IN MEMORIAM

E.C. GEORGE SUDARSHAN

Ennackal Chandy George Sudarshan, an eminent theoretical physicist, was born September 16, 1931, in Pallam, Kerala in India. He studied at CMS College in Kottayam and at Madras Christian College where he received his B.Sc. and M.Sc. with honors. He obtained his Ph.D. at the University of Rochester under the supervision of Robert Marshak in 1958. George then held positions at Harvard, the University of Rochester, and Syracuse University before joining the faculty at The University of Texas at Austin where he was a Professor of Physics from 1969 until his death on May 13, 2018, at the age of eighty-six. During his long career at UT Austin, George served as Director of the Center for Particle Theory, 1970-91, leading a world-class effort in this field.

George was recognized for his work by many awards and honors, including the Padma Bhushan (Order of the Lotus) presented by the President of India in 1974, the Bose Medal from the Indian National Science Academy in 1977, the Padma Vibhushan (Highest Order of the Lotus) in 2007, and the Dirac Medal from the International Center for Theoretical Physics in 2010. However, no award adequately captures the magnitude of his contributions to science, his enduring legacy, and the admiration of countless colleagues and friends from all over the globe who have been greatly inspired by this truly outstanding physicist and humanitarian.

George's numerous ground-breaking contributions started when he was a graduate student and continued until his death. They were celebrated at a special conference in his honor on the occasion of his seventy-fifth birthday, "Sudarshan: Seven Science Quests," held November 6-7, 2006, in Austin, Texas. These "Seven Science Quests" are V-A: Universal

Theory of Weak Interaction; Symmetry; Spin Statistics; Quantum Optical Coherence; Quantum Zeno Effect; Theory of Tachyons; and Quantum Mechanics of Open Systems. A complete review is impossible to cover in a short Memorial Resolution, so we provide a brief review of a few highlights.

In 1957, George, together with Marshak, submitted his ground-breaking paper, "The Nature of the Four-Fermion Interaction," of which George (then a graduate student) was the first-named author. They presented a comprehensive analysis of existing experimental data in elementary particle physics, which, along with the imposition of an elegant chiral symmetry principle, allowed them to deduce a unique form for the weak nuclear interactions, the so-called V-A theory. Their daring hypothesis was accompanied by a list of four experimental results that, it was said, "cannot be reconciled with this hypothesis... All of these experiments should be redone." Indeed, the experiments were redone, and the results confirmed their hypothesis. The Sudarshan-Marshak V-A theory has now withstood the test of time and is a cornerstone of the Standard Model of Elementary Particle Physics.

This work by George Sudarshan as a graduate student was remarkable, a lifetime achievement for any scientist, but George was just getting started. He continued his work on Symmetry as a guiding principle for theory, and developed a "no-go" theorem to provide a deeper understanding of mass differences of particles belonging to spin- degenerate multiplets. His work on spin-statistics led to the concept of the color charge of quarks, a breakthrough in explaining the strong nuclear force in a theory known as Quantum Chromodynamics.

George's scientific contributions were not limited to elementary particle physics: he was also a pioneer in the emerging field of Quantum Optics where he developed a quantum description of light. This work, carried out independently by George Sudarshan and Roy

Glauber, presented a quasi-probability distribution of the electromagnetic field in which observables are expressed in normal order. This work serves as the foundation of Quantum Optics to this day.

George, who had a lifelong interest in foundational problems in quantum mechanics, was especially interested in the behavior of unstable quantum systems such as radioactive atoms that decay over time. In 1976, George and Misra published a paper entitled "The Zeno's Paradox in Quantum Theory," in which they proposed that the decay of a quantum system can be inhibited by frequent measurements during the non-exponential time of the state's evolution. This bold prediction attracted widespread popular interest and also inspired experimentalists to meet the challenge. The difficulty was that, in practice, the non-exponential time is typically too small to allow a measurement that resets the quantum dynamics. In 1990, the quantum Zeno effect was observed by the Wineland group at the National Institute of Standards and Technology (NIST) in Boulder, Colorado. They measured the evolution of a two-level system of trapped atomic ions as one of the states was repeatedly interrogated, thereby inhibiting the transition. In 2001, the quantum Zeno effect was first observed experimentally in an unstable quantum system, as predicted by Misra and Sudarshan, by the Raizen group at UT Austin in quantum tunneling of ultra-cold atoms confined to an accelerating optical lattice.

In all of the above, George's theoretical predictions were always confirmed by experiment, an enviable achievement for any theorist. Yet George has left us a bold prediction that has not so far been observed, a grand challenge for future experimentalists. He predicted that certain particles could travel *faster* than the speed of light and showed that their doing so would not violate any physical laws, specifically Einstein's theory of special relativity. If this prediction is one day confirmed by experiment, it would be a true revolution in physics.

When George entered a field, he usually changed it fundamentally. And when he did not, he left indelible marks of his visit, marks that remained long after he had gone off to distant lands. When he had one of his frequent epiphanies, those who had the good fortune to be around were forever inspired; his generous sharing of thoughts and ideas catalyzed the emergence of thoughts and ideas in several generations of physicists. Many would say that the ability to seed fertile minds is what makes a great teacher—add to it kindness and care and one defines the perfect prescription for honing young minds. And George honed a multitude. George Sudarshan, a giant of science and a wonderful human being, brought much honor and prestige to The University of Texas at Austin and will be greatly missed.

Gregory L. Fenves, President
The University of Texas at Austin

Alan W. Friedman, Secretary
The General Faculty

This memorial resolution was prepared by a special committee consisting of Professors Mark G. Raizen (Chair), Charles B. Chiu, and Swadesh M. Mahajan.