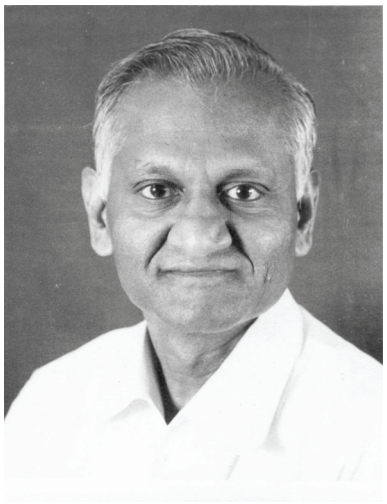
Chindhu Sona Warke (1931–2020)

Professor Chindhu S. Warke, a leading figure in the Indian nuclear physics community, passed away in Mumbai on 23 July 2020, after a distinguished career at the Tata Institute of Fundamental Research. Warke was born on 23 November 1931 in an impoverished family of farmers, in the village Hingona, Jalgaon district, Maharashtra, and did his schooling locally in Marathi. With the help of kind and generous mentors, Warke overcame language and socio-economic barriers to become a first-generation college graduate in his family. His egalitarian outlook, possibly an outcome of those early struggles, made him a highly approachable and empathetic teacher, advisor and colleague, as we note in detail below.

Warke obtained his B.Sc. degree in mathematics, physics and chemistry from Pune University in 1954, receiving the G. K. Gadgil prize for earning top marks in chemistry. In 1956 he received his M.Sc. degree in applied math from the same university, obtaining first rank. In August 1956, he joined the theory group in TIFR as a research assistant. Later, and following the innovative pattern created by Homi J. Bhabha to counter the shortfall of theoretical faculty in India at that time, he was sent to the University of California San Diego (UCSD). There he earned his Ph.D. degree in 1964, specializing in theoretical nuclear physics, with Keith Brueckner as his supervisor. In 1966, after a year as a postdoc in nuclear physics at UCSD, Warke rejoined TIFR to eventually retire as a Professor in 1991. During 1970–72 he was the recipient of the Canadian NRC award for distinguished scientists from developing countries. Later he spent 1975–76 at McMaster University Canada and 1980–82 at the Institute of Physics, Goethe University, Germany as a visiting Professor.

In the late sixties and mid seventies, Warke worked on a variety of problems in nuclear spectroscopy and nuclear reactions. One of his most notable works in nuclear spectroscopy was the description of the spectra of deformed nuclei using a variational, effective single-particle approach. This was done using projected Hartree–Fock theory with a phenomenological residual nucleon–nucleon interaction and projection of good angular momentum states from the deformed Hartree–Fock state. The method was remarkably successful for lighter open-shell (2s-1d) nuclei. However, for heavier nuclei, it appeared that the pairing correlations between nucleons needed to be considered to best describe their spectra. Warke, in collaboration with M. R. Gunye and S. B. Khadkikar, addressed this issue by considering a Hamiltonian that included a pairing interaction term. The spectra were calculated using a BCS-type many-body wave function and projecting the good number and angular momentum states from this HF-BCS state. This variational method was able to predict remarkably well the spectral properties over a wide range of stable nuclei.



At this stage, the subject of heavy-ion collisions witnessed some interesting developments. It was conjectured that during heavy-ion collisions, the colliding nuclei paired up forming an intermediate very heavy nucleus with very high spin states. It was also speculated that some of these states (called yrast traps) might have relatively long half-lives. Warke (along with Gunye) started investigating whether these unstable states can be described with the projected HF-BCS method. They showed that both the computed theoretical spectra and the half-lives of some of the very heavy and unstable nuclei formed during heavy-ion collisions were in good agreement with experimental results.

In the case of nuclear reactions, Warke together with R. K. Bhaduri at McMaster University, generalized the Jost–Pais theorem to a central non-local potential in any angular momentum state. This generalized function was related to Fredholm determinants that appear in the potential scattering theory. Further, for a general non-local interaction, he generalized the results of the potential scattering theory to off the energy shell.

Additional notable works of Warke, especially in the theory of effective interactions, include renormalization of the effective nucleon–nucleon interaction by core-polarization processes (with E. Osnes) and derivation of a local, central density dependent potential from a two-nucleon tensor force in nuclear matter which can be used in finite nuclei (with Bhaduri).

