RAMAN RESEARCH INSTITUTE

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CONTENTS

PREAMBLE

As in the previous years, the Annual Report is a terse account of the main scientific activities of the Institute. It also gives, as part of the introduction, a general background to and the flavour of the research activities at the Institute, written in plain language for an uninformed but interested reader. The Annual Report gives the list of papers published in scientific journals, discussion meetings and seminars/colloquia held, and of the Ph.D. degrees awarded during the period 1 April 2002 to 31 March 2003. It also lists the visitors to the Institute – 41 of them from different parts of the world during this period.

As in the past a Summer Programme in Physics was held, 13 May - 30 June, 2002. The two other important events that took place during the year were: (1) A Discussion Meeting on Recent Advances in Loop Quantum Gravity held 28 November to 9 December 2002, and (2) A Conference on Liquid Crystals and Soft Materials held 18-20 December 2002 to **celebrate the Silver Jubilee of the discovery of Columnar Liquid Crystals at the Institute.** Details are given on page 31 of the Report.

A Department-Related Standing Committee of the Parliament on Science & Technology, Environment and Forests, led by Mr. C. Ramachandraiah, visited the Institute on 7 September 2002.

The collaborative scientific work covered in the Report and the list of visitors indicate the extent of national and international interactions of the Institute. The list of RRI colloquia given by the members of the Institute, by those from the neighbouring institutions, and by the visitors at the Institute clearly reflect the breadth of the areas covered.

Two Ph.D. degrees were awarded to the students of the Institute, and three have submitted their theses during the year. Research papers published in refereed journals and in conference proceedings for the same period counted 52 and 34 respectively, apart from an invited review and a few popular articles.

Bangalore
20 September 2003

N. KUMAR
Director

RAMAN RESEARCH INSTITUTE
Bangalore

Annual Report 2002-2003

INTRODUCTION

The Raman Research Institute founded by Prof. C.V. Raman in the late forties was reorganised, after his death in 1970, as a national Institute for research in basic science, and it 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, Theoretical Physics (gravitation and polarization optics), Liquid Crystals (thermotropic and polymeric), Astronomy & Astrophysics (radioastronomy, interstellar medium, and pulsars). More recently, research in high-energy astrophysics (X-rays and γ-rays) and cosmology has been initiated. Also, the Liquid Crystals research has been expanded so as to include soft-condensed matter and biological physics (studies on membranes and single-DNA segments). Also, an Optics Lab has been set up for studying laser cooling and trapping of atoms, imaging through turbid media, and ultra-fast atomic processes using femtosecond (10^{-15} s) laser pulses.

1. Theoretical Physics

Here research is focussed on two main areas – gravitation and polarization optics. Gravitation is known to be the weakest of all known forces of nature, but it dominates all structure and motion on the astronomical scale because of its attractive universality (everything gravitates everything else), its long range, and the fact that matter on the large scale is essentially neutral. The correct theory of gravitation is now believed to be Einstein's General Theory of Relativity (GTR). One of the fundamental predictions of GTR is that of gravitational waves – waves of distortion of spacetime itself – propagating at a finite speed (of light). This replaces the Newtonian gravitational force which was instantaneous. Such waves are expected to be emitted when, e.g., two massive inspiralling stars tend to coalesce under their mutual gravitational attraction. Accurate calculation of this gravitational radiation – its waveform – has been one of the major research programmes in the Theoretical Physics Group at the Institute, and is expected to be a crucial input towards its eventual detection. It is hoped that these gravitational waves, though abysmally weak in strength, will be detected by the ultra-sensitive gravitational wave detectors expected to become operational in a few years in different parts of the world. One such detector LIGO (in the USA) is already on trial runs. Space based detectors (LISA) are also being planned internationally.

Einstein's General Theory of Relativity is central to the study of universe as a whole (cosmology) as also to the study of compact self-gravitating objects, such as the black holes – yet another prediction of Einstein's General Relativity. So intense is the Black Hole gravity that nothing, not even light can escape from its interior. There is little doubt now about their existence. While the theory has a beautiful geometrical structure, it is a challenge to analyse the behaviour of gravitational field and its coupling to matter and other fields as the equations involved are nonlinear – interactions too interact! Many conceptual questions and aspects of the formal structure continue to be fruitfully investigated more than seventy years after the theory came into being. Over the years, the work at the Institute has ranged over topics such as perturbations, the exploitation of symmetries, rotation and the analogy with magnetic fields, and a new Lagrangian formulation. One of the challenges in the field is to make contact with quantum theory, i.e., to combine consistently the two great framework theories of the twentieth century – the general theory of relativity and quantum mechanics. This is a long term programme. But some work on Quantum Gravity has already emerged at the Institute.

Coming now to optics, two of the main interests have been in propagation of light waves in periodic media (like some liquid crystals) and the associated polarization phenomena, including the now well known geometric phase. There is a pleasing continuity with work in the fifties at the Institute on the optics of crystals and minerals. At the same time, introduction of a more modern viewpoint and techniques, bring about connections with other areas such as quantum theory, differential geometry, etc. In addition, astrophysics throws up a whole range of interesting optical problems in areas like that of gravitational lensing (i.e., bending and focussing of light rays by the strong gravitational fields of massive stars and galaxies which, therefore, act as lenses), scintillation and quantum effects in radiation and detection, making the study of optics in a broad sense particularly appropriate to this Institute. Indeed, RRI has been home to Optics!

2. Optics

In view of the rapid and important recent advances happening worldwide in modern optics, its clearly enormous potential, and taking full advantage of our proven traditional strength in this field, a modern optics laboratory has been set up at the Institute with facilities to address several interesting and basic questions involving, e.g., cooling and trapping neutral atoms using laser lights, studying fast atomic processes using ultra-short light pulses barely 10^{-15} second wide, polarization optics and geometrical phases, interferometry, and imaging through turbid media, and non-linear optics. This is expected to have

substantial overlap with our research activities in the field of liquid crystals and astronomy.

3. Liquid Crystals

Liquid Crystals are states of condensed matter showing a variety of orderings of molecular positions and orientations intermediate between those of liquids and crystalline solids. Thus, for example, we may have a crystalline periodicity along one direction and a liquid-like, albeit viscous, fluidity in the planes perpendicular to that direction – the so-called smectic (soap-like) liquid crystals. We can also have the nematic liquid crystals in which the rod-like molecules are orientated parallel to a certain direction on the average, but without any positional order. Yet another kind of liquid crystal is the discotic one in which the disc-like molecules form liquid-like parallel columns which are, however, arranged periodically in the plane perpendicular to the columns. Many other complex forms of ordering are known. Many organic compounds whose molecules have pronounced shape anisotropy exhibit such phases. The unique combination of fluidity, softness and anisotropic properties of liquid crystals makes them readily respond to even a weak external stimulus, for example, an applied electric field. This has led to many technological applications of these materials, e.g., the very common liquid crystal displays. The Liquid Crystals Laboratory of the Raman Research Institute has contributed outstandingly to the development of this field over the past three decades.

The laboratory has been organised to undertake studies of most of the fundamental properties of liquid crystals. Theoretical and experimental work on liquid crystals covers areas like their unique mechanical and electrical properties, defects, X-ray and light scattering, and synthesis of new materials. Work on applications such as the liquid crystal displays is also being carried out. A new dimension has now been added to our LC research – the study of soft-condensed matter including membranes and the single-DNA molecules which are of great biological-physical significance.

4. Astronomy and Astrophysics

Astronomy, which is one of the oldest sciences, studies heavenly bodies, i.e., planets, stars, galaxies, clusters of galaxies, and the intervening matter such as gas and dust, and, indeed, the universe as a whole – its beginning, its large-scale structures and its evolution. This, it does by investigating the radiation received on earth from or through them. Optical Astronomy deals with the visible part (wavelength 300 nm to 650 nm, 1 nm = 1 nanometre = 10^{-10} metre) of the electromagnetic spectrum. Radioastronomy, which had its beginnings in 1932 also deals with the study of these heavenly bodies, but the radiation

received by the radio telescopes on earth is in the radio range of wavelengths (30 metres to 1 millimetre) of the same electromagnetic spectrum. The lower and upper limits in wavelength of the radio spectrum are set by the earth's atmosphere and ionosphere respectively. In spite of these limitations, the radio window is very wide (30,000 to 1 compared to the 2:1 wavelength ratio in the visible part), and studies within it over the years have yielded information leading to many exciting discoveries, such as the 3 degree kelvin cosmic background radiation (a relic from the hot big bang origin of the universe which is estimated to have taken place about 14 billion years ago, and which in fact, contributes some of the noise ("snow") on our TV channels even today!); quasars (very bright but very distant quasi-stellar sources of radiation), pulsars (rotating neutron stars barely 10 kilometres in diameter, but still about as massive as the Sun); and now almost certainly the black holes (gravitationally collapsed objects from which even light cannot escape).

The Raman Research Institute has observational programmes in Radio Astronomy extending over most of the available radio spectrum. It has set-up a Decametrewave Radio Telescope at Gauribidanur about 80 km from Bangalore, jointly with the Indian Institute of Astrophysics. It is one of the few largest among the telescopes in the world operating at a wavelength of 10 metre and is being used to study radio emission from various types of celestial objects such as the Sun, Jupiter, and the radio sources of various kinds in our Galaxy and external Galaxies. Moving to somewhat shorter wavelengths, members of the Institute use the Ooty Radio Telescope (ORT) operated by the Tata Institute of Fundamental Research (TIFR), Mumbai. This instrument operates at a wavelength of approximately 1 metre and is used for carrying out observations of pulsars, and nebulae of various kinds in the Galaxy. There is an active programme under way to make observations using the Giant Metre wavelength Radio Telescope (GMRT), built by TIFR near Pune. In fact, RRI was and is deeply involved in the GMRT instrumentation. Another interactive project is the low-frequency (150 MHz) Mauritius Radio Telescope (MRT) built at Mauritius by RRI in collaboration with the University of Mauritius and the Indian Institute of Astrophysics. A radio map of the southern sky at full resolution of 4 arcminute × 4 arcminute is getting ready.

During the past two decades, millimetrewave astronomy has assumed great importance because of the discovery of numerous molecules in the vastness of the interstellar space (combinations of Hydrogen, Carbon, Nitrogen, Oxygen, Silicon, etc.). These are identified by their emitted line radiation (spectra) in the shortest wavelength region of the radio spectrum. These molecules are generally found in dense molecular clouds in our own and other Galaxies, where star formation is thought to be taking place. The Raman Research

Institute has set-up a millimetrewave telescope of diameter 10.4 metre on campus, which is being used for such studies.

In addition to the above observational programmes, the Institute has theoretical research programmes in many areas of Astrophysics, e.g., Pulsars, their evolution, structure and the emission mechanism; Supernova Remnants; the Inter-Stellar Medium; Galaxies and large-scale structure in the universe and cosmology; and high-energy astrophysics – the X-ray astronomy and the gamma-ray bursts.

A detailed, but admittedly technical account of the work carried in the past year at RRI is given in the pages that follow.

THEORETICAL PHYSICS (TP)

AREAS OF RESEARCH: Condensed Matter & Statistical Physics
Physics in Biology
Optics, Quantum Mechanics & General Physics
Gravitation

CONDENSED MATTER AND STATISTICAL PHYSICS

Carbon nanotube flow sensors: It is reported that the flow of a liquid on single-walled carbon nanotube bundles induces a voltage in the sample along the direction of the flow. The voltage that was produced fit a logarithmic velocity dependence over nearly six decades of velocity. The magnitude of the voltage depended sensitively on the ionic conductivity and on the polar nature of the liquid. Measurements suggest that the dominant mechanism responsible for this highly nonlinear response involves a direct forcing of the free charge carriers in the nanotubes by the fluctuating Coulombic field of the liquid flowing past the nanotubes. An explanation is proposed based on pulsating asymmetric ratchets. This work highlights the device potential for nanotubes as sensitive flow sensors and for energy conversion. [N. Kumar + Shankar Ghosh and A.K. Sood (IISc)].

Bosonic stimulation and the irreproducibility of condensate fragmentation: It is pointed out that the quantum statistical phenomenon of Bosonic stimulation, inherent to Bose statistics and the associated Bose-Einstein correlation, can be effectively mapped on to the statistical problem of the Polya urn scheme. Thus, an irreproducibility for the limiting non-degenerate values of the relative populations of two, or more equivalent but separated condensates is predicted resulting from the fragmentation of a given source condensate. Experiments are proposed that should verify this prediction - using the dilute gas Bose-Einstein condensates, or a pulsed degenerate multi-mode laser, where one would look for the run-to-run (or the pulse-to-pulse) fluctuations of the relative populations. [N. Kumar].

Stripes and the Cuprate Superconductors: Stripes can be traced back to the early 1990s, or even earlier. Over the years, experimental evidence has been steadily mounting in support of the theoretical proposition that the high-temperature superconductors (HTSC) may be intrinsically inhomogeneous in the distribution of their spins and charges in the CuO_2 sheets, and that this inhomogeneity may hold a clue to the very mechanism of high-T_c superconductivity in these cuprate layered perovskites. This in-plane inhomogeneity is, however, self-organized in an interesting way as a one-dimensional (1D) alternant spin and charge density modulations in the two-

dimensional (2D) CuO_2 sheets – that is, as stripes. The growing realization that the stripes matter, has indeed enlivened the debate on, and emphasized once again the incompleteness in our understanding of, high temperature superconductivity in these ceramic materials, discovered way back in 1986, by Bednorz and Müller. Any discussion of the role of stripes in the high-T_c layered cuprates is necessarily inconclusive at present. It is possible, however, that stripes may well be a solitonic route to hole doping. In any case, as of now the stripes cannot confidently signify superconductivity. [N. Kumar + C.N.R. Rao (JNCASR)].

Transport in nonlinear systems with directional asymmetry: The problem of wave propagation in a nonlinear medium with a left-right directional asymmetry was studied. Unlike in linear systems, there is non-reciprocity in energy propagation from left-to-right and right-to-left. This leads to the possibility of directional energy transport between two thermal baths kept at the same temperature. This apparent violation of the second law and various other aspects of the problem was examined. [Abhishek Dhar + Onuttom Narayan (University of California, Santa Cruz, USA)].

Transport properties of quantum wires: The formalism of generalized Langevin equations, developed earlier in the context of classical transport has been extended to the quantum mechanical case and several exact results on ballistic transport have been obtained. This leads to a generalization of the Landauer formalism to the case of general forms of reservoirs and contacts. Experimental consequences are being investigated. [Abhishek Dhar + B. Sriram Shastry (IISc)].

Dynamics of Vibrated Grains: This work focuses on the number density distribution and the behavior of time correlation functions in the density of grains for a quasi-two-dimensional system of vibrated grains. The system is studied at various packing fractions, from low to high. At low densities, usual gas like behavior is recovered, reflected in a Poissonian statistics for the number density distribution. At higher densities formation of cages of the kind that are seen in glass transition are noticed. These effects are studied with a perspective of understanding the similarities and differences between an atomic fluid and a scaled up fluid like a vibrated granular system. This experimental work done in the Theorists' Laboratory at RRI along with some theoretical work in this area is in progress. [Supurna Sinha and Abhishek Dhar].

Entropy fluctuation theorems in non-equilibrium systems: It is well known that for quasi-static processes the work done on a system equals the change in equilibrium free energy. This is no longer true when the work is done at a finite rate, as is the case in most realistic situations. Recently some interesting

results have been obtained on the statistical properties of the work done in a non-equilibrium process and its relation to the equilibrium free energy. Some of the experiments done in this context have been analysed. A simpler derivation of some of the results has been proposed. [Abhishek Dhar + Onuttom Narayan (University of California, Santa Cruz, USA)].

