Constraining AGN feedback model with SZ profile

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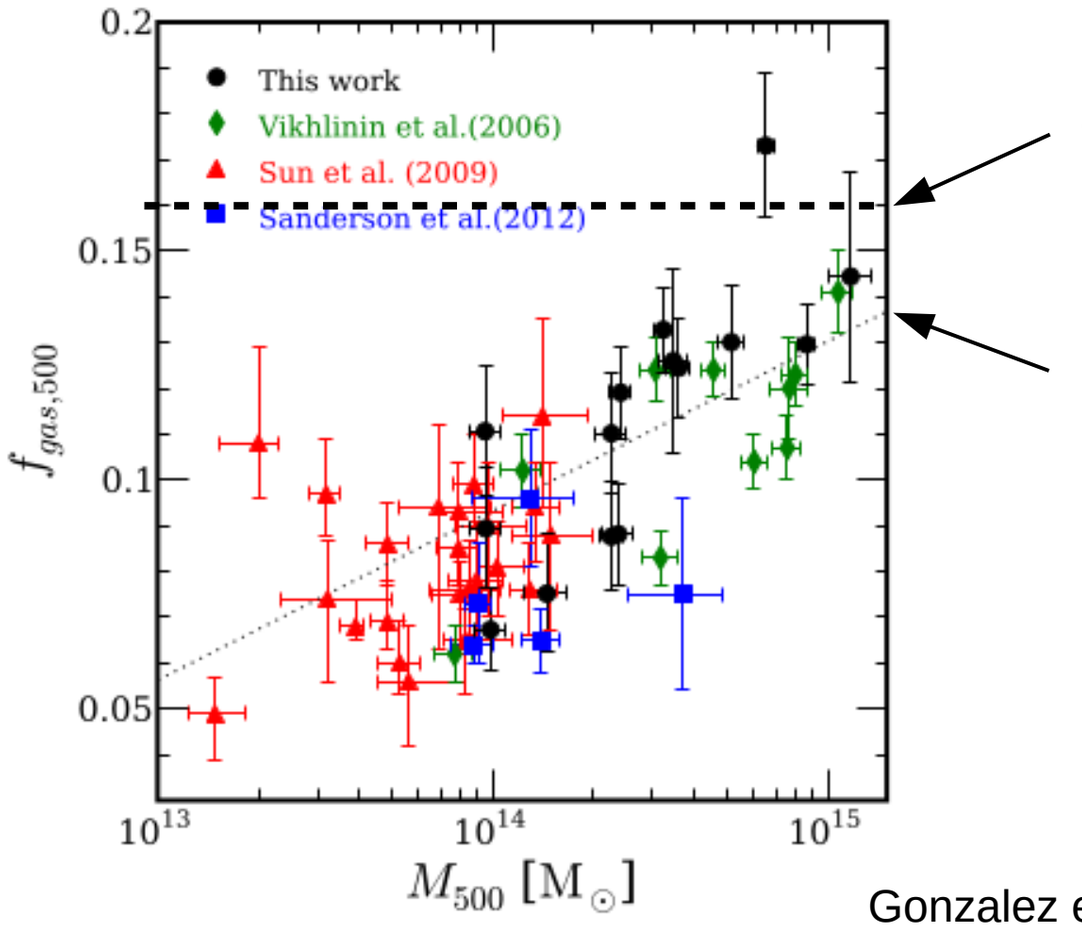
Baryonic effects via self-similar relation

The self-similar relation is the relation that does not depend on the scale
, which is valid when the process is dominated by gravity.
The deviation from this relation implies the presence of more complex processes.

(fgas,500=Mgas/M500)



Cosmic baryon fraction (Ωb/Ωm)

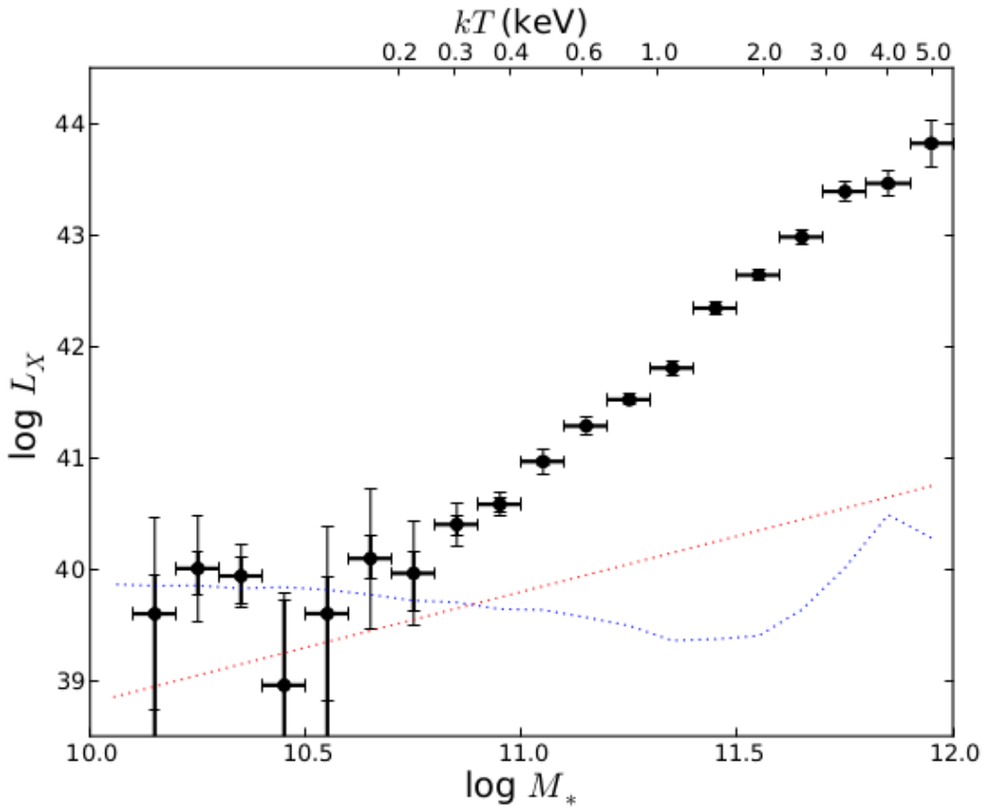
fgas,500 ∝ M500 $^{0.26\pm0.03}$

Gonzalez et al (2013)

X-ray measurement of gas fraction in galaxy clusters shows non self-similarity.
It suggests that non-gravitational effect is important.

