Thermal axions with multi-eV masses are possible in low-reheating scenarios

Based on
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Thermal axion production


Hadronic axions are produced by pion interactions

\[
\mathcal{L}_{a\pi} = \frac{C_{a\pi}}{f_{\pi} f_a} \left( \pi^0 \pi^+ \partial_\mu \pi^- + \pi^0 \pi^- \partial_\mu \pi^+ - 2\pi^+ \pi^- \partial_\mu \pi^0 \right) \partial^\mu a
\]

where

- \( f_a \) is the Peccei-Quinn scale
- \( f_\pi = 92.4 \text{ MeV} \) is the pion decay constant
- \( C_{a\pi} = \frac{1-z}{3(1+z)} \), \( z = m_u/m_d \approx 0.48 \)
The cosmological axion bound


Axions are Hot Dark Matter: constraints from $N_{\text{eff}} \sim 3.046$ and $\Omega_{h} h^2 \lesssim 2 \times 10^{-3}$

Constraint on the axion mass: $m_a \lesssim 0.53$ eV
Low-reheating cosmologies


The inflaton decay into Standard Model particles happens at $T_{RH}$

![Graph showing the relationship between $H$ (MeV) and $T$ (MeV) for different reheating temperatures.]

The reheating temperature might be as low as $T_{RH} \sim 5$ MeV

The axion mass bound in LTR cosmologies

The axion relic density is diluted by the faster cosmic expansion

Decoupling temperature vs $f_a$

Axion density vs $f_a$

A recent work questioned the validity of the $\pi\pi \rightarrow \pi a$ rate calculation for $T_D \gtrsim 60$ MeV.

Axion Cold Dark Matter in a LTR scenario

The axion temperature is lowered: axions act as Cold Dark Matter in a LTR scenario
The relaxation of the bound

The cosmological axion bound is strongly relaxed in a LTR scenario

![Graph showing the cosmological axion bound relaxation](graph.png)
Conclusions

- The cosmological axion bound is relaxed in a LTR scenario.

- Axions at the eV scale are probed by astrophysics (Supernova axions? Resonant solar conversions?)

- Also many experiments are planned to study this region (AMELIE, CUORE, WIMP-like experiments)

THANKS FOR YOUR ATTENTION!