

## Ramaswami Srinivasan – a complete physicist and a teacher par excellence

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If one would like to define a true ‘Karma Yogi’ as described in *Bhagavad Gita*, this person could be a good example. A keen and meticulous experimentalist, a very good theoretician, self-made low temperature physicist, outstanding teacher much admired by his students and above all, a very kind human being – yes all these qualities are of one person. Over the last six decades his untiring services to the physics community in India include seminal contributions to solid state theory, especially to the field of lattice dynamics; setting up of cryogenic and low temperature facilities at IIT Madras; establishing an institute called Inter University Consortium for DAE Facilities (IUC-DAEF) at Indore (now known as UGC-DAE Consortium for Scientific Research) with world class facilities for research in condensed matter physics, especially for Indian university researchers; helping to set up the cold atom research laboratory at Raman Research Institute, Bengaluru; developing novel experiments and conducting Refresher Courses in Experimental Physics for teachers and students from Indian colleges and universities and the list can go on and on. He is Professor R. Srinivasan or RS as he is affectionately known to his colleagues, students and friends. RS is a man of convictions and principles which he never bent to be expedient. He devoted all his attention, energy and time, to any problem he took up and rested only after he had solved it, even if it meant a considerable loss to his personal gain or fame. He never hankered for awards or positions, but did full justice to whatever came to him.

RS was born on 15 December 1931 in Vellore, Tamil Nadu. He was the third among five children born to S. Ramaswami Ayyangar and Rukmani Ammal. The parents inculcated good values in all the five children which stood by RS throughout the various responsibilities he undertook in his career. RS was very religious during his younger days, but his interactions with the world at large modified his outlook to a more pragmatic and mature one. S. Ramaswami Ayyangar was a civil engineer in the Public Works

Department of erstwhile Madras Presidency. Due to the transferrable service of the father, young Srinivasan did most of his schooling in Andhra Pradesh and Chennai. For his intermediate education he joined Loyola College, Chennai and later completed his B Sc (Hons.) from Madras Christian College, Chennai in 1951.

For his Ph D he joined the legendary R. S. Krishnan at the Physics Department, Indian Institute of Science (IISc), Bengaluru. Here he worked on thermal expansion of crystals down to 90 K. After obtaining his Ph D from University of Madras in 1957 (in those days, IISc did not confer degrees) he continued to work at IISc as a post-doctoral fellow. In the next five years he went on to work on the dispersion of photo elastic constants of alkali halides in the UV region and also started theoretical work in lattice dynamics and thermal expansion of crystals. He is very well remembered by his colleagues and seniors for his theoretical and experimental acumen.

RS’s career has many dimensions. He took up many activities and devoted his attention to each one of them fully, as if that was the passion of his life. It is difficult to do justice to all his contributions. If one tries to put all his achievements together, one sees a tall person of enormous inner strength. Here I dare to make an attempt to bring out the different facets of his life as a physicist, a teacher and overall a good human being.

Soon after his Ph D, RS began researching in the area of lattice dynamics. He switched from experiment to theory and started working on the lattice dynamics of Calcium fluoride and Cesium Chloride. That was the time first inelastic neutron scattering studies on the phonon dispersion curves in Germanium were carried out by B. N. Brockhouse and P. K. Iyengar. RS realized that C. V. Raman’s ideas on lattice dynamics of crystals were wrong and worked on Max Born’s lattice dynamics, though being a student of R. S. Krishnan. RS always listened to his heart rather than getting swayed away or buckling to peer pressure. With one of his students, S. Gane-

san, he started working on the lattice dynamics of calcium fluoride. This work was considered a classic piece of investigation and their model was extensively used by others for the calculation of defect properties in fluoride lattices. He worked on the theory of thermal expansion in CsCl structures and the predicted the behaviors of thermal expansion at low temperatures in cesium halides. This was verified experimentally down to liquid helium temperatures.

In 1962, RS joined the Physics faculty of IIT Madras as Assistant Professor. He served this institution for twenty seven years. Here he rose to different ranks to become Professor and Head of the Department of Physics and also to serve in the capacity of Deputy Director of IIT Madras. During this long period, he and his collaborators and students worked on many different aspects of Condensed Matter Physics.

During the first ten years in IIT, he developed the Keating’s approach to the calculation of anharmonic properties of hexagonal metals. He also worked on surface modes in ionic compounds and showed that except for the {100} face of NaCl, all other surfaces of ionic crystals of different systems were unstable to certain surface modes. He critically examined the contribution of the exchange correlation correction of the dielectric screening function of the electron gas to the third order elastic constants of the simple metals. Earlier he visited the Materials Research Laboratory at the Pennsylvania State University as a Senior



RS and his Goa team with participants of a Refresher Course.

