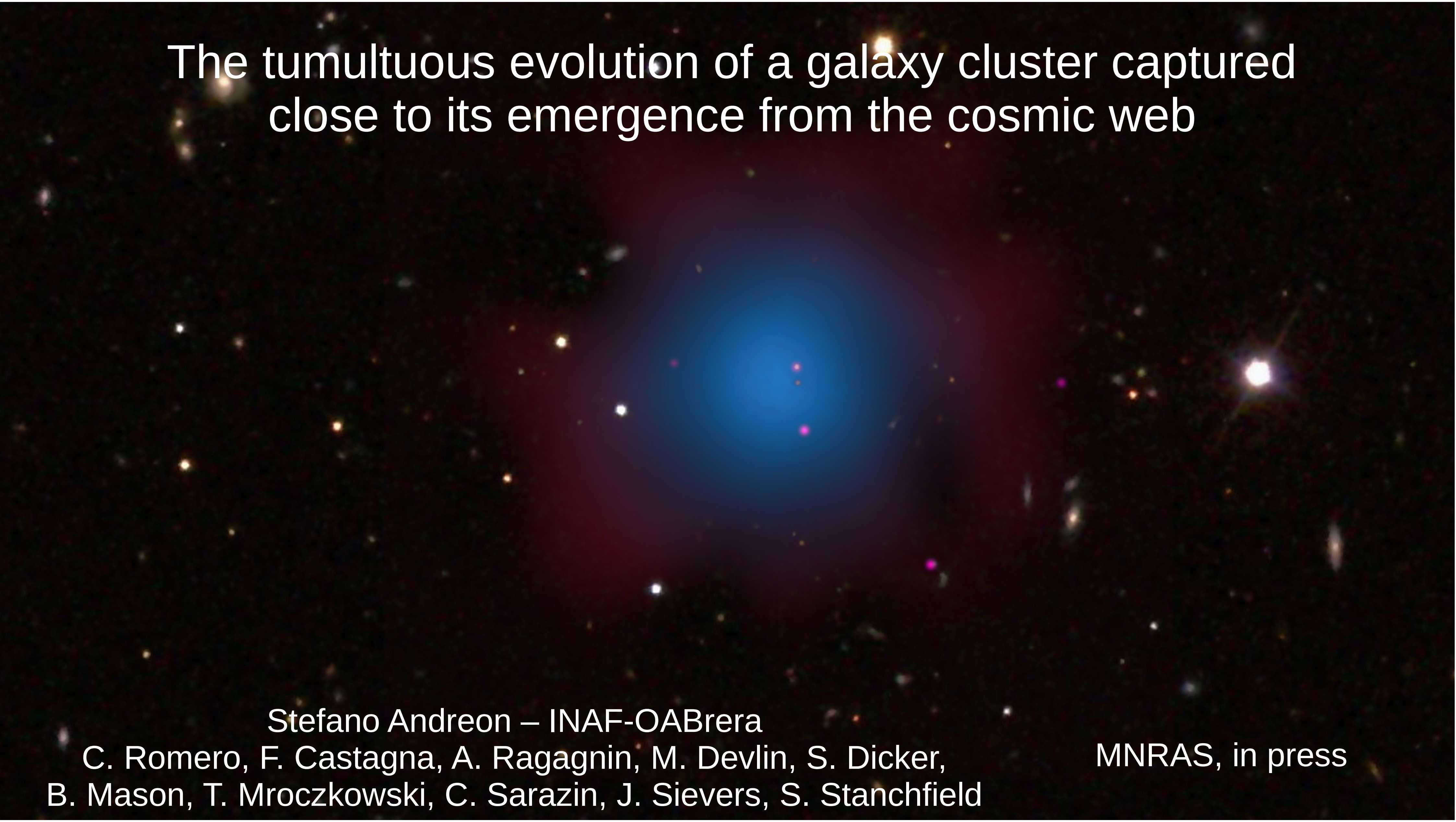
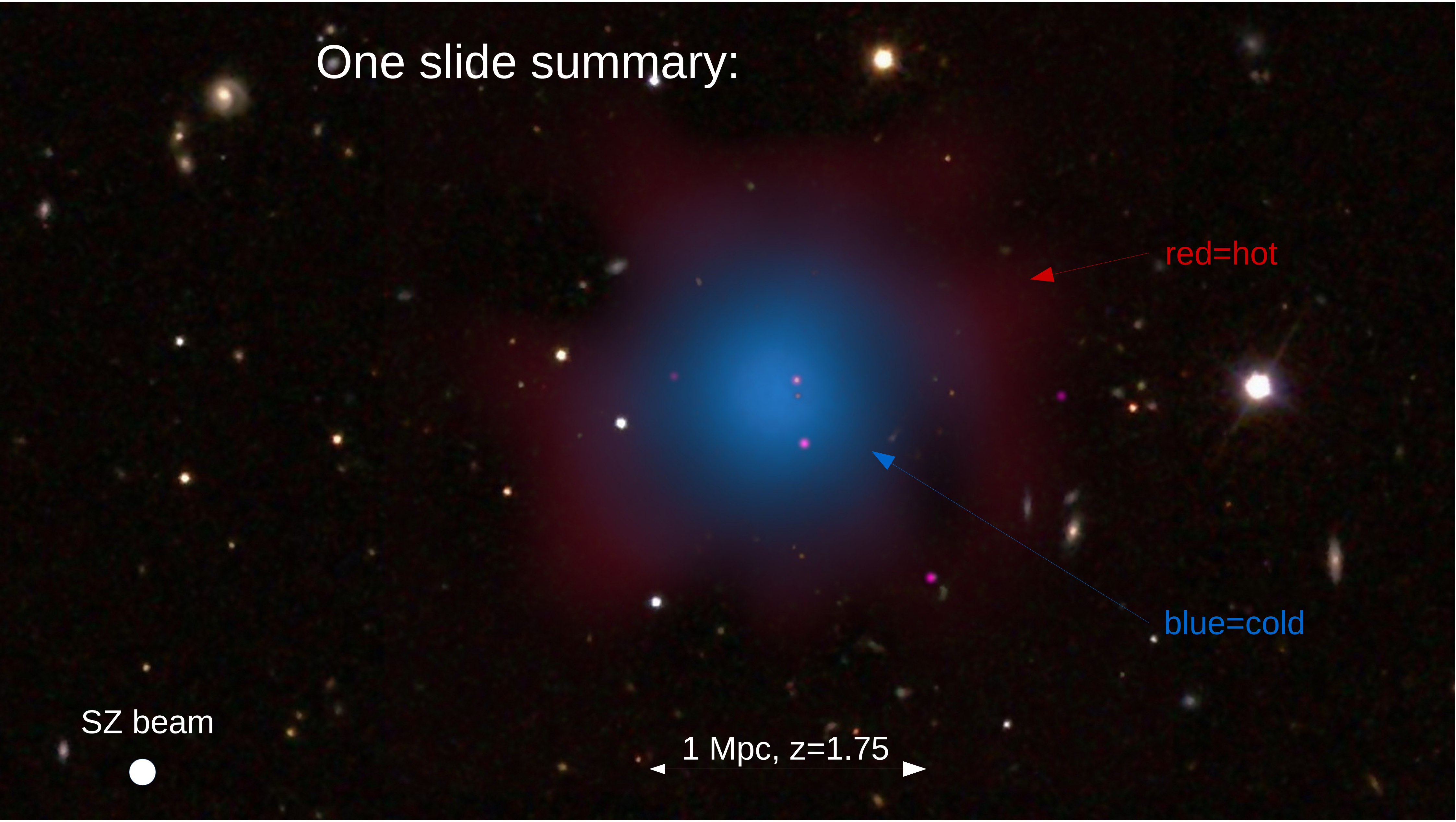
