RAMAN RESEARCH INSTITUTE

BANGALORE

ANNUAL REPORT - 1981-82

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 & 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 a 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.

While liquid crystals, exhibited by rod-like molecules, were discovered back in 1888 it was only in 1977 that the Raman Institute group discovered that some disc-like molecules also exhibit such phases with an altogether new kind of order which was established with the help of X-ray studies. This has opened up an entirely new field of study which is being pursued in many laboratories of the world.

The laboratory has been organised to undertake studies on most of the fundamental properties of liquid crystals. The physical investigations include high pressure studies (with a locally fabricated 200-ton Press), and those on the thermal, optical, electrical and elastic properties. The spectroscopic laboratory has facilities for near-infrared, far-infrared and Raman studies. Several theoretical lines of research including statistical theories, structures and interaction of defects and hydrodynamic flow properties are being pursued.

Practically all the electronic watches being manufactured in the world use liquid crystal displays, since they are the lowest power consuming of all the display systems. Sensing the importance of developing the know-how for this technology, the RRI group has tackled the problem in its entirety for use in such display systems, and a few patents have been taken for new processes of synthesising the liquid crystalline materials used in watch displays. These chemicals have undergone stringent tests for chemical, photochemical and electrical stability, and a well known private firm has started production of these materials in Bangalore. The scientists at RRI in cooperation with some engineers of Bharat Electronics Ltd., a public sector undertaking, have developed the know-how for producing liquid crystal displays. In other words, the R & D effort at the laboratory has resulted in the know-how for a totally indigenous production of this vital component of not only watches but many other electronic devices.

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 light" part (wavelength 3000 Angstroms to 6500 Angstroms, 1 Angstrom = 10^{-8} centimeter) of the electromagnetic spectrum. Radio Astronomy, which has 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 radio window is very wide (30,000 to 1 compared to the 2 : 1 wavelength ratio in the visible part) and studies within it over the years have yielded information leading to 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. Operating 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.

The research programme that is being carried out by the theoretical group involves to a large extent problems in astrophysics and the general theory of ralativity. While astronomical observations have been revealing natural phenomena that are both extraordinary and intriguing, it is the challenging task of the

theoretician to explain and correlate them. One such phenomenon we are investigating is the supernova in which the outer envelope of a star explodes violently while the central part collapses under its own gravity, and could end up as a neutron star. Pulsars, that are observed to send out radiation in regular pulses as their name suggests, are believed to be such neutron stars. The theoretical physics group is engaged in studying the various aspects of these phenomena, such as the mechanism and occurrence of supernovae, the birth rate of pulsars and the nature and evolution of the magnetic fields that are associated with them.

In many of the phenomena encountered in astrophysics, gravitation plays a predominant role. Einstein's theory of general relativity, which properly incorporates gravitational effects, often predicts strange effects. The role of this theory, both from a purely theoretical standpoint and within the context of astrophysics, is being studied by the group. For example, some interesting properties of black holes, and the behaviour of particles in the presence of strong gravitational fields have been and continue to be investigated.

A significant step in Astronomy education came into operation this year. An astronomy programme was started at the Indian Institute of Science as a joint programme with the Raman Research Institute, Indian Institute of Astrophysics, Tata Institute of Fundamental Research, Physical Research Laboratory and the Indian Space Research Organisation. The faculty was drawn from the various collaborating establishments and the first batch of students started its course at the Indian Institute of Science this academic year.

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 work on liquid crystals is continuing along the lines indicated in the previous year's report. Some of the more important results obtained during the current year are summarized below.

I. Theoretical Studies

Theory of fluctuation in the columnar liquid crystal

The columnar phase of thermotropic liquid crystals (discovered in Bangalore) is a system with translational order in two dimensions but not in the third. The problem of fluctuations in such a system is of fundamental interest, especially in view of the fact that the 2D lattice is known to be unstable. The present study has shown that the curvature elasticity of the liquid-like columns stabilizes the 2D order in the columnar structure. However, the mean square fluctuation is much more sensitively dependent on the sample size than in the case of the 3D lattice, and the Debye–Waller factor significantly different from that for the 2D or 3D lattice or the smectic A liquid crystal. A remarkable consequence of this is that the structure factor for X-ray or neutron scattering shows a certain dependence on the dimensions of the sample.

A mean field theory of the columnar–nematic–isotropic transition

McMillan's model of smectic A has been extended so that the translational order parameter now describes a two-dimensionally periodic structure. When the lattice

is hexagonal or departs from it only slightly, it turns out that the transition from the columnar to the isotropic phase may take place either directly or *via* a nematic phase, depending on the model potential parameters (α). Interpreting α to be a measure of the chain lengths as in McMillan's theory, the phase diagram is in broad agreement with the trends exhibited by the hexa-n-alkoxybenzoates of triphenylene. When the departure from hexagonality is slightly greater, the theory predicts a columnar–smectic A transition as well. The new smectic A phase is biaxial. The possibility of such a phase occurring in real systems is discussed.

Statistical theory of the nematic phase of disc-like molecules

A statistical model has been developed which can be conveniently used to study the nematic phase of disc-like molecules. It is a scaled particle theory of a system of right circular cylinders. The advantage of choosing this shape for the particles is that by varying the radius to height ratio R, one can investigate either rod-like molecules ($R < 0.5$) or disc-like molecules ($R > 0.5$). Various thermodynamic properties have been evaluated for a range of values of R for a system of hard cylinders as well as for one with a superposed attractive potential. The properties appear somewhat symmetrical for the rod-like and disc-like regions if they are plotted as functions of the ratio (larger dimension/shorter dimension) of the cylinders.

II. New Compounds with unusual Properties

Several new compounds exhibiting the re-entrant nematic phase at atmospheric pressure were synthesized in the chemistry laboratory. They belong to two new homologous series, viz., 4-cyanophenyl-3-methyl-4-(4-alkoxycinnamoyloxy) benzoates and 4-cyanophenyl-4-(4-*n*-alkoxy-α-methyl cinnamoyloxy)benzoates. The phases have been identified by detailed miscibility studies. One of the compounds exhibits enantiotropic re-entrant nematic phase, and is therefore extremely useful for physical studies.

