Title: Constraining cluster and group ecosystems with joint and consistent SZ and x-ray observations

Speakers: Gerrit Farren

Collection/Series: Cosmic Ecosystems

Subject: Cosmology

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Abstract:

I will present work on measuring thermal and kinetic Sunyaev-Zeldovich signals alongside x-ray fluxes from clusters and groups of galaxies identified either in the DESI Legacy Survey or selected from eROISTA x-ray observations. I will show joint inference of matter and gas density as well as temperature and x-ray emissivity to better understand the structure within these objects and the feedback processes which are relevant to the modelling of cosmological observables. Among other aspects, I will address claims of discrepancy between the feedback observed in x-ray cross-correlations with cosmic shear and inferred from kSZ observations.

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Joint view of SZ and X-ray observations

from ACT and eROSITA around DESI LRGs

Gerrit S. Farren gfarren@lbl.gov

Chamberlain Fellow @ Lawrence Berkeley National Laboratory, Berkeley, CA

based on work with Simone Ferraro and Boryana Hadzhiyska

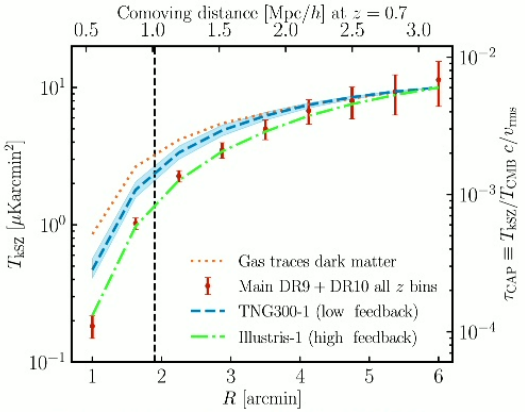
Cosmic Ecosystems, July 29 2025, Perimeter Institute, Waterloo, Canada

Context

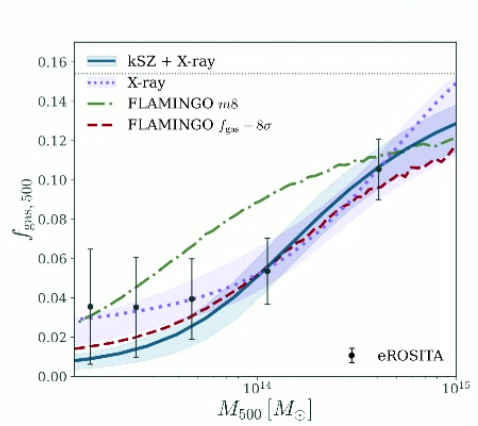
What is the baryon distribution around objects of different mass and redshift?

- Have seen hints at stronger-than-expected feedback
- different tracers $\rightarrow$ different scales/masses/redshifts

Can we produce an *apples-to-apples* comparison?



