Title: Probing baryonic feedback and cosmology with patchy screening in the FLAMINGO Simulations.

Speakers: Jonah Conley

Collection/Series: Cosmic Ecosystems

Subject: Cosmology

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Abstract:

Understanding the impact of baryonic feedback across different cosmic environments is crucial for accurate interpretation of large-scale structure in Stage-IV cosmological surveys. Hydrodynamical simulations offer a valuable tool for capturing how gas is redistributed by energetic processes, such as AGN feedback, and for predicting how this redistribution alters observable tracers of structure formation. Traditionally, feedback models have been constrained through X-ray and Sunyaev-Zel'dovich measurements of galaxy groups and clusters. However, new observational tracers are emerging that open up alternative windows into the baryonic content of the cosmic web.

One such tracer is the patchy screening effect, a subtle CMB anisotropy arising from excess Thomson scattering along the line of sight to groups/clusters due to their higher electron optical depths. This effect is sensitive to the diffuse baryons in the outer regions of the gas profile of the halo, tracing the structure of the cosmic web. It is complementary to the kinetic Sunyaev-Zel'dovich effect, as it probes optical depth without dependence on velocity.

In this talk, we present predictions of the patchy screening signal from the FLAMINGO suite of large-volume cosmological hydrodynamical simulations. By generating mock patchy screened CMB maps and cross-correlating them with simulated galaxy populations, we explore how feedback and cosmology shape the optical depth field. Our goal is to assess the sensitivity of this signal to the cosmology and baryonic physics, and to evaluate its potential as a new probe of the gas distribution within the anisotropic structure of the cosmic web.

PROBING BARYONIC FEEDBACK AND COSMOLOGY WITH PATCHY SCREENING IN THE FLAMINGO SIMULATIONS.

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BACKGROUND

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Cosmic Microwave Background & Circumgalactic Medium (CGM):

