RAMAN RESEARCH INSTITUTE

BANGALORE

ANNUAL REPORT - 1983-84

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 generous grants from the Department of Science and Technology of the Government of India since 1972. The main fields of research are Liquid Crystals, Astronomy and Astrophysics.

1. Liquid Crystals

Liquid Crystals are states of matter intermediate between the liquid and crystalline states. Many organic compounds whose molecules have pronounced shape anisotropy exhibit such phases. The unique combination of fluidity and anisotropic properties of liquid crystals has led to many applications of these materials. The Liquid Crystals Laboratory of the Raman Research Institute has contributed significantly to the development of the field over the past decade.

The laboratory has been organised to undertake studies on most of the fundamental properties of liquid crystals. Theoretical and experimental work on liquid crystals is continuing along the lines indicated in the previous year's report.

2. Astronomy and Astrophysics

Astronomy which is one of the oldest sciences is concerned with the study of heavenly bodies by investigating the radiation received on earth from them. Optical astronomy deals with the "visible" part (wavelength 3000 Angstroms to 6500 Angstroms, 1 Angstrom = 10^{-8} centimeter) of the electromagnetic spectrum. Radio Astronomy, which had its beginnings in 1932 also deals with the study of these heavenly bodies, but the radiation received by radio telescopes on earth is in the radio wavelength part (30 metres to 1 millimeter) 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 raido 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 some exciting discoveries such as the 3 ° K cosmic background radiation, quasars, pulsars, etc.

The institute has set up a Decameter Wave Radio Telescope at Gauribidanur jointly with the Indian Institute of Astrophysics. It is among the largest telescopes in the world. It consists of two long antenna arrays; one oriented in the E-W and the other in the N-S direction of lengths 1.5 KM and 0.5 KM respectively. Operat-

ing at a wavelength of ten meters, the telescope can resolve objects whose angular separation is about 25 arc minutes in the sky. It is being used to study radio emissions from various types of celestial objects such as the Sun, Jupiter, our galaxy and external galaxies. The Sun emits intense radio bursts very frequently. Observations of the characteristics of these radio bursts give valuable information on the structure of the solar corona. Moving further out in our galaxy, we have the so-called ionised hydrogen regions, which are the birth places of stars. The Decameter Wave Radio Telescope is a very sensitive instrument for detection and study of such ionized hydrogen regions. These are just two examples of the kind of studies carried out with this telescope.

During the past decade, millimeter wave astronomy has assumed great importance because of the discovery of several molecules (combinations of Hydrogen, Carbon, Nitrogen, and Oxygen atoms) by their emitted line radiations in the millimeter wave part of the electromagnetic spectrum. These molecules are generally found in dense molecular clouds in our Galaxy where star formation is thought to be taking place. Hence, studies of the radiation from them should lead to an understanding of the nature and mechanism of star formation.

The Raman Research Institute is currently engaged in constructing a telescope to do advanced research in millimeterwave astronomy. The wavelength of operation will be a few millimeters. This puts a stringent requirement on the accuracy of the surface of the reflector which forms a major part of the radio telescope and will be of diameter 10.4 meters. The Institute is also engaged in building very sensitive receivers to operate in this wavelength band. This whole effort will help in the generation of technological know-how which has not been available in India hitherto.

Th Ooty Radio Telescope operated by the Tata Institute of Fundamental Research was used for pulsar observations, recombination line observations, etc., by members of the Institute's staff.

As reported last year, there are also theoretical research programmes in the fields of ionic crystals, maximum entropy method, pulsars, supernova remnants, general relativity and gravitation.

A somewhat more technical account of the research carried out in the past year by the various groups in the Institute is given in the following.

Liquid Crystals

Theoretical and experimental studies on liquid crystals are being pursued along the lines indicated in previous reports. Some of the more important results obtained during the current year are summarized below.

I. Theoretical Studies

In principle, thermomechanical coupling should exist in cholesteric liquid crystals, but as yet there is no conclusive evidence that it is of measurable magnitude. With a view to detecting this effect two experimental geometries have

been suggested which should yield a quantitative estimate of the thermomechanical coefficients. The consequences of thermomechanical coupling on the hydrodynamics of cholesterics have also been studied. It is found that second sound should be present in the cholesteric phase, but more interestingly it turns out that second sound should be accompanied by a temperature wave as well, thus bringing the analogy with superfluids even closer.

Some consequences of the Ginzburg-Landau gradient term have been investigated. For example, it has been found that the core structure of disclinations in smectic C should be exactly like that of the quantized vortex filament in a superfluid or the magnetic fluxoid in a type II superconductor. Additionally, it has been shown that if the smectic C director is subjected to a uniform in-plane distortion, and the distortion exceeds a certain critical value, a second order transition should take place from smectic C to the smectic A phase. This effect is analogous to the critical current effect in a superconductor.

It is a matter of time before thermotropic biaxial nematic liquid crystals are discovered, and indeed a search is going on in this laboratory as well. In anticipation of the discovery, a theoretical study has been undertaken of the hydrodynamics of this phase. The theory shows that 15 elastic and 15 viscous constants are required to describe the complete hydrodynamical behaviour of the orthorhombic biaxial nematic. Possible geometries for extracting the material parameters are being examined.

II. Experimental Studies

The precision of the high pressure apparatus has been imporved. Using this improved set up, the topology of the Pressure-Temperature diagram near the reentrant nematic-smectic C-smectic A (RN-C-A) multicritical point has been investigated in detail. It is found that the phase diagram near the RN-C-A point is characterized by the absence of the pronounced singularities that have been observed near the NAC point. The significance of this result is under study.

Other important results emerging from these studies are:

i) The maximum pressure of smectic stability of reentrant nematogens is found to be uniquely related to the range of the nematic phase at atmospheric pressure.

ii) The pressure behaviour of the smectic A phase is strongly related to the extent of the inter-digitation of the molecules in the layer.

iii) Pressure has the influence of suppressing the smectic C phase regardless of the nature of the temperature variation of the layer spacing.

