Title: New measurements of the gas fraction in galaxies and groups with the kinematic Sunyaev-Zel'dovich effect and CMB lensing

Speakers: Boryana Hadzhiyska

Collection/Series: Cosmic Ecosystems

Subject: Cosmology

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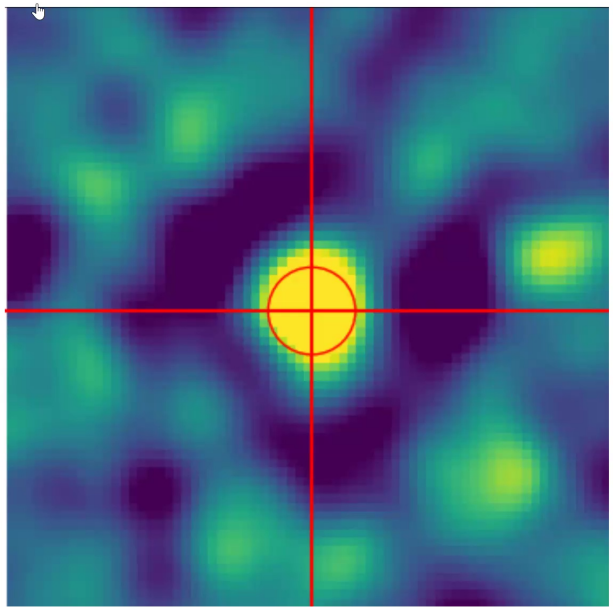
Abstract:

I will present new constraints on the halo masses and gas fractions of DESI galaxy groups via cross-correlations with the ACT DR6 CMB lensing map. This lensing-based calibration addresses a key uncertainty in interpreting kSZ measurements: the underlying halo mass distribution and allows us to estimate the amount by which baryons have been redistributed relative to the dark matter. Our results indicate that while baryons trace dark matter on large scales, the gas is significantly more extended, with cumulative gas fractions falling well below predictions from hydrodynamical simulations like TNG300. These discrepancies, seen at 4σ significance or higher, point to strong feedback processes in the real Universe. I will also highlight the excellent agreement between our lensing-based gas fraction measurements and recent results from X-rays, and discuss the implications for modeling feedback, galaxy formation, and baryon cycling in halos.



Where are the baryons relative to the dark matter? A CMBiosis with large-scale structure

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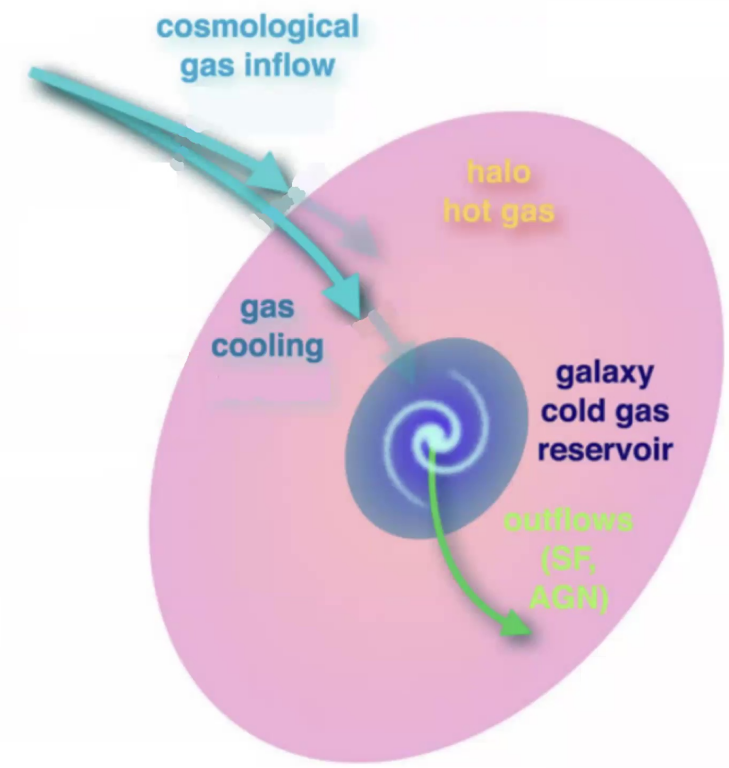
Cosmic Ecosystems

7/29/2025

Why study the baryon distribution?