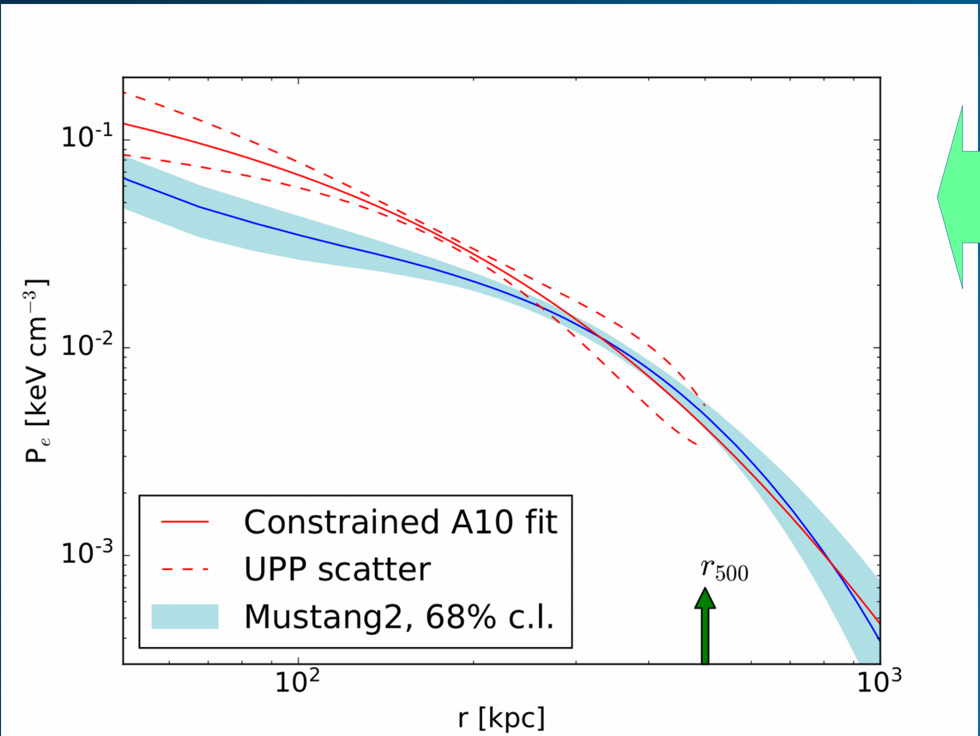
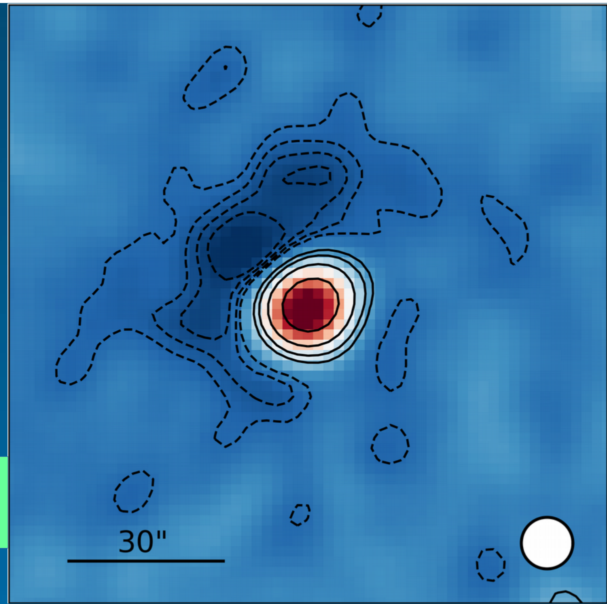

