

Title: Ultra-light axions, the high-redshift galaxy population and implications for the  $S_8$  tension

Speakers: Keir Rogers

Collection: Dark Matter, First Light

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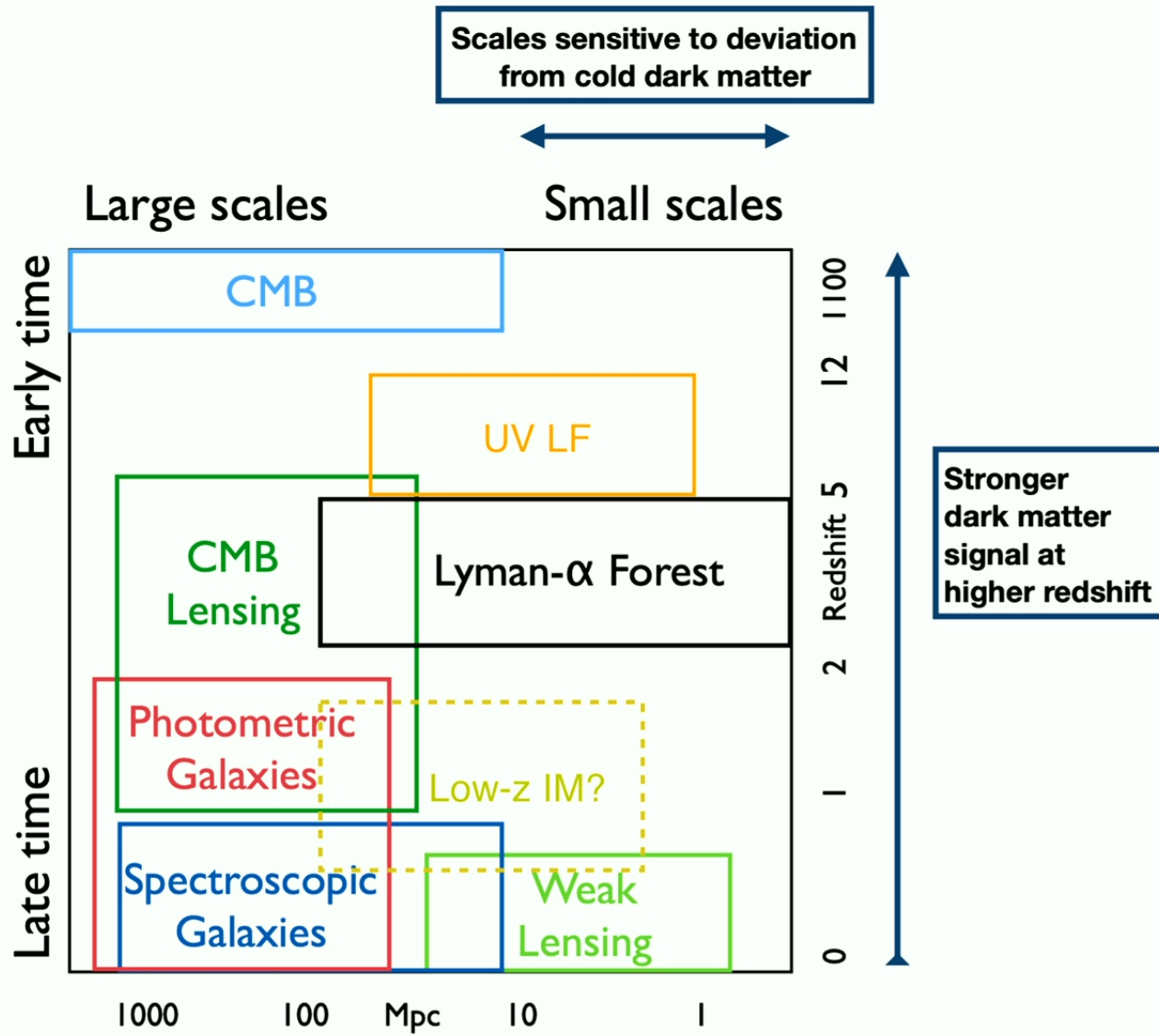
Abstract: The fundamental nature of dark matter (DM) so far eludes direct detection experiments, but it has left its imprint in the cosmic web. The standard cold DM model is remarkably well tested by cosmic microwave background and low-redshift galaxy surveys, but well-motivated particle candidates like ultra-light axions will leave signatures on small cosmic scales. These signatures are stronger at earlier times. Future 21 cm observations will transform our view of the primordial Universe, but we are already observing some of the first visible tracers of cosmic structure in the high-redshift galaxy population through the Hubble and James Webb Space Telescopes. I will present calculations of the effects of DM candidates like ultra-light axions on the high- $z$  galaxy UV luminosity function. I will then present Hubble and Webb constraints on the allowed fraction of ULAs, accounting for uncertainties in how early galaxies trace the halo population, and discuss the implications for DM solutions to discrepancies in the late-time clustering of matter ( $S_8$  tension).

