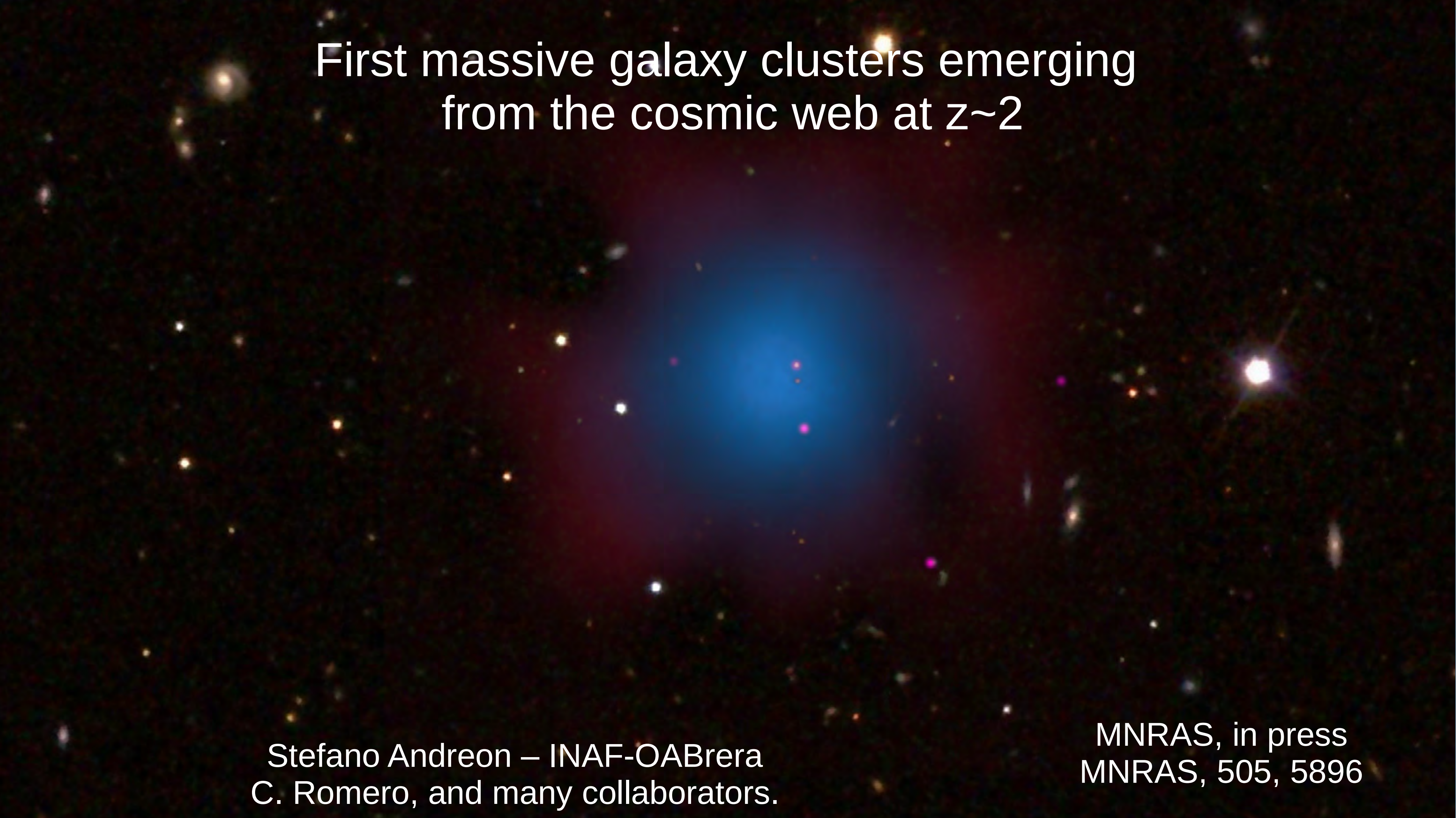
First massive galaxy clusters emerging from the cosmic web at z~2



Stefano Andreon – INAF-OABrera
C. Romero, and many collaborators.

MNRAS, in press
MNRAS, 505, 5896

Outline

- Introduction
  - Focus on the cluster growth and pressure evolution in the last 10 Gyr
  - Similarity of pressure profiles at z=0
  - Pressure profile determination from SZ data
- JKCS041 (z=1.803) and IDCSJ1426 (z=1.75)
  - JKCS041 is extremely faint, also for its mass
  - Both are just emerging from the cosmic web
- Perspectives

Why galaxy clusters?

- Cosmology: the comparison of the observed and predicted abundance of clusters as f(M,z) allows us to infer cosmological parameters (counts have an exponential sensitivity to some cosmological parameters)
- Astrophysics: interesting laboratories, the physics of processing going on in the ICM

Two stage cluster growth

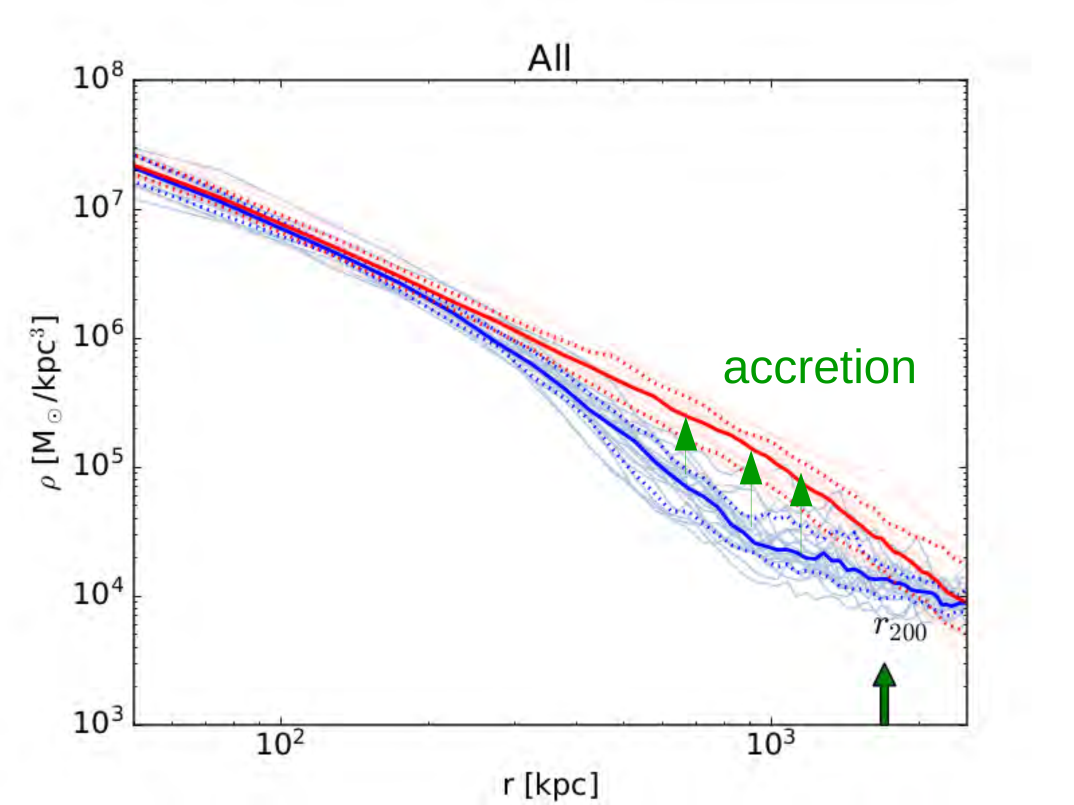
the core sets early, the remaining part grows later, mostly from the cosmic web (not spherical infall)

Outer regions == last to come

Magneticum (i.e. with full gas physics), 25 most massive clusters at z=1.71

Light curves: individual objects
Solid and dotted: mean and std

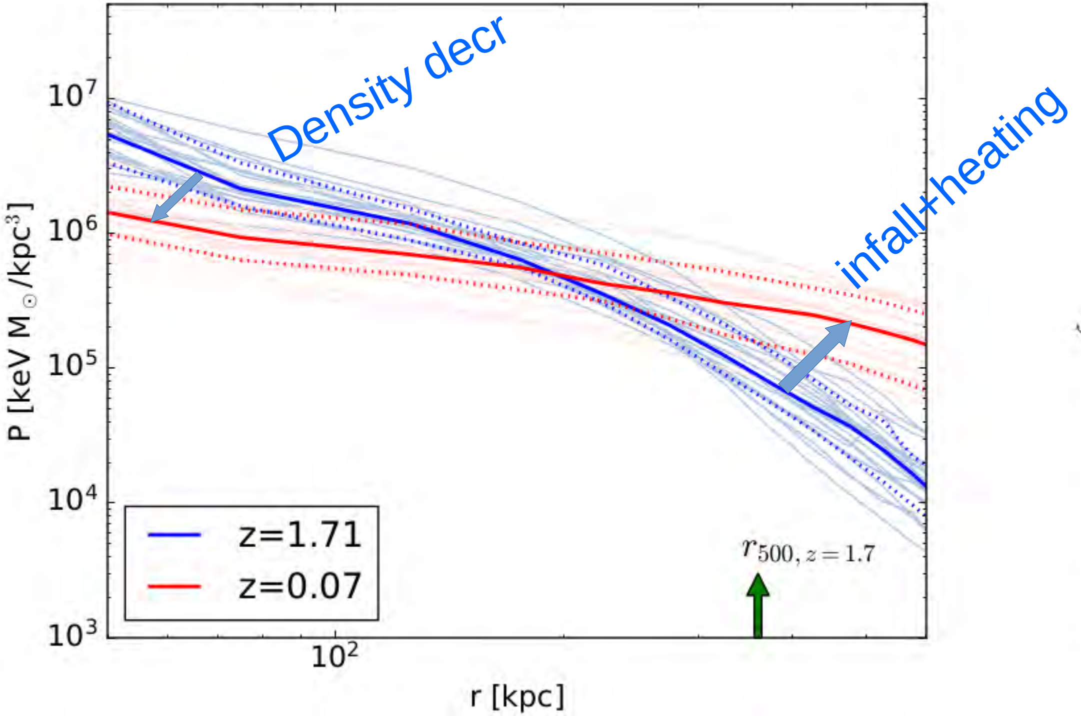
SA+21



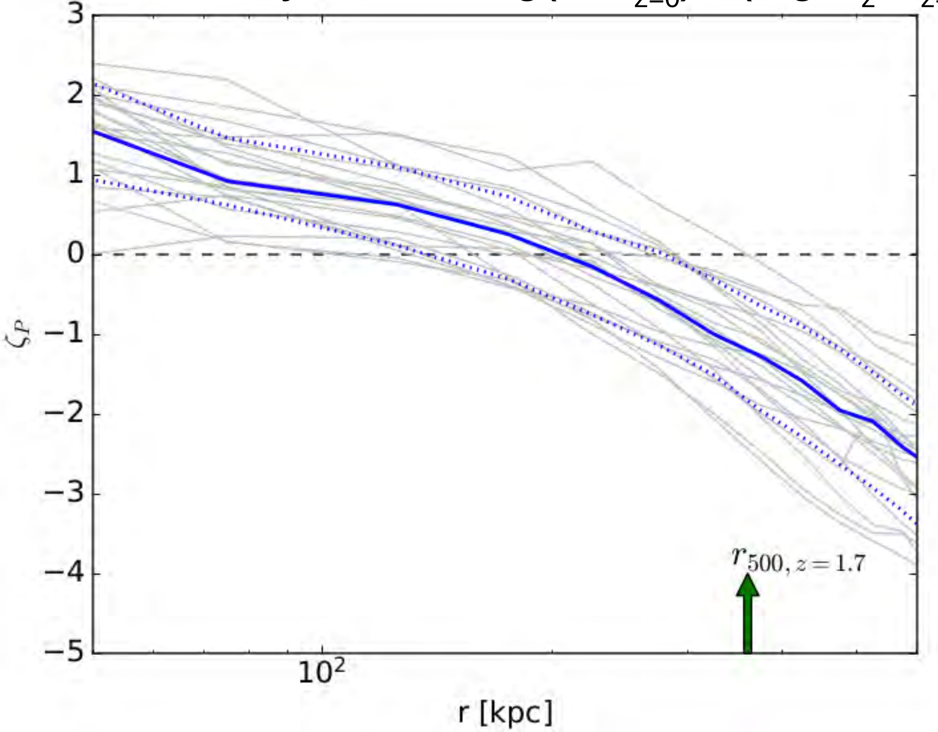
In Magneticum simulations, at z=1.7 clusters have central parts with larger P and outer regions with lower P