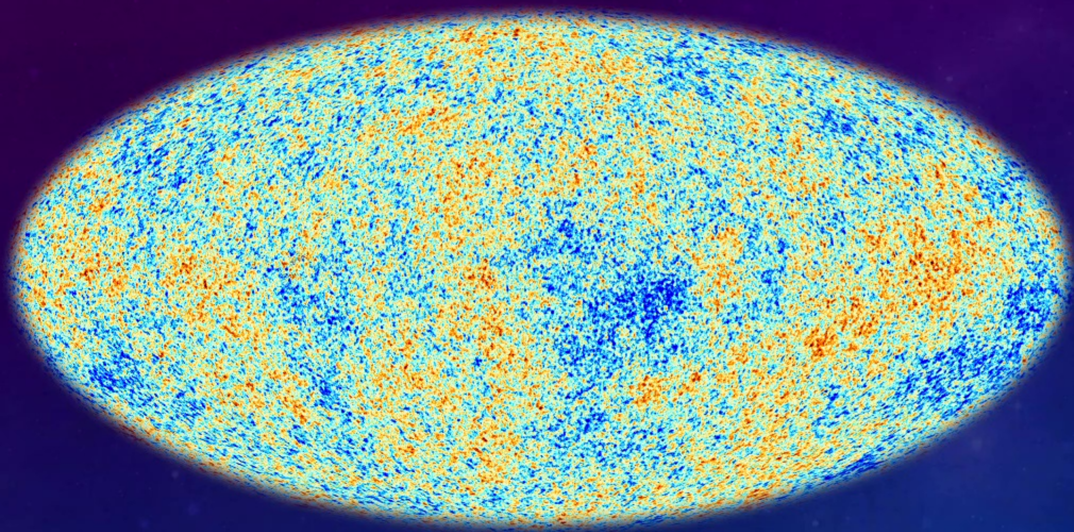

Image credit: ESA and the Planck Collaboration

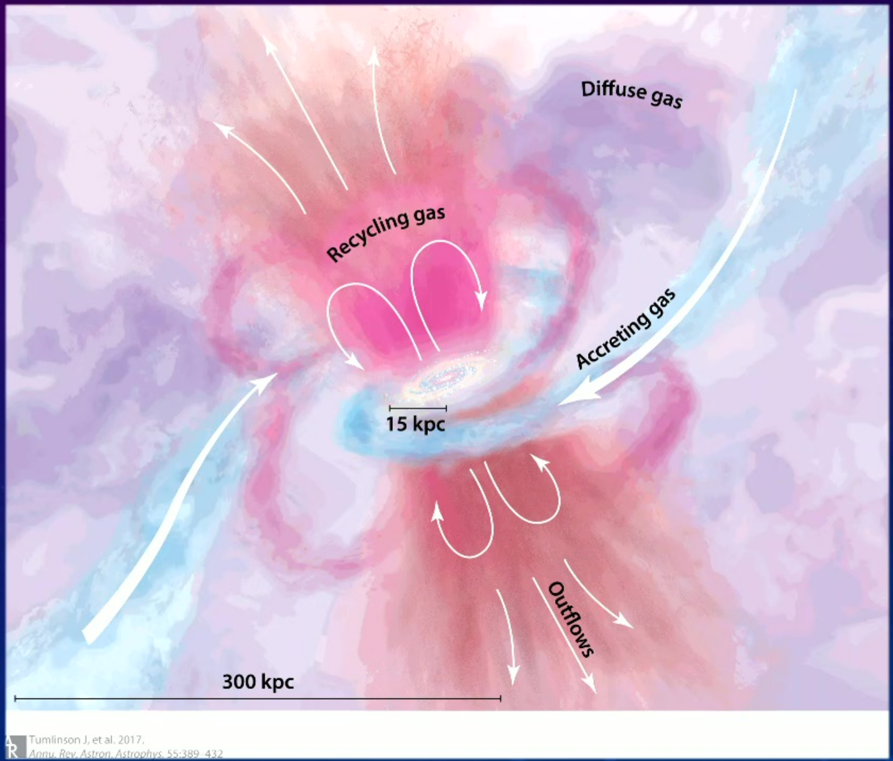

Image credit: Tumlinson, Peeples & Werk (2017)

MOTIVATION

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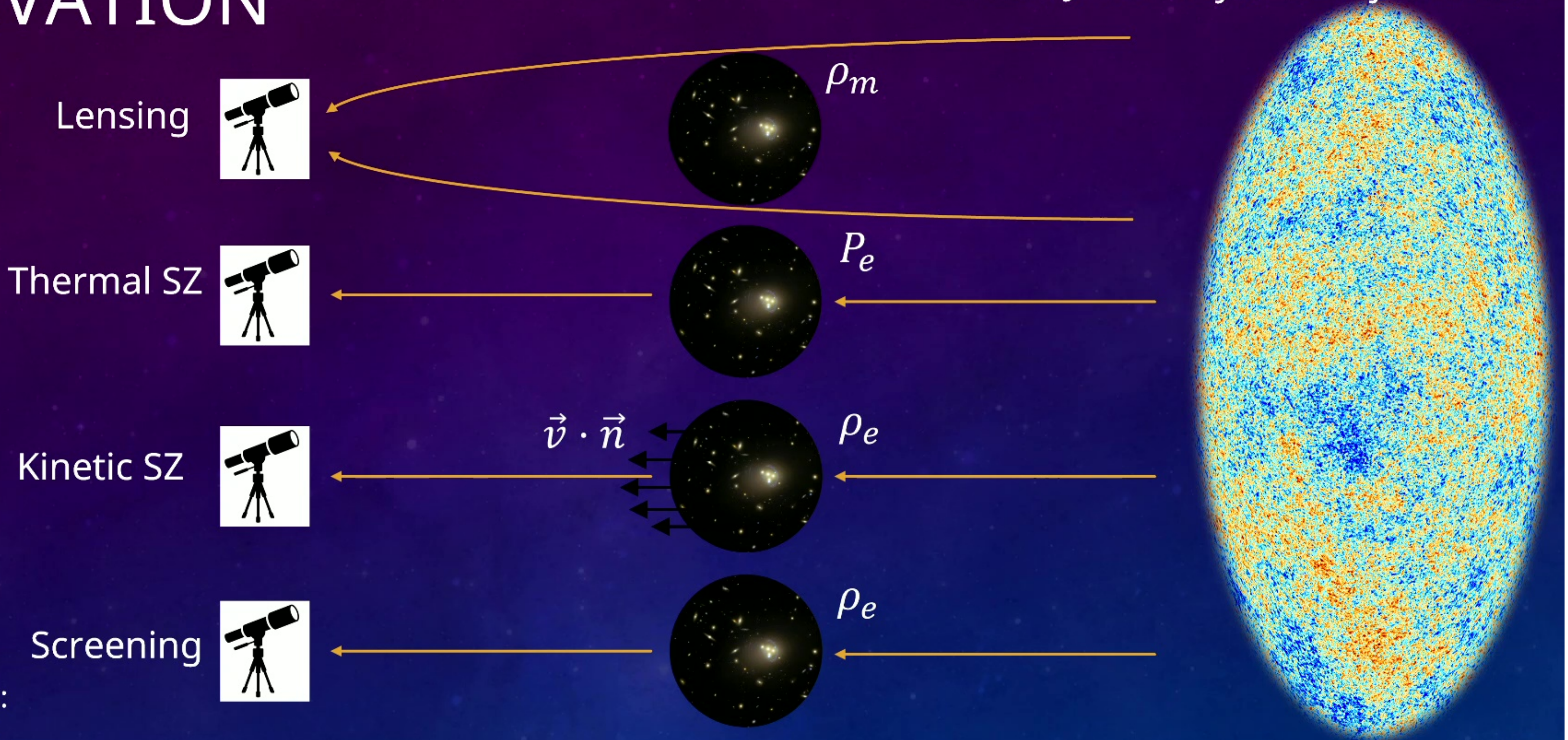