A visualization of the cosmic web, showing a complex network of blue filaments and nodes against a dark background. The nodes represent galaxy clusters, and the filaments represent the large-scale structure of the universe.

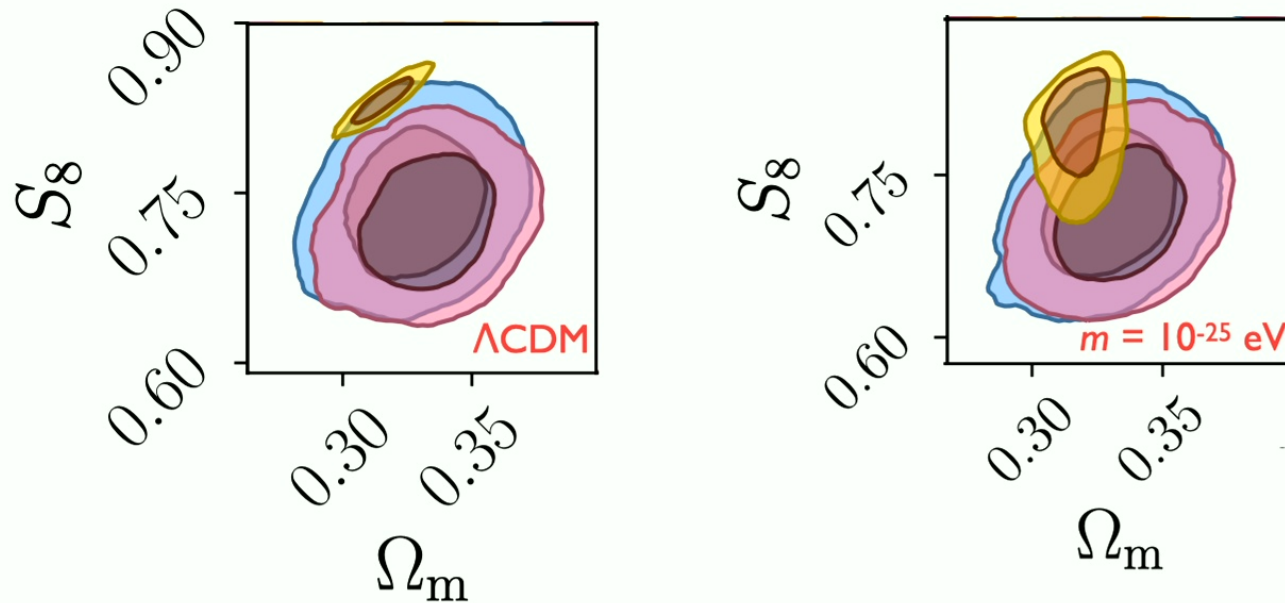
# EARLY TIME, SMALL SCALE TESTS OF THE NATURE OF DARK MATTER

**Keir K. Rogers**

*Dunlap Fellow, Dunlap Institute for Astronomy & Astrophysics,  
University of Toronto*



