

in 2011, etc. He was a recipient of awards such as the ICFRE Award of Excellence in Forest Conservation, 2001; Science and Technology Excellence Award 2019–20 by UCOST Dehradun and Indian Science Congress 100th Platinum Jubilee Lecture award, 2014. Rawal was a life member of several learned societies and served as President of the Environmental Science Section in the Indian Science Congress 2020. As a IPBES lead author, he contributed for the regional and subregional assessment on biodiversity and ecosystem services of Asia-Pacific Regions. He also organized various events at global forums.

As Director of GB Pant National Institute of Himalayan Environment, Rawal made continuous efforts to develop wide partnerships and institutional collaborations to expedite the flow of R&D-based evidences for decision support on the environment and sustainable development issues

across the IHR. He was a great source of inspiration for many young minds and budding researchers working in the diverse fields of research and always available for guidance. Besides being an outstanding researcher, he was an exceptionally humble human being. With his sudden demise, the Institute has not only lost its Director, but also a committed scientist who had the vision to shape it leading to scientific excellence in the coming years. He initiated bringing together many institutions and organizations from academia and R&D across the Himalaya, towards addressing some of the key challenges of IHR. The contributions made by Rawal towards conservation and sustainable development of the IHR will always be remembered by the scientific fraternity. Rawal was a visionary and dynamic leader who established a strong organizational bond, was ready to accept new ideas, mentor youngsters, mod-

est and approachable, and a kind-hearted person, who will be remembered by all the staff members of the Institute.

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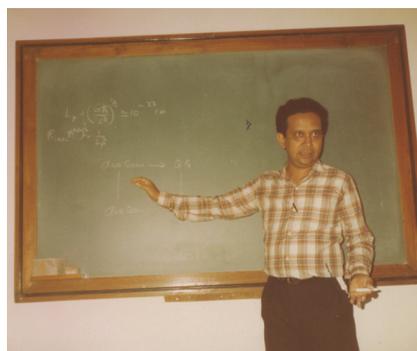
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Thanu Padmanabhan (1957–2021)

Thanu Padmanabhan, or Paddy as he was known to his friends, was born on 10 March 1957 in a lower middle-class family at Thiruvananthapuram, Kerala. His father, Thanu Iyer, worked in the Forest Department of the Government of Kerala. Lakshmi, his mother, was a home-maker. Paddy's father and several relatives of that generation were passionate about mathematics, especially geometry. It was in this ambience that Paddy grew up. Mathematics and chess were his primary passions in the early years. His father, and an elder relative, Neelakanta Sarma provided inspiration and guidance. They insisted on striving for excellence and maintaining a high level of integrity. The family credo was often summarized by Paddy as 'excellence is not negotiable'. This also reflected in the poster he had in his office: 'If you can't join them, beat them. Every time.'

School education was in Malayalam. Paddy studied at the Government Karamana High School in Thiruvananthapuram. He remained in the top group of students in his class, while being well ahead in mathematics and geometry. Chess remained a lifelong passion but Paddy dropped any thoughts of competitive chess at an early stage as he realized that he cannot devote enough time to both mathematics and chess competitions.

Paddy completed high school in 1972 and joined the Government Arts College in Thiruvananthapuram for pre-degree studies, as senior secondary studies were known at the time. The transition came with access to a library, and introduction to students with similar interests. Paddy came across the *Feynman Lectures in Physics*, and found physics to be more fascinating than pure mathematics. He worked through the five-volume *Berkeley Physics Course* at this stage.



Paddy joined Trivandrum Science Society, which was run by students from colleges in the city and financed by membership fees and donations. Members of the Society used the platform to learn and educate each other about different as-

pects of science, following their interests and going well beyond the curriculum. The process of self-study and peer learning was empowering, and this was something that Paddy tried to inculcate in students and younger colleagues. The society also provided pragmatic support by running help sessions for students, including preparation for the National Science Talent Search (NSTS) examination. This scheme of the Government of India was an earlier version of present-day schemes like INSPIRE and KVPY (Kishore Vaigyanik Protsahan Yojana), and was organized by NCERT (National Council for Educational Research and Training).

The NSTS fellowship included a handsome scholarship for pursuing a career in science. Paddy secured this fellowship and this permitted him to support his own studies. NSTS scholars were also expected to participate in a month-long summer camp each year, where they interacted with active researchers.

Paddy joined the University College, Thiruvananthapuram in 1974 for a B.Sc. degree. He and a few others had an informal self-study group which concentrated on theoretical physics, and in a span of about three years, Paddy managed to master the volumes of the *Course of Theoretical Physics* by Landau and Lifshitz. He

found general relativity and gravitation a fascinating subject and was strongly influenced by the book *Gravitation* by Misner, Thorne and Wheeler. Hand-written notes from this book in a set of notebooks were his treasured possession. Paddy wrote his first paper while still doing B.Sc. This paper, published in *Pramana*, considered the solutions of scalar fields and electromagnetic fields in an external gravitational field.

