Neutrinos: The most standard-model friendly option for dark matter

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Searches at the Large Hadron Collider have so far not yielded any beyond-the-standard-model physics. In particular, supersymmetry is not found and neither its WIMP dark matter particle. Likewise, many direct searches in mines, under mountains or with satellites like Fermi, yield at best hints, but no proof, of a WIMP. Heavy (GeV mass) particles like the WIMP would call for a strong revision of the Standard Model (SM) of elementary particles, for which there is at present no direct indication. Also standard axions appear to be ruled out.

Another case deals with (sterile) neutrinos as dark matter particles. Due to neutrino oscillations, right-handed partners must exist. They are "sterile", i. e., they do not couple to SM processes. Sterile neutrinos would lead to a minimal extension of the SM, in particular, they would not affect the gauge symmetry and renormalizability. If the masses have a Dirac structure, the masses of left- and right-handed partners are just equal. An additional Majorana matrix may split this degeneracy. Sterile masses can be considered from sub-eV to TeV scales.

It is well known that solar and atmospheric oscillations imply very small mass-squared differences. Taken together with reactor experiments which point at eV^2 differences, the case of eV-scale neutrino masses is well motivated. This will be tested at the 2015 Katrin experiment, which searches down to 0.2 eV. A discovery would pose severe questions to ΛCDM, the standard model of cosmology. Even though the latter works rather well, Planck has shown that it does not work really well, while it also contains many ill understood features, and may appear to be an effective model only.

Analysis of very precise weak and strong lensing data for the galaxy cluster Abell 1689 is compatible 1.5 eV neutrinos [1,2]. Next to reactor experiments, this supports the case of (light) neutrino hot dark matter. The scenario will be constrained by nucleosynthesis, while the needed non-linear galaxy structure formation, related to turbulence, is poorly understood.

[1] Theo M. Nieuwenhuizen, Do non-relativistic neutrinos constitute the dark matter? Europhysics Letters 86, 59001 (2009)

[2] Theo M. Nieuwenhuizen and Andrea Morandi, Are observations of the galaxy cluster Abell 1689 consistent with a neutrino dark matter scenario? MNRAS, to appear