Hadzhiyska *et al.* 2025



Kovač *et al.* 2025

X-rays observations

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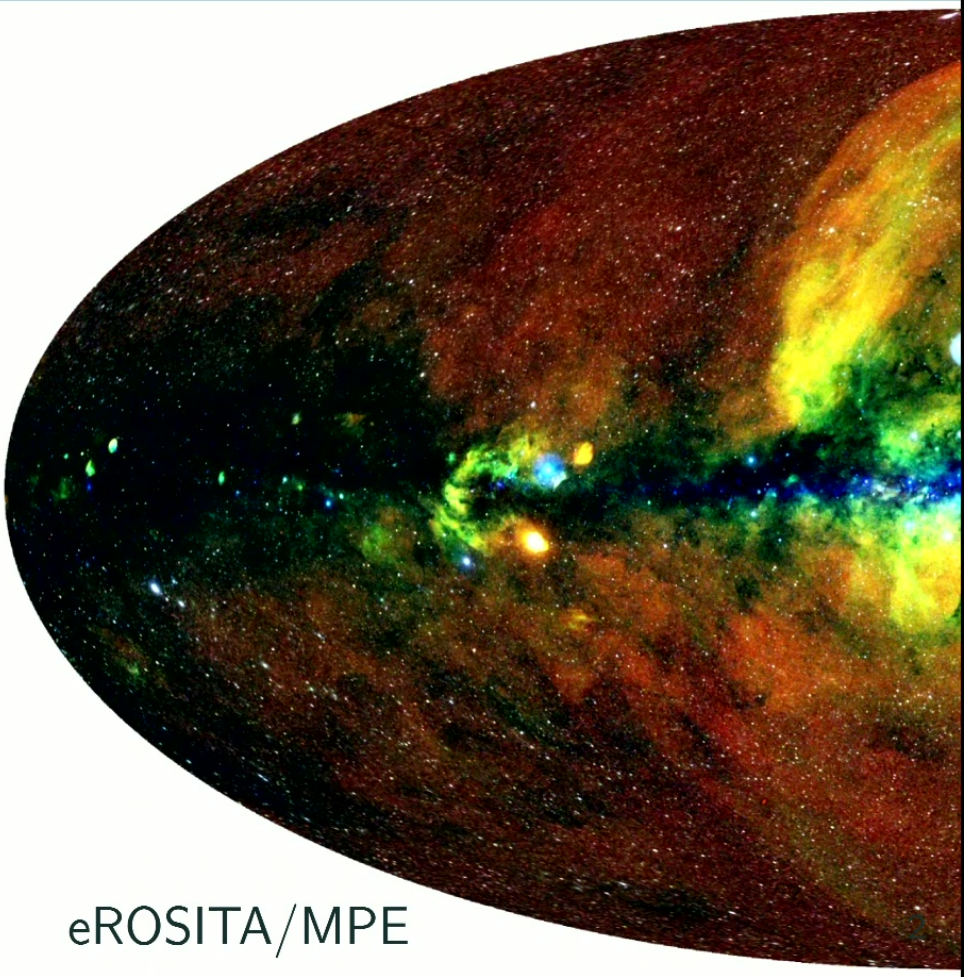
Bremsstrahlung + Metals

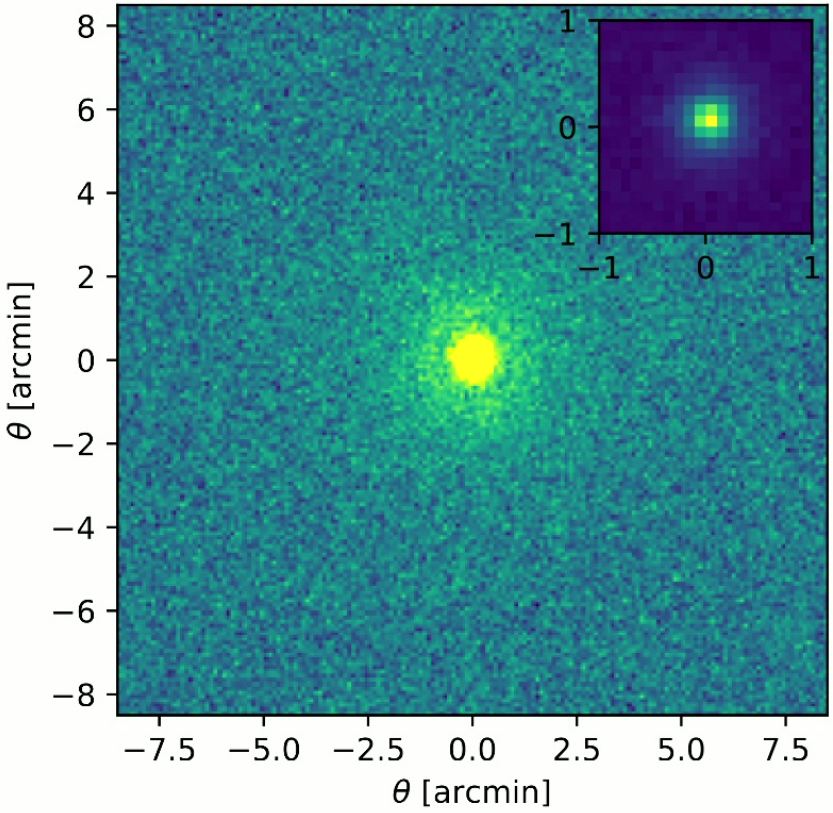
$$n_{\rm counts}(r) \propto n_e^2(r)\Lambda_c\left(Z(r), T(r)\right)$$

