

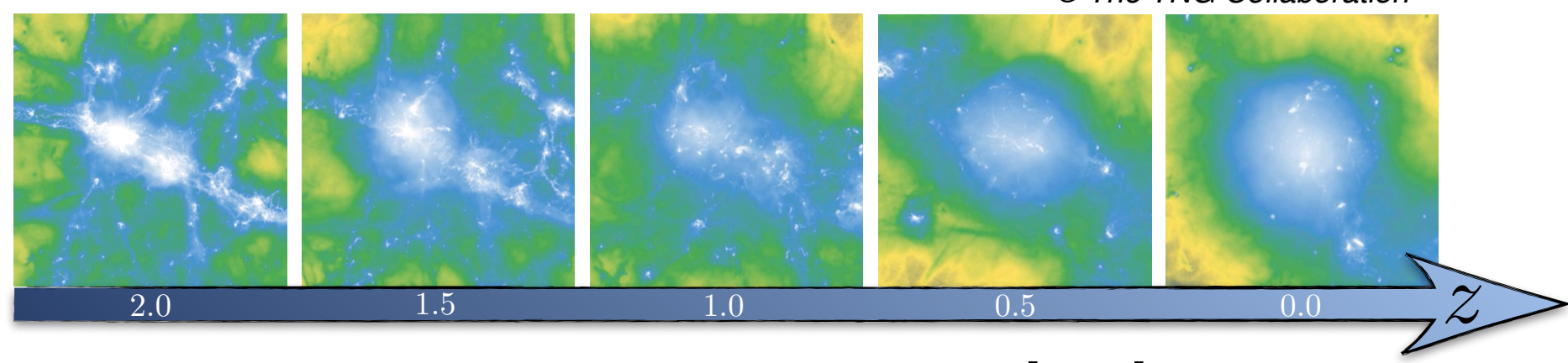


Uncovering ICM evolution at $z > 1$ with a joint analysis of X-ray and Sunyaev-Zel'dovich data

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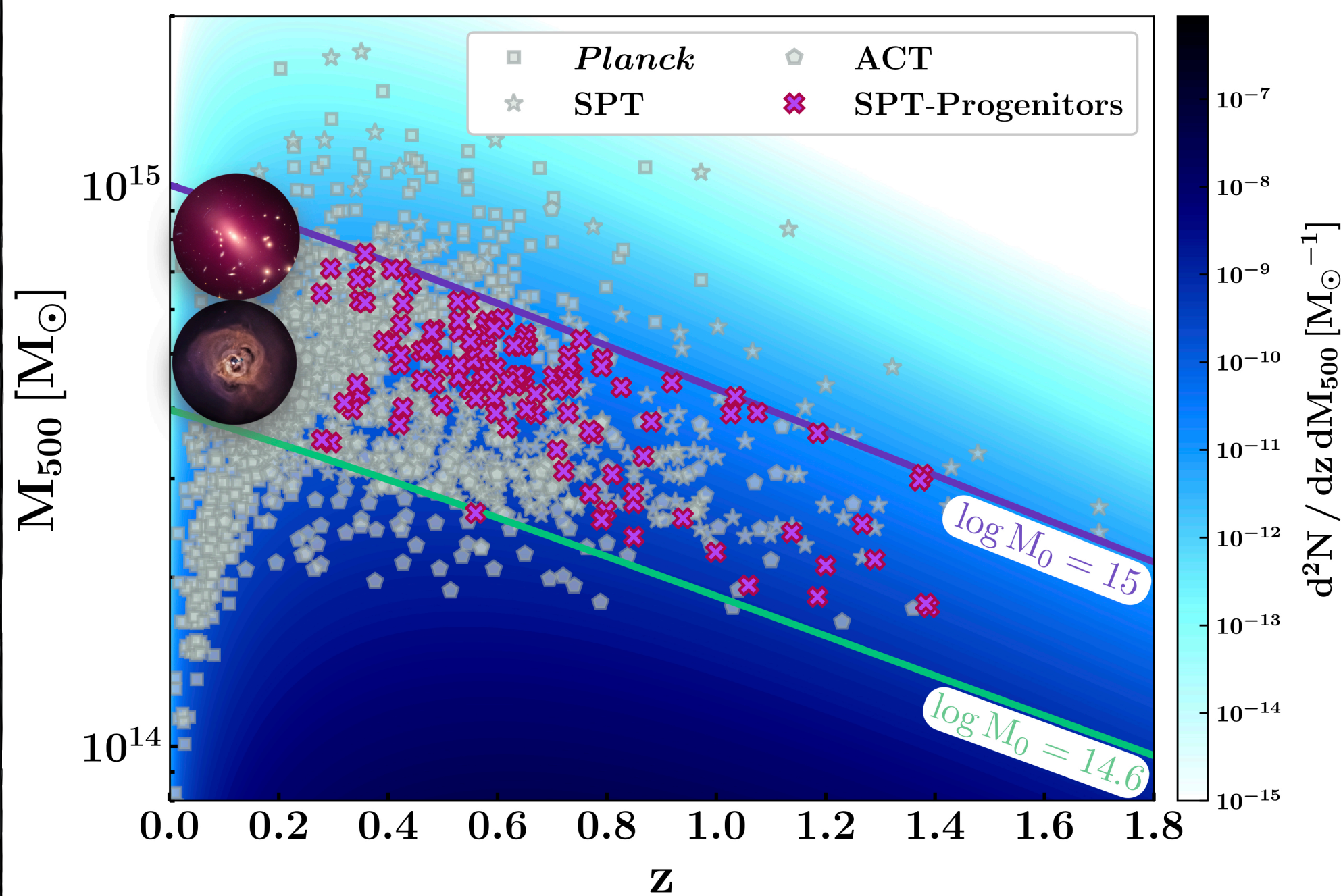
Context