Critical exponents of disordered systems: In a disordered system one can either consider a microcanonical ensemble, where there is a precise constraint on the random variables, or a canonical ensemble where the variables are chosen according to a distribution without constraints. The question addressed is whether critical exponents in these two cases can differ. This is done through a detailed study of the example of the random transverse-field Ising chain. [Abhishek Dhar + A. P. Young (University of California, Santa Cruz, USA)].

PHYSICS IN BIOLOGY

Onset of Shear Waves in a Bacterial Bath: Recent experiments on particle diffusion in bacterial baths indicate the formation of correlated structures in the form of bacterial swirls. In the present work it has been predicted that such a structural ordering would imply propagating shear waves in a bacterial bath at length scales of the order of a bacterial swirl, which corresponds to time scales of the order of the lifetime of a bacterial swirl. This prediction can be tested by future experiments in bacterial baths. [Supurna Sinha].

Elasticity of Semiflexible Polymers: One of the thrust areas of research this year has been in the area of elasticity of semiflexible polymers. This area has recently emerged as an important area in biological physics due to its relevance to single molecule experiments on biopolymers such as DNA. Work has been done on the bend and twist elasticity of semiflexible polymers.

In addition, an interesting limit of the problem of Elasticity of Semiflexible polymers, the Paraxial Worm Like Chain (PWLC) has been studied. A simple, analytically tractable theoretical model for describing the twist elasticity of stretched polymers has been proposed. The model described can be thought of as a particular limit of the worm-like chain model. Contact has been made with recent experiments in which single DNA molecules are stretched and twisted. [Supurna Sinha and J. Samuel].

OPTICS, QUANTUM MECHANICS AND GENERAL PHYSICS

Correcting the quantum clock: Can the quantum-mechanical sojourn time be clocked without the clock affecting the sojourn time? The previously proposed non-unitary clock, involving absorption/amplification by an added inifinitesimal imaginary potential (iV_i), was examined and found not to

preserve, in general, the positivity of the sojourn time, conditional on eventual reflection or transmission. The sojourn time is found to be affected by the scattering concomitant with the mismatch, however small, due to the very clock potential (iV_i) introduced for the purpose, as also by any prompt scattering involving partial waves that have not traversed the region of interest. A formal procedure is proposed whereby the sojourn time so clocked can be corrected for these spurious scattering effects. The resulting conditional sojourn times are then positive-definite for an arbitrary potential, and have the proper high- and low-energy limits. It is noted that such a correlation also applies to the Larmor clock and identical results are obtained by applying our procedure in that case as well. [N. Kumar + S. Anantha Ramakrishna (Imperial College, London, UK)].

Diffusion at constant speed in a model phase space: The problem of diffusion of particles at constant speed is reconsidered and a generalization of the Telegrapher process to higher-dimensional stochastic media (d>1) where the particle can move along 2^d directions is presented. The equations for the probability density function are derived using the formulae of differentiation of Shapiro and Loginov. The model is an advancement over similar models of photon migration in multiply scattering media for it results in a true diffusion at constant speed in the limit of large dimensions. [N. Kumar + S. Anantha Ramakrishna (Imperial College, London, UK)].

Left-handed medium is just right: A medium is said to be left handed if it has a negative magnetic permeability simultaneously with a negative electric permittivity in a certain band of frequencies. In these materials the electric field (**E**), the magnetic field (**H**) and the propagation wavevector (**k**) form a left-handed system with the concomitant inversion of behaviour, e.g., a reversed Doppler shift and negative radiation pressure, an inversion of the Cerenkov cone, and even a reversal of the Snell effect, that is negative refraction, leading to possible imaging at sub-wavelength resolution by a planar slab of such a material having $\mu = -1$, $\varepsilon = -1$. While the idea and the physical realizability of such a left-handed material was considered more than thirty years ago, no such material occurring naturally has so far been found. Recently, however, the question of realizing such an outlandish negative material has been resolved critically in the affirmative. This has led to a resurgence of interest in such materials. Indeed, a left-handed discrete composite consisting of a periodic array of continuous copper wires intercalated with stacks of split-ring resonators has been proposed theoretically and realized experimentally at microwave frequencies, and some of the reversals of normal behaviour. Left-handed materials and their curious properties were studied theoretically. [N. Kumar].

Hidden Symmetries in Microwave Resonators: In experiments by Lauber, a microwave cavity was cyclically deformed around its rectangular shape. The standing electromagnetic waves in the cavity were mapped and the wave functions followed through the cyclic deformations to measure the Berry phase. Apart from the Berry phases of interest Lauber et al. also noticed a curious hidden symmetry which the wave functions displayed. The purpose of this work was to understand the Hidden Symmetries. This was done using the symmetries of the unperturbed cavity and perturbation theory. [J. Samuel and Abhishek Dhar].

Microwave cavities as analog quantum systems: Microwave cavities provide a simple and powerful method of simulating single particle time-independent quantum mechanics in two dimensions. This follows from the fact that under appropriate geometrical constraints, Maxwell's equations in a cavity reduce to the Schrödinger equation. Using this equivalence, various quantum mechanical phenomena such as quantum chaos, localization, isospectrality, etc., have been investigated. Recently a new class of isospectral cavities has been constructed. [Abhishek Dhar and Udaya Shankar].

GRAVITATION

Measuring the General Relativistic Curvature of Wavefronts: Einstein's general theory of relativity predicts that an initially plane wavefront will curve because of gravity. This effect can now be measured using Very Long Baseline Interferometry (VLBI). A wavefront from a distant point source will curve as it passes the gravitational field of the Sun. An experiment is proposed to directly measure this curvature, using four VLBI stations on earth, separated by intercontinental distances. Expressed as a time delay, the size of the effect is a few hundred picoseconds, which can easily be measured with present technology. [J. Samuel].

Gravitational waves from black hole binary inspiral and merger: The span of third post-Newtonian effective-one-body (EOB) templates: It is shown that the standard 3PN bank of EOB templates span the space of signals opened up by the seven flexibility parameters, that affect the two-body dynamics and gravitational radiation emission in that their maximized mutual overlaps are larger than 96.5%. This confirms the effectualness of 3PN EOB templates for the detection of binary black holes in gravitational-wave data from interferometric detectors. The plausible ranges of these flexibility parameters, notably the parameter characterising the fourth post-Newtonian effects in the dynamics, are estimated. The possibility to drastically reduce the number of EOB templates using a few universal phasing functions is suggested. [Bala R. Iyer + T. Damour (IHES, France), P. Jaranowski (Institute of Theoretical

Physics, University of Bialystok, Poland) and B.S. Sathyaprakash (Cardiff University, Cardiff, UK)].

3.5PN updates in search templates for gravitational waves from binary inspiral: Recent theoretical progress made in the dynamics of, and radiation from, binary systems to 3.5PN order have implications for construction of templates for inspiralling compact binaries. The expressions for higher order coefficients in various phasing formulae are computed and provided for data analysis. [Bala R. Iyer + T. Damour (IHES, France) and B.S. Sathyaprakash (Cardiff University, Cardiff, UK].

Third post-Newtonian dynamics of compact binaries: Equations of motion in the center-of-mass frame: The relative dynamics of a compact binary system in the center-of-frame frame is investigated. 3PN-accurate expressions of the center-of-mass positions and equations of the relative binary motion are obtained. It is shown that the equations derive from a Lagrangian (neglecting the radiation reaction), from which are deduced the conserved center-of-mass energy and angular momentum at the 3PN order. The harmonic-coordinates center-of-mass Lagrangian is equivalent, *via* a contact transformation of the particles variables, to the center-of-mass Hamiltonian in ADM coordinates that is known from the post-Newtonian ADM-Hamiltonian formalism. As an application, the dynamical stability of circular binary orbits at the 3PN order is studied. [Bala R. Iyer + Luc Blanchet (IAP, Paris)].

Gravitons from SU(2) distributions in Loop Quantum Gravity: It is important to understand how gravitons (which correspond to small quantum perturbations of flat space-time) are described in non-perturbative loop quantum gravity. A preliminary step towards solving this problem was made by relating certain non-normalizable states in kinematic loop quantum gravity to the perturbative vacuum state as well as to certain 1-graviton states. [Madhavan Varadarajan].

Perturbative and non-perturbative sectors of quantum gravity: The analysis revisited and clarified the earlier work by Iwasaki and Rovelli using current techniques in the field. In accord with their ideas, the relation takes the form of an approximately linear mapping between the relevant non-perturbative and perturbative sectors. The mapping interacts consistently with the action of operators in the non-perturbative and perturbative sectors. Since the relation needs to be elucidated between the perturbative and the fully dynamical non-perturbative sector, this work was only a first exploratory step. [Madhavan Varadarajan].

OPTICS

AREAS OF RESEARCH: Laser Cooling and Trapping of Atoms
Ultra-fast Processes
Light in Random Media

LASER COOLING AND TRAPPING OF ATOMS

A second magneto-optic trap (MOT) has been built for cooling and trapping rubidium atoms. This larger MOT has greater optical access making possible a variety of experiments on the cold cloud. Two experiments have been carried out in detail, and the results are being analysed.

The first experiment involves the study of the response of the cold cloud to an externally applied oscillatory magnetic field. A resonance was seen at about 9Hz, based on which the temperature was estimated be ~40 micro Kelvin. [Andal Narayanan, Hema Ramachandran, N. Kamaraju, M. Meena, R. Srinivasan and Uday Kumar Khan].

The second experiment concerns the fluorescent emission from the cold atoms in an optical molasses under the influence of two driving fields. The fluorescent spectrum shows sub-natural line-width features as the frequency of one of the driving fields is scanned. The origin of this narrow feature is being investigated both theoretically and experimentally. [Andal Narayanan, Hema Ramachandran, N. Kamaraju, R. Srinivasan, Uday Kumar Khan, Ashok Vudayagiri and Jimmy Sebastian].

ULTRA FAST PROCESSES

The laboratory that was moved to the new premises in mid-2002 has become fully operational. A PC-based data acquisition system was designed and fabricated, which is now routinely used in the Z-scan experiments using the femtosecond laser system experiments. Third-order nonlinear properties of several core-shell type metal nanoparticles and of ferro fluids were studied. [Anijà, Navinder Singh, Reji Philip and Jinto Thomas].

LIGHT IN RANDOM MEDIA

Imaging in turbid media using polarization discrimination, which was studied by us earlier in colloidal suspensions, has now been extended to media like fog, where the scattering is by water droplets that are a few microns in diameter. It is seen that even though the scattering in such cases is anisotropic, it is possible to image through up to 3km of fog using incoherent sources. A scheme for navigation of aircraft under poor visibility is being devised. [R.S. Umesh (IISc) and Hema Ramachandran].

LIQUID CRYSTALS (LC)

AREAS OF RESEARCH:

L.C. Synthesis
Phase Transitions
Monolayers
Electrochemistry
Soft Matter Physics
Liquid Crystals Displays
Theoretical Investigations

EXPERIMENTAL INVESTIGATIONS

Synthesis and characterization of new compounds exhibiting liquid crystalline phases: Research and scientific investigations were continued on the design, synthesis and characterization of a number of bent-core compounds, which form the basis for a new sub-field of liquid crystals. In addition, a few polycatenar mesogens and their metal complexes were also investigated. The mesophases exhibited by these compounds were analyzed by a number of different techniques. The significant results obtained from these are summarized below.

The influence of fluorine substituent on the mesomorphic properties of over a hundred achiral compounds composed of banana-shaped molecules derived from resorcinol have been investigated. All these symmetrical five-ring compounds are esters. This systematic study has shown that the position of fluorine substituent plays a major role in influencing the type of mesophases formed. Interestingly, ferroelectric phases are induced when a fluorine is substituted *ortho* to the terminal *n*-alkoxy chain [R. Amaranatha Reddy and B.K. Sadashiva].

Ferroelectric properties in compounds composed of achiral banana-shaped molecules: The higher homologues of a series of compounds were prepared in which three of them were found to be smectic and the remaining two showed a two-dimensional structure. These represent the first example of two different banana-mesophases exhibited by two homologues of the same series which show ferroelectric properties. The ferroelectricity was clearly demonstrated in both the mesophases by bistable switching behaviour. [R. Amaranatha Reddy and B.K. Sadashiva].

Helical superstructure in the mesophases of strongly polar achiral banana-shaped compounds: Three new series of symmetrically substituted

compounds composed of banana-shaped molecules have been investigated. These are derived from 2-cyano- and 2-nitro-resorcinol. The fascinating and beautiful optical textures coupled with the XRD, miscibility and electro-optical studies indicate that the mesophase is indeed B_7. Though the structure of this phase is not yet resolved, intense investigations are going on. [R. Amaranatha Reddy, H.N. Shreenivasa Murthy and B.K. Sadashiva].

Polycatenar mesogens and their metal complexes: The synthesis and characterization of some polycatenar ligands and their copper (II) and palladium (II) complexes have been investigated. The ligands exhibit disordered hexagonal columnar and cubic phases. Some metal complexes show a disordered hexagonal columnar phase which can be cooled down to room temperature. The first pentacatenar mesogen with only four phenyl rings in the core has also been reported. [B.K. Sadashiva and V.A. Raghunathan].

Studies on mixtures of compounds made of rod-like and bent-core molecules: Investigations on mixtures of rod-like and bent-core molecules were continued. A physical model for the occurrence of the following sequence of phases as the chain is increased in a homologous series of compounds made of bent-core molecules has been given: (i) the B_6 phase with intercalated layered structure; (ii) the two-dimensionally ordered B_1 phase, and (iii) the layered B_2 phase in which the molecules are tilted. It has also been shown that by mixing a long chain bent-core compound with appropriate rod-like molecules, the same sequence can be obtained as the concentration of bent-core molecules is increased. [R. Pratibha, N.V. Madhusudana and B.K. Sadashiva].

Unusual growth patterns of the biaxial smectic A phase: Some unusual new growth patterns in binary mixtures of 4-n-octyloxy-4'-cyanobiphenyl and a bent-core compound, in a concentration range in which there is a direct transition from the nematic to the biaxial smectic A phase, have been found. The biaxial smectic A phase was found to separate in the form of forked structures instead of batonnets with focal-conic domains usually seen with uniaxial smectics. A possible origin for the branching has been described. Also, it has been shown that at intermediate composition ranges, the mixtures exhibit a new type of mutual organization between the two types of molecules which results in a two-dimensionally ordered structure. [R. Pratibha, N.V. Madhusudana and B.K. Sadashiva].

Studies on twist grain boundary (TGB) phases: The meniscus region of free-standing films of twist grain boundary smectic A (TGB_A) phase and undulating twist grain boundary smectic C* ($UTGB_{C*}$) phase has been investigated using fluorescence confocal polarizing microscope (FCPM). Distinct regions of the meniscus with different director structures and defects have been characterized

in detail based on these studies. A radial pattern unique to the TGB phases, occurring in the intermediate thickness region of such films, has been attributed to layer undulations of the unwound smectic layers in the freely suspended film. The undulations occur due to the large tensile (dilative) strain occurring between the dislocations of large Burger's vector. A model has been proposed for the 3D-director structure in this region of the meniscus based on the FCPM studies. [R. Pratibha, N.V. Madhusudana + I.I. Smalyukh and O.D. Lavrentovich (Liquid Crystal Institute, Kent State University, USA)].