Synthesis and physical studies of another new series of compound, viz., 4-*n*-alkylphenyl-4′-methyl-4′-(4″-nitrobenzoyloxy) benzoates have been taken up. The tenth homologue which exhibits the smectic A and nematic phases shows a most remarkable expansion of the bilayer spacing (of the order of 20%) as it is *cooled* in the mesomorphic range. This is accompanied by a reversal in the sign of the dielectric anisotropy which becomes negative at lower temperatures. The origin of this behaviour is being investigated.

III. High pressure studies

One of the problems of great current interest in condensed matter physics is the multicritical NAC point observed in the temperature–concentration diagram of some binary mixtures. We have observed by high pressure studies a new kind of polycritical point, viz., NCA point in a single component liquid crystal system. The detailed topological features of the P–T diagrams are being investigated.

High pressure studies have been conducted on several new re-entrant nematogens synthesized in our laboratory and extremely accurate P–T diagrams have been obtained. The noteworthy feature of these P–T diagrams is that the smectic A–nematic phase boundary is elliptic in shape. Also, it is found that the maximum pressure of stability of the smectic A phase is sensitive to changes in

molecular structure and is related to the range of the nematic phase at atmospheric pressure. These experiments were conducted using the optical (sapphire) cell fabricated in our laboratory. A special feature of this cell is that only a very small quantity (< 10mg) of the sample is required for the experiments.

It has long been recognized that the temperature variation of the tilt angle in the smectic C phase depends very much on the phase that exists at a higher temperature. If the higher temperature phase is smectic A, the tilt angle shows a strong temperature dependence whereas if it is the nematic phase then the tilt angle is temperature independent. Very recently de Vries made the interesting observation that in the case of *n*-penthyl-4-(4′-*n*′-decyloxybenzylidene amino) cinnamate the tilt angle in the smectic C phase is temperature independent although the C phase precedes the A phase. Pressure studies have been carried out on compounds exhibiting the three kinds of smectic C with a view to seeing if pressure affects these phases differently. The results show that in all three cases the C phase is suppressed at high pressures showing thereby that a tilted phase is somehow not favoured at high pressures. X-ray high pressure studies are being taken up to understand the role of the pressure dependence of the layer spacing on the stability of smectic C phases.

IV. Applications

A 32-character multiplexed alphanumeric liquid crystal display has been constructed and operated. Design is underway to obtain improved display characteristics.

V. NMR Work

1) The new method using mixed liquid crystals of opposite diamagnetic anisotropies for the determination of chemical shift anisotropy and the NMR spectral parameters which cannot be determined otherwise, reported last year has been exploited to obtain such information in various systems such as benzene, methanol and organoselenium compounds. The results are being interpreted theoretically using mean field theory.

2) The use of bond-polarisation hypothesis for the preferred conformation of molecules has been made to postulate the structure and conformation of N:N-dimethyl uracil, benzo(b)furan and benzo(b)thiophene and the results have been verified experimentally.

3) The structure and conformation of iron dicyano and tetracyano complexes of phenanthroline and 2,2′-bipyridyl have been determined. It is established that the tetracyano iron complex of phenanthroline exists as a mixture of two species rather than having an unsymmetrical conformation as predicted by earlier workers in order to explain the ^{13}C-NMR spectra.

4) The interaction of cytosine arabinoside (a drug used for the treatment of lukaemia) and lysozyme (a protein whose serum level increases in leukaemic patients) has been studied with the help of NMR. It is inferred that the C_6-proton of the pyrimidine moiety of the drug and the C_2-proton of the histidine participate in the binding process. Under similar conditions, cytosine does not associate with lysozyme indicating positive role of arabinose in the binding phenomenon. The result indicates that the drug penetrates the protein interior.

Astronomy and Astrophysics

(*i*) *Decameter Wave Radio Astronomy at Gauribidanur–a joint project of RRI and IIA*

1) *Sun*

Weak continuum emission has been detected from the sun during extremely quiet periods when there is no transient burst activity from the Sun. Based on the brightness temperatures derived from one dimensional (E-W) scans this has been interpreted as the extension of the Slowly Varying Component to decameter wavelengths. Two dimensional maps of this type of continuum emission have now been made for the first time and have revealed many interesting features. One is now able to derive the brightness temperatures more accurately and they are found to vary from 0.2 to 1.5 $\times$ 10^6 K. It is also found that the position of the centroid of the brightness distribution can sometimes be shifted by as much as 2 to 3 solar radii from the center of the Sun. Model calculations with various types of density and temperature distributions to interpret the above results are under way.

Several types of radio "bursts" in absorption have been detected for the first time from the Sun. These bursts are characterised by a sudden or gradual decrease of the background continuum and subsequent rise to the preabsorption level.

Preliminary classification of these bursts in terms of their time structure have revealed that there are essentially three types. It is believed that these bursts are due to either partial interruption of the instability responsible for the generation of the continuum emission, or due to wave-wave interaction where the energy is transferred from one spectral region to another.

The time structure of weak Type III radio bursts from the Sun has also been studied. It is found that the time profiles can take a variety of forms of which three distinct types are (1) profiles where the intensity rises to a small but steady value before the onset of the main burst (2) the intensity of the main burst reduces to a finite level and remains steady before it decays to the base level and (3) the steady state is present during the rise as well as the decay phase of the main burst. It is found that these profiles are not due to random superposition of bursts with varying amplitudes. They are also not manifestations of f–h pairs. Some of these observed profiles can be due to bursts caused by ordered electron beams ejected with a constant time delay at the base of the corona.

