Mapping the outer part of high-z cluster combining X-ray and SZ observations

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Collaborators:
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ASTROPHYSICS
HARVARD & SMITHSONIAN

The high-z SPT sample

- *SPT* S/N > 6
- $z > 1.25$
- Objects with deep *Chandra* and *XMM-Newton* data

- 750+575 ks in *XMM-Newton* AO-16 (PI E. Bulbul, and A. Mantz)
- 560+60+100 ks in *Chandra* AO-16 (PI M. McDonald, G. Garmire, and S. Murray)

->Tot 2.045 Ms

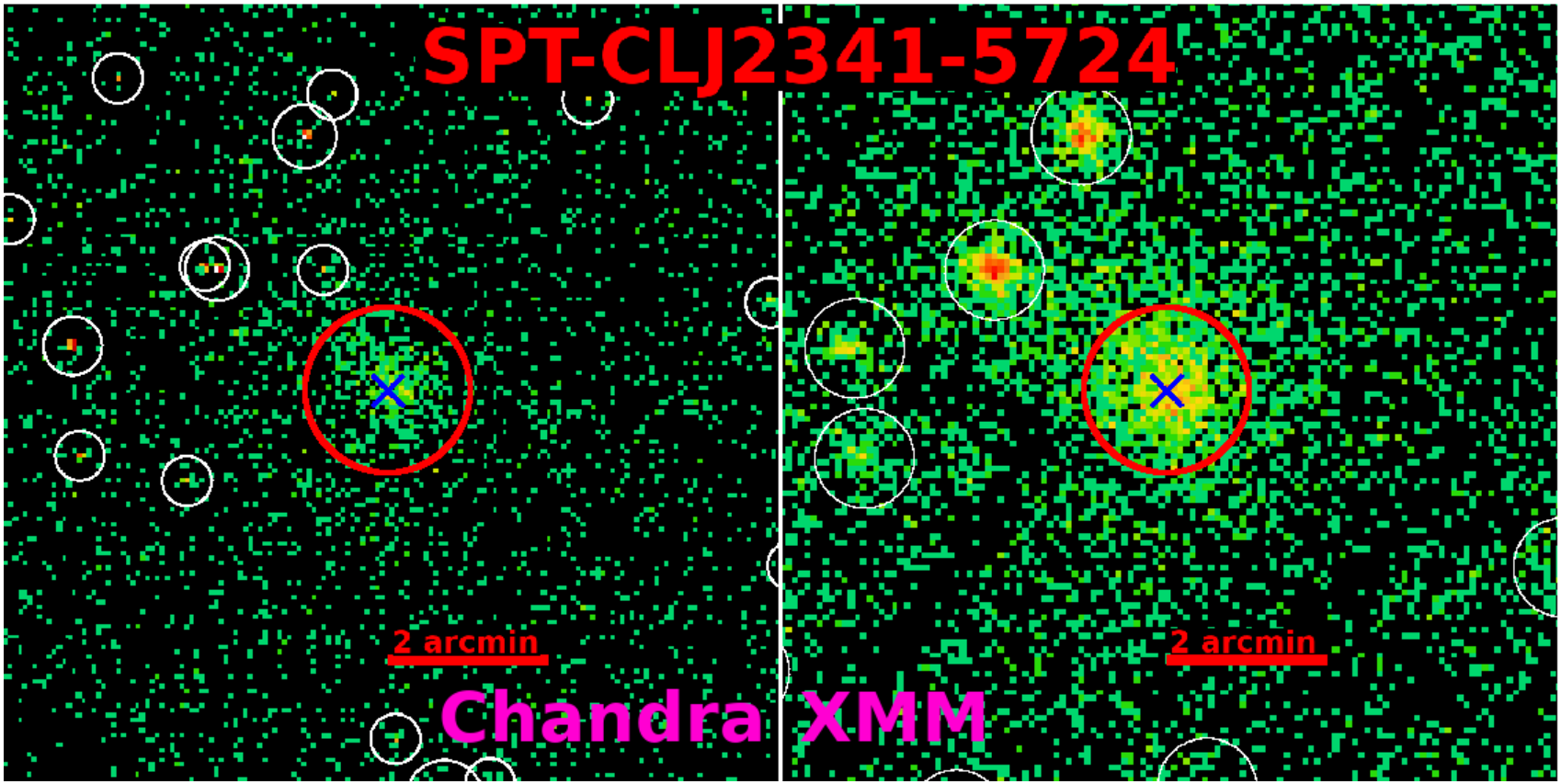
Goals

- Study the thermodynamic properties in the high redshift Universe
- And their evolution with cosmic time

