

RAMAN RESEARCH INSTITUTE

BANGALORE

ANNUAL REPORT — 1979-80

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 sciences 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, Radio Astronomy and Theoretical Physics and Astrophysics.

During the year in question research in liquid crystals in the Institute has led to the discovery that the re-entrant phenomenon which till recently had been observed only in mixtures or in pure compounds at elevated pressures also exists in certain pure compounds even at atmospheric pressure. On the theoretical side, the most outstanding achievement during the year relates to the problems of defects in nematic liquid crystals taking into account elastic anisotropy.

In theoretical physics and astrophysics several interesting problems in general relativity and in pulsar physics were studied. Among the most interesting results obtained in the last year were those connected with the work on neutron stars. It was shown that not all neutron stars formed in supernova explosions function as pulsars, and that the type of remnant left behind by the supernova is a consequence of this behaviour.

During the year, the Institute's project of setting up a 10 metre mm-wave radio telescope made very good progress. The telescope which is being fabricated entirely in the country is expected when completed to compare favourably with mm-wave telescopes anywhere in the world.

Even though the main emphasis in the Institute is on research in basic sciences, the work done at the Institute has resulted in the application of the results achieved to technology of relevance to the country as a whole. Research in liquid crystals has led to the development in the Institute of liquid crystal display devices for use in watches, clocks, digital instruments, etc. This development is ready for commercial exploitation by firms like Bharat Electronics Ltd. The technology developed in the fabrication of high precision antennas for use as radio telescopes is also bound to be very useful in communications and space research.

An international conference on liquid crystals was held in the Institute during December 1979 in which some of the leading scientists in the world participated.

About 100 delegates from 16 countries (including 4 from USSR and 3 from China) attended the conference.

The work carried out on these and other projects in the Institute during the year 1979-80 is summarised below :

Liquid Crystals

Work is continuing along the lines indicated in the previous report, but in addition some significantly new results have been obtained, which are summarised below.

The re-entrant phenomenon

Till recently the phenomenon (so named in analogy with similar phenomena observed in superconductors, He-3, etc.) had been observed only in mixtures, or in pure compounds at elevated pressures. The remarkable discovery was made here that certain pure compounds show re-entrant behaviour even at atmospheric pressure. (A similar discovery was made independently at about the same time by the group at the Centre de Recherche Paul Pascal, France.) Systematic studies were carried out using several techniques : (a) X-ray diffraction at atmospheric pressure and at high pressures, (b) static dielectric measurements and dielectric relaxation, (c) light scattering, (d) infrared and optical measurements, and new results have been found that throw light on the origin of the re-entrant behaviour. In particular it has been established that there is a structural rearrangement in the bilayer as a precursor to the formation of the re-entrant nematic phase, and that the molecular associations are quite different in the two nematic phases. (Incidentally it may be pointed out that these are the first high pressure X-ray diffraction studies ever to have been carried out on liquid crystalline materials. Subsequently similar studies were reported from Bell Laboratories, but those were limited to pressures of less than 1 kbar whereas our set-up is capable of going up to pressures of 10-20 kbars.)

Defects in nematics

On the theoretical side the most outstanding achievement relates to the problem of defects in nematic liquid crystals taking into account elastic anisotropy. It is of course to be expected that the director configuration around an isolated defect as well as the radial force of interaction between two defects will be modified because of elastic anisotropy. In addition, it has been shown that there is an entirely new type of interaction not anticipated in the simpler theory, viz., an angular force between disclinations. An extension of the theory to long pitch cholesterics brings out some of the features that have been observed, e.g., that pairs of singularities should adopt a helical configuration.

Electrohydrodynamic instabilities

EHD instabilities have been studied in nematics with positive dielectric anisotropy and *negative* conductivity anisotropy. The instability pattern seen in

homeotropically aligned samples develops with a circular symmetry and goes over to the dynamic scattering state at high enough voltages. This new combination of parameters has demonstrated for the first time that in addition to the usual model (the Carr-Helfrich mechanism) which involves a bend deformation, EHD can arise from a splay deformation as well.

Raman studies

The Cary-81 Raman spectrometer has been set up with necessary modifications in the external optics and detection systems and its performance has been found to be extremely satisfactory. The instrument is now being used for systematic polarized Raman scattering studies of liquid crystalline materials. The surprising result first reported by the Harvard Group that the order parameter (P_4) is negative in some nematics has been confirmed by us in some other compounds. Moreover, a correlation has been found between the magnitude of (P_4) and the length of the alkyl chain, a result which may throw light on the origin of the negative order parameter, which still defies an explanation in terms of the molecular statistical theory.

Flow properties

The problem of radial flow in a cholesteric subjected to a rotary (torsional) shear about the helical axis has been investigated theoretically. The motivation for the study was an interesting observation recently reported by Jannossy. A planar cholesteric sample was sandwiched between two infinite plane parallel discs one of which is rotating in its own plane relative to the other at a constant angular velocity; for one sense of rotation, dust particles in the sample drifted towards the centre of the discs whilst for the opposite sense of rotation they drifted away from the centre. The theory provides a possible explanation of this effect.

Theoretical studies have also been carried out of instabilities in nematic liquid crystals, in particular homogeneous and roll instabilities in the presence of a magnetic field.