2) *Supernova Remnants*

The extended supernova remnants HB 9 (G 160.5 + 2.8) and IC 443 (G 189.1 + 2.9) have been mapped at 34.5 MHz with a resolution of 26′ $\times$ 40′ The integrated flux density of HB 9 at 34.5 MHz is 750 $\pm$ 150 Jy. The spectral index in the frequency range from 34.5 MHz to 2700 MHz is found to be constant ($-$ 0.58 $\pm$ 0.06) without any spectral break such as was earlier believed. There is no significant variation of the spectral index across the remnant. The integrated flux density of IC 443 at 34.5 MHz is 440 $\pm$ 88 Jy. The spectral index in the frequency range from 20 MHz to 10700 MHz is $-$ 0.36 $\pm$ 0.04. The reduction in flux at very low frequencies is attributable to free–free absorption in the interstellar medium and/or in the H II region S 249.

3) *Ionised Hydrogen Regions*

Several galactic H II regions have been detected as absorption features against the background radiation from the galaxy. Detailed maps of the two large regions, the Rosette Nebula and W51 have been made. The average kinetic temperature of the Rosette Nebula is found to be around 4500K. This value agrees quite well with previous measurements based on recombination lines and the high frequency continuum.

4) *Instrumentation*

The present beam switching system of the N–S array is being replaced by a more sophisticated one with sixteen beam positions. A limited tracking system in the E–W array is also being installed. It will then be possible to track a source for about an hour around the meridian.

(ii) Meter Wave Astronomy

Radio Spectral line observations with the Ooty Radio Telescope using the 128 channel Auto correlator installed two years ago is continuing. With the development of an efficient computer analysis package and a standard method of observation, spectral line observation are now being carried out on a routine basis.

Observations at the frequency of the H-272α and C-272α radio recombination lines have been completed in the direction of 35 galactic H II regions and 10 supernova remnants (SNR's). Spectral lines have been detected towards the majority of these sources and in most of the cases this is the first time that a low frequency recombination line has been observed in that direction. The recombination lines detected in the direction of SNR's are particularly interesting. As such spectral lines are not expected from SNR's themselves, they must originate either from ionized matter along the line of sight, or from shock-ionized gas close to the SNR; neither of these has hitherto been detected on a large scale. Interpretation of these lines and also those from H II regions is currently in progress.

A new programme of observation of recombination lines in 7 directions in the galactic plane, *free* of any continuum sources has just been started. Observations have been completed in 3 of these directions and the H-272α line has been detected. These observations are expected to yield information on the diffusely distributed ionized component of the interstellar medium.

(iii) Millimeterwave Telescope Project

The precision mount which was built at Richardson & Cruddas Ltd., Bombay was transported to the National Aeronautical Laboratory, Bangalore where it was dismantled and each part was thoroughly tested. Several tests were made to determine accurately the concentricity and parallelism of the elevation bearings. A special jig was made to test the gear boxes under dynamic loading conditions. Hardening of the azimuth ring posed several problems which are being tackled. Rough machining of the reflector surface has been completed and the final machining will be undertaken after resurveying the guide rail for the required accuracy. These measurements are in progress at present.

Receiver development for the millimeterwave telescope has progressed quite well. An 80–120GHz band mixer has undergone several tests. Efforts to improve the IF bandwidth of the mixer block to at least 400MHz are in progress. The GaAs FET amplifier which immediately follows the mixer as the 1st IF amplifier has shown very encouraging results. A two stage amplifier using Mitsubishi MGF-1412 GaAs FET's has been built giving a gain of 25dB over a 300MHz band, centred around 1.4GHz. The average input noise temperature over the band is 50 ± 5K for room temperature operation. When the amplifier is cooled to an ambient temperature of 20K in a closed cycle Helium refrigerator, it gave an average input noise temperature of 12 ± 3K. The amplifier is stable for all input/output reactive loads, and its overall performance is comparable to the best achieved anywhere.

The control system for a 256 channel Data Acquisition system for the spectral line receiver of the millimeterwave Radio Telescope has been designed and tested. The control parameters for this system will be given from the host computer a PDP 11/34, for ON-line Data Acquisition. Design of interface circuitry to drive cables of around 60 metres in length for fast data transfer is under progress.

A Memory system for a "Spectrum Expander" for the 256 channel filter receiver was designed and tested. A memory control scheme for the memory system was also tested. Design of IF input and output electronics is under progress.

An eight channel prototype of the Fourier Transform machine was installed at Gauribidanur, along with its Local oscillator system, clock generators for quadrature sampling and interference monitor for the entire front end. Various observations to test the Fourier Transform machine using the Gauribidanur telescope are under progress. Production and testing of the 128 channel front end system is also under progress.

Theoretical Physics and Astrophysics

1. *Foundations of Quantum Mechanics and Statistical Mechanics*

Selection of special broken-symmetry states in nature plays an important part in determining the familiar characteristic behaviour of classical objects as opposed to quantum objects. Some interesting aspects of this selection were studied on a simple, prototype, two-state system.

A paradox in statistical mechanics, namely, Gibbs' paradox in its modern form was studied and a possible resolution proposed.

Further work on both these problems, which also appear interrelated is in progress.

2. *Maximum Entropy Method in Radio Astronomy*

A FORTRAN program has been developed to implement the Maximum Entropy Method (MEM) of image reconstruction for radio astronomical applications. The gradient method of maximisation is employed. A process called FLOAT is incorporated to control the resolution of the restoration. Simulations on model data have substantiated the theoretically deduced properties of the MEM.

3. *Maximum Entropy Method in Crystallography*

The Maximum Entropy Method (MEM) has been tested in preliminary computer simulations on model two-dimensional structures with typically about 15 equal atoms. Encouraging results have been obtained in (i) phase refinement and (ii) *ab initio* phase determination from random starting phases. *A priori* phase information on the equality of atoms has also been imposed in some cases. The MEM appears to have great promise for crystallographic problems.

