

## R. G. Rastogi (1929–2018)

Professor Ram Gopal Rastogi was born in Allahabad on 26 December 1929. He obtained M Sc degree in physics from Allahabad University in 1949 and started his academic career as a lecturer at Sagar University, Sagar, Madhya Pradesh. He was keen to do research in the field of ionosphere and on learning that K. R. Ramanathan was starting ionospheric research at the Physical Research Laboratory (PRL), Ahmedabad, he joined PRL in July 1951 as a research scholar. Rastogi was the first student of Ramanathan to do research on the ionosphere and in fact the first person at PRL to do regular work in that field. An automatic ionosonde, British Mark II built by National Physical Laboratory (NPL) in UK was being acquired by PRL then and this was made operational since January 1953. Rastogi's doctoral work was based on the study of different features of the E and F1 layers of the ionosphere over Ahmedabad from radio soundings and detailed examination of the ionosphere during the total solar eclipse events of 1954 and 1955. A number of radio transmissions were used and receiving systems set up at PRL to measure field strengths for the solar eclipse campaigns. After completing his Ph D, Rastogi worked as a postdoctoral fellow at the National Research Council in Ottawa, Canada, from October 1958 to December 1960. Later, he worked as a postdoctoral fellow at the High Altitude Observatory, Boulder, Colorado, USA and was guest worker at the Central Radio Propagation Laboratory at Boulder, USA from December 1960 to December 1961. Some of his important contributions in the early years were the diurnal development of equatorial ionization anomaly and longitudinal inequality of equatorial electrojet. He made an extensive use of the global ionospheric and geomagnetic data.

After his return to India, Rastogi headed the ionospheric physics group at PRL and was involved in consolidating ionospheric research at the laboratory. He initiated several new activities. His most important contribution was the setting up of ionospheric observatory near magnetic equator at Thumba (now Vikram Sarabhai Space Center), where India's first rocket range was established. A spaced receiver drift experiment was established

in November 1963 to measure the drift velocity of ionization irregularities in the ionosphere. This experiment was initially set up to complement the rocket-borne measurements of neutral winds from Thumba, with the first rocket flown on 21 November 1963. An automatic ionosonde model C-4 for radio sounding of the ionosphere, two riometers operating at 21.3 and 16.5 MHz for the study of ionospheric absorption and a radio beacon receiver to record Faraday rotation for the study of total electron content and radio scintillation were also set up at Thumba. It became a prominent facility



to probe the equatorial ionosphere. Ionospheric drift studies from Thumba provided a new platform to explore equatorial electrojet and electric field in the ionosphere. Combined with ionosonde and the ground magnetometer from the magnetic observatory at Thiruvananthapuram, the multi-technique studies revealed several new features of the equatorial ionosphere. Reversal of electric fields leading to counter electrojet and disappearance of equatorial sporadic-E both during geomagnetic quiet and disturbed conditions were established from such measurements at Thumba. The role of interplanetary magnetic field on the ionosphere was also demonstrated for the first time from the ionospheric drift measurements at Thumba. Rastogi was the first to identify the role of the southward turning of the interplanetary magnetic field in modifying the ionospheric electric field at low latitudes. The ionosonde measurements at Thumba near the magnetic equator and at Ahmedabad in the ionization anomaly crest region provided a unique set of data to understand

the electro-dynamical processes at the equatorial and low latitude ionosphere.

Another important contribution of Rastogi was the setting up a sophisticated beacon receiver system at Ootacamund, near the magnetic equator, with collaboration of Ken Davies (NOAA, Boulder, USA) during the ATS-6 phase II for a year in 1975–76. Multi-frequency (40, 140 and 360 MHz) measurements of Faraday rotation, differential phase, group delay, amplitude and phase scintillations constituted one of the best radio beacon data collected anywhere. In addition, a chain of radio polarimeters at 140 MHz to measure Faraday rotation at six stations from the magnetic equator to beyond the equatorial anomaly crest region was set up in collaboration with different institutions/universities in India. The radio beacon data collected during the ATS-6 phase II in India provided a wealth of information and several new results.

Rastogi worked in a number of research fields that included the study of equatorial electrojet and counter electrojet phenomena, ionospheric drifts, equatorial sporadic-E, equatorial spread-F, equatorial ionization anomaly, total electron content and scintillations during different geophysical conditions like geomagnetic quiet and disturbed days, and geomagnetic storms. He also made extensive studies on the lunar tides in geomagnetic field and ionospheric parameters to infer the relationship between electric fields and ionosphere at low latitudes. He always preferred to work with original data recordings rather than the hourly published data. In his research career he must have examined a large number of magnetograms and ionograms. He was gifted with finding any minute abnormal signature in the records and thus he was able to report many of new features; for example, a new kind of ionospheric irregularity in the equatorial F-region, which he christened 'kinks', they were successfully used to infer vertical velocities in the F-region. From 1977 to 1980, he worked as a Senior Research Associate of the National Research Council, at Air Force Geophysics Laboratory, Boston, USA.

