Session: Neutrino Astronomy

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Basic natures of neutrinos

Neutrino was introduced in 1930 by W. Pauli in order to save the energy conservation law in nuclear beta decay processes, in which the emitted electron exhibits a continuous energy spectrum. It was assumed that the penetration power of neutrinos is much higher than that of the gamma rays. More than 20 years later, the existence of neutrinos was experimentally confirmed by an experiment that measured neutrinos produced by a nuclear power reactor.

Since then, the basic nature of neutrinos has been understood through various theoretical and experimental studies: Neutrinos interact with matter extremely weakly. The number of neutrino species is three. They are called electron-neutrino, muon-neutrino and tau-neutrino. In addition, recent neutrino experiments discovered that neutrinos have very small masses.

Observing the Universe by neutrinos (1)

Because of the extremely high penetration power of neutrinos, neutrinos produced at the center of a star easily penetrate to the outer space. Theories of astrophysics predict that there are various processes that neutrinos play an essential role at the center of stars. For example, the Sun is generating its energy by nuclear fusion processes in the central region. In these processes, low energy electron neutrinos with various energy spectra are generated. Thus the observation of solar neutrinos directly probes the nuclear fusion reactions in the Sun.

Another example is the supernova explosion. While the optical measurements observe an exploding star, what is happening in the central region of the star is the collapse of the core of a massive star. During the core collapse, the central region becomes very dense and hot, and all kinds of neutrinos and anti-neutrinos are produced thermally. The observation of neutrinos gives us unique information on the core collapse of the star.

These examples show the unique feature of “neutrino astrophysics”. Indeed, the great scientific achievements by two pioneers in this field, Profs. M. Koshiba and R. Davis, Jr., have been recognized, and the Novel Prize in physics was given to them in 2002. This field has a significant recent progress. Today, Prof. Masayuki Nakahata, one of the leading scientists in this field will tell us recent topics in solar and supernova neutrinos.

Observing the Universe by neutrinos (2)

There is a problem that has not been fully understood for nearly a century: Cosmic rays are high energy particles that come to our Earth from somewhere in the Universe. The major components of them are protons and heliums. The energy spectrum of these particles extends up to 10^{20} eV, which is a huge energy. Cosmic ray scientists are very interested in the mechanism to produce such high energy particles. However, since its discovery in the early 20th century, the objects (stars) that produce the cosmic ray particles have not been identified. One of the difficulties in identifying them is the fact that the cosmic ray particles are charged. Because of the existence of the magnetic field in the Universe, these particles cannot go straight. Therefore, the measurement of the particle direction does not give any information on the position of the star where particles are accelerated.

However, there is a way to get the information on the particle acceleration position. One should observe neutral, stable particles. They are gamma rays and neutrinos. These particles could be produced at the position of the cosmic ray acceleration: At the cosmic ray acceleration position, it is likely that there is a low density matter. The accelerated particle could interact with the surrounding matter and produce pions. A neutral pion decay to 2 gamma rays, while a charged pion decay to a muon and a neutrino. Therefore, observations of these gamma rays and neutrinos should probe the cosmic ray acceleration point. Our second speaker, Prof. Steven Barwick, is one of the leading scientists in the field of high-energy neutrino astronomy. He will tell us the status and prospect of the high-energy neutrino astronomy.