



K. Ranga Lakshmana Rao



K RANGADHAMA RAO

(1898-1970)

Elected Fellow 1973

PROFESSOR K RANGADHAMA RAO, was born in 1898. He hailed from a middle class family in Berhampur. His early education was mainly in Visakhapatnam and Vijayanagaram. In 1923, he took MA degree in physics from Tiruchirapally. He joined MR College staff and simultaneously carried out research in spectroscopy under the pioneer Dr AL Narayan of Andhra.

Professor Rao took DSc (Madras) degree in spectroscopy and also associated with Professor MN Saha FRS at Allahabad through visits and work. The year 1928 was a turning point in his life as he was the first candidate to have been selected by Andhra University for studies abroad. He worked under Professor A Fowler, FRS at the Imperial College of Science and Technology, London where he carried out very significant research in atomic spectra for two years. For this, he was awarded the DSc degree of London University. In 1930, he got an opportunity of spending six months in Berlin at the Physikalische Technische Reichsanstalt under Professor F Paschen, Nobel Laureate. Later, he spent six more months in Upsala under Professor Manne Seigbahn, an authority on vacuum spectroscopy. His interest in the field was so much that he purchased from his pocket a vacuum spectrograph of his design from Potsdam, Germany.

His appointment as Lecturer in Andhra University in 1932, and subsequently as Reader in 1934 and Professor in 1941 was followed by his appointment as Head of the Physics Department and he reached the principal's post in 1949. He became Special Officer for the starting of SV University. He taught BSc (Hons) classes, MSc classes and guided 33 students for DSc/PhD degree in Andhra University in different branches of spectroscopy and dielectrics in addition to guiding a good number of students for MSc degree in physics. After retirement, Professor Rao was appointed as Emeritus Professor in Andhra University at Physics Department with honorarium and full research facilities. He was a very good administrator and was responsible in the developing of physics, mathematical physics, applied physics, geophysics, meteorology and oceanography and nuclear physics into full-fledged departments.

He was also the builder of separate engineering college in the university. His contributions in a number of policy matters in the administration are well accepted by the university. He was a powerful senator and was the principal of all colleges of the university which include science, technology, arts, commerce, law and engineering.

His research career ranged from 1923 to 1970, the year, he breathed his last. His allotting a specific sub-field to one or two reserch students with a view to developing



each sub-branch continuously and simultaneously forever was his unique characteristic feature and was well respected. Another striking feature of Professor Rao was that he never allowed his name to be put anywhere among the authors of any publication which had gone out of his laboratory and under his direction. Thus all the publications which went out of his laboratory under his guidance, do not contain his name as one of the authors! This feature is considered to be very remarkable in the sense that the student is given all encouragement for further investigations. This is undoubtedly an unequivocal sacrifice on the part of Professor Rao.

Professor Rao started from simple atoms, then passing on to ionised atoms using different experimental techniques for various types of excitations using different spectrographs, glass, quartz and finally vacuum UV spectrographs to range the spectral investigations from photographic ($10,000\text{\AA}$) infrared upto the vacuum UV (300\AA). He opened a branch of his own design on atomic, ionic and high resolution vacuum spectrograph.

While these investigations were going on, he simultaneously developed diatomic molecular spectroscopy laboratory, first aiming at a high resolution vibrational structure in electronic transitions and later on proceeded to high resolution rotational structural investigations in diatomic molecules. At the same time, he concentrated on polyatomic molecular spectroscopy dealing with UV absorption, infrared absorption, Raman scattering, fluorescence and phosphorescence and crystal spectra. While the two fields so developed were left to senior members, Professor Rao switched on to the three new fields in spectroscopy, namely NQR, NMR and ESR spectroscopy.

Another field which he developed simultaneously was dielectrics. Starting from scrap, he reached the level of construction of microwave test benches and using these techniques, he opened different lines of investigations in dielectrics.

Professor Rao encouraged theoretical investigations in all branches with a strong belief that both experimental and theoretical work should go together for a more comprehensive and complete understanding of the problem.

Finally, he entered into developing radio frequency spectroscopy which branched into three different lines, namely, NQR, NMR, and ESR. He constructed various electronic accessories and designed different systems and cells which formed the components of the concerned spectrographs.

It is no where in history that such wide and extensive investigations of different nature could be so successfully completed by dynamism and foresight of a single individual. It is equally extraordinary that a single individual could enthuse a number of students to become motivated scientists. This is very clear from the list of doctorates he produced (as given in Annexure I) in different fields of his development period of forty years.



The simplicity of the person, the enormous patience and the excellent commitment to research, never caring for fame and name, and above all not accepting his name on publications are considered to be unique characteristics of Professor Rao.

Professor Rao evinced interest in spectral investigations of molecules by preparing them synthetically. His readiness for constructing the various components required for experimental investigations was many a time surprising to his students resulting in giving a very good incentive for the students leading to self-reliance. His teaching was highly analytical and left an everlasting impression on the minds of the students. He continued, with extraordinary zeal, giving periodical research seminars on a wide variety of topics on dielectrics and spectroscopy to his research group till his last day in the laboratory. These are considered to be a model in promoting various capabilities in the students. His excellence both in synthesis and analysis throughout his scientific research and university administration are unparalleled.

WORK DETAILS PROMOTED BY RAO IN DIFFERENT BRANCHES

Atomic Spectroscopy

In atomic spectra, the experimental investigations of multiple ionised line spectrum of various atoms such as Columbium Molybdenum and Bromine were conducted to arrive at the multiple separation of different electronic configurations. The experimental work was extended from photographic infrared to vacuum UV region and even under high resolution using gratings.

Diatomic Molecular Spectroscopy

In diatomic molecules, Dr Rao's first attempt was to study under high resolution, the vibrational structure of different electronic transitions in a number of molecules such as ZnI, CoCl, HgI, NiCl, Bi I, Manganese, halides, and Thallium halides, mostly under emission spectroscopy. The absorption spectrum was also investigated. The study facilitated the identification of new electronic transitions through different vibrational bands. In high resolution the vibrational analysis was conducted and the anharmonicity was estimated. Further extensions in the study of diatomic molecules were the study of high multiplicity states, rotational analysis, intensity formulae for bands involving high multiplicity terms and calculation of perturbations in molecular electronic terms. In the first instance, the high resolution spectral work for studying the rotational structure of diatomic molecules was carried out by taking spectra using high resolution gratings available at Calcutta. Later, his constant effort in setting a high resolution 21 feet concave grating spectrograph in his labs at Andhra University to study the rotational analysis of the various vibrational bands in different electronic transitions is worthy of mention and his guidance in developing this field of investigation was gratefully acknowledged. Quite a good amount of research was successfully carried out later by his research group.



Polyatomic Molecular Spectroscopy

The experimental work on polyatomic molecular spectroscopy was confined to different types (1) Near ultraviolet absorption spectroscopy in different states of aggregation of the molecules with a view to studying the different electronic transitions and the vibrational structure on the violet side thus identifying new transitions and vibrational frequencies of excited states and this feature is considered to be unique, (2) Infrared absorption spectra in the region ($200-4000\text{Cm}^{-1}$) were recorded and analysed for their vibrational frequencies for almost all polyatomic molecules which were investigated in Professor Rao's labs. Leitz semi automatic IR spectrograph was commissioned and the IR spectral investigations were carried out in liquid, solid and vapour phases. The last one is used mainly for the vibrational symmetry evaluation. The frequencies thus reported together with those obtained from Raman effect investigations belong to ground state vibrations. A consolidated study of all these three namely, ultraviolet, absorption, infrared absorption and Raman scattering studies was very systematically planned by Professor Rao and it was considered to be a significant achievement. In addition, the development of solid state spectroscopy in crystals both at ambient and liquid nitrogen temperatures is another novelty built by him. The extension of spectroscopic studies of luminescence, (Fluorescence and Phosphorescence) both at room temperature and low temperature are very good additions in the sense that the mirror image of absorption spectrum showing the vibrational frequencies of the ground state and the phosphorescent triplet state detection from phosphorescence spectroscopy are considered to be useful in the electronic spectra. These phosphorescence states can also be experimented through ESR spectroscopy which was successfully attempted later in his labs.

One of the important works that was planned by Professor Rao was to study the electronic absorption spectrum of polyatomic hydrocarbons like Benzenes, Napthlenes, anisoles and their substitutions. For example :

Para Dibromobenzene, Anisoles, $\langle \text{-----} \rangle$ Furan, pyrrole, pyrro,
 Substituted thio naphthenes, cresols, $\langle \text{-----} \rangle$ lidene, thiophene and
 anilines, substituted Benzenes, Toluenes, $\langle \text{-----} \rangle$ substitutions
 cumarins, indenenes etc., isomers.

