation of this path-integral, it has been shown that any semiclassical universe which emerges from this formulation should admit at least one totally-geodesic spatial surface. This turns out to be a strong result.

Seriu has applied this formulation to investigate the global properties of the universe and obtained several results. He could prove that, if the natural energy condition for matter is satisfied, then the allowed spatial topology of the universe is extremely restricted, essentially S^3 or $S^1 \times S^2$. Since this formulation respects the causal characteristic of the semiclassical Einstein equation, this result demonstrates a tight connection between causality and topology in quantum cosmology. Secondly, the universe should begin from and end with a singularity. Thirdly, in the context of the standard cosmology, the allowed universe in this formulation is either closed or has a negative cosmological constant.

This formulation can also give a new insight into the cosmological constant problem. Since the allowed models of the universe should possess a totally-geodesic surface (this means, roughly speaking that, there should be a stage of maximal expansion), the cosmological constant cannot take a large, positive value. Thus, there is a theoretical upperbound for the cosmological constant, which turns out to be of the order $(H_0/c)^2$.

This formulation can also be utilized as a tool to investigate the conditions of validity for the semiclassical Einstein equation, which was attempted by *Seriu* in collaboration with T.P. Singh. The conditions for validity can be obtained in a general, systematic manner, as an approximation of a certain type of integral. One condition among them, viz, the vanishing dispersion of stress-tensor, T_{ab} has been inferred by several authors before, but mostly in restricted models. The discussion in terms of path-integral demonstrates clearly that the semiclassical situation is the one in which the fluctuations in geometry are negligible to some extent, but it is not directly related to the situation in which G can be regarded as small. In other words, the scheme, based on expansion in G, which has been a traditional way of investigating the semiclassical gravity, may not grasp the true essence of the problem.

Why does gravitational action have second derivatives?: It is usual to describe dynamical systems by Lagrangians of the form $L(\dot{q}, q)$ which depends on the dynamical variable only upto the first derivative. Such a Lagrangian will yield the equation of motion under variations of $q(t)$ which leaves the end values of q fixed. Given a Lagrangian $L(\dot{q}, q)$, it is possible to construct another Lagrangian L' such that: (i) L' gives the same equations of motion as L and (ii) while varying the path in L' we can keep the momenta fixed at the end points

rather than the dynamical variable. The Lagrangian L' will contain $\ddot{q}$ explicitly. *T. Padmanabhan* and Lynden-Bell have shown that if one takes the Γ^2- form of the Lagrangian in relativity (which contains the metric tensor only upto the first derivatives) as L then the Lagrangian L' turns out to be the standard Einstein-Hilbert Lagrangian $R\sqrt{-g}$. This suggests that while varying $R\sqrt{-g}$ to obtain the equations of motion one should treat the momenta as fixed at the end points rather than the metric .

This result has important implications for quantum gravity and quantum cosmology. In the conventional approaches to quantum gravity, the Hamiltonian constraint of general relativity is converted into an operator equation called Wheeler-deWitt equation. The functional solutions to these equations represent the wave functional in the "coordinate representation" of quantum gravity. An equivalent path-integral prescription will provide transition amplitude between two different 3-geometries. The above result suggests that what is relevant in quantum gravity is the wave function in momentum representation which can be obtained by a functional Fourier transform of the solutions to Wheeler-deWitt equations. The equivalent path-integral will now provide transition amplitude between two momentum states or between two 3-geometries with different extrinsic curvatures.

Accelerated particle detectors : One of the major features of conflict between gravity and quantum theory lies in the local nature of the former in contrast to the global nature of the latter. If these principles have to be reconciled effectively it is important to understand the results of quantum mechanical processes by a local description.

As an example, consider the detection of a particle by a detector. The excitation of a hydrogen atom by a photon can be thought of as an elementary detection process for a quantum particle. It turns out, however, that such a process is not generally covariant. In other words, a hydrogen atom, accelerating through the vacuum will get excited and mimic the detection of particles. This result arises, to some extent, because the quantum response of the detector (i.e. the hydrogen atom) is non-local and depends on its entire trajectory.

The non-local behaviour described above leads to difficult conceptual issues in reconciling the quantum theory with gravity. A localised description of elementary quantum processes will offer better framework for bringing together gravity and quantum theory. With this view in mind, *L. Sriramkumar* and *Padmanabhan* have started a series of investigations to understand the behaviour of simple quantum systems localised in space and time in non-inertial frames. Their preliminary results suggest that it is indeed possible to provide semi-local description of quantum mechanical processes which could form a basis for combining the principles of quantum theory and gravity.

Euclidean self - dual solutions and gravitational instantons: Euclidean self-dual (SD) solutions of the Einstein equations are significant in quantum gravity since they correspond to saddle points of the Einstein-Hilbert action and give large contribution to a path integral over Euclidean metrics. To obtain such SD solutions, one has to solve, in general, second order non-linear partial differential equations. One easier way to generate new SD solutions is to assume some special form for the metric and to demand the self-duality of the O(4), Levi-Cevita connection. This automatically guarantees the self-duality of the Riemann tensor and hence solves the vacuum Einstein equations automatically. The self-duality of Riemann tensor is equivalent to vanishing of Ricci tensor. This way the problem of obtaining SD solutions reduces to that of solving first order partial differential equations. *S. Koshti* and *N. Dadhich* have used this method and obtained a new family of SD solutions of the vacuum Einstein equations which includes the well known SD solutions, the Eguchi-Hanson and the Taub-NUT metrics.

In 1986, Abhay Ashtekar reformulated general relativity in terms of a new set of canonical variables, now called Ashtekar variables. The SD Einstein equations take very simple form when written in terms of the Ashtekar variables. Using these variables, *Koshti* and *Dadhich* establish the correspondence between Maxwell instantons and the SD solutions of the vacuum Einstein equations. It turns out that every SD solution of the vacuum Einstein equation corresponds to three Maxwell instantons on the background metric determined by the SD solution. As an illustration they explicitly find the three Maxwell instantons on the Eguchi-Hanson background metric.

Classical Gravity

Avoiding the singularities in gravity : The question of singularities in general relativity was dramatised by the big-bang singularity of the standard Friedmann model. Occurrence of singularity is an important question in any theory but it acquires special and crucial proportion in general relativity for it means a singularity in spacetime structure as well.

Friedmann model is spherically symmetric and has homogeneous and isotropic distribution of matter content. This raises the question: Is the big-bang singularity a consequence of highly specialised properties of the model or a generic feature of the theory? The Singularity Theorems (ST), proved in the sixties, seemed to establish in all generality that the existence of singularity is inescapable in GR under

reasonable physical assumptions. This belief was shaken in 1990 when Senovilla found a singularity free solution describing a radiation universe with physically acceptable behaviour in all respects. How did this happen? A fresh look at the assumptions of ST showed that while most of the assumptions are physically reasonable and obvious, there is one that demands the occurrence of compact trapped surfaces (such a surface arises when the gravitational field becomes so strong that even photons get trapped in a surface). This is by no means a simple demand since the behaviour of the field is entirely governed by the field equations and there is in general no room for additional prescription. This is precisely the condition violated by the singularity free solution to escape the grips of ST.

Subsequent to this important discovery, L.K. Patel, R. Tikekar and *Dadhich* have been studying the singularity free spacetimes extensively. They have been able to obtain a number of interesting results:

1) It can be argued that a natural inhomogenisation of the FRW open model leads to the unique family of singularity free cosmological models with cylindrical symmetry with the metric separable in space and time variables. It may be noted that the result of the inhomogenisation process gives the whole set of non-singular solutions.

2) The general form of the metric can be shown to be geodesically complete exhibiting absence of singularity of any kind.

3) Their more recent investigations indicate that inhomogeneous, non-static, fluid models are not admissible in spherically symmetric cases and hence, for inclusion of inhomogeneity, one has to work with spacetimes with lesser symmetry. Models with cylindrical symmetry admit non-singular solutions with acceptable physical properties. At whatever scale the universe is required to be inhomogeneous, it could at best be cylindrical there. This is how cylindrical symmetry gets associated with the inhomogeneous and non-singular models. Since cylindrical symmetry prohibits occurrence of compact surfaces in a natural manner, ST will be inapplicable in general leaving the field open for non-singular models to occur.

The most important question now is how to obtain the Friedmann model from a non-singular cylindrical model? This is however a very difficult question, and a preliminary investigation in one of the aspects of this question has been initiated by *Dadhich* and S. Mukherjee.

Cosmology and Structure Formation

The big bang challenged: For over two and a half decades the big bang theory of the universe has ruled supreme in cosmology. The idea that the universe was born in a hot explosive event that took place some ten to fifteen billion years ago began to gain support from the late sixties through the observations of the very homogeneous and featureless radiation background in the microwaves and the abundances of light nuclei in the universe. Both these aspects seemed almost impossible to explain unless one assumed the hot big bang scenario.

In the late seventies and eighties big bang cosmologists became more daring and speculative in their studies of the initial moments after the big bang event, for in their attempts they acquired unexpected and unlikely allies in particle physicists who were just as anxious to find the "theory of everything" that would explain all fundamental interactions of physics in a single unified framework. It seems that the sought after unification would need energies of participating particles far higher than can be attained by today's high energy particle accelerators. On the other hand, the early moments after the big bang provided the high energies needed for working out the particle physics speculations.

However, speculations in two fields do not add up to a testable scientific theory even if they go hand in hand. To gain credibility, the exercise required definite predictions that we can test here and now. For the particle physicist they could be in the form of esoteric non-baryonic matter that is not normally found in the laboratory experiments. For the cosmologist the predictions should match the features of the large scale structure of the universe. To what extent has the joint exercise been successful?

In 1990 five scientists H. Arp, G. Burbidge, F. Hoyle, *J.V. Narlikar* and C. Wickramasinghe expressed grave reservations with the entire big bang approach in a joint article published in Nature. They highlighted several shortcomings of the big bang + particle physics approach and suggested looking for alternative scenarios in cosmology. Some of the shortcomings are briefly listed below:

1. As yet there is no coherent and consistent theory that relates the large scale structures of today to primordial seedlings that can be linked with any observed tiny fluctuations in the intensity of the microwave background.

2. The age distribution of galaxies with very young and very old star-systems cannot be explained by the big bang concept of galaxy formation.

3. The nature of dark matter still remains a mystery despite several alternative models of cold or hot or mixed non-baryonic versions being tried.

4. The observations of discrete source populations within the expanding world models require numerous ad-hoc evolutionary hypotheses to explain them.

5. The present temperature of the microwave background is not derived from any fundamental

concept but is assumed as given.

These and other aspects of criticism were countered by the big bang cosmologists either on the grounds that they were not serious defects of the present approach which, with a few minor improvements would get round them or that in the absence of a serious alternative one cannot carry the debate any further.

Denying the first alternative Hoyle, Burbidge and *Narlikar* have gone for the second and produced a new cosmological model called the "Quasi-Steady State Cosmology". In a series of papers they have discussed the details of the QSSC. What are the claims made for this new cosmology ? In what way does it fare better than the big bang cosmology ?

In the QSSC, the creation of matter is not beyond the purview of physics as it is in the big bang model. Instead it is explained as a normal field theoretic process that occurs in strong gravitational fields, near highly collapsed objects. A negative energy scalar field is also created to conserve the overall matter and energy; and this field reacts back on spacetime geometry to produce rapid expansion. Thus instead of one singular primary big bang creation, here we have a continuing process of creation through energy conserving minibangs.

The universe itself expands as a result of these minicreation events with an exponential time factor but with smaller time scale oscillations representing ups and downs of the creation activity. The typical time scale for exponential expansion is around a thousand billion years while the period of one oscillation is 40 to 50 billion years. Thus old and young galaxies can coexist and the dark matter in the galaxies and in clusters could be baryonic, being made of either old burnt out stars or brown dwarfs or jupiters.

The cosmological surveys of discrete objects like galaxies or radio sources can be easily accounted for by the above oscillatory expanding model. The model predicts a few faint galaxies (say with magnitudes fainter than 25) to have modest blueshifts.

Finally, on the two crucial observations that boosted the case for a hot big bang the QSSC performs at least as well. The microwave background is explained as thermalized starlight from stars of previous generations. The thermalization is supposed to be performed by needleshaped grains of iron in the intergalactic space, a process that not only produces the black body spectrum but also obtains the correct temperature. Further, the observed temperature fluctuation by COBE and other experiments can also be traced to the inhomogeneity of the grain distribution.

The other observation, that of light nuclear abundances, is explained by the result that the particle created in a minibang is a particle with Planck mass (of a few tens of microgrammes) which decays into nucleons which in turn combine into light nuclei. Calculations lead to a good agreement with observations, without imposing any restriction on the baryonic density as in the big bang case. Thus the QSSC can live with baryonic dark matter.

Work on the model is continuing on several fronts: (1) To find the robustness of the theory vis-a-vis its assumed parameters and the numerous observational constraints, (2) to relate the parameters to the theory of matter creation, (3) to explore the interface with particle physics to see how the decay of the Planck particle to baryons takes place and (4) to work out a detailed theory of structure formation.

Numerical simulations and nonlinear clustering: It is generally believed that structures like galaxies, clusters, etc. were formed through the amplifications of small density perturbations which had existed in the early universe. As long as these inhomogeneities are small they can be studied using linear perturbation theory. But when the density contrast is of order unity, it is necessary to use numerical simulations to accurately track the formation of structures.

During the evolution of density inhomogeneties in an $\Omega = 1$, matter dominated universe, the typical density contrast changes from $\delta \simeq 10^{-4}$ to $\delta \simeq 10^{2}$. However, during the same time, the typical value of the gravitational potential generated by the perturbations changes only by a factor of order unity. This significant fact was exploited by *J.S. Bagla* and *Padmanabhan* to provide a new, powerful, approximation scheme for studying the formation of nonlinear structures in the universe. This scheme evolves the initial perturbation using a Newtonian gravitational potential frozen in time. This procedure is carried out for different initial spectra and the results are compared with the Zeldovich approximation and the frozen flow approximation (proposed by Mattarrese et. al. last year). Their results are in far better agreement with the N-body simulations than the Zeldovich approximation in the nonlinear epochs. This analysis also provides a dynamical explanation for the fact that pancakes remain thin during the evolution. While there is some superficial similarity between the frozen flow and frozen potential results, they differ considerably in the velocity information. Actual shell crossing does occur in the frozen potential approximation; also there is motion of particles along the pancakes leading to futher clumping. These features are quite different from those in frozen flow model. They have also studied the evolution of the two-point correlation function in various approximations.

This approximation scheme opens up several new avenues of investigation and could lead to significant progress in the understanding of non-linear gravitational clustering. For example, it will now be possible to handle gas dynamics at high redshifts in a manner which does not require a full scale

hydrodynamic code. It is also possible to derive several semi-analytic results regarding the formation of voids and filaments in an expanding background. In particular, it was possible to make an estimate of the rate of expansion of voids in an expanding universe using an analytic solution to the equations of frozen potential approximation. This result agrees well with the results of numerical simulation.

During the last year *Padmanabhan* and R. Nityananda did some work which attempted to understand a universal relation between linear and nonlinear density contrasts that is observed in N-body simulations. Recently *Bagla* and *Padmanabhan* have investigated the validity of this universality relation in the frozen potential approximation. It turns out that the universality is maintained to a high level of accuracy even when the potential is frozen. This shows that the universality relation is not dependent on self-consistent gravitational dynamics but arises more due to the random, statistical nature of the potential. They are now investigating the generality of this.

The work described above motivated *Bagla* and *Padmanabhan* to develop a full-fledged cosmological N-body code for studying the evolution of perturbations in an expanding universe. The code is tested in 2 dimensions and the results are robust and agree with previously published results. They are now in the process of optimising the code in 3-dimensions. It may be mentioned that, this is the first group in India to develop an N-body code to do cosmological simulations. They now plan to introduce gas dynamics and baryonic physics into the code using approximations similar to that of frozen potential and are hopeful that they will be able to obtain the essential physics of baryons without really using a full-fledged hydrodynamical code.

Analytic approximations to nonlinear clustering: The growth of density fluctuations in the universe can be characterised by two essentially distinct epochs. During the first – the linear epoch – the growth of density fluctuations proceeds in an essentially self-similar manner, as a result the physics of this epoch is fairly straight forward to analyse theoretically. The second epoch is characterised by the development of non-linearity, and is more interesting from a physical point of view since it witnesses the extremely rapid growth of density perturbations accompanied by such singularly non-linear features as mode-mode coupling, and the formation of a cellular structure in the universe consisting of pancakes, filaments and voids.

The physics of non-linear gravitational instability is very complex, as a result a number of approximation methods have been proposed in recent years which attempt to mimick some of its aspects.

D. Munshi and A. Starobinsky, have compared the accuracy of different approximations to nonlinear gravitational clustering in the weakly non-linear gravitational regime. Investigating three such approximations, namely the Zeldovich approximation, the frozen flow approximation and the frozen potential approximation, *Munshi* and Starobinsky derive the velocity-density relation and determine the skewness parameter characterizing the departure of the density (or velocity) field from its initial distribution which is assumed to be Gaussian. They find that the Zeldovich approximation is more accurate than the other two approximations (when compared with the exact solution) in second order perturbation theory for a wide class of initial conditions. *Munshi* and Starobinsky together with *V. Sahni* are now extending their work to include higher order moments of the density distribution, and also to incorporate other approximation methods in addition to the three mentioned above.

The methods used by *Munshi, Sahni* and Starobinsky, although providing a deep insight into the phenonmenon of weakly nonlinear gravitational instability, break down in the strongly nonlinear regime. In order to probe the validity of the different nonlinear approximations to gravitational clustering in the strongly nonlinear regime one has to resort to numerical methods. *B.S. Sathyaprakash, Sahni, Munshi,* D. Pogosyan and A. Melott, have begun a detailed comparison of some nonlinear approximations both with one another as well as with the results of N-body simulations. The approximations considered are: (a) the adhesion model, (b) the frozen flow approximation, (c) the frozen potential approximation and (d) the truncated Zeldovich approximation. With the aid of robust statistical indicators they propose to discuss the domain of validity of each of these approximations to gravitational instability in the strongly nonlinear regime.

Formation and evolution of voids in the universe: The universe on very large scales consists of voids of different shapes, sizes and texture. The study of the formation and evolution of voids has gained a lot of momentum in recent years with the recent discovery of a large number of both big and small voids in redshift samples of the universe. *Sahni, Sathyaprakash* and S. Shandarin, have carried out a comprehensive treatment of the evolution of voids using the adhesion approximation. Performing simulations for the standard Cold Dark Matter model and for a variety of other initial density spectra, they find that the characteristic sizes of voids evolves as does the void distribution. For the COBE-normalised Cold Dark Matter model they find that the maximum void size is in the neighbourhood of 60 Mpc. Contrary to popular belief they find that voids not only expand but can also contract as they are encroached upon by

neighbouring larger voids. This process leads to the elimination of small voids in a given void ensemble and to an increase in the mean void diameter with time. They also find support for the suggestion that non-linear gravitational instability proceeds along two complementary epochs. During the first epoch, matter flows out of voids and collects in pancakes, filaments and clumps which together define a coherent cellular structure. Pancake formation however happens to be an intermediate asymptote. During the second epoch most of the matter flows along sheets into filaments and along them collecting finally in clumps. This leads to gravitational clustering taking place hierachically hereafter and results in the eventual destruction of cellular structure. (Cellular structure can also form during the second phase due to the formation of second generation pancakes).

