Title: Establishing kSZ as a benchmark for simulations

Speakers: Leah Bigwood

Collection/Series: Cosmic Ecosystems

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Abstract:

TBD

A roadmap to establishing the kSZ effect as a benchmark for hydrodynamical simulations

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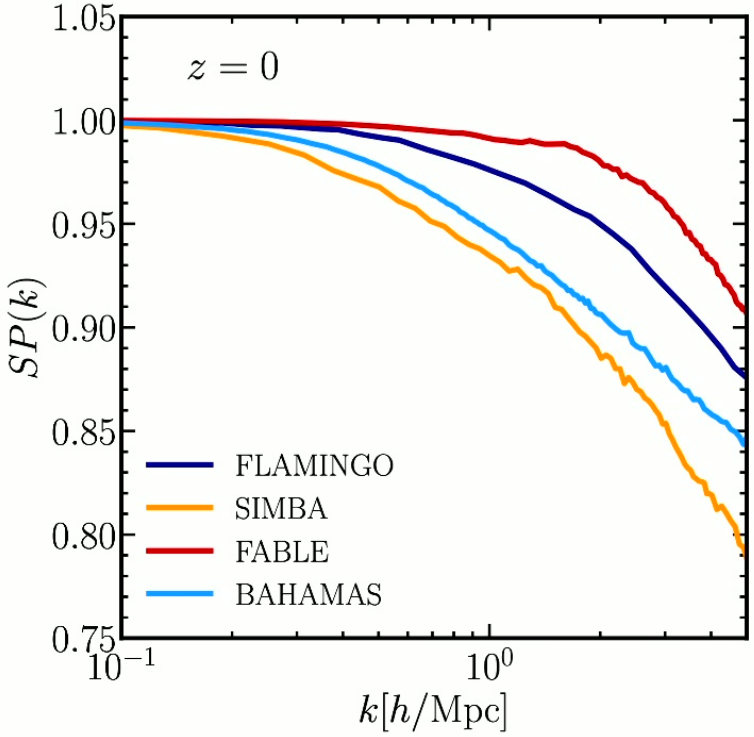
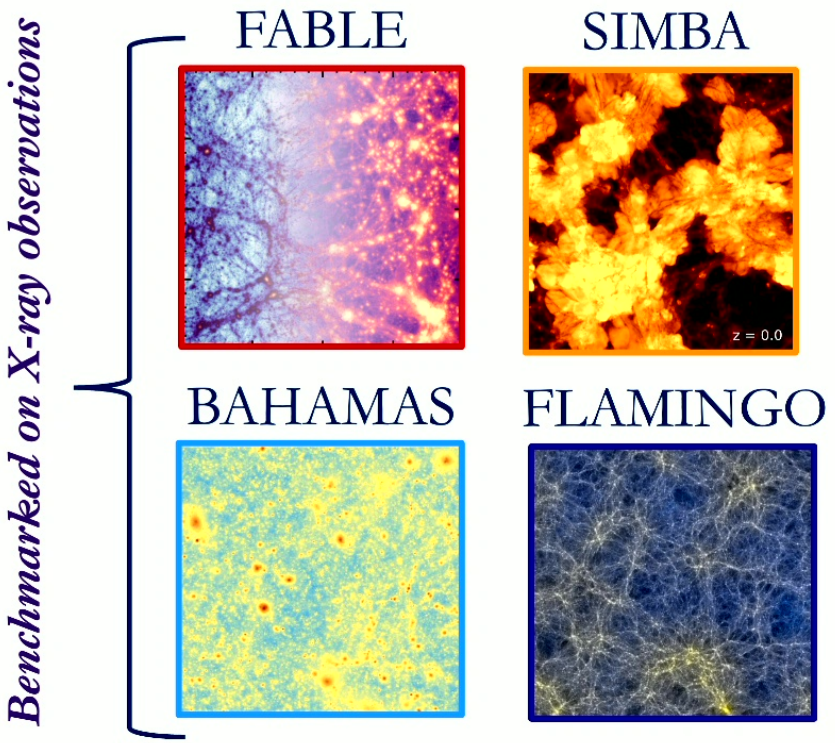
Extracting unbiased cosmology from weak lensing

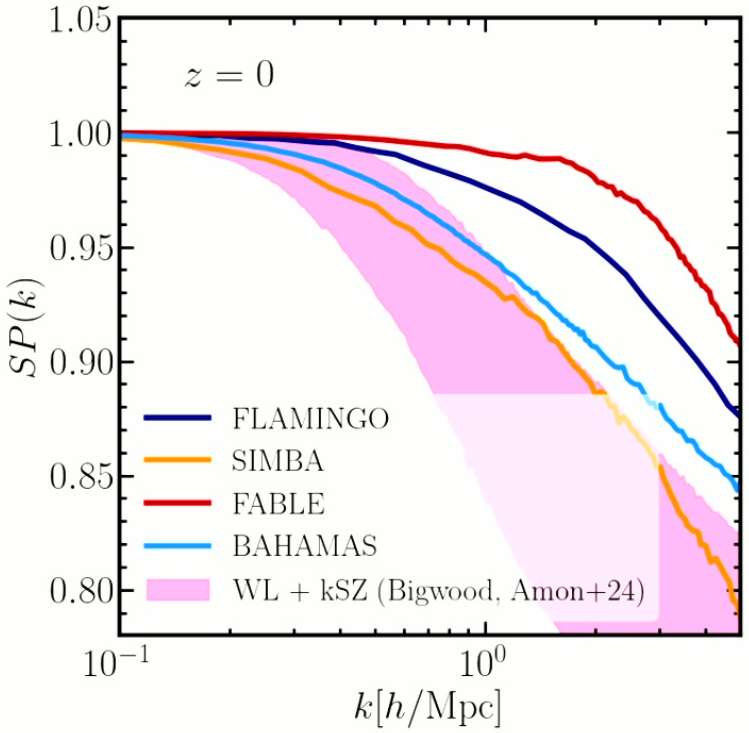
Weak lensing requires accurate predictions for the impact of baryonic feedback processes on the non-linear matter distribution