X-ray studies on the thermal evolution of the layer spacing in the smectic A phase of several structurally related smectogenic compounds have led to the following observations:

i) If the dipole moments of the linkage groups in a mesogenic molecule oppose that of the terminal polar group, and there is also a bulky lateral group, the compounds exhibit large bilayer spacings that are extremely sensitive to

temperature. One of the compounds with a cyano end group exhibits an $A_d - A_2$ transition while its nitro analogue does not.

ii) If the dipole moments of the linkage groups reinforce that of the terminal polar group, the bilayer spacing is small (~ 1.4 molecular length) and show weak thermal dependence.

The large thermal contraction of the bilayer spacing in some of these compounds is revealed in the dielectric and conductivity properties as well. The dielectric anisotropy reverses its sign becoming negative at lower temperatures. Conductivity studies have established the strong influence of the permeation process on the transport properties.

Experiments on systems exhibiting temperature dependent skewed cybotactic short range order show an unusual thermal variation of the dielectric anisotropy, $\Delta\epsilon$ becoming *negative* at *higher* temperatures.

It has been demonstrated that the solvent effects on molecular structure and conformation are minimal at the critical point where the macroscopic diamagnetic anisotropy ($\Delta\chi$) of binary mixtures of liquid crystals of opposite $\Delta\chi$ vanishes and hence it has been suggested that, in general, studies should be undertaken near the critical point. A direct observation of the coexistence of two spectra in liquid crystals of opposite $\Delta\chi$ has been made for the first time from deuterium NMR studies without the use of dissolved probe molecules. A combined use of potential energy calculations and NMR spectroscopy has been made to derive conformational information which otherwise is hard to obtain reliably. The use of multiple liquid crystals of similar and opposite $\Delta\chi$ has been demonstrated to obtain structural information which is not possible to derive from individual liquid crystals. Such applications have been made to several organic and organometallic compounds, the systems providing deceptively simple spectra. A study of differential exchange rate in 2, 6-dichlorophenol in various liquid crystals has been made. A slowing down of the OH exchange/rotation has been observed in liquid crystals formed by cyclohexane derivatives.

THEORETICAL PHYSICS AND ASTROPHYSICS

1. *Violation of Cauchy relation in alkali halides*

A cubic crystal with central two body forces should have the elastic constants c_{12} and c_{44} equal (Cauchy relation). This relation is observed to be violated in most cubic crystals. The polyhedral cell approach to repulsion developed earlier by us has been applied to the alkali halides and this predicts that the Cauchy relation should indeed be violated. Quantitative agreement with the observed magnitudes of the Cauchy discrepancies is however not very good.

2. *Test of maximum entropy phase refinement on real crystal data*

Ab initio solution of three-dimensional crystal structures by Maximum Entropy (ME) phase refinement was attempted. Starting with random phases for the

reflections our ME algorithm progressively refines the phases by the gradient method. The results are quite encouraging. Test runs on data from three real crystals two with 12 atoms and one with 38 atoms, revealed a large fraction of the atoms in the unit cell, suggesting that ME may soon compete with other established techniques in crystal structure analysis.

3. *Simulation of maximum entropy reconstructions of polarised maps*

A computer program has been written to compute Maximum Entropy (ME) reconstructions of polarised brightness maps from partial Fourier data. A general form of "entropy" function f(B) is used with the extension to polarisation developed earlier by us. Simulations on model data give good results. In particular, it is found that ME effectively reconstructs the Q, U and V maps even though there is no direct positivity constraint.

4. *Evolution of plerions*

The discovery of some supernova remnants resembling the Crab Nebula has led to the hypothesis that they, too, may be powered by a central pulsar. In trying to model these synchrotron nebulae one had always assumed that the Crab pulsar was a prototype. We have developed the first detailed evolutionary scenario, relaxing the above assumption. The statistics of such nebulae place a strong constraint on the birthrate of fast pulsars with high magnetic fields.

5. *The brightest galaxies in clusters*

The problem posed by the brightest galaxies in clusters has been investigated. Remarkably, these galaxies are observed to have an absolute magnitude dispersion of only 0.35. Is this uniformity an indication of a special status for these objects or are they consistent with being the tail-end of a statistical distribution? This question, which has been debated for several years, has been studied using a 1928 result by Fisher and Tippett which gives the asymptotic distribution of extrema, independent of the parent distribution. It has been shown that these first-ranked galaxies can neither be merely the tail end of a distribution, nor do they have the characteristic Gaussian distribution of a 'standard mold'. A model in which these galaxies are drawn statistically from each of these two distributions, and the physical consequences of this model have been studied. Quantitative predictions of the model are borne out by recent observations.

6. *Study of filamentary structure in the distribution of galaxies*

This problem is under investigation using graph theoretical and pattern recognition techniques. We have devised new techniques to look for 'Filaments'. Work is in progress towards developing algorithms that would help solve this rather difficult problem.

7. *Gravitational lensing*

This field is concerned with the multiple imaging and amplification of background sources such as quasars by foreground galaxies. The statistical theory of

multiple scattering by galaxies in a cluster was further developed. It was possible to derive expressions for the expected number of images, the separation of the images and the probability distribution of image amplification.

The theory of lensing by point masses in the isothermal half of a galaxy was considered. The amplification as well as the number and geometry of the images depend on the so-called shear of the beam, i.e., the tidal gravitational field of the point masses. The probability distribution of the tidal force was computed.

One of the outstanding problems in gravitational lensing concerns the missing third or fifth image and the missing lensing galaxy in many of the known cases. A new type of lensing event, caused by a cluster of galaxies but with image separations less than ten arc seconds, was proposed. Observational tests for this kind of lensing were worked out.

8. *Accretion model for quasars and active galactic nuclei*

One of the pictures of the central engine of an active galactic nucleus involves a thick accretion disc around a massive black hole with a super-Eddington luminosity pouring out of two narrow funnels. The transfer of the energy from where it is generated in the interior of the disc to the funnel walls was considered. Two alternative possibilities are (i) break-up of the disc by the unbalanced forces of radiation pressure, (ii) dragging of a large fraction of the generated energy into the black hole.