Image credits:
David Alonso,
Will Coulton,
ESO,
ESA and the
Planck
Collaboration

From Coulton et al. (2024),
Patchy Screening equation:

$$\Delta T^{\text{patchy screen}}(\mathbf{n}) = -\delta\tau(\mathbf{n})\Delta T^{\text{primary}}(\mathbf{n}),$$

METHODOLOGY

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From Coulton et al. (2024)

Sign estimator:

$$\widehat{\delta\tau}^{\text{stacked}}(\mathbf{n}) = \frac{-\sum \text{Sign}[T^{\text{large-scale}}(\mathbf{n_o}+\mathbf{n})]T^{\text{small-scale}}(\mathbf{n_o}+\mathbf{n})}{N_{\text{objects}}\langle|T^{\text{large-scale}}|\rangle},$$

Frequency band-pass filters:

$$f_L(\ell) = \begin{cases} 1 & \text{if } \ell < 600, \\ \cos\left(\pi\frac{(\ell-600)}{100}\right) & \text{if } 600 \le \ell < 650, \\ 0 & \text{if } \ell \ge 650. \end{cases}$$

$$f_S(\ell) = \begin{cases} 0 & \text{if } \ell < 850, \\ \sin\left(\frac{(\ell-850)\pi}{100}\right) & \text{if } 850 \le \ell < 900, \\ 1 & \text{if } \ell \ge 900. \end{cases}$$

unWISE galaxy sample:

Sample	Mean Redshift	Mean Halo Mass ($M_\odot$/h)	Source density (arcmin^{-2})
Blue	0.6	1.4×10^{13}	0.58
Green	1.1	1.3×10^{13}	0.32
Red	1.5	1.6×10^{13}	0.018