The tumultuous evolution of a galaxy cluster captured close to its emergence from the cosmic web
Stefano Andreon – INAF-OABrera
C. Romero, F. Castagna, A. Ragagnin, M. Devlin, S. Dicker,
B. Mason, T. Mroczkowski, C. Sarazin, J. Sievers, S. Stanchfield
MNRAS, in press


One slide summary:
red=hot
blue=cold
SZ beam
1 Mpc, z=1.75

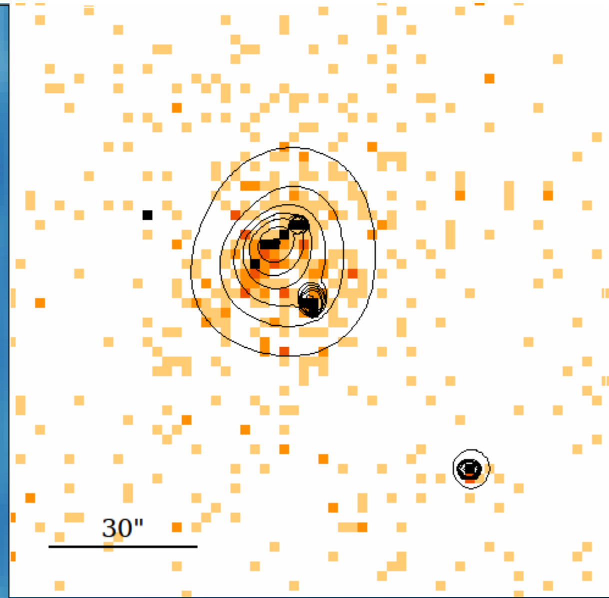
IDCS J1427.5+3508

z=1.75, M_{500}~2.5 10^{14} M_{sol}, massive for its z





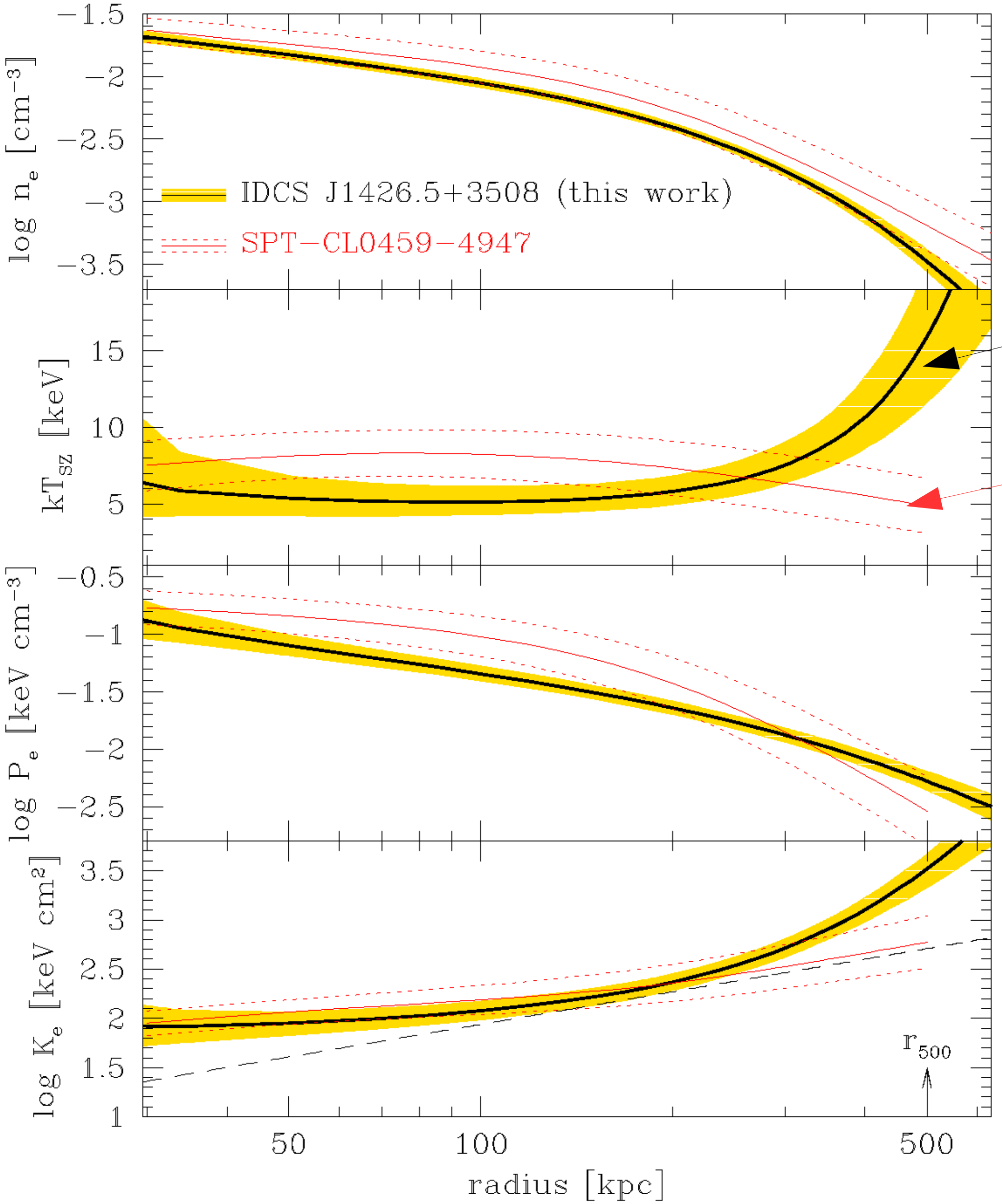
