Barry Ramachandra Rao (1922–2005)

Barry Ramachandra Rao, an eminent space scientist and a teacher who had inspired generations of physics students at Andhra University (AU), passed away on 24 September 2005 at his residence in Visakhapatnam.

Rao had a humble beginning, born on 21 November 1922 into a fisherman's family in Yalamanchili, a remote village in Visakhapatnam district, Andhra Pradesh. He had early schooling in his native village and high school and intermediate education in Visakhapatnam. That he was an immensely talented student was known quite early, but how extraordinarily gifted he was came to be realized only after he joined the B Sc (Hons.) physics course at AU. It would not have been possible for him to pursue university education, but for the timely support and encouragement by his elder brother, B. S. Prakasa Rao, a junior employee in the postal department at that time. S. Bhagavantham, greatly impressed by the talented young Rao, had taken special interest in him and provided whatever support possible in the way of tuition and hostel-fee concessions. Rao secured the first rank among all students of B Sc (Hons.), not just in physics but all disciplines combined, and was awarded the prestigious Sripathi Medal in 1944. In M Sc too he stood first and was awarded the Metcalf Medal in 1945. That was the beginning of a brilliant research career.

Rao joined research in 1945 for his D Sc under the supervision of Bhagavantham. During his doctoral programme, Rao was supported first through a laboratory demonstratorship and later by a senior research fellowship of CSIR. His doctoral work was on diffraction of light by high frequency ultrasonic waves for which he was awarded D Sc in 1949. Rao continued this line of work which led to the discovery that in the high frequency region, the diffraction pattern follows Bragg's law. He and his students developed new techniques for high precision measurement of ultrasonic velocities in liquids and solids. The above pioneering research in ultrasonics led to a series of seven papers, six of them in *Nature*.

In 1951, Rao was awarded a Commonwealth Senior Research Fellowship to work at CSIRO, Australia with D. F. Martyn, who was at that time beginning to formulate the ionospheric dynamo theory, now regarded as one of the most outstanding contributions in ionospheric physics. Martyn invited Rao to join him to work on this theory, but it would involve commitment to stay longer than what Rao intended to spend at CSIRO. Rao's primary objective was to work on experimental techniques that would help him start a school of experimental space physics at AU. On returning from Australia, Rao and a dedicated group of his doctoral students started building an ionospheric research laboratory that over the years developed into one of the most advanced space science centres of international repute. There was tremendous diversity in the type of instruments that had been designed and developed, taking the laboratory to the forefront of radio and space research in the country in a short time.

The first multi-frequency HF pulse radar in spaced-receiver configuration was developed by Rao's group and a comprehensive study was made of ionospheric plasma drifts over low latitude. The group was also the first to adopt advanced correlation techniques to derive the scale size and anisotropy characteristics of the irregularities along with their turbulent and steady drift velocities. These were the first measurements based on which the low-latitude upper atmospheric winds were derived. The winds so derived formed the reference against which the early theoretical models developed by the MIT group in USA were tested. The group led by Rao was also the first to make extensive measurements on radio-wave absorption and polarization, and the specialized instruments needed to perform these experiments had been realized through enormous development efforts. These measurements have been successfully interpreted in terms of the magneto-ionic theory of Appleton–Hartree.

One of the most interesting phenomena of the ionospheric F-region plasma is the generation of a wide spectrum of irregularities immediately following sunset. Spread-F is the generic term by which these irregularities are commonly referred to, since they cause spreading of the reflected signal recorded by a sweep frequency ionospheric sounder (ionosonde). Some of the basic features of these irregularities, including the background plasma state conducive for their occurrence, were first reported by Rao's group. These early observations greatly helped in understanding the plasma instability processes causing spread-F. This class of irregularities, as it turned out, has come to be regarded as an important aspect of Space Weather with direct relevance to the GPS-based navigation and satellite communication applications. The early observations of Rao's group made more than four decades ago, covering a wide range of geophysical conditions, still offer valuable insight into the mechanism of spread-F.