Rastogi moved to the Indian Institute of Geomagnetism (IIG) in Mumbai in

1980 as its Director. He was responsible for expanding the research activities of IIG and the chain of magnetic observatories, including the permanent magnetic observatory at Maitri in Antarctica, modernization of instruments, new instruments for micro-pulsation and magnetotelluric studies, and setting up of the Equatorial Geophysical Research Laboratory (EGRL) at Tirunelveli and the K. S. Krishnan Regional Centre of IIG at Allahabad. He also initiated several new programmes to study the ionosphere. Collaborations were established with research groups from different countries to start new experiments like medium frequency (MF) partial reflection radar for mesospheric winds, all-sky imaging camera to map night airglow emissions for the study of large-scale plasma depletions associated with equatorial spread-F, photometers for spaced receiver airglow emissions, and a chain of VHF receivers for ionospheric scintillation studies.

As chairman of the Steering Committee of the All India Coordinated Programme on Ionospheric–Thermospheric Studies (AICPITS) of Department of Science and Technology, Government of India, Rastogi organized a collaborative inter-university programme on ionospheric studies as part of the International WITS programme. As part of this programme, a chain of 20 stations right from the magnetic equator to beyond the anomaly crest region provided unique dataset for VHF scintillation studies at low latitudes, involving and inspiring many university groups to take up ionospheric research. He also initiated SERC schools on the upper atmosphere and under this DST-sponsored programme, five SERC schools were organized at different institutes/universities in India during the pe-

riod 1991–2003. Rastogi encouraged a number of university groups to start research programmes in the field of ionospheric studies; for example, his initiative to set up ionospheric drift measurements at Tiruchirappalli, Udaipur, Nagpur and Patiala.

As founder chairman of the Commission on Developing Countries of IAGA (International Association of Geomagnetism and Aeronomy), Rastogi coordinated research programmes in the developing countries. He organized international schools on ionosphere and geomagnetism at Pune, India in 1985 and at ICTP, Trieste, Italy in 1987.

Rastogi continued research activity after his retirement from IIG in 1989; he worked as CSIR Emeritus Professor at PRL (1990–1993) and Gujarat University (1993–1995). He also worked as INSA Emeritus Professor at Gujarat University from 1995 to 2000 and as an Honorary Professor at PRL from 2000 to 2018. Over the last decade, Rastogi was mainly working on space weather events, where he used global ionospheric and geomagnetic data to examine the space weather effects at different longitude regions. In his scientific career both at PRL and IIG, he guided 24 Ph D students, and many of them are now well-established scientists in India or abroad. He published 435 papers in reputed international journals, including 17 papers in the high-impact journal *Nature*. He contributed greatly to the field of equatorial aeronomy and geomagnetism.

Rastogi was a Fellow of all the three science academies of India, and of the Indian Geophysical Union. He had represented India at several International meetings of URSI, COSPAR, IUGG, IAGA, Radio Beacon Group, ISEA and

several other symposia. In recognition of his contributions, Rastogi was bestowed with the Hari Om Ashram Prerit Gokuldas Bombbadi Research Award in Physics by Gujarat University for 1971–76; NASA Award for excellent performance of ATS-6 Radio Beacon Program 1977, NASA Award for excellent performance in MAGSAT Program 1982; USSR Academy of Science Commemoration Medal for developing the Indo-USSR joint research programme in geomagnetism; Japanese Geophysical Society Commemoration medal for contribution to geomagnetism and ionospheric research in 1984; and Prof. Kalpathi Ramakrishna Ramanathan Medal in recognition of his contributions in atmospheric sciences and meteorology in 2002. He was appreciated by many internationally known stalwarts in the field like R. F. Woodman, H. Rishbeth, M. Mendillo and others for his keen observations and painstaking analysis of data, bringing out important physical insights.

I had the privilege of working with Rastogi for over five decades, initially as a Ph D student and later as a colleague and collaborator.

Rastogi passed away, on 10 July 2018 at Ahmedabad after a brief period of illness. His contributions to ionospheric and geomagnetic research will be remembered for years to come by the international scientific community.

Rastogi is survived by four sons and a daughter.

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