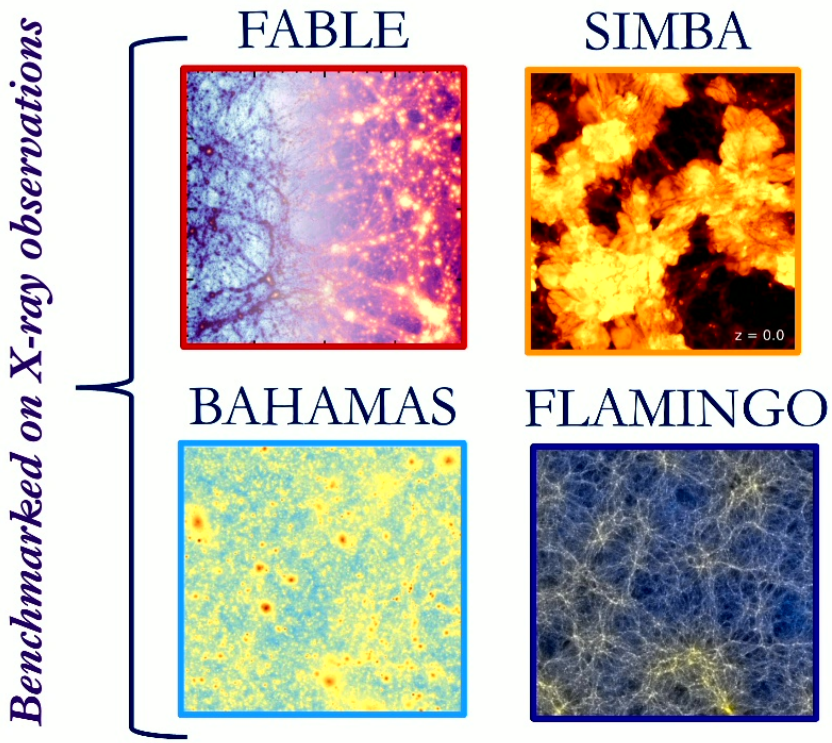




Extracting unbiased cosmology from weak lensing

The kSZ effect has opened up the possibility of 'extreme' feedback scenarios…





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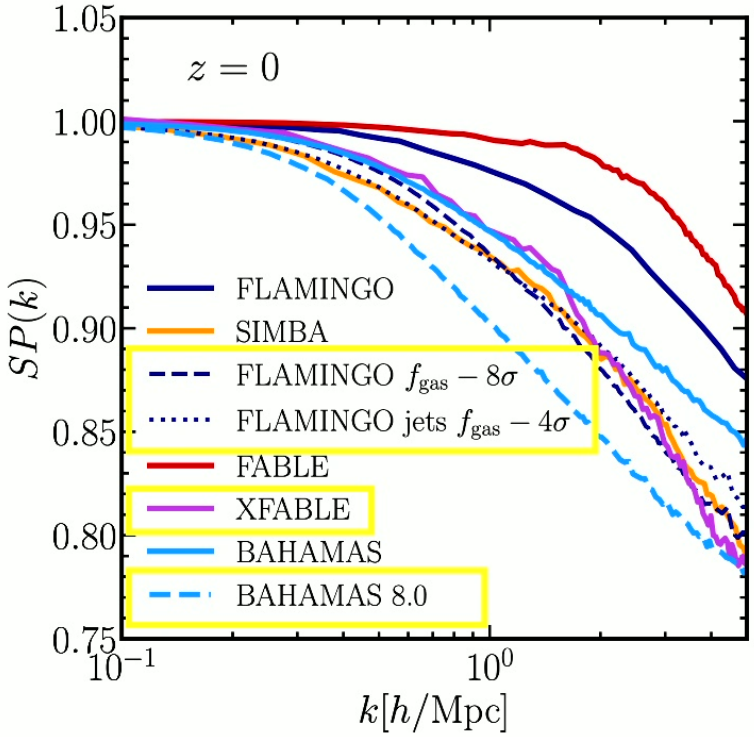
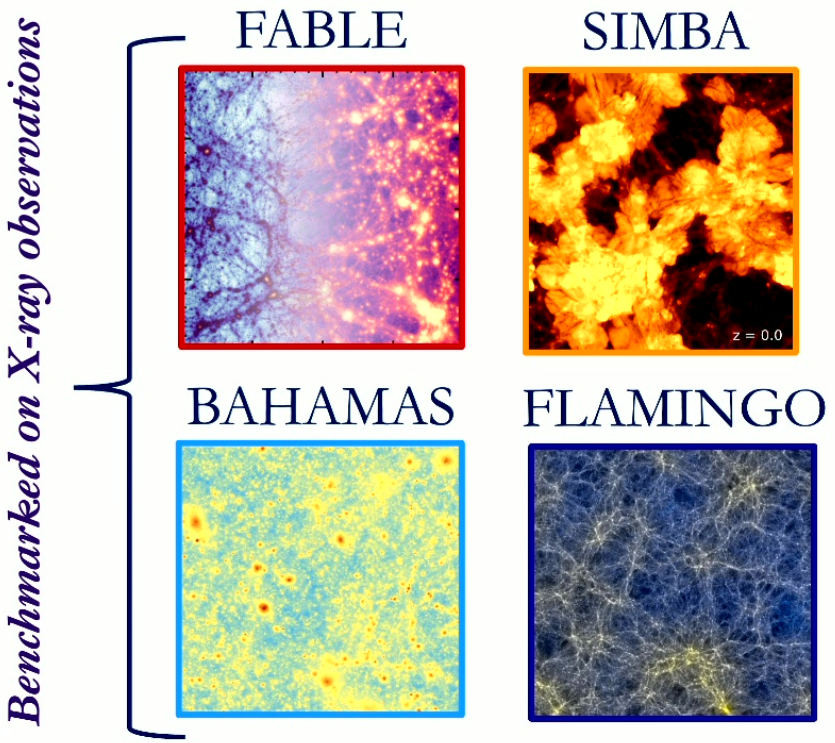
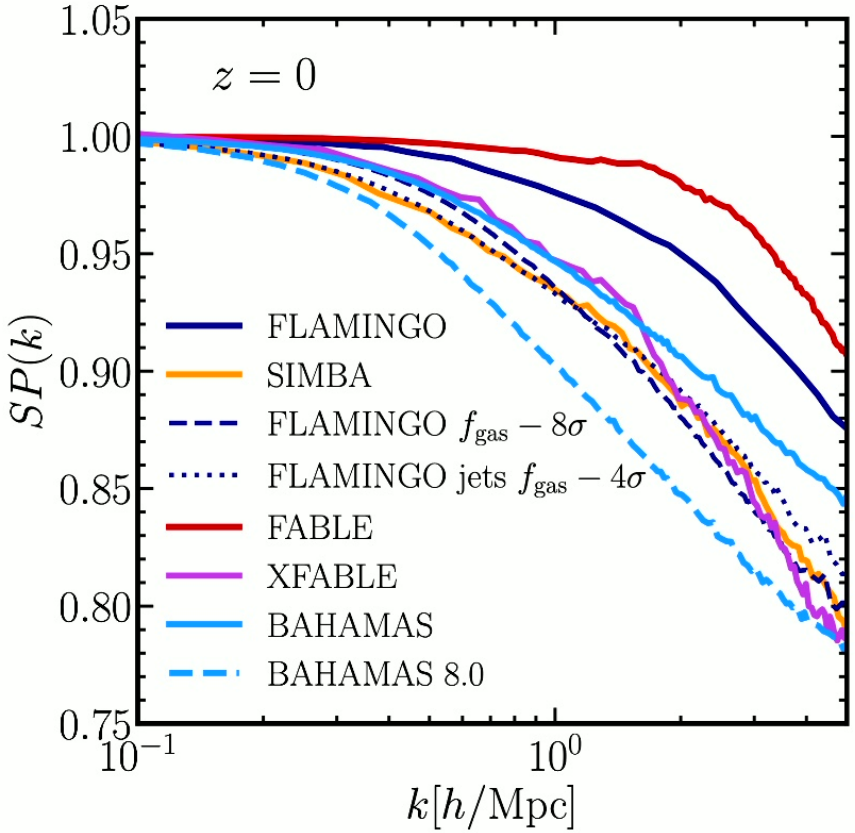