Research Associate from 1965 to 1967. In a group meeting Gerhard Barsch introduced the activities of the research group that he was heading at the Materials Research Laboratory. Some of the open theoretical and experimental questions were also discussed. RS took it upon himself to address some of these questions and for the next two years worked independently and single-handedly to produce five major papers (including one landmark paper) that provided the microscopic lattice dynamics foundation for the phenomenological theory of the material coefficients that describe the linear dependence on strain and electric field of the elastic, dielectric and piezoelectric constants including numerical application to fluorite type ionic crystals and covalent group IV elements. He also developed the theory of non-linear Piezo-optics. This opened the doors for the analysis of precision optical measurements at very high pressures and thus to describe in quantitative terms the various non-linear piezo and elasto-optic behaviours observed in a number of materials.

It was almost an accident that he was given the responsibility of developing the cryogenic section at IIT Madras by the then Director of the Institute. He was not a low temperature physicist by training. But he put in diligent work to learn cryogenic techniques. From early mornings to late in the night he helped with practical details, acquainted himself with the special ways and tricks of low temperature technology, learned to run and maintain the liquefiers, planned a set of experiments to train his students and established a low temperature laboratory at IIT. It was an amazing transformation of a competent theorist into a successful experimentalist. With active help from G. Klipping of Freie University, Berlin and other colleagues and students at IIT,



R. Srinivasan with participants during lab session.

he put together a research group working in all areas of low temperature condensed matter physics. With tremendous hard work and enthusiasm of his colleagues, driven by even greater amount of hard work and enthusiasm of RS, this low temperature laboratory became one of the best low temperatures laboratories in the country.

During this period, RS along with his students and collaborators worked on cryopumping and cryosorption pumping, temperature variation of electrical resistivity and thermopower of several Chevral phase compounds, flux penetration in type I superconductors, AC susceptibility of rare earth magnetic pyrochlores, fluctuation effects in high  $T_c$  superconductors, thermal conductivity, thermopower and quasi particle tunneling. As Chairman of DST Programme Advisory Committee in Cryogenics, he also initiated applications programme in the field of cryogenics in India. Several students obtained their Ph D working in this laboratory in low temperature physics. Even two students of biochemistry worked for their Ph D on polyelectrolyte complexes of poly-saccharides.

During a year of sabbatical leave in 1984 at the Institut für Technische Physik at KFK (Karlsruhe), Germany, he made a very useful contribution to the understanding of heat transfer to flowing helium II and losses in the fountain effect pump. He was invited to deliver a lecture on this work as one of the plenary speakers at the International Cryogenic Engineering conference in 1986. The small plant of 'superconducting magnet cooling by forced flow of liquid He-II' that RS planted at KFK, not only survived the era of high  $T_c$  superconductors but grew into a strong tree. More than a decade later, in 1996, KFK demonstrated one of the largest superconducting magnets cooled by fountain effect pumps. The physical basis for this technology was created by RS.

After spending most of his working life at IIT Madras, RS accepted a challenging job of starting up a new institution. He undertook the responsibility with some apprehension. However, the idea of doing something useful for physics community was too tempting and this institution in a way was novel. It involved developing collaborations between University research groups and scientists from Department of Atomic Energy – an idea nurtured by Yash Pal,

M. R. Srinivasan and V. G. Bhide. This institution was known as Inter-University Consortium for Department of Atomic Energy Facilities (IUC-DAEF). Later its name was changed and it is now called UGC-DAE Consortium for Scientific Research (UGC-DAE CSR). RS again put in untiring efforts with a team of dedicated scientists to build state-of-the-art facilities in almost every branch of condensed matter physics from a scratch. He brought in an old liquid nitrogen plant as gift from IIT Madras and a second hand helium liquefier from Freie University, Berlin to start low temperature physics activity. Many young students from Indian Universities, including the author, benefited from the use of these facilities. Based on a report he made, the Department of Science and Technology set up a National Centre for Low temperature High Magnetic Field in UGC-DAE CSR in Indore. Even today, it is like a mecca for many university researchers who generally face fund crunch, to go to UGC-DAE CSR and perform advanced experiments using the state of the art facilities established at the Indore centre of UGC-DAE CSR.

The main objective of UGC-DAE CSR was to make available major DAE facilities like Dhruva Reactor in Trombay, Variable Energy Cyclotron at Kolkata, and the then upcoming synchrotron at RRCAT, Indore and particle irradiation facilities at IGCAR, Kalpakkam and IOP Bhubaneswar to university research groups. Here again, RS with the help of his friends and colleagues in the DAE establishment put together a system of funding collaborative research schemes of University researchers that formally enabled them to make use of these facilities. The proposals submitted by the University researchers were critically evaluated and monitored for their progress every six months. RS in his characteristic style did not hesitate to pull up a University professor, however senior, if the progress of the scheme was not up to the mark. At the same time he also ensured that all facilities were made available to University researchers to achieve the stated objectives of the project.