4. *Structure of the Ammonium Halides*

Taking a distributed charge of + 0.2 e on each of the five atoms of the NH_4^+ ion, an ionic theory has been developed for the ammonium halides which explains for the first time the structures of these crystals. The thermal and pressure transitions are also explained reasonably well. In particular, the theory correctly predicts a pressure transition in NH_4^+F at room temperature from the SnO structure directly to the CsCl structure without an intermediate NaCl phase.

5. *Pulsar Injection*

A statistical analysis of the periods P and period derivatives $\dot{P}$ of pulsars was carried out using the model independent theory of pulsar flow in the P–$\dot{P}$ diagram developed earlier. It was concluded that a large majority of pulsars makes their first appearance at periods greater than 0.5 s. This "injection" runs counter to present thinking and is probably connected with the physics of pulsar radio emission. It appears to be a natural explanation for the poor association between pulsars and supernova remnants.

6. *Selection Effects in Pulsar Searches*

Two hitherto neglected selection effects have been identified. It is shown that short period pulsars are more difficult to detect, particularly if their dispersion measures are high. A declination dependent selection effect has also been identified. There is evidence in the data from the II Molonglo Survey for both selection effects. It has been confirmed that the new effects do not affect the earlier conclusions regarding the "injection" of pulsars.

7. *Electron Density in the Galaxy*

Using the dispersion measures of pulsars, a statistical investigation was made of the galactic thermal electron density (n_e) using the reasonable assumption that the distribution of pulsars in the galaxy is cylindrically symmetric about the galactic centre. A mean n_e of $0.037^{+0.020}_{-0.012}$ electrons/cm^3 was obtained. The scale height of electrons was estimated to be larger than that of neutral hydrogen clouds. This has implications for models of the interstellar medium. Combining all available evidence, the galactic electrons were modelled in the form $n_e(z) = 0.021 + 0.022 \exp(-z/70)$, where z(pc) is the height above the galactic plane.

8. *Implications of the evolution of close binaries for pulsar statistics*

According to the standard picture of evolution of massive close binaries, the first born neutron star will have a complicated history of slowing down, spinning up,

etc. It was shown in an earlier investigation from here that the characteristics of the pulsar PSR 1913 + 16 can be understood along these lines. Recently, it was suggested that the properties of most of the pulsars must, in fact, be understood in terms of their evolution in binaries. An analysis of statistics of such binaries suggests, however, that only 1–2% of pulsars could have had such an origin. This is in good agreement with the observed number of pulsars in binaries and those that are likely to have been born in them.

9. *How unique are supernova remnants resembling the CRAB NEBULA?*

It is generally accepted that such nebulae are produced by rapidly spinning pulsars; the Crab Nebula and Vela X, with their associated pulsars, support this argument. Recent observations to detect a nebulosity around the third fastest pulsar PSR 1930 + 22 has yielded a negative result. We have suggested that though the pulsar is only 36,000 years old, if it were located in a region of the interstellar medium with relatively low density, then one would not be able to detect the nebula.

It is commonly believed that most pulsars are born spinning rather rapidly. If so, they should build up an observable nebula during the first few thousand years. From an analysis of the statistics of known SNRs resembling the Crab Nebula, it has been argued that the birth rate of pulsars with characteristics similar to the Crab pulsar is only one in 350 years or so. This is in good agreement with the fraction of pulsars which have short P and high $\dot{P}$.

10. *Statistics of Galactic Neutral Hydrogen Clouds*

The number density and random motions of interstellar HI clouds have been studied using an entirely novel method involving the comparison of terminal velocities of HI absorption spectra in the direction of HII regions and their recombination line velocities. The HI terminal velocities exceed the recombination line velocity in the large majority of cases. This was shown to be the result of overlapping of velocities due to chaotic motions of two populations of HI clouds charactised by quite different velocity dispersions. It was concluded that resolving the kinematic distance ambiguity from a comparison of the recombination line and HI terminal velocity may be misleading if the velocities are within 10–20 km s^{-1} of the tangential velocity. The analysis has yielded independent estimates of the number densities and dispersion of random motions for the "slow" and "fast" clouds. The results support a two population picture as proposed by Radhakrishnan & Srinivasan (1980) on the basis of an analysis of the HI absorption spectrum in the direction of the galactic centre.

11. *Maximum Luminosity of Accretion Disks*

The constraints on the luminosity of an accretion funnel imposed by the balance between radiation pressure and gravity have been investigated. The new feature is a proper allowance for the irradiation of any part of the funnel by the rest. It is found that the maximum luminosity of an accretion disk cannot greatly exceed the Eddington limit if one requires equilibrium of the surface or steady viscous flow. Super-Eddington luminosities imply blowing off of matter.

12. *Core envelope models for collapsed Objects*

With the framework of core envelope models for collapsed objects as formulated by Sabbadini, Hartle and Chitre, one has been studying the possible ranges of radius to mass ratio for such configurations, since general relativistic effects depend on the degree of compactness. Of particular interest is the existence of ultracompact objects with radius $r < 3M$ since such objects exhibit unusual general relativistic effects. Using the Baym-Bethe-Pethick-Sutherland equation of state for the envelope it is found that ultracompact objects exist even if the constraints of causal cores is imposed. One has also investigated the question of whether the requirement of stability brings down the maximum mass limit. It is found that the incompressible core-BBPS envelope configuration with no density discontinuity at the interface, which leads to a maximum mass of around 3 solar masses, is also stable.

13. *A new class of solution of the Einstein-Maxwell equation*

By the method of applying a Harrison type transformation to the most general stationary cylindrically symmetric vacuum metric, new solutions of the Einstein-Maxwell equations have been obtained. These include generalizations of the Melvin magnetic universe and the Weyl Levi Civita magnetic solution in addition to a new class of stationary axially symmetric metrics which no longer retain their original cylindrical symmetry. The structure of the electromagnetic fields inherent to the above spacetimes have also been examined.