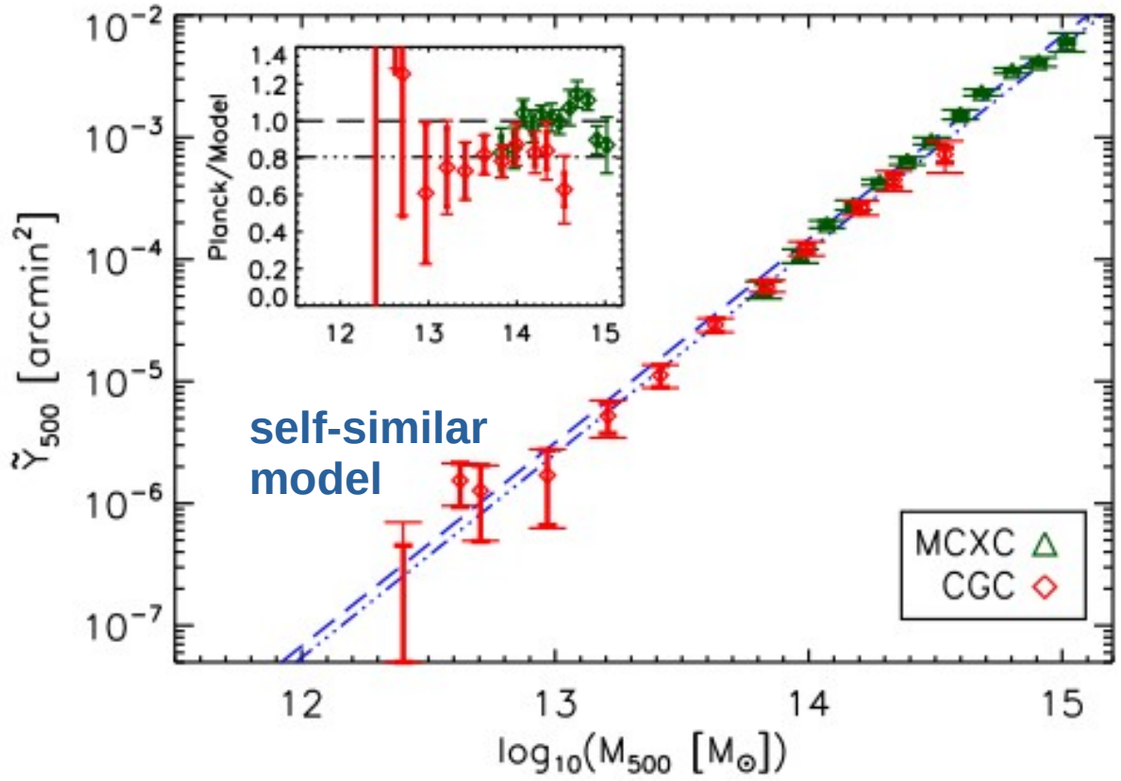
Gas fraction in galaxy cluster is self-similar?

Lx-M scaling relation
from X-ray measurements from ROSAT
(Anderson et al 2015)



Lx∝M^(1.33) in case of self-similar,
but measured slope is 1.85±0.15.
Not self-similar

Y-M scaling relation
from SZ measurements from Planck
(Planck Intermediate Results. XI, 2013)

