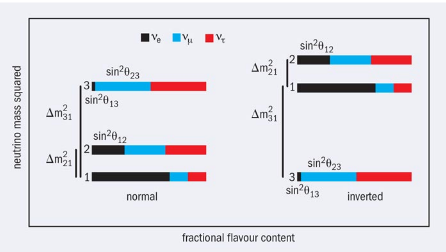
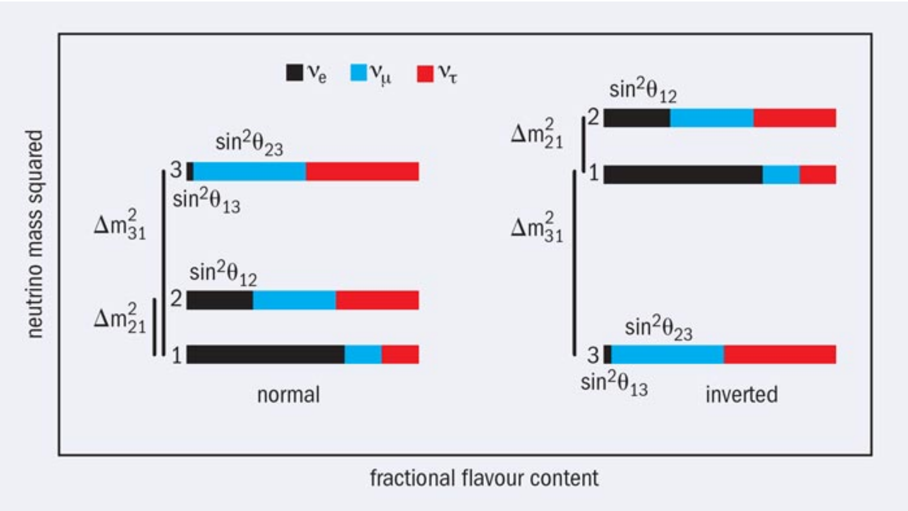
Pasquale SERPICO contributed to the September 2014 Edition of Scientific American (Pour La Science) that covered a few aspects of the fascinating neutrinos. His contribution explained how the signal from a supernova can be used to infer the pattern of masses of these elusive particles.



Neutrinos (and their antiparticles, antineutrinos) are copiously produced in numerous particle physics processes at different depths in the core of collapsing stars (Supernovae). They also come in three varieties (or flavours), as defined by the process by which they were created.

While the detailed form of these signals is the result of a complicated and sometimes poorly known interplay of phenomena-which is why astrophysicists are so interested in detecting them!-some features are quite robustly established: as an example, which species have "hotter" fluxes and which ones have "colder" ones depends on the strengths of the neutrino interactions, which are well known from particle physics.

If neutrinos were massless, these different type of fluxes at production would map unchanged in the signal detectable on the Earth in giant underground detectors. However, nowadays we know that neutrinos do possess tiny masses thanks to the phenomenon of neutrino oscillations: a neutrino with a given mass is in general a quantum superposition of neutrinos of different flavours and vice versa. A number of probes has shown that the flavour content of a neutrino flux changes with propagation, which is a signature of the massive nature of neutrinos. The phenomenon of oscillations has ananalogy with the case of polarized light: a linearly polarized beam of light can be thought of as a superposition of different circular polarization states, which propagate differently in a birefringent medium, i.e. they have different indexes of refraction. The measurable polarization angle (analogous of the neutrino flavour) thus changes as the beam propagates. Still, we do not know yet precisely the proportions with which different mass states combine into different flavour states.



While the dense SN medium between the production point and outer space is extremely opaque to light, it behaves for weakly interacting neutrinos as a birefringent medium, with a refractive index that is different for neutrinos of different flavours. As a result, the fluxes detectable at the Earth are a combination of the ones produced in the inner parts of the star. But which combination depends on the type of refraction index, hence on the mass pattern! So, if one could determine their spectrum at the Earth in some detail, its similarity to one or the other of the initial flux expectations (hotter or colder, etc.) one could complete our reconstruction of the neutrino mass pattern. Still, characterizing in detail the refractive properties of this peculiar medium presents some challenges: for instance, neutrinos are so numerous that they contribute themselves to the birefringent properties of the medium they propagate through, with remarkable non-linear effects yet to be fully understood!