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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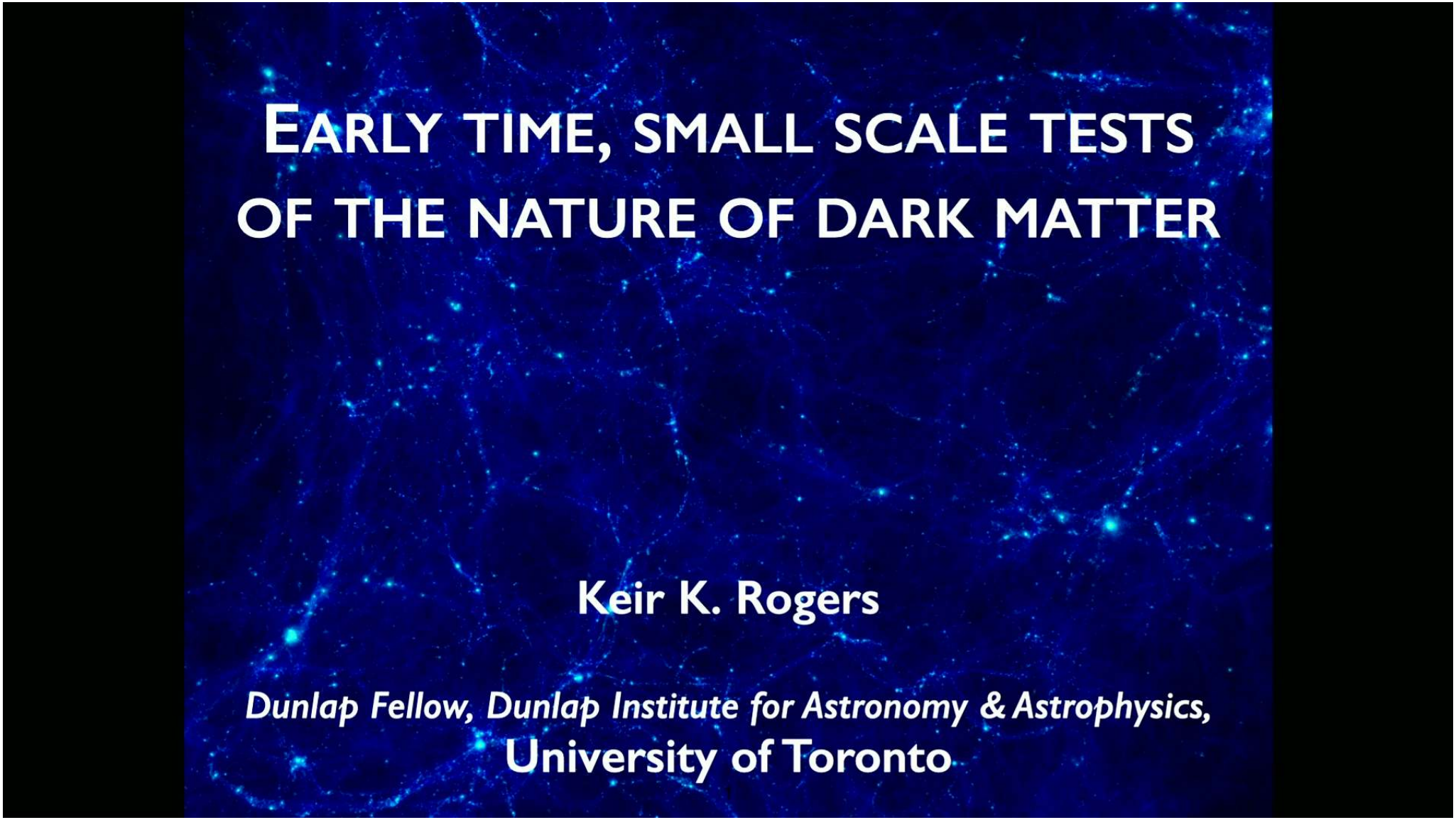
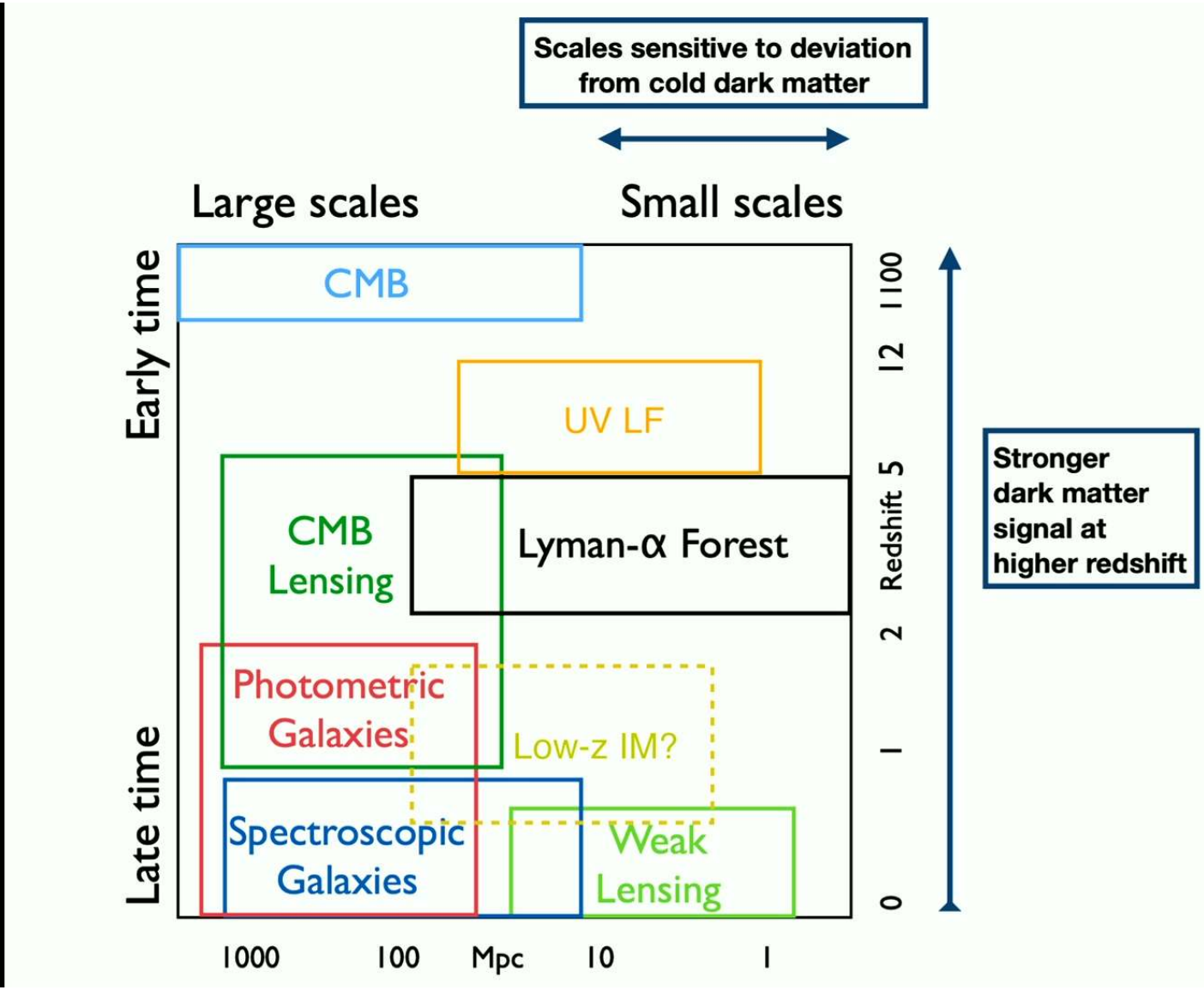
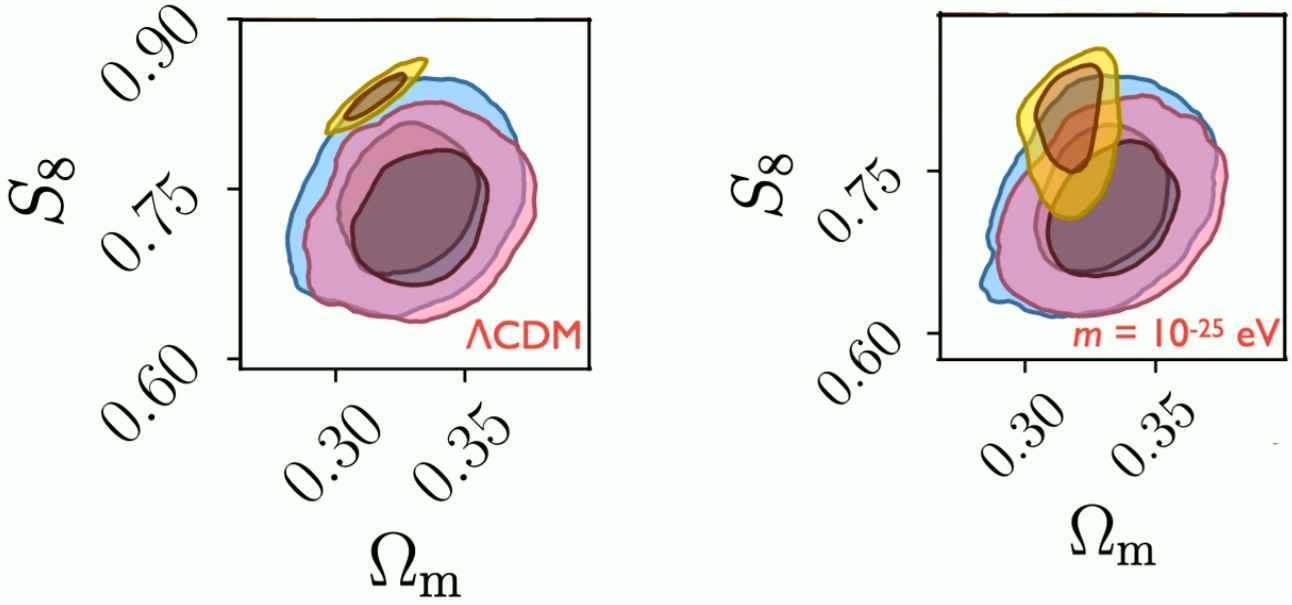
Abstract: The fundamental nature of dark matter (DM) so far eludes direct detection experiments, but it has left its imprint in the cosmic web. The standard cold DM model is remarkably well tested by cosmic microwave background and low-redshift galaxy surveys, but well-motivated particle candidates like 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).