OMP Fluoro chloro Benzenes

OMP Fluoro Bromo Benzenes

OMP Fluoro Iodo Benzenes etc.,

- i) to detect origins of various electronic transitions in the near ultraviolet region.
- ii) to get information on excited state vibrational frequencies.
- iii) to have a comparative study between the spectra obtained in different states of aggregation of molecules, solids liquids or vapour.



- iv) to get information on the ground state vibrational frequencies from the study of IR absorption and also Raman scattering experiments. Here also experiments were conducted in different states of aggregation. Thus, he opened a branch for the study of excited state vibrational frequencies and compared them with ground state vibrational frequencies. His further extension of the work into the emission spectra, fluorescence, phosphorescence spectra (at liquid nitrogen temperatures) was pursued by his students. The latter was aimed at detection of the lowest lying phosphorescence triplet states which Professor Rao had a mind to couple with ESR studies. His ambition to study the application of spectroscopy to different fields, in his days, could not be pursued. But he was constantly referring to that topic. His contemplation on crystal spectra has paved way to a new line of investigation, which was later taken up by his students.

Nuclear Quadrupole Resonance Spectroscopy (NQR)

Andhra University was among the first to introduce NQR spectroscopy into the research in radio frequency spectroscopy. Every aspect of research in NQR spectroscopy was adequately pursued by the dedicated school nurtured by Professor KR Rao. It started with the construction of a self-quenched superegenerative oscillator at 20-40 MHz for observing chlorine NQR in para dichloro Benzene and other chlorine substitutions of Benzene. Simultaneously techniques to grow single crystals of organic solids and Ionic solids were developed. NQR absorption frequency measurement techniques, and recording techniques were also developed. Zeeman assemblies with three degrees of freedom were designed and constructed to study the Zeeman splittings.

Methods were developed to theoretically calculate the electric field gradients, the NQR frequencies, asymmetry parameters, and orientation of principal axes in the case of ionic crystals based on point charge model. Cuprous chloride, Sodium chlorate, Mercuric chloride, Thorium tetrachloride have been theoretically studied. Extensive theoretical investigations were carried out on quadrupole interactions of Al, Be nuclei in the crystal Chrysoberyl for which detailed data were available from NMR measurements. The field gradient tensor was evaluated considering the effect of oxygen dipoles at the two inequivalent Al^{27} and Be^9 sites. The effect of position parameters of the various ions in the crystal and the polarizability of oxygens on the quadrupole interactions had been investigated. The quadrupole coupling constant and asymmetry parameters were computed for $\beta\text{-G}'a_2O_3$ and had been found to conform to the experimental values.

Sternheimer anti-shielding factors and dipole polarisation effects on the electric field gradients were theoretically studied. The energy level spacings of F^{18} were estimated. Theoretical calculations of the temperature variation of NQR frequencies for a number of compounds were attempted.



After the success with chlorine oscillators in NQR, the exploration was widened to cover Bromine, iodine and nitrogen NQR frequencies. In fact the first Bromine NQR resonance was observed in India at Professor KR Rao's laboratories in Andhra University. An externally quenched super-regenerative oscillator with 955 acorn tube in push-pull grounded grid configuration with a pair of transmission lines shorted at the other end of the oscillator was constructed at 250-300 MHz. The suitable Zeeman assembly and temperature variation attachments were designed and constructed and in no time a whole new range of Bromine substituted organic crystals were investigated thoroughly. NQR spectrometers at 2-5 MHz to cover nitrogen frequencies and at 500-600 MHz to cover iodine frequencies were also developed in his laboratory to complete the range.

Many new resonances were observed in organic crystals, like 4-chloro 2 nitro phenol and 2 dibromo sniline etc. Many ionic crystals, covalent crystals were also studied. The main line of investigation had been to estimate the electric field gradients, asymmetry parameters, non-equivalent sites in crystals and correlating the experimental findings with the existing theoretical models. Phase transitions in compounds, like P-bromo phenol, and in many organic crystals were detected and explained. Thus the investigations carried out in NQR in Professor Rao's laboratory were both extensive and deep.

Electron Spin Resonance Spectroscopy (ESR)

When Professor KR Rao started research in electron spin resonance, the challenge was formidable, as there was difficulty in getting foreign exchange to obtain microwave components from abroad. Every unit and microwave component had to be designed and assembled from scrap and the position became worse with time. The first spectrometer was of the transmission type with a cylindrical cavity resonator, 50Hz magnetic field modulation and phase sensitive detector followed by DC amplifier and pen recorder. It was improved by changing the magnetic modulation frequency to 80Hz, and also by incorporating a narrow band amplifier after the crystal detector.

Because of the limited sensitivity and resolution of the spectrometer, most of the work in ESR was confined to the studies of variation of g factors and line widths in single crystals and polycrystalline materials, with orientation of external magnetic field. Copper sulphate Penta hydrate, Copper Ammonium chloride dihydrate, Chromium potassium sulphate dodeca hydrate, manganese acetate tetrahydrate, manganese sulphate tetrahydrate, ferric ammonium sulphate dodeca hydrate and many organic complexes of copper, like copper dipyridine sulphate dihydrate, copper tetra pyridine fluoborate and copper dipyridine thiocyanate were among the many complexes, investigated. Optical absorption in organic complexes of copper were studied and the covalency factors were estimated. Considerable covalency had been reported in the metal-ligand bonding.



Considerable amount of theoretical work was also simultaneously done. A new method of estimating the effects of crystalline fields on the energy levels and wave functions of the configurational ground state of the ion was developed which was found to be simpler and more effective than the previous methods. Theoretical estimates of g_{11} and g_1 had been made for all the crystals mentioned earlier and they had been found to agree with the experimental values well. The structure of copper ammonium chloride was unambiguously established which had two competing structures in X-Ray diffraction studies. g factors were calculated for hexane nitro copper complexes using point charge point dipole model.

Experimental investigation on this complex suggested that charge on oxygen atom was minus two. The isotropic character of the observed g value for these complexes was explained on the basis of dynamic Jahn-Teller distortion operating in the complex and not due to the exchange interaction between different copper ions. The covalency reduction factors calculated from ESR experimental g factors and the estimated ligand field energy obtained from optical absorption data were used effectively to predict the metal-ligand bonding in the organic copper complexes. Thus the ESR results backed by good theoretical calculations could resolve the structural ambiguities in many copper complexes.

Nuclear Magnetic Resonance (NMR)

Thanks to a special equipment grant by the Department of Atomic energy, Bombay to Professor KR Rao for obtaining a varian 2100B power supply unit to be used in conjunction with a varian 4012-3B 12 electro-magnet secured from UGC, that NMR research could be started in Andhra University. Many electronic accessories like a Robinson type low level NMR oscillator working around 16 MHz with an adjustable RF power, AF pre amplifier, balanced pentode mixer, D-C cathode follower, AF power amplifier, AF phase shifter and amplifier, a field sweep unit and electron regulated power supplies, were constructed. A high temperature unit and a low temperature unit were also designed.

$\text{Na Br } 2\text{H}_2\text{O}$ is investigated in poly crystalline form. New Formulae were developed using certain theorems in probability theory and the properties of spherical triangles. These formulae formed extension over the second moment formulae given by Pederson for single crystals. These formulae were applicable for powders in explaining the temperature variation of the second moment from 90K to 295K. A quantitative estimate of the potential barrier, which was hindering the rotation of one of the two inequivalent water molecules was made. This was significant contribution for second moment study.

Many hydrated crystals like $\text{Li}_2 \text{SO}_4 \cdot \text{H}_2\text{O}$, $\text{Ba}(\text{ClO}_3)_2 \cdot 2\text{H}_2\text{O}$ had been studied and a new method had been suggested for calculating the equilibrium proton-proton distance. Second moment transitions were detected, in ammonium formate and ammonium acetate and they were explained as due to the onset of random reorientation of NH_4^+ ions.



Phase transitions of some organic molecules like 2,5 and 2,6 dichloroaniline were studied by NMR methods. 1,5 and 1,4 dihydroxy quinones were investigated and second moment transitions were attributed to the rotation of OH groups.