Paddy topped in the B.Sc. exam of Kerala University, bagging the gold medal. He studied for his M.Sc. in the same college and topped in this as well. At this stage Paddy was spending most of his time in self-study and research. It was clear to his contemporaries in the NSTS camps that Paddy was in a class of his own. Senior scientists who attended these camps as resource persons also noted the exceptional level of drive and competence. Towards the end of his M.Sc., Paddy attended the Einstein centenary conference that was held in 1979 at the Physical Research Laboratory, Ahmedabad. This was an opportunity to learn about the latest developments in the area of gravitation, and interact with leading scientists working in the area.

Limited family finances implied that a Ph.D. outside India was not a feasible option. Paddy joined the Tata Institute of Fundamental Research (TIFR), Mumbai for his Ph.D. There is an interesting anecdote that he insisted that Professor Jayant Narlikar take him as a student during the interview. An assurance was given by the chairperson of the interview committee even though Narlikar was abroad at that time, and this assurance was respected by Narlikar.

There was no graduate school at TIFR in that year and the students organized themselves to teach each other or approach a faculty member if they wanted to learn something that none of them was familiar with. Some of the students already knew each other through the NSTS camps. As his fellow students put it, peer learning sessions started after dinner and went on till late at night. Although the format was supposed to be that of one student teaching others, much time was spent in discussions and clarifying doubts. This emphasis on discussions along with self-study remained with Paddy as he started, or encouraged others to start learning in this mode. He valued different perspectives and approaches to any given concept or problem, as this often led to fresh insights. Jokingly, he would say that it is important to listen to

others when they are stuck because you can learn from their mistakes.

Paddy became a Research Associate at TIFR in February 1980 and was on track to become a faculty member. He worked on a number of problems during his Ph.D. The bulk of Paddy's work during this time fell in one of two main categories: quantum fluctuations in gravitational fields and the impact on singularities, and, quantum cosmology. He independently developed the concept of the wavefunction of the Universe at this time, with ideas which were also being explored by Hawking and Hartle. Paddy completed his Ph.D. thesis in 1983.

Soon after completing his Ph.D., Paddy married Vasanthi. She was a fellow student and they had already known each other for nearly three years. Vasanthi was working with Professor Ramnath Cowsik on the nature and distribution of dark matter. Paddy and Vasanthi went on to write a few papers together, including a paper in *Nature* where they explored cosmological constraints on unstable massive neutrinos.

At this stage Paddy started to commit time to science outreach. He started with articles in *Science Today*, *Science Reporter* and *Science Age*. He used to contribute crossword puzzles and syndicated columns to these magazines regularly. The lasting work in science outreach from this time is his cartoon series on the history of physics, 'Story of Physics' that appeared in *Science Age*. This has since been published in book form and translated into many different languages. It is available for free distribution and translation. Over the last four decades, Paddy continued to write articles in a variety of publications. He wrote several series of articles for *Resonance*. Paddy has also authored/co-authored popular science books.

The genesis of an idea that was to occupy much of Paddy's time more than ten years later was presented by him in an essay that won the fifth prize in the Gravity Research Foundation essay competition in 1985. Here, Paddy speculated about the possibility of a zero point length or length quantization and its implications. A decade later two approaches to quantum gravity: string theory as well as loop quantum gravity provided hints that this may indeed be the case. Paddy worked on various implications of this hypothesis through the later part of the 1990s.

Paddy continued to work on various aspects on the interface of quantum fields and gravitation. Of the first two students to work with him, Tejinder Pal Singh worked

on problems in this area. T. R. Seshadri worked on cosmology and the early universe, and this was a new direction for Paddy. Here they applied the ideas of quantum fields and gravitation to inflation and related problems in the early Universe. It is interesting that both the students joined Paddy soon after he finished Ph.D.

Following up on his interest in dark matter and its distribution in galaxies, Paddy decided to study related topics during a sabbatical. He spent one year at the Institute of Astronomy, Cambridge, UK. Donald Lynden-Bell was an inspirational figure amongst others and Paddy started to study the statistical mechanics of gravitating systems. While his primary interest was gravitating systems, the results could be carried over to other systems with long-range interactions. Several years of detailed study of this subject is summarized in a *Physics Reports* review article published in 1990.

Another influence from the visit to Cambridge was a suggestion by Martin Rees to write a book on cosmology and structure formation. This took shape over the next four years during a time when cosmology itself was being transformed by new observations. Paddy and others started a group to study galaxy formation at TIFR in early 1990s. A workshop was organized to discuss aspects of galaxy formation. A review article written jointly with K. Subramanian, aka Kandu, was an outcome of this collective learning. *Structure Formation in the Universe* was published by Cambridge University Press in 1993. This was quickly followed by another book: *Cosmology and Astrophysics through Problems*. Paddy worked actively on structure formation through the 1990s.

Paddy moved to the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune in 1992, where he took charge as Dean of core programmes. He was to remain in this position for more than two decades and guide the Institute. There was a steady stream of students through this period, mostly working on the interface of quantum fields and gravitation. The number of students and postdocs who worked with Paddy was in excess of 20, and counting their students and postdocs, the number of researchers influenced by Paddy through close interaction makes up a good fraction of researchers in these areas.