(SA+21)

Pressure=ρ*T

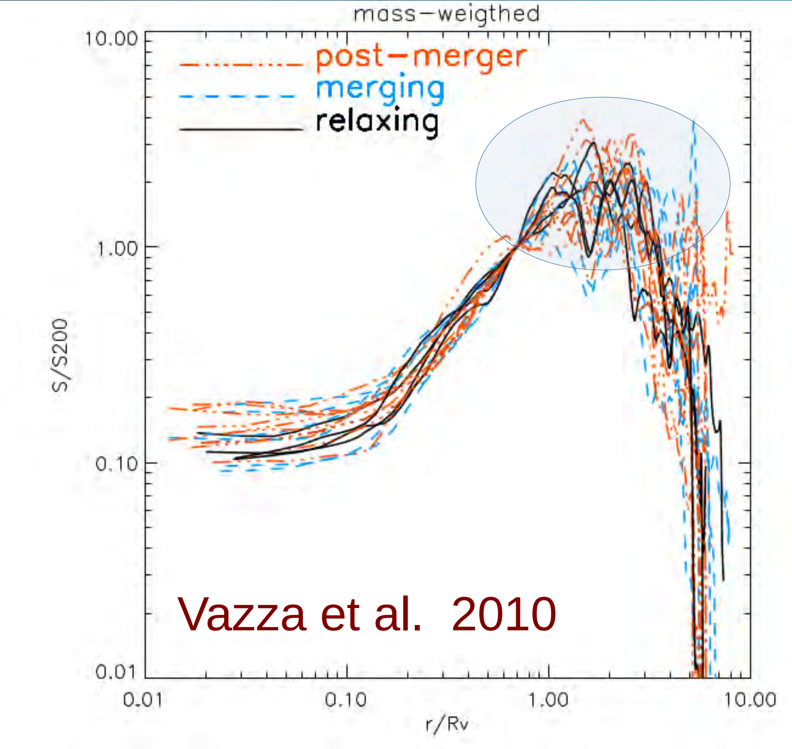


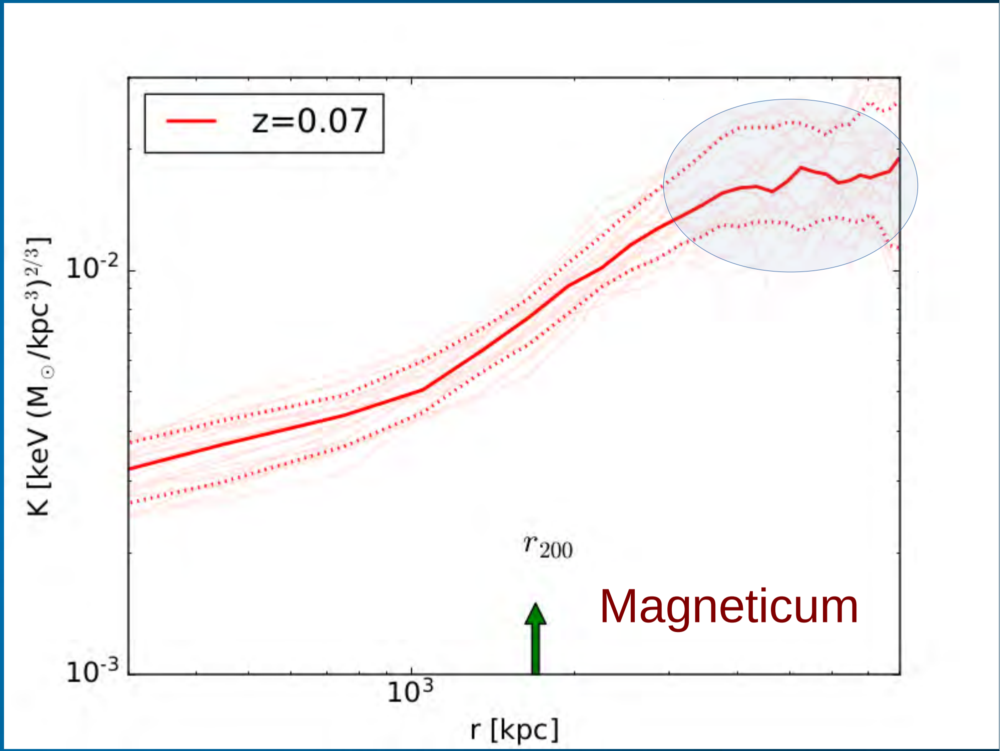
Evolutionary rate $\zeta = \log(P/P_{z=0}) / (\log E_z/E_{z=0})$



Simulations differ in detail (e.g. entropy flattening not at the same radius)

$S==K=P/n_e^{5/3}$





Redshift ~2 is the key epoch

because we expect that at this epoch clusters start to emerge from the cosmic web and because feedback from AGN and SF is maximal (peak there!)

