RAMAN RESEARCH INSTITUTE
BANGALORE

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Annual Report

2006 – 2007

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PREAMBLE

The Annual report of the Raman Research Institute for the year 2006-2007 is a synopsis of the research and academic activities of the Institute during the year. The Annual Report lists research publications made in scientific journals, seminars/colloquia and joint scientific discussions held at the Institute, and of the Ph.D. degrees awarded during the period 1 April 2006 to 31 March 2007. Six students received Ph.D. degrees and another six have submitted their theses during the year. The report also lists the scientists who have visited the Institute from within India and from overseas during this period.

The Visiting Student Programme introduced during the year is aimed at offering research experience to highly motivated students who are pursuing their undergraduate or masters studies in universities in India; exceptional high school students may also be given an opportunity to interact with research scientists. Under this programme, which runs throughout the year, selected students will work with research staff and engineers at RRI on projects, usually participating in ongoing research programmes and in the laboratories of the Institute. Students seeking such opportunities during their summer vacation will continue to be supported under this programme. Several students benefited from this scheme during the year.

The lists of Colloquia given at the Institute, the Journal-Club discussions held at the Institute and the visitors to the Institute display the remarkable breadth of research at the Institute and the extent of interactions and collaborative work with scientists across the world. The linkages are strengthened by the visitors to the Institute, by the visits made by the Institute scientists to other research organizations, and the scientific discussions and collaborations that such interactions spawn. All these are a tribute not only to the scientists of the Institute, but also the untiring efforts of the administration that has admirably supported the endeavours.

Bangalore
September 10, 2007

RAVI SUBRAHMANYAN
Director

RAMAN RESEARCH INSTITUTE

Bangalore

Annual Report 2006 - 2007

INTRODUCTION

The Raman Research Institute was founded by Prof. C.V. Raman in the late forties. After his death in 1970, it was reorganised as a national institute for research in basic science. The Institute has been receiving grants from the Department of Science and Technology of the Government of India since 1972. The main fields of research have been, and continue to be, Astronomy & Astrophysics, Light & Matter Physics, Soft Condensed Matter and Theoretical Physics. The Liquid Crystals research has expanded and diversified and is today the Soft Condensed Matter research theme that includes inter-disciplinary soft condensed matter and biological physics, which has a significant overlap and interaction with the Theoretical Physics activity. In addition, Laboratories in the theme of Light and Matter Physics are making experimental studies in the emerging fields of laser cooling and trapping of atoms and molecules, imaging through turbid media, and ultra-fast atomic processes using femtosecond (10^{-15} s) laser pulses.

1. Astronomy & Astrophysics and related signal processing, imaging, and instrumentation development

Astronomy measures phenomena in outer space, i.e., planets, stars, galaxies, clusters of galaxies and the intervening gas and dust in interstellar and intergalactic space; astrophysics develops physical models that deepen our understanding of the universe. An important aspect of modern astronomy and astrophysics is the study of the evolution of the universe and its constituents: the formation of stars and galaxies out of the primordial gas. These studies are accomplished by examining the radiation received on Earth from or through them, developing theoretical models for the observed phenomena, and simulating the physical processes in powerful computers.

The diverse objects in the Universe emit radiation across the electromagnetic spectrum: from low frequency radio waves to extremely energetic gamma ray photons. Studies of phenomena in space, or objects in the Universe, require a holistic approach if a deep understanding is to be attained. Telescopes have been built to cover all bands of the electromagnetic spectrum and in those wavelength bands in which our atmosphere is opaque, telescopes have been launched into space in our quest for a deeper understanding of our universe and its origins.

The Raman Institute has participated in several telescope projects. It has built a Decametre wave Radio Telescope at Gauribidanur – about 80 km from Bangalore – jointly with the Indian Institute of Astrophysics. Members of the Institute use the Ooty Radio Telescope (ORT), which is operated by the Tata Institute of Fundamental Research (TIFR), Mumbai, and have also contributed by modernising its capabilities with state-of-the-art reconfigurable digital receivers that enhance its capabilities and versatility with a view to continuing to use it for new research programmes. The Radio Astronomy Lab of the Institute has in the past built receivers in the 20-cm wavelength band for the Giant Metre wave Radio Telescope (GMRT), operated by TIFR, and also built specialized pulsar receivers for GMRT. Today, members of the Institute are giving new capabilities to the GMRT: equipping the telescope with very low frequency receivers in the 30-90 MHz band. Another project that was executed previously is the low-frequency (150 MHz) Mauritius Radio Telescope (MRT) built at Mauritius in collaboration with the University of Mauritius and the Indian Institute of Astrophysics; research in the form of PhD theses presenting surveys of the southern sky using data taken with that telescope continue to appear. The Raman Institute has also built a millimetre wave telescope of diameter 10.4 metres on campus and is currently engaged in refurbishing and modernising the telescope and installing receivers for spectral-line surveys of star-forming regions in the 40-50 GHz band.

The Raman Research Institute is now a full partner in an international collaboration to build a large low radio frequency telescope array in a remote Western Australian radio-quiet location. The participation includes contributing to engineering in the form of digital systems and software – which challenge and stretch our in-house capabilities in appropriate directions – and involvement in specific science goals by sharing in the development of innovative observing techniques, analysis methods, detection algorithms and parameter extraction tools. The Institute continues its development of low-cost 12-15 metre class parabolic dish antennas, based on the pre-formed parabolic dish concept, as a strategic initiative; also in this category are the innovative filters, amplifiers described in this report.

The year saw developments at the Institute laying the foundations for venturing into space based astronomy – a laboratory for the development of X-ray polarimeters is being established; a conceptual proposal was prepared and the first steps taken towards developing relevant technologies for a space based low radio frequency array. Additionally, the Raman Institute contributes to the Indian ASTROSAT mission, which is a high-energy astrophysics space observatory due to be launched by ISRO in 2009. Other activities include the development and construction of an interferometer array for satellite astrometry and a demonstration

of capability to estimate differential Doppler motions of satellites with extreme precision.

Members of the Astronomy & Astrophysics group are currently engaged in research into the understanding of events in the evolving universe and a variety of phenomena associated with cosmic bodies: the evolution in the gas during the epoch of reionization, the nature and composition of the gaseous medium in galaxies at high redshifts, in clusters of galaxies at high redshift, in galaxy groups, in galaxies – normal, active and low-surface-brightness galaxies – in the present era. Phenomenological studies target the enigmatic and amazingly energetic gamma ray bursts, giant pulses from pulsars, recurrent active galaxies, X-ray binaries, hydroxyl and methanol maser sites and sources, and photon-dominated regions of the interstellar medium. Theoretical advances include understanding specialized issues like strong MHD turbulence, the survival of dust in supernovae, the role of Pancharatnam phase in certain optics arrangements, and unsolved problems associated with neutron stars, magnetars, and strange stars.

The telescopes and receivers developed and built in the Radio Astronomy Laboratory provide vital observational clues for this research; however, it may be noted that the windows covered by the Institute's facilities cover only a part of the electromagnetic spectrum. Additionally, a holistic investigation of space phenomena often requires observing capabilities not available in India; therefore, the astronomers of the Institute propose and successfully win the use of valuable observing time on facilities throughout the world.

2. Light and Matter Physics

Quantum optics, requiring advanced technologies related to the laser cooling and trapping of atoms in magneto-optic traps, is a very fast advancing field of research and development in the world today, particularly because of its potential applications in industry. The LAMP group has adopted a basic science research approach, as opposed to a competitive technology development approach, in keeping with the overall philosophy of the Institute.

The last several years of committed effort has brought the experimental capability to the stage where confidence has been established in the setting up of laser systems, vacuum chambers, and laser cooling and trapping of atoms in magneto-optic traps, and efforts are on to produce ultra-cold atom clouds in configurations appropriate for addressing interesting questions in quantum optics. Additionally, members of the group are well on the road to setting up a double-Magneto-optic trap and producing Bose-Einstein condensates (BECs) for researches into this

novel state of matter.

In parallel with the development of the BEC capability, the members of the LAMP group are on the road to pursuing experimental laboratory research into selected problems related to quantum interactions and in ultra-cold molecules; for this, experimental capabilities is currently under development and along this long road several smaller scale experiments have been attempted as different sub-systems were developed and opportunities for interesting investigations presented themselves.

Experimental studies of the interaction of ultra-short light pulses – barely 10^{-15} seconds wide – with nano-particles are another activity within the group. During the year, this research included non-linear interactions of intense laser light with thin-film structures and nanocomposite films. First results from the interaction of intense light with liquid micro jets, and resulting plasmas, have been obtained.

Studies of light-matter interactions at the Raman Institute are diverse. An example is the study of the propagation of light in a new kind of random medium consisting of active amplifying fibre segments embedded in a passive scattering medium: the statistics of intensity fluctuations was studied experimentally and via simulations yielding new insights and demonstrating fascinating behaviours. The conception and development of novel optical diodes, investigation of slow light propagation in a photosynthetic pigment used by certain bacteria, and research involving electromagnetically induced transparency are further examples of the breadth of the research work in this activity area.

3. Soft Condensed Matter

The Raman Research Institute has made outstanding contributions to the development of the field of liquid crystals for over three decades. Liquid crystals are a thermodynamic stable phase of matter that has anisotropy of properties without the 3-dimensional order of crystal lattices. Nematic liquid crystal molecules are rod-like and tend to point in the same direction but without positional order; smectic liquid crystal molecules align themselves in layers that can flow past each other; in discotic liquid crystals disc-like molecules are stacked in parallel columns. There are many more complex forms of molecular ordering known with interesting and subtle properties; research in this field at the Raman Institute is unique in that it enjoys the interactions between chemists, electrochemists, condensed matter physicists, theoretical physicists and members with statistical physics expertise.
Liquid crystalline substances have interesting optical properties, and external

perturbations can cause significant changes in their macroscopic properties; the theoretical and experimental research at the Raman Institute is towards understanding these unique effects and synthesizing new liquid crystalline materials.

Research continued during the year with the synthesis of exceedingly complex bent-core shaped molecules: intelligent design of the terminal groups yielded soft matter with remarkable liquid crystalline properties, which were often novel. Synthesis of series of compounds with gradations in molecular structure, and studies of their liquid crystalline properties, is an iterative and ongoing activity that is contributing to an elucidation of the physical relationships between structure and function. A variety of molecules exhibiting liquid crystalline properties have also been chained with specific bridges to form dimers – sometimes the synthesis has been assisted by microwaves – and studies have been made of their properties and behaviour. During the year, research in the soft matter group has touched upon a variety of phenomena and materials – tent-like structures in polymer crystals, silk fibroins from silkworms, enzymes, carbon nanotubes functionalized with discotic moiety and carbon nanotubes functionalized with enzymes, to name a few.

The ordering of molecules, when bent-core molecules and rod-like molecules are combined to form a mixture, or when ionic surfactants are constructed with different head groups, have been subjects of study; in particular, the interesting changes in the ordering and behaviour with control parameters. Effects of dispersing gold nanoparticles into liquid crystalline structures have also been studied. Another curious topic of study is into ordering of liquid crystalline molecules into chevron structures and the stability and phase changes in the ordering.

The organization and behaviour of monolayers of liquid crystalline molecules and cholesterol in surfaces at liquid-air and solid-air interfaces is another theme of current research. The behaviour of lipid-sterol membranes and cell membranes, as well as DNA-surfactant complexes provides a link between the soft matter group and biological physics, which is an emerging activity at the Institute.

We are witness to a proliferation of liquid crystal display devices at home and beyond and industrial research has invested enormous resources into research in this field. Nevertheless, a niche area of research at the Raman Institute, which is a significant contribution to this highly competitive field, is in the development of techniques for driving the matrix displays: using sophisticated signal processing algorithms and methods to reduce power consumption in the display drivers.

Soft matter research has in some cases used specialized investigative techniques, for example, oscillatory rheology studies and magnetic susceptibility studies, for appropriate problems. All of the investigations into the fascinating behaviours, quantitative measurements of the properties and the response to various control parameters, and the experimental elucidation of the molecular ordering in different circumstances, require sophisticated and modern equipment. The group has, in its laboratories, instruments like an atomic force microscope, scanning tunnelling microscope, polarization and confocal microscopes, and apparatus for X-ray diffraction. Upgrades to existing equipment and measuring devices, as well as the acquisition of new facilities that open new windows to the studies, are an ongoing activity so as to maintain the relevance and to enable new dimensions and directions in the research.

4. Theoretical Physics

Theoretical physics research in the Institute is primarily in the areas of condensed matter physics, statistical physics and gravitation, which includes classical and quantum gravity and gravitational radiation. The activity in the theoretical physics group has recently diversified into physics in biology, in an active effort to research in inter-disciplinary areas and to build bridges with the newly founded National Centre for Biological Sciences (NCBS) at Bangalore.

Recent theoretical work considered a variety of issues, including questions related to the equipartition of currents below superconducting transitions, the quantum Zeno effect and problems associated with quantum information and quantum computing. In non-equilibrium statistical mechanics, research continues in the formalisms associated with transport properties, conduction, and equilibration.

In general relativity, research has been on precise calculations of the gravitational wave-forms expected from in-spiralling binaries. This problem is of contemporary significance because of the coming on-line of gravitational wave detectors, which need an accurate 'template' with which the data may be cross correlated in order to detect cosmic signals. During the year, research has moved into examining signal detection with future space based gravity-wave detectors, pointing out the need for improved accuracy in the derivation of templates, and showing the improvements possible in detection limits via the utilization of more complete treatments of the waveforms.

An interesting analogy made between ideas proposed in quantum gravity for understanding the cosmological constant – which might very well be a good description of the dark energy in the Universe – and phenomena associated with

surface tension in membranes in fluids is an example of connections that emerge from the interactions at the Institute between different fields of research.

Work in quantum gravity includes the approach initiated by Ashtekar which is based on the prejudices common among general relativists that the failure of perturbative approaches means that theory must be background independent and defined non-perturbatively. Any such definition must confront the conceptual and technical problems of defining quantum field theory in the absence of fixed space time geometry. Investigations into these problems have been carried out either in the extremely promising 'head on' approach of Loop Quantum Gravity (LQG) or in the context of simpler yet highly instructive model systems. Apart from the canonical approach to quantum gravity, there is an interest in the covariant path integral approach within which the question of dynamical topology can be addressed, and recent work of the Institute explores issues within the causet approach.

Biological physics research is attracting increasing interest among theoretical physicists as well as scientists from soft condensed matter areas of the Institute. Here again is an example of the value of having a relatively small institute with a wide range of professional research interests and scientists who are open minded and willing to move into new areas and apply their experience to related fields. Recent work includes investigations on vesicle formation and transport, mitochondrial distribution dynamics, and the physics in experiments of DNA stretching and twisting. There is also related experimental activity both on campus and in the neighbouring NCBS.

Technical summaries of the work carried in the past year at the Raman Institute are given in the pages that follow.

ASTRONOMY AND ASTROPHYSICS (A & A)

Areas of research:

Cosmology and Structure Formation
Extragalactic Astronomy
Neutron Stars and Pulsars
The Galaxy and the Interstellar Medium
Surveys
Topological Phase
Instrumentation and signal processing

COSMOLOGY AND STRUCTURE FORMATION

HI signal from the epoch of reionization: A pilot observation with the GMRT: A programme for spectral-line imaging of redshifted HI 21-cm line from the reionization epoch was initiated: the observations used the 150-MHz band of the Giant Meterwave Radio Telescope (GMRT). The observing frequency corresponds to a redshift of about 8.5. Data were collected toward a cold sky region (RA: 09:30:43.5 & DEC: +28:21:09.2; J2000 epoch). Analysis of this data set shows that the noise in the spectral-line image cube is severely limited by radio frequency interference. The RMS noise obtained in the spectral cube and continuum image, after significant data editing for obvious interference, is about 40 mJy on smoothing to an angular resolution of about 2′. This is significantly higher than the expected thermal noise and the expectations for the cosmological signals suggesting that sophisticated interference mitigation and excision would be needed. [D. Anish Roshi, Shiv K. Sethi, R. Subrahmanyan + U.-L. Pen, (CITA, Canada), J. Peterson, (Carnegie Mellon University), T.-C. Chang, (UC Berkeley), C. Hirata, (Princeton University), J. Roy & Y. Gupta (NCRA, Pune)]

EXTRAGALACTIC ASTRONOMY

Gamma Ray Bursts (GRB): Radio observations of the afterglow of GRB030329 were continued through this entire year at two frequencies (1280 and 610 MHz) using the GMRT. The coverage now extends to four years. Modelling of the afterglow emission in the non-relativistic phase has been done and the data is being examined for signatures of emission from any counter jet component. [D. Bhattacharya, Atish P. Kamble, L. Resmi + C.H. Ishwara Chandra, (NCRA, Pune)]

Optical observations and modelling of the peculiar GRB afterglow 060124 were performed, and the signature of an 'injection break' in the electron energy spectrum was found. [D. Bhattacharya + K. Misra, R. Sagar, (ARIES, Nainital),

G.C. Anupama ((IIA, Bangalore), D.K. Sahu (CREST, Hosakote, Bangalore) A.J. Castro-Tirado (IAA-CSIC, Granada, Spain), S. S. Guziy (IAA-CSIC, Granada, Spain & Nikolaev State University, Nikolskaya, Ukraine), B.C. Bhatt (CREST, Hosakote, Bangalore)].

Along with the optical observations of the afterglow of GRB 050319 a model for the multiband afterglow of GRB 050319 was presented. The break seen in the optical light curve at ~0.02 days could be understood as arising due to the transition in the circum-stellar medium between the stellar wind and the constant density medium beyond. This is perhaps the first ever detection of the transition and might be a confirmation of the scenario of massive star collapse for GRB progenitors, independent of and apart from supernova signatures. [A.Kamble, L.Resmi + K. Misra (ARIES)].