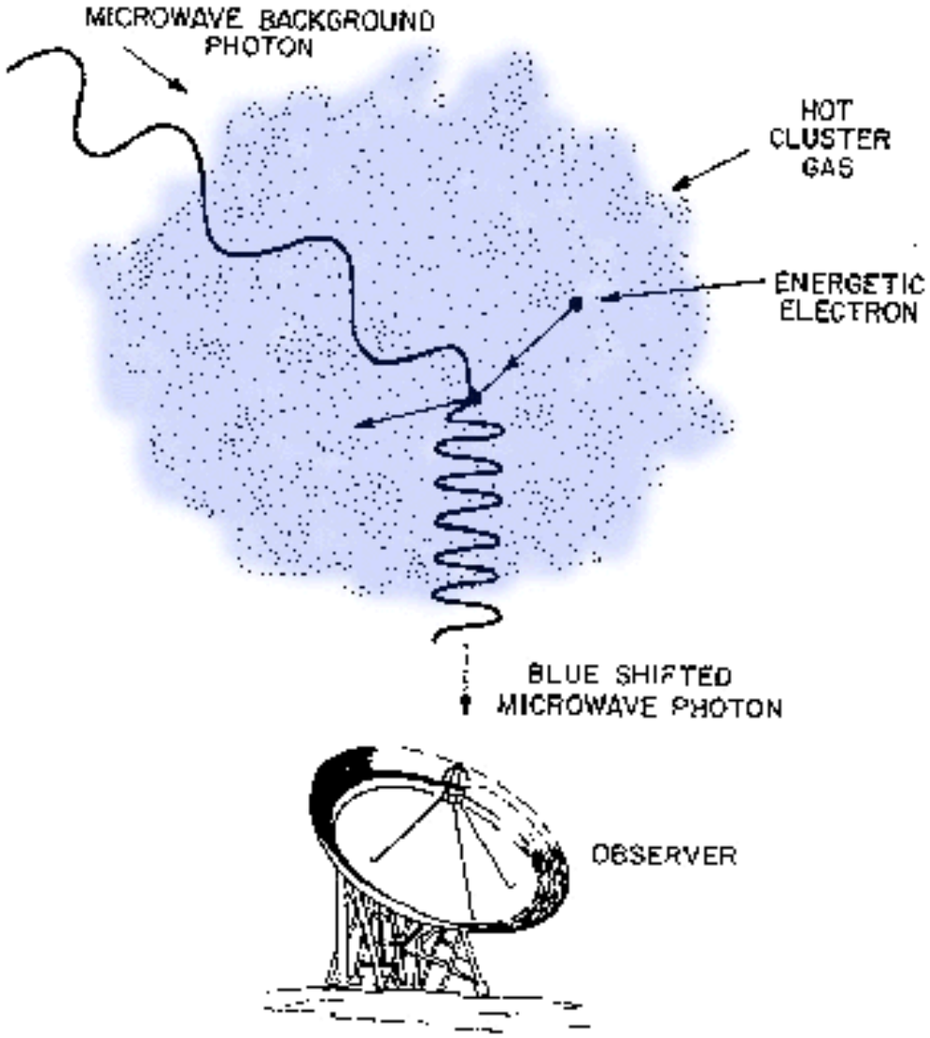


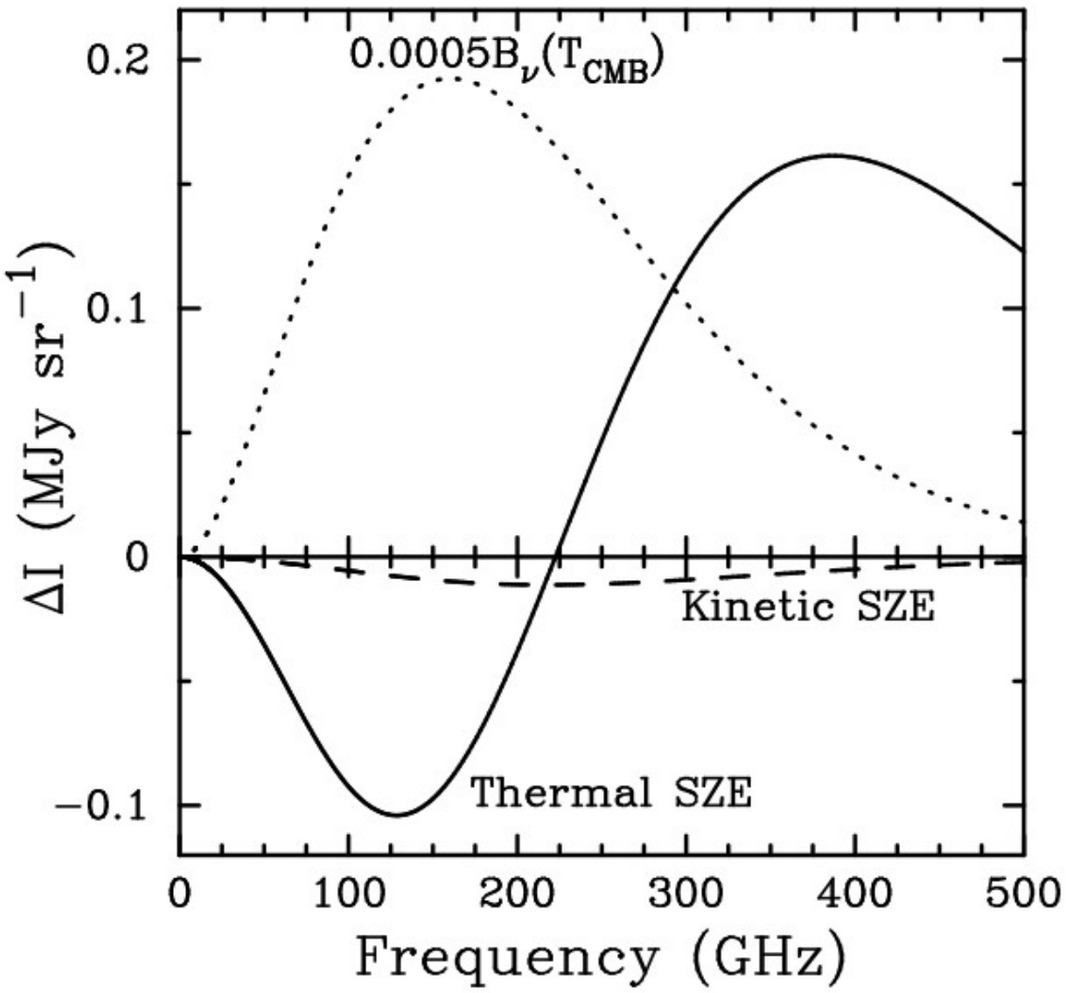
Y∝M^(1.67) in case of self-similar.
Self-similar

However, there are larger uncertainties in low-mass halos below 10^{14} Msun.

Sunyaev-Zel'dovich(SZ) Effect

SZ effect is the distortion of the CMB spectrum
caused by high energy electrons in galaxy clusters.





Spectral distortion of the CMB by a galaxy cluster
with T=10 keV, y=1e-4, Vpec=500 km/s (Carlstrom et al 2002)

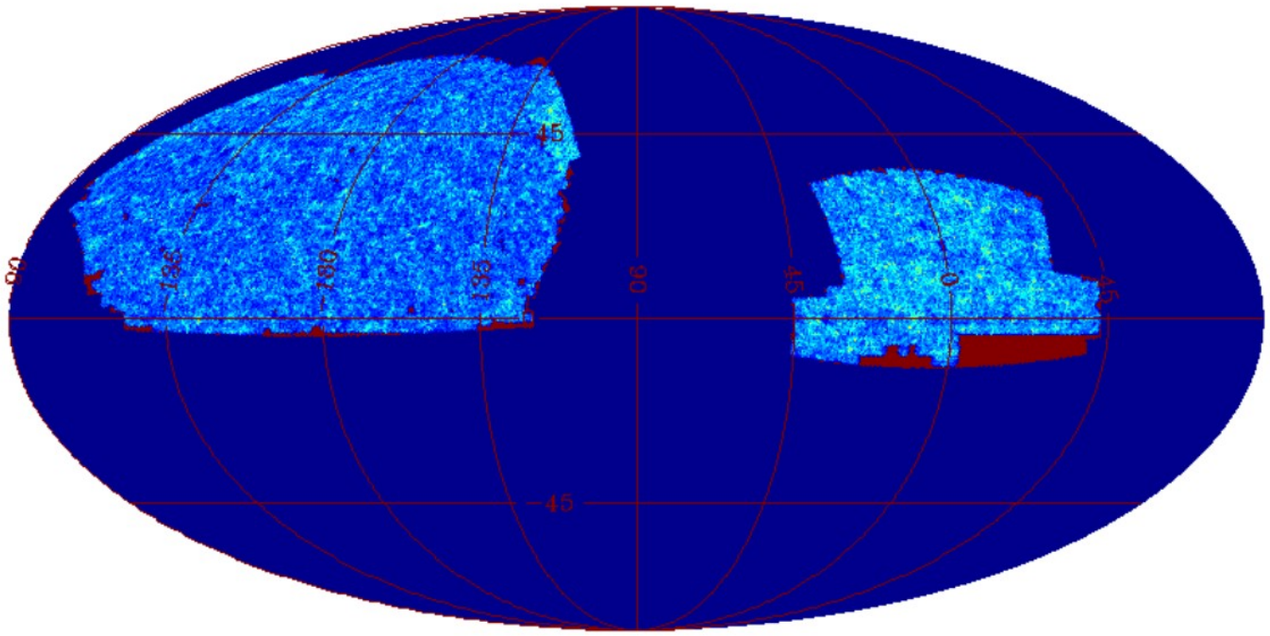
Data set

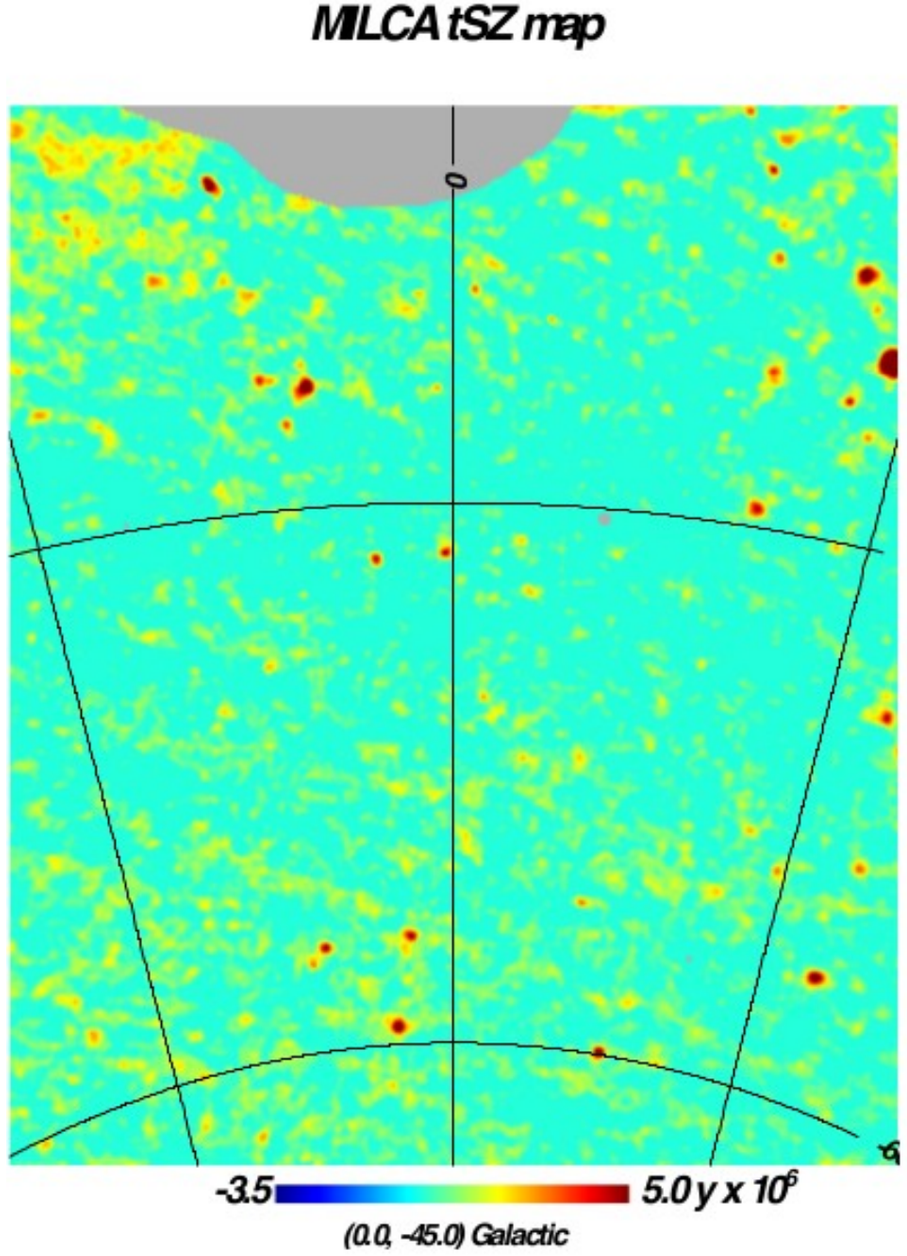
~65,000 LRGs from SDSS DR7
(LRG: Luminous red galaxies)

Redshift: $0.16 < z < 0.47$

Stellar mass: $10^{11.2}\,M_\odot < M^* < 10^{11.7}\,M_\odot$

(in Halo mass, $10^{13}\,M_\odot < M_{500} < 10^{14}\,M_\odot$)

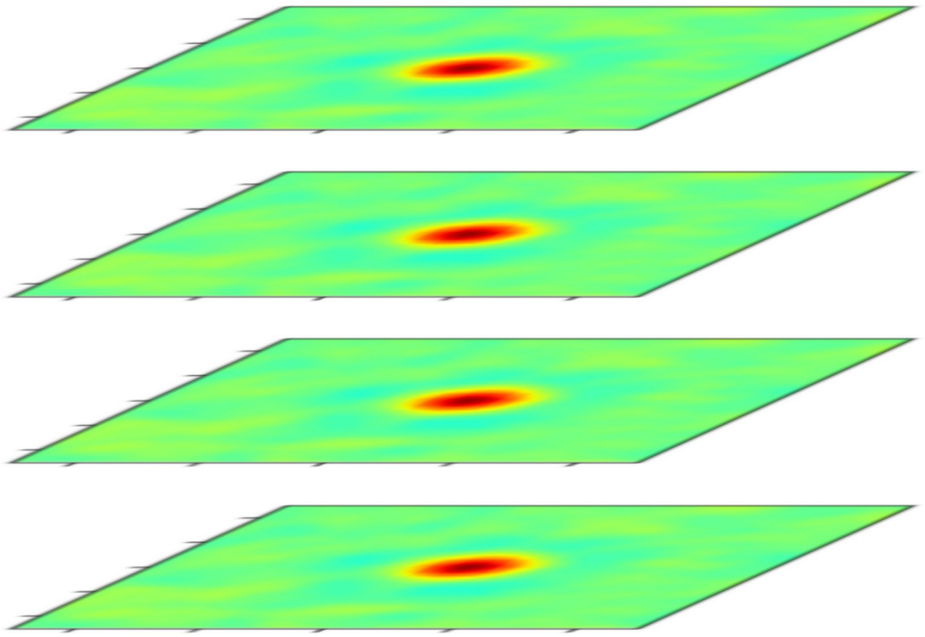




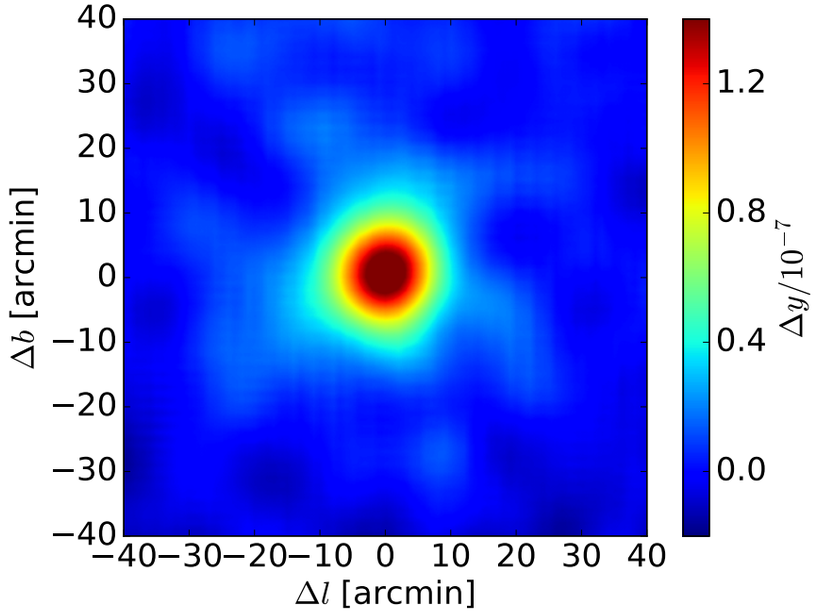
- The LRGs can be used to point the center of galaxy groups and clusters.
- The Planck SZ map probes the hot gas in dark matter halos.

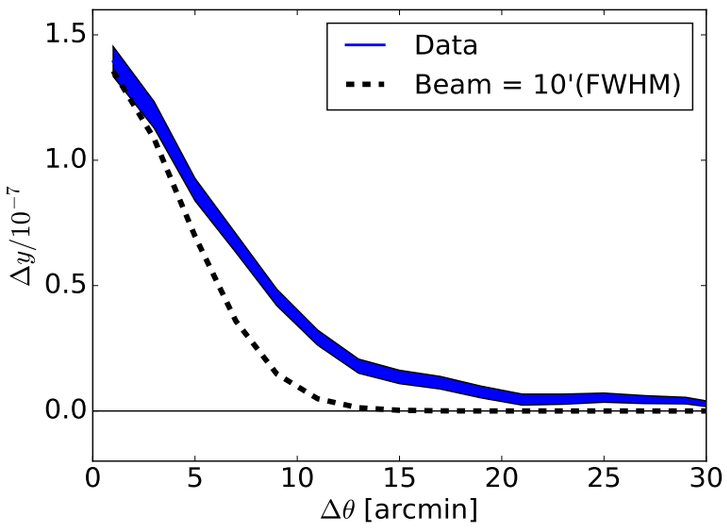
Methodology (Stacking)

We stack the Planck SZ map
at the positions of ~65,000 LRGs.



(Planck SZ map)





We detected the SZ signal at ~17σ detection from LRG halos with M_{500}~3×10^{13}Msun.
The signal extends out to ∼ 30' well beyond the 10' resolution of the Planck SZ map.

cosmo-OWLS hydrodynamical Simulation

• cosmo-OWLS is an extension of the OverWhelmingly Large Simulation project (Schaye et al. 2010). Designed to study cluster cosmology and large scale-structure.

• Suite consists of box-periodic hydrodynamical simulations, with volumes of $(400\ h^{-1}\ \mathrm{Mpc})^3$ and 1024^3 baryon and dark matter particles each.
See Brun et al. (2014); Van Daalen et al. (2014); McCarthy et al. (2014).

• McCarthy et al. (2014) extract ten 5°×5° light-cones with simulated SZ signal out to z=3, with ~10^6 galaxies in each cone.

• Each simulation was run with 5 different models of baryon sub-grid physics.
Earlier studies demonstrate that the “AGN 8.0” model reproduces a variety of observed gas features in local groups and clusters of galaxies, selected by optical or X-ray data.

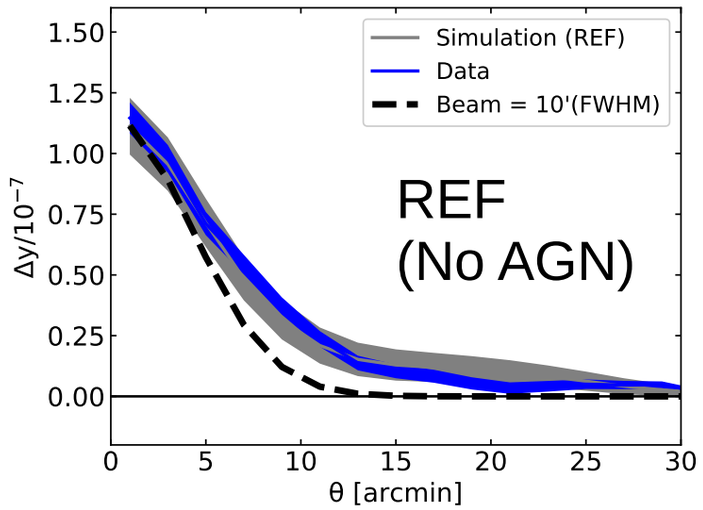
Simulation	UV/X-ray background	Cooling	Star formation	SN feedback	AGN feedback	ΔT_{heat}
NOCOOL	Yes	No	No	No	No	...
REF	Yes	Yes	Yes	Yes	No	...
AGN 8.0	Yes	Yes	Yes	Yes	Yes	$10^{8.0}$ K
AGN 8.5	Yes	Yes	Yes	Yes	Yes	$10^{8.5}$ K
AGN 8.7	Yes	Yes	Yes	Yes	Yes	$10^{8.7}$ K

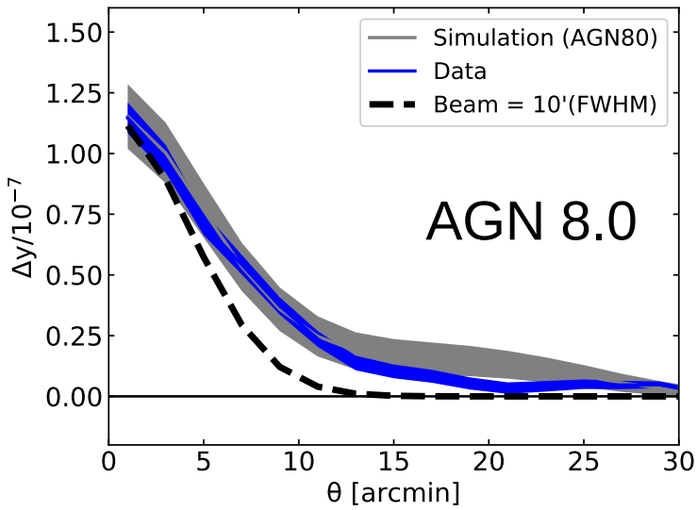
AGN-8.x:

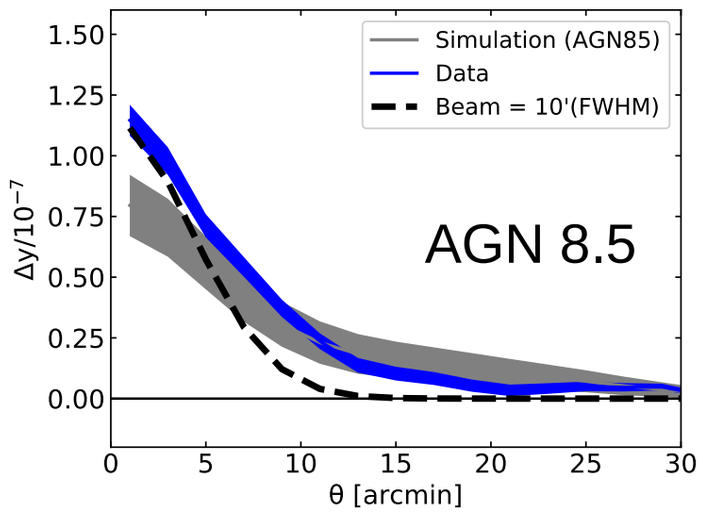
$T_{heat} = 10^{8.x}$ K

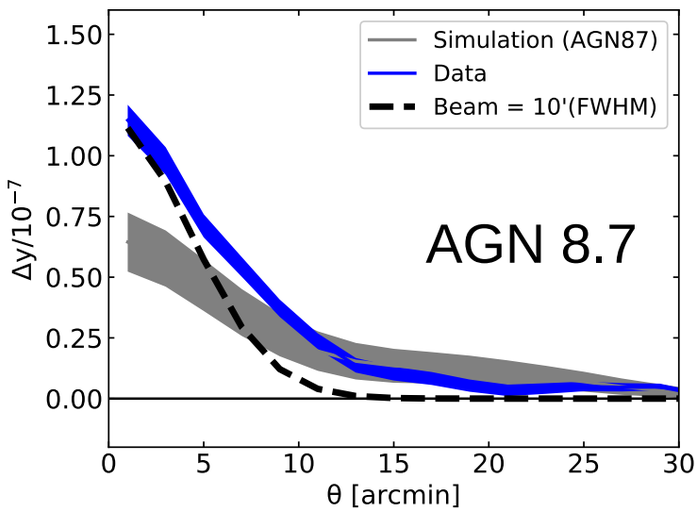
Comparison with simulations (with Mh)

We estimated the halo mass of LRGs using the WL-based stellar-to-halo mass relation from Coupon et al. (2015) and matched the halo mass and redshift, and then compared the measured SZ profile with the ones from different AGN feedback models.





