ν signals in dark matter detectors

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Solar and atmospheric neutrinos are a well-known background in direct dark matter searches, which will become relevant once these experiments reach the ton scale. Here, we argue that, if there is new physics in the neutrino sector, neutrino signals might already be observable in the present generation of experiments, and the phenomenology will be much richer in future detectors. Consider, for instance, a scenario in which the Standard Model is augmented by the introduction of a very light (< 1 eV) new gauge boson, which we will call the "dark photon" A', and by one or several light sterile neutrino flavors. (The existence of sterile neutrinos is not strictly necessary, but it allows for larger new physics signals than a model with only a dark photon.) We assume that the A' coupling to Standard Model particles is very weak (it could for instance arise through a small kinetic mixing term), but the coupling to sterile neutrinos is sizeable. Thus, dark photon-mediated processes among Standard Model particles are strongly suppressed, whereas the cross sections for sterile neutrino–electron scattering and sterile neutrino–nucleus scattering can be relatively large. Moreover, since A' is very light, these scattering cross sections will be larger if the momentum transfer q in the scattering process is small. (This can be easily understood by recalling that the A' propagator is given by $-ig_{\mu\nu}/q^2$.) On their way to the Earth, some of the solar neutrinos can oscillate into sterile neutrinos, which could then be detected by looking for their scattering on electrons or nuclei. Because of the low-energy enhancement, dark matter detectors are better suited for this than higher-threshold detectors like Borexino or SNO. Note that the neutrino signal can also show seasonal variation induced by the varying Earth–Sun distance L, L-dependent oscillations, Earth matter effects, and possibly direction-dependent detection efficiencies. New physics in the neutrino sector can thus lead to signals very similar to those expected from dark matter, and if a signal is observed, it is important to disentangle these possibilities, for instance by measuring precisely the energy spectrum of events and the modulation pattern. On the positive side, dark matter detectors provide a new tool to constrain or discover new physics in the neutrino sector.

Non-standard neutrino physics can not only affect direct dark matter searches, but also searches for neutrinos from WIMP annihilation in the Sun. In particular, if there are sterile neutrinos, new MSW resonances will exist at high energy, and depending on the model parameters these can lead to a complete conversion of some neutrino flavors into sterile states. Thus, if sterile neutrinos exist, IceCube limits on WIMP annihilation might be weakened. On the other hand, if in the future the annihilation cross section and annihilation channels are precisely measured elsewhere, for instance at the LHC, IceCube can be used to study the properties of sterile neutrinos, using the neutrino flux from WIMP annihilation in the Sun.

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