Ultralight axion dark matter and CMBS4

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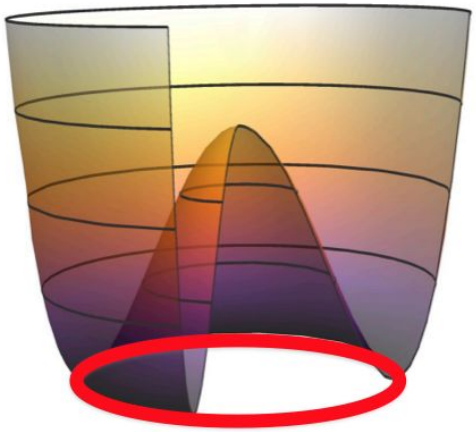
Ultralight axions

Axions originally solved the CP problem - but we are considering the ultralight axions (ULAs) that may arise from string theory.



$\theta = \phi / f_a$

Axion dynamics specified by the scalar field potential:

$$\ddot{\phi}_0 + 2\mathcal{H}\dot{\phi}_0 + m_a^2 a^2 \phi_0 = 0$$

Simple harmonic oscillator

$$\rho_a = \dot{\phi}^2/2 + m_a^2\phi^2/2 \sim \begin{cases} \text{const. for } H \gtrsim m_a\,, \\ 1/a^3 \quad \text{for } H \lesssim m_a\,. \end{cases}$$

ULAs and the CMB

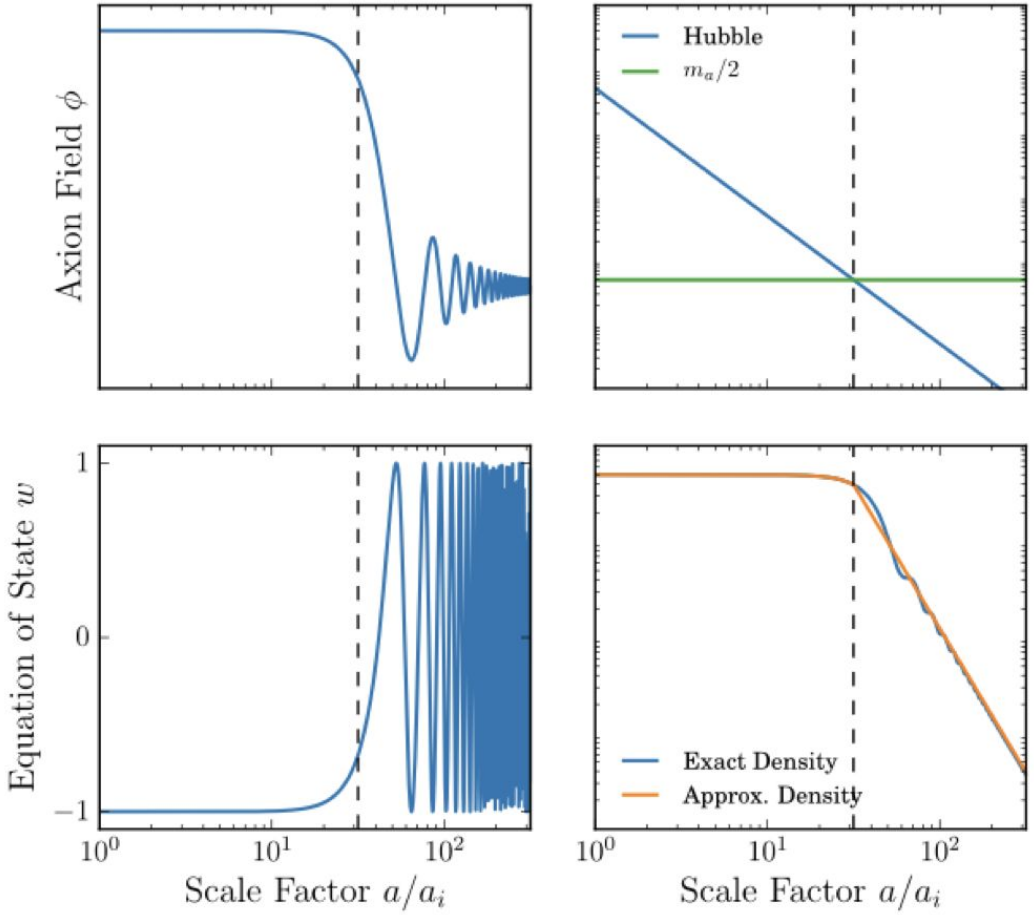
Ultra-light axions dark matter have macroscopic de Broglie wavelengths, suppress structure on small scales.
The goal is to detect or bound the axion contribution to dark matter.