## Axions improve consistency between *Planck* CMB & BOSS galaxy power spectrum

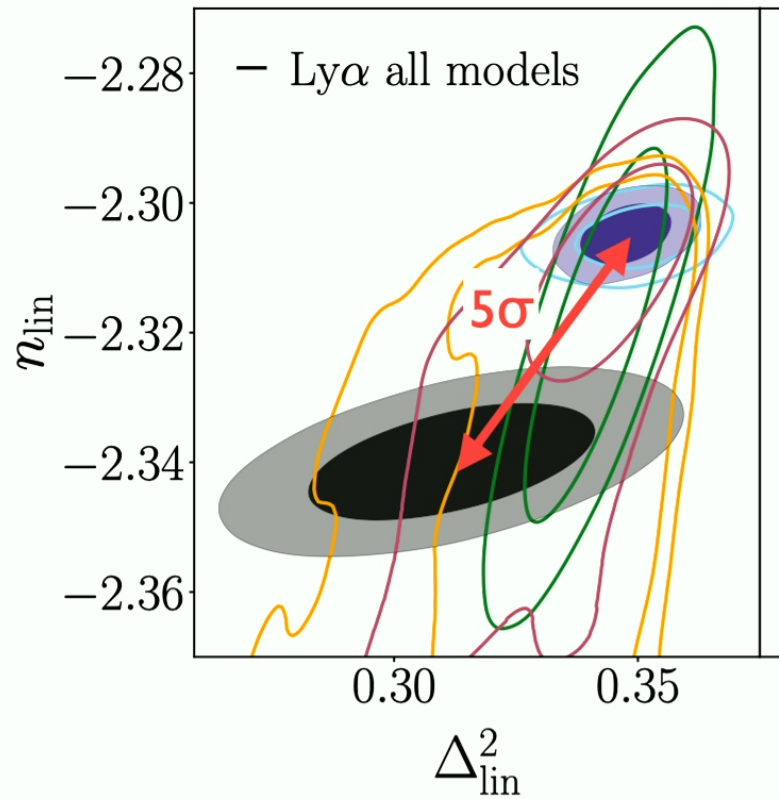


- *Planck* cosmic microwave background
- BOSS galaxy power spectrum
- BOSS galaxy power spectrum + bispectrum

3

Rogers, Hložek, et al. (JCAP, 2023)

# CMB+BAO+SNe vs Ly $\alpha$



- $\Lambda$ CDM
- $\Sigma m_\nu$
- $\alpha_s$
- ULA
- WDM

**Power spectrum  
running:  $0.92\sigma$ ;  
ultra-light axions:  $0.56\sigma$ ;  
warm DM:  $1.63\sigma$**

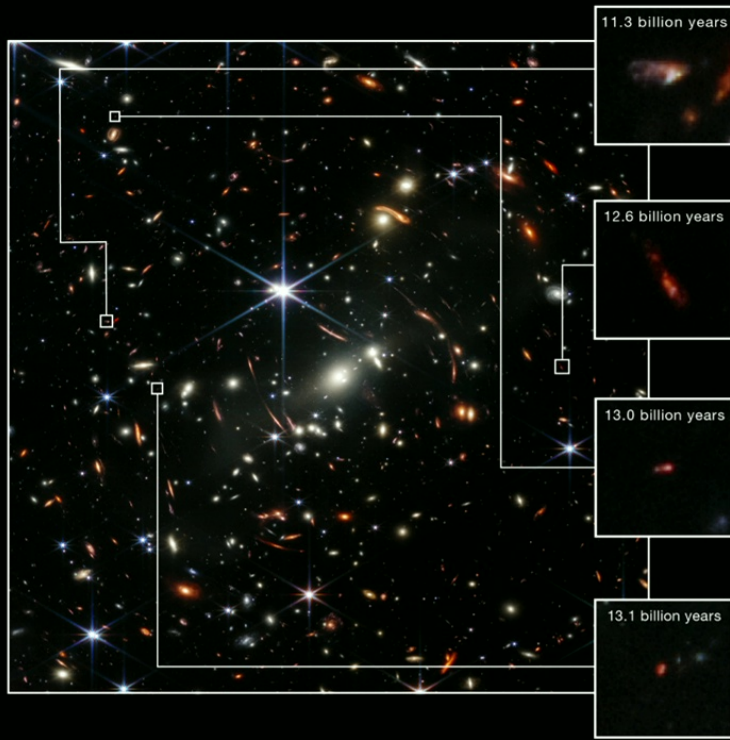
Rogers & Poulin (arXiv: 2311.16377)

