Krityunjai Prasad Sinha (1929–2023)

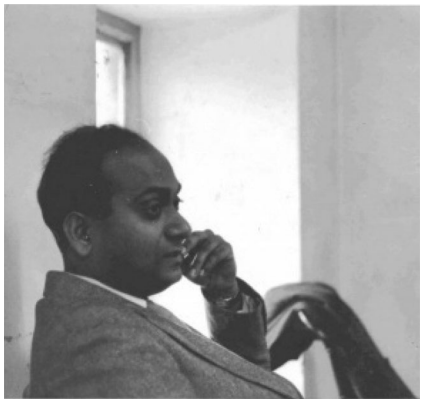
Professor K. P. Sinha, a theoretical physicist, had an extensive range of interests in science and beyond. He passed away at the age of 93 peacefully in his residence in Bengaluru on 23 January 2023. He continued to be an active researcher in theoretical physics, except for the last few years when a declining memory handicapped him. His evolution as a theoretical physicist, eventually becoming a Senior Professor of Theoretical Physics at the Indian Institute of Science (IISc), Bengaluru, in 1970, is unusual.

Sinha was born on 5 July 1929 in Akhtiyarpur, Bihar, and completed his M.Sc. in Chemistry in 1950 from Allahabad University. He worked under the guidance of George Ingel Finch, Director of the National Chemical Laboratory (NCL), Pune, on electron diffraction studies and secured a Ph.D. in experimental solid-state physics in 1956. He studied systems such as iron oxides and manganese ferrites. Moving to the UK, Sinha did post-doctoral work, during 1957–59, at the HH Wills Laboratory in the group of Maurice Henry Pryce. Sinha started his work in theoretical physics at Bristol while analysing his own experimental work for his Ph.D. at NCL. He earned a second Ph.D., now in theoretical physics, from the University of Bristol.

It is interesting to recall the styles of research of Sinha's mentors: G. I. Finch, in addition to being a versatile physical chemist, was a leading mountaineer in the world. He was the first to prove the great value of supplementary oxygen for climbing at extreme altitudes. M. H. L. Pryce got his Ph.D. under the supervision of Max Born and Ralph Fowler; he also worked with Pauli and von Neumann. His interests ranged from the theory of photons, the general theory of relativity, atoms in intense magnetic fields, magnetism in solids and nuclear fission. One can see the effect of these in Sinha's daring jumps across fields in physics and sometimes beyond.

Using electron diffraction, Sinha studied in detail, during his Ph.D., octahedral and tetrahedral distortions in manganese ferrite and iron oxide. He synthesized his samples, in collaboration with his colleague A. P. B. Sinha at NCL. A. P. B. Sinha, a distinguished solid-state chemist, passed away in 2021 at age 94. Interestingly, K. P. Sinha's first research paper was in 1954, on the 'Theory of photographic processes', in collaboration with his colleague A. B. Biswas – it tried to go beyond the well-known theory of Gurney and Mott.

Sinha's long career in solid state theory started with his work on the 'Jahn–Teller' effect and 'cooperative Jahn–Teller effect' in transition metal oxides with M. H. L. Pryce at Bristol and with Japanese physicist Yukito Tanabe. In 1958, while at Bristol, he wrote a single-author article in *Nature*. This was on the importance of understanding structural transitions in spinel oxides – it is a forerunner to modern theory and the phenomenon of the cooperative Jahn–Teller effect.



On returning from Bristol to NCL in 1959, he became a group leader of the Solid State and Molecular Physics unit. During Sinha's time at NCL, he met young Narendra Kumar, a dynamic electrical engineer who was an NMR Machine Maintenance Engineer. Kumar quickly finished a Ph.D. with Sinha and started working on a variety of problems in theoretical physics, including some in the general theory of relativity and cosmology, even during his Ph.D. period. Kumar went on to become a distinguished physicist, President of the Indian Academy of Sciences, working at IISc from 1970. Kumar retired as Director of the Raman Research Institute and passed away in 2017.

While at NCL, Sinha worked on interesting issues raised by new experiments in metallic and superconducting systems. In 1964, with B. N. Ganguly, he showed how interband hybridization gets modified by pressure, resulting in an increase in superconducting T_c. With Ganguly and U. N. Upadhyaya, Sinha studied a surprising experimental observation of enhancement of superconducting T_c when magnetic atoms were added to metals like titanium when local moments were not yet formed. It is fascinating that in modern parlance, Ganguly–Upadhyaya–Sinha theory could be interpreted as the emergence of Cooper pair singlet coupling (super exchange), via the virtual transition of two electrons into the empty impurity d-orbitals – somewhat analogous to super exchange physics used in RVB theory of superconductivity. In another interesting paper with Upadhyaya, again inspired by some experimental anomaly, Sinha discussed the possibility of resistance minimum (which is usually attributed to the Kondo effect), even in the absence of local moment formation and magnetic Kondo scattering.