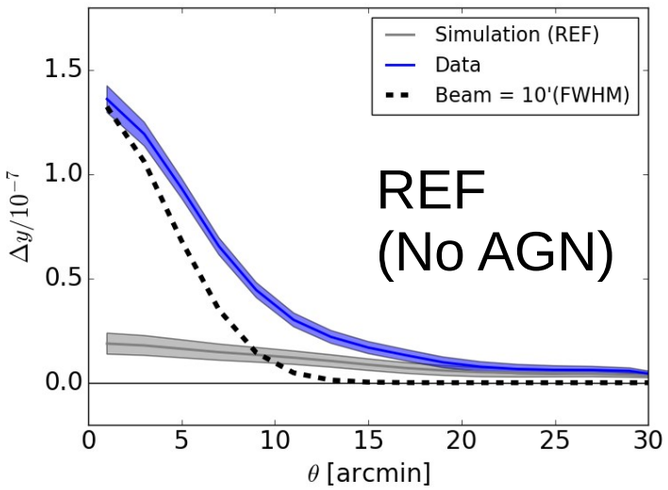


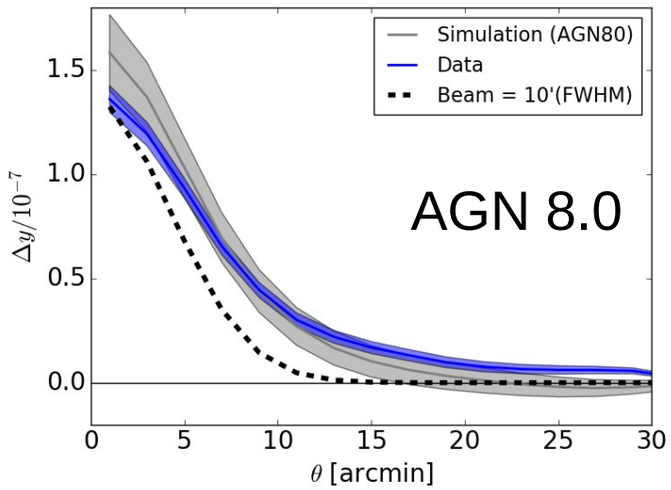


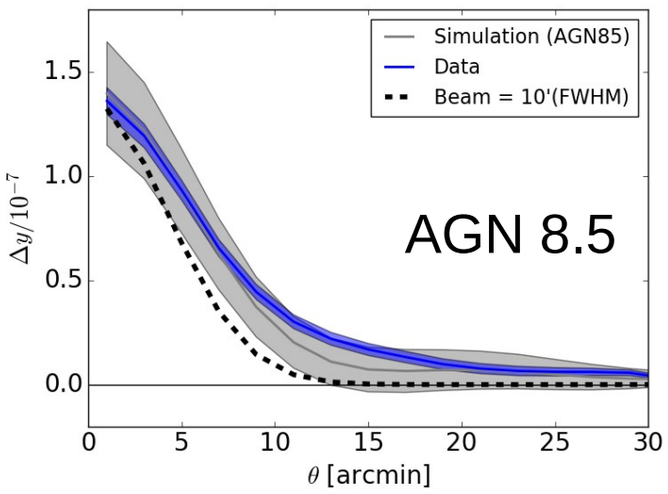
Here, we assume that stellar-to-halo mass relations (stellar evolutions) are same in different models.

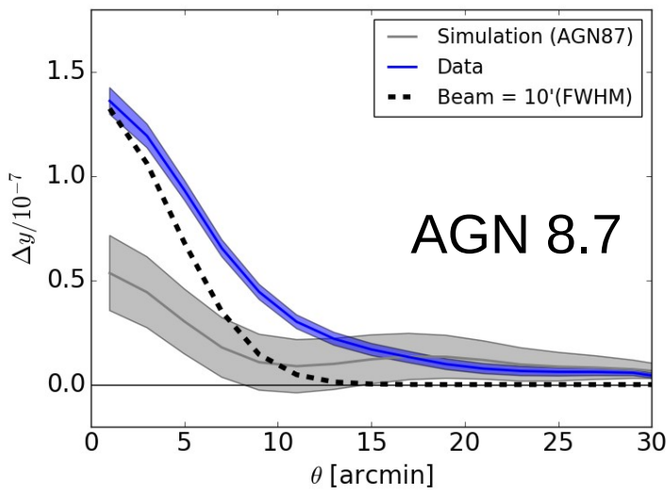
Direct comparison with M*

We compared our measured SZ-profile with stellar masses, instead of halo masses.





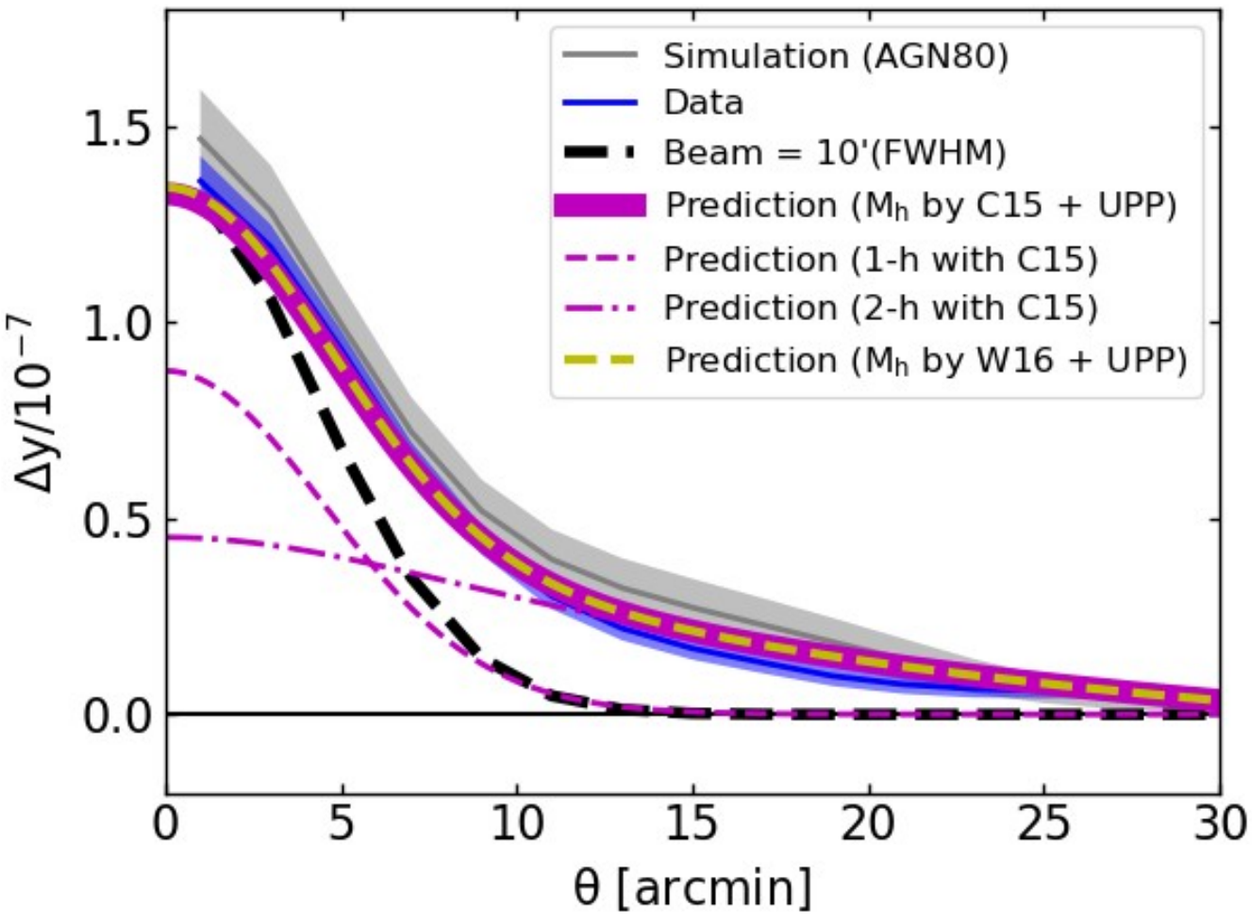




- Stellar-to-halo mass relation (stellar evolution) is largely affected by AGN feedback.
- The data agree well with hydro simulations that include AGN feedback
  but not without it (REF) or bursty AGN model (AGN 8.7).