Sahni, Sathyaprakash and Shandarin have determined the rate of infall of matter into caustics and interestingly found that it is spectrum independent for power law spectra. This result could be used for constraining an early epoch of galaxy formation in different cosmological models. An interesting result of their analysis is that voids are likely to be populated with small Zeldovich pancakes that can run through a given void bounded on the outside by major pancakes. This result seems to be a generic feature of scenarios of clustering based on gravitational instability and may be of considerable importance in view of the fact that several large voids such as the Boote's void and voids in the CfA survey, have been found to possess galaxies within them.

Sahni, Sathyaprakash and Shandarin find that the distribution of volume amongst voids of various sizes, sometimes called the "void spectrum", is quite sensitive to the initial fluctuation spectrum of density perturbations. Hence a proper understanding of the void spectrum of the universe could in principle lead to a precise estimation of the primordial spectrum. They have also pointed out that the void spectrum can potentially be used to determine the value of the density parameter Ω once the shape and amplitude of the initial perturbation spectrum are independently known. Thus, the statistics of voids can be an important measure in characterizing the large scale structure of the universe.

Inflation and the anisotropy of the cosmic microwave background radiation: The COBE detection of the anisotropy in the cosmic microwave background radiation (CMBR) has opened up an exciting area in cosmology. There is a distinct possibility that density fluctuations generated during inflation could have led to the formation of galaxies and large scale structure in the universe today via gravitational instability. As density perturbations enter the horizon during matter domination, they induce distortions in the CMBR through the Sachs-Wolfe effect.

Sahni and *T.S. Ghosh* are continuing their investigations into the relationship between cosmological density perturbations and the spectrum of relic (primordial) gravity waves which are also generated (quantum mechanically) during inflation. In a recent work they showed that the relative contribution of gravity waves towards the large scale anisotropy of the cosmic microwave background radiation could be significant for inflationary models with non-flat potentials. *Sahni* and *Ghosh* are now developing a formalism which will determine the relative amplitude of gravity waves and primordial density perturbations, for generalised inflationary models with multiple scalar fields and/or polynomial potentials. This could permit them to address questions like which class of primordial spectra can best explain the observed features of large scale structure, such as : (a) the anisotropy in the cosmic microwave background, (b) the two point correlation function for galaxies, (c) the bulk peculiar velocities of galaxies on scales of $\sim$ 50 Mpc, and (d) the existence of high redshift objects such as QSO's. They are also investigating the possibility that the inflationary spectral index might be larger than unity.

The relative contribution to the large angle CMBR anisotropy (as detected by the COBE, FIRS and the Tenerife experiments) from gravity waves and density perturbations (GW induced bias) is extremely sensitive not only to the underlying model of inflation but also to the present matter content of the universe. *Sahni* and *Ghosh* have studied this effect in the presence of a cosmological constant and plan to look at open universes in the near future. They also find that the amplitude of the stochastic gravity wave background at scales which will be probed by terrestrial detectors like LIGO depends on the present matter content of the universe.

Recently, a formulation for reconstructing the inflation potential from the observable density perturbation spectrum was proposed. The relative contribution to the CMBR anisotropy from gravity waves and density perturbations (GW induced bias) is a free parameter when an inflaton potential is reconstructed from the density perturbation spectrum alone. This quantity is measurable using CMBR anisotropy measurements at small angular (sub-degree) scales. *Ghosh* has been trying to quantify the sensitivity of the reconstruction procedure to the error bars in the estimate of the GW induced bias and in the estimate of the spectral index of the density perturbation spectrum.

Bounds on Higgs mass from cosmology : In our universe, we observe an excess of baryons over antibaryons which can be quantified by the ratio

(n_B/n_γ), where n_B is the excess number of baryons and n_γ is the number of photons; this ratio $n_B/n_\gamma \simeq 10^{-10}$ in our universe. Such a baryon asymmetry in the universe can be produced dynamically by processes which satisfy the three conditions enunciated by Sakharov: The process: (a) must violate baryon number conservation, (b) must violate symmetry under charge conjugation and charge conjugation–parity, and (c) must occur out of thermal equilibrium. All these conditions can be fulfilled in the phase transition occurring at the energy scale of electroweak symmetry breaking which occured when the temperature of the universe was about 246 GeV.

This process has been studied extensively in the recent years. However, in such a scenario, the mass of the Higgs boson m_H of the standard electroweak model with one Higgs doublet is bounded from above, to prevent excessive dilution of the baryons formed during the electroweak phase transition. *S. Sethi*, in collaboration with A. Majumdar, S. Mahajan, A. Mukherjee, R.P. Saxena and N. Panchapakesan, has attempted to improve this bound by using the temperature dependent renormalisation group analysis. They discovered that though there is a good agreement with the earlier results for top quark masses 75 GeV $< m_t <$ 85 GeV, unlike the earlier results, this bound depends more strongly on the top quark mass. For instance, if $m_t = 100$ GeV, even $m_H = 20$ GeV is ruled out. This result, in light of experimental results which suggest that 135 Gev $< m_t <$ 150 GeV and $m_H > 64$ GeV, rules out the single Higgs doublet standard model more strongly than the previous results.

Ionising the universe with unstable neutrinos : In the standard big bang model, nearly all the protons in the universe are in the form of neutral hydrogen or helium just after recombination ($z \leq 1000$). However, observations show that the number density of neutral hydrogen is less than 10^{-12} cm^{-3} at a redshift of $z = 2.6$. The number density of baryons, in the standard model, is nearly seven orders of magnitude larger at this epoch. Clearly, there must be some source of ionizing photons which could cause such a high degree of ionization at $z \geq 5$. No astrophysical process seems efficient enough to cause such a high degree of ionization. Radiatively decaying neutrinos can possibly provide the requisite photon flux. However several observations, like the Planckian nature of the spectrum of the CMBR, amount of diffuse background of ultra-violet photons seen at present, and negligible emission of high energy photons from Supernova 1987A, severly restrict the mass and lifetime of the neutrino. The process of structure formation puts additional constraints. *Sethi* has investigated the possibility that the radiatively decaying neutrino can provide the photons to ionise the universe, while satisfying all the above constraints. He considered neutrinos in the mass range of 100-1000 eV with a life time exceeding 10^{12} seconds, which decay into photons and massless neutrinos with a small branching ratio. His results show that there is a narrow window in the parameter space which satisfies all the conditions.

Big bang nucleosynthesis : The astrophysical S-factor for the nuclear reaction ^{8}Li $(\alpha, n)^{11}$B was derived from its newly measured direct reaction cross sections by T. Mathew, S. Ramani and *N.C. Rana*. The existing numerical code of the standard hot big bang model dealing with the details of the primordial nucleosynthesis process was extensively revised and the nuclear reaction rates were updated. Work by Mathew, Sonali Shah and *Rana* show that the discrepancy between the predictions of the model and the observational estimates of the primordial abundances of the light elements is still present.

In Search of Gravitational Waves

Coalescing binaries : The recent nobel prize to Hulse and Taylor has spurred on researchers working on gravitational waves to investigate with renewed vigour sources of this type—compact coalescing binaries, which could be the most promising sources for the LIGO/VIRGO detectors. Although PSR 1913+16 will coalesce in about 10^8 years, several events per week are likely to be seen with these large scale interferometers which have ranges upto a Gpc or so. In analysing LIGO/VIRGO data from coalescing binaries, two different types of strategies will have to be adopted: (i) *detection* of the binary spiral signals from noisy data (ii) *extraction* of parameters of the signal or information from the signal. The detection strategy involves seeking a yes/no answer by means of templates which span the function space of the binary in spiral waveforms. *R. Balasubramanian* and *S.V. Dhurandhar* have investigated the effectiveness of Newtonian templates which were earlier designed by *Sathyaprakash* and *Dhurandhar*. The Newtonian templates are based on the quadrupole formula. On the other hand, the signal waveform has been computed by Cutler et. al. to the third post-Newtonian order, by numerically integrating the orbit equation in the test mass approximation. For the power spectral densities of the noise for the LIGO detector, in the initial and advanced stages the correlations were found to be fairly high although this meant a considerable mismatch in the signal and filter parameters. These investigations suggest that the detection problem is under control although more work is necessary to device optimal templates.

A very important aspect related to filtering is the number of indepéndent filters needed to filter out signals in a given range of parameters in the parameter space. The covariance among the samples in the

filtered output when the data is passed through a series of filters suggests that full information must be available in a smaller subset of the filtered output and hence an optimal set of filters must exist. *Dhurandhar* and B. F. Schutz addressed this question restricting to one parameter, namely, the time of arrival of the signal. They found that the narrow band filter of the coalescing binary leads to a correlated output which must be resampled at a much lower rate if the samples are to be statistically independent. This effective number of degrees of freedom was tested with threshold simulations which lent empirical support to their conjectured formula. The formula needs to be proved and the concept extended to other parameters of the signal.

As a system of binary stars approaches coalescence, the gravitational wave sweeps up in frequency and secular post-Newtonian corrections to the phase of the waveform become substantial. When such corrections are incorporated in the templates used in detecting the signal, it is possible to glean tremendous amount of astrophysical information such as the masses of the component stars, their equation of state, etc. In addition, observation of several such coalescence events can facilitate an accurate determination of cosmological parameters, like the Hubble constant and the density parameter. In order to extract information of this kind, it is absolutely essential that the parameters of the waveform be determined very accurately. Optimal Weiner filtering is a data analysis technique which allows very precise determination of signal parameters. However, to take full advantage of this technique it is necessary that the inspiraling binary waveform be known to a high degree of accuracy. One should, therefore, include as many post-Newtonian terms as possible in the construction of the templates. When post-Newtonian corrections are included, the parameter space of the waveform acquires an extra dimension. It was feared that this would mean a severe burden on data analysis. However, *Sathyaprakash* and *K. Jotania* have shown that when first post-Newtonian corrections are included in the phase of the waveform it is possible to make a judicious choice of the parameters so that the effective dimension of the parameter space remains unchanged. While such a strategy is suitable for an unambiguous and easy detection of the waveform it does by no means guarantee a precise estimation of the binary's parameters. *Sathyaprakash* and *Jotania* have cautioned that this algorithm be employed in catching the waveform and have shown how an off-line analysis may be carried out to extract accurately other useful information.

Higher order post-Newtonian corrections are rich in information regarding nonlinearity of gravitational interaction. For instance, at 1.5 post-Newtonian order beyond the well known quadrupole gravitational radiation reaction, general relativity predicts the so called "tail" effect. This effect is essentially due to the fact that gravitational radiation propagates on the curved background space-time generated by its own source. More specifically, the tail of the radiation results from the nonlinear interaction between the time-varying quadrupole moment of the source and its monopole moment, or total mass. Luc Blanchet and *Sathyaprakash* have shown that the observations of inspiraling compact binaries, with advanced LIGO detectors, will permit verification of this fundamental prediction of general relativity. Further, they have shown that this will provide an independent measurement of the total mass of the source. Such a detection will yield an interesting test of the non-linearity of general relativity in the "gravitodynamics" regime of the theory, involving rapidly varying strong gravitational fields.

The test proposed by Blanchet and *Sathyaprakash* is analogous to verifying the existence of gravitational radiation in the binary pulsar PSR 1913+16, where the change in the orbital period of the pulsar, the relativistic periastron shift of the orbit, and the red-shift–Doppler parameter are plotted in the m_p–m_c plane of the pulsar and its companion. The test would consist of verifying the intersection at *one* point, of the three (or more) curves, in the m_1–m_2 plane, corresponding to measurements of the total mass, (which is in fact the wave tail) and of the two (or more) parameters of the wave front namely, the chirp mass, the reduced mass, etc., each being independently varied and measured in the filtering process.

Pulsars : The long integration times required for detecting gravitational waves from non-axisymmetric pulsars entails taking into account the motion of the detector as it moves along with the earth. The response of the detector is therefore frequency and amplitude modulated. *Jotania* and *Dhurandhar* have performed a detailed study and obtained the response as a function of the detector and pulsar orientations. Since the response is dependent on the detector orientation, *R. Parui* is looking into the problem of optimally orienting the detector for a given distribution of pulsars. The ground work on this has already been done by M. Sc. project students, S. Barve and S. Sane.

Modelling the interferometer : Detecting gravitational waves is a formidable task due to the extreme weakness of the interaction. Reducing the noise in the interferometer is of paramount importance to the experimenter. The precision needed is so high that the measurement can be impeded by the quantum uncertainty principle. The photon shot noise is the main source of noise over the band width of detection. This noise may be reduced by effectively increasing the laser power by recycling the light that comes

out of the laser input port. But one cannot reduce the noise or increase the sensitivity indefinitely by increasing the laser power due to quantum constraints. Introduction of *squeezed* light at the output port can alleviate this difficulty to some extent. *B. Bhawal* and *V. Chickarmane* have investigated this issue when both the techniques, recycling and squeezing are used in conjunction. Their preliminary results for a single pass delay line interferometer show that the two strategies can reinforce each other. Further issues to be investigated involve broadband squeezing, losses, etc. A computer model for recycling and squeezing is being worked out.

Quasars and Extragalactic Astronomy

The origin of quasar absorption lines: The quasi-stellar objects – or quasars – have emission lines which show large redshifts. It is generally believed that the redshifts are cosmological in origin which could make quasars useful probes of high redshift universe.

One important feature of the quasars in this connection is the existence of absorption lines in their spectra. Not all quasars show absorption lines: indeed, it would be fair to say that there has been no systematic search for absorption lines in all the quasars that are known to date. Nevertheless those that have been looked at show absorption features at more than one redshifts. Of these, quite a few called broad absorption lines appear with redshifts not much different from the emission redshift and these are believed to have come from the absorption processes in the quasars themselves. Then there are a host of absorption lines of neutral hydrogen (Lyman-alpha) that are considered to be due to clouds of intergalactic hydrogen between the quasar and ourselves.

There is a third category of narrow metal absorption lines which also occur at varying redshifts and it is tempting to apply the same "intervening cloud" interpretation to them. Only, in this case the more plausible alternative is to think of the absorbers as galaxies or galactic halos with sizes ranging from 20 to 40 kpc. In which case, the multiplicity of absorption line distribution and the distribution of absorption redshifts should be related to what we know about the distribution of galaxies in the expanding universe.

D. Duari and *Narlikar* have attempted such an exercise with the currently available database of quasar absorption lines compiled by V. Junkkarinen, A. Hewitt and Burbidge. The prima facie results are not encouraging for the intervening galaxy/halo hypothesis (IGH). First, there are far too many multiple redshift systems than can be accounted for by the IGH. Secondly, the predicted redshift distribution does not match the observed one.

At this stage it is possible to defend the IGH by arguing that the JHB database is by no means a complete sample and that several selection effects might have contrived to generate the above discrepancy. *Duari* and *Narlikar* argue that despite incompleteness of the database their findings are significant: for example, there are discrepancies which would grow worse if the database were made more complete. Likewise they discuss various selection effects and show that they are inadequate to explain the gap between the IGH predictions and the data.

Indeed, if the IGH is to survive one must assume that the typical absorber sizes may be as large as 70 - 80 kpc (i.e., much larger than the visible parts of galaxies) and that there are evolutionary factors at work determining the metal abundances in galaxies that we do not yet understand.

Quasars as X-ray sources: Quasars are known to be powerful X-ray emitters, and contribute substantially to the diffuse X-ray background especially around a few keV. In the region of 2-10 keV, quasars, like Seyfert galaxies, have spectra which can be approximated by a simple, almost universal, power-law form. There is some direct and a lot of indirect evidence that for X-ray energy of about 1 keV, there must be excess emission over the extrapolation of the high energy spectrum. Because of the difficulties in making measurements, the spectral form of the excess and its energy content is poorly known. *A.K. Kembhavi*, in collaboration with A. Fabian has shown how the form of this excess may be constrained, by using quasar luminosity functions, and assumed forms of the low-energy spectrum, to predict the number of quasars which should be observed per unit area of the sky, as a function of their X-ray flux. Comparison with recent deep X-ray surveys from ROSAT provide information about the spectral form. It has been shown that quasars and other active galactic nuclei can contribute only a fraction of the deep survey sources, and that a substantial contribution must come from an unevolved population.

Damped Lyman alpha systems and models for structure formation : Models for structure formation attempt to predict the power spectrum of density perturbations in the present universe from the initial power spectrum and the nature of dark matter. Observational constraints on the power spectrum at different scales in the present epoch can, therefore, be used to eliminate (or choose between) different theoretical models. Such a comparison is fairly easy at large scales (at which linear theory is valid), and one can use observations like the MBR anisotropy, large scale streaming motions, etc. to constrain the models. But to discriminate between the models effectively, it is necessary to constrain the power spectrum at small scales. The most reliable constraints on the power spectra at small scales come from the predicted abundance of bound systems which can be estimated reasonably and accurately

using Press-Schecter (or similar) methods. In the past, this method has been used in conjunction with the quasar abundance and cluster abundance. Recently, K. Subramanian and *Padmanabhan* have shown that the abundance of damped Lyman alpha systems (DLAS), provides a far stronger constraint on the models for structure formation. Models with a mixture of hot and cold dark matter (which are consistent with large scale observations) are strongly ruled out by the DLAS constraints while models with cosmological constant are marginally inconsistent. It is also possible to combine the constraints from the abundance of clusters, DLAS and QSO's to obtain model-independent bounds on the power spectrum at the nonlinear scales. These bounds are to be respected by any viable model for structure formation.

Imaging the galaxies : The appearance of galaxies in the sky varies from smooth, almost structureless ellipticals to complex spiral galaxies with arms and other large scale features like bars and rings. The detailed study of the distribution of radiation across a galaxy provides information on the distribution of visible and dark matter and therefore its structure and dynamics. Using Charge Coupled Device (CCD) cameras, it is relatively easy to obtain an image of a galaxy which spans a wide range of brightness. The power of the camera is complemented by sophisticated image processing techniques, which allow the large as well as the small scale structures in galaxies to be studied with greatly improved sensitivity. The data for these studies has been obtained using the 2.3 m Vainu Bappu telescope, and 1 m telescope at the Uttar Pradesh State Observatory as well as some telescopes in other countries.

As a part of this programme, *Kembhavi* and *G.C. Anupama*, in collaboration with M. Elvis and R. Edelson, have been studying Seyfert galaxies which have been selected on the basis of their being strong X-ray emitters. The observed light distribution has been decomposed into nuclear, bulge and disc components and these have been related to other properties of the galaxies. The morphological properties of the sample are being studied in detail, so that they may be correlated to the presence of the active nucleus. The Seyfert galaxy NGC 7172, which is a part of the sample, has an exceptionally prominent dust lane. Using optical extinction measurements from broad band images, it has been possible to estimate the total neutral hydrogen content in the dust lane, and this is found to be consistent with 21 cm line estimates.

Some spiral galaxies have peculiar nuclear regions, which show well defined structures like small spirals, rings, knots or an amorphous appearance. These features are associated with large scale star formation, which could be triggered internally in the galaxy, or due to interaction with other galaxies. It is of great interest to study in detail the nature of the knots and other features, and to relate them to the large scale morphological features in the galaxy as well as the possible presence of an active nucleus. *A. Mahabal* and *Kembhavi* are involved in the observation of a large sample of such galaxies. The data here consists of broad band images, as well as images taken at the wavelengths of prominent emission lines, which provide information on the physical conditions, like, density and temperature, prevailing in the regions of interest. In collaboration with T.P. Prabhu, *Anupama* and *Kembhavi* have mapped and studied in detail the knots and dust lanes in NGC 2903, which is an important example of the class of galaxies with peculiar nuclei.