Molecular gas in restarting radio galaxies: CO line observations of a sample of nine restarting radio galaxies were carried out using the IRAM 30-m telescope. A low CO detection rate for these relatively young objects is derived. The observations suggest instabilities in the fuelling process rather than fuel depletion followed by fuel acquisition as playing a role in the cessation of the nuclear activity and its subsequent restarting. Abundant molecular gas content at the level of 10^8-10^9 $M_\odot$ does not necessarily accompany the nuclear restarting phenomenon. [Lakshmi Saripalli + Karl-Heinz Mack (INAF-Istituto di Radioastronomia, Bologna, Italy)]

Episodic ejection from super-massive black holes: A complete sample of giant radio galaxies was examined for morphological evidence of restarted activity. It is found that lower-power radio galaxies more frequently show signs of restarted activity compared to powerful radio galaxies, suggesting that they are more susceptible to episodic central-engine activity compared to powerful radio galaxies. The results imply that low and high power radio galaxies may have very different accretion rates while in their active phase. Low power radio sources may have greater episodic accretion on to their supermassive black holes with timescales of a few million years. [Lakshmi Saripalli, Ravi Subrahmanyan + Richard W. Hunstead (University of Sydney, Australia)]

Low Surface Brightness (LSB) Galaxies: Several giant LSB galaxies were observed with the GMRT. Preliminary analysis reveals that radio cores and jets are present in these galaxies even though they are very poor in star formation. The neutral hydrogen distribution in the LSB galaxy 1300+0144 was imaged and revealed a lopsided disk. Molecular gas distribution has been imaged with HERA on IRAM for 3 LSB galaxies. Water maser emission in the nuclei of 15 galaxies

was searched with the Green Bank telescope; none have been detected so far. Chandra observations to detect AGNs in LSB galaxies are underway and followup optical studies with the Hanle HCT are continuing. [Mousumi Das + F.Boone & F.Viallefond (IAP, France), K.O'Neil, & J.Braatz (NRAO, USA), C.Henkel, & K.Menten (MPIFR, Germany), C.Reynolds, S.N.Vogel, S.S.McGaugh (UMD, USA) & T.P.Prabhu (IIA, Bangalore)]

Barred Galaxies: It has been found that the bar strength has a significant correlation with the nuclear stellar velocity dispersion in barred galaxies. This indicates that galaxies with weaker bars have centres that are dynamically hotter and hence have a larger central mass concentration. Central mass concentrations in bars may eventually cause bar dissolution and so this result is an important step in understanding the secular evolution of barred galaxies. [Mousumi Das + E.Laurikainen & H.Salo (Oulu, Finland), R.Buta (UA, USA)]

Survival of dust particles in primeval SN remnants: A theoretical estimate was made of the survival of dust particles of different composition, which are produced in Type II supernovae, as the stellar ejecta goes through the reverse shock. Since dust particles are crucial as cooling agents for the generation of stars after the very first generation stars collapse, it is important to determine the fraction of dust grains that actually survive. The detailed analytical calculations show that reverse shock does not in general destroy a substantial fraction of dust grains except in some special circumstances. [Biman Nath + T. Laskar (St. Stephen's College, Delhi) & J. M. Shull (U. Colorado)]

AGN Activity in X-Ray underluminous Galaxy Groups: Four X-ray underluminous groups of galaxies (NGC 524, 720, 3607, and 4697) were observed using the Giant Metrewave Radio Telescope (GMRT). The GMRT observations carried out at low frequencies (235 and 610 MHz) were aimed at detecting low surface brightness, steep-spectrum sources indicative of past AGN activity in these groups. No detectable radio emission was observed in any of these four groups and an upper limit of 3×10^{57} erg was set on the total energy in relativistic particles. This value is more than two orders of magnitude below that required in the AGN-heating scenario to account for the decreased X-ray luminosities of these four groups. We conclude that the intra-cluster medium might have been pre-heated before the assembly of galaxy clusters. [K. S. Dwarakanath & Biman Nath]

Gas in cluster galaxies at high redshifts: A pilot study with the new powerful backend of the Westerbork Synthesis Radio Telescope (WSRT) of the galaxy clusters A 963 and A 2192 at $z \sim 0.2$ has revealed neutral hydrogen emission from 39 member galaxies. In Abell 963, most of the gas-rich galaxies are located to the

northeast, at 13 Mpc from the cluster centre in projection. These could constitute a gas-rich galaxy group falling into the cluster from the front. Abell 2192 is relatively less massive and more diffuse, and in this case the gas-rich galaxies are more uniformly distributed over a large region of the cluster. The HI masses of the detected galaxies range from 5×10^9 to 4×10^{10} $M_\odot$. In A 963 we find evidence that the blue BO galaxies are gas poor compared to their counterparts in the field. (K. S. Dwarakanath + M. Verheijen (Kapteyn), J. H. van Gorkom & D. Schiminovich (Columbia), A. Szomoru (JIVE) , B. Poggianti (Padova)]

The inter-stellar medium of galaxies in X-ray bright groups: 21-cm line observations of 13 galaxies from four X-ray bright groups NGC5044, NGC720, NGC1550 and IC1459 were carried out with the aim of studying the morphology of the neutral hydrogen in these galaxies and to examine whether the hot IGM has in any way affected their HI content or distribution. In addition to a disturbed HI morphology, most of these galaxies have shrunken HI disks compared to spiral galaxies located in the field and away from groups and clusters. The current observations indicate that IGM assisted ram pressure may have stripped gas from the outer edges of these galaxies. [C. Sengupta, B. Ramesh & K. S. Dwarakanath].

Spatial and Kinematical Lopsidedness of Atomic Hydrogen in the Ursa Major Group of Galaxies: A harmonic analysis was carried out of the atomic hydrogen (HI) surface-density distribution and velocity fields for 11 galaxies belonging to the Ursa Major group. This analysis gives the radial variation of spatial lopsidedness, quantified by the Fourier amplitude A_1 of the m=1 component normalised to the average value. The kinematical analysis gives a value for the elongation of the potential to be about 10%. The mean amplitude of spatial lopsidedness is found to be about 0.14 in the inner disc, similar to the field galaxies, and is smaller by a factor of about 2 compared to the Eridanus group galaxies. The physical origin of lopsidedness in the Ursa Major group of galaxies is expected to be tidal interactions. [R. A. Angiras, K. S. Dwarakanath + C. J. Jog (IISc), M. Verheijen (Kapteyn)].

Neutral hydrogen in the Highest Redshift (z ~5.2) Radio-loud Objects: Observations were made using the Giant Metrewave Radio Telescope aimed at detecting HI 21-cm line absorption toward the two brightest radio AGNs at high redshift: J0924–2201 (z=5.20) and J0913+5919 (z=5.11). In the case of J0924–2201 the upper limit on the column density, per 20 km s^{-1} channel, was derived to be $N(HI) < 2.2 \times 10^{18}$ T_s cm^{-2} over a velocity range of –700 to +1180 km s^{-1} centred on the galaxy redshift, which was determined through CO emission assuming a covering factor of 1. In the case of J0913+5919 the column density limit, per 40 km s^{-1} channel, is $N(HI) < 2.2 \times 10^{19}$ T_s cm^{-2} within ± 2400 km s^{-1} of

the optical redshift. These data rule out the presence of any cool, high column density HI clouds along the line of sight and within roughly ± 1000 km s^{-1} of the galaxies - as are often seen in compact steep-spectrum radio AGNs - or clouds that might correspond to residual gas left over from cosmic reionization [(K. S. Dwarakanath + C. L. Carilli (NRAO), R. Wang (Peking), M. B. van Hoven (Leiden), J. N. Chengalur (NCRA), S. Wyithe (Melbourne)]

NEUTRON STARS AND PULSARS

Spectra of giant pulses from the Crab pulsar at low radio frequencies: Simultaneous multifrequency observations of giant radio pulses from the Crab pulsar were conducted at 23, 111, and 600 MHz, and giant pulses were detected at a frequency as low as 23 MHz for the first time. The power-law spectral indices for the giant-pulse energies are seen to range from −3.1 to −1.6, with a mean of −2.7+/−0.1. The measurements suggest that the spectra of the individual giant pulses do not actually follow a simple power law. The observed shapes of the giant pulses at all three frequencies are determined by broadening due to interstellar scattering, estimated as $20\times(f/100)^{(-3.5+/-0.1)}$ ms, where frequency f is in MHz. The lower frequency observations were made using the telescopes at Pushchino and Kharkov, through RRI's portable pulsar receivers. [A. A. Deshpande + M.V. Popov, V. I. Kondrat'ev, S. V. Kostyuk and V. A. Soglasnov (Lebedev Institute, Russia), A. D. Kuz'min, A. A. Ershov, B. Ya. Losovskia (Pushchino Observatory, Puchino, Russia) O. M. Ul'yanov, V. V. Zakharenko (IRA, Ukraine)]

A mini-survey for radio recombination lines using the Gauribidanur Radio Telescope: A search was made for radio recombination lines of carbon at 34.5 MHz towards several Galactic regions using the portable voltage-signal recording system at the Gauribidanur Radio Telescope. Suitable analysis software was developed. The preliminary analysis has already enabled detections of several Cα lines in the directions of Cas A, Galactic Centre, G10+0, and G14+0. β and γ lines were also detected towards Cas A. [A. A. Deshpande, N. Udaya Shankar & H. A. Aswathappa + N. G. Kantharia, (NCRA, Pune), S. V. Stepkin & A. A. Konovalenko (IRA, Ukraine)]

On the Uniqueness of the Equation of state of Neutron stars: It is one of the firm beliefs in the understanding of neutron star (NS) physics that these objects form a single sequence. This translates, at the microscopic level, into the existence of a unique equation of state (EOS). However NSs are born/evolve under conditions where macroscopic/external factors like rotation, magnetic field and accretion may play an important role. These may lead to NSs which do not lie on the main sequence. [N. Prasad]

Formation Scenario of Magnetars: The Puzzle of Isolation: Magnetars (SGRs and AXPs) are one of the extreme evolved states of a neutron star. These objects are believed to have an ultra-strong magnetic field ($B > 10^{15}$ G) at their surface and display persistent X-ray pulsations and transient bursts. To date there are 14 magnetars known: 5 SGRs (4 confirmed, 1 candidate), and 9 AXPs (7 confirmed, 2 candidates). The question as to why all these objects are isolated and none have been found in binaries is as yet unanswered. Formation scenarios which may lead to such circumstances and other consequences of these models are being investigated. [N. Prasad]

Type I X-ray Bursts on Strange stars: Type I X-ray bursts are regular occurrences in some of accreting low mass X-ray binaries (LMXB). The reason for such bursts is the runaway nuclear fusion reaction of the accreted matter on the surface. Strange stars (SS) differ from normal NS in their composition and so will these bursts if they occur. An attempt is being made to find a signature that might distinguish a SS from a NS. [N. Prasad]

Quasi-periodic Oscillations in XTE J0111.2–7317: Quasi-periodic oscillation features were discovered at a frequency of 1.27 Hz in the high-mass X-ray binary pulsar XTE J0111.2–7317 during a transient outburst of the source in 1998 December. This is the highest frequency QPO ever detected in an HMXB pulsar. In the absence of a cyclotron absorption feature in the X-ray spectrum, the QPO frequency, the pulse period and X-ray flux measurement were used to constrain the magnetic field strength of the neutron star. [(B. Paul, H. Raichur + R. Kaur & Ram Sagar (ARIES, Nainital)]

Orbital evolution and orbital phase resolved spectroscopy of the HMXB Pulsar 4U 1538–52: The orbital evolution and orbital phase resolved spectroscopy were studied for the HMXB Pulsar 4U 1538–52 with RXTE-PCA and BeppoSAX. It was established that the earlier report of an orbital decay in this system is incorrect. The variation of the column density of absorbing material in the line of sight with orbital phase was found to be in reasonable agreement with a simple model of a spherically symmetric stellar wind from the companion star. [H. Raichur, B. Paul + U. Mukherjee (TIFR), S. Naik (ISAS, Japan), N. Bhatt (BARC)]

Broadband X-Ray Spectrum of the HMXB pulsar KS 1947+300 with BeppoSAX: The broadband X-ray spectrum of a transient X-ray pulsar KS

1947+300 was investigated with BeppoSAX. This is the first detailed study of its energy spectrum, which has resulted in the identification of different spectral components and thrown light on their probable origins. [B Paul + S. Naik & T. Dotani (ISAS, Japan), P. Callanan (Cork College, Ireland)]

Orbital evolution studies of several HMXB pulsars: Using archival data from RXTE, significant progress was made in the study of the orbital evolution of several X-ray binary pulsars. For the first time, eccentricities of very small values were determined for the close X-ray binary pulsars Cen X-3 and SMC X-1 and their orbital period evolution was measured with higher accuracy. Orbital period evolution and apsidal motion were discovered in a transient X-ray pulsar 4U 0115+63 in the presence of complex luminosity-dependent evolution in the intrinsic spin period. [H. Raichur & B. Paul]

THE GALAXY AND THE INTERSTELLAR MEDIUM

Intrinsic short time scale variability in W49 Hydroxyl masers: New observations of OH masers in W3(OH) and W49 were made using the Very Long Baseline Array (VLBA). Preliminary analysis of the OH maser sources in W49 reveal that the sizes of the sources are almost a factor of 2-3 smaller than that reported by previous studies. Fluctuation spectral analysis on a few strong maser sources suggests variability on time scales of about 30 minutes or slower, implying a longitudinal spatial dimension of a few AU for the maser sources, consistent with the findings in W3(OH). [A. A. Deshpande + R. Ramachandran (UC, Berkeley), W. M. Goss (NRAO, USA)]

Imbalanced Strong MHD Turbulence: A phenomenological model of imbalanced MHD turbulence in an incompressible magnetofluid was presented. The steady-state cascades, of waves travelling in opposite directions along the mean magnetic field, carry unequal energy fluxes to small length scales, where they decay due to viscous and resistive dissipation. The inertial-range scalings are well-understood when both cascades are weak. The case was studied when both cascades are, in a sense, strong. The inertial-range of this imbalanced cascade has the following properties: (i) the ratio of the r.m.s. Elsasser amplitudes is independent of scale, and is equal to the ratio of the corresponding energy fluxes; (ii) in common with the balanced strong cascade, the energy spectra of both Elsasser waves are of the anisotropic Kolmogorov form, with their parallel correlation lengths equal to each other on all scales, and proportional to the two-thirds power of the transverse correlation length; (iii) the equality of cascade time and wave period (critical balance) that characterizes the strong balanced cascade does not apply to the Elsasser field with the larger amplitude. Instead, the more

general criterion that always applies to both Elsasser fields is that the cascade time is equal to the correlation time of the straining imposed by oppositely-directed waves. [S. Sridhar + Y. Lithwick, (CITA, Canada), P. Goldreich (IAS, Princeton)]

A Search for 6.7 GHz Methanol Masers in M33: A sensitive search for 6.7 GHz methanol masers in the nearby spiral galaxy M33 was carried out using the Arecibo telescope. In none of the 14 Giant Molecular Cloud (GMC) directions, observed in the central 4 kpc of the Galaxy, were methanol masers found above a 3-sigma limit of about 9 mJy (at a velocity resolution of 0.069 km/s). After velocity shifting and combining the spectra from the positions observed, the effective 3-σ upper limit on the average emission is about 1 mJy in a 0.25 km/s wide channel. These limits lie significantly below expectations based on the estimates of the methanol maser luminosity function in the Milky Way. The most likely reason for the absence of detectable methanol masers appears to be the metallicity of M33, which is modestly less than that of the Milky Way. [A. A. Deshpande + P. D. Pandian (Cornell University/MPIFR), P. F. Goldsmith, Jet Propulsion Laboratory)]

CI 492 GHz imaging towards Cas A: The [CI] $^3P_1$-$^3P_0$ emission at 492 GHz towards the supernova remnant Cas A was imaged. The [CI] emission was detected from the periphery of the diffuse photon-dominated region (PDR) covering the disc of Cas A and from the denser PDRs associated with the molecular clouds towards the South-East. [CI] emission from both the Perseus and the Orion arm molecular clouds were detected. The C/CO relative abundance is estimated to be 0.2 at the position of the identified CO clouds and exceeds unity over most of the cloud. The distribution of [CI] emitting regions compared to the C+ region and molecular cloud is consistent with a scenario involving PDRs. The estimated densities of the [CI] emitting regions are between 10^2 and 10^3 cm^{-3}. The rather high volume filling factors (~50%) suggests that the [CI] emission mainly arises from the diffuse neutral gas in the Perseus arm. [D. Anish Roshi + B. Mookerjea, (UMD, USA), N. G. Kantharia, (NCRA, (Pune), M. Masur, (University of Cologne, Germany)]

SURVEYS

The Arecibo Methanol Maser Galactic Plane Survey: An unbiased survey for 6.7 GHz methanol masers in the Galactic plane was carried out using the 305-m Arecibo radio telescope. A total of 18.2 square degrees over Galactic coordinates $35°.2 \leq l \leq 53°.7$ and $|b| \leq 0°.41$ was completed with uniform sampling. This survey, complete at the level of 0.27 Jy, is the most sensitive blind survey to date. A total of 86 sources were detected, 48 of which were new detections. Most of the new detections have a peak flux density below 2 Jy. Many methanol masers are

clustered, reflecting the formation of massive stars in clusters. [A. A. Deshpande + P. D. Pandian (Cornell University), P. F. Goldsmith (JPL)]

TOPOLOGICAL PHASE

Pancharatnam phase: The role of the Pancharatnam phase in the operation of some recently proposed interferometer devices, which were based on a geometric phase caused by out of plane propagation of light, was clarified. It was shown that in the case where light with an arbitrary polarization state is incident on the device, the phase between the interfering beams has the same counter-intuitive behaviour, originating in phase singularities, as was earlier observed in interference experiments with polarized light. [R.Bhandari]

Beam Splitters: An arbitrary stack of parallel films each of which could be transparent, absorbing, birefringent and/or dichroic can be loosely defined as an arbitrary beamsplitter and its reflection and transmission properties can be completely specified by 32 real parameters. An investigation into the constraints on these 32 parameters resulting from fundamental symmetries like isotropy of the media, symmetry of the stack, unitarity and time-reversal invariance was initiated during the year and yielded promising insights; these are being followed up. [R.Bhandari]

INSTRUMENTATION AND SIGNAL PROCESSING

Single Pulse Search Technique - Scope at Low Frequencies: A recently demonstrated single-pulse search technique was implemented and modified suitably for application in pulsar and transient search at low radio frequencies, to include matched-filtering appropriate for scatter-broadened pulse shapes, and RFI detection/excision. The technique was tested successfully on pulsar data collected from the Gauribidanur telescope. Spurious detections occur particularly if the RFI is a swept-frequency signal. A procedure is being developed for discriminating between real and spurious signals. [A.A.Deshpande + Yogesh Maan (JAP-IISc/RRI)]

Blind deconvolution for profiles with high signal-to-noise ratio: Explorations continued into the possible application of direct deconvolution to resolve complex one-dimensional profiles, e.g., in the case of pulse and spectral-line profiles. [A.A. Deshpande]

Multi-bandstop filter to combat RFI: An analogue solution to combat RFI was explored, by designing a multi-passband filter that would simultaneously admit multiple observing bands that are all free of RFI. The necessary filtering is

accomplished by concatenating directional couplers and band-pass filters together. The band-pass filters are designed to cover the RFI bands – and may be available commercially for the transmission/reception of the signals that constitute RFI; when used with directional couplers/circulators appropriately, they act effectively as band-stop filters for the respective RFI bands. This approach has significant advantages over a conventional filter-bank solution. [A.A. Deshpande + Sonal Asgotraa (SBSCET, Ferozepur)

Holography of the 10.4 m RRI radio Telescope: A setup for holography of the 10.4 m Radio telescope at RRI is being developed, using a small reference antenna, to make measurements of the voltage beam pattern of the dish in interferometer mode. Preliminary measurements have been carried out using a satellite signal as a probe; calibration/analysis procedures are being developed. [A.A. Deshpande, Wasim Raja, Ramesh Balasubramanyam, Gopalkrishna]

X-ray Polarimeter: A proposal was prepared for an astronomical X-ray polarimeter experiment onboard a small satellite of ISRO; this was considered favourably by an expert review committee setup by ISRO. A Thomson scattering X-ray polarimeter was designed and an X-ray laboratory was set up for astronomical instrumentation including a clean room, a radiation shielded X-ray room, X-ray beam line and vacuum chamber, a gas manifold for gas detectors etc. [B. Paul, P.V. Rishin, R. Verma, G. Arun, D. Kunneriath, H. Raichur and R. Durai Chelvan]

ASTROSAT LAXPC: Development work was carried out for a timing calibration system for the LAXPC detectors of ASTROSAT. Software development was done for reduction of LAXPC raw data and simulation of its energy response. [B. Paul, P. V. Rishin, R. Verma, G. Arun, D. Kunneriath, H. Raichur and R. Durai Chelvan]

Non-linearity in the GMRT 150 MHz receiver system and Radio Frequency Interference: An analysis of the effect of receiver non-linearity - in the presence of radio frequency interference (RFI) - on spectroscopic observations with the 150 MHz system of the GMRT was made. First, power levels of narrow band RFI at the input of the receiver system were measured. From these measurements, 10 RFI components with power levels > −85 dBm were selected for the analysis. These interfering signals were passed through the receiver system and the power of inter-modulation products was estimated. The estimated values were compared with the power level due to thermal fluctuations. Observations with a spectral resolution of 1 kHz and integration time of 8 hrs were used for the estimation of thermal fluctuations. Analysis showed that many inter-modulation products would have a

power level above the thermal noise power and, therefore, will have a deleterious affect on spectral-line observations with the 150 MHz system. [D. Anish Roshi]

12 m Preloaded Parabolic Dish: The installation of the 12 m dish was completed. First light was seen using both L-band and C-band receivers. Fine tuning of mechanical and receiver systems and observations to evaluate the system performance in terms of aperture efficiency, sensitivity and stability are in progress. [N. Udaya Shankar, C.M. Ateequlla, A. Raghunathan, Durai Chelvan, B.S. Girish, A. Krishnan, P.V. Rishin, S. Krishna Murthy, K.B. Raghavendra Rao]

A new Digital backend for the Ooty radio telescope: An FPGA-based digital backend was built for the Ooty Radio Telescope. The instrument can be reconfigured to support observations for the continuum and spectral line modes. In this instrument, the signals from each of the 22 modules of ORT are digitized immediately after the IF stage and the raw voltages are either recorded directly or may be used to form a set of beams on the sky. The system is currently configured to process 2-bit quantized signals for a band 10-MHz wide in the beam-forming mode and a band 1-MHz wide in the direct-recording mode. [C.R. Subrahmanya, T. Prabu, P.A. Kamini].

