

# Cluster X-ray Scaling Properties and their Cosmological Implications

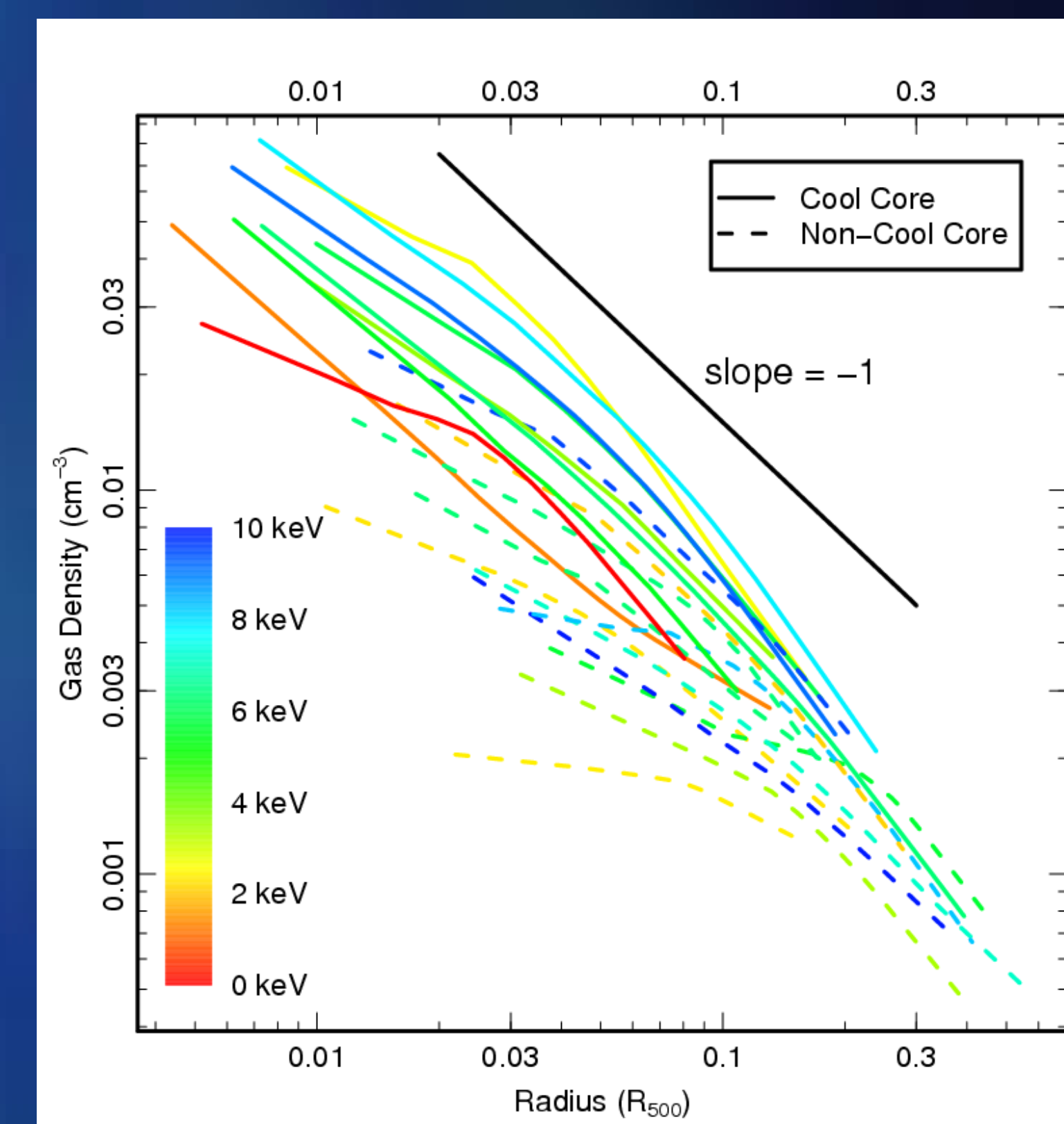
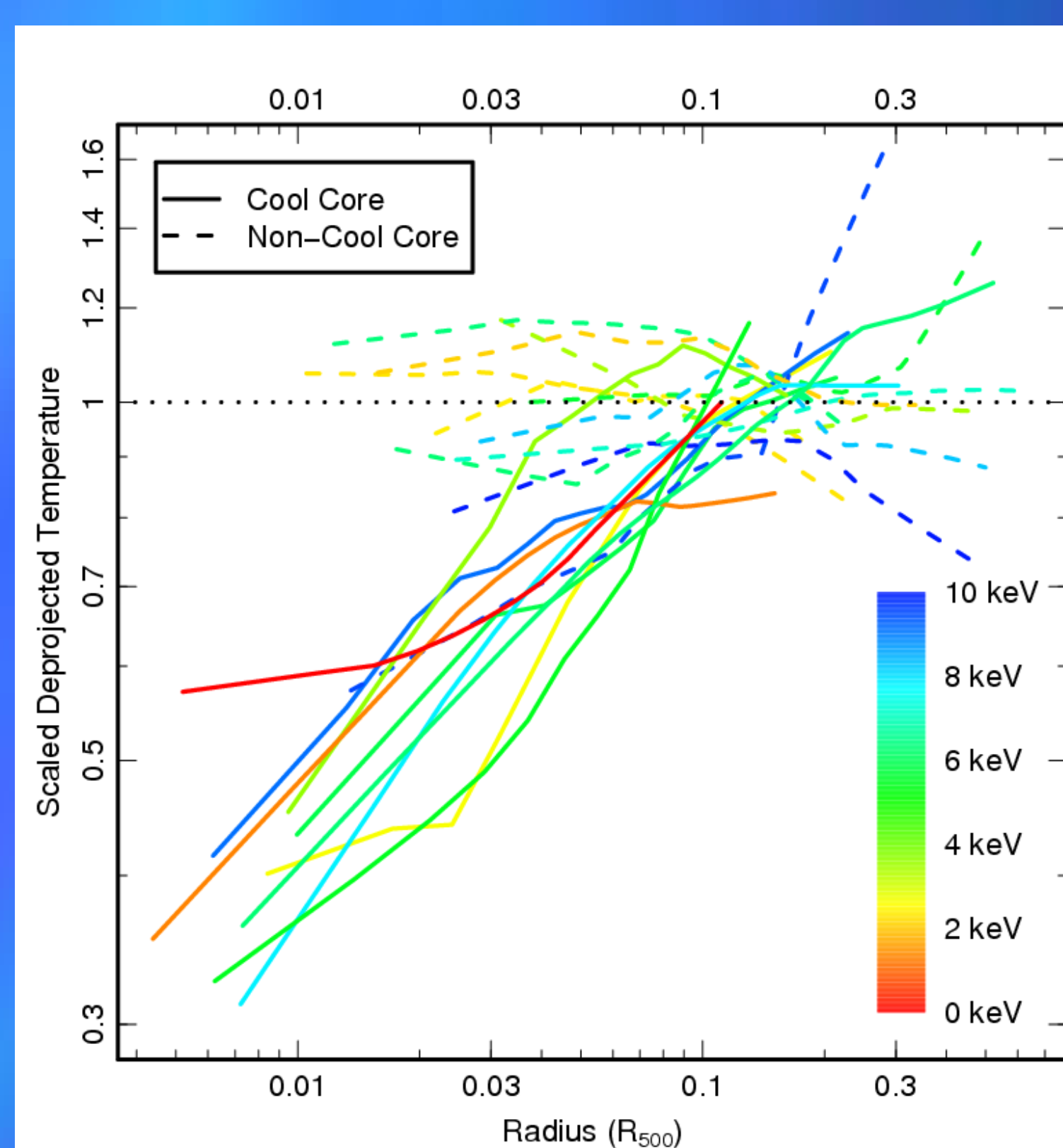
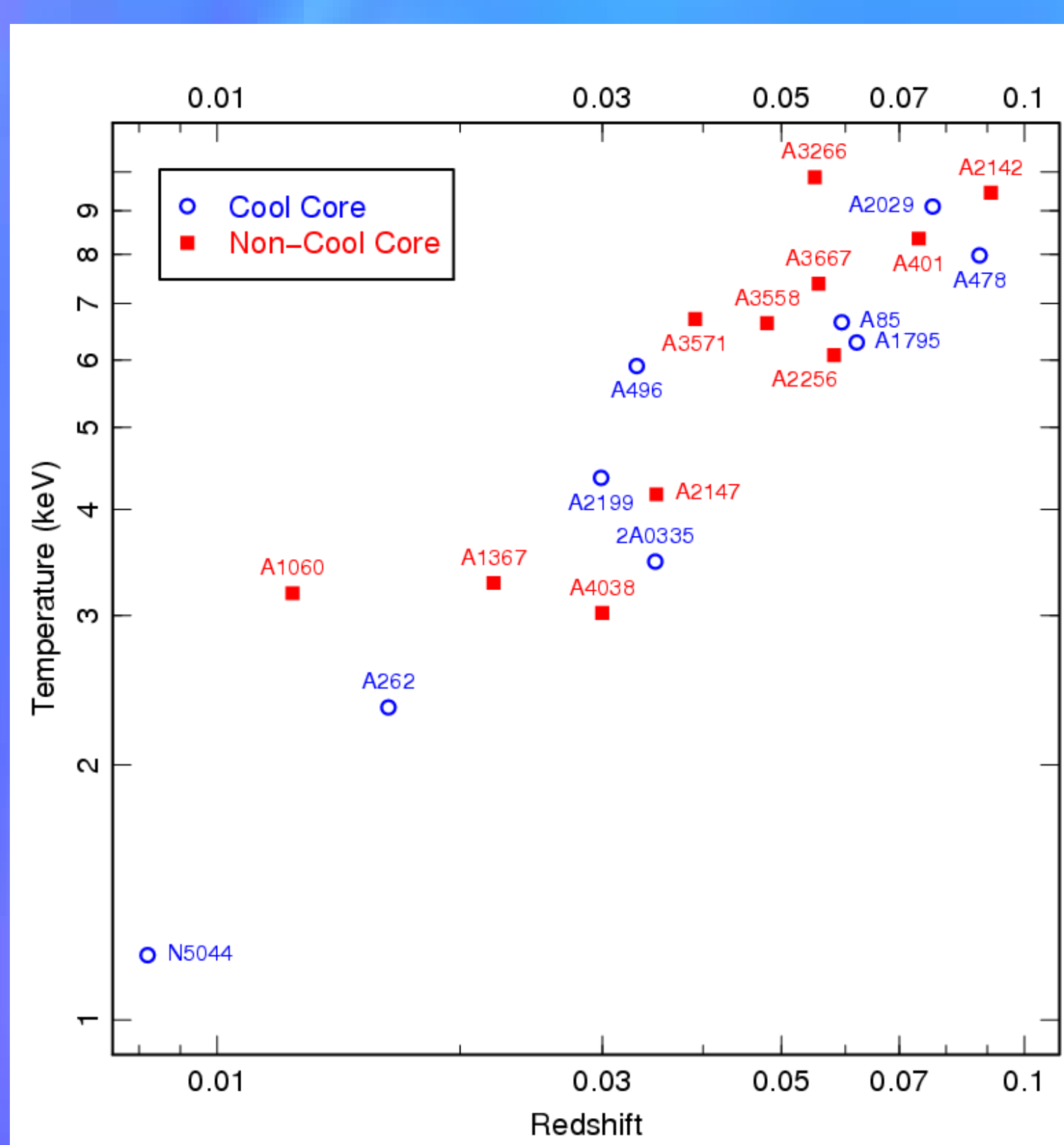
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We present an analysis of a nearly flux-limited sample of 20 galaxy clusters observed with the *Chandra* X-ray satellite, focussing on the density and temperature structure of the inner regions of the hot, gaseous intracluster medium (ICM). The sample comprises the 20 highest flux clusters from the sample of Ikebe et al. (2002), excluding those objects with extremely large angular sizes (the Coma, Fornax and Centaurus Clusters), which are difficult to observe with *Chandra*, owing to its limited field of view.

