RAMAN RESEARCH INSTITUTE

BANGALORE

ANNUAL REPORT – 1980-81

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.

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 chemists have synthesised a few hundred new liquid crystalline compounds. 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. A 270 MHz high resolution NMR Facility has been set up in cooperation with other sister institutions and is being used for studies on pure liquid crystals and for investigating structures of molecules dissolved in liquid crystalline solvents. Further, several theoretical lines of research including statistical theories, structure 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. Several 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.

Radio Astronomy

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 "visible light" wavelength part (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 radition received by radio telescopes on earth is in the radio wavelength part (30 meters to 1 millimeter) of the same electromagnetic spectrum. The lower and upper limits in wavelengths of the radio spectrum are set by the earth's atmosphere and ionosphere respectively. In spite of these limitations, the radio window is quite wide (30,000 to 1 compared to 2 : 1 wavelength ratio in the visible part) and studies within it have yielded valuable information leading to some exciting discoveries such as the 3^0 K cosmic background radiation, Quasars, Pulsars etc.

Clues to the mechanism of emission of these radiations are obtained by studying the strength of the received radiation at different wavelengths. For example, at meter wavelengths the radiation is emitted mainly by a non-thermal process, whereas at centimeter and visible wavelengths a thermal process of generation of radiation predominates. An excellent example of such a thermal source is our own SUN which is so strong in visible light because it is so hot (6000_o K). The above mentioned processes give rise to broadband emission whose strength either increases or decreases with increasing wavelength. There is a third type of radiation called line radiation which is emitted spontaneously by atoms or molecules in excited states. The strength of such radiations is concentrated in a narrow band of wavelength. The study of such line radiation gives clues to the existence and distribution of various atoms and molecules. An excellent example is the hydrogen line

radiation occuring at a wavelength of 21 centimeters. The study of the intensity and the wavelength of the peak of this radiation has shown, for the first time,the large scale structure of our own Galaxy because hydrogen is the major constituent of the matter that forms the Galaxy.

Decameter wave Radio Astronomy

The Raman Research Institute is also engaged in work in Radio Astronomy at much longer wavelengths. The Institute has set up a Decameter Wave Radio Telescope at Gauribidanur. 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. The lengths of these arrays are 1.5 KM and 0.5 KM. Operating at a wavelength of ten metres, 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 and the planet Jupiter emit intense radio bursts very frequently. Observations of the characteristics of these radio bursts at various wavelengths will give valuable information on the structure of the solar corona and the outer atmosphere of Jupiter. In the case of our galaxy one of the most interesting topics is the determination of the spiral structure. The birth places of stars, the so-called ionized hydrogen regions are the best tracers of spiral structure. The Decameter Wave radio telescope is a very sensitive instrument for detection of ionized hydrogen regions and hence is being used to study the structure of our galaxy.

Millimeter wave Radio Astronomy

During the past decade, millimeterwave astronomy has assumed great importance because of the discovery of several molecules (combination of Hydrogen, Carbon, Nitrogen and Oxygen) 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, these studies should lead to the understanding of the nature and mechanism of star formation.

The Raman Research Institute is currently engaged in constructing a millimeter wave telescope to do advanced research in millimeterwave astronomy. The wavelength of operation will be between 8 mm and 1 mm. This puts a stringent requirement on the accuracy of the surface of the reflector which forms a major part of the radio telescope. The diameter of the radio telescope is 10.4 meters and we hope to achieve a surface accuracy of about one-twentieth part of the minimum wavelength of operation. We have also undertaken to build very sensitive receivers to operate in this wavelength band. This whole effort is also leading to the generation of technological know-how which has not been available in India hitherto.

Theoretical Physics and Astrophysics

The research programme that is being carried out by the theoretical physics group involves to a large extent problems in theoretical astrophysics and the general theory of relativity. As is well known, phenomenal progress has been made in the field of astronomy in recent years. 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. The latter could end up as a neutron star. Pulsars, that are observed to send out radiation in regular pulses as their name suggests, have been identified as neutron stars. The theoretical physics group is engaged in elucidating the various aspects of these phenomena, such as the mechanism and occurence of supernovae, the birth rate of pulsars and 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 our group. For example, some interesting properties of black holes, and the behaviour of neutrinos in the presence of strong gravitational fields have been and continue to be investigated.

In addition to the problems with emphasis on astrophysics, research is also being carried out in the fields of atomic physics and crystallography.

A some what 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

High Pressure Studies

Of late there has been considerable interest in a multicritical point of a new type which has been named the Lifshitz point. In liquid crystalline systems the Lifshitz point would correspond to the intersection of the smectic C-smectic A and smectic A-nematic and smectic C-nematic transition lines in a phase diagram. Such an intersection was reported very recently in the composition-temperature phase diagrams of certain mixtures, but it is evidently of the greatest importance to establish this intersection in a single component system. A systematic search was undertaken in this laboratory during the last year to locate a Lifshitz point in a pure compound. High pressure studies were carried out on a large number of compounds, and evidence has been obtained for the first time of a possible Lifshitz point in a single component system. Further studies are underway.

The facilities in the high pressure laboratory have been extended to conduct optical studies on liquid crystals. Two new high pressure optical cells have been designed. One of these can be incorporated in the piston cylinder device of the 200 Ton hydraulic press - designed and fabricated earlier-wherein the pressure is transmitted normally to the sample by a solid medium. In the other cell, the pressure is transmitted radially to the sample using a hydrostatic fluid through fluron tubing. In both the cases the sample is sandwiched between two sapphire rods in a aluminium gasket. The cells can be used to conduct a variety of experiments, e.g., optical studies, light scattering and infrared absorption as functions of pressure.