The early HF radars employed for ionospheric sounding were all based on amplitude detection of the ionospherically reflected radar signal. Signal phase measurement along with amplitude provides a more sensitive method of studying ionospheric plasma dynamics. The first HF phase path sounder was designed and developed by Rao's group and was used for extensive studies on low-latitude gravity waves and plasma drifts. The group under Rao was also the first to design and develop two other major atmospheric sounding systems, a meteor radar and a sodar. The meteor radar offers a unique technique for wind and temperature measurements in the lower thermosphere (~90–100 km), using radar backscatter from meteor-induced ionization trails. Meteor radar observations have also been used to understand the formation of sporadic ionization layers in the E-region (Es). The sodar was successfully operated to study boundary layer processes, including pollution dispersal. The current-day HF Doppler radar, Doppler meteor radar and Doppler sodar systems are but a logical evolution of those early systems developed by the group at AU. It is rather amazing that Rao had not only visualized the importance of these innovative techniques to atmospheric science so early, but successfully implemented

them while the technology to realize them was still in its infancy.

The AU space science group under Rao was also among the first to undertake the important area of satellite radio beacon studies of total electron content and scintillations, while the field was still in its initial stages, even at the international level. The radio beacon studies now assume great significance under the newly emerged discipline of 'space weather – science and applications'. Contributions of the AU group in this area over the past three decades, with direct relevance to satellite-based navigation and communications, have made immense impact at the international level. Other original contributions of the AU group include theoretical and modelling studies of low-latitude ionosphere and application of advanced magneto-ionic theory of Sen–Weyller for accurate interpretation of radiowave absorption measurements. The AU space science group is now in the forefront, contributing greatly to the success of several national programmes like ISRO Geosphere Biosphere Program (IGBP), Coherent Radio Beacon Experiment (CRABEX) and Climate and Weather of the Sun–Earth System (CAWSES). In recognition of its excellence in space research, the University Grants Commission (UGC) has elevated the AU space science laboratory to Advanced Centre for Space Research, with provision for special assistance. The Centre has the distinction of receiving financial assistance from UNDP, besides several national and international agencies.

The outstanding academic contributions of Rao are reflected in the award of more than 40 D Sc/Ph D degrees under his guidance and in the publication of over 300 papers, mostly in highly reputed international journals. Considering the kind of academic record that Rao had, it did not take long for him to receive professional recognition that was due. He received the highly prestigious Shanti Swarup Bhatnagar Award in 1965 and had the distinction of being elected to all the three national academies (FNA–1969; FASc–1974 and FNASc–1978). He served as President of the National Academy of Sciences, Allahabad during 1981–82 and President of the Indian Science Congress during 1982–83. He was conferred D Sc (*honoris causa*) by Andhra University in 1970. The above are but a few among the numerous awards and honours he received for his academic accomplishments.

In 1976, the UGC appointed Rao as its Vice-Chairman, in recognition of his administrative and organizational abilities and academic excellence. He served as UGC Vice-Chairman for two terms during 1976–82 and introduced some important reforms in the university system. These include semester system with internal assessment, major changes in the structure and course content at the Master's degree level, closer linkages between academic institutions and national laboratories, establishment of centres of excellence in science, university service and instrumentation centres (USICs) and state-of-the-art computing facilities at some major universities.

Under the initiative of the then Prime Minister Indira Gandhi, Rao was elected as a member of Rajya Sabha for one term during 1982–88. He also had the distinction of serving as Chairman of the National Fisheries Advisory Board, Chairman of the Educational Consultants of India Limited and member of governing bodies of several R&D organizations, apart from serving on the top academic bodies of several universities. He was part of several foreign delegations of the Government of India, either as leader or member, under numerous exchange programmes of the Ministries of HRD and Science and Technology.

Rao's involvement in the progress of academic institutions and R&D organizations has been so extensive and his interests and contributions have been so varied, it is not easy to narrate all that he has done in his long and illustrious career without missing something important. Finally, for all his outstanding academic accomplishments, he remained all along a simple and unassuming person. Rao will be long remembered as much for the fine values of life that he lived by as for his academic brilliance.

B. R. Rao has left behind his wife, an elder brother and two younger sisters.

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