Elliptical galaxies generally appear to have simple structures, represented by similar elliptical isophotes. However, sensitive observations show that the eccentricity and position angle of the ellipses may change with distance from the centre, and the isophotes may even show departures from a pure elliptical nature. These peculiarities may be traced to the triaxial nature of the three dimensional ellipsoids of which the observed ellipses are projections. Elliptical galaxies also show small scale features which can be isolated only with deep exposures and careful image processing, as well as faint large scale features like shells and rings. These are indicative of disturbances due to interactions, mergers at previous epochs, the presence of cooling flows, etc. In collaboration with S.K. Pandey, D. Sahu and N. Thakur, *Kembhavi* has been studying a sample of elliptical galaxies to detect peculiarities of the kind mentioned above. A number of galaxies have been found to exhibit complex features, while a parallel study initiated by K.P. Singh and P.N. Bhat has shown for the first time the presence of blue rings in elliptical galaxies. A sample of radio ellipticals is also being studied by *Mahabal, Anupama* and *Kembhavi* in collaboration with K.P. Singh and P.N. Bhat.

MACHOS and microlensing : There is considerable evidence to suggest that galaxies like ours are embedded in large halos of dark matter. The nature of dark matter is still unknown and several possible choices have been suggested in the literature. These possibilities may be classified as baryonic (say, made of jupiters or low mass stars) or non baryonic (say, massive neutrinos or other exotic particles).

If the halo is made of compact baryonic objects, then these objects will act as gravitational micro lenses and will induce variations in the intensity of stars in nearby galaxies. The variations can be detected, for example, by systematic monitoring of stars in LMC. The recent detection of such microlensing of stars of LMC by compact objects in the halo of our galaxy suggests that our galaxy is surrounded by a non-luminous halo made of compact objects with mass of about $(0.03 - 0.5)M_{\odot}$.

The rate of detection could be consistent with the assumption that these halo objects are distributed with a softened isothermal profile with a core radius of $(2 - 8)$Kpc and asymptotic circular velocity of 220 km s^{-1}. Taken in isolation, this observation is consistent with a universe having only baryonic dark matter (BDM) contributing $\Omega_b = \Omega_{total} \simeq 0.06$. Such a model, however, will violently contradict several other large scale observations, notably the COBE-DMR results. The simplest way to reconcile the microlensing observations with such constraints is to assume that galaxies like ours are surrounded by both BDM and non-baryonic dark matter (NBDM). *Padmanabhan* and Subramanian have investigated the consequences of this hypothesis. They find that a model with a single component for NBDM with, say, $\Omega_b \simeq 0.06, \Omega_{cdm} \simeq 0.94$, is also ruled out if they demand that BDM and NBDM are distributed with similar scale lengths. If, further, microlensing observations suggest that half or more of the dark matter within 100 kpc is baryonic, then one is led to the powerful constraint that the maximum value of Ω_{dm}, contributed by NBDM clustered at galactic scales, is about $\Omega_{max} \simeq 0.29$. Hence, if one demands that $\Omega_{tot} = 1$, then about 70 percent of dark matter must be distributed smoothly over galactic scales. Models with C+HDM cannot satisfy this constraint but Λ+CDM models are still viable. Even in such hybrid model it is not clear whether one can consistently explain the abundance of quasars and absorption systems.

Evolution of Galaxies and Clusters

The dynamics of galaxy interactions: Interactions between galaxies play a very important role in their evolution. Galaxy interactions are most frequent in groups and clusters where the galaxy density is high. Extensive studies of violent tidal interactions between pairs of galaxies have shown that such interactions can completely alter the morphology and internal dynamics of a galaxy. Galaxies in clusters interact less frequently with other members, but are constantly subjected to the mean tidal field of the cluster potential. The effects of the weak mean tidal field of the dark matter potential of a cluster or compact group on the internal dynamics of a galaxy are less well understood. The effects of weak tidal perturbations have been frequently underestimated and are found to play an important role in the dynamics of the galaxies in clusters and groups. Spiral galaxies in clusters are known to differ quite significantly from their more isolated counterparts. One of the more controversial observations indicates that while the rotation curves of most field spirals are flat or rising out to the largest observable radius, the optical rotation curves of cluster spiral galaxies were found to decline significantly in the outer parts of their optical disks. The standard explanation for this has been that the dark matter halos of cluster spiral galaxies have been tidally truncated and result in the falling rotation curves.

M. Valluri has carried out a series of simulations to study the effects of tidal fields on the internal dynamics of spiral galaxies. She found that rotation curves of tidally perturbed galaxies declined even when their dark matter halos were unperturbed. This was found to arise from the large increase in the velocity dispersion of the stars in the disk galaxy. The increased velocity dispersion is a consequence of the tidal interaction. The radial velocity dispersion provides an additional anisotropic "pressure" which adds to the centrifugal force in supporting the disk against gravitational collapse. This additional "pressure" support implies that a high-velocity dispersion stellar component will have a smaller rotation velocity at the same radius. (This is called the "asymmetric-drift phenomenon" in the literature). The rotation curves of cluster spirals are affected not only by the mass distribution in the spiral galaxies but also by the velocity distribution.

It has been widely recognised that the evolution of the galaxy population in clusters is considerably more rapid than would have been expected from normal galaxy evolution theories. *Valluri* is studying the question of whether the mean tidal fields arising from the hierarchical mergers of sub-clusters in rapidly evolving cluster potentials can affect galaxy evolution. The motivation is to determine the cause for activity in cluster galaxies and thereby explain this rapid evolution in the fraction of blue galaxies (the Butcher-Oemler effect) and to understand the origin of the morphology-density relation in clusters.

In the first part of the project the effect of time-dependent cluster tides are being investigated through dynamical simulations of relaxing clusters. The simulations study the collapse of a cluster after the region has separated from the Hubble flow and follows the collapse till an epoch just prior to virialization. Cluster collapse is simulated using the spherical top-hat scenario. These simultions are in progress and will be used to determine how the internal dynamics of galaxies in clusters is affected by the mean tidal field.

Weak tidal interactions can affect the dynamics of gas in elliptical galaxies. *Valluri*, S.M. Chitre and Subramanian have been studying the dynamics of hot and warm ionised gas in the centres of elliptical galaxies. The aim is to understand the origin of the energy source which maintains the ionised gas disks in elliptical galaxies. Hot gas in hydrostatic equilibrium in an elliptical galaxy can be perturbed by a satellite. Since the Brunt-Vaisäla frequency of the gas at any radius is comparable to the rotation frequency of a perturber in equilibrium at that radius the perturber can resonantly excite g-waves. The temperature and density profiles of the interstellar hot gas in systems

with cooling flows allow the waves to be focussed inwards. The velocity and amplitudes of the waves increase towards the centre causing them to shock. The energy transfered to the gas is greater than about 10^{39} erg s^{-1} and is adequate to keep the gas ionised. The mean tidal interaction may also explain the presence of shocked emission lines in the ionised gas discs and is likely to be an important energy source in galaxies which do not have activity at their centres.

Chemical evolution of the Galaxy: Chemical evolution of the Galaxy is a study of the cycling and recycling of diffuse interstellar matter (gas and dust) through stars. The diffuse matter forms stars which evolve, and in that process, return some of the diffuse matter to the interstellar medium after varying degrees of nuclear processing. Any theory of stellar and galactic evolution has to account for the observed spatial and temporal distributions of the different chemical species. Such a framework is needed for various other purposes, such as extrapolating back to the big bang, studying radioactive cosmochronology, and interpreting the magnitudes and colours of distant galaxies. *Rana* has continued his investigations in the field of chemical evolution of the galaxy and investigated several ramifications of the model suggested by S. Basu and *Rana* in 1993. The initial mass function of the stars was used by *Rana* and M. Chandola to calculate the baryonic M/L ratio contributed by the field stars in the solar neighbourhood using variable upper and lower limits of stellar masses. Mass-luminosity calibration of main-sequence stars using the available physical binary data for 92 binaries was derived with a revision of the bolometric corrections. This was applied to a test of evolutionary models for stellar population studies by N. Srivastava, *R.K. Gulati* and *Rana*. From the evolutionary template H-R diagrams a method has been evolved to determine mass and age of about 400 field stars after its successful demonstration to a sample of binary stars by A. Kulkarni and *Rana*. A proper calibration for systemic mass-luminosity relation using data on stellar multiplicities and the mass ratios was obtained and applied for deriving mass function of stars in the solar neighbourhood by K. Rajeev and *Rana*.

Stellar Physics

Understanding the stars : The knowledge of stellar physics is essential for the study of evolutionary phenomenon near the solar neighbourhood and in stellar systems (globular clusters, galaxies, etc.). For instance, the conditions prevailing in stellar atmospheres can provide physical and chemical information about stars which in turn can be studied by analysing stellar spectra. *Gulati* and *R. Gupta* have been pursuing both theoretical as well as observational methods to extract useful physical information about stars.

One of the methods for this study consists of classifying individual stellar spectra on the basis of a set of templates. Stellar classification provides four-fold information: (i) a detailed study of the prototype star in each group avoids the necessity of studying it separately, (ii) gives estimations for astrophysical parameters, e.g., effective temperature, luminosity and metallicity, (iii) peculiar objects can be isolated to form a separate group for further study and (iv) the distribution of stars in various groups can be used for stellar populations and evolutionary studies.

A project on automated classification of stellar spectra in the optical window has been initiated by using conventional statistical and by risingly popular Artificial Neural Network (ANN) techniques. Initial attempts of application of these techniques on available ground-based digitised databases have shown that a given spectrum has been classified automatically to an accuracy of two spectral sub-classses. The scope of these techniques is being extended to other databases.

With the opening of new wavelength windows through satellite astronomy, there has been a large growth of observational databases. Over the last decade, the successful operation of International Ultraviolet Explorer (IUE) satellite has rendered a large database of ultraviolet spectra. In order to classify these spectra, *Gulati, Gupta*, P. Gothoskar and S. Khobragade, have extended the ANN technique to the IUE atlas of stellar spectra.

A key project on systematic spectroscopic survey of cool stars has been undertaken by *Gulati, Gupta* and N.K. Rao to study the chemical evolution of solar neighbourhood. In the first phase of this project they have observed about 55 stars using the VBT (2.3 m) and B & C spectrograph. The data is now being reduced with the IRAF package available at IUCAA computer centre.

The statistical method has been tested by *Gulati* and *Gupta* on a new library of optical spectra for the determination of fundamental stellar atmospheric parameters, viz. effective temperature and surface gravity. With the current library of synthetic spectra, these parameters can be determined to an accuracy of ± 250 K and ± 0.50 dex respectively.

On the theoretical side, *Gulati* in collaboration with Malagnini and Morossi, has studied the contribution of molecular species to cool stars by generating library of synthetic stellar spectra for different model stellar atmospheres.

At wide band photometric levels, the role of metallicity has been investigated by Sridharan, *Gulati* and *Rana* in the light of two-colour diagram. A plausible link between the distribution of cool stars on the two-colour diagram and evolutionary models

for single generation of stellar systems of different metallicity is noticed.

At the narrow band photometric level, Kulkarni, *Gulati* and *Rana* have supplemented the catalogues of Stromgren photometric systems of stars near the solar neighbourhood with atmospheric parameters, which were estimated from the calibrations of the systems with stars of known parameters. Improved evolutionary models have been tested for consistency between the stellar properties determined from models and from observational quantities. Preliminary results show that new models which incorporate improved input physics and updated opacity data faithfully reproduce the observed parameters within the uncertainty of observed quantities.

Spectroscopy of novae: Novae are important members of the class of cataclysmic variables. These are binary systems with a white dwarf accreting hydrogen-rich material from its mass losing companion. Thermonuclear runaway (TNR) reactions in the accreted matter, on the surface of the white dwarf, leads to an ejection of matter at high velocities. A study of the spectroscopic evolution of the outburst gives information about the dynamics, temporal evolution of the ionization, temperature and density of the ejected shell, and also the abundance of the ejected material. These quantities are important inputs to the theoretical models of a nova outburst.

Anupama and Prabhu have obtained spectra of novae N Cyg 1992, N Sgr 1993 and N Cas 1993 during outburst using both the 102 cm and the 234 cm VBT at VBO, Kavalur. Analyses of the data are under progress.

Recurrent novae form a subset of novae. These objects show nova outbursts at a recurrence rate of a few decades. The mass losing star in these systems is a late type giant. TNR theories of outburst demand a massive white dwarf with high accretion rates to explain the observed recurrence rates. An alternative theory attempts to explain the outburst of a subclass of recurrent novae as a result of accretion instability, with the accreting star being a main sequence star, instead of a white dwarf. It is hence important to establish the nature of the accreting star in order to establish the theory of outbursts, and also to understand these systems. Towards this attempt, a spectroscopic study of the recurrent nova RS Oph has been made by *Anupama* and R. Gilmozzi. UV spectra obtained by IUE and optical data obtained from VBO were used. No signature of a main sequence accretor is present, implying a white dwarf accretor. A power law fit of the form $F_\lambda \propto \lambda^{-\alpha}$ was made to the continuum. A mean value of $\alpha = 0.45$ was obtained for all the spectra, implying a low inclination angle for the system. The total UV flux ($\sim 200 L_\odot$) indicates a high mass accretion rate ($\dot{M} \sim 10^{-8} M_\odot$ yr^{-1}) onto the white dwarf primary, assuming $M_{\rm wd} = 1.3 M_\odot$. This result supports the models explaining recurrent nova outbursts as thermonuclear runaway events on white dwarfs. *Anupama* and Prabhu have continued monitoring the recurrent novae TCrB and RSOph in order to study long term variations in the spectrum during their inter-outburst quiescence period.

IR observations of star-forming regions: Observations in the far-infrared band provide a powerful tool of studying objects with dust and gas, these objects could be as diverse as star-burst galaxies, star forming regions in our Galaxy and comets. For several years, *S.N. Tandon* has been collaborating with the Infra-red Astronomy Group of TIFR for observations on star-forming regions and galaxies with the 1m balloon borne telescope of TIFR. The telescope has been used to map the dust temperature and optical depth, which lead to the conclusions on the sources of energy and its transfer within the object, in these objects, with a spatial resolution of 1.5'.

In order to increase its productivity both in terms of a higher sensitivity and in terms of the number of observations, the telescope was used with a new array of 12 detectors cooled to 0.3°K for observation of star forming complexes in two bands centred at 58 μm and 150 μm respectively, during the two balloon-flights in November 1993 and February 1994. As the detector system was being used for the first time, a major part of the work was connected with integrating it with the telescope in a manner which keeps the electrical noise low, and in evolving procedures for optimising the observations. The observations are expected to yield intensity, temperature and optical depth maps with a resolution of 1.5'

Sun, Earth and the Solar System

Sun being the closest of all stars and the earth being the home planet, they are among the objects that have been studied extensively throughout the centuries. Despite this fact, some aspects of the solar astrophysics are still poorly understood – one of which is the origin of the eleven-year sunspot cycle and its possible connection with the thermonuclear process occuring at the radiative core of the sun. For earth, the fluctuations in the weather pattern and the hydrostatic disequilibrium of the plastic interior of the earth are still unpredictable.

S. Chakrabarty and *Rana* have made an effort to understand a plausible connection between the predominantly convective phenomenon of sunspot activity and the nucleosynthesis in the radiative environment of the core region of the sun. Assuming that the electron energy spectrum in the core region of the sun is slightly non-thermal, they have shown that a new cycle in p-p1 chain of nuclear reactions can be

TREE PLANTATION

Anthony Hewish

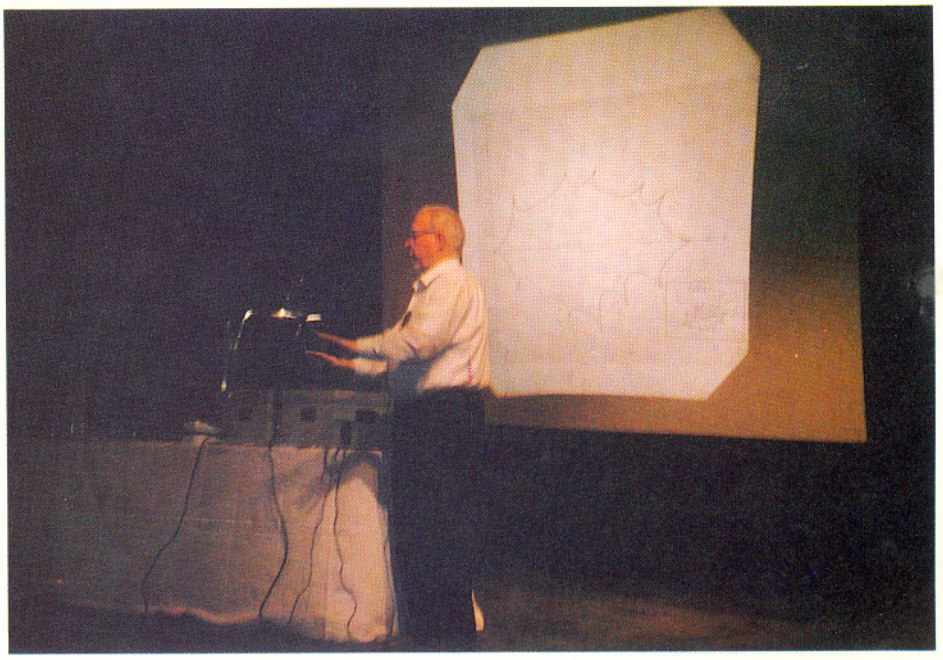
G. Burbidge

5th Foundation Day Lecture by Vandana Shiva

Participants of XX IAU International School for Young Astronomers during the tea party at the Director's lawn

SCHOOL STUDENTS LECTURE DEMONSTRATION PROGRAMME ON SECOND SATURDAYS

S. N. Tandon : Polarization and Scattering of Starlight



Sir Fred Hoyle : An Unusual Adventure

The participants of the VI IAU Asian Pacific Regional Meeting on Astronomy

operative leading to thermal flux variations on a time scale of 10 to 300 years.

Possible hidden symmetries in the planetary orbits around the sun were explored by S. Bhide and *Rana* to find that apex of the fitted conics whose sections represented individual planetary orbits bear a definite relation with the inclination of the axes.

The terrestrial weather data for 1120 stations spanning over the past 220 years were analysed by B. Mitra, N. Srivastava, G.B. Pant and *Rana* using sophisticated periodograms and autocorrelation techniques. An 11-year periodicity in global weather data, sunspot cycle and length of day fluctuations was reconfirmed along with a number of other short period fluctuations newly reported.

Instrumentation

Imaging polarimeter : Several astrophysical processes give rise to polarised radiation, e.g., synchrotron emission, scattering by electrons or dust, and thus for many objects polarisation measurements provide new insights into the processes occuring in them. For example, polarisation measurements provide vital clues in the study of objects as diverse as active galaxies and comets.

In India, the Physical Research Laboratory has been using a single aperture polarimeter for observations in the visible band, but no imaging polarimeter is available in the country. Considering the great advantages of an imaging device over a non-imaging one, either in the observations of diffuse objects or in the observations of multiple stars, an imaging polarimeter is being developed by *A. Sen, R. Gupta, A.N. Ramaprakash* and *S.N. Tandon* for observations in the range 4000 Åto 8000 Å. It is expected to measure linear polarisations as small as 1% and therefore it is designed to keep the instrumental polarisation effects well below 1%. A low instrumental polarisation is obtained by keeping all the parts stationary except a half wave plate, which is rotated to change the direction of plane of polarisation of the incoming beam. The outgoing beam from the half wave plate is analysed into two orthogonal components whose intensities are measured simultaneously. The aperture would be 30 $\times$ 30 mm^2 (3.5 $\times$ 3.5 square arc min at the Cassegrain focus of Vainu Bappu Telescope, Kavalur), and it would reach sensitivities of $\sim$ 17 mag. per square arc second for long exposure broad band images.