50 MHz system for GMRT: With the intention of enhancing the low frequency observing capabilities of GMRT, four antennas of GMRT were equipped with feeds and receiver systems in the frequency band 30 to 90 MHz. System tests were carried out. Initial results are encouraging. Detailed testing is in progress. [N. Udaya Shankar, K.S. Dwarakanath, Shahram Amiri, R. Somashekar]

Design and development of a hybrid FX correlator for four antennas: An FX correlator system was configured using Virtex-4 FPGA chip (to Fourier Transform), two PCs (for multiplying) and a homemade data acquisition card (for data transfer). During the course of development of software for cross-correlation, basic Message Passing Interface (MPI) routines were also evaluated for management of the computational load share between the two computers and to access and accumulate the processed data. Simulations have indicated that the hardware configuration could perform satisfactorily up to 100 MHz sampling rates. However, due to the limitations in transferring the Fourier-transformed data to the PC, the system has been tested only up to a sampling rate of 32 MHz. Detailed testing is in progress. [B.S. Girish, K.S. Srivani, N. Udaya Shankar]

The sub-systems developed for the FX correlator were used to set up an RFI monitoring system at GMRT. The results of RFI monitoring were used in arriving at

a configuration for the low frequency receiver system for GMRT. [B. S. Girish, Shahram Amiri, R. Somashekar, N. Udaya Shankar, K. S. Dwarakanath]

An all-sky EOR telescope: Study of several design aspects of an all-sky EOR telescope was undertaken. The main innovation in the design is the usage of a beam splitter in front of a two-antenna system. Reflection, transmission and attenuation properties of a suitable mesh, which can be used as a beam splitter, are under study. [A. Raghunathan, Ravi Subrahmanyan]

A lightweight cryo-cooler for prime focus operation: A lightweight and efficient cryogenic cooling system for prime focus operation of a radio telescope has been configured using a twin piston Sterling cryo-cooler based on a linear motor compressor. It has been tested successfully at cryogenic temperatures on an existing 4.6 m telescope by cooling a low noise amplifier (LNA) at the prime focus. A decrease in the noise temperature of the LNA from 25K to 10K at 1400 MHz was observed. Development of a pulse-cooled cryo-cooler is in progress in collaboration with the Centre for Cryogenic Technology, IISc. [A. Raghuanthan, N. Udaya Shankar, K.B. Raghavendra Rao + S. Kasthurirengan, N.B. Anand & N.S. Dinesh (IISc.)]

Design of a low noise amplifier with ultra wide bandwidth and high dynamic range for low frequency radio astronomy: In the first phase of this development program, the design and testing of a low noise HEMT amplifier (Noise temperature of 50 K) with wide bandwidth (30 to 300 MHz) using thermal noise cancellation technique was completed. In the second phase, attempts are being made to increase the dynamic range performance using pre/post-distortion techniques. [A. Raghunathan, N. Udaya Shankar, Palwai Rajkumar & K. J. Vinoy (IISc)]

A Q-band spectral-line receiver for the 10.4m radio telescope: A Q-band receiver for the 10.4 m radio telescope to study Silicon Masers is in its final phase of development. The front-end receiver contains a cryogenically cooled Low Noise Amplifier (LNA), with a design goal of achieving a noise temperature of about 45 K. [P.G. Ananthasubramanian]

A 4096-channel spectrometer, capable of processing a bandwidth of about 40 MHz, is being developed. An 8192-point FFT engine and the logic required to obtain the power spectrum of the input band has been implemented on a Virtex 4-SX35 FPGA. [M.R. Gopalakrishna, C. Vinutha, B. S. Girish]

Partnership in the MWA project

The MIRA Wide field Array (MWA) is a joint project led by the Massachusetts Institute of Technology (MIT) with several other partner institutions in the US and Australia. The goal of the MWA project is to develop powerful new capabilities for Radio Astronomy in the frequency range 80 - 300 MHz, optimized for extremely wide fields of view and unprecedented sensitivity for a few key science goals.

RRI had submitted a proposal for scientific and technical participation in MWA as a partner institution. The astronomy topics of interest to RRI, such as radio transients, polarized emissions from the galaxy, Faraday tomography, Pulsar studies, studies of the epoch of reionization and radio recombination lines were highlighted in our proposal. The MWA consortium has accepted the proposal and currently RRI is a full partner institution in this international endeavor. Discussions have been initiated to actively participate in the design, development and installation of a few subsystems of the MWA radio telescope.

SATNAV:

A special Technology Development Project ("SatNav") has been initiated for using radio astronomy techniques to estimate the components of the instantaneous state vector of a geosynchronous navigation satellite.

A collaborative project with ISRO is being considered to set up an array of helical antennas in a location which has access to signals being uplinked as part of the GAGAN project. Prototypes are being tested for the embedded systems being designed indigenously as part of a high speed signal processing cluster to meet various real-time signal processing requirements of the array. The prototyped cards include high speed analog-to-digital converters (exceeding hundred Ms/s), digital-to-analog converter (upto 1000 Ms/s), and Blackfin DSP modules on which Linux operating system is being ported at RRI.

The use of the 1178 MHz signals, which are being broadcast for the GAGAN project to estimate the ionospheric contribution, is being investigated in the context of improving the dynamic range of a transit survey using the GMRT at low radio frequencies. [C.R. Subrahmanya, Peeyush Prasad]

LIGHT AND MATTER PHYSICS

AREAS OF RESEARCH: Light Scattering
Ultrafast and Nonlinear Optics
BEC, Laser Cooling and Trapping of Atoms
Quantum Optics
Quantum interactions

LIGHT SCATTERING

Lévy statistics arises when statistically rare events, despite their rarity, dominate a phenomenon due to their strength. In Random Amplifying Media, we believe it is the rare extremely long diffusive paths that cause the Lévy fluctuations in the intensity, as the high gain of the system renders these as events with enormous amplification. That this is the case was conclusively proved by creating a novel system – a Fibre-RAM (FRAM) – a random aggregate of segments of amplifying fibre with a tailored length distribution in which we demonstrated the Gaussian to Lévy crossover, and the tuning of the Lévy exponent by altering the parameters of the FRAM. This FRAM also happens to be an optical analogue of the Arrhenius cascade. This work has appeared in Optics Letters. [Divya Sharma, Hema Ramachandran and N. Kumar].

The crossover from Gaussian to Lévy statistics in the intensity fluctuations of emissions from dye-scatterer Random Amplifying Media (RAMs) that was observed by us in experiments last year was now studied by Monte-Carlo simulations, which enabled us to explore regions of parameter space inaccessible to experiments. A systematic increase in the variance was observed with increasing scattering strength and increasing amplification, leading to the Lévy microscope effect in the limit of extremely high gain. This work has been accepted for publication in Optics Communications. [Divya Sharma, Hema Ramachandran and N. Kumar].

The case of a Reverse-RAM – a random amplifying medium with a passive bulk and random active scatterers has been numerically investigated. Unlike the more-commonly studied Direct-RAM (or simply RAM), where scattering enhances amplification, it has been found that in the Reverse-RAM, increased scattering could lead to decreased amplification. This is due to reduced transit through the active scatterers. [Divya Sharma and N. Kumar].

ULTRAFAST AND NONLINEAR OPTICS

Nonlinear optical properties of amorphous nanolayered Se/AS_2S_3 thin film structures, [Suchand Sandeep and Reji Philip + K.V. Adarsh, K.S. Sangunni (IISc), S.Kokenyesi and V.Takats (Univ. of Debrecen, Hungary)], nanocomposite films of PbS stabilized in a synthetic glue matrix [Suchand Sandeep and Reji Philip + P.A. Kurian, C. Vijayan and K. Sathiyamoorthy (IIT Madras)], and a newly synthesized copolymer containing oxadiazole and substituted thiophenes [Suchand Sandeep and Reji Philip + A.J. Kiran, D.Udayakumar, N.V. Adhikari, H.D. Shashikala (NIT-Surathkal) and K. Chandrasekharan (NIT-Calicut)] were investigated and results published. Collaborative experiments with D.P.Mahapatra of IOP Bhubaneswar and S.Sivaramakrishnan, SSSIHL, Prasanthi Nilayam are in progress. The first manuscript written from laser-induced plasma studies in a planar microjet (250 microns thickness) of water will be communicated shortly [M. Anija, Reji Philip]. Laser-induced plasma studies in solid targets have been initiated.

A novel optical diode combining a saturable absorber and a reverse saturable absorber [Reji Philip and M.Anija + Chandra S. Yelleswarapu and DVGLN Rao (Univ. of Mass., Boston, USA)] was developed, and the results are communicated for publication. This optical diode has a number of advantages compared to those based on other materials like photonic crystals. Slow light propagation based on coherent population oscillations in bacteriorhodopsin, which is a protein molecule having the photoisomerization property, was investigated and results published [Reji Philip + Chandra S. Yelleswarapu, F.J. Aranda, B.R.Kimball and DVGLN Rao (Univ. of Mass., Boston, USA)]. A US Patent titled "Systems and methods for limiting power using photo-induced anisotropy" (No. 7196794) was granted on March 27, 2007 [Reji Philip + Pengfei Wu and DVGLN Rao (Univ. of Mass., Boston, USA)]. A conference paper [Reji Philip + A.P.Detty, J.R.Rani, K.J.Lethy and V.P.M. Pillai (Kerala Univ., Trivandrum)] was selected as one of the best five papers presented at the 6^{th} DAE-BRNS National Laser Symposium held at Raja Ramanna Centre for Advanced Technology, Indore (Dec 5-8, 2006).

The linear molecule CS_2 is known to fragment on application of intense light fields, with anisotropic distribution of fragments due to spatial alignment of the induced dipoles prior to rupture. It had been observed by my collaborators in TIFR, Mumbai that this anisotropy is absent if two colour light fields are used. This is now interpreted as an Electro-magnetically Induced Transparency (EIT) – like effect where dipoles cease to be induced due to quantum interference in the presence of two light fields. This work has been accepted for publication in

Chemical Physics Letters. [Hema Ramachandran + Deepak Mathur, Firoz Rajgara (TIFR, Mumbai)]

BEC, LASER COOLING AND TRAPPING OF ATOMS

The Bose-Einstein Condensate (BEC) setup that is being built had to be dismantled, shifted, and reassembled. This was necessitated as the existing position was found to be mechanically and thermally very noisy, which caused instability in the lasers. The process took nearly six months, as it meant re-aligning 8 lasers, optimizing their operation characteristics, realigning the Magneto-optic trap beams, reassembling the Vacuum chambers and baking them. We now have a fairly stable Upper-MOT of ^{87}Rb. The lower chamber is now at an extremely good vacuum of 4×10^{-12} Torr. [Hema Ramachandran, Nandan Satapathy + Visiting students Srihari and Dhanalakshmi, for some time Andal Narayanan, Amudha and Sanjay Kumar]

A two-dimensional MOT of ^{85}Rb was obtained using a modified coil and polarization configuration during the year. Efforts are on to get ultra-cold (below 10 μK) samples of Rubidium in 2D and 3D MOT configurations for experiments. [Lakshmi P, Preethi T.M. and Andal Narayanan]

QUANTUM OPTICS

An experiment which exhibited third-order non-linear effect and Electro-magnetically Induced Transparency was performed in a room temperature gaseous sample of Rubidium atoms. The non-linearity which we have seen is the first such signal in a laser which is not involved in the transparency effect. The results have been written up and communicated. [Andal Narayanan, Archana Sharma, Preethi T.M and Hema Ramachandran]

QUANTUM INTERACTIONS

Rapid progress has been made with the development of the vacuum system for the ultra-cold molecule project. This vacuum system will be the chamber where the laser cooling and trapping on Rubidium and Potassium atoms will be performed. The basic objective is to synthesize ultra-cold molecules from these laser cooled atoms in an efficient way. [A. Sharma, K. Ravi and S. A. Rangwala]

Long before it was possible to execute the above vacuum system for laser cooling the atoms, it was positioned such that lasers for Rubidium were ready. This inspired us to try a "High Pressure Magneto-Optic Trap (MOT)" in a spectroscopy

cell. This experiment did not behave as expected; however, the experience allowed solving several problems related to the laser systems, polarization settings, magnetic field control etc. Undoubtedly this experience will result in a quicker production of the MOT when the vacuum system is put into operation. Once the main MOT starts working, we might revisit this experiment and perhaps understand the issues better. [K. Ravi, A. Sharma and S. A. Rangwala]

Molecular spectroscopy of the Rb-Rb dimer was studied in spectroscopy cells with the idea of using spectroscopy and light collection techniques to make an accurate determination of the monomer to dimer concentrations. While the spectroscopy was successful, the experimental objectives proved difficult to realize in the first attempt. The lessons learnt from this experiment have been used to refine the experimental method. [A. Sharma, K. Ravi and S.A. Rangwala + V. Acosta, D. Budker (U.C. Berkeley, USA) + D.F. Jackson-Kimball (C.S.U. Eastbay, USA)]

Large changes in atomic absorption of resonant light on the application of strong electric fields across paraffin coated alkali vapour cells were found. Several peculiar aspects have emerged during this study. Complementary studies have been executed at CSU Eastbay and RRI to investigate these observations. A probable mechanism has been proposed for consistent interpretation of the data. The manuscript detailing these experiments is currently under preparation. [K. Ravi, A. Sharma, S. A. Rangwala + V. Prabhudesai (TIFR, Mumbai), + K. Nguyen, D.F. Jackson-Kimball (C.S.U. Eastbay, USA) + D. Budker (U.C. Berkeley, USA)]

The production of a translationally cold beam of D_2O by electrostatic manipulation was demonstrated. This was experimentally very challenging as D_2O has only quadratic Stark shifts, which are relatively small. All previous manipulations of slow/cold molecules used linear Stark states. A consequence of acting on quadratic states of D_2O is the effective state selection of the beam sourced from a thermal ensemble of molecules. This work has appeared in Phys. Rev. A. [S. A. Rangwala + T. Rieger, T. Junglen, S. A. Rangwala, G. Rempe, P. W. H. Pinkse (Max Planck Institute for Quantum Optics, Germany) + J. Bulthuis (Vrije Universiteit, The Netherlands)]

SOFT CONDENSED MATTER

AREAS OF RESEARCH: Liquid Crystals
- Synthesis
- Structure, Phase Behaviour and Physical Properties
- Displays

Amphiphilic Systems
Surface Science and Nanocomposites
Biological Physics

LIQUID CRYSTALS

SYNTHESIS

Novel mesogens with bent-core molecules: Two novel series of achiral five-ring bent-core compounds derived from 2-cyano – and 2-nitro-resorcinol containing n-alkyl carboxylate groups in the terminal positions were synthesized and their mesomorphic properties investigated. All these compounds exhibit a B7 phase, which shows ferroelectric characteristics. In addition, homologues of 2-cyano substituted compounds display a transition from a switchable to a non-switchable phase. This is the first observation of such a dimorphism of the B7 phase. [S. Umadevi and B.K. Sadashiva]

Another novel series of five-ring bent-core symmetric compounds containing terminal n-alkyl carboxylate groups were synthesized and characterized. Several of the lower homologues show B2 structures with an interesting odd-even effect concerning their tilt and polar arrangements. Three of the middle homologues display a B7' phase: this is bistable and shows linear electro-optic switching with a transition to the chiral antiferroelectric smectic phase at a lower temperature. [S. Umadevi and B.K. Sadashiva]

Mesogenic symmetric dimers of bent-core molecules: Three series of mesogenic symmetric dimers composed of bent-core molecules and linked covalently by an alkylene spacer were synthesized and their mesomorphic behaviour investigated. The structure property relationship was examined by varying the length of the terminal chains for a fixed spacer length and vice-versa. Remarkably, all the dimers investigated show the same type of mesophase. These investigations suggest that the parity of the alkylene spacer has no effect on the nature of the mesophase in these dimers. [S. Umadevi and B.K. Sadashiva]

Microwave-assisted synthesis of novel liquid crystalline materials: Microwave promoted synthesis of liquid crystalline dimers containing calamitic-calamitic, calamitic-discotic and discotic-discotic moieties has been carried out. Classical reactions failed to produce these dimers. The thermotropic liquid crystalline properties of these salts were investigated using polarizing optical microscopy, differential scanning calorimetry and X-ray diffraction. Mesogenic nonsymmetrical hexa-alkoxytriphenylenes containing a branched chain and derivatives of rufigallol have also been synthesized using this technique. [Santanu Kumar Pal, Hari Krishna Bisoyi and Sandeep Kumar]

Novel disulphide-bridged alkoxycyanobiphenyl dimers: The synthesis and characterization of novel mesogenic disulphide-bridged alkoxycyanobiphenyl dimers have been carried out. Dimers with shorter spacers are found to exhibit only the nematic phase, whereas those with longer spacers display nematic as well as smectic phases. X-ray diffraction studies reveal the intercalated structure of the smectic A phase of these dimers and the presence of smectic-like short range order in the nematic phase. [Santanu Kumar Pal, V. A. Raghunathan and Sandeep Kumar]

STRUCTURE, PHASE BEHAVIOUR AND PHYSICAL PROPERTIES

Self-propulsion of nematic droplets: Systematic experiments on the propulsion of nematic droplets suspended in the isotropic phase have been carried out. These studies show that the motion of the droplets is a consequence of the Marangoni effect, due to gradients in the interfacial tension around the droplets. The motion of the droplets has also been satisfactorily reproduced by computer simulations. [S. Thakur, P.B. Sunil Kumar, P.A. Pramod and N.V. Madhusudana]

Influence of high electric fields on the nematic–isotropic transition: The enhancement of the nematic order parameter and that of the nematic – paranematic transition point in a material with negative dielectric anisotropy have been measured as a function of an applied electric field. Several novel results have been obtained from these investigations. The enhancement of the order parameter was found to be dominated by the quenching of director fluctuations by the applied field, whereas the shift in the transition point depends linearly on the magnitude of the field. [S. Dhara and N.V. Madhusudana]