Cluster	redshift	R.A. [deg]	Dec. [deg]	t_{CXO} [ks]	t_{MOS1} [ks]	t_{MOS2} [ks]	t_{pn} [ks]
SPT-CLJ0205-5829	1.322	31.4437	-58.4855	57.8	69.4	70.2	52.7
SPT-CLJ0313-5334	1.474	48.4809	-53.5781	113.6	186.0	195.2	164.5
SPT-CLJ0459-4947	1.700	74.9269	-49.7872	136.2	461.9	471.6	410.3
SPT-CLJ0607-4448	1.401	91.8984	-44.8033	111.1	132.7	144.8	98.7
SPT-CLJ0640-5113	1.316	100.0645	-51.2204	173.4	127.7	131.9	114.0
SPT-CLJ2040-4451	1.478	310.2468	-44.8599	96.7	76.2	76.6	72.8
SPT-CLJ2341-5724	1.259	355.3568	-57.4158	112.4	107.7	107.7	93.0

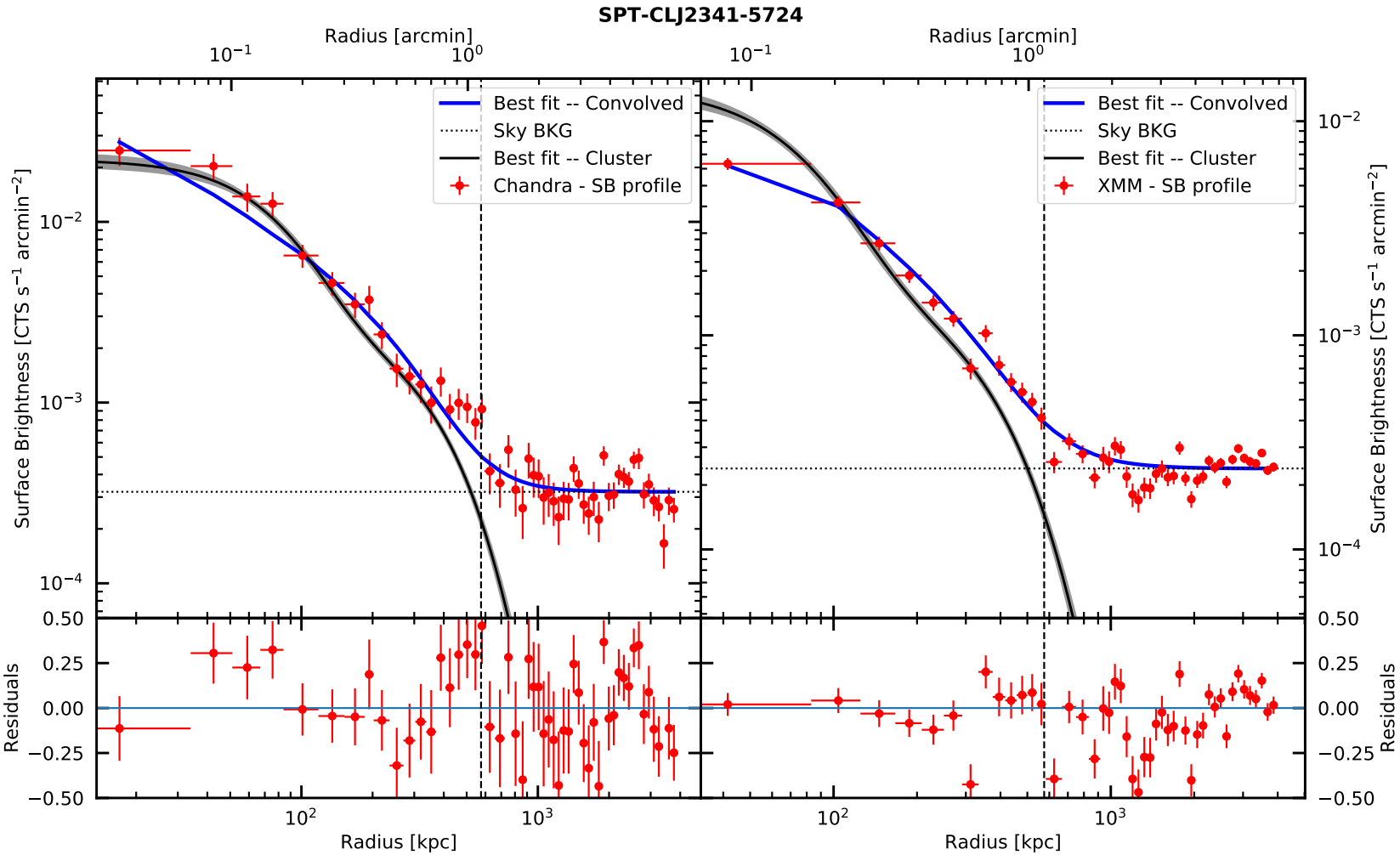
Images

-*Chandra*: exquisite spatial analysis
-*XMM-Newton*: large effective area



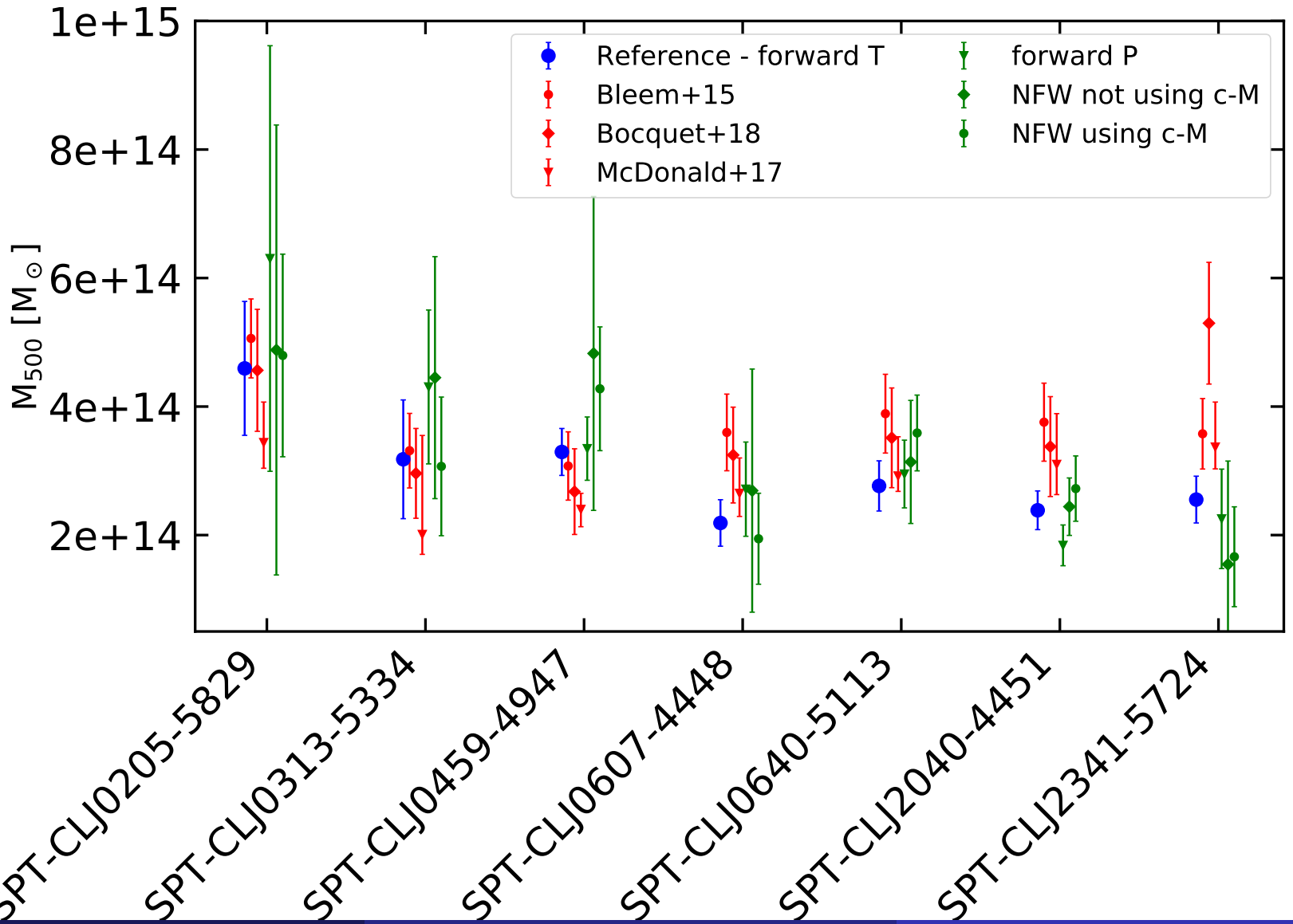
Joint *Chandra* - *XMM-Newton* analysis