Many inorganic crystals like barium diethionite dihydrate and kernite were studied and bond angles and bond distance in the water molecules contained in the hydrated crystals determined. In cases where X-ray data was available the hydrogen bonding scheme was uniquely determined. $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, $\text{Ca}(\text{ClO}_3)_2 \cdot 2\text{H}_2\text{O}$ were investigated and their structures were established from the Pake curves. The influence of deuterons on proton relaxation times in para magnetic solutions was also studied and interesting observations were made on the proton exchange across the hydrogen bond. Studies on the variation of proton relaxation times with concentration of acetic acid, formic acid and acetone in water mixtures were also made and the chemical shifts on relative concentrations have been established.

It could be seen from the above that a variety of problems had been attempted and solved using proton magnetic resonance method.

Dielectrics

Dielectric studies were made at RF U-HF, X band K band regions, for many organic molecules in liquid and solid state at various temperatures. Equipment capable of measuring dielectric constant and loss at various frequencies was designed, fabricated, and assembled. In the process many components such as attenuators, matching units standing wave indicators, suitable dielectric cells were newly designed and assembled at X band and K band, coaxial region, and RF region. The auxiliary electronic accessories like stabilised power supplier, crystal oscillators, amplifiers and temperature controls were designed and constructed. Besides, cavity methods were also developed at microwave region. In short, a laboratory had been established which could measure dielectric dispersion of solids and liquids at various temperatures and at frequencies from 1 MHz to 1000 MHz.

The dielectric constant and loss, measured at the wide range of frequencies had given a measure of the relaxation times, and rate processes in many long chain organic molecules, esters and other polar molecules. The relaxation times were also measured spectroscopically thus establishing a relation between Dielectrics and Rayleigh scattering. The dipole moments of many polar molecules were determined, both theoretically and experimentally. The influence of chain length, substitution, and association in many organic molecules and their solutions on the dielectric properties had been thoroughly investigated. The role of hydrogen bond in causing dielectric dispersion in organic liquids and solids was systematically studied.

A new method of determining dipole moment and relaxation time from measurements of polar liquids in non-polar solvents at single frequency had been evolved. A new method of determining energy of dipole-dipole interaction



measurement on relaxation times of any given polar substance in liquids and in solutions was developed using Eyring's concept of dielectric relaxation as a rate process. Six halides of group IV of periodic table, NF_3 , AlF_3 , AlCl_3 , PF_3 , PCl_3 , were theoretically investigated and their ionic character and hybridization were established. It was found that lone pair of electrons made a significant contribution to the dipole moment. The influence of viscosity on the relaxation times was studied for some polar molecule-paraffin mixtures. All the results had been published in various national and international Journals of good repute.

Professor Rao had the foresight and vision to gauge as early as 1950 the immense potential the dielectric research had for defence. The moment the know-how, power sources like klystrons and measurement techniques at microwaves were declassified Professor KR Rao lost no time in developing a powerful research school in dielectrics so that applications for defence could be pursued in Andhra University.

The expertise gained in microwave techniques in Professor KR Rao's laboratory was even more spectacular. It flowed literally to the defence laboratories from his laboratory.

Theoretical Work

Professor KR Rao developed keen interest in (1) Estimating dipole moments (Dielectrics) (2) Evaluation of g factors (ESR) (3) Development of new formula for second moments (NMR) (4) Evaluation of field gradients and asymmetry parameters and theoretical estimates of NQR frequency with temperature (NQR) and (5) Quantum mechanical applications in the study of ESR for estimating the energy levels. These were also simultaneously investigated experimentally. In atomic spectroscopy the term values of different electronic configurations could be electronic levels when computed quantum mechanically. In polyatomic molecular spectroscopy his interest was mainly (1) On group theoretical applications to vibrational activity, the electronic transitions and rotational energies. (2) Evaluation of electronic energy levels, by applying molecular orbital theory. (3) Determination of force constants using vibrational frequencies obtained from IR and Raman spectroscopy. Both these were also supplemented by experimental investigations.

In molecular orbital theory, particularly five membered rings and substituted benzenes and naphthalenes were studied, taking into consideration configuration interactions. His other interest was in the calculations of electronic origin shifts on substitution. The experimental investigation was mostly on near ultraviolet spectra of such molecules. The group theory applications were mostly on the vibrational spectra derived either from IR absorption studies or from scattering experiments.



CONTRIBUTIONS TO THE GROWTH OF ALLIED PHYSICS AT ANDHRA UNIVERSITY

Physics Department of the Andhra University was among the first few departments commissioned at the start of the university. Professor K Rangadhama Rao was among the three eminent professors, who planned the strategies, created the necessary infrastructure and initiated the programmes in mid 1930s. Two of the professors (Professor S Bagavantham and Professor IR Rao) left the department for other positions elsewhere, while Professor Rangadhama Rao continued the envisaged programme and is mainly responsible for the growth of the department and all the achievements, recognised at the national and international levels.

Among the several strategies adopted for development of physics at Andhra University, perhaps the most significant was to plan for a wide base to enable the department to provide facilities for teaching and research in a variety of specializations. It was already clear by mid 1930s that "Physics" was essential to understand all processes in nature from the microscopic state of matter (molecular, atomic and nuclear) to the macroscopic state (Astrophysics and Cosmology). Professor Rao therefore thought that it would be fitting to provide for as many aspects of study as possible in this wide range of specializations. With this intention, he planned for Mathematical Physics, Applied Physics, Geophysics, Meteorology, Oceanography and Nuclear Physics specialisations. It is well known that a good training in theoretical physics is very essential for fruitful and creative research in physics. Mathematical Physics was therefore the first specialisation to be started by inviting Professor S Meenakshisundaram and Professor T Venkatarayudu. This function was admirably organised by the mathematical physics unit which was later separated as a department. Its work in Group theory is internationally recognised. This department is now renamed as Applied Mathematics Department. Later, applied physics specialisation was started in mid-1940s and Professor Rao realised that it was a very essential specialisation to provide training for developing all the instrumental and engineering sciences. Accordingly, he chose to initiate optical, electronic and electrical technologies. Professor S Krishnaswami Chetty and Professor D Seethapathi Rao were entrusted with this task and they were trained abroad to take up the new responsibilities. A special grant was obtained from the State government to develop applied physics as a separate department. After developing the necessary infrastructure for applied physics and organising courses for a few years, Professor D Seethapathi Rao was entrusted with the task of starting an Engineering College in the campus during mid-1950s. Thus the credit of planning an engineering campus also goes to Professor KR Rao. It is interesting to note that the former Applied Physics Department is now transferred to the Engineering College and is renamed as the Instrumentation Technology Department.



Professor B Sundara Rama Rao and Professor R Ramanadham were later specially trained to start specialisations in Geophysics (physics of earth) and Meteorology and Oceanography in 1949. The departments were also separated later in 1961 and special grants were obtained to develop the infrastructure from the UGC and India Meteorological Department. While the leadership of experts like Professor NK Sur and Professor SR Savur moulded the disciplines of meteorology and oceanography, the guidance and expertise of Professor MS Krishnan and Professor C Mahadevan laid the foundations in geophysics. Extensive support was obtained from Department of Ocean Sciences, Government of India to develop the oceanography department. The University is at present organising an inter-disciplinary course in marine sciences at postgraduate level. Andhra University is one of the 12 UGC centres offering a special programme of MTech (Atmospheric Sciences) on an All India basis. Geophysics department which was started initially to study magnetic properties of rocks in the region extended its studies to include geohydrology and seismology with grants from MHRD, DST & CSIR. Geophysics department is well developed and is now well recognised for its specialisation in the field of gravity and magnetics with collaboration of Tata Institute of Fundamental Research.

The last in the series of specialisations to be started was the nuclear physics. Professor Rangadhama Rao was specially interested in this subject for two reasons—firstly his own research area (Hyper-fine interactions) was intimately connected with nuclear effects in atomic spectroscopy and secondly he realised that future developments in nuclear and sub-nuclear physics areas would have far reaching consequences to basic understanding of nuclear forces and also solving several particle physics and cosmological problems. In addition, it was already recognised all over the world that nuclear energy and techniques would solve several problems and help the society in several areas. Department of Atomic Energy was started by Government of India. A special Institute of Nuclear Physics was started at Calcutta University and there were no facilities for offering postgraduate level courses in nuclear physics in the whole of South India. Professor Rangadhama Rao rightly thought of inviting Professor Swami Jnanananda, an experienced international nuclear physicist working at National Physical Laboratory in New Delhi. The then Vice-Chancellor Professor VS Krishna also supported the idea and nuclear physics specialisation was started in the Physics Department in 1954. It was later formed into a separate department in 1956. With active financial support of UGC, DAE and State Government, it was quickly developed and acquired a national status. For over 5 or 6 years it was the only department offering MSc (nuclear physics) and students from all over South Indian universities used to take that course.

