Bikash Chandra Sinha (1945–2023)

Dr Bikash Chandra Sinha was born on 16 June 1945 in Kandi, Murshidabad district of West Bengal. He passed away in Kolkata on 11 August 2023 at the age of 78.

After schooling and undergraduate study, Sinha left Calcutta in 1964 and went to Cambridge University in the United Kingdom for Physics Tripos. He subsequently obtained a Ph.D. degree in 1970 from London University. He then carried out post-doctoral research at the King's College of London University before returning to India in 1976. During these twelve years of stint in England, he came into contact with true luminaries of physics, most notably his teachers Sir Neville (Neville Mott) and Lord Alexander (Alexander Todd). Bikash absorbed from them true Western values of intellectual honesty and hard but enjoyable work that characterized the Cambridge atmosphere. And it is not just the union with physicists but also the society at large – be it in operas, theatres, concerts and cricket fields – that further shaped Sinha's cultural refinement, already inherent because of his genesis in Bengal's nobility, steeply rooted in eastern cultures of emancipated philosophy and education. Thus, Bikash became a man juxtaposed between the East and the West.

As indicated above, Sinha was raised in a wealthy environment of Bengal's Renaissance; he travelled from his ancestral home in Paikpara to the Scottish Church Collegiate School and then to the Presidency College of Calcutta. Evidence of the Sinha family's deep commitment to education can be discerned from the progressive school they had established called the Kandi Raj school, significantly in 1857, which coincided with the 'Sepoy Uprise' against the British Raj. No less a luminary than Ishwar Chandra Vidyasagar came for the school's inauguration, the noted poet (who had read physics and chemistry for his B.Sc.) Ramendra Sundar Tribedi studied there. Exactly one hundred years earlier, in the same soil of Murshidabad, we lost our freedom to the East India Company of the Raj.

Apart from the close friendship I enjoyed with Bikash, there are two other interesting coincidences. Like Bikash, I was also born in Murshidabad (though in a modest middle-class family of school teachers), and both of us permanently returned to India in the same year of 1976 – Bikash from the UK and I from the USA – to join the Department of the Atomic Energy (DAE). However, he and I came to two opposite corners of the Indian peninsula: Bombay and Madras. Bikash joined the Bhabha Atomic Research Centre (BARC) in Trombay, while I joined the Reactor Research Centre, now called the Indira Gandhi Centre for Atomic Research, in Kalpakkam. Curiously though, my interests in Response Theory, Diffusion and Phase Transitions have overlapped with Sinha's contributions over the years in completely different areas of Nuclear and High Energy Physics, which I will now enumerate.

In the mid-1970s, Bikash made an outstanding foray into what in my domain is called the Linear Response Theory and the Kubo formula. This is in the context of the optical potential and nuclear structure applicable to nuclear reactions of light-charged particles as well as heavy ions with nuclei. He did an innovative calculation by relating the nuclear response (to the field of the projectile) to the imaginary part of the optical potential. This is quite akin to the magnetic scattering cross-section being connected with the imaginary part of the magnetic susceptibility. The crucial input in this formulation is an effective two-body scattering potential (considering the saturation of strong nuclear coupling). The stratagem was later amplified in a joint paper in 1983 with S. C. Phatak in which the field created by one nucleus at the nucleons of the other nucleus is evaluated by treating the other nucleus as a Fermi gas. This gives rise to the imaginary component of the non-local nucleus–nucleus potential in which the intermediate states correspond to particle-hole excitations of the Fermi surface. What followed was a couple of review articles that bore testimony to the efficacy of Sinha's approach.

Later, in a related piece of work in 1983, Bikash computed the mean-free path of a nucleon in nucleus–nucleus collisions similar to the evaluation of the Drude scattering time that determines the electrical conductivity of a solid through the Kubo formula. These findings have significant implications for hot spots formed in nuclear collisions.