Binary mixtures of bent-core and rod-like molecules: A biaxial smectic-A phase has been observed in certain mixtures of compounds with bent-core and rod-like molecules. These mixtures also exhibit the uniaxial nematic phase at higher

temperatures. An experiment has been devised to measure the mutual orientation of the two types of molecules in this phase. At high temperatures the bow axis of the bent-core molecules is found to be parallel to the long axis of the rods. However, at lower temperatures in the vicinity of the nematic-smectic transition temperature the medium develops short-range smectic-like order and the bent-core molecules reorient in such a way that their arrow axis becomes parallel to the long axis of the rods. [B. Kundu, R. Pratibha, N.V. Madhusudana]

Pattern formation in mixtures of bent-core and rod-like molecules: Mixtures of bent-core and rod-like molecules that exhibit the biaxial smectic-A phase are found to show a periodic stripe pattern in the presence of surface charges. These stripes correspond to alternating uniaxial and biaxial smectic regions. Using fluorescence confocal microscopy, it has been shown that the bright biaxial smectic domains have a higher concentration of bent-core molecules. Model calculations confirm that the stripe structure has a lower free energy compared to the structure with uniform concentration. [R. Pratibha and N.V. Madhusudana]

Nematic liquid crystals made up of dimeric molecules: Studies on the phase behaviour of nematics – that is made up of dimeric molecules and their mixtures – have been taken up. Some of the mixtures are found to exhibit a reentrant nematic phase making it possible to compare the physical properties of the nematic and reentrant nematic phases. A nematic – nematic transition has also been observed in some of these systems. [B. Kundu, R. Pratibha and N. V. Madhusudana]

Chevron structures and the stability of the anticlinic smectic-C phase in the surface stabilized geometry: A bilayer model has been developed to describe the chevron structures in surface stabilized antiferroelectric liquid crystalline phases and in the anticlinic smectic-C phase. It is found that the chevron structures in the anticlinic smectic-C phase can have three arms as has been observed in some experiments, in contrast to the two arm chevron structures usually found in the synclinic smectic-C phase. Surface interactions are found to stabilize the smectic-C phase even for compounds that do not exhibit this phase in the bulk. The phase diagram of these systems in the 'temperature-cell thickness' parameter plane has been computed and the existence of a triple point has been predicted, where the smectic A, smectic C and the anticlinic smectic-C phases coexist. [Arun Roy]

Charge transport instability in the smectic-A phase: The steady state charge transport through a smectic-A liquid crystal has been studied in the case where the electric field is applied along the smectic layer normal. Instability in the charge transport with a fairly low threshold voltage has been observed and the temperature dependence of the threshold voltage has been determined. Attempts are underway

to understand the origin of this instability. [Antara Pal and Arun Roy]

Viscoelastic coefficient of novel thiol terminated alkoxy-cyanobiphenyl nematic liquid crystals: The twist viscoelastic coefficient of novel thiol terminated alkoxycyanobiphenyl nematic liquid crystals has been measured as a function of temperature and length of the alkoxy chain using dynamic light scattering. It is found to be about three times smaller than that in alkoxycyanobiphenyl nematics. These experiments yield the ratio of dielectric anisotropy to twist viscosity. The activation energy corresponding to twist viscosity has also been estimated. [Amit Agarwal, Santanu Kumar Pal, Sandeep Kumar and K.A. Suresh]

DISPLAYS

Development of low power techniques for driving matrix displays: An analysis was made of the power consumption in the successive-approximation technique that is based on line-by-line addressing: the waveforms have been modified to reduce the power consumption in the driver circuit. The possibility of reducing the power consumption by rearranging the select pulses and increasing the duration of the select pulse corresponding to the most significant bit has been explored. A prototype has been built to demonstrate the technique. [A. R. Shashidhara, Anil Shenoy (NIT, Suratkal) and T.N. Ruckmongathan]

An analysis of power consumption in displays driven by several multi-line addressing techniques has been taken up. The possibility of displaying gray shades using triangular waveforms, which have the least power consumption, is also being explored. [T.N. Ruckmongathan]

AMPHIPHILIC SYSTEMS

Magnetic susceptibility of a micellar solution: The magnetic susceptibility of the isotropic phase of the cesium perfluorooctanoate-water system has been measured as a function of temperature and water content. It is found to show a non-monotonic behaviour with a maximum at a particular temperature. The temperature corresponding to the maximum is found to decrease with increasing water content. The observed temperature dependence of the susceptibility is deemed to be related to the concentration of bound water in the system. [D. Vijayaraghavan and K.A. Suresh]

Rheology of a micellar system exhibiting inverse crystallization: The triblock copolymer Synperonic F-108 (consisting of 'polyethylene oxide (PEO) - polypropylene oxide (PPO) - polyethylene oxide' blocks) forms micellar

aggregates in water at high temperatures. At sufficiently high concentrations of the copolymer, these micelles are arranged in a body-centred-cubic lattice, giving rise to the intriguing phenomenon of inverse crystallization. The concentration-versus-temperature phase diagram of this system has been determined using oscillatory rheology. The yielding behaviour of polycrystalline samples was also studied using large-amplitude oscillatory strains. The experimental data are found to closely match theoretical estimates for soft solids. The frequency dependence of the viscoelastic moduli was shown to point to a broad distribution of relaxation times. The average zero-shear relaxation time of these slow dynamics was measured by performing strain rate frequency sweep experiments. [Ranjini Bandyopadhyay]

Influence of strongly bound counterions on the phase behaviour of ionic surfactants: Earlier studies on these systems have been extended to cover surfactants with different head groups. It is found that mesh phases with different symmetries may be obtained by small changes in the structure of the headgroup. An unusual sequence of phase transitions is observed in one of the systems, where the initially cylindrical micelles first shorten and then become disc-like on increasing the concentration of the strongly bound counterion. [Sajal Ghosh, V.A. Raghunathan and A.K. Sood (IISc, Bangalore)]

POLYMER PHYSICS

Rheology of regenerated silk fibroin solutions: The linear and nonlinear rheology of dialysed and undialysed silk fibroin solutions, obtained by dissolving silk fibroins from Bombyx Mori silkworms in a calcium nitrate-methanol solvent, were measured. As a followup on these experiments, the strain hardening and shear thinning properties of these solutions from liquid-like to gel-like consistencies, as the sample temperature is steadily increased, is being examined. [Ranjini Bandyopadhyay and S. Ananthamurthy (Bangalore University)]

Formation of tent-like structures in crystalline polymer membranes: The geometry and energetics of tent-like structures observed in crystalline polymer films have been worked out. Analysis shows that a unique apex angle of the tent is determined by the lattice constants of the polymer crystal. [A. Jayakumar, Yashodhan Hatwalne, Madan Rao and M. Muthukumar (University of Massachusetts, USA)]

SURFACE SCIENCE AND NANOCOMPOSITE

Ionic discotic liquid crystals at liquid-air and solid-air interfaces: The monolayer phases formed by two ionic discotic mesogens – pyridinium tethered

with hexa-alkoxytriphenylene with a bromide counterion, and imdazolium tethered with hexa-alkoxytriphenylene with a bromide counterion – at the air-water and air-solid interfaces have been studied using surface manometry and Brewster angle microscopy. Both systems are observed to form uniform monolayers with negligible hysterisis on expansion and compression. These monolayers were transferred to solid substrates at different surface pressures using the Langmuir-Blodgett technique and were studied using atomic-force microscopy. The topography of these films that were transferred at low and high surface pressures indicates a transformation of the monolayer from a face-on to an edge-on structure. [Alpana Nayak, K.A. Suresh, Santanu Kumar Pal and Sandeep Kumar]

Studies on novel H-shaped mesogenic molecules at liquid-air and solid-air interfaces: The Langmuir monolayers and Langmuir-Blodgett films formed by the H-shaped dimer, hexanedioic acid bis-[5-(4-n-dodecyloxy-benzoyloxy)-2-p-tolyazo-phenyl] ester has been studied. This material exhibits a smectic-C phase between 50° and 45° C. Surface manometry studies showed the formation of a stable monolayer with a small collapse pressure of 2 mN/m. Brewster angle microscopy studies show liquid-like domains coexisting with gas regions, which transform to a uniform liquid phase with increasing surface density. Atomic-force microscopy studies on films transferred to freshly cleaved mica showed domains about 3.8 nm high, which corresponds to the estimated length of the molecule. Photostability studies on the monolayer was carried out by shining light of appropriate wavelengths. Switching between *trans* and *cis* isomers is found as indicated by the change in surface pressure. [Bharat Kumar, K.A. Suresh, A.K. Prajapati and M.C. Varia]

Single walled carbon nanotubes as enzyme carriers for biosensors: A novel method has been developed for the surface immobilization of redox proteins using self-assembled monolayers on gold surfaces. This method combines the ability of the protein to wrap around single-walled carbon nanotubes and their non-covalent binding to the 4-aminothiophenol self-assembled monolayer on gold. This leads to the enhancement of the surface concentration, interfacial electron transfer and electrocatalytic activity of the proteins. The surfaces were characterized using scanning probe techniques, cyclic voltametry and chronoamperometry. This is the first time that enzyme functionalized carbon nanotubes have been shown to act as 'molecular wires' in enhancing electron transfer processes. [M. Nagaraju and V. Lakshminarayanan]

Dispersion of gold nanoparticles in a hexagonal lyotropic liquid crystalline medium: A novel method of dispersing gold nanoparticles in the hexagonal and inverted hexagonal lyotropic liquid crystalline phases has been demonstrated. The

organization of the nanoparticles in the matrix has been deduced using X-ray diffraction and scanning tunneling microscopy. [P. Suresh Kumar, V. Lakshminarayanan, D. Vijayaraghavan and Sandeep Kumar]

Electrical conductivity of discotic liquid crystals doped with gold nanoparticles: A novel hybrid nanomaterial consisting of gold nanoparticles and a discotic liquid crystalline material has been prepared. The DC electrical conductivity of the composite is found to be a million times higher than that of the liquid crystalline matrix. A model has been proposed for the increase in the electrical conductivity based on the donor-acceptor mechanism of charge transport. [P.Suresh Kumar, Santanu Kumar Pal, Sandeep Kumar and V. Lakshminarayanan]

Synthesis of discotic-covered nanomaterials and their insertion into a columnar matrix: Single-walled carbon nanotubes functionalized with a discotic moiety have been synthesized for the first time and were dispersed in a discotic columnar liquid crystalline medium. Polarizing optical microscopy, differential scanning microscopy and X-ray diffraction studies suggest that the nanotubes are inserted between the columns of the liquid crystalline matrix. [Hari Krishna Bisoyi and Sandeep Kumar]

Structure and electrochemical barrier properties of cholesterol monolayers and multilayers: The structure and electrochemical barrier properties of cholesterol monolayers and multilayers formed using Langmuir-Blodgett deposition on self-assembled monolayers of 2-naphthalenethiol were studied using scanning tunneling microscopy, atomic force microscopy, grazing angle infra-red spectroscopy and electrochemical techniques. The cholesterol monolayers form a stripe pattern with a spatial periodicity of about 1.0 nm. The area per molecule is found to be 0.5 nm^2 with the long axis of the cholesterol molecule making a tilt angle of 18° with the surface normal. The electrochemical studies show a large increase in charge transfer resistance and a lowering of the interfacial capacitance due to the formation of the multilayers of cholesterol. [R.K. Pandey, K.A. Suresh and V. Lakshinarayanan]

BIOLOGICAL PHYSICS

Influence of sterols on model and cell membranes: The phase behaviour of some lipid-sterol membranes have been determined using X-ray diffraction. The organization of the sterol molecules in the membranes were inferred from these experiments. These studies are being extended to cell membranes with a view to understanding the influence of the actin cytoskeleton on the organization of sterols in the membrane. [Bibhu Ranjan Sarangi, V.A. Raghunathan, Madan Rao and

Satyajit Mayor (NCBS, Bangalore)]

Novel Structures of DNA-surfactant complexes: DNA forms complexes with cationic surfactants and a few different structures of these complexes have been reported. In the case of a strongly bound surfactant counterion many novel structures of these complexes are observed. The formation of these structures can be understood in terms of the competition between the counterions and the DNA polyion to bind to the surfactant micelles. [Sajal Ghosh, A.V. Radhakrishnan, V.A. Raghunathan and A.K. Sood (IISc, Bangalore)]

THEORETICAL PHYSICS (TP)

Areas of Research: Condensed Matter and Statistical Physics
Gravitation
Optics
Physics in Biology

CONDENSED MATTER AND STATISTICAL PHYSICS

Microscopic models of pumps and engines: A new class of classical models of heat and particle pumps was studied. These are built along the lines of recently studied models of quantum pumps. The models studied include a two-coupled-spins system, a coupled-oscillator system and a system of diffusing hard-core particles. The effect of time-dependent driving forces on these systems was considered and it was shown that DC currents can be obtained in these systems using AC signals. [Abhishek Dhar, Abhishek Chaudhuri, Rahul Marathe + Arun Jayannavar (IOP, Bhubaneshwar), Kavita Jain (Weizmann Institute of Science, Israel)]

Transport in mesoscopic systems: A microscopic model of electron transport in the presence of inelastic scatterers was studied. The conducting wire was modelled by the tight binding lattice Hamiltonian and inelastic scattering was incorporated by connecting each site of the lattice to one-dimensional leads. This incorporates Büttiker's idea of dephasing probes. Both electrical and heat transport with applied chemical potential and temperature gradients was studied. In the linear response limit the model was exactly solved and expressions for various transport coefficients obtained. Heat dissipation in the wire was computed explicitly and studied in the context of the transition from Ohmic to ballistic transport. [Abhishek Dhar, Dibyendu Roy]

Heat transport in one dimension: Through extensive numerical simulations the exponent which determines the system size dependence of the heat current in a one-dimensional system of interacting particles was obtained. [Abhishek Dhar + Onuttom Narayan, Trieu Mai (University of California, Santa Cruz)]

Heat conduction through a trapped solid: Effect of structural changes on thermal conductance: The conduction of heat across a narrow solid strip trapped by an external potential and in contact with its own liquid was studied. Structural changes consisting of addition and deletion of crystal layers in the trapped solid were produced by altering the depth of the confining potential. Non-

equilibrium molecular dynamics simulations and, wherever possible, simple analytical calculations were used to obtain the thermal resistance in the liquid, solid and interfacial regions (Kapitza or contact resistance). It was shown that these layering transitions are accompanied by sharp jumps in the contact thermal resistance. Dislocations, if present, were shown to increase the thermal resistance of the strip drastically. [Abhishek Chaudhuri + Debasish Chaudhuri (Max Planck Institute for the Physics of Complex Systems, Dresden, Germany) and Surajit Sengupta (S.N. Bose National Center for Basic Sciences, Kolkata)]

Thermal and electrical transport in model systems: The fundamental problems in mesoscopic physics are to incorporate interactions (basically Coulomb interactions between electrons) and decoherence in microscopic theory of transport. Incorporation of dephasing via external probes in microscopic theory of thermal and electrical transport in lower dimensional systems was studied. The similarity between the quantum Langevin equation approach and non-equilibrium Green's function formalism for heat transport in harmonic lattice connected to external reservoirs at different temperatures was pointed out. As an application, the formalism was used to calculate thermal conductivity of a harmonic chain with each site connected to self-consistent heat reservoirs. Temperature dependent thermal conductivity was found, which exactly matches the result by Bonetto, Lebowitz, Lukkarinen (JSP, 116:783, 2004) in the high temperature classical limit. [Abhishek Dhar, Dibyendu Roy]

Electrical transport: Electron transport was studied in a ring modelled by the tight binding lattice Hamiltonian coupled to two electron reservoirs. First, Büttiker's model of incorporating inelastic scattering, hence decoherence and dissipation, has been extended by connecting each site of the open ring to one-dimensional leads for uniform dephasing in the ring threaded by magnetic flux. This extension shows that conductance remains symmetric under flux reversal, and Aharonov-Bohm oscillations with changing magnetic flux reduce to zero as a function of the decoherence parameter, thus indicating dephasing in the ring. This extension helps to find local chemical potential profiles of the ring sites with changing magnetic flux and the decoherence parameter analogously to the four probe measurement (de Picciotto et al., Nature 2001, v.411). The role of the closed ring's electronic eigenstates in the persistent current around Fano antiresonances of an asymmetric open ring for both ideal leads and tunnel barriers is pointed out. By determining the real eigenvalues of the non-Hermitian effective Hamiltonian of the ring, the existence of discrete bound states in the continuum of scattering states for the asymmetric ring even in the absence of magnetic flux is shown. [Dibyendu Roy]

Transport and N-S phase transition: Equipartition of current in parallel conductors on cooling through the superconducting transition. It has been shown experimentally that for two or more pieces of a wire, of different lengths in general, combined in parallel and connected to a DC source, the current ratio evolves towards unity as the combination is cooled to the superconducting transition temperature T_c, and remains pinned at that value below it. This redistribution of the total current towards equipartition without external fine-tuning is a surprise. It may be physically understood in terms of a mechanism that involves the flux-flow resistance associated with the transport current in a wire of type-II superconducting material. It is a fact that the flux-flow resistance increases with the current that drives the current division towards equipartition. [N. Kumar + S.V. Bhat, S.P. Chockalingam, Raghav G.Mavinkurve, S. Sarangi (Department of Physics, IISc., Bangalore)]

Crossover from normal (N) Ohmic subdivision to superconducting (S) equipartition of current in parallel conductors at the N-S transition: Theory. The recently observed equipartition of current at and below the Normal-Superconducting (N-S) transition may be understood in terms of a Landau-Ginzburg order-parameter phenomenology. This complements the explanation proposed earlier based on the flux-flow resistance providing a non-linear negative current feedback towards equipartition when the transition is approached from above. The present treatment also unifies the usual textbook inductive subdivision expected much below T_c, and the equipartition as T_c is approached from below. The question of metastability is also briefly discussed. [N. Kumar]

Open quantum systems: In the scheme of a quantum non-demolition (QND) measurement, an observable is measured without perturbing its evolution. QND measurement schemes have been suggested to be able to surpass the standard quantum limit of phase measurements and reach the Heisenberg limit. In this work such schemes have been studied taking into consideration the effect of decoherence. A study was made of a number of QND 'Open System' Hamiltonians and their propagators are obtained. Two of these propagators have been shown to be connected to the squeezing and rotation operations. Squeezing and rotation being both phase space area-preserving canonical transformations, this brings out an interesting connection between the energy-preserving QND Hamiltonians and homogeneous linear canonical transformations. [S. Banerjee + R. Ghosh (School of Physical Sciences, JNU, New Delhi)]

A study was made of open quantum systems where the coupling between the system and its environment is of a QND type. Such a system undergoes decoherence without dissipation of energy. The master equation for the evolution

of such a system under the influence of a squeezed thermal bath is obtained. From the master equation it may be seen explicitly that the process involves decoherence without any dissipation. A comparison was made between the quantum statistical properties of QND and non-QND (i.e., involving decoherence as well as dissipation) types of evolution. [S. Banerjee + R. Ghosh (School of Physical Sciences, JNU, New Delhi)]

A paradox involving the classical limit of a single harmonic oscillator coupled to an oscillator bath, for different initial conditions of the system, both separable and with thermal initial conditions has been resolved thereby clarifying the physical relevance of different initial conditions. [A. Dhar, S. Banerjee]

The dynamics of quantum phase distribution associated with the reduced density matrix of a system, as the system evolves under the influence of its environment with a quantum non-demolition type of coupling, has been quantitatively analyzed. The system is taken to be either an oscillator (harmonic or anharmonic) or a two-level atom (or equivalently, a spin-1/2 system) and the environment modelled as a bath of harmonic oscillators, which are initially in a general squeezed thermal state. The impact of the different environmental parameters is explicitly brought out on the dynamics of the quantum phase distribution of the system starting at various initial states. The results are applicable to a variety of physical systems now studied experimentally with QND measurements. [S. Banerjee + J. Ghosh, R. Ghosh (School of Physical Sciences, JNU, New Delhi)]