In 1967, while at NCL, Sinha and Kumar started thinking about the possibility of light-induced non-equilibrium high-temperature superconductivity in special situations, where the conventional mechanism of electron–electron attraction mediated by a single-phonon is replaced by photon (one-boson process) and by one-phonon and one-photon (two-boson process) mediated attraction. Their article on 'Photon induced superconductivity' appeared in *Physical Review* in 1968. R. K. Shankar pursued his Ph.D. thesis on this topic with K. P. Sinha at IISc, in mid-70s. Vinod Krishan, then a UGC Associate at IISc (a renowned Astrophysicist who later retired from the Indian Institute of Astrophysics, Bangalore), wrote an article on this problem with Sinha. Nearly half a century later, in recent times, experimental results on femtosecond laser pulse-induced room temperature transient superconductivity and electromagnetic cavity-modified superconductivity are widely discussed, using a variety of mechanisms. Though not well cited, it is clear Kumar–Sinha mechanism (1968) is at work in some situations – it is gratifying that they were far ahead of their time.

Sinha's wide-ranging contribution, in what could be called modern theory of solid state at that time, got him a job at the prestigious Bell Laboratories in 1968. After a stint of three years, he was invited as a senior Professor at the IISc, by the then Director Satish Dhawan. It was Dhawan who also invited N. Kumar as a young Assistant Professor in late 1970 when Kumar was a Post-Doctoral Fellow at the University of British Columbia, Vancouver, working with M. H. L. Pryce (former Post-Doctoral adviser of K. P. Sinha), who had moved from Bristol to British Columbia. Sinha

and Kumar, in some sense, laid the foundation for a famous and vibrant condensed matter theory group developed and nurtured later by T. V. Ramakrishnan at the Physics Department of IISc.

Many of Sinha's Ph.D. students from NCL days worked on the interaction between important elementary excitations in quantum magnets, namely magnon, phonon and electron quasiparticles. It started with work with U. N. Upadhyaya, N. Kumar, S. S. Shah and others. Sinha continued to work, at IISc, on the magnetic properties of solids. 'Plasmon–magnon interaction in magnetic semiconductor' by K. P. Sinha and one of us (GB) appeared in the first issue of *Pramana* in 1973. It reported, based on theory, that this novel interaction is weak – a somewhat negative result. However, thanks to experimental advances in the field of spintronics, magnonics and plasmonics over decades, this work has been picked up recently, after nearly 50 years. It is likely that even this weak effect could be measured and made use of.

A remarkably big and versatile IISc is known for its eclectic-wide ranging activities, motivated and open-minded research students with varied interests. It provided a bigger platform for Sinha to perform. Further, Satish Dhawan's efforts to expand research activities saw him invite E. C. G. Sudarshan, a renowned theoretical physicist at the University of Texas, Austin, to spend a few weeks each year at IISc. K. P. Sinha, N. Mukunda, Madhav Gadgil, Sulochana Gadgil, Sharat Chandra, R. Rajaraman, A. K. Rajagopal, J. Pasupathy, V. Nanjundiah and others became founding and early members of the Centre for Theoretical Studies (CTS) that was established in 1972, under the Directorship of Sudarshan. CTS brought researchers from different backgrounds to work on theoretical problems in subjects ranging from ecology to cosmology. The same year, the departments in the Institute were reorganized into four Divisions, and Sinha became the first Chair of the Division of Physical and Mathematical Sciences.

A unique feature of IISc is its collaboration and synergy with other research institutes in Bengaluru: National Aeronautical Laboratory (NAL), Raman Research Institute (RRI) and later, The National Centre for Biological Sciences (NCBS), International Centre for Theoretical Sciences (ICTS), Jawaharlal National Centre for Advanced Scientific Research (JNCASR). Thanks to R. Jayaraman (a high-pressure physicist from Bell Labs visiting NAL and IISc for a year, on invitation by S. Ramaseshan, then director of NAL) and young Rajaram Nityananda (a Ph.D. student of Ramaseshan), new discussions started with K. P. Sinha and N. Kumar's group at the Physics Department of IISc. Research on Mott insulators, Mott transition, valence fluctuations, strongly correlated systems, etc., were carried out. Sinha encouraged his research students to interact and collaborate with visitors to CTS and IISc.