In the early 1980s, Sinha transited from medium energy Nuclear Physics to High Energy Heavy Ion Nuclear Physics, delving into questions on what happens deep inside the nucleons. That is the beginning of his entry into Quark Gluon Plasma (QGP) physics, in which the quarks are like Brownian particles diffusing through a sea of gluons. This simple-minded picture would, of course, have to be elevated to the domain of quantum dissipation, in which the quarks or the Brownian particles are endowed with quantum mechanical attributes, whereas the surrounding heat bath would have to be envisaged as a many-body collection of bosons and fermions. This scenario is very much in tune with the topical interest in the quantum Langevin equation in the field of dissipative condensed matter physics. A related semiclassical approach is that of Sinha with his collaborators Sibaji Raha and Jan-e Alam in 1994, wherein they dealt with a Fokker–Planck equation for the phase space distribution function.

An important discovery of Bikash Sinha's research group in the 1980s is that the QGP is a distinct phase of the nuclear matter reached through a phase transition in the hadronic world. Two key ingredients in this finding are the ratios of dileptons to photons and dileptons to π mesons which yield suitable signatures of this new phase. It was also established by Sinha's group that these ratios are independent of the baryonic potential at an appropriately defined critical temperature, thus rendering the signals for the QGP independent of the baryonic background. Later, it was also discerned that the ratio of π mesons to dileptons could be a true signal of the QGP provided measurements are made within an appropriate kinematic window, determined by simultaneous recording of the ratio of the photon to the dilepton. The theoretical claim of photons and dileptons to be possible snapshots of QGP has been incorporated in the Large Hadron Collider (LHC) of the CERN in Geneva and the Radioactive Heavy Ion Collider (RHIC) of the Brookhaven National Laboratory in New York.

In recent years Bikash Sinha turned to Hawking radiation in the context of quark nuggets in the QCD (Quantum Chromo

Dynamics) phase transition (2020). He looked at the transition from a chiral symmetric QGP phase to a broken-chiral hadronic phase and the possibility of its connection with the early Universe microseconds after the Big Bang. In the 2020 paper, Sinha took this picture to the arena of Black Hole Thermodynamics by making an analogy between gravitational confinement due to black holes and quark confinement due to strong interaction. Supercooling, an essential ingredient of the Glass Transition in Condensed Matter Physics, is invoked as a possible source of quark nuggets. An intriguing simile is also predicted between the Hawking radiation from the gravitational field of the black holes and the quantum tunnelling of neutrons from the quark nuggets.

I now turn the discussion to Institution Building. Between 1976 and 1999, I would meet with Bikash during my sporadic visits to Bombay and Calcutta. The rendezvous became more frequent when I made a reentry in 1999, after a gap of thirty years, to the city, which was now renamed Kolkata, to the Satyendra Nath Bose National Centre for Basic Sciences. In between, our professional trajectories had diverged as I parted ways with the DAE and adopted a teaching career at two central universities: Hyderabad and JNU (Jawaharlal Nehru University) between 1981 and 1999. Bikash, on the other hand, remained a loyal DAE soldier. After moving to Kolkata, I had a closer glimpse of Sinha's numerous projects that underscore his unflinching dedication to institution-building.

Sinha moved from Trombay to Calcutta in 1984, first as the Head of the Computer and Research Facilities of the Variable Energy Cyclotron Centre (VECC) and later as the Head of the Theory Division and eventually as the Director of the Centre, in 1987. Subsequently, from 1992, he held the dual position of the Director of the Saha Institute of Nuclear Physics (SINP).

The VECC was already in possession of a room-temperature cyclotron of Berkeley design ($K = 130$). Bikash Sinha's early challenge as the Director was to develop in the VECC, a superconducting cyclotron. This was indeed a formidable task because of the scarce know-how in the country for the requisite cryogenic technology for making superconducting wires. An accompanying task of winding nearly 42 km of wire in the α and the β bobbins of the magnet proved to be another hurdle. Eventually, following an arduous effort over twelve years, the internal beam was sighted in 2009. However, extracting the external beam posed an extremely daunting task. It took ten more years when the external beam was detected in November 2019. Meanwhile, a parallel push was given to the production of radioisotopes for the treatment of cancer tumours, for which it was incumbent to buy a medical cyclotron from Belgium. This was a satisfying step indeed – a journey that Bikash Sinha and his colleagues had embarked upon, finally culminated in turning the 'City of Joy' into a 'City of Cyclotrons', endowed with a trio of cyclotrons: the original one of $K = 130$ design, the superconducting version of $K = 500$ and finally the 30 MeV medical cyclotron. Concurrently, Sinha had initiated in the VECC a Radioactive Ion Beam (RIB) facility, an ongoing project.