EARLY TIME, SMALL SCALE TESTS
OF THE NATURE OF DARK MATTER
Keir K. Rogers
Dunlap Fellow, Dunlap Institute for Astronomy & Astrophysics,
University of Toronto

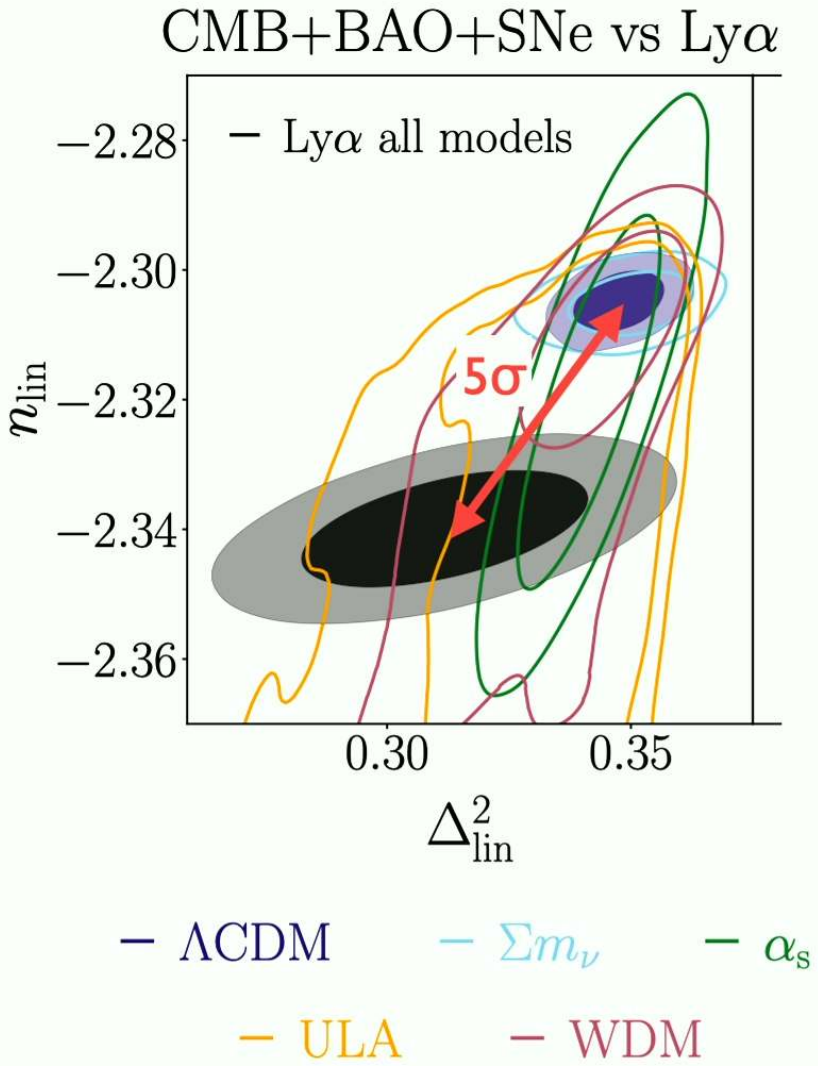

Scales sensitive to deviation from cold dark matter
Large scales
Small scales
Early time
Late time
CMB
UV LF
CMB Lensing
Lyman-α Forest
Photometric Galaxies
Low-z IM?
Spectroscopic Galaxies
Weak Lensing
1000
100
Mpc
10
1
0
1
2
5
12
1100
Redshift
Stronger dark matter signal at higher redshift