The previous work has been extended to study the phase distribution in QND as well as in dissipative systems. The impact of the different environmental parameters on the dynamics of the quantum phase distribution for the system starting out in various initial states has been explicitly brought out. A result is that the relationship between squeezing and temperature effects depends on the type of system-bath interaction. The phase distributions have been used to bring out a notion of complimentarity in atomic systems. A study was made of the variance of the phase using the phase distributions conditioned on particular initial states of the system. This might be of direct relevance to a number of experiments. [S. Banerjee, R. Srikanth]

Open quantum systems in quantum computation and quantum information: Geometric phase is intrinsically related to the kinematics of the path followed by the system in its Hilbert space. Both from the point of view of theoretical interest as well as practical implications – as for example with respect to quantum computers – it is interesting to study geometric phase in the context of open quantum systems. In this work a study has been made of a number of open system

models with the bath (reservoir) being modelled as a squeezed thermal bath, with the system-bath interaction being taken to be both non-dissipative (QND) as well as dissipative. An interesting aspect that has emerged from this work is the contrasting interplay between squeezing and thermal effects in the two types of system-bath interactions. This could have practical implications in the design of realistic geometric phase gates for quantum computation. [S. Banerjee, R. Srikanth]

Environment-induced decoherence presents a great challenge to realizing a quantum computer. In this work the somewhat surprising fact has been brought out that decoherence can be useful, indeed necessary, for practical quantum computation; in particular, for effective erasure of quantum memory by way of preparing the initial state of the quantum computer. The environment must in general be dissipative. A specific example is the amplitude damping channel provided by a two-level system interacting with its environment in the weak Born-Markov rotating wave approximation. [S. Banerjee, R. Srikanth]

A study has been made of some discrete symmetries of unbiased (Hadamard) and biased quantum walks on a line, which has been shown to hold even when the quantum walker is subjected to environmental effects. The noise models considered in order to account for these effects are the phase flip, bit flip and generalized amplitude damping channels. The numerical solutions are obtained by evolving the density matrix, but the persistence of the symmetries in the presence of noise is proved using the quantum trajectories approach. These investigations can be relevant to the implementation of quantum walks in various known physical systems. The implementation in the case of NMR quantum information processor and ultra cold atoms has been discussed. [S. Banerjee, R. Srikanth + C.M. Chandrashekar (Institute of Quantum Computing, University of Waterloo, Canada)]

DNA elasticity: Topology of self-avoidance: A theoretical treatment of DNA stretching and twisting experiments was presented in which global topological subtleties of self avoiding ribbons are described and an underlying justification for the worm-like rod chain (WLRC) model proposed by Bouchiat and Mezard was discussed. Some theoretical points regarding the WLRC model were clarified: the writhe of open curves and the use of an adjustable cutoff parameter to 'regularize' the model. A new class of experiments has been proposed to probe the continuous transition between the periodic and aperiodic behavior of the free energy. [A. Ghosh, J. Samuel, S. Sinha.]

Semiflexible polymer elasticity: Research to study the elasticity of stiff polymers is in progress. This work is motivated by recent single-molecule experiments on stiff polymers like actin. [A. Ghosh, J. Samuel, Supurna Sinha]

Jamming Dynamics in Grain Mixtures: An Extended Hydrodynamic Approach: Jamming in granular mixtures has been studied from the novel point of view of extended hydrodynamics. This work leads to the following experimentally testable prediction: a few large grains would get caged more effectively in a matrix of small grains compared to a few small grains in a matrix of larger ones. A similar effect has been experimentally observed in the context of colloidal mixtures. [Supurna Sinha]

GRAVITATION

Probing the non-linear structure of general relativity with black hole binaries: A unique opportunity to test the non-linear structure of general relativity is expected to present itself with observations of the inspiral of massive binary black holes (BBH) made by the Laser Interferometer Space Antenna (LISA), and stellar mass binary black holes by the European Gravitational-Wave Observatory (EGO). A powerful test has been proposed in which the various post-Newtonian coefficients in the gravitational wave phasing are systematically measured by treating three of them as independent parameters and demanding their mutual consistency. LISA (EGO) will observe BBH inspirals with a signal-to-noise ratio of more than 1000 (100) and, thereby, test the self-consistency of each of the nine post-Newtonian coefficients that have so-far been computed, by measuring the lower order coefficients to a relative accuracy of $\sim 10^{-5}$ (respectively, $\sim 10^{-4}$) and the higher order coefficients to a relative accuracy in the range $10^{-4} - 0.1$ (respectively, $10^{-3} - 1$). [K.G. Arun, Bala R. Iyer, Mohd. S.S. Qusailah + B.S. Sathyaprakash (Cardiff University, UK)]

Inspiralling compact binaries in quasi-elliptical orbits: 3PN instantaneous angular momentum flux and the evolution of orbital elements: The instantaneous terms in the 3PN angular momentum flux from the inspiral phase of a binary system of compact objects, which are moving in quasi-elliptical orbits, is computed using the Multipolar post-Minkowskian wave generation formalism. Using the 3PN quasi-Keplerian representation of elliptical orbits this flux is averaged over the binary's orbit. The evolution of orbital elements, under these contributions to 3PN gravitational radiation reaction, has been studied in the quasi-elliptic case. [K.G. Arun, Bala R. Iyer, Mohd. S.S. Qusailah + Luc Blanchet (IAP, Paris)]

Implications of Post-Newtonian amplitude-corrected templates for detection of supermassive black holes by LISA: Current expectations on the signal to noise ratios and masses of supermassive black holes, which the Laser Interferometer Space Antenna (LISA) may observe, are based matched filtering using only the dominant harmonic of the inspiral waveform at twice the orbital frequency. Other harmonics will affect the signal-to-noise ratio of systems currently believed to be observable by LISA. More significantly, inclusion of other harmonics in our matched filters means that more massive systems, which were previously thought to be not visible in LISA, could be detectable with reasonable SNRs. It is shown that it might be possible to significantly increase the mass reach of LISA and observe the more commonly occurring supermassive black holes of masses $\sim 10^8$ $M_\odot$.[Bala R. Iyer, Siddhartha Sinha + K.G. Arun (Virgo Collaboration, Laboratoire de l' Acceleratuer Lineaire, Universite Paris, Paris), B.S. Sathyaprakash (Cardiff University, UK)]

Parameter estimation of supermassive black holes using amplitude corrected waveforms with LISA: Work is in progress to study the accuracy of parameter estimation for LISA using the Fisher matrix formalism when higher harmonics are included in the templates. The additional structure in the signal is expected to significantly impact LISA's ability to measure the source parameters. In particular, the accuracies of angular position and luminosity distance of the source are being studied to investigate implications for cosmology. [Bala R. Iyer, Siddhartha Sinha + K.G. Arun (Virgo Collaboration, Laboratoire de l' Acceleratuer Lineaire, Universite Paris, Paris), B.S. Sathyaprakash, Chris van den Broeck (Cardiff University, UK)]

3PN gravitational wave polarisations from inspiralling compact binaries in circular orbits: Work is in progress to calculate the 3PN waveform and polarisation for compact binaries inspiralling under radiation reaction in quasi-circular orbits. The instantaneous terms in the waveform have been completed. A calculation of the hereditary terms continues. [Bala R. Iyer, Siddhartha Sinha + Luc Blanchet, Guillaume Faye (IAP, Paris)]

Surface Tension and the cosmological constant: An outstanding problem in modern cosmology is the problem of the cosmological constant Λ: (a) Why is the cosmological constant so nearly zero? (b) Why is it not exactly zero? A proposal due to Sorkin addresses part (b) of this dilemma. Assuming that some mechanism has been found to solve part (a), Sorkin proposes that (b) can be understood as a fluctuation originating in quantum gravity. The order of magnitude of the root mean square fluctuations in Λ predicted by Sorkin agrees with the astronomically

observed value of Λ. In the present work, this simple idea of Sorkin is realised in an analogous soft matter context, leading to the possibility of probing quantum gravity effects in analogue experiments. The soft matter analogy also points towards a resolution of part (a) of the cosmological problem. [J. Samuel, Supurna Sinha; there has been a special coverage of this work in an article in New Scientist by Jennifer Ouellette in the 24 February 2007 issue.]

Geometric flows and Black Hole entropy: This work explores the subject of Black Hole entropy from the viewpoint of Geometric differential equations. The relations between the entropy function introduced by Perelman in his gradient formulation of the Ricci flow and Black hole entropy were investigated. A study of the fixed points of the flow shows that these two entropies are not the same since the fixed points of the flows differ. However, a modified Ricci flow was found which has the Schwarzschild space as a fixed point. [J. Samuel, Sutirtha Roy Chowdhury]

Energy, Entropy and the Ricci flow: This work investigates the evolution of physically interesting geometric quantities under the Ricci flow. Specifically, the area of apparent horizons is related to geometric entropy. The Hawking mass is a measure of the total mass enclosed within a surface. The evolution of these quantities under the Ricci flow is studied. Some inequalities which are satisfied by these quantities are proved. [J. Samuel, Sutirtha Roy Chowdhury]

Quantum resolution of the black hole information loss problem in 1+1 black holes: The Hawking Information Loss Puzzle was analysed in the context of a non-perturbative quantization of a toy model of black holes in 2 spacetime dimensions. The puzzle was resolved within a unitary quantum framework and it was shown that the resolution came about because of the existence of a quantum extension of spacetime beyond the classical singularity. A detailed proposal for the operator equations in the non-perturbative quantum theory was outlined. It was shown how, in the context of appropriate approximations, the proposed equations led to the right classical limit as well as to semiclassical theory with Hawking radiation. Combining results from non-perturbative quantization, asymptotic analysis and prior numerical analysis of the semiclassical theory (the latter done by earlier workers), a detailed proposal for a unitary description of the evaporation process was described. Work continues on the final details regarding the recovery of a pure state. The work also touched upon fascinating issues involved in the definition of quantum field theory on a quantum spacetime. [Madhavan Varadarajan + Abhay Ashtekar, Victor Taveras (Penn State University, USA)]

Towards a new representation for background independent quantum gravity: Loop Quantum Gravity (LQG) is a quantization of a classical reformulation of canonical gravity in terms of non-abelian gauge potentials and triads. Recently a uniqueness theorem for the representation used in Loop Quantum Gravity (LQG) was proven by Lewandowski, Okolow, Sahlmann, Thiemann and Fleischhack. Some of the assumptions needed were not physically well motivated but mathematically necessary. By violating some of these assumptions, a representation is constructed which respects background independence and is unitarily inequivalent to the representations used in LQG. This work constitutes a first step in the exploration of physically viable representations distinct from the one used in LQG. In this work attention is restricted to the case of abelian gauge potentials but it is expected that our constructions generalise to the case of gravity. [Madhavan Varadarajan]

Polymer quantization of Parametrised Field Theory (PFT): Building on prior work, a Dirac quantization of Parametrised Field Theory on the cylinder was constructed using a representation and techniques similar to those used in Loop Quantum Gravity (LQG). While key ideas due to earlier work on 2-dimensional PFT were used to construct the quantum kinematics and dynamics, the novel feature of this work is the definition of gauge invariant observables in the absence of any triangulation. Indeed, this constitutes the first triangulation independent construction of Dirac observables in a LQG type quantization of a generally covariant field theory. Many interesting issues such as the construction of semiclassical states and comparison with the standard Fock quantization of free field theory are being analysed. [Madhavan Varadarajan + Alok Laddha (IMSc, Chennai)]

A model for 2D causal set quantum gravity: In this work, the 'entropy problem' encountered in many sum-over-histories approaches to quantum gravity was addressed within the framework of causal set quantum gravity. This entropy problem arises in approaches in which the spacetime continuum is replaced by a more fundamental entity, for example in dynamical triangulations and in graph based approaches. Typically, there is an overwhelming 'entropic' contribution to the partition function from configurations that have no resemblance to spacetimes, so that obtaining the proper classical/continuum limit of the theory becomes very difficult. It was shown that this entropy problem is tamed in a model of 2D causal set quantum gravity. Using results on partial orders it was shown that the partition function is dominated by causal sets which approximate to an interval of 2D Minkowski spacetime. Thus, Minkowski spacetime and all its physical attributes is a prediction of this model. This work provides a causal set discretisation of the standard path integral for the first time. It has the interesting consequence that

continuum spacetime is recovered from the discretisation in the large volume limit. [S. Surya + Graham Brightwell (London School of Economics, UK), Joe Henson (University of Utrecht, Netherlands)]

Numerical tests for manifold-likeness in a causal set: A computational tool has been developed to test for manifoldlikeness of a causal set. Within certain restrictions, it should provide a necessary though not sufficient condition for a causal set to be manifoldlike. Simulations have been carried out for causets which embed into 2D and 3D spacetimes with good results. [S. Surya + Seth Major (Hamilton College, USA), David Rideout (Imperial College, UK)]

Decoherent histories: Using the decoherent histories approach to quantum theory, the quantum-Zeno effect was examined. This effect is the fact that frequent observation delays the expected evolution of the system in question, and the expectation might be that at the limit of continuous observation the system would freeze. The customary explanation is that this has to do with the observing technique (measuring devices, environment). It is of interest to consider what may be inferred about such physical systems in a formulation of quantum mechanics in which observers do not have special position. Decoherent histories is the most well developed observer independent formulation of closed system quantum mechanics. It was found that in this approach, the quantum-Zeno effect arises only in very special cases, and the effect of the observer is replaced by a restrictive decoherence condition. [Petros Wallden]

PHYSICS IN BIOLOGY

Modeling mitochondrial morphology and dynamics: Mitochondria are a dynamic network of tubular organelles that are the sites of ATP synthesis in the cell. Organization of the mitochondrial reticulum depends on the differing energy requirements in the cell. Together with collaborators at National Center for Biological Sciences, Bangalore, the dynamics of mitochondrial distribution and its function using high resolution fluorescence imaging was tracked. Mitochondrial morphology is a result of motor assisted translation, cytoskeletal reorientation and actively regulated fission and fusion. A coarse-grained dynamical model to describe the steady state mitochondrial distribution is being worked on and quantitative comparisons made with the experiments performed. [Abhishek Chaudhuri, Madan Rao + G. Goyal, V. Sriram (NCBS, Bangalore)]

COMPUTERS

Transition to the switched Gigabit LAN was undertaken.

After due process, the link to the World Wide Web was upgraded from shared 512 Kbps (1:4) to dedicated 2 Mbps (1:1).

Procurement of better hardware as servers to accommodate increased workloads was initiated.

Procurement process for the first phase replacement of CRT monitors with energy efficient TFT monitors was initiated.

Upgrades and suitable steps to safeguard against data loss were implemented. Software upgrades to all key systems and services was carried out, where required, to improve functionality and security. Routine maintenance of computer systems, and networking for overall improvement in the computational facilities were undertaken.

LIBRARY

The Library continued to provide need based information services to the staff/faculty/students and others. In order to share information resources, a close liaison was continued to be maintained with Bangalore Special Libraries Group and the FORSA Libraries.

Library Resources Development:

- Books : Scientific and technical - 510; Gratis: 45
  Hindi - 106
  E – Books - 4
  CD collection - 20
- Bound volumes of journals - 1147
- Scientific/technical journals subscribed - 168

  Print + Online - 131
  Online - 26
  Print - 11
  Through Consortia- online - 19
  IoP Noncancellation Option (Online) - 19

- General Periodicals – English - 12
  Hindi - 5
  Kannada – gratis - 1

- News Papers English - 6
  Hindi - 2
  Kannada - 1

The collection at the end of the reporting period is: Books – 24475; bound volumes of journals: 35468 and the total library collection is: 59,943.

Strengthening Library Facilities:

Two CD stakkas for CD storage and one Digital Page Scanner were procured. The Libsys updates were received and installed in the existing system. Two printers HP Laserjet 2420dn and HP Color Laserjet 2605dn were procured.

Consortia Activities:

Under FORSA activities, the following consortia were continued and one more consortium with University of Chicago Press was realized for three AAS Journals for the year 2007.

- FORSA Consortium for Nature, Nature Physics, Nature Materials and Nature Photonics (all online);
- Indian Astrophysics Consortium for Springer Physics and Astronomy Journals (print + Online);
- University of Chicago Press and FORSA Consortium for AAS Journals: Astrophysical Journal, Astrophysical Journal Supplement Series and Astronomy Journal (Online);
- FORSA Consortium for Scientific American Archive Online;
- Under FORSA - Open Consortium: Lecture Notes in Physics;
- Under Indest Consortium (MHRD) – renewed for IEEE/IEE Electronic Library (IEL Online).

Digital Library Initiatives:

New additions are made continuously to the RRI Digital Repository, including research papers, miscellaneous publications, and Gandhi Memorial Lectures. Also, RRI digitized and hosted the entire collection of collected works of C.V.Raman and announced accessibility of this collection on the National Science Day, 28 February 2007. Ph.D. theses are digitized and the process of getting consent of each author/guide to host these in the repository is in progress. The following are the Communities where posting of related articles are indicated:

Communities and Collections:

Astronomy and Astrophysics (A&A) – 411
Light and Matter Physics (LAMP) – 58
Soft Condensed Matter (SCM) – 290
Theoretical Physics (TP) – 158

Archives:

- Annual Reports – 28
- Gandhi Memorial Lectures – 12
- C.V.Raman's News Paper Clippings – 707

C.V.Raman and his work:

- Biographical sketches and other articles on C.V.Raman - 9
- C.V.Raman – Lectures and miscellaneous writings – 16
- C.V.Raman – Scientific Papers, vol.1: Scattering of light – 103
- C.V.Raman Scientific Papers, vol.2: Acoustics – 53
- C.V.Raman – Scientific Papers, vol.3: Optics – 67
- C.V.Raman – Scientific Papers, vol.4: Optics of Minerals and Diamond – 77
- C.V.Raman – Scientific Papers, vol.5: Physics of Crystals – 89
- C.V.Raman – Scientific Papers, vol.6: Floral Colours and Visual Perception – 85

Miscellaneous Publications – 66

Scientific slides relating to astronomy and astrophysics were digitized and now available in CD.

Library Visitors:

Three Scientists from CPRI, Bangalore visited RRI Library in connection with discussion on Consortium formation amongst the power related institutions in the country and expert opinion on the matter was provided.

Library Consultancy:

The NIAS and JNCASR Libraries were given expert opinion for developing their libraries on modern lines. The JNCASR library was given advice for developing the library, streamlining procedures and best practices for purchase of books, subscription of journals and involved in developing infrastructure to facilitate better services to the users.

Seminars/Symposia, courses attended:

The library staff participated in several symposia, workshops and other conferences covering the following areas:

- digital libraries using DSpace
- setting up and maintaining institutional repositories
- records management
- e-learning
- information management
- information technology in agriculture
- quality assessment and indicators for LIS education & information science
- semantic web and digital libraries

Papers published:

- Patil, Y.M., Birdie, Christina, Bawdekar, Nirupama, Barve, Sunita and Nishtha, Anil Kumar.
  Indian Consortia Models: FORSA Libraries Experience.
  Paper presented at the LISA V Conference: Common challenges and uncommon solutions. Cambridge, Massachusetts, USA, June 18 – 21, 2006. (In Press).
- Sangam, S. L. and Savanur, K.P.
  Dr. N. Rudraiah : A biobibliometric study
  SRELS Journal of Information Management, 43(2), 2006, pp.185-199.
- Patil, Y. M. and Savanur, K.P.
  Consortium approach to e – resource sharing: A case study.
  Paper presented in: AFITA 2006: The Fifth International Conference of the Asian Federation of Information Technology in Agriculture, November 9 – 11, 2006, Bangalore, edited by V.C.Patil. New Delhi: Macmillan India, p.157 – 176.
- Girija Srinivasan, Y.M.Patil and Jacob Rajan.
  Scholarly communication in a digital world: the role of the Digital Repository at the Raman Research Institute.
  In: Paper presented in International Conference on "Semantic Web and Digital Libraries" – ICSD – February 21 – 23, 2007. (Indian Statistical Institute Platinum Jubilee Conference Series), ed. By Prasad, A.R.D. and Devika P. Madalli. Bangalore: ISI – DRTC, 2007, p.285 –294.