GALAXY CLUSTER SMACS 0723

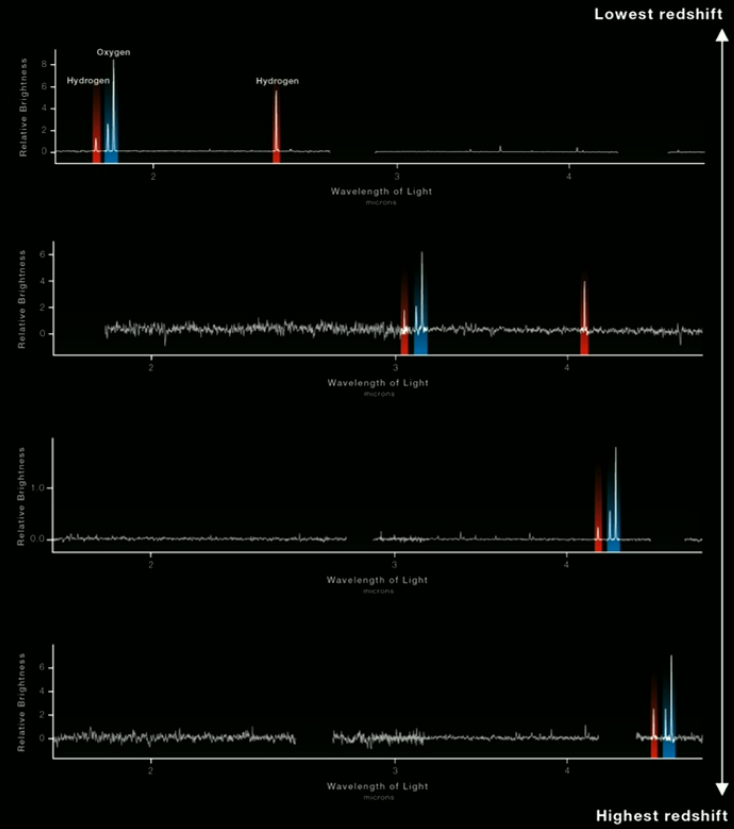
# WEBB SPECTRA IDENTIFY GALAXIES IN THE VERY EARLY UNIVERSE

NIRCam Imaging

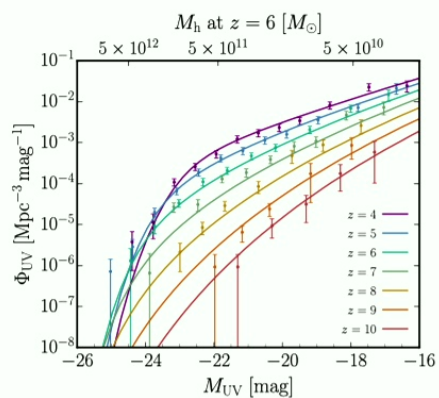
NIRSpec Microshutter Array Spectroscopy



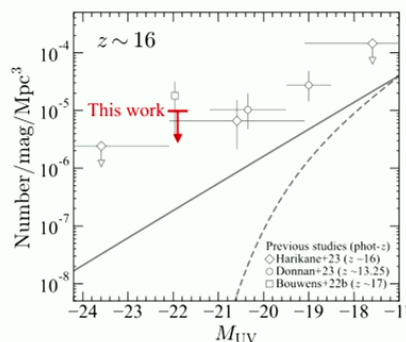
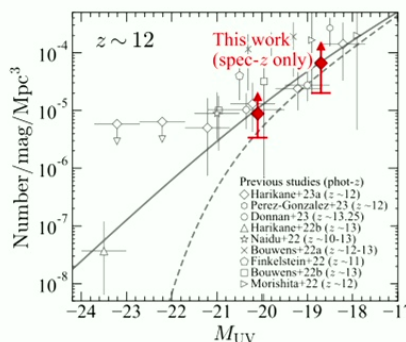
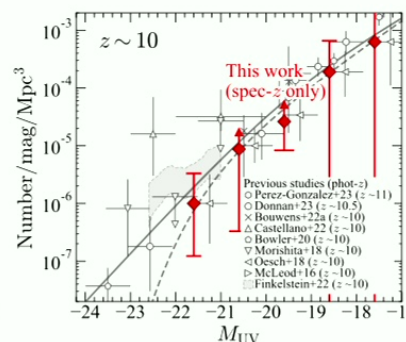
