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Constraining ALP-nucleon interactions with neutrino water Cherenkov detectors via the diffuse flux of MeV ALPs from galactic supernovae

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Axion-like particles (ALPs) can be copiously produced in core-collapse supernovae (SNe) due to their coupling to SN matter. If they are weakly coupled, ALPs leave the star unimpeded after being produced. This regime has already been tightly constrained by cooling bounds. In this talk, I will focus on the trapping regime, where the SN environment becomes optically thick for ALPs and, therefore, they cannot free-stream out of the star and become trapped. Even in this regime, a vast flux of ALPs can escape and arrive to Earth. In particular, I will consider MeV ALPs that are produced in the SN interior through their coupling to nucleons and escape with semi-relativistic velocities. I will argue that they can constitute a diffuse flux formed by the overlap of ALP fluxes from different SN, which can be probed by current neutrino water Cherenkov detectors via $a\,p \to p\,\gamma$. Using existing Super-Kamiokande data, we can place new constraints on ALP interactions with nucleons, extending existing bounds beyond cooling limits. In particular, we exclude a region spanning more than one order of magnitude in the ALP-proton coupling above cooling bounds for ALP masses in the range of $1 - 80$~MeV and ALP-proton couplings between $8 \times 10^{-6} - 2 \times 10^{-4}$.

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