Services to other laboratories

As in the 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 Liquid Crystals Laboratory helped the users in the interpretation of the data. The number of spectra, etc., recorded this year are as follows:

1.	Optical rotatory dispersion	94 samples
2.	Infrared spectra	5 samples
3.	Differential scanning calorimetry	4 samples

Training offered to Teachers

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

Name	Topic of Study	
A. N. Kalkura Vijaya College Mulki, S.K.	High pressure optical studies on Liquid Crystals	UGC Faculty Improvement programme
B. S. Srikanta AES National College Gauribidanur	Order and Elasticity in Liquid Crystals	

M. Subramanya Raj Urs Sahyadri College Shimoga	Synthesis of some new mesogenic compounds

Theses Submitted

The following candidate who submitted a thesis from the Institute has been declared eligible for the award of the Ph.D. degree of Mysore University:

Mr. K. P. Lakshminarayan Moodithaya	Optical and Elastic Properties of 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 appeared and those in press is given at Annexure I **(Page 16)**.

Conferences/Seminars and Meetings

The staff of the Institute visited various institutions in India and abroad and attended 21 conferences and presented papers. In addition, 34 lectures were given by them elsewhere.

Colloquia

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

Neighbourhood Astronomy and Journal Club Meetings

A neighbourhood astronomy meeting was held on October 22nd and 23rd, 1981. This meeting gave the participants, who were from Indian Institute of Astrophysics (IIA), Indian Space Research Organisation (ISRO), Tata Institute of Fundamental Research (TIFR) and Raman Research Institute (RRI), an opportunity both to present their current research and learn about that of others. This meeting was considered a success while recognising that there was scope for a regular series of such gatherings. These would each be devoted to a specific astronomical area and act as a forum both for presenting new ideas and for building up collaboration between the participating institutions.

A Journal Club, meeting once every two weeks, was started in October, 1981. In each meeting two important papers of current interest are reviewed with half and hour allotted to each. The topics covered include areas of astronomy, physics and electronics and the speakers and audience include people from IIA and TIFR as well as RRI.

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 scientific and technical staff of the Institute given towards the end of this report.

Library

Four hundred and seventy six new books were added to the library during the year bringing the total book collection to 12,530. The library has been subscribing to 136 current scientific journals and has 15,364 bound volumes in its collection.

General

I. The following grants were sanctioned by the Department of Science and Technology during the year:

Recurring:	Non-Plan	Rs. 17.85 lakhs	
	Plan	Rs. 20.00 lakhs	
			Rs. 37.85 lakhs
Non-Recurring – Plan			Rs. 56.00 lakhs
			Rs. 93.85 lakhs

II. The Department of Science and Technology also sanctioned grants amounting to Rs. 6.25 lakhs and Rs. 1.15 lakhs for the NMR Studies of Diffusion Selectivity and Bangalore N.M.R. Facility, respectively.

III. In addition to the above, a sum of Rs. 3,94,000/- was received from the Electronics Commission for the project "Development of Multiplexed Liquid Crystal Display Systems".

IV. The Audited Statement of Accounts with the auditor's report is given in Annexure II **(Page 21).**

Awards

Dr. A. C. Kunwar was awarded the INSA Young Scientist Award during 1981 for his work on NMR.

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. G. Srinivasan
9. R. Shashidhar
10. G. S. Ranganath
11. A. C. Kunwar
12. V. Surendranath
13. R. Sivaramakrishnan*
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. A. Subramanya
32. T. Ramachandran
33. K. Smiles Mascarenhas
34. N. Udayashankar
35. U. N. Maiya
36. M. Selvamani
37. T. N. Ruckmongathan
38. P. A. Johnson
39. G. Sarabagopalan
40. B. V. Nataraja
41. R. Ganesan
42. H. Subramaniam
43. Antony Joseph
44. G. Rengarajan
45. A. Deshpande
46. Vijaya Gopala Ratnam*
47. K. Sukumaran*
48. S. Chanthrasekharan*
49. B. Sudhinder*
50. K. G. Girish
51. S. Chandrasekhar
52. P. G. Ananthasubramanyan*
53. R. Vijayalakshmi*
54. Elizebath Vincent
55. V. Lakshmy Narayan*
56. Mohamed Ateequlla
57. M. N. Ramanuja
58. B. R. Ratna
59. M. Vivekanand

Visiting Positions

1. S. Ramaseshan
2. G. S. R. Subba Rao
3. R. Srinivasan
4. S. Panchapakesan

Medical Consultant

A. R. Pai

Research Fellows

1. G. V. Vani
2. K. L. Savithramma
3. K. S. Dwarakanath
4. BRIJER
5. Sanjeev V. Dhurandhar
6. M. Subramanya Raj Urs
7. B. S. Srikanta
8. H. K. Jayaram*
9. S. Krishna Prasad*
10. R. Pratibha*

Resignations

1. S. Venugopalan
2. L. Susairaj

†on leave with Radio Physics Division, CSIRO, Australia.
‡on leave with University College, Cardiff, Wales, UK.

A list of short period visiting scientists is given below

1. Dr. V. B. Sheorey Physical Research Laboratory Ahmedabad	April 14–April 24, 1981
2. Dr. Paul J. Wiita University of Pennsylvania Philadelphia, U.S.A.	May 21–May 23, 1981 July 10–August 10, 1981
3. Dr. G. H. Pettengil Dept. of Earth & Planetary Sciences Massachusetts Institute of Technology Cambridge, U.S.A.	June 9–June 16, 1981
4. Dr. R. Cowsik Tata Institute of Fundamental Research Bombay	June 4–June 17, 1981
5. Samir Bhattacharya Louisiana State University Baton Rouge Campus, U.S.A.	June 20–July 14, 1981
6. Dr. J. L. Osborne University of Durham, U.K.	August 3–August 10, 1981
7. Dr. F. Rondelez Physique de la Matiere Condensee College de France, Paris	Dec. 12, 1981–Jan. 13, 1982
8. Prof. S. Chandrasekhar University of Chicago, U.S.A.	Feb. 22–Feb. 25, 1982
9. Mr. Srinivas Kulkarni Department of Astronomy University of California Berkeley, U.S.A.	March 15–March 22, 1982