High electric field experiments on a nematogen with a large *negative* dielectric anisotropy: The first high electric field experiments on a nematogen with a large negative dielectric anisotropy have been carried out. Under the influence of the field, the uniaxial nematic goes over to a biaxial nematic phase, and the isotropic phase to a uniaxial paranematic phase with a *negative* order parameter. Interestingly, the results clearly show that the nematic to paranematic transition temperature increases *linearly* with the applied field while the usual Landau theory in which the dielectric coupling of the order parameter to the field is incorporated, gives rise to a quadratic dependence. [N.V. Madhusudana and Surajit Dhara].

Studies on phase transitions in liquid crystals under negative and positive pressures: Such studies have shown the occurrence of an induced smectic A_d phase in appropriate binary mixture of highly polar compounds under negative pressures. The effect of high pressures on the $UTGB_{C*}$ to TGB_A phase transition temperature as well as the biaxial smectic A phase to uniaxial smectic A phase transition temperature has been examined [N.V. Madhusudana and V. Manjula Devi].

Atomic force microscope (AFM) studies on the Langmuir-Blodgett (LB) films of cholesterol: The LB films of cholesterol on different substrates has been studied using an AFM. The studies show that cholesterol forms single layer on hydrophilic (HPL) surfaces but does not form multilayers on it. However, multilayers of cholesterol could be formed on hydrophobic (HPB) surfaces. Also, interesting features were seen on the HPB surfaces. One cycle of LB deposition on the HPB substrate showed a homogeneous covering wherein the molecules are normal to the surface. The two-cycle deposition revealed elongated domains of molecular thickness with its long axis normal to the surface. The four-cycle deposition showed the torus shaped domains of uniform size. The repeated adsorption and desorption of the molecules during LB deposition led to supramolecular assembly. Based on the height profile over the AFM images for different deposition cycles, models are being made to explain the molecular assembly of cholesterol on substrates. [K.A. Suresh and Raj Kumar Gupta].

Studies on the hydrophobic gap at the self-assembled monolayers [SAM]-water interface: The existence of a thin nanometer size interfacial gap at the alkanethiol SAM-water interface has been demonstrated by several experiments. Addition of anionic, cationic and neutral surfactants to the system of highly hydrophobic film-water interface shows pronounced rise in the capacitance. Normally, addition of surfactant to the monolayer film decreases the film capacitance as the interfacial thickness of the dielectric film increases. This counter intuitive result can be explained in terms of the existence of a water depleted gap of nanometer dimension. The results obtained are crucial for providing evidence for the existence of hydrophobic gap. The results are also in conformity with a model proposed by Lum, Chandler and Weeks on the length scale dependent hydrophobicity. [V. Lakshminarayanan and Ujjal Kumar Sur].

Studies on the behaviour of a bilayer of sodium dodecylsulphate (SDS) and alkanethiol as a function of change in hydrogen ion concentration in the system and as a function of the applied potential have been carried out. These experiments reveal an interesting effect of water dipole orientational changes near a charged interface of SDS bilayer. Similarly, carboxyl group terminated long chain thiols have also been used as they are charged at alkaline pH and neutral at acidic pH. Their potential dependent behaviour shows interesting effects which can be related to the water dipole orientation at positive and negative ranges with respect to the potentials of zero charge. [V. Lakshminarayanan and Ujjal Kumar Sur].

Studies on template electro-deposition: Lyotropic surfactant systems have been used for template electro deposition studies and very high surface area catalytical deposits obtained. The surface area of nickel obtained is nearly 2000 times the geometric area, which is one of the highest values reported. The large surface area contributes to large interfacial capacitance, which means that this method can be used to develop electrochemical supercapacitors [V. Lakshminarayanan and V. Ganesh].

Structural transformation of deoxyribonucleic acid (DNA)-surfactant complexes: Complexes of double stranded DNA with the cationic surfactant cetyltrimethyl-ammonium bromide (CTAB) have been studied using small angle X-ray diffraction at varying concentrations of DNA and the cosurfactant hexanol. At low DNA concentrations, an intercalated hexagonal (H_I^c) lamellar $\rightarrow(L_\alpha^c)\rightarrow$inverted hexagonal ($H_{II}^c$) transformation is found on increasing the hexanol content. The (H_{II}^c) structure is converted into (L_α^c) on adding more DNA. Further increase in hexanol content leads to a phase separation in the surfactant solution, and reentrant $L_\alpha^c \rightarrow H_{II}^c \rightarrow L_\alpha^c$ transition is observed as

DNA concentration is increased. Such structural transformations of DNA-surfactant complexes, driven by DNA concentration have not been observed before. [V.A. Raghunathan and Rema Krishnaswamy].

Structure of lipid-cholesterol membranes: X-ray diffraction studies have been carried out on dipalmitoyl phosphatidylcholine (DPPC) bilayers containing cholesterol, and a partial phase diagram of the system has been deduced from the X-ray data. A modulated phase at 15 to 20 mol% cholesterol content has been found in this system. The occurrence of this phase seems to be related to the existence of a non-zero tilt of the lipid molecules in the gel phase of DPPC. It has also been observed that a miscibility gap in the DPPC-cholesterol system exists at around 40 to 50 mol% cholesterol, which indicates that cholesterol is not distributed uniformly in these fluid bilayers. Since many biomembranes have cholesterol concentrations in this range, it is envisaged to see if these observations have any biological significance. [V.A. Raghunathan and Sanat Karmakar].

Thermal unbinding of a membrane stack: Theoretical studies have indicated the possibility of thermal unbinding of a stack of membranes, due to steric repulsion, resulting from thermal undulations of the membranes. For the first time, such an unbinding transition of lipid bilayer stacks using X-ray diffraction has been observed. This has been found to be reversible and coincides with the main ($L_\beta \rightarrow L_\alpha$) transition of the lipid mixture. Interbilayer interaction potentials were deduced from the diffraction data which reveal that the bilayers in the L_β phase are only weakly bound. The unbinding transition is driven by the abrupt increase in steric repulsion resulting from increased thermal undulations of the bilayers upon entering the fluid L_α phase. [V.A. Raghunathan + scientists at the Austrian Academy of Sciences, Austria, and the National Research Council, Canada].

Formation of unilamellar vesicles in lipid mixtures: Small-angle neutron scattering studies have been carried out on a biomimetic system composed of the phospholipids, dimyristoyl phosphatidylcholine (DMPC) and dihexanoyl phosphatidylcholine (DHPC). Doping DMPC/DHPC multilamellar vesicles with either the negatively charged lipid, dimyristoyl phosphatidylglycerol (DMPG), or the equivalent cation, calcium, leads to the spontaneous formation of monodisperse unilamellar vesicles. The size of these vesicles is found to be independent of the lipid concentration, in contrast to both theoretical expectations and previous experimental observations. The cause of this unusual behaviour is under investigation. [V.A. Raghunathan + scientists at the National Research Council, Canada, and the National Institute of Standards and Technology, USA].

LIQUID CRYSTALS DISPLAYS (LCD)

Development of a Display for an automobile dashboard: A liquid crystal display to substitute the panel meters in a car has been developed. This display has a pointer to show the speed, fuel in the tank and engine temperature. Standard indicators for the seat belt, battery level, oil level, hand brake, high beam, parking lights, etc., have also been incorporated in the display. [T.N. Ruckmongathan with project students from engineering colleges and A.R. Shashidhara].

Development of an analog clock: A liquid crystal display has been designed to mimic the mechanical analog clock with minute and hour hands. The display has radial electrodes meandering on one glass plate and two sets of radial sectors in the other plate. Twelve sectors each consisting of five radial hand positions to form the sixty positions are used for the minute, and another twelve inner sectors are used for both the hour and the minute hands. [T.N. Ruckmongathan, A.R. Shashidhara and S.V. Ashoka].

Development of a display controller for multi-line addressing: A liquid crystal display controller using complex programmable logic devices is being developed. The controller will have the flexibility to choose the number of rows, number of rows in a sub-group, orthogonal function used for multiplexing and the scanning sequence. [T.N. Ruckmongathan and M. Govind].

THEORETICAL INVESTIGATIONS

Thermo-nonlinear optical properties of cholesteric liquid crystals: In cholesteric liquid crystals the pitch of the structure can be altered by changing the temperature, which itself can be effected through an absorption of laser light. In a right-handed cholesteric, right circularly polarized light has a nonlinear optical coefficient of the order 10^{-4} - 10^{-5} cm^2/W, which is comparable to the giant nonlinear optical coefficient due to laser induced director reorientation in nematics. The left circularly polarized light on the other hand has a nonlinear coefficient of the order of 10^{-6} - 10^{-7} cm^2/W which, though much smaller, is still many orders of magnitude higher than that found in ordinary nonlinear media like carbon disulfide. If the pitch variation with intensity is slow, then a large change in intensity to bring about even a small change in the pitch is required. In such a situation, the nonlinear optical coefficient may even change sign. The pitch becomes very sensitive to the laser intensity in a compensated cholesteric. This can lead to periodic stacks of twist disclination loops inside the medium. In a wide beam, a heterogeneous

structure is obtained where the handedness of the structure changes at a particular point on the twist axis. [A.K. Agarwal and G.S. Ranganath].

The cone phase of liquid crystals: Triangular lattice of double-tilt cylinders: The existence of the cone phase of liquid crystals near a first order nematic→ smectic C phase transition is predicted and a mechanism responsible for stabilizing the same explained. The cone phase is a triangular lattice of double-tilt cylinders each of which is a +1 disclination in the form of a stack of conical layers. It is estimated that the cone phase composed of double-tilt cylinders of radius 200Å would be stabilized if the coefficient of the Gaussian curvature term in the free energy $K_G \cong 3 \times 10^{-6}$ dyne. Some experiments have been planned in the laboratory to test the theoretical ideas. [Yashodhan Hatwalne and N.V. Madhusudana].

ASTRONOMY AND ASTROPHYSICS (AA)

AREAS OF RESEARCH: Extragalactic Astronomy
The Galaxy and the Interstellar Medium
Neutron Stars and Pulsars
Instrumentation and Observational Techniques
Others

EXTRAGALACTIC ASTRONOMY

Primordial magnetic fields and the structure of the universe

The effect of primordial magnetic fields on the formation of large scale structures in the universe is being studied. The two-point correlation function of the matter distribution in the presence of such fields in the redshift space has been computed to derive constraints on the magnetic field strengths. [S. K. Sethi].

Cosmological aspects of galaxy clusters

Recently it has been shown that radiative cooling can also rid the diffuse gas in galaxy clusters (the intracluster gas) of its low entropy part and as a result raise the mean entropy of the gas. Radiative cooling in the central region, however, would set the gas in the outer regions in motion towards the centre. The effect of such a cooling flow on the entropy of the gas has been worked out and it was found that the mass flux consistent with observations is required to be in excess of ~1000 $M_{\odot}$ per year, which is much larger than those deduced for nearby clusters. This is also consistent with recent numerical simulations which found that the accumulated amount of cold gas is much larger than observed values if the radiative cooling alone is used to increase the entropy to the required level. [Biman B. Nath].

The implications of a temperature profile obtained from a recent simulation taking into account only gravitational processes has also been worked out. It was found that the entropy for gravitational processes alone is much larger than previously considered in the literature, but it still falls short of the observed values, clearly indicating the need for non-gravitational heating. [Suparna Roychowdhury and Biman B. Nath].

It has been suggested that thermal conduction is suppressed in the intracluster gas, owing to the presence of magnetic fields, although the degree of suppression has been a topic of debate. Estimates for the suppression factor have ranged from 10^{-3} to being as large as 1/3 of the classical Spitzer value.

The heat diffusion equation in the case of a spherically symmetric intracluster gas has been solved numerically, with varying degrees of suppression of the thermal conductivity, for non-cooling flow clusters. The resulting evolution of a temperature profile for a duration of 10^{10} yr was then compared to the observed temperature profile of nearby clusters. The comparison yielded the allowed suppression factor of $\leq 10^{-3}$. Work on the improvement of this limit is continuing, taking into account the fact that the duration of passive evolution for the intracluster gas is much less than 10 billion years, as assumed above. [Biman B. Nath].

Kinematics of Galaxies

A kinematical method of recovering the (usually unmeasurable) transverse velocities of steadily rotating, non-axisymmetric patterns in flat galaxies was developed. The method uses as data two-dimensional maps of a tracer surface brightness and radial current density. The data-maps could be viewed as the zeroth and first velocity moments of the line-of-sight velocity distribution, which is the natural output of integral-field spectrographs. This procedure is closely related to the Tremaine-Weinberg method of estimating pattern speeds of steadily rotating patterns, when the tracer surface brightness satisfies a source-free continuity equation. It was proved that under identical assumptions about the pattern, two-dimensional maps may be used to recover not just one number (the pattern speed), but the full vector field of tracer flow in the disc plane. The recovery process has been illustrated by applying it to simulated data, and test its robustness by including the effects of noise. [S. Sridhar + N. Sambhus (Astronomisches Institut, Universität Basel, Switzerland)].

Gravitational lensing

The source PKS 1830−211 is an AGN at redshift z = 2.51, which is imaged into a radio ring and two core images by a gravitational lens at z = 0.9. High resolution Very Large Baseline Interferometry (VLBI) observations over the past few years have indicated relative positional shifts between the core images on a scale of a few tens of micro arc seconds. Combined with previous observations these shifts are being modelled as due to helical jet motion in the source. [Sunita Nair + C. Jin (Beijing Astronomical Observatory, Beijing), M. A. Garrett (JIVE, NFRA, Dwingeloo), R.M. Porcas (MPIfR, Bonn)].

The quintuplet quasar PMN J0134−0931 exhibiting five images of the same source has been modelled by a single elliptical lens mass distribution. The unusual image results due to the source location being near the "hyperbolic umblic point". Refined modelling is continuing. [Sunita Nair + N. Mohan (IAP, Paris)].

Gamma Ray Bursts

Four gamma ray burst afterglows, and one related event called a hypernova were optically followed up and their physical parameters were determined. Successful optical observations of four gamma-ray burst afterglows, GRB021004, GRB021211, GRB030226 and GRB030329, and that of a possible GRB-related event, the hypernova SN2002ap, were conducted in collaboration with the State Observatory, Naini Tal and Himalayan Chandra Telescope, Hanle. In most of these sources a clear signature has been obtained of collimated initial ejection, with the cone angle of a few degrees. One case (GRB021004) showed unusual variations in the observed intensity with time, possibly due to the variation of density in the circumburst matter. An overall model of the afterglow emission was constructed which fitted the underlying smooth light curves in optical, X-ray and radio wavelengths. For SN2002ap a bolometric light curve was constructed until 330 days after maximum light. From this, it was estimated that around 0.06 solar masses of radioactive Nickel (^{56}Ni) was ejected in the explosion. [D. Bhattacharya and L. Resmi].

Radio observations (HI & OH lines)

GMRT detection of HI 21 cm line in absorption in the high redshift red quasar 3C 190: The implications of the recent GMRT detection of HI 21 cm-line absorption in the red quasar 3C 190 at a redshift of 1.1946 were investigated. Most of the absorption is blue-shifted with respect to the systemic velocity. The absorption is broad and complex, with the width between the nulls of ~400 km s^{-1}. Since the core shows self-absorption at this frequency, the absorption must be towards the hotspots in the lobes. Comparison of the radio and deep optical images reveal linear filaments in the optical which overlap with the brighter radio jet. It is therefore suggested that the HI 21 cm line absorption could be occurring in the atomic gas shocked by the south-west jet. [K.S. Dwarakanath (RRI & NRAO) + C.H. Ishwara-Chandra (NCRA)].