OTHER ACTIVITIES

Ph. D.

Awarded

Rajesh Gopal	Magnetic fields and large-scale structure in the Universe *Jawaharlal Nehru University, New Delhi*
Mohammed S.S. Qusailah	Generation of gravitational waves from Inspiralling compact binaries: 3PN luminosity, 2PN inear momentum flux and applications *Jawaharlal Nehru University, New Delhi*
K. G. Arun	Gravitational waves from inspiralling compact binaries: 2.5PN waveform, 3PN angular momentum flux and 3.5PN parameter estimation *Jawaharlal Nehru University, New Delhi*
Raj Kumar Gupta	Studies on Langmuir monolayers and Langmuir-Blodgett films of mesogenic and organometallic molecules *Jawaharlal Nehru University, New Delhi*
Navinder Singh	Electronic relaxation and diffusion on dynamically disordered lattices and nanoparticles: decoherence and dissipation *Jawaharlal Nehru University, New Delhi*
Ganesh V	Electrochemical studies and molecular self-assembly on surfaces in surfactant based systems *Jawaharlal Nehru University, New Delhi*

Submitted

V. N. Pandey	Southern sky at 151.5 MHz using the Mauritius Radio Telescope *Jawaharlal Nehru University, New Delhi*
T. Roopa	Forcing self-assembled biomelecular structures: a study on membrane nanotubulation and chromatin fibers *Jawaharlal Nehru University, New Delhi*

S. Umadevi	Liquid crystals of some compounds composed of bent-core molecules: synthesis and characterization *Jawaharlal Nehru University, New Delhi*
Sudipto Muhuri	Rheology and transport in active and passive filaments *Jawaharlal Nehru University, New Delhi*
Divya Sharma	Investigation of wave propagation in random and specially structured media *Jawaharlal Nehru University, New Delhi*

Gandhi Memorial Lecture

The Gandhi Memorial Lecture for 2006, entitled "Secularism and Popular Indian Cinema", was delivered by Mr. Shyam Benegal, Mumbai on 2 October 2006.

Hindi Cell

A section dedicated to Hindi literature has been functioning in the Library; a number of books and journals have been acquired during this year.

A study programme has been initiated through the Hindi Language Cell at the Institute. Classes were conducted, and a batch of 16 employees appeared for the examinations held in May 2007.

Publications

The research work done by the staff of the Institute has been published in a number of journals. A list of publications that have already appeared, as well as those submitted and in press, is given at Annexure I (Pages 68-82).

Visiting Student Programme (VSP)

From this year, the Visiting Student Programme is introduced and is aimed at offering research experience to highly motivated students who are pursuing their undergraduate or masters studies. Under this programme, selected students will be able to work on projects at RRI during any part of the year. Students seeking such opportunities during their summer vacation will also be continued to be supported under this programme.

During the year, 18 students from different parts of the country attended the programme. The average duration was around 3 months.

Colloquia

The scientists of the Institute and visiting scientists both from within and outside the country gave colloquia at the Institute on different topics during the year (Annexure II, Pages 83-94).

Journal Club Meetings

Forty meetings were held during the year. Preprints as well as recently published papers dealing with topics of current interest were reviewed in the meetings (Annexure III, Pages 95-99).

And, as in the past, several informal Group meetings in Theoretical Physics, Light & Matter Physics, Soft Condensed Matter and Astronomy & Astrophysics were held on a regular basis throughout the year.

Visiting Scientists

A number of scientists from institutions within the country and from outside visited the Institute during the year. Their names are listed separately (Pages 59-63).

In-House Meeting

An In-House Meeting, which is an annual feature at the Institute, was held on 28 and 29, April 2006 where the staff and students presented their research work. The presentations were followed by lively scientific discussions with critical comments and suggestions relevant to the reported research from the members.

General

The following grants were received from the Department of Science and Technology during the year:

PLAN (Recurring & Non-Recurring)	Rs.2,000.00 lakhs
NON-PLAN (Recurring)	Rs. 240.00 lakhs
Total	Rs.2,240.00 lakhs

COUNCIL

Dr. K. Kasturirangan Chairman	Member of Parliament, Rajya Sabha, & Director, National Institute of Advanced Studies, Bangalore
Mr. K.P. Pandian	Joint Secretary & Financial Adviser Ministry of Science & Technology Government of India, New Delhi 110 016
Prof. P. K. Kaw	Director, Institute of Plasma Research Gandhinagar 382 428
Prof. Ravi Subrahmanyan	Director, Raman Research Institute Bangalore 560 080
Prof. A.K. Sood	Department of Physics Indian Institute of Science Bangalore 560012
Dr.T.Ramsami	Department of Science & Technology Ministry of Science & Technology New Delhi 110 016
Prof. V. Radhakrishnan	Member-Secretary Raman Research Institute Trust Bangalore 560 080
Prof. O. Siddiqi	TIFR; National Centre for Biological Sciences GKVK Campus, Bangalore 560 065

FINANCE COMMITTEE

Dr. K. Kasturirangan Chairman	Member of Parliament, Rajya Sabha, & Director National Institute of Advanced Studies, Bangalore
Mr. K.P Pandian	Joint Secretary & Financial Adviser Ministry of Science & Technology Government of India, New Delhi 110 016
Prof. Ravi Subrahmanyan	Director, Raman Research Institute Bangalore 560 080
Prof. V. Radhakrishnan	**Member-Secretary** Raman Research Institute Trust Bangalore 560 080

STAFF

RAVI SUBRAHMANYAN
Director

V. RADHAKRISHNAN
Distinguished Professor Emeritus

N. KUMAR
Homi Bhabha Distinguished Professor

N.V. Madhusudana
INSA Scientist

THEORETICAL PHYSICS

Research
Abhishek Dhar *(Coordinator)*
B.R. Iyer
Joseph Samuel
Madan Rao
Madhavan Varadarajan
Sumati Surya
N. Kumar

Research Associate
Supurna Sinha

Post-Doctoral Fellows
Demian Cho (up to 14.5.2007)
Subhashish Banerjee
Abhishek Chaudhuri
Petros Wallden (from 18.10.2006)

Secretary
G. Manjunatha

Research Students
Abhijit Ghosh
K.G. Arun (up to 25.1.2007)
G. Kripa
Mohd. Arif Kamal
Mohd. S.S. Qusailah
Rahul Marathe
Siddhartha Sinha *(JAP)*[*]
Sudipto Muhuri
Sutirtha Roy Chowdhury
Anupam Kundu (from 17.7.2006)
Chaitra Hegde (from 19.7.2006)
P.R. Venkatramanan (from 19.7.2006)

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[*] *Joint Astronomy Programme*

LIGHT AND MATTER PHYSICS

Research

Sadiqali Rangwala (Coordinator)
N. Andal
Hema Ramachandran
Reji Philip

Post-Doctoral Fellows

B. Kartikeyan (up to 15.4.2006)
R. Srikanth (up to 25.9.2006)

Technical Assistant

M.S. Meena

Research Students

M. Anija
Archana Sharma
Arijit Sharma
Divya Sharma (up to 29.12.2006)
Nandan Satapathy
Navinder Singh (up to 31.8.2006)
K. Ravi
Suchand Sandeep
Deepak Pandey (from 19.7.2006)

Visiting Professor

R. Srinivasan (upto 31.3.2007)

SOFT CONDENSED MATTER

Research

V.A. Raghunathan (Coordinator)
B.K.Sadashiva
Arun Roy
V. Lakshminarayanan
N.V. Madhusudana
R. Pratibha
Ranjini Bandyopadhyay
T.N. Ruckmongathan
Sandeep Kumar
K.A. Suresh
Yashodhan Hatwalne

Scientific/Technical

A. Dhason
Mohammed Ishaq

Research Students

Alpana Nayak
Amit Kumar Agarwal
Antara Pal
Bharat Kumar
Biburanjan Sarangi
Brindaban Kundu
Dibyendu Roy
Dipanjan Bhattacharya
M. Govind (upto 30.5.2006)
Harikrishna Bisoyi
A. Jayakumar
D.H. Nagaraju
A.V. Radhakrishnan
S. Radhika (from 6.7.2006)

SOFT CONDENSED MATTER
(Contd.)

Scientific/Technical
N. Ravi Sankar
A.R. Shashidhara
H.T. Srinivasa
H. Subrahmonyam
K.N. Vasudha
D. Vijayaraghavan

Visiting Scientist
G. V. Shivashankar

Research Students
Rakesh Kumar Pandey
T. Roopa (up to 14.7.2006)
Sajal Kumar Ghosh
Santanu Kumar Pal
Satyam Kumar Gupta
P. Suresh Kumar
Tripta Bhatia
S. Umadevi (up to 12.9.2006)

Secretary
K. Radhakrishna

ASTRONOMY & ASTROPHYSICS

Research
K.S. Dwarakanath (Coordinator)
Anish Roshi
R. Bhandari
Biman B. Nath
A.A. Deshpande
Dipankar Bhattacharya
B. Ramesh
Shiv Kumar Sethi
C.S. Shukre
S. Sridhar
C.R. Subrahmanya
N. Udaya Shankar
Biswajit Paul

Research Associates
Sunita Nair
Mousumi Das

Post-Doctoral Fellows
Christian Zier (up to 25.5.2006)
Nirvikar Prasad

Research Students
Atish Kamble
Chandreyee Sengupta
V.N. Pandey (up to 18.9.2006)
Peeyush Prasad
Rajesh Gopal (up to 31.7.2006)
Raju Ramakrishna Baddi
L. Resmi *(JAP)*[*]
Ruta Kale
Shahram Amiri
Wasim Raja
Harsha Raichur (JAP-7.6.2006)
Yogesh Maan (JAP-5.7.2006)

Technical
B.T. Ravishankar (upto 14.8.2006)

Honorary Visiting Professor
P. Sreekumar

Secretary
V. Vidyamani

[*] *Joint Astronomy Programme*

RADIO ASTRONOMY LAB

Scientific/Technical

N. Udaya Shankar *(In-Charge)*
P.G. Ananthasubramanian
K. Chandrashekara
M.S. Ezhilarasi
B.S. Girish
M.R. Gopala Krishna
P.A. Kamini
S. Kasturi
S. Krishnamurthy
S. Madhavi
T.S. Mamatha
H.N. Nagaraja
T. Prabu
K.B. Raghavendra Rao
A. Raghunathan
B.T. Ravishankar (upto 14.8.2006)
P.V. Rishin
P. Sandhya
G. Sarabagopalan
P.S. Sasi Kumar
R. Somashekar
S. Sujatha
C. Vinutha

Visiting Scientist

A. Krishnan

Secretary

R. Mamatha Bai

GAURIBIDANUR TELESCOPE

Technical

H.A. Aswathappa

Support Staff

Bheema Naik
Gangaram
M. Muniyappa *(Nandi Hills)*
Papanna
Prahllada Rao
N. Raja Rao
R.P. Ramji Naik
Ranoji Rao
Shivarudraradhya
Thippanna
Venkataswamy

GRAPHIC ARTS

Raju Varghese

LIBRARY

Y.M. Patil, *Librarian*
S. Geetha
Girija Srinivasan
Hanumappa
Kiran P. Savanur
M. Manjunath
M.N. Nagaraj
Vrinda J. Benegal

Support Staff

K. Chowdasetty
C. Elumalai

COMPUTERS

Jacob Rajan
R. Nanda Kumar (in-charge)
B.T. Ravishankar (upto 14.8.2006)
B. Sridhar

MECHANICAL ENGINEERING SERVICES

C.M. Ateequlla, *In-Charge*
S. Abdul Rahim (retd. 28.2.2007)
M.Achankunju
I. Charles Paul
V. Dhamodaran
R. Durai Chelvan
R. Elumalai
K.O. Francis
V. Gokula Chandran
N. Gopal
G. Gopi
I. Henry
M. Mani
K.M. Mohandas
V.K. Muthu
V. Nagarajan
N. Narayanaswamy
T. Puttaswamy
P. Srinivasa
D. Sunand
S Sunderaj
M. Suresh Kumar
V. Venu

TRANSPORT

V. Jayaraman, *In-Charge*
Abdul Khader
M. Balarama
R. Jayaram
C.K. Mohanan
G. Prakash
Rahamath Pasha
G. Raja
M.K. Raju Kutty
Balaji (*Consultant*)

ADMINISTRATION

K. Krishnama Raju, *Admin. Officer*
K. Raghunatha, *Dy. Admin. Officer*
L.P. Kumar
Marisa D'Silva
K. Radha
S.R. Ramasubramaniyan
V. Raveendran
R.Ganesh
V.S.Shailaja (from 2.1.2007)
G.V. Indira (from 6.9.2006)

ACCOUNTS

K.R. Shankar, *Accounts Officer*
R. Ramesh
S. Srinivasa Murthy
P.V. Subramanya
V. Raghunath

PURCHASE

B. Srinivasa Murthy
M.Prema

STORES

S. Rajasekharan Nair, *Stores & Purchase Officer*
C.N. Ramamurthy
M.V. Subramanyam

MEDICAL

Consultant Paediatrician
Dr. M.R. Baliga

Consultant Physicians
Dr. A.R. Pai
Dr. B.V Sanjay Rao

Technician
R. Shanthamma

ESTATES & BUILDINGS

G.B. Suresh, *Civil Engineer*
R. Sasidharan, *Supervisor*
R. Anantha Subba Rao, *Consultant*
S. Anantha Raman
K. Bhoopalan
D. Gangappa
Gunashekar
C. Haridas
K. Palani
M. Rajagopal
C. Sampath
S. Sreedhar
K.N. Srinivas
T. Subramaniyam Naidu
K.G.Narasimhalu (from 22.5.2006)
K. Palani
M. Rajagopal
M. Ramesh (from 1.2.2007)

AMENITIES (Guest Houses & Hostels)

C.V. Bhargavan
Mangala Singh
Muniratna
T. Naganna
N. Narayanappa
D.B. Padmavathy
P.C. Prabhakar
N. Puttaswamy
A. Raju
N. Seetharam
Sharadamma
Shivamallu
Uma
K. Velayudhan
V. Yeshodha
N. Seetharam

UPKEEP

Hanumantha
Jayamma
K.N. Kawalappa
D. Krishna
C. Lakshamma
T. Mahadeva
T. Murali
Narayana
A. Ramanna
Ranjithamma
A. Sarojamma
Sidde Gowda
V. Venkatesh

HORTICULTURE

V. Krishnappa, *Consultant*
Bylappa
Govind K. Kundagol
Lakshmamma
Lingegowda
D. Mahalinga
Mailarappa
Marappa
D. Muniraja
S. Muniraju
Rahamathulla Khan
Rangalakshmi
Varalakshmi

SECURITY

V. Jayaraman, *In-Charge*
B.M. Basavarajaiah
U.A. Earappa
H. Gangaiah
K. Govindappa (retd. 31.5.2006)
Joseph Kunjachan
Keshavamurthy
Balaji (*Consultant*)
K. Krishnappa
Munihobalaiah
K. Pushparaj
O.M. Ramachandra
G. Ramakrishna
M. Sannaiah
Suresha
H. Vaderappa

VISITORS

Dr. Shashi Bhushan Pandey Institute Astrofysica de Andalucia Spain	3 -13 April 2006
Prof. S. Dattagupta Indian Institute of Science Education & Research, Kolkata	10 April 2006
Dr. Jagannath Jha Tata Institute of Fundamental Research Homi Bhabha Road, Colaba, Mumbai	9 - 14 April 2006
Ms. Chetana Jain Delhi University, Delhi	1 May - 20 June 2006
Prof. S. V. Dhurandhar IUCAA, Pune	2 - 4 May 2006
Prof. Ue-Li Pen CIIA, Canada	4 - 5 May 2006
Prof. Alak K Ray TIFR, Mumbai	7 -16 May 2006
Prof. Govind Swarup NCRA, Pune	14 - 18 May 2006
Dr. Tirthankar Roy Choudhury IIT, Kharagpur	21 - 26 May 2006
Dr.Bhas Bapat Physical Research Laboratory Ahmedabad	28 - 30 May 2006
Mr. Soobash Daiboo Mauritius Radio Telescope, Mauritius	6 June - 6 November 2006

Dr. Gin Jose Department of Physics Indian Institute of Technology Guwahati	8 - 15 June 2006
Prof. S. R. Shenoy School of Physics University of Hyderabad Hyderabad	15 - 30 June 2006
Ms. Ramanpreet Kaur ARIES, Nainital, Uttaranchal	20 June - 20 Sept. 2006
Dr. Ashish Asgekar BITs, Goa	20 June - 15 July 2006
Dr. Vikram Soni National Physics Laboratory, New Delhi	20 - 30 June 2006
Dr. Indranil Chattopadhyay Chungnam National University South Korea	28 June - 3 July 2006
Mr. Soobash Daiboo Mauritius Radio Telescope, Mauritius	1 July - end December 2006
Dr. Vikram Soni National Physics Laboratory, New Delhi	2 - 10 July 2006
Prof. D.V.G.L.N. Rao University of Massachusetts Boston	19 July - 4 August 2006
Ms. Kuntal Misra ARIES, Nainital	19 July - 30 Sept. 2006
Mr. Arif Ahmed Cochin University of Science & Tech. Cochin, Kerala	20 - 25 July 2007

Prof. E. Tosatti The Abdus Salam International Centre for Theoretical Physics, Italy	9 - 26 July 2006
Prof. Ashoke Sen Harish-Chandra Research Institute Allahabad	28 July 2006
Mr. Punyabrata Pradhan Tata Institute of Fundamental Research Mumbai	29 July - 22 August 2006
Prof. A R P Rau Lousiana State University, USA	30 July - 6 August 2006
Dr. Siddhartha Lal University of Koln, Germany	1 August 2006
Dr. Subir K Das Institute of Physical Sciences & Tech. University of Maryland, USA	1 - 2 August 2006
Mr. Radhakrishna Somanah Dept. of Physics, University of Mauritius	1 August - Sept. 18 2006
Dr. Shiraz Minwalla Tata Institute of Fundamental Research Mumbai	4 August 2006
Mr. Victor Acosta University of California Berkeley, U.S.A.	4 - 28 August 2006
Mr. Boby Joseph Institute of Physics Bhubaneswar	5 - 7 August 2006
Prof. Derek Kimball California State University East Bay	5 August 2006

Dr. C. S. Unnikrishnan Tata Institute of Fundamental Research Mumbai	8 - 12 August 2006
Dr. Chandrashekar Madaiah University of Oxford, UK	16 August 2006
Dr. Saswat Sarangi Columbia University, USA	18 - 25 August 2006
Mr. Nirmalya Karar National Physics Laboratory New Delhi	20 - 25 August 2006
Dr. David Lambert Texas	10 August 2006
Dr. John Philip IGCAR, Kalpakkam	20 - 24 August 2006
Dr. Aditi Sen ICFO – The Institute of Photonic Sciences, Spain	28 - 31 August 2006
Dr. Santosh Vadawale Physics Research Laboratory Ahmedabad	7 - 8 September 2006
Dr. Archana Majumdar S.N.Bose Centre, Kolkata	10 Sept. - 13 Sept., 2006
Dr. Kavita Jain Weizmann Institute of Science Israel	24 - 30 September 2006
Dr. Jagdish K Vij Trinity College, University of Dublin Ireland	28 September - 2 October 2006
Dr. Trieu Mai University of California, Santa Cruz	30 September - 26 October 2006