A simulation study of the kSZ effect



[*Bigwood, Yamamoto, Siegel, Amon, McCarthy+ in prep. 2025*]

1. Do any of the hydrosimulations predict kSZ signals in agreement with observations?

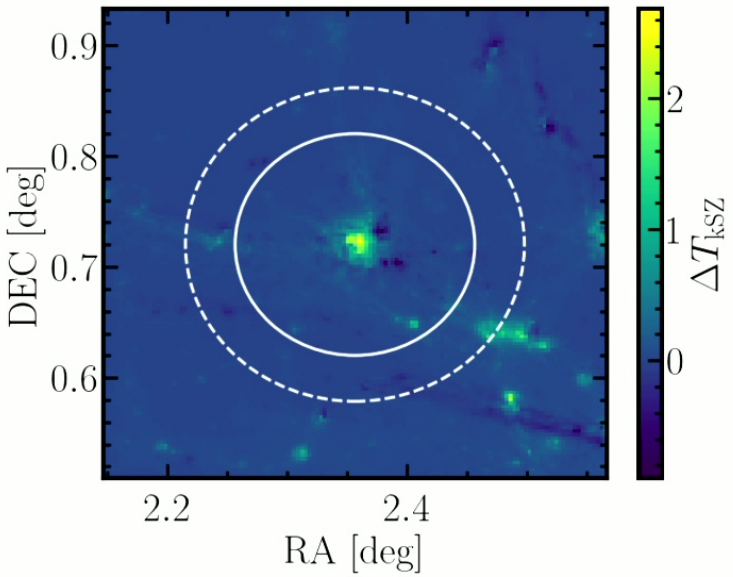
2. How do we establish the kSZ effect as a benchmark for AGN feedback models in hydrodynamical simulations?