- Tells us about gas inflow and outflow (feedback):
  - Crucial for obtaining tight & unbiased cosmology with weak lensing surveys (e.g., LSST, Euclid)
    →Making use of the high-precision small-scale data
  - At the crux of understanding galaxy formation and evolution
    →AGN shapes quenching and galaxy-halo link



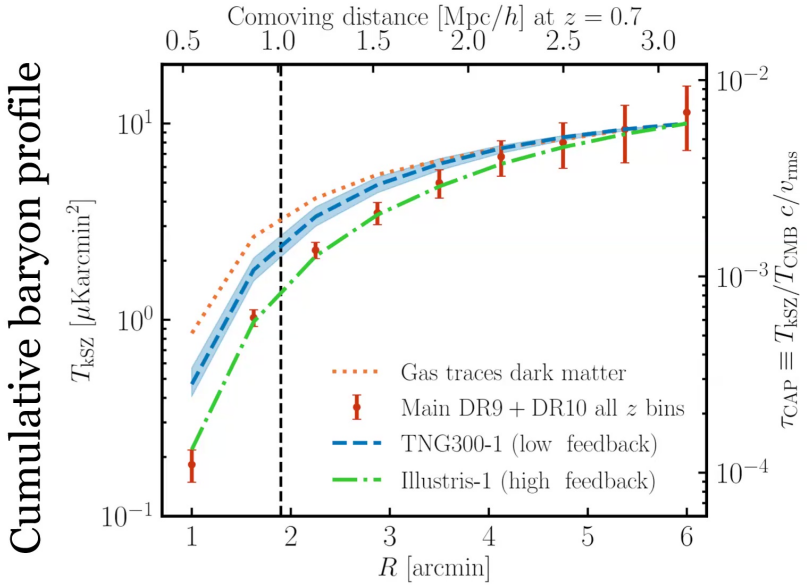
Peeples+ 19

How to study the baryon distribution?

kSZ: a direct measure of baryon distⁿ

- Current highest SNR of gas density profile (13σ, Photometric LRGs)*
- Jets: anisotropic feedback via oriented stacking (Simone's talk)
- Strength of feedback: need to know where the dark matter is!

*X-ray: higher SNR if robustly interpreted (Gerrit's talk)



Distance from center

Hadzhiyska+ (ACT & DESI) 24,
Ried Guachalla+ (ACT & DESI) 25

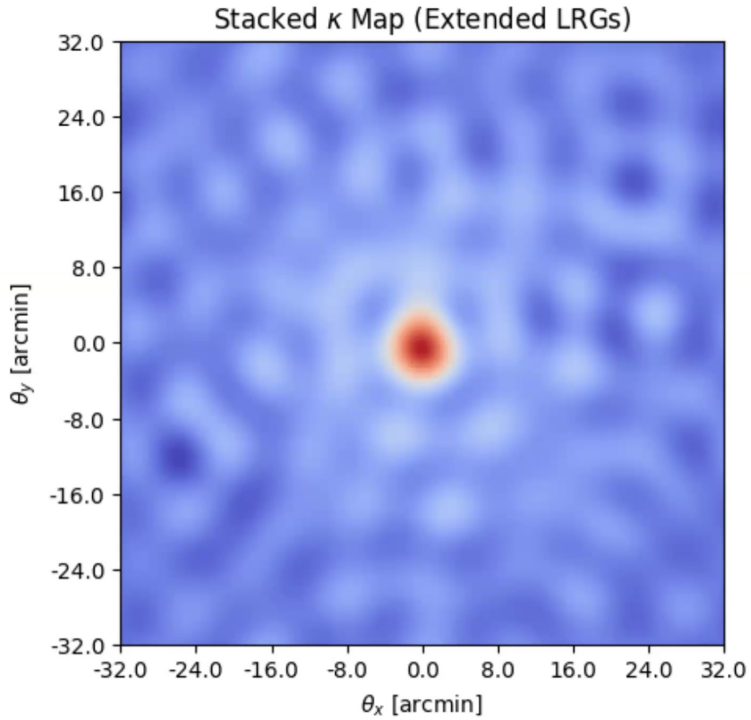
An unbiased tracer of the total matter profile

CMB lensing is an ideal probe:

- High significance (>30σ) measurement of total matter profile
- Clean of systematics (no intrinsic alignment, no photo-z uncertainties)
- Self-consistent galaxy selection (stacking on same LRG sample)

Apples-to-apples comparison!

also see McCarthy+ 24, Sunseri+ 25, Lucie-Smith+ 25



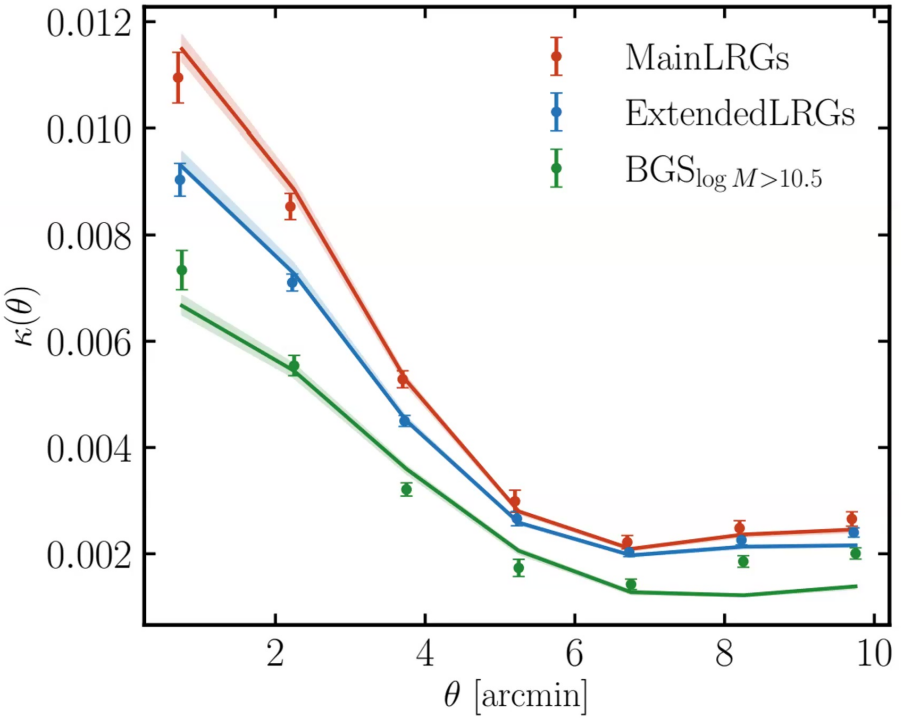
Hadzhiyska+ 25

I. Accurate masses with a robust model

- Accurate host halo masses of DESI galaxies (negligible bias)
- Full *N*-body emulator: marginalized over 2-halo term, galaxy selection, satellite fraction, HOD, ACT beam, etc.

$$\log(M_{\rm halo}/M_\odot\, h^{-1})$$

MainLRGs	ExtendedLRGs	BGS
$13.179^{+0.029}_{-0.021}$	$13.025^{+0.022}_{-0.016}$	$13.022^{+0.091}_{-0.061}$

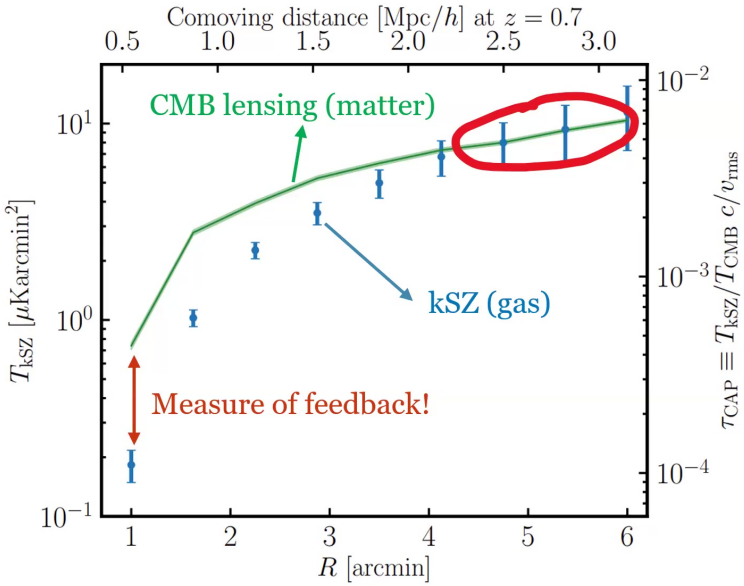


II. Can compare directly with gas density profile

Consistency on large scales suggests:

- Cosmic baryon fraction recovered ~3 virial radii
- Data-based solution to missing baryon problem
- Little evidence for unbound gas
- Validates kSZ stacking calibration

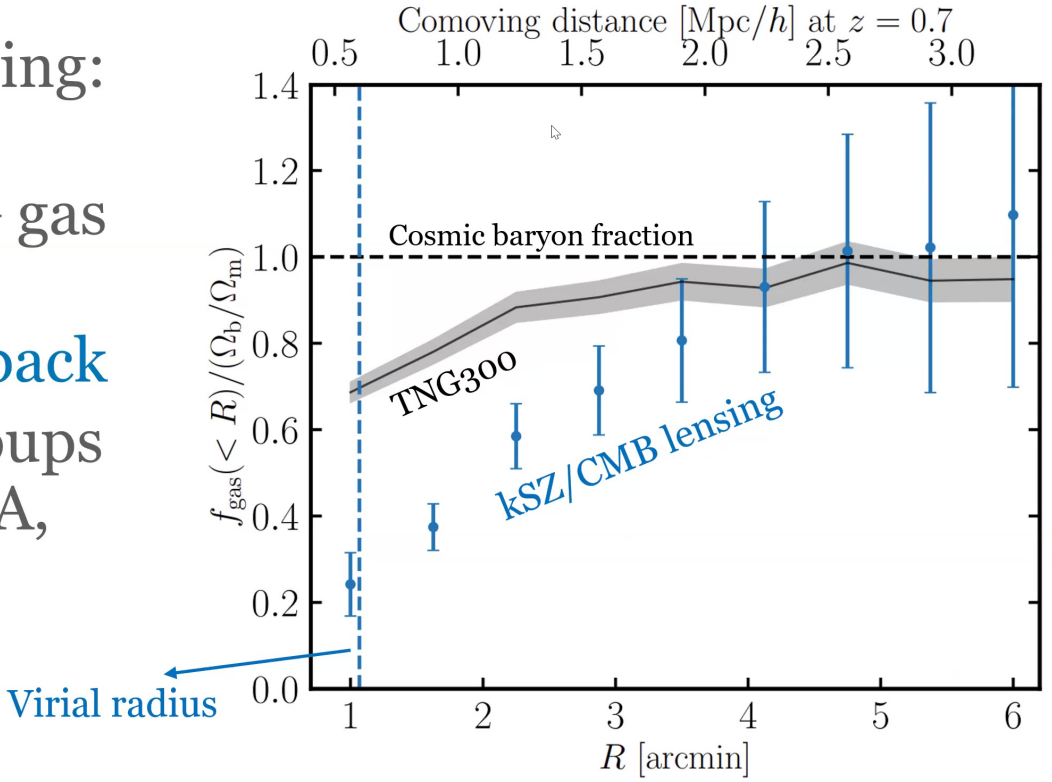
Cumulative gas and total matter profiles of LRGs



Hadzhiyska+ 25

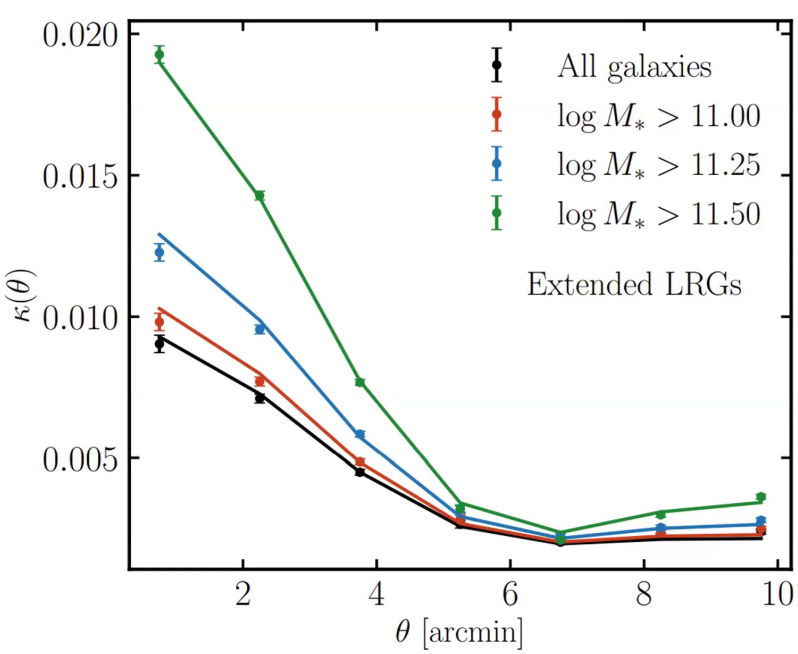
III A. Strong baryonic feedback in groups

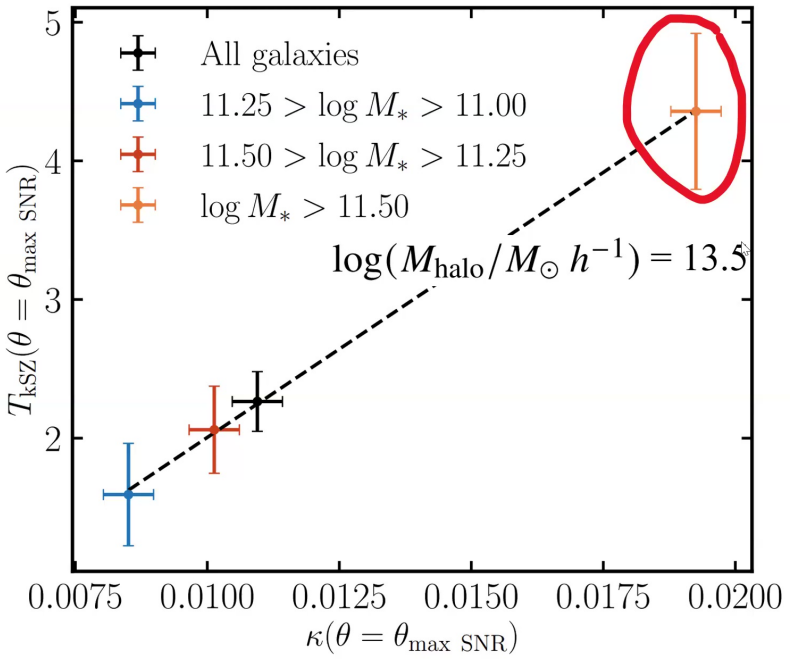
- Ratio of kSZ and CMB lensing: low gas fraction
- ~4-5σ difference with TNG gas fractions
- Data prefers stronger feedback
- Consistency with X-ray groups at similar masses (eROSITA, Popesso+ 24)*



III B. Mass evolution of baryonic feedback

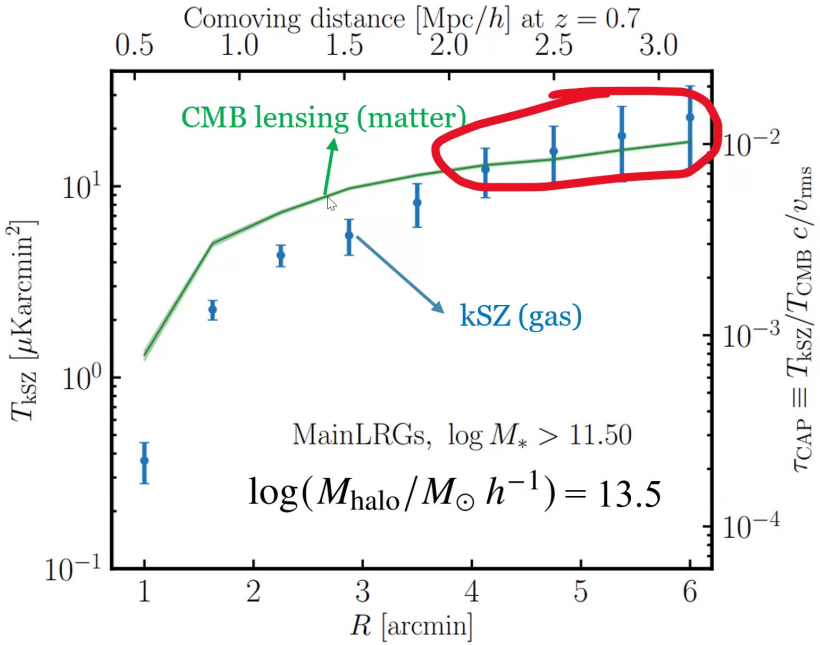
- Split LRGs into stellar mass bins: halo mass ∝ gas mass





What happens as we approach cluster masses?

- No evidence for unbound gas
- Weaker feedback as physically expected
- Consistent with deeper potential
- Consistent with X-ray gas fractions (Popesso+ 24)



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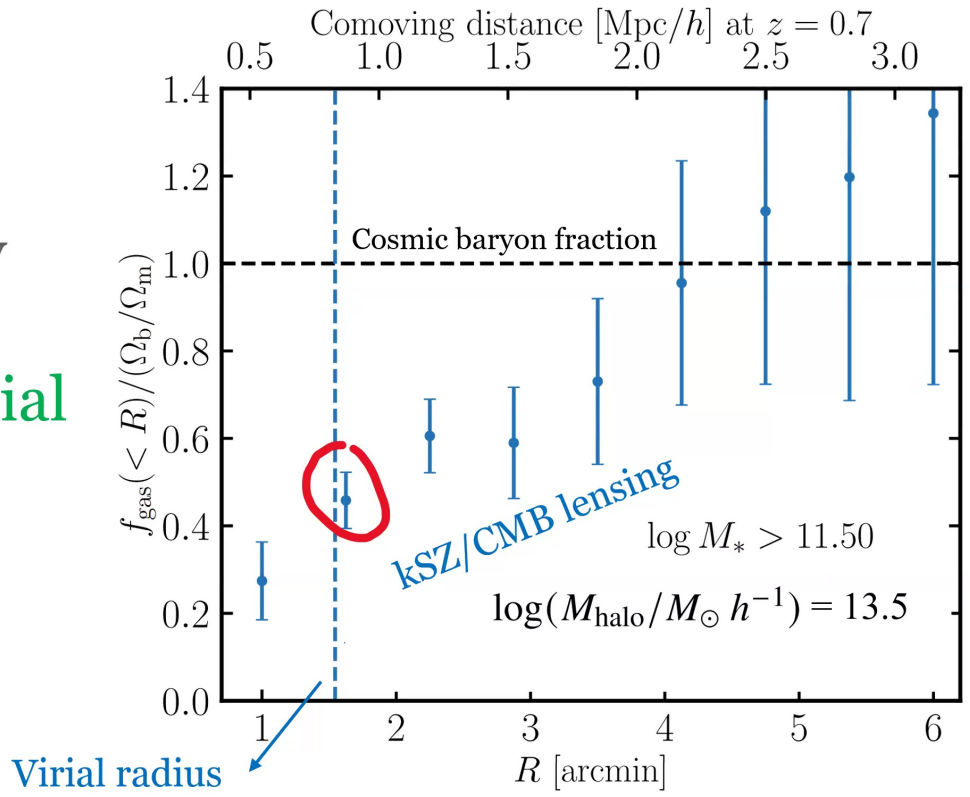

Summary & conclusions

- Consistent CMB lensing and kSZ stacks on DESI galaxies
- Data-driven study of gas distribution relative to dark matter
- High accuracy, clean measurements of DESI group masses
- No evidence of large unbound gas: missing baryons recovered
- Low gas fractions at group mass, indicating large feedback
- Most massive groups/clusters have weaker feedback (as physically expected)
- Precision cosmology with kSZ, CMB lensing and X-ray data!

☺ Thank you! ☺