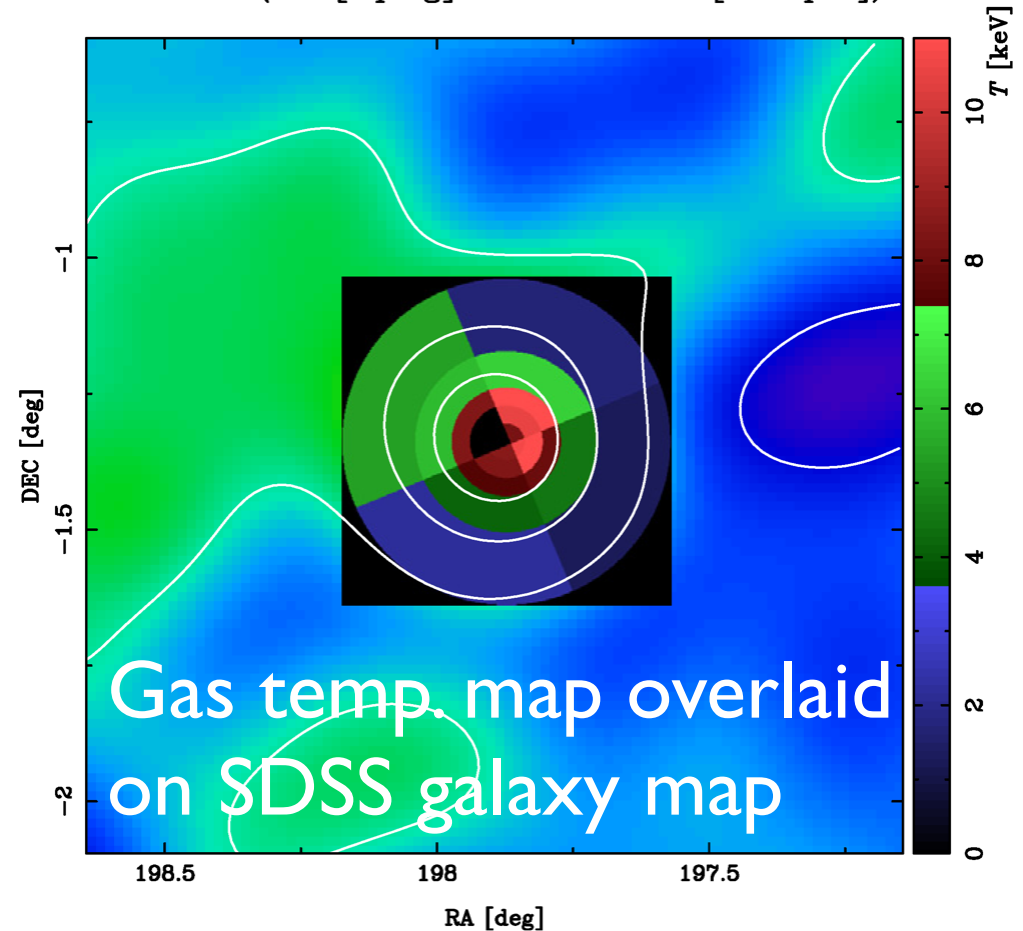
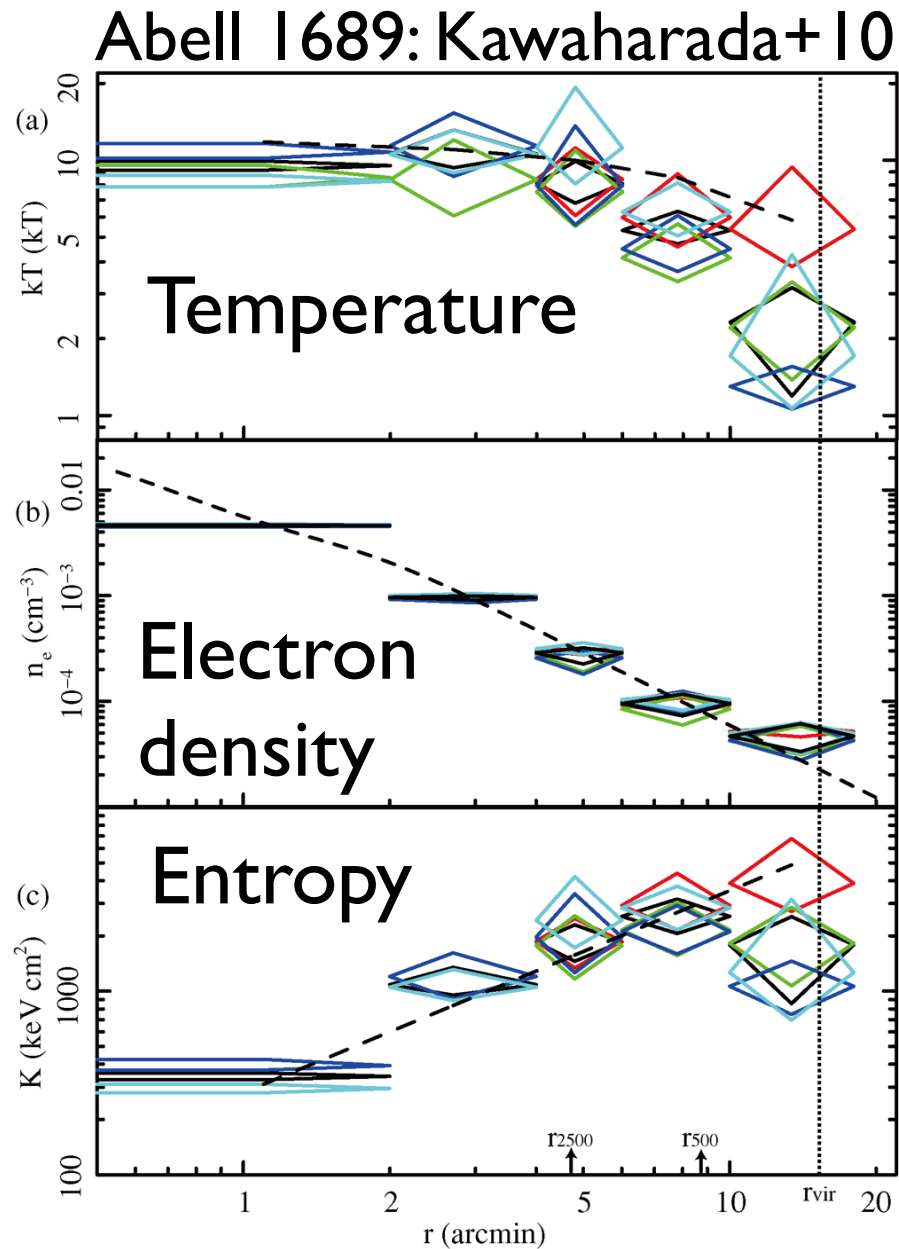