Applications

A convenient method has been developed for multiplexing liquid crystal matrix displays. The major advantages of the present scheme over the conventional scheme is that it requires only *one* power supply and has a very large duty factor. The simplicity of the scheme has been exploited to construct and operate a 16-segment alphanumeric display panel.

NMR Work

(a) ^{13}C -NMR study of non-planar distortions in amides : The use of ^{13}C -NMR spectroscopy of oriented molecules has been demonstrated to investigate non-planar distortions in substituted amides. The studies in conjunction with the ^1H -NMR data in N-methyl formamide provide all the dipolar couplings between

the interacting nuclei in the system. The dipolar couplings, obtained from ^{13}C - and ^1H -NMR experiments under non-identical conditions, have been used to determine unambiguously the non-planar distortions around the nitrogen atom together with other geometrical parameters and the molecular orientations.

(b) *Determination of covalent and van der Waals radii* : Using the NMR spectroscopy of oriented molecules a definite relationship between the ratio of the distance (R) between the two α -protons to the two β -protons and the covalent radius of the heteroatom in 5- and 6-membered heterocyclic aromatic systems has been obtained. Similar expressions were obtained between the distance ratios R and the van der Waals radii of the heteroatoms. These relations, therefore, provide a new method for the determination of the covalent and van der Waals radii.

(c) *Molecular structure of tricyclic systems* : The first ^1H -NMR investigation in an oriented phase of a tricyclic molecule, dibenzo-pyrazine, has been performed and molecular structure has been obtained. Other tricyclic molecules are also being investigated currently.

(d) *Molecular structure of monocyclic fluoro compounds* : 2-fluoropyridine was studied by ^1H -NMR in the nematic phase. It was found that the fluorine substitution does not change the proton geometry from that in pyridine. Some other fluoro-substituted systems are also being investigated to look for possible distortions of the proton geometry due to fluorine substitution.

Theoretical Physics and Astrophysics

Anomalous scattering in protein crystallography

In protein crystallography, anomalous scattering is often used to determine the phases of reflections. A theory was developed to investigate the errors in the experimentally derived phases. Using this, it was possible to suggest means of optimising the choice of X-ray wavelengths and the experimental time devoted to each wavelength.

Unification of closed shell ions and rare gas atoms

The radii and compressibilities of a number of closed shell ions were determined earlier from data on ionic crystals. Using the systematic trends in these properties, the radii and compressibilities of the rare gas atoms were derived. These successfully explained the properties of the rare gas crystals.

Maximum entropy method

The maximum entropy method of image reconstruction in one dimension was examined. Analytical as well as numerical studies revealed the reasons for unphysical results obtained with this method, and the conditions under which it could be used safely. The extensions of this method to two dimensions and polarised brightness distributions were also considered.

Interstellar Medium

An analysis of a 21 cm absorption measurement over a long path length free of the effects of differential galactic rotation has revealed the existence of two distinct cloud populations in the plane. One of them consisting of cold, dense clouds has been well studied before. The newly found hot clouds appear to be at least five times more numerous, have twice the total mass, and hundred times the kinetic energy of the cold clouds. It is proposed that they are shocked clouds found only within supernova bubbles, and that the cold clouds are found in the regions in between old remnants and immersed in an intercloud medium. The presence of a substantial amount of intercloud gas, and the deficiency of hot clouds in the solar neighbourhood is attributed to the Sun's location in-between old supernova remnants rather than within one.

Pulsar magnetic fields

The hypothesis that spark discharges in the Ruderman-Sutherland model of pulsar radio emission are triggered by diffuse background gamma rays was proposed and investigated. This triggering was found effective only within a narrow range of pulsar magnetic fields around 2.5×10^{12} gauss (the pulsar magnetic window). Thus only those neutron stars whose magnetic fields are within this window can function as pulsars. The peaking around this value of the pulsar magnetic fields, derived from observations, has been a long standing puzzle, which now finds a natural explanation here. The long period cut-off at 4 seconds for pulsars found observationally also follows as a result.

Morphology of supernova remnants

The magnetic window concept has been applied to explain the variation in morphology of supernova remnants. The striking difference between shell-type and filled-type remnants is attributed to the magnetic fields of the neutron stars inside them. Fields lying inside the window result in particle production and Crab-like filled remnants. Other fields lead to strong magnetic dipole radiation and shell remnants. Several inconsistencies concerning pulsar-supernova associations appear to find a logical explanation on the basis of this hypothesis.

Integrated pulse profiles of pulsars

It was proposed that integrated pulse profiles of pulsars are a consequence of the surface relief of the polar caps. A possible mechanism for developing such surface relief has been worked out in the framework of the Ruderman and Sutherland model of pulsars.

Gravitational radiations

Following Rosenblum's work on gravitational radiation, where he has questioned the validity of the Einstein quadrupole formula, a study of the problem based on the quantum gravity method was undertaken. The problem was attacked

by using both the conventional Feynman graph technique and the novel Low Energy Theorem technique. The conclusion reached was that there is no reason to doubt the validity of the quadrupole formula in the regime where it was expected originally to be valid.

Neutrinos in gravitational collapse

The behaviour of neutrinos emitted from the interior of a collapsing spherically symmetric star is being studied in the null geodesic approximation. The background geometry consists of the Friedmann dust interior matched on to the Schwarzschild static exterior. A detailed analysis of the neutrino trajectories was carried out in both parts of the geometry in conjunction. The analysis reveals interesting phenomena such as the backward emission of neutrinos and the confinement against escape to infinity. Criteria were derived for the occurrence of these phenomena. These investigations are essential to the determination of the flux profile observed at infinity. Such flux computations are being carried out at present.