Mustang2@GBT



Chandra

Cluster is “depressed”, relevant for gastrophysics (see next slides) and cosmology (easier to miss than assumed, or with a biased mass for its SZ signal).

Such non-universal profiles start to be common with data allowing to detecting this feature and also when considering clusters non ICM-selected (Andreon et al. 2019, Dicker et al. 2020)



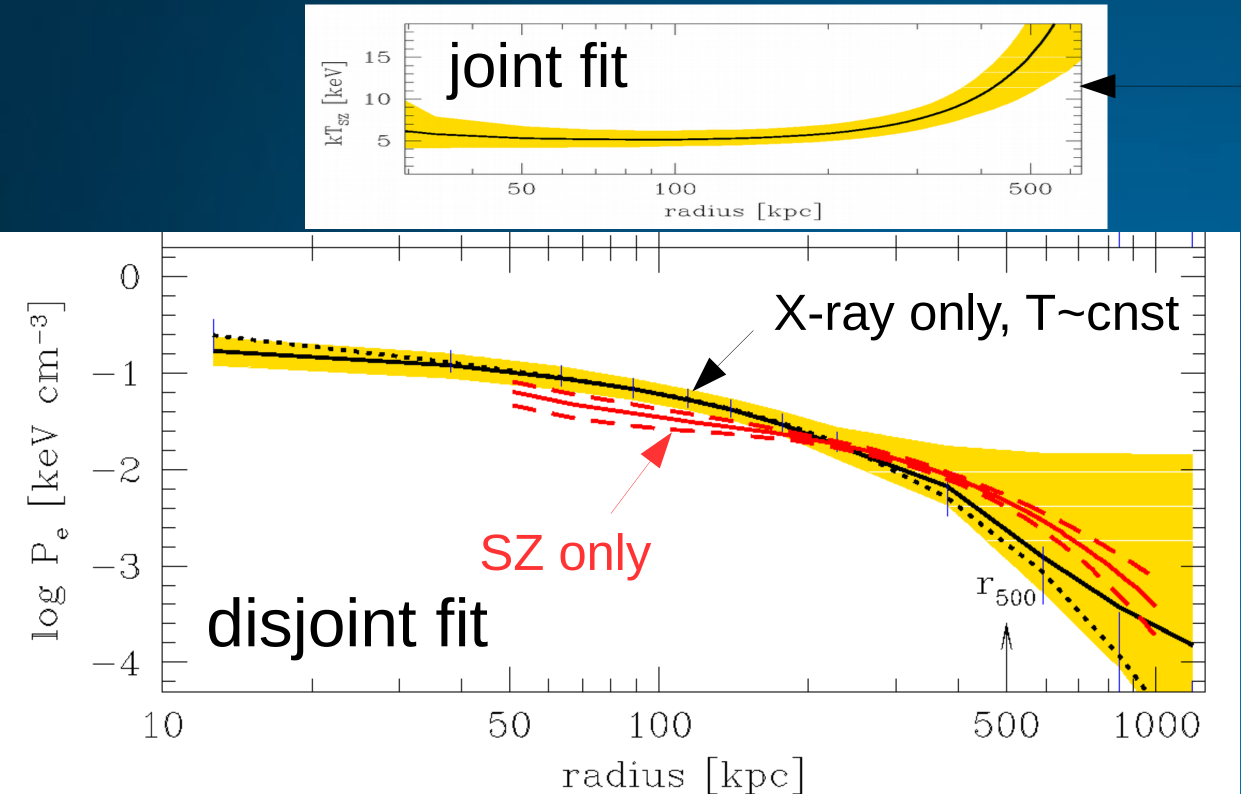
Efficiency of SZ+Xray

Black: IDCS, z=1.75, 100 ks Chandra + 36 ks Mustang2. 1σ errors shaded.