n_e: electron number density ($\propto \rho_{\rm gas}$)
$\Lambda_c(Z, T)$: cooling function
Z: metallicity
T: temperature



eROSITA/MPE

X-ray profiles around DESI LRGs



- eROSITA count rates in the 0.2 - 2.3 keV band
- stacked on ∼5M DESI LRGs in the Western Galactic Hemisphere
- masking all X-ray sources detected at $> 5\sigma$ significance in eROSITA

$$n^{\mathrm{2D}}_{\mathrm{counts}}(\theta) \propto \int_{\mathrm{LOS}} d\ell \; n_{\mathrm{counts}} \left(\sqrt{\ell^2 + d_A^2 |\theta|^2} \right)$$

X-ray profiles around DESI LRGs

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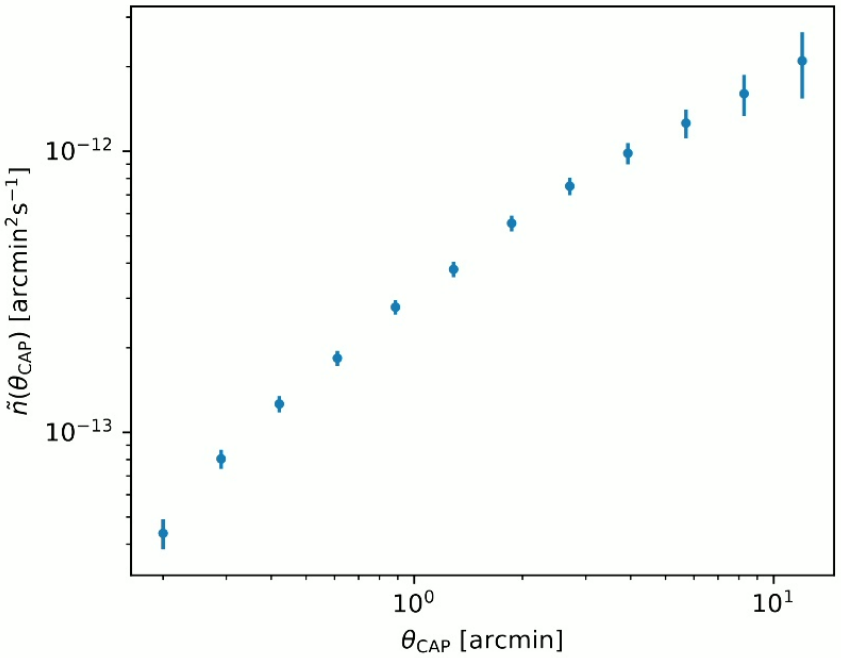

$\mathrm{SNR} = 172$ (showing 5σ uncertainties)

CAP filter

$$\tilde{n}_{\rm counts}(\theta_{\rm CAP}) \propto \int \theta d\theta \; n^{\rm 2D}_{\rm counts}(\theta) W_{\theta_{\rm CAP}}(\theta)$$

with

$$W_{\theta_{\rm CAP}}(\theta) = \begin{cases} 1 & \theta \leq \theta_{\rm CAP} \\ -1 & \theta_{\rm CAP} < \theta \leq \sqrt{2}\theta_{\rm CAP} \\ 0 & \text{otherwise} \end{cases}$$