9. *Ultra compact objects in general relativity*

We have systematically investigated the possible existence of ultra-compact, i.e., $R<3M$ objects in genral relativity. Within the genral framework of core-envelope models both with and without the causality constraint such configurations are possible. We have next looked into the stability of such objects and find that they are also stable. This study also proves that stability requirements do not bring down the mass limit. The variation of maximum compactness including stability was examined as a function of the fiducial P/ρ at the interface and also the equation of state. We find that no available equation of state leads to stable ultra compact objects in variance with the results of the more general core-envelope treatments.

10. *Separation of the Dirac equation in a class of perfect fluid spacetimes with local rotational symmetry*

As a prelude to the study of massive spin half perturbations in the above spacetimes we have analysed the separability properties of the Dirac equation in these backgrounds. We find that the Chandrasekhar separation method for the Kerr case can be extended to a certain subclass of these spacetimes which can be described as locally static in one case and locally diagonal in the other. A detailed study of the angular and radial functions is in progress.

11. *Electromagnetic, neutrino and gravitational fields in the Kasner universe*

The Hertz-Debye superpotential formalism has been applied to study the behaviour of the perturbative zero rest-mass fields namely, the electromagnetic massless neutrino and gravitational fields in the rotationally symmetric Kasner

universe. The effects of anisotropy inherent to the background spacetime on the superposed fields were analysed. The relative behaviour of the three fields was studied with the similarities and differences in their evolution being highlighted. Finally, in the geometric optics approximation the propagation of the fields was compared with the null geodesics.

12. *The definition of angular momentum in the Kerr spacetime*

We have been studying the definition of angular momentum for a particle following a geodesic in the spacetime of a Kerr black hole. In general, the definition of physical quantities in a curved spacetime is not straightforward. In a few special cases the symmetries of the spacetime (Killing vectors) suggest a physically reasonable definition. We have devised a way of defining angular momentum about any axis not necessarily the symmetry axis in the Kerr spacetime. The definition is an invariant one which is independent of the choice of co-ordinates and is motivated by the existence of a Killing spinor for the Kerr metric. We are presently looking at the relationship between Carter's fourth constant and the angular momentum as defined in this way.

13. *Equivalence of approaches in relativistic mechanics*

There are now several approaches to the problems of describing interacting relativistic particles. Two of these - one due to Komar and another due to Rohrlich - were compared with the aim of seeing if they were equivalent. We have shown that the two methods were similar but inequivalent.

Radio Astronomy

Decameter Wave Radio Astronomy at Gauribidanur - A joint programme with the Indian Institute of Astrophysics, Bangalore.

Sun

Observations on the continuum and transient radio emission from the sun were continued whenever possible. The maps of the continuum radio emission are being compared with the K-Coronameter data of Mauna Loa Solar Observatory and also with the Solwind satellite data supplied by the Naval Research Laboratory, Washington, USA. Initial results indicate positional coincidences of depressions of radio emissions in our maps and coronal holes seen by the K-Coronameter. We also have radio maps on some days when the Solwind satellite detected coronal transients. This data is being analysed to determine the temperature and density structure of coronal transients in the outer corona.

High sensitivity observations on the fine structure of transient radio bursts from the sun are being made in the frequency range 30 to 65 MHz. Many interesting fine structures like drifting spike brusts, etc., have been detected. Theoretical models to interpret these fine structures are being constructed.

The Galaxy

i) H II Regions

Observations on galactic H II regions in continuum absorption at 34.5 MHz are

being continued. We have completed analysis of our observations of the giant H II region complex W 51. The mean electron temperature of W 51 is found to be 9500 ± 600 K. The derived background temperature on the far side of W 51 is $28{,}000 \pm 2600$ K. The proportion of non-thermal emission originating on the near side of W 51 corresponds to a mean galactic emissivity of 2K pc^{-1} at 34.5 MHz. The present observations also indicate that the H II region complex is surrounded by a non-thermal ring which is probably a supernova remnant.

ii) Pulsars

A sixteen channel filter bank receiver with a channel width of 50 KHz is being used to observe pulsars at 34.5 MHz. Using a sampling time of 4 milliseconds for each channel and a total integration time of 40 minutes the two pulsars PSR 0950+08 and PSR 1919+21 have been detected. The mean flux density of PSR 0950 + 08 at 34.5 MHz is 1.82 ± 0.05 Jy, and the pulse energy is $461 \pm 115 \times 10^{-29}$ $J/m^2/Hz$. We hope to detect several more pulsars and the data will be used to study scattering properties of the Interstellar medium.

Instrumentation

A broad band array operating in the frequency range 30 to 65 MHz has been constructed. It consists of 64 broad band dipoles placed inside corner reflectors. The beam is fixed in the E-W direction but can be tilted in the N-S direction to $\pm 45°$ of the zenith. This tilting is achieved by inserting delays at appropriate junctions, by means of diode switches. The effective area of the array is $64\ \lambda^2$. The antenna system is being used for high time and frequency resolution studies of solar radio bursts.

A 32 channel correlation receiver was installed at Gauribidanur. Various performance measures of the receiver system were satisfactory. Testing of the system using astronomical sources is under progress.

An antenna test equipment for Gauribidanur decameter telescope to test field amplifiers, phase shifters and transmission lines has been designed. This can be operated on both AC & DC power. This will avoid having to carry special equipment like signal genrators, counter and vector voltmeter (mains operated) to the field.

Meterwave Astronomy using the Ooty Radio Telescope

Radio Recombination Lines: The program of radio recombination line observations at 325 MHz and their interpretation is now complete. The main results of these investigations over five years can be summarized as follows. Out of the 53 directions observed H272α line was detected towards 47 directions and possible carbon lines (C272α) in 12 directions. The observed line intensities were found to correlate well with, the total continuum intensity, which at this frequency is dominated by the non-thermal galactic background. This correlation therefore implies that most of the observed lines arise due to *stimulated* emission by the

backgound radiation, unlike at higher frequencies where spontaneous emission is responsible.