Masa Yamamoto

Measuring stacked kSZ profiles in simulations

1. In the simulations we measure:

- *Gas mass*
- *Gas line of sight velocity*
- *Halo line of sight velocity*

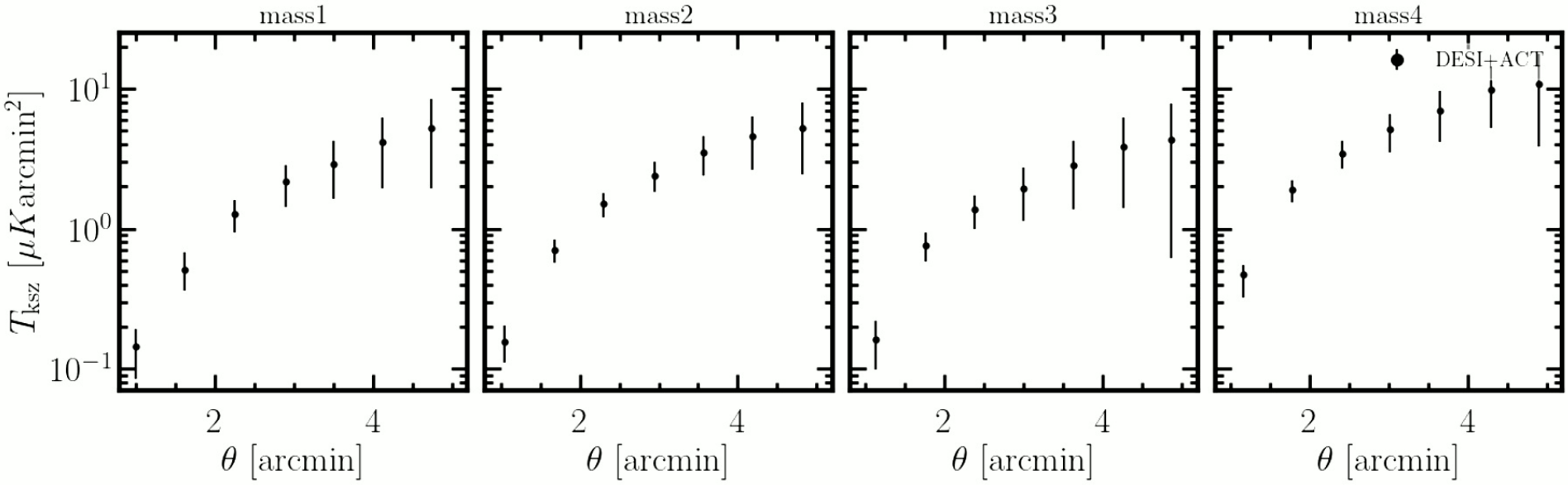


2. We follow the methodology used in the observations, *i.e. CAP filtering, modelling the beam.*

3. We measure a velocity-weighted stack over many galaxies: selecting the sample is key!

The stellar mass dependence of the kSZ: comparing to DESI x ACT

How do we select the right galaxy sample in the simulations?

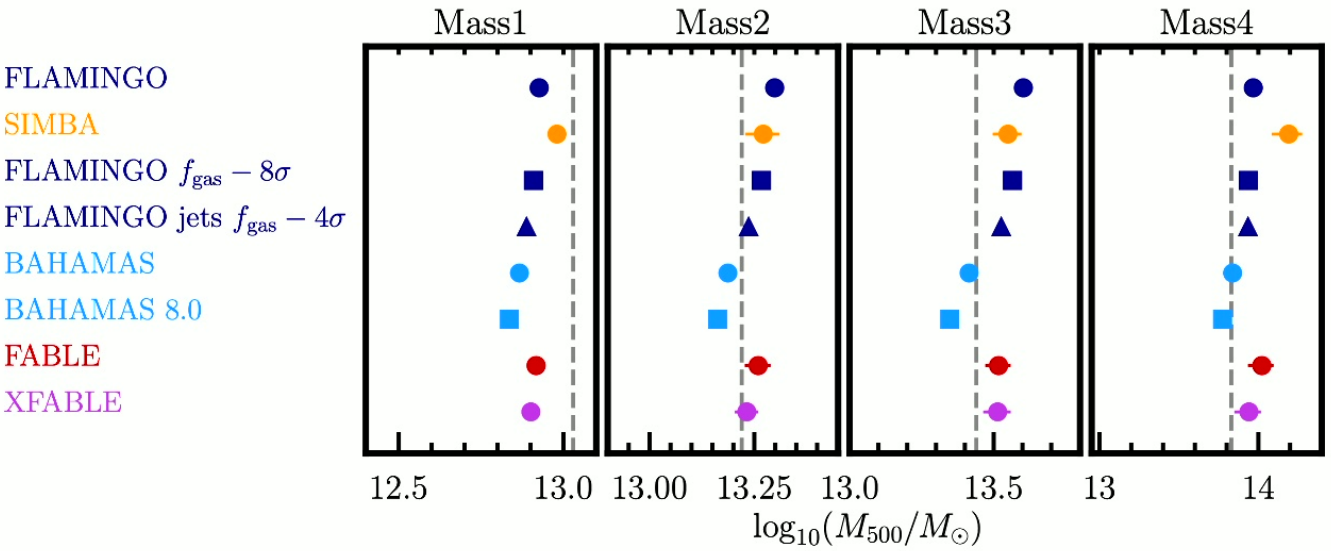


[*Ried Guachalla+2025*]

CHALLENGE 1!