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



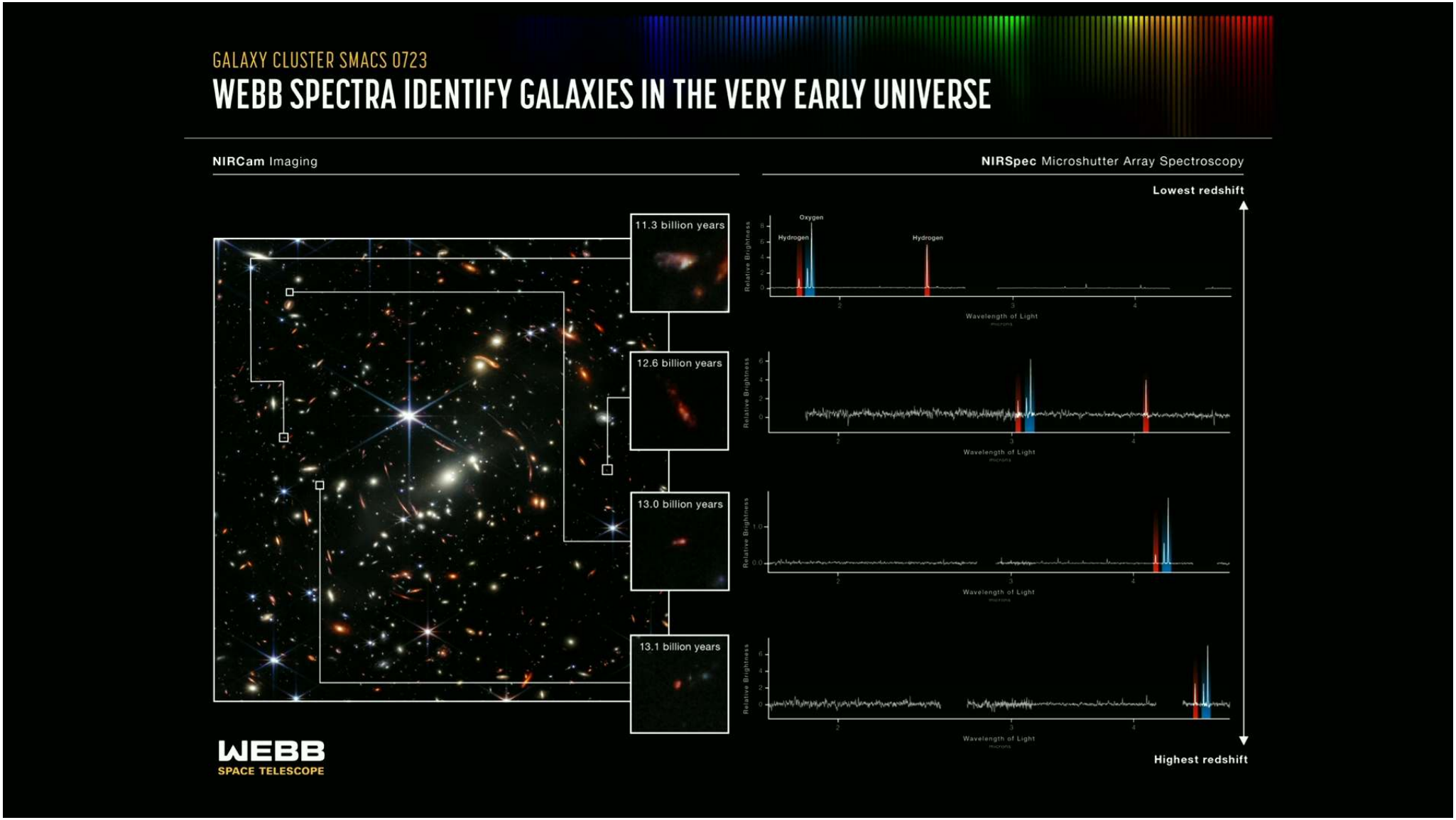
- *Planck* cosmic microwave background
- BOSS galaxy power spectrum
- BOSS galaxy power spectrum + bispectrum

Rogers, Hložek, et al. (JCAP, 2023)