This has led to a picture in which the H272α lines observed here originate in the low denity outer envelopes of the HII regions. Using the line parameters observed here and invoking geometrical arguments the density, temperature and sizes of the outer envelopes were deduced. It was found that the envelopes have densities of 1-10 cm^{-3} temperature of 5000-8000K and sizes of 50-300 pc.

The results of this study indicate that most, and probably all of the galactic ridge recombination lines observed at centimeter wavelengths originate in outer low density envelopes of conventional HII regions, which are prominent in the radio continuum surveys of the galaxy. The conventional HII regions are so large in number in the longitude range $l \leq 40°$, that given the sizes of their outer envelopes deduced in the present study, they intersect practically every line of sight within this longitude. This study has therefore answered the long standing question of the origin of the galactic ridge recombination lines, as has formed the basis of a Ph.D. thesis suubmitted to the Bangalore University.

Millimeterwave Telescope

The cutter track (guide rail) which forms the reference template for the 10.4 meter reflector was further improved using a new technique and the r.m.s. error reduced to 22 microns. Wobble of the air bearing was studied and it was determined that a max. error of 35 microns r.m.s. might be contributed due to wobble. After a series of cutting and measuring experiments on trial panels and making required modifications in the cutting set-up, the final cutting of the reflector surface was undertaken and completed. A preliminary survey of the reflector surface has yielded a surface accuracy of about 55 microns r.m.s. from a best-fit paraboloid. The whole reflector, including the back-up structure was disassembled and reassembled again. Then a repeat survey of the reflector surface was performed and the measurements showed negligible degradation of the surface accuracy. This test gave us tremendous confidence and showed that our method of fabrication of the back-up structure and the reflector was proper and the results are in accordance with the original design philosophy. All the reflector panels are now removed from the back-up structure and a thin aluminium sheet is being epoxy-bonded to the top surface of each panel. This bonding has to be done very carefully under controlled condition so that it will not introduce additional surface errors. After the bonding is over, we plan to install them on the back-up structure and make a final survey of the reflector surface. There is still some scope to improve the surface accuracy by fine adjustment of the support studs of the panels. We plan to do this only in the final stages, if required. The reflector will be shifted from its present location at the National Aeronautical Laboratory to the Raman Research Institute campus after all the final tests are completed.

The mount for the reflector is ready. A new counterweight has been fabricated. Fabrication of the receiver cabin at one end of the Elevation axis has begun. A new hardened azimuth ring has been installed in the mount and the cluster bearings were adjusted for its smooth rotation. Telescope Control system was

connected and tests have been performed on the rotation around El and Az axis. Actual computer control will be tried out only when the mount and the reflector are shifted to the RRI campus.

Continued efforts in the development of solid state Gunn oscillators at millimeter wavelengths have yielded good results. CW output powers of 100 mW or more have been achieved in the range 30-58 GHz. In the W-band range, we have achieved output power of 20 mW at 93 GHz. A varactor doubler was designed and tested at the higher frequency end of the W-band. CW power output of 10 mW has been measured at the second harmonic frequency in the range 108-115 GHz for an input power of 100 mW at the fundamental frequency. Preliminary tests have been undertaken to cool the millimeter wave mixers to liquid Nitrogen temperature and the results were encouraging. Efforts to improve the performance are still continuing.

A start has been made in fabricating quasi optical components at millimeter wavelengths. A 50% beam-splitter using a wire grid has been designed and fabricated for the frequency range 80-115 GHz and the tests showed good agreement with theoretical predictions. Based on these results, we are at present designing a quasi optical diplexer for feeding both RF and LO signals into the mixer with minimum loss. This diplexer will help a great deal in reducing the LO power requirement and facilitate the use of solid state Gunn oscillators as LO sources at higher frequencies.

A 256 channel Data Acquisition system (DAS) for spectral line receiver of the mm-wave radio telescope was developed. The unit acts as an interface to the mm-wave receiver and the computer used for telescope control. The various filter banks of the receiver are sampled, multiplexed and converted to digital signals at a rate of 300 KHz. The computer is situated about 200 feet away from the DAS and a suitable line driver-receiver system was designed to transfer the data at a sufficiently high speed.

A proto unit was built and is undergoing final testing. Software necessary to control this system on LSI 11/23 computer system at the Institute is also being developed.

10 Meter Telescope Control

For better operational convenience some changes in the location of the three control boxes of the telescope control system were introduced. Preliminary tests on the elevation mount (without reflector) and azimuth mount were independently carried out with the anti-backlash system of two motors and gear boxes. Certain improvements were made to perfect the system. Development of control software on PDP 11/34-RT 11 FB system is in progress.

1.5 M TELESCOPE

The mechanical mount for the telescope was completed and the same is being assembled at site.

The electronic control for Dome tracking, azimuth encoder tracking and tele-

scope controls was completed. The necessary interface to LSI 11/23 was also made. The receiver and the computer room is in the final stages of completion. Preliminary tests and the control of the telescope through the computer will be taken up as soon as the mount assembly is over.

Astronomical Clock

An astronomical clock was built for the 90" optical telescope at Kavalur. This has sidereal micro-second outputs which will be useful to drive the telescope.

Advanced training in research is being offered to the following teachers from other organisations:

Name	Topic of Study	
S. Somasekhara Vijayanagar College Hospet	Experimental studies of phase diagrams of liquid crystals	UGC Faculty Improvement Programme
S. Nagabhushana Veerashaiva College Bellary	Experimental studies on the dielectric properties of liquid crystals	UGC Faculty Improvement Programme
Ph.D. (Awarded/submitted)		
K. Venkatachala Rao	Experimental studies of the reentrant phenomenon in liquid crystals Bangalore University	Awarded
A. N. Kalkura	High pressure optical studies on liquid crystals, Mysore University	Awarded
S. N. Prasad	Vibrational spectra of liquid crystals Mysore University	Awarded
S. Krishnaswamy	Studies on the surface properties of liquid crystals, Mysore University	Reports Awaited
D. K. Ravindra	Digital correlation receiver for Gauribidanur Decametre Wave Radio Telescope, Indian Inst. of Science, Bangalore	Reports Awaited
U. N. Maiya	Comparative study of precipitable water in the atmosphere by radio, optical and other methods. Mysore University.	Reports Awaited

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 and those submitted and in press is given in Annexure-I (Page 16).