Causality conditions

The causality conditions imposed on a space-time have been studied with special reference to their effect on the lengths of non-space-like curves. The space of causal curves connecting p and q denoted by $C(p, q)$, where p and q are chronologically related events, was studied carefully. It was found that this space exhibits interesting topological properties. It was shown that the proper-time length of causal curves of $C(p, q)$ may not have a finite upper bound if global hyperbolicity is replaced by weaker causality conditions. Conversely if the causal curves of $C(p, q)$ have an upper bound for every p and q then this implies chronology but not causality.

Rotational effects in general relativity

Some of the effects of rotation in general relativity have been studied by several authors using the perturbative approach, particularly in the case of a rotating spherical shell. These calculations yield ambiguous results, especially in identifying the "centrifugal" and "coriolis" terms. Such effects are being investigated by obtaining the exact solution for a rapidly rotating infinite cylindrical shell. By analysing the geodesics in the flat interior, the above terms can be unambiguously identified and their interrelation examined. Further, the dragging of inertial frames, both inside and outside the shell, can be studied as a function of the rotation of the shell.

Radio Astronomy and Associated Electronics

Decameter wave radio astronomy at Gauribidanur—a joint project of RRI and IIA

A multibeam scanning system has been incorporated in the NS array of the Decameter Wave Radio Telescope at Gauribidanur. The scanning system auto-

matically points the beam in succession to five declinations anywhere in the range -30° to $+60^\circ$. The fastest rate of scanning is ten times per second. The receiver output at each of the five declinations is now available in both analog and digital forms.

An 8-channel receiver for high time and frequency resolution observations of radio bursts from the Sun and Jupiter has been built. The center frequency of this receiver can be set anywhere in the range 25 to 35 MHz. The channel separations are 50 KHz, the bandwidth of each channel is 10 KHz, and the time resolution is 20 milliseconds. An 8-channel high speed galvanometric recorder is used with the receiver.

A two channel scintillometer for measuring the scintillation index of sources which exhibit IPS has been built. This equipment measures the total and scintillating fluxes of sources. A band pass filter in the range 0.1 to 1.5 Hz is used to give the fluctuations which are squared and smoothed to give the scintillating flux.

The following programs are being carried out with the above equipment.

Galaxy

We have completed observations of the Cygnus Loop with the single beam system and the results are being analysed. Observations on several other regions, *e.g.*, W41, Monoceros, Rosette Nebula are being continued.

Sun

We have observed the slowly varying component (SVC) of the radio emission from the sun at a frequency of 34.5 MHz. These are the first observations of this type. It was found that the peak brightness temperature of the SVC at 34.5 MHz varies in the range 0.3×10^6 K to 1.5×10^6 K, and that the half power width of the brightness distribution is about 3 solar radii. These observations have been interpreted in terms of thermal emission from regions where the electron density is five to ten times that in the normal corona and with a temperature of the order of a million degrees.

Sources

Interplanetary scintillation observations of some strong sources are continuing.

Metre Wave Astronomy

Radio spectral line observations at 327 MHz are being continued using the Ooty radio telescope.

Computer software for efficient analysis and display of the data from the 64 channel autocorrelator installed last year has been developed on the newly acquired PDP 11/70 computer at Ooty. A series of experiments were conducted

with different frequency and declination switching schemes to evolve a reliable observing procedure for the measurement of very weak spectral lines.

A more refined measurement of the $H271\alpha$ recombination line in the direction of the galactic centre, and a preliminary detection of the same line from the galactic HII region W43 has been made. Observations in the direction of the strong radio sources of the Crab and the Orion nebula have only yielded upper limits for the strength of this line, but will be useful in putting constraints on the physical conditions in these regions.

Millimeter wave project

The 10 meter millimeter wave radio telescope has progressed well during the last year and some of the important developments are mentioned below.

Fabrication of the various parts of the mount was completed by M/s. Richardson and Cruddas, Bombay and the assembly of the mount was taken up at their works during January 1980. Detailed inspection and testing of the mount for the required performance was taken up by our consulting engineers M/s. Indian Design Centre (P) Ltd. and the mount will be transported to Bangalore only after it meets our stringent requirements during the tests at Bombay. It is hoped that it will be possible to shift the mount to Bangalore in July 1980.

The development and manufacture of a 10.4 diameter precision reflector which was taken up as a collaborative programme between the Raman Research Institute and the Materials Science Division of the National Aeronautical Laboratory, Bangalore, is progressing. The back-up structure which supports the reflecting surface has been fabricated using a laser measurement system and it has been assembled on top of the 3.5 m diameter aerostatic bearing. The whole structure weighs about 3 tons and can be easily rotated by hand on the frictionless air bearing. The survey of the guide rail structure (both horizontal reference platform and the parabolic curved surface) and initial setting has been completed to an accuracy of about 75 microns, but it is yet to be adjusted to the final required accuracy of 20 microns.