Studies on Induced Smectic Phase

The term 'induced smectic mesomorphism' is used to describe the occurrence of a smectic A phase in a binary mixture, even though each component by itself does not exhibit the smectic A phase. When two nematogenic compounds, only one of which has the strongly polar cyano end group, are mixed together, the mixtures show the 'induced smectic' phase (A_1). Several such mixtures have been studied here to elucidate the nature of this phase. X-ray studies have helped in proposing a physical mechanism for the formation of this phase. In the highly polar cyano-compound, neighbouring molecules have antiparallel correlations (as was proposed by us some years ago) which lead to a 'bilayer' smectic with a layer spacing of about 1.4 times the molecular length. In the mixtures exhibiting the A_1 phase, the spacing is 'monolayer' for compositions relatively rich in the weakly polar component. As the concentration of the cyano-component is increased, the layer spacing increases and finally reaches the bilayer value for the pure cyano component. Mutual interactions between the polar and non-polar compounds both due to the polarization of the medium and due to the formation of change transfer complexes favour the formation of layers, reaching to the A_1 phase. The elastic constant data on such systems show some very interesting features : k_{33}/k_{11}, the ratio of the bend to splay elastic constants, attains very low values (about 0.6) for compositions rich in the weakly polar component. This result, which can be related with the x-ray layer spacings, is the first observation of such a lowering of k_{33}/k_{11} in mixtures.

Nematic Instabilities

Theoretical investigations of instabilities in liquid crystals are being continued. A study has been made of the effects of a magnetic field on director orientation in a nematic cell with the director reversely tilted at the boundaries. Depending upon the tilt angle at the boundaries, a splay-dominant (S) or a bend-dominant (B) director orientation can be achieved in the sample. It is shown that starting with S (or B), a transition can be effected to B (or S) by applying a magnetic field of sufficient strength. The variation of field thre-

shold with the boundary tilt of the director (antisymmetric and asymmetric) and with the direction of the field has been investigated. Homogeneous instability thresholds in shear flow and plane Poiseuille flow of nematics for perturbations imposed in and out of the plane of shear have been studied as functions of shear rate, boundary orientation, and the strength and direction of a magnetic field. Interestingly, in the case of plane Poiseuille flow the threshold is found to depend on the order in which shear and magnetic field are imposed for reversely tilted director anchoring at the boundaries. In both flows qualitative differences can be made out between a nematic which has the flow aligning property and another which does not.

Statistical Theory of of the Nematic Phase

The development of a suitable molecular statistical theory of the nematic phase has continued to attract considerable attention in many laboratories. We have recently made some significant progress in this field by applying the Andrews method to study the problem. Andrews recently proposed a model to calculate the equation of state of a system of spheres. We have extended it to a system of spherocylinders and used the theory to calculate several thermodynamic properties of the nematic phase. The results are in much better agreement with the experimental data on a typical nematic substance like p-azoxyanisole than the results of the best available theory, viz., the scaled particle theory.

Applications

The Electronics Commission has cleared the transfer of the know how developed in the laboratory for the preparation of liquid crystalline materials for displays, and Dadha Pharma Private Ltd., Madras, have taken up the production of these LC materials.

NMR Work

a) A hypothesis governing the preferred conformations of molecules in terms of polarizations of the bonds has been given and experimentally verified. The preferred conformations of various molecules such as phenyl silane, phenyl propyne and a variety of other organic compounds have thus been determined. The hypothesis is quite general and is extremely useful in predicting the preferred conformations.

b) The use of NMR spectroscopy of oriented molecules to biologically and chemically important systems such as dimethyl uracil, N-methyl imidazole and phenazine has been demonstrated and the preferred conformations of the molecules determined. The results are supported by theoretical energy calculations. The limitations and uses of the method to more complicated systems have been critically examined.

c) Average orientation of molecules dissolved in mixtures of nematic liquid crystals with opposite diamagnetic anisotropies has been investigated. At a critical concentration and temperature of the two solvents, the existence of two orientations of the dissolved molecules has been observed. At this critical point the dipolar couplings between two interacting nuclei are in the exact ratio of 1:-2. The experiments give a unique method to change the dipolar couplings to twice with opposite sign. A new method for the precise determination of chemical shift anisotropy has thus been suggested. In addition, the determination of the indirect and the direct coupling constants between heteronuclei which was up till now not possible from the NMR spectra of oriented molecules, has been made possible from such experiments. The results have been theoretically understood, and have proved to be very valuable from the chemical point of view.

Theoretical Physics and Astrophysics

1. Atomic Physics

A part of the work which was continuing on extrapolation properties of quantum defects and phase shifts of electron ion system with respect to angular momentum has been completed. The tangent of the zero energy phase shift has been expressed as a ratio of two entire functions of angular momentum for electron scattering by Coulomb plus short range potentials. This facilitates calculation of corresponding phase shifts.

2. Structures of Simple Ionic Crystals

By means of a semi-quantitative theory, it has been shown that the CsCl, NaCl and ZnS structures occur in well-defined regions of the (r_+/r_-)-(c_{+-} / r_0^5) plane. There is good agreement with experiment. Among AB_2 crystals, the CaF_2, $PbCl_2$, SnO_2 and CdI_2 structures are well demarcated in the (r_+/r_-) — $(a_+ + a_-)$ plane.

3. Thermal Effects in Ionic Crystals

A simple theory of thermal effects in ionic crystals was developed. The intuitive picture of uncorrelated vibrations used in this theory gave a surprisingly accurate account of thermal expansion in these solids. A more formal approach based on the variational principle of statistical mechanics made it possible to rederive the theory, understand the reasons for its success, and include the effect of correlated vibrations. An interesting by-product is that the ratio of repulsion energy to electrostatic energy is the small parameter in this theory.

