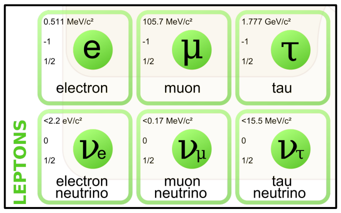
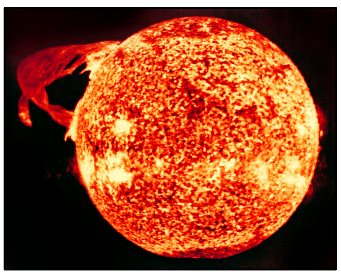
Neutrinos

The tiny neutral particles



Neutrinos are in the lepton family of the standard model of particle physics.

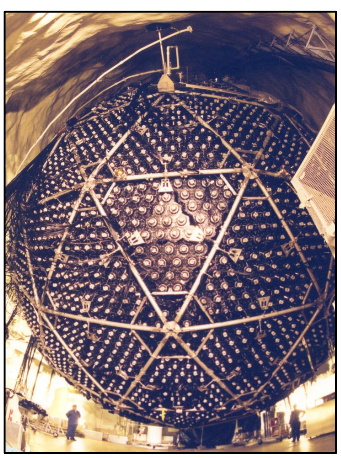
Neutrinos are tiny elementary particles that are part of the lepton family in the standard model of particle physics. With very little mass and no charge, they pass through everything on Earth – including you – at all times. Of the four fundamental forces that exist in the universe (strong force, weak force, electromagnetic force, and gravity) they are only affected by the weak force and gravity. Because both of these are very weak, neutrinos pretty much just pass through normal matter (like people, buildings, oceans, and rocks) without interacting with them in any way. There are three known *flavours* of neutrinos: electron neutrinos, muon neutrinos, and tau neutrinos.



Neutrinos from the Sun constantly travel towards Earth.

Where do neutrinos come from?

Neutrinos come from many sources. The majority of them are relic neutrinos left over from just after the big bang, when the universe cooled down enough for neutrinos to break away from other particles. Others include solar neutrinos, which are produced in nuclear fusion reactions in the Sun. About 60 billion solar neutrinos pass through your thumb nail every second! Supernovae neutrinos are produced when a star collapses at the end of its life. During this process, a large number of protons combine with electrons and are converted into neutrons and supernovae neutrinos. These types of neutrinos escape the star and reach Earth much sooner than the light from a supernova, making them excellent messengers for determining when a supernova is happening before it can even be seen from Earth. Geo-neutrinos are electron antineutrinos produced when radioactive materials in the Earth (in particular uranium and thorium) decay. Finally, artificial neutrinos are those that are created by fission reactors and proton accelerators under controlled conditions.



SNO detector in Sudbury, Canada.

Why is studying neutrinos important?

Neutrinos are important building blocks of our universe. By studying them, scientists can explore why there is more matter than antimatter in the universe and what intricate processes go on in the Sun, in supernovae, and in the Earth's crust. They do this by measuring neutrinos that arrive on Earth from space (including solar neutrinos and supernovae neutrinos) as well as from the Earth (geo-neutrinos).

A brief history of neutrino discoveries

In the *1930s*, Wolfgang Pauli proposed that a tiny neutral particle existed (later named “neutrino” by Enrico Fermi). The first experimental evidence to prove Pauli’s theory came in *1956* from two American scientists Frederick Reines and Clyde Cowan. They used a fission reactor to produce neutrinos in a laboratory and placed a very sensitive and well-shielded scintillator nearby to detect the neutrinos that were produced. In *1962*, scientists from Columbia University and Brookhaven National Laboratory demonstrated the existence of two neutrino *flavours*: the electron neutrino, and the muon neutrino. In *1975*, a group at the Stanford Linear Accelerator Centre, found strong evidence for the existence of a third neutrino flavour, the tau neutrino.

For a long time, scientists around the world who were measuring *solar* neutrinos found significantly fewer of them than they expected. Then, between 2001 and 2002, the Sudbury Neutrino Observatory (SNO) experiment in Canada and the KamLAND experiment in Japan solved this *solar neutrino problem* by providing direct evidence that neutrinos come in three flavours and that they change between flavours as they travel from the Sun’s core to the Earth.

These neutrino experiments are currently underway at SNOLAB:

- **SNO+** is a new experiment using the former SNO detector infrastructure. By replacing the heavy water used in the SNO experiment with liquid scintillator, the detector will be able to study low energy solar neutrinos, geo-neutrinos, and reactor neutrinos, as well as conduct a supernova search. The SNO+ experiment will also add tellurium into the scintillator to search for neutrinoless double beta decay from the 130Te isotope.

- **HALO** (Helium And Lead Observatory) is used to detect supernovae (collapsing stars) using 3He proportional counters. When a star collapses, an influx of neutrinos is produced and travels outwards. The HALO experiment can observe the neutrino burst from the supernova and alert other laboratories and astronomers in the world that a supernova is occurring before it can be seen from Earth.