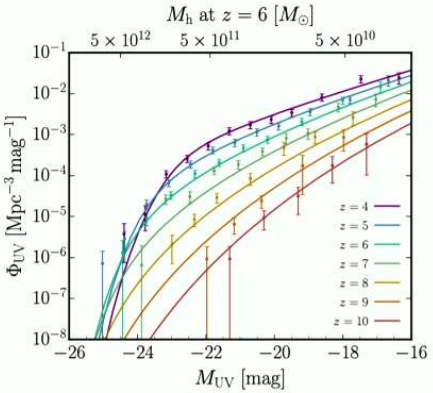


Power spectrum running: 0.92σ; ultra-light axions: 0.56σ; warm DM: 1.63σ

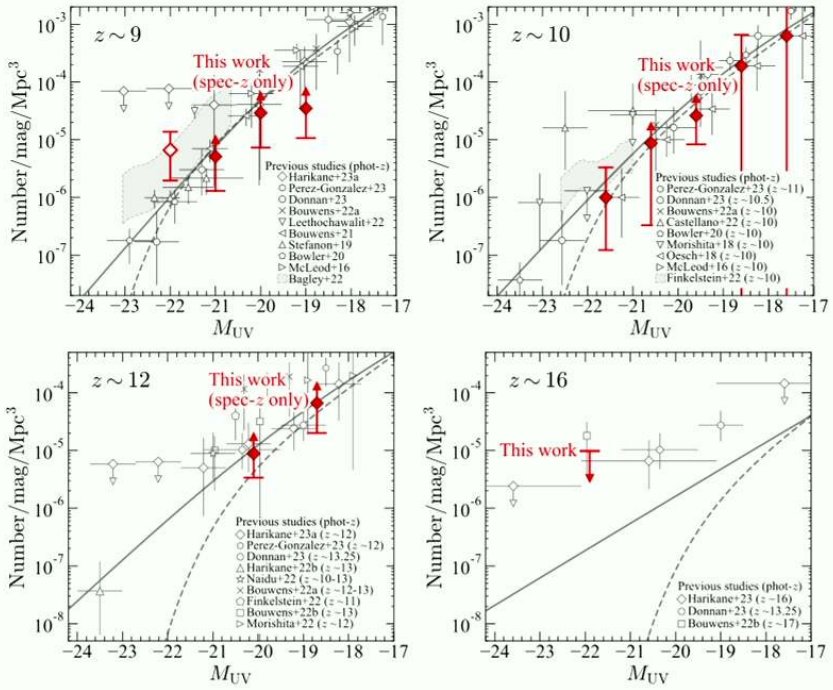
Rogers & Poulin (arXiv: 2311.16377)


GALAXY CLUSTER SMACS 0723
WEBB SPECTRA IDENTIFY GALAXIES IN THE VERY EARLY UNIVERSE
NIRCam Imaging
NIRSpec Microshutter Array Spectroscopy
Lowest redshift
11.3 billion years
12.6 billion years
13.0 billion years
13.1 billion years
Oxygen
Hydrogen
Hydrogen
Relative Brightness
Wavelength of Light
microns
Highest redshift
WEBB
SPACE TELESCOPE