Extensive research facilities were built up in the areas of "Interaction of Gamma Radiation with Matter", "Nuclear Spectroscopy" and "Hyper-fine Interactions". A number of magnetic spectrometers and coincidence combinations of Scintillation Spectrometers were setup. A fast neutron generator was also developed using a 600 kV deuteron cascade multiplier type of accelerator built in the laboratory. This facility enabled



studies of fast neutron-induced-nuclear reactions of interest for "fusion physics" which would be the future source of power.

Subsequently, to promote applied aspects of nuclear physics, a "Centre for Nuclear Techniques" was set-up with the assistance of DAE in 1982. At present a number of investigations on applications of nuclear isotopes in medicine, biology and engineering are being carried out with these facilities. Recently, the DAE has accepted to provide a 100 KW nuclear reactor to further promote these applied aspects of work.

Professor Rangadhama Rao was a typical physicist intrinsically interested in spectroscopy of radiations, all over the electromagnetic spectrum and study of physics in all its aspects. He successfully laid down the foundations and provided guidelines for developing these aspects to the present state, as seen at Andhra University today. Starting from Professor DS Kothari, several Chairman of UGC accepted that physics at Andhra University was the biggest such department, if one considers all related-physics-departments together. There were even suggestions to combine them into one "grand physics department" to provide to it national and international visibility. But perhaps because of several "human problems" such suggestions may not work out in the present times.

Professor KR Rao was a man of few words and was soft-spoken. He was a Gandhian in principle. He was very unassuming and was never seen to exhibit the craving for name and fame. He had a strong opinion that if any student failed to get the research degree, the responsibility had to be borne by the Director. He also used to express that a research worker should get on to the dias only when he does the work. He always liked systematic investigations rather than ad-hoc or sporadic type of work.

He was very kind to the people in need and helped them tide over the financial difficulties which was not known to many outsiders. He had a very good taste for classical Carnatic music. He was mostly seen in the university in fullsuit (with tie) in Khadi. His devotion to the work, his sincerity, and systematic approach and hard work, unassuming nature, simplicity, and soft-spokenness are some of the significant characteristic features which every scientist has to emulate. He is remembered with utmost respect affection appreciation and admiration.

C SANTHAMMA
Principal Investigator
Dept. of Physics
Andhra University, Visakhapatnam-530 003.



BIBLIOGRAPHY

- 1927 *Proc. Phy. Soc.* **39**, 16.
- *Curr. Sci.* **13**, 72.
- 1931 (With BADAMI) *Proc. Roy. Soc. Lond.* **131**, 154.
- 1934 (With SUBBA RAO A) *Proc. Phy. Soc.* **46**, 53.
- 1937 (With KRISHNA MURTHY SG) *Proc. Roy. Soc. Lond.* A161, 38.
- 1941 (With SUNDRA RAO AL) Visible absorption bands of mercuric halides HgCl, HgBr & HgI. *Ind. J. Phy.* 393.
- (With GOWRINADHA SASTRY) Ultraviolet band spectrum of mercuric chloride. *Proc. Nat. Inst. Sci.* **7**, 351.
- (With GOWRINADHA SASTRY) Structure of the electronic bands of the OD molecule. Part I. *Ind. J. Phy.* **15**, 27.
- 1942 (With GOWRINADHA SASTRY) Structure of the electronic bands of the OD molecule. Part III. *Ind. J. Phy.* 455.
- (With GOWRINADHA SASTRY) Structure of electronic bands of OD molecules. *Part-IV Ind. J. Phy.* 27.
- (With GOWRINADHA SASTRY) Structure of the electronic bands of the OD molecules Part V. *Ind. J. Phy.* 169.
- (With GOWRINADHA SASTRY) Structure of the electronic bands of the OD molecules. Part VI. *Ind. J. Phy.* 343.
- 1943 (With GOWRINADHA SASTRY) Intensity distribution in molecular spectra. Class I systems of HgCl and HgBr. *Ind. J. Phy.* 141.
- 1944 (With GOWRINADHA SASTRI) Ultraviolet band system of mercury iodide molecule. Part I. *Ind. J. Phy.* **18**, 323.
- (With KRISHNA MURTHY VG) UV band systems of the Hgl molecule. *Ind. J. Phy.* **18**, 323.
- 1945 (With RAMAKRISHNA RAO V) *Proc. Roy. Soc. A* 161, 38, 1937.
- (With RAMAKRISHNA RAO V) New ultra--violet bands of mercury iodide *Curr. Sci.* **14**, 319 Dec.
- (With KRISHNA MURTHY V) UV Band systems of the Hgl molecule. *Curr. Sci.* **14**, 69.
- 1946 (With RAMAKRISHNA RAO V) Bands in the copper ARC *Curr. Sci.* **3**, 69, Mar.
- (With RAMAKRISHNA RAO V) Ultra-violet bands of mercury iodide *Curr. Sci.* **3**, 70.
- (With RAMAKRISHNA RAO V) Ultra-violet band system of the mercury iodide molecule, Part II *Ind. J. Phy* **147**, XX.
- (With RAO PT) Ultraviolet bands of zinc iodide *Curr. Sci.* **15**, 122.
- (With RAO PT) Ultraviolet bands of zinc iodide *Ind. J. Phy.* **20** 49.
- (With RAMA SASTRY C) Ultraviolet bands of mercury iodide. Part III. *Ind. J. Phy.* 143.
- (With RAMA SASTRY C AND RAO KR) Note on the emission bands of silver iodide molecules *Ind. J. Phy.* 136.
- 1948 (With RAMA SASTRY C) Ultraviolet bands of mercury iodide. Part IV, *Ind. J. Phy*-95.
- (With RAMA SASTRY C) A source of continuous spectrum in the ultraviolet. *Ind. J. Phy.*



- (With SASTRY CR AND KR RAO) Band spectrum of carbon disulphide. Part I. (Triatomic molecules CS_2). *Ind. J. Phy.* 313.
- (With SASTRY CR) Ultraviolet bands of the zinc iodide molecule. Part II. *Ind. J. Phy.* 22, 119.
- (With SASTRY CR) The Band spectrum of cadmium chloride. *Ind. J. Phy.* 267 1948.
- (With RAMAKRISHNA RAO V) Multiplet separation in complex spectra of d^3 & d^4 configurations. *Ind. J. Phy.* 22, 175.
- (With RAMAKRISHNA RAO V) Multiplet separation in complex spectra, Part II *Ind. J. Phy.* 22, 189.
- (With RAMAKRISHNA RAO V) Term values in complex spectra (Columbium I & II). *Ind. J. Phy.* 22, 429.
- (With RAO PT) Band spectrum of thallium iodide *Curr. Sci.* 17, 121.
- (With RAO PT) Band spectrum of thallium iodide *Curr. Sci.* 17, 182.
- (With RAO PT) Manganese chloride emission band *Curr. Sci.* 17, 209.
- (With SREE RAMA MURTHY K) Far ultra-violet emissions bands of phosphorous. *Curr. Sci.* 17, 119.
- 1949 (With RAMAKRISHNA RAO V) Note on a correction by Laporte to Ostrofsky's Formulae. *Curr. Sci.* 18, 435.
- (With RAMAKRISHNA RAO V) The band Spectrum of chromium chlorode. *Curr. Sci.* 18, 72.
- (With RAMAKRISHNA RAO V) The Complex Spectrum of the Diatomic molecules of Chromium chloride ($CrCl$) *Ind. J. Phy.* 23, 505.
- (With RAMAKRISHNA RAO V) The band spectrum of chrome bromide *Curr. Sci.* 13, Sept.
- (With RAMAKRISHNA RAO V) The band spectrum of $TiCl$ *Curr. Sci.* 19, 245.
- (With RAMAKRISHNA RAO V) The band spectra of titanium chloride (The diatomic molecule $TiCl$) *Ind. J. Phy.* 23, 535.
- (With RAMAKRISHNA RAO V) Forty electron system of molybdenum Mo III. *Ind. J. Phy.* 23, 258.
- (With RAMAKRISHNA RAO V) Forty one electron system of molybdenum Mo II. *Ind. J. Phy.* 23, 387.
- (With SASTRY CR) Ultraviolet Bands of the zinc iodide molecule. Part III. *Ind. J. Phy.*, 35.
- (With RAO PT) Band spectrum of thallium iodide *Ind. J. Phy.* 23, 185.
- (With RAO PT) New Band system of $TiCl$ molecule *Curr. Sci.* 18, 42.
- (With RAO PT) Emission spectrum of lead iodide *Ind. J. Phy.* 23, 321.
- (With RAO PT) Emission spectrum of lead iodide *Curr. Sci.* 18, 8.
- (With RAO PT) Emission spectrum of bismuth iodide *Curr. Sci.* 18, 42.
- (With RAO PT) Emission spectrum of Bismuth iodide *Ind. J. Phy.* 23, 379.
- (With RAO PT) Emission spectrum of manganese halides *Curr. Sci.* 18, 245.
- (With RAO PT) Emission spectrum of diatomic halides of manganese-Part I $Mn Cl$ *Ind. J. Phy.* 23, 301.
- (With RAO PT) Emission spectrum of Manganese halides *Ind. J. Phy.* 23, 517.
- (With RAO PT) Thallium isotopic effect in the band spectrum of thallium bromide *Ind. J. Phy.* 23, 365.
- (With RAO PT) New band of $TiCl$ molecule *Ind. J. Phy.* 23 393.



