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# Observing axions from supernovae through their many (loop-induced) couplings

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Supernova (SN) explosions could emit vast amounts of axions, and axionlike particles, in a short time. In this talk, we will show how the spectrum of these axions is calculated to unprecedented precision in recent years. In particular, in the SN plasma quantum-loop effects can dominate axion production or absorption processes, and can also play a vital role in their conversion to visible particles once they escape the stellar remnant. The relevant interactions of axions with leptons, photons, nucleons, and pions can all induce one another on the quantum level mdash; with phenomenologically relevant implications in many of these combinations. Taking these considerations into account, we derive accurate predictions for the number and energy of axions emitted in a SN, as well as a large range of observable signatures caused by this emission. Among those are gamma-ray bursts originating from axions that escaped the stellar remnant and subsequently decay or convert into photons (through tree or loop-level processes). We show that those bursts could have also been detected from extragalactic SNe such as SN 2023ixf with the Fermi-LAT, and how we can use the absence of a detection to constrain the axion parameter space. We present our findings of a wide range of significantly improved bounds on axions from supernovae.

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