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Research Highlight

Nobel Prize 2015: Kajita and McDonald

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The 2015 Nobel Prize in Physics has been awarded to Takaaki Kajita and Arthur B. McDonald "for the discovery of neutrino oscillations, which shows that neutrinos have mass".

It is perhaps a testament to their enduring fickleness and elusive nature that neutrinos have been central to four Nobel prizes. The first three (awarded in 1988 to Leon Lederman, Melvin Schwartz and Jack Steinberger, co-awarded in 1995 to Frederick Reines, and co-awarded in 2002 to Raymond Davis Jr) chart an impressive, albeit inevitably incomplete, path through the history of this area of particle physics. The latest one is guaranteed to bring neutrinos to the fore of the public's attention once again.

First proposed in the early 1930s to explain an anomaly observed in the radioactive decay of atomic nuclei, neutrinos are fundamental particles similar to electrons, but much lighter and with no electric charge. They also interact very weakly with normal matter and, although we now know they are among the most abundant particles in the Universe, this means that they can travel through entire stars almost as if they were travelling through a vacuum. Only 0.001% of neutrinos passing through Earth interact with it — making the chance of detecting a neutrino interaction in a particle detector on the order of one per trillion.

That neutrinos were detected at all is therefore a mark of the practical ingenuity of the early pioneers of the field. But the particle was still shrouded in mystery. For example, when Ray Davis and colleagues detected fewer neutrinos than they expected from their studies of thermonuclear reactions inside the Sun, there was very little to go on to discriminate between experimental error and limits to existing theoretical models as the likely cause.

Enter Samoil Bilenky and Bruno Pontecorvo, who made the intriguing suggestion of neutrino oscillations. The standard model of particle physics predicts three 'flavours' of the particles, called electron, muon and tau neutrinos, all with zero mass. Bilenky and Pontecorvo noted that, assuming neutrinos did have mass, the laws of quantum mechanics would allow the electron neutrinos emitted at the core of the Sun (and to which the Davis experiment was sensitive) to change type, and therefore evade detection. This proposal took some time to build up theoretical credibility, but by the end of the 1990s neutrino oscillations had firmly entered the sights of experimentalist groups worldwide.

In 1998, the Super-Kamiokande experiment located in the Mozumi mine near Kamioka in Japan, which was designed to detect 'atmospheric' neutrinos coming from cosmic-ray interactions in the Earth's atmosphere and led by Takaaki Kajita, reported evidence for neutrino oscillations. A few years later, in 2001, the Sudbury Neutrino Observatory (SNO) in Canada led by Arthur McDonald reported the number, or flux, of all flavours of neutrinos from the Sun measured during a single experiment. A flurry of ingenious experiments and painstaking theoretical work followed to make sure the Super-Kamiokande and SNO experiments were consistent with each other, but by the mid-2000s the evidence was overwhelming.

Nevertheless, as the many international collaborations devoted to neutrino physics that have sprung up around the world demonstrate, a complete understanding of the neutrino has not yet been achieved. This is not only of primary importance for elementary particle physics, but also for astrophysics and cosmology. As the Nobel committee itself has remarked, "the discovery of neutrino oscillations has opened a door towards a more comprehensive understanding of the Universe we live in."

FURTHER READING

[The Nobel Prize in Physics 2015]

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