Observation = Cluster # Projected # Instrument # + bkg # Poisson

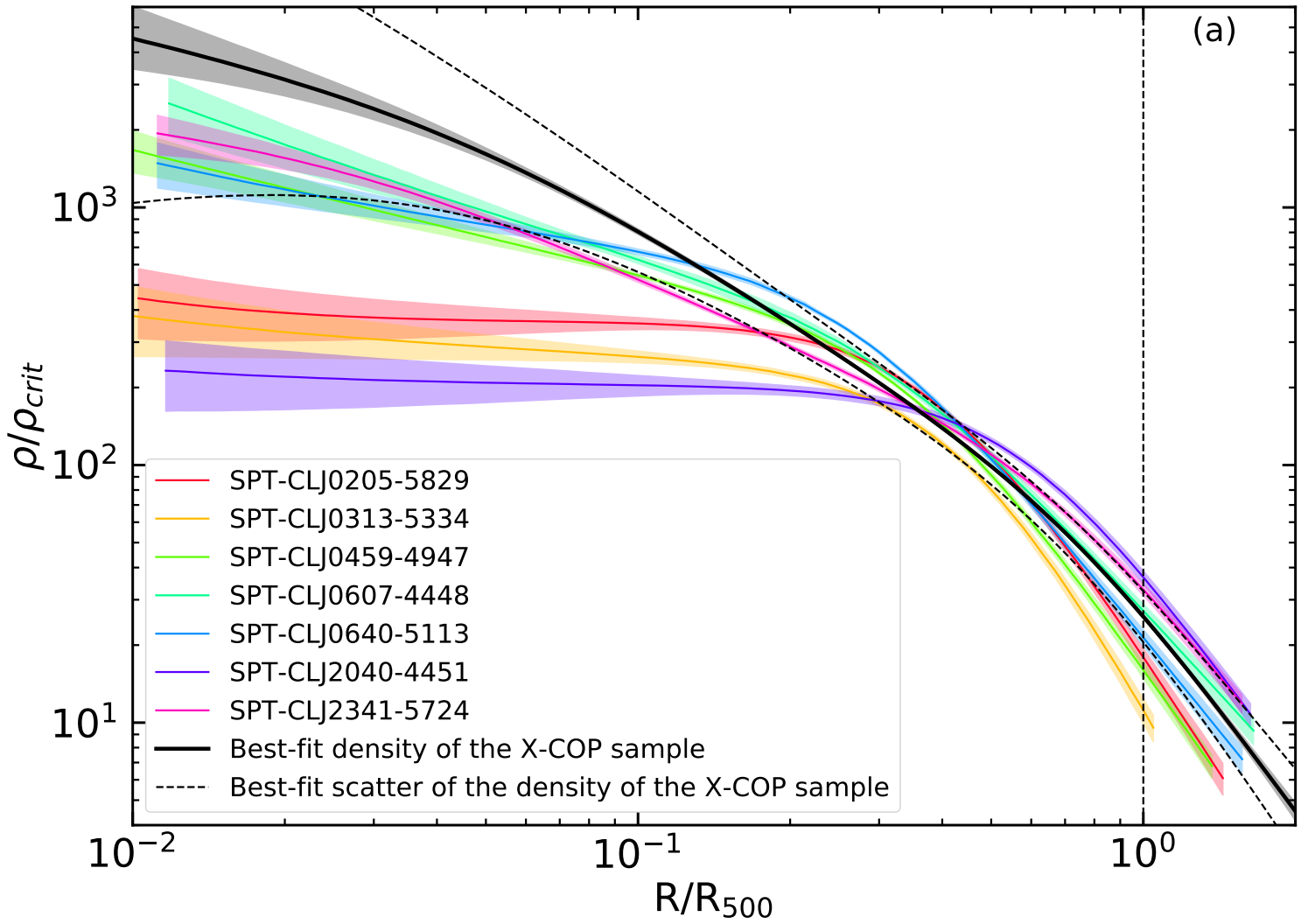


Mass comparison

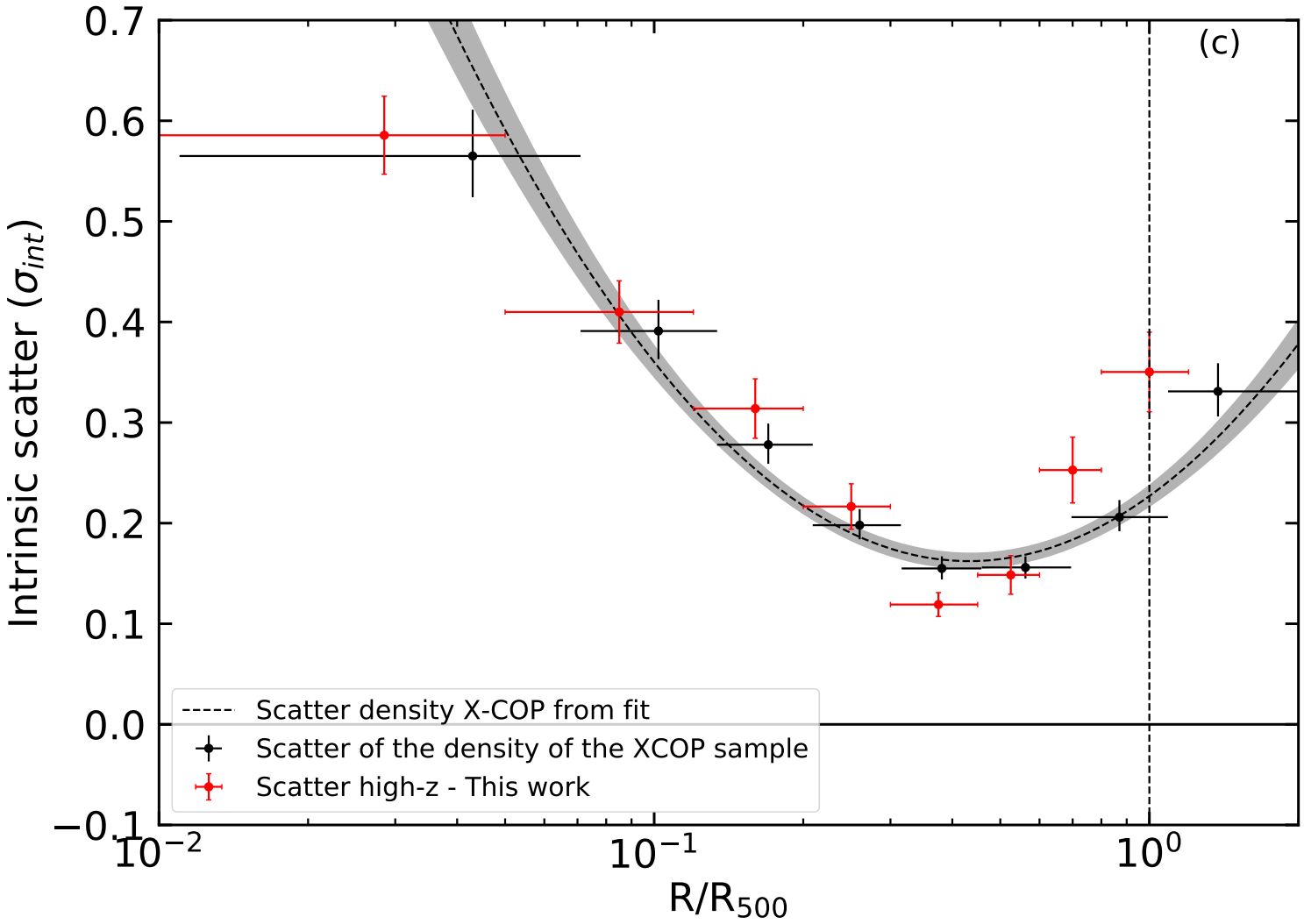
$$M(< R) = -\frac{R k_B T}{G \mu m_p} \left[\frac{d \log \rho_g}{d \log R} + \frac{d \log T}{d \log R} \right]$$