It has taken longer than expected to establish the infrastructure facilities required for the development of millimeter wave mixers and to procure the test equipment and components for the above developmental work. Some of the facilities required, e.g., a diode contacting laboratory with microscopes, capacitance bridge, curve tracer and fume hood in clean room atmosphere, an ultrasonic cleaning facility, a gold plating and electroforming facility, have already been established, and we hope to produce home-made mixers in the 80–120 GHz band by the end of 1980. Pending this development we have procured commercially available low noise mixers in the 20–24 GHz band and 90–140 GHz band to be used in the first tests on the telescope.

A phase-lock system to produce the stable local oscillator signals for the front-end mm-wave mixer has been developed. This system uses both a phase-lock

loop and a frequency discriminator loop to lock a mm-wave Klystron at 22 GHz frequency, but it has also been tested for locking a Klystron at 100 GHz frequency.

A low noise amplifier operating at 1.4 GHz using Ga As FET's has been developed. A minimum noise figure of 1.3 dB has been measured at room temperature and efforts are under way to cool this amplifier to 20 K and to reach noise temperatures in the range 20-30 K. This amplifier will form the I.F. stage of the various mm-wave mixers. Alignment and testing of the 256 channel (250 KHz bandwidth and 250 KHz separation) filter bank receiver has been completed and these are being assembled into separate chassis for rack mounting. For the study of molecular lines produced by maser action, we are at present building a 128 channel filter bank receiver with narrower bandwidths namely, 50 KHz bandwidth and 50 KHz separation between centre frequencies.

Measurements of the atmospheric water vapour content using instruments built earlier, namely, an Infrared Spectral Hygrometer (IRSH) and a microwave radiometer operating at 22.5 GHz have been continued throughout the year at Nandi Hills site and also at the Raman Research Institute campus. Several radiosonde flights were also organised simultaneously with the above measurements in order to obtain absolute calibration of the water vapour content of the atmosphere. A preliminary analysis of all the data obtained till May 1979 revealed the following:

1. The variability in all the meteorological parameters from month to month and year to year remains high, particularly in the cloud cover pattern. However, Bangalore had better night time seeing conditions.
2. Water vapour measurements made during two clear seasons show that Nandi Hills records less total water vapour content (6-13 mm) compared to Bangalore (9-35 mm).
3. Simultaneous IRSH and radiosonde sounding data at Nandi Hills and Bangalore showed good agreement with the French IRSH instrument; the RRI IRSH instrument was calibrated against the French IRSH instrument.

The general picture that emerges from these investigations is that Nandi Hills site is definitely better in the matter of water vapour content but may not be better off in cloud cover conditions. The data is being further analysed.

1.5 Meter millimeter wave project

Measurements on mm-wave antennas: The problem of measuring the surface profile of the 1.5 metre mm-wave dish was further pursued. The 'mouse' method of measuring the surface profile tried earlier was replaced by another method using the laser interferometer with several decisive advantages. This method involves measuring the two coordinates of a number of points on a radial line directly and simultaneously, using the HP laser interferometer system; successive radials are measured by rotating the dish on an air bearing. The system is being further developed to get a complete two-dimensional map of the surface and it is expected that a method of perfecting the surface by repeated

measurement and scraping operations to an accuracy of at least 20 microns r.m.s. will soon be available. The entire scheme has tremendous potential for further refinement to higher accuracies, in view of the high basic accuracy of the laser interferometer system.

Electronics

64 additional channels have been built and will shortly be installed to extend the existing autocorrelator system at the Radio Astronomy Centre, Ooty.

The 128 channel digital correlator and integrator system for Decameter wave Telescope has been fabricated and bench tested. The front-end system for this telescope to convert the RF signals to one bit information is under progress.

A PDP 11/34 computer system was commissioned and is under use for program development in the Institute.

An experiment to measure various parameters of shadow bands which appear a few minutes before and after a total solar eclipse was set up at Raichur on 16th February 1980. Data was recorded on a 4-channel instrumentation recorder. Processing is under way.

Interface units for transfer of data from the HP 9820 calculator and Tesa LYDT measuring system on to a Digital Magnetic Tape Recorder for recording on industry standard magnetic tape medium was designed and fabricated. This is being used on the 1.5 mm wave dish for checking the surface accuracy.

A two-channel Data Acquisition and Logging unit with variable sample periods was developed for use with the Decameter Wave Telescope.

International Conference on Liquid Crystals, December 3-8, 1979

An International Conference on Liquid Crystals was organised in Bangalore. About 100 delegates from 16 countries (including 4 from USSR and 3 from China) participated in the Conference and 84 papers were presented. The proceedings of the Conference will be published by Heyden and Son (London). Probably the two most thoroughly discussed topics at the meeting were 'mesophases of disc-like molecules' (discovered in 1977 at the Raman Research Institute) and 'the re-entrant phenomenon'; there were a number of important and up-to-date contributions on both these topics from France, Germany and USA, and of course, Bangalore. Altogether the Conference was a success, attended by some of the leading scientists in the field, and the deliberations were by and large of a high standard.

It was heartening to find that a number of scientists from different parts of India who had attended the Winter School on Liquid Crystals conducted by us in December 1973 had started research work in this area and had come up with some fairly interesting and useful papers at this Conference. It would appear therefore that our attempts over the last few years to stimulate interest in this subject amongst Indian scientists have been reasonably successful.

