Scientific Article

The puzzle of neutrino – an elementary particle in the Universe

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Pauli stated that "I have done a terrible thing, I have postulated a particle that cannot be detected". This was the theoretical birth of an electrically neutral, weakly interacting and very light particle called neutrino. But as the time elapsed this tiny particle revolutionised both particle physics and cosmology.

In Italian language neutrino means "little neutral one"!!. Pauli postulated the emission of neutrino particle in a desperate attempt to explain conservation of energy in beta decay as there was discrepancy in energy and momentum during beta (β) decay. In a research paper in December 1930, he suggested that some of the energy is carried away by the β particle during the radioactive decay process. The word "neutrino" entered the international vocabulary through Enrico Fermi, who used it during a conference in Paris in July 1932.

The original equation of β decay, $n \rightarrow p + e^{-} (\beta)$, is Fermi,s theory of β decay and indicates that an electron i.e., β particle is emitted during the radioactivity due to the conversion of neutron into proton in the nucleus. However it has taken a quarter of a century for the discovery of neutrino particle with the streaming of the neutrinos from nuclear power plants then being built in 1950's. In June 1956, two American physicists, Frederick Reines and Clyde Cowan sent a telegram to Wolfgang Pauli stating the neutrinos had left traces in their detector. This discovery showed that the ghostly neutrino, or Poltergeist as it had been called, was a real particle. Frederick Reins and Clyde Cowan were jointly awarded the Nobel Prize in Physics in the year 1995 for the discovery of leptons and neutrino particle.

Solar neutrino problem

In fact we live in a world of neutrinos. Billions of neutrinos are flowing through our body every second. We cannot see them and do not feel them. Neutrinos rush through space almost at the speed of light and hardly ever interact with matter and the question is where do they come from? Some were created already in the Big Bang, others are constantly being created in various processes in space and on Earth – from exploding supernovas, the death of massive stars, to reactions in nuclear power plants and naturally occurring radioactive decays. Even inside our bodies an average of 5,000 neutrinos per second is released when an isotope of potassium decays. The majority of those that reach the Earth originate in nuclear reactions inside the Sun. Second only to particles of light[electromagnetic spectrum]- photons, the neutrinos are the most numerous particles in the entire universe.

Since the 1960s, scientists had theoretically calculated the number of neutrinos [using energy mass relation] that are created in the nuclear reactions that make the Sun shine. But while carrying out measurements on Earth, up to two thirds of the calculated number of neutrino was missing. Where did the neutrinos go? One suggestion was that there was some error in the theoretical calculations of how the neutrinos are produced in the Sun. Second suggestion that came to solve the solar neutrino puzzle was that the neutrinos change identities. According to the Standard Model of particle physics there are three types of neutrinos – electron-neutrinos, muon-neutrinos and tau-neutrinos. The second suggestion was more realistic as explained later.

In order to detect the neutrinos , the search was on day and night, in colossal detectors built deep underground, in order to shield out noise from cosmic radiation from space and from spontaneous radioactive decays in the surroundings.

Following this search, in 1998 Takaaki Kajita presented the discovery that neutrinos seem to undergo metamorphosis i.e., they switch identities during their passage in the Super-Kamiokande underground detector in Japan. The neutrinos captured there are created in reactions between cosmic rays and the Earth's atmosphere.

Meanwhile, scientists at the Sudbury Neutrino Observatory in Canada, SNO, were studying neutrinos coming from the Sun. In 2001, the research group led by Arthur B. McDonald proved that these neutrinos, too, switch identities.

Together, the two experiments have discovered a new phenomenon – neutrino oscillations. A far-reaching conclusion of the experiments is that the neutrino, for a long time considered to be massless, must have a mass. This is of great importance for particle physics and for our understanding of the universe.

In summary, the neutrino particle took birth in *Pauli's theory to explain the discrepancy in the explanation of beta decay. At that time this massless particle was only a hypothesis. Pauli himself expressed the doubt about its real existence. Later, Frederick Reines and Clyde Cowan proved the existence of the neutrino particle. But the massless assumption of the neutrino particle again created the problem of number or quantity of the particle as the energy has to be conserved. Last year, Takaaki Kajita and Arthur B. McDonald with their discovery of neutrino oscillations showed that neutrinos indeed have mass. For solving the neutrino puzzle they were jointly awarded with the Nobel Prize in Physics 2015.

**Pauli got the Nobel prize in 1946 not for his prediction of beta particle but for the discovery of exclusion principle.*

Sources: nobelprize.org