Temperature / entropy / mass profiles to the virial radius of galaxy clusters observed with Suzaku

K. Sato, K. Matsushita, K. Ichikawa, T. Sato (Tokyo univ. of Science),
N. Okabe (ASIAA), K. Nakazawa (Univ. of Tokyo),
Y. Fujita (Osaka univ.), M. Kawaharada, M. Takizawa (Yamagata univ.)
T. Tamura, N.Y. Yamasaki (ISAS/JAXA),
S. Sasaki, and T. Ohashi (Tokyo Metropolitan univ.)

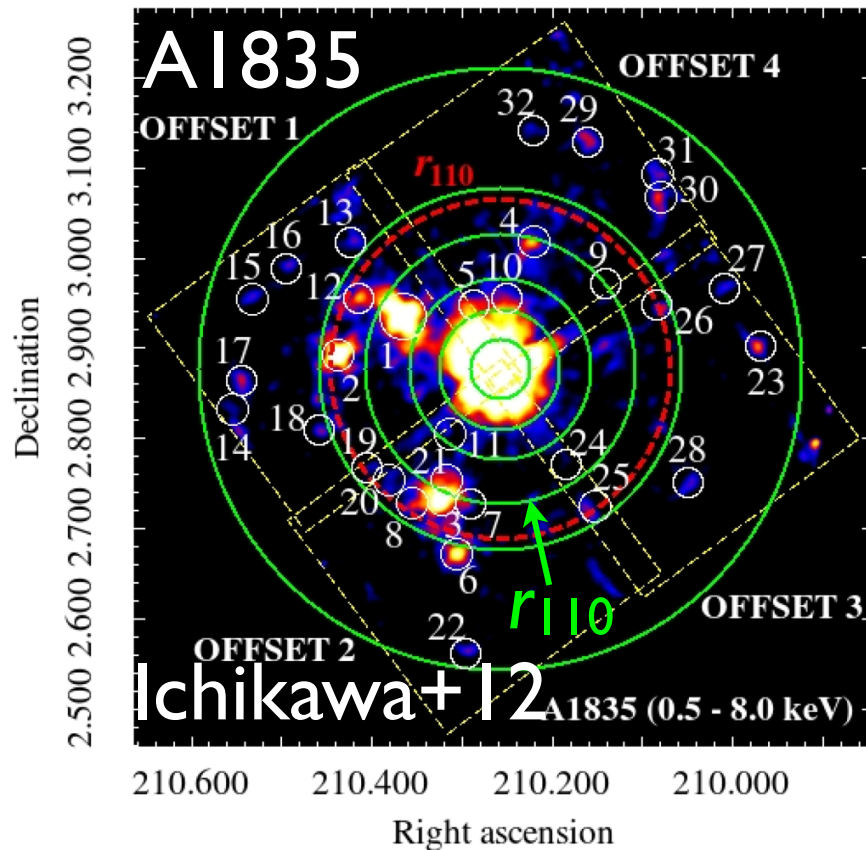
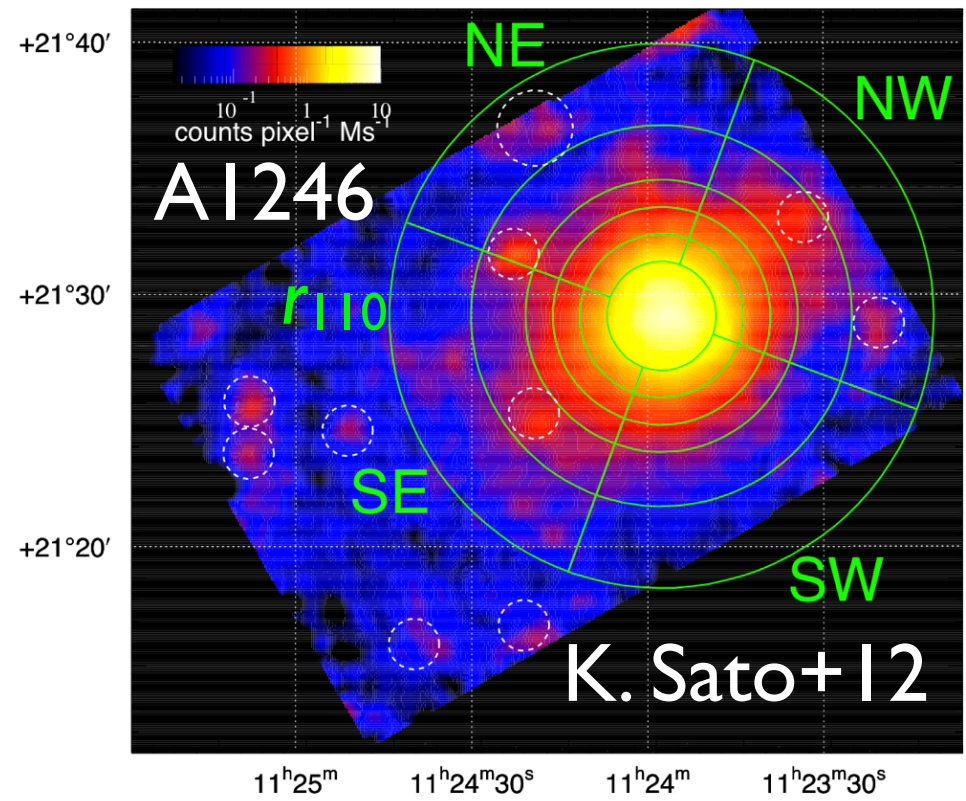
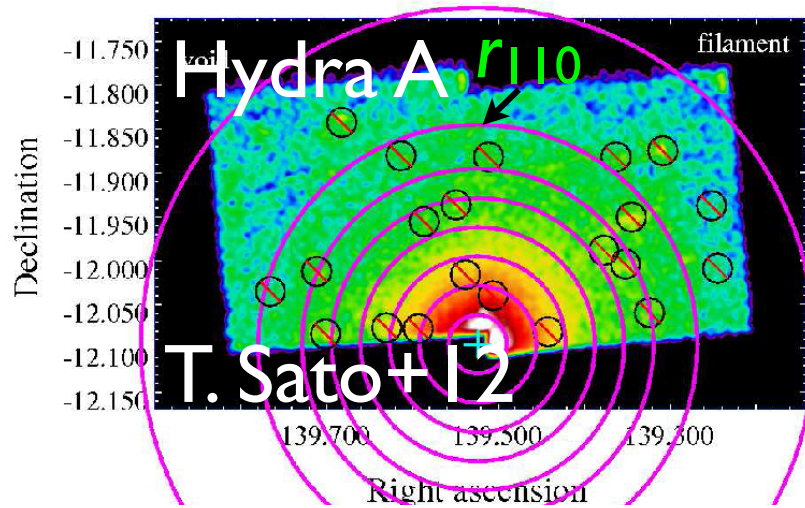
Profiles to the virial radius