X-ray profiles around DESI galaxies

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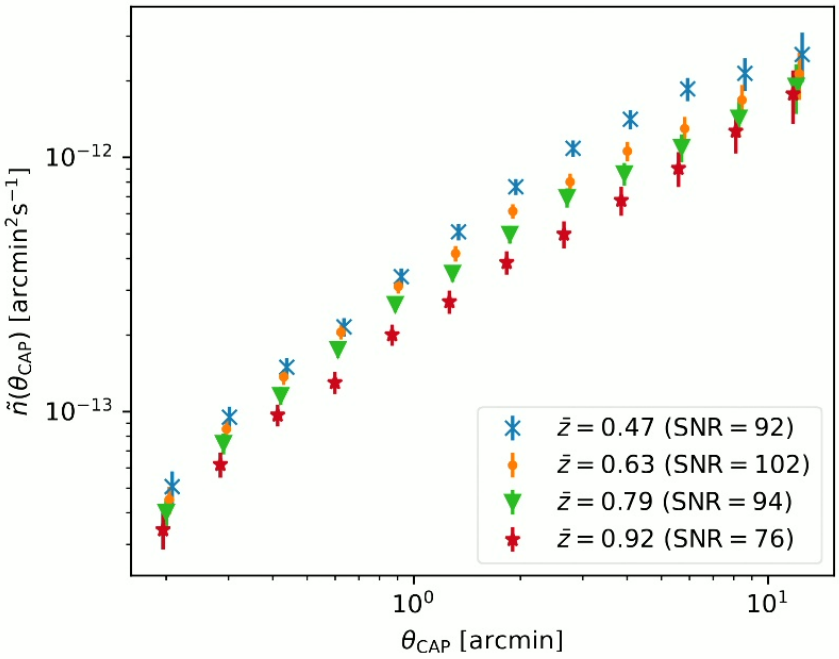
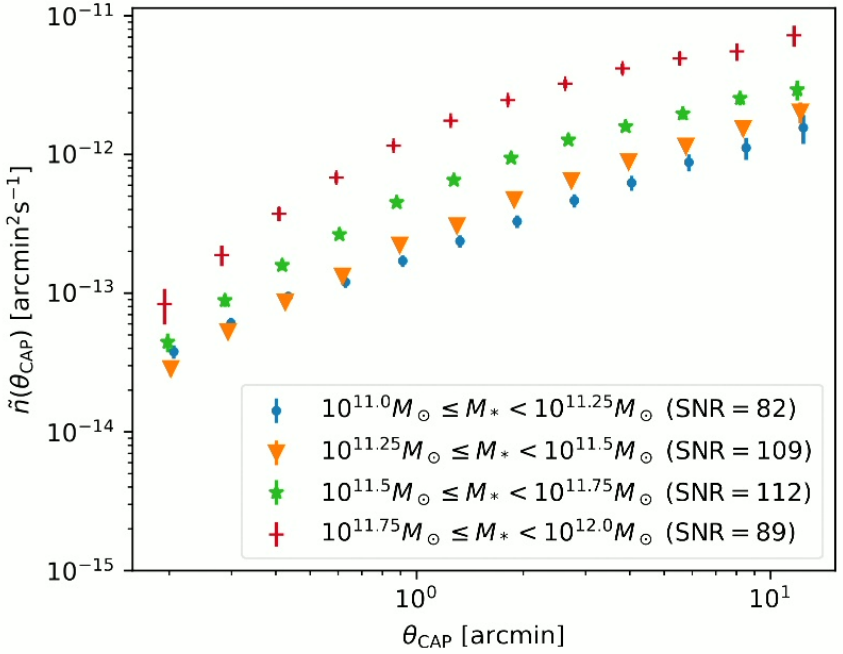
by redshift bin