Red: brighter cluster at z=1.71, 190 ks Chandra + 500 ks XMM (from Ghirardini et al. 2021). 1σ errors with corridor.

Compare uncertainties!

Black: Fully joint fit of X-ray data cubes, SZ image, accounting for background and calibration systematics, PSF and transfer function, etc. (adapted version of JoXCS, Castagna & Andreon 2020).



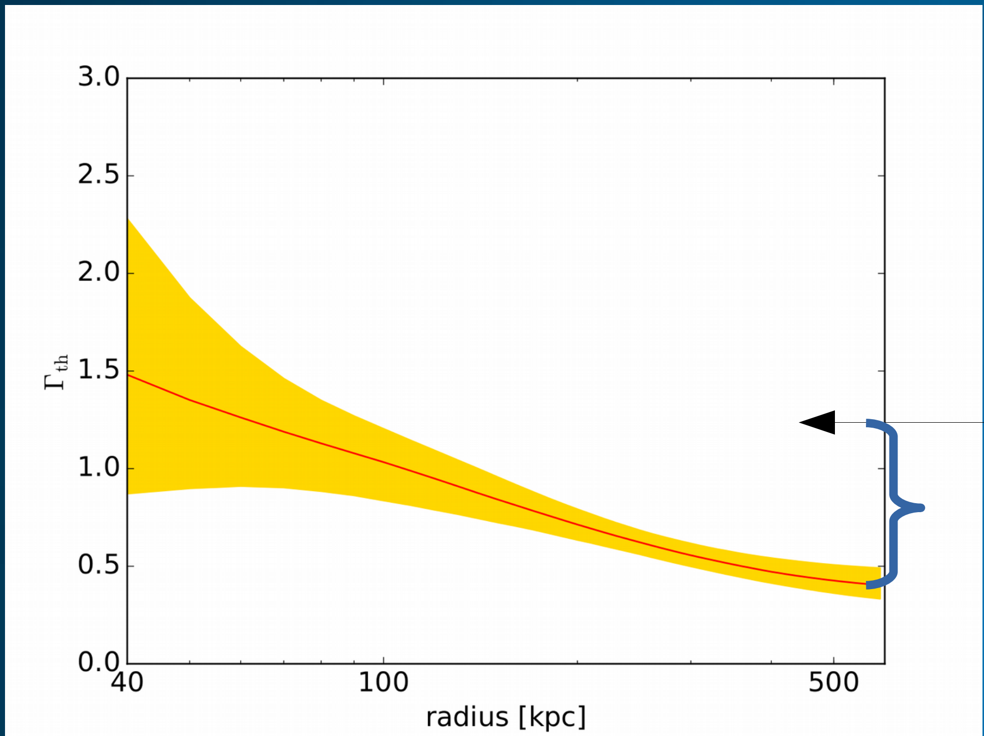
Unusual T profile

Robust feature: ultimately coming from a P profile shallower than the n_e profile

The SZ-based P profile and the X-raybased n_e profile are tightly constrained by data.

Uprising T profile, unstable (and already seen in other clusters)

Polytropic index profile Γ= d ln P /d ln n_e



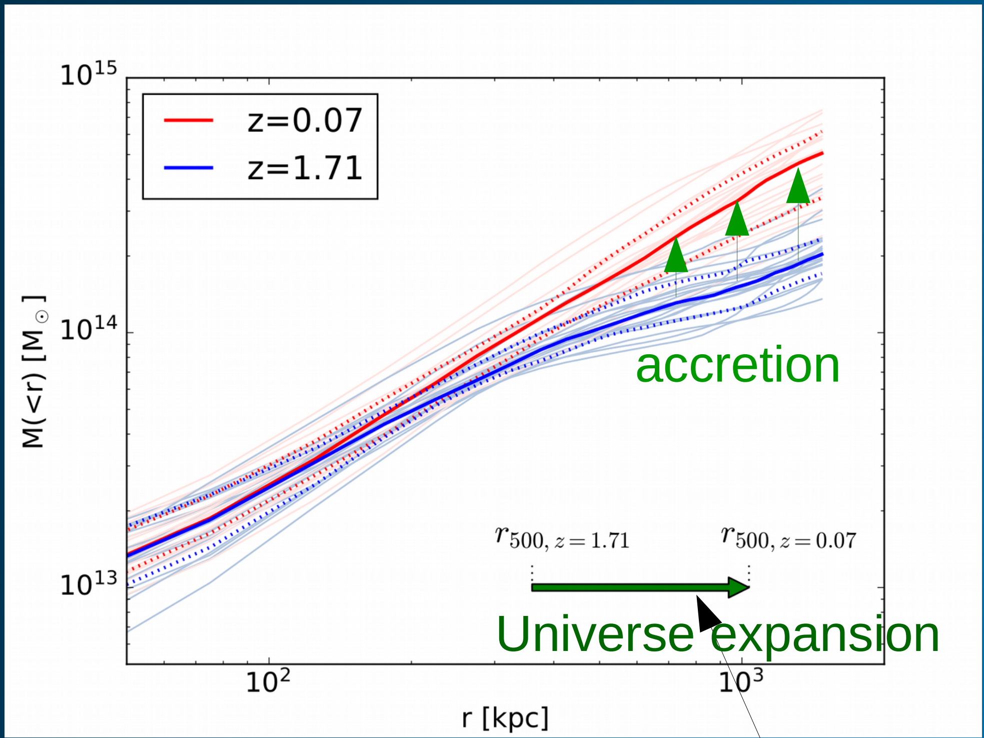
Expected value in absence of non-thermal pressure support

