Japan Academy Prize to:

Takaaki KAJITA
Director and Professor, Institute for Cosmic Ray Research, The University of Tokyo

for "Discovery of Atmospheric Neutrino Oscillations"

Outline of the work:

Dr. Takaaki Kajita discovered neutrino oscillations in atmospheric neutrinos. This discovery implied the existence of finite neutrino masses.

Atmospheric neutrinos are produced by the collision of cosmic rays with the air. More specifically, the protons in cosmic rays collide with the nucleus of atoms in the air and produce pions. Atmospheric neutrinos mostly come from the decay of those pions. In this case, the ratio between the number of muon-neutrinos and electron-neutrinos is two in good approximation. (Here, particles and antiparticles are not distinguished.) This is because most of the charged pions decay into the muon and muon-neutrino, and the muon subsequently decays into the electron, electron-neutrino and muon-neutrino.

Through their observations at KAMIOKANDE, Dr. Kajita and his collaborators first discovered that the flux of the muon-neutrino is significantly less than theoretically expected. KAMIOKANDE is a large water-tank detector containing 3,000 tons of pure water placed deep underground in the Kamioka mine. It is designed to detect Čerenkov light from charged particles moving in the water. Dr. Kajita established a method for distinguishing electrons and muons using Čerenkov light patterns. With it, he determined the type of neutrino that reacts with water and found the ratio between the muon-neutrino and electron-neutrino to be about 60% of the theoretical prediction, and that this is mostly due to a deficit of muon-neutrinos. Further, he analyzed the data assuming the deficit to be caused by neutrino oscillation and obtained the range of oscillation parameters.

Dr. Kajita also studied the zenith-angle dependence of atmospheric neutrinos and found that there is a large deficit in upward-going neutrinos with relatively high energy, compared to downward-going ones. The zenith-angle dependence of the deficit is good evidence of neutrino oscillation as the upward-going neutrinos can change into other neutrinos while travelling across the earth.

In the mean time, the Super-KAMIOKANDE detector was constructed with data-taking started in 1996. Dr. Kajita made more detailed observations of atmospheric neutrinos and confirmed that the anomalous deficit of their flux is caused by neutrino oscillations. This result was reported by Dr. Kajita at the Neutrino'98 Conference held in Takayama and has attracted much attention.

Neutrino oscillation takes place only when the neutrinos are in a state of superposition of neutrinos with different masses. Accordingly, the discovery of neutrino oscillation implies that neutrinos have finite masses. Neutrino masses used to be regarded as zero, because they are below the measurement limit of conventional methods. Therefore, it is greatly significant that decisive evidence of the existence of neutrino masses was obtained through Dr. Kajita's experiments.

Today, the deficit of solar neutrinos is also explained by neutrino oscillations. The electron-neutrino, muon-neutrino and tau-neutrino are regarded as superposition states of three neutrinos with different masses. Although the same structure is seen in the quark sector, a remarkable fact is that the mass scale of the neutrinos is extremely small. Hence, it is thought that this is related to physics beyond the standard model, so further development is expected on the mass of neutrinos.

Dr. Kajita has been a central figure in a series of studies on atmospheric neutrinos, among many important research subjects advanced at KAMIOKANDE and Super-KAMIOKANDE. At the same time, he occupies a leadership position in the overall project.

Dr. Kajita was awarded the Nishina Memorial Prize, Panofsky Prize and Yoji Totsuka Prize for his aforementioned achievements. The KAMIOKANDE group was awarded the Asahi Prize and Bruno Rossi Prize, and the Super-KAMIOKANDE group the Asahi Prize.

Selected publications:

Original research papers

1) "Observation of a Neutrino Burst from the Supernova SN1987A", K. Hirata et al., Phys. Rev. Lett. **58** (1987) 1490-1493.
2) "Experimental study of the atmospheric neutrino flux", K.S. Hirata et al., Phys. Lett. B **205** (1988) 416-420.
3) "Observation of a small atmospheric ν_μ/ν_e ratio in Kamiokande", K.S. Hirata et al., Phys. Lett. B **280** (1992) 146-152.
4) "Atmospheric ν_μ/ν_e ratio in the multi-GeV energy range", Y. Fukuda et al., Phys. Lett. B **335** (1994) 237-245.
5) "Solar Neutrino Data Covering Solar Cycle 22", Y. Fukuda et al., Phys. Rev. Lett. **77** (1996) 1683-1686.
6) "Measurement of a small atmospheric ν_μ/ν_e ratio", Y. Fukuda et al. (Super-Kamiokande Collaboration), Phys. Lett. B **433** (1998) 9-18.
7) "Evidence for oscillation of atmospheric neutrinos", Y. Fukuda et al. (Super-Kamiokande Collaboration), Phys. Rev. Lett. **81** (1998) 1562-1567.
8) "Measurement of the Flux and Zenith-Angle Distribution of Upward Through-going Muons by Super-Kamiokande", Y. Fukuda et al. (Super-Kamiokande collaboration), Phys. Rev. Lett. **82** (1999) 2644-2648.
9) "Tau neutrinos favored over sterile neutrinos in atmospheric muon neutrino oscillations", S. Fukuda et al. (Super-Kamiokande collaboration), Phys. Rev. Lett. **85** (2000) 3999-4003.
10) "Solar ^{8}B and Hep Neutrino Measurements from 1258 Days of Super-Kamiokande Date", S. Fukuda et al. (Super-Kamiokande collaboration), Phys. Rev. Lett. **86** (2001) 5651-5655.
11) "Evidence for an oscillatory signature in atmospheric neutrino oscillations", Y. Ashie et al. (Super-Kamiokande collaboration), Phys. Rev. Lett. **93** (2004) 101801.
12) "A measurement of atmospheric neutrino oscillation parameters by Super-Kamiokande-I", Y. Ashie et al. (Super-Kamiokande collaboration), Phys. Rev. D **72** (2005) 052007.

Review papers

1) "Atmospheric neutrinos and discovery of neutrino oscillations", T. Kajita, Proc. Jpn. Acad. Ser. B **86** (2010) 303-321.

Conference papers

1) "Atmospheric neutrino results from Super-Kamiokande and Kamiokande – Evidence for ν_μ oscillations –", T. Kajita (for the Super-Kamiokande and Kamiokande collaborations), Nucl. Phys. B (Proc. Suppl.) **77** (1999) 123-132.