Axion impact on CMB observables (all mass dependent):

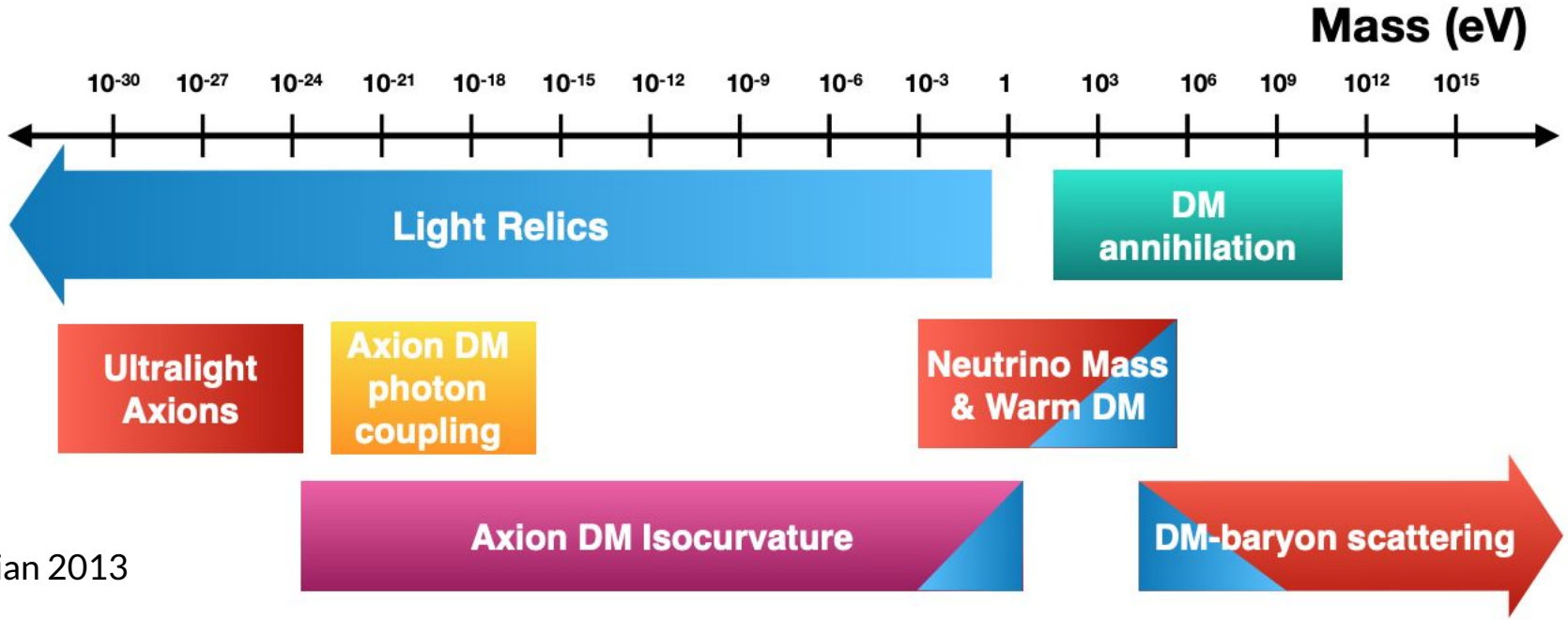
- Large-scale ISW effect on CMB power spectrum on large scales through the ISW effect
- Small-scale suppression to the damping tail of CMB power spectrum.
- Suppression of s small-scale lensing deflection ← changes to matter power spectrum. Big improvement from CMB-S4
- Boost in kSZ signal due to increased bias in structure-suppressed cosmology → can be detected via cross-correlation of CMB maps with galaxy surveys.
- Boost to Ostriker-Vishniac (OV) signal induced by gas inhomogeneities during the mildly nonlinear reionization epoch
- Birefringence due to axion-photon coupling

Eg. https://arxiv.org/pdf/2203.07064.pdf
https://arxiv.org/pdf/2203.14923.pdf
https://arxiv.org/pdf/2203.14915.pdf