by stellar mass



showing 3σ uncertainties

The other pieces of the puzzle: kSZ & tSZ

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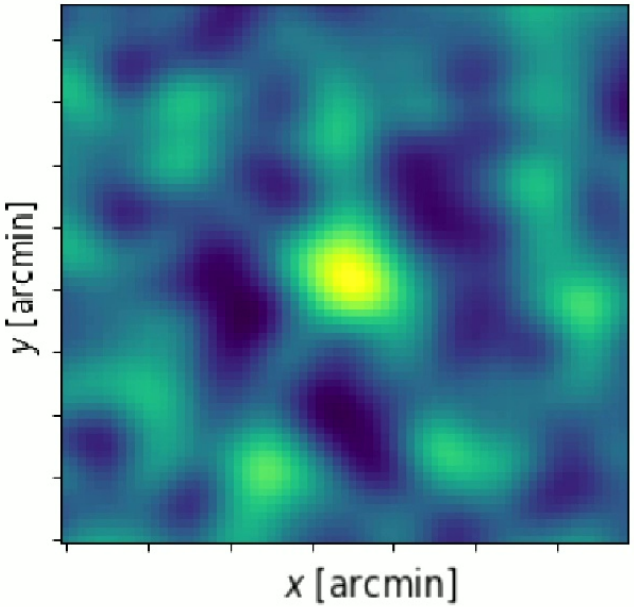
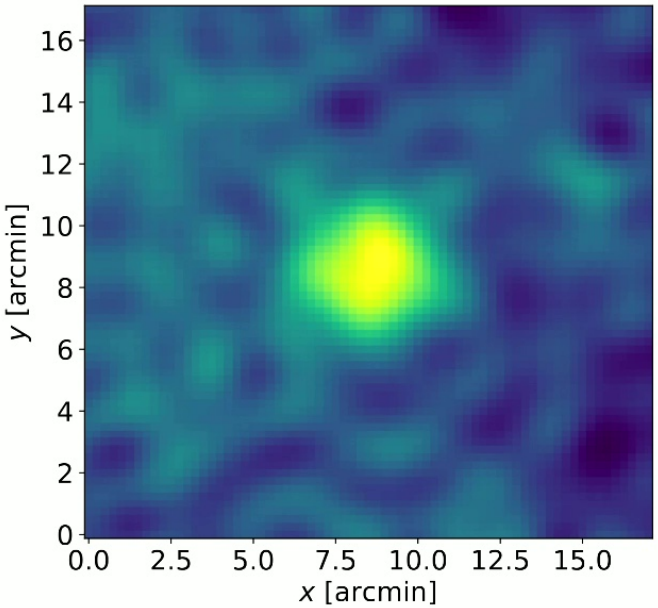
Around the same galaxies