In addition, a Photon Multiplicity Detector was developed, which proved to be extremely useful in detecting the so-called azimuthal flow in the sulphur run at the CERN that lends confirmation to the equation of state of strongly interacting nuclear matter. Related experimental programmes are also being planned at the LHC in the CERN.

As I mentioned earlier, Sinha was also at the helm of the twin institute of the SINP since 1992. The SINP plays a dual role to the VECC, much like what the Tata Institute of Fundamental Research in Mumbai does to the BARC. While the VECC runs on a project mode, the SINP is more in the model of a research institute with a built-in post-M.Sc. teaching curriculum. It could boast of some excellent physicists. But it is fair to say that it is Bikash Sinha and his exemplary leadership attributes that helped elevate SINP to an international platform by initiating a host of collaborative activities such as the Frena (Facility for Research in Nuclear Astrophysics) to accurately measure cross-sections at very low energies, relevant for nuclear astrophysics, especially for the so-called 'r' and 's' processes. A magnetic spectrometer facility was also commissioned at the SINP during Sinha's tenure. Furthermore, Sinha spearheaded a large-scale collaborative programme with the CERN, hitherto unprecedented, in which the SINP acted as the Indian nodal centre with an active partnership with other institutions, including universities such as Jammu and Delhi.

As the Director of the VECC and the SINP, Bikash Sinha had led an Indian team for participation in ion and anti-proton facilities with the acronym FAIR (Facility for Antiproton and Ion Research) – another landmark international collaborative project. Finally, the ALICE (A Large Ion Collider Experiment) detector was developed to look into thermometric signals of quark-gluon plasma, especially comprising photons and di-muons. Simultaneously, the MANAS (Multiplex Analog Signal-Processor) chip was designed for muon spectrometry.

From the above descriptions, it is amply clear that Bikash Sinha the individual was very much a synthesis of science and society. His heart was in the search for the societal benefit of fundamental science. The medical cyclotron, in collaboration with the Cancer Hospital in Thakurpukur, Kolkata, was dedicated to developing PET (Positron Emission Tomography) for diagnostics of prostate cancer, the dreaded disease that ironically afflicted Sinha himself in the end.

On Sinha's abiding concern for making the fruits of scientific research available for the good of humanity, it is worth mentioning the scheme for the extraction of helium (He) from the natural springs at Bakreswar and Tantloi, about 250 km northwest of Kolkata. One concrete fallout of that project is the tantalizing correlation between the enhancement of He content (by a factor of 2 to 3 in the natural gas in springs) and earthquake and volcanic activities. It remains to be seen whether the increase in the He production can be envisaged as precursors for tremors.

Bikash Sinha's inner urge to stay close to society propelled him to the confluence of science and philosophy. True to his cultural upbringing, his holistic personality delved deep into science-related Bangla literature. Indeed, he engaged himself in creative writings that brought him recognition, such as the 'Rabindra Puraskar' from the Government of West Bengal, in 2022. An epitome of his fascination with the Bengali culture is the Tagore Centre for Natural Sciences and Philosophy (TCNSP) which he was inspired to create in order to propagate the vision of the great philosopher-poet who also viewed Nature as a living laboratory of science. One of the stated objectives of TCNSP is to take science to remote rural schools and popularize science through the medium of vernacular language, embodied in Rabindranath Tagore's 'Viswa-Parichay'.