METHODOLOGY

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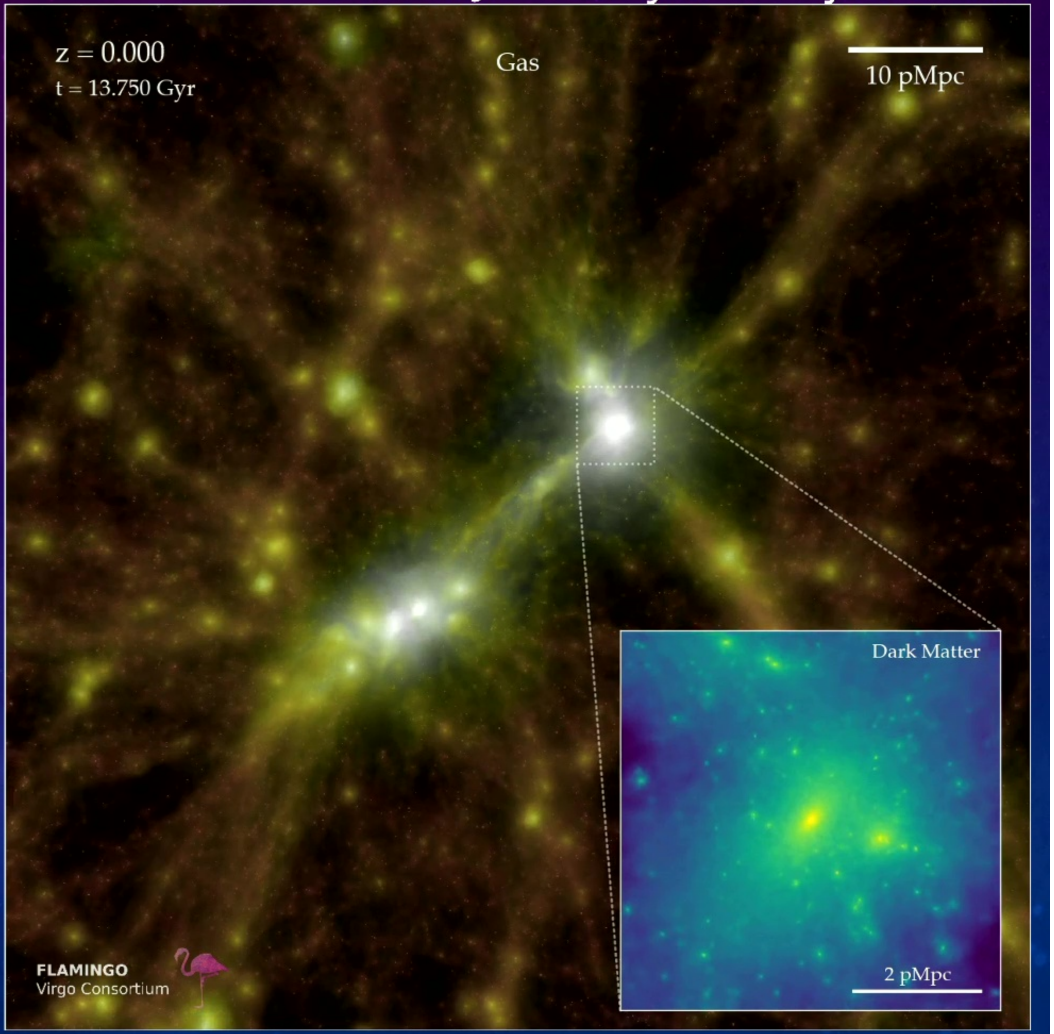
FLAMINGO simulations (Schaye et al., 2023):

- Large, calibrated cosmological hydrodynamic simulations, run to z=0.
- Suite contains variations in box size; variations in cosmology & variations in baryonic feedback (AGN & stellar).