Automated photoelectric telescope : In recent years, many special purpose automated telescopes have been developed at various observatories. In a typical automated telescope, (a particular class of) observations are implemented under the control of a computer. The important merits of such a telescope are high efficiency and low costs, as compared to those of a general purpose telescope, for the chosen class of observations.

Considering the potential of small automated telescopes for photometric observations of variable stars, and the suitability of such an instrument for use by small groups at our universities, the development of such a telescope was started in the year 1991. It is built around a 14" aperture optical tube of Celestron's C-14 telescope, and it uses microstepping motors and a single stage friction gear (ratio 1:24) for the RA and DEC drives. The pointing and tracking are done using thermoelectrically cooled CCD, e.g., ST4 from SBIG of USA; a pointing accuracy of several arc seconds is expected during the operations.

As this development was taken up to provide the university groups with an efficient tool of observations, two workshops were organised to familiarise the participants from universities with the technology and potential of automated telescopes for photoelectric photometry. Further, during this development process, adequate laboratory facilities as well as documented know-how have been developed so that any interested group from a university can assemble, and test for observations, such a telescope in IUCAA's laboratory. A prototype of such a telescope is under test on the terrace in the laboratory block, and two groups (from Bangalore University, and Gujarat University) have shown keen interest in acquiring such telescopes for their use. *Gupta, Tandon* and R. Deo are involved in this programme.

CCD camera : The use of CCD detectors for imaging has rapidly grown in the last few years and these are increasingly being used with small telescopes too. In order to be able to use the new versions of CCD's optimally in observations, the development of a liquid N_2 cooled CCD camera was taken up by *M. Deshpande, D. Gadre, P. Chordia* and *Tandon*. A related aim was to provide the university groups an access to the know-how and facilities for developing their CCD cameras.

The camera consists of three main blocks: the CCD with its cooling dewar, etc., the controller for CCD, and a suitable small computer for human interaction and image acquisition, etc. The CCD controller can be programmed for any 3-phase CCD, and although it is being developed for liquid N_2 cooled devices, it can be also used with thermoelectrically cooled CCDs suitable for small telescopes. The controller has been tested with a EEV (U.K.) CCD-02-06 working at room temperature, and the expected read noise at low temperatures is about $10e^-$

Seeing monitors : The productivity of an optical telescope is directly affected by the conditions at the site. Therefore, in order to maximise the potential productivity of a telescope, careful prolonged observations are made of the conditions at the

prospective sites before a decision is taken on locating a major telescope. In addition to the low cloud cover and low extinction, seeing is a critical parameter defining quality of an astronomical site; with the increasing interest in high angular resolution observations, seeing has acquired a much higher importance in recent years.

In view of the importance of the seeing parameter, as a part of the DST project on the feasibility study for National Large Optical Telescope, development of two seeing monitors has been taken up by *A. Paranjpye* and *Tandon*. These would be used to monitor the seeing at potential sites for the telescope, and would help to give an objective measure of the seeing.

The instrument is based on the principle of measuring differential motion between two images of a star formed through two independent apertures. Two 150 mm diameter $f/10$ lenses are used for getting the two images, and these lenses are mounted 1000 mm apart on a common structure. The two images of Polaris are brought near each other by use of mirrors, and the separation between the images is measured for short ($\sim$ 10 ms) exposures on a thermoelectrically cooled CCD. The instrument is expected to give a sensitivity of < 0.5 arc seconds.

(II) RESEARCH WORK BY ASSOCIATES

R.S. Tikekar and *L.K. Patel*, working in close collaboration with N.K. Dadhich, have been considering the problems pertaining to singularity-free solutions of Einstein equations. They have made a critical analysis of the singularity-free family of fluid models obtained by Senovilla and his collaborators. It has been shown that these fluid models can be obtained by simple inhomogenization and anisotropization of the FRW metric with negative curvature. The uniqueness of these solutions for cylindrically symmetric spacetimes with separable functions of radial and time coordinates as the metric potentials is established. The common property of these solutions is that they do not have any physical or geometrical singularity. It is likely that the unvanishing shear and acceleration in these solutions is the necessary condition for singularity free property. *Tikekar, Patel* and Dadhich have also studied a new class of physically relevant explicit solutions for string cosmological models endowed with cylindrical symmetry on the background of singularity free cosmological spacetimes.

U.S. Pandey is investigating exact analytic solutions of Einstein equations with perfect fluid sources under the assumption of plain symmetry and one-parameter group of conformal motions. *Pandey* has also studied the equation of geodesic deviation for an infinitesimal, compressible, inhomogeneous self-gravitating object, assuming the value of Newtonian theory for the elastic structure of the orbiting body. The solution of this equation has been found under the assumption of slow rotation which can be applicable to the tidal breaking up of stars by black holes.

L. Radhakrishna has been engaged in the study of the applications of rheotetrad to black hole theory with N.C. Rana and has been discussing several aspects of regular thermodynamics with *Patel* and *Tikekar*.

S.S. Prasad has had interactions with S.V. Dhurandhar and B.S. Sathyaprakash on the availability of data obtained from gravitational wave detectors which are being developed in the near future. *Prasad* has also been working on the exact solutions of Einstein equations in collaboration with *Tikekar* and *Patel*. He has found some perfect fluid solutions of the equation with the assumption of the existence of one-parameter group of conformal motions for the case of plane symmetry in four dimensions and spherical symmetry in higher dimensions.

D.C. Srivastava has been interacting with the gravitational wave group at IUCAA on the data analysis from gravitational wave detectors. In particular, attention is being paid to : (a) the optimal orientation problem of laser interferometric detector for pulsar in galactic plane, (b) threshold criteria and matched filtering techniques for coalescing binaries, (c) the analysis of noisy data.

Srivastava has been involved in searching of shear free perfect fluid distributions in n+2 dimensions. The solutions obtained reduce to their analogues for n=2. He has also analysed charged Wyman solution in higher dimensions.

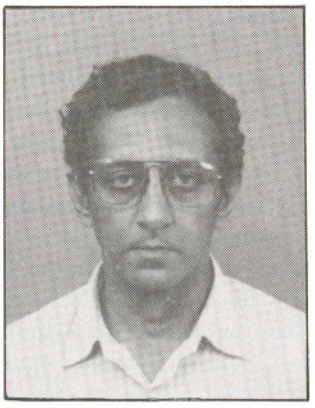
P. Das Gupta has been interacting with J.V. Narlikar on the production of gravitational waves from mini-creation events. A scenario was proposed in which creation of matter takes place in bursts which can be described by a Bianchi Type I line-element. They have shown that a LIGO type detector can easily detect an event that generates 100 - 1000 solar masses and that timing data from millisecond pulsars place severe constraints on the mass and anisotropies of the burst events that generate a stochastic gravitational wave background.

A.C. Balachandra Swamy studied time variations of the gravitational constant and Hubble constant.

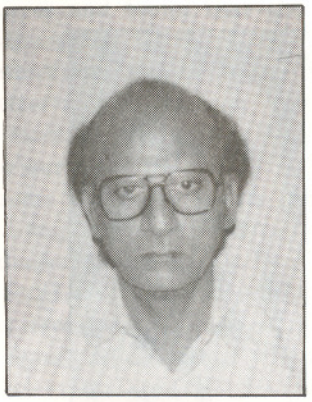
P. Khare continued her research on Lyman alpha, C IV and Mg II absorption lines in the QSO spectra using appropriate models for galactic halos, photoionization histories and cloud parameters. *P.P.Saxena* has also been involved in establishing a connection between the infrared and X-ray properties of quasars. *B. Basu* worked on star formation efficiency.

S.K. Pandey and *D.K. Chakraborty*, along with their students, have been involved in the programme of optical observations of galaxies in collaboration with A.K. Kembhavi and others at IUCAA. The programme involves mapping the distribution of light across the

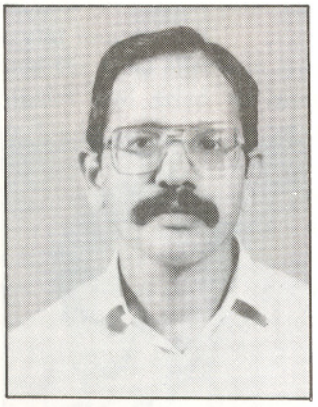
SENIOR ASSOCIATES of IUCAA



M. N. Anandaram



Asit Banerjee



A. D. Gangal

G. K. Johri

ASSOCIATES of IUCAA

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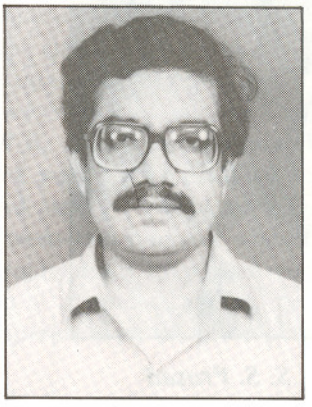
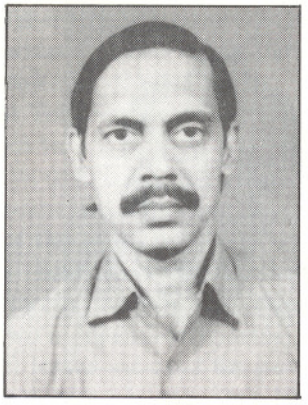
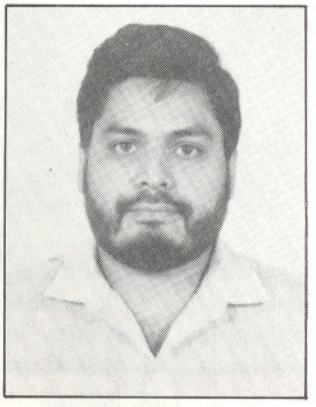


Somenath Chakrabarty

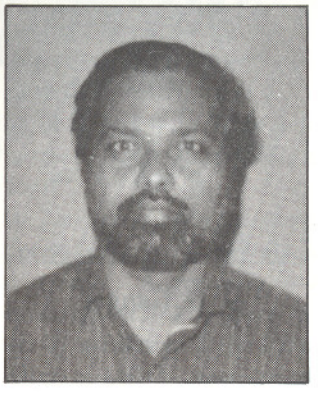


D. K. Chakraborty

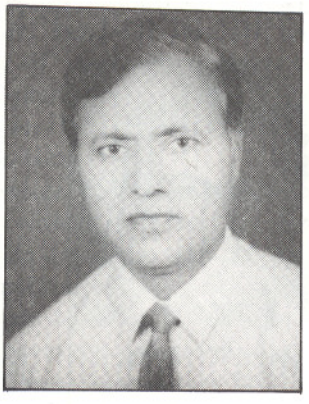


P. Das Gupta

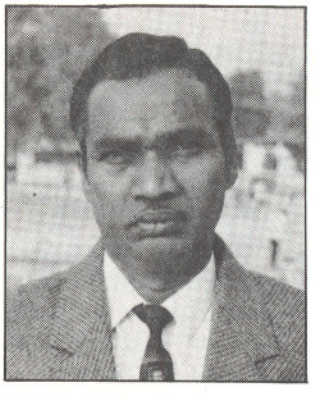
M. K. Das



B. A. Kagali



S. S. Prasad



A. C. Balachandra Swami

face of the galaxies of different types. *Pandey* along with his student has obtained data on elliptical and spiral galaxies using the 2.3 m VBT and the 1 m UPSO telescope. The data has been processed at IUCAA. The scientific aim was to find small scale features of several kinds in the galaxies by looking at the residual maps, colour maps, etc. by using simpler restoration techniques and so on. The analysis shows the presence of shells, dust lanes, rings and patches in several elliptical galaxies and he intends to pursue observations of complete samples of elliptical galaxies in the coming years in an attempt to quantify these features and understand the nature of their origin.

S.M. Alladin in collaboration with *G.M. Ballabh*, K.S.V.S. Narasimhan and *V.R. Venugopal* has been pursuing the programme of interaction between galaxies. He has developed an analytical expression for the merger time of interacting galaxies in terms of the orbital energy and angular momentum. The results are consistent with those obtained by N-body simulations. It was found that the merger time depends very strongly on the angular momentum.

Alladin has also studied the tidal effects in Hickson compact groups of galaxies and tried to interpret the difference in radio loudness in terms of tidal interactions between galaxies.

A.D. Gangal has been trying to isolate the effect of non-scaling noise from the chaotic signal using wavelet transforms. *Gangal* has, in collaboration with A.K. Kembhavi and colleagues in the Physics Department in the University of Poona, taken up the study of tidal interactions between stars from the point of dynamical systems.

L.M. Saha in collaboration with *Alladin, K.B. Bhatnagar* and others has been involved in the study of chaotic phenomena appearing in non-linear dynamical systems and are working on how the regular motion changes into a chaotic one when parameters involved in the equation of a motion are varied. He has been actively involved in studying chaos in problems relating to rotational motion and scattering.

B. Ishwar has been working on celestial mechanics, in particular on the restricted three body problem. He and his colleagues are examining the non-linear stability and wish to show that Hz is zero by solving an analytically formulated problem.

A. Goyal has been involved in studying the properties of high density matter in the core of neutron stars and collapsing stars. He has, in particular, studied the cooling of the high density matter through neutrino emission via a variety of processes like URCA, neutrino pair bremssthralung, plasma decay, etc. He has also been working on the formation, properties and possible survival of soliton stars formed during phase transition in the early universe. He has studied the effects of gravitation on the stability of soliton stars.

B.K. Pal has been involved with the neutrino astroparticle physics on the conceptual development of the quantum astronomy.

H.L. Duorah has been working on X-ray burst energy sources and found that the magnesium- aluminium-silicon cycle to be an important X-ray energy source. He has developed a new equation of state for neutron matter and for various compressibility factors trying to examine a stable matter present in the neutron star surface. *Duorah* has been studying the possible gamma ray burst events that involve the conversion of Langmuir waves into an escaping electromagnetic radiation at the plasma frequency.

Das Gupta in collaboration with A.N. Ramaprakash has developed a procedure that uses cross-correlation of signals to determine whether two faint gamma ray burst events are just gravitationally lensed images of a single burst event. They tested their procedure by performing several numerical experiments.

K. Boruah formulated a computer simulation of the atmospheric air showers using Monte Carlo method.

U. Narain with *S. Chandra* and Pankaj Agarwal, is studying the solar coronal heating by magneto waves. *Narain* has found that the turbulent motions in the convection zone which generate magnetoacoustic waves are not well understood and consequently the heating estimated due to these sources is still uncertain.

S.G. Tagare has been working on the magneto hydrodynamics of the solar photosphere. He has studied the finite amplitude magneto convection in the presence of a horizontal magnetic field. He has extended the model to study non-linear magneto convection due to oblique magnetic field. Both these works model the convection in penumbral region of sunspot.

P.P. Saxena has been working on the nature of the comets and has put forth an argument which cast doubt on the parent nature of cometary S_2 molecules. He has suggested an alternative mechanism for the production of these molecules.

D.B. Vaidya has been studying the inter-relationships among circumstellar, interstellar and interplanetary dust. He has carried out calculations on the typical M-type star to establish mass loss rates, the dust to gas ratios and ejection velocities. He has computed grain ejection velocity for various grain sizes in the circumstellar atmosphere. He has suggested that the interplanetary dust has a fluffy structure made up of very small interstellar dust particles.

R.R. Reddy, in collaboration with *S.H. Behere*, has been working to establish the relationship between bond energy and the electronegativity difference between two items of diatomic molecules for various astrophysically important molecules. These studies are helpful in understanding the upper atmospheres and temperature at the given place.

Behere made UV spectroscopic studies of LaO, a diatomic molecule to be found in the spectra of S and M type stars, and the potential energy curves for the ground states and excited states of InI and SrS were calculated.

S.D. Verma, *D.B. Vaidya* and and their associates, and *M.N. Anandaram* and *B.A. Kagali* have used the facilities at IUCAA and the know-how of the laboratory for developing photometers for use at their respective universities. These photometers are based on the design developed at the IUCAA laboratory. In addition, they have been working on assembling the structures of automated photoelectric telescopes.

Duorah has interacted with S.N. Tandon to develop an observational programme at Gauhati University. He has set up a telescope and photometer on the campus.

(III) 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 an Associate/Senior associate of IUCAA, the name of the latter is displayed in italics.]

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e) Popular Science Articles

Dadhich, N. (1993), V.V. Narlikar: a teacher par excellence, (Bull. Bombay Math. Colloquium, **9**, 12).

Kembhavi, A.K. (1993), Heavenly gift to the relativist, (The Economic Times, October 23).

— The Nobel Prize for Physics-1993, (Physics News, March).

Narlikar, J.V. (1993), Parsecstones in Astronomy–2 : Does the earth move? (Khagol No. 14, April).

— Cultivating a scientific temper, (Business India, 15th Anniversary Issue, 199).

— IUCAA dedicated, (Current Science, **64**, 551).

— Sci-Fi and I, (Deccan Herald, May 30).

— Challenge for the big bang, (New Scientist, June 19, 27).

— Parsecstones in Astronomy–3 : The spin of the earth (Khagol No. 15, July).

— Need for scientific temper, (Mainstream, July 3, 7).

— Parsecstones in Astronomy–4 : Advent of the heliocentric theory (Khagol No. 16, October).

— The excitement of doing science, (Souvenir of Poornaprajna Education Centre, October).

— Homage to the infinite, (The Statesman, Sunday Supplement, November 7).

— Vidnyankatha ani mi, (Shri Malhar, Diwali issue, 18).

— Gurutvakarshanachi Kimaya, (Nirmal Ranavara, Diwali issue, 22).

— Vidnyan Sahitya, (Marathi Vangmayatil nave pravah, ed. Sharankumar Limbale, 171-179).

— The Bane of Brain-Drain, (Deccan Herald, January 9).

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— A random walk down memory lane, (Seminar, 409, 38).

— Education through Astronomy, (Science in Society, ed: Yash Pal, Ashok Jain, Subodh Mohanti, Gyan Publishing House, New Delhi, 71).

Padmanabhan, T. (1993), Fine-tuning, *Cosmic Canvas* - 4, (Economic Times , April 10).

— Matter of gravity, *Cosmic Canvas* - 5, (Economic Times , May 8).

— The star power, *Cosmic Canvas* - 6, (Economic Times, June 12).

— The death of a star, *Cosmic Canvas* - 7, (Economic Times , July 17).

— A matter of gravity, *Cosmic Canvas* - 8, (Economic Times, August 14).

— Galactic recession, *Cosmic Canvas* - 9, (Economic Times, September 11).

— The coded cosmos, *Cosmic Canvas* - 10, (Economic Times , October 16).

— Tell-tale relics, *Cosmic Canvas* - 11, (Economic Times, November 13).

— Through the stars, darkly, *Cosmic Canvas* - 12, (Economic Times, December 11).

— Dea(r)th of antimatter, *Cosmic Canvas* - 13, (Economic Times, January 15).

— Creative inflation, *Cosmic Canvas* - 14, (Economic Times, February 14).

— The Quantum Leap, *Cosmic Canvas* - 15, (Economic Times, March 12).

Tandon, S.N. (1993), Astroproject-2 : Limb darkening of Sun, (Khagol No. 14, April).

— Astroproject-3 : Measurement of solar constant, (Khagol No. 15, July).