## Mean Temperature and Cool Core Status

The mean cluster temperature was measured from the spectrum extracted within  $0.1-0.2 r_{500}$  determined using the formula  $r_{500} = 391 \times T^{0.63}$  kpc, inferred from the Mass-Temperature relation of Finoguenov et al. (2001). An iterative process was used to derive both  $T$  and  $r_{500}$  self consistently. A similar temperature was measured from the spectrum within  $0.1 r_{500}$ , which was used to quantify the influence of central cooling: a cluster is defined as having a cool core if the ratio of  $T$  within  $0.1-0.2 r_{500}$  to  $T$  within  $0.1 r_{500}$  exceeded unity at  $>3$  sigma significance.  $T$  and  $r_{500}$  are used subsequently to scale certain derived cluster properties, in order to allow for the effects of variations in halo mass when comparing the properties of different clusters.

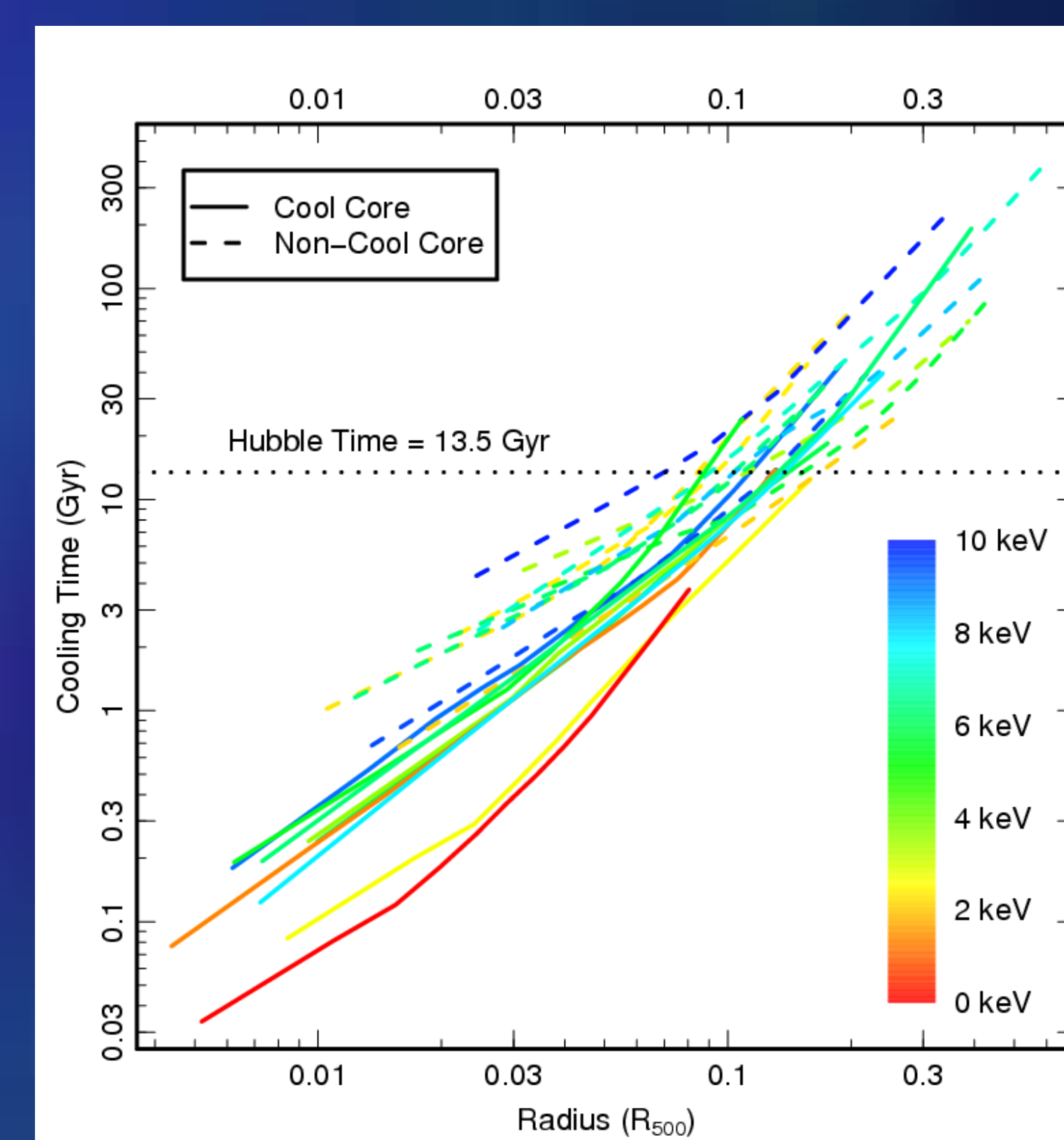
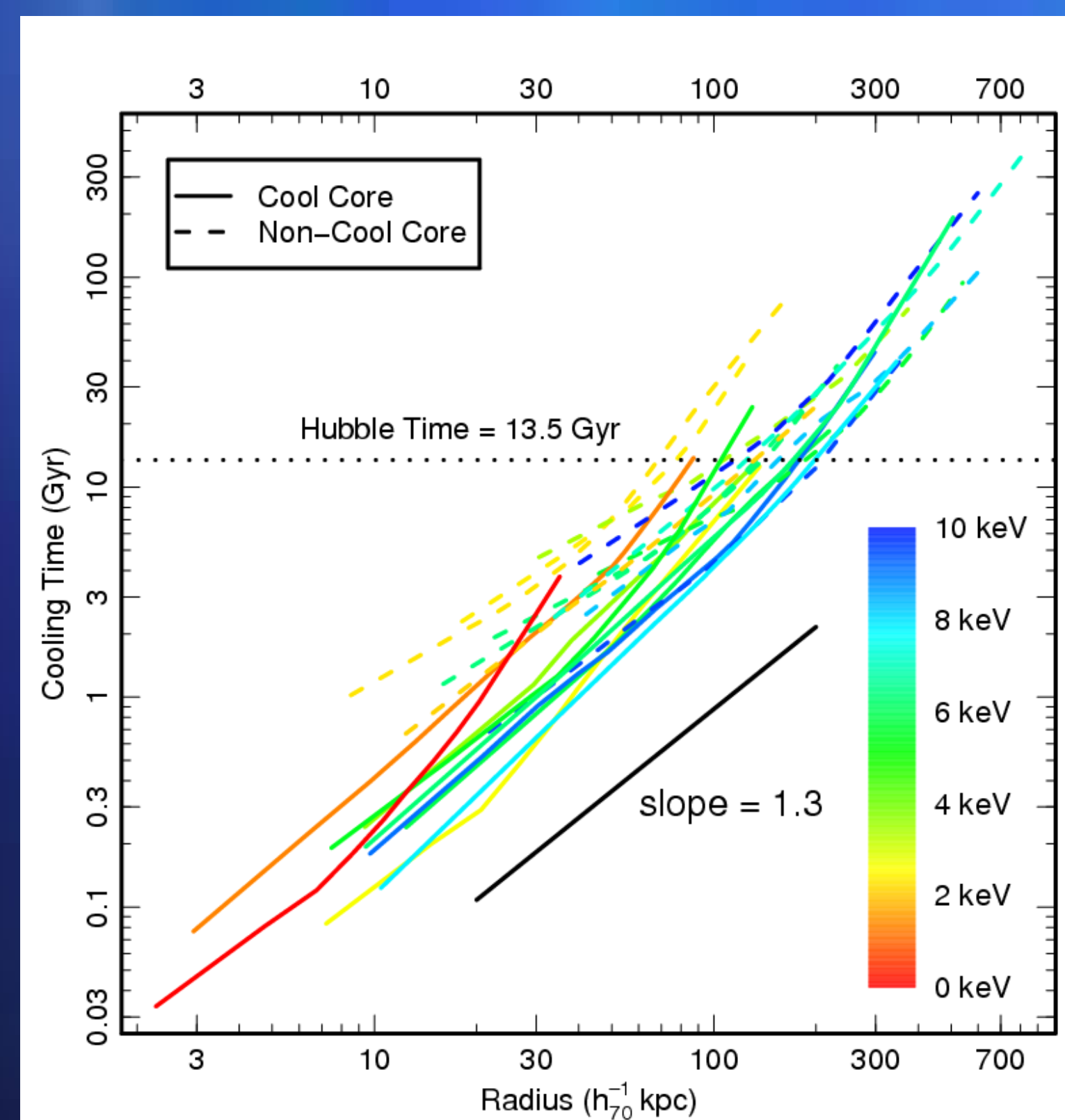


## Gas Cooling Time

The cooling time ( $t_{cool}$ ) is simply the energy of the gas divided by its bolometric X-ray luminosity. Cool core (CC) and non-CC clusters have somewhat similar  $t_{cool}$  profiles, showing little scatter between clusters (also found by Bauer et al., 2005). In all cases, the gas cooling time reaches low values ( $\sim$ few Gyr) within the core.

## Gas Entropy

Entropy is defined as  $S = T / n_e e^{2/3}$ , where  $n_e$  is the gas electron number density, and is an ideal probe of non-gravitational physics, since it is conserved in any adiabatic process and can only be decreased by cooling. The entropy profiles plotted here have been normalized by  $T^{0.65}$ , as per Ponman et al. (2003), and show excellent agreement with that empirical scaling.



## Conclusions

- Radiative cooling imposes a universal gas entropy profile
- Gas density is lower in cooler (smaller) clusters => preheating?
- Even non-cool core clusters have some gas with very low cooling time
- The similarity in  $t_{cool}(r)$  suggests a universal form for the cooling time of gas in collapsed halos => radiative cooling is important in cosmology
- There is evidence of morphological disturbance in non-cool core clusters which *may* indicate that cluster merging prevents cool cores formation, although some simulations have shown that merging cannot destroy cool cores (e.g. Poole et al., 2006).

## References

- Bauer et al., 2005, MNRAS, 359, 1481  
 Finoguenov et al., 2003, A&A, 368, 749  
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 Ponman et al., 2003, MNRAS, 343, 331  
 Poole et al., 2006, MNRAS, submitted

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