Annexure I

Publications

1. The re-entrant phenomenon in 4'-*n*-octyloxy-4-cyanobiphenyl: High pressure X-ray study of the smecticA layer spacing (S. Chandrasekhar, R. Shashidhar and K. V. Rao)-Advances in Liquid Crystals Research and Applications, Ed. L. Bata, Academic Press (1981) p. 123.
2. Liquid Crystals of Disc-Like Molecules (S. Chandrasekhar)-invited lecture-Eighth International Liquid Crystals Conference, Kyoto, Japan, June 1980-Molecular Crystals and Liquid Crystals, **63**, 171 (1981).
3. The search for a Lifshitz point in a single-component liquid crystalline system: A high pressure study of 50.6 (R. Shashidhar, A. N. Kalkura and S. Chandrasekhar)-Molecular Crystals and Liquid Crystals Letters, **64**, 101 (1981).
4. A new class of thermotropic liquid crystalline materials (S. Chandrasekhar)-Dr. A. R. Verma's 60th Birthday Volume-Indian Journal of Pure and Applied Physics, **19**, 769 (1981).
5. New Liquid Crystalline States (S. Chandrasekhar)-Current Science, **50**, 47 (1981).
6. A new class of thermotropic liquid crystals: Discotic systems (S. Chandrasekhar and S. Kobayashi)-Butsuri (Physical Society of Japan)-in Japanese-**37**, 231 (1982).
7. The physics and chemistry of liquid crystal devices, Ed. G J. Sprokel, Plenum Press-Book Review (S. Chandrasekhar)-Acta Cryst., **A37**, 448 (1981).
8. Molecular flexibility and orientational statistics in liquid crystals: Raman study of 7CB and 8OCB (S. Venugopalan and S. N. Prasad)-Eighth International Liquid Crystal Conference, Kyoto, Japan, June 1980-Journal of Chemical Physics, **75**, 3033 (1981).
9. Scaled particle theory of the nematic phase of a system of particles having the shape of right circular cylinders (K. L. Savithramma and N. V. Madhusudana)-Eighth International Liquid Crystal Conference, Kyoto, Japan, June 1980-Molecular Crystals and Liquid Crystals, **74**, 243 (1981).
10. Experimental studies on the electrical conductivity of two re-entrant nematogens (B. R. Ratna, R. Shashidhar and K. V. Rao)-Eighth International Liquid Crystal Conference, Kyoto, Japan, June 1980-Molecular Crystals and Liquid Crystals, **74**, 1743 (1981).
11. Statistical theories of nematic liquid crystals (N. V. Madhusudana)-Invited lecture-Bulletin of Materials Science, **3**, 119 (1981).
12. New compounds with re-entrant nematic phases (M. Subramanya Raj Urs and B. K. Sadashiva)-Molecular Crystals and Liquid Crystals Letters, **72**, 227 (1982).
13. Effect of molecular ordering on the nematic-isotropic transition in re-entrant nematic mixtures: A high pressure DTA and optical study (R. Shashidhar, H. D. Kleinhans and G. M. Schneider)-Molecular Crystals and Liquid Crystals Letters, **72**, 119 (1981).
14. Observation of a smecticA-smecticA transition at high pressures: Optical microscopy and DTA studies on 60PDOB (R. Shashidhar, J. Herrmann and H. D. Kleinhans)-Molecular Crystals and Liquid Crystals Letters, **72**, 177 (1982).

15. Piezothermal studies on 8OCB (R. Shashidhar, L. Ter Minassian, B. R. Ratna and A. N. Kalkura)–Journal de Physique Letters, **43**, L-239 (1982).
16. Study of phase transitions in liquid crystals under pressure using the diamond anvil cell (R. Shashidhar)–Invited lecture–International Symposium on Physics of Solids under High Pressure, Ban Honnef, West Germany, August 1981–Proceedings of the Symposium, Eds. J. Schilling and R. Shelton, North Holland, p. 109.
17. Pretransitional effects in the electrical conductivity of re-entrant nematic mixtures (M. Bock, G. Gobl-Wunsch, G. Heppke, B. R. Ratna and R. Shashidhar)–Molecular Crystals and Liquid Crystals Letters, **72**, 277 (1982).
18. Proton NMR spectra including ^{13}C- and ^{77}Se-satellites in organoselenium compounds in the nematic phase. Part I. The spectrum of 2,1,3-benzoselenadiazole (C. L. Khetrapal and A. C. Kunwar), J. Molecular Structure, **74**, 343 (1981).
19. A ^{13}C-NMR study of non-planar distortions in amides (C. L. Khetrapal and A. C. Kunwar)–Journal of Biochem. Biophys. Methods, **4**, 185 (1981).
20. An NMR study of the structure of and the internal rotation in phenyl silane (C. L. Khetrapal and E. D. Becker)–J. Mag. Res., **43**, 8 (1981).
21. PMR study of partially oriented 1-phenyl propyne (C. L. Khetrapal and R. Highet)–Org. Mag. Res., **16**, 117 (1981).
22. Application of NMR of oriented systems in biochemistry and biophysics (C. L. Khetrapal)–Int. J. Quantum Chem., **20**, 485 (1981).
23. Average orientation of molecules dissolved in nematic liquid crystals of opposite diamagnetic anisotropies (C. L. Khetrapal and A. C. Kunwar)–Mol. Cryst. Liquid Cryst., **72**, 13 (1981).
24. Determination of chemical shift anisotropy without a reference and of direct and indirect spin-spin couplings between heteronuclei (C. L. Khetrapal and A. C. Kunwar)–Chem. Phys. Lett., **82**, 70 (1981).
25. Molecular structure and the indirect spin-spin coupling constants in azulene–A proton NMR study in the nematic phase (S. Arumugam, A. C. Kunwar and C. L. Khetrapal)–Organic Magnetic Resonance, **17**, 257 (1981).
26. NMR Spectroscopy of oriented molecules and its application to inorganic chemistry (C. L. Khetrapal)–J. Ind. Chem. Soc., **59**, 164 (1982).
27. NMR Spectroscopy of oriented molecules–New developments (A. C. Kunwar)–Science Academy Medal for Young Scientists Lectures, 1981, p. 15, Indian National Science Academy, New Delhi.
28. Anomalous motions of HI clouds (V. Radhakrishnan, K. R. Anantharamaiah, P. A. Shaver, D. S. Retallack, W. Wamsteker and A. C. Danks), Astronomy and Astrophysics, **106**, 105 (1982).
29. The Structure of the Cygnus loop at 34.5 MHz (Ch. V. Sastry, K. S. Dwarakanath and R. K. Shevgaonker), J. Astrophysics and Astronomy, **2**, 339–347 (1981).
30. Water Vapour Content over two Indian sites tested for millimeterwave radio observatory (U. N. Maiya and Patrick Dierich), Proc. Indian Acad. Sciences (Earth and Planetary Sciences), **90**, 281 (1981).
31. A Phase-locked Gunn Oscillator at 21 GHz (R. S. Arora and N. V. G. Sarma), J. Inst. Electronics and Telecommunication Eng., **28**, 22 (1982).
32. Neutrinos in Gravitational Collapse I: Analysis of trajectories (S. V. Dhurandhar and C. V. Vishveshwara), Astrophysical J., **245**, 1094 (1981).