Services to other laboratories

As in previous years, a large number of differential scanning calorimetric records, infrared spectra, etc., were run for laboratories from different parts of the country, and the staff of the Institute helped the users in the interpretation of the data. The number of spectra, etc., recorded this year are as follows:

Infrared spectra	50 samples
Optical rotatory dispersion	47 samples
Differential scanning calorimetry	25 samples

Training offered to teachers

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

<i>Name</i>	<i>Topic of study</i>	
G. Venkatesh AES National College Gauribidanur	High pressure studies on liquid crystals	UGC Faculty Improvement Programme
K. P. L. Moodithaya Vivekananda College Puttur	Optical and elastic properties of liquid crystals	do.
S. N. Prasad Regional College of Education, Mysore	Vibrational spectra of liquid crystals	do.
K. Venkatachala Rao St. Aloysius College Mangalore	High pressure x-ray studies of liquid crystals	do.
A. N. Kalkura Vijaya College Mulki	High pressure optical studies on liquid crystals	do.

Theses Submitted

The following candidates who submitted theses from the Institute have been declared eligible for the award of the Ph.D. degree of Mysore/Bangalore University.

G. V. Vani	X-ray analysis of the crystal structures of some mesogenic compounds.
B. R. Ratna	Dielectric properties and short range order in liquid crystals.
J. R. Fernandes	Infrared studies of liquid crystals.
B. K. Sadashiva	Synthesis and properties of some thermotropic liquid crystals.

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 at Annexure I (page 17).

Conferences Seminars Meetings

The staff of the Institute attended 12 conferences and presented papers. In addition, 26 lectures were given by the staff elsewhere.

Colloquia

During the year the scientists of the Institute and visiting scientists both from within and outside the country gave 16 colloquia at the Institute on different topics. In addition 18 discussion meetings were held on topics in theoretical physics.

Visiting Scientists

A number of scientists from institutions both 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

The book section and the periodical section were shifted to the new building. All the sections of the library are now housed in the new building. 513 new books were added to the library during the year. This brings the total number of books to 11,499. The library now subscribes to 117 periodicals and has 14,760 bound volumes in its collection. Two special bibliographies one on "Gamma Ray Astronomy" and the other on "Radio Recombination Lines" were prepared during the year.

General

I. The following grant was received from the Department of Science and Technology during the year.

<i>Plan</i> :	Recurring	..	Rs. 18.00 lakhs
	Non-Recurring	..	Rs. 12.42 lakhs
<i>Non-Plan</i> :	Recurring	..	Rs. 16.50 lakhs
	Millimeter-wave project	..	Rs. 31.58 lakhs
	New Building	...	Rs. 4.00 lakhs
	Development of High Accuracy		
	Reflectors	..	Rs. 3.00 lakhs
	Building for NMR Facility	..	Rs. 1.00 lakhs
			<hr/>
	Total	..	Rs. 86.50 lakhs

II. In addition to the above, the following amounts were also received from the Department of Science and Technology during the year 1979-80:

1. Science and Engineering Research Council (SERC)	..	Rs. 5.70 lakhs
2. Bangalore NMR Facility	..	Rs. 1.25 lakhs
3. Liquid Crystals Conference at Bangalore	..	Rs. 0.75 lakhs
		<hr/>
Total	..	Rs. 7.70 lakhs

III. The audited statement of accounts along with the auditor's report is given in Annexure II (page 21).

Staff

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

Scientific Staff of the Institute

- | | |
|--------------------------------|-------------------------------|
| 1. Prof. V. Radhakrishnan | 41. Mr. P. A. Johnson |
| 2. Prof. S. Chandrasekhar | 42. Mr. Saraba Gopalan |
| 3. Dr. S. Krishnan | 43. Mr. L. B. Susairaj |
| 4. Mr. N. V. G. Sarma | 44. Mr. B. V. Nataraja |
| 5. Dr. C. V. Vishveshwara | 45. Mr. R. Ganesan |
| 6. Dr. C. L. Khetrapal | 46. Mr. H. Subramaniam |
| 7. Dr. N. V. Madhusudana | 47. Mr. Anthony Joseph* |
| 8. Dr. G. Srinivasan | 48. Mr. G. Rengarajan* |
| 9. Dr. N. D. Hari Dass | 49. Mr. H. B. Sreedhar* |
| 10. Dr. R. Shashidhar | 50. Mr. A. Balachander Reddy* |
| 11. Dr. S. Venugopalan | |
| 12. Dr. G. S. Ranganath | <i>Visiting Positions :</i> |
| 13. Dr. A. C. Kunwar | 1. Dr. S. Ramaseshan |
| 14. Dr. V. Surendranath | 2. Dr. G. S. R. Subba Rao |
| 15. Dr. Rajendra Bhandari | 3. Dr. Anand Kumar |
| 16. Dr. C. S. Shukre | 4. Miss A. Mani |
| 17. Dr. Rajaram Nityananda | 5. Dr. R. Srinivasan |
| 18. Dr. Ramesh Narayan | |
| 19. Dr. U. Devappa Kini | <i>Medical Consultant :</i> |
| 20. Dr. K. A. Suresh | Dr. A. R. Pai |
| 21. Dr. B. K. Sadashiva | |
| 22. Mr. J. Padmanabhan | <i>Research Fellows :</i> |
| 23. Mr. K. T. Balakrishnan | 1. Mr. M. N. Ramanuja |
| 24. Mr. D. K. Ravindra | 2. Dr. G. V. Vani |
| 25. Mr. K. M. Chandrakumar | 3. Dr. B. R. Ratna |
| 26. Mr. R. S. Arora | 4. Mrs. K. L. Savithramma |
| 27. Mr. K. R. Anantharamaiah | 5. Mr. M. Vivekanand |
| 28. Mrs. Jayanthi Ramachandran | 6. Mr. N. Kedarnath |
| 29. Mr. M. O. Modgekar | 7. Mr. K. S. Dwarakanath |
| 30. Mr. M. R. Subramanyam | 8. Mr. Sanjeev V. Dhurandhar* |
| 31. Mr. P. N. Ramachandra | 9. Mr. K. P. L. Moodithaya |
| 32. Mr. R. Nandakumar | 10. Mr. K. V. Rao |
| 33. Mr. K. Subramanya | 11. Mr. S. N. Prasad |
| 34. Mr. T. Ramachandran | 12. Mr. G. Venkatesh |
| 35. Mr. K. Smiles Mascarenhas | 13. Mr. K. L. Venkatakrishna |
| 36. Mr. N. Udayashankar | |
| 37. Mr. U. N. Maiya | <i>Resignations :</i> |
| 38. Mr. M. Selvamani | 1. Dr. D. M. Chitre |
| 39. Mr. T. N. Ruckmangathan | 2. Dr. P. Anantha Reddy |
| 40. Mr. A. Ipthigarudeen | |