— Astroproject-4 : Measuring distance to Moon, (Khagol No. 16, October).

• **by Associates/Senior Associates**

[Publications co-authored by Associates/Senior Associates and a member of IUCAA staff appear in the previous section and are not repeated here].

a) Journals

Alladin, S.M. (1992) Galactic dynamics. Indian J. Phys., **66B** (5 & 6), 623.

Narasimha Rao, M., **S.M. Alladin** and K.S.V.S. Narasimhan (1994) Orbits of colliding galaxies, Celest. Mech. Dyn. Astron. **58**, 65.

Bhui, B., S. Chatterjee and **A. Banerjee** (1993) Spectral shift from an evolving dust sphere, Int. Journ. Mod. Physics D, **2**, 489.

Behre, S.H. (1994) Ground state dissociation energies and RKR curves of a state of InI and SrS molecules, Indian J. Physics **68B** (1), 79.

Bhatnagar, K.B. and **Saha, L.M.** (1993) N-body problem, Bull. Astron. Soc. India, **21**, 1.

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Bhatnagar, K.B., Ayub Khan and **Saha, L.M.** (1994) Non-linear planar oscillation of a satellite in elliptical orbit under the influence of solar radiation pressure-I, Bull. Astron. Soc. India, **22**, 47.

Chandra, Suresh and Alok Sahu (1993) Einstein A-coefficients for rotational transitions in the ν_3 vibrationally excited state of SiG, A & A **272**, 700.

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Das, M.K., A.K. Chaudhary and V.B. Bhatia (1993) A note on large amplitude non-linear radial oscillations in polytropic stellar models, Ap. Space science, **206**, 171.

Duorah, H.L. (1993) Mg-Al-Si cycle as X-ray burst energy source in an accreting neutron star surface, J. Assam Sci. Soc. 35 (2), 102.

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Goyal, Ashok and Deepak Chandra (1993) Evolution of soliton stars in the Lee-Wick model, Phys. Rev. D **47**, 1302.

Goyal, Ashok (1994) Strange stars, Physics Education, 10, No. 4.

Ishwar, Bhola (1993) Effect of perturbations and oblateness of smaller primary on the location of equilibrium points in the restricted problem of three bodies, Journ. of Aleppo University, Aleppo, Syria, 1.

Johri, M. and **G.K. Johri** (1994) Theoretical formulation of the interaction energy using irreducible tensor operator and the cross-sections for the symmetric top molecule, Indian J. Pure and Ap. Phys. **32**, 201.

Khan, Z.H., M.M. Hussain and E. Haselbach (1993) On the correlation between electronic spectra of alternante aromatic hydrocarbons and their radical cations, Applied Spectroscopy, **47**, 2140.

Khare, Pushpa (1993) Halo model for Mg II absorption lines in the QSO spectra, Ap. J. **413**, 486.

— Differential evolution of Lyman alpha lines, Jour. Astrophys. and Astronom. **14**, 97.

— Chemical evolution of high redshift galaxies, Jour. Astrophys. and Astronom. **14**, 83.

Narain, Udit and Sushil Kumar (1993) On the electric circuit approach of coronal heating: a review, Bull. Astron. Soc. India **21**, 85.

Pal, B.K. (1993) Neutrino astroparticle physics, Physics Education **9**, 333.

Patel, L.K. and S.R. Yadav (1993) A radiating Kerr-Newman metric in expanding universe, Math. Today XIA, 21.

Singh, T. (1993) Lysa's geometry and cosmology : A review, Fortschider Physik, **41**, 737.

Tikekar, R. and V.O. Thomas (1993) Einstein's clusters in psuedo-spheroidal space time, Math. Today, **XI-A**, 51.

— Static relativistic fluid distributions in spheroidal space time, Prajna (Journal of S.P.Uni) **3**, 71.

Anandarao, B.G., S.R. Potasch and **D.B. Vaidya** (1993) Circumstellar dust in Mira variables and the mass loss mechanisms, A & A **273**, 570.

Shah, H.S., D.S. Adroja and **D.B. Vaidya** (1993) Estimation of reflectance spectra of particulate matter from size and refractive index, Ind. J. Pure and Appld. Phys. **31**, 560.

Vaidya, D.B. and B.G. Anandarao (1993) Interstellar grains in the regions of anomalous extinction, Bull. Astron. Soc. India **21**, 591.

b) Popular Science Articles

Johri, G.K. (1993), The background and profile of IUCAA for reorientation of higher education, (Bull. IAPT, **10**, 336).

(IV) PEDAGOGICAL ACTIVITIES

a) IUCAA–NCRA Graduate School

G.C. Anupama	Galactic and Stellar physics
N. Dadhich	Electromagnetic theory and Radiative Processes
T. Padmanabhan	Cosmology and Extragalactic Astronomy
	Aspects of Quantum Field Theory
B.S. Sathyaprakash	Mathematical Physics

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

S.V. Dhurandhar	Astrophysics II
R. Gupta	Practicals (Astronomy and Astrophysics)
J.V. Narlikar	General Theory of Relativity
N.C. Rana	Astrophysics I

c) Supervision of Projects

G.C. Anupama	Y. Wadadhekar (VSP) *Optical Image Processing*
N. Dadhich	K. Srinivasan (VSP) *Black Holes*
S.V. Dhurandhar	S. Mukherjee (VSP) *The sound wave equation and responses of bar detectors*
R. Gulati	Sridharan (VSP) *Determination of interstellar extinction from the two-colour diagram*
R. Gupta	Mahua Hajra (VSP) *White light contribution in Tandem Fabry Perot spectrometer*
A. Kembhavi	Mujeeb A. (M.Sc.) *Introduction to astronomical image processing*
	Rajeshkumar S. (M.Sc.) *Introduction to astronomical image processing*
	George Chempalathara (M.Sc.) *Introduction to astronomical image processing*
J.V. Narlikar	Deepak Sharma (VSP) *Observational tests in cosmology*
	Gravitational lensing & Foucault pendulum (Summer project for 11 school students)
T. Padmanabhan	B. Ashok (M.Sc.) *Electrodynamics in Schwarzschild spacetime*
	S.K. Seal (M.Sc.) *Blackholes and Price's theorem*
	Shantanu Jha (IIT School) *Thermal history of the universe*
	Suneeta Varadarajan (IIT School) *Dynamics in an expanding universe*
	N. Vivek (IIT School) *Quantum theory in Rindler frame*
N.C. Rana	Mridula Chandola (M.Sc.) *Baryonic dark matter in the solar neighbourhood and the clusters of galaxies*
	Ajit Kulkarni (M.Sc.) *Determination of mass and age of field stars from the evolutionary fittings*
	Sonali Shah (M.Sc.) *Comparison of the primordial abundances of light elements as obtained from model calculations and observational estimations*

	Shreyas Bhide (B.Sc.) *Hidden symmetries in the orbits of objects in the solar system*
	Anjali Gopalan(B.Sc.) *Dynamics and themodynamics of the early universe*
	B.D. Ketkar (B.Sc.) *Play of Coriolis forces in astronomical phenomena*
	Mandar Kulkarni (B.Sc.) *Classical interpretations of electron's spin and rest mass*
	Mridula Chandola (VSP) *M/L ratio of disc stars*
	Ajit Kulkarni (VSP) *Calibration of stellar masses from evolutionary models*
V. Sahni	Mrinalini Puranik (VSP) *A numerical study of linearised gravitational instability*
B.S. Sathyaprakash	H. Gupta (M.Sc.) *Application of wavelets in the detection of chirp waveforms*
	Mrinalini Puranik (M.Sc.) *Evolution of phase under gravitational instability*
	Sushila Rajagopal (M.Sc.) *Filtering chirp waveforms using wavelets*
A.K. Sen	N. Gundiah (VSP) *Fabrication of a prototype polarimeter*
	B. Jain (VSP) *Calculation of instrumental polarization of 2.3 m VBT*
S.N. Tandon	R. Sankaranarayanan (VSP) *Image position detection for seeing measurements*
	Soumya Datta and Suman Datta (B.E. Students) *Analysis of image separation in a seeing monitor*

(V) SEMINARS, LECTURES, ETC. BY IUCAA MEMBERS

(a) Seminars

G.C. Anupama

The old nova GK Persei , (Arizona State University, Tempe, USA, May 6).

Optical observations of X-ray selected Seyfert galaxies, (Indo-US workshop on AGN and Quasars, IUCAA, December 10).

J. Bagla

Quasilinear approximations, (Young Astronomers' Meet, IISc, Bangalore, July 20).

Quasilinear evolution of density perturbations, understanding structure formation in the universe, (Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, September 27).

Quasilinear evolution of density perturbations, (University of Delhi, October 11).

Nonlinear evolution of density perturbations, (IX SERC School in Theoretical High Energy Physics, Gauhati University, Guwahati, November 22).

R. Balasubramanian

Gravitational waves, (XX-IAU International School for Young Astronomers, IUCAA, January 18).

B. Bhawal

Hulse-Taylor binary pulsar, (Gravitational wave miniworkshop, IUCAA, June 1; Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, May 5).

Causal structure of spacetimes I, (Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, April 29 and May 4).

V. Chickarmane

Squeezing and dual cycling techniques in gravitational wave laser interferometric detectors, School of Physics, Hyderabad University, December 7).

N. Dadhich

On singularity free cosmological models in general relativity, (Jadavpur University, December 15).

Magnetic Penrose process, (Indo-US workshop on AGN and Quasars, IUCAA, December 9).

S.V. Dhurandhar

Detection of coalescing binaries in coloured noise, (Gravity wave workshop at Perth, Australia, April 26-29).

The last three minutes, (Department of Physics and Astronomy, UWCC, Cardiff, UK, November 10).

Electrodynamics around blackholes, (Department of Physics and Astronomy, UWCC, Cardiff, UK, December 9).

Real data analysis of coalescing binaries: issues concerning thresholds, optimal sampling, (Workshop on Merging Binaries, Caltech, Pasadena, USA, January 7).

D. Duari

QSO absorption spectra and intervening galaxies hypothesis (Indo-US workshop on AGN and Quasars, IUCAA, December 14).

Quasar absorption systems and the intervening galaxies hypothesis (ICAC, Saha Institute of Nuclear Physics, Calcutta, December 22).

Quasars and cosmology (IAGRG Silver Jubilee Conference, IUCAA, February 16).

T.S. Ghosh

Post COBE gravity waves and density fluctuations from generalised inflationary scenarios, (Harvard Smithsonian Center for Astrophysics, Cambridge, September 7; Canadian Institute for Theoretical Astrophysics, University of Toronto, Toronto, Canada, October 1; University of Pennsylvania, Philadelphia, USA, September 16; Yukawa Institute for Theoretical Physics, University of Kyoto, Japan, October 26).

Relic gravity waves and cosmological structure formation, (California Institute of Technology, Pasadena, USA, October 21; Institut d' Astrophysique, Paris, France, August 31; University of Wisconsin, Milwaukee, USA, October 11).

Gravity waves, density perturbations and the CMBR anisotropy, (Fermilab Theoretical Astrophysics Seminar, Fermi National Accelerator Laboratory, Batavia, USA, October 5; Brown Theory Group Seminar, Brown University, Providence, USA, September 9; Bartol Research Institute, University of Delaware, Newark, USA, September 23).

Post COBE constraints on generalised inflationary scenarios, (Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, USA, October 15; Center for Particle Astrophysics, University of California, Berkeley, USA, October 13).

R. Gupta

A step towards qualitative and quantitative spectral classification of stars, (International Conference on Astrophysics and Cosmology, Saha Institute of Nuclear Physics, Calcutta, December 21).

Stellar spectral classification using automated schemes, (Indian Statistical Institute, Calcutta, December 23).

Artificial neural network – applications in astrophysics, (Pune Institute of Computer Technology, February 18).

A. Kembhavi

Soft X-ray excess in quasars, (Institute of Astronomy, Cambridge, UK, June 18; IAU Symposium 159 at Geneva, Switzerland, September 2; Institut D'Astrophysique, Paris, France, September 10).

Quasar and AGN Luminosity Function, (University of Rome, Italy, September 7).

D. Munshi

Non-linear gravitational clustering, (Young Astronomers' Meet, IISc., Bangalore, July 19–21).

J.V. Narlikar

Gravity waves from mini-creation events, (Laser Interferometer Gravity Wave Detectors Workshop at University of Western Australia, Nedlands, Perth, April 26).

Some conceptual problems in general relativity and cosmology, (Department of Mathematics and Applied Mathematics, University of Natal, South Africa, September 21; University of Cape Town, South Africa, September 22; University of South Africa, Pretoria, September 30).

Statistics of absorption line systems in QSO and the intervening galaxies hypothesis, (University of Cape Town, South Africa, September 22).

Quasi - steady state cosmology, (Second ASSA Symposium, University of South Africa, Pretoria, September 27).

Alternative to the big bang cosmology, (Mauritius University, Reduit, Mauritius, October 3).

Creation of matter in cosmology, (Mehta Research Institute of Mathematics and Mathematical Physics, November 8).

T. Padmanabhan

Structure formation, QSO's and absorption spectrum, (Indo-US workshop on AGN and Quasars, IUCAA, December 11).

Open questions in QFT in CST, (Institute of Mathematical Sciences, Madras, February 1).

V. Sahni

The formation and evolution of voids in the universe, (VI-IAU Asian Pacific Regional Meeting on Astronomy, IUCAA, Pune, August).

M. Seriu

On the relation between causality and topology in the semiclassical universe, (Tata Institute of Fundamental Research, Bombay, September 2).

On the smallness of the cosmological constant, (Department of Physics, Oxford University, November 8; University of Pittsburgh, November 15).

Quantum cosmology and the cosmological constant problem, (Institute for Cosmology, Tufts University, December 8; Department of Physics, University of Utah, January 5).

Causality and topology - selection mechanism in quantum cosmology, (IAGRG Silver Jubilee Conference, IUCAA, February 16).

S.K. Sethi

Spectrum of the CMBR, (Mehta Research Institute of Mathematics and Mathematical Physics, April).

Decaying neutrino, spectral distortion of the CMBR, and Gunn-Peterson effect, (Workshop on Astroparticle Physics, IUCAA, February 24).

S. Sinha

Radiation flows in Reissner Nordström spacetimes, (IAGRG Silver Jubilee Conference, IUCAA, February 17).

Cauchy horizon singularity without mass inflation, (University of Maryland, December 3).

L. Sriramkumar

Thermal ambience relative to an accelerated frame, (Young Astronomers' Meet, IISc, Bangalore, July 21).

M. Valluri

Intermediate redshift clusters and the "Butcher-Oelmer" effect, (Indo-US workshop on AGN and Quasars, IUCAA, December 13).

(b) Lectures

G.C. Anupama

Novae at quiescence, (Miniworkshop on Cataclysmic Variables, IUCAA, August 24).
Recurrent novae, (Miniworkshop on Cataclysmic Variables, IUCAA, August 25).

J. Bagla

Gravitational clustering in the non-linear regime, (IAGRG Silver Jubilee Conference, IUCAA, February 16).

B. Bhawal

Squeezing and dual recycling in laser interferometric gravitational wave detectors, (IAGRG Silver Jubilee Conference, IUCAA, February 15).

S.V. Dhurandhar

Gravitational waves, (VSP, IUCAA, June 9).

T.S. Ghosh

Stochastic gravity wave background (Gravitational wave miniworkshop, IUCAA, June 5).

Cosmological probes of inflation, (Workshop on Astroparticle Physics, IUCAA, February 25).

COBE: Signature of inflation?, (IAGRG Silver Jubilee Conference, February 16).

R. Gulati

Stellar atmospheres, (VSP, IUCAA, June 22).

R. Gupta

Spectroscopic observations at optical wavelengths, (VSP, IUCAA, June 22).

Astronomical spectroscopy–I & II, (Introductory School on Astronomy for IIT Students, IUCAA, December 8).

A. Kembhavi

Active galaxies - what sets them off ?, (Introductory School on Astronomy for IIT Students, IUCAA, December 14).

Galaxy surface photometry, (Uttar Pradesh State

Observatory, Nainital, November 10).

The story of gravity, (Department of Mathematics, Shivaji University, Kolhapur, December 29).

Statistics and pulsars, (Indian Statistical Institute, Calcutta, January 17).

Image processing, (Indian Statistical Institute, Calcutta, January 18).

The binary pulsar, (Indian Statistical Institute, Calcutta, January 19).

Active galaxies, (Birla Planetarium, Calcutta, January 19).

Our universe and life on other planets, (K.T.H.M. College, Nashik, February 4).

Charge coupled devices, (K.T.H.M. College, Nashik, February 5; College of Engineering, Bharathi Vidyapeeth, Pune, February 24).

Our universe, (K.K.W. Arts, Science and Commerce College, Pimpalgaon, February 5).

J.V. Narlikar

Origin of the universe, (Summer School Students, MACS, Pune, April 20).

The interaction between astronomy, physics and mathematics, (Refresher Course in Astronomy and Astrophysics for College and University Teachers, IUCAA, May 19).

The present status of cosmology, (Refresher Course in Astronomy and Astrophysics for College and University Teachers, IUCAA, May 25).

Some challenging problems in high energy astrophysics, (SERC School on Plasma Surface Interaction and Plasma Processing, University of Poona, Pune, June 2).

Cosmology and high energy physics, (VSP, IUCAA, June 3).

Astronomical telescopes of today, (Summer School for Navodaya Vidyalaya Senior School Teachers, Physics Department, University of Poona, June 17).

Interaction between physics and astronomy, (P.G. Diploma Course, Birla Institute of Astronomy and Planetarium Science , Calcutta, July 3.)

Direct particle formulation of Mach's principle, (Conference on Mach's Principle, Germany, July 27).

From intuitive physics to rigorous mathematics - A few examples from group theory, (Refresher Course in Mathematics, University of Poona, August 7).

The remarkable properties of gravity (in English) and *Gurutwakarshanachi Kimaya* (in Marathi), (School students, IUCAA, August 14).

The scientific foundations of astronomy, (Secondary School Teachers' Meet of the IAU, August 23).

An alternative to the big bang cosmology, (University of Delhi, September 14).

Prakash ani gurutwakarshan, (School students, Mahatma Phule Museum, Pune, October 17).

Astronomy and the scientific outlook, (CRPF Public School students, Delhi, November 7).

The impact of Saha's work on modern astronomy, (Saha Centenary Lecture at Physics Department, University of Allahabad, Allahabad, November 10).

The Saha equation in the cosmological context, (International Conference on Astrophysics and Cosmology at Saha Institute of Nuclear Physics, Calcutta, December 20).

Introduction to cosmology, (Introductory School on Astronomy for IIT Students, IUCAA, December 6).

The quasi-steady state cosmology; achievements and challenges, (Institut d'Astrophysique, France, January 14).

The interface between particle physics and cosmology in the quasi-steady state model, (Institute of Physics, Bhubaneswar, February 22).

Particle physics aspects of quasi-steady state cosmology, (Workshop on Astroparticle Physics, IUCAA, February 25).

T. Padmanabhan

Cosmology today - Models and constraints, (VI-IAU Asian Pacific Regional Meeting on Astronomy, IUCAA, Pune, August 17).

Ionizing the universe, (Saha and Bose: Birth Centenary Seminar, Saha Institute of Nuclear Physics, Calcutta, September 24).

The scale of things, (Introductory School on Astronomy for IIT Students, IUCAA, December 6).

Quantum theory and gravity, (Introductory School on Astronomy for IIT Students, IUCAA, December 17).

