Neutrinos and their flavor

The most elusive and mysterious particles

The Standard Model of Particle Physics

What are we made of?

Everything around us is made up of elementary particles, for instance the quarks within protons and neutrons in atomic nuclei, and the leptons, like the electrons which orbit around nuclei. Together they form the atoms which are constituents of matter. Leptons also include another kind of particle: neutrinos. There are 3 families of quarks and leptons, with identical properties, except for their masses.

What holds particles together?

Elementary particles are subject to forces associated to four fundamental interactions: electromagnetism, the strong force, the weak interaction, and gravity. Each one of these interactions is associated with one or several force particles, the gauge bosons: the photon, the Z and W bosons, the gluons and the (still hypothetical) graviton.

Neutrinos come in 3 varieties or “flavors”, depending on their interaction

Neutrinos are elementary particles with neither electric charge nor color, they only feel the weak interaction. Their mass is extremely small, millions of times smaller than that of electrons.

Neutrinos are very abundant particles in the universe. For each electron, proton or neutron, there are 10^9 000 000 000 neutrinos. Neutrinos have very feeble interaction with any form of matter, which makes them extremely difficult to detect. Neutrinos can travel huge amounts of matter without interacting, your body is at this very instant being crossed by millions of billions of neutrinos.

Nevertheless, it is possible to detect neutrinos by using underground experiments, like SuperKamiokande in Japan, an enormous tank filled with 50 000 tons or very pure water, covered with 11 000 Cherenkov radiation detectors, and located some 1 000 meters underground.

These experiments allow to study neutrino properties, specially neutrino oscillations and their relation with neutrino masses.

Neutrinos come in 3 varieties or “flavors”, depending on their interaction with electrons, muons or tau leptons. These flavors can mix at the quantum level, leading to the phenomenon of neutrino oscillations.

Matter particles (quarks and leptons) are classified in 3 families, with identical properties except for their mass. There are 3 kinds or “flavors” of neutrinos, known as electronic, muonic and tauonic, depending on the kind of charged lepton (electron, muon or tau) to which they connect via the weak interaction.

These 3 flavors mix among themselves in the propagation of neutrinos. In Quantum Mechanics, these neutrino states are described as waves formed by the interference of waves associated to the 3 basic flavors. Neutrino oscillation (in flavor) corresponds to the changing of the interference pattern during neutrino flight. Hence, a neutrino born as electronic at the core of stars, may turn into a muon, by emitting positrons (the antiparticle of the electron) and neutrinos.

Thus, bordered light, the Sun emits neutrinos, as can be seen from this neutrino image of the Sun.

Why do stars shine?
The weak force and neutrinos

Thanks to their subtle properties, neutrinos are key players in the shining of stars. Stars produce energy by fusion processes in which 4 hydrogen nuclei (protons) combine into Helium-4 nuclei (2 protons and 2 neutrons). This requires an interaction able to transform the particles, the weak interaction, mediated by the W and Z. At the core of stars, these W and Z turn into neutrinos by emitting positrons (the antiparticle of the electron) and neutrinos.

Thus, bordered light, the Sun emits neutrinos, as can be seen from this neutrino image of the Sun.

The solar neutrino problem

For a long time, scientists could not explain why the solar neutrino flux in Earth seemed lower than what the astrophysical solar model predicted. We now know that the apparently missing electronic neutrinos from the Sun have oscillated into muon neutrinos during their travel to the Earth. La Tierra. Experiments able to detect all neutrino flavor make no discrepancy.

Neutrino Astronomy

Detection of neutrinos from astrophysical sources (for instance the Sun, supernova explosions, active galactic nuclei, or gamma ray bursts) provides new methods to observe violent astrophysical processes, paving the way for the field of Neutrino Astronomy, which offers new tools for the study of the universe.