4. Choice of Wavelengths in the Multiwavelength Method

The anomalous scattering multiwavelength method of crystallography is a powerful experimental technique. Theories have been developed to assist in the optimum choice of wavelengths in the following two problems:

a) Protein crystallography
b) Structures of binary liquids.

5. New techniques of Image Reconstruction in Crystallography

a) The Maximum Entropy Method (MEM) has been applied to the phase problem of crystallography leading to new phase relations. Successful simulations with model one-dimensional structures suggest that MEM could be used to solve crystal structures from random initial phases. MEM has been shown to be closely related to the Maximum Determinant Method of Crystallography.

b) It is suggested that the technique called CLEAN can be used to improve sharpened Patterson maps and E-maps in crystallography. Trial calculations have been encouraging.

6. Study of Maximum Entrophy Image Restoration

A convenient algorithm capable of extrapolating the Fourier transform of the brightness distribution consistent with the "maximum entropy" criterion was developed. Its advantages are speed, suitability to any form of entropy function and to two (or more) dimensional distributions. An important analytical result is that the noise in the data should not be treated by the method of least squares as is often done. This leads to unphysical residuals which do not have a random distribution.

7. Pulsar Birth Rate

Using the novel concept of pulsar current in the PP diagram, a lower bound for the birth rate of pulsars in the galaxy has been estimated to be one pulsar every 18^{+15}_{-6} years. The important features of the present study are: a) No model of pulsar evolution is assumed; b) Luminosity selection effects have been included for the first time and are found to be very significant.

8. Frequency of Supernova in our Galaxy

The birth rate of Pulsars (neutron stars) is estimated to be once in 10-25 years, whereas the frequency of Supernova estimated from the statistics of Supernova Remnants (SNR) is once every 80-120 years. To reconcile this discrepancy a thorough reanalysis of the data on SNRs was undertaken. Using a new method for determining the ages of SNRs, we have arrived at a birth rate of 1 every 25 years for SNRs, thus making it consistent with the pulsar birth rate. The implications of this for the standard evolutionary picture of SNRs is presently being investigated.

9. Pulsar Magnetic fields

The previous work on pulsar magnetic fields based on the hypothesis that spark discharges in the Ruderman-Sutherland model are triggered by diffuse background gamma rays was extended to include the effect of gravitational

blue shifts on the gamma photons. This inclusion complicates the analysis considerably. Also the effect of this blue shift is not negligible as one would have expected in the beginning. However, it was shown that the position of the pulsar magnetic window is not affected substantially by it.

The relative importance of the above and another mechanism proposed recently by Cheng and Ruderman for triggering the above spark discharges involving ion emission from the pulsar surface was investigated. The ion emission mechanism is extremely sensitive to the neutron star temperature. It can dominate over the other if temperature is above about 2×10^6 K. The neutron star temperatures are, however, not known yet.

10. Effect of back Reaction on Black hole Evaporation

Recently, it was suggested that Hawking's description of black hole evaporation suffers from an internal inconsistency. This claimed inconsistency was found to be due to the wrong choice of initial conditions in the differential equation governing the evolution of the event horizon. It was possible to show that this equation possesses stable solutions which conform to the Hawking description.

11. Neutrinos in Gravitational Collapse : The null geodesic Formalism

The classical trajectories (null geodesics) of neutrinos were studied in the interior geometry of the collapsing Friedmann model with zero pressure matched onto the Schwarzchild exterior. Based on the computation made earlier, the nature of the flux profile was investigated for neutrinos emitted from an interior shell in a very short interval. The flux profile as seen by a remote observer exhibits interesting features. Depending on the progress of the collapse, one observes pulses, bursts and decays. Thus the escaping neutrinos may carry a characteristic signature of the collapse process.

12. Neutrinos in Gravitational Collapse : The Dirac Formalism

The principal general relativistic effects on the neutrinos in a collapse scenario are being investigated by studying the Dirac equation in a background space time consisting of a Friedmann interior matched to a Schwarzschild exterior. These studies are meant to set up the relevant formalism and complement the studies that use the null geodesic approximation.

13. Neutrinos in Perfect Fluid Space times with Local Rotational Symmetry

The above mentioned spacetimes are algebraically special (Petrov D) and lend themselves to the Hertz potential formalism which yields a decoupled equation for a single scalar characterizing the neutrino field. The solutions may be obtained in the generic form and specialised to particular spacetimes of interest which belong to this category. Investigations in this direction are in progress.

14. Dirac Field Theory in Rotating Coordinates

The initial formalism to set up an alternative quantization scheme for the Dirac field in rotating coordinates has been studied. The resultant quantization scheme will be compared with canonical quantization in Minkowskian coordinates as also quantization in uniformly accelerated coordinates (Rindler space) and contrasted with the results for the scalar field.

Radio Astronomy and Associated Electronics

Decameter Wave Radio Astronomy at Gauribidanur - a joint project of RRI and IIA

The Radio Telescope set up at Gauribidanur is in the form of a 'T'. It operates in the frequency range 25-35 MHz. It is a transit array and the beam can be switched to eight zenith angles on the meridian successively. The switching time from one angle to another is of the order of 100 milliseconds. The output of the telescope for all zenith angles is available in both analog and digital forms.

A 16 channel multi frequency receiver working in the band 34.5 to 35.5 MHz is being operated in conjunction with NS array of the Decameter wave telescope for very high time and frequency resolution observations of the radio emissions from the Sun and Jupiter. The time and frequency resolutions are 10 milliseconds and 50 MHz respectively.

Observations

Galaxy :

We have completed mapping of three extended supernova remnants. Cygnus loop, IC 443, HB 9 and radio maps at 34 MHz have been prepared. A comparative study of these maps with those obtained at high frequencies is being made and is expected to give important information on the structure and spectra of these sources.