A list of short period visiting scientists is given below:

1. Prof. R. H. T. Bates June 3-10, 1979
University of Canterbury
New Zealand
2. Dr. B. Turner June 5-11, 1979
National Radio Astronomy
Observatory
Charlottesville, USA
3. Prof. R. C. Jennison June 8-12, 1979
University of Kent at Canterbury, UK
4. Prof. G. H. Pettengill June 8-15, 1979
Department of Earth and Planetary
Sciences
Massachusetts Institute of Technology
USA.
5. Prof. A. R. P. Rau June 13-July 21, 1979
Department of Physics and
Astronomy
Louisiana State University, USA
6. Dr. R. D. Ekers June 26-July 31, 1979
Kapteyn Astronomical Laboratory
Groningen, The Netherlands
7. Dr. Abhay Ashtekar June 21-August 30, 1979
Universite de Clermont
Laboratoire de Physique Corpusculaire
Aubiere, France
8. Dr. Anne Magnon-Ashtekar June 21-August 30, 1979
Universite de Clermont
Laboratoire de Mathematique
Corpusculaire
Aubiere, France
9. Dr. P. T. Gough December 8-15, 1979
Department of Electrical Engineering
University of Canterbury
New Zealand
10. Dr. P. Dierich December 6, 1979-January 3, 1980
Observatoire de Paris
Meudon, France

11. Dr. John Madore
Physique Theoretique
Institut Henri Poincare
Paris, France
February 1-28, 1980

12. Dr. R. Shankar
Yale University, USA
February 11-22, 1980

13. Mr. D. J. Carr
Institut fur Medizinische Psychologie
der Universitat Munchen
Munchen, FRG
February 2-June 14, 1980

Publications

Published in 1979-80

1. High pressure studies of liquid crystals (S. Chandrasekhar and R. Shashidhar)—review article—*Advances in Liquid Crystals* 4, 83 (1979)—Academic Press, New York and London.
2. Liquid Crystals (S. Chandrasekhar and N. V. Madhusudana)—review article—*Annual Review of Materials Science* 1, 133 (1980), Annual Reviews Inc., USA.
3. Crystal and molecular structure of isomorphous cholesteryl chloride and cholesteryl bromide (G. V. Vani and Kalyani Vijayan)—*Molecular Crystals and Liquid Crystals* 51, 253 (1979).
4. The electrooptic characteristics of a nematic liquid crystal cell with asymmetrically treated electrodes (N. V. Madhusudana and K. P. L. Moodithaya)—*Molecular Crystals and Liquid Crystals* 51, 137 (1979).
5. Mesomorphic properties of a homologous series of substituted benzoyl-oxybenzoates (B. K. Sadashiva)—*Molecular Crystals and Liquid Crystals* 53, 253 (1979).
6. Biphenyl benzoates : Synthesis and thermodynamic properties (B. K. Sadashiva)—*Molecular Crystals and Liquid Crystals* 55, 135 (1979).
7. Submillimeter wave absorption in a homologous series of liquid crystals (S. Venugopalan and S. N. Prasad)—*Journal of Chemical Physics* 71, 5293 (1979).
8. NMR of bicyclic diazines oriented in a lyotropic mesophase (C. L. Khetrapal, A. C. Kunwar and A. V. Patankar)—*Molecular Crystals and Liquid Crystals* 51, 247 (1979).
9. The structure of phosphacymantrene (C. L. Khetrapal, A. C. Kunwar and F. Mathey)—*Journal of Organometallic Chemistry* 181, 349 (1979).
10. NMR of oriented monosubstituted amides—*cis* and *trans* N-methyl formamide (S. Ramaprasad, A. C. Kunwar and C. L. Khetrapal)—*Int. J. Peptide and Protein Research* 149, 123 (1979).
11. Oriented molecules (C. L. Khetrapal and A. C. Kunwar)—*Specialist Periodical Reports : NMR*, 8, 304 (1979), Chemical Society, London.
12. Two dimensional NMR spectra of oriented molecules (C. L. Khetrapal, Anil Kumar, A. C. Kunwar, P. C. Mathias and K. V. Ramanathan)—*Journal of Magnetic Resonance* 37, 349 (1980).
13. Elasticity and orientational order in some *trans-p-n*-alkoxy- α -methyl cyanophenyl cinnamates (P. P. Karat and N. V. Madhusudana)—*Molecular Crystals and Liquid Crystals* 55, 119 (1979).
14. Anomalous smectic mesomorphism of 4,4'-di-*n*-pentyloxyazoxybenzene (S. N. Prasad S. Venugopalan and J. Billard)—*Molecular Crystals and Liquid Crystals Letters* 49, 271 (1979).
15. Miscibility studies of disc-like molecules (J. Billard and B. K. Sadashiva)—*Pramāna* 13, 309 (1979).
16. Re-entrant nematic phase in pure compounds at atmospheric pressure (N. V. Madhusudana, B. K. Sadashiva and K. P. L. Moodithaya)—*Current Science* 48, 613 (1979).
17. A new method for the determination of covalent radii (C. L. Khetrapal, A. C. Kunwar and K. P. Sinha)—*Chemical Physics Letters* 67, 444 (1979).
18. NMR spectra of 2-fluoropyridine in nematic liquid crystals (N. Suryaprakash, A. C. Kunwar and C. L. Khetrapal)—*Current Science* 49, 1 (1980).

