

## Rohini Godbole

When noted physicist Rohini Madhusudan Godbole passed away peacefully in the early hours of October 25, 2024, she left empty a unique place which she had created all for herself with her talent, her energy, her amiability and her indomitable will.

Rohini was born at Pune on November 12, 1952 to Madhusudan Ganesh Godbole and his wife Malati, the second of their four daughters Mrunalini, Rohini, Kalpana and Vibhawari. Theirs was a cultured and highly-educated middle-class family, where different members felt free to pursue different academic disciplines. The father Madhusudan, had been a topper in Economics at the University of Mumbai, but could not pursue academics further due to financial constraints. Instead, he joined the Defence Accounts, from where he retired in a senior position. The mother Malati, a high school topper, excelled in Sanskrit, but early marriage came in the way. Later she completed her Master's in Hindi and became a school teacher. Rohini's siblings are all highly educated — Mrunalini (now Sunita Karlekar) studied and taught Mathematics, Kalpana (now Godbole-Kelkar) became a medical doctor and a professor of Anaesthesiology, and the youngest Vibhawari (now Godbole-Thakar) also worked as a science and mathematics teacher. However, Rohini, the physicist, was undoubtedly the star of the family.



Rohini was educated first at the iconic Huzurpaga (HHCP) High School in Pune, where she graduated in the merit list. She then joined the historic Sir Parashurambhau (S.P.) College from where stood second in the Intermediate examination and first in her B.Sc. examination under the Savitribhai Phule Pune University. This won her a scholarship under the National Science Talent Scheme (NSTS), which then enabled her to join the Indian Institute of Technology (IIT) Bombay for her Master's in Physics, where she again topped and won the Institute silver medal. She herself has mentioned the major non-family influences in her education period as her schooldays science tutor Bhau Sowani, and Professor S.H. Patil in the IIT, whose influence induced her to become a theoretical physicist. Interestingly, in view of her later role as a star crusader for women in science, she reminisced that she had faced no discrimination in the IIT as a woman in a STEM subject, but was more worried about being able to speak in English, her schooling having been in the Marathi medium. Fortunately, Rohini had the gift of the gab, winning numerous prizes in elocution and debate competitions, and it was not hard for her to bridge the language gap — which in postcolonial India means a cultural gap.

Rohini's scientific horizons opened wider when she moved to the USA in 1974, joining the State University of New York (SUNY) at Stony Brook, then a Mecca for aspiring Indian theorists. She took to the world of theoretical high energy physics like a duck to the water, and with her warm, gregarious nature, made many lifelong friends in the community. She completed her Ph.D. in 1979, under the supervision of Professor Jack Smith (himself a student of Nobel Laureate Peter Higgs), one of the pioneers of quantum chromodynamics (QCD), the theory of strong interactions. However, Rohini, even as a student, did not confine her *œuvre* to strong interactions, but also worked on electroweak interactions i.e. on the entire Standard Model of particle physics, then, in the 1970s, still something of a novelty.

Returning to India in 1979, Rohini joined the Tata Institute of Fundamental Research (TIFR), as a postdoctoral fellow in what was then called the Theory Group. In the three years she spent here, she worked with senior theoreticians like K.V.L. Sarma, D.P. Roy, Probir Roy and Biswarup Banerjee. One research work, which she completed with D.P. Roy and Sandip Pakvasa (who was then visiting TIFR) involved suggesting a technique to discover the top quark (then predicted but not yet discovered) at high-energy particle collider machines by looking for hadronic jets accompanied by isolated high-momentum leptons. This was, in fact, the technique used in 1994 to discover the top quark at the USA's Fermi National Laboratory (Fermilab), near Chicago. It also made Rohini one of the pioneers of collider-based theory in India, which has now become a mainstay of the high energy physics community in the country. Some of this early work was done in collaboration with Sourendu Gupta, then a graduate student in the Theory Group, and later a recognized expert in nonperturbative QCD.

Moving on from TIFR, Rohini had a few months' stint as a CSIR Research Associate at the Institute of Science, Mumbai before joining the University of Mumbai in November 1982, as a very young Lecturer, aged just 30 years. She spent the next 13 years at the University, making a name for herself as a brilliant young teacher and researcher. During this time, she continued to research the Standard Model and its testing at collider machines, but also started working on physics beyond the Standard Model, in particularly supersymmetric models, which were then coming into vogue and dominated particle physics research for the next quarter of a century. With Probir Roy and Xerxes Tata, another lifelong friend and collaborator, Rohini wrote the first Indian paper on an aspect of supersymmetry called R-parity violation, a thread which was later taken up in a bigger way by many younger scientists in the Indian high energy community. But it was during her sabbatical year at the University of Dortmund (1988–89), in then-West Germany, that she met and collaborated with a young German postdoc, Manuel Drees. Together they worked on the vacuum polarization created by a high energy photon (a point particle) in a quantum field theory, and showed that its behaviour could be characterized in

terms of structure functions just like a composite hadron. This work and its follow-up research made a very significant impact on the high energy world, and indeed, these ideas are now being used in the design of new, higher energy colliders. In her later career, both before and after the discovery of the Higgs boson, Rohini was intrigued by the determination of its discrete quantum numbers, in particular, its parity and charge conjugation behavior. A series of articles by her and her collaborators may be found in the literature, exploring various ingenious ideas that could be used by experimentalists in this regard. Though the full list of Rohini's scientific collaborators crosses a hundred, lifelong collaborators with whom she wrote more than 30 articles each were Giulia Pancheri, Saurabh Rindani, Agnes Grau, Genèvieve Bélanger, Sabine Kraml and Yogendra Srivastava.

