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Higher order dark matter annihilations in the Sun and implications for IceCube

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Dark matter particles that have been captured inside the Sun can annihilate producing high-energy neutrinos which would be a smoking-gun signal if observed in terrestrial neutrino detectors such as IceCube. Annihilation channels like e^+e^- or $\mu^+\mu^-$, or $q\bar{q}$ however, only produce neutrinos in the MeV range due to the interaction of the annihilation products with the solar material and were consequently partly neglected in the literature. Still, the interaction mediating these annihilation processes necessarily produces gauge bosons by higher order effects, which in turn produce highly energetic neutrinos. We consider the annihilation into a fermion-antifermion pair in a model-independent contact interaction approach. Concretely, we investigate the annihilation into $f\bar{f}$ and associated emission of one gauge boson as well as annihilations into two gauge bosons at the one-loop level in order to calculate limits on the scattering cross section of dark matter and protons from the non-observation of an excess of events in IceCube. We show that the limits on the spin-dependent cross section are, for some annihilation channels, stronger than those reported by COUPP and SIMPLE. Furthermore, we give an example of a simple Particle Physics model to which the model-independent techniques can be mapped.

Primary author: TOTZAUER, Maximilian (Technische Universität München)

Presenter: TOTZAUER, Maximilian (Technische Universität München)

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