- Unknown ICM thermal balance at $z \in [1, 2]$
- Onset of cooling? Entropy floor? Link with merger dynamics?
- **Need to study ICM properties at $z > 1$**

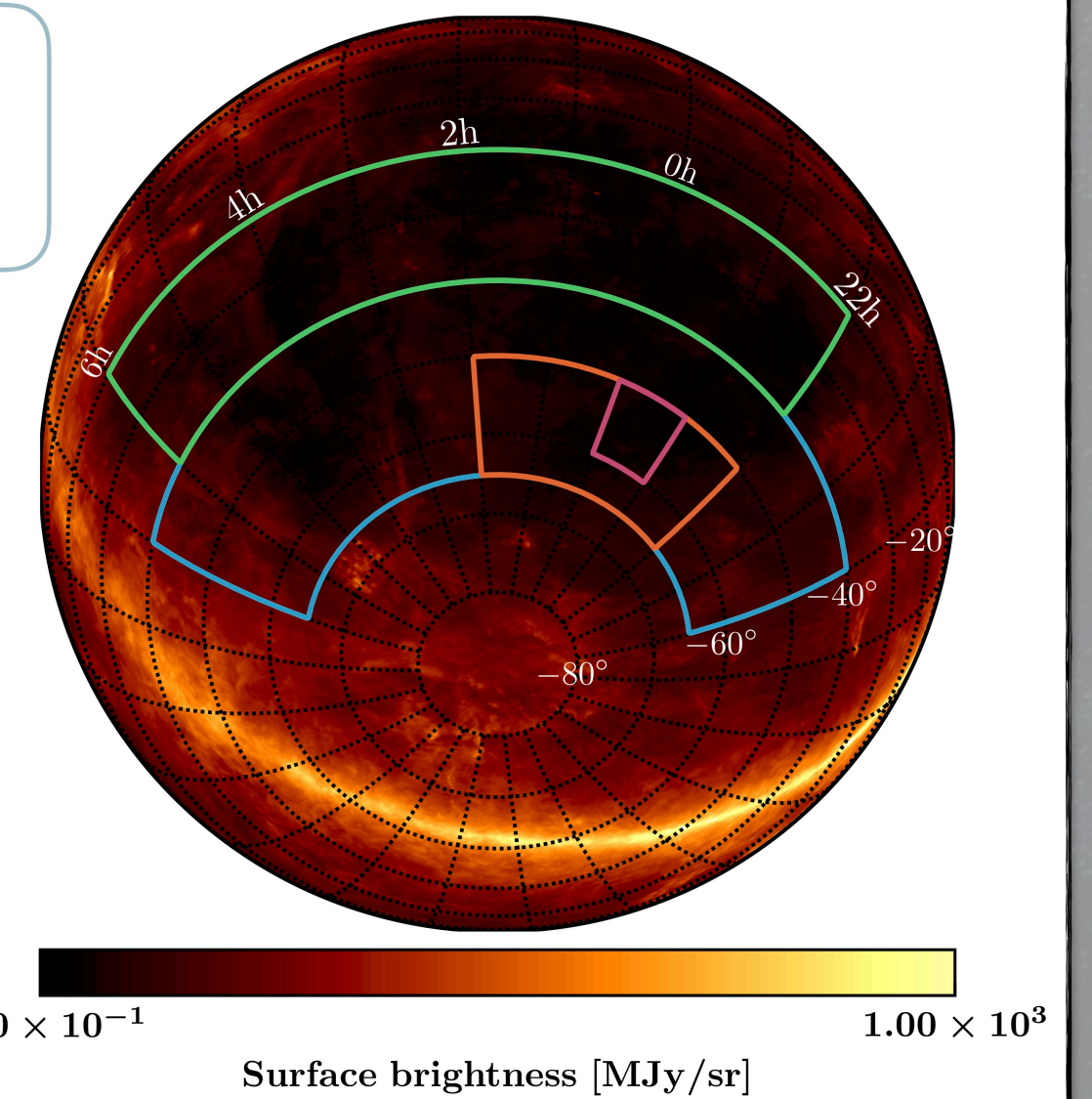
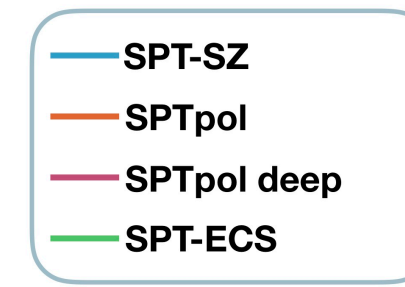
Progenitors of the Perseus cluster