A1689 (2.2 [sqdeg] $\approx 11.7 \times 11.7 [h^{-2}\text{Mpc}^2]$)



Cluster outskirts are important for investigating cluster thermal and evolution process.

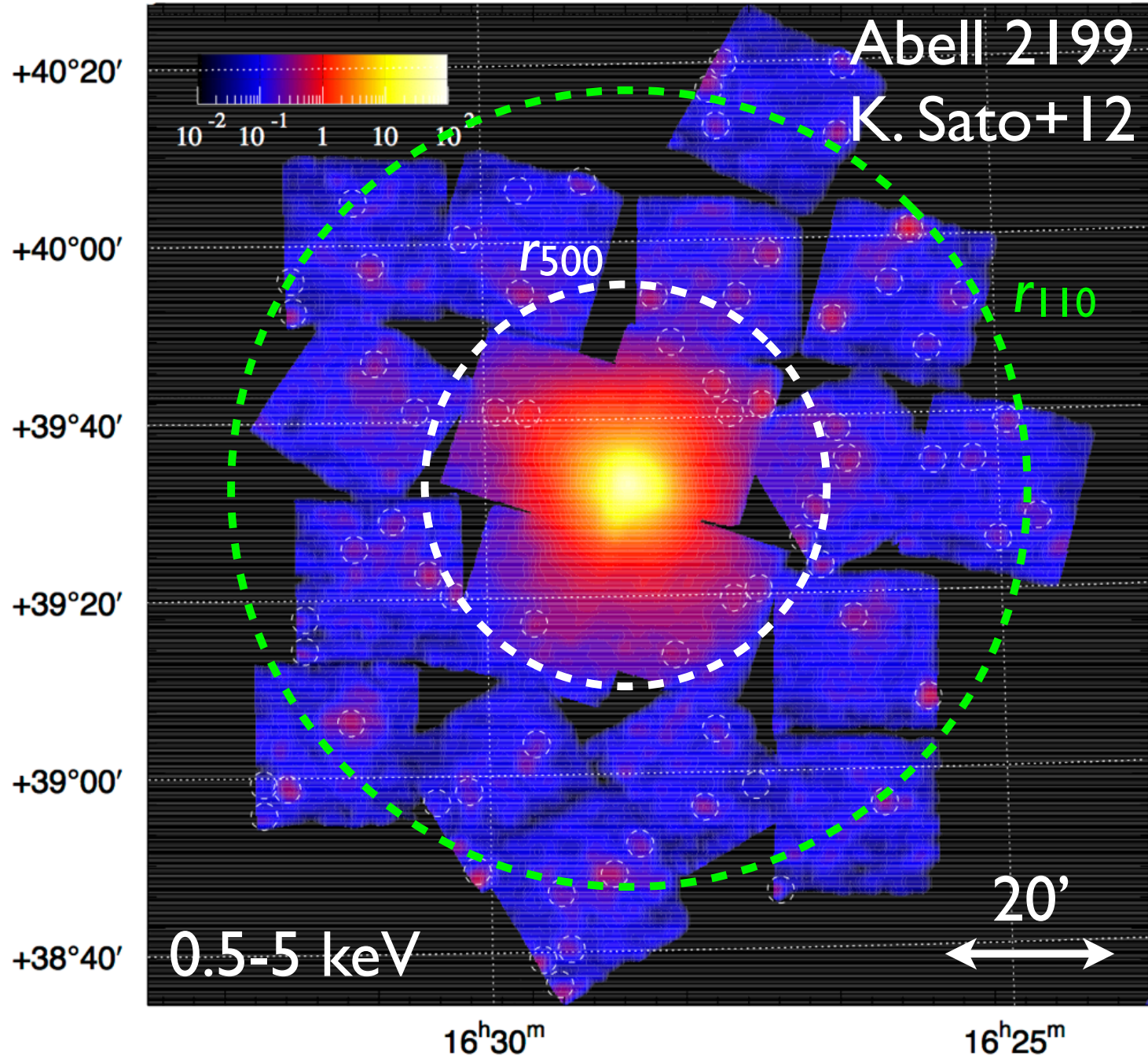
Hydra A, Abell 1246, and Abell 1835 clusters with Suzaku



Properties in the outskirts:

- ◆ ICM temperatures
- ◆ Entropy profiles
- ◆ Hydrostatic equilibrium?

Abell 2199 observed with Suzaku as “AO-6 keyproject”



ex. Abell 2199 results

Radial profiles

to $2.5 r_{500} \sim r_{100}$

✓ Temperature

- 4.4 keV \rightarrow \sim 1 keV

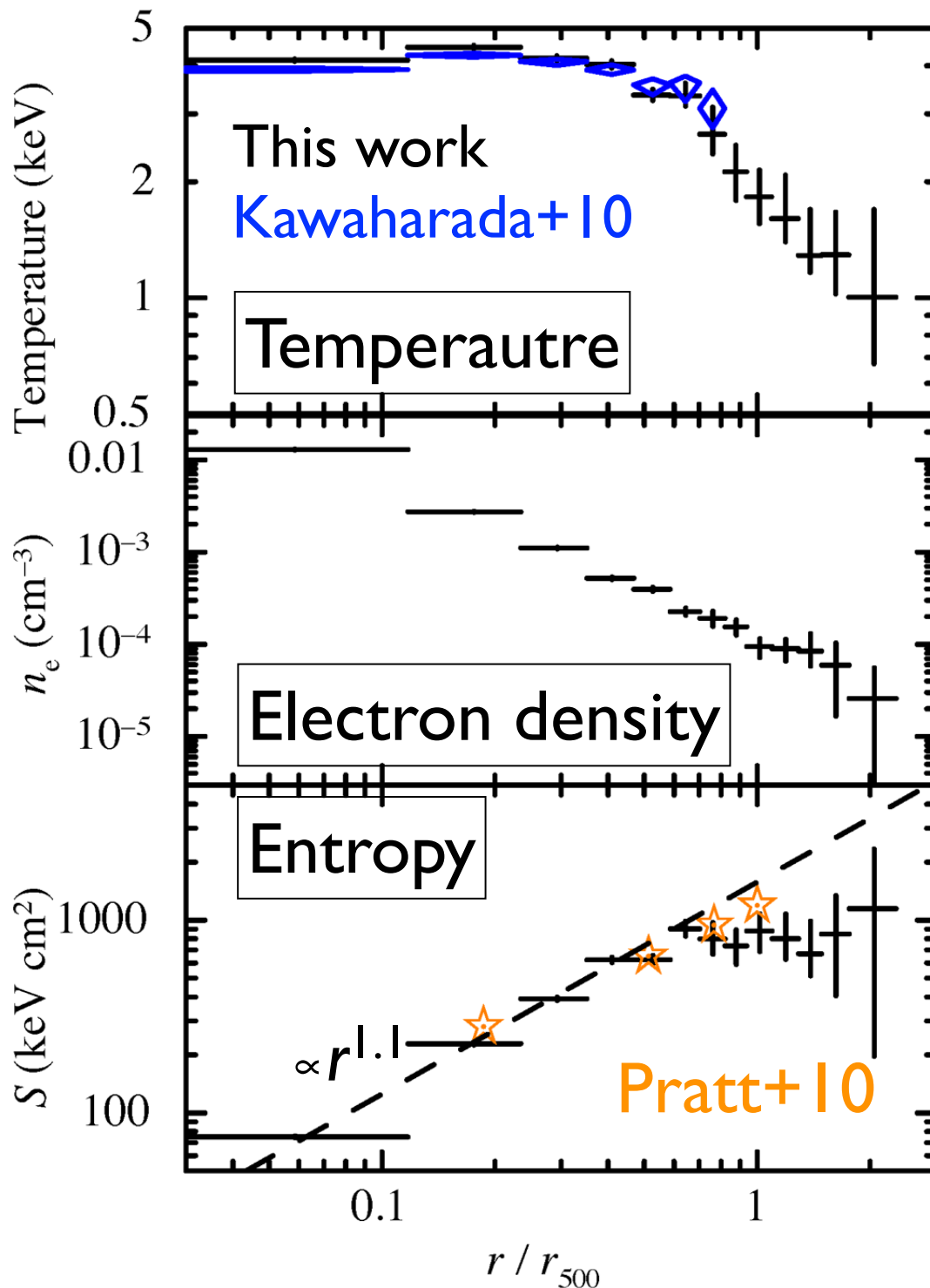
✓ Electron density

- Slightly steeper than beta-model at center

✓ Entropy

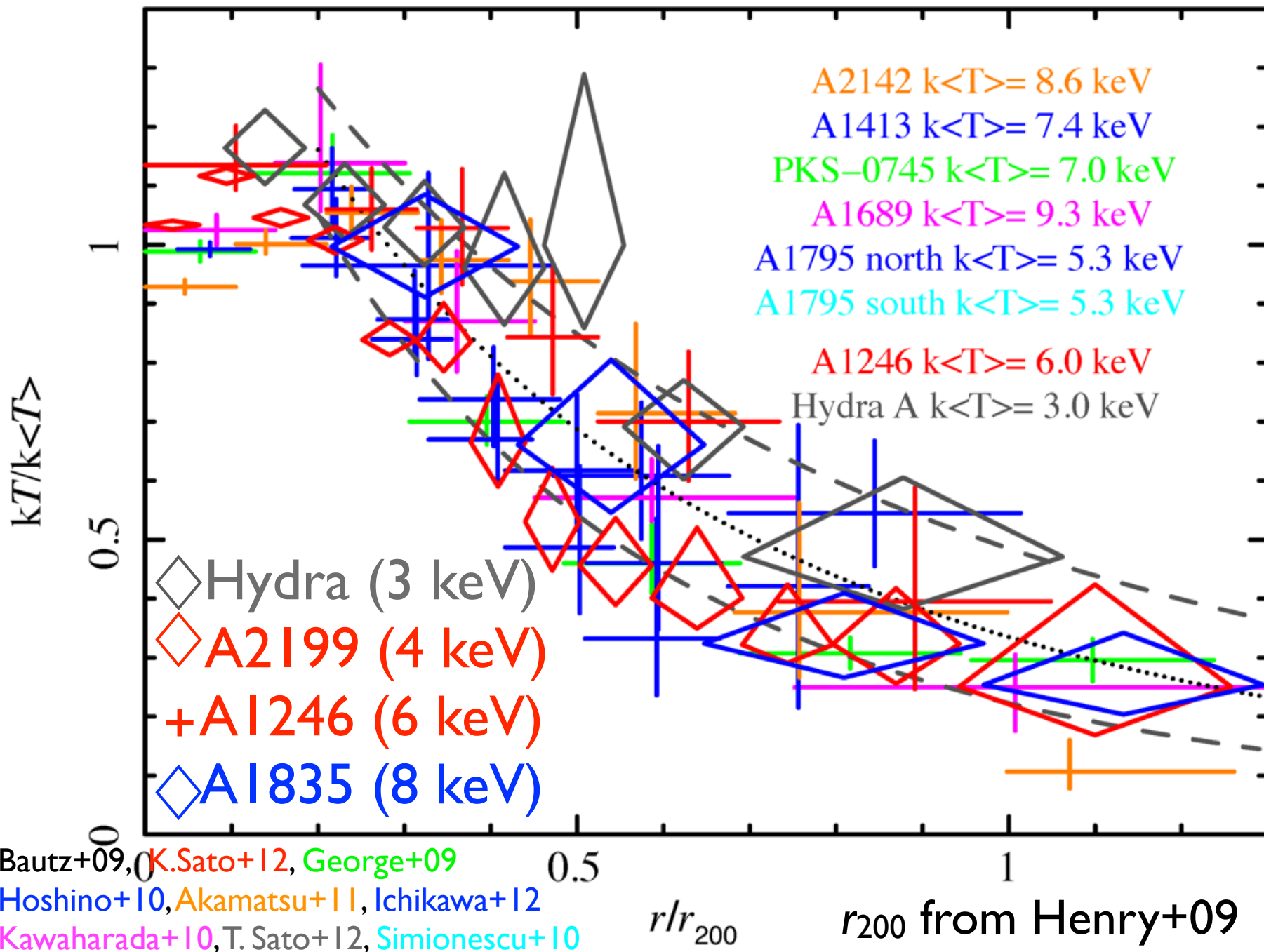
- Consistent with the previous XMM results

- Flatter slope in $r > \sim r_{500}$ than the expected slope from simulations

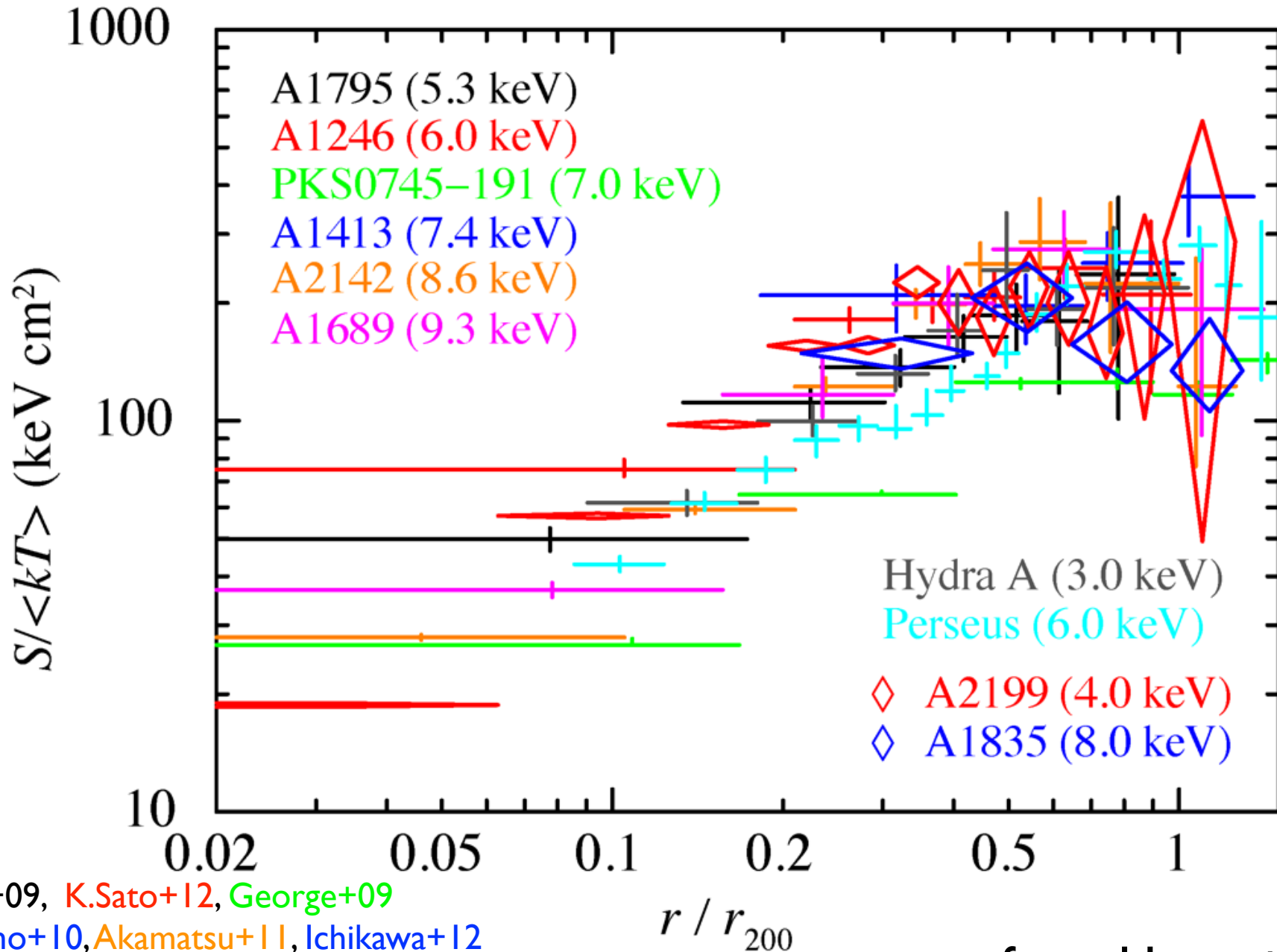


Scaled temperature profile of clusters

Akamatsu+11



Entropy profile scaled by the average temperatures

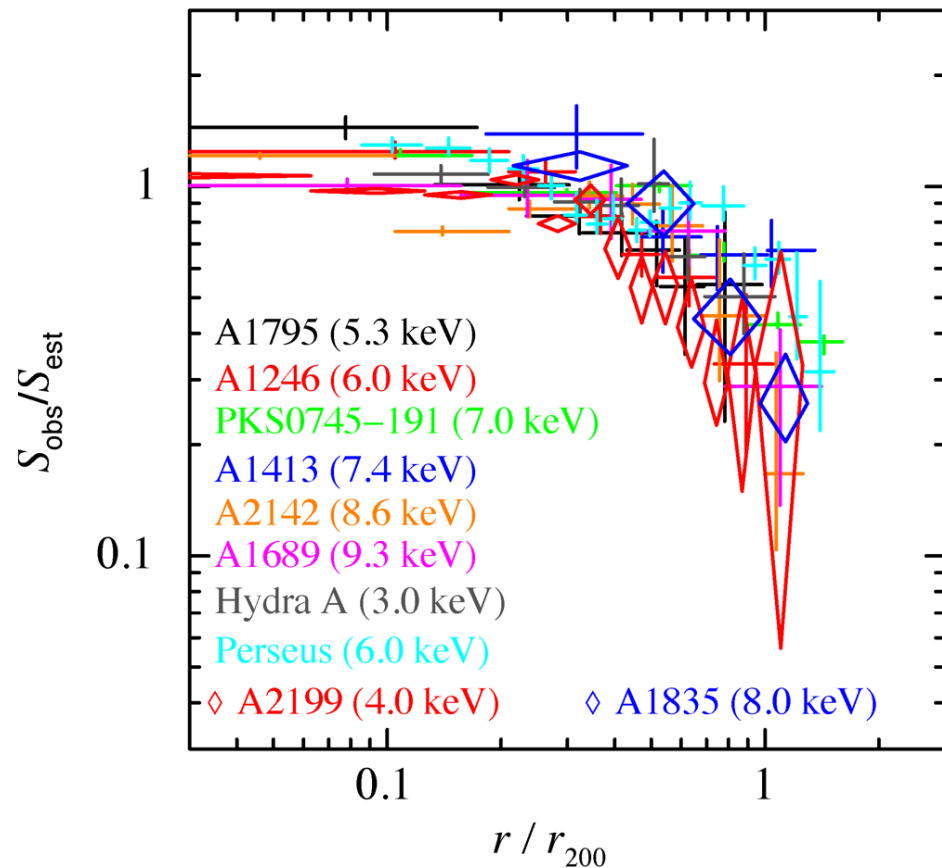


Bautz+09, K.Sato+12, George+09
Hoshino+10, Akamatsu+11, Ichikawa+12
Kawaharada+10, T. Sato+12, Simionescu+10

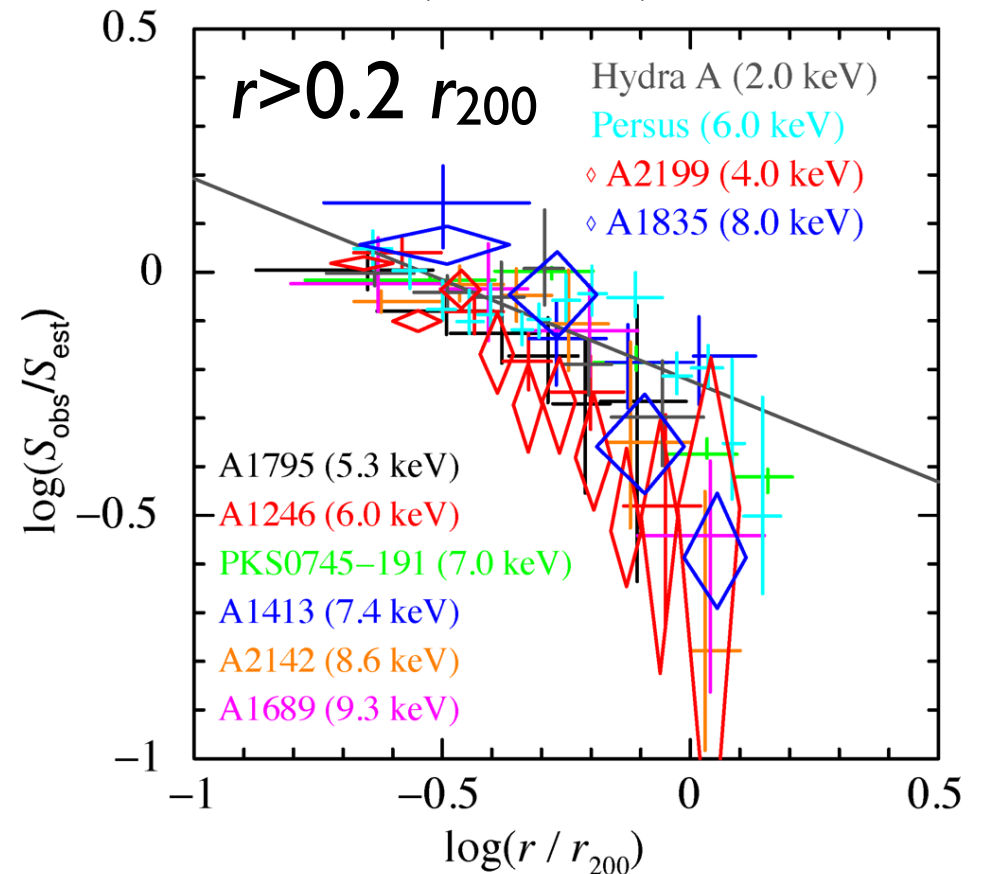
r_{200} from Henry+09

$S_{\text{obs.}}$ to $S_{\text{est.}}$ ($\propto r^{1.1}$) ratios

K. Sato+12



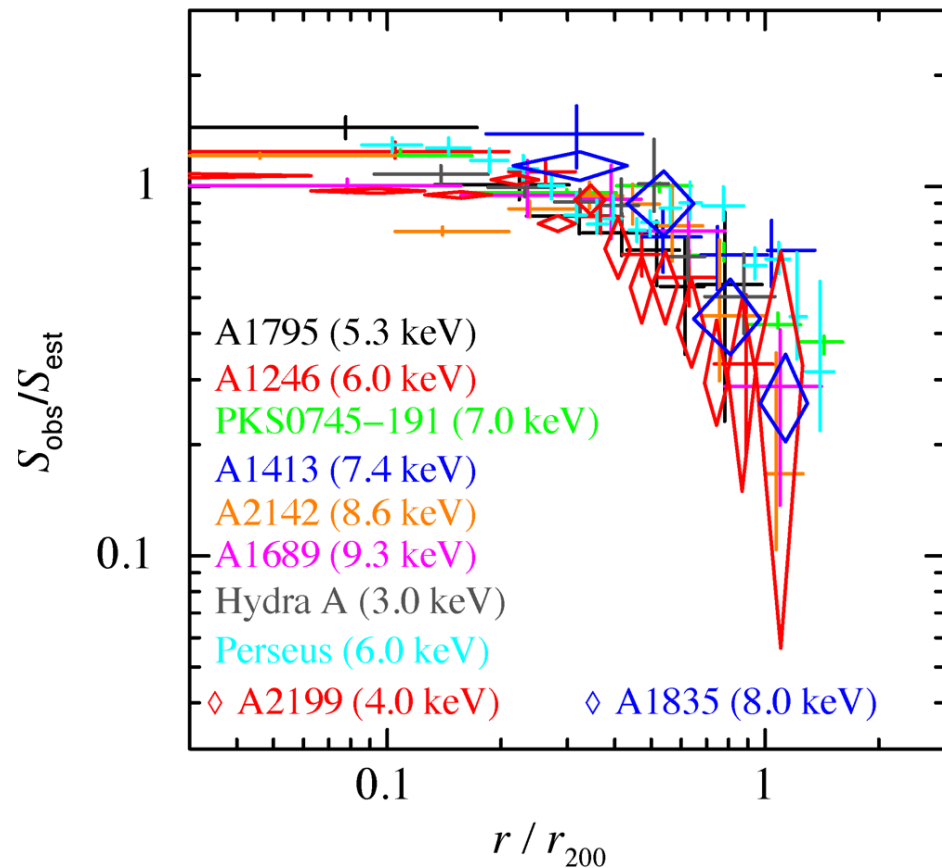
Bautz+09, K.Sato+12, George+09
Hoshino+10, Akamatsu+11, Ichikawa+12
Kawaharada+10, T. Sato+12, Simionescu+10



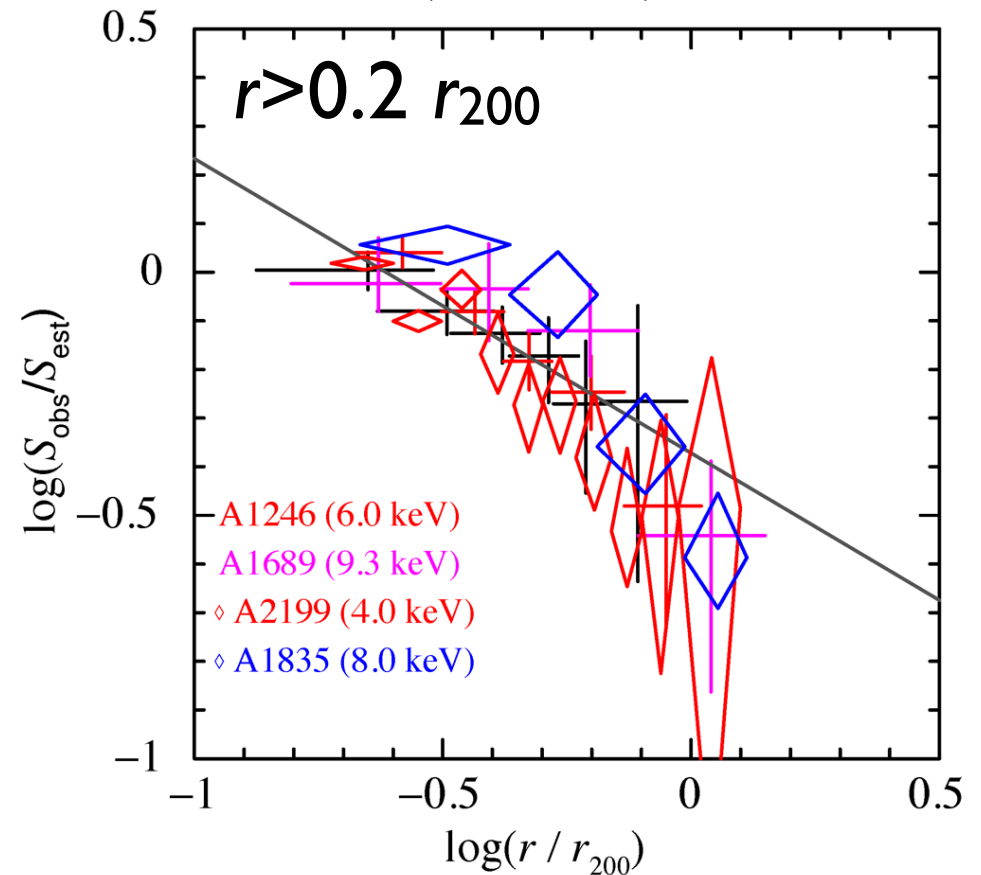
- ✓ Comparison of S ratios of the observed to the expected from numerical simulations in $r > 0.2 r_{200}$
- ✓ Good indicator for estimating cluster thermal history?

$S_{\text{obs.}}$ to $S_{\text{est.}}$ ($\propto r^{1.1}$) ratios

K. Sato+12



Bautz+09, K.Sato+12, George+09
Hoshino+10, Akamatsu+11, Ichikawa+12
Kawaharada+10, T. Sato+12, Simionescu+10