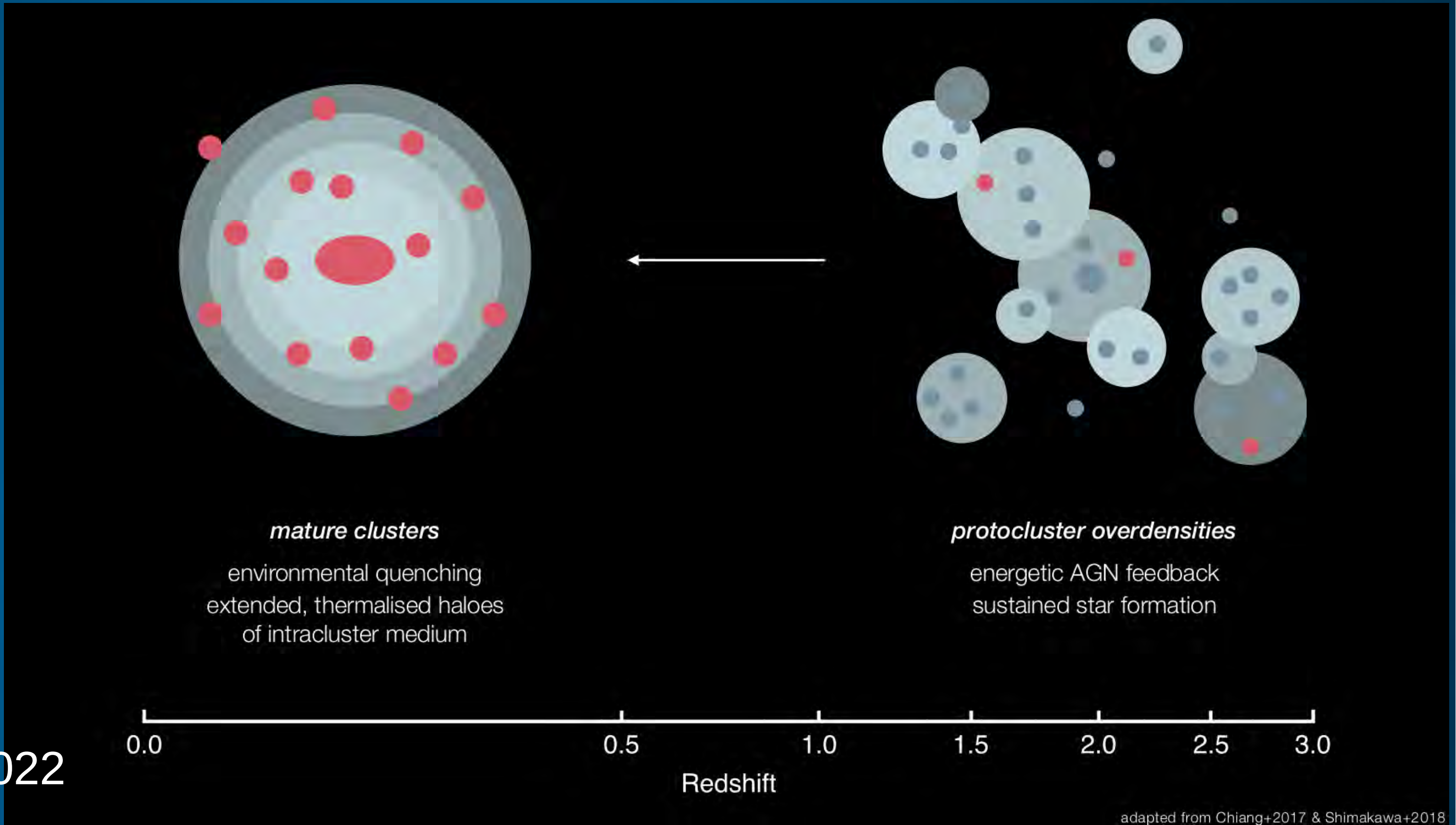


Figure credit: Di Mascolo 2022

Yet, z~2 is observationally almost un-sampled

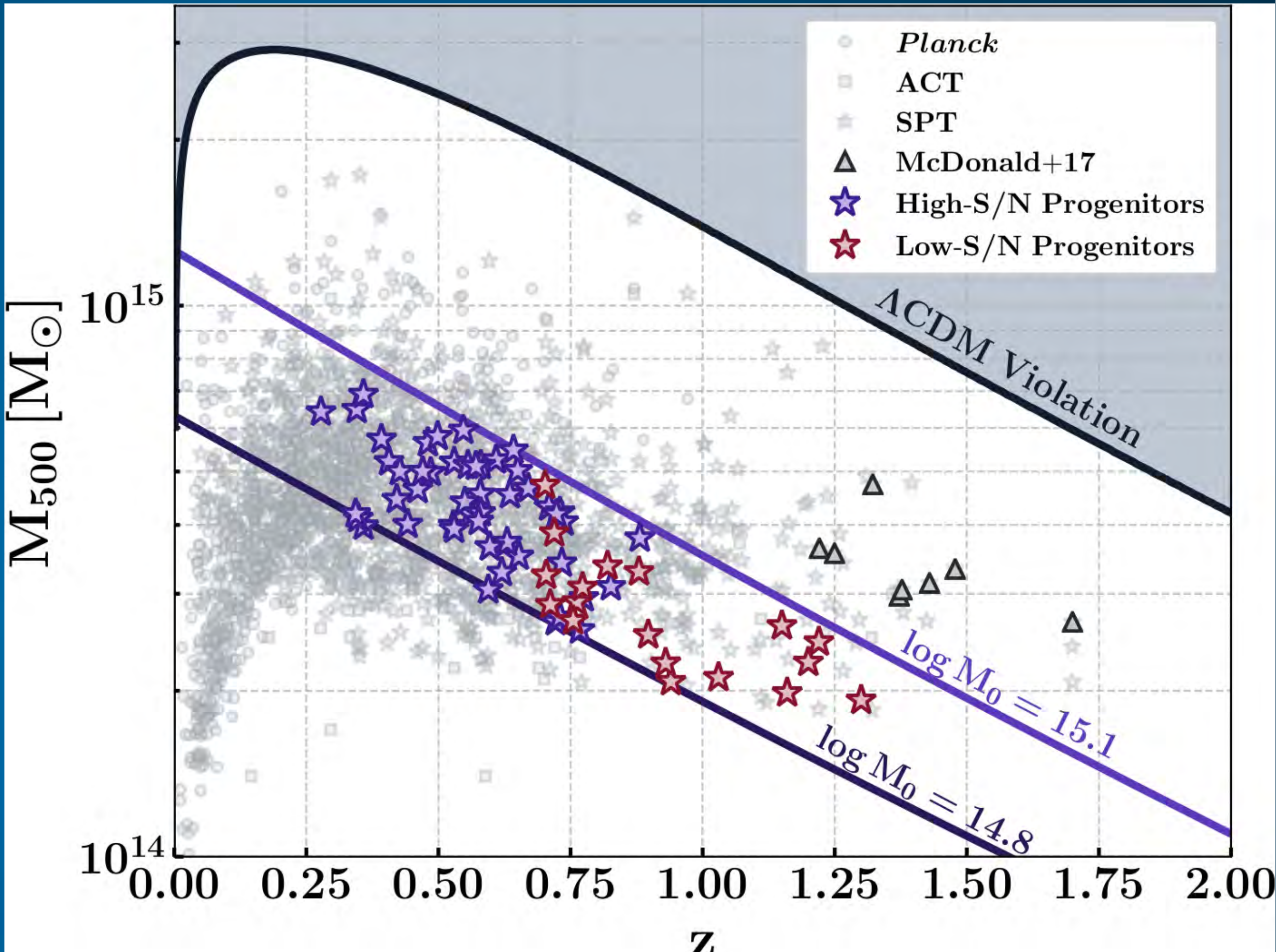
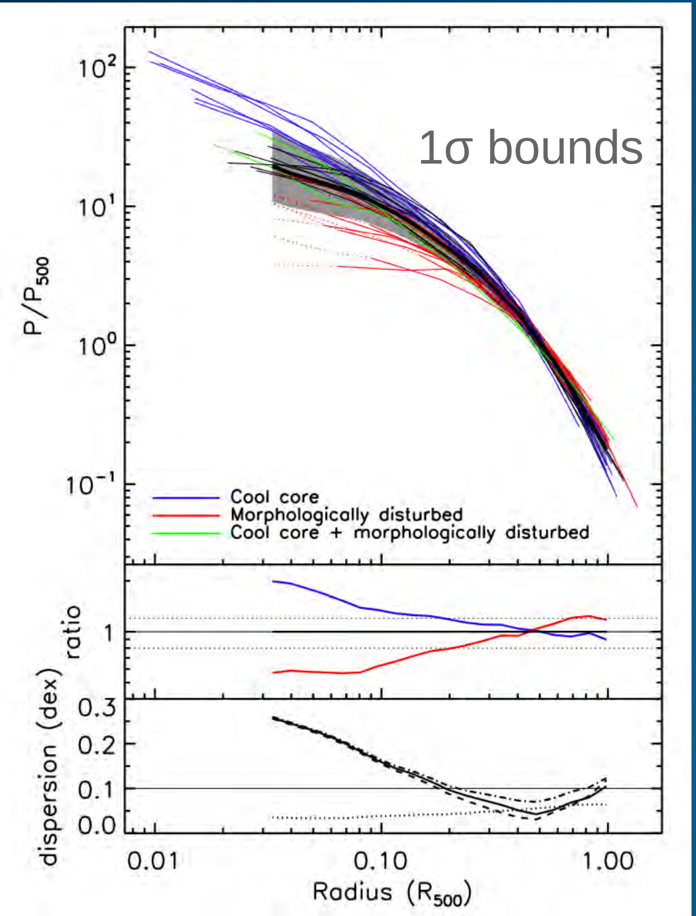


Figure credit: F. Ruppin webpage

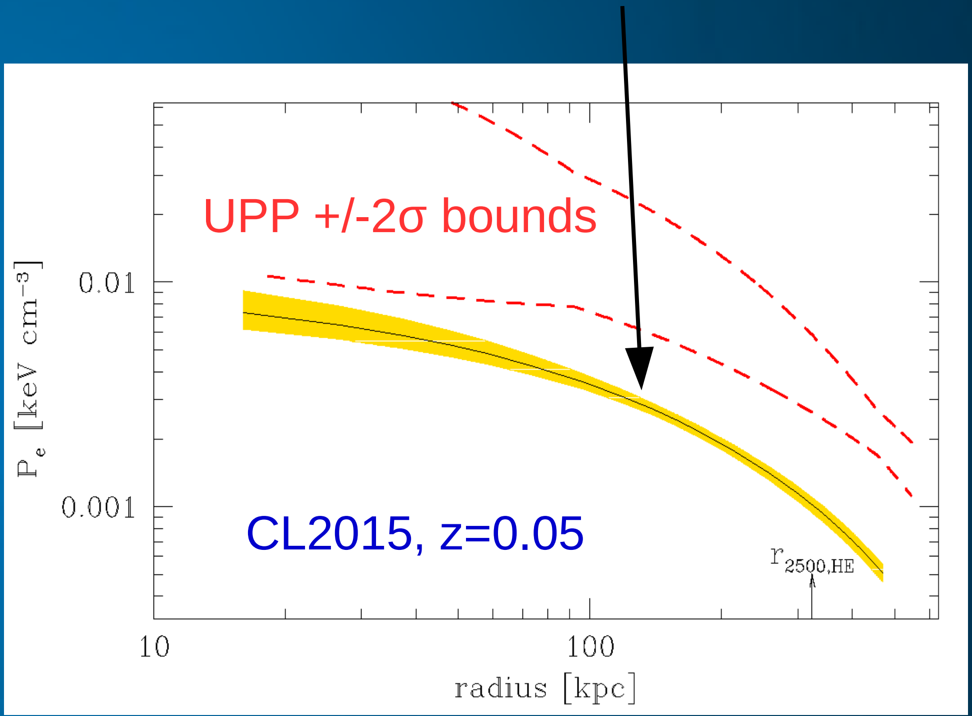
At low z: low scatter around the Universal Pressure Profile

Arnaud et al. 2010



exploited to detect clusters in SZ surveys or to estimate cluster mass from them.

Outliers start to be found (SA et al. 2016, 2017a, 2017b, 2019)