The stellar mass dependence of the kSZ signal: *abundance matching*

We don't trust the stellar masses reported in simulations, so we could abundance match to an observed GSMF

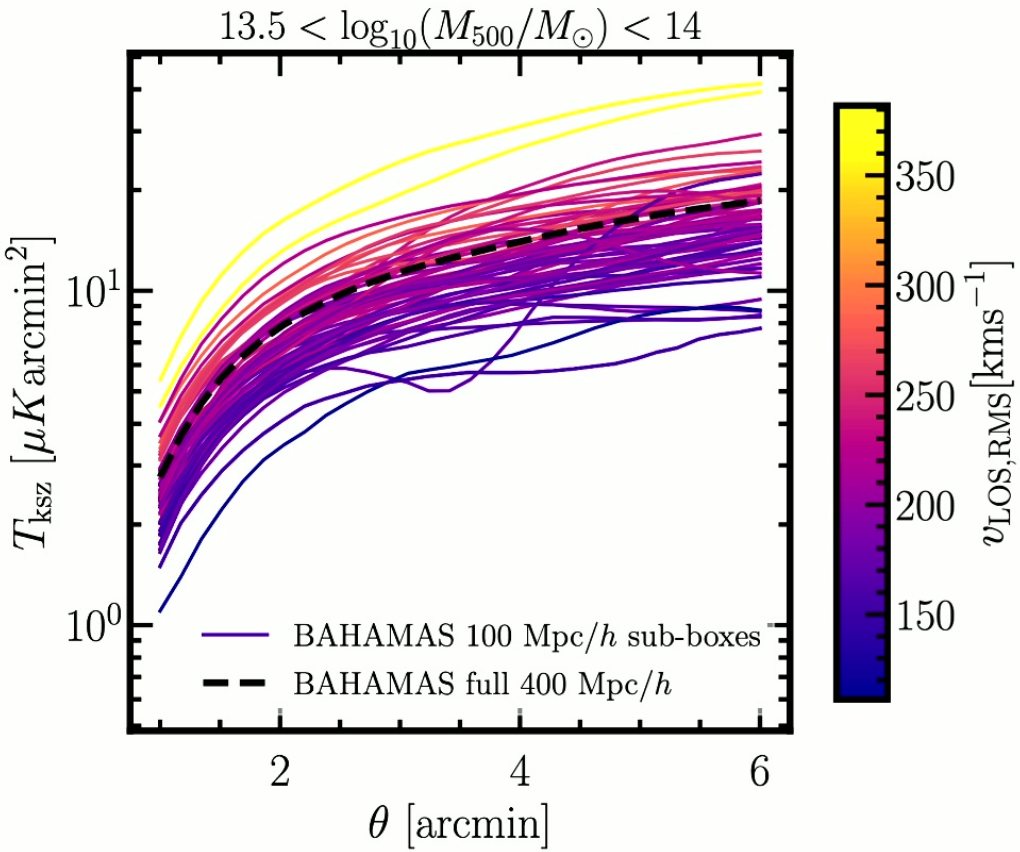


But this leaves us with huge differences in the mean halo mass of our stacked objects between simulations

[*Bigwood, Yamamoto, Siegel, Amon, McCarthy+ in prep. 2025*]

CHALLENGE 2!

Managing cosmic variance



$$\hat{T}_{\rm kSZ}(\theta_{\rm d}) = -\frac{1}{r_v}\frac{v_{\rm rms}^{\rm rec}}{c}\frac{\sum_i \mathcal{T}_i(\theta_{\rm d})(v_{{\rm rec},i}/c)/\sigma_i^2}{\sum_i (v_{{\rm rec},i}/c)^2/\sigma_i^2}$$

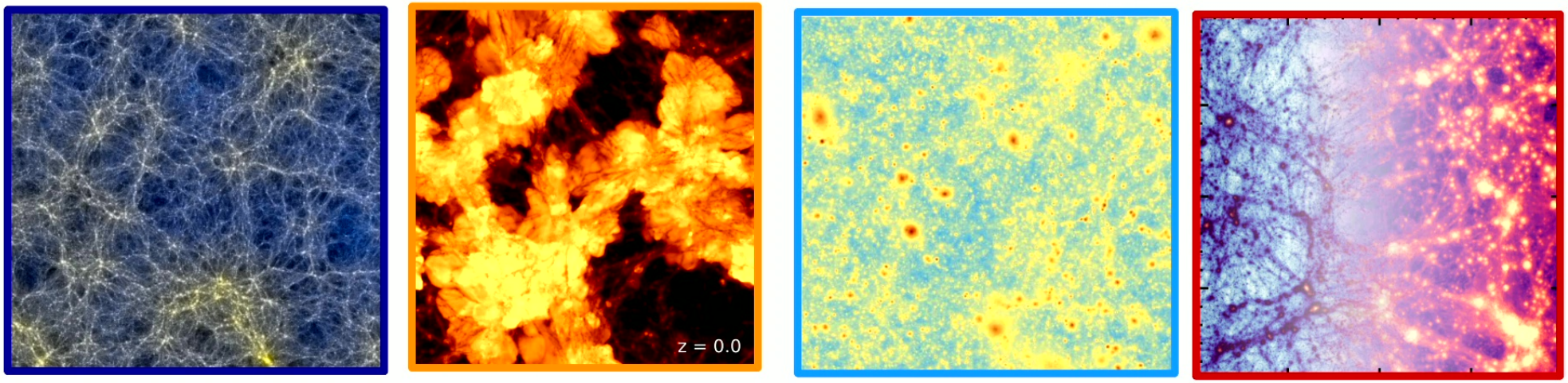
Poor statistics in 100Mpc/h boxes means scatter in $v_{\rm LOS,RMS}$ significantly impacts the kSZ amplitude

CHALLENGE 3!