INITIAL RESULTS

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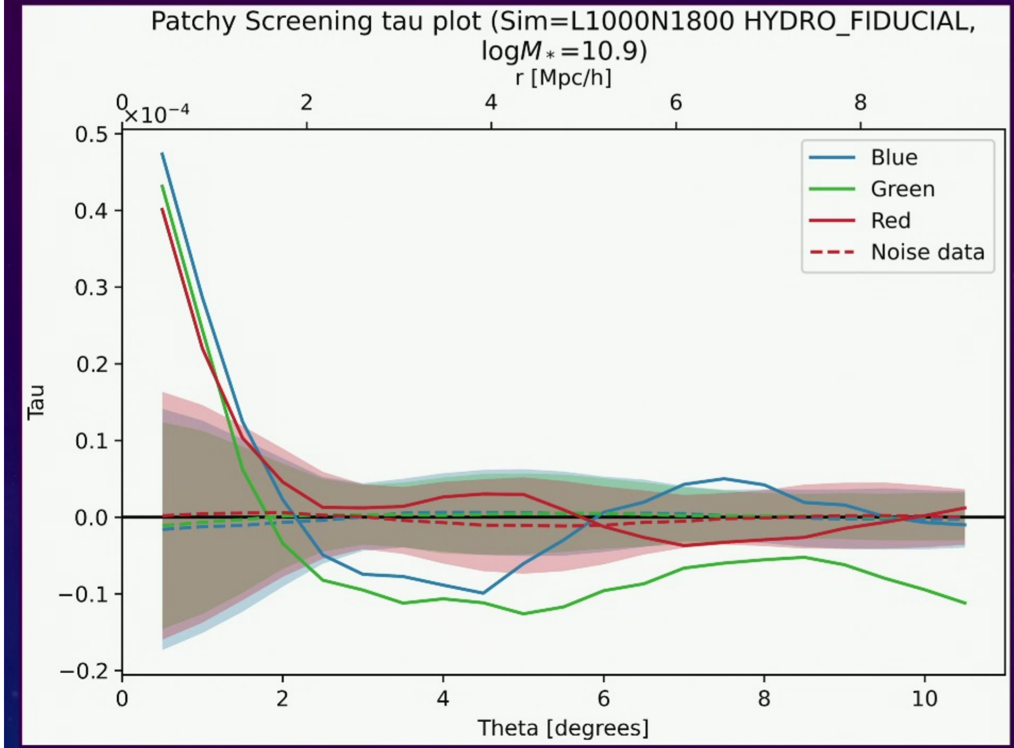

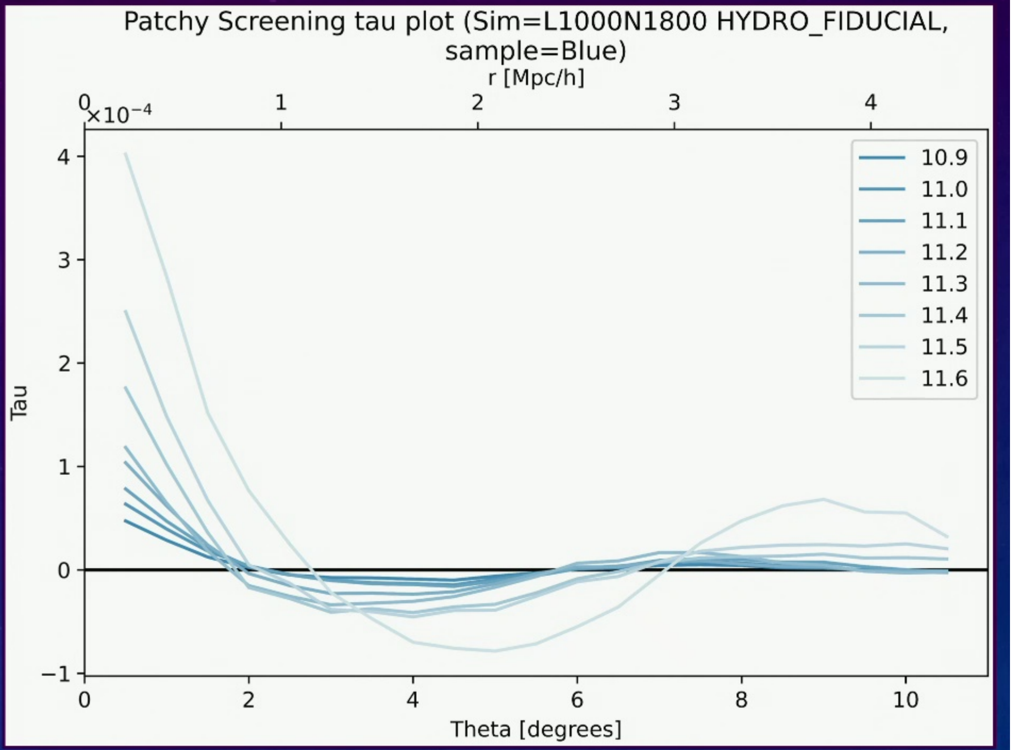

^ Varying stellar mass cut; fixed galaxy sample.

< Varying galaxy sample; fixed stellar cut. Noise level quantified.

