Solar Neutrinos
Adam Skalenakis – 4/5/04

Background (What is a neutrino, and why do we care?)

When studying certain fusion reactions, as well as the decay of certain particles, physicists discovered that energy and momentum was not completely conserved. To explain this mysterious loss of energy, it was theorized that a small particle was ejected; this particle was named the neutrino.

Now we know that the neutrino is in the family of particles known as leptons, which include 6 types of particles. The neutrino particle is uncharged and associated with the charged particle in its pair.

- Electron and electron neutrino
- Muon and mu neutrino
- Tau and tau neutrino

Solar Neutrinos

Of the many pathways that fusion reactions take in the Sun, they all lead four hydrogen nuclei to fuse into one helium nucleus. So, no matter the path, we have four protons that become two protons and two neutrons. The conversion of the protons to neutrons is known as beta decay, and during this process, a neutrino is emitted. So for every fusion path we expect two emitted neutrinos.

Each neutrino has an incredibly small, non-zero mass, and thus have a very small cross section for interacting with other particles. A neutrino created in the sun has an average path length ten times the width of the sun, so they are unique in that they can reach earth without colliding with any other particles since their creation.

Due to predictions of fusion occurring inside the sun, astrophysics suggests that we should have a flux of \( 6.5 \times 10^{10} \) neutrinos sec\(^{-1}\) cm\(^{-2}\). Many apparatuses have been constructed to experimentally measure and “count” the solar neutrinos that pass through Earth. It was for this purpose that the Super-Kamiokande, a massive underground pool of water surrounded by photomultipliers, was built. The idea was that high-energy particles passing through the water would cause some bluish light known as Cherenkov light to be emitted, and thus detected by the apparatus.

The Problem

Only 37% of the number of neutrinos predicted by our solar model have been observed by this and other experiments. This is a currently outstanding issue in astrophysics. The current popular explanation is known as neutrino oscillations, and suggests that neutrinos may actually oscillate between separate states as they travel, thus we only recognize a fraction of them. This suggests that there would be different amounts of neutrinos showing up as the Earth changes its distance from the sun, and so far the evidence is inconclusive.

Sources
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