y is a quasi-direct measurement of P

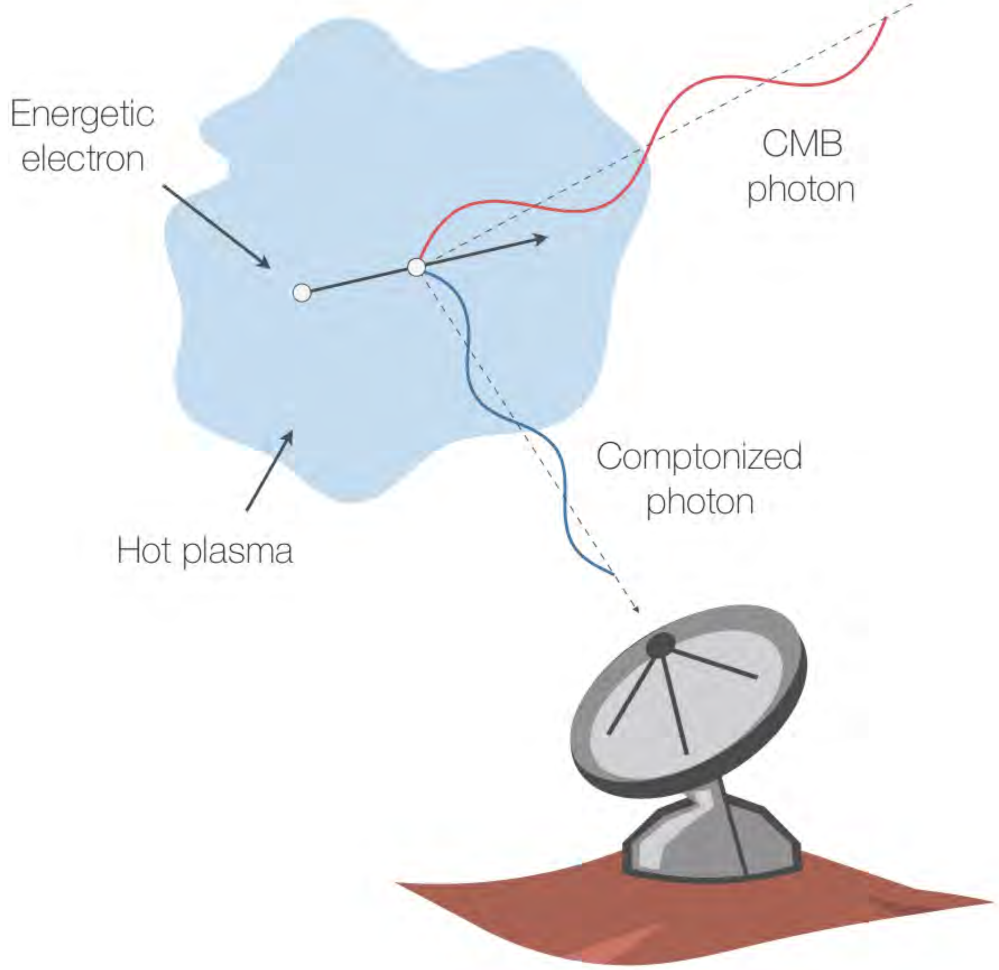


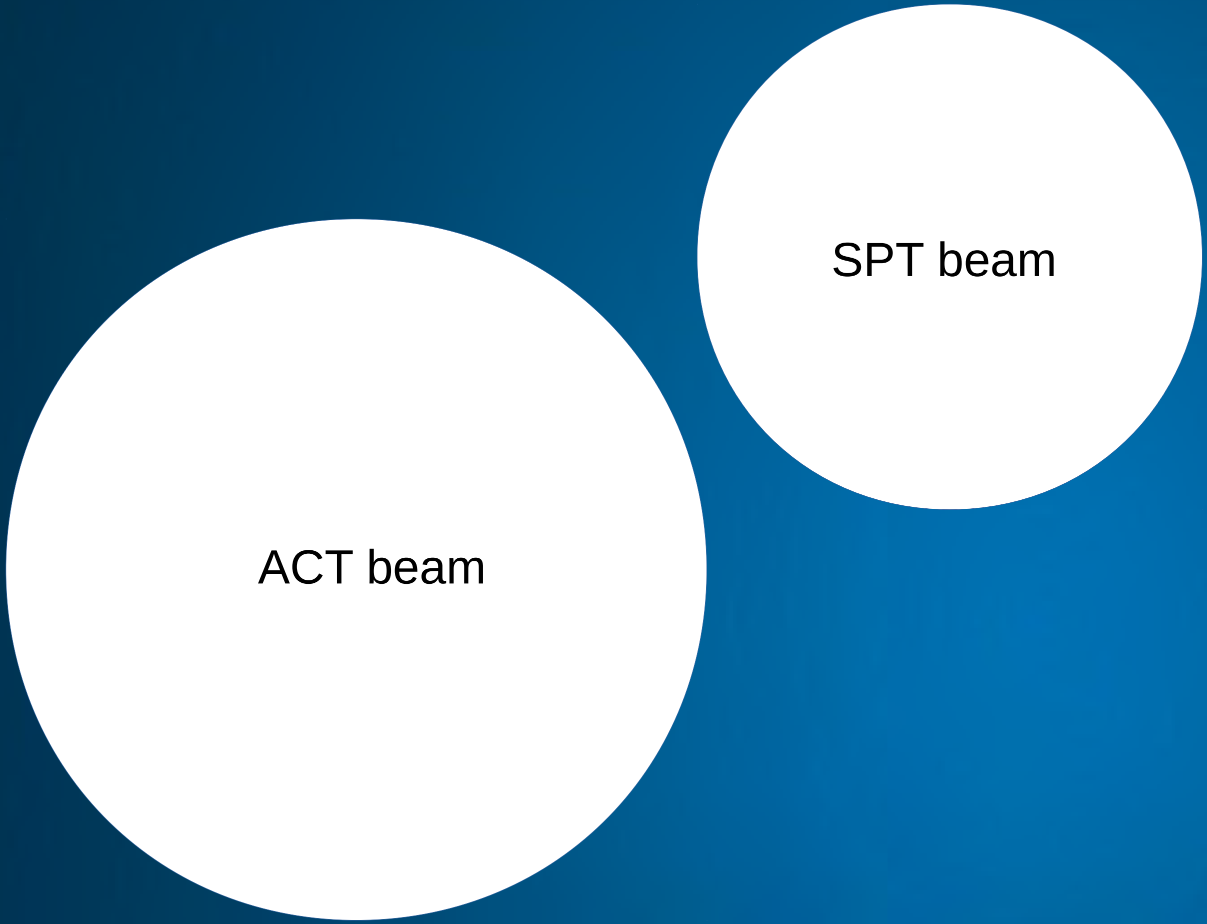
Figure credit: Mroczkowski 2019

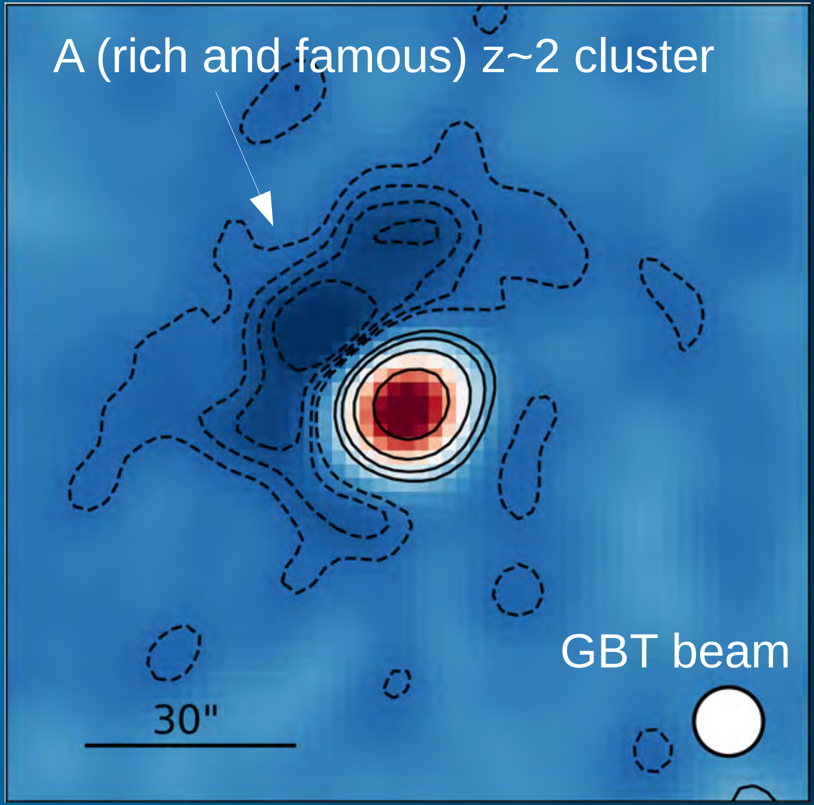
Not subject to cosmological dimming → hi-z accessible

$$y \propto \int n_e T_e \partial\ell$$

P_e

SZ is wonderful, but … sizes





JKCS041

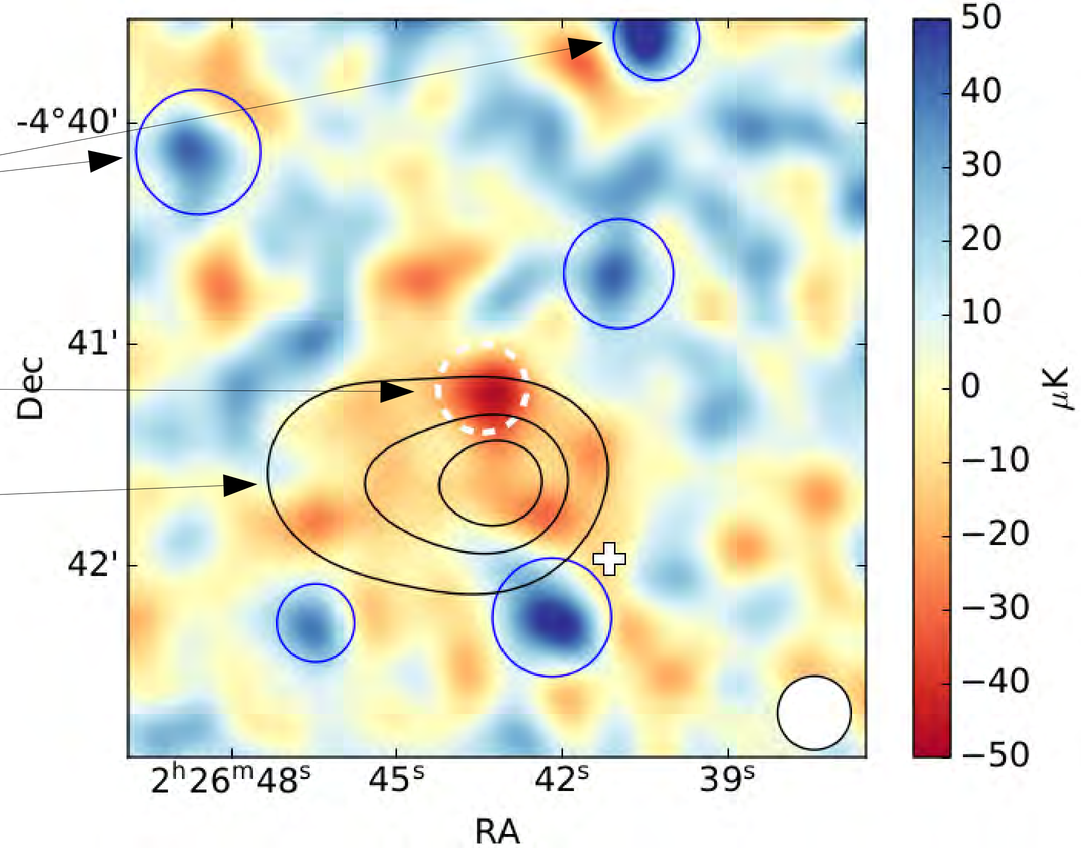
z=1.803, $M_{200,wl}$~4.7 10^{14} M_{sol}, massive at this z (Kim+23)