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



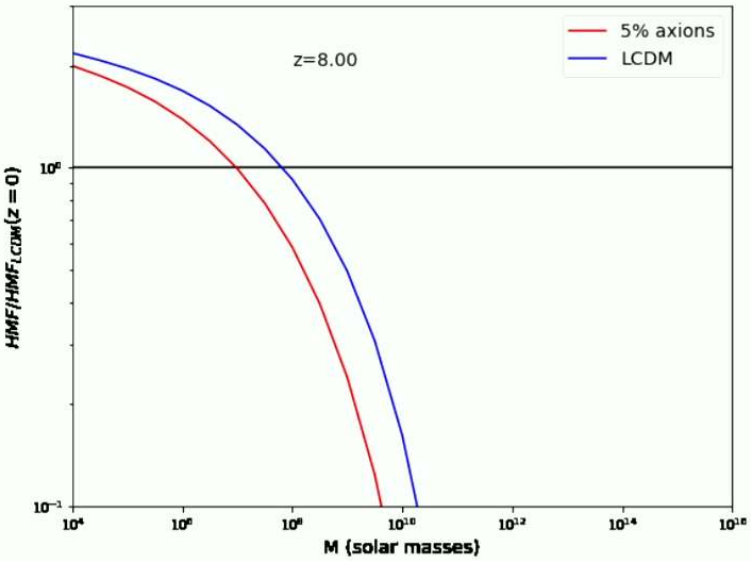
Hubble Space Telescope



James Webb Space Telescope

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

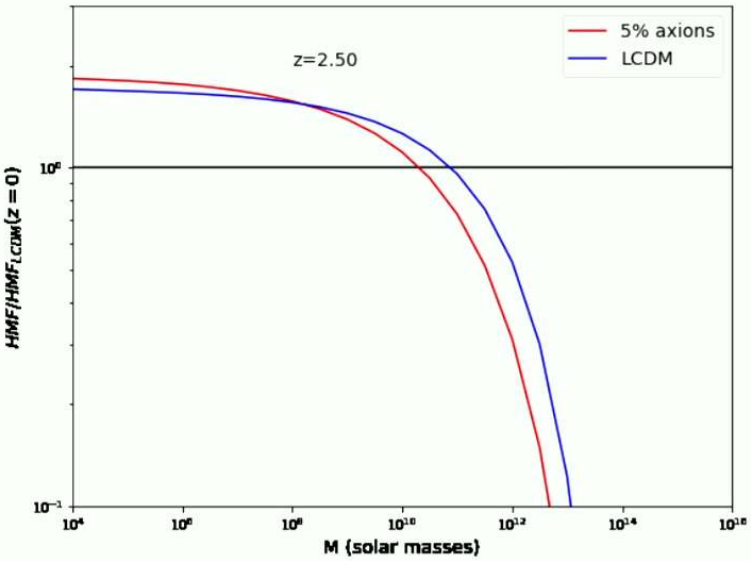
A modified halo model for axion structure formation



- 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.)

A modified halo model for axion structure formation



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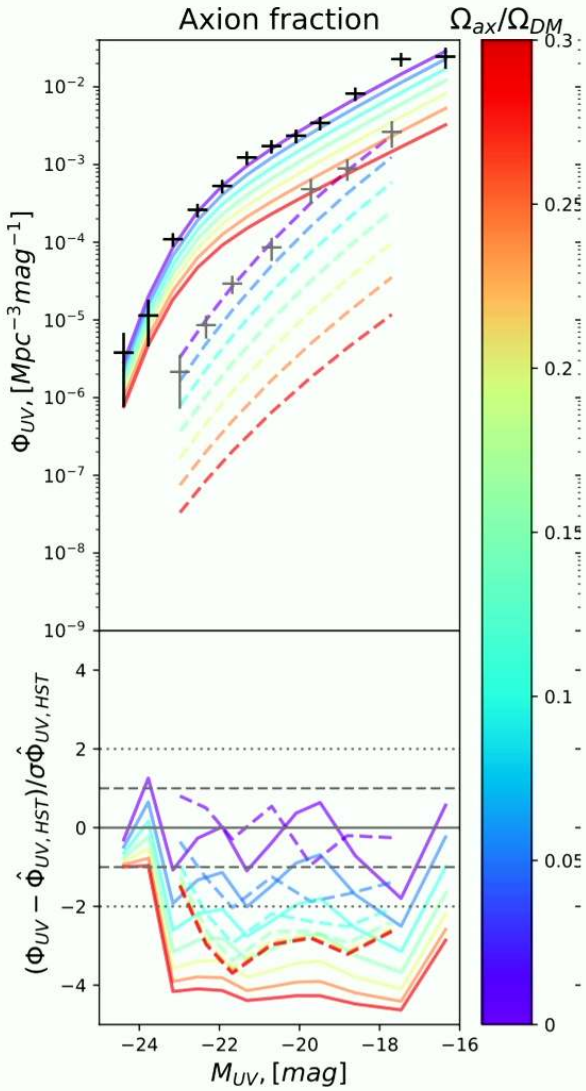
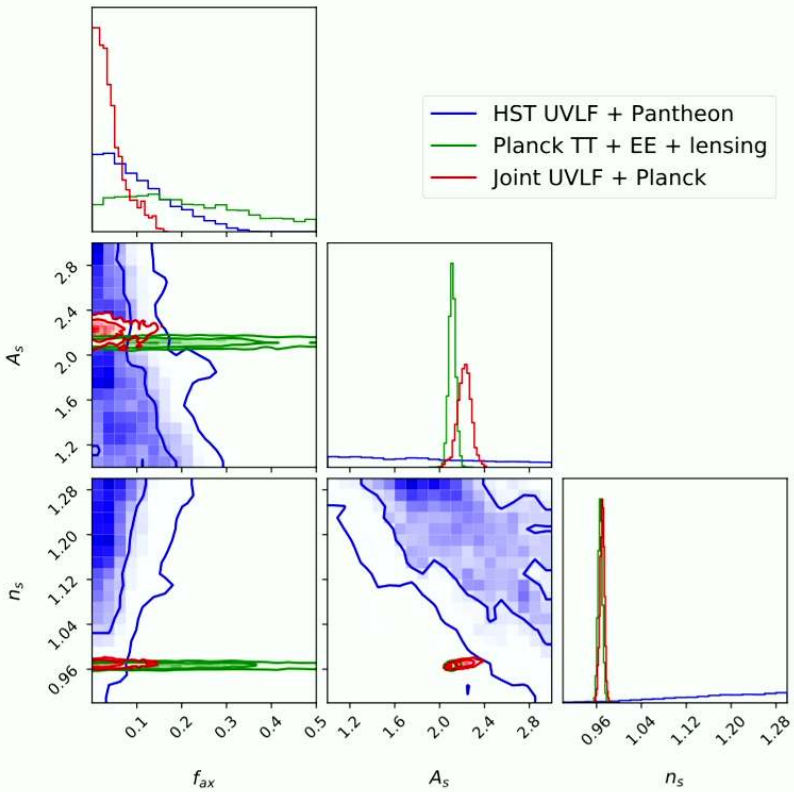


