

Matter Effects on Neutrino Oscillations

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Neutrino types or flavors are described as different linear combination of several distinct mass eigenstates. When neutrinos propagate through space, the type appears to oscillate due to phase shifts between the mass eigenstates: a mass eigenstate of mass m and energy E acquires the phase $L(E-m^2/E)$ after propagating a distance L in vacuum (if the mass is much smaller than the energy). When propagating through matter, elastic scattering of electron-neutrinos differs from those of other types which results in additional phase shifts affecting the oscillations. The large density of the solar core resonantly converts solar electron-neutrinos above an energy of about five MeV to the second mass eigenstate (Mikheyev-Smirnov-Wolfenstein resonance), while solar electron-neutrinos below one MeV oscillate only because of the propagation phase difference. On earth this appears as an energy dependence of the fraction of electron-neutrinos in the solar neutrino beam. In addition, some of the non-electron solar neutrinos passing through the Earth at night convert back to electron-neutrinos leading to a diurnal variation of the electron-neutrino fraction. Super-Kamiokande has searched for both energy dependence and diurnal variation and found a $\sim 3\sigma$ significance indication of a $\sim 5\%$ diurnal variation, but so far no evidence of the energy dependence of the solar resonance.

