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New opportunities for axion dark matter searches in nonstandard cosmological models

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We study axion dark matter production from a misalignment mechanism in scenarios featuring a general nonstandard cosmology. Before the onset of Big Bang nucleosynthesis, the energy density of the universe is dominated by a particle field ϕ described by a general equation of state ω. The ensuing enhancement of the Hubble expansion rate decreases the temperature at which axions start to oscillate, opening this way the possibility for axions heavier than in the standard window. This is the case for kination, or in general for scenarios with $\omega > 1/3$. However, if $\omega < 1/3$, as in the case of an early matter domination, the decay of ϕ injects additional entropy relative to the case of the standard model, diluting this way the preexisting axion abundance, and rendering lighter axions viable. For a misalignment angle $0.5 < \theta_i < \pi/\sqrt{3}$, the usual axion window becomes expanded to 4×10^{-9} eV m_a 2×10^{-5} eV for the case of an early matter domination, or to 2×10^{-6} eV m_a 10^{-2} eV for the case of kination. Interestingly, the coupling axion-photon in such a wider range can be probed with next generation experiments such as ABRACADABRA, KLASH, ADMX, MADMAX, and ORGAN. Axion dark matter searches may therefore provide a unique tool to probe the history of the universe before Big Bang nucleosynthesis.

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