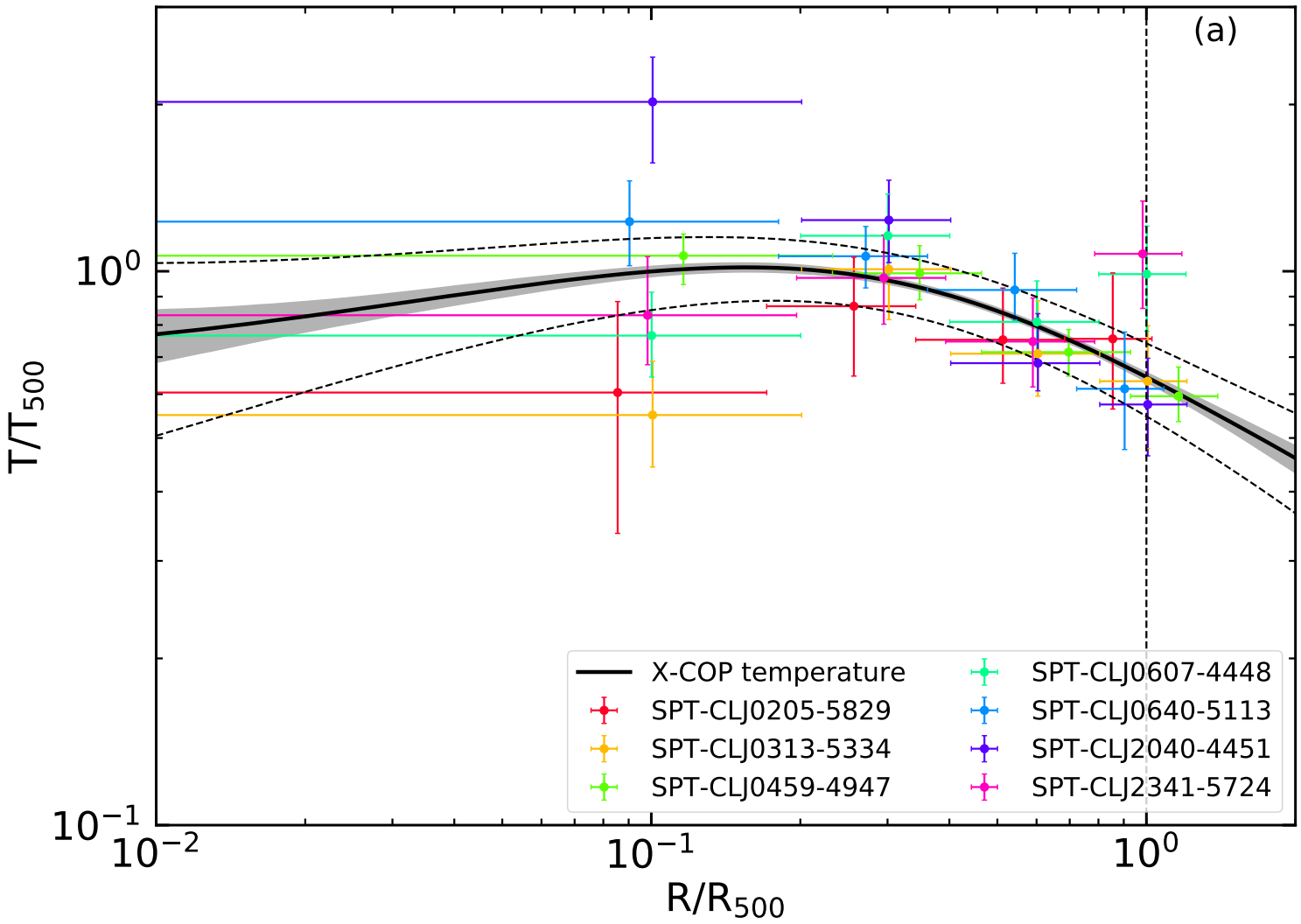
Density


(a)
10^3
10^2
10^1
ρ/ρ_{crit}
10^{-2}
10^{-1}
10^0
R/R_{500}
SPT-CLJ0205-5829
SPT-CLJ0313-5334
SPT-CLJ0459-4947
SPT-CLJ0607-4448
SPT-CLJ0640-5113
SPT-CLJ2040-4451
SPT-CLJ2341-5724
Best-fit density of the X-COP sample
Best-fit scatter of the density of the X-COP sample

Density – Scatter



Temperature (*XMM-Newton* only)



Systematics

Mass bias

- Masses of high-low z samples are hydrostatic ⇒ same effect on the profiles
- Scatter in mass measurement is an estimate of the hydrostatic bias in the outskirts (12% vs the 7% in X-COP)

Clumpiness bias

- 5% temperature **Avestruz et al. 2016**
- 10% density **Eckert et al. 2015**

Progenitors bias

- Using some theoretical recipe (**Fakhouri et al. 2010**) these are not progenitor of X-COP
- We can correct using $c - M - z$ relation

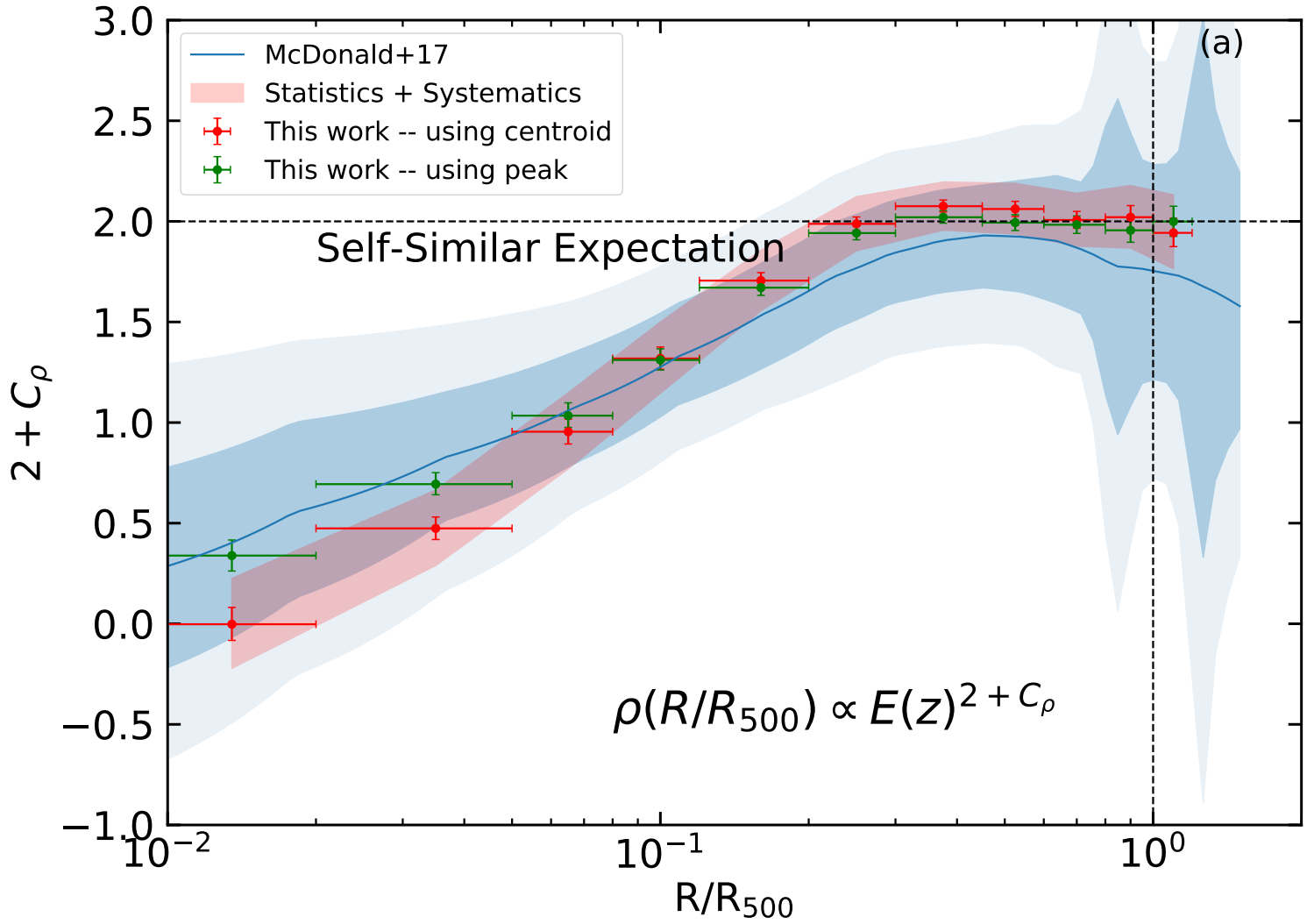
Temperature bias

- *Chandra* and *XMM-Newton* measure different temperature (about 20% for these objects, see **Shellenberger+15**)