During this period, Sinha expanded his research activities into cosmology and the general theory of relativity. He had visitors like Eric Lord, a mathematician and relativist from the UK who spent a few years at IISc. The Department of Physics of IISc, well known for being strong in experimental physics, made new inroads into modern theoretical condensed matter physics and other fields. His students, R. K. Shankar, V. M. Nandakumaran, R. Jagadish and several others, worked on quantum matter issues such as superconductivity and exciton condensation.

C. Sivaram, a fresh Ph.D. student, was well up in general relativity, quantum theory, particle physics, etc. Sinha, as a guide, encouraged him to go deep. The result was a number of publications from the 'Bangalore group', as referred to by Abdus Salam and Yuval Ne'eman. On his request, Sivaram gave a full-fledged course on Astrophysics. C. Usha (Usha Raut), B. S. Satyaprakash and other students joined the 'Bangalore Group' soon, contributed and grew independently.

Every new experimental discovery in solid-state physics could be exciton condensation in semiconductors or high T_c superconductivity in cuprates, or a claim of observation of cold fusion in some electrochemical reactions excited Sinha. He attempted to develop theories and explanations. In 1989, at a Cold Fusion meeting in Bangalore, he suggested the role of electron pairing in that context based on his work in superconductivity. He returned to that theme in 1998 in an obituary he wrote for Professor F. C. Frank. In 1999, with the assistance of Epoch Engineering in Gaithersburg, Maryland, he further documented and presented his ideas in the USA. In the summer of 1999 at Harvard University, he completed and published a mathematical description of his concept in *Infinite Energy* magazine. He then joined MIT as a visiting scientist in the year 2000 to work with Peter Hagelstein, Louis Smullin and Andrew Meulenberg of Draper Laboratories on theoretical models for microgap thermal photovoltaic devices. These models provided a theoretical basis for greatly improving the efficiency of such devices for directly converting heat into electricity.

Sinha returned to Bangalore in 2004 and was joined there in 2005 by Meulenberg to begin a decade of work and publication on cold fusion. While the physics world remains sceptical about cold fusion, as always, reproducible experiments and nature are the final judges for confirming the validity of an intriguing phenomenon of 'cold fusion' and the relevance of his theory.

Sinha also joined ranks with Nobel Laureate Brian Josephson in attempting to explain paranormal phenomena and issues such as consciousness using physics and quantum physics. He interacted with people like Maharishi Mahesh Yogi. With E. C. G. Sudarshan, he wrote a couple of articles on the field theory of consciousness, etc. It is said that every thinking physicist worries about the above problems. However, most physicists and scientists are convinced that these are 'hard problems' beyond our ability even to comprehend using physics in the hierarchy of emergence, Sinha dared.

An anecdote and acknowledgement from one of us (G. Baskaran): Sinha gave his students the freedom to work on problems of their choice and collaborate with anyone. IISc was a Science Paradise. Baskaran enjoyed any science that came on his way and completely ignored his Ph.D. thesis work. At the end of 3rd year, Sinha asked, 'Baskaran, are you ready to write your thesis?'. His answer was, 'Professor Sinha, I am not ready'. He repeated the question after 6 months and after another 6 months. The answer was the same. Apparently, after the 3rd attempt, Sinha sadly concluded it was unlikely that Baskaran will ever finish his Ph.D. However, his upcoming marriage, close to the end of his 5th year, woke him up. GB wrote a thesis reluctantly, putting together whatever he was working on then, and handed over the manuscript to Sinha. Being afraid that Baskaran might change his mind, Sinha grabbed the opportunity and corrected all 5 chapters of the thesis in a 'record' 3 days. Usually, guides take one to three months or even more to correct the thesis. Because of a timely and quick action from Sinha, Baskaran managed to submit his Ph.D. thesis.

Besides holding the directorship of the Institute of Fundamental Research on Complex System of North Eastern Hill University during 1991–94, Sinha held several Visiting Professor positions in top

Institutions in Europe and USA. He has guided 35 Ph.D. students and mentored 10 post-doctoral Fellows. After retirement, he continued his service at IISc in various capacities: National level Fellowships and Emeritus Professorship.

A Shanti Swarup Bhatnagar Award winner in Physics, Sinha was the Fellow of three Science Academies of India and The World Academy of Sciences. He won the Distinguished Alumni Award of University of Bombay (1974) and IISc Bangalore (1985). He is survived by his wife, two sons, two daughters, three grandchildren and two great-grandchildren.

G. Baskaran thanks T. V. Ramakrishnan and Jayant Sinha for the discussions. A very nice account of K. P. Sinha (when he completed 90) is given by Narayana Rao in the article 'KP Sinha – a Vortex of Ideas', published in '*Connect*' from IISc (March 2019): https://connect.iisc.ac.in/2019/03/kp-sinha-a-vortex-of-ideas/

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