Ram Kumar Varma (1935–2014)

Ram Kumar Varma, former Director of the Physical Research Laboratory (PRL) Ahmedabad, passed away on 14 May 2014 following a massive heart attack. He was an internationally renowned plasma physicist and one of the pioneers of this field in the country.

Varma was born in Sardhana in Meerut district of Uttar Pradesh on 31 March 1935. He obtained his B Sc in 1953 from Agra University. Soon after completing his M Sc in 1956 from Lucknow University, he joined the Tata Institute of Fundamental Research (TIFR), Bombay as a Research Assistant. He was proud of the fact that his selection interview was done by Homi Bhabha himself. At TIFR, Varma received training in many areas of theoretical physics, including plasma physics, when Hannes Alfven (Royal Institute of Technology, Stockholm) visited the Institute and taught a course. He also began his research work during this period on cosmic ray acceleration and plasma kinetic theory. In 1961, he sailed to the United States under a Fulbright Scholarship, to pursue his Ph D at the University of California in La Jolla. He obtained his Ph D in 1965 under the guidance of the legendary plasma physicist Marshall Rosenbluth and worked on plasma instabilities and general stability theories relevant to magnetic fusion devices. After spending a year as a Resident Research Associate at the NASA Langley Research Center, Hampton, Varma returned to TIFR in 1966 to join the plasma group of the institute. It was around this time that he started his fundamental work on the non-adiabatic effects in the motion of charged particles in a magnetic field and wrote a novel Schrödinger-like equation for the dynamics of the particle. His seminal paper on this topic published in *Physical Review Letters* received much attention from the fusion community, as it provided a useful model to understand certain aspects of particle losses in a magnetic mirror machine. In 1968, at the invitation of Vikram Sarabhai, Varma moved to PRL, where a new plasma physics programme was being initiated. On arriving at PRL, he quickly familiarized himself with the Laboratory's research activities related to space plasmas – particularly ionospheric physics, solar wind interactions with the Earth's magnetic field and cosmic ray acceleration, and began to actively contribute towards theoretical modelling and interpretation of experimental observations. He continued to work on various aspects of plasma instabilities and plasma turbulence with applications to fusion as well as space phenomena. He made seminal contributions in many areas of theoretical plasma physics, including tokamak physics where he provided valuable insights into a 'pinch' effect, dusty plasmas, plasma interaction

with neutral matter, soliton physics and laser plasma interactions. However, his primary love and passion in research was to explore and exploit quantum–classical relationship that had found its first expression in his work on non-adiabatic effects in charged particle trajectories in a magnetic field. Over the years, he developed a number of new ideas to explore this relationship and to suggest a new conceptual framework for explaining certain macroscopic experimental phenomena. In fact, he was not content with just developing a theoretical framework and predicting its possible experimental manifestations, but was keen to participate actively in doing the experiments as well.

Thus with the formation of an experimental programme in plasma physics in the early seventies, Varma became an enthusiastic experimentalist. He became involved with this group in a very sophisticated experiment on the tunnelling of electrons from a non-adiabatic magnetic mirror. The motivation was his own theory, which attributed the non-adiabatic loss of particles from a mirror trap to tunnelling from the adiabatic potential well, by particles of energy lower than the maximum height of the potential barrier and predicted the decay of the number of particles from the trap with multiple lifetimes. A long ultra high vacuum chamber with multiple water-cooled solenoids forming a symmetric mirror was set up. Electrons were injected into this from a thermionic injector. An electrode beyond a mirror throat collected electrons leaving the trap. The low electron density of the order of $10^4/\mathrm{cm}^3$ ruled out collective behaviour. The experimental results conformed to theoretical predictions in some essential aspects, namely the existence of more than one decay time, their dependence on the magnetic field, its gradient and the particle energy. The ratio of the values of the slope of lifetime versus magnetic field at different pitch angles, radial positions and particle densities agreed with theoretical predictions.

Varma persistently pursued a related problem of behaviour of charged particle motion in a magnetic field in the presence of a retarding electric potential. When a beam of electrons is propagated in a magnetic field and scanned in terms of its 'parallel' energy using a retarding potential, the response of the transmitted current as a function of the retarding potential was found to be oscillatory, as against the monotonic response, expected according to the standard initial value paradigm of classical mechanics. The unexpected 'peaks' and 'dips' in the transmitted current plots are interpreted as 'allowed' and 'forbidden' energy states of the system. The peaks (or dips) are found to fit very well with a theoretical relationship that motivated the search for such a behaviour; also 'quantum numbers' for the peaks have been identified. An astonishing aspect of the relationship is the dependence of the energies of the allowed states on the length of the box. These interference effects on the macro-scale have been shown here to be an interesting consequence of quantum entanglement between the parallel and perpendicular degrees of freedom of the particle. Treating the problem in the framework of the inelastic scattering theory, Varma showed that these macro-scale matter waves are generated in the 'parallel' degree of freedom as a modulation of the plane wave state of the particle along the field concomitantly with the excitation of Landau levels in the perpendicular degree of freedom in an inelastic scattering episode.

Alfven had proposed that when a plasma and neutral gas in relative motion across a magnetic field interact, rapid ionization of the neutral gas would happen when the velocity exceeds a critical value $V_{cr} = [2eV_i/M_n]^{1/2}$, where M_n is the atomic mass of the neutral gas and V_i is the ionization potential. Varma had proposed the existence of a threshold velocity determined by the kinetic energy of the ion species for the interaction to happen. The experimental device built in PRL to study this problem produced fast-moving plasma streams from a coaxial plasma gun which impinged on a neutral gas cloud formed by the release of gas into vacuum through a fast-opening gas valve. The experiment confirmed the critical velocity phenomenon, while showing the absence of the threshold velocity.

Apart from his research work, Varma was also a dedicated and excellent teacher who mentored many generations of young physicists at PRL – several of whom are now well-known, established researchers all over the world. For many years he conducted a successful school on plasma physics at ICTP, Trieste that benefited a large community of young plasma physicists in the developing world. He contributed a great deal to the scientific growth of PRL as well – particularly during his tenure as Director during the period 1987–1995. Well loved by students and colleagues, he was a cheerful soul – a lover of Urdu poetry and ghazals, a talented singer of Hindustani classical music and a great raconteur and fun-loving personality.

From the exploratory beginnings in the seventies to international partnership in building a miniature sun on earth, few fields of physics have had such rapid growth in India as plasma physics. Varma contributed to a formative influence in this growth. The community will always cherish his insightful advice and creative mentorship, both to his peers and to the large community of students.

Varma was elected a Fellow of all the three national science academies of the country (Indian Academy of Sciences, Bangalore in 1977; Indian National Science Academy, New Delhi in 1985 and the National Academy of Sciences, India, Allahabad in 1988) as well as the Astronautical Society of India. He served as the Chairman of the Plasma Society of India (1978–1982) and was a recipient of the H. C. Shah Award and Gold Medal (1977).

He leaves behind his wife Sushma, sons Hemant and Rajat and family members.

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