28h GBT Mustang2 integration

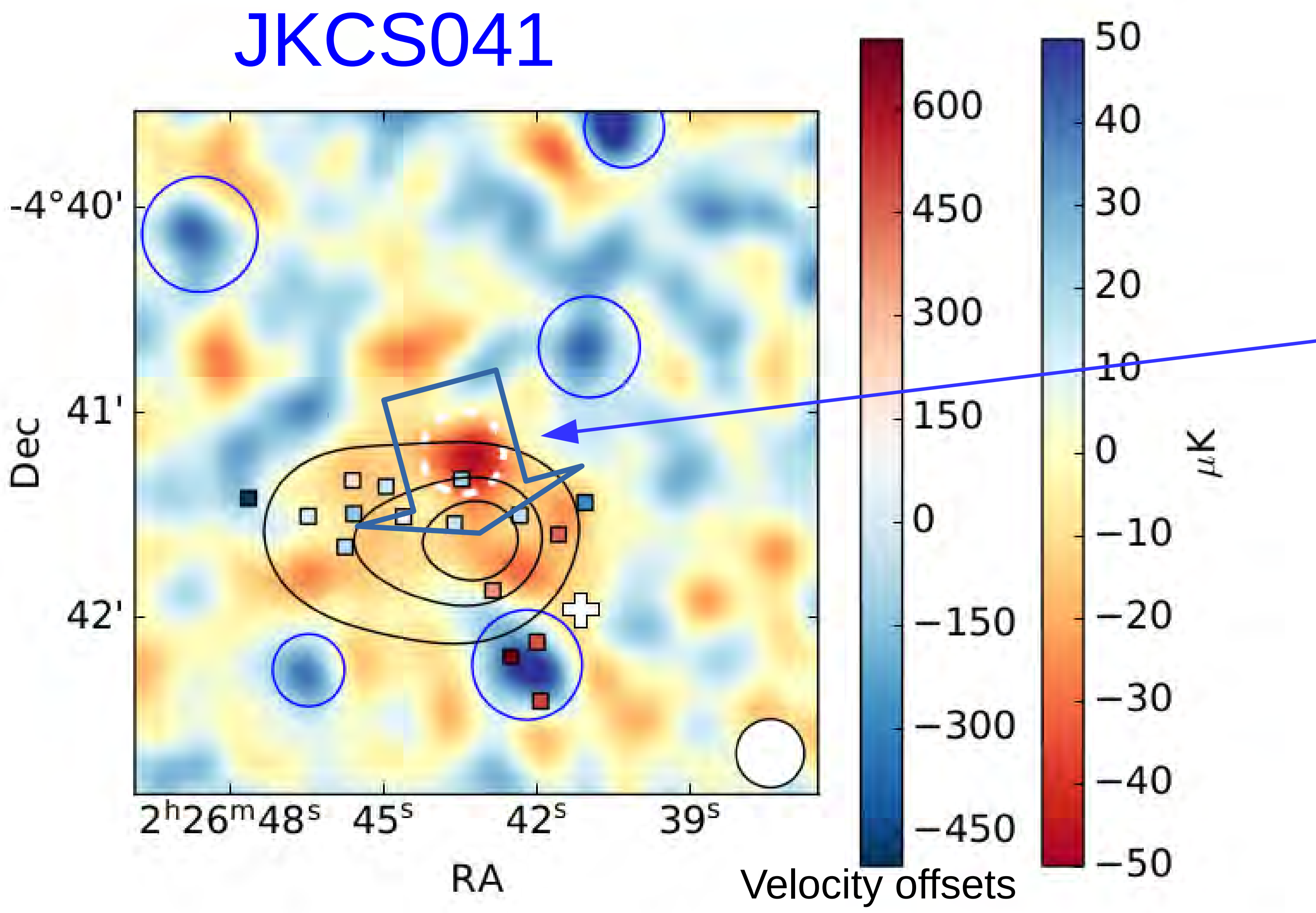
mm point sources

SZ (negative) peak

Chandra X-ray contours



26 arcsec, 220 kpc, SZ X-ray offset
First indication of a major merger



Major merger of two massive sub-clusters

Direction of the SZ-X-ray offset and of the galaxy velocity gradient

Spatial offset (220 kpc) gives time after pericentric passage (~0.5 Gyr, Zhang et al. 2014). Tailored simulations being analysed -> merging of 1 and 2 10^{14} M_{sun} (Felix et al, in prep).

IDCS J1427.5+3508

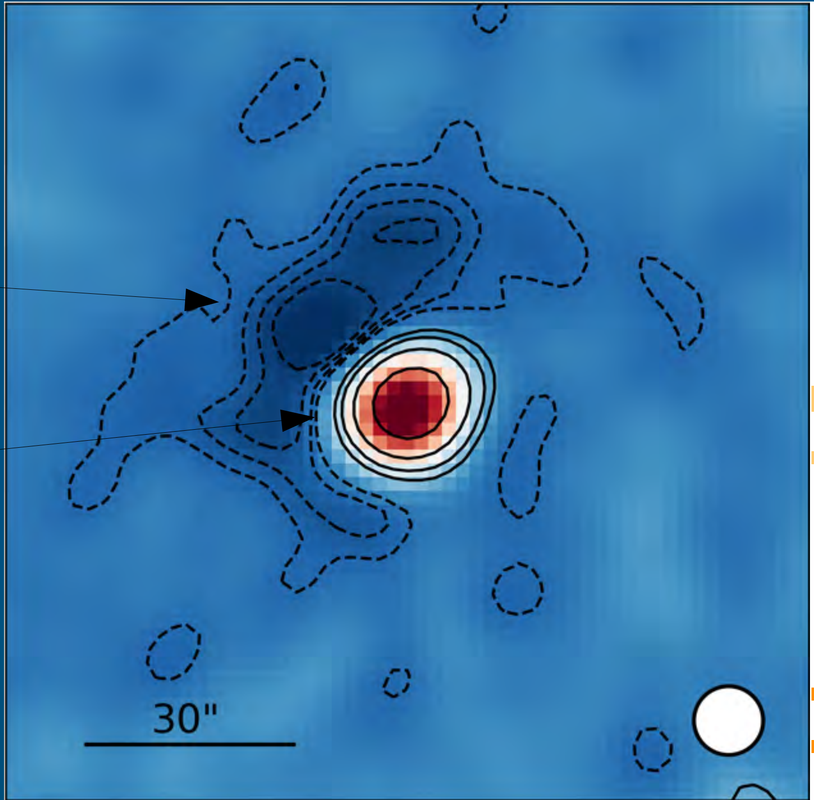
z=1.75, $M_{200,wl}$~2.2 10^{14} M_{sol}, massive at this z (Jee+17)