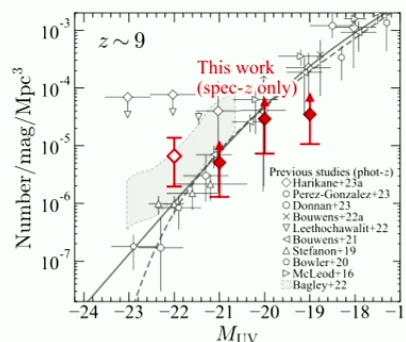
**WEBB**  
SPACE TELESCOPE



# First spectroscopic limits on very-high-redshift galaxy UV luminosity function



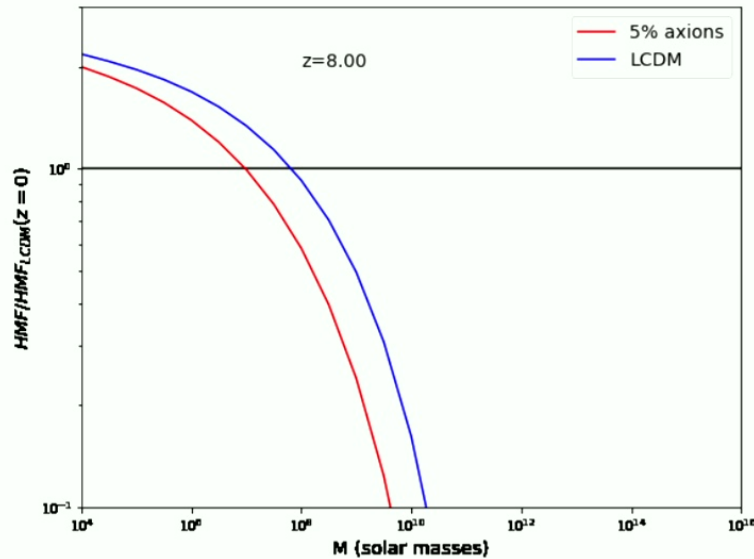
Hubble Space Telescope



James Webb Space Telescope

Oesch et al. (2018); Bouwens et al. (2021); Sabti et al. (2022); Harikane et al. (2023)

