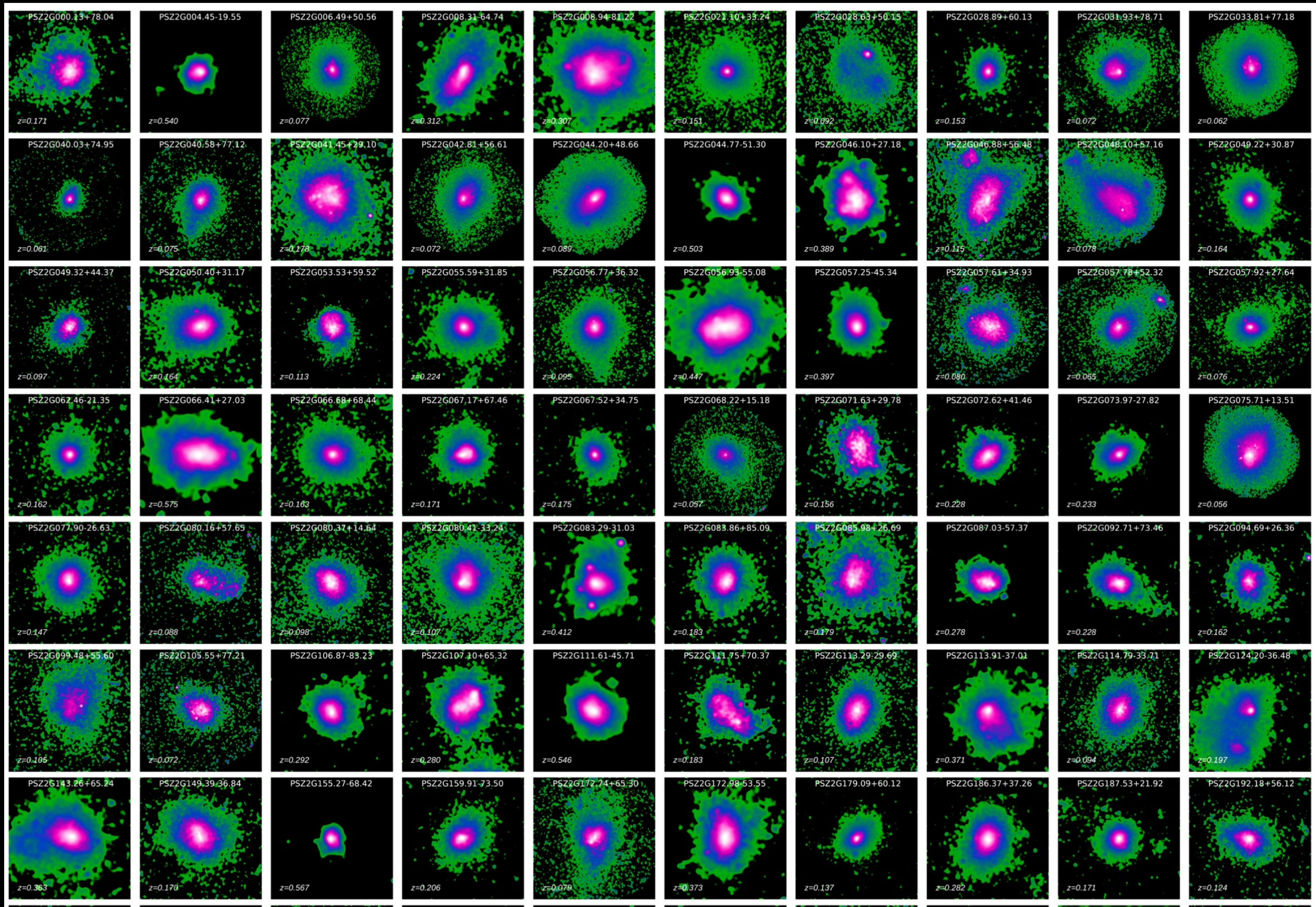
AHEAD / Task 14.8

contribution by Ettori, Lovisari, Angelinelli et al.