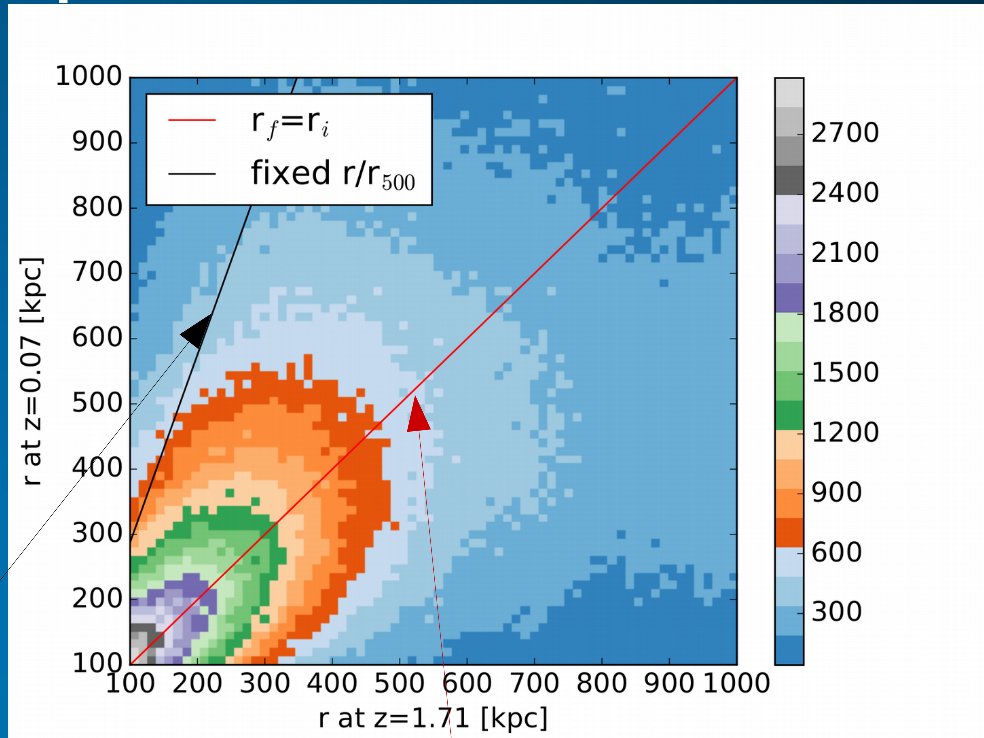
Δ implies bulk motion/turbulence

An unstable/far from equilibrium cluster

Γ =1 isothermal sphere, Γ=1.67 adiabatic gas

Clusters grow their outer region but do not expand





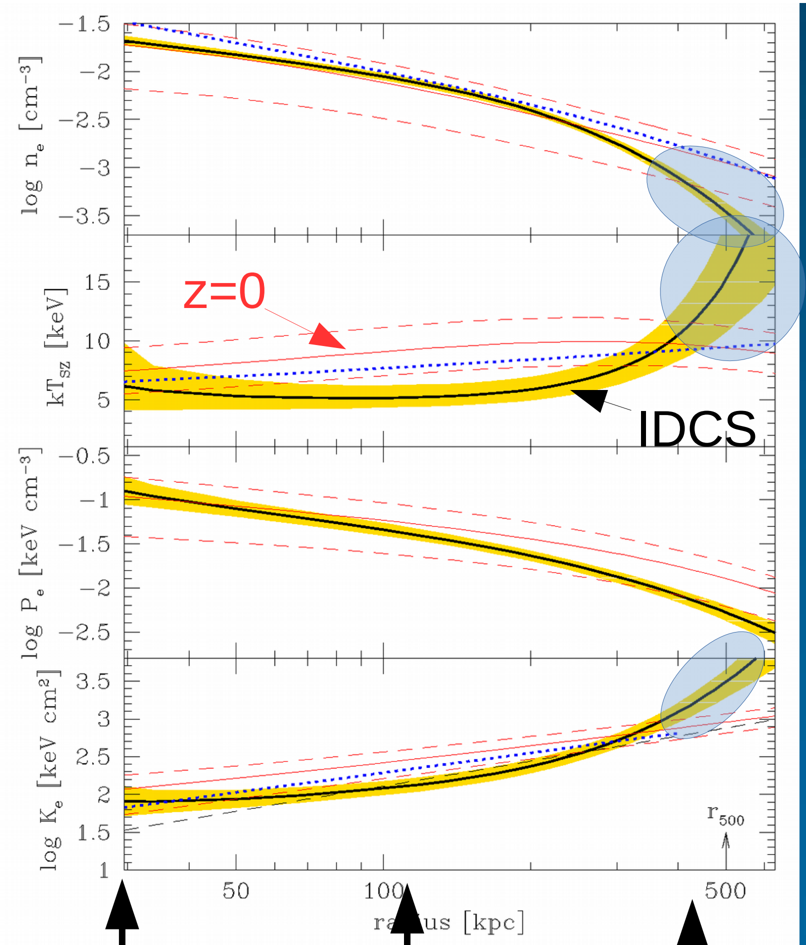
Self-similar choice

$r_{initial}$=r_{final}

Based on Magneticum (hydro, with baryons) simulations, yet known since Gott & Rees 1975, Peebles 1980

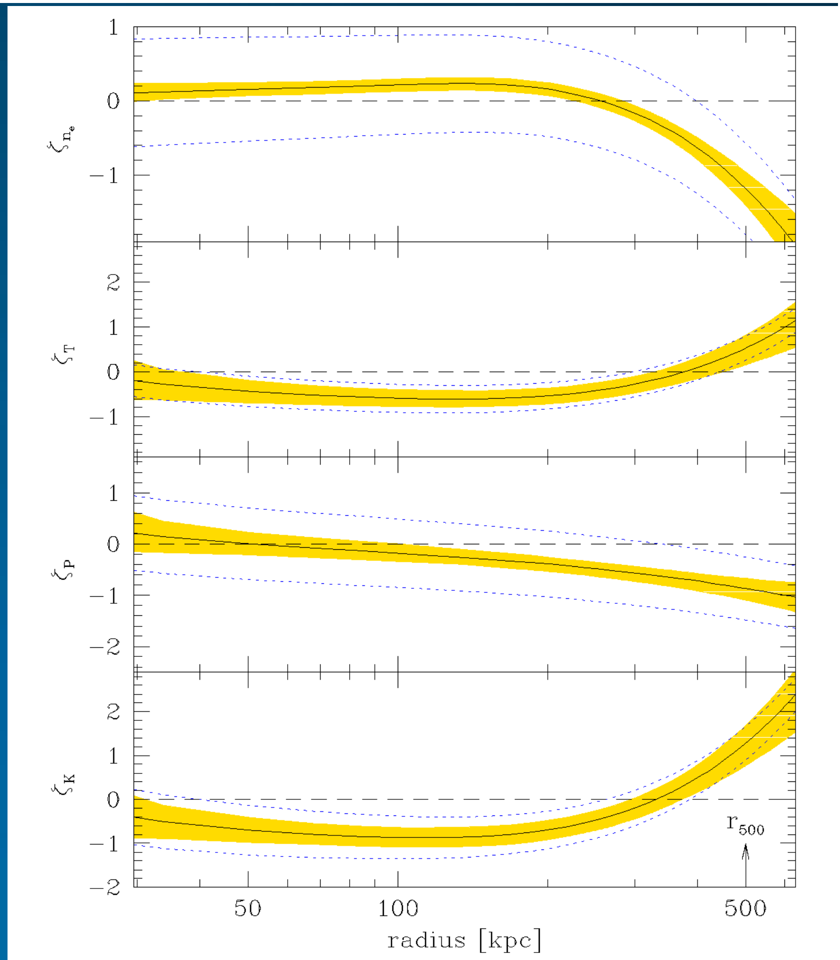
Evolution

- at fixed r. Clusters don't expand. Would clusters become smaller in a contracting Universe? Remember Birckoff theorem. Comparisons at fixed r (unlike most recent literature, using r/r_{500}).
- progenitor vs descendants. M_{500} increases with time, at least because of the decreasing $\rho_{crit}(z)$. Since we don't like "to compare unripe apples to ripe oranges in understanding how fruit ripens" (Andreon & Ettori, 1999, ApJ), comparisons at different look-back times are at fixed progenitor (e.g. ΔlogM=0.62 dex between z=1.7 and z=0), not at fixed mass (sometime used even in some recent papers). Scatter in mass accretion history accounted for (and subdominant).
- compared one cluster at high z to a library (X-COP) at z=0 with ΔlogM=0.6 dex more massive, shown as ±2σ corridors in next slides
- Caveat: do not generalize from 1 example (cluster)!