Apart from nuclear physics, Warke's interest in condensed matter physics was strong and present almost from the beginning of his career. While still a graduate student at UCSD, he collaborated with Katuro Sawada, an eminent visiting scholar, on the problem of rigorously demonstrating the sharpness of the Fermi surface with repulsive interactions. The existence of a sharp jump in the momentum distribution function is a central, and unproven assumption in Landau's theory of Fermi liquids. The usual textbook justification for this assumption makes an appeal to the convergence of perturbation theory. When interactions become strong, the use of perturbation theory is questionable, and one needs the extra support of non-perturbative arguments. The latter are hard to come by, and remain in great demand to present date. For a particular type of strongly repulsive interactions, Warke and Sawada showed that a certain exact quantum mechanical inequality for the ground state expectation of certain combinations of operators, named after them in recent years, can be harnessed towards this goal successfully. This work presaged important activity in these topics in later years.

In the theory group of TIFR after 1967, Warke collaborated with almost all the condensed matter theorists on a continuous basis. With Sudhanshu Jha, he worked on many-body aspects of harmonic generation at metallic surfaces, nonlinear response of Bloch electrons to a magnetic field, and on nonlinear optical effects in semi-conductors (also

involving Kailash Rustogi). With Chanchal Majumdar, who shared an office with him for several years, he worked on the effects of paramagnetic impurities on the life-time of positron in liquid ammonia, a popular material that provides a laboratory idealization of the theoretically postulated homogeneous electron liquid with a variable density.

In 1978, he became interested in the exact solution of time-dependent Hartree–Fock equations, and wrote important papers with Y. Nogami. He collaborated on several projects at TIFR with Arun (A. C.) Biswas: on developing a Hartree-type description of two-dimensional superfluid helium, on developing action-angle-type description of the ac Josephson effect in superfluid helium, and on propagation of solitons in mixtures of helium (III) and helium (IV) liquids.

Among Warke's most notable contributions in later years was his seminal work with his graduate student R. Shanker, on the derivation of nucleon–nucleon interaction from phenomenological quark–quark potential. Two distinguishing features of this work were the inclusion of the detailed radial dynamics of quarks, and the use of realistic values of the quark masses and the coupling constants. In this rigorous derivation, they showed how the strong short-range repulsion in the *NN* interaction arises from coloured quark exchanges, and how the spin–orbit term and the tensor-interaction term in the quark–quark potential lead to the corresponding terms in the *NN* potential. In those early years of quantum chromodynamics when it was still being considered as a candidate theory of strong interactions, and the direct evidence of gluons had just been found, this was an important piece of work in support of QCD.

After retiring from TIFR in November 1991, Warke spent a few years at IIT Bombay as Emeritus Scientist (CSIR). During these years, he collaborated with Yogi Gambhir, and revisited nuclear structure physics, but now in the framework of the relativistic mean-field (RMF) approach. They investigated, among other things, the existence of the broken pseudo-spin symmetry in the shell-model spectra. Both spherical RMF and constrained deformed RMF calculations were carried out employing realistic Lagrangian parameters. The quasi-degenerate pseudo-spin doublets were confirmed to exist near the fermi surface for both spherical and deformed nuclei.

Notwithstanding his remarkable accomplishments, Warke remained very approachable and down-to-earth. He had a keen interest in the research work of graduate students, not only in nuclear physics (both theory and experiment) but also in condensed matter physics, astrophysics, high-energy physics, and indeed in most other fields studied at TIFR. He would take a serious interest in the work of any student who approached him, often helping them with their calculations, and selflessly giving his time. One personal characteristic that a freshly inducted graduate student noted about Warke, was how helpful and precise he was in answering their apparently mundane questions. He pushed the students and colleagues to be precise and to avoid giving hand-waving arguments.

Seminars given by graduate students became extra lively whenever he attended; he was always interested in finding out how they were progressing. He was full of questions, suggestions, and ideas for further exploration. He was outspoken in his encouragement of students who often found extra motivation, after experiencing his enthusiasm for a broad range of topics, and the constructive nature of his interest. Indeed these traits marked him as an exceptionally influential mentor of the broader student community; not just in India but also elsewhere. Similar anecdotes are reported about his interactions with German students, during his long visits to Walter Greiner's group in Frankfurt.

Overcoming formidable initial odds, Chindhu Warke rose to be an eminent theoretical physicist, a great teacher and a generous mentor. He retained a highly curious and sharp mind until the end. His daily routine to the end, included two or more extreme level games of the combinatorial puzzle Sudoku each day! In the passing away of Chindhu Warke the physics community has lost a remarkable man and a highly respected intellectual leader. His contributions will be remembered and will influence physics in India for a long time. He is survived by his wife Smt Anjani Warke, and their children Sarita Mahajan, Manisha Rohtagi and Nirmal Warke who live in the United States of America.

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