[*Bigwood, Yamamoto, Siegel, Amon, McCarthy+ in prep. 2025*]

The stellar mass dependence of the kSZ signal: *galaxy-galaxy lensing*

FLAMINGO
FLAMINGO jets $f_{\rm gas} - 4\sigma$
FLAMINGO $f_{\rm gas} - 8\sigma$
SIMBA
BAHAMAS
BAHAMAS 8.0
FABLE
XFABLE



[Bigwood, Yamamoto, Siegel, Amon, McCarthy+ in prep. 2025]

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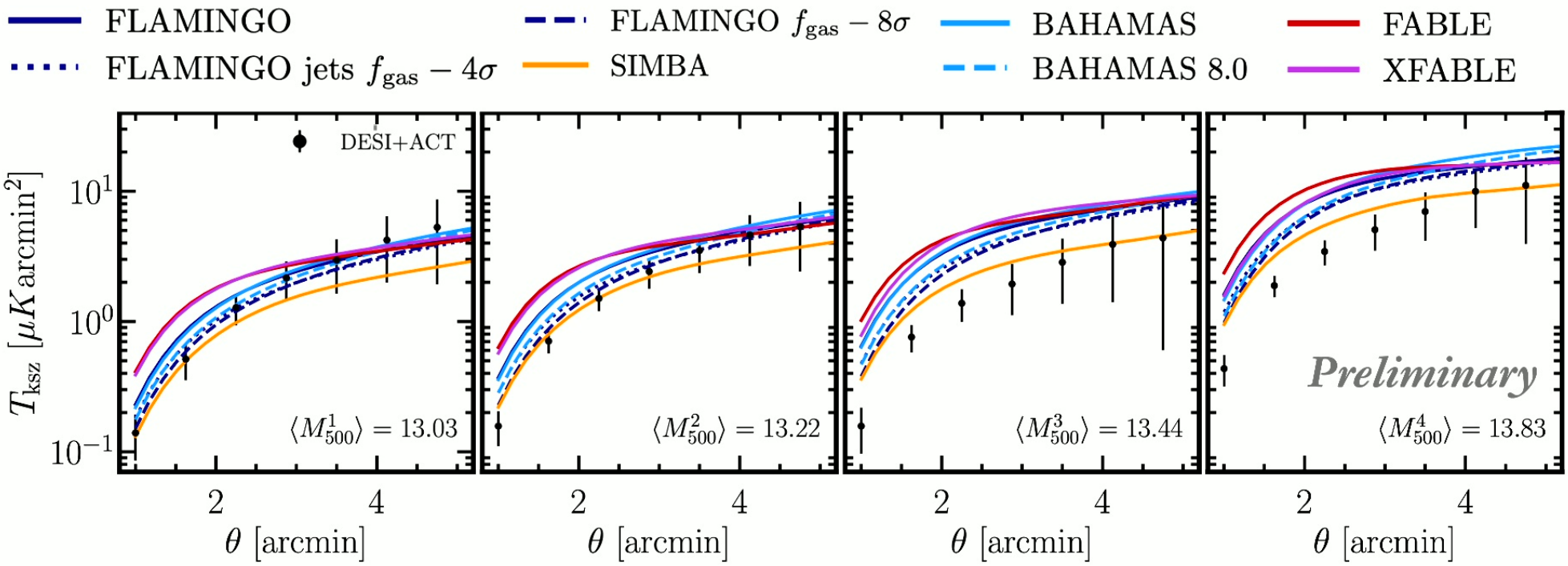
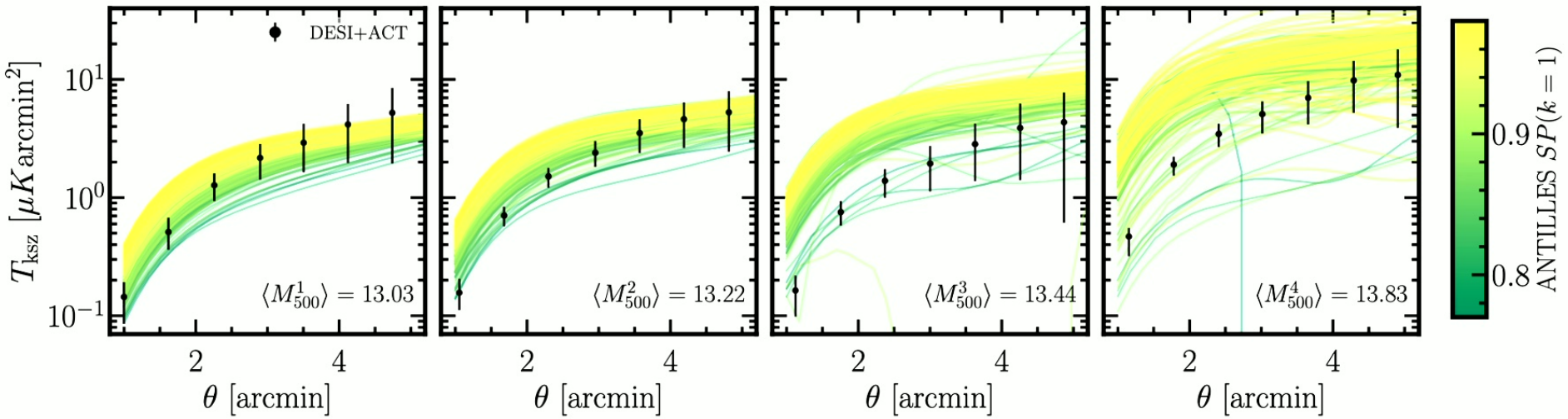


