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Axion hot dark matter bound, reliably

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Axions originally emerged as low-energy remnants of the Peccei Quinn solution to the strong CP problem, but they also unavoidably contribute to the energy density of the Universe. The thermal axion population contributes to the effective number of extra relativistic degrees of freedom, whose value is constrained by cosmic microwave background (CMB) experiments.
In the talk I will discuss axion thermalization at temperatures below 150 MeV, where the main thermalization channel is the axion-pion scattering. Based on the leading order (LO) axion-pion chiral effective field theory (EFT), the highest attainable axion mass is approximately below the eV. However, this bound is found to be not reliable, since in a heat bath of 100 MeV the axion-pion scattering happens at center of mass energies above the validity of the 2-flavour chiral EFT.
To prove this, I will provide the full axion-pion thermalization rate to next-to-leading order, and show that the LO bound is indeed obtained by extrapolating the chiral expansion in a region of temperatures where the effective field theory breaks down.
Thus, in order to set targets for future CMB experiments, new strategies are required to obtain a reliable bound.
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