At the end of his term as Director, UGC-DAE CSR, it was announced that RS would retire to Mysore, where he had built a house. He had many reasons to do that – he had achieved everything one could in one's career, he had built an institution and put in place a successful

working model for that institute to achieve its objectives, and perhaps most importantly his beloved sister was also staying in the neighbourhood. It was the time when cooling of atoms using laser light was just achieved. A few groups around the world had successfully achieved Bose–Einstein condensate of alkali atoms. Not to be left far behind, a few institutions in India also started this activity. The then Director of Raman Research Institute, N. Kumar, requested RS to help Hema Ramachandran to develop an ultra-cold atom laboratory. He toiled shoulder to shoulder with his young colleagues, tightening nuts and bolts, staying up all night, till the objective was achieved. RRI was the second institute in the country to achieve ultra-cold atoms in the laboratory. Hema Ramachandran, recently recounted that RS, despite being injured due to a fall at Indore, came back to Bengaluru and straight to the lab to be with his colleagues.

During the late 1990s the Science Education Panel of the Indian Academy of Sciences (Bengaluru) led by N. Mukunda deliberated on the falling standards of science education in the country. The Academy decided that it would run Refresher Courses for teachers from Indian universities and colleges in order to update their knowledge of the subject. The Panel also decided to run Refresher Courses on both theoretical as well as experimental aspects of Physics, Chemistry and Life sciences. Though courses in theory took off almost instantly, experimental courses need more planning and finances. The responsibility of developing a Refresher Course in experimental physics was entrusted to RS. He found a new mission in his life. He along with the late K. R. Rao carefully formulated the course structure. RS was very clear; that the course in experimental physics should involve experiments that verify different laws of physics. He also decided to embrace modern methods of measurements, which were hitherto only found in research laboratories. For this one needed to build some electronic circuits like a constant current source, a temperature controller, etc. He sought the help of the author, who was then a faculty member at Physics Department of Goa University. Along with couple of other members from the teaching fraternity in Goa, RS conducted the first Refresher Course in Experimental Physics

in Goa in October 2001. In this course, spread over 15 days, every participant had to build a constant current source, a furnace, a power supply and a temperature controller by themselves. There was a tremendous enthusiasm amongst the participants to solder the components, wire the circuits, test them and assemble them in their respective boxes. These were later given as a gift by the Academy to the respective institutions of the participants. The success of this course, made RS work even harder. At the age of 70 he learnt electronics. With the help of his ‘Goa team’, he developed many more experiments and electronic circuits which included a lock-in-amplifier, a signal generator, integrator, non-linear dynamics circuits, measurement of thermal conductivity of copper, measurement of thermal diffusivity of brass, experiment to verify Debye relaxation law, etc. Every year about two courses were conducted. RS wrote to many institutions all over the country to host these courses. After about seven such courses, an exhibition of all experiments developed under this activity was held for physics teachers attending a convention of Indian Association for Physics Teachers (IAPT) at Bengaluru. IAPT suggested that RS should make available these experimental equipment in the market as it would help in popularizing the course. RS found a company to produce these equipment and market them for the Academy. With the availability of the experimental setups, RS took upon himself to conduct many courses per year. He travelled the length and breadth of this country to different institutions and conducted the courses. He built a team of resource persons to help him in doing so. This was a tremendous feat for a person in his eighties. At Bengaluru, he established a permanent laboratory in the Academy’s residential hostel for summer fellows at Jalahalli. T. G. Ramesh joined him and they both planned some advanced



At Mysuru home with RS.

experiments in superconductivity, percolation phenomena, phase transitions, differential scanning calorimetry, etc. These experiments now form a part of another Refresher Course in Materials Science. So much was his dedication to this programme, that he setup a small workshop at his home in Mysuru. Whatever little time he would spend in Mysuru, after his travels for conducting the Refresher Courses, was also used up in development and testing new experiments. Till date more than 50 experiments have been developed and about 87 Refresher Courses in experimental physics have been conducted ranging from Aizwal in the East to Bhavnagar in the West and Srinagar in the North to Trivandrum in the South. This has been one of the flagship programmes of the Joint Science Education Panel of the three science academies in India.

