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What Role do Neutrinos Play in the Universe?
– Recent Results on Neutrino Properties –

Neutrinos are the most abundant particles in the Universe, provided the Big Bang theory is correct. Their number density is about 100 /cm3/flavor. Note that there are three ‘flavor’ states of neutrinos which are called electron-neutrino, muon-neutrino and tau-neutrino denoted as ne, nm, nt. They are supposed to have been decoupled and left behind in the Universe 1second after the Big Bang. They should obey the Fermi-Dirac distribution. As the Universe expanded, the average temperature of the neutrino gas became red-shifted and should be only 1.9K at the present time.

Since the cross section of neutrino-matter interactions is a sharp decreasing function of the neutrino energy, it is technically impossible to directly detect signals of these relic neutrinos.

The Standard Model (SM) of particle physics assumes that the neutrino masses are identically zero. Hence the relic neutrinos, though abundant, do not play any role for the evolution of the Universe. However, the SM is not the ultimate theory and neutrinos could have masses if one extends the particle theory beyond the SM, say the regime of Grand Unified theories. If so, the relic neutrinos might influence the fate of the Universe.

Recent experiments have indeed revealed compelling evidence for finite but very tiny masses of at least nt and nm. Several large-scale experiments, notably Super-Kamiokande in Japan and SNO in Canada were carried out deep underground to study solar and atmospheric neutrinos. The experiments have also discovered that the mixings among neutrino flavors are large, quite different from the quark sector and unexpected from conventional wisdom of particle theory.

In this lecture I will present recent experimental results on the basic neutrino masses and mixings and their possible implications to the Universe. I will also discuss on future prospects of neutrino experiments which will study among other things the CP violation in the neutrino sector, which might have caused the matter-antimatter asymmetry in the Universe.