- (With SREE RAMA MURTHY K) Ultra-violet absorption spectrum of Iodobenzene. *Curr. Sci.* **18**, 418.
- (With SREE RAMA MURTHY K) Spectrum of Monobromobenzene. *Curr. Sci.* **18**, 437.
- 1950 (With RAMAKRISHNA RAO V) Some new relations in the integral factors & the general case of Electron Configuration. *Ind. J. Phy.* **24**, 257.
- (With RAMAKRISHNA RAO V) Term values in the f^3 electron configuration. *Diatomic molecular spectro curr. sc.* **19**, 8.
- (With RAO PT) Absorption Spectrum of thallium halides *Curr. Sci.* **19**, 174.
- (With RAO PT) Absorption Spectrum of thallium halides *Ind. J. Phy.* **24**, 434.
- (With SURYANARAYANA RAO K) Term values of f^4 electron configuration. *Ind. J. Phy.* **24**, 51.
- (With SURYANARAYANA RAO K) Multiplet separations in the f^4 electron configuration. *Ind. J. Phy.* **24**, 296.
- (With SREE RAMA MURTHY K) Band spectrum of Zinc bromide. *Proc. of Nat. Inst. Sci.* **16**, 305.
- (With SREE RAMA MURTHY K) Absorption spectrum of Anisole. *Ind. J. Phy.* **24**, 421.
- (With SREE RAMA MURTHY K) Absorption spectrum of Anisole. *Curr. Sci.* **19**, 48.
- 1951 (With SREE RAMA MURTHY K) Absorption spectrum of p-cresol. *Ind. J. Phy.* **25**, 125.
- (With SREE RAMA MURTHY K) Electronic Bands of Para-dibromobenzene. *Curr. Sci.* **20**, 176.
- (With SREE RAMA MURTHY K) The near Ultra-violet absorption spectrum of pseudocumene. *Proc. of Nat. Inst. Sci.* **17**, 305.
- (With SREE RAMA MURTHY K) Ultra-violet absorption spectrum of Cresol Part I. Paracresol. *Trans Faraday* **47**, 1256.
- (With SREE RAMA MURTHY K) Absorption spectrum of 3-Chloro-thionaphthene. *Curr. Sci.* **22**, 296.
- (With SREE RAMA MURTHY K) Absorption spectrum of 3-Chloro-thionaphthene. *Proc. of Natl. Inst. Sci.* **20**, 318.
- (With KRISHNA MURTHY VG) $5\pi - 5\epsilon$ Electronic transition in cobalt chloride. *Curr. Sci.* **20** 323.
- Electronic bands of certain benzene derivatives *Curr. Sci.* **20** 291.
- 1952 (With KRISHNA MURTHY VG) $5\pi - 5\epsilon$ Electronic transition in cobalt chloride. *Ind. J. Phy.* **26**, 177.
- (With KRISHNA MURTHY VG) The Complex band spectra of NiCl. *Curr. Sci.* **21**, 66.
- (With KRISHNA MURTHY VG) Complex Band spectra of NiBr. *Curr. Sci.* **21**, 98.
- (With SURYANARAYANA RAO K) Spin splitting of 5 & 6 electron status. *Ind. J. Phy.* **26**, 47.
- (With KRISHNA MURTHY VG) Electronic transitions in complex hand spectra of NiCl. *Curr. Sci.* **21** 37.
- (The complex land Spectra of NiCl. *Curr. Sci.* **26** 207.
- (With SURYANARAYANA RAO K) High multiplicity states in diatomic molecules. *Ind. J. Phy.* **26**, 254.
- (With VISWANADH G) Absorption spectrum of P-chloro-toulene. *Ind. J. Phy.* **26**. 263.
- (With VISWANADH G) Absorption spectrum of acetophenone. *Curr. Sci.* **21**, 159.
- (With VISWANADH G) Calculation of electronic energy levels of indene. *Curr. Sci.* **21**, 275.
- (With VISWANADH G) Electronic spectra of molecules containing six and five membered rings Part I. Calculation of energy levels of Indene. *Ind. J. Phy.*



- (With VISWANADH G) Ultraviolet absorption spectra of halogenated toluenes. *Curr. Sci.*
- (With VISWANADH G) Absorption spectra of ortho and meta Toluene. *Proc. Nat. Inst. Sci.*
- (With VISWANADH G) Absorption spectrum of Ortho bromo toluene. *Ind. J. Phy.*
- (With VISWANADH G) Electronic spectra of molecules containing six and five membered rings. Part-II. *Ind. J. Phy.*
- (With VISWANADH G) Absorption spectrum of Indene. Absorption spectrum of thiophene and Indene. *Curr. Sci.*
- 1953 (With PREMSWARUP D) The complex band spectrum of Diatomic molecules CbO in the photographic infrared. *Ind. J. Phy.* **28**, 399.
- (With PREMSWARUP D) Intensity formula for bands involving high multiplicity terms. Part-I, 5ϵ - 5ϵ & 6ϵ - 6ϵ transitions. *Ind. J. Phy.* **27**, 415.
- (With PREMSWARUP D) Intensity formula for bands involving high multiplicity terms. Part-II, 5π - 5ϵ & 5π - 6π transitions. *Ind. J. Phy.* **27**, 578.
- (With SURYANARAYANA RAO K) Intensities $4-4$ transitions. *Ind. J. Phy.* **27**, 268.
- (With SANTHAMMA C) a) Force constants for BF_3 molecule. *Curr. Sci.* **22**, 298.
- 1954 (With PREMSWARUP D) Intensity formula for bands involving high multiplicity terms. Part-III, 6π - 6ϵ & 6π - 6π transitions. *Ind. J. Phy.* **28**, 48.
- (With PREMSWARUP D) Calculation of perturbations in certain molecular electronic terms Part - I. 2ϵ - 4π *Ind. Phy* **28** 256.
- (With PREMSWARUP D) Calculation of perturbations in certain molecular electronic terms Part - II. 2π - 4ϵ , 2π - 4π , 4ϵ - 4π & 4π - 4π . *Ind. J. Phy.* **28**, 581.
- (With SLNG KRISHNAMACHARI) Force constants for methyl cyanide & methyl isocyanide. *Ind. J. Phy.* **28**, 463.
- (With SLNG KRISHNAMACHARI) The calculated thermodynamic properties of carbonyl fluoride. *Curr. Sci.* **23**, 397.
- (With SANTHAMMA C) b) Force Constants for BF_3 molecule. *Proc. Nat. Inst. Sci.* **20**, 245.
- (With SANTHAMMA C) a) The Force constants for the non-planar vibrations of 1, 3, 5- trimethyl benzene preliminary report. *Curr. Sci.* **23**, 18.
- (With SANTHAMMA C) b) Force constants for 1, 3, 5 trimethyl benzene. *Proc. Nat. Inst. Sci.* **20**, 576.
- (With RAO DVGLN) Calculation of dipole moments of H_2S & AsH_3 . *Curr. Sci.* **23**, 324.
- (With RAO DVGLN) Dipole moments of Indene. *Curr. Sci.* **23**, 336.
- (With RAMA MURTHY S) Theoretical calculation of shifts in substituted benzenes. *Ind. J. Phy.* **28**, 325.
- 1955 (With SURYANARAYANA RAO K) Rotational analysis of Columbium oxide bands. *Nature* **173**, 1240.
- (With SURYANARAYANA RAO K) Rotational analysis of Columbium bands. *Proc. of Nat. Inst. Sci.* **21A**, 219.
- (With SURYANARAYANA RAO K) Further investigations on Columbium bands. *Proc. of Nat. Inst. Sci.* **21A**, 188.
- (With SURYANARAYANA RAO K) Further investigations on Columbium bands. *Proc. of Nat. Inst. Sci.* **21A**, 188.
- (With PREMSWARUP D) Vibrational analysis of Tantalum oxide bands. *Curr. Sci.* **24**, 57