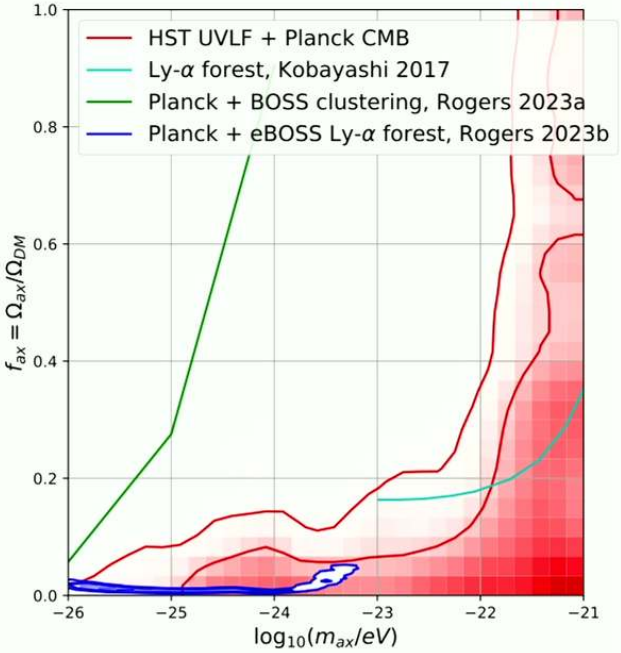
Axions suppress faint galaxy population

Harrison Winch & Keir Rogers (in prep.)



Planck CMB to anchor primordial power

UVLF allows 10 - 20 % axion fraction



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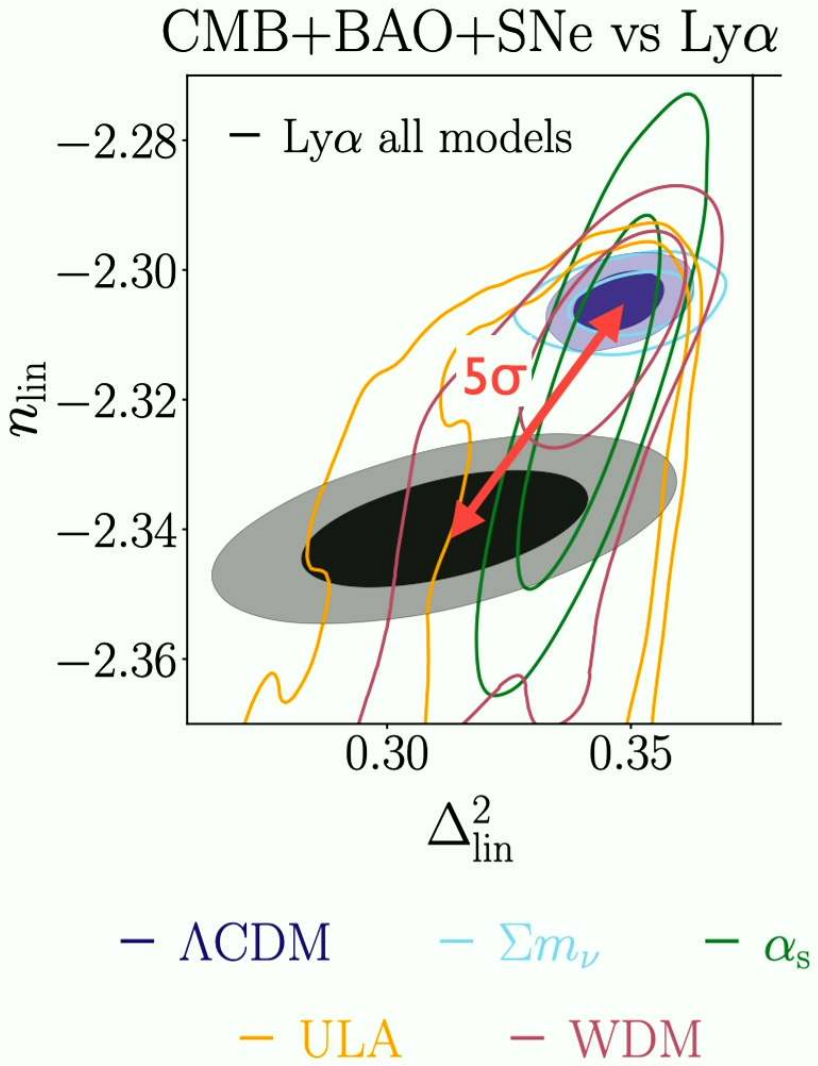
Summary