- ICM evolution in the progenitors of well-known clusters at $z \sim 0$
 → X-ray observations of low-mass systems at $z > 1$
- Expected exposure to obtain an X-ray temperature profile for a $2 \times 10^{14} M_{\odot}$ cluster at $z > 1$: **~1 Ms**
 → Joint analysis of X-ray and SZ data: no X-ray spectroscopy
- SZ observations of galaxy clusters at $z > 1$
 → Sample selection and Data analysis



Galaxy clusters detected with SPT [1-2]

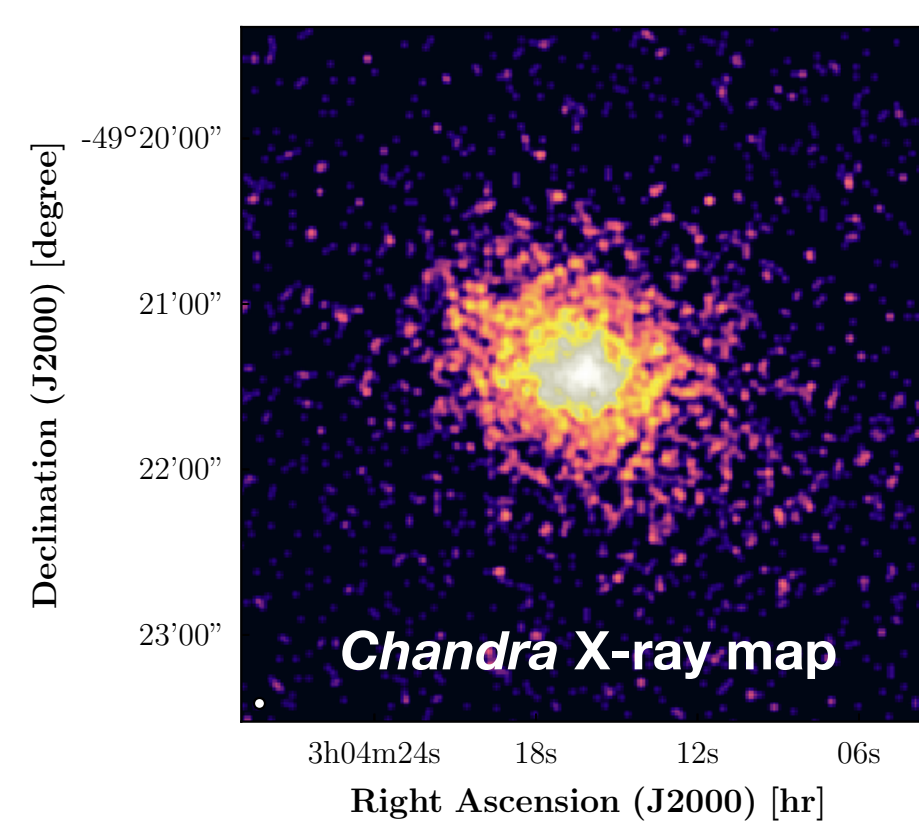
- SPT-SZ 2500 deg² field: **677** detected clusters
- Deep observations realised in a 100 deg² field with SPTPol: **18** progenitors at $0.8 < z < 1.4$
- New SPT-ECS 2770 deg² field: **470** detected clusters



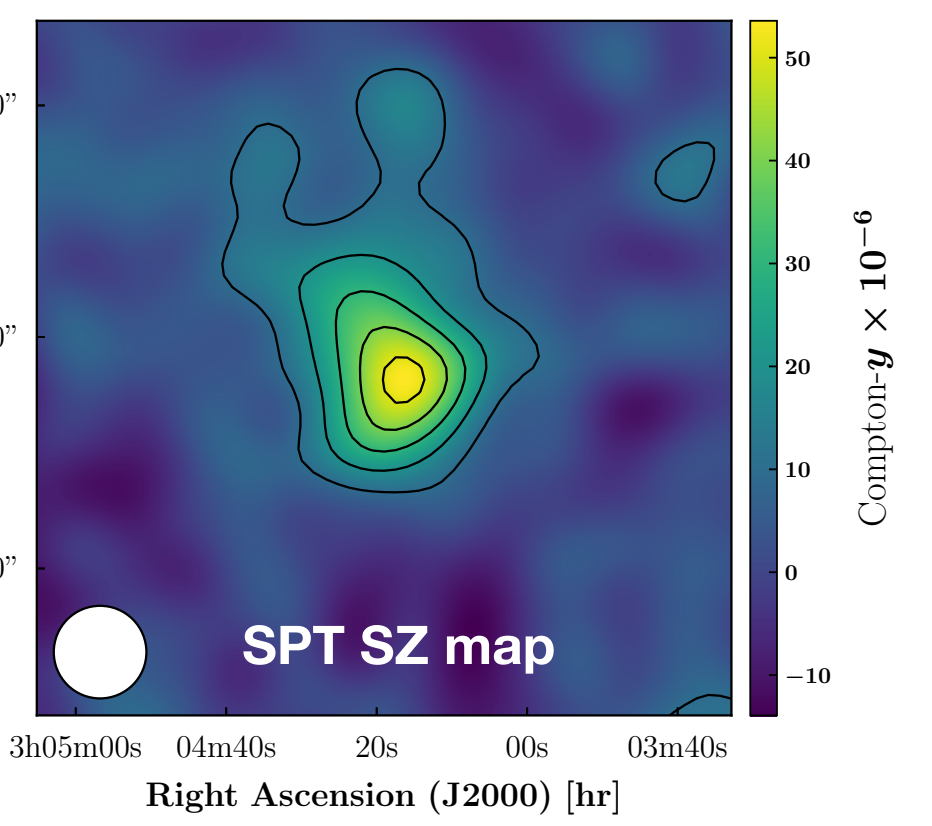
~150 ks *Chandra* exposure on each SPTPol progenitor cluster

Complementarity of X-ray and SZ observations [3-4]

- X-ray surface brightness (S_x) profile from cleaned *Chandra* event list
- Compton parameter (y) profile from SPT map
- **Simultaneous estimation of the ICM density and pressure profiles**



$$S_x \propto \int n_e^2 \Lambda \left(\frac{P_e}{n_e} \right) dl$$



$$y_{SZ} \propto \int P_e dl$$

- Temperature: $k_B T_e(r) = P_e(r)/n_e(r)$
- Entropy: $K_e(r) = P_e(r)/n_e(r)^{5/3}$
- Morphological indicator: comparison of the SZ/X-ray ICM morphologies

Analysis procedure

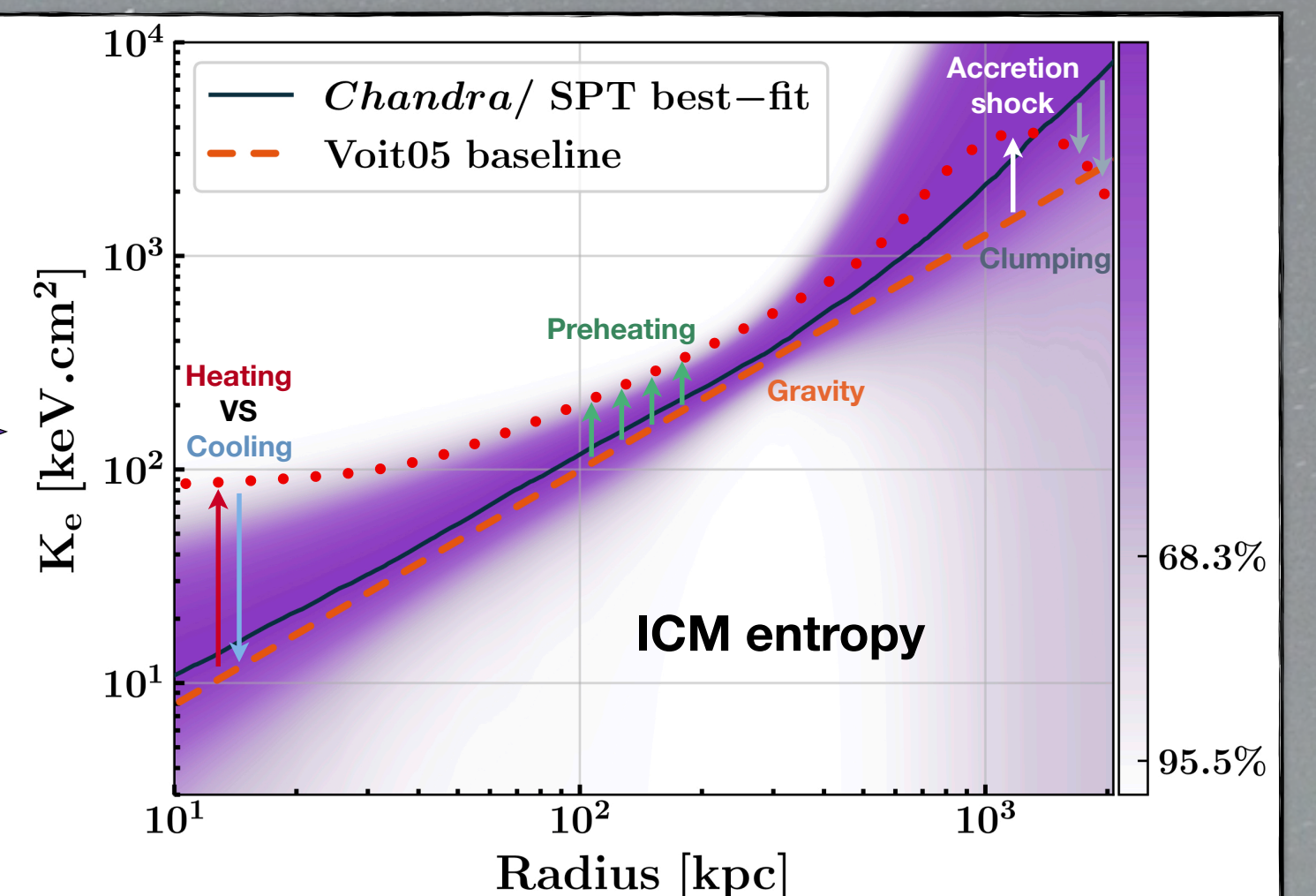
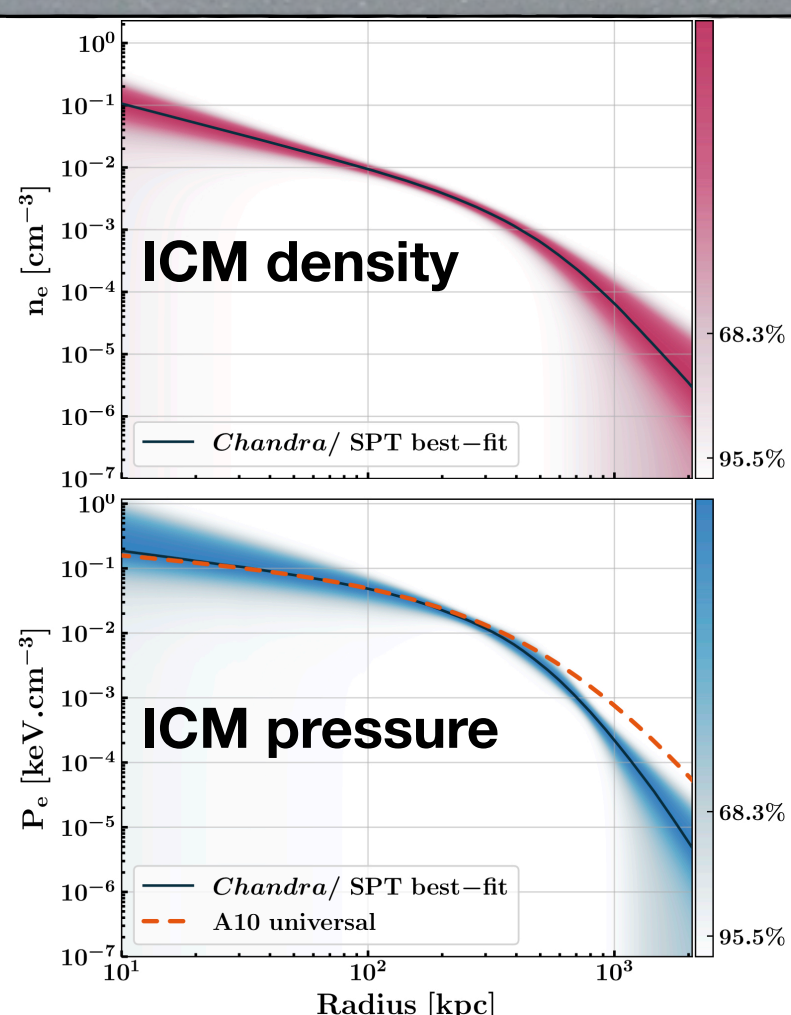
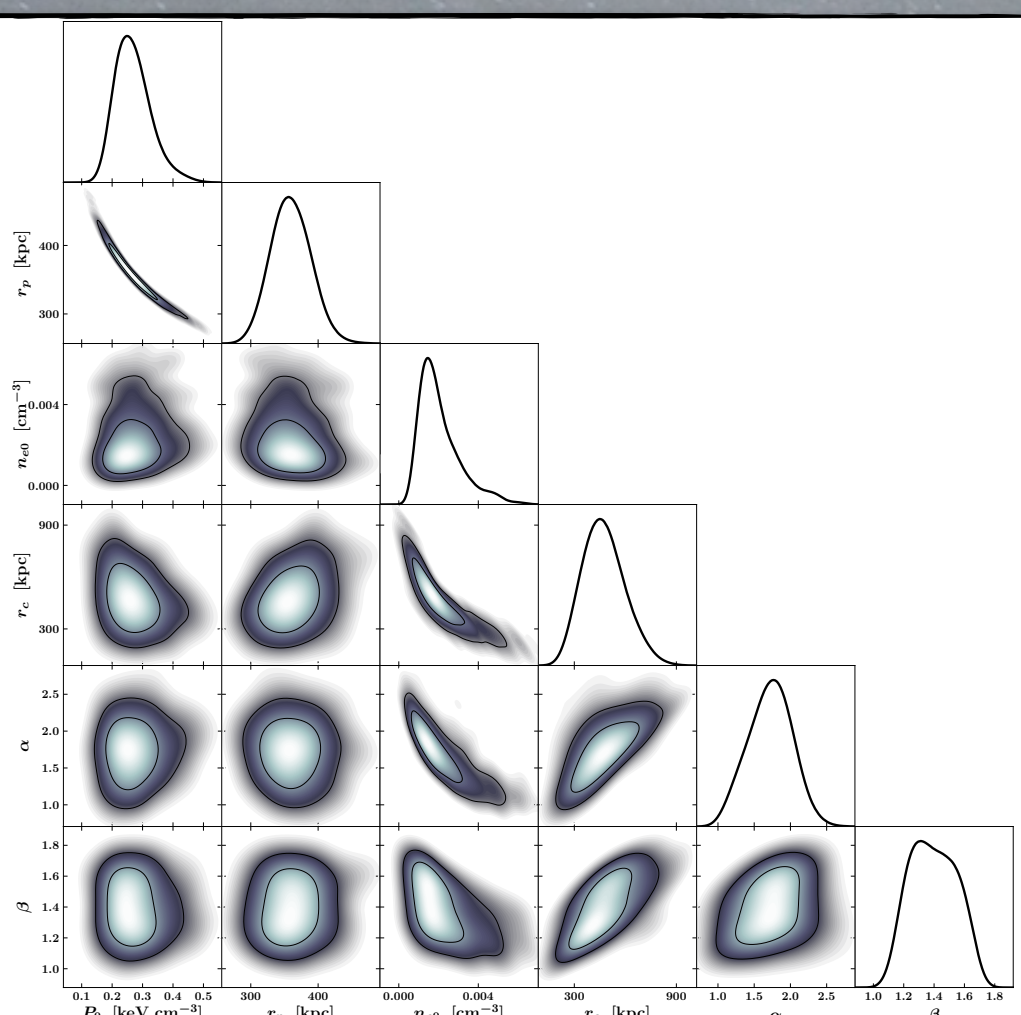
- MCMC analysis of the *Chandra* S_x and SPT Compton- y profiles