- (With PREMSWARUP D) Vibrational analysis of Tantalum oxide bands. *Ind. J. Phy.* **29**, 109.
- (With PREMSWARUP D) Rotational analysis of Tantalum oxide bands. *Nature*, **175**, 1003.
- (With RAO DVGLN) Calculation of dipole moments of Tri substituted benzenes. *IJP*, **29**, 49-54.
- (With RAO DVGLN) Dipole moments of Indene. *IJP*, **29**, 398.
- (With RAO DVGLN) Dipole moments of 2,4-dinitro Fluoro benzene. *Curr. Sci.* **24**, 407.
- (With SANTHAMMA C.) Force constants for BCl_3 molecule. *Curr. Sci.* **24**, 262.
- (With SANTHAMMA C) The inverse kinetic energy matrix elements for the out of plane variations in furan, pyrrole, thiophene, cyclopentadiene & their substituted compounds. *Ind. J. Phy.* **30**, 429.
- (With KRISHNAMACHARI SLNG) Force constants for Germanes. Part I GeH_3Cl & GeD_3Cl . *Ind. J. Phy.* **29**, 147.
- (With KRISHNAMACHARI SLNG) Force constants for substituted germanes. Part II GeCl_3H & GeCl_4 . *Ind. J. Phy.* **29**, 364.
- (With KRISHNAMACHARI SLNG) Raman Spectrum of o-chloroethyl-benzene. *Ind. J. Phy.* **29**, 254.
- (With KRISHNAMACHARI SLNG) The ultra-violet absorption spectrum of O fluorochlorolengene. *Ind. J. Phy.* **29** 603.
- 1956 (With BHUPALA RAO Y) Structure of the spectrum of bromine Br. II and III. *Ind. J. Phy.* **30**, 95.
- (With BHUPALA RAO Y) Experimental technique involved in the production and measurement. Identification of the spectrum due to different stages of ionization of atoms from photographic IR to Vac. UV region (λ 350 AU). *Ind. J. Phy.* **30**, 371.
- (With SANTHAMMA C) Contribution of electronic repulsion to the energy of the molecular states of furan, pyrrole and thiophene. *Proc. Nat. Inst. Sci.* **22**, 204.
- (With SANTHAMMA C) The near Ultra-violet absorption spectrum of 2,5-dimethyl furan. *Trans. Faraday. Soc.* **53**, 1069.
- (With SANTHAMMA C) The near Ultra-violet absorption spectrum of 2-Furfuraldehyde. *Proc. Nat. Inst. Sci.* **22**, 216.
- (With SANTHAMMA C) Near ultraviolet absorption spectra of certain substituted hetrocyclic compounds. *Curr. Sci.* **25**, 49.
- (With KRISHNAMACHARI SLNG) The Ultra-violet absorption spectrum of m-Fluorochlorobenzene. *Ind. J. Phy.* **30**, 151.
- (With KRISHNAMACHARI SLNG) Raman Spectrum of m-fluorochlorobezene *Curr. Sci.* **25** 355.
- (With KRISHNAMACHARI SLNG) Infrared spectrum of O fluorochlorobenzene. *Curr. Sci.* **25** 355.
- (With KRISHNAMACHARI SLNG) Raman spectrum of o-Fluorobromobenzene. *Curr. Sci.* **25**, 185.
- (With KRISHNAMACHARI SLNG) The Ultra-violet absorption spectrum of o-Fluorochlorobenzene. *Ind. J. Phy.* **30**, 151.
- (With KRISHNAMACHARI SLNG) The Ultra-violet absorption spectra of p-Flurochlorobenzene. *Ind. J. Phy.* **30**, 319,
- (With KRISHNAMACHARI SLNG) The Ultra-violet absorption spectra of o, m, p-Flurochlorobenzenes. *Ind. J. Phy.* **30**, 487.
- (With RADHAKRISHNA MURTHY C) On the determination of dipole-moment & relaxation time at 3 cms. *J. Sci. Ind. Res.* **15B**. 346.
- (With RADHAKRISHNA MURTHY C) Dipole moment of some substituted benzenes and pyridine. *J. Sci. Ind. Res.* **15B**, 260.



- (With RADHAKRISHNA MURTHY C) On the determination of dipole-moment & relaxation time at 3 cms. *Curr. Sci.* **25** 49.
- (With RAMA MURTHY S) a) The Ultraviolet absorption of 2-fluoro naphthalene. *J. Sci. Ind. Res.* **15B**, 262.
- (With GOPAL KRISHNA KV) Dielectric properties of ethyl acetate in the ultra high frequency region. *Curr. Sci.* **35**, 49,
- (With GOPAL KRISHNA KV) Calculation of dipole moments of the tetra substituted benzenes Part I. *Ind. J. Phy.* **30**, 206.
- (With GOPAL KRISHNA KV) A new method for computing the complex dielectric constant from ultra high frequency impedance measurements. *Trans. Faraday. Soc.*, **52**, 1710.
- (With GOPAL KRISHNA KV) A method for measuring the dipole moment and relaxation time from microwave measurements. *Trans. Faraday. Soc.*
- (With GOPAL KRISHNA KV) Dipole moments of some esters.
- (With GOPAL KRISHNA KV) Calculation of dipole moments of the tetra-substituted benzenes Part II. *Ind. J. Phy.*
- (With GOPAL KRISHNA KV) Dielectric relaxation - Influence of Chain Length.
- (With GOPAL KRISHNA KV) Dielectric relaxation - Influence of temperature
- (With GOPAL KRISHNA KV) Dipole moments of some tetra-substituted benzenes.
- (With RAO DVGLN) Dielectric properties of 2,4-Dinitro fluoro benzene. *IJP*, **30**, 91-94.
- (With RAO DVGLN) Dipole moments and relaxation times of mono halogenated benzenes. *J. Sci & Ind. Res.* **15B**, 350.
- (With RAO DVGLN) Determination of dipole moments and relaxation times at 3 cms. *J.Sci. & Ind. Res.* **15B**, 346.
- (With RAO DVGLN) Determination of dipole moments and relaxation times at 3 cms. *Curr. Sci.* **25**, 49.
- (With RAO DVGLN) Dipole moments of ethylene chloro & bromohydrins. *Curr. Sci.* **25**, 217.
- (With RAO DVGLN) Dipole moments of Trisubstituted benzenes.
- (With RAO DVGLN) Dipole moments of Trisubstituted benzenes. Part I, *IJP*, **30**, **11**, 582-583.
- 1957 (With SANTHAMMA C) Shifts in wave number of the electronic transitions due to substitution for furan, pyrrole and thiophene. *Proc. Nat. Inst. Sci.* **23**, 522.
- (With KRISHNAMACHARI SLNG) Infrared and Raman absorption spectrum of ortho and meta-fluorobromo, fluoroiodo and bromochloro benzenes. *Curr. Sci.* **26**, 144.
- (With KRISHNAMACHARI SLNG) The Ultra-violet absorption spectra of o, m, p-fluoroiodo and bromochloro benzenes. *Ind J. Phy.* **31**, 387.
- (With KRISHNAMACHARI SLNG) Analysis of the near ultraviolet absorption spectra of o,m, p-Fluorochloro benzenes vapours. *Ind. J. Phy.* **31**, 447.
- (With RADHAKRISHNA MURTHY C) Dipole moment and relaxation times of mono halogenated benzenes. *J. Sci. Ind. Res.* **15B**. 350.
- (With RADHAKRISHNA MURTHY C) Relaxation time and nature of orienting light. *J. Sci. Ind. Res.* **16B**, 334.
- (With RADHAKRISHNA MURTHY C) Dipole moments of some substituted benzenes and pyridines Part I, Fluorotoulenes. *Ind. J. Phy.* **31**, 256.