- 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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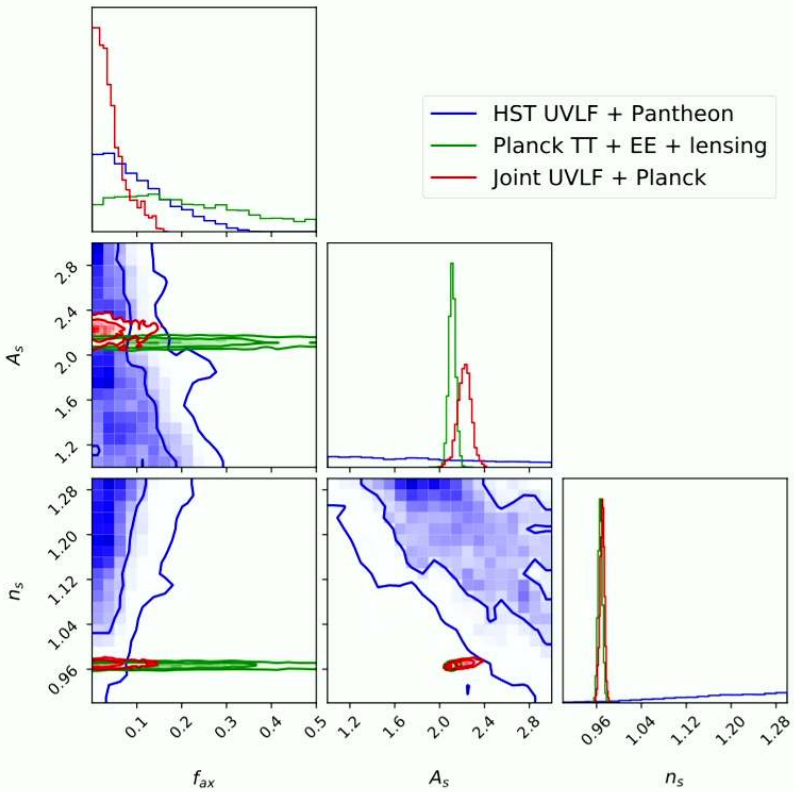

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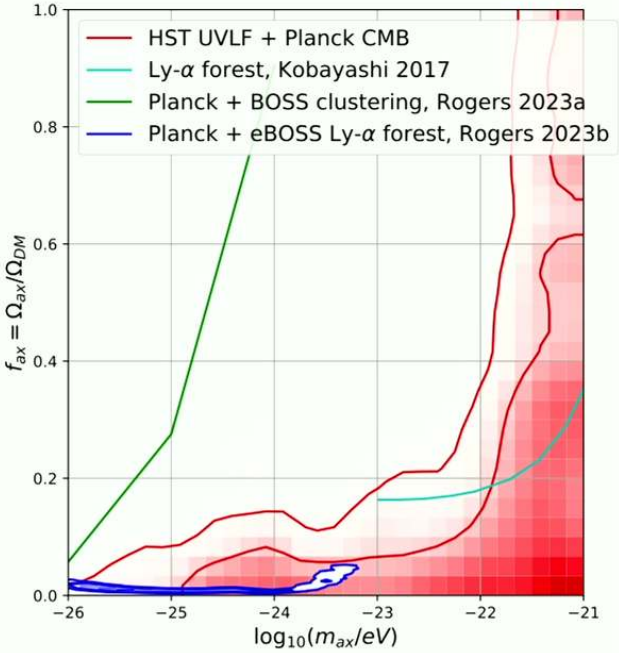
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