19. The book "Liquid Crystals" (S. Chandrasekhar), Cambridge Monograph on Physics has been translated into Russian (Published by Mir Publishing House, Moscow, 1980) and issued as a paper back edition (Cambridge University Press, 1980).
20. A new theory of repulsion and structural stability in ionic crystals (Ramesh Narayan and S. Ramaseshan)—*Physical Review Letters* **42**, 992 (1979).
21. Ionic compressibilities and ionic radii—systematic trends (Ramesh Narayan)—*Pramāna* **13**, 559 (1979).
22. Some studies on the relative stabilities of NaCl, CsCl and ZnS structures (Ramesh Narayan)—*Pramāna* **13**, 571 (1979).
23. A new theory of compressible ions—structures of the alkali halides (Ramesh Narayan and S. Ramaseshan)—*Pramāna* **13**, 581 (1979).
24. A method of reducing termination errors in radial distribution functions (Ramesh Narayan and S. Ramaseshan)—*Journal of Applied Crystallography* **12**, 585 (1979).
25. Alternative searches for parity violation in atomic physics (N. D. Hari Dass and A. R. P. Rau)—*Physics Letters B*, **89**, 375 (1980).
26. Non-equatorial tachyon trajectories in Kerr space-time and the second law of black hole physics (S. V. Dhurandhar)—*Physical Review D* **19**, 2310 (1979).
27. Electromagnetic fields in the Godel universe (J. M. Cohen, C. V. Vishveshwara and S. V. Dhurandhar)—*Journal of Physics A* **13**, 933 (1980).
28. A new upper limit to the abundance ratio of atomic deuterium to hydrogen in the direction of the galactic centre (K. R. Anantharamaiah and V. Radhakrishnan)—*Astronomy and Astrophysics* **79**, L-9 (1979).
29. Polarity effect in spark erosion machining (N. Udaya Shankar and A. Krishnan)—*Indian Journal of Technology* **17**, 363 (1979).
30. Observations on the structure of Type IIIb radio bursts. (Ch. V. Sastry, K. R. Subramanyan and V. Krishan) in *Proceedings of IAU Symposium No. 86 on Radio Physics of the Sun*.
31. A large decametric wavelength array for IPS observations of radio sources (Ch. V. Sastry)—in *Proceedings of the IAU Symposium No. 91 on Solar and Interplanetary Dynamics*.

Papers submitted and in press (1979-80)

1. Magnetic and electric birefringence in the isotropic phase of a nematic large positive dielectric anisotropy (B. R. Ratna)—*Molecular Crystals and Liquid Crystals*.
2. Polarization field and orientational order in liquid crystals (N. V. Madhusudana)—*Molecular Crystals and Liquid Crystals*.
3. The re-entrant phenomenon in 4'-n-octyloxy-4-cyanobiphenyl: high pressure X-ray study of the smectic A layer spacing (S. Chandrasekhar, R. Shashidhar and K. V. Rao)—Presented at the Third Liquid Crystals Conference of Socialist Countries, Budapest, Hungary, August 1979.
4. Polymorphism of the smectogen ethyl-p-azoxybenzoates: far-infrared and Raman study (S. Venugopalan and S. N. Prasad)—*Journal of Chemical Physics*.
5. The nematic-isotropic phase transition: Application of the Andrews method (K. L. Savithramma and N. V. Madhusudana)—*Molecular Crystals and Liquid Crystals*.
6. Steady low shear rate cholesteric flow normal to the helical axis (U. D. Kini)—*Pramāna*.