## A modified halo model for axion structure formation



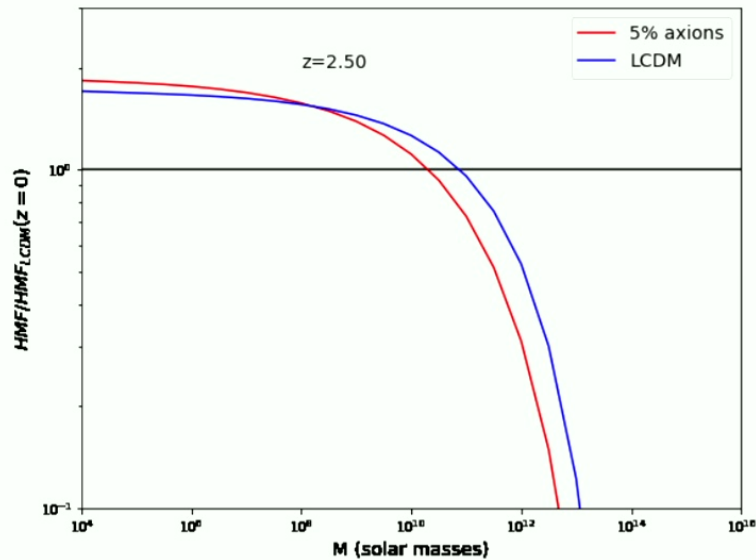
- Axions do not cluster below de Broglie wavelength
- Suppressed halo population at Jeans scale
- Structure formation delayed leading to small-scale enhancement



Harrison Winch & Keir Rogers (in prep.)



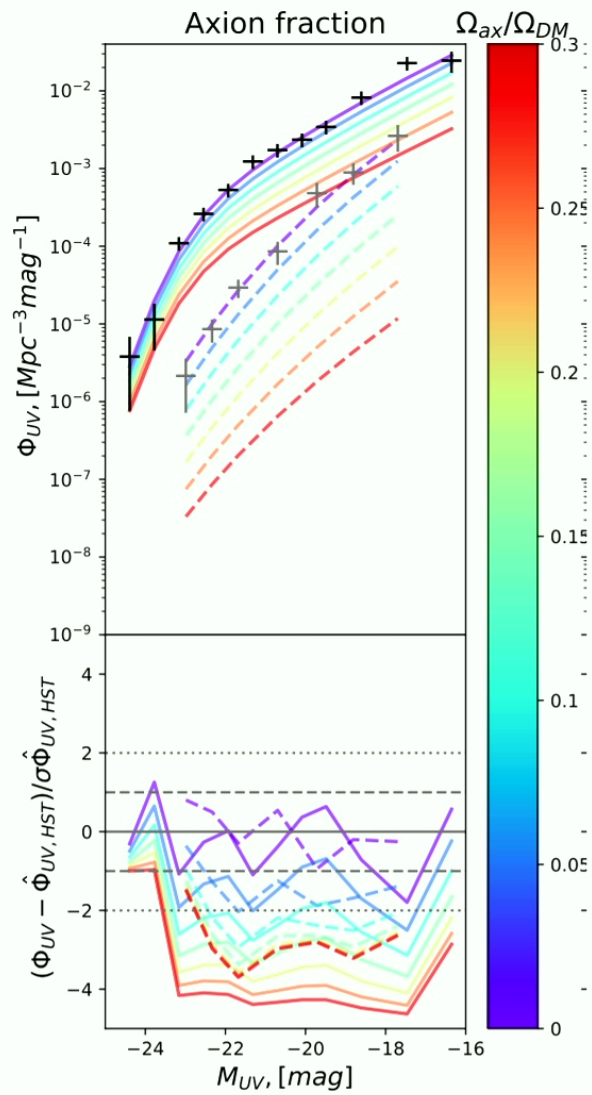
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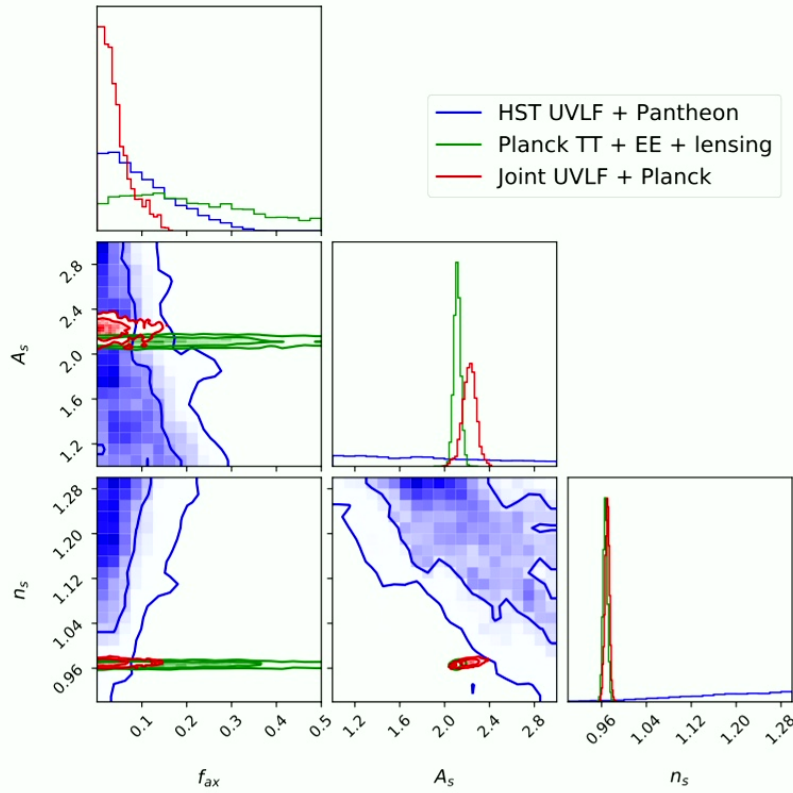