Imaging of the high redshift galaxy cluster A2192 using the GMRT and the VLA: With a view to studying the evolution of gas content in galaxy clusters over the redshift range 0 - 0.5, the rich galaxy cluster Abell 2192 at a redshift of 0.185 was imaged in the HI 21 cm-line and in the radio continuum using the GMRT and the VLA. About 50% of the emission line cluster galaxies were detected in radio continuum with star formation rates (M> 0.1 $M_\odot$) in the range 10 - 100 $M_\odot$ yr^{-1}. There is a hint that galaxies with higher star formation rates are farther from the cluster center. This might be indicative of effects of cluster environment on star formation in cluster galaxies. A preliminary analysis has detected a cluster galaxy at a projected distance of 2.7 Mpc from the cluster center with an HI mass of 10^{10} $M_\odot$. This is the highest redshift HI emission detected yet. The implications are being explored. [K.S. Dwarakanath

(RRI & NRAO) + M. Verheijen (Potsdam), B. Poggianti (Padova), and J. H. Van Gorkom (Columbia)].

GMRT Observations of Eridanus Group of galaxies: The observations of Eridanus group of galaxies were continued with additional HI 21 cm-line observations of 20 galaxies and 327 MHz continuum observations of 8 galaxies using the GMRT. In addition, optical observations in the R band were carried out using the 1m telescope at Naini Tal. It was found that the HI morphologies of galaxies in the Eridanus group often show warps, lopsidedness, sharp HI edge at one side with extended HI on the other side, and bent HI disks. In general, HI disk diameters of galaxies are comparable to or sometimes even smaller than their optical R band extent. The velocity fields of several galaxies are asymmetric in their receding and approaching parts which implies a lopsidedness in the rotation curves of such galaxies.

Since such features are expected to be present only in clusters of galaxies, the finding of shrunken and bent HI disks in some galaxies was a surprise. Another surprise was the presence of diffuse X-ray emission in this group centred on some bright elliptical galaxies suggesting that the intra-cluster medium is dense and hot, and may eventually become a core as the group evolves to a cluster. Our observations of the Eridanus group indicate that this group is in an early phase of cluster formation where the gas-removal processes have just begun. [Amitesh Omar, K. S. Dwarakanath + R. Sagar, S.B. Pandey (State Observatory, Naini Tal)].

HI observations of M104 with GMRT: Observations of a nearby S0 galaxy M104 with GMRT in HI were made. Deep optical photographs indicate a stellar polar ring in this galaxy, indicating a past minor merger event. No evidence was found for a ring, although both the sensitivity and spatial coverage in observations was not good enough to conclude this with confidence. This is the first high resolution HI image of this S0 galaxy. [B. Ramesh, Chandrayee Sengupta + K. Bekki (University of New South Wales)].

Radio Observations (Continuum)

MRT Survey: Low resolution (13 x 18 arcmin) images of the southern sky have been produced using the Mauritius Radio Telescope (MRT) observations covering baselines up to 178m. In order to speed up the full resolution imaging from the available MRT observations, extensive software scripts have been developed to automate the data analysis including editing, calibration and imaging from MRT observations. [V.N. Pandey and N. Udaya Shankar + R. Somannah (University of Mauritius)].

Observations of giant radio galaxies: Observation of two giant radio galaxies J0114-476 and B1545-321 were carried out in 1999 using the Australian Telescope Compact Array (ATCA). Preliminary results for J0114-476 gave the first clear observational evidence for recurrent activity in a radio galaxy.

Images of the giant radio galaxy PKS B1545-321 show a pair of oppositely directed beams emerging from a radio core and ending in bright symmetrically located components on either side. These inner beams are embedded within edge-brightened outer lobes of lower surface brightness and the bright ends of the inner beams are well recessed from the ends of the outer lobes. All share a common central core and radio axis. It is proposed that the observed inner beams are double lobes which have been created within relic outer lobes as a consequence of a restarting of the central activity. The inner double representing the new episode has features which agree with this proposal. Therefore, PKS B1545-321 is a rare opportunity for examining the development of restarted beams within a relic synchrotron plasma cocoon. [N. Udaya Shankar + L. Saripalli and R. Subrahmanyan (ATNF)].

THE GALAXY AND THE INTERSTELLAR MEDIUM

Radio Observations (HI & OH lines)

Discovery of large velocity dispersion HI surrounding the galactic center region Sgr A*: Using the VLA, a system of large velocity dispersion (LVD) HI surrounding Sgr A* has been discovered. The LVD HI is distributed over 10 pc×5 pc (4′ ×2′) and at a position angle of ~40° E. The LVD HI line has a mean peak optical depth of 0.32 ± 0.12 centered at a mean velocity of V_{lsr} = -4 ± 15 km s^{-1}. The mean velocity dispersion is 51±18 km s^{-1} which is ten times that observed in most of the diffuse, cold HI concentrations. The mean value of HI column density is 7×10^{21}, T_{100} cm^{-2}, implying a mean volume density, total mass, and kinetic energy to be, respectively, ~600 T_{100} cm^{-3}, ~3000 T_{100} $M_{\odot}$ and ~10^{50} T_{100} erg. (T_{100} is the temperature of the LVD HI in units of 100 K). The LVD HI is not bound by the self-gravity of its HI mass. The velocity dispersion appears to increase away from Sgr A* indicating that the LVD HI is presumably rotating about a distributed mass near Sgr A*. The implied total mass within a radius of 3 pc is ~1.2×10^{7} $M_{\odot}$. [K.S. Dwarakanath (RRI & NRAO) + W. M. Goss (NRAO), J. H. Zhao (CfA) and C. C. Lang (Uni. Iowa)].

High galactic latitude HI absorption survey using GMRT: To study the kinematics of diffuse interstellar clouds in the solar neighbourhood, HI absorption measurements were carried out using the GMRT towards 104 extragalactic radio continuum sources with galactic latitudes |b| >15°. This is

the most sensitive HI absorption survey to be made so far, reaching an rms sensitivity of 0.003 in HI optical depth. The analysis and interpretation of data is in progress. So far about 120 absorption features have been detected, out of which 13 are at velocities exceeding 15 km/s, implying a significant contribution from random velocities. The higher velocity absorptions are found to have smaller optical depths as well as HI column densities. The radial velocity distribution is found to have two Gaussian components, with dispersions of ~7 km/s and ~20 km/s. The presence of a wider component is consistent with the recent discovery of a population of HI clouds in the lower galactic halo. [Rekesh Mohan, K.S. Dwarakanath and G. Srinivasan].

HI absorption studies of the warm neutral medium: Although the knowledge of spin temperature and the filling factor of the warm neutral medium (WNM) are very important to model the interstellar medium (ISM), only two measurements of HI absorption from the WNM exist till date. In order to fill the gap, a high sensitivity HI 21 cm-line absorption study was carried out using the Westerbork Synthesis Radio telescope leading to detection of HI absorption in the WNM towards three directions out of five. The measured optical depth ranged from 0.0014 to 0.004. The estimated spin temperatures, in the range ~2500K – 1400K, agree with the predictions of the two-phase models of ISM. In addition, an unusual HI absorption feature (optical depth ~0.0009) was seen whose position and width seem to be correlated to a low brightness temperature (0.1 K) and wide (width ~66 km/s) HI emission features in the Leiden Dwingeloo survey, corresponding to a large velocity dispersion system. [Rekesh Mohan, K.S. Dwarakanath and G. Srinivasan].

High mass young stellar objects: Observation of about 70 radio quiet Far infra-red sources with associated 6.7 GHz methanol maser emission were imaged at 1200 μm using the latest bolometer (called MAMBO) on the Swedish ESO Submillimeter Telescope (SEST) in Chile. A subset of these has also been observed for 22 GHz Ammonia (NH_3) emission using the 70 m dish at the Tidbinbilla Deep Space Station in Australia. The interpretation of these observation is continuing. [B. Ramesh + T. K. Sridharan, T. Bourke, Q. Zhang and H. Beuther (all at CfA)].

NEUTRON STARS AND PULSARS

Radio pulsar emission altitudes: Past work showed that by attributing different altitudes to core and conal emission regions in pulsars; the frequently observed longitude offsets between core and conal components can be explained as resulting from differential aberration and the magnetic field line sweepback, as well as leading to many interesting consequences. To further test if this method provides a systematic understanding of radio pulsar emission altitudes, these

ideas were applied to several pulsars and were successful in explaining various characteristics such as one missing component from an expected conal pair.

Interpulsars exhibit two pulses per rotation period, i.e., the main pulse and the interpulse. Usually interpulsars are interpreted as rotators whose magnetic dipole axis is near orthogonal or near aligned with the rotation axis. For interpulsars PSR 1702-19 and PSR 0823+26, using the core/cone longitude offsets it was shown to be possible to provide a geometrically consistent understanding of the otherwise puzzling pulse morphologies. However, some new issues including those about the emission mechanism came up. In particular, the core-cone longitude offset implies that in PSR 0823+26 the core component emanates nearly from the light cylinder, which in turn implies that this pulsar although an *interpulsar* may actually be an oblique rotator. [C.S. Shukre + R.C. Kapoor (IIA)].

The Vela pulsar's radio nebula: The observations of the radio nebula surrounding the Vela pulsar have been analysed. The full extent of the radio nebula has two lobes to the North and South of the pulsar. Indications of this object have been reported previously, but its symmetric morphology around the pulsar and other details had not been identified as they were hidden due to poor sensitivity to low spatial frequencies.

The structure is highly polarised and the polarisation vectors, once corrected for Faraday rotation, surround the pulsar in an axially symmetric fashion. The X-ray emission found by Chandra Observatory lies at the centre of this structure, in a region which has no detectable excess of radio emission. With present observations total and regional fluxes from the northern and southern lobes, and the X-ray region were estimated at four radio frequencies, i.e., 1.4, 2.4, 5 and 8.5 GHz. The corresponding images in both the total and polarised intensities, as well as those showing the derotated linear polarisation vectors have been constructed. [A.A. Deshpande + D. Lewis (Uni. of Tasmania), R. Dodson (Uni. of Tasmania), D. McConnell (ATNF)].

Pulsar timing with the Ooty Radio Telescope: The pulsar timing observations, for long-term monitoring, and the related developments are continuing. [A.A. Deshpande + V. Balasubramaniam (RAC, Ooty), Alak Ray (TIFR)].

Search for pulsars using the Gauribidanur telescope: The intensive observational program initiated last year for pulsar search using the Gauribidanur telescope is continuing. Observations now cover one third of the planned span. [A.A. Deshpande and H.A. Aswathappa].

Intensity fluctuation in single-pulses of pulsar B0834+06: Recent results regarding subpulse-drift phenomenon in pulsar B0943+10 have led to the identification of a stable system of subbeams circulating around the magnetic axis of this star. The single-pulse analysis has been carried out for another interesting pulsar B0834+06 at 35 MHz where a periodic amplitude modulation is evident. The circulation time and drift direction of the underlying emission pattern responsible for the observed modulation have been estimated using the *Cartographic Transform* mapping technique developed by Deshpande & Rankin (2001) to study the properties of the polar emission pattern. A comparison of the polar emission patterns of the two pulsars B0834+06 & B0943+10 was made and ensuing implications were investigated. (A.A. Deshpande + Ashish Asgekar, RRI/Univ. of Manitoba).

Solar system

Jupiter observations: Observations of Jupiter made by Chandra X-ray Observatory (CXO) in 2000 have revealed new and puzzling features of Jovian X-ray emission, e.g., the auroral X-ray emission was observed to pulsate with a 40-minute period. Jupiter was observed for 80 hours using GMRT in the 610 - 235 MHz (50 - 126 cm) band, simultaneously with CXO, with an aim to search for the pulsation in the decimeter radio emissions from Jupiter. Preliminary data analysis have been completed and images obtained clearly indicate a few of the well known properties such as the total power variance with Jovian longitude and wobbling of the line connecting the peak emissions in the two hemispheres of Jupiter. Further data analysis to investigate any periodicity and its correlation with the X-ray emission is continuing. [N. Udaya Shankar + A. Bhardwaj (VSSC, Trivandrum), Ishwar Chandra (NCRA)].

OTHERS

Topological phases: The problem of $2n\pi$ topological phases in systems with more than two states and the nature of singularities in mixed state evolution in two-state systems has been pursued further and several useful insights obtained. [R. Bhandari].

The Honours Course on Space Sciences at St. Joseph's College: Based on an enthusiastic response, the Honours Course on Space Sciences was continued for a second year at St. Joseph's College, Bangalore. From about three hundred applicants, 35 students were selected (*including nine engineering students*) on the basis of an entrance test. Ten college lecturers also enrolled for the course. This year, like in the first year, the course was received enthusiastically by participants. Visits to Sriharikota Range (to see GSLV) and other centres were highly appreciated by the participants. The second year saw a small centre

developing around the course in the college. There is now a small library for the programme with roughly 35 books and two PCs for the project work, based on contributions from RRI.

INSTRUMENTATION AND OBSERVATIONAL TECHNIQUES

12-m Radio Telescope

The assembly of the backup structure for the 12-m radio telescope has been completed using wire mesh panels. The root-mean-square deviation with respect to the ideal parabola along the radial direction has been measured to be 1.2 mm. An impulse hammer test was carried out using accelerometers at eight different locations, from which the natural frequency of the antenna has been measured to be about 2 Hz. The design of the mount has been completed with the help of consultancy firms. While the azimuth design is based on the conventional slew-ring bearing, two possibilities have been explored for elevation – screw jack and bull gear concept. Detailed drawings for these designs are in preparation. [N. Udaya Shankar, Manohar Modgekar, C. M. Ateequlla and N.V.G. Sarma].

A prototype control system has been built using the programmable multi-axis controller based on a Motorola 56303 DSP processor and brushless DC motors. Several tests related to back torque made using this setup showed that the achievable back torque increased the striction to the level required for providing the necessary pointing accuracy for the 12-m dish at the highest operating frequencies. [N. Udaya Shankar, P.V. Rishin, Sabir Hussain Syed and A. Krishnan].

An uncooled single polarization 4 to 8 GHz receiver system consisting of a high performance miniaturized compact corrugated horn along with an orthomode transducer (OMT) and a multioctave single stage low noise amplifier has been developed. A multioctave bandwidth trapezoidal structure for the purpose of interference monitoring in the frequency range 0.5 to 10 GHz has been designed and developed. [A. Raghunathan].

10.4 m Telescope

Wide band correlator for the 10.4 m telescope: The wide band correlator has been interfaced with an analog-to-digital converter using bandpass sampling on the L-band RF signal at 64 MHz effective sampling rate. [B. S. Girish].

Digital backend for 10.4 m and 12m telescopes: Replacement of the existing data acquisition systems on the 10.4 m telescope with a PCI-based card which will include provision for field programmable gate arrays for application specific real-time processing is being investigated. [T. Prabu and B.S. Girish].

Low cost reflectors for optical and submillimetre wavelengths: A Luneberg lens (named after the original proposer, Luneberg) employs a radial refractive index gradient in a spherical lens leading to a very wide field of view. It appears that such a lens can be realised by manipulating a novel material called the aerogel. Using this idea a cylindrical Luneberg lens will be made as a first step and the possibility of spherical lens will be explored later. [B. Ramesh + A.V. Rao (Shivaji University, Kolhapur)].

A technique for making low cost spherical panels suitable as reflectors at submillimetre wavelengths is being investigated. A rotating table has been developed for spin casting high quality mirrors, which will be used to get a 30 cm mirror cast of an *ester monomeric solution.* [B. Ramesh and V. Lakshminarayanan].

