Supporting Online Material for

Neutrino Spectroscopy Can Probe the Dark Matter Content in the Sun

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Published 9 September 2010 on Science Express
DOI: 10.1126/science.1196564

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The capture rate of dark matter particles in the Sun depends on the characteristics of the Milky Way dark matter halo and the relative velocity of the Sun in the Milky Way. This halo has a local density of 0.3 GeV/cm\(^3\), with a dark matter dispersion velocity of 270 km/s. The solar rotation velocity around the Milky Way is 220 km/s. We computed the capture rate of dark matter particles by the Sun's plasma by taking into account such dynamical conditions (16-17). The presence of dark matter inside the Sun decreases the central temperature by creating an additional mechanism for the transport of energy (18-21).

The efficiency of the energy transport by dark matter particles depends, among other factors, on the scattering cross-sections of dark matter particles on baryons (18-19). In our calculations, the dark matter haloes are composed of massive particles, with spin-dependent and spin-independent scattering cross-sections with baryons of the order of 2.0x10\(^{-36}\) cm\(^2\) and 4.0x10\(^{-40}\) cm\(^2\), respectively. The total amount of dark matter particles in the Sun's core depends on the self-annihilating cross-section of the dark matter particles. Therefore, we have considered two distinct scenarios, one where the constituent particles are non-annihilating, and another one composed by weakly annihilating particles. In the latter dark matter scenario, the product of the self-annihilation cross-section with the velocity of colliding dark matter particles at freeze-out is of the order of 1.0x10\(^{-36}\) cm\(^3\) s\(^{-1}\). The motivation for the existence of such particles with predominantly spin-dependent interaction cross-section with baryons is presented elsewhere (22).

Figure 1 left shows the percentage changes in solar neutrino fluxes for the different nuclear reactions occurring in the solar core, for the case of weakly annihilating dark matter.

Figure 1 right shows the fractional changes in solar neutrino fluxes of \(8\text{B}\)-\(\nu\), \(13\text{N}\)-\(\nu\), \(15\text{O}\)-\(\nu\) and \(17\text{F}\)-\(\nu\) as a function of \(7\text{Be}\)-\(\nu\) for the two dark matter scenarios mentioned previously. It follows that the strong variation in the fractional changes of solar neutrino fluxes of \(8\text{B}\)-\(\nu\) and of \(7\text{Be}\)-\(\nu\) occurs in the case of light non-annihilating dark matter particles. In such scenarios, we observed that the dark matter inside the Sun’s core reduces the \(8\text{B}\)-\(\nu\) neutrino flux by 90% and the \(7\text{Be}\)-\(\nu\) neutrino flux by 50%. These values differ significantly from recent measurements (13-14) which are comparable to the solar neutrino fluxes predicted by the solar standard model. Therefore, some of the “lighter” non-annihilating massive particles can already be ruled out based on current measurements, if the solar standard model is to be believed (7).

The inclusion of well-known physical processes in the Sun's evolution, such as differential rotation and the transport of angular momentum will lead to structural changes throughout the evolution of the star (15). The presence of dark matter particles in the Sun produces an isothermal core which solar neutrino spectroscopy will be able to probe. Such a constant temperature profile in the Sun’s deep core is intrinsically associated with the dark matter signature, and hence is difficult to relate to other astrophysical mechanisms.
References and Notes