- (With RAO DVGLN) Dipole moments of Trisubstituted benzenes. Part II, *IJP*, **31**, 60.
- (With RAO DVGLN) Dipole moments of Trisubstituted benzenes. Part III, *IJP*, **31**, 334.
- (With RAO DVGLN) Calculation of dipole moments of H_2S & PH_3 . *Trans. Far. Soc.* **53**, 1160.
- 1958 (With RADHAKRISHNA MURTHY C) Study of variation of relaxation time with solvent. *J. Sci. Ind. Res.* **17B**, 441.
- (With RADHAKRISHNA MURTHY C) Dipole moments of some substituted benzenes and pyridines Part II, meta disubstituted benzenes. *Ind. J. Phy.* **32**, 365.
- (With RADHAKRISHNA MURTHY C) Dipole moments of some substituted benzenes and pyridines Part III, chloro & bromo ethyl benzenes. *Ind. J. Phy.* **32**, 492.
- (With RADHAKRISHNA MURTHY C) Dipole moments of some substituted benzenes and pyridines. *Ind. J. Phy.* **32**, 516.
- (With RADHAKRISHNA MURTHY C) On the calculation of relaxation times. *Ind. J. Phy.* **32**, 580.
- (With SHOBANADHRI J) Dielectric relaxation in relation to viscosity. I. *J. Sci. Ind. Res.* **18B**, 508.
- (With SHOBANADHRI J) Relaxation time of alcohols. *J. Sci. Ind. Res.* **17B**, 202.
- (With LAKSHMINARAYANA B) Absorption of Ultra high frequency radiowaves in substituted anilines. *J. Sci. Ind. Res.* **17B**, 173.
- (With RAMA MURTHY S) b) Analysis of the near ultraviolet absorption spectrum of 2-fluoro naphthalene. *Ind. J. Phy.* **31**, 497.
- Evaluation of Electronic shifts in fluorinated naphthalenes. *Ind. J. Phy.* **30**, 584
- 1959 (With RADHAKRISHNA MURTHY C) Determination of dipole moments from measurements on pure liquids. *J. Sci. Ind. Res.*, **18B**, 268.
- (With SANTHAMMA C) The near Ultra-violet absorption spectrum of Pyrrolidine. *Proc. Nat. Inst. Sc.* **25** 77.
- (With SHOBANADHRI J) Temperature variation of dielectric relaxation in six polar liquids. *Ind. J. Phy.* **33**, 511.
- (With LAKSHMINARAYANA B) Relaxation times of some alcohols and esters. *J. Sci. Ind. Res.* **8B**, 304.
- (With MURLIDHAR RAO V) Ultra-high frequency absorption in liquid mixtures. *J. Sci. Ind. Res.*, **18B**, 103.
- (With NAGARAJAN V) Observations on Nuclear Magnetic Resonance, variation of spin relaxation time with concentration of paramagnetic ion and viscosity of the medium. *J. Sci. Ind. Res.* **18B**, 84.
- 1960 (With SHOBANADHRI J) Dielectric relaxation and dipole-dipole interactions. *Trans. Farad. Soc.* **56**, 965.
- (With SHOBANADHRI J) Dipole moments & ionic character for PCl_3 , PF_3 & NF_3 . *Proc. Nat. Inst. Sci.* **26A**. 110.
- (With SHOBANADHRI J) Calculations on ionic character and hybridisation from dipole moments for AsF_3 and $AsCl_3$. *Proc. Phy. Soc.* **76**, 267.
- (With SHOBANADHRI J) A method for evaluating relaxation time from microwave measurements at a single frequency. *Trans. Farad. Soc.* **56**, 340.
- (With SHOBANADHRI J) Dielectric relaxation in relation to temperature II. *Ind. J. Phy.* **34**, 217.



- (With SHOBANADHRI J) Dipole moment and relaxation time of certain Trisubstituted benzenes. *Ind. J. Phy.* **34**, 577.
- (With LAKSHMINARAYANA B) A new relation between Cole-Cole distribution parameters and temperature. *J. Sci. Ind. Res.* **19B**, 114.
- (With LAKSHMINARAYANA B) Dielectric dispersion of polar liquids-Part I, asymmetric dispersion in glycerol. *J. Sci. Ind. Res.* **19B**, 329.
- (With SAROJINI V) Study of the dielectric behaviour of liquid mixtures (Binary Mixtures) Part I. *J. Sci. Ind. Res. Vol.* **19B**, 91.
- (With SAROJINI V) Study of the dielectric behaviour of liquid mixtures. (Binary Mixtures - contd.) Part II. *J. Sci. Ind. Res. Vol.* **19B**, 91.
- (With SAROJINI V) Study of the dielectric behaviour of liquid mixtures. (Binary Mixtures) Part III. *J. Sci. Ind. Res. Vol.* **19B**, 115.
- (With SAROJINI V) Study of Dielectric behaviour of methanol-1 propanol mixtures. *J. Sci. Ind. Res.*
- (With SAROJINI V) Study of Dielectric behaviour of Ethyl alcohol + Diethylene glycol mixtures. *J. Sci. Ind. Res.*
- 1961 (With SHOBANADHRI J) Dielectric relaxation in relation to viscosity II. *J. Sci. Ind. Res.* **20B**, 42.
- (With LAKSHMINARAYANA B) Dielectric dispersion on polar liquids-effects of temperature. *J. Sci. Ind. Res.* **20B**, 46.
- (With LAKSHMINARAYANA B) Dielectric dispersion of polar liquids-Part V, Ethyl cinnamate. *J. Sci. Ind. Res.* **20B**, 153.
- (With LAKSHMINARAYANA B) Dielectric dispersion of polar liquids-Part VI, Secondary dispersion in certain alcohols. *J. Sci. Ind. Res.* **20B**, 568.
- (With SAROJINI V) Dielectric behaviour of certain alcohol-diox as mixtures. *Trans. Faraday. Soc.*
- (With SAROJINI V) Dielectric behaviour of certain alcohol-benzenes and alcohol-water mixtures. *Trans. Faraday. Soc.*
- (With MURLIDHAR RAO V) Dipole moment and relaxation time of 2-amino-methyl-pyridines. *J. Sci. Ind. Res.*, **20B**, 81.
- 1962 (With SHOBANADHRI J) Dielectric relaxation in relation to viscosity. III. *J. Sci. Ind. Res.* **21B**, 17.
- (With SHOBANADHRI J) Dielectric Relaxation in relation to temperature III. *Ind. J. Phy.*
- (With NAGARAJAN V) Chlorine pure quadropole resonance in solids. *Curr. Sci.* **31**, 233.
- (With NAGARAJAN V) Chlorine pure quadropole resonance in some multi-substituted benzenes. *Curr. Sci.* **31**, 279.
- (With NAGARAJAN V) Chlorine pure quadropole resonance in substituted benzenes. *Ind. J. Pure & Applied Phy.* 1962.
- (With NAGARAJAN V) NQR Zeeman Spectrum of 2,5-dichloronitrobenzene.
- (With NAGARAJAN V) NQR Zeeman Spectrum of 6-chloro-2-nitro toluene.
- (With NAGARAJAN V) Crystal structure and bond character study in 2,5-dichloro nitrobenzene by NQR.
- (With RAMAKRISHNA J) Temperature dependence of iodine pure quadropole resonance frequency in methyl iodide. *Proc. Phy. Soc.* **79**, 1069.
- 1963 (With BHANUMATHI A) Eyring's equation of relaxation time and dipole-dipole interaction energy- I, measurements in pure liquids. *Ind. Journal of Pure and Applied Physics.*