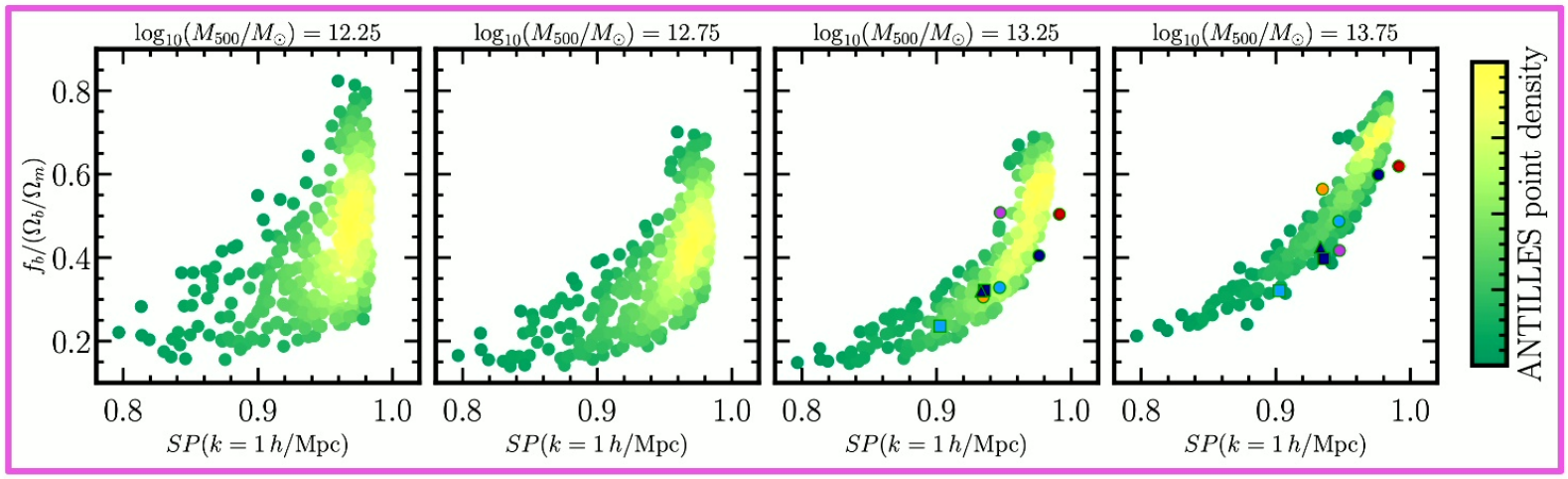
No single hydrosimulations can match the mass dependence of the kSZ signal seen in the data

[Bigwood, Yamamoto, Siegel, Amon, McCarthy+ in prep. 2025]

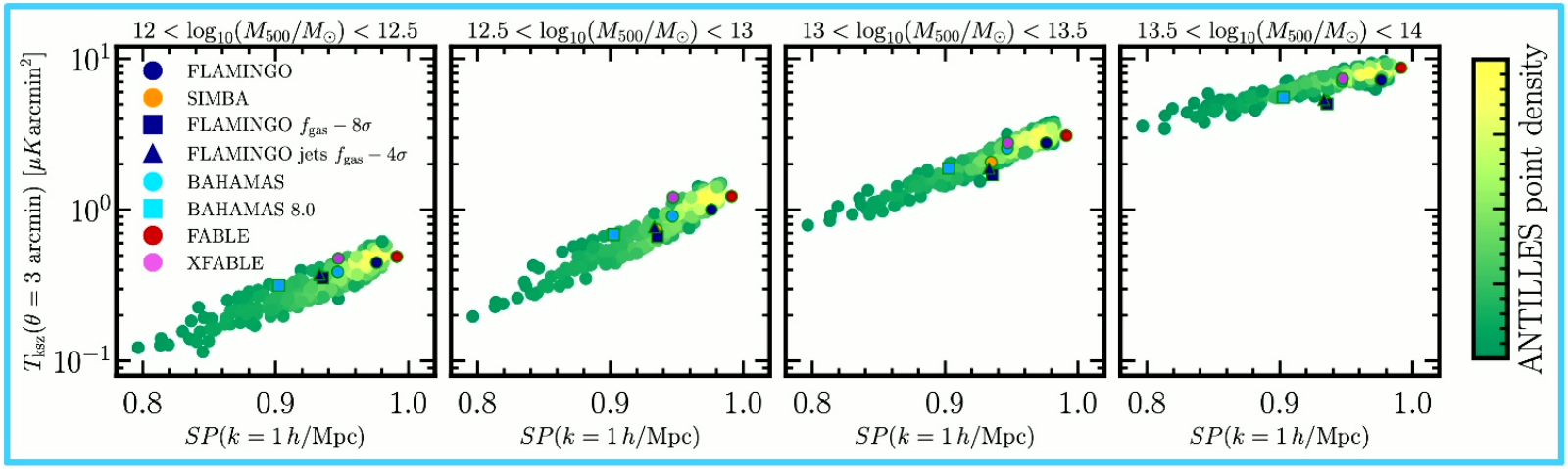
Looking ahead: *a simulated-based emulator for kSZ-SP(k)*



Looking ahead: *a simulated-based emulator for kSZ-SP(k)*



Baryon fraction
vs
P(k) suppression
(van Daalen+2020)