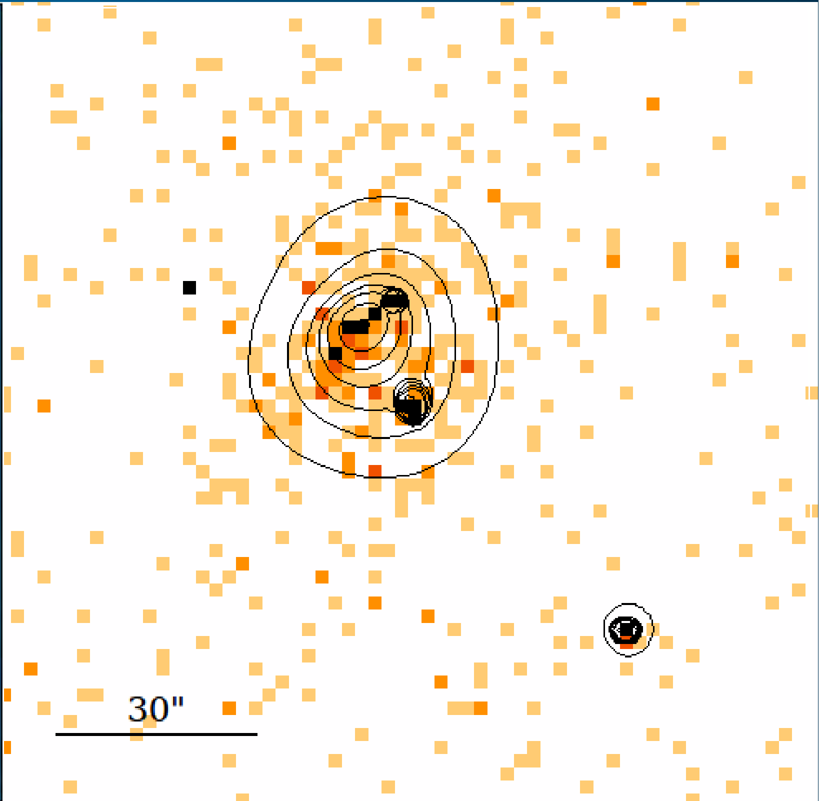
Mustang2@GBT

Chandra

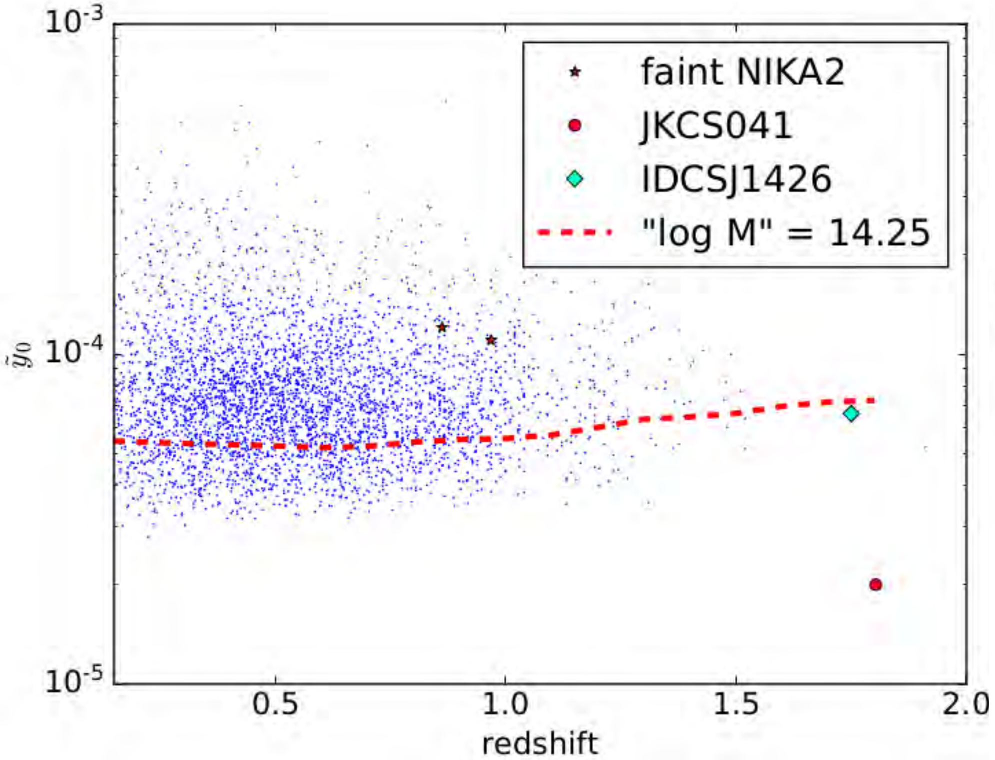
SZ (negative) emission

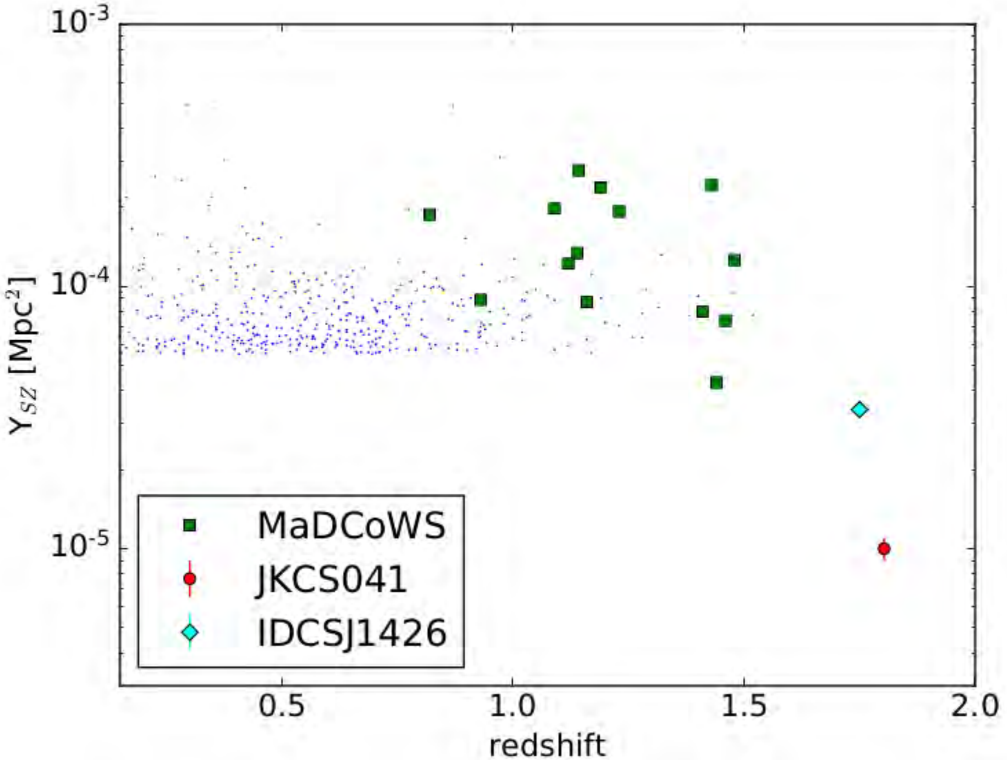
mm point source





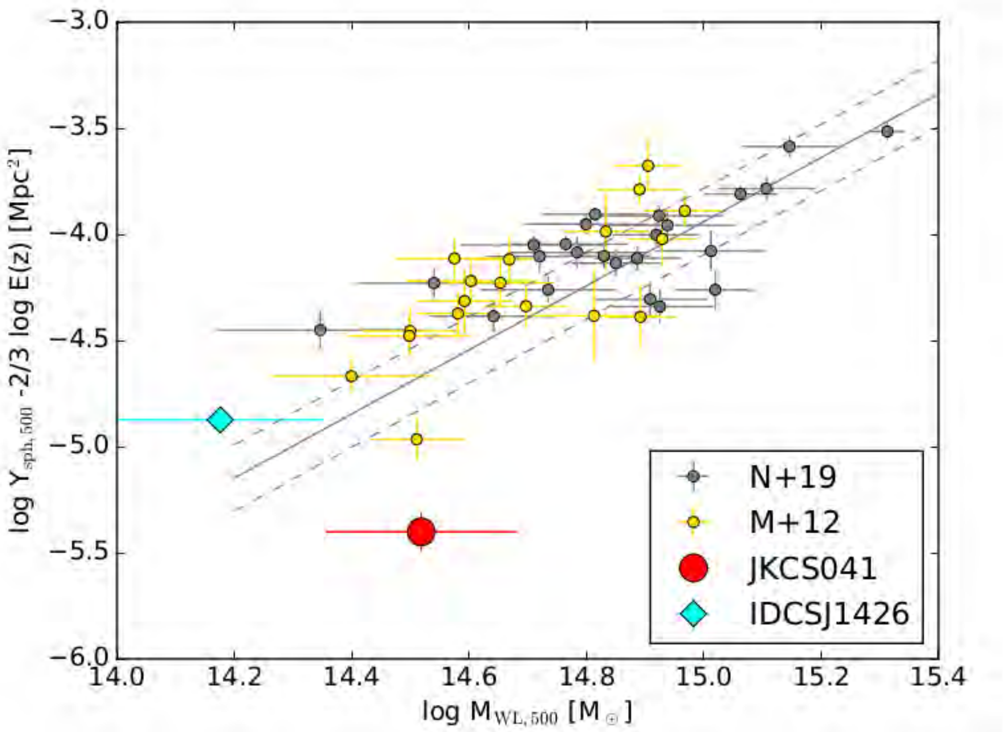
JKCS041 is very faint



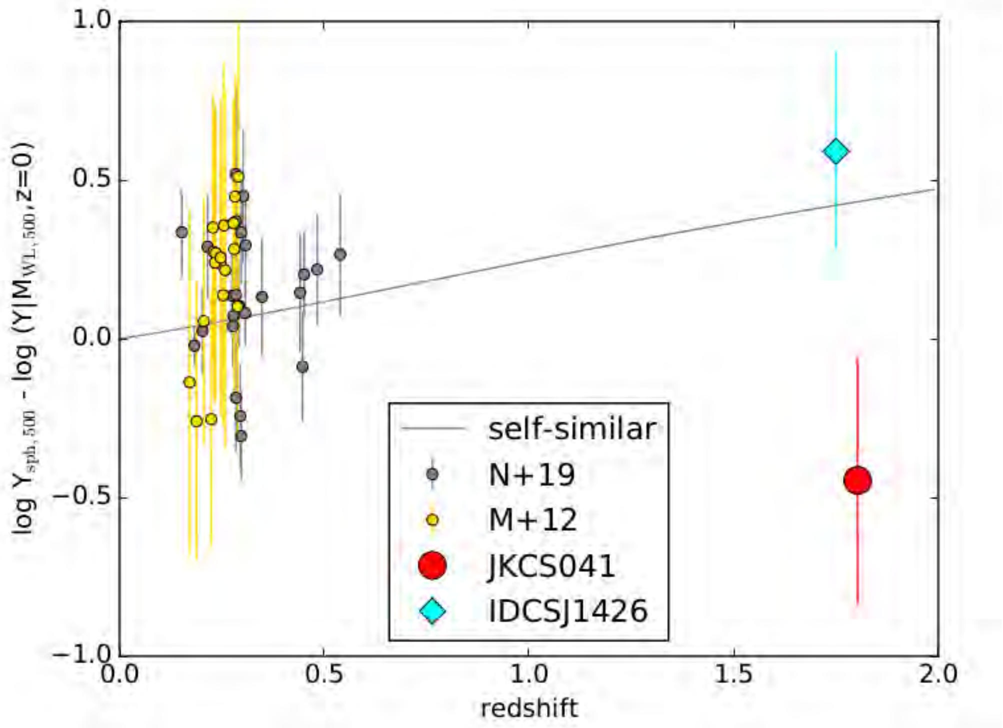


Faint != less massive (i.e. Y_{SZ} !=mass)

During major merger expected down-scatter (Wik+08, Krause+12); hi-z is a period of enhanced merger activity -> we expect many massive clusters to be SZ-weak



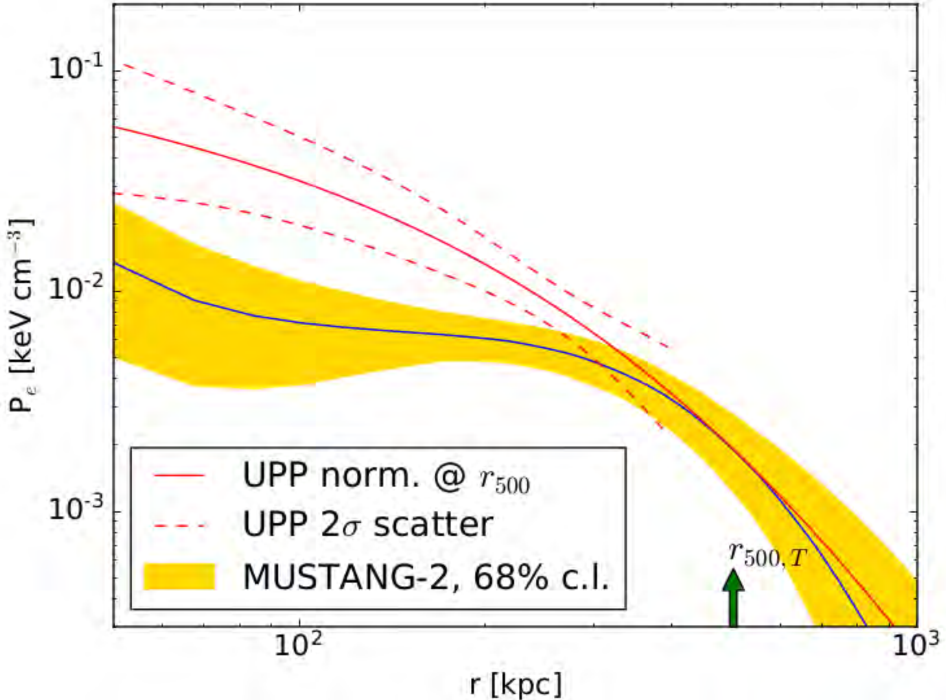
Evolution



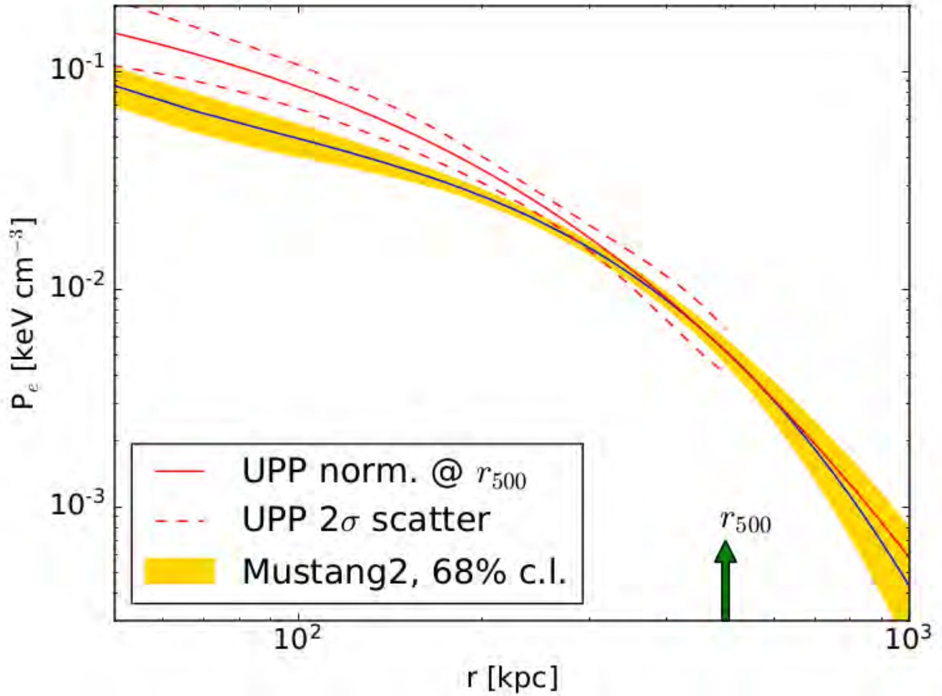
Depressed (for the today standard) pressure profiles

relevant for cosmology (affect detectability and mass estimate) and astrophysics (next slides).