Task 14.8 Hyperspectral imaging and fitting & advanced analysis of extended sources [M6-M48]
(Lead INAF. Partners: CEA) // Coordinator: H. Bourdin

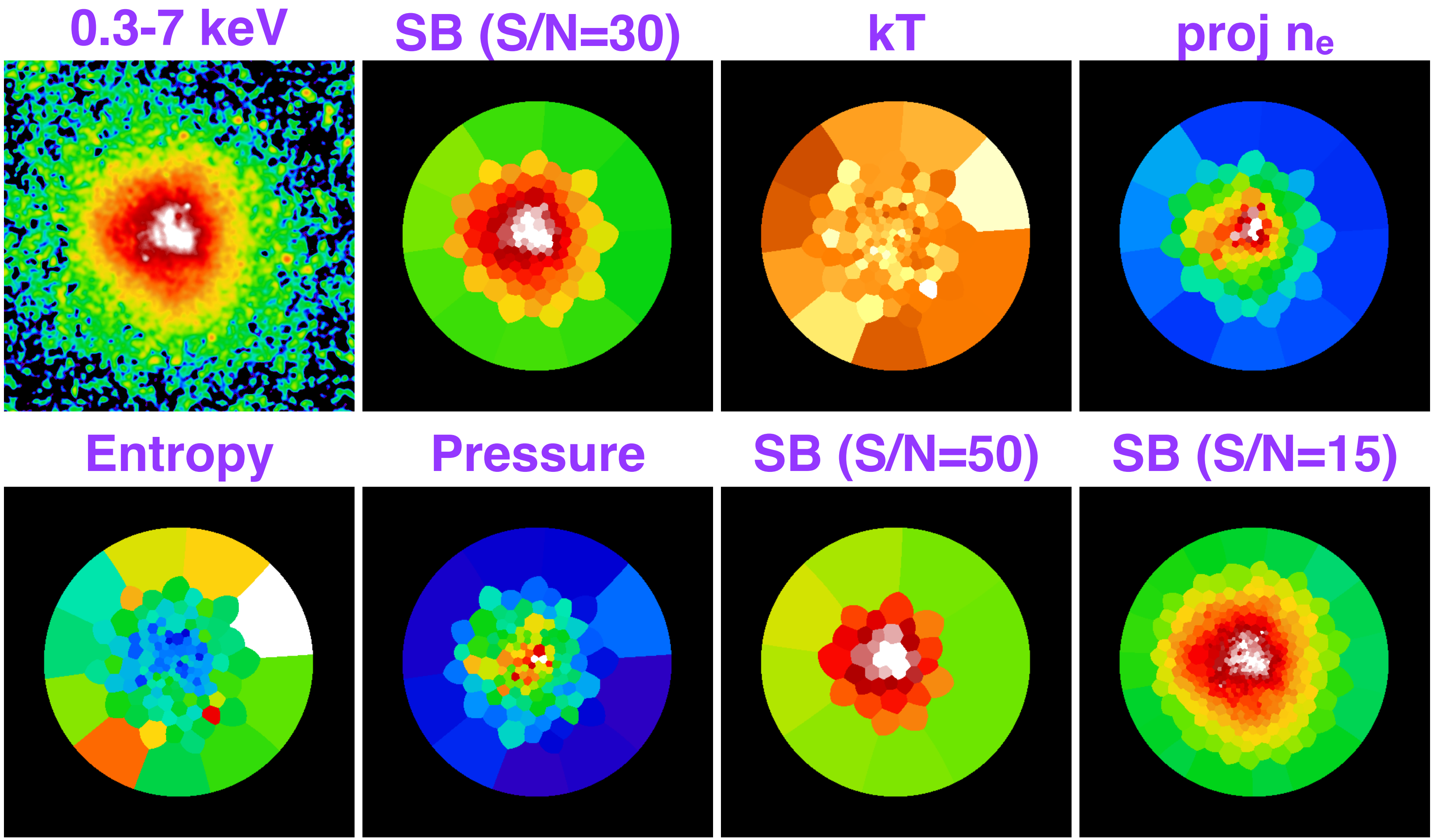
Athena/X-IFU unprecedented spectral resolution calls for innovative approaches in spectral fitting, including development of physical models to be fitted to high resolution spectra, in addition to standard parametric models.
We will develop physical models for 1) AGN nuclear winds, both MHD and radiation driven; 2) AGN accretion disks; 3) AGN driven shocks. Prototype codes will be linked to popular fitting tools such as Xspec. We will test prototype models on Athena/X-IFU simulations and XRISM real data.
We will study best algorