Title: Cosmological feedback from a halo assembly perspective

Speakers: Hiranya Peiris

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Subject: Cosmology

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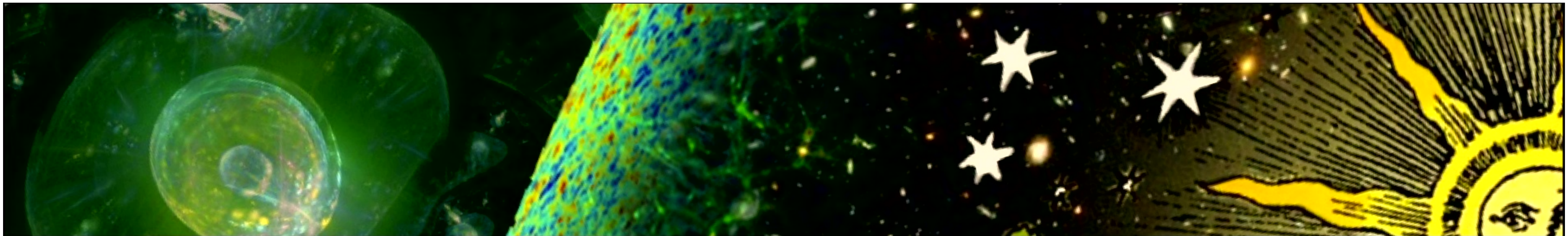
Abstract:

The impact of feedback from galaxy formation on cosmological probes is typically quantified in terms of the suppression of the matter power spectrum in hydrodynamical compared to gravity-only simulations. In this paper, we instead study how baryonic feedback impacts halo assembly histories and thereby imprints on cosmological observables. We investigate the sensitivity of the thermal Sunyaev-Zel'dovich effect (tSZ) power spectrum, X-ray number counts, weak lensing and kinetic Sunyaev-Zel'dovich (kSZ) stacked profiles to halo populations as a function of mass and redshift. We then study the imprint of different feedback implementations in the FLAMINGO suite of cosmological simulations on the assembly histories of these halo populations, as a function of radial scale. We find that kSZ profiles target lower-mass halos (M200m~10^13.1M⊙) compared to all other probes considered (M200m~10^15M⊙). Feedback is inefficient in high-mass clusters with ~10^15M⊙ at z=0, but was more efficient at earlier times in the same population, with a ~5-10% effect on mass at 2<z<4 (depending on radial scale). Conversely, for lower-mass halos with ~10^13M⊙ at z=0, feedback exhibits a ~5-20% effect on mass at z=0 but had little impact at earlier times (z>2). These findings are tied together by noting that, regardless of redshift, feedback most efficiently redistributes baryons when halos reach a mass of M200m≃10^12.8M⊙ and ceases to have any significant effect by the time M200m≃10^15M⊙. We put forward strategies for minimizing sensitivity of lensing analyses to baryonic feedback, and for exploring baryonic resolutions to the unexpectedly low tSZ power in cosmic microwave background observations.



Cosmological feedback from a halo assembly perspective

Hiranya V. Peiris

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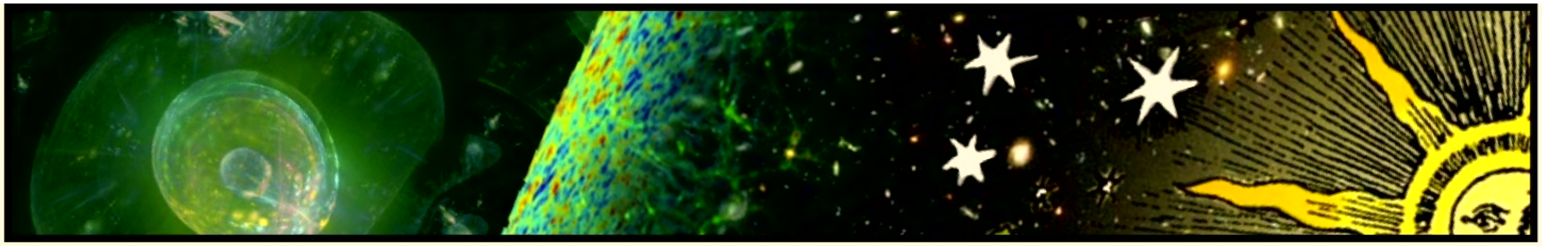


Cosmological feedback from a halo assembly perspective

Luisa Lucie-Smith
(Hamburg)

Hiranya Peiris
(Cambridge)

Andrew Pontzen
(Durham)

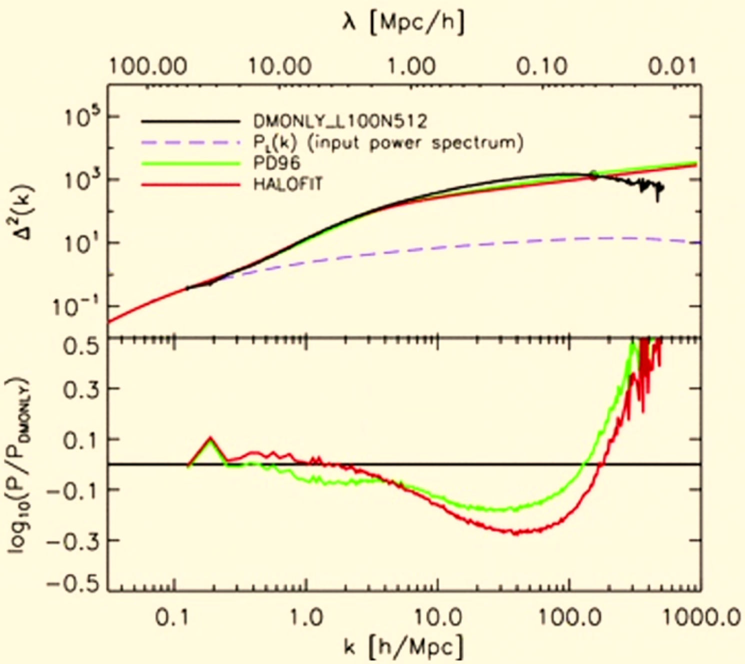
Anik Halder
(Cambridge)

+ FLAMINGO: Joop Schaye, Matthieu Schaller, John Helly, Robert J. McGibbon, Willem Elbers

LUCIE-SMITH, PEIRIS, PONTZEN, HALDER ET AL (ARXIV: 2505.18258)

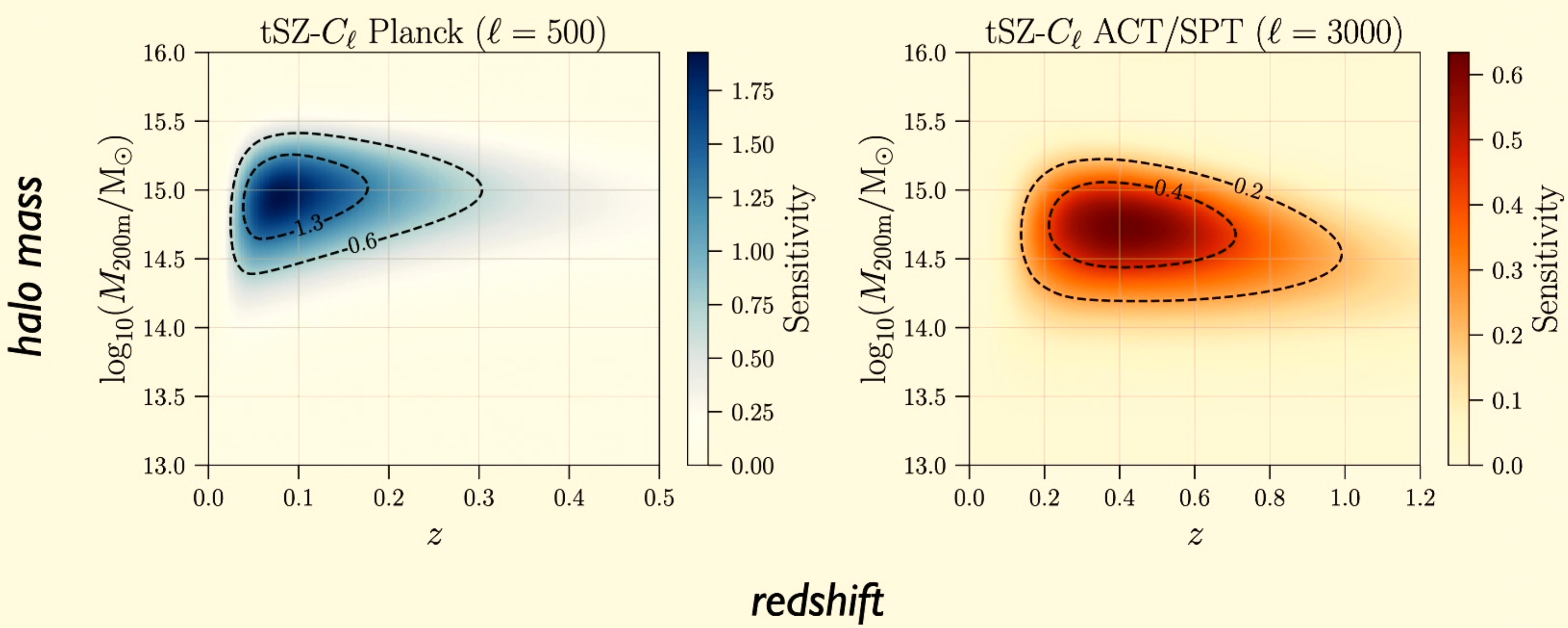
Feedback for cosmologists. Why care?

- ***Key modelling systematic in cosmic shear / weak lensing analyses***
- ***Low S8 / low tSZ anomalies have been linked to feedback***
- ***kSZ opening up a new probe of cosmic baryons***
- ***Usually studied using summary statistics (e.g. modifications to P(k))***
- ***Here: impact of feedback on halo assembly histories***



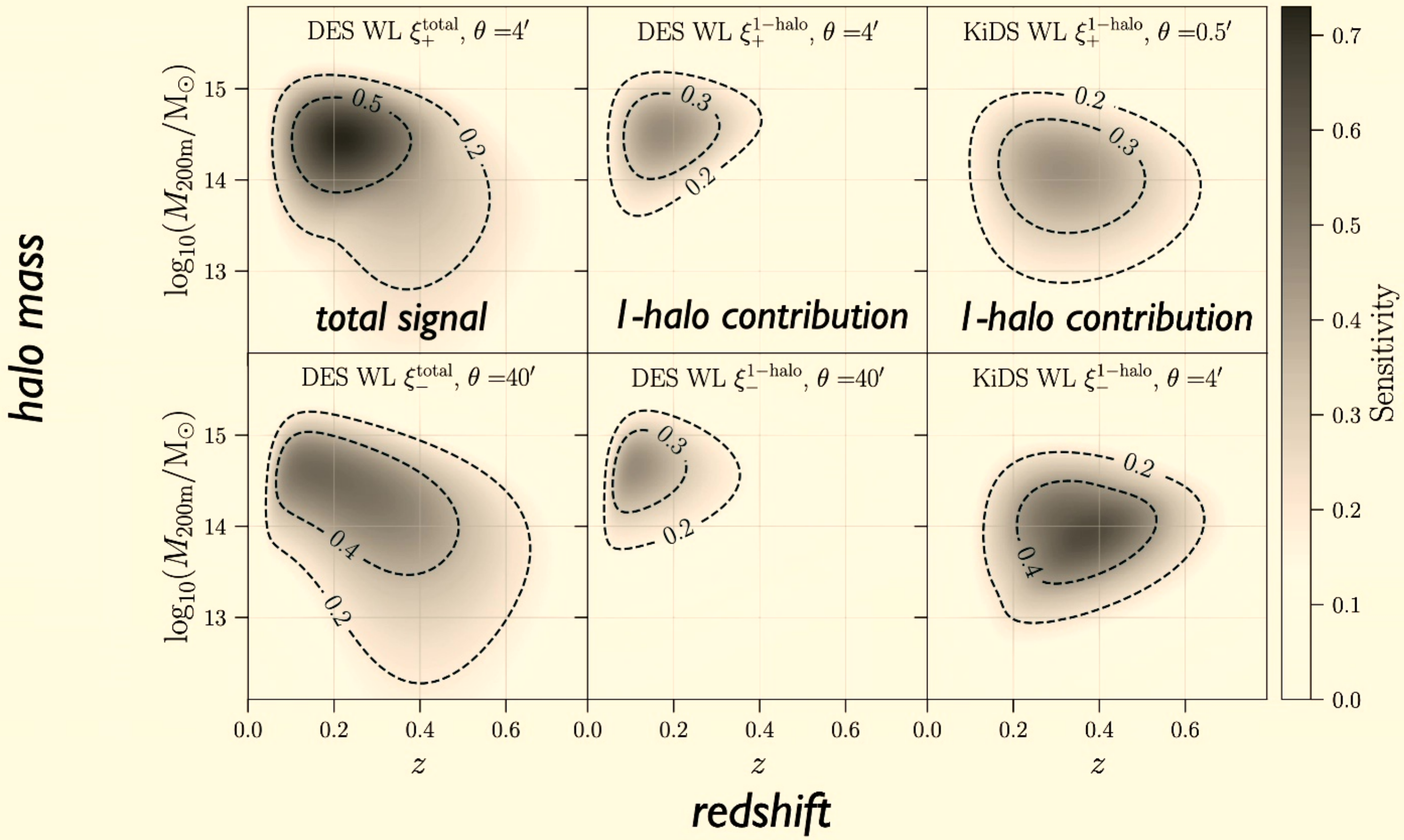
van Daalen, Schaye, Booth, Dalla Vecchia (2011)

Thermal Sunyaev-Zel'dovich sensitivity



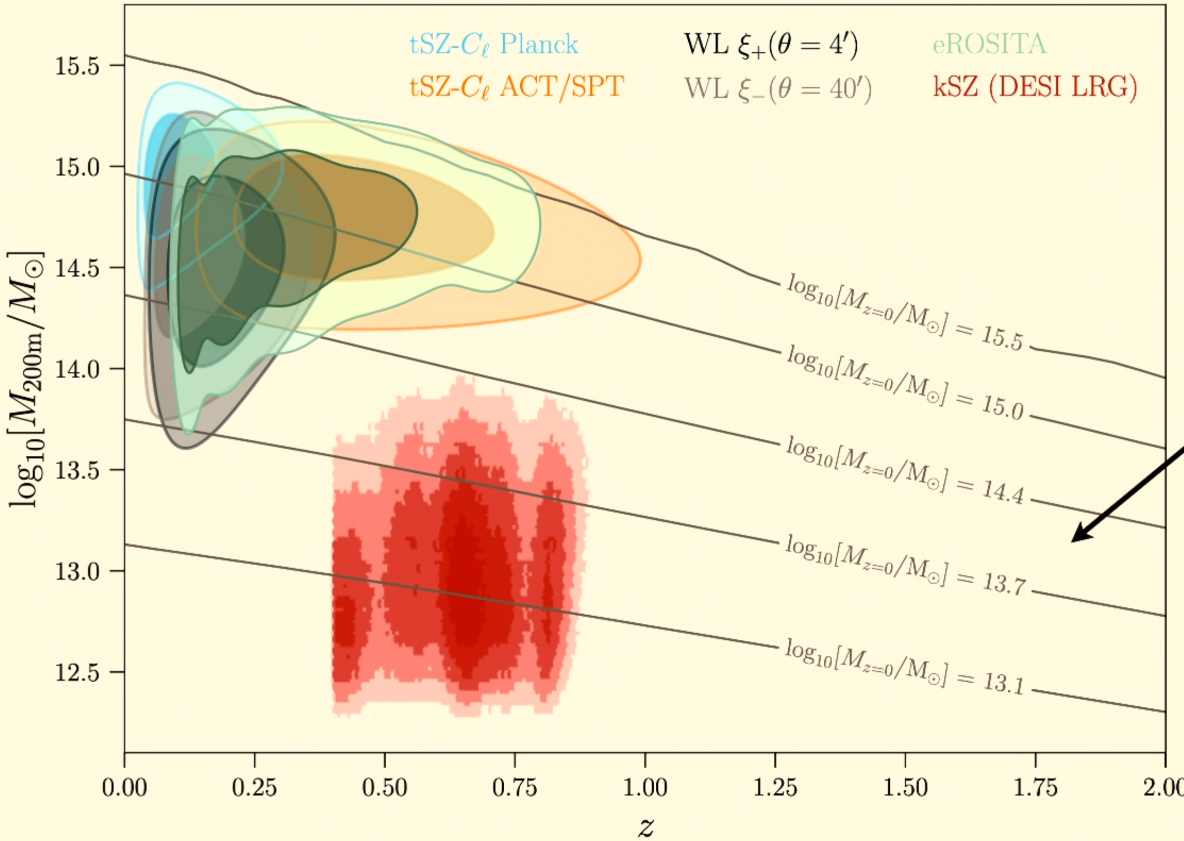
CLASS-SZ: THANK YOU TO BORIS BOLLIET AND COLLABORATORS

Weak lensing sensitivity



Halo populations probed by different cosmological probes

halo mass



halo mass growth tracks

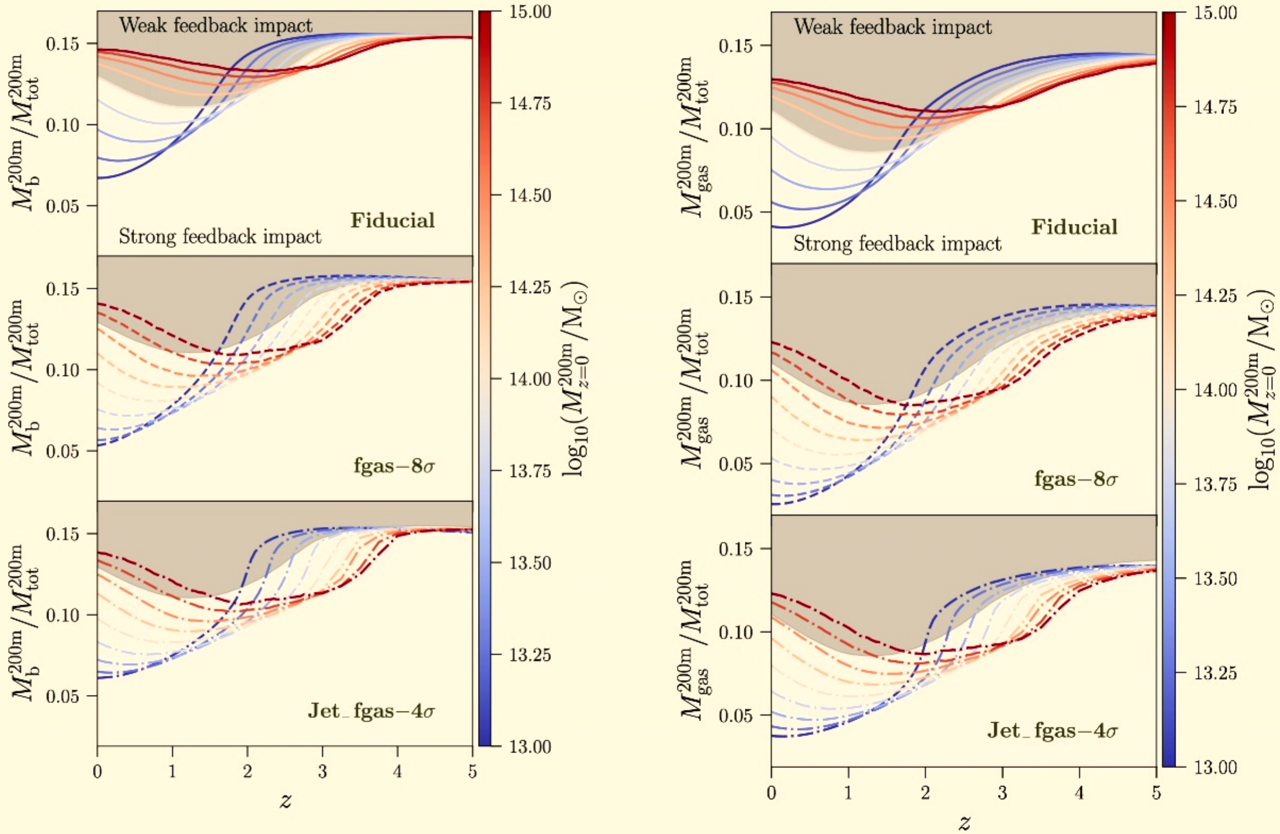
redshift

Imprint of feedback variations on halo assembly histories

fiducial

fgas-8σ

Jet fgas-8σ



baryons

gas

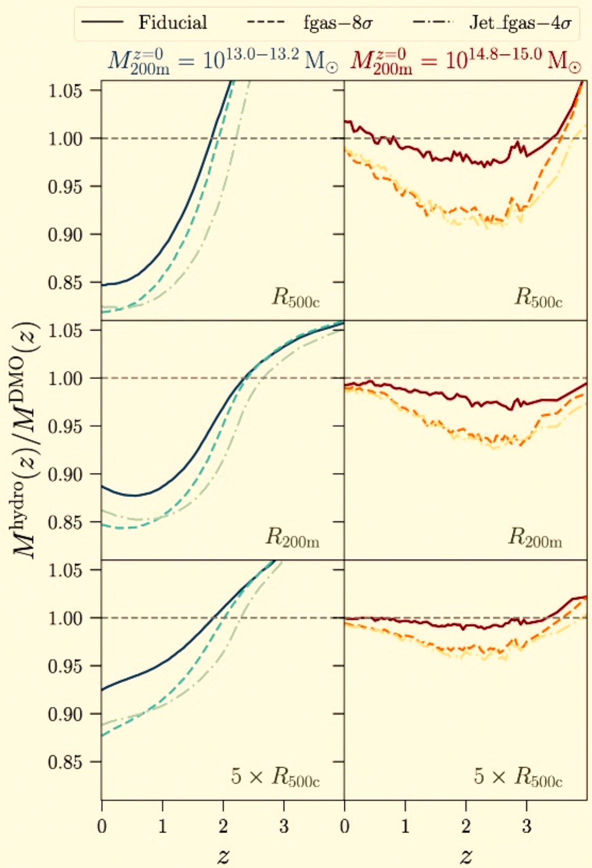
SIMULATIONS FROM SCHAYE ET AL (2023)

Radial dependence of impact of feedback variations: baryons

inner halo ~ Xray

virial radius ~ tSZ

outer halo ~ kSZ



~groups *~clusters*

Radial dependence of impact of feedback variations: gas

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virial radius ~ tSZ

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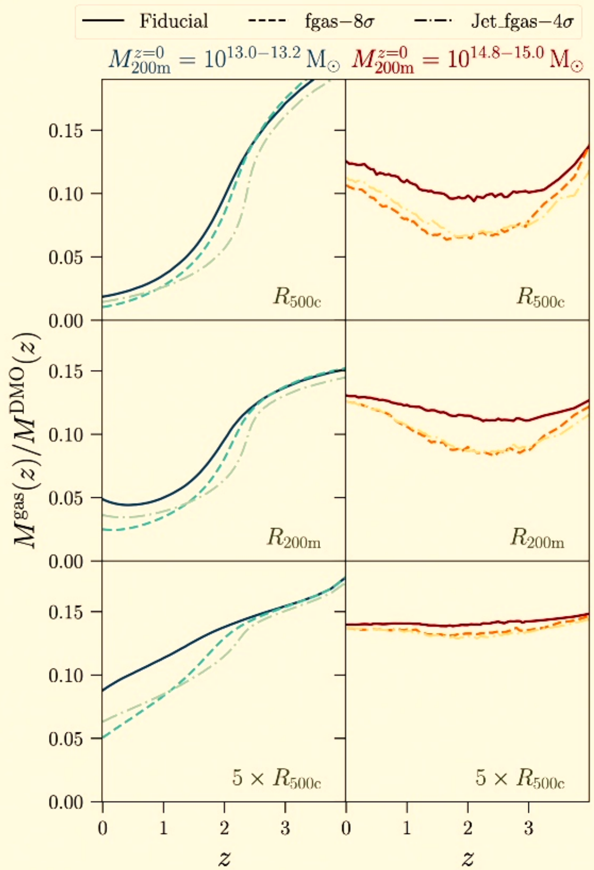
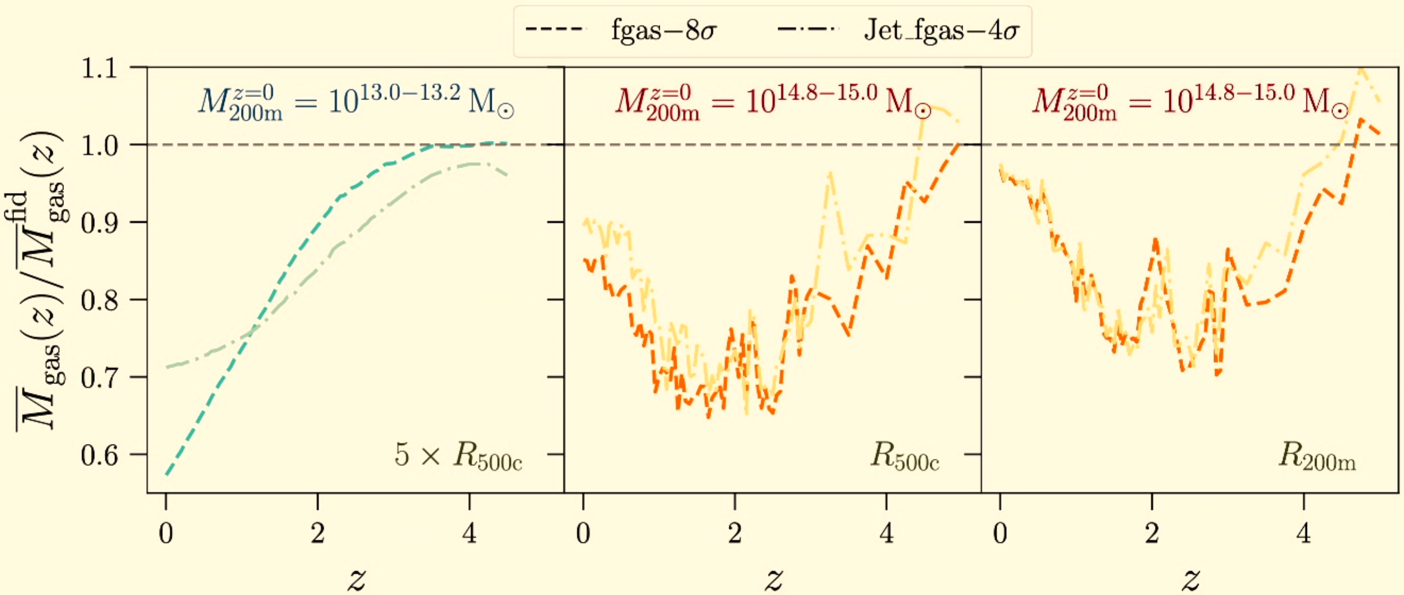


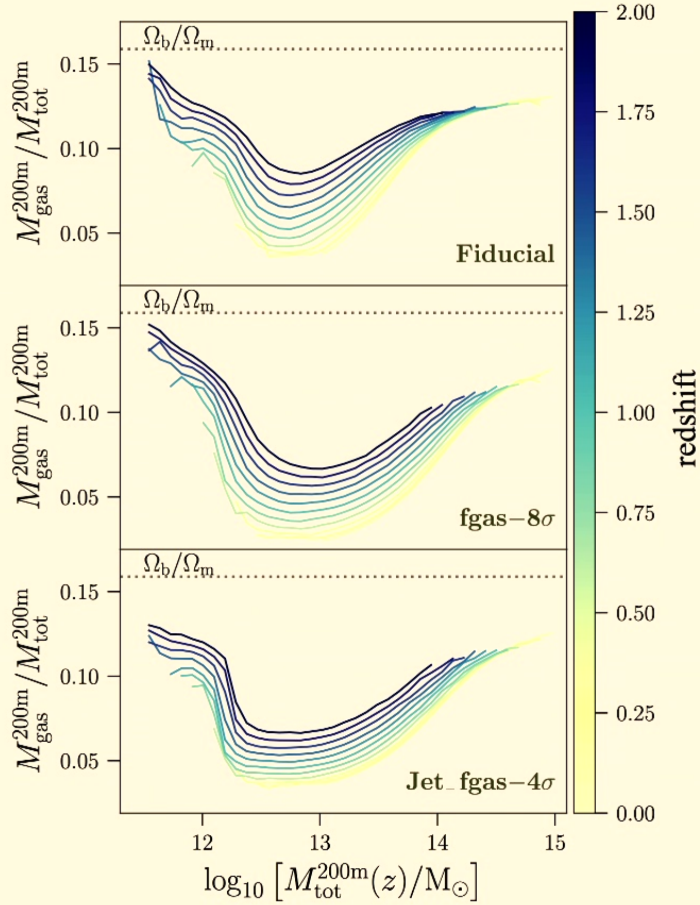
~groups ~clusters

Impact on gas of feedback variations



~kSZ ~X-ray ~tSZ

Unified picture of feedback impact on halos



Outlook

- *kSZ-relevant halos can be straightforwardly modified by feedback processes.*
  (both AGN feedback and other physics e.g. cosmic rays)

- *Challenging to explain low measured tSZ amplitude with AGN feedback.*
  (need to push gas outside virial radius at high-z or turn gas into stars)

- *Scale cuts are effective at mitigating feedback in cosmic shear analyses.*

- *Nulling tomography or (simply) masking massive clusters may be even more effective.*

- *Halo population perspective useful for interpreting combined constraints and separating cosmological implications from astrophysics.*

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