ULA cosmology

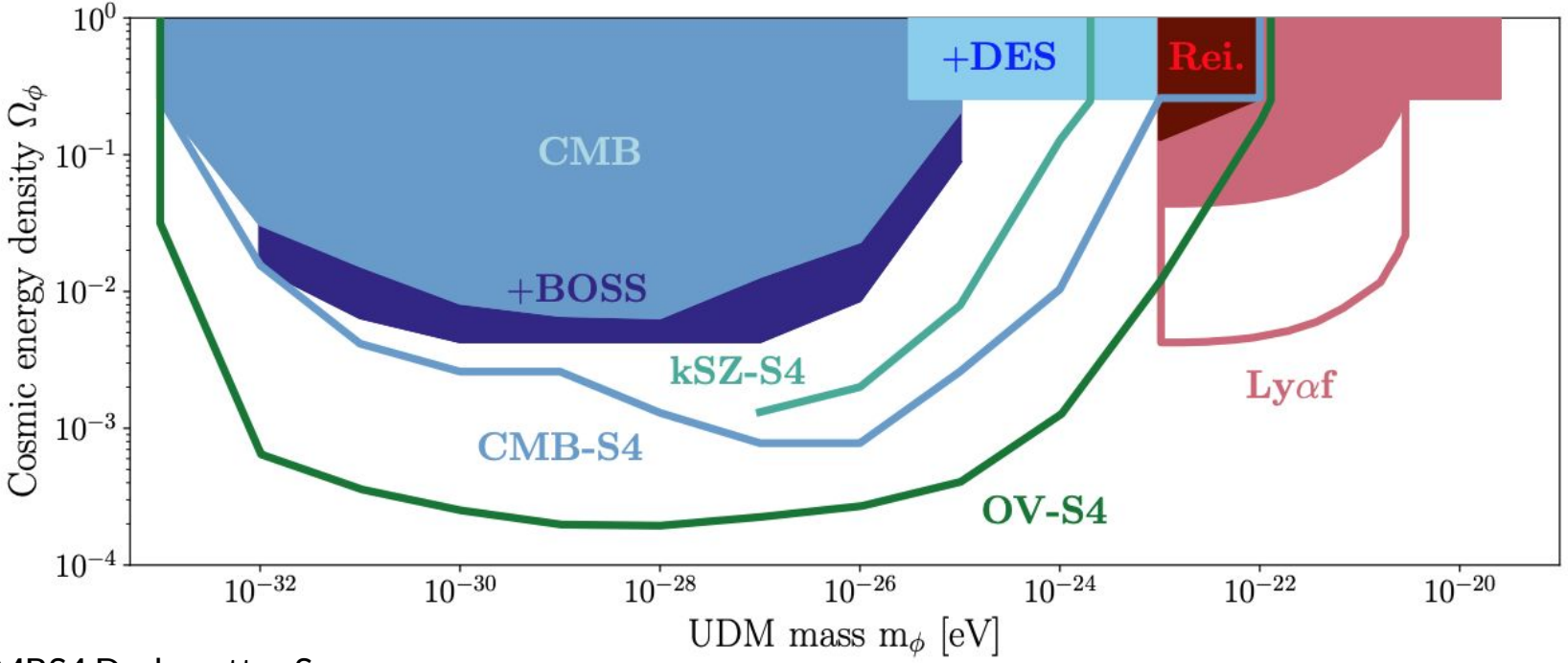


Ultra-light Axions in context



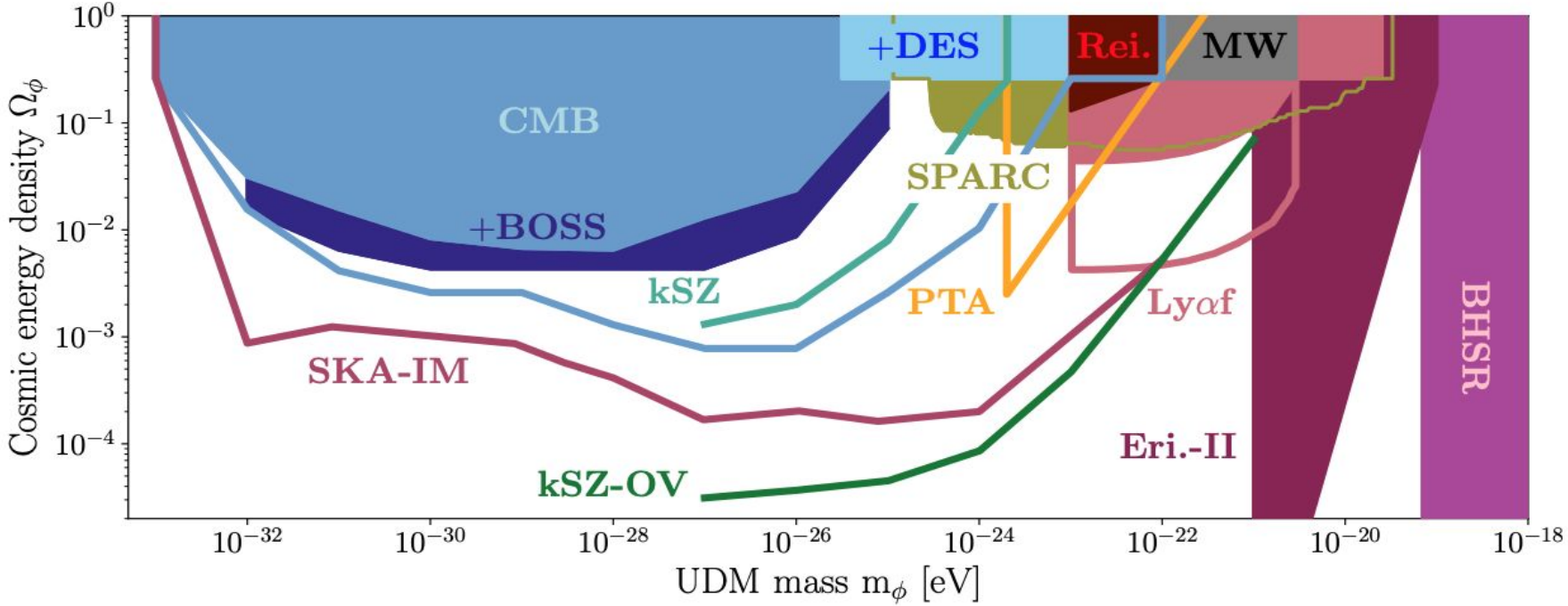
Abazajian 2013

ULAs and CMB-S4



CMBS4 Dark matter Snowmass paper

ULAs and CMB-S4



Axion physics Snowmass paper