OBITUARY

Yoji Totsuka (1942–2008)

Leader in the discovery of neutrino oscillations.

Yoji Totsuka, a major figure in the world of particle physics, died on 10 July after a long battle with cancer. He was a leading light in the thrilling advances in the physics of neutrinos over the past 30 years, and was a notably resolute figure in seeing through the rebuilding of the Super-Kamiokande neutrino detector after a disastrous accident in 2001.

Born on 6 March 1942, in Fuji, Japan, Totsuka received his bachelor's, master's and PhD degrees from the University of Tokyo. His thesis project studied ultra-high-energy particle interactions, so kick-starting his lifelong passion for particle physics. As a research associate with the University of Tokyo, he then travelled to the Deutsches Electron Synchrotron Laboratory in Germany to investigate electron–positron collisions. He went on to accept an associate professorship at Tokyo in 1979.

Perhaps the turning point in Totsuka's career came in 1981, when he started work on the Kamiokande experiment with Masatoshi Koshiba — who was later jointly awarded the Nobel Prize in Physics with Ray Davis Jr for the detection of cosmic neutrinos. The Kamiokande project was originally designed to detect proton decays. A tank of ultra-pure water acted as a source of protons; the products of proton decay would interact with the water to produce distinctive Cherenkov radiation, which could be observed by hundreds of photomultiplier tubes arranged around the inner surface of the tank. A huge volume of water was required (3,000 tons), which was buried deep underground to block out background noise from cosmic rays.

The experiment set stringent limits on the proton-decay process and was also able to study both low-energy neutrinos from the Sun and neutrinos produced in Earth's atmosphere by cosmic rays. Solar neutrinos had previously been detected by Ray Davis Jr in the late 1960s with the use of a chlorine-based detector, but only one-third of the expected neutrino flux was observed. This discrepancy with theory became known as the solar neutrino deficit and was an early indication of a problem in understanding neutrinos.

In 1987, the Kamiokande collaboration had a stroke of luck when a supernova exploded in the Large Magellanic Cloud. Along with the Irvine–Michigan–Brookhaven consortium in the United States, the Kamiokande detector observed the resulting burst of neutrinos. This event was hailed as the birth of neutrino astronomy. More than 800 scientific papers were subsequently written that used the data to extract information about the properties of the supernova and of the neutrinos themselves.

Shortly after the supernova, Koshiba retired and Totsuka became leader of the Kamiokande project. Two seminal results from the group were subsequently published. The first observed a deficit in atmospheric neutrinos that could not be explained by systematic experimental errors or uncertainties in the background neutrino flux. Instead, some "as-yet-unaccounted-for physics", as the paper put it, might explain the data. The second crucially confirmed the solar neutrino deficit recorded by Davis.

In 1991, Totsuka obtained funding for a successor to Kamiokande. This was Super-Kamiokande, an underground detector that contained 50,000 tons of water. Super-Kamiokande provided the first definitive evidence for neutrino oscillations and neutrino mass. Neutrino oscillation is a process in which neutrinos convert between one of three types: electron neutrinos, muon neutrinos and tau neutrinos. Atmospheric neutrinos are predominantly muon and electron neutrinos. Because these particles can pass through the Earth without being absorbed, it was predicted that as many atmospheric neutrinos should come up from the ground as travel down from the sky. But the observations with Super-Kamiokande found that, although there were equal numbers of electron neutrinos travelling in these directions, fewer muon neutrinos were detected coming up than were going down.

We now know that, because the upward-going muon neutrinos had travelled much farther — through the planet — than those that came directly down through the atmosphere, they had more time to convert into tau neutrinos (which were essentially invisible to the detector). This evidence of neutrino oscillation suggested an explanation for the solar neutrino deficit: the 'missing' electron neutrinos from the Sun might simply have been converted into tau neutrinos and muon neutrinos, which could not be spotted by the earlier detectors. This was later confirmed through work at Super-Kamiokande and at the Sudbury Neutrino Observatory in Canada.

In 2003, Totsuka became the Director General of Japan's high-energy physics organization, KEK. Over the next three years, he oversaw the K2K neutrino-oscillation experiment, in which a beam of neutrinos was sent 250 km from the KEK accelerator to Super-Kamiokande. This experiment confirmed the earlier findings of atmospheric neutrino oscillation. During this period, Totsuka also supervised the successful Belle B-factory, where particles known as B-mesons were generated to study differences between matter and antimatter.

Totsuka proved his mettle as a leader in the aftermath of the Super-Kamiokande accident in 2001, when thousands of photomultipliers in the detector imploded. The day after the accident, he announced that the detector would be reconstructed within a year. In just two months he established a road-map to achieve this, and the detector was indeed ready for action 13 months after the accident.

During the last year or so of his illness, Totsuka wrote a blog in which he aired his views on science and science policy. He also used this forum to describe his own illness, plotting the extent of his cancer as a function of time, and evaluating the effectiveness of the chemical treatment. And, revealing entirely different interests, he discussed the flowers in his garden and in the village where Super-Kamiokande is located.

Totsuka received international recognition for his work, winning many academic prizes — perhaps most notably the Order of Culture, the most prestigious prize in Japan. It is a testament to his achievements that neutrino physics continues to generate enormous interest. The efforts of the Super-Kamiokande collaboration laid the foundations for the current, detailed understanding of the atmospheric neutrino anomaly and the solar neutrino problem. Yoji Totsuka was central to those efforts, and his vision and leadership will be sorely missed.

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