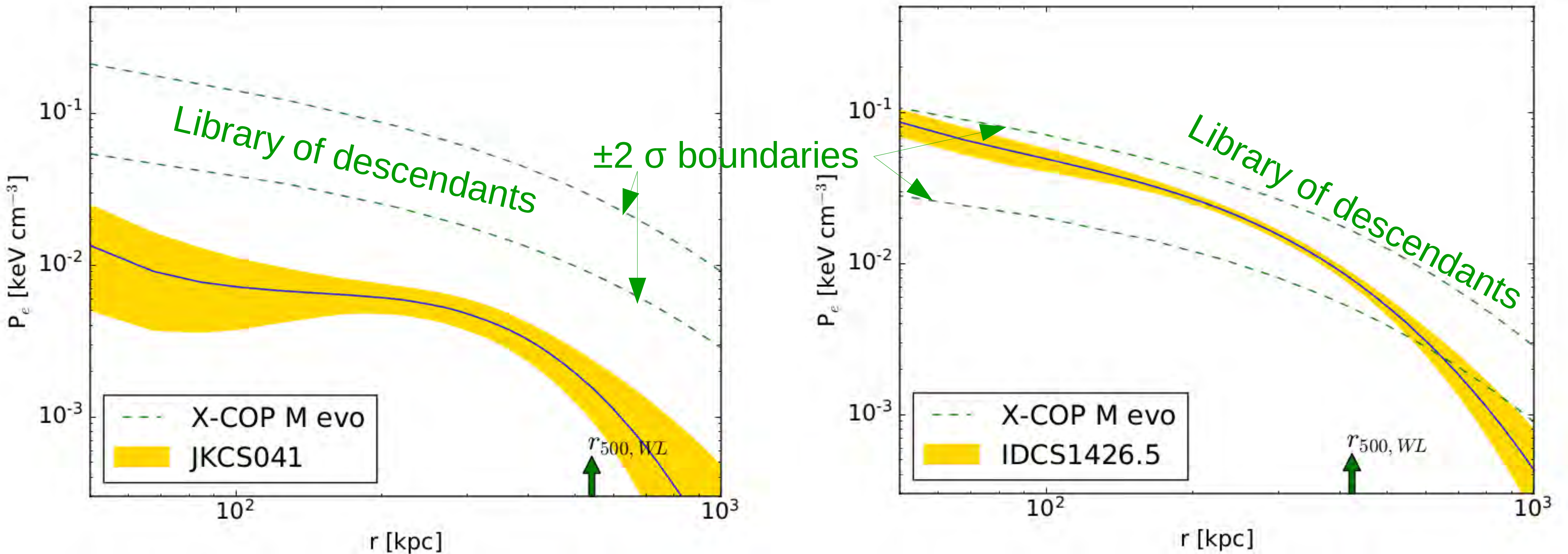
JKCS041, z=1.803



IDCSJ1426, z=1.75 (SA+21)



Evolution

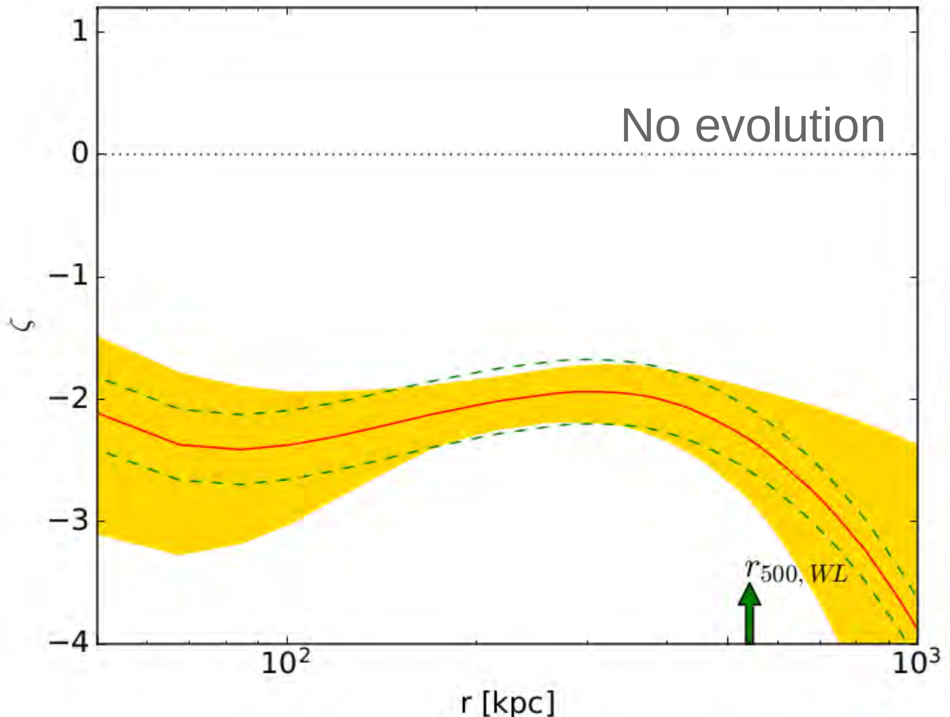

Library of descendants
±2 σ boundaries
Library of descendants
X-COP M evo
JKCS041
X-COP M evo
IDCS1426.5
$r_{500,\,WL}$
$r_{500,\,WL}$
P_e [keV cm^{-3}]
r [kpc]
10^{-1}
10^{-2}
10^{-3}
10^2
10^3

Evolution

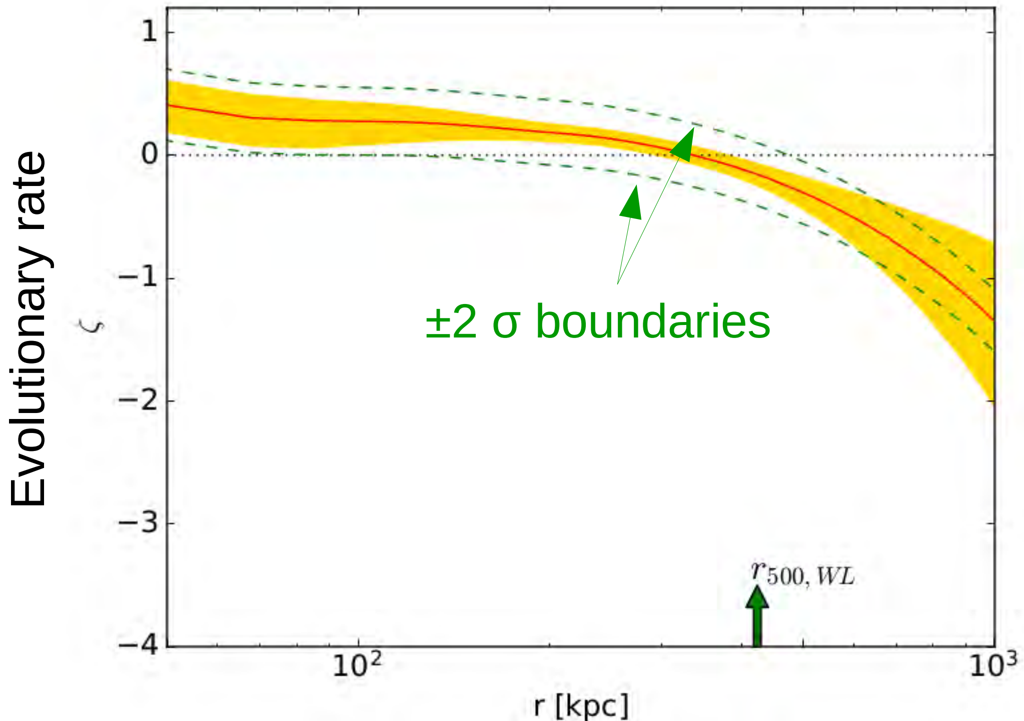
Dramatic evolution at all radii

Core in place, detailed constraints on evolution at other radii (SA+21 and SA+ in prep.)

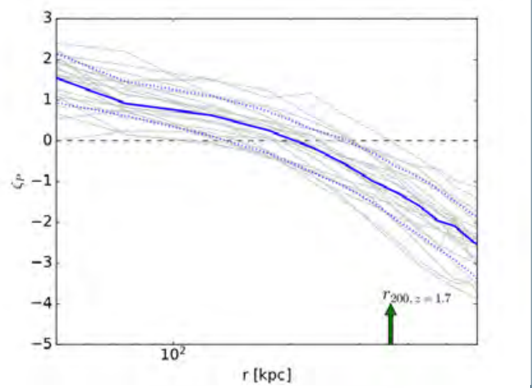
JKCS041, WL mass



IDCSJ1426, WL mass

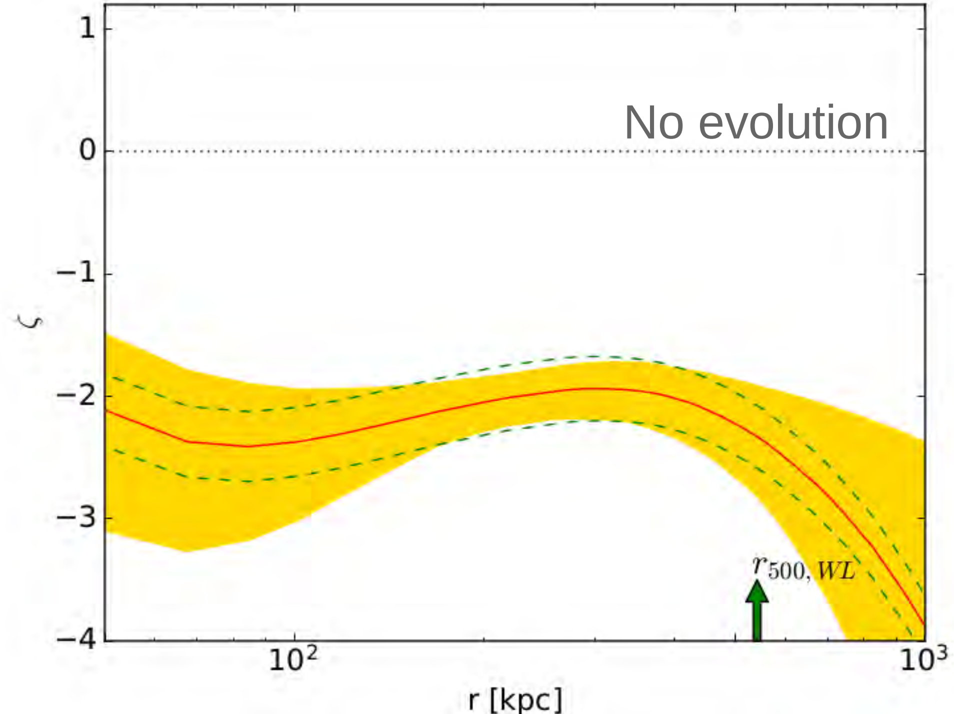


Simulations →



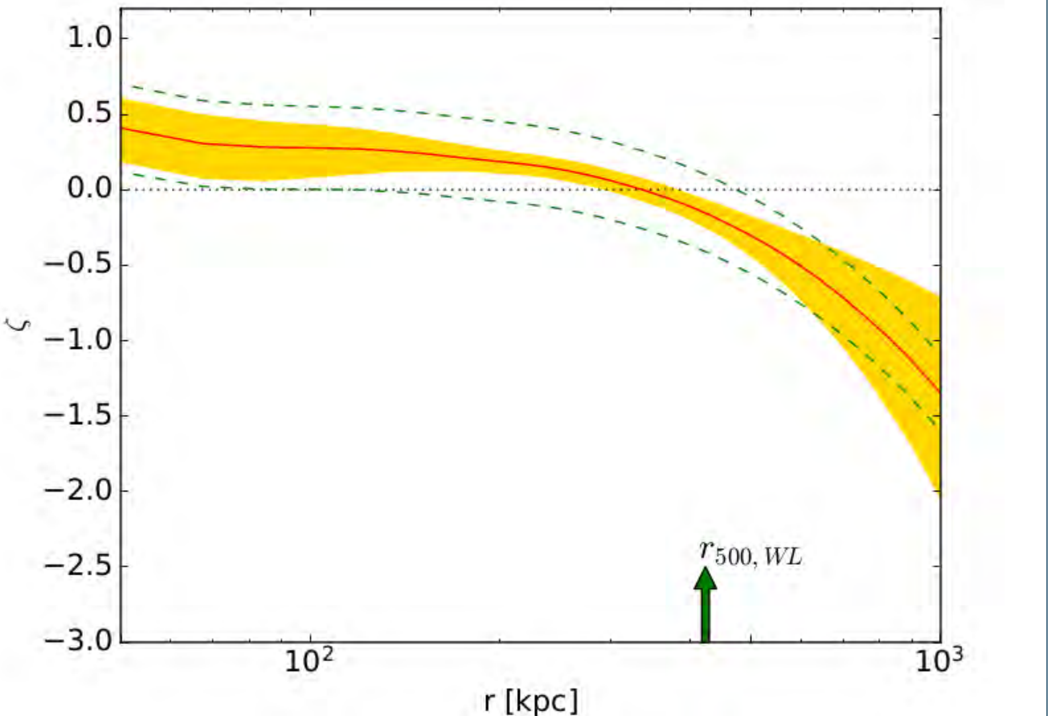
Tailored simulations being run (Felix et al., in prep)

