

E. C. G. Sudarshan and the development of weak interaction theory

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E. C. G. Sudarshan turned sixty in September 1991. To mark the occasion and honour his contributions to many areas of theoretical physics, a Workshop was held at the University of Texas at Austin. (The Proceedings are being published by World Scientific Publishing Company, Singapore, under the editorship of A. M. Gleeson.) This issue of *Current Science* contains the text of a talk given by Robert E. Marshak during the Workshop, entitled 'The Pain and Joy of a Major Scientific Discovery'. Perhaps it is not out of place to explain briefly the background to this talk, and, in particular, to its title.

Marshak guided Sudarshan for the PhD degree at the University of Rochester during the period 1955–57. The work done by student and teacher at that time led to the universal V–A theory of weak interactions. This was a time of rapid and stunning advances in this area of elementary particle physics, following upon the proposal by Lee and Yang in 1956 that parity was not conserved in weak processes, and the confirmation of this in Madame C. S. Wu's classic experiment. The work of Lee and Yang was honoured by the award of the physics Nobel prize the very next year.

Marshak was one of the leading theorists in particle physics at that time, with a particularly keen appreciation of the developing experimental situation. After training under Hans Bethe at Cornell in problems of astrophysics involving weak processes, he joined the University of Rochester in 1939, and stayed there till 1970. He has always had a strong motivation and interest in promoting exchanges and contacts among physicists at the international level and has worked devotedly for these aims. In fact, soon after the historic Shelter Island conferences around 1947, held under the inspiring leadership of Robert Oppenheimer, Marshak conceived of the Rochester conferences in particle physics, which over the decades have become the most important international meetings on the

subject. (For a fascinating historical perspective of the development of particle physics viewed through these conferences, see J. C. Polkinghorne's *Rochester Roundabout*, published by W. H. Freeman.) To his own department at Rochester, Marshak brought many talented students from many countries, names familiar to those working in particle physics as well as in other areas: Albert Messiah, Susumu Okubo, Tullio Regge, Bunji Sakita and others, apart from Sudarshan. It was during an extended visit by Marshak to the Tata Institute of Fundamental Research in Bombay in 1953, at Homi Bhabha's invitation, that he and Sudarshan (then E. C. George) first met, and the decision that the latter go to Rochester was taken.

Marshak's talk records these early events, and the background against which the work on the V–A theory was done. About the significance and brilliance of this work there can be no question. Following Fermi's original 1934 theory of the four fermion weak interaction, and its extension by Gamow and Teller in 1936, the next really major advance had been the work of Lee and Yang. Compared to five possible forms of interaction earlier allowed invoking Lorentz invariance and parity conservation, there were now ten independent possibilities. By bold and incisive reasoning and analysis of the experimental situation, Sudarshan and Marshak had reduced it to two, namely vector and axial vector, and that too in a precise combination involving maximal parity violation. In the process the elegant principle of chirality invariance was also developed. But more important was their assertion in 1957 that four crucial experiments, not agreeing with this theory, were incorrect, and ought to be repeated -- this was in fact done, and all of them fell into line with V–A.

While the joy of this work is evident, the pain has to do with personalities, the competitive aspects of science, human failings, and such factors. Over the years

this work of Sudarshan and Marshak has been more or less systematically denied the credit it deserved. To say that today it is superseded by the unified electroweak theory of Glashow, Salam and Weinberg is no argument at all. In the steady development of weak interaction theory from Fermi in 1934 to the present, the V–A theory was a crucial and important landmark achievement, naturally paving the way for later basic advances.

Those involved in this story of credit denied are no mean characters—they include Feynman and Gell-Mann, to whom reference is most often made for the V–A theory. In retrospect one sees that there were errors of judgement on the part of Marshak—the teacher and senior person—in not properly projecting the work with Sudarshan, and possibly also in not providing a suitable and early occasion for the latter to announce the theory. Keeping all this in mind, on reading Marshak's talk one is deeply touched by his sense of regret for the 'blunders' he committed, and the candid and generous way in which he has expressed himself. In Sudarshan's own account of the entire story, told in 1985 under the title 'Mid-Century Adventures in Particle Physics,' he had said in conclusion: 'It has been a sad but wise experience to recognize that the universality of science does not imply unbiased acclaim for scientific truth and a true history of science; and that if you have neither powerful alliances nor influential sponsors you should learn to do science for its own sake and not be depressed by lack of appreciation.' I find an even more eloquent statement to sustain one in such circumstances in these well-known words: 'One's place in science, as posterity will duly assign, depends very largely on one's continuous exertion, at the edge of one's ability ...'

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