Conceptual issues in quantizing gravity, (IAGRG Silver Jubilee Conference, IUCAA, February 17).

Models for structure formation, (Workshop on Astroparticle Physics, IUCAA, Pune, February 24 and 25).

Observational constraints on cosmological models, (IAU colloquium 148 on 'Future Utilisation of Schmidt Telescopes', Bandung, Indonesia, March 11).

V. Sahni

The role of consciousness in quantum mechanics, (ICCR/IGNCA symposium on future of the mind: mind of the future, IIC, New Delhi, August).

Large scale structures in the universe, (Introductory School on Astronomy for IIT Students, IUCAA, December 7).

Gravity waves as probes of the early universe, (International conference on Non-Accelerator Particle Physics, Bangalore, January).

The inflationary universe, (Workshop on Astroparticle Physics, IUCAA, Pune, February 23).

B.S. Sathyaprakash

Statistical theory of signal detection, (VSP, IUCAA, June 30 and July 1).

Ripples of curvature, (Introductory School on Astronomy for IIT Students, IUCAA, December 14 and 15).

Gravitational radiation reaction, (IAGRG Silver Jubilee Conference, IUCAA, February 15).

S.N. Tandon

Plans for a large Indian telescope, (VI-IAU Asian Pacific Regional Meeting on Astronomy, IUCAA, Pune, August 18)

Universe, (Orientation Course for School Teachers, Department of Physics, University of Poona, March 7-10).

Measuring light of stars, (JES College, Jalna, February 25).

M. Valluri

Environmental influences on spiral galaxies in clusters, (Department of Physics, Indian Institute of Science, Bangalore, September 2).

(c) Lecture Courses

S.V. Dhurandhar

Quantum mechanics and statistical physics, (Refresher Course, IUCAA, May 10–28), 6 lectures.

A. Kembhavi

Quasar space distribution and luminosity functions, (Indo-US Workshop on AGN and Quasars, IUCAA, December 6–17), 3 lectures.

Galaxies and high energy astrophysics, (XX IAU International School for Young Astronomers, IUCAA, January 3–21), 5 lectures.

Galaxies, (Gauhati University, Guwahati, January 21–23), 4 lectures.

T. Padmanabhan

Cosmology, (XX-IAU International School for Young Astronomers, IUCAA, January 3-21), 6 lectures.

Astroparticle physics, (IX SERC School in Theoretical High Energy Physics, Gauhati University, Guwahati, November 15-27), 15 lectures.

Quantum theory in curved spacetime, (Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, March 21-28), 4 lectures.

V. Sahni

Particle physics and cosmology, (Tata Institute of Fundamental Research, Bombay, April), 5 lectures.

B.S. Sathyaprakash

Introduction to gravitational waves, (IUCAA, January 1994), 6 lectures.

Gravitational wave data analysis, (Miniworkshop on Gravity Waves, IUCAA, May 31-June 4), 5 lectures.

(d) Popular Lectures

R. Gupta

Observations of astronomical objects, (School Students, IUCAA, September 11).

Artificial intelligence in astronomy, (Jyotirvidya Parisanstha, Pune, February 20).

J.V. Narlikar

The astronomers' view of the universe, (National Insurance Academy, Pune for their Management Development Programme, June 4).

Vaidnyanikanchya jeevanatil kahi preranadiyi prasang (in Marathi), (Nowrosjee Wadia College, Pune for Awardees of Pune Pradnya Shodh Scholarship, June 5).

Origin of the universe and our solar system, (College of Military Engineering, Pune, June 11).

New challenges in astronomy and astrophysics, (First M.P. Birla Memorial Lecture, Calcutta, July 4).

Punyatil Jagatik Khagolshastriya Parishad (in Marathi), (Radio talk, All India Radio, regarding the 6th Asian Pacific Regional Meeting, August 21).

Close interaction between amateurs and professionals, (Jyotirvidya Parisanstha, Pune, Golden Jubilee Celebrations, August 21).

Vishwachi sahal (in Marathi), (Tilak Smarak Mandir, Pune, Kesariwada Ganeshotsava Centenary Celebrations, August 27).

Technological contributions to modern astronomy, (Gianchand Jain Memorial Lecture, Ambala, September 15).

Observations in conflict with the big bang theory, (University of South Africa, Pretoria, South Africa, September 27).

Are we alone in the universe?, (Indira Gandhi Centre for Indian Culture, Mauritius, October 6).

Science and religion: Conflict or synthesis?, (National Seminar on Science and Religion, Ramakrishna Mission, Delhi, October 15).

Taronki jeevangatha: Krishnameghase krishnavivartak (in Hindi), (Jawaharlal Nehru Memorial Lecture, Allahabad, November 9).

Udatya tabakadya ani parakiya jeevasrishti; Krishnavivar ani adrishya padartha (in Marathi), Late Shri Lalji Pendse and Late Shri Dadasaheb Pendse Lecture Series, Maharashtra Mandal, Goregaon, Bombay, January 23).

Antaral ahe tari kase? (in Marathi), (Abhniva Dnyan Mandir High School, Karjat, January 24).

New challenges in astronomy, (Binode Kanungo Memorial Lecture, Bhubaneswar, February 22).

Contributions of technology to modern astronomy, (Institute of Engineers, Pune, February 26).

Khagolshastratun disanare vishwa (in Marathi), (Late Sriramji Bhangadiya Memorial Lecture Series at Selu, District Parabhani, March 25-26, 2 lectures).

Impact of modern science on human life, (M.N. Roy Memorial Lecture arranged by Indian Radical Humanist Association, Bombay, March 20).

S.N. Tandon

Scattering and polarisation of light (a lecture-demonstration in Hindi for school students, IUCAA, December 11).

(e) Colloquia

G.C. Anupama

The recurrent nova RS Ophiuchi, (IIA Bangalore, August 10).

S.V. Dhurandhar

The search for gravitational waves, (Anglo Australian Observatory, Sydney, Australia, May 3; Georgia State University, Atlanta, USA, January 5).

J.V. Narlikar

The Quasi steady state cosmology – an alternative to big bang, (TIFR, Bombay, April 22; Australian National University, May 3).

Quasar absorption lines and the intervening galaxies hypothesis, (Anglo Australian Observatory, May 4; Sydney University, Australia, May 7).

T. Padmanabhan

Do we know our universe?, (RRI, Bangalore, July 22).

Quantum gravity, (Gauhati University, Guwahati, November 27).

V. Sahni

The cosmological adhesion model and the statistics of voids, (Indian Institute of Astrophysics, Bangalore, May).

Gravity waves from inflation and the anisotropy of the CMBR, (Indian Institute of Science, Bangalore, May).

(VI) SCIENTIFIC MEETINGS

Workshops

Making Your Own Planetarium : A national workshop on 'Making Your Own Planetarium' was held at IUCAA during the period November 1-6. Each of the twenty four participants, mostly teachers from schools, colleges and universities and some amateur astronomers, made a sky projector using a plastic glow ball and flash light bulb arrangement. Even though it was a laborious job, practically everyone enjoyed finishing the project. On the last day, they also observed the transit of Mercury. Some of the participants also gave lectures and demonstrations. In particular, Bharat Trivedi from Baroda made one star clock for finding sidereal time as a project work, which was also constructed by every participant. The workshop demonstrations were assisted by M. Barve, M. Dinakaran, S. Menon, B.

Mitra, K. Rajeev and A.N. Ramaprakash. [During December 24-28, the Rural Centre for Educational Studies and Development Programmes, Sanjeevan Vidyalaya, Panchgani, Maharashtra, conducted a similar workshop on a similar scale using IUCAA expertise].

Indo-US Workshop on AGN and Quasars : As a programme of Indo-US co-operation in astronomy and astrophysics, the first in a series of the workshops was held at IUCAA during the period December 6 – 18 on Active Galactic Nuclei and Quasars. Funds for the workshop were provided by the Harvard Smithsonian Center for Astrophysics, USA. There were about forty participants, in addition to the speakers from various institutions, university departments and colleges in the country. There were lectures on topics such as continuum emission and absorption lines from quasars and AGN, X-ray , UV and IR properties, radio emission from quasars, modelling of the emission lines regions, accretion disks and high redshift radio galaxies and luminosity functions by R. Antonucci, M. Elvis, G. Ferland, P. Ghosh, P. Gondhalekar, V. Kapahi, A. Kembhavi, M. Malkan and P. McCarthy. Some of the participants presented seminars on their research work. Some of the seminars were conducted in the salubrious surroundings of the Mahabaleshwar Club, during a two-day trip to Mahabaleshwar.

Astroparticle Physics : A workshop on Astroparticle Physics was organized at IUCAA *(Co-sponsored by S.N. Bose Centre for Basic Sciences, Calcutta)*, during February 21–25. The workshop consisted of a series of invited review talks covering cosmology and particle physics, inflationary models, baryogenesis, detection of WIMPS in the laboratory, experiments on neutrino mass, supernovae, astroparticle physics, etc. In addition, there were a few seminars on selected topics related to the main theme.

Speakers included P. Bhattacharya, S.M. Chitre, R. Godbole, K. Kar, J.V. Narlikar, T. Padmanabhan, N. Panchapakesan, V. Sahni and K. Subramanian. About 30 participants from various institutes and universities attended the workshop.

Miniworkshops

Gravity Waves : A miniworkshop on gravity waves was held, to generate interest in this new frontier field, at IUCAA during the period May 31 – June 4 and attended by many university teachers and students, experts from various institutes within India and IUCAA visitors. The topics discussed at the school included linear and post-linear gravity, Post-Newtonian, Post-Minkowskian and higher order approximation methods and data analysis techniques. The lectures were delivered by B.R. Iyer, S.V. Dhurandhar, B.S. Sathyaprakash, T.S. Ghosh, K. Jotania and B. Bhawal. There were computer demonstrations for illustrating the data analysis techniques.

Cataclysmic Variables: A miniworkshop on Cataclysmic Variables (CVs) was held at IUCAA during the period August 23 – 25 and attended by about fifteen scientists and students. The workshop discussed several aspects of CVs such as their evolution, accretion discs in CVs, magnetic CVs in globular clusters, multiwavelength studies of novae and γ-ray detection from AM Her stars.

Schools

Introductory school on Astronomy for IIT students : An introductory School on Astronomy for IIT students was held at IUCAA during the period December 6-20 and was attended by fourteen students from all the IITs in India. The programme consisted of twenty formal lectures, mini project work, visit to GMRT construction site and informal sessions. All the students felt that this kind of introduction to Astronomy and Astrophysics was extremely useful and stimulating. It is planned to continue this as a regular academic activity of IUCAA in future.

XX-IAU International School for Young Astronomers (ISYA) : During January 3–21, IUCAA hosted the XX International School for Young Astronomers of the IAU. About 35 students from 12 countries including Russia, Iran, Vietnam, Turkey, South Korea, Bulgaria, Argentina, Ukraine, Ireland, Nepal and the USA attended. The teaching faculty included, apart from the ISYA Secretary, D. Wentzel and the IAU representative M. Gerbaldi, S. Isobe from the National Astronomical Observatory, Japan, P. Eggleton from the Institute of Astronomy, University of Cambridge and six Indian scientists. The school covered a wide ranging syllabus in astronomy and astrophysics and included observing with the IUCAA's 8 and 14 inch telescopes.

Minischool

Numerical Relativity : In minischool on Numerical Relativity held during the period June 28– July 6, N.T. Bishop of University of South Africa, conducted a course on initial value and characteristic Cauchy problem in general relativity. The school was held at IUCAA and attended by eight research workers from IUCAA and outside.

Conferences

VI-IAU Asian Pacific Regional Meeting on Astronomy : The 6th IAU Asian Pacific Regional Meeting on Astronomy was held at IUCAA during the period August 16–20. This is the first time that India has hosted a Regional Meeting on Astronomy. Over 300 astronomers from 20 countries attended the conference; 200 from the host country, India. The plenary sessions were held in the mornings in the IUCAA Auditorium (which had just been completed in time for the meeting) and in the afternoons, two parallel workshop sessions were held in the IUCAA Lecture Halls (named after the ancient Indian astronomer, Bhaskara). The SOC had planned an academic programme consisting of plenary sessions on Stellar Physics (R. Cannon: Chemical Compositions and Ages of Globular Clusters and D. Lambert: The R Coronae Borealis Stars), Interstellar Medium (T. Hasegawa: The Large Scale Variation of the Physical Conditions of Molecular Gas in the Galaxy), Cosmology (T. Padmanabhan: Cosmology Today-Models and Constraints, K. Sato: Early Universe and Inflation and A. Starobinsky: Inflation and Cosmology), Solar Physics (S.M. Chitre: Probing the Solar Interior and T. Kosugi: The Yohkoh Result), Astronomical Instrumentation and New Observing Facilities (Ye Shuhua: New Observing Facilities and Instrumentation in China, S.N. Tandon: Plans for Large Indian Telescope, S. Ananthakrishnan: Giant Metrewave Radio Telescope, H. Nakajima: New Nabeyama Radioheliograph, N. Kaifu: Subaru Project, D. Enard: Concept and status of the ESO Very Large Telescope Project and P. Hall: The Australia Telescope), QSO and AGN (J.J. Perry: Activity in the Nuclei of Galaxies: Symbiosis of Starbursts and Black Holes? Gopal Krishna: Unified Schemes for Radio - Loud AGN and R.W. Hunstead: The Lyman Alpha Absorbers as Probes of the High Redshift Universe) and Pulsars (M. Bailes: New Lessons from Old Pulsars). In addition, there were discussion sessions on Teaching of Astronomy, Regional Cooperation in Astronomy and Astrophysics and Astronomy in Antarctica. To commemorate two eminent Indian astronomers, Meghnad Saha and M.K. Vainu Bappu, two evening lectures were organized. The 1993 Birth Centenary year of Meghnad Saha was celebrated with D. deVorkin's talk on Saha's Influence on Modern American Astrophysics and Tom Gehrels delivered the Vainu Bappu Lecture on 'The Beauty and Danger of Comets and Asteroids'.

The delegates enjoyed the visit to the GMRT construction site, conference banquet and Kathak dance recital by Rohini Bhate.

IAGRG Silver Jubilee Conference : The Indian Association for General Relativity and Gravitation celebrated its Silver Jubilee while holding its XVII meeting during February 14–18, at IUCAA, Pune. The meeting was funded by UGC and DST. Several eminent scientists around the world participated in the meeting and delivered plenary talks on cosmology, gravitational waves, classical general relativity and quantum cosmology. There were workshops on classical general relativity and gravitational wave detection and a symposium was held on 'Fifty years of the Vaidya metric'. The Vaidya–Raychaudhuri endowment lecture was delivered by N. Panchapakesan on February 18.

About 100 members attended the meeting from various institutions, universities and colleges in the country. Some of the participants presented their work during the course of the meeting.

An essay competition had been conducted by the IAGRG and the prize winners of the essay competition presented their essays in brief. C.S. Unnikrishnan, TIFR, Bombay, won the first prize, Anuradha Das Purkayastha, Cotton College, Guwahati, the second prize and Masafumi Seriu, IUCAA, the third prize.

A sight-seeing trip of Pune and a banquet followed by an 'After Dinner Talk' by C.V. Vishveshwara, were some of the additional activities arranged during the conference.

Meetings

The Secondary School Teachers' Meet : Following the 6th IAU Asian Pacific Regional Meeting on Astronomy, a two day workshop on Astronomy for secondary school teachers was organised at IUCAA on August 22 and 23, by A.H. Batten, Chairman, IAU Working Group for the Worldwide Development of Astronomy. There were sixty paticipants with only two, one each from Bangladesh and Nepal, coming from outside India, though we had sought participation from the SAARC countries. A.H. Batten, D. Hoff, S. Isobe, C. Iwaniszewska, J.V. Narlikar and N. Raghavan gave lectures and conducted participatory exercises on how to teach simple and basic astronomical concepts to school students.

Confederation of Indian Amateur Astronomers : The National Organizing Committee of All India Amateur Astronomers' Meet in a meeting of the committee, attended by fifteen members and held at IUCAA during August 28-29, decided to form a confederation of Indian Amateur Astronomers. It was agreed that D.K. Soman will be its President and Pune the headquarters, with four other regional centres to start with. The memorandum of association alongwith its constitution was formulated and is ready for submission for formal registration. Anyone requiring further information may please contact its General Secretary, Mrs. K.V. Barve, Indraprastha, 755/1, Mayur Colony, Kothrud, Pune - 411029, INDIA.

Marathi Science Writers' Meet : The Marathi Vidnyan Parishad in collaboration with IUCAA, conducted the ninth meeting of Marathi Science Writers on the IUCAA campus during the period September 10-11. More than hundred writers participated from different parts of the state of Maharashtra. A distinguished playwright and journalist, Vidyadhar Gokhale in his opening address highlighted the need for science popularisation and the development of the scientific temper with special emphasis on informing the mass, the difference between real science and pseudo-science. The five workshops discussed the state of science reporting and science writing in newspapers, the problems of translations of science books and articles, the need for revamping current science textbooks in schools, the ways of spreading the scientific temper and the challenges of writing good science fiction. A public session in the city highlighted the new vocational training methods being tried near Pune by S. Kalbag, and a review of India's space programme by E. Chitnis. In both these lectures, the emphasis was how new techniques of science and technology could be harnessed for the welfare of the society.

Refresher Course : Under the UGC's programme of Refresher Courses for the College and University teachers, the first Refresher Course in Astronomy and Astrophysics (A&A) was conducted at IUCAA during May 10-28. Twenty five teachers attended the course. Since most of the teachers had no prior exposure to A&A, as it is not part of masters programme in most universities, the course was devised at an introductory level with an eye on orientation. About 40% of the lectures were devoted to basic Physics for Astrophysics and the other two topics covered were Stellar Structure and Evolution and Extragalactic Astronomy. The main lecturers were S. Dhurandhar, S. Kandaswamy, N.C. Rana and D.J. Saikia. Introductory lectures on identification of objects in the sky were given by K.S.V.S. Narasimhan. Ranjan Gupta and Arvind Paranjpye conducted observation sessions. Besides, there were seminars by IUCAA-NCRA faculty and visitors.

(VII) VACATION STUDENTS PROGRAMME

The Vacation Students Programme was conducted at IUCAA during June 1 - July 5, 1993. Under this programme 12 students were selected to spend 6 weeks at IUCAA and completed projects under supervision of 10 of the IUCAA faculty members and post-docs. A total of 23 lectures were delivered by the academic staff of IUCAA and NCRA during the programme.

PROTECTING THE FREEDOM OF SCIENCE: THE CHALLENGE OF THE LATE 20TH CENTURY

Fifth IUCAA Foundation Day Lecture

by

Vandana Shiva

Diverse Creativities

Science is an expression of human creativity; both individual and collective. Since creativity has diverse expressions, I see Science as a pluralistic enterprise which refers to different "ways of knowing". For me, Science is not restricted to modern western science, but includes the knowledge systems of diverse cultures in different periods of history.

Recent work in the history, philosophy and sociology of science has revealed that scientists do not work in accordance with an abstract scientific method, putting forward theories based on direct and neutral observation. Scientific claims, like all others, are now recognised as arising not in accordance with a verificationist model but from the commitment of a specialist community of scientists to presupposed metaphors and paradigms, which determine the meaning of constituent terms, concepts and status of observation and facts. These new accounts of modern science, based on its practice, do not leave us with any criteria that distinguish the theoretical claims of indigenous non-western sciences from those of modern western science. That, it is the latter that is more widely practised in non-western cultures has more to do with western cultural and economic hegemony than with cultural neutrality.