Ms. Chetna Jain Delhi University, Delhi	1 - 16 October 2006
Dr. P. A. Pramod University of Bayreuth, Germany	2 - 4 October 2006
Prof. Satoshi Yamamoto Graduate School of Science The University of Tokyo	29 October - 4 November 2006
Dr. Nimisha G Kantharia NCRA, Pune	1 - 7 November 2006
Dr. Subroto Mukerjee University of California, Berkeley	14 November 2006
Dr. Yogesh M Joshi Indian Institute of Technology Kanpur	15 November 2006
Dr. Vipin K Yadav Centre for Space Physics, Kolkata	20 November - 2 December 2006
Dr. Ashok Ambastha Physics Research Laboratory, Ahmedabad	21 - 23 November 2006
Dr. A. K. Pande ARIES, Nainital	21 - 22 November 2006
Prof. Govind Swarup NCRA, Pune	21 - 25 November 2006
Prof. Tamio Endo School of Engineering MIE University, Japan	5 December 2006
Prof. Deepak Mathur Tata Institute of Fundamental Research Mumbai	7 - 8 December 2006

Dr. Hasi Ray India Institute of Technology Roorkee Uttaranchal	8 - 15 December 2006
Prof. Kameshwar Wali Syracuse University	9 - 12 December 2006
Prof. Hakuta Dept. of Applied Physics & Chemistry Univeristy of Electro Communications Ohotu, Tokyo, Japan	11 - 13 December 2006
Dr. Sourin Das Weizmann Institute of Science Israel	15 - 16 December 2006
Dr. Anantha Ramakrishna S Dept. Of Physics, IIT, Kanpur	18 - 24 December 2006
Prof. Alain Aspect Institute d' Optique France	18 December 2006
Prof. G.S. Agarwal Oklahama State University U.S.A.	27 December 2006
Dr. N.M. Ashok } Dr. S. Vadawale } Physics Research Laboratory Ahmedabad	13 - 15 December 2006
Dr. Surajit Dhara Hyderabad Central University Hdyerabad	18 - 22 December 2006
Ms. Chetna Jain Delhi University, Delhi	23 December - 7 January 2007

Dr. Anand Yethiraj Memorial University of Newfoundland Canada	26 - 28 December 2006
Prof. A.R.P. Rau Lousiana Staff University, USA	3 - 7 January 2007
Prof. V. V. Sreedhar Indian Institute of Technology Kanpur	8 January - 7 June 2007
Prof. Manjari Bagchi Presidency College, Kolkata	8 - 13 January 2007
Ms. Kuntal Misra ARIES, Nainital	9 January - 6 February 2007
Mr. Pranesh A Sundarajan Massachussetts Institute of Technology USA	10 - 11 January 2007
Prof. Joanna Rankin University of Vermont, USA	11 - 14 January 2006
Dr. Archana Pai Albert-Einstein-Institute Germany	17 - 19 January 2007
Prof. Georg Pabst Austrian Academy of Sciences Graz, Austria	20 January - 10 February 2007
Dr. Guillaume Faye Institut d'Astrophysique de Paris France	20 January - 3 February 2007
Prof. Govind Swarup NCRA, Pune	22 - 26 January 2007
Mr. S. Tapde ECIL, Hyderabad	22 - 24 January 2007

Dr. Sanjay Kumar Banaras Hindu University Varanasi	24 January 2007
Prof. Oliver Morizot University of Paris, Nord Paris, France	26 January - 25 February 2007
Mr. Soobash Daiboo Mauritius Radio Telescope, Mauritius	29 January - end July 2007
Dr. Subhashis Roy ASTRON, Netherlands	4 - 6 February 2007
Prof. Dan Mckenzie Earth Sciences, Cambridge, UK	4 - 27 February 2007
Dr. Vaibhav Prabhudesai Tata Institute of Fundamental Research Mumbai	5 - 28 February 2007
Prof. Vinay Ambegaokar Cornell University, USA	10 February - 10 March 2007
Dr. Vikram Soni National Physics Laboratory, New Delhi	20 February - 5 March 2007
Prof. Oleg Lavrentovich Kent State University, Kent, Ohio, USA	19 - 21 February 2007
Dr. Rajesh K Nayak University of Texas at Brownsville, USA	19 - 22 February 2007
Mr. Alok Laddha Institute of Mathematical Sciences Chennai	21 - 24 February 2007

Dr. A Gopakumar Friedrich-Schiller-Universtat Germany	24 February - 3 March 2007
Dr. Sumithra Shankaraman University of Washington, USA	26 February 2007
Dr. Sandhya S.N. Indian Institute of Technology, Kanpur	28 February - 3 March 2007
Dr. V. Venkatasubramani } Dr. V.K. Kulkarni } Dr. Y. Gupta } NCRA, Pune	11 - 15 March 2007
Ms. Antonella Maselli MPA, Germany	18 - 22 March 2007
Prof. Anjan Barman Indian Institute of Technology, Delhi	21 - 23 March 2007
Dr. Soma Datta Dept. of Physics, North Eastern Hill University, Shillong	27 - 31 March 2007

ANNEXURE I

PUBLICATIONS

Papers in Journals

1. Broad band X-ray properties of GRO J1948+32/KS 1947+300
   Naik S*; Callanan P J*; Paul B
   Advances in Space Research **38**, 2771, 2006

2. Orbital phase spectroscopy of X-ray pulsars to study the stellar wind of the companion
   Mukherjee U*; Paul B
   Advances in Space Research **38**, 2774, 2006

3. Orbital evolution studies of two HMXB pulsars
   Raichur H; Paul B; Naik S*; Bhatt N*
   Advances in Space Research **38**, 2785, 2006

4. Imaging with the ASTROSAT scanning sky monitor
   Bhattacharya D
   Advances in Space Research **38**, 2999, 2006

5. Instantaneous radio spectra of giant pulses from the crab pulsar from decimeter to decameter wavelenghs
   Popov M V*; Kuzmin A D*; Ul'yanov O M*; Deshpande A A; Ershov A A*; and 5 co-authors
   Astronomy Reports **50**, 562, 2006

6. Extensive multiband study of the X-ray rich GRB 050408: A likely off-axis event with an intense energy injection
   de Ugarte Postigo A; Fatkhullin T A*; Bhattacharya D; Kamble A P; and 39 co-authors
   Astronomy and Astrophysics **462**, L57, 2007

7. Optical observations of GRB 060124 afterglow: A case for an injection break
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   Astronomy and Astrophysics **464**, 903, 2007

8. VLA observations of carbon 91α recombination line emission in W49 north
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   Astrophysical Journal **644**, 279, 2006

9. Very large array H53α line observations of the central region of NGC 253
   Rodriguez-Rico C A*; Goss W M*; Zhao J H*; Gomez Y*; Anantharamaiah K R
   Astrophysical Journal **644**, 914, 2006

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Hodge, Jacqueline*; Deshpande A A
Astrophysical Journal **646**, 232, 2006

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Naik S*; Callanan P J*; Paul B; Dotani T*
Astrophysical Journal **647**, 1293, 2006

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Das, Mousumi; Neil K O*; Vogel S N*; McGaugh S*
Astrophysical Journal **651**, 853, 2006

13. Intrinsic short-timescale variability in W3(OH) hydroxyl masers
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Astrophysical Journal **653**, 1314, 2006

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Dwarakanath K S; Nath, Biman B
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15. Imbalanced strong MHD turbulence
Lithwick Y*; Goldreich P*; Sridhar S
Astrophysical Journal **655**, 269, 2007

16. The Arecibo methanol maser galactic plane survey. I.Data
Pandian J D*; Goldsmith P F*; Deshpande A A
Astrophysical Journal **656**, 255, 2007

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Deshpande A A; Radhakrishnan V
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20. Orbital evolution and orbital phase resolved spectroscopy of the HMXB pulsar 4U 1538-52 with RXTE-PCA and BeppoSAX
Mukherjee U*; Raichur, H; Paul B; Naik S*; Bhatt N*
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21. GMRT and VLA observations at 49 cm and 20 cm of the HII region near l=24.8°, b=0.1°
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23. Origin of disc lopsidedness in the Eridanus group of galaxies
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28. HI imaging of galaxy clusters at z≈0.2, a pilot survey of Abell 963 and Abell 2192
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Soni, Vikram*; Bhattacharya, D
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Ramachandran, Hema; Kastberg, Anders*; Narayanan, Andal; Srinivasan R^+
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45. Spectral studies on Cu^{2+} doped sodium leadbismuthate glasses
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46. Langmuir-Blodgett films of octadecanethiol - properties and potential applications
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55. New symmetric and asymmetric supercapacitors based on high surface area porous nickel and activated carbon
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Journal of Power Sources **158**, 1523, 2006

56. Design and implementation of a wavelet-based addressing technique (WAT)
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57. Electron-transfer studies in a lyotropic columnar hexagonal liquid crystalline medium
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58. Dispersion of thiol stabilized gold nanoparticles in lyotropic liquid crystalline systems
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59. Structure of mesh phases in a cationic surfactant system with strongly bound counterions
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Langmuir **23**, 3606, 2007

60. Light induced formation of curved needle texture by circularly polarized light irradiation on a discotic liquid crystal containing a racemic chromium complex
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Liquid Crystals **33**, 671, 2006

61. Phase transitions in novel disulphide-bridged alkoxycyanobiphenyl dimers
Pal, Santanu Kumar; Raghunathan V A; Kumar, Sandeep
Liquid Crystals **34**, 135, 2007

62. Synthesis and characterization of lower size, laurylamine protected palladium nanoparticles
Rao, Chepuri R K*; Lakshminarayanan V; Trivedi D C*
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63. Effect of slow cooling on a discotic nematic liquid crystal: Evidences for nematic-nematic transitions
Vijayaraghavan D; Kumar, Sandeep
Molecular Crystals and Liquid Crystals **452**, 11, 2006

64. The effects of a laser field on phase transitions in liquid crystals
Agarwal, Amit K; Ranganath G S
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65. Microwave-assisted facile synthesis of liquid-crystalline alkoxycyanobiphenyls and their dimers
Bisoyi, Hari Krishna; Kumar, Sandeep
Phase Transitions **79**, 285, 2006

66. Mesomorphism in columnar phases studied by solid-state nuclear magnetic resonance
Dvinskikh S V*; Thaning, Johan*; Stevensson, Baltzar*; Jansson, Kjell*; Kumar, Sandeep; Zimmermann H*; Maliniak, Arnold*
Physical Review E **74**, 021703, 2006

67. Escape configuration lattice near the nematic-isotropic transition: Tilt analogue of blue phases
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Physical Review Letters **96**, 157801, 2006

68. Self-propulsion of nematic drops: Novel phase separation dynamics in impurity-doped nematogens
Thakur, Snigdha*; Sunil Kumar P B*; Madhusudana N V; Pullarkat P A*
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70. Slow dynamics, aging, and glassy rheology in soft and living matter
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Solid State Communications **139**, 589, 2006

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Karmakar S; Sarangi B R; Raghunathan V A
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72. Simultaneous purification and spectrophotometric determination of nickel present in as-prepared single-walled carbon nanotubes (SWCNT)
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73. Microwave-assited synthesis of novel imidazolium-based ionic liquid crystalline dimers
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Tetrahedron Letters **47**, 8993, 2006

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80. On recovering continuum topology from a causal set
Major, Seth*; Rideout, David*; Surya, Sumati
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81. Functional integral treatment of some quantum non-demolition systems
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Physical Review D **73**, 104021, 2006

84. Probing the nonlinear structure of general relativity with black hole binaries
Arun K G; Iyer B R; Qusailah M S S; Sathyaprakash B S*
Physical Review D **74**, 024006, 2006

85. Dirac quantization parametrized field theory
Varadarajan, Madhavan
Physical Review D **75**, 044018, 2007

86. Classical limit of master equation for a harmonic oscillator coupled to an oscillator bath with separable initial conditions
Banerjee, Subhashish; Dhar, Abhishek
Physical Review E **73**, 067104, 2006

87. Heat conduction in a confined solid strip: Response to external strain
Chaudhuri, Debasish*; Dhar, Abhishek
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Marathe, Rahul; Jayannavar A M*; Dhar, Abhishek
Physical Review E **75**, 030103, 2007

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Samuel J; Sinha, Supurna
Physical Review Letters **97**, 161302, 2006

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Srinivasan, Girija; Patil Y M; Rajan, Jacob
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*denotes co-authors who do not belong to RRI
+ denotes co-authors who are Visiting Professors

IN PRESS

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4. Nonequilibrium work fluctuations for oscillators in non-Markovian baths
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5. Light propagation through a coiled optical fiber and Pancharathan phase,
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7. Spatial and kinematical lopsidedness of atomic hydrogen in the Ursa major group of galaxies
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12. Hydrogen 2p-2s transition: Signal from the epoch of reionization and recombination,
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13. An environment-mediated quantum deleter
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16. Twist viscoelastic coefficient of novel thiol terminated alkoxy-cyanobiphenyl nematic liquid crystals
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18. Possible EIT-like effects in strong-fied photodissociation of carbon-di-sulphide
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19. The AGN and Gas Disk in the Low Surface Brightness Galaxy PGC 045080" 2007
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20. Observation of three-photon absorption and saturation of two-photon absorption in amorphous nanolayered Se/As_2S_3 thin film structures
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21. The Small-scale Structures in Interstellar HI: A resolvable puzzle?
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22. Gray shades in RMS responding displays with wavelets based on the Slant Transform Ruckmongathan, T.N.; Nadig; Deepa P. R. S and Ranjitha
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23. Line-by-line addressing of RMS responding matrix displays with wavelets
Ruckmongathan, T.N Arun V. and Kumar, Babu Hemanth
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24. Techniques with low hardware complexity of the driver electronics
Ruckmongathan, T.N.
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25. Geometric Flows and Black Hole Entropy (Samuel, Joseph; Roy, Chowdhury Sutirtha)
Classical and Quantum Gravity

26. Can we detect the anisotropic shapes of cosmic HII regions during reionization Through the small-scale redshifted 21cm power spectrum?
Sethi, Shiv K and Haiman, Zoltas
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27. Quantum zeno effect in the decoherent histories
Petros, Wallden,
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28. Trapping of neutral rubidium with a macroscopic three-phase electric trap. Rieger, T.; Windpassinger, P.; Rangwala, S.A.; Rempe G. and. Pinkse P.W.H
Physical Review Letters

29. Fluctuations at a constrained liquid-solid interface
Chaudhuri, Abhishek; Chaudhuri, Debasish and Sengupta Surajit
Physical Review E

ANNEXURE II

COLLOQUIA

Name	Title	Date
Alessandra Buonanno Institut de Astrophysique de Paris, France	Gravitational waves and the very early universe	3.4.2006 & 10.4.2006
Somak Raychoudhury University of Birmingham, U.K.	The evolution of galaxies in groups	4.4.2006
Rohini Balakrishnan Indian Institute of Science Bangalore	Acoustic communication in crickets: Solos, choruses and symphonies	6.4.2006
S. Dattagupta S.N. Bose National Centre for Basic Sciences, Kolkata	Quantal to classical crossover in a dissipative spin system	10.4.2006
Jagannath Jha Tata Institute of Fundamental Research Mumbai	Doped clusters in ultrashort intense laser fields	12.4.2006
Rajiv Bhatia SpotOptics s.r.l., Padova, Italy	Next generation wavefront sensors	19.4.2006
Sumati Surya Raman Research Institute Bangalore	Causal sets: A discrete approach to quantum gravity	20.4.2006
Ue-Li Pen University of Toronto Canada	Modeling and searching for first light in the universe	4.5.2006

Name	Title	Date
Tirthankar Roychowdhury Indian Inst. of Technology Kharagpur	Observational constraints on self-consistent models of reionization	23.5.2006
Bhas Bapat Physical Research Lab. Ahmedabad	Momentum spectroscopy of molecular fragmentation	30.5.2006
Tanmay Vachaspati Case Western Reservematter University	Cosmic problems for condensed experiment	12.6.2006
Tanmay Vachaspati Case Western Reservematter University	Cosmic problems for condensed experiment	19.6.2006
Kameswaran V Linkoping University Sweden	An efficient digital post-processing scheme for aperture delay mismatch compensation time-interleaved analog-to-digital converters	21.6.2006
R. Srikanth, RRI	Locking information in black holes	26.6.2006
R. Cowsik University of Washington U S A	1 Dwarf spheroidals and the dynamics of the dark matter halo of our galaxy	29.6.2006
	2 How to observe torsional normal model oscillations of the earth?	21.7.2006
Indranil Chattopadhyay Chungnam National Univer- Sity, South Korea	Equation of State in Numerical Relativistic Hydrodynamics	30.6.2006
Gary Horowitz University of California Santa Barbara, USA	Spacetime in string theory	3.7.2006
Sharada Srinivasan National Institute of Advanced Studies, Bangalore	Wootz steel: An advanced material of Indian antiquity	6.7.2006

Name	Title	Date
Sumati Surya Raman Research Institute	A guide to algebraic topology	12.7.2006
Nimisha G. Kantharia NCRA, Pune	Tidal and ram pressure effects in groups Holmberg 124 & 565	14.7.2006
Erio Tosatti SISSA & ICTP Trieste, Italy	New phenomena in simple theoretical studies of friction	20.7.2006
Sumati Surya Raman Research Institute	A guide to algebraic topology	24.7.2006
D V G L N Rao University of Massachusetts, Boston U S A	Slow light and photonic devices with biology	27.7.2006
Ashoke Sen Harish-Chandra Research Institute, Allahabad	Black hole entropy function	28.7.2006
Sumati Surya Raman Research Institute	A guide to algebraic topology	31.7.2006
Siddhartha Lal University of Koln Germany	Towards an understanding of transport through junctions in quantum-Hall systems	1.8.2006
A.R.P. Rau Louisiana State University Baton Rouge, USA	Three bodies bind even when two do not	1.8.2006
Subir K. Das University of Maryland U S A	Critical dynamics in fluids: Verifying theory through simulations	2.8.2006
Subir K.Das Institute for Physical Science and Technology, University of Maryland, USA	Critical Dynamics in Fluids: Verifying theory through simulations	2.8.2006

Name	Title	Date
G Srinivasan Raman Research Institute (Retired), Bangalore	Spinning up a star	3.8.2006
Shiraz Minwalla Tata Institute of Fundamental Research Mumbai	Black holes in Yang Mills theory	4.8.2006
G. Horowitz University of California Santa Barbara, USA	A new end point for Hawking evaporation	7.8.2006
Punyabrata Pradhan Tata Institute of Fundamental Research Mumbai	Probability distribution of residence times of grains in sandpile models	8.8.2006
C S Unnikrishnan Tata Institute of Fundamental Research Mumbai	Chasing light in the once given universe: First measurements of the one-way speed of light and implications to relativity	9.8.2006
Jogesh Babu Pennsylvania State University U S A	Statistical problems in astronomy	11.8.2006
C S Unnikrishnan Tata Institute of Fundamental Research Mumbai	Experiments with laser-cooled atoms and Bose-Einstein condensates near sufaces and in cavities: can one get to probe the dark side of Physics?	11.8.2006
Derek F. Kimball California State University [East Bay]	Gravitational dipole moment of elementary particles and the matter/ antimatter asymmetry of the universe	14.8.2006
Chandrashekar Madaiah University of Oxford, UK	Quantum (Hadamard) walks and its implementation using BEC	16.8.2006
Derek F. Kimball California State University East Bay, USA	A new search for an atomic gravitational dipole moment	17.8.2006

Name	Title	Date
Saswat Sarangi Institute of Strings, Cosmology & Astroparticle Physics, Columbia University, NY	Brane Cosmology and the string landscape	21.8.2006
Aditi Sen (De) The Institute of Photonic Sciences, Spain	Computation and communication in a quantum world	29.8.2006
K.Sekar Department of Psychiatric Social Work, NIMHANS	Psychosocial care for survivors of disaster	31.8.2006
Demian Cho	What is Instanton? Story of Vacuum Decay	4.9.2006
Rama Chari Centre for Advanced Technology, Indore	Fibre nonlinearity as a monitor of of ultrashort pulse characteristics	7.9.2006
Sudip Bhattacharyya University of Maryland, USA	What can thermonuclear X-ray Bursts tell us about Neutron Stars	11.9.2006
Bhanu Pratap Das Indian Institute of Astrophysics Bangalore	Present and future atomic clocks	21.9.2006
Kavita Jain Weizmann Institute of Science, Israel	Deterministic and stochastic regimes of asexual evolution on rugged fitness landscapes	27.9.2006
Pramod Pullarkat Institute of Physics University of Bayreuth Germany	Understanding cell mechanics: from axonal instabilities to oscillating cells	3.10.2006

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P. Sreekumar ISRO Satellite Centre Bangalore	Chandrayaan –1: India's first Mission to the Moon	5.10.2006
Michael Dopita The Australian National University, Australia	All about HII regions	17.10.2006
Satoshi Yamamoto University of Tokyo Japan	Chemical evolution of molecular clouds	31.10.2006
Divya Sharma Raman Research Institute	Investigation of wave propagation in random and specially structured media	31.10.2006
Vijay Kumar The Institute of Mathematical Sciences, Chennai	Computer aided design of Nanomaterials: Predictions of silicon fullerenes and nanotubes	2.11.2006
Piotr Crusciel Dept. of Mathematics of Universite de Tours, France	Is there a satisfactory uniqueness theory for stationary black holes	13.11.2006
Subroto Mukerjee University of California Berkely, USA	Aspects of high temperature transport in strongly correlated systems	14.11.2006
Yogesh M. Joshi Dept. of Chemical Engg., IIT, Kanpur	Aging Dynamics in soft glasses	15.11.2006
Avinash A. Deshpande Raman Research Institute Bangalore	Evidence for collimated particle beams from pulsars and precession	16.11.2006
Nikolay Zheludev University of Southampton Southampton	"Planar meta-materials: "invisible metals", magnetic mirrors, chirality, asymmetric transmission and sub-wave length focusing	24.11.2006

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Victoria M. Kaspi McGill University Physics Dept., Quebec, Canada	Observations of young neutron stars: The high magnetic field puzzle	28.11.2006
Anindya Rana Sinha National Institute of Advanced Studies & Nature Conservation Foundation, Mysore	How monkeys see the world: The search for an animal mind	30.11.2006
Hirofumi Yamasaki AIST, Tsu, Japan	Deposition of thick high-current-density $Yba_2Cu_3O_7$ films without microcracks on CeO_2-buffered sapphire substrates for fault-current limiters	5.12.2006
Tamio Endo Mie University Tsu, Japan	Magnetic properties of LBMO thin films – phase separation and magnetostriction models	5.12.2006
P. Sreekumar ISRO Satellite Centre Bangalore	Chandrayaan-1: India's first mission to the Moon	7.12.2006
Tom Statler Astrophysical Institute Ohio University, USA	The hot interstellar medium in normal elliptical galaxies	8.12.2006
Kameshwar Wali Syracuse University New York, USA	Bose and Einstein: The discovery of Bose-Einstein statistics	11.12.2006
Mohan Srinivasarao Georgia Inst. of Technology Atlanta, USA	Nematic liquid crystals at polymer interfaces	11.12.2006
Kohzo Hakuta University of Electro- Communictions, Tokyo Japan	Optical nano fibers for manipulating and probing single atom fluorescence	12.12.2006

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Hasi Ray Indian Inst. of Technology Roorkee	The physics of atoms through collision of positronium (Ps)	13.12.2006
Sourin Das Weizmann Inst. of Science Israel	Quasi-particle tunneling across an insulating island in fractional quantum hall edge states (FQHE)	15.12.2006
Alain Aspect Laboratoire Charles Fabry, Institut d'Optique, Palaiseau, France	Wave-particle duality with a single photon: the delayed choice *Gedanken Experiment* at last a real experiment	18.12.2006
S. Anantha Ramakrishna Indian Inst. of Technology Kanpur	Negative refraction at optical frequencies	22.12.2006
G S Agarwal Oklahoma State University U S A	Realization of quantum mechanical weak values of observables using entangled photons	27.12.2006
Anand Yethiraj Department of Physics Memorial University of Newfoundland, Canada	Tunable colloids	28.12.2006
E.N.Parker University of Chicago, USA	X-ray Astronomy & the Maxwell Stress Tensor	5.1.2007
Manjari Bagchi Presidency College, Kolkata	Strange Stars: An interesting member in the compact object family	9.1.2007
Pranesh A Sundararajan Massachusetts Institute of Technology, Cambridge	Numerical evolution of black hole perturbations	10.1.2007
Ashoka V. Sathanur DAUIN,Politecnico di Torino, Turin, Italy	Design challenges in Nano CMOS	10.1.2007

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Joanna M Rankin University of Vermont, USA	Connecting Pulsar Phenomena with the Emission Physics	12.1.2007
Lord Rees President, Royal Society, London	21st Century Science: Cosmic Perspectives and Terrestrial Challenges	12.1.2007
Archana Pai Albert-Einstein Institute Germany	Best Net-CC: Detection of unmodeled chirps with a Gravitational Wave interferometric network	17.1.2007
Archana Pai Albert-Einstein Institute Germany	Optimal source tracking and beaming of LISA	18.1.2007
Gulab Chand Dewangan Dept. of Physics, Carnegie Mellon University, Pittsburgh, USA	X-ray emission from Active Galactic Nuclei & Ultra-luminous X-ray sources	18.1.2007
Mats Jonson Goteborg University, Sweden	Quantum Nano-Mechanics	18.1.2007
Gulab C. Dewangan Carnegie Mellon University USA	Soft X-ray excess, broad iron line and Compton reflection from Seyfert galaxies	19.1.2007
Deepak G. NXP Semiconductors BV The Netherlands	Development of Rail Based ESD Protection Techniques for DC/DC Converters	19.1.2007
Rajesh Nayak University of Texas atwith Lisa Brownsville, USA	Gravitational wave astronomy	19.1.2007
Rajesh Nayak University of Texas Brownsville, USA	Tomographic approach to at resolving galactic binaries	20.1.2007

Name	Title	Date
Guillaume Faye Institut d'Astrophysique De Paris, France	Higher-order spin effects in the dynamics of compact binaries-II	22.1.2007
Andy Ruina Cornell University New York, USA	Energetics of legged locomotion: People and Robots	23.1.2007
Sanjay Kumar Banaras Hindu University, Varanasi	Force induced transitions in biopolymers	24.1.2007
Rafael D. Sorkin Syracuse University, USA	Quantum dynamics without the wave function	25.1.2007
Andrew M. Essin, David J. Griffiths	Quantum Mechanics of the $1/x^2$ potential	25.1.2007
Guillaume Faye Institut d'Astrophysique De Paris, France	Higher-order spin effects in the dynamics of compact binaries-II	29.1.2007
Rama Govindarajan JNCASR, Bangalore	Why and how a shear flow becomes turbulent	1.2.2007
Subhashis Roy ASTRON, The Netherlands	Recent low frequency studies near the Galactic Centre	5.2.2007
Georg Pabst Institute of Biophysics and Nanosystems Research, Austrian Academy of Sciences, Graz, Austria	How Interdigiated Phase Formation may couple to lipid/peptide interactions	7.2.2007
Deepak Dhar TIFR, Mumbai	Orientational ordering of long rods on a lattice	13.2.2007
Olivier MORIZOT University of Paris, France	Bose-Einstein condensation and low dimensions rf traps	19.2.2007
Oleg Lavrentovich Kent State University, Kent Ohio, U.S.A.	Lyotropic chromonic liquid crystals	20.2.2007

Name	Title	Date
Vinay Ambegaokar Cornell University, USA	Equilibration of a dissipative quantum oscillator	21.2.2007
B.S. Girish Raman Research Institute Bangalore	Digital backend receivers – a status review	21.2.2007
Achamveedu Gopakumar Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universitat, Jena, Germany	Gravitational wave astronomy	26.2.2007
Vaibhav S. Prubhudesai TIFR, Mumbai	Controlling molecular fragmentation using electrons	26.2.2007
Sumithra Sankararaman Dept. of Physics, Washing-Ton University in St. Louis, USA	Entropic compression of interacting DNA loops	26.2.2007
J.S.Bagla HRI, Allahabad	Does size matter: Effects of finite box size in cosmological N-body simulations	27.2.2007
Achamveedu Gopakumar Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universitat, Jena, Germany	Inspiral dynamics of compact binaries: its applications and implications	27.2.2007
Syama Sundar Joshi and Dr.Shantha Joshi Univ. of Agricultural Sciences, Bangalore	More Crop per drop	28.2.2007
Vinay Ambegaokar Cornell University, USA	Entropy and time	1.3.2007
Vaibhav S. Prabhudesai TIFR, Mumbai	Velocity map imaging for low energy electron experiment	1.3.2007

Name	Title	Date
Vikram Soni National Physical Laboratory	Diversity increases the lifetime and stability of a model evolutionary Network	2.3.2007
Gary J. Ferland University of Kentucky, USA	Orion: A case study of star formation in a magnetized medium	14.3.2007
Rohini Godbole Centre for High Energy Physics, IISc, Bangalore	Physics at the Large Hadron Collider (LHC)	15.3.2007
Antonella Maselli Max Planck Institute for Astrophysics, Garching, Germany	Radiative transfer simulations for studying the intergalactic medium	20.3.2007
B.Ananthanarayan CHEP, IISc., Bangalore	Low energy strong interactions at high precision	21.03.2007
Anjan Barman IIT, Delhi	Ultrafast nanomagnets & their coherent control: future perspective	22.3.2007
Petros Wallden Raman Research Institute	Introduction to the Quantum Mechanics of Closed Systems	27.3.2007
Soma Datta Dept. of Physics, North Eastern Hill University, Shillong	Vibrational band shape analysis and intermolecular interactions in some complex molecules	28.3.2007
V.V.Sreedhar Assoc. Professor, Chennai Mathematical Institute, Chennai	Classical topology and quantum entanglement	29.3.2007

ANNEXURE III

JOURNAL CLUB

Discussed by	Paper discussed	Date
Raghunathan A	Noise-enhanced cutaneous sensitivity in patients with diabetes and stroke Jason D. Harry, James B. Niemi, Attila A. Priplata and James J. Collins *IEEE Spectrum*, **42**, 28 (2005)	13.4.2006
Joseph Samuel	Fate of the Josephson effect in thin-film superconductors Michael Hermele, Gil Refael, Matthew P.A. Fisher and Paul M. Goldbart *Nature Physics*, **1**, 117 (2005)	13.4.2006
D. Vijayaraghavan	Nanomotor rotates microscale objects Javier Vicario *et al.* *Nature*, **440**, 163 (2006)	11.5.2006
Sandeep Kumar	Covalently bridging gaps in single-walled carbon nanotubes with conducting molecules Xuefend Guo *et al.* *Science*, **311**, 356-359 (2006)	11.5.2006
Raghunathan A	Noise-enhanced cutaneous sensitivity in patients with diabetes and stroke Jason D. Harry, James B. Niemi, Attila A. Priplata and James J. Collins *IEEE Spectrum*, **42**, 28 (2005)	25.5.2006
Biman Nath	A low level of extragalactic background light as revealed by gamma-rays from blazars F. Aharonian *et al.* *Nature*, **440**, 1018 (2006)	25.5.2006
Anish Roshi D	The large-scale axisymmetric magnetic topology of a very-low-mass fully convective star Jean-Franois Donati *et al.* *Science*, **311**, 633-635 (2006).	22.6.2006
Sethi S K	Recent WMAP Results	22.6.2006

Discussed by	Paper discussed	Date
Mousumi Das	Radio emission on sub-parsec scales from the intermediate mass black hole in NGC 4395 J.M. Wrobel and L.C. Ho *Astroph Journal Letters*, 0606600 (2006)	13.7.2006
Arun Roy	Crystallization of a quasi two-dimensional granular fluid P.M. Reis *et al.* *Phys. Rev. Lett.*, **96**, 258001 (2006)	27.7.2006
Supurna Sinha	Mach cone in a shallow granular fluid P. Heil *et al.* *Phys. Rev. E*, **70**, 060301(R) (2004)	27.7.2006
Andal Narayanan	Cochlea's graded curvature effect on low frequency waves D. Manoussaki *et al.*, *Phys. Rev. Lett.* **96**, 088701 (2006)	10.8.2006
Sumati Surya	The first axion? E. Zavattini *et al.*, *Phys. Rev. Lett.* **96**, 110406 (2006)	10.8.2006
Rahul Marathe	Ising model for a Brownian donkey B. Cleuren, *et al.*, *Europhys. Lett.*, **54(1)**, 1-6 (2001)	24.8.2006
Diptiman Sen	Electrical and thermal conductance of quantum wires: when are they related? O.Chiatti *et al.*, *Phys. Rev. Lett.*, **97**, 056601 (2006)	24.8.2006
Joseph Samuel	**Special Journal Club Session on** ***The Poincare Conjecture***	14.9.2006
Deshpande A A	Tests of general relativity from timing the double pulsar M. Kramer *et al.* *Science Express*, 14th September 2006	28.9.2006

Discussed by	Paper discussed	Date
Srikanth R	Experimental interference of independent photons R. Kaltenbaek *et al.* *Phys. Rev. Lett.*, **96**, 240502 (2006).	28.9.2006
Biswajit Paul	Detection of small solar system objects by X-ray occultation Hsiang-Kuang Chang *Nature*, **442**, 660 (2006)	12.10.2006
Bibhu Ranjan Sarangi	Suppressing Brownian motion of individual biomolecules in solution Adam E. Cohen *et al.* *PNAS*, **103(12)**, (2006)	12.10.2006
Santanu Kumar Pal	Switchable surfactants Yingxin Liu *et al.* *Science*, **313**, 958 (2006)	26.10.2006
Udaya Shankar N	Signals from the noise: Image stacking for quasars in the first survey R.L.White *et al.*, *Astro-Ph.*, **2**, 0607335 (5 September 2006)	26.10.2006
Ravi Subrahmanyan	**Special Session on the Nobel Prize in Physics, 2006**	9.11.2006
Ruckmongathan TN	High-performance transparent inorganic-organic hybrid thin-film *n-type* transistors Lian Wang *et al.* *Nature Materials*, **5**, (November 2006)	23.11.2006
Abhishek Chaudhuri	Solitary modes of bacterial culture in a temperature gradient H.Salman *et al.*, *Phys. Rev. Lett.*, **97**, 118101 (2006)	11.1.2007
Shivakumar Jolad Penn State University USA	Numerical tests of the chiral Luttinger liquid theory for fractional hall edges J.J. Palacios and A.H. Macdonald *Phys. Rev. Lett.*, **76**, 118-121 (1996)	11.2.007

Discussed by	Paper discussed	Date
Petros Wallden	Quantum dynamics without the wave function Rafael D. Sorkin *Journal of Physics A*, **arxive: quant-ph / 0610204**	25.1.2007
Demian Cho	Quantum mechanics of the $1/x^2$ potential Andrew M. Essin, David J. Griffiths *Am. J. Phys.* **74 (2)**, 109 (2006)	25.1.2007
Suresh Kumar P.	Photoconductive coaxial nanotubes of molecularly connected electron donor and acceptor layers Yohei Yamamoto *et al.*, *Science*, **314**, 1761, (15 December 2006)	8.2.2007
Anish Roshi D.	New measurements of cosmic infrared background fluctuations from early epochs Kashlinsky *et al.*, *Astrophysical Journal Letters*, **654**, L5 (2007)	8.2.2007
Hema Ramachandran	Six-axis inertial sensor using cold-atom interferometry B. Canuel *et al.*, *Phys. Rev. Lett.*, **97**, 10402-10404, (2006)	22.2.2007
Dipankar Bhattacharya	Pulsar spins from an instability in the accretion shock of supernovae J.M.Blondin and A.Mezzacappa *Nature*, **445**, 58-60 (2007)	22.2.2007
Biman Nath	The removal of cusps from galaxy centres by stellar feedback in the early universe Sergey Mashchenko *et al.*, *Nature*, **442**, 539 (2006)	8.3.2007
Anish Roshi D.	New measurements of cosmic infrared background fluctuations from early epochs *A.* Kashlinsky *et al.*, *Astrophysical Journal Letters*, **654**, L5 (2007)	8.3.2007

Discussed by	Paper discussed	Date
Sunita Nair	Discovery of a probable physical triple quasar S.G.Djorgovski *et al.*, *ApJL, astro-Ph*/0701155 (2006)	22.3.2007
V.V.Sreedhar	Two-timing nature Itzhak Bars *et al.*, *Quant. Grav.*, **18**, 3113-3130 (2001)	22.3.2007

List of Abbreviations

ARIES	Aryabhatta Research Institute of Observational Sciences
ASTROSAT	ISRO's Astronomical Satellite
BARC	Bhabha Atomic Research Centre
CITA	Canadian Institute for Theoretical Astrophysics
CREST	Centre for Research and Education in Science & Technology
FPGA	Field Programmable Gate Array
GAGAN	GPS Aided Geo-augmented Navigation
GMRT	Giant Meterwave Radio Telescope
HERA	Heterodyne Receiver Array
HESS	High Energy Stereoscopic System
HI	Atomic Hydrogen
HII	Ionized Hydrogen
IGM	Inter Galactic Medium
IAP	Institut d Astrophysique de Paris
IAS	Institute for Advanced Study
IIA	Indian Institute of Astrophysics
IAA	CSIC - Instituto de Astrofísica de Andalucía
INSAT	Indian National Satellite
IRAM	Institut de Radioastronomie Millimetrique
ISAS	Institute of Space and Astronautical Science
ISRO	Indian Space Research Organisation
JIVE	Joint Institute for VLBI in Europe
JPL	Jet Propulsion Laboratory
HEMT	High Electron Mobility Transistor
HMXB	High Mass X-ray Binary
LNA	Low Noise Amplifier
LAXPC	Large Area Xenon Proportional Counter
LMXB	Low Mass X-ray Binary
MHD	Magneto Hydro Dynamics
MPIFR	Max Planck Institute for Radio Astronomy
NGC	New General Catalogue
NCRA	National Centre for Radio Astrophysics
OH	Hydroxyl Radical
ORT	Ooty Radio Telescope
RFI	Radio Frequency Interference
r.m.s.	root mean square
RXTE	Rossi X-ray Timing Explorer
SATNAV	SATallite NAVigation
TIFR	Tata Institute of Fundamental Research
UA	University of Alabama
UMD	University of Maryland
VLBI	Very Long Baseline Interferometry
VSAT	Very Small Aperture Telescope
XTE	X-ray Timing Explorer

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