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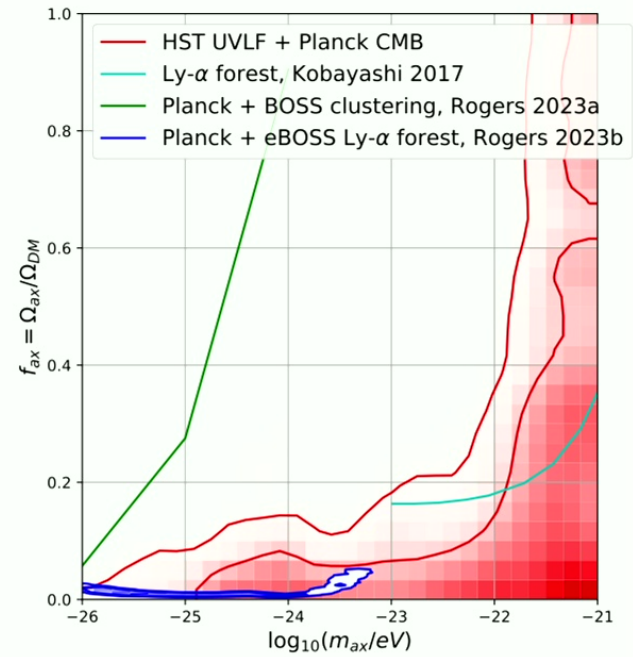
**Axions suppress faint galaxy population**

Harrison Winch & Keir Rogers (in prep.)



