

## Erode Subramanian Raja Gopal (1936–2018)

Professor E. S. Raja Gopal, popularly known as ESR to all of us, a well-known experimental condensed matter physicist of the Department of Physics, Indian Institute of Science (IISc), Bengaluru passed away on 15 November 2018 at the IISc campus. His demise brings to an end of an era of high-quality indigenously trained physicists with a lifetime commitment to the subject and to its spread in the country (of the sort IISc seemed to host in numbers). He was an exemplar, in the sixties and seventies, of world-class instrumentation confronting cutting-edge problems of physics under conditions of almost no financial support.

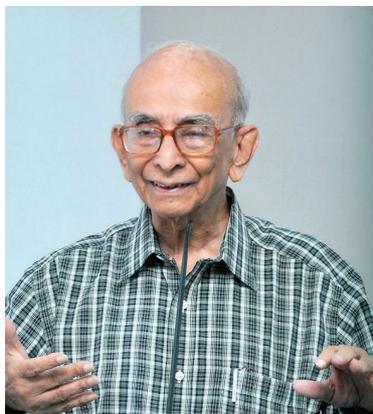
ESR was born on 12 May 1936 in Salem, Tamil Nadu. He studied in the Municipal College Salem and at St Joseph's College, Tiruchirappalli. He graduated with an M A Physics from the University of Madras, having completed the B Sc (Hons.) course in St Joseph's College. He then joined the Department of Physics at IISc for research and obtained his Ph D in 1961 under the supervision of late R. S. Krishnan, a distinguished scientist and a pioneer in high-quality instrumentation for physics research. ESR was in IISc essentially from then until his passing away.

ESR's Ph D thesis consisted of reprints of published articles added to the introduction and acknowledgements typed out by him. At that time it was the thinnest Ph D thesis the IISc had seen. One of the papers was 'On the rate of ultrasonic emulsification' published in *Current Science* (1957). Following it was a totally different but significant paper entitled 'Elastic constants of diamond', which appeared in *Nature* (1958). Another Ph D work was on compressibility and sound velocity in two phase mixtures; this is classic textbook material. He then spent a year at the Clarendon Laboratory, University of Oxford, UK, as Royal Commission 1851 Exhibition Fellow and worked with K. Mendelssohn (FRS) to understand the low-temperature specific heat and superflow of liquid helium.

ESR joined IISc in 1964 as a CSIR Scientist Pool Officer in the Department of Physics. In 1969, he became a full Professor at the age of 33; the youngest professor in IISc at that time.

ESR's research interests have been in instrumentation of different kinds, e.g.

electronic instrumentation as exemplified in a micro-kelvin temperature controller, analytical instrument facilities for ultrasonic velocity measurements, thermal instrumentation for heat capacity measurements, and high-pressure measurements on solids. With severe financial constraints, ESR and his team contributed to globally challenging research frontiers. In the early seventies, for example, he and his group studied critical behaviour of binary liquid-liquid mixtures, a highly demanding, competitive and cutting-edge area then, and obtained new results of significance.



In the eighties, his interests turned to amorphous matter. The work of his group on rapidly cooled metallic alloys culminated in the preparation and characterization of Al-Mn and Al-Fe quasi crystals in 1986. His work in semiconducting glasses led to studying ultrasonic velocity and thermal expansion in chalcogenide semiconducting glasses such as Se-Te, Ge-Se-Te, As-Se systems, work on pressure-induced crystallization and metal-insulator transition, chemical and mechanical percolation threshold in them, etc.

ESR's commitment to developing a culture of instrumentation took many concrete forms, in addition to his own work and that with students. For example, he played a key role in converting the CISL-Centre for Instruments and Services Laboratory – and Regional Instrumentation Centre at IISc to the 'Instrumentation and Services Unit (ISU)', which is now the 'Department of Instrumentation and Applied Physics'. He was the Chairman of ISU during 1983–89 and started new experimental activities like

high-pressure studies and mass spectrometer fabrication. ESR strongly supported the activities of thin-film fabrication for sensor applications and the solar energy research there. He also emphasized the need for developing indigenous equipment for experimental research. In all these cases, a strong emphasis on affordability was married to sensitivity to quality. ESR was one of the pioneers of cryogenic activities in India, and also one among those responsible for what is now a major cryogenic centre in IISc. He helped start Master's level courses in IISc, which emphasized instrumentation and applied physics. He propagated and supported the 'Make in India' concept way back in 1984, well before it became fashionable.

ESR became the Director of the CSIR-National Physical Laboratory (NPL), New Delhi in September 1991. During his time, and because of his inspiration, NPL developed further its role as a national laboratory tasked with maintaining standards of various physical quantities; e.g. a high-pressure standard and a force standard. The activity also involved correcting, through a series of careful measurements extended in space and time, an erroneous but widely propagated methane emission budget, due to the Environmental Protection Agency of USA. It turned out that they had overestimated the budget by nearly a factor of ten. ESR also stimulated research and development activity in a number of areas in which NPL had intrinsic strength, e.g. thin films.

In his long career at IISc, ESR served it in many capacities, e.g. as Dean of the Faculty of Science, in looking after the Central Library and the Computer Centre. He was also an active member of the Indian science community. He travelled far and wide to participate in scientific activities and gave lectures all over the country (for example, the week before his passing away, he was in Varanasi to take part in the annual meeting of the Indian Academy of Sciences; the week after, he was to go to Guwahati to participate in a workshop on experimental physics). He was mentor to a large number of Indian professional scientific/technological societies such as the Acoustical Society of India, the Instrument Society of India, the Indian Cryogenics Council,

Indian Society for Mass Spectrometry, Ultrasonics Society of India and Metrology Society of India. He was an early chief editor of the journal *Pramana* (1984–89). ESR's broad and deep knowledge of physics and physicists was evident, as was his work culture: he would spend about half an hour every morning (every day, including weekends) before 8 am in editorial work (e.g. choosing the reviewers and going through the authors' replies) before meeting his students for an hour and then starting the day. This has inspired a number of his students to take up academic careers in several national laboratories like CSIR, DAE, DRDO, ISRO and universities in India.

ESR wrote and edited several books, out of which those authored by him on *Specific Heat at Low Temperatures* (Plenum Press, New York, 1966) (written when he was only thirty), *Statistical Mechanics: An Introduction to its Applica-*

*tions* (Van Nostrand Reinhold, London, 1973) and *Statistical Mechanics & Properties of Matter: Theory and Applications* (John Wiley, 1974) are widely cited and used.

ESR's contributions have been widely recognized. He was awarded the Shanti Swarup Bhatnagar Award for Physical Sciences in 1978. He was a Fellow of all the three national science academies. A large number of national awards and named lectureships came his way.

ESR was much more than just an experimental physicist. He had the very rare quality of humming and whistling at the same time tunes usually from classic Tamil and Hindi songs; one could hear him in the corridors of the Physics Department at IISc. He was fond of traveling and attending all kinds of meetings related to academics in any part of the country. He was also a highly dedicated student to his guru, the late Krishnan,

and used to seek his advice about taking decisions regarding his academic career (including his joining date as Director of NPL). He was fortunate to have married Shakuntala, a gracious and hospitable lady who extended all her support till his death. Raja Gopal is survived by his wife, son, daughter and grandchildren.

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