Rates:

$\zeta = d \ln f(r) / d \ln E_z$



$\zeta=0$ means no-evolution (with our choices)

$\zeta<0$ means lower in the past

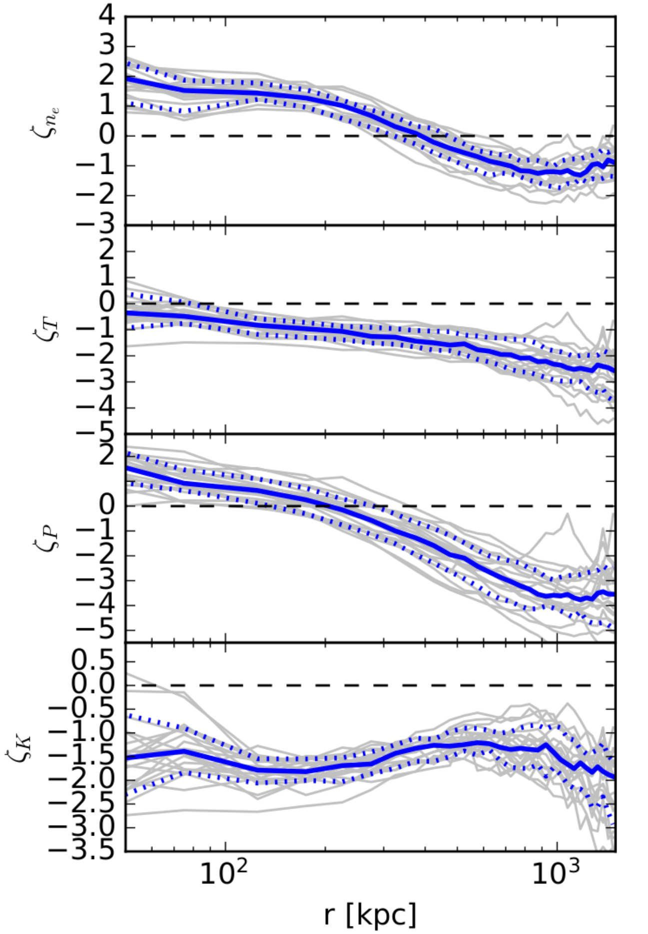
No changes at r~30 kpc

At intermediate r, gas will be heated with little net gas transfer

At large radii, heat should be evacuated, gas accumulated and entropy lowered

Rates:

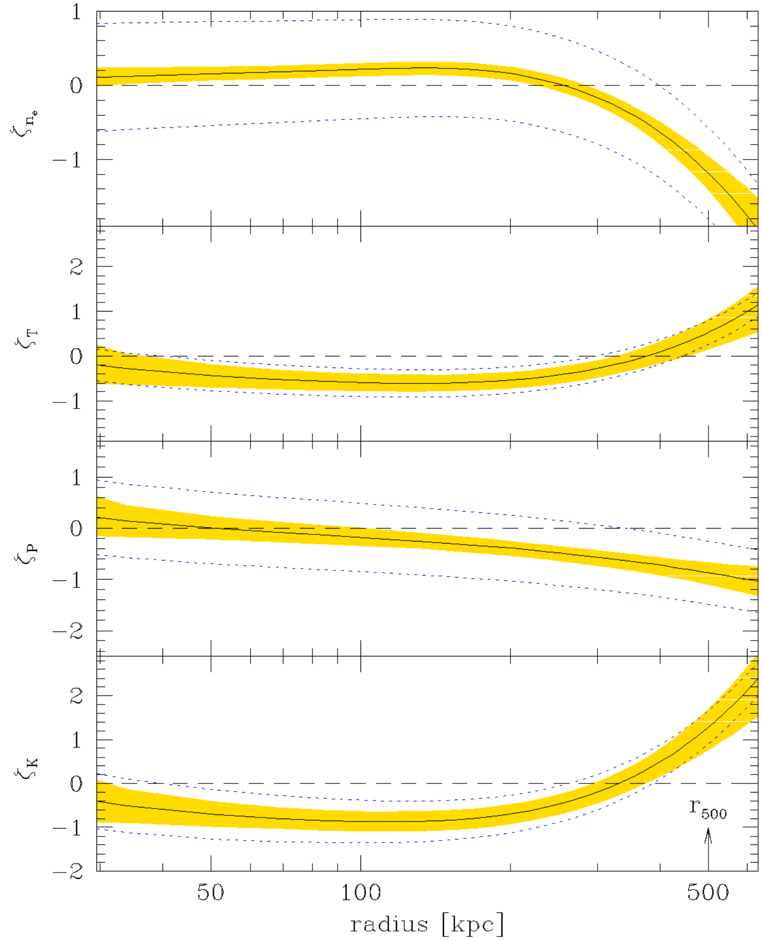
$\zeta = d \ln f(r) / d \ln E_z$



Expected evolution (Magneticum)

←Broad similarity →

Caveat: qualitative match only



Observed

In simulations, bulk motion can be directly seen (not inferred). As for observations, heat and entropy is transferred inward with little net gas transfer at intermediate r, whereas at large r n_e grows by accretion of cold, lower entropy gas.

Summary

a) most accurate resolved (40 kpc resol.) thermodynamic profiles, & for the most distant (z=1.75) cluster (thanks to SZ+X-ray)

b) far from the final configuration (T & Γ profiles)

c) heat and entropy need to be transferred inward with little net gas transfer at intermediate r, whereas at large r n_e grows by accretion of cold, lower entropy gas.

d) no evolution at r~30 kpc, unveiling a delicate balance between matter infall and a yet unidentified feedback mechanism

e) clusters grow in mass and don't expand. Don't compare at fixed r/r_{500} and/or fixed mass, please.