7. Evidence of a tilted columnar structure for mesomorphic phases of benzene-hexa-*n*-alkanoates (F. C. Frank and S. Chandrasekhar)—*Journal de Physique*.
8. New disc-like mesogens (S. Chandrasekhar, B. K. Sadashiva and K. A. Suresh) *Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
9. A high pressure X-ray cell for liquid crystals : Pressure dependence of the smectic A layer spacing of 8 OCB in relation to its re-entrant behaviour (R. Shashidhar and K. V. Rao)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
10. The re-entrant nematic phase in some pure compounds and their mixtures at atmospheric pressure (K. P. L. Moodithaya and N. V. Madhusudana)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
11. Temperature dependence of the smectic A layer spacing in two pure re-entrant nematogens (S. Chandrasekhar, K. A. Suresh and K. V. Rao)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
12. Dielectric studies of re-entrant nematogens (B. R. Ratna, R. Shashidhar and K. V. Rao)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
13. Re-entrant nematic phase in a pure compound at atmospheric pressure (B. K. Sadashiva)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
14. Absolute configuration of cholesteryl chloride and cholesteryl bromide (G. V. Vani, Kalyani Vijayan and S. Chandrasekhar)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
15. Disclinations and their radial force of interaction in elastically anisotropic nematic liquid crystals (R. Nityananda and G. S. Ranganath)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
16. Angular forces between disclinations in elastically anisotropic nematic liquid crystals (G. S. Ranganath)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
17. Attraction between two like half singularities in nematic liquid crystals (G. S. Ranganath)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
18. Radial flow in a cholesteric subjected to a rotary (torsional) shear about the helical axis (S. Chandrasekhar, U. D. Kini and G. S. Ranganath)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
19. Cholesteric shear flow normal to the helical axis : The effect of a magnetic field (U. D. Kini)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
20. Induced smectic mesomorphism in some binary mixtures : a new type of electrohydrodynamic pattern in the nematic phase of the mixtures (K. P. L. Moodithaya and N. V. Madhusudana)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
21. A convenient multiplexing scheme for addressing small liquid crystal matrix displays (N. V. Madhusudana and T. N. Ruckmangathan)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
22. High pressure studies on 4,4'-*n*-alkoxyazoxybenzenes (G. Venkatesh, R. Shashidhar and D. S. Parmar)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.
23. Orientational statistics in 8 OCB—Raman and infrared study (S. N. Prasad and S. Venugopalan)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979*.

24. A new application of NMR spectroscopy of oriented molecules (C. L. Khetrapal, A. C., Kunwar and K. P. Sinha)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979.*
25. Proton NMR study including ^{13}C - ^1H satellites in acetone oriented in a nematic solvent (C. L. Khetrapal, Anil Kumar and A. C. Kunwar)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979.*
26. 2-Dimensional NMR spectroscopy of molecules oriented in liquid crystals (C. L. Khetrapal, Anil Kumar, A. C. Kunwar, P. C. Mathias and K. V. Ramanathan)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979.*
27. Experimental determination of the surface tension of two liquid crystals (S. Krishnaswamy)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979.*
28. Mesomorphic properties of some phenyl benzoates derivatives with lateral hydroxyl substituent (V. Surendranath and M. Subramanya Raj Urs)—*Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979.*
29. Oriented molecules (C. L. Khetrapal and A. C. Kunwar)—*Specialist Periodical Reports, NMR 9* (The Chemical Society, London, 1980).
30. NMR study of the oil build-up in sunflower seeds (M. R. Lakshminarayana, A. Seetharam, K. V. Ramanathan and C. L. Khetrapal)—*Current Science.*
31. Diffuse gamma radiation and pulsar magnetic fields (C. S. Shukre)—*Bulletin of the Astronomical Society of India.*
32. Causality conditions and the lengths of nonspacelike curves (S. V. Dhurandhar and P. S. Joshi)—*GRG Journal.*
33. Neutrinos in compact objects (Ajit Khembhavi and C. V. Vishveshwara)—*Physical Review 'D'.*
34. The maximum entropy method of image reconstruction—Properties and limitations (M. M. Komesaroff, Ramesh Narayan and Rajaram Nityananda)—*Astronomy and Astrophysics.*
35. On anomalous scattering and the multiple wavelength method (Ramesh Narayan and S. Ramaseshan) in *Structural Studies on Molecules of Biological Interest*. Edited by E. Dodson and D. Sayre, Oxford University Press.
36. Quantum gravity vindication of quadrupole formula for gravitational radiation (N. D. Hari Dass and V. Soni)—*Physics Letters 'B'.*
37. Low energy theorems for quadrupole radiation in electromagnetism and gravitation (N. D. Hari Dass)—*Physics Letters 'B'.*
38. HI absorption in the direction of the galactic centre (V. Radhakrishnan and N. V. G. Sarma)—*Astronomy and Astrophysics.*
39. Pulsar activity and the morphology of supernova remnants (V. Radhakrishnan and G. Srinivasan)—*Journal of Astrophysics and Astronomy.*
40. Evidence for a large population of shocked interstellar clouds (V. Radhakrishnan and G. Srinivasan)—*Journal of Astrophysics and Astronomy.*
41. Observations and interpretation of the slowly varying component of the radio emission from the Sun at decametric wavelengths (Ch. V. Sastry, K. S. Dwarakanath, R. K. Shevgaonkar and V. Krishan)—*Solar Physics.*
42. The effect of the diffuse gamma radiation on pulsars (V. Radhakrishnan)—*Proceedings of the Symposium on Non-Solar Gamma Rays* (COSPAR 22nd Plenary Meeting, 1979).