Conferences/Seminars and Meetings

The staff of the Institute visited various institutions in India and abroad and attended 25 conferences and presented papers. In addition, 57 lectures were given by them at other places.

Colloquia

During the year the scientists of the Institute and those visiting the Institute both from within and outside the country gave twenty four colloquia at the Institute on different topics.

Journal Club and Neighbourhood Astronomy Meetings

The Journal Club meetings started two years back was continued and 20 meetings were held during the year on different topics relating to the scientific activities of the Institute. The Third Neighbourhood Astronomy meeting was held at the Institute during June 21-22, 1983. Apart from the scientists of this Institute, scientists from the Indian Institute of Astrophysics, the Indian Space Research Organisation and the Tata Institute of Fundamental Research participated in this meeting.

Visiting Scientists

A number of scientists from institutions within the country and outside visited the Institute during the year. Their names are listed following those of the scientific and technical staff of the Institute given towards the end of the report.

Library

Five hundred and one new books were added to the library during the year. This brings the total book collection to 13,420. The library is presently subscribing to one hundred and forty seven current periodicals and has 16,374 bound volumes.

General

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

Recurring Non Plan	:	Rs. 23,00,000.00
Recurring Plan	:	Rs. 26,20,000.00
Non-Recurring Plan	:	Rs. 42,00,000.00

II. The Audited Statements of Account with the auditor's report are given in Annexure II (Page 23).

Staff

The Scientific and Technical staff of the Institute is given below. Additions during the year are marked with an asterisk.

1. V. Radhakrishnan
2. S. Chandrasekhar
3. S. Krishnan
4. N. V. G. Sarma
5. C. V. Vishveshwara
6. C. L. Khetrapal
7. N. V. Madhusudana†
8. A. Krishnan
9. G. Srinivasan
10. R. Shashidhar
11. G. S. Ranganath
12. A. C. Kunwar††
13. V. Surendranath
14. Rajendra Bhandari
15. C. S. Shukre
16. Rajaram Nityananda
17. Ramesh Narayan†††
18. U. Devappa Kini
19. K. A. Suresh
20. B. K. Sadashiva
21. J. Padmanabhan
22. K. T. Balakrishnan
23. D. K. Ravindra
24. R. S. Arora
25. K. R. Anantharamaiah
26. Jayanthi Ramachandran
27. M. O. Modgekar
28. M. R. Subramanyam
29. P. N. Ramachandra
30. R. Nandakumar
31. K. Subramanya
32. T. Ramachandran
33. K. Smiles Mascarenhas
34. N. Udaya Shankar
35. M. Selvamani
36. T. N. Ruckmongathan
37. P. A. Johnson
38. G. Sarabagopalan
39. B. V. Nataraja
40. R. Ganesan
41. H. Subramoniam
42. Antony Joseph
43. G. Rengarajan
44. A. Deshpande
45. K. Sukumaran
46. S. Chanthrasekaran
47. K. Chandrasekhara
48. P. G. Ananthasubramanian
49. R. Vijayalakshmi
50. Elizabeth Vincent
51. V. Lakshminarayan
52. Mohamed Ateequlla
53. M. N. Ramanuja
54. B. R. Ratna
55. M. Vivekanand
56. B. R. Iyer
57. K. S. Dwarakanath
58. T. S. Ravishankar
59. G. Jayakumar
60. C. J. Pasupathy
61. K. Srinivasa Prasad
62. C. Ramachandra Rao
63. N. Jayaprakash*
64. Joseph Samuel
65. Suketu P. Bhavasar*

Visiting Positions

1. S. Ramaseshan
2. G. S. R. Subba Rao

Medical Consultant

1. A. R. Pai

Research Fellows

1. G. V. Vani
2. S. Krishna Prasad
3. R. Pratibha
4. K. R. Sumathy
5. V. N. Raja*
6. V. Raghunathan

Resignations

1. Vijaya Gopalaratnam
2. B. Sudhindra
3. K. G. Girish
4. K. L. Savithramma
5. H. K. Jayaram
6. S. K. Srinivasan

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† On leave with Universite de Paris-Sud, Laboratoire de Physique des Solides, Centre d'Orsay, Orsay, France.

†† On leave with School of Chemical Sciences, University of Illinois, Urbana Champaign, Illinois, USA

††† On leave with Theoretical Astrophysics Group, California Institute of Technology, Pasadena, USA.

List of Visitors

1.	Dr. Martin D. Pollock Institute Galileo Galilei Padua, Italy	April 23 - May 3, 1983
2.	Dr. Francois Biraud Observatoire de Meudon Paris, France	April 9 - 14, 1983
3.	Dr. W. C. Erickson University of Maryland U.S.A.	April 24 - June 5, 1983
4.	Dr. R. Shankar Department of Physics Yale University New Haven, U.S.A.	August 2 - 8, 1983
5.	Dr. A. G. Lyne Nuffield Radio Astronomy Laboratories Jodrell Bank England	September 5 - 9, 1983
6.	Ms. Susan Scott Department of Mathematical Physics University of Adelaide Australia	September 12 - 19, 1983
7.	Dr. A. R. P. Rau Department of Physics and Astronomy Louisiana State University U.S.A.	August 10 - December 2, 1983
8.	Dr. Bernard Carr Institute of Astronomy Cambridge U.K.	October 10 - 18, 1983
9.	Prof. Brandon Carter Groupe d'Astrophysique Relativiste Observatoire de Paris France	November 13 - 18, 1983
10.	Prof. R. K. Varma Physical Research Laboratory Ahmedabad	November 13-21, 1983