H II Regions :

The observations on several galactic thermal sources like W40, W51 etc., are complete and radio maps of these regions are being made.

Small diameter sources :

Interplanetary scintillation observations on several such sources are being made on a synoptic basis for the study of both the structure of the sources and the interplanetary medium.

Sun :

The two dimensional brightness distribution across the sun of the slowly varying component is obtained whenever the sun is quiet. The 16 channel

receiver is being used to obtain high time and frequency resolution structure of the radio bursts from the sun when the sun is active.

Digital Receiver Development :

The design of the front end for the F.T. machine for the Gauribidanur Telescope was finalised. An eight channel prototype of the front end is under progress. In the present design the R. F. signal at 34 MHz is down converted to an I.F. at 4 MHz, the quadrature samples required for correlation being obtained from this I. F.

Metrewave Astronomy

Spectral line observations with the Ooty Radio Telescope are being continued.

The 64 channel autocorrelation spectral line receiver has been expanded to 128 channels. Computer programs for data acquisition and analysis have been modified to accommodate the additional channels. The expanded auto-correlator now provides the higher spectral resolution needed to study narrow spectral lines (like carbon recombination lines). The additional channels also provide more data points on the observed spectrum which helps in fixing the zero level of the spectrum accurately which in turn is essential for accurate determination of line parameters.

Systematic observations of Hydrogen and Carbon recombination lines, H 272α and C 272α in the direction of well known H II regions in the galactic plane, is in progress. Hydrogen recombination lines have been detected in the direction of several sources like Sgr A, W 49, W 43, 3C391, M8, M16, W 35, W 29, W 31 etc. It may be mentioned that this is the lowest frequency at which spectral lines have been observed for several of these sources. Analysis and interpretation of the spectra in terms of physical conditions in the line emitting regions is in progress.

Millimeterwave Telescope Project

The progress of the millimeterwave telescope project is satisfactory. It could have been better but for some problems encountered during the setting up of the precision mount. During the detailed testing of the mount it was found that the gear boxes were noisy. They had to be taken apart, repaired and reassembled. Detailed testing of the mount was carried out in Bombay during the end of 1980, and is at present undergoing further tests with the drive system at the National Aeronautical Laboratory, Bangalore.

The reflector of the telescope consists of a back-up structure and about 84 honey comb panels mounted on the back-up structure. These sandwiched panels are of two layered construction and have been assembled now. This involved expansion of the honeycomb 'hobe' blocks (which were imported) to the proper size, and epoxy bonding of two layers and the bottom skins

with front surface exposed for machining. The panels are hexagonal in shape with average dimension of about 1.2 m between parallel sides. Precision machining of the top surface of the mounted panels will be taken up after setting the reference guide rail to an accuracy of about 20 microns.

Millimeterwave front-end receiver development has progressed very well and the diode laboratory is fully equipped now to under take whisker contacting of 2 micron diodes on Ga As substrate. Several Sharpless wafers were produced using old practice Ga As diode chips and these have been mounted in mixer blocks for use as harmonic mixers at around 115 GHz. They exhibit a conversion loss of 45 dB for a harmonic number of 13. This result compares very favourably with the commercially available harmonic mixers. Block type mixers for the 80-120 GHz band have also been designed and fabricated. These mixers use better quality Ga AS diode chips and have been tested as fundamental mixers giving a single side band (SSB) conversion loss of 7.5 dB and a mixer noise temperature (SSB) of 2500 K. The performance deteriorates at the upper end of the band. The transformer design of the mixer block has been modified to improve the performance at the higher frequencies. This type of mixer block is undergoing tests at present.

A phase locked Gunn oscillator operating at a frequency at 21 GHz was developed which may be used as a solid state replacement source for the conventional klystron tube source. The oscillator gives an output power of 60 mw and has a bias tuning range of 40 MHz. Development of a Gunn Oscillator operating at 86 GHZ is under progress. The oscillator mount has been designed and fabricated.

Development of low noise I.F. amplifiers at 1.4 GHZ and 2.0 GHz using Ga As FETs is progressing well. Using Mitsubishi Ga As FET type MGF 1412 we were able to achieve at room temperatures a noise temperature of 100 K. The same amplifier when cooled to 30 K gives an input noise temperature of about 40K. The cryogenic cooling of the amplifier was done in a closed cycle Helium refrigerator system.

Back-end receiver development and construction has been completed. A 128-channel filter bank receiver with 50 KHz resolution and 50 KHz channel separation has been constructed and tested. In addition, a 64 channel filter-bank receiver with 1 MHz resolution and 1 MHz channel separation has also been designed and construction work is in progress. This receiver will be mostly used for the detection of new molecular spectral lines and for the study of atmospheric ozone content and its distribution

Monitoring of atmospheric water vapour content was continued at the Institute campus using the 22 GHZ water vapour radiometer and the Infra Red Spectral Hygrometer. A detailed analysis of the meteorological data and the water vapour data collected at both the sites, namely, RRI campus and the Nandi hills site for the past three years was completed. This analysis

has clearly indicated the desirability of establishing the millimeterwave telescope on top of Nandi hills. It has further revealed some very interesting facts about the distribution and variability of the water vapour content in the atmosphere over tropical areas.