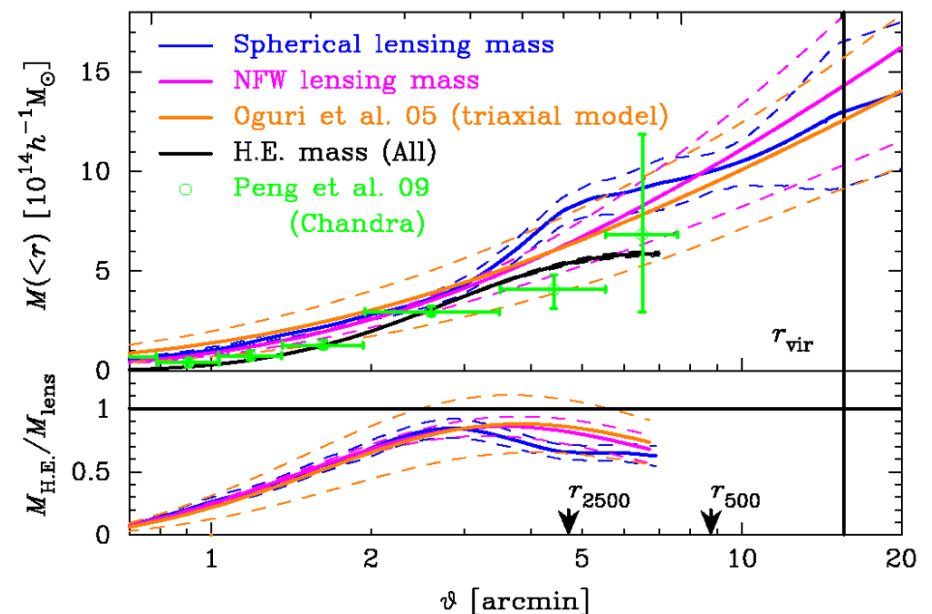
- ✓ Comparison of S ratios of the observed to the expected from numerical simulations in $r > 0.2 r_{200}$
- ✓ Good indicator for estimating cluster thermal history?

The flattening feature of Entropy profiles

- ✓ Electron \neq Ion temperature?
(Hoshino+10, Akamatsu+11)
- ✓ Clumping? Flow from the large filament?
(Simionescu+11)
- ✓ Bulk motion? Out of hydrostatic equilibrium (H.E.)?
(Kawaharada+10)

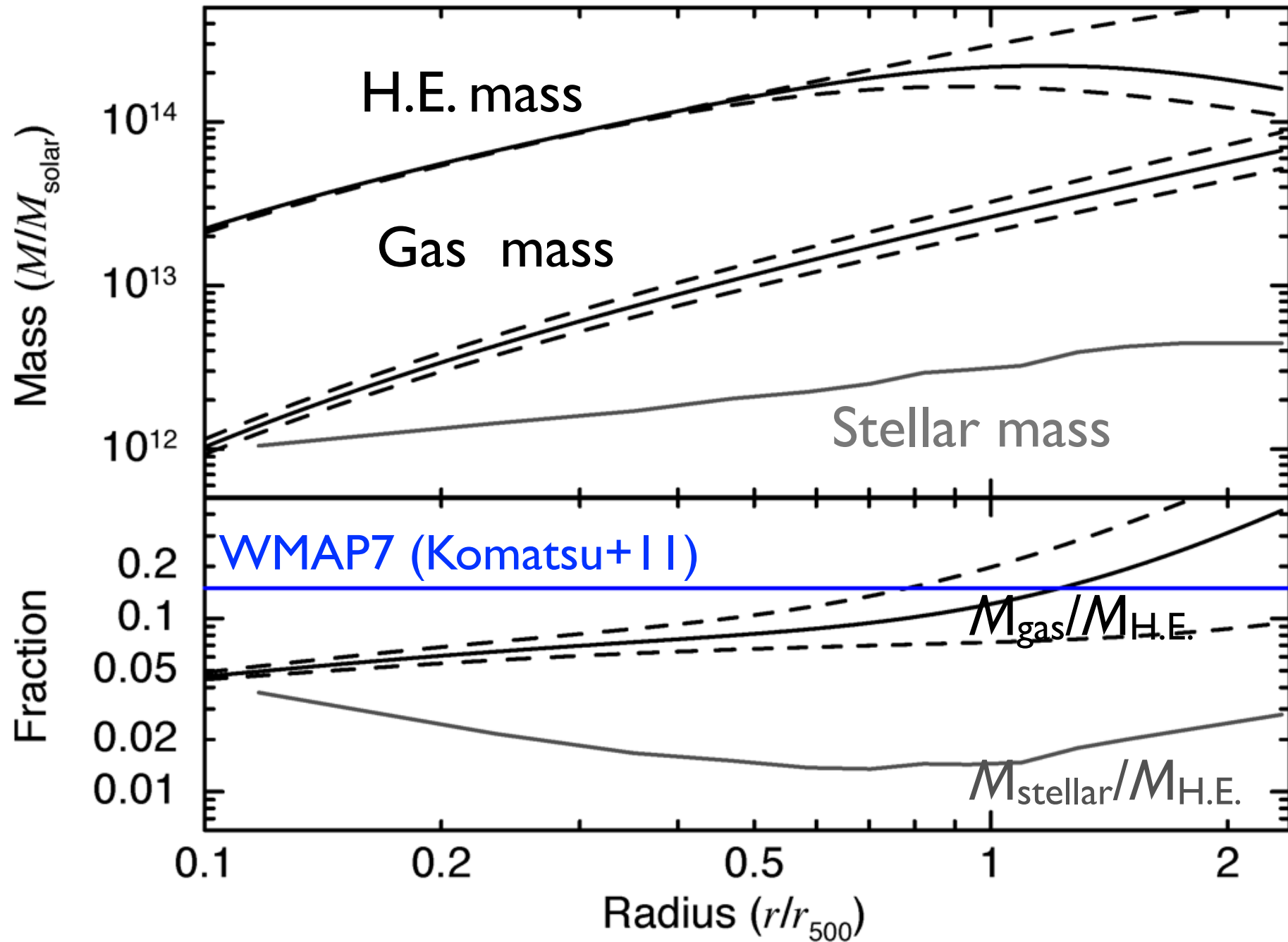
↓

Total / gas / stellar mass
estimation
from X-ray/lens/SZE



H.E. / gas / stellar mass profiles

ex. Abell 2199



Summary

- ✓ Several cluster obs. with Suzaku to the virial radius
- ✓ $kT / n_e / S$ profiles to the outskirts:
 - Consistent with the Suzaku & XMM results to $\sim r_{500}$
 - kT drop is also similar to other Suzaku results at r_{200}
 - S is lower than the S from simulations in $r > r_{500}$
 - S does **not** depend on kT , and the slope looks similar for each cluster
- ✓ H.E. / gas / stellar mass:
 - Out of H. E. in $r > r_{500}$?
 - Gas / stellar mass fractions agree with the cosmic baryon fraction

X-ray / weak lens / SZE obs. as complementary probe would be need to estimate cluster mass without biases