11.	Dr. William Saslaw University of Virginia and NRAO U.S.A.	November 28 - December 4, 1983
12.	Prof. A. K. Ramdas Department of Physics Purdue University W. Lafayette, Indiana U.S.A.	December 20 - 21, 1983
13.	Prof. F. Rustichelli Instituto di Fisica Generale e Fisica Tecnica Ancona Italy	December 22 & 27, 1983
14.	Prof. E. U. Franck Director Institut de Physikalische Chemie der Universitat Karlsruhe F.R.G.	December 28 - 30, 1983
15.	Dr. Lisbeth Ter-Minassian-Saraga Directeur de Recherche au CNRS UER Biomedicale, Paris France	January 21, 1984
16.	Prof. Hanbury Brown School of Physics Univ. of Sydney, Australia	January 25 - 27, 1984
17.	Dr. A. Buka Central Research Institute for Physics, Budapest, Hungary	February 17 - March 6, 1984
18.	Dr. Karen Villere Ames Research Centre Moffett Field California, U.S.A.	February 22 - 26, 1984

Annexure-I

Publications

1. Liquid Crystals of disc-like molecules. (S. Chandrasekhar) - Invited lecture presented at the Royal Society Discussion Meeting on Liquid Crystals. London, October 27-28, 1982 - Phil. Trans. Royal Society, London **A309,** 93 (1983).
2. Liquid Crystals. (S. Chandrasekhar) - Special issue on 'Perspectives in Frontier Areas in Science' - Golden Jubilee Series of the Indian National Science Academy (1984).
3. Extension of McMillan's model to liquid crystals of disc-like molecules. (S. Chandrasekhar, K. L. Savithramma and N. V. Madhusudana) - Invited lecture - Presented at the Fourth International Symposium on Liquid Crystals and Ordered Fluids, Las Vegas, USA, March 28-April 2, 1982 - Liquid Crystals & Ordered Fluids, Vol. 4 (1984).
4. New addressing techniques for multiplexed liquid crystal displays. (T. N. Ruckmongathan and N. V. Madhusudana) - Society For Information Display Proceedings, **24,** 259 (1983).
5. Thermomechanical effects in Cholesteric liquid crystals. (G. S. Ranganath) - Molecular Crystals & Liquid Crystals Letters **92,** 105 (1983).
6. On dislocations in cholesteric liquid crystals. (G. S. Ranganath) - Molecular Crystals & Liquid Crystals **94,** 285 (1983).
7. Network of point disclinations at the nematic-isotropic interface. (N. V. Madhusudana and K. R. Sumathy) - Molecular Crystals and Liquid Crystals Letters **92,** 193 (1983).
8. Nematic droplets with a new structure. (N. V. Madhusudana and K. R. Sumathy) - Molecular Crystals & Liquid Crystals Letters **92,** 179 (1983).
9. Some consequences of the Ginsburg - Landau - de Gennes gradient term in smectics. (G. S. Ranganath) - Molecular Crystals & Liquid Crystals Letters **92,** 201 (1983).
10. Hydrodynamics of cholesteric liquid crystals in the coarse-grained limit. (G. S. Ranganath) - Bulletin of Materials Science **5,** 333 (1983).
11. On the polymorphism of the smectic A phases of highly polar compounds. (N. V. Madhusudana) - Proc. Indian Acad. Sciences (Chem. Sci.) **92,** 509 (1983).
12. High pressure studies of liquid crystalline transitions. (R. Shashidhar) - Bulletin of Materials Science, **5,** 207 (1983).
13. Pressure variation of the smectic C layer spacing in HOAB (R. Shashidhar and S. Chandrasekhar) - Ninth Int. liquid Crystal Conf. Bangalore, 1982 - Molecular Crystals & Liquid Crystals **99,** 297 (1983).
14. Thermomechanical effect in cholesteric liquid crystals. (H. K. Jayaram, U. D. Kini, G. S. Ranganath & S. Chandrasekhar) - Ninth International Liquid Crystal Conf., Bangalore, 1982 - Molecular Crystals & Liquid Crystals **97,** 155 (1983).
15. Studies on some smectogenic compounds with large bilayer spacings. (N. V. Madhusudana, B. S. Srikanta, M. Subramanya Raj Urs) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **97,** 49 (1983).

16. Scaled particle theory of a system of spherocylinders: Extension of calculations to high pressures (K. L. Savithramma & N. V. Madhusudana) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **98,** 407 (1983).
17. Effect of electric field on the nematic-isotropic phase transition of compounds with strongly polar molecules. (K. L. Savithramma & N. V. Madhusudana) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **103,** 99 (1983).
18. Experimental determination of the curvature-induced reduction in the smectic A-nematic transition point. (N. V. Madhusudana and B. S. Srikanta) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **99,** 375 (1983).
19. Studies on binary mixtures of systems which exhibit a maximum as well as a minimum in the S_A-N transition boundary. (B. S. Srikanta & N. V. Madhusudana) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **99,** 203 (1983).
20. Dielectric and conductivity studies on 2-cyano-4-heptyl-phenyl-4'-pentyl-4-biphenyl-carboxylate and its mixtures with 4-n-heptyl-4'-cyanophenyl. (B. S. Srikanta and N. V. Madhusudana) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **103,** 111 (1983).
21. Effect of skew cybotactic structure on the optical properties of a nematogen with a lateral cyano substituent. (N. V. Madhusudana, K. P. L. Moodithaya and K. A. Suresh) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **99,** 239 (1983).
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23. Studies on high strength defects in nematic liquid crystals. (N. V. Madhusudana and R. Pratibha) - Ninth International Liquid Crystal Conf., Bangalore 1982 - Molecular Crystals & Liquid Crystals **103,** 31 (1983).
24. Pressure studies of liquid crystalline transitions. (R. Shashidhar) - Ninth International Liquid Crystal Conf., Bangalore, 1982 - Molecular Crystals & Liquid Crystals, **99,** 13 (1983).
25. Pressure studies on 7.S.5, 8.S.5 and their mixtures. (A. N. Kalkura and R. Shashidhar) - Ninth International liquid Crystal Conf., Bangalore, 1982 - Molecular Crystals & Liquid Crystals, **99,** 193 (1983).
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28. Effect of smectic ordering on the dielectric properties of re-entrant nematic mixtures. (B. R. Ratna, R. Shashidhar, M. Bock, A. Gobl - Wunsch and