Recognition of diverse traditions of creativity is an essential component of keeping diverse knowledge systems alive. This is particularly important in this period of rampant ecological destruction in which the smallest source of ecological knowledge and insights can become a vital link to the future of humanity on this planet. Indigenous knowledge systems are by and large ecological, while the dominant model of scientific knowledge, characterised by reductionism and fragmentation, has not been equipped for taking the complexity of interrelations in nature fully into account.

This inadequacy becomes most significant in the domain of life sciences which deal with living organisms. Creativity in the life sciences has to include three levels of creativity :

1. The creativity inherent to living organisms which allows them to evolve, recreate and regenerate themselves.
2. The creativity of the knowledge systems of indigenous communities which have learnt how to conserve and utilise the rich biological diversity of our planet.
3. The creativity of modern scientists in university or corporate labs, who find ways to use living organisms to generate profits.

The recognition of these diverse creativities are essential for the conservation of biodiversity as well as for the conservation of intellectual diversity – across cultures, and within the university setting.

Intellectual Property Rights and the destruction of Intellectual Diversity

Intellectual Property Rights (IPRs) are supposed to provide recognition and reward for intellectual creativity. However, knowledge and creativity have been so narrowly defined in the context of IPRs that the creativity of nature and the creativity of non-western knowledge systems have been ignored.

The IPRs are supposed to be property rights to products of the mind. If IPR regimes reflected the diversity of knowledge traditions that account for creativity and innovation in different societies, they would necessarily have to be plural, reflecting a triple plurality - of intellectual modes of property systems, and of systems of rights - leading to an amazing richness of permutations and combinations. However, IPRs as currently discussed in global platforms such as General Agreement on Tariffs and Trade (GATT) and the Biodiversity Convention, or as unilaterally imposed through Special 301 clause of the U.S. Trade Act, are a prescription for a monoculture of knowledge. These instruments are being used to universalise the U.S. patent regime world wide, which would inevitably lead to an intellectual and cultural impoverishment since it would displace other ways of knowing, other objectives for knowledge creation and other modes of knowledge sharing.

The Trade Related Aspects of Intellectual Property Rights (TRIP) treaty of the Draft Final Act of GATT is based on a highly restricted concept of innovation. By definition, it is weighted in favour of transnational corporations, and weighted against citizens in general, and Third World peasants and forest dwellers in particular. People everywhere innovate and create. In fact, the poorest have to be most innovative, since they have to create survival while it is daily threatened.

However, IPRs as construed in the trade negotiations have been restricted and reduced at a number of levels.

The first restriction is the shift from common rights to private rights. As the preamble of the TRIPs agreement states, intellectual property rights are recognised only as private rights. This excludes all

kinds of knowledge, ideas and innovations – that take place in the "intellectual commons" – in the villages among farmers, in forests among tribals and even in universities among scientists. TRIPs is therefore a mechanism for the privatisation of the intellectual commons, and a de-intellectualisation of civil society, so that the mind becomes a corporate monopoly.

The second restriction of intellectual property rights is that they are recognised only when knowledge and innovation generates profits, not when it meets social needs. Article 27.1 refers to the condition that to be recognised as an IPR, innovation has to be capable of industrial application. This immediately excludes all sectors that produce and innovate outside the industrial mode of organisation of production. Profits and capital accumulation are recognised as the only ends to which creativity is put. The social good is no longer recognised. Under corporate control a "deindustrialisation" of production in the small scale in the informal sectors of society takes place.

By denying the creativity of nature and other cultures even when that creativity is exploited for commercial gain, intellectual property rights become another name for intellectual and bio-piracy. Simultaneously, people's assertion of their customary, collective rights to knowledge and resources are turned into "piracy" and "theft".

The U.S. trade commission has been claiming that U.S. industry is losing between U.S. dollars 100 million and 300 million due to "weak" intellectual property protection in Third World countries[1]. However, when the value of Third World biodiversity and Third World intellectual traditions that are used freely by commercial interests in the U.S. are taken into account, it is the U.S. and not countries like India, which are engaged in piracy.

Even though many of the patents being claimed in the U.S. are based on Third World biodiversity and Third World knowledge, it is falsely assumed that without IPR protection, creativity lies buried. As Sherwood states, "Human creativity is a vast national resource for any country. Like gold in the hills, it will remain buried without encouragement for extraction. Intellectual property protection is the tool which releases that resource"[2].

This interpretation of creativity, as unleashed only when formal regimes of IPR protection are in place, is a total negation of creativity in nature and creativity generated by non-profit motives in both industrial and non-industrial societies. It is a denial of the role of innovation in traditional cultures as well as in the public domain. In fact, the dominant interpretation of IPRs leads to a dramatic distortion in the understanding of creativity and, as a result, in the understanding of the history of inequality and poverty.

The economic inequality between the affluent industrialised countries and the poor Third World countries is a product of 500 years of colonialism, and the continued maintenance and creation of mechanisms for draining wealth out of the Third World. According to the United Nations Development Programme, while 50 billion U.S.$ flow annually from the North to the South in terms of aid, the South loses 500 billion U.S.$ every year in terms of interest payments on debt and loss of fair prices for commodities due to unequal terms of trade. Instead of seeing the structural inequality of the international economic system as lying at the roots of Third World poverty, IPR advocates and explains poverty as arising from lack of creativity which in turn is seen as rooted in lack of IPR protection.

For example, Robert Sherwood in his book, Intellectual Property and Economic Development relates two stories, one real and one quite imaginary. In his words they are meant to draw a contrast between the mindset of ordinary people in a non-protection country and in a country with effective protection.

A salesman for a U.S. pump manufacturer, who was a neighbour of the author some years ago in upstate New York, noticed while visiting customers that a certain type of pressure valve would be useful. Although his wife was skeptical, he took time at night and weekends to design such a valve and applied for a patent on the design and was granted. He placed a second mortgage on his house and later obtained a bank loan, largely on the strength of the patent. He created a small business, employed a dozen people and contributed to the multiplier effect before the valve was superceded some 20 years later by other types of valves. The man never thought much about intellectual property. He simply took it for granted that he could get a patent and build a business from it.

In Lima, Peru, Young Carlos (a fictional proxy for much of the developing world) earns a meagre living welding replacement mufflers under trucks and cars. He thinks of a clamp for simplified muffler installation. His wife is skeptical. Should he spend his nights and weekends to design and develop the clamp? He will need help fabricating a prototype. Should he involve his friend the metal worker? He needs money for metal and tools. Should he use the money saved under the mattress? Should he take a bus across town to ask his sister's husband for a loan? The answer to each question is strongly biased toward the negative by weak intellectual property protection. Without thinking much about intellectual property, his wife, the brother-in-law and Carlos himself, each knows from community wisdom that his idea is vulnerable and likely to be taken by others. He cannot take it for granted that his idea can be protected. In this story, lack of confidence that his idea can be protected would in all probability lead Carlos to a negative decision at each of these decision points.

If the story of Carlos is multiplied many times across a land-scape, that country's opportunity loss is devastating[3].

When an effective protection system becomes a reality, confidence will grow that intellectual assets are valuable and protectable. Then the inventive and creative habit of mind, which is at the heart of an intellectual property protection system, will spread in the minds of people[4].

Central to the ideology of IPRs is the fallacy that people are creative only if they can make profits and their profits are guaranteed through IPR protection. This negates the scientific creativity of those not spurred by the search for profits. It negates the creativity of traditional societies and the modern scientific community in which free exchange of ideas is the very condition for creativity, not its antithesis.

Patents as a block to free exchange

Patents are the strongest form of IPR protection. Wherever patents have been associated with scientific research, the result has been closure of communication. While scientists have never been as open as popular mythology portrays, the threat to scientific communication posed by scientists working with commercial enterprises who seek patent protection is becoming a major cause for concern. As Emanuel Epstein, a noted microbiologist states, in the past it was the most natural thing in the world for colleagues to swap ideas on the spur of the moment, to share the latest findings hot off the scintillation counter or the electrophoresis cell, to show each other early drafts of papers, and in other such ways to act as companions in zealous research.

No more. Any University of California at Davis (UCD) scientist with a promising new slant for crop improvement... will think twice before talking about it to anyone who is connected with either of the two Davis crop genetic private enterprises – or even with colleagues who in turn might speak to any such person. I know that this type of inhibition is already at work on this (the UCD) campus[5].

Reflecting on the closure of scientific openness in the University Industrial Complex, Martin Kenny observes that the fear of being scooped or of seeing one's work transformed into a commodity can silence those who presumably are colleagues. To see a thing that one produced turned into a product for sale by someone over whom one has no control can leave a person feeling violated. The labour of love is converted into a plain commodity –the work now is an item to be exchanged on the basis of its market price, money becomes the arbiter of a scientific development's value[6].

The openness, the free exchange of ideas and information, the free exchange of materials and techniques, have been a critical component in the creativity and productivity of the research community.

By introducing secrecy in science, IPRs and the associated commercialisation and privatisation of knowledge will kill the scientific community, and hence its potential for creativity. IPRs exploit creativity while killing its very source. We know that reservoirs that are not replenished soon run dry. Common sense tells us that when roots of a tree are not nourished, it dies.

Threats to the tree of knowledge :

There are subtle processes by which the roots of the tree of scientific knowledge is being starved even while it is being more rapidly exploited and harvested for profits.

The most significant is what David Ehrenfield has called "Forgetting". As certain disciplines and specialisations in science spin profits through commercialisation, others are neglected, even though they are essential to the foundations of a knowledge system. IPRs lead to the skewing of research to targets of greater commercial interest. As molecular biology becomes a major source of techniques for the biotechnology industry, other disciplines of biology shrivel up and die. We are on the verge of losing our ability to tell one plant or animal from another, and of forgetting how the known species interact among themselves and with their environment.

Earthworms are among the species which are crucial to our survival. Earthworms are significant among the soil fauna for improving the fertility of the soil by deposition of their faceal material and for increasing permeability of the soil to air and water.

In 1881, Charles Darwin published his last work, the result of a lifetime study of earthworms in which he wrote:

"It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organised creatures.[7]"

Agriculture depends on soil fertility, and soil fertility depends heavily on earthworms. Yet, as David Ehrenfield reports, the people who have been trained in earthworm ecology are disappearing.

At the time of this writing, there is just one actively working scientist who is familiar with the taxonomy of the earthworms of North America. He is at a small private university in Iowa. Another earthworm taxonomist works at a university in Puerto Rico, but she was only recently trained in Spain. A third earthworm taxonomist, trained by his mother, has been working for a post office in Oregon. The fourth, and last, person in North America, North of Mexico who has expert knowledge of earthworm taxonomy is presently earning a living as a police lawyer in New Brunswick, Canadâ. There are no more graduate students studying earthworm taxonomy in the United

States and Canada. Fifty years ago, at least five American scientists, plus their students, were at work in this field. Nor is the situation different in other parts of the world: Australia, long noted for earthworm research, now has none; the British Museum has ended its earthworm taxonomy, and so on.

The example of earthworms is not typical. The more advances we make, the more we forget. What use is our expensive technology in a sea of ignorance[8].

Once priorities shift from social need to potential return on investment, which is the main criterion for commercially guided research, entire streams of knowledge and learning will be forgotten and will go extinct. While these diverse fields might not be commercially profitable, they are socially necessary. We need epidemology, ecology, evolutionary and developmental biology as a society facing ecological problems. We need experts on particular taxonomic groups such as microbes, insects and plants to respond to the crisis of biodiversity erosion. The moment we ignore the useful and necessary and concentrate only on the profitable, we are destroying the social conditions for the creation of intellectual diversity.

Enclosure of the intellectual commons

The tree of knowledge also withers because of what I have called the "enclosure of the intellectual commons". Innovation in the public domain is necessary for innovation that is privatised by IPRs. However, the return on investment logic linked to IPRs, fails to replenish the public support to the public domain. Much of the background research that underlies any patentable development has been publicly funded. Yet the results are often employed in applied research that does result in patentable discoveries, the rewards of which are appropriately private.

IPRs and intellectual piracy

Even more serious than the appropriation of public knowledge within modern science is the appropriation of indigenous knowledge traditions. One of the examples of such intellectual piracy in the name of intellectual property rights is the patenting of Neem for its agricultural and medicinal uses.

For centuries the Western world ignored the neem tree and its properties: the practices of Indian peasants and doctors were not deemed worthy of attention by the majority of British, French and Portuguese colonists. However, in the last few years, growing opposition to chemical products in the west, in particular to pesticides, has led to a sudden enthusiasm for the pharmaceutical properties of neem.

In 1971, U.S. timber importer Robert Larson observed the tree's usefulness in India and began importing neem seed to his company headquarters in Wisconsin. Over the next decade he conducted safety and performance tests upon a pesticidal neem extract called Margosan-O and in 1985 received clearance for the product from the U.S. Environmental Protection Agency (EPA). Three years later he sold the patent for the product to the multinational chemical corporation, W.R. Grace and Co.

Since 1985, over a dozen U.S. patents have been taken out by US and Japanese firms on formulae for stable neem-based solutions and emulsions and even for a neem-based toothpaste. At least four of these are owned by W.R. Grace and Co., three by another U.S. company, the Native Plant Institute, and two by the Japanese Terumo Corporation. Having garnered their patents and with the prospect of a licence from the EPA, Grace have set about manufacturing and commercialising their product by establishing a base in India. The company approached several Indian manufacturers with proposals to buy up their technology or to convince them to stop producing value-added-products and instead supply the company with raw material.

In many cases, Grace met a rebuff. M.N. Sukhatme, Director of Harringer Pvt. Ltd., which manufactures the neem-based insecticide Indiara, was put under pressure by Grace to sell the technology for a storage-stable neem extract which does not require heating or any chemical change. Sukhatme refused their offers, stating: "I am not interested to commercialise the product"[9].

But Grace eventually managed to arrange a joint venture with a firm called P.J. Margo Pvt. Ltd. They are now setting up a plant in India which will process neem seed for export to the U.S. Initially, the plant will process 20 tons of seed a day. They are also setting up a network of neem seed suppliers, to ensure a constant supply of the seeds and a reliable price.

Grace is likely to be followed by other patent-holding companies. In 1992, the U.S. National Research Council published a report[10] designed to "open up the Western world's corporate eyes to the seemingly endless variety of products the tree might offer".

According to one of the members of the NRC panel, "In this day and age, when we're not very happy about synthetic pesticides, (neem) has great appeal"[13]. This appeal is blatantly commercial. The U.S. pesticides market is worth about 2 billion U.S.$. At the moment biopesticides, such as pyrethrum, together with their synthetic mimics, constitute about 450 million U.S.$ of this, but that figure is expected to rise to over 800 million U.S.$ by 1998[11]. "Squeezing bucks out of the neem ought to be relatively easy", observes Science Magazine[14].

Plagiarism or Innovation?

Grace's aggressive interest in Indian neem production has provoked a chorus of objections from

Indian scientists, farmers and political activists, who assert that multinational companies have no right to expropriate the fruit of centuries of indigenous experimentation and several decades of Indian scientific research. This has stimulated a bitter transcontinental debate about the ethics of intellectual property and patent rights. In April 1993, a Congressional Research Service (CRS) report to U.S. Congress set out some of the arguments used to justify patenting:

Azadirachtin itself is a natural product found in the seeds of the neem tree and it is the significant active component. There is no patent on it, perhaps because everyone recognises it as a product of nature. But...a synthetic form of a naturally occurring compound may be patentable, because the synthetic form is not technically a product of nature, and the process by which the compound is synthesized may be patentable.[12]

However, neither azadirachtin, a relatively complex chemical, nor any of the other active principles have yet been synthesized in laboratories. The existing patents apply only to methods of extracting the natural chemical in the form of a stable emulsion or solution, methods which are simply an extension of the traditionl processed used for millennia for making neem-based products. The biologically active polar chemicals can be extracted using technology already available to villages in developing countries, says Eugene Schulz, chair of the NRC panel, "Villagers smash'em (the seeds) up. Soak (them) in cold water overnight, scoop the emulsion off the top and throw it on the crops.[15]

W.R. Grace's justification for patents therefore pivots on the claim that these modernised extraction processes constitute a genuine innovation:

Although traditional knowledge inspired the research and development that led to these patented compositions and processes, they were considered sufficiently novel and different from the original product of nature and the traditional method of use to be patentable.[16]

Azadirachtin which was being destroyed during conventional processing of Neem Oil/Neem Cake is being additionally extracted in the form of water soluble Neem Extract and hence it is an add-on rather than a substitute to the current neem industry in India.[17]

In short, the processes are supposedly novel and an advance on Indian techniques. However, this novelty exists mainly in the context of the ignorance of the West. Over the 2000 years that neem based biopesticides and medicines have been used in India, many complex processes were developed to make them available for specific use, though the active ingredients were not given Latinized scientific names. Common knowledge and common use of neem was one of the primary reasons given by the Indian Central Insecticide Board for not registering neem products under the Insecticides Act, 1968. The Board argued that neem materials had been in extensive use in India for various purposes since time immemorial, without any known deleterious effects.

The U.S. EPA, on the other hand, does not accept the validity of traditional knowledge and has imposed a full series of safety tests upon Margosan-O.

The allegation that azadirachtin was being destroyed during traditional processing is inaccurate. The extracts were subject to degradation, but this was not a problem since farmers made such extracts to use as and when they needed them. The problem of stabilization only arose when it needed to be packed for a long time to be marketed commercially. Moreover, stabilisation and other advances attributable to modern laboratory technology had already been developed by Indian scientists in the 1960s and 1970s, well before U.S. and Japanese companies expressed an interest. R.P. Singh of the Indian Agricultural Research Institute asserts:

Margosan-O is a simple ethanolic extract of neem seed kernel. In the late sixties we discovered the potency of not only ethanolic extracts of neem.... Work on the neem as pesticide originated from this division as early as 1962. Extraction techniques were also developed by a couple of years. The azadirachtin-rich dust was developed by me.[18]

The reluctance of Indian scientists to patent their work, may in part derive from a recognition that the bulk of the work had already been accomplished by generations of anonymous experimenters. This debt has yet to be acknowledged by the U.S. patentors and their apologists. The CRS report claims that "the method of scattering ground neem seeds as a pesticide would not be a patentable process, because this process..... would be deemed obvious".[19] - a statement that betrays either lamentable misjudgement or a racist dismissal of indigenous knowledge. The discovery of neem's pesticidal properties and of how to process it was by no means "obvious" but evolved through extended systematic knowledge development in non-western cultures. In comparision to this first non-obvious leap of knowledge, it is the subsequent minor derivatives that are obvious.

Playing God

Patents on life do not merely deny the creativity of indigenous knowledge traditions. They also deny the creativity of nature.

In 1971, General Electric and one of its employees, Ananda Mohan Chakravarty applied to the U.S. patent on a genetically engineered Pseudomonas bacteria. Taking plasmids from three kinds of bacteria he transplanted them into the fourth. As he explained 'I simply shuffled genes, changing bacteria that already existed'.

Chakravarty was granted his patent on the grounds that the micro-organism was not a product of nature, but Chakravarty's invention and therefore patentable. As Andrew Kimbrell, a leading U.S. lawyer recounts:

In coming to its precedent shattering decision, the court seemed unaware that the inventor himself had characterised his "creation" of the microbe as simply "shifting" genes, not creating life.[20]

On such slippery grounds the first patent on life was granted and in spite of exclusion of plants and animals in U.S. Patent Law, the U.S. has since then rushed on to grant patents on all kinds of life forms.