1.5 Metre pilot mm-wave project

Surface measurements on the 1.5 m diameter dish made out of fibre glass HP laser measurements system have been completed. These measurements were fitted to a best-fit paraboloid to yield the errors. Based on these errors, the surface was hand-scraped and the measurements were repeated. The successive surface-scraping and measurements improved the surface accuracy from 107 microns (r.m.s.) to an accuracy of 40 microns (r.m s.). It is planned to explore the possibility of improving the surface accuracy of the paraboloid even further by a combination of selective metal deposition and laser measurements of the surface profile. The mount which takes this reflector is also under fabrication. The telescope will be housed inside an already existing dome. Drive for the dome to move it in unision with the azimuth motion of the telescope is also completed. This telescope will be initially used for atmospheric studies and for testing of feeds and millimeter wave receivers.

13. M Telescope Control :

Anti-blacklash Gear System

An electromechanical tension system using two d.c. servo motors was developed. The two servo motors drive the gear system in opposite directions to eliminate the inevitable backlash in the gear/pinion of the drive mechanism. This was tested on the elevation axis for its performance and found satisfactory.

Encoder Interfacing with PDP II/34 A Computer

To simulate real-time tracking on the telescope and to test the 21 bit encoder, a set up was made comprising a stepper motor driver and necessary circuits to interface with the PDP 11/34 through the general purpose interface DRIIC. The tests were generally satisfactory and the detailed results have been stored on magnetic tape.

Multiplexer

As the computer will be situated about 60 meters from the encoder, drive motors, etc., which are on the telescope mount, the analog and digital information has to be transmitted over this distance. There are other signals also to be transmitted between the two centres. As no commercial ready made system is available for this purpose, a 16-bit, 10 port multiplexer was designed and constructed. Each digital bit employs a suitable line driver/ receiver arrangement. This unit is under test.

Control Console

In the early stages of installation, the telescope will need to be operated manually. It is also preferable to have the controls near the telescope mount. The actual controls should also be available at the central computer cabin. For this purpose, suitable control consoles for both locations have been designed. Fabrication of the units will commence shortly. The design can accommodate any reasonable additional control functions and interlocks.

Electronics

A new project on a 256 channel data acquisition system for the spectral line receiver of the mm-wave Radio Telescope was initiated. A fast analog multiplexer for 256 channel and an A/D converter was fabricated and tested. The control unit for the above system alongwith the interface unit for dumping the data on to PDP 11/34A computer system is under progress.

A spectrum expander which accepts signals of various bandwidths and fills a 256 channel filter receiver with 64 MHz bandwidth is being planned. A circuit design of a prototype which can expand signals to fill 8 MHz bandwidth spectrometer is currently under testing.

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	136 samples
2.	Infrared spectra	14 samples
3.	Differential scanning calorimetry	10 samples

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 scheme
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.	

U. M. Maiya Vijaya College Mulki, S. K.	Study of Atmospheric Water Vapour Content for site selection of mm wave telescopes.

Theses submitted :

The following candidates have submitted their theses for the award of the Ph.D. Degree of Mysore/Bangalore University.

1.	Mr. G. Venkatesh	High Pressure Studies of Liquid Crystals.
2.	Mr. K. P. Lakshminarayana Moodithaya	Optical and Elastic Properties of Liquid Crystals.
3.	Mr. K. Venkatachala Rao	Experimental studies of the Re-entrant Phenomenon in 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 Annxure I. (Page 20)

Conferences/Seminars and Meetings :

The staff of the Institute visited various institutions in India and abroad and attended 16 Conferences and presented papers. In addition, 28 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 11 colloquia at the Institute on different topics. In addition 13 discussion meetings were held on topics in theoretical physics.

Visiting Scientists :

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

Library :

During the year 553 new books were added to the library bringing the total book collection to 12,053. The library is subscribing to 125 current periodicals and has 15,206 bound volumes. To help the scientists/librarians locate the latest issues of scientific journals available in Bangalore, the library compiled a list of "Scientific and Technical Journals received by AIR MAIL IN BANGALORE LIBRARIES".

General

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

Plan :	Recurring	Rs. 19.00 lakhs
	Non recurring	Rs. 10.00 lakhs
Non-plan :	Recurring	Rs. 17.00 lakhs
Millimeter-wave project		Rs. 14.50 lakhs
Buildings		Rs. 8.50 lakhs
Development of high accuracy reflectors		Rs. 2.00 lakhs
	Total	Rs. 71.00 lakhs

II. In addition to the above, the following amounts were also received from the Department of Science and Technology during the year 1980-81.

1.	Science and Engineering Research Council (SERC)	Rs. 3.42 lakhs
2.	Bangalore NMR Facility	Rs. 1.00 lakh
	Total	Rs. 4.42 lakhs

III. The audited statement of accounts with the auditor's report is given in annexure II (page No. 27).

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
2. Prof. S. Chandrasekhar
3. Dr. S. Krishnan
4. Mr. N. V. G. Sarma
5. Dr. C. V. Vishveshwara
6. Dr. C. L. Khetrapal
7. Dr. N. V. Madhusudana
8. Dr. G. Srinivasan
9. Dr. R. Shashidhar
10. Dr. S. Venugopalan
11. Dr. G. S. Ranganath
12. Dr. A. C. Kunwar
13. Dr. V. Surendranath
14. Dr. Rajendra Bhandari
15. Dr. C. S. Shukre
16. Dr. Rajaram Nityananda
17. Dr. Ramesh Narayan
18. Dr. U. Devappa Kini
19. Dr. K. A. Suresh
20. Dr. B. K. Sadashiva
21. Mr. J. Padmanabhan
22. Mr. K. T. Balakrishnan
23. Mr. D. K. Ravindra
24. Mr. R. S. Arora
25. Mr. K. R. Anantharamaiah
26. Mrs. Jayanthi Ramachandran
27. Mr. M. O. Modgekar
28. Mr. M. R. Subramanyam
29. Mr. P. N. Ramachandra
30. Mr. R. Nandakumar
31. Mr. K. A. Subramanya
32. Mr. T. Ramachandran
33. Mr. K. Smiles Mascarenhas
34. Mr. N. Udayashankar
35. Mr. U N. Maiya
36. Mr. M. Selvamani
37. Mr. T. N. Ruckmongathan
38. Mr. A. Iphthigarudeen
39. Mr. P. A. Johnson
40. Mr. G. Sarabagopalan
41. Mr. L. B. Susairaj
42. Mr. B. V. Nataraja
43. Mr. R. Ganesan
44. Mr. H. Subramaniam
45. Mr. Antony Joseph
46. Mr. G. Rengarajan
47. Mr. A. Deshpande*