- ICM thermal pressure:

$$P_e(r) = \frac{P_0}{\left(\frac{r}{r_p}\right)^c \left(1 + \left(\frac{r}{r_p}\right)^a\right)^{\frac{b-c}{a}}}$$

- ICM electron density:

$$n_e(r) = n_{e0} \frac{(r/r_c)^{-\alpha/2}}{\left(1 + r^2/r_c^2\right)^{3\beta/2 - \alpha/4}}$$

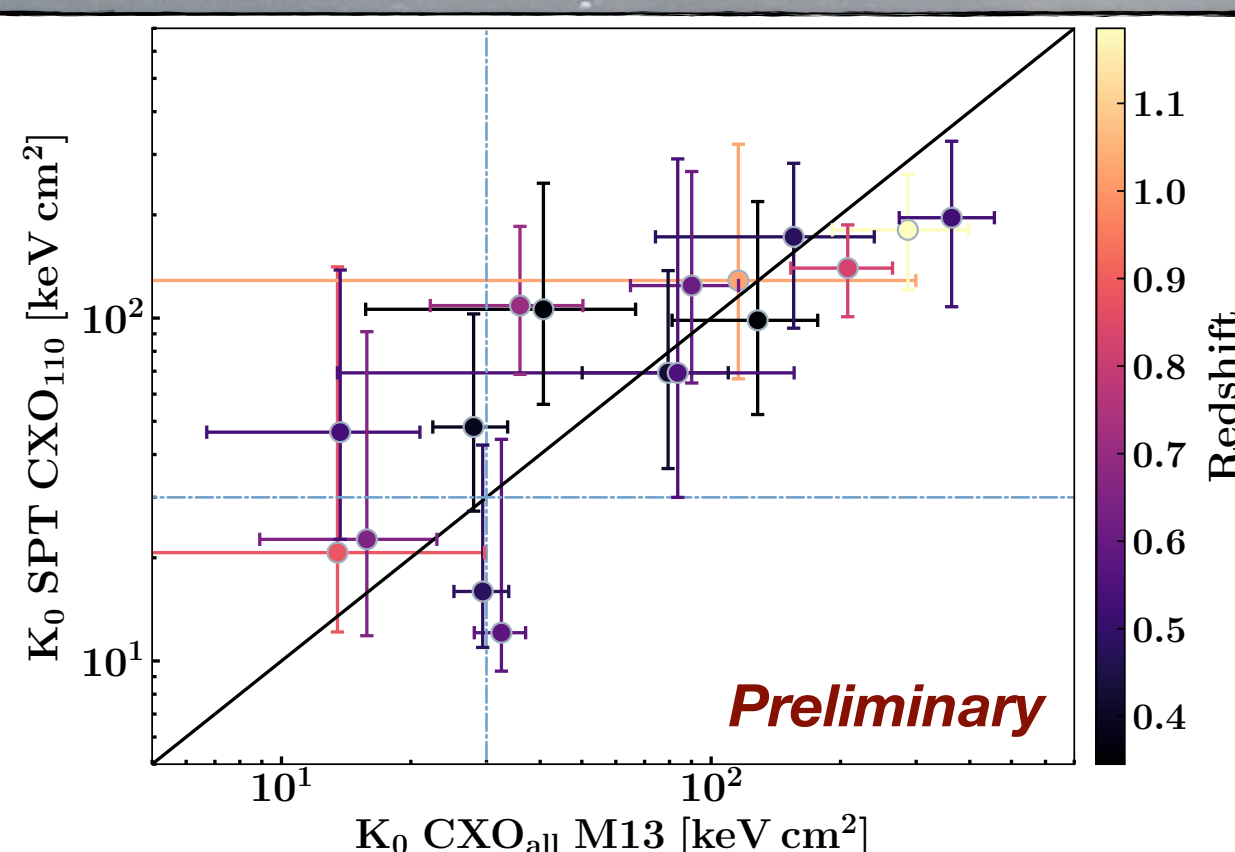


Validation [5]

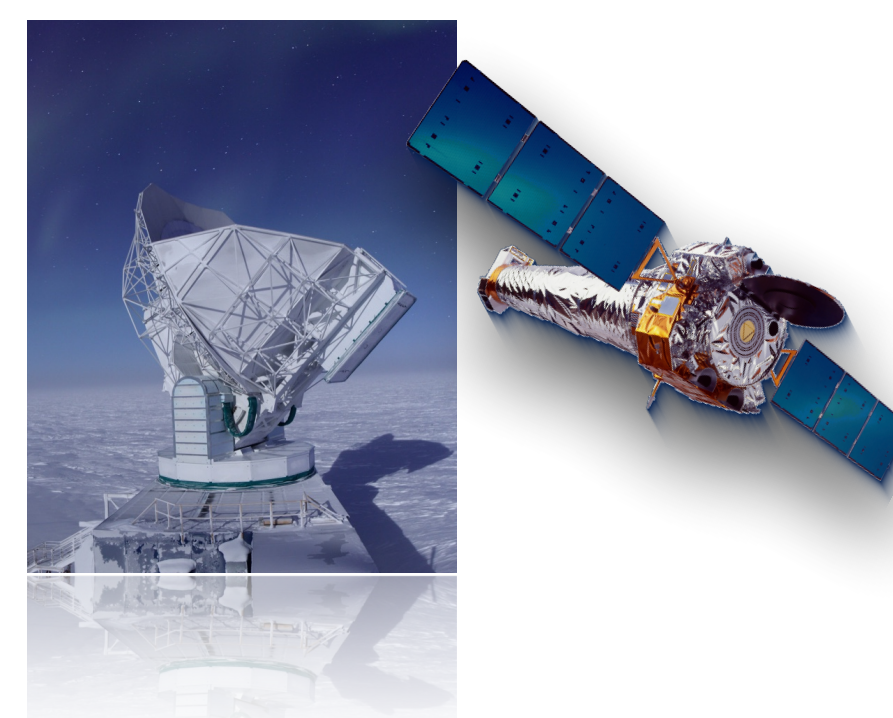
- Downsample *Chandra* observations of SPT clusters with known K_0

- Estimate K_0 using the SPT/*Chandra* pipeline: no X-ray spectroscopy

→ Compatible results at all redshifts



Conclusions / Perspectives



- ICM thermodynamic properties from a combination of shallow *Chandra* data and SPT SZ signal
- Uncover ICM thermal balance at $z > 1$
- Correlate central entropy and density profile cusps with radio AGN luminosity and cluster morphology
- Characterize heating processes at $z > 1$

References: [1] Bleem, L. E., Stalder, B., de Haan, T., et al. 2015, ApJS, 216, 27
 [2] Bleem, L. E., Bocquet, S., Stalder, B., et al. 2019, ApJ, arXiv:1910.04121
 [3] Ruppin, F., McDonald, M., Brodwin, M., et al. 2019, ApJ, arXiv:1911.00560
 [4] Ruppin, F., Mayet, F., Pratt, G. W., et al. 2018, A&A, 615, A112
 [5] McDonald, M., Benson, B. A., Vikhlinin, A., et al. 2013, ApJ, 774, 23

Additional information:

Find more about my work in SZ/X-ray →



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