COMPARING TO CMB LENSING

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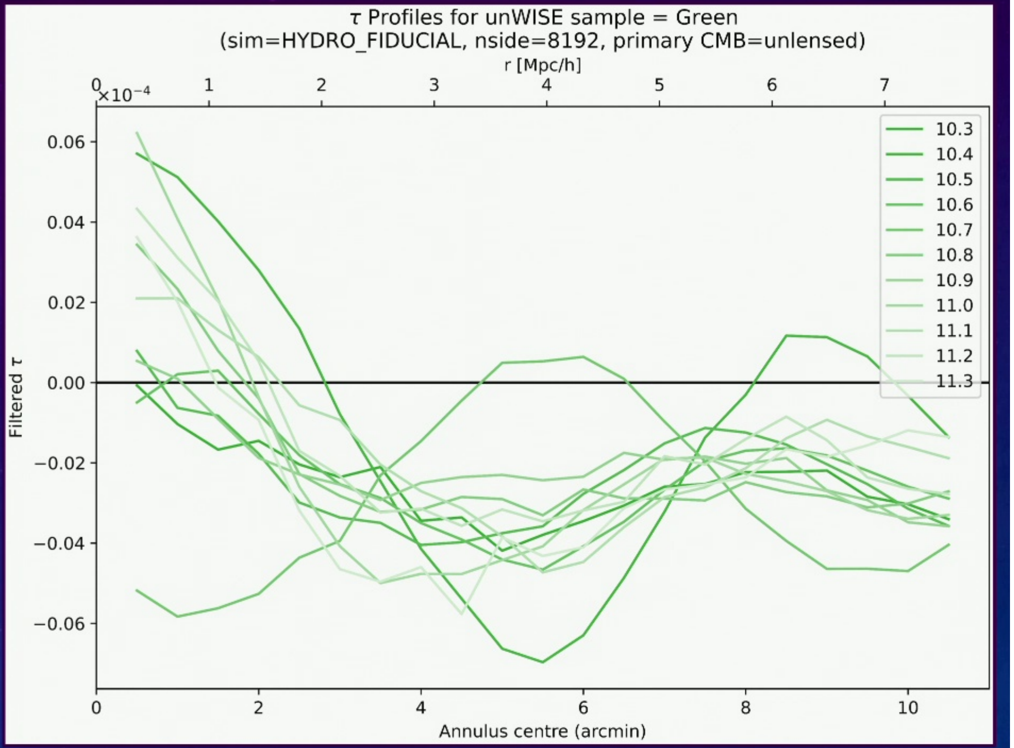
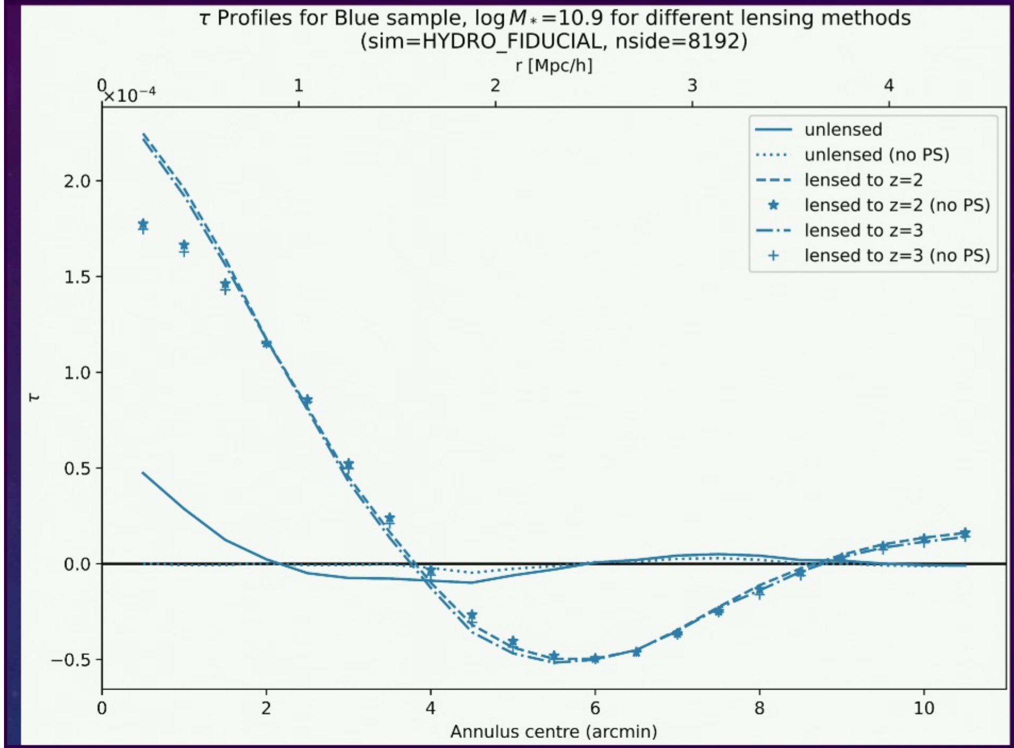