Visiting Position

1. Prof. S. Ramaseshan
2. Dr. G. S. R. Subba Rao
3. Dr. Ananda Kumar
4. Miss A. Mani
5. Dr. R. Srinivasan
6. Mr. Panchapakesan

Medical Consultant

Dr. A. R. Pai

Research Fellows

1. Mr. M. N. Ramanuja
2. Dr. G. V. Vani
3. Dr. B. R. Ratna
4. Mrs. K. L. Savithramma
5 Mr. M. Vivekanand
6. Mr. K. S. Dwarkanath
7. Mr. Sanjeev V. Dhurandhar
8. Dr B. R. Iyer*
9. Mr. M. Subramanya Raj Urs*
10. Mr. Vivek Dhawan*
11. Mr. B. S. Srikanta*

Resignations

1. Dr. N. D. Hari Dass
2. Mr. K. M. Chandrakumar
3. Mr. H. B. Sreedhar
4. Mr. A. Balachandra Reddy
5. Mr. K. L. Venkatakrishna
6. Mr. N. Kedarnath

A list of short period visiting scientists is given below

1. Mr. B. R. Iyer
   Bombay University
   Bombay — May 2 – May 17, 1980

2. Dr. J. R. Fisher
   National Radio Astronomy Observatory
   Green Bank, W. Virginia
   U. S. A. — May 17 – July 15, 1980

3. Prof. Hubert Reeves
   Centre D'Etudes Nucleaire de Saclay
   91190 Gif-sur-Yvette, Saclay
   France — May 29 – June 2, 1980

4. Dr. D. Morris
   Max-Planck Institute for Radioastronomy
   Bonn, West Germany — June 2 – June 22, 1980

5. Dr. J. P. Wild
   Chairman of the Executive, Commonwealth
   Scientific & Industrial Research Organisation
   Australia — June 25 – June 27, 1980

6. Dr. J. S. Anandan
   University of Maryland
   College Park, Maryland, U. S. A. — June 22 – July 24, 1980

7. Prof. Leon Mestel, FRS
   University of Sussex
   U. K. — August 8 – August 11, 1980

8. Mr. Varun Sahni
   Moscow State University
   Moscow, USSR — August 18 – August 19, 1980

9. Dr. Cornelius Hoenselaers
   Max-Planck Institut fur Physik
   and Astrophysik
   Munich, Germany — Sept. 19 – Sept. 25, 1980

10. Dr. V. J. Roche and
    Dr. O. P. Kevdin
    Institute of Chemical Physics
    Academy of Sciences of the USSR
    Moscow, USSR — Nov. 24 – Dec. 4, 1980

11. Dr. Jayant R. Banavar
University of Chicago
Chicago, U.S.A. — Nov. 25 – Dec. 25, 1980

12. Dr. C. H. Schiel
Secretary-General
International Relation Dept.
German Research Society
FRG — Dec. 7 – Dec. 10, 1980

13. Dr. J. Wiercimok
Head, International Relation Dept,
German Research Society
FRG — Dec. 7 – Dec. 10, 1980

14. Prof. V. L. Ginzburg
Lebedev Institute of Physics
Moscow, USSR — March 8 – March 13, 1981

Annexure I

List of Publications

1. Liquid Crystals, Proceedings of the International Liquid Crystals Conference Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden & Son, London (1980)

2. Evidence of a tilted columnar structure for (mesomorphic) phases of benzene-hexa-n-alkanoates (F. C. Frank and S. Chandrasekhar) - Journal de Physique, **41**, 1285 (1980).

3. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 131 (1980)

4. Absolute configuration of cholesteryl chloride and cholesteryl bromide (G. V. Vani, Kalyani Vijayan & S. Chandrasekhar) - Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p. 167 (1980).

5. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 247 (1980).

6. New Liquid Crystalline States (S. Chandrasekhar) – Current Science **50**, 47 (1981).

7. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 121 (1980).

8. Induced smectic mesomorphism in some binary mixtures : A new type of electrohydrodynamic pattern in the nematic phase of the mixtures (K.P.L. Modithaya and N. V. Madhusudana) – Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p. 297 (1980).

9. A convenient multiplexing scheme for addressing small liquid crystal matrix displays (N.V. Madhusudana and T.N. Ruckmongathan)-Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p. 499 (1980).

10. 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, Ed. S. Chandrasekhar Heyden and Son, London, p 115 (1980).

11. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 135 (1980).

12. Re-entrant nematic phase in a pure compound at atmospheric pressure (B. K. Sadashiva)– Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p. 165 (1980).

13. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 205, (1980).

14. Angular forces between disclinations in elastically anisotropic nematic liquid crystal (G. S. Ranganath) – Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p. 213 (1980).

15. Attraction between two like half singularities in nematic liquid crystals (G. S. Ranganath) - Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p. 219 (1980).

16. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 255 (1980).

17. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 373 (1980).

18. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 381 (1980).

19. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 461 (1980).

20. Proton NMR study including $^{13}C-^{1}H$ 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 465 (1980).

21. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 469 (1980).

22. 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, Ed. S. Chandrasekhar, Heyden and Son, London, p. 595 (1980).