Currently, well over 190 genetically engineered animals, including fish, cows, mice and pigs are figuratively standing in line to be patented by a variety of researches and corporations. According to Kimbrell, "the Supreme Court's Chakravarty decision has been extended to be continued, up the chain of life. The patenting of microbes has led inexorably to the patenting of plants, and then animals".

Biodiversity has been redefined as "biotechnological inventions" to make the patenting of life forms appear less controversial. These patents are valid for 20 years and hence cover future generations of plants and animals. However, even when scientists in universities or corporations shuffle genes, they do not "create" the organism which they patent.[22]

Referring to the landmark Chakravarty case in the U.S. in which the court found that Chakravarty "has produced a new bacterium with markedly different characteristics than any found in nature....", Key Dismukes, Study Director of the Committee on vision of the National Academy of Sciences in the U.S. said:

Let us at least get one thing straight: Anand Chakravarty did not create a new form of life; he merely intervened in the normal processes by which strains of bacteria exchange genetic information, to produce a new strain with an altered metabolic pattern. "His" bacterium lives and reproduces itself under the forces that guide all cellular life. Recent advances in recombinant DNA techniques allow more direct biochemical manipulation of bacterial genes than Chakravarty employed, but these too are only modulations of biological processes. We are incalculably far away from being able to create life de novo, and for that I am profoundly grateful. The argument that the bacterium is Chakravarty's handiwork and not nature's wildly exaggerates human power and displays the same hubris and ignorance of biology that have had such devastating impact on the ecology of our planet.[23]

GATT and politics of knowledge :

It is because of the far reaching impact of IPRs in the area of life forms that major movements have emerged against the TRIPs treaty of the GATT.

Article 27.5.3 (b) of the TRIPs text of the Dunkel Draft of GATT refers to the patenting of life. The Article states :

Parties may exclude from patentability plants and animals other than micro-organisms, and essentially biological processes for the production of plants and animals other than non-biological and microbiological processes. However, parties shall provide for the protection of plant varieties either by patents or by an effective sui generis system or by any combination thereof. This provision shall be reviewed four years after the entry into force of the Agreement.[21]

The problem with the TRIPs text of GATT is that while it appears to be an agreement about Exclusion of living organisms from patentability, it will in fact put every country on slippery slope of patenting of life forms that has already been travelled in the U.S. Patent office and U.S. Courts. It is in any case a tragedy than an issue that is directly related to the ecological and ethical fabric of our society, and to the economic options of survival of our people should be left to the Ministry of Commerce. GATT–TRIPs is not about trade. It is also about the ethics of how we relate to other species and what we hold as moral and cultural values of our civilisation. It is about how our biodiversity is used and controlled - by local communities who have protected it, or by corporations which have found new ways to exploit and own it.

In our culture, and according to our patent laws, life cannot be patented because it cannot be owned and it is not manufactured. GATT will force us to give up our moral values, our creativity, our economic priorities and our sovereignty. GATT - TRIPs pushes us into making all living organisms property of a handful of corporations. On first reading, it appears that the article is about the exclusion of plants and animals from patentability. However, this phrase also exists in U.S. Patent Law. The existence of this phrase has however not prevented the U.S. from allowing patents for plants and animals. The problem is that the phrase "plants and animals other than micro-organisms" does not cover parts of animals and plants, nor does it include altered plants and animals. It therefore allows the patenting of biological organisms.

Further, the words "other than micro-organisms" excludes the exclusion of micro-organisms from patentability. It therefore makes patenting of micro-organisms compulsory. Since micro-organisms are living organisms, making their patenting compulsory is the beginning of a journey down what has been called the slippery slope that leads to the patenting of all life.

The best example of this slippery slope can be seen in the recent history of United States patent law where the granting of patents to micro-organisms signalled the taking of a first step to granting patents to so called higher life forms.

The second part of Article 27.5.3 (b) states that "parties shall provide for the protection of plant varieties either by patents or by an effective "sui generis" system or by any combination thereof. This provision shall be reviewed four years after the entry into force of the agreement".

This is the part that will most directly affect farmers' rights as innovators, plant breeders, and their community ownership of seed and plant material. TRIPs recognises only the western industrialised model of innovation and has failed to recognise the more informal, communal system of innovation through which Third World farmers produce, select, improve and breed a plethora of diverse crop varieties. Farmers' seeds reflect the ingenuity, inventiveness and genius of our people. However, the protection of the collective intellectual property of Third World farmers does not even find place in TRIPs.

While the phrase "sui generis" gives the impression that each country is free to set up its own IPR system, the key term "effective" makes the adoption of a global regime necessary.

This word was inserted by the U.S. in the Biodiversity Convention and in the TRIPs agreement. The first sentence of that draft refers to the need to "promote effective and adequate protection of intellectual property rights". The same phrase is in Section 301 of the Trade and Competitiveness Act of 1988 which has been used to retaliate against countries whose IPR laws do not conform to U.S. standards. The term was defined by the office of the U.S. Trade Representative.

The use of the term "effective" in all negotiations related to IPRs and biodiversity is a result of U.S. attempts to globalise its IPR regimes which allow patenting of all life, including plants and animals. In the Dunkel text, the phrase "effective sui generis system" implies that such a system will not be determined by countries but by GATT.

Further, given the trend of the developments in international negotiations the only system recognised as "effective" at the international level is the system of plant breeders' rights as codified in the international convention for the Protection of New Varieties of Plants (UPOV). Plant breeders' rights as recognised in UPOV give monopoly markets to breeders of new varieties. The amendments of UPOV in 1991 have increased the monopoly role of breeders' rights. The farmers' exemption which gave farmers the right to save their own seeds has also been removed from the amended version of the UPOV Convention. Farmers now have to pay royalties for saving seed on their own farms even under breeders' rights regimes. Thus, whether it is patents or it is "effective sui generis systems" either system threatens farmers' rights.

The farmers' movement in India has been resisting GATT-TRIPs because of these far - reaching implications. On 2nd October 1992 the farmers of Karnataka started the seed satyagraha at their five hundred thousand strong rally in Hospet. In March 1993, farmers from across the country gathered in Delhi at the historic Red Fort grounds to reject the Dunkel draft and burn it. In October 1993, half a million farmers gathered in Bangalore. The farmers are not satisfied with the weak government statements that India will negotiate to allow farmers the right to save and exchange seed non-commercially. For farmers, the right to seed is a positive right, not a negative one. It is a fundamental right, not a concession.

The farmers have started to assert farmers' right to seed through "Common Intellectual Rights" (CIRs). The first public demonstration of the positive assertion of farmers' rights took place on Independence Day, 15th August, 1993 when farmers declared that their knowledge and biodiversity is protected by a "Samuhik Gyan Sanad". According to them any company using their local knowledge or local resources with the permission of local communities is engaging in intellectual piracy as in the case of the patents on "neem".

The positive assertion of "Collective Intellectual Rights" creates an opportunity to define a sui generis system centered on farmers' rights arising from their role in protecting and improving plant genetic resources. Effectively then has to get interpreted to mean effective in the specific context of different countries. Diversity of IPR systems would then become a possibility, and only such legal diversity can protect the biological and cultural diversity of peasant societies across the Third World. IPR diversity that has room for plurality of systems, including on CIRs would reflect different styles of knowledge generation and dissemination in different contexts. Sui generis systems would have to work out on merely a positive protection system for farmers rights as plant breeders. It would have to develop the relationship between CIRs reflecting Third World farmers concerns and IPR regimes that have evolved with the western bias toward individualized and juridical application procedures which are not sympathetic to the style of inventiveness common to Third World rural societies. This relationship would need to be such that it is effective in preventing the systematic exploitation of Third World biological resources and Third World biological knowledge, while it maintains the free exchange of knowledge and resources among Third World farming communities.

Sui generis systems that protect CIRs must necessarily be based on the assumption of biodemocracy - that all knowledge systems and production systems using biological organisms have

equal validity. TRIPs is based on the assumption of bioimperialism - that only the knowledge and production of western corporations need protection. If unchallenged TRIPs will become an instrument for displacing and dispensing with the knowledge and creativity, the resources and the rights of Third World farmers.

The movements against TRIPs and patents on life are movements to protect the creativity of nature and of diverse knowledge systems. It is on the conservation of this creativity that our future depends.

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Facilities

(I) Computer Centre

The IUCAA Computer Centre now has a fully integrated network of computers which includes about 25 workstations and 46 PCs of different kinds. The workstations include 2 SUN SPARC 10s and a Silicon Graphics Indigo 2. A DEC Alpha 3000/800 has been ordered. A new state-of-the-art file server will be replacing the aging SUN 4/280, which was the first element of the network introduced into IUCAA three years ago.

IUCAA is a node of ERNET and is linked by dedicated line to the National Centre for Software Technology in Bombay. Several institutions, university departments, colleges as well as commercial establishments communicate with the outside world through the node at IUCAA.

IUCAA has extended the E-mail facility to several universities and it is expected that this number will grow substantially in the coming years. A one-day workshop on E-mail and related facilities was conducted at IUCAA to familiarise users in Pune and the surrounding region with the available facilities.

(II) Astronomical Data Centre

The Astronomical Data Centre (ADC) at IUCAA has a collection of several hundred astronomical catalogues which can be easily accessed using the software developed for this purpose. The catalogues are continously updated by obtaining data from other data centres all over the world. Several users have visited IUCAA to use the facility provided by the Data Centre. Data is also provided when requests are received by ordinary mail or E-mail, and it is possible to access data through "ftp" when this facility is available at the user's home institute. A recent addition to the modes of access is a computer programme which automatically processes requests received by E-mail without human intervention. The Data Centre is also able to provide copies of software systems like IRAF, upon request, and can provide access to SIMBAD through a special arrangement.

(III) Library

The IUCAA Library specialises in literature on astronomy, astrophysics and closely related areas. However, it also has a good collection of books in physics, mathematics, statistics and computer science, a representative collection from other areas of science and a small number of books from fields of learning as diverse as anthropology and economics. The library now has a total of 7278 books and 2553 journals. Most of the journals are received by airmail so that visitors to IUCAA have up-to-date access to the literature.

The collection of books and journals is augmented by current literature in the form of pre-prints which are received from a number of organisations. The library also makes full use of literature available in various computer data banks which can be accessed through E-mail and related facilities. This enables the library to procure pre-prints within hours after they are made available by the authors.

Apart from providing service to users who visit IUCAA, the library also handles a number of requests for books to be sent out on inter-library loan, request for photocopies on research papers and so on.

(IV) Instrumentation laboratory

The resources of the laboratory have been used towards development of several instruments – Imaging Polarimeter, Automated Photoelectric Telescope, CCD Camera, and Seeing Monitors – for which details can be seen elsewhere in this report. Several visitors from universities and colleges have used the laboratory for developing photometers.

Amateur astronomer groups were also provided support for some of their observations.

Science Popularization Programmes

(I) National Science Day

As in previous years, IUCAA celebrated the National Science Day on February 28, 1994, giving special emphasis to programmes involving school students. In the morning, a science test was held to select teams for the quiz contest. The first prize, the rolling trophy for the quiz contest, was won by Kendriya Vidyalaya, Range Hills Estate; the second prize, the rolling cup, by the Muktangan English School and the third prize by St. Vincents' School. Since the year 1994 marks the Silver Jubilee of Man's landing on the Moon, a competition for making models and drawings of Apollo Rocket, Command Module, Lunar Module and Man Walking on the Moon was organized for school students. The best three entries were given prizes donated by the Rotary Club of Pune, Hillside. The Jnana Prabodhini School, Modern High School and Muktangan English School won the first, second and third prizes respectively. The Sanjeewan Vidyalaya, Panchgani, presented an Astroballet on the origin of the universe which was very much appreciated by the audience. In the afternoon, IUCAA facilities were kept open for the public.

(II) Popularization of Astronomy and IUCAA Telescopes

IUCAA has six 3-inch refractors made by Scientific Instruments Organization, Chandigarh, one 8-inch

Ultima and one 14-inch CompuStar (both from Celestron).

The three-inch telescopes being portable, have been used extensively outside IUCAA's campus. These telescopes have been taken to various organizations to observe celestial objects. Normally such demonstrations are preceded by a slide show and a question–answer session.

Two of the three-inch telescopes are given to the local amateur astronomers and they were used for street side shows. Members from public and amateurs very enthusiastically participated in this activity. These telescopes were also used for public viewing of the transit of Mercury in November 1993, at IUCAA and at a school in the town.

In February'94 a very low cost photometer was made to be used with this telescope. It has been used by amateurs and students to estimate the sky brightness.

For advanced observing, C8 Ultima was taken to the star parties of amateur astronomers. These star parties are held at sites far away from the Pune city. A few amateurs are experts in handling the telescopes and some have even tried astronomical photography and photometry.

Fourth Friday sky shows with C14 telescope (which started last year) have become very popular. About 40 visitors are invited for each show.

List of demonstrations (outside IUCAA campus and important events) :

13.5.93: Children's Adventure Training Camp organized by BEG and Centre Training Battalion 2 at Fort Purandhar (3-inch telescope).

22.5.93: Star Party, Jyotirvidya Parisanstha at Khanapur (8-inch telescope).

6.11.93: For transit of Mercury and Star Party, Jyotirvidya Parisanstha at Khodad (3-inch and 8-inch telescopes).

10.11.93: Childrens' Camp at Seth Dagaduram Kataria High School, Pune (3-inch telescope).

4.2.94: K.T.H.M. College, Nashik (3-inch telescope).

19.2.94: Introductory Workshop on Astronomy, organized by Jyotirvidya Parisanstha at Khanapur (3-inch and 8-inch telescopes).

Programme for School Students

As a part of IUCAA's ongoing science popularisation programme, IUCAA has initiated two programmes for the school students in the current year in order to motivate and train a selected number of students towards their opting for a possible research career in astronomy and astrophysics. The initial response has been quite encouraging.

(I) Summer Programme for School Students

From May 3 – June 12, sixty seven students from thirty two schools participated in the newly introduced Summer Programme for school students to motivate participants towards careers in Astronomy and Astrophysics. Each school deputed 2-3 students from standard IX/X for a week. They interacted with IUCAA research scholars and senior faculty members and completed a project. Projects included the study of the Foucault pendulum, gravitational bending of light and the lens effect, the construction of a horizontal sundial, determination of Earth's shape and radius, etc. Students were encouraged to acquire 'do-it-yourself' attitude towards scientific activities. All IUCAA facilities were used extensively in this programme.

(II) Lecture Demonstration Programme for School Students

For conveying the excitement of doing science to secondary school students, the new programme comprising of lecture demonstrations was instituted. This is being held on every second Saturday of the month. Under this programme, the following lecture demonstrations were conducted:

10.7.93: A. Kembhavi (in Marathi) and N.C. Rana (in English)

14.8.93: J.V. Narlikar (in Marathi and English)

11.9.93: R. Gupta and A. Paranjpye (in English)

9.10.93: J.V. Narlikar (in Marathi)

11.12.93: S.N. Tandon (in Hindi)

8.1.94: A.W. Joshi (in Marathi)

12.2.94: Sir Fred Hoyle (in English)

Except the first one, all others were conducted in the newly built auditorium with a capacity nearly 500, which is very handy for such a mass programme. The response from the schools was tremendous; on few occasions, IUCAA was forced to decline admissions to students due to lack of sitting space in the auditorium.

Indo-US Project : Progress Report

Approval and funds for one Indo-US project entitled "Indo - US Cooperation in Astronomy and Astrophysics", with J.V. Narlikar as Indian Principal Investigator and G. Fazio from Smithsonian Astrophysical Observatory, Cambridge, as US Principal investigator, were received from Smithsonian Institution, Washington, USA. The project commenced from September 1, 1993 and will continue initially for three years.

The first workshop approved in the project on Active Galactic Nuclei and Quasars was held at IUCAA, during December 6 to 18.

Visits of six US scientists to India, including the visit of five scientists to attend the first Indo-US workshop have taken place. Visits of three Indian scientists to USA under the project will be completed by June 1994.

Clearance for the visit of one postdoc from North Carolina University, USA to IUCAA has been accorded. A circular for inviting Visiting Fellows from graduate students of US Universities to do research at IUCAA under the project has been issued. The Fellowships will commence from October 1, 1994.

Action to organise second Indo-US workshop on "Array detectors and image processing", to be held at IUCAA, during November 28 to December 10, 1994 has been initiated.

Administration

Various administrative measures were undertaken to meet the evergrowing challenges for smooth running of academic activities of IUCAA. Upgrading of financial accounting software has resulted in generating asset register and effective budget monitoring. The concept of one person handling jobs – the policy adopted by IUCAA – helped enormously in the successful organisation of the 6th IAU Asian Pacific Regional Meeting. Visits of staff to scientific institutions in India and abroad and deputations to training programmes and lectures were arranged for increasing the efficiency of staff to maintain the quality of existing paperless office of IUCAA. The details are as below:

T. Sahay: Visited Institute of Astronomy, University of Cambridge, Isaac Newton Institute of Mathematical Sciences, UK and International Centre for Theoretical Physics, Trieste, Italy, January 7–26.

K.M. Abhyankar: Visited Indian Institute of Science, Indian Institute of Astrophysics, National Aeronautical Laboratory, Raman Research Institute, Jawaharlal Nehru Centre for Advanced Scientific Research, Indian Academy of Sciences, all in Bangalore, and Defence Food Research Laboratory, Mysore, October 4-9.

S.U. Ingale: Received training regarding Air Circuit Breaker (ACB), Siemens Kedwa Factory, December 22-24; attended seminar on Air Conditioning–Compressor 570, Maratha Chamber of Commerce, Pune.

E.M. Modak: Attended Symposium on Departmental Security, Intelligence Bureau, Government of India and Maharashtra, August 25-26.

P. Krishnan: Attended intensive course on Imports Management, Institute of Management Development and Research, Pune, June 14-19; and lecture course on Reservation in services for SC/ST and OBC, Centre for Research, Planning and Action, New Delhi, February 10-11.

R. Pardeshi: Attended the workshop on Law relating to Contractual Labour in Maharashtra, Pragati Communication and Management Centre, Pune, September 18; and received training for improving office services, Centre for Work Study in Educational Administration, Punjab University, Chandigarh, December 6-16.

Varghese Thomas: attended INFLIBNET National Convention at Ahmedabad, February 19-20.

Selected persons from administration, Computer and Library sections visited R&D Engineers, Dighi on November 11.

One-day internal administration symposium was arranged at Warasgaon on October 16.

Special lectures on communication and human relations were delivered by M.A. Parelkar.

Computer awareness lectures were given by *A.M. Kane,G. Molakala* and A. Sohoni.

Extramural Activities

Vasant Palsikar: *The crisis of Indian nationhood and its resolution*, April 6

V.N. Shrikhande: *Surgery : Science, discipline and art*, August 28

Video screening of Ashvin Mehta's Exhibition : *Contemplative Colour* (Photographer's tribute to abstract painting), October 12

Students of Sanjeewan Vidyalaya, Panchgani, presenting an astroballet on the origin of universe, on the National Science Day , February, 28 1994

Participants of Introductory School on Astronomy for Indian Institute of Technology students during the star party

After the road naming ceremony on December 23, 1994, Govind Swarup, Director , GMRT, J. V. Narlikar, Shreedhar Gupte, Vice Chancellor, Poona University (who named the roads) and V. G. Bhide former ViceChancellor, Poona University

The other road was named , Meghnad Saha Marg

The Samrat Yantra
(Masonry Sundial)

Cover page : Entrance to the Devayani complex from Meghnad Saha Marg
(Photo : Ashwin Mehta)