33. Causality conditions and the length of nonspacelike curves (S. V. Dhurandhar and P. Joshi), J. Gen. Relativity and Gravitation, **13**, 913 (1981).
34. A lower bound for the birth rate of pulsars (R. Narayan and M. Vivekanand), Nature, **290**, 571, (1981).
35. A new look at Pulsar statistics–birth rate and evidence for injection (M. Vivekanand and R. Narayan), J. Astrophysics and Astronomy, **2**, 315 (1981).
36. Optimum choice of wavelengths in the anomalous scattering technique with synchrotron radiation (R. Narayan and S. Ramaseshan), Acta Cryst., **A37**, 636 (1981).
37. The stability of ionic structures (R. Narayan), Procd. Nuclear Physics and Solid State Physics Symposium, Invited talks volume.
38. The maximum determinant method and the maximum entropy method (R. Narayan and R. Nityananda), Acta Cryst., **A38**, 122 (1982).
39. Multiwavelength method with synchrotron radiation (S. Ramaseshan and R. Narayan), Commemmoration volume for the 70th birthday of Acad. B. K. Vainshtein, U.S.S.R. Acad. of Sciences.
40. Semiquantitative theory of the structure of simple ionic liquid crystals (R. Narayan), Pramana, **17**, 13 (1981).
41. The application of CLEAN to crystallographic problems (R. Narayan), Pramana, **17**, 327 (1981).
42. Some constraints on the evolutionary history of the binary pulsar PSR 1913 + 16 (G. Srinivasan and E. P. J. van den Heuvel), Astronomy and Astrophysics, **108**, 143 (1982).
43. The pulsar magnetic window (C. S. Shukre and V. Radhakrishnan) in Pulsars, Proceedings of the IAU Symposium No. 95, Eds. R. Wielebinski and W. Sieber, Dordrecht, Reidel (1981).
44. Pulsar activity and supernova remnant morphology (V. Radhakrishnan and G. Srinivasan) in Pulsars, Proceedings of the IAU Symposium No. 95, Eds. R. Wielebinski and W. Sieber, Dordrecht, Reidel (1981).
45. Polar cap relief and integrated pulse structure (M. Vivekanand and V. Radhakrishnan) in Pulsars, Proceedings of the IAU Symposium No. 95, Eds. R. Wielebinski and W. Sieber, Dordrecht, Reidel (1981).
46. Concluding Review (V. Radhakrishnan) in Pulsars, Proceedings of the IAU Symposium No. 95, Eds. R. Wielebinski and W. Sieber, Dordrecht, Reidel (1981).
47. Improved precision solar and sidereal clock (N. Udaya Shankar and M. Selvamani) Journal of the Institution of Electronics and Telecommunication Engineers, **27**, 514 (1981).
48. On the correlation between exciter duration and decay constant of solar decameter type III radio bursts (K. R. Subramanyan, V. Krishan and Ch. V. Sastry), Solar Physics, **70**, 375 (1981).
49. Observations and interpretation of the slowly varying component of solar radio emission at decameter wavelengths (Ch. V. Sastry, K. S. Dwarakanth, R. K. Shevgaonkar and V. Krishan), Solar Physics, **73**, 363 (1981).
50. Pulsating radio emission at decameter wavelengths from the Sun (Ch. V. Sastry, V. Krishan and K. R. Subramanyan), Journal of Astrophysics and Astronomy, **2**, 59 (1981).