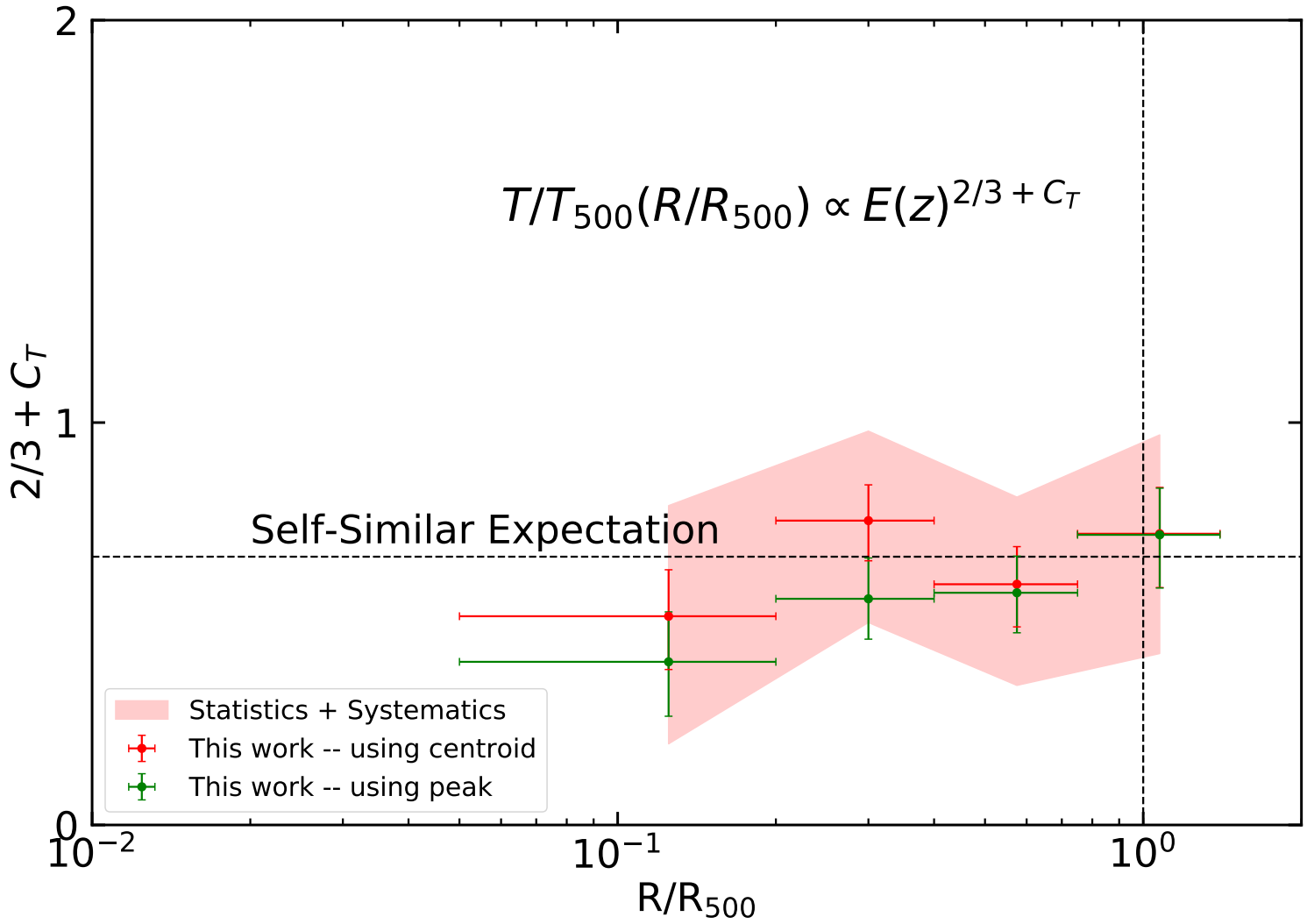
Center bias

- Redo the analysis using X-ray peak or centroid

Density evolution



Temperature evolution



Conclusion

- Density
  - Above 0.3 R_{500} we are fully consistent with self-similarity
  - Below 0.1 R_{500} more than 5σ deviation with respect to self-similarity
  - At 0.01 R_{500} results consistent with no evolution
  - In the core the scatter is consistent at low and high redshift
- Temperature
  - Consistent at all radii with self-similar evolution
  - Not possible to measure the evolution below 0.1 R_{500} because of *XMM-Newton*'s PSF