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The importance of quantum loops for astrophysical ALPs

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We investigate the effect of quantum loops on the theory of axionlike particles (ALPs) coupled to electrons. Contrary to some statements in the recent literature, the effective ALP-photon coupling induced by an electron loop can be sizeable in the plasma of a supernova. We define a general effective coupling that depends on the kinematics of the specific process in which an ALP scatters, decays, or is produced. Using this effective coupling, it can be shown that production of ALPs by loop processes is in fact slightly more efficient than the respective tree-level processes in a numerical model of SN1987A. We update the bound on g_{ae} imposed by the observed duration of the neutrino burst of SN1987A. Moreover, we derive a new bound, which does not exist at tree-level for ALPs only coupled to electrons, from the non-observation of gamma-rays from ALP decays directly after the initial neutrino burst was observed in 1987. These are the leading constraints on g_{ae} in the ALP-mass range of roughly 30 keV to 300 MeV.

Using the effective coupling, we furthermore point out that ALP dark matter coupled to electrons is not stable in the keV mass range due to loop-induced decays into photons. Large parts of the parameter space that direct detection experiments are sensitive to are therefore either (i) incompatible with the assumption of ALPs being dark matter as their lifetime is shorter than the age of the universe, or are (ii) already excluded by indirect detection searches for x-rays and gamma-rays as products of ALP decays.

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