In 1997, Rohini moved again, this time from Mumbai to Bengaluru, where she joined the Centre for Theoretical Studies or CTS (now Centre for High Energy Physics or CHEP) in the Indian Institute of Science (IISc). She spent the remaining 27 years of her life there, only moving back to her hometown for the last few months during her terminal illness. At the CHEP, she thrived as never before, chairing the Centre from 1996 – 2002 and, for some years, holding the MSIL Chair for Physical Sciences. Unlike most scientists, whose productivity peaks early, and then tapers off as they grow older and more engaged in multiple activities, Rohini's peak productivity period started at the age of 55 and continued till the age of 67, when the Covid-19 pandemic brought most activity to a standstill. Just before this, in 2018, on turning 65, Rohini had officially retired from the Indian Institute of Science, but authorities were not going to let go of her so easily. She was promptly appointed as Honorary Professor, a position she retained till her last breath. Despite her failing health in her last year, she kept up her pace of research, the last research paper appearing as late as June 2024.

While science metrics can never catch the quality and variety of her work, it is still worth noting that her scientific career spanned 48 years, during which she wrote about 350 articles, interviews, reports, conference talks, etc., at the astonishing rate of 7 a year, in spite of all her other activities. The impact of her work is enshrined in the more-than-16,000 citations her work has collectively acquired, again at the astonishing average of 60 per paper ( $h$  index 63). She was also the co-author, with Manuel Drees and Probir Roy, of a very well-known textbook on supersymmetry, called *Theory and Phenomenology of Sparticles*, which was published by the World Scientific Publishing Company. Her last project was to write a definitive textbook on the Standard Model, for which she and co-author Sunil Mukhi had signed a contract with Cambridge University Press and put in a great deal of hard work, but unfortunately, death intervened before the book could be finished.

During the 1990s, Rohini married German physicist Marek Nowakowski, but, sadly, the marriage was short-lived. For the rest of her life, she remained married to her profession, spending every waking hour in its pursuit. She utilized the relative freedom this gave her to become a familiar figure at national and international conferences, where her insights, enthusiasm and networking skills combined to make her the best-known face of Indian particle physics in the international arena. However, in the midst of all this hectic activity, much travelling and her teaching duties — which she always took very seriously — she found time to remain very close to her family and friends in Pune, who were, in fact, the ones that cared for her in her last — mercifully brief — illness.

As Rohini grew more senior, she grew more and more concerned with the poor representation of women in STEM subjects, especially in India. She then teamed up with a few women physicists, like Nandini Trivedi, Sumathi Rao, Neelima Gupte and others to represent India in the IUPAP's first *'International Conference on Women in Physics'* held at Paris in March 2001, where she spoke as India's 'success story' for a woman working in science. From that point, she became a tireless crusader for the inclusion and encouragement of women to seek careers in STEM subjects, including in her own subject, physics, where women's representation is one of the lowest. Together with Ram Ramaswamy, she co-authored an important work *Lilavati's Daughters* (2008), in which the important contributions (some long-forgotten!) of Indian women to science were highlighted. It was followed up in 2015 by *The Girl's Guide to a Life in Science*, covering similar topics. In 2010, she had co-authored the IAS-NIAS Research Report entitled *The trained scientific woman power — how we are losing and why?* which brought these issues to the notice of the policy makers. And thus, when the Indian Physics Association (IPA) finally created a Gender in Physics Working Group (GIPWG), Rohini was one of its leading lights, playing an important role in setting up gender groups and panels, which she also did for the Indian science academies. This was a cause which she believed in passionately, and fought for with dedication, diplomacy and perseverance. It is due to her efforts (and that of her co-crusaders) that the issue of gender equality has become a major goal of Indian science policy planners, though alas! full parity is still a long way in coming.

It was, perhaps, a combination of Rohini's scientific contributions as well as her contribution to the cause of women in science that brought her two signal recognitions. In 2019, she was awarded the *Padma Shri* by the Government of India, and in 2021, the *Ordre National du Mérite* by the French Government, the latter also mentioning her important role in furthering scientific ties between India and France. Apart from these, Rohini had acquired a long list of awards and honours, including, among others, fellowship of all the Indian science academies, chair professorships, distinguished alumnus medals, research awards and half a dozen honorary

doctorates. She was also the Indian scientist of choice on many international panels, including the High Energy Physics Advisory Panel, USA (2018–20). In India, she played a crucial role in the furtherance of high energy physics, supporting enhanced Indian participation in the planned International Linear Collider (ILC) project in Japan as well as the indigenous INO, so long as the latter project was active. She strongly supported the cause of internationalism in science and encouraged young scientists from India to go abroad to hone their skills, and come back with them to enrich the scientific scene in India. She was a leading organizer and most enthusiastic participant in the series of international Workshops on High Energy Physics (WHEPP), the DST-SERC Schools in Theoretical High Energy Physics, where she chaired the National Committee from 2006–10, and finally, she played a major role in organizing the international Asia-Europe-Pacific Schools in High Energy Physics (AEPSHEP), of which the second school was held in Puri, India (2014).

It may easily be guessed that an engaging personality like Rohini would attract many students and collaborators. Apart from her 14 Ph.D. students, who are spread across India and the world, she would guide M.Sc. students and undergraduates with the same care and was always happy to talk to students from anywhere and answer their questions. At conferences, she was easily the most approachable senior scientist, and would, in fact, go out of her way to buttonhole young participants and put them at their ease, encouraging them to ask questions and approach other scientists with their doubts. It will be difficult for the community to adjust to existence without her ubiquitous presence, friendliness and patronage. Certainly, she will be remembered as a pioneer as long as the high energy physics community in India thrives, and women continue to make science their career choice. This will ultimately be the historical niche which she created all by herself and which her memory will adorn for the years to come.