- (With BHANUMATHI A) Eyring's equation of relaxation time and dipole-dipole interaction energy-II, dilute solutions measurements. *Indian Jour of Pure and Applied Physics*.
- (With A BHANUMATHI) Eyring's equation of relaxation time and dipole-dipole interaction energy-III, estimation of the interaction energy. *Indian Jour of Pure and Applied Physics*.
- (With HARNADH C) Dielectric relaxation in polar liquids-Tetra hydro furfural alcohol, 2-methyl-2,4-pentanediol and 1,5-Pentanediol. *Trans Farraday Soc.* 59 2728.
- (With HARNADH C) Dielectric dispersion in certain aldehydes. *Ind. J. Pure & Applied Phy.*
- (With HARNADH C) Dielectric dispersion in aromatic esters-phenyl acetates. *Ind. J. Pure & Applied Phy.*
- (With HARNADH C) Spectroscopic determination of relaxation times. *Ind. J. Pure. & Applied. Phy.*
- (With HARNADH C) Asymmetric dispersion in glycol-dipropylene and chloropropylene glycols and 1,3-Propanediol.
- (With HARNADH C) Measurement of complex Dielectric constant in certain liquids at 8mm.
- (With HARNADH C) Effect of dilution on the asymmetric dispersion of glycols.
- (With HARNADH C) Dielectric relaxation in Iso Amylnitrite, Iso Amyl chloride and Hexamethylene glycol.
- (With RAMAKRISHNA J) Temperature dependence of Iodine pure quadrapole resonance frequency in iodic acid. *Proc. Nat. Inst. of Sci.* 29A (5).
- (With RAMAKRISHNA J) Temperature dependence of Iodine pure quadrapole resonance frequency. *Ind. J. Pure and Applied Physics*.
- (With RAMAKRISHNA J) Electric field gradients in ionic crystals nuclear quadropole resonance in mercuric chloride. *Trans. of Faraday Soc.*
- (With RAMAKRISHNA J) Temperature dependence and certain other features of chlorine pure nuclear quadropole resonance frequency in certain chlorine derivatives of benzene.
- (With RAMAKRISHNA J) Electric field gradients in ionic crystals nuclear quadropole resonance in cuprous oxide.
- (With RAMAKRISHNA J) Electric field gradients in ionic crystals nuclear quadropole resonance in Cuprous oxide.
- (With RAMAKRISHNA J) Electric field gradients in ionic crystals nuclear quadropole resonance in sodium chlorate and potassium chlorate.
- (With RAMAKRISHNA J) Zeeman Effect of chlorine nuclear quadropole resonance line in mercuric chloride.
- (With LALITHA DV) Calculation of electric field gradients and nuclear quadropole coupling constants in chrysoberyl. *IJPAP*, 2, 404,
- (With LALITA DV) Quadropole interactions in chrysoberyl.
- (With LALITA DV) Calculations of g-factors and zero field splitting for Cr⁺⁺⁺ in β Ga₂O₃.
- (With LALITA DV) NQR in doped sodium chloate.
- 1965 (With RAMAKRISHNA RAO KS) Dielectric constants of 2-methoxy 4- nitroaniline and 2-methoxy 5-nitro aniline. *Cur. Sci.* 34, 455.
- (With RAMAKRISHNA RAO KS) Measurements on the dielectric constant and loss for certain solid disubstituted anilines at 3 cm, wavelength. *Ind. J. Pure and Applied Physics*.
- (With RAMAKRISHNA RAO KS) Measurements of the dielectric constant and loss for certain disubstituted anilines Part-II, R.F. region. *Ind. J. Pure and Applied Physics*.



- (With RAMAKRISHNA RAO KS) Dielectric dispersion in ortho and meta hydroxy anilines. *Ind. J. Pure and Applied Physics*.
- (With RAMAKRISHNA RAO KS) Dielectric dispersion of aromatic ketones temperature cycle at a single frequency. *Canadian Journal of Physics*.
- (With RAMAKRISHNA RAO KS) Dielectric dispersion of aromatic ketones frequency variation at three different temperatures. *Ind. J. Pure and Applied Physics*.
- (With RAMAKRISHNA RAO KS) Variation of the distribution parameter and with temperature in certain solid substances. *Ind. J. Pure and Applied Physics*.
- (With RAMAKRISHNA RAO KS) Anomalous variation of the dielectric properties of carboxylic acid water mixtures. *Ind. J. Pure and Applied Physics*.
- (With RAMAKRISHNA RAO KS) Dipole moment determination of 2-methoxy, 4-nitro aniline and ortho hydroxy aniline. *Current Science*.
- (With RAMAKRISHNA RAO KS) Determination of dielectric constant of a chalcone and chalcone epoxide. *Ind. J. Pure and Applied Physics*.
- 1966 (With SARMA JSM) Nuclear magnetic resonance spectrum of azulene: Calculation of chemical shifts by Johnson and Bovey's method. *Ind. J. Phy.* 4, 365.
- 1966 (With PADMAVATHI G) Dependence of nuclear spin-lattice relaxation time on viscosity Part I Studies in certain liquid mixtures. *IJPAP*, 4, 166.
- 1967 (With PADMAVATHI G) studies on dependence of nuclear relaxation times in paramagnetic solutions. *IJPAP*, 5, 391.
- 1968 (With PADMAVATHI G) Influence of deuterons on proton relaxation times in paramagnetic solutions. *IJPAP*, 6, 216.
- (With PADMAVATHI G) Variation of proton relaxation time in carboxylic acid-water mixtures. *IJPAP*, 6, 292.
- (With PADMAVATHI G) NMR studies of barium diathionate dihydrate ($\text{BaS}_2\text{O}_6 \cdot 2\text{H}_2\text{O}$). *Curr. Sci.*, 11, 311.
- (With PADMAVATHI G) Determination of P-P vectors in single crystals of calcium nitrate tetrahydrate.
- (With PADMAVATHI G) Determination of P-P vectors in single crystals of calcium chlorate dihydrate.
- (With PADMAVATHI G) Proton magnetic resonance study on single crystals of kernite.
- (With SARMA JSM) A study of the motion of water molecules in $\text{NaBr} \cdot 2\text{H}_2\text{O}$ by the NMR method. *J. Chem. Physics*.
- 1969 (With MURTHY PVG K) ESR Study of copper II in tetra methylene diamine chloride. *Ind. J. Phy.* 42, 136.
- (With MURTHY PVG K) ESR study of copper dipyrindine sulphate dihydrate. *Ind. J. Phy.* 43, 725.
- (With MURTHY PVG K) ESR study of copper zinc sulphate heptahydrate. *Ind. J. Phy.* 44, 761.
- 1970 (With MURTHY PVG K) ESR and optical absorption studies on certain copper complexes. *Ind. J. Phy.* 44, 91.
- (With RAMA MURTHY S) Configurational interaction in MO theory as applied to Furan and Pyrrole.
- (With RAMA MURTHY S) Evaluation of one electron coulomb integrals.



ANNEXURE I

List of Scientists who took DSc-PhD under the guidance of Professor KR Rao

Atomic and Ionised Spectroscopy

1934	Dr A Subba Rao	DSc	<i>Atomic Spectroscopy</i>
1934	Dr S Gopalakrishna Murthy	DSc	<i>Atomic Spectroscopy</i>
1949	Dr V Ramakrishna Rao	DSc	<i>Studies in the complex spectra of certain atoms and diatomic molecules</i>
1956	Dr Y Bhupala Rao	DSc	<i>Structure of the spectra of Bromine (Br II and Br III)</i>

Diatomic Molecular Spectroscopy

	Dr Gowrinadha Sastry	DSc	<i>Diatomic Molecular spectroscopy</i>
1948	Dr C Ramasastry	DSc	<i>Band spectra of the diatomic halides of zinc, cadmium and mercury and band spectrum of triatomic molecule CS₂.</i>
1949	Dr V Ramakrishna Rao	DSc	
1949	Dr PT Rao	DSc	<i>Band spectra of the halides of certain heavy elements (Tl, Pb, Bi, Mn)</i>
1952	Dr VG Krishna Murthy	DSc	<i>Structure of the band spectra of the halides of Co and Ni</i>
1951	Dr K Suryanarayana Rao	DSc	<i>Certain Theoretical studies in complex spectra and rotational analysis of Co. O.</i>
1955	Dr D Premaswarup	DSc	<i>Some intensity and perturbation calculations in complex molecular spectra and the structure of the band spectrum of tantalum oxide.</i>

Polyatomic Molecular (Optical) Spectroscopy

1950	Dr K Sree Rama Murthy	DSc	<i>Electronic transitions in certain substituted benzenes in the near ultra violet.</i>
1952	Dr G Viswanadh	DSc	<i>Absorption spectra of certain bicyclic compounds and disubstituted benzenes.</i>
1955	Dr C Santhamma	DSc	<i>Some theoretical and experimental spectroscopic investigations on certain polyatomic molecules</i>
1956	Dr SLNGK Chari	DSc	<i>Calculation of force constants of certain polyatomic molecules and investigations on the Raman effect, infrared and ultraviolet absorption of Fluorinated, Disubstituted Benzenes.</i>



Microwaves and Dielectrics

1956	Dr C Radhakrishna Murthy	DSc	<i>Studies in dielectrics at microwave and radio frequencies.</i>
	Dr Premaswarup	DSc	
1956	Dr KV Gopala Krishna	DSc	<i>Dipole moment calculations of some tetra substituted benzenes and investigations of dipole moments and relaxation times at microwaves frequencies.</i>
1957	Dr DVGLN Rao (USA)	DSc	<i>Certain theoretical and experimental studies in dielectric at microwave and radio frequencies.</i>
1959	Dr J Sobhanadri	DSc	<i>Calculations from dipolemoments of some halides of group V elements and studies on microwve measurements on relaxation times.</i>
1959	Dr B Lakshminarayana	DSc	<i>Experimental investigations on dielectric disperison of certain polar liquids.</i>
1960	Dr V Sarojini	DSc	<i>Experimental investigations on the dielectric behaviour of certain liquid mixtures.</i>
1961	Dr V Muralidhara Rao	DSc	<i>Development of the 8mm technique, measurements on the dielectric dispersion of certain liquids.</i>

