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Mesonic contributions to axion thermalization below the QCD crossover in the KSVZ axion model

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Constraints on axions as hot dark matter (HDM) from $\Delta N_{\rm eff}$ provide an important and independent probe of axion properties. In hadronic axion models such as the KSVZ model, the axion thermalization rate below the QCD crossover temperature is typically estimated under two key assumptions: (1). thermal corrections to the reaction amplitudes are negligible at $T < M_{\rm th}/2$ with Mth the reaction threshold and (2). axion-pion interaction ($a\pi \leftrightarrow \pi\pi$) dominates unless specically suppressed.
In this talk, we critically reexamine these assumptions by systematically calculating the relevant corrections to the axion thermalization rate in the KSVZ axion model. Our analysis emphasizes the role of nonperturbative mesonic dynamics in the relevant processes. The results also have implications for meson-driven thermalization in other axion models.

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