Planck CMB to anchor primordial power

UVLF allows 10 - 20 % axion fraction

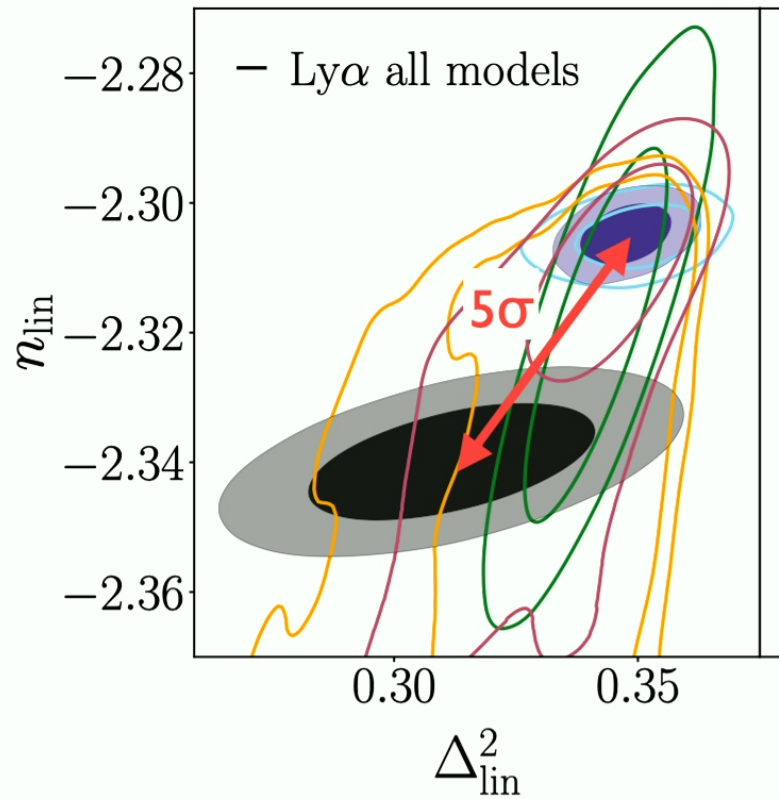


Harrison Winch & Keir Rogers (in prep.)

## Summary

- Test dark matter structure formation at **high redshift & on small scales**
- **Hubble & Webb high-z galaxies** consistency check on late-time probes
- **10 - 20 % fraction of axions ( $m < 10^{-22}$  eV)** allowed by UV luminosities

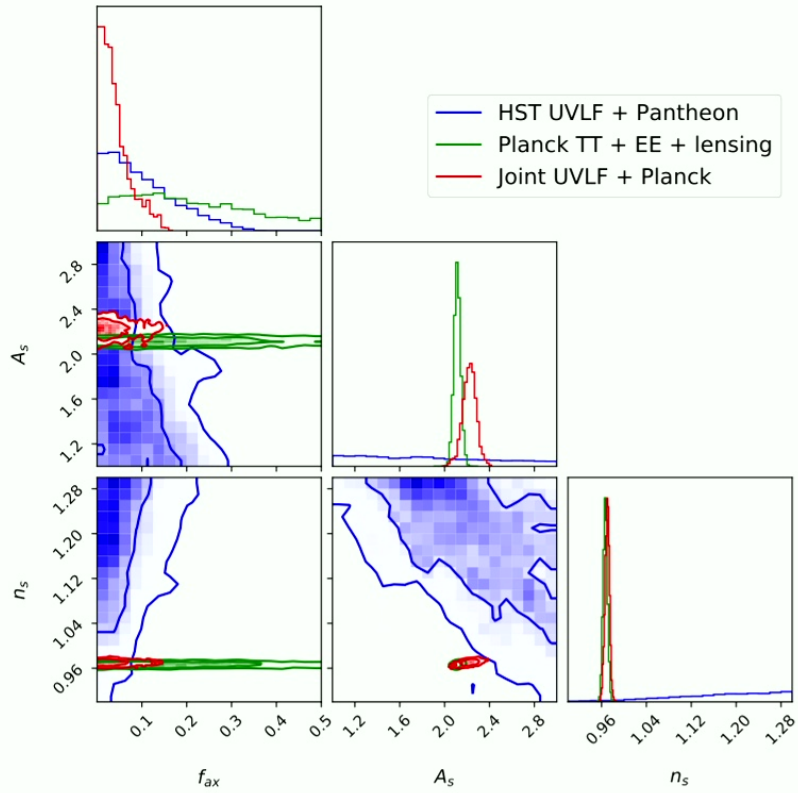
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