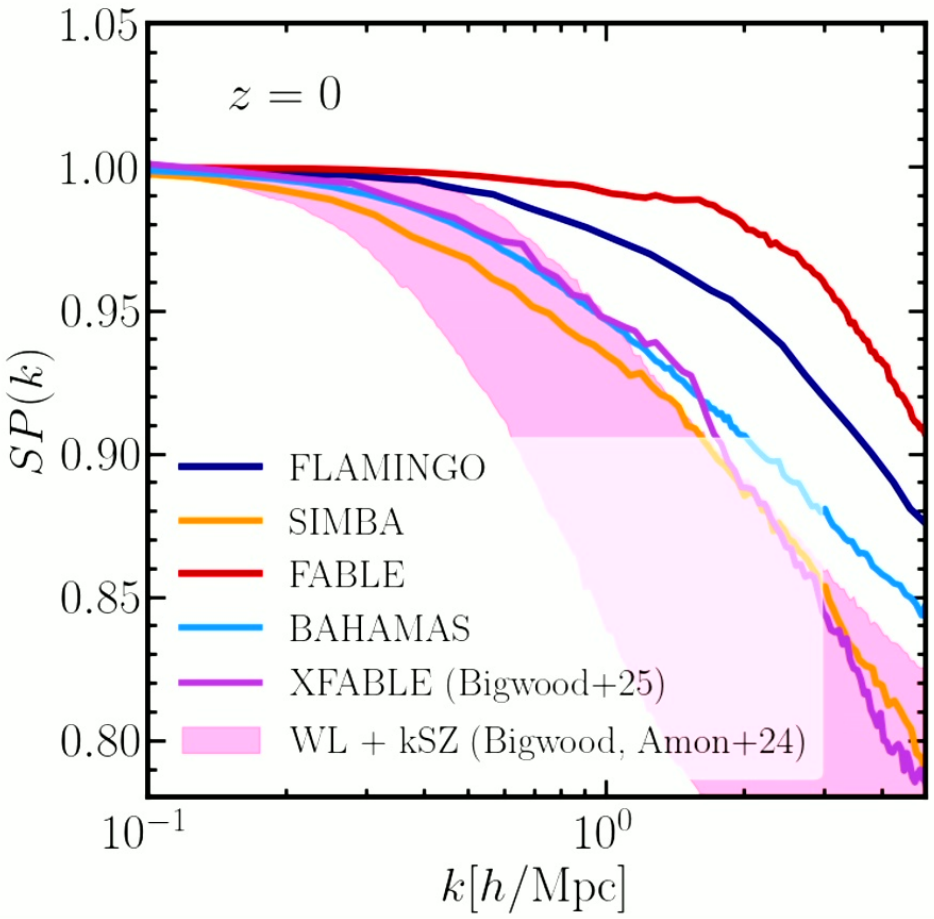
kSZ
vs
P(k) suppression

What should come next?

1. Given the kSZ is definitively telling the story of strong feedback - how do we jointly analyze these measurements with X-ray to create a consistent picture of feedback? **See Jared's talk next!**

2. How do we realize simulations that can reproduce the extreme feedback preferred by the DESI Y1 + ACT kSZ measurements?

XFABLE: *the case for large-scale AGN feedback in hydrosimulations*



XFABLE demonstrates larger scale AGN feedback, whilst remaining consistent with all key group & cluster properties

FABLE

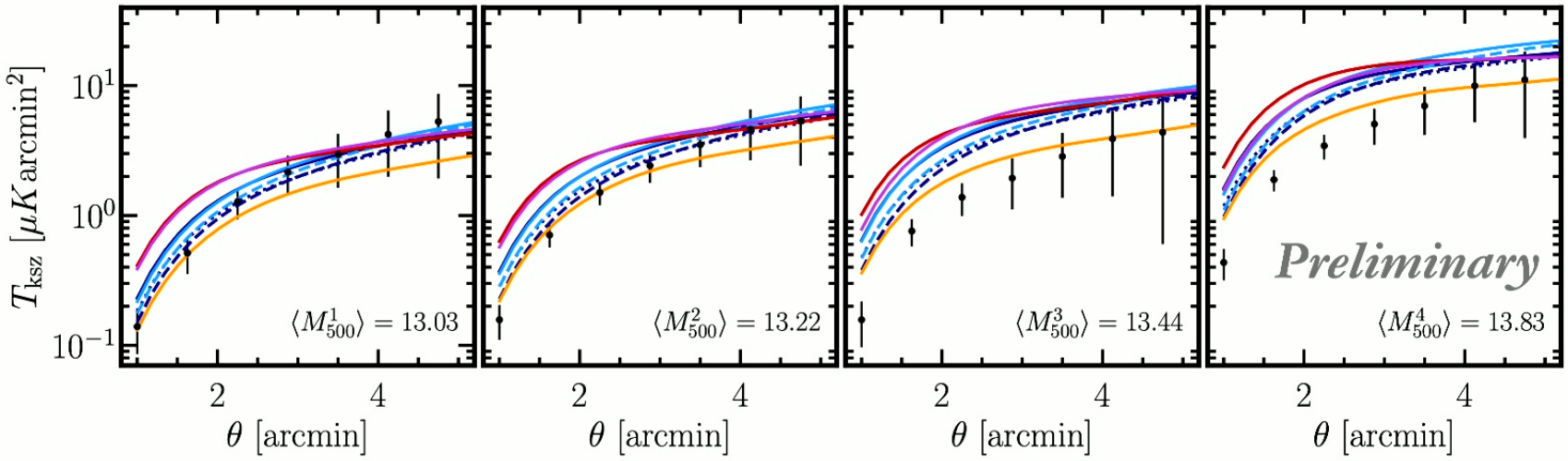
Fiducial AGN feedback model

XFABLE

Radio mode acting in a larger population of black holes, with jets thermalizing at larger cluster-centric distances

[Bigwood+2025]

We have established a roadmap for using kSZ as a benchmark of feedback models



kSZ measurements indicate that feedback is more extreme than any of the fiducial simulations.

No simulation can reproduce the mass dependence of the DESI+ACT measurements; scrutinizing both the simulations and the data is required

(Bigwood, Yamamoto, Siegel, Amon, McCarthy+ in prep. 2025)