Contribution ID: **42** Type: **Regular talk**

Constraints on extended axion structures from the lensing of fast radio bursts

Thursday, 26 June 2025 14:30 (30 minutes)

Axions are hypothetical pseudoscalar particles that have been regarded as promising dark matter (DM) candidates. On the other hand, extended compact objects such as axion stars, which are supported by gravity and axion self interactions, may have also been formed in the early Universe and comprise part of DM. In this work, we consider the lensing of electromagnetic signals from distant sources by axion stars as a way to constrain the properties of axion stars and fundamental axion parameters. Accounting for the effect of the finite size of the axion star, we study the lensing effect induced by gravity and by axion-photon interactions. The latter effect is frequency dependent, and is relevant in the low frequency band, which motivates the use of fast radio burst (FRB) signals as a probe. We calculate the predicted number of lensed FRB events by specifying the fundamental axion parameters, axion star radial profile, fraction of DM residing in axion stars, and imposing lensing criteria based on the flux ratio and time delay between the brightest images from lensing. Assuming an optimistic case of 10^4 observed FRB events, and a timing resolution of 1 μs, the lack of observed FRB lensing events in CHIME allows us to probe axion stars with mass
$gtrsim 10^{-2} M_\odot$, corresponding to axion masses
$lesssim 10^{-10}\,\mathrm{eV}$ and for negligible axion-photon couplings. Even lighter axion stars up to $\sim 10^{-3} M_\odot$ can be probed, assuming axion-photon couplings of at least $10^{-6}\,\mathrm{GeV}^{-1}$. Our results indicate that while FRB lensing by axion stars leads to sensitivities that are competitive with conventional microlensing searches operating in the optical band, it remains a challenge to probe axion-photon induced lensing effects.

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Dark Matter

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Session Classification: Dark Matter