23. Experimental determination of the surface tension of two liquid crystals (S. Krishnaswamy) - Proceedings of the International Liquid Crystals Conference, Bangalore, December 1979, Ed. S. Chandrasekhar, Heyden and Son, London, p.487 (1980).

24. Magnetic and electric birefringence in the isotropic phase of a nematic large positive dielectric anisotropy (B.R. Ratna) - Molecular Crystals and Liquid Crystals, **58**, 205 (1980).

25. Polarization field and orientational order in liquid Crystals (N.V. Madhusudana) - Molecular Crystals and Liquid Crystals, **59**, 117 (1980).

26. Polymorphism of the smectogen ethyl-p-azoxybenzoates : far-infrared and Raman study (S. Venugopalan and S. N. Prasad) - Journal of Chemical Physics, **72**, 4153 (1980).

27. Steady low shear rate cholesteric flow normal to the helical axis (U. D. Kini) - Pramana **14**, 463 (1980).

28. The nematic - isotropic phase transition : Application of the Andrews methods (K. L. Savithramma and N.V. Madhusudana) Molecular Crystals and Liquid Crystals, **62**, 63 (1980).

29. Oriented molecules (C. L. Khetrapal and A. C. Kunwar) - Specialist Periodical Reports : NMR, Vol. 9, The Royal Society of Chemistry, London (1980).

30. NMR study of the oil build-up in Sunflower seeds (M.R. Lakshminarayan, A. Seetharam, K.V. Ramanathan and C.L. Khetrapal) - Current Science, **49**, 308 (1980).

31. NMR spectra of oriented biologically important molecules. Part I. The structure and conformation of N-methyl imidazole (C.L. Khetrapal, C.L. Chatterjee and Herman J. Yeh, Chemical Physics Letters, **76**, 553 (1980).

32. NMR spectra of tricyclic compounds oriented in the nematic phase (C.L.-Khetrapal) - Organic Magnetic Resonance, **15**, 238 (1981).

33. Properties and limitations of the maximum entropy method (M. M. Komesaroff, R. Narayan and R. Nityananda) Astronomy and Astrophysics **93**, 269 (1981).

34. Validity of the quasistatic assumption in the theory of black hole evaporation (R. Nityananda and R. Narayan) - Physics Letters, ~~89A~~ 82A, 1 (1981).

35. On anomalous scattering and the multiple wavelength method (S. Ramaseshan and R. Narayan) in Structural Studies on Molecules of Biological Interest, Eds. G. G. Dodson, J. P. Gulsker and D. Sayre Oxford. Oxford, University Press (1980).

36. A simple theory of thermal effects in ionic crystals (R. Narayan and S. Ramaseshan) Current Science, **49**, 725 (1980).

37. A new approach to electronic transitions in the Samarium Monochalcogenides (R. Narayan and S. Ramaseshan) - Journal of Physics 'C' **14** 211 (1981).

38. Crystal structure analysis with the maximum entropy method (R. Narayan and R. Nityananda) - Current Science **50**, 168 (1981).

39. Pulsar activity and morphology of supernova remnants (V. Radhakrishnan and G. Srinivasan) - Journal of Astrophysics and Astronomy **1**, 25 (1980).

40. Evidence for a large population of shocked interstellar clouds (V. Radhakrishnan and G. Srinivasan) – Journal of Astrophysics and Astronomy **1**, 47 (1980).

41. Structure of integrated pulse profiles (M. Vivekananda and V. Radhakrishnan) - Journal of Astrophysics and Astronomy **1**, 119 (1980).

42. Electromagnetic fields in spacetimes with local rotational symmetry (S. V. Dhurandar, C. V. Vishveshwara and J. M. Cohen) - Physical Review 'D' **21**, 2794 (1980).

43. Diffuse gamma radiation and pulsar magnetic fields (V. Radhakrishnan and C. S. Shukre) - Bulletin of Astronomical Society of India **7**, 113 (1979).

44. Neutrinos in compact objects (A. K. Kembhavi and C. V. Vishveshwara) - Physical Review 'D' **22**, 2349 (1980).

45. Observations and interpretation of Type IIIb radio bursts (V. Krishan, K. R. Subramanyan and Ch. V. Sastry) - Solar Physics **66**, 347 (1980).

46. Observations on the structure of Type IIIb radio bursts (Ch. V. Sastry, K. R. Subramanyan and V. Krishan) in Radio Physics of the Sun-Proceedings of the IAU Symposium No. 86, Eds. M. R. Kundu and T. E. Gergely, Dordrecht, Reidel, (1980).

47. A large decametric array for IPS observations of radio sources (Ch. V. Sastry) in Solar and Interplanetary Dynamics, Proceedings of IAU Symposium No. 91, Eds. M. Dryer and E. Tandug-Hanssen, Dordrecht Reidel (1980).
48. A study of the SNR IC 433 and decameter wavelengths (K. S. Dwarakanath and Ch. V. Sastry) Bulletin of the Astronomical Society of India **9**, 1 (1981).
49. On the time structure of drift pair radio bursts from the sun (K. R. Subramanyan and Ch. V. Sastry) Bulletin of the Astronomical Society of India, **9**, 1 (1981).
50. HI absorption in the direction of the galactic centre (V. Radhakrishnan and N. V. G. Sarma) Astronomy and Astrophysics **85**, 249 (1980).
51. The effect of the diffuse gamma radiation on pulsars (V. Radhakrishnan) in Proceedings of the Symposium on Non-Solar Gamma Rays – COSPAR 22nd Plenary Meeting, Eds. R. Cowsik and R. D. Willis, Pergamon, Oxford (1980).