Paddy tried to cultivate the culture of peer learning and discussions that had served him well, amongst students at

IUCAA. He encouraged students to start a series of after-dinner talks titled 'PEP talks' (Perceptions of Evolving Physics). The talks had to be without any aids like slides or transparencies. There was no upper cut-off, so the discussion could continue till late. Paddy anchored a Landau club where students, postdocs and some faculty members from IUCAA and National Centre for Radio Astrophysics (NCRA), Pune used to attend. Over a period of two years the group worked through a large number of topics from the Landau volumes and related material. The third forum was another set of after-dinner talks, where each series of talks was on consecutive evenings covering one topic in detail. The mandate for the speaker was to start from a general astronomy background and build up to a discussion of open problems in the area. This series of talks was hosted at NCRA and a typical series ran for three to four evenings with each session lasting two to three hours. Some of the earliest themes in this series were pulsars (by M. Vivekanand), the inter-stellar medium (by S. Sridhar), and, Quasar absorption systems (R. Srikanand). All these efforts were over and above the smooth management of the graduate school and programme at IUCAA. Paddy was always available for discussions related to almost any topic. Anyone could walk into his office and either discuss right away or book a slot at a later time. He also felt free to contact any of his former students and associates with queries.

Paddy continued to write books on a diverse set of topics. A three-volume *Course of Theoretical Astrophysics*, a book on *Gravitation*, and one on *Quantum Field Theory* are amongst the books he wrote.

Teaching, mentoring, writing books, science outreach and administration took up a lot of time and Paddy took all of these seriously. He considered that the only way to grow intellectually was to keep challenging himself and those around him. He was working on a course for senior undergraduates. It was his intention that this be published as a four-volume book. He wanted to structure this as an unconventional approach, where all the essential topics

could be covered in about 150 lectures or 4 semesters.

The main research focus of Paddy in the last 15 years was in the area of emergent gravity. The premise here is that the theory of gravity, as in the general theory of relativity, is a derived construct. In this approach pioneered by Paddy and others, the true degrees of freedom lie elsewhere. Thus the whole approach of quantum gravity has been trying to quantize effective degrees of freedom and not the underlying fundamental degrees of freedom. Paddy and his students and postdocs in this period worked out many aspects of this approach.

Paddy served in a number of key committees and took a leading role in the development of astronomy in India. Here are a few examples: (a) The Department of Science and Technology appointed him as the Convener of the Advisory Group (2008–10) to facilitate India's entry into one of the international collaborations building the next-generation Giant Segmented Mirror Telescopes. This led India into joining the Thirty Meter Telescope (TMT). (b) He served as the Chairperson (2006–09) of the Time Allocation Committee of the Giant Meterwave Radio Telescope (GMRT). (c) He was the Chairperson (2008–11) of the Indian National Science Academy's National Committee which interfaces with the activities of the International Astronomical Union. (d) He was the President of the Commission 47 on Cosmology of the International Astronomical Union (2009–2012), and the Chairperson of the Commission 19 (Astrophysics) of the International Union of Pure and Applied Physics (2011–2014).

Paddy was an elected Fellow of all the three Science Academies of India as well as of The World Academy of Sciences. Awards received by him include the *Padma Shri* (2007), the J.C. Bose Fellowship (2008–), the Inaugural Infosys Prize in Physical Sciences (2009), The World Academy of Sciences Prize in Physics (2011), the Millennium Medal (2000), the Shanti Swarup Bhatnagar Award (1996), the INSA Vainu-Bappu Medal (2007), the Al-Khwarizmi International Award (2002), the Sackler Distinguished Astronomer of

the Institute of Astronomy, Cambridge (2002), the Homi Bhabha Fellowship (2003), the G.D. Birla Award for Scientific Research (2003), the Miegunah Award of the Melbourne University (2004), the Goyal Prize in Physical Sciences (2012–13), the Birla Science Prize (1991) and the INSA Young Scientist Award (1984).

Paddy passed away on 17 September 2021 following a cardiac arrest. He is survived by his wife Vasanthi and daughter Hamsa. Vasanthi had been the anchor of Paddy's life for nearly four decades, providing support in a variety of ways. Book projects taken up by Paddy could progress at a fair speed because of Vasanthi's active involvement. Paddy and Vasanthi wrote a book titled *The Dawn of Science: Glimpses from History for the Curious Mind*. Hamsa has established herself as a cosmologist with very wide interests. She is working at the University of Geneva.

Paddy leaves behind a rich legacy in terms of research, a large number of students and postdocs, a number of textbooks, monographs, review articles and popular books. His relation with his students started as that of a mentor and gradually transformed into that of a collaborator and friend. It can be seen from the comments and anecdotes related by many of them (*Life and Science of Thanu Padmanabhan*, arxiv:2110.03208). Also see the tributes page maintained by IUCAA: <https://www.iucaa.in/tributes/paddy/>, Paddy and Vasanthi were family for all of his students and the loss is felt very deeply. He had a productive life and would have continued in the same vein for many years if his life had not been cut short so soon. Paddy's books, lectures and other resource materials will continue to guide students and researchers. His research work contains numerous ideas that will continue to be developed in years to come.

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