JKCS041, WL mass



Evolutionary rate

IDCSJ1426, WL mass



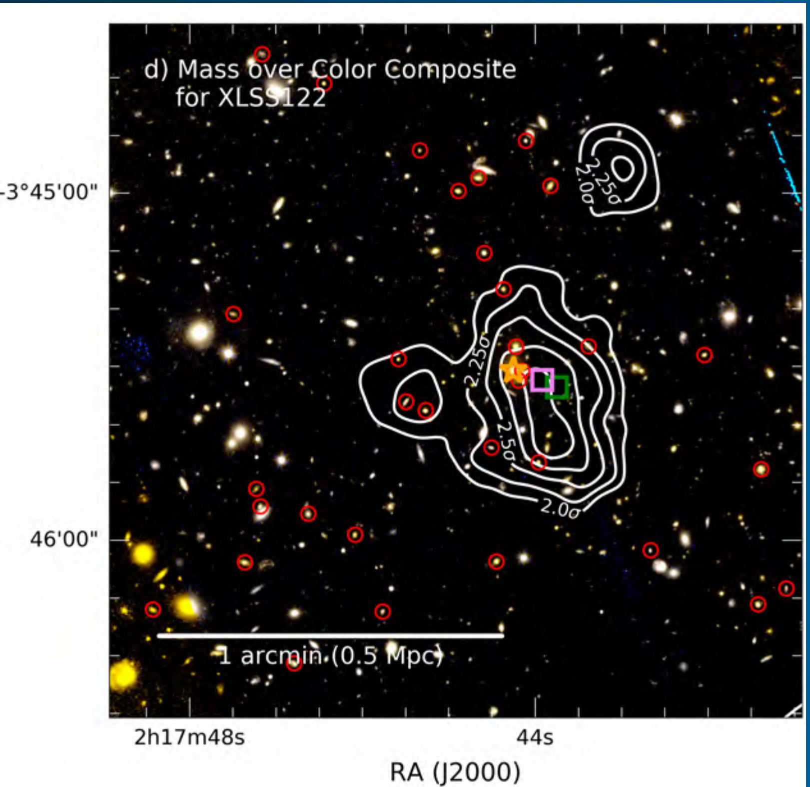
Summary:

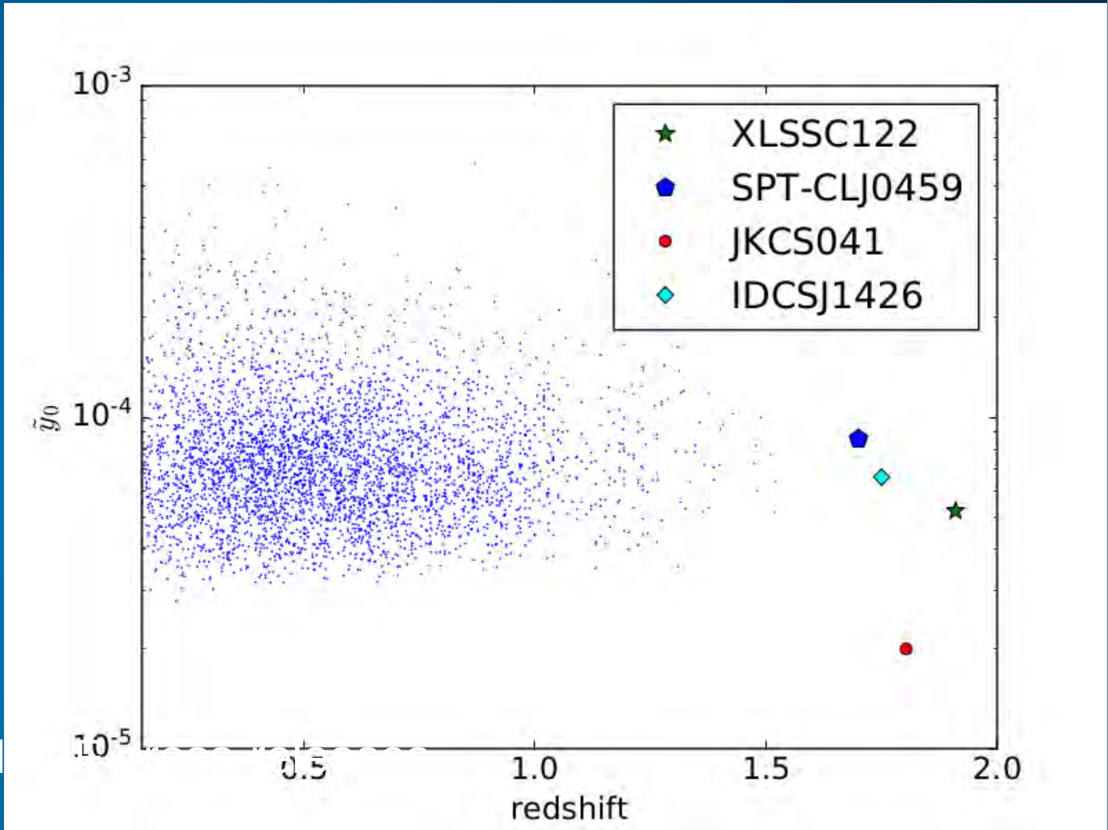
- IDCSJ1426: at small radii is close to (not so far from) the likely final status, is far at large radii
- JKCS041: far away from the final status at all radii because observed ~0.5 Gyr after a major merger of massive clusters. Not even the center (which one? X-ray or SZ?) is close to the end status.
- JKCS041 has low Y_{SZ} |M, enhanced scatter at z~2 expected (and Y_{SZ} is not M!)
- Two studied clusters, two different cases. Z~2 is a period of enhanced (AGN, SFR, cluster) variety!

Short-term perspectives: XLSSC122

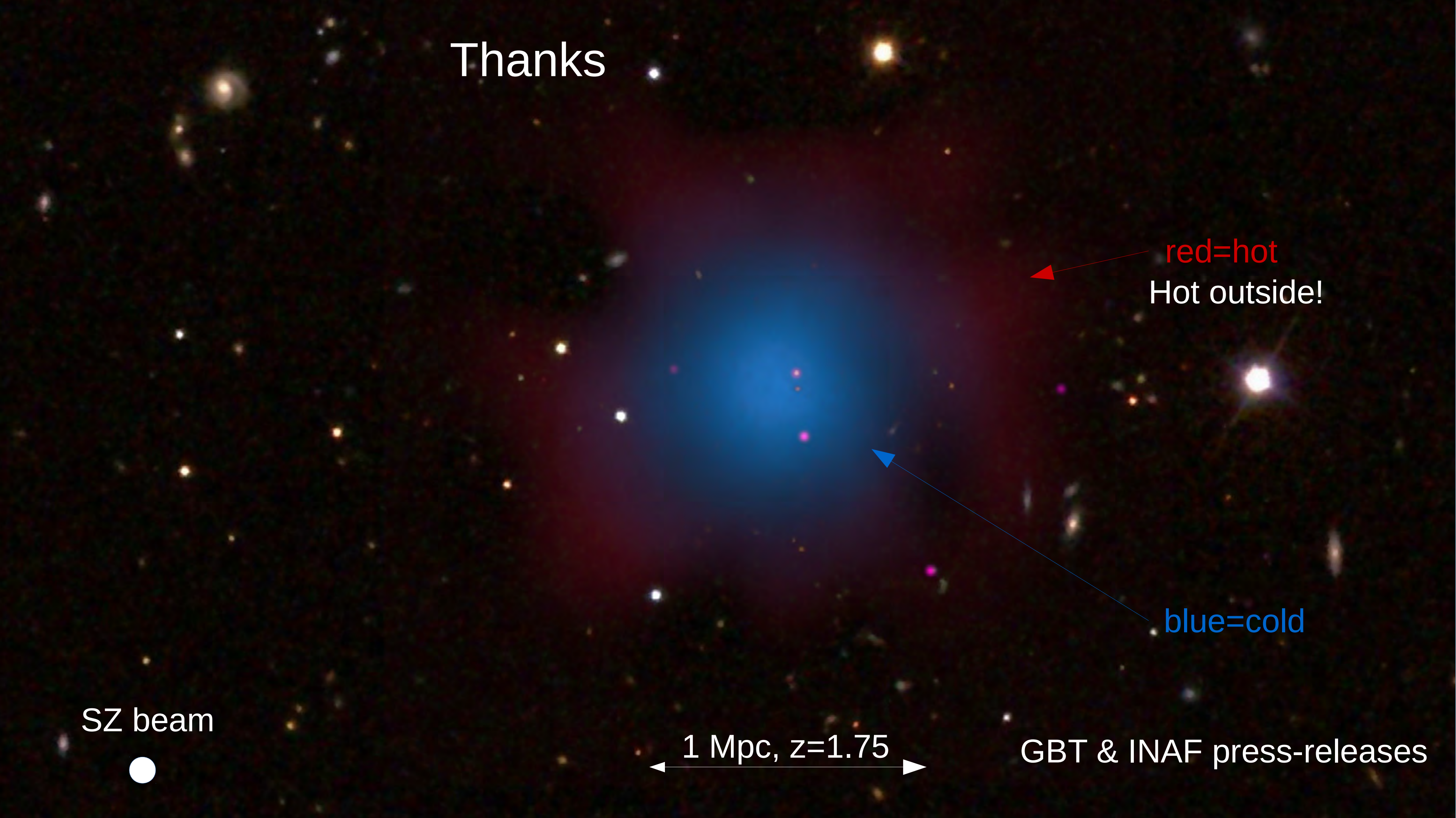
Another, z~2, example useful, if different from the two/three already available.

XLSSC122 (z=1.98). X-ray selected, compact; compared to JKCS041 has lower mass, yet larger Y. GBT proposal.





GBT & I


Thanks
red=hot
Hot outside!
blue=cold
SZ beam
1 Mpc, z=1.75
GBT & INAF press-releases