Papers in Press

1. Liquid Crystals of disc-like molecules (S. Chandrasekhar)–Review article–Advances in Liquid Crystals (Academic Press).
2. Molecular interactions and dynamics in liquid crystals (S. Chandrasekhar and N. V. Madhusudana)–Review article–Molecular Interactions, Vol. 4, Ed. W. J. Orville–Thomas (Wiley).
3. Instabilities in low molecular weight nematic and cholesteric liquid crystals (S. Chandrasekhar and U. D. Kini)–Review article–International Seminar on Polymer Liquid Crystals, Santa Margherita Ligure, Italy, May 1981 (Academic Press).
4. 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, April–June, 1980 (Plenum Press).
5. Twist disclinations in elastically anisotropic nematic liquid crystals (G. S. Ranganath)–Molecular Crystals and Liquid Crystals.
6. Some unusual properties of 4-*n*-decylphenyl-4'-methyl-4'-(4''-nitrobenzoyloxy) benzoate (N. V. Madhusudana, B. S. Srikanta and M. Subramanya Raj Urs)–Molecular Crystals and Liquid Crystals Letters.
7. Extension of McMillan's model to liquid crystals of disc-like molecules (S. Chandrasekhar, K. L. Savithramma and N. V. Madhusudana)–Invited lecture–Fourth International Symposium on Liquid Crystals and Ordered Fluids, Las Vegas, USA, March 28–April 2, 1982 (to be published in Proceedings).
8. High pressure studies on polymorphic liquid crystals (A. N. Kalkura, R. Shashidhar, G. Venkatesh, D. Demus and W. Weissflog)–Molecular Crystals and Liquid Crystals.
9. High pressure studies on liquid crystals (R. Shashidhar)–invited lecture–8th AIRAPT and 19th EHPRG Conference, Uppsala, Sweden, August 1981–in 'High Pressure in Research and Industry', Eds. C. M. Beckman, T. Johannisson and L. Tegner.
10. High pressure and thermodynamic studies on re-entrant nematogens (R. Shashidhar)–invited paper–Bunsen Kolloquium Strukturen und Phasenumwandlungen thermotroper flussigekristalle, Paderborn, West Germany, September 1981.
11. Influence of ordering on the pressure behaviour of the nematic–isotropic transition (H. D. Kleinhans, R. Shashidhar and G. M. Schneider)–Molecular Crystals and liquid Crystals Letters.
12. Polarization microscopy and differential calorimetric studies on liquid crystals at high pressure (J. Herrmann, H. D. Kleinhans, G. M. Schneider and R. Shashidhar)–Bunsentangjung Meeting, Ulm, West Germany.
13. Effects of Magnetic and Boundary conditions on homogenous instabilities of shear flow of nematics (U. D. Kini)–Molecular Crystals and Liquid Crystals.
14. Two-dimensional films of discotic molecules at an air-water interface (F. Rondelez, D. Koppel and B. K. Sadashiva), J. de Physique Letters.
15. Scaled particles of a system of right circular cylinders subjected to an attractive potential (K. L. Savithramma and N. V. Madhusudana)–Molecular Crystals and Liquid Crystals.

16. NMR spectrum of benzo(b)furan in a nematic phase (S. Arumugam, A. C. Kunwar and C. L. Khetrapal)–Organic Magnetic Resonance.
17. NMR–Oriented Molecules (C. L. Khetrapal and A. C. Kunwar), Specialist Periodical Reports, Vol. 11, The Royal Society of Chemistry, London.
18. NMR spectrum of pyridine-N-oxide in a nematic phase (N. Surya Prakash, S. Arumugam, A. C. Kunwar and C. L. Khetrapal)–J. Mag. Res.
19. NMR studies of molecules oriented in mixed thermotropic liquid crystals of opposite diamagnetic anisotropies (C. L. Khetrapal, A. C. Kunwar and M. R. Lakshminarayana)–Proc. IV International Conference on Liquid Crystals and Ordered Fluids, Las Vegas, USA (1982).
20. A new look at the birth rate of Supernova remnants (G. Srinivasan and K. S. Dwarakanath), J. Astrophysics and Astronomy.
21. Are many pulsars processed in binaries? (V. Radhakrishnan and G. Srinivasan), Procd. of the Second Asian–Pacific Regional Meeting of the IAU held at Bandung, August 1981.
22. Gibb's paradox–a possible resolution (Rajendra Bhandari), American J. Physics.
23. Neutrinos in Kerr and Robertson Walker geometries (S. V. Dhurandhar, C. V. Vishveshwara and J. M. Cohen), J. of Physics, 'A'.
24. Neutrinos in spacetimes with local rotational symmetry (S. V. Dhurandhar, C. V. Vishveshwara and J. M. Cohen), Physical Review 'D'.
25. Neutrinos in gravitational Collapse: The Dirac formalism (B. R. Iyer, S. V. Dhurandhar and C. V. Vishveshwara), Physical Review 'D'.
26. The structure of the ammonium halides (G. Raghurama and R. Narayan), J. Physics and Chem. of Solids.
27. Luminosity limits for funnels in thick accretion discs (R. Nityananda and R. Narayan), Monthly Notices of Royal Astronomical Society.
28. Maximum luminosity of an accretion disc around a black hole (R. Narayan and R. Nityananda), Invited talk volume of the Meeting of the Astronomical Society of India held at Roorkee, November/December 1981.
29. On selection effects in pulsar searches (M. Vivekanand, R. Narayan and V. Radhakrishnan), J. Astrophysics and Astronomy.
30. Dirac field theory in rotating coordinates (B. R. Iyer), Physical Review 'D'.
31. Observations of the supernova remnants HB9 and IC443 at 34.5 MHz (K. S. Dwarakanath, R. K. Shevgaonkar and Ch. V. Sastry), Journal of Astrophysics and Astronomy.
32. Time structure of solar decameter Type III radio bursts (G. Thejappa and Ch. V. Sastry), Journal of Astrophysics and Astronomy.
33. Absorption bursts in the radio emission from the Sun at decameter wavelengths (Ch. V. Sastry, K. R. Subramanian and V. Krishan), Astrophysical Letters.
34. The diffuse gamma-ray background and the pulsar magnetic window (V. Radhakrishnan and C. S. Shukre), Astrophysical Journal.
35. On the nature of Pulsars (V. Radhakrishnan), Contemporary Physics.
36. On the statistics of galactic HI clouds (V. Radhakrishnan, K. R. Anantharamaiah and P. A. Shaver) in the Proceedings of the Second Asian–Pacific Regional Meeting of the IAU held in Bandung, Indonesia, August 24–29, 1982.
37. Magnetic fields around compact objects (V. Radhakrishnan) in a special volume containing all the invited papers presented at the National Space Science Symposium, Bangalore, February 1982.