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30. Energetics of disclinations in liquid crystals. (G. S. Ranganath) - Invited talk - Ninth International Liquid Crystals Conf., Bangalore, 1982 - Molecular Crystals & Liquid Crystals, **97,** 77 (1983).
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35. Phenyl-4-benzoyloxybenzoates with lateral methoxyl substituent. (M. Subramanya Raj Urs and V. Surendranath) - Ninth International Liquid Crystal Conf., Bangalore, 1982 - Molecular Crystals & Liquid Crystals, **99,** 279 (1983).
36. The crystal and molecular structure of reentrant nematogen: 4-cyanophenyl-3-methyl-4'- (4''-n-undecyloxy-cinnamoyloxy) benzoate. (G. V. Vani) - Ninth International Liquid Crystal Conf., Bangalore, 1982 - Molecular Crystals & Liquid Crystals, **98,** 275 (1983).
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38. NMR spectra of molecules oriented in mixtures of thermotropic solvents of opposite diamagnetic anisotropies - Invited paper - (C. L. Khetrapal and A. C. Kunwar) - Israel J. Chem, **23,** 299 (1983).
39. A theory of temperature dependent switching transition in mixed liquid crystals of opposite diamagnetic anisotropies. (K. P. Sinha, R. Subburam, A. C. Kunwar and C. L. Khetrapal) - Molecular Crystals and Liquid Crystals, **101,** 283 (1983).
40. A direct observation of the switch-over transition in mixed liquid crystals of opposite diamagnetic anisotropies. (C. L. Khetrapal, H. J. C. Yeh and A. Saupe) - Molecular Crystals and Liquid Crystals, **92,** 243 (1984).
41. The conformation of (μ-butatriene) hexacarbonyl diiron complex from proton NMR studies in three nematic phases. (S. Arumugam, A. C. Kunwar

and C. L. Khetaapal) - J. Organometallic Chem. **265,** 73 (1984).
42. The influence of bond polarizations on the molecular structures of halofluorobenzenes. (N. Suryaprakash, A. C. Kunwar and C. L. Khetrapal) - J. Mol. Struct. **101,** 121 (1983).
43. Determination of indirect spin-spin couplings between heteronuclei from NMR spectra of oriented molecules. The spectrum of phenylselenyl chloride. (N. Suryaprakash, A. C. Kunwar and C. L. Khetrapal) - J. Magn. Res. **54,** 502 (1983).
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48. NMR studies of tetracyanophenanthroline complexes of iron (II). (B. V. Agarwala, K. V. Ramanathan and C. L. Khetrapal) - Bull. Mag. Res. **5,** 224 (1983).
49. NMR spectra of oriented trimethylphosphine oxide and sulphide (C. L. Khetrapal, A. C. Kunwar and M. R. Lakshminarayana) - Bull. Mag. Res. **5,** 234 (1983).
50. Determination of indirect spin-spin couplings between heteronuclei from NMR spectra of oriented molecules. (C. L. Khetrapal, A. C. Kunwar and N. Suryaprakash) - Bull. Mag. Res. **5,** 235 (1983).
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52. The Structure of the ammonium halides (Raghurama, G. and Narayan, R.,) - J. Phys. Chem. Solids. **44,** 633, (1983).
53. Variable anion polarisability in ionic crystals (Raghurama, G. and Narayan, R.,) - Curr. Sci. **52,** 210 (1983).
54. Maximum entropy - a new approach to the phase problem in Crystallography (Narayan, R., Nityananda, R. and Vani, G. V.,) - Proc. of Indian Acad. Sci. **92,** 341 (1983).
55. The maximum entropy method of image reconstruction - a non information theoretic practical approach (Nityananda, R. and Narayan, R.,) - J. Astrophys. Astron. **3,** 419 (1983).
56. Reconstruction of a polarized brightness distribution by the maximum entropy method (Nityananda, R. and Narayan, R.,) - Astron. Astrophys. **118,** 194 (1983).
57. The luminosity of particle beams from thick accretion discs (Narayan, R., Nityananda, R. and Wiita P. J.,) Mon. Not. R. Astr. Soc. **205,** 1103 (1983).
58. Interstellar Electron density (Vivekanand, M. and Narayan, R.,) J. Astrophys. Astron. **3,** 399 (1983).

59. Evidence for evolving elongated pulsar beams (Narayan, R. and Vivekanand M.,) Astron. Astrophys. **122,** 45 (1983).
60. A new model for the emission geometry in PSR 0950 + 08 (Narayan, R. and Vivekanand, M.,) Astrophys. J., **274,** 771 (1983).
61. Theory of divalent ions in crystals (Raghurama, G. and Narayan, R.,) Pramana **21,** 301 (1983).
62. Improved parameters for 40 pulsars (Vivekanand, M., Mohanty, D. K., and Chris Salter.,) Mon. Not. R. Astr. Soc., **204,** 81p (1983).
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64. Comments on 'The question of an upper bound on entropy' (Iyer, B. R. and Joseph Samuel,) Phys. Lett. **97A,** 99 (1983).
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66. Electromagnetic, neutrino and gravitational fields in the Kasner spacetime with rotational symmetry (Dhurandhar, S. V., Vishveshwara, C. V. and Cohen, J. M.,) Classical Quantum Grav. **1,** 61 (1984).
67. Relativistic particle interactions - a comparison of independent and collective variable models. (Joseph Samuel and Mukunda, N.,) Pramana **22,** March-April, 1984.
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69. Observations on the slowly varying component of solar radio emission at decameter wavelengths. (Sastry, Ch. V., Shevgaonkar, R. K., and Ramanuja, M. N.,) Solar. Phys. **87,** 391, 1983.
70. Observations and interpretation of solar decametric absorption bursts. (Gopalaswamy, N., Thejappa. G., and Sastry, Ch. V.,) Journ. Astrophys. Astron. **4,** 215, 1983.
71. The decameter wave radio telescope (Sastry, Ch. V.,) Bull. Astr. Soc. India, **11,** 167, 1983.
72. The decameterwave radio telescope at Gauribidanur (Sastry, Ch. V.,) Physics News, **14,** 59 (1983).
73. A new design for a millimeter wave (W-band) Gunn oscillator using circular waveguide (Arora, R. S. and Sarma, N. V. G.,) IETE Technical Review, **1,** 25, 1984.
74. On the association between pulsars and supernova remnants (V. Radhakrishnan and G. Srinivasan) in Proceedings of the IAU Symposium No. 101 on Supernova remnants and their X-ray emission. ed. by J. Danziger and P. Gorenstein. Dordrchet, Reidel, 1983.