Astronomical Imaging

Coded Mask Imaging: Imaging techniques for the ASTROSAT Scanning Sky Monitor have been developed for continuous rotation mode operation. Starting with the list of photon strike positions and times, two different methods of de-rotation have been explored: one in the detector plane and the other in the image (sky) plane. Following this, iterative response modelling has been used to recover images with a good dynamic range. [D. Bhattacharya and B. T. Ravi Shankar].

Reconstruction of images of astronomical sources: An investigation of a novel use of wavelets for the reconstruction of images from radio interferometric data is in progress. [Sunita Nair].

Satellite Astrometry

Encouraged by the results of ongoing collaboration between MCF and RRI on frequency transfer and satellite ranging, a new method has been proposed for precise estimation of satellite orbits using a hybrid of techniques normally employed for connected element interferometry and Very Long Baseline Inteferometry (VLBI). It was found that the local oscillator reference distribution and other infrastructure offered by GMRT provide a unique opportunity for realising a system based on this concept with minimal

infrastructure development. An ISRO-sponsored project has recently been initiated to establish a network of four commercially available 4.5-metre antennas (Very Small Aperture Telescopes - VSAT) spread over 20 km, but close to a GMRT antenna so that the GMRT local oscillator reference can be tapped for these VSATs. A prototype version of one complete receiver chain has been built and is being tested at RRI. Most of the design details have been worked out for various receiver subsystems, backend digital systems, clock synthesizers and distribution, and many subsystems are in various stages of prototyping. The final data recording and realtime processing will be on a PC platform augmented by indigenously developed reconfigurable computing systems based Xilinx Virtex and Spartan family field programmable gate arrays (FPGA). Microcontrollers belonging to the 8051 family, particularly ADuc812/832 processors, have been identified for online control and monitor applications while the custom-developed embedded systems will have a ADSP2181/2191 processors to provide a faster control or when auxiliary real-time processing is required from onboard processors. The host operating system and compilers have been standardized on Linux and related public domain tools. Software development currently in progress includes device drivers on a Linux platform, fast algorithms for Fourier Transform, light-weight communication protocols between the Linux host and the embedded systems. [C. R. Subrahmanya, R. Somashekar, T. Ananthaprakash, Madhavi Bichile, T. C. Pavan, Peeyush Prasad, Pushpa Jain, G. C. Rashmi, J. Sandhya, S. Shameem, A. L. Sheshadri, G.B.Sharada, M. Soumya].

COMPUTERS

As a part of modernization, new Pentium based computers were procured and deployed to take advantage of the lower maintenance costs and higher capability over the existing systems. Continued maintenance of the large number of installed personal computer systems deployed as also the campus network was undertaken to reduce downtimes. New printers with enhanced capabilities were added to the existing ones. In view of the increasing storage needs, file servers with large storage capacities are being commissioned. Backup of these storage systems need faster and automated backup storage devices. Procurement of such storage systems has been initiated. The campus LAN has been extended to the new water tower building on campus.

As the division over the years has deployed a large number of workstations running the open source Linux operating system, continued upgrades were implemented on both the OS and packages front. Experiments with diskless nodes were carried out and deployed.

Security of our systems accessible from the outside was enhanced where necessary. The system running one of the proxy servers on Windows operating system was replaced by the more robust open source Squid software running on Linux. In an effort to handle the large number of SPAM mails being received, Spam Association open source software was deployed on the primary mail server.

The FORSA and Libsys Library database was hosted on the RRI web server. With this, users outside the campus can have access to our database and the merged database from a few other institutions to make searches for books and periodicals.

LIBRARY

The Library continued with its basic activities of collecting, organizing and disseminating scientific and technical information; maintaining liaison with local and outside libraries for resource sharing and exchange of information; providing need based information services and facilitating on-line access to external databases and on-line journals.

Library Resources Development

During the period, the following resources were procured/added.

Books	417 (46 of them on *gratis*)
Bound volumes	979
Liquid Crystal database	v.4.3
Journals	164
Print + Online	77 (13 by air mail)
Online only	5
Online Consortium-Basis	41

The total collection at the end of the period stood at: Books: 22,209, and Bound Volumes: 31,505, Totalling to 53,714.

Modernization

The library application software LIBSYS was added with new features on LINUX v.7.2. Procured two PCs with Windows XP for use in book and journal sections.

Consortium

Continued subscription of 23 Kluwer journals under "Indian Astrophysics Consortium". In addition, action was initiated for an on-line subscription of Nature under FORSA Consortium roping in IIA, PRL, NCRA, IUCAA and JNCASR. This way, the cost of subscription of this journal was only one third to each of the participating partners when compared to individual library subscriptions.

Negotiated with IoP for "Non-Cancellation Offer 2003" and entered into subscription for the years 2003 and 2004 facilitating for an on-line access to additional 23 physics journals. The additional on-line journals of Kluwer and IoP are placed on our library home page for access by our staff members.

Digital Library Initiatives

Digitization of about 125 books which were out of purview of the Copyright Act was completed at SERC, IISc. Plans are afoot to host these books on the Institute network server for on-line reference.

Three library staff members were trained in the theoretical/practical aspects of digitization. Initiated usage of the Green Stone Digital Library open software.

Other activities

All the database of FORSA Libraries – IIA, IUCA, NCRA, PRL and RRI – were merged and hosted on RRI server so as to access it within and outside RRI. Serials Holding List was up-dated up to 2003 and copies were distributed to other libraries for reference. Prof. S. Dhawan's collection has been indexed and fed to LIBSYS system for easy access and retrieval.

OTHER ACTIVITIES

Ph. D.

Awarded

Name	***Topic of Study***
S. Shubashree	Synthesis and physical properties of compounds exhibiting ferro-, ferri-, anti-ferroelectric and twist grain boundary phases. *Bangalore University, Bangalore.*
Sushil Mujumdar	Some investigations of light scattering in active and passive random media *Jawaharlal Nehru University, New Delhi.*

Submitted

Niruj R. Mohan	Radio recombination line study of ionized gas in nearby starburst galaxies *Indian Institute of Science, Bangalore*
Rekesh Mohan	Kinematics of diffuse interstellar clouds in the galaxy *Jawaharlal Nehru University, New Delhi.*
A.S. Govind	Theoretical studies on phase transitions in liquid crystals *Bangalore University, Bangalore.*

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 also those submitted and in press, is given at Annexure I (Page 48).

Summer Programme in Physics, 13 May - 30 June 2002

The Summer Programme has been an important annual event in the Institute over the last few years. This year twenty students drawn from different parts of the country representing universities, IITs and Colleges were selected out of the one hundred and sixty who had applied. Thirteen M.Sc., one B.Tech., and three B.Sc. students, a total of seventeen finally participated. There were twenty two lectures covering statistical physics, structure and stability of stars, dynamics of stellar systems, gravitational lenses, diffuse matter and masers in space, liquid crystals, interaction of light with atoms and with Bose-Einstein condensates, interaction of intense light with matter, linear response theory, monolayers, colloidal dispersions and scattering techniques. A few special lectures on unusual topics were also included. The students worked on one of the ten projects offered by the faculty. Educational films were screened as part of the programme. Presentation by students of their project work was held in the last week. Visits were also arranged to Labs and to the Radio Astronomy Centre, Ooty.

Conference on Liquid Crystals and Other Soft Materials

To celebrate the **Silver Jubilee of the discovery of the columnar phase at the Institute**, the above Conference was organized from 18-20 December 2002. Since the research activities of the laboratory have been diversified during this long period of time, experts from different areas of soft condensed matter were invited to speak at the conference. A total of twenty-nine scientists from different parts of the world including Indian scientists presented papers during the conference. Many doctoral students and postdoctoral fellows from various regions of the country were selected to participate in the deliberations. The proceedings of the conference is being published as a special issue of PRAMANA by the Indian Academy of Sciences.

Discussion Meeting on Recent Advances in Loop Quantum Gravity

The above meeting was held 28 November to 9 December 2002. Apart from members of the Theory Group, RRI, invitees from the following institutes participated in the meeting: Pennsylvania State University (USA), University of Utah (USA), Institute of Mathematics and Fundamental Physics, CSIC (Spain), Institute of Mathematical Sciences (Chennai), Harish-Chandra Research Institute (Allahabad), Indian Institute of Science (Bangalore), and Indian Statistical Institute (Bangalore).

The morning sessions at the Meeting were devoted to approximately 10 one-and-a-half hour talks each by Professor Abhay Ashtekar (Quantum geometry, Black hole entropy and Semiclassical issues) and Dr. Martin Bojowald (Loop Quantum Cosmology). The afternoon sessions were devoted to 1 hour presentations by the rest of the participants on a wide variety of topics in classical and quantum gravity, namely: Stochastic semiclassical gravity, Quantum corrections to black hole entropy, Signatures of Planck scale physics via inflationary mechanisms, Recent developments in de Sitter gravity, A new test of general relativity using radio interferometers with intercontinental baselines, Discrete time evolution in a toy model for Loop Quantum Cosmology, Gravitons from a loop representation of linearised gravity, Diff-invariant and non diff-invariant free actions and their use in perturbative quantum gravity.

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, page 59).

Journal Club Meetings

Nineteen meetings were held during the year. Preprints as well as recently published papers dealing with topics of great current interest were reviewed in the meetings (Annexure III, page 65).

And, as in the past, several informal Group meetings in Theoretical Physics, Optics, Liquid Crystals and Radio Astronomy were held on a regular basis throughout the year.

In-House Meeting

An In-House Meeting, which is an annual feature at the Institute, was held on 2-3 March 2003 where the staff and students presented their research work. In all, 35 oral presentations spread over 8 sessions chaired by Faculty Members were made. There were also 17 poster presentations. The presentations were followed by lively scientific discussions with critical comments and suggestions relevant to the reported research from the members.

Visit of Parliamentary Standing Committee for Science & Technology, Environment and Forests

A Department-Related Standing Committee of the Parliament on Science & Technology, Environment and Forests, chaired by Mr. C. Ramachandraiah, visited the Institute on 7 September 2002. Prof. N.V. Madhusudana, Dean of Research, briefed the Committee of the on-going research activities at the Institute. The Committee went around the campus and paid visits to labs, library and the museum after the meeting. The visit of the Committee to five other scientific institutions in Bangalore during the period 6-9 September 2002 was also coordinated by the Institute.

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 (page 41).

General

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

PLAN (Recurring & Non-Recurring)	Rs. 1,000.00 lakh
NON PLAN (Recurring)	Rs. 315.00 lakh
Total	Rs. 1,315.00 lakh

COUNCIL (2000 – 2004)

Dr. K. Kasturirangan *Chairman*	*Member of Parliament, Rajya Sabha* *Antariksh Bhavan, Bangalore 560 094*
Mr. Arun Sharma	*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 382 248*
Prof. N. Kumar	*Director, Raman Research Institute* *Bangalore 560 080*
Prof. G. Mehta	*Director, Indian Institute of Science* *Bangalore 560 080*
Prof. V.S. Ramamurthy	*Secretary, Ministry of Science & Technology,* *Government of India* *New Delhi 110 016*
Prof. S. Ramaseshan	*Raman Research Institute Trust* *Bangalore 560 080*
Prof. O. Siddiqi	*TIFR National Centre for Biological Sciences* *GKVK Campus, Bangalore 560 065*

FINANCE COMMITTEE (2000 – 2004)

Dr. K. Kasturirangan *Chairman*	*Member of Parliament, Rajya Sabha* *Antariksh Bhavan, Bangalore 560 094*
Mr. Arun Sharma	*Joint Secretary & Financial Adviser* *Ministry of Science & Technology* *Government of India, New Delhi 110 016*
Prof. N. Kumar	*Director, Raman Research Institute* *Bangalore 560 080*
Prof. S. Ramaseshan	*Raman Research Institute Trust* *Bangalore 560 080*

STAFF

N. KUMAR
Director

V. Radhakrishnan
Distinguished Professor Emeritus

S. Ramaseshan
Distinguished Professor Emeritus

N.V. Madhusudana, *Dean of Research*

THEORETICAL PHYSICS

Research
B.R. Iyer
Joseph Samuel (*Chairman*)
Madan Rao
Madhavan Varadarajan[¶]
G.S. Ranganath
Abhishek Dhar

Research Students
Abhijit Ghosh (*from 2.1.03*)
Azam Gholami
K.G. Arun
Javed Ahmad (*from 29.7.02*)
Kripa G (*from 2.1.03*)
Mohd. S.S. Qusailah (*from 26.7.02*)
Sarasij Rai Chaudhari
Sudipto Muhuri
Suthirtha Roy Chowdhury (*from 29.7.02*)

Post-Doctoral Fellows
Shrirang Deshingkar (*up to 20.6.2002)*

Research Associate
Supurna Sinha

Visiting Professor
S.K. Rangarajan

Technical Assistant
V.S. Gayathri (*from 13.9.02*)

Secretarial
G. Manjunatha

[¶]*On leave visiting Technical University, Munich, Germany, Inst. of Mathematics & Theoretical Physics, Madrid, Spain & Penn State University, Pennsylvania, USA*

OPTICS

Research
N. Andal
Hema Ramachandran (*In-Charge*)
A.A. Deshpande
N. Kumar
Reji Philip
C.S. Shukre

Visiting Professors
A. K. Sood
R. Srinivasan

Post-Doctoral Fellow
Ashok Vudyagiri (*from 2.9.02*)

Research Students
Archana Sharma (*from 30.7.*02)
M.Anija
Divya Sharma
Navinder Singh
Uday Kumar Khan
Vandna Gokhroo (*from 14.8.02*)

Technical Assistants
Jimmy Sebastian (*from 2.9.02*)
Jinto Thomas (*from 16.10.02*)
Kamaraju
Meena
Poornima N. Katti (*from 18.11.02*)

LIQUID CRYSTAL LABORATORY

Research
V. Lakshminarayanan
N.V. Madhusudana
R. Pratibha
V.A. Raghunathan
G.S. Ranganath
T.N. Ruckmongathan
B.K. Sadashiva (*Chairman*)
Sandeep Kumar (*from 19.12.02*)
K.A. Suresh
Yashodhan Hatwalne

Scientific/Technical
S.V. Ashoka (*from 1.8.*02)
Deepa Jacob (*from 5.8.02*)
A. Dhason
Jyotsna Rao (*from 1.2.03*)
S. Lakshmanan (*up to 31.3.*03)
Mary Janet (*from 7.6.02*)
Mohammed Ishaq
B.P. Neena (*up to 8.4.02*)
P.N. Ramachandra
N. Ravi Sankar
A.R. Shashidhara
H. Subramonyam
D. Vijayaraghavan

Visiting Scientist
Anand Kumar
G.V. Shivashankar

Research Students
Amaranatha Reddy
Amit Kumar Agarwal
Brindaban Kundu (*from 29.7.02*)
Debashish Kumar Har (*up to 31.3.03*)
Dipanjan Bhattacharya
V. Ganesh
M. Govind (*from 26.7.02*)
V. Manjula Devi
K.G. Pani Kumar
Pratiti Biswas
Raj Kumar Gupta
K. Rema
T. Roopa
Sanat Karmakar
K.L. Seetharamachar (*up to 12.6.02*)
H.N. Shreenivasa Murthy
Surajit Dhara
Ujjal Kumar Sur
Uma Devi (*from 31.7.02*)
Vani Kulkarni (*from 3.10.02*)
K.N. Vasudha
G.R. Vijaya Kumar (*from 16.9.02*)
P. Viswanath

Post-Doctoral Fellow
Sandhya (*from 7.6.02*)