RS is a great teacher, so say all his Ph D and M Sc students. Some of us who had the good fortune of hearing him lecture at short workshops were also swayed away by his characteristic style of making everything simple right down to the ground level. His grasp of the subject was amazing. He would derive everything on the black board and explain things in a very simple and no frills way. He also expected the students to be serious about their work. In that sense he had the image of a hard task master. Nothing made him angrier than utter ignorance of his students. Students used to be scared of discussing Physics with him. But at the same time there was a joy in discussing with him as he would come down to the students’ level of understanding and explain. At this point I would like to share a personal experience. As a Ph D student, I used to visit IUC-DAEF for low temperature resistivity measurements. I was one of the first users of liquid helium. RS was very keen that I get my data and my experiments work successfully. Every morning he would come up and ask me about the progress of my work. So, when I got my first measurements, I was told to go to his room and show him the data. He was very happy to see the resistivity measured down to 4 K. He asked me some questions about my samples and the objectives of my work and then spent the next one hour explaining to me what all I should do to achieve my objectives. This was my first experience with RS as a teacher. A few years later he conducted a

workshop on Theory of Diffraction. Some of us who attended the workshop still vividly remember his lectures and use his notes till date. Even while lecturing at the Refresher Courses, he would involve himself so much that he would readily stand up and explain any difficulty raised by the participants, however trivial or simple.

It is often said that good scientists or academicians are not so good at administration. With RS it was a bit different. His meticulous nature that helped him to be a very good experimentalist, his honesty, dedication and hard work were all put to good use, even when he held different administrative posts. Be it as Deputy Director of IIT Madras or as a Chairman of DST-PAC, he did all the hard work to simplify most complex problems and presented them to his colleagues. All this was never at the cost of academics. He did exceptionally well as a researcher even when he was Deputy Director at IIT Madras. He supervised the setting up of liquid helium plant at IUC-DAEF, Indore by staying up all night even when he was the Director of that Institute. Even while conducting the Refresher Courses, RS would plan every minute detail related to the course – from planning, to execution. He would arrive a couple of days earlier to unpack the boxes containing experimental setups, set and test the experiments and repack the instruments at the end of the course. He would also take lectures (many times more than everyone else) and explain the experiments during lab hours to the participants.



RS with his wife and other family members.

RS is a simple, selfless and loving person. His siblings affectionately call him Babanna. In fact this name was first given to him by his younger perhaps most loving sister Madhuri Thathachari. After all RS was instrumental in marrying her to one of his closest friend late Y. T. Thathachari. Mrs Thathachari calls him Aapath Bandhawa. Apart from the sincerity and total commitment to his work, RS is a very compassionate man in his personal life. This quality of his has been aptly described by the devoted care he gave to his brother-in-law during his last days. During the last days of late Thathachari, RS was the Director of IUC-DAEF. Despite his commitments, he made frequent visits to Chennai to be with his brother-in-law and his loving sister. RS is also a favourite among children. Not only his grandchildren, but any child that spends some time in his company develops an instant liking to him. He has this uncanny way of constructing adventures and humorous stories based on fictitious characters and narrating them to children.

It is often said that behind every successful man there is a woman telling him where he went wrong. But in case of RS, his wife, Mrs Radha Srinivasan stood behind him all these decades, supported him and encouraged him to devote his entire attention to his obsession – Physics. Despite being a very good artist trained at Kalakshetra, Chennai, she gave up her career to take care of their children and household activities, thus allowing RS to concentrate on his Physics and related activities – a fact RS himself acknowledges at every opportunity. Together, they were great hosts. Everyone, be it an Indian or a foreigner, a collaborator or a student, who visited their house has fond memories of the food and the long conversations on many different subjects. RS and his wife took special care of their guests. For everyone it was always a home, away from home. He has two children, a daughter settled in Pennsylvania, USA and a son working in Bengaluru. His daughter is an artist and has made a name for herself in water colour paintings in the Pennsylvania art circuit.

His son works on large volume data analytics. RS has three grand daughters, two through his daughter and one through his son.

One remarkable quality of RS is the utter dedication to the task he takes up, whether it is a research project or managing a centre or conducting Refresher Courses. This combined with his deep understanding of condensed matter and low temperature physics, his simplicity and his ability to interact with young people, have been responsible for his achievements as well as for the universal admiration he has received. His is an example of high values, dedicated service, indifference to rewards and sincerity of purpose beyond the ordinary. He is a living example of man of action. During one of the courses, while sitting in the guest house and waiting for our dinner, he remarked ‘You know, Priolkar, all I wanted was to be a good teacher, I am happy I have been able to achieve it’. I was shocked by this statement. A person of his stature, with all the accomplishments to his credit, he just wanted to be a good teacher!! RS never took any job lightly. To be a good teacher was his dream and he worked hard for it. He set newer and higher benchmarks in all activities he undertook on the way to achieve his dream. That is a true Karma Yogi. With all the interactions that I have had with RS, I realized one thing – a lesson for life – no work is small, if it is done with total commitment and to the best of your abilities. RS during his long career, not only worked hard, not only did he inspire generations of youngsters, not only did he build institutions, not only did he win friends and gave care to his loved ones, he also found inner peace – ‘atmashanti’ in whatever he did. That is why he could on that day say – ‘I am happy, I have been able to achieve my dream’.

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