Papers in press

1. Stable high strength defects in nematic liquid Crystals. (S. Chandrasekhar) - Invited talk - First Asia Pacific Physics Conference, Singapore, June 1983 - Proceedings of the Conference.

2. Some recent studies of liquid crystals: A review. (S. Chandrasekhar) - Invited lecture - 15th IUPAP International Conference on Thermodynamics & Statistical Mechanics, Edinburgh, July 1983. Journal of Statistical Physics.
3. Physics of Liquid Crystals. (S. Chandrasekhar) - A course of 10 lectures delivered at the Spring College on the Physics of Polymers, Liquid Crystals and Low-dimensional Solids, International Centre for Theoretical Physics, Trieste, Italy, April-June 1980 - Plenum Press.
4. High pressure studies on liquid crystals. (R. Shashidhar) - Invited lecture, National Symposium on Instrumentation, Indian Institute of Science, Bangalore, July 1982 - Proceedings of the Conference.
5. Induction of smectic C pnase in binary mixtures of compounds with cyano end groups. (N. V. Madhusudana, V. A. Raghunathan and M. Subramanya Raj Urs) - Molecular Crystals and Liquid Crystals.
6. Comparative X-ray dielectric studies on some structurally related smectogenic compounds. (N. V. Madhusudana, B. S. Srikanta and M. Subramanya Raj Urs) - Molecular Crystals & Liquid Crystals.
7. Dielectric relaxation studies on systems exhibiting the induced smectic A phase. (B. S. Srikanta and N. V. Madhusudana) - Molecular Crystals & Liquid Crystals.
8. Isothermalhydrodynamics of orthornombic nematics. (U. D. Kini) - Molecular Crystals and Liquid Crystals.
9. Pressure studies on ferroelectric liquid crystals. (S. Krishna Prasad, R. Shashidhar and V. Surendranath) - Special issue of Ferroelectrics.
10. Langmuir Monolayers of liquid crystalline forming monomers and polymers. (K. A. Suresh, A. Blumstein and F. Rondelez) - Journal de Physique.
11. The structure of dibenzofuran and dibenzothiophene - Proton NMR study in nematic phase. (S. Arumugam, A. C. Kunwar and C. L. Khetrapal) - Organic Magnetic Resonance.
12. NMR investigations on di-and tri-azanaphthalenes oriented in liquid crystals. (S. Arumugam, A. C. Kunwar and C. L. Khetrapal) - Molecular Crystals and Liquid Crystals.
13. Differential exchange and molecular structure of 2, 6-dichlorophenol as studied by NMR in nematic solvents. (M.R. Lakshminarayana, A. C. Kunwar and C. L. Khetrapal) - Journal of Magnetic Resonance.
14. Absolute signs of the order parameters and the structures of benzo (C) bisisothiazoles. (R. Subburam, K. P. Sinha, A. C. Kunwar and C. L. Khetrapal) - Molecular Crystals and Liquid Crystals.
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16. The use of two nematic solvents in the determination of molecular structure of systems providing deceptively simple spectra. (C. L. Khetrapal, A. C. Kunwar and S. Arumugam) - Organic Magnetic Resonance.
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18. Some partially resolved problems in NMR of mixed liquid crystals of opposite

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19. The preferred conformation(s) of trimethyl phosphate as derived from NMR spectra of partially oriented molecules and potential energy calculations. (C. L. Khetrapal, G. Govil and H. J. C. Yeh) - J. Mol. Struct.
20. Oriented Molecules. (C. L. Khetrapal) - Specialist Periodical Reports. NMR., Vol. 11, The Royal Society of Chemistry.
21. Maximum entropy - flexibility versus fundamentalism (Narayan, R. and Nityananda R.) Proc. of the IAU/URSI workshop on measurement and processing for indirect imaging, Sydney, Aug-Sept, 1983.
22. The relevance of the Eddington luminosity in thick accretion discs (Nityananda, R. and Narayan, R.,) Proc. of the IAU/COSPAR meeting on advances in high energy astrophysics and cosmology, Rogan, Bulgaria July 18-22, 1983.
23. Rare gas repulsion from compression properties of closed shell ions. (Raghurama, G. and Narayan, R.,) J. Phys. C:Solid State (1983).
24. On the nature of supernova remnant 0540-69.3 in the large magellanic cloud (Srinivasan, G., and Dipankar Bhattacharya,) Curr. Sci. (1984).
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26. Gravitational lensing by stars in the galaxy halo - theory of combined weak and strong scattering (Nityananda R., and Ostriker J. p.,) J. of Astrophys. Astron. (1984).
27. Multiple imaging of quasars by galaxies and clusters (Narayan, R., Roger Blandford and Rajaram Nityananda,) Nature.
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31. Neutrinos in gravitational collapse: Analysis of Flux profile (Dhurandhar, S. V. and Vishveshwara C. V.,) Pramana (1983).
32. Observations of the Rosette Nebula using the decameter wave radio telescope at Gauribidanur (Deshpande, A. A., Shevgaonkar, R. K., and Sastry, Ch. V.) Astrophys. and Space Sci.