Secretarial
K. Radhakrishna

ASTRONOMY & ASTROPHYSICS

Research
Anish Roshi (*from 17.2.03*)
R. Bhandari
Biman B. Nath
A.A. Deshpande✕
Dipankar Bhattacharya
K.S. Dwaraknath
V. Radhakrishnan
B. Ramesh
Shiv Kumar Sethi (*from 1.4.02*)
C.S. Shukre
S. Sridhar (*from 12.8.02*)
G. Srinivasan
C.R.Subrahmanya (*Chairman*)

Research Students
Amitesh Omar
Ashish Asgekar *(JAP)**(*up to 5.5.02*)
Atish Kamble
Chandrayee Sengupta
Kanak Saha (*from 2.9.02*)
R. Niruj Mohan(*JAP*)*(*up to 23.11.02*)
V. N. Pandey
Rajesh Gopal (*from 18.7.02*)
Rekesh Mohan
L. Resmi (*JAP*)*
Supurna Roychowdhury

**Joint Astronomy Programme*
✕*On leave visiting the Radio Astronomy Deparment, Arecibo Observatory, USA*

Research Associate
Sunita Nair

Post-Doctoral Fellow
Christian Zier (*from 3.3.03*)

Visiting Scientist
P. Sreekumar

Secretarial
V. Vidyamani
Latha V. Murthy (*from 3.8.02*)

RADIO ASTRONOMY LAB

Technical
T. Anantha Prakash
P. G. Ananthasubramanian
M.S. Ezhilarasi
B.S. Girish
M. R. Gopala Krishna
Gurushant Y. Tadasalur
M. Jayadevaiah
P.A. Kamini
S. Kasturi
M. Krishna Murthy
Madhavi Bicheli (*from 15.7.02*)
S. Madhavi
T.S. Mamatha
T.C. Pavan (*from 1.8.02*)
Peeyush Prasad (*from 5.9.02*)
T. Prabu
Pushpa Jain
K.B. Raghavendra Rao
S. Raghunandan (*up to 30.7.02*)
A. Raghunathan
G.C. Rashmi (*from 1.8.02*)
D.K. Ravindra (*Consultant*)
B.T. Ravishankar
P. Sandhya
G. Sarabagopalan
G.B. Sharada (*from 15.7.02*)
S. Siva
R.Somashekar
M. Soumya
K.S. Srivani (*from 2.5.02*)
S. Sujatha
S.R. Swaroopa (*up to 31.12.02*)
B.K. Udaya Shankar (*from 17.6.02*)
N. Udaya Shankar (*In-Charge*)

OBSERVATORY

Technical
V.G. Balachandran (*from 2.11.02*)
D. Madhusudana Rao
Manohar O. Modgekar
P.V. Rishin
A. Satish Jadhav (*up to 11.11.02*)
Shib Shankar Roy (*from 7.8.02*)
Sunil Castroe (*up to 22.11.02*)
K.R. Venkatesh (*up to 8.4.02*)
K.R. Vinod

Visiting Scientist
A. Krishnan

Secretarial
Mamatha Bai
Anand Kumar (*up to12.10.02*)

ELECTRONICS & INSTRUMENTATION

Technical
K. Chandrashekara
S. Krishnamurthy
H. N. Nagaraja
P.S. Sasi Kumar
M. Selvamani (*Consultant*)
S. Shameem
G. Suresh (*up to 20.7.02*)
C. Vinutha

COMPUTERS

C.R. Subrahmanya (*Head*)
Jacob Rajan
R. Nanda Kumar
B. Sridhar
B.T. Ravishankar

LIBRARY

Geetha S.
Girija Srinivasan
Hanumappa
M. Manjunath
M. N. Nagaraj
Y.M. Patil (*Librarian*)
Vrinda J. Benegal

Support Staff

K. Chowdasetty
C. Elumalai

MECHANICAL & ENGINEERING SERVICES

S. Alok Kumar (*from 23.10.02*)
S. Abdul Rahim
M. Achankunju
I. Charles Paul
V. Dhamodaran
R. Duraichelvan
R. Elumalai
K.O. Francis
K.T.Gangadharan(*In-Charge Genl.Workshop*)
V. Gokula Chandran
N. Gopal
G. Gopi
I. Henry
M. Mani
K.M. Mohandas
C.M.Ateequlla (*In-Charge, Basement Workshop*)
V.K. Muthu
V. Nagaraja
V. Narayanaswamy
T. Puttaswamy
D. Sunand
P. Srinivasa
S.Sundaraj
M. Suresh Kumar
V. Venu

GAURIBIDANUR TELESCOPE

Technical

H.A. Aswathappa

Support Staff

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

ADMINISTRATION

K. Krishnama Raju (*Administrative Officer*)
K. Raghunatha (*Dy. Administrative Officer*)
S. Raghavachar (*Asst. Admn. Officer*)
Marisa D'Silva
K. Radha
L.P. Kumar
S.R. Ramasubramaniyan
V. Raveendran
R. Ganesh

ACCOUNTS

R. Ramesh
K. R. Shankar (*Accounts Officer*)
S. Srinivasa Murthy
P.V. Subramanya

PURCHASE

Lakshmi Rajagopal (*Purchase Offr.*)
Sowjanya Kumar
Sujatha Anil Kumar
B. Srinivasa Murthy

STORES

S. Rajasekharan Nair (*Stores Officer*)
C. N. Ramamurthy
M.V. Subramanya

GRAPHIC ARTS

Raju Varghese

ESTATE & BUILDINGS

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

Secretarial: V. Raghunath

CARPENTRY

M. Gopinath
K. M. Lakshmanan (*Supervisor*)
L. Muthu
V. Ramu
T. Subramani(*up to 31.8.02*)

MEDICAL

Dr. M.R. Baliga (*Consultant Paediatrician*)
Dr. A.R. Pai (*Consultant Physician*)

Lab. Technician: R. Shanthamma

TRANSPORT

Abdul Khader
M. Balarama
R. Jayaram
C. K. Mohanan
G. Raja
G. Prakash
Rahamath Pasha
Rahamathulla Khan
M. K. Raju Kutti

AMENITIES (Canteen, Guest House and Hostels)

C.V. Bharghavan
T.V. Janardhanan
Mangala Singh
Muniratna
T. Naganna
N. Narayanappa
P. C. Prabhakar
N. Puttaswamy
A. Raju
N. Seetharam
Sharadamma
Shivamallu
Uma
K. Velayudhan
V. Yeshodha

HORTICULTURE

Bylappa
Chikkamunivenkatappa (*up to 9.12.02*)
V. Krishnappa (*Consultant)*
Lakshmamma
Lingegowda
Maiga
Mailarappa
Marappa
Munilakshmi
D. Muniraja
D. Mahalinga
S. Muniraju
Rangalakshmi
Thimmarayappa
Varalakshmi

UPKEEP

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

SECURITY

V. Arputha Raj (*up to 31.7.*02)
B. M. Basavarajaiah
U. A. Earappa
H. Gangaiah
Govind K. Kundagol
K. Govindappa
V. Jayaraman (*In-Charge, from 1.8.02*)
Joseph Kunjachan
Keshavamurthy
K. Krishnappa
Munihobalaiah
K. Pushparaj
O. M. Ramachandra
G. Ramakrishna
M. Sannaiah
Suresha
H. Vaderappa

VISITORS

Nitant Kenkre Consortium of the Americas for Inter-Disciplinary Science University of New Mexico U S A	31 March – 7 April 2002
G. Swarup National Centre for Radio Astrophysics Tata Institute of Fundamental Research Pune	1 – 4 April 2002, 22-27 May 2002 & 11-12 February 2003
Ger de Bruyn Netherlands Foundation for Radio Astronomy Dwingeloo, The Netherlands	4 – 6 April 2002
Francois Viallefond DEMIRM Meudon Observatory Paris, France	8 – 15 April 2002
Supriya Krishnamurthy Santa Fe Institute New Mexico, USA	8 — 22 April 2002
G.V. Vijayagovindan Mahatma Gandhi University Kottayam	15 April – 14 May 2002
Nadeem Oozeer University of Mauritius Mauritius	23 April – 1 July 2002 & 15 June – 30 April 2002
A. Venkateswara Rao Air Glass Laboratory Shivaji University, Kolhapur	9-10 May 2002
Miller Goss National Radio Astronomy Observatory Socorro, New Mexico USA	9 – 13 May 2002

Gopal Krishna National Centre for Radio Astrophysics Tata Institute of Fundamental Research Pune	12 – 16 May 2002
Prasenjit Singha Deo S N Bose National Centre for Basic Sciences Kolkata	25 May – 2 June 2002
R. Simon Institute of Mathematical Sciences Chennai	30 – 31 May 2002
N.R. Mantena L A Southwest University USA	3 – 10 June 2002
Mira Dey Presidency College Kolkata	10 – 25 June 2002
R. Ramachandran Institute of Mathematical Sciences Chennai	4 – 6 July 2002
Swapan K. Ghosh Bhabha Atomic Research Centre Mumbai	4- 6 July 2002
Soumya Mohanty Max Planck Institut Germany	8 – 10 July 2002
Soma Mukherji Max Planck Institut Germany	8 – 10 July 2002
A.R.P. Rau Louisiana State University Baton Rouge USA	9 – 13 July 2002

R. Gopakumar Harish-Chandra Research Institute Allahabad	8 – 22 July 2002
S. Sridhar Northeastern University Boston, U S A	15 July – 2 Sept. 2002
Shashi Bhushan Pandey State Observatory Nainital	22 July – 31 August 2002
M. Muthukumar University of Massachusetts Amherst, U S A	24 – 27 July 2002
N.D. Hari Dass Institute of Mathematical Sciences Chennai	16-17 August 2002
Vikram Soni National Physical Laboratory New Delhi	26 Aug. – 26 Sept. 2002
Devashish Sanyal Indian Association for the Cultivation of Science Kolkata	9 Sept. – 25 Oct. 2002
P. Hariharan University of Sydney Australia	11 Sept. – 20 Sept. 2002
T. Padmanabhan Inter-University Centre for Astronomy and Astrophysics Pune	7 – 25 October 2002
S. Anantha Ramakrishna Blackett Laboratory Imperial College London, U K	10 – 13 November 2002

G. Rajasekharan Institute of Mathematical Sciences Chennai	13 – 14 November 2002
Sumati Surya University of Alberta Canada	17 – 21 November 2002
Abhay Ashtekar Centre for Gravitational Physics & Geometry Penn State University U S A	27 Nov. – 10 Dec. 2002
Martin Bosowald Penn State University USA	27 Nov. – 10 Dec. 2002
L. Sriramkumar Harish-Chandra Research Institute Allahabad	21 – 26 July 2002, & 28 Nov. – 9 Dec. 2002
Fernando Barbero CSIC, Madrid, Spain	28 Nov – 10 Dec 2002
Alok Laddha Utah University USA	29 Nov – 9 Dec 2002
Sukanya Sinha Indian Statistical Institute Bangalore	28 Nov. – 9 Dec. 2002
Ganshyam Date Institute of Mathematical Sciences Chennai	28 Nov. – 10 Dec 2002
Parthasarathy Majumdar Institute of Mathematical Sciences Chennai	28 Nov. – 7 Dec 2002
Golam Hossain Institute of Mathematical Sciences Chennai	28 Nov – 9 Dec 2002

Soumen Basak Institute of Mathematical Sciences Chennai	28 Nov – 9 Dec 2002
James Rhoads Space Telescope Science Institute Baltimore USA	4 – 6 December 2002
D. Morris Institut de Radioastronomie Millimetrique St. Martin D'Heres France	2 Jan. – 31 March 2003
I. Janossy Research Institute for Solid State Physics and Optics, Budapest Budapest, Hungary	11-22 December 2002
S.T. Lagerwall School of Physics and Engineering Physics Chalmers University of Technology Goteborg, Sweden	13-21 December 2002
A.C. Ribeiro Centro de Fisica da Materia Condensada-UL Lisboa, Portugal	15-22 December 2002
H.T. Nguyen Centre de Recherche Paul Pascal Universite Bordeaux I Pessac, France	16-22 December 2002
W. Haase Technische Universitat Darmstadt Germany	17-21 December 2002
O.D. Lavrentovich Liquid Crystal Institute Kent State University USA	17 – 24 December 2002

Satyendra Kumar Kent State University USA	17 – 20 December 2002
K.S. Krishnamurthy College of Military Engineering Pune	17-21 December 2002
B.D. Malhotra National Physical Laboratory New Delhi	17-21 December 2002
Mohan Srinivasarao Georgia Institute of Technology Atlanta, USA	17-21 December 2002
Ou-Yang Zhong-can Institute of Theoretical Physics Chinese Academy of Sciences Beijing, China	17-23 December 2002
B. Pansu Universite Paris-Sud Orsay, France	17-22 December 2002
C.K.S. Pillai Regional Research Laboratory Thiruvananthapuram	17-21 December 2002
A. Strigazzi Politechnico di Torino Torino, Italy	17-22 December 2002
S.I. Torgova Federal State Unitary Enterprise State Research Centre NIOPIK Mosco, Russia	17-22 December 2002
C. Tschierske Martin-Luther University Halle-Wittenberg Halle, Germany	18-21 December 2002
Yashwant Singh Banaras Hindu University, Varanasi	18-21 December 2002

Dinesh Somanah Feb.2003 University of Mauritius Mauritius	16 Dec. 2002 – 28
Badri Krishnan Albert Einstein Institut Potsdam, Germany	23 – 25 December 2002
L. Woltjer Switzerland	31 Dec.2002 – 14 Jan.2003
Pier A. Mello Universidad Nacional Autonoma de Mexico Mexico	28 Feb. – 28 March 2003
Dipanjan Mitra Max Planck Institut for Radio Astronomie Bonn, Germany	6 – 8 March 2003
Sanjay Kumar Sahay Inter-University Centre for Astronomy and Astrophysics Pune	9 – 14 March 2003
Kaushik Ghosh Saha Institute of Nuclear Physics Kolkata	11 – 15 March 2003
Shrirang S. Deshingkar University of South Africa Pretoria South Africa	27 – 29 March 2003

Annexure I

PAPERS PUBLISHED

In Journals

1. "Diffusion with constant speed in a model phase space" (S Anantha Ramakrishna and ***N. Kumar***), *Int. J. Mod. Phys.* **B 16** (2002) 3715.

2. "Carbon nanotube flow sensors" (Shankar Ghosh, A K Sood and ***N Kumar***), Science, **299** (2003) 1042.

3. "Correcting the quantum clock: Conditional sojourn times" (S Anantha Ramakrishna and ***N Kumar***), Europhysics Letters, **60** (2002) 491.

4. "A comparison of search templates for gravitational waves from binary inspiral: 3.5PN updates" (T. Damour, ***B.R. Iyer*** and B.S. Sathyaprakash), *Phys. Rev. D*, **66**, 027502 (2002).

5. "Second post-Newtonian Gravitational wave polarisations for compact binaries in elliptical orbits" (A. Gopakumar and ***B.R. Iyer***), Phys. Rev D., **65**, 084011 (2002).

6. "Gravitational waves from black hole binary inspiral and merger: The span of third post-Newtonian effective-one-body templates" (T. Damour, ***B.R. Iyer***, P. Jaranowski and B.S. Sathyaprakash), *Phys. Rev. D*, **67**, 064028 (2003).

7. "Third post-Newtonaian dynamics of compact binaries: Equations of motion in the center-of-mass frame" (Luc Blanchet and ***B.R. Iyer***), *Classical and Quantum Gravity*, **20**, 755 (2003).

8. "Hidden symmetries in microwave resonators" (***J. Samuel*** and ***Abhishek*** **Dhar**), Phys. Rev. A, **66**, 044102 (2002).