kSZ*



Hadzhiyska *et al.* 2025

tSZ



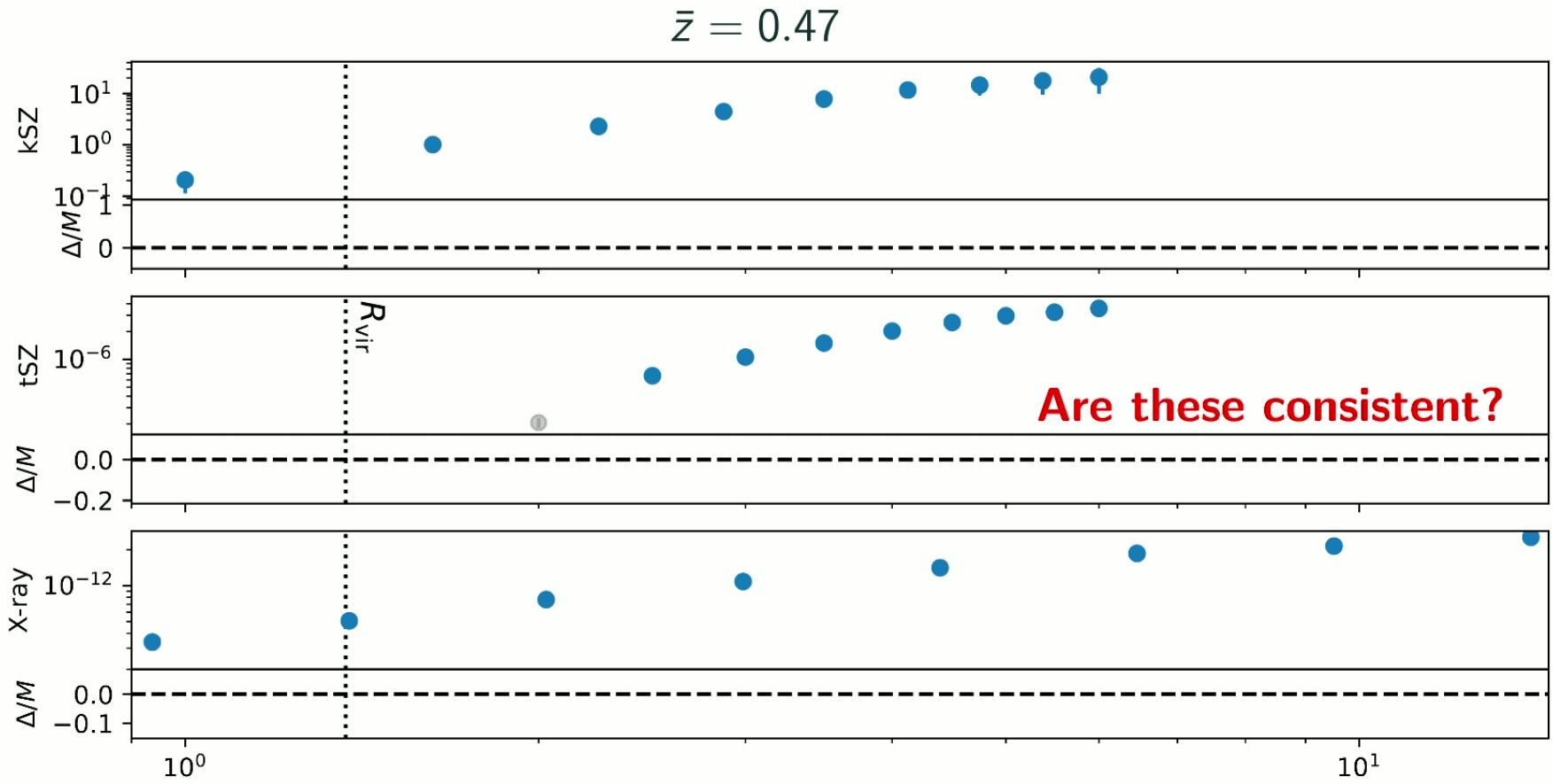
Liu *et al.* 2025

\+ CMB lensing masses *(more from Boryana later)*

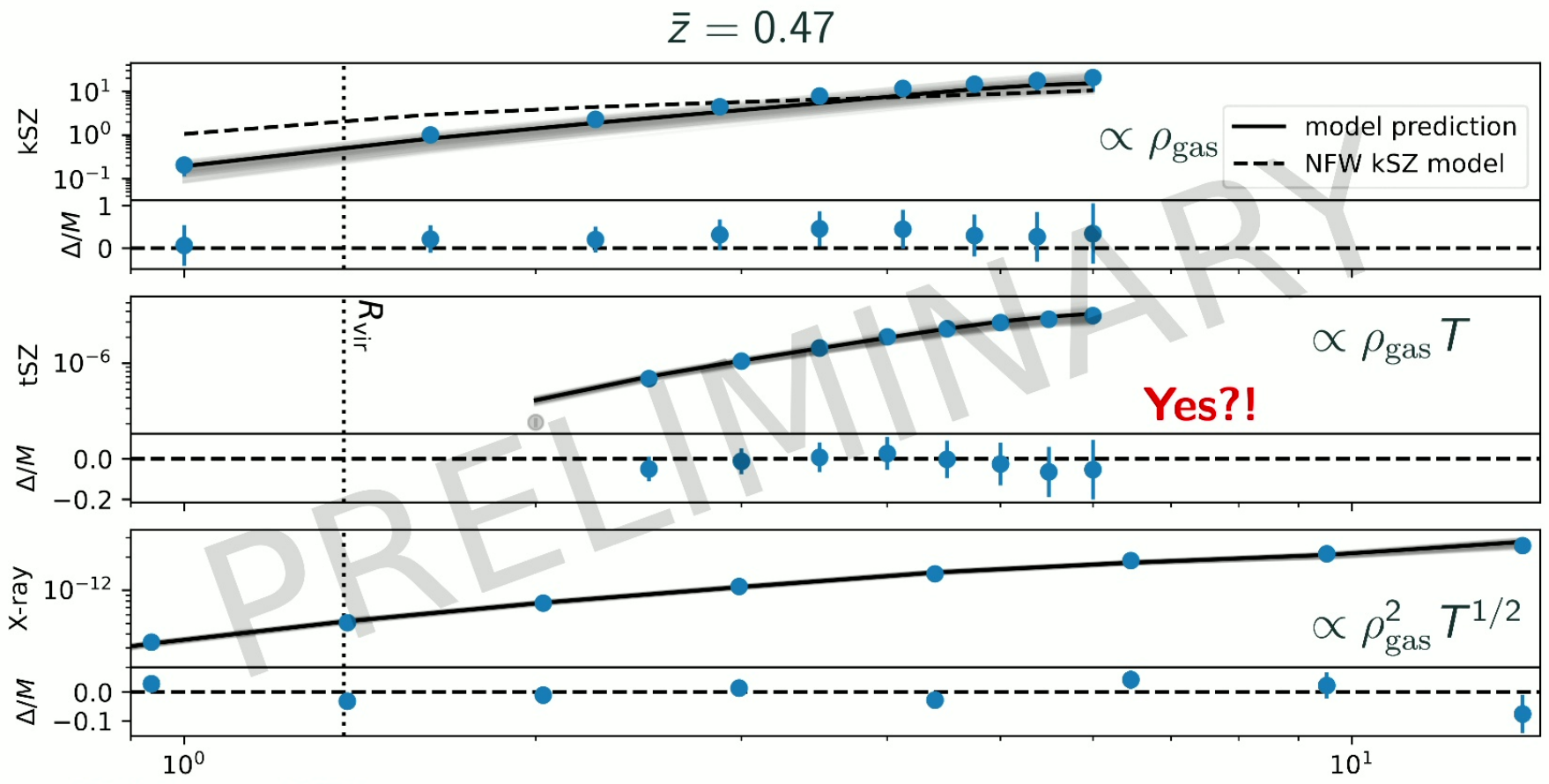
Hadzhiyska *et al.* (incl. **GSF**) 2025b

*here shown with a high-pass filter applied

A unified gas profile: preliminary joint model



A unified gas profile: preliminary joint model



Caveats and future directions

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- free parameter $A_{\mathrm{X-ray}}$ relating $\rho_{\mathrm{gas}}^2 T^{1/2}$ to n_{counts} $\rightarrow$ relate count rates more principally
- $\Lambda_c \neq T^{1/2}$ $\rightarrow$ include cooling function and eROSITA bandpass
- $\langle \rho_{\mathrm{gas}}^2 \rangle \neq \langle \rho_{\mathrm{gas}} \rangle^2$ $\rightarrow$ Can we detect clumping?

What can we learn about the underlying matter and temperature profiles?

Future: How about the inverse problem?