^ Varying stellar mass cut; fixed galaxy sample.



< Varying primary CMB method; fixed galaxy sample and stellar cut.

MOCK HALO CATALOGS & LENSING CONSIDERATIONS

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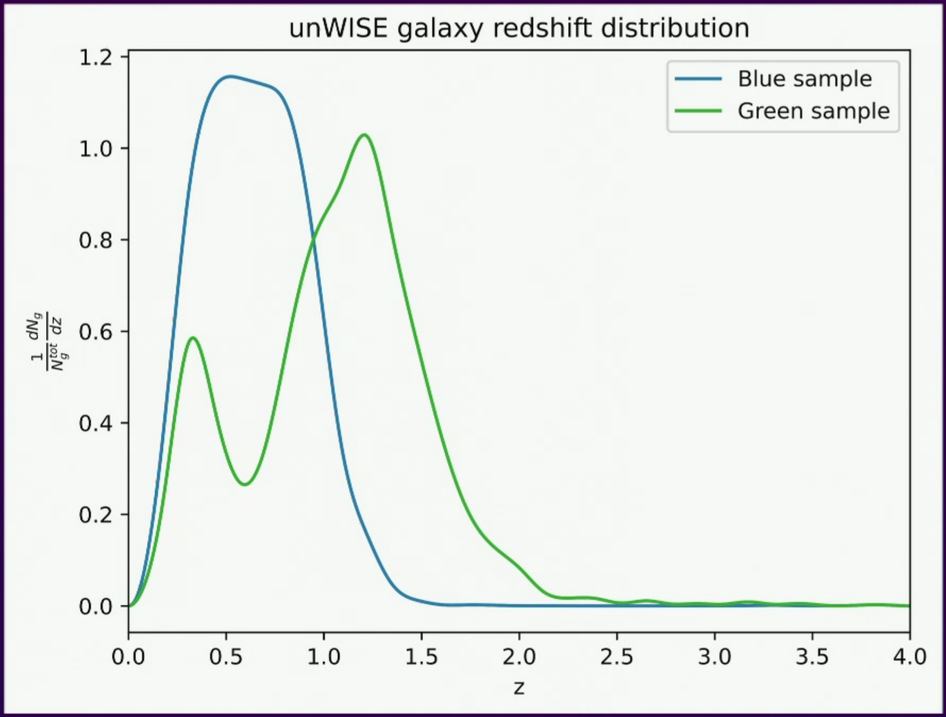

- Comparing to mock primary CMB maps that are both lensed and unlensed.
- Rescaling unWISE redshift distribution for halo sampling.
- Using a z-dependant stellar cut:

$$\log_{10} M_{star}(z) \geq \frac{d\left(\log_{10} M_{star}\right)}{dz}(z - z_{mean}) + \log_{10} M_{star,cut,\, z_{mean}}$$