Comparison with model prediction

We compared our measured y-profile with model prediction
using the Universal pressure profile (one-halo term) and halo model (two-halo term).



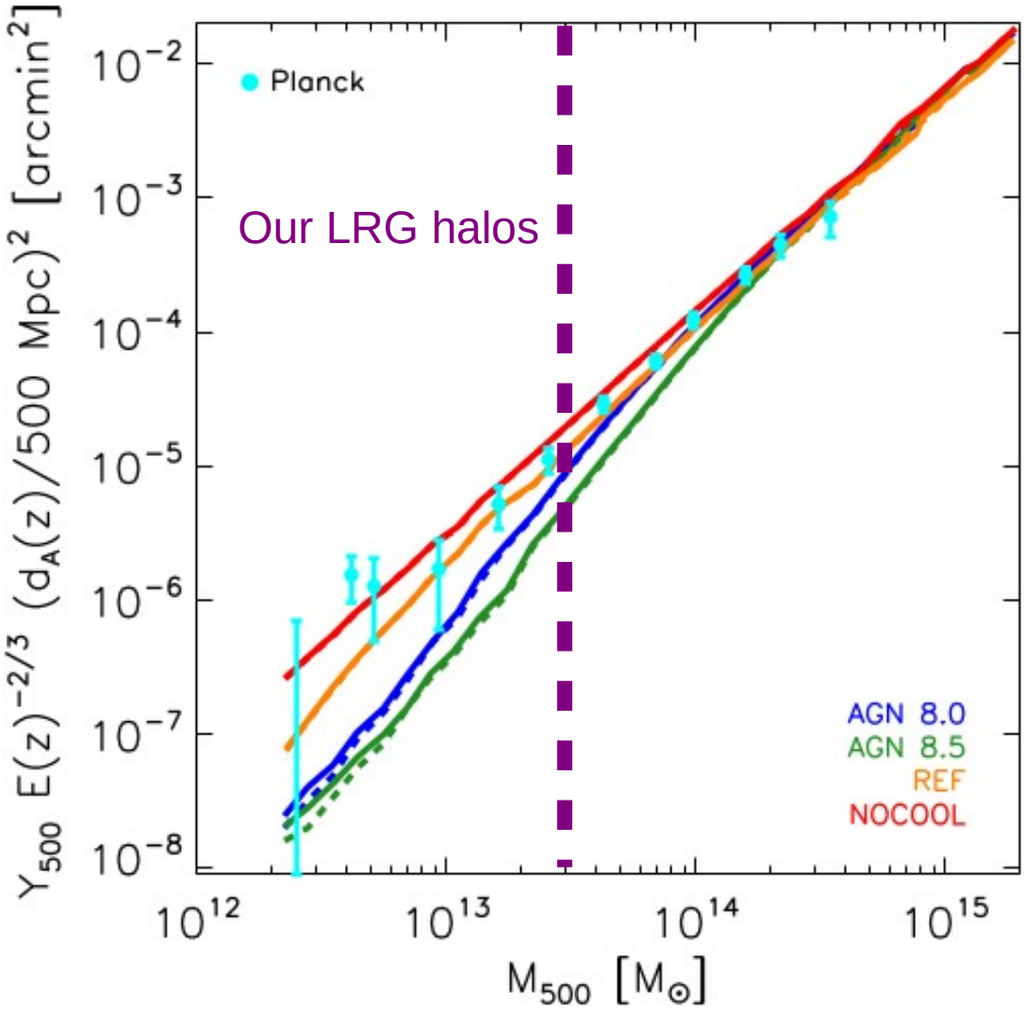
Halo mass is estimated
using the WL-based stellar-to-halo mass relation.
C15: Coupon et al. (2015)
W16: Wang et al. (2016)

The Universal Pressure Profile (UPP) is
measured with galaxy clusters ($10^{14.4}$-$10^{15.3}$ M⊙)
in Planck intermediate results V (2013).
The UPP is scaled down to LRG halos (3×10^{13} M⊙)
with the self-similar relation.

The data agree well with predictions using the UPP, scaled with the self-similar relation.

Interpretation

* Data agree with model prediction using UPP, scaled with self-similar relation.
  → It suggests no deviation from the self-similar relation.
* Data agree with AGN 8.0 model of the cosmo-OWLS simulations.
  → It suggests a deviation from the self-similar relation.



Le Brun et al 2015.

The deviation starts to appear below $5*10^{13}$ Msun,
Which is about the average mass of the LRG halos.

The angular resolution of the Planck y-map is 10’,
while the average angular size of the LRG halos is ~5’.

→ Need better sensitivity to probe lower-mass haloes
as well as higher angular resolution

Summary

- We detected a significant SZ signal at ~17σ around the LRG halos (M500~$10^{13.5}$Msun) out to ~30', well beyond the extent of the 10' beam of the Planck SZ map.

- We compared our measured SZ profile with Cosmo-OWLS simulations with different AGN feedback models. Our measurement agrees best with the AGN 8.0 model, but not without it (REF) or bursty AGN model (AGN 8.7).
  → It suggests a deviation from the self-similar relation.

- We compared our measured SZ profile with predictions using the UPP and halo model. Our measurement agrees with predictions using the UPP scaled with self-similar relation.
  → It suggests no deviation from the self-similar relation.

But the deviation is minor at M500~$10^{13.5}$Msun based on Cosmo-OWLS simulations, and we need a further study with lower-mass halos to confirm it.