Papers submitted and in press

1. 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.
2. The re-entrant phenomenon in 4'-n-octyloxy-4-cyanobiphenyl : High pressure retain X-ray study of the smectic A layer spacing (S.Chandrasekhar, R. Shashidhar and K. V. Rao) – Proc. Third Liquid Crystal Conference of Socialist Countries, Budapest, Hungary. August 1979 – Academic Press.
3. Liquid Crystals of disc-like molecules (S. Chandrasekhar) – invited lecture-Eighth-International Liquid Crystal Conference, Kyoto, Japan, June 1980 – Molecular Crystals and Liquid Crystals.
4. A new class of thermotropic liquid crystals: Discotic systems (S. Chandrasekhar and S. Kobayashi)-Butsuri (Physics Today of the Physical Society of Japan) in Japanese.
5. Thermotropic liquid crystals : An introductory review (S. Chandrasekhar)-Chapter in a Book in Chinese, Science Press, Beijing.
6. The search for a Lifshitz point in a single-component liquid crystalline systems : A high pressure study of 50.6 (R. Shashidhar, A. N. Kalkura, and S. Chandrasekhar) - Molecular Crystals and Liquid Crystals Letters.
7. Molecular flexibility and orientational statistics in liquid crystals: Raman study of 7CB and 8 OCB (S. Venugopalan and S. N. Prasad)-Eighth International Liquid Crystals Conference, Kyoto, Japan, June 1980-Journal of Chemical Physics.

8. 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 Crystals Conference, Kyoto, Japan, June 1980 - Molecular Crystals and Liquid Crystals.
9. Experimental studies on the electrical conductivity of two re-entrant nematogens (B. R. Ratna, R. Shashidhar and K. V. Rao) - Eighth International Liquid Crystals Conference, Kyoto, Japan, June 1980 - Molecular Crystals and Liquid Crystals.
10. Studies on some binary mixtures exhibiting the induced smectic A phase (N. V. Madhusudana and K. P. L. Moodithaya) - Molecular Crystals and Liquid Crystals.
11. Proton NMR spectra including ^{13}C and ^{77}Se-satellites in organoselenium compounds oriented in the nematic phase. Part I. The spectrum of 2, 1, 3-benzoselenadiazole (C. L. Khetrapal and A. C. Kunwar)-Journal of Molecular Structures.
12. A ^{13}C-NMR study of non-planar distortions in amides (C. L. Khetrapal and A. C. Kunwar) - Journal Biochem. Biophys. Methods.
13. An NMR study of the structure of and the internal rotation in phenylsilane (C. L. Khetrapal and Edwin D. Becker) - Journal of Magnetic Resonance.
14. PMR study of partially oriented 1-phenyl propyne (C. L. Khetrapal and R. Highet) Organic Magnetic Resonance.
15. Application of NMR of oriented systems in biochemistry and biophysics (C. L. Khetrapal) - International Journal of Quantum Chemistry.
16. The Physics and Chemistry of Liquid Crystal Devices, Ed. G. J. Sprokel, Plenum Press - Book Review (S. Chandrasekhar) - Acta Crystallographica.
17. Optimum choice of wavelengths in the anomalous scattering technique with synchrotron radiation (R. Narayan and S. Ramaseshan) - Journal of Applied Crystallography.
18. A lower bound for the birth rate of pulsars (R. Narayan and M. Vivekanand) - Nature.
19. The stability of ionic structures (R. Narayan)-Proceedings of the Nuclear Physics and Solid State Physics Symposium - Invited talks volume.
20. The maximum determinant method and the maximum entropy method (R. Narayan and R. Nityananda), Acta Crystallographica 'A'.
21. Multiwavelength method with synchrotron radiation (S. Ramaseshan and R. Narayan) - Commemmoration volume for the 70th birthday of Academician B. K. Vainshtein. USSR Academy of Sciences.
22. 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.

23. Neutrinos in gravitational collapse I: 'Analysis of Trajectories' (S. V. Dhurandhar and C. V. Vishveshwara) Astrophysical Journal.
24. Neutrinos in gravitational collapse II: 'Analysis of flux profiles' (S. V. Dhurandhar and C. V. Vishveshwara) Astrophysical Journal.
25. Causality conditions and the lengths of non space-like curves (S. V. Dhurandhar and P. Joshi) Journal of General Relativity and Gravitation.
26. The diffuse gamma ray background and the pulsar magnetic window (C.S. Shukre and V. Radhakrishnan) Astrophysical Journal.
27. The pulsar magnetic window (C. S. Shukre and V. Radhakrishnan) in "Pulsars"-Proceedings of the IAU Sumposium No. 95, Eds. R. Wielebinski and W. Sieber.
28. No detectable supernova remnant near the pulsar PSR 1930+22 (W. M. Goss and D. Morris) Journal of Astrophysics and Astronomy.
29. 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.
30 Observations and interpretation of the slowly varying component of solar radio emission at decameter wavelengths (Ch. V. Sastry, K. S. Dwarakanath, R. K. Shevgaonkar and V. Krishan) Solar Physics.
31. Pulsating radio emission at decameter wavelengths from the sun (Ch. V. Sastry, V. Krishan and K. R. Subramanyan) Journal of Astrophysics and Astronomy.
32. Phase locked Gunn oscillator at 21 GHz (R. S. Arora and N.V.G. Sarma) Journal of Institution of Electronics and Telecommunication Engineers.
33. Evaluation of two Indian sites for millimeter wave radio astronomy (U. N. Maiya and P. Dierich), Proceedings of the Indian Academy of Sciences 'A'.
34. Improved precision solar and sidereal clock (N. Udayashankar and M. Selvamani) Journal of Institution of Electronics and Telecommunication Engineers.
35. 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.
36. 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.