Given his illustrious career, it is expected that Bikash Chandra Sinha would have been embellished with numerous laurels along the way, and he did receive – Fellowship of Science Academies, both Indian and foreign, honorary degrees from universities, state awards and the honour of chairing various committees. But what is more enduring is the love and warm-hearted affection inside him for the multitude of his adoring and admiring research students, colleagues and friends. A profound signature of that intrinsic feeling of Sinha is most aptly captured by the following quotes of two stalwart poets of whom Bikash was an avid reader:

As long as there is one heart on Earth where I still live, my memory will not die.
– Alexander Pushkin

My love for this world is the only truth, a gift of my birth. As I depart, this indelible truth would push death to oblivion.
– Rabindranath Tagore

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J. Gopalakrishnan (1944–2023)

Jagannatha Gopalakrishnan (JG) was born in 1944 in Villupuram, Tamil Nadu, India. He earned his B.Sc. and M.Sc. degrees from Madras University and Ph.D. from Indian Institute of Science (IISc), Bengaluru. Soon after, he joined the Chemistry Department faculty at the Indian Institute of Technology, Madras. In 1977, JG joined the newly founded Solid State and Structural Chemistry Unit at IISc.

JG contributed immensely to Preparative and Structural Solid-State Chemistry with emphasis on the synthesis of non-molecular solids (especially metal oxides), development of a general chemistry-based (*Chimie douce*) approach for the synthesis of metastable inorganic solids alongside a rational synthesis of extended inorganic solids. He employed a variety of inorganic solids and their solid solutions as precursors and transformed them to the desired products using appropriate chemical reactions, namely dehydration, decomposition, reduction/oxidation, atom insertion/extraction and so on. His work on many d^0-metal oxides has led to recognition of second order Jahn–Teller effect in the formation, structure and properties of d^0-oxides. He pursued a unit-by-unit assembly approach through appropriate metasynthesis to build novel inorganic architectures with targeted materials properties. JG authored in excess of 400 publications and his book with Prof. C. N. R. Rao on *New Directions in Solid State Chemistry* is highly acclaimed. He was a Senior Fellow at the AvH Foundation (Humboldt), Germany. He spent a year as a Visiting Scientist at Dupont CR&D, Wilmington, USA. He also spent a year as Visiting Professor at the University of Maryland, USA.

Early in his academic career, JG recognized that synthesis, the art of creating new substances, be they discrete molecules or extended solids, would remain as the major forte of solid-state chemistry. He strongly believed, 'if room-temperature superconductors or synthetic bacteria are ever created, it will not be physicists and biologists who will make them!'. He passionately pursued the role of structural inorganic chemistry in the quest for new materials with technological applications. In his own words, 'while the discipline of chemistry as a whole plays a crucial role in this quest – physical chemistry, for instance, helps resolve issues like stability versus metastability/thermodynamics versus kinetic control of synthesis, inorganic chemistry, by its very nature of being the chemistry of all the elements and their compounds, is of special significance in the quest for new materials, for the simple reason that almost all the new materials that are sought are extended inorganic solids, mostly oxide materials comprising transition and non-transition elements'. He always recognized the need for a sound knowledge of the chemistry of both transition and non-transition elements to practice high quality materials synthesis. Throughout his career, he judiciously combined his vast knowledge in structural inorganic chemistry with fundamental inorganic concepts such as acidity/basicity, redox reactions, crystal field theory, Jahn–Teller distortions, mixed valence, electron transfer and metal–metal bonding to design new nonmolecular solids. JG was a voracious reader with exceptional memory and had an unusual ability to relate structures that are not obvious. He successfully employed his strength to generate new synthetic methodologies. His selected papers include: Metathetic route (*J. Am. Chem. Soc*., 2000, **122**, 6237–6241); Ion exchange reaction (*J. Am. Chem. Soc*., 2000, **122**, 6237–6241; *Mat. Res. Bull*., 1987, **22**, 413–417); Oxidative deintercalation (*Chem. Mat.*, 1992, **4**, 745–747); Broensted acidity (*Inorg. Chem*., 1995, **34**, 3760–3764).

JG served as an Editorial Advisory Board Member for *Chemistry of Materials*, an ACS Journal, which provides testimony to his international academic standing. He was a Fellow of the Indian Academy of Sciences, Indian National Science Academy, and National Academy of Sciences. He also received several awards.

JG was a dedicated teacher, a sought-after mentor, and a brilliant yet humble scientist. His death on 19 July 2023, has created a huge vacuum in the field of Materials Chemistry in the country.

JG was a loving father and is survived by his wife and daughter.

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