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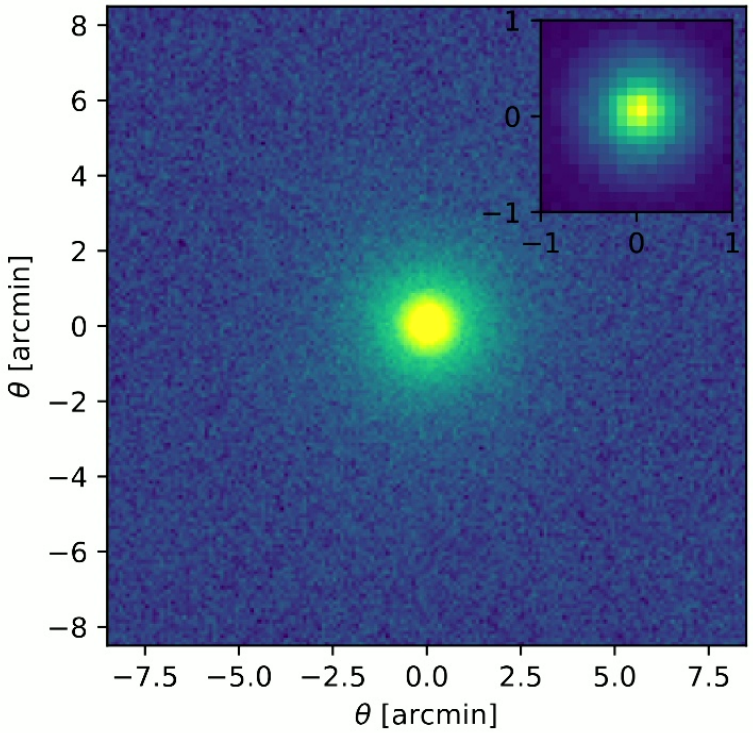
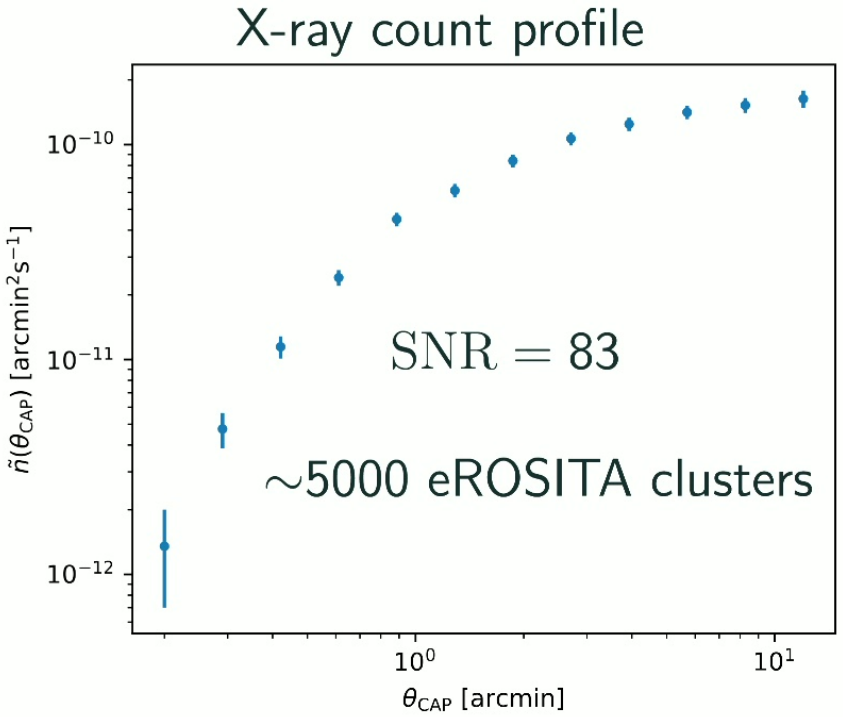
Can we measure kSZ and tSZ around X-ray selected clusters?





Thank you!