9. "Elasticity of semiflexible polymers" (***J. Samuel*** and ***Supurna Sinha***), *Phys. Rev.E*, **66**, 050801(R) (2002).

10. "Molecular elasticity and the geometric phase" (***J. Samuel*** and ***Supurna Sinha***), Phys. Rev. Lett., **90**, 098305 (2003).

11. "Gravitons from a loop representation of linearised gravity" (***Madhavan Varadarajan***), *Phys. Rev.*, **D66**, 024017 (2002).

12. "Driven Heisenberg magnets: Non-equilibrium criticality, spatio-temporal chaos and control" (***J. Das***, ***Madan Rao*** and S. Ramasway), *Europhys. Lett.*, **60**,,418 (2002).

13. "Statistical mechanics of nucleation in solids: a kinetics driven morphological transition"(S. Sengupta and ***Madan Rao***), *Physica A*, **318**, 251 (2002).

14. "Triple minima in free energy of semiflexible polymers" (***Abhishek Dhar*** and D. Chaudhuri), *Phys. Rev. Lett.*, **89**, 065502 (2002).

15. Magnetic trapping of metastable $^3P_2$ atomic strontium" (S.B. Nagel, C.E. Simien, S. Laha, P. Gupta, ***Vudayagiri S. Ashoka*** and T.C. Killian), *Phys. Rev. A*, **67**, 011401(R) (2003).

16. "Freely dispersible Au@TiO_2, Au@ZrO_2, Ag@TiO_2 and Ag@ZrO_2 core-shell nanoparticles: One-step synthesis, characterization, spectroscopy, and optical limiting properties" (Renjis T. Tom, A. Sreekumaran Nair, ***Navinder Singh***, M. Aslam, C.L. Nagendra, ***Reji Philip***, K. Vijayamohanan and T. Pradeep), *Langmuir*, **19**, 3439 (2003).

17. "Photo-physical and lasing characterization of neat films of 4-methyl-TPD and of an alternating copolymer of 4-methyl-TPD with MEH-PPV" (***Reji Philip***, W. Holzer, A. Penzkofer, H. Tillmann and H.-H. Hoerhold), *Synthetic Metals*, **132**, 297 (2003).

18. "Magnetoelastic study of amorphous $Fe_{90+x}Zr_{10-x}$ alloys" (K. Balakrishnan, P.D. Babu, V. Ganesan, ***R. Srinivasan*** and S.N.Kaul), *J. Magnetism & Magnetic Materials*, **250**, 110 (2002).

19. "Novel chiral fluoro-substituted benzoyloxybenzoates exhibiting an antiferro-electric mesophase" (***S. Shubashree, B.K. Sadashiva*** and ***Surajit Dhara***), *Molec. Cryst. Liquid Cryst.*, 381, 21 (2002)

20. "Helical superstructures in the mesophase of compounds derived from 2-cyano-resorcinol" *(**R. Amaranatha Reddy*** and ***B.K. Sadashiva**), Liquid Cryst.*, **29**, 1365 (2002).

21. "Ferroelectric properties exhibited by mesophases of compounds composed of achiral banana-shaped molecules" *(**R. Amaranatha Reddy*** and ***B.K. Sadashiva**), J. Mater. Chem.*, **12**, 2627 (2002).

22. "Occurrence of the B_7 mesophase in two homologous series of seven-ring achiral compounds composed of banana-shaped molecules" *(**R. Amaranatha Reddy** and **B.K. Sadashiva**), Liquid Cryst.*, **30**, 273 (2003).

23. "Banana-shaped mesogens: effect of lateral substituents on seven-ring esters containing a biphenyl moiety" (***H.N. Shreenivasa Murthy*** and ***B.K. Sadashiva***), *Liquid Cryst.*. **29**, 1223 (2002).

24. "Design and fabrication of a novel intermediate vacuum receiver adapter with a single stopcock" (***A. Dhason***), *British Society of Scientific Glassblowers Journal*, **40**, 146 (2002).

25. "Some experimental investigations on type-II chiral liquid crystals" (***Surajit Dhara, R. Pratibha*** and ***N.V. Madhusudana**), Ferroelectrics*, **277**, 13 (2002).

26. "A molecular theory of smectic C liquid crystals made of rod-like molecules" (***A.S. Govind*** and ***N.V. Madhusudana***), *Euro. Phys. J.E.*, **9**, 107 (2002).

27. "Structure and interactions in the anomalous swelling regime of phospholipid bilayers" (G. Pabst, J. Katsaras, ***V.A. Raghunathan*** and M. Rappolt), *Langmuir*, **19**, 1716 (2003).

28. "Existence of a hydrophobic gap at the alkanethiol SAM-Water interface: An interfacial capacitance study" (***Ujjal Kumar Sur*** and ***V. Lakshminarayanan***), *J. Colloid and Interface Science*, **254**, 410 (2002).

29. "Driving passive-matrix LCDs with low hardware complexity and reduced supply voltage" (***K.G. Pani Kumar*** and ***T.N. Ruckmongathan***), *J. Soc. Information Display*, **10**, 363 (2002).

30. "Development of an optical tweezer combined with micromanipulation for DNA and protein nanobioscience" (G.V. Soni, F.M. Hameed, ***T. Roopa*** and ***G.V. Shivashankar***), *Curr. Sci.*, **83**, 12 (2002).
31. "Nanomechanics of membrane tubulation and DNA assembly" (***T. Roopa*** and ***G.V. Shivashankar***), *Appl. Phys. Lett.*, **82**, 1631 (2003).

32. "Singularities of the mixed state phase" (***R. Bhandari***), *Phys. Rev. Lett.*, **89**, 268901 (2002).

33. "Cooling flows and the entropy of the intragroup medium" (***B.B. Nath***), *Mon. Not. R. Astron. Soc.*, **339**, 721 (2003).

34. "Suppression of thermal conduction in non-cooling flow clusters" (***B.B. Nath***), *Mon. Not. R. Astron. Soc.*, **340**, L1 (2003).

35. "HI Fluctuations at large Redshifts: I – Visibility correlation" (Somnath Bharadwaj and ***Shiv K. Sethi***), *J. Astrophys. Astr.*, **22**, 293 (2001).

36. "A flattening in the optical light curve of SN 2002ap" (S.B. Pande, G.C. Anupama, R. Sagar, ***D. Bhattacharya***, D.K. Sahu and J.C. Pandey), *Mon. Not. R. Astron. Soc.*, **340**, 375 (2003).

37. "Optical observations of the bright long-duration peculiar GRB 021004 afterglow" (S.B. Pandey, D.K. Sahu, ***L. Resmi***, R. Sagar, G.C. Anupama, ***D. Bhattacharya***, V. Mohan, T.P. Prabhu, B.C. Bhatt, J.C. Pandey, P. Parihar and A.J. Castro-Tirado), *Bull. Astr. Soc. India*, **31**, 19 (2003).

38. "GMRT and VLA observations of HI and OH from the Seyfert galaxy Mrk 1" (***Amitesh Omar***, ***K.S. Dwarakanath***, M. Rupen and ***K.R. Anantharamaiah***), *Astron. & Astr.*, **394**, 405 (2002).

39. "An HI survey of clusters in the local universe: Outlining the project" (J.H. Van Gorkom, H. Bravo-Alfaro, ***K.S. Dwarakanath***, P. Guhathakurta, B.M. P{oggianti, D. Schiminovich, M. Valluri, M. Verheijin, E. Wilcots and A. Zabludofi), *Astrophys. and Space Sci.*, **285**, 219 (2003).

40. "Carbon recombination lines near 327 MHz. I. 'Diffuse' C11 regions in the galactic disk" (D. Anish Roshi, N.G. Kantharia and ***K.R. Anantharamaiah***), *Astron. & Astr.*, **391**, 1097 (2002).

41. "Very large array detection of radio recombination lines from the radio nucleus of NGC 253: Ionization by a weak AGN, an obscured SSC or a compact Supernova remnant?" (***Niruj R. Mohan***, ***K.R. Anantharamaiah*** and W.M. Goss), *Ap. J.*, **574**, 701 (2002).

42. "The maximum mass of neutron stars" (***G. Srinivasan***), *The Astron. Astrophys. Rev.*, **11**, 67 (2002).

43. "Imaging with the Mauritius radio telescope: Challenges and results" (***N. Udaya Shankar***, K. Golap, S. Sachdev, R. Dodson, M. Katwaroo and Ch.V. Sastry), *Astrophys. & Space Science*, **282**, 15 (2002).

44. "Full resolution images from the Mauritius radio telescope" (***V.N. Pandey***, ***N. Udaya Shankar*** and R. Somanah), *Astrophys. & Space Science*, **282**, 29 (2002).

45. "Limitations of the tangent plane approximation for wide-field imaging using the Mauritius radio telescope" (N. Oozeer and ***N. Udaya Shankar***), *Astrophys. & Space Science*, **282**, 43 (2002).

46. "Study of extended radio galaxies at 151.6 MHz using the Mauritius radio telescope" (R. Somanah and ***N. Udaya Shankar***), *Astrophys. & Space Science*, **282**, 57 (2002).

47. "A spectral line survey of IRAS 17470-2853 from 86.1 to 92.1 GHz" (H. Kim, ***B. Ramesh***, M.G.Burton), *Publications of the Astron. Soc. Australia*, **19**, 505 (2002).

48. "Multi-frequency GMRT observations of the HII regions S 201, S 206, and S 209: Galactic temperature gradient" (***Amitesh Omar***, J.N. Chengalur and D. Anish Roshi), *Astron. & Astro.*, **395**, 227 (2002).

49. "220 GHz zenith atmospheric transparency at IAO, Hanle" (***P.G. Ananthasubramanian***, S. Yamamoto and T.P. Prabhu), *Int. J. Infrared and Millimeter Waves*, 23, 227 (2002).

50. "The topology and polarization of sub-beams associated with the *drifting* subpulse emission of pulsar B0943+10 - III. Analysis of Pushchino 103/40-MHz observations" (J. M. Rankin, S.A. Suleymanova and ***A.A. Deshpande***), *Mon. Not. R. Astron. Soc.*, 340, 1076 (2003).

51. "Changes in the measured image separation of the gravitational lens system PKS 1830-211" (C. Jin, M.A. Garrett, ***S. Nair***, R.W. Porcas, A.R. Patnaik and R. Nan), *Mon. Not. R. Astron. Soc.*, **340**, 1309 (2003).

52. "Action and energy of the gravitational field" (J.D. Brown, ***S.R. Lau*** and J.W. York), *Ann. Phys.*, **297**, 175 (2002).

In Conference Proceedings

1. "Gravitational wave astronomy: Probing physics and unraveling astrophysics" (**B.R. Iyer**), in *Proceedings of the twenty first Meeting of the Astronomical Society of India, Pune, 2002, Bull. Astron. Soc. India*, **30**, 735 (2002).

2. "STM, FT-IR, and electrochemical impedance spectroscopic studies on the permeability of alkanethiol SAMs" (***Ujjal Kumar Sur*** and ***V. Lakshminarayanan***), in *Proceedings of the International Symposium on Advances in Electrochemical Science & Technology*, Vol. I (Society for Advancement of Electrochemical Science & Technology, 2002), pp 24-27.

3. "Study of electron transfer kinetics on SAM of alkanethiol formed in non-aqueous solvents" (***Ujjal Kumar Sur*** and ***V. Lakshminarayanan***), in *Proceedings of the International Symposium on Advances in Electrochemical Science & Technology*, Vol. I (Society for Advancement of Electrochemical Science & Technology, 2002), pp B1-B4.

4. "Displaying gray shades in passive matrix LCDs using successive approximation" (***K.G. Pani Kumar*** and ***T.N. Ruckmongathan***), in *Proceedings of the Seventh Asian Symposium on Information Display* (ASID2002), September 2002, p. 229.

5. "Geometric phase in phasing of antenna arrays" (***R. Bhandari***), in *Proceedings of the Symposium No.199 "The Universe at Low Radio Frequencies"*, eds. A. Pramesh Rao, G. Swarup and Gopal-Krishna, (2002), p.514).

6. "Imaging with the scanning sky monitor on ASTROSAT" (***D. Bhattacharya*** and B.T. Ravi Shankar), in *Proceedings of the twenty first Meeting of the Astronomical Society of India, Pune, 2002, Bull. Astr. Soc. India*, **30**, 833 (2002).

7. "Evolution of neutron star magnetic fields" (***D. Bhattacharya***), in *Proceedings of the International Conference on Multi-Colour Universe, TIFR, Mumbai, 2002, J. Astrophys. Astron.*, **23**, 67 (2002).

8. "General relativistic spectra from accretion disks around rapidly rotating neutron stars" (S. Bhattacharya, ***D. Bhattacharya***, R. Misra, A.V. Thampan), in *ASP Conference Proceedings "The Physics of Cataclysmic Variables and Related Objects"*, ed. B.T. Gänsicke, K. Beuermann and K. Reinsch (Astronomical Society of the Pacific, San Francisco, 2002) p. 467.

9. "Low frequency recombination lines of hydrogen" (***K.R. Anantharamaiah***), in *Proceedings of the Symposium No.199 "The Universe at Low Radio Frequencies"*, eds. A. Pramesh Rao, G. Swarup and Gopal-Krishna, (2002), p.319.

10. "VLA Observations of the galactic centre at 74 MHz" (***K.R. Anantharamaiah***, N.E. Kassim, T.J.W. Lazio, W>M. Goss and HK. Falcke), in *Proceedings of the Symposium No.199 "The Universe at Low Radio Frequencies"*, eds. A. Pramesh Rao, G. Swarup and Gopal-Krishna, (2002), p. 272.