MATCHING TO OBSERVED CLUSTERING DATA

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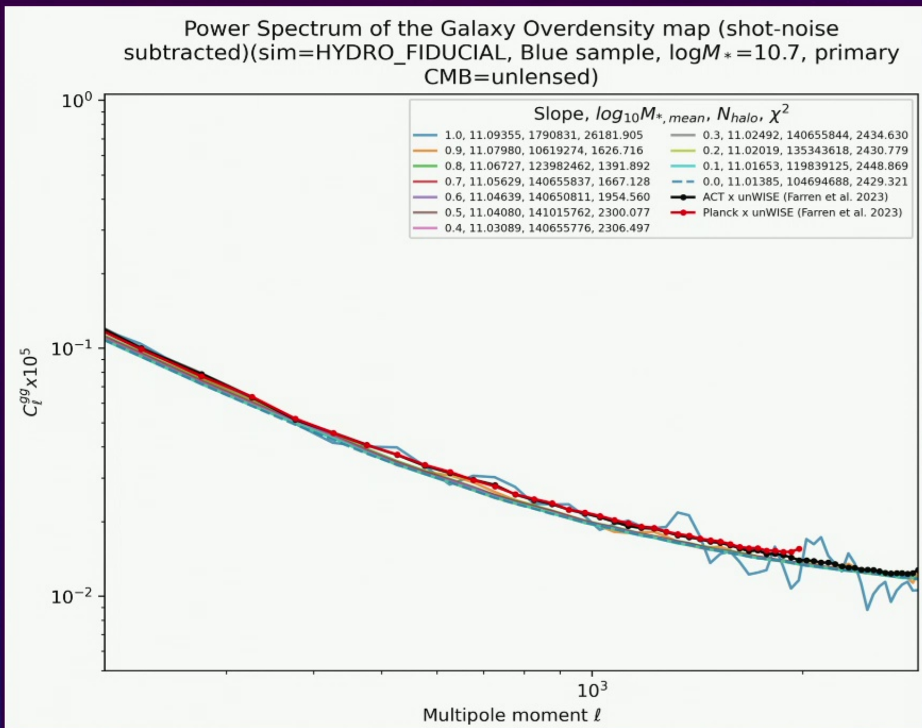
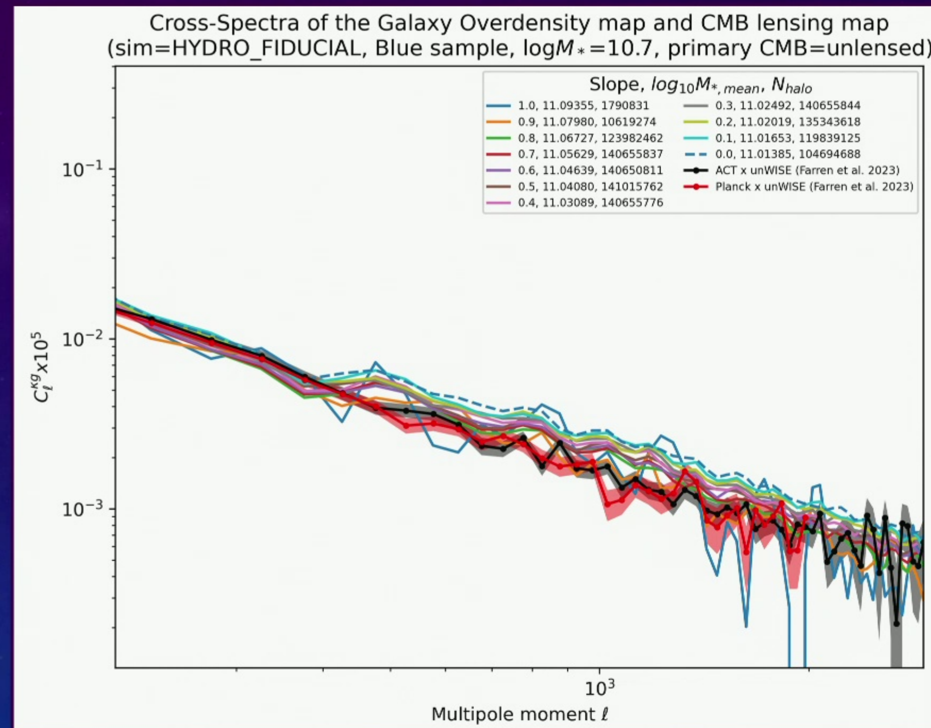


^ Galaxy-galaxy clustering power spectra for different choices of stellar cut parameters.



^ CMB lensing (κ)-galaxy cross spectra for different choices of stellar cut parameters.

STAY TUNED FOR MORE RESULTS!
ANY QUESTIONS?

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GitHub: https://github.com/J0nl15a/Patchy-Screening