Annexure - II

COLLOQUIA

Name	Title	Date
V. M. Kenkre University of New Mexico U S A	Theory of charge transport in organic crystals: Lessons from the past and prospects for the future	3.4.2002
Ger de Bruyn NFRA, Dwingeloo	Interstellar scintillation and ultra-compact radio AGN: The case of J1819+3845	5.4.2002
Mark Zreda & Darin Desilets University of Arizona U S A	Cosmogenic Isotopes and their applications in geosciences	10.4.2002
C. S. Shukre Raman Research Institute Bangalore	The Lore of Pulsars	11.4.2002
Dibyendu Nandy Indian Institute of Science Bangalore	The non-occurrence of sunspots at high solar latitudes and its implication for material flows in the Sun□s interior	12.4.2002
C.H. Ishwara Chandra ISRO Satellite Centre Bangalore	GMRT observations of the galactic microquasar GRS 1915+105: Evidence for synchrotron bubbles	26.4.2002
M.S. Giridhar University of Arizona U S A	Design of a liquid crystal electroactive lens	26.4.2002
Francois Viallefond Paris Observatory France	Contribution of LERMA to phase 1 studies for the ALMA project	9.5.2002
G.S. Ranganath Raman Research Institute Bangalore	Opto-elasticity of liquid crystals	9.5.2002
A. Venkateswara Rao Shivaji University Kolhapur	Aerogels and their applications	10.5.2002
Crystal Brogan National Radio Astronomy Observatory, Socorro U S A	A low frequency survey of the inner galactic plane	10.5.2002

Name	Title	Date
Tracy Clarke National Radio Astronomy Observatory, Socorro U S A	Low frequency observations of the diffuse radio emission in Abell 754	10.5.2002
Prosenjit Singha Deo S N Bose National Centre for Basic Sciences Kolkata	Deformed many body states in mesoscopic systems	29.5.2002
Stan Terras Renishaw Plc. U K	Applications of Raman spectroscopy	31.5.2002
R. Simon Institute of Mathematical Sciences, Chennai	Entanglement and quantum informtion theory	31.5.2002
Mira Dey Presidency College Kolkata	Are there strange quark stars?	21.6.2002
Sudhir Jain Bhabha Atomic Research Centre, Mumbai	Quantum chaos	26.6.2002
Prasenjit Sen Jawaharlal Nehru University New Delhi	Non-equilibrium processess for generating silicon nanostructures in single crystalline silicon	3.7.2002
Joseph Samuel Raman Research Institute Bangalore	Molecular elasticity	4.7.2002
Avinash Khare Insitute of Physics Bhubaneshwar	Linear superposition for nonlinear equations and new identities for Jacobi elliptic functions	5.7.2002
Ashok Vudayagiri Rice University Houston, USA	Laser coling of strontium	9.7.2002
Soumya Mohanty Max-Planck Institut für Gravitationsphysik AEI, Golm, Germany	Current problems in gravitational wave data analysis	9.7.2002

Name		Title	Date
Soma Mukherjee Max-Planck Institut für GravitationsPhysik AEI, Golm, Germany		Detector characterization for the gravitational wave interferometric directors	10.7.2002
A.R.P. Rau Louisiana State University U S A		Time evolution, including dissipation and decoherence	11.7.2002
Rajesh Gopakumar Harish-Chandra Research Institute, Allahabad		Solitons in non-commutative field theories	18.7.2002
L. Sriramkumar Harish-Chandra Research Institute, Allahabad	1	Cavity with a trembling wall and Bekenstein□s bound on specific entropy	22.7.2002
	2	Semi callsical gravity – Issues, resolutions and prospects	24.7.2002
M. Muthukumar University of Massachusetts Amherst, U S A		Polymer crystallization: Entropic quench and spontaneous selection of finiteness	25.7.2002
P.K. Mohanty Tata Institute of Fundamental Research, Mumbai		Percolation and self organised criticality	1.8.2002
M.K. Mathew National Centre for Biological Scieces Bangalore		Molecular motors	12.8.2002
Umakant D. Rapol Indian Institute of Science Bangalore		Laser cooling and trapping of Ytterbium from a thermal source	12.8.2002
N.D. Hari Dass Institute of Mathematical Sciences, Chennai		Do single quntum states have any statistical significance?	16.8.2002
S. Sridhar Northeastern University Boston, U S A		Left-handed light	29.8.2002
Ajay Kandhari Olympus Microscopes New Delhi		Confocal microscope	30.8.2002

Name		Title	Date
B. Viswanathan Indian Institute of Technology Chennai		Carbon nanotubes and their recent developments	3.10.2002
T. Padmanabhan Inter-University Centre for Astronomy & Astrophysics Pune	1 2	Gravity from spacetime thermodynamics Statisticalmechanics of gravitating systems in static and cosmological backgrounds (*Series of three lectures*)	16.10.2002 18,21,23 October 2002
C.S. Unnikrishnan Tata Institute of Fundamental Research, Mumbai		Collapse of the state or Collapse of the theory? The need for a change in quantum interpretation	22.10.2002
S.G. Bhargavi Indian Inst. of Astrophysics Bangalore		Gamma ray bursts	25.10.2002
S. Yashonath Indian Inst. of Science Bangalore		Mixture separation of nano length scales:	6.11.2002
Sumati Surya University of Alberta Canada	1 2	Tales of the AdS solition The shape of the Universe	18.11.2002 20.11.2002
H. Meier Institut fuer Organische Chemie, Duesbergweg Germany		Conjugated oligomers — Linear, cyclic and dendritic systems	26.11.2002
James Rhoads Space Telescope Science Institute, Baltimore U S A		Observational tests of gamma ray burst collimation	5.12.2002
Kheya Sengupta Technische Universitaet Muenchen, Garching Germany		Mimicking biological tissues and probing very soft-surfaces	13.12.2002
Mathew Bailes Centre for Astrophysics & Supercomputing, Australia		Pulsar timing and general relativity	18.12.2002
Badri Krishnan Albert Einstein Institut Potsdam, Germany		Dynamical horizons: Energy, angular momentum, fluxes and balance laws	23.12.2002

Name	Title	Date
Kandaswamy Subramanian Inter-University Centre for Astronomy & Astrophysics Pune	Magnetic helicity: What is it and what is it bad for?	31.1.2003
Zeev Luz The Weizmann Institute Rehovot, Israel	Solving problems with soap films — A lecture with demonstration	6.2.2003
Sandeep Kumar Raman Research Institute Bangalore	Supramolecular materials for molecular electronics	20.2.2003
Suryadeep Ray Harish-Chandra Research Institute, Allahabad	Clustering of collapsed objects in	21.2.2003
G Srinivasan Raman Research Institute Bangalore	The realm of the supermassive black	6.3.2003
Dipanjan Mitra Max-Planck Institut fur Radioastronomie, Bonn Germany	Using pulsars to study the magnetic field in the milky way	7.3.2003
Sanjay Kumar Sahay Inter-University Centre for Astronomy & Astrophysics Pune	Search for continuous gravitational wave sources	10.3.2003
Kaushik Ghosh Saha Institute of Nuclear Physics, Kolkatta	Entanglement entropy of scalar field in 3+1 dimensional Reissner-Nordstrom de Sitter black hole background	13.3.2003
Himansu Mohapatra Indian Inst. of Science Bangalore	Hydrogen bonding dynamics and hydrogen transfer process in solution	17.3.2003
P.A. Mello Institute of Physics UNAM, Mexico	Statistical wave scattering and maximum entropy: Successes, failures and open questions	19.3.2003
D. Anish Roshi Raman Research Institute Bangalore	C^+ Line emission in the inner Galaxy	21.3.2003

Name	Title	Date
Andal Narayanan Raman Research Institute Bangalore	Experiments with ultra cold Rubidium atoms	24.3.2003
Shrirang S. Deshingkar University of South Africa Pretoria, South Africa	New approach to calculating the news	28.3.2003

11. "A GMRT HI imaging survey of the ERIDANUS group of galaxies" (***Amitesh Omar***, ***K.S. Dwarakanath*** and ***K.R. Anantharamaiah***), in *Proceedings of the Twenty First Meeting of the Astronomical Society of India, Pune, 2002, Bull. Astr. Soc. India*, 30, 749 (2002).

12. "GMRT detection of HI absorption in the high-redshift red quasar 3C 190" (C.H. Ishwara Chandra, ***K.R. Anantharamaiah*** and ***K.S. Dwarakanath***), in *Proceedings of the twenty first Meeting of the Astronomical Society of India, Pune, 2002, Bull. Astron. Soc. India*, 30, 747 (2002).

13. "The maximum mass of neutron stars" (***G. Srinivasan***), in *Proceedings of the twenty first Meeting of the Astronomical Society of India, Pune, 2002, Bull. Astr. Soc. India*, 30, 523 (2002).

14. "Full resolution deconvolved images from the Mauritius radio telescope" (***V.N. Pandey***, N. Oozeer, ***N. Udaya Shankar*** and R. Somanah), in *Proceedings of the twenty first Meeting of the Astronomical Society of India, Pune, 2002, Bull. Astr. Soc. India*, 30, 773 (2002).

15. "Carbon recombination lines at 34.5 MHz from the galactic plane", (N.G. Kantharia and ***K.R. Anantharamaiah***), in *Proceedings of the Symposium No.199 "The Universe at Low Radio Frequencies"*, eds. A. Pramesh Rao, G. Swarup and Gopal-Krishna, (2002), p.347.

16. "Galactic carbon recombination lines near 327 MHz", (D. Anish Roshi, N.G. Kantharia and ***K.R. Anantharamaiah***), in *Proceedings of the Symposium No.199 "The Universe at Low Radio Frequencies"*, eds. A. Pramesh Rao, G. Swarup and Gopal-Krishna, (2002), p.345.

17. "A study of low density ionized gas in the galactic plane" (D. Anish Roshi and ***K.R. Anantharamaiah***), in *Proceedings of the Symposium No.199 "The Universe at Low Radio Frequencies"*, eds. A. Pramesh Rao, G. Swarup and Gopal-Krishna, (2002), p.335.

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5. "Banana-shaped mesogens: A new homologous series of compounds exhibiting B_7 mesophase" (***H.N. Shreenivasa Murthy*** and ***B.K. Sadashiva***); *Liquid Cryst.*

6. "Role of molecular dipoles in liquid crystals" (***N.V. Madhusudana***), *Molec. Cryst. & Liquid Cryst.*

7. "Free standing films of twist grain boundary TGBA and UTGBC* liquid crystals studied by fluorescence confocal polarizing microscopy" (I.I. Smalyukh, ***R. Pratibha***, O.D. Lavrentovich and ***N.V. Madhusudana***), *Liquid Crystals*

8. "Polar head group interactions in mixed Langmuir monolayers" (***P. Viswanath*** and ***K.A. Suresh***), Phys. Rev. E

9. "Unusual features in the surface pressure-area isotherm in the Langmuir monolayer of a siloxane polymer" (***A. Bhattacharyya*** and ***K.A. Suresh***), *Molec. Cryst. Liquid Cryst.*

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13. "Cyclic voltammetric and electrochemical impedance studies on the structure, adsorption kinetics and barrier properties of some organic dithiols self-assembled monolayers on gold" (***Ujjal Kumar Sur, R. Subramanian*** and ***V. Lakshminarayanan***), *J. Colloid and Interface Science.*

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16. "Large scale magnetic fields: Galaxy two-point correlation function" (***Shiv K. Sethi***), *Mon. Not. R. Astron. Soc.*

17. "Evolution of an afterglow with a hard electron spectrum" (***D. Bhattacharya*** and ***L. Resmi***) Proceedings of the GRB Workshop, Rome, 2002.

18. "Changes in the measured image separation of the gravitational lens system PKS 1830-211" (C. Jin, M.A. Garrett, ***S. Nair***, R.W. Porcas, A.R. Patnaik and R. Nan) , *Mon. Not. R. Astron. Soc.*

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20. "The Vela Pulsar's Radio Nebula" (R. Dodson, D. Lewis, D. McConnell and ***A.A. Deshpande***), *Mon. Not. R. Astron. Soc.*

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6. "Viscoelastic modes in chiral liquid crystals" (***K.A. Suresh***), Proceedings of the Conference on Liquid Crystals and Other Soft Materials, Bangalore, December 2002 – Special issue of *Pramana*

7. "Structures of some surfactant-polyelectrolyte complexes" (***Rema Krishnaswamy***, **V.A. *Raghunathan*** and A.K. Sood), Proceedings of the Conference on Liquid Crystals and Other Soft Materials, Bangalore, December 2002 – Special issue of *Pramana*

8. "Molecular engineering of discotic nematic liquid crystals" ***(Sandeep Kumar)***, Proceedings of the Conference on Liquid Crystals and Other Soft Materials, Bangalore, December 2002 - Special Issue of *Pramana.*

9. "Experiments on mixtures of compounds made of rod-like and bent-core molecules" (***R. Pratibha, N.V. Madhusudana*** and ***B.K. Sadashiva***), Proceedings of the Conference on Liquid Crystals and Other Soft Materials, Bangalore, December 2002 - Special Issue of *Pramana.*

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Annexure III

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Discussed by	Paper discussed	Date
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H.N. Shreenivasa Murthy	A rational chemical synthesis of C_{60} Lawrence T. Scott *et al.* *Science*, **295**, 1500 (22 February 2002)	4.4.2002
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C.S. Shukre	Spinning eggs – A paradox resolved H.K. Moffat and Y. Shimomura *Nature*, **416**, 385 (2002)	2.5.2002
Pratiti Biswas	Spintronics: A new twist in computing David D. Awschlom *et al.* *Scientific American* (June 2002)	1.8.2002
Navinder Singh	Sub-laser-cycle electron pulses for probing Molecular dynamics Hiromichi Nilkura *et al.* *Nature*, **417**, 917 (27 June 2002)	1.8.2002

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N. Udaya Shankar	Observations of the anisotropy of the microwave background radiation with the cosmic background imager B.S. Mason *et al.* *astro-ph/02025834*	12.9.2002
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Joseph Samuel	Geometry and physics of wrinkling E. Cerda and L. Mahadevan *Phys. Rev. Lett.*, **90**, 074302-1 (21 February 2003)	27.3.2003

ABBREVIATIONS

ADC	Analog-to-Digital Converter
ADM	Arnowitt-Deser-Misner
AFM	Atomic Force Microscope
ASTROSAT	ISRO's Astronomical Satellite
ATCA	Australia Telescope Compact Array
ATNF	Australia Telescope National Facility
BAO	Beijing Astronomical Observatory, China
Cfa	Harvard Smithsonian Centre for Astrophysics, USA
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
CTAB	Cetyltrimethyl Ammonium Bromide
DDS	Direct Digital Synthesis
DHPC	Dihexanoyl Phosphatidyl Choline
DMPC	Dimyristoyl Phosphatidyl Choline
DMPG	Dimyristoyl Phosphatidyl Glycerol
DNA	Deoxyribose Nucleic Acid
DPPC	Dipalmitoyl Phosphatidyl Choline
DSP	Digital Signal Processor
EOS	Effective-One-Body
ERGs	Extremely Red Galaxies
FCPM	Fluorescence Confocal Polarizing Microscope
FPGA	Field Programmable Gate Array
FWHM	Full Width at Half Maximum
GHz	Giga Hertz
GMRT	Giant Meterwave Radio Telescope
GPS	Global Positioning System
HI	Neutral Atomic Hydrogen
HII	Ionized Hydrogen
HPB	Hydrophobic
HPL	Hydrophilic
IAP	Institut D'astrophysique de Paris, France
IF	Intermediate Frequency
IIA	Indian Institute of Astrophysics, Bangalore, India
IHES	Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, France
INSAT	Indian National Satellite
IRA	Institute of Radio Astronomy, Ukraine
ISRO	Indian Space Research Organisation, Bangalore, India
IUCAA	Inter University Centre for Astronomy & Astrophysics, Pune, India
JIVE	Joint Institute for VLBI in Europe

LB	Langmuir Blodgett
LCD	Liquid Crystal Display
MCF	INSAT Master Control Facility, Hassan
MHz	Mega Hertz
MPIfR	Max-Planck Institut für Radio Astronomie, Germany
MRT	Mauritius Radio Telescope
MST	Mesosphere Statosphere Troposphere Radar Facility, Tirupati, India
NAO	National Astronomical Observatory, Japan
NCRA	National Centre for Radio Astrophysics, Pune, India
NeII	Singly Ionized Neon
NRAL	National Radio Astronomical Laboratory, UK
NRAO	National Radio Astronomical Observatory, USA
OH	Hydroxyl Radical
OIII	Doubly Ionized Oxygen
PLL	Phase Lock Loop
PPD	Pre-stressed Parabolic Dish
PSF	Point Spread Function
RAC	Radio Astronomy Centre, Ooty, India
SAM	Self-Assembled Monolayer
SDS	Sodium Dodecyl Sulphate
SON	State Observatory Nainital, UP, India
TGBA	Twist Grain Boundary Smectic A phase
TIFR	Tata Institute of Fundamental Research, Mumbai, India
UOM	University of Mauritius, Mauritius
UTGBC*	Undulating Twist Grain Boundary Smectic C* Phase
VLA	Very Large Array, USA
VLBI	Very Long Baseline Interferometry
VSAT	Very Small Aperture Telescope
VSSC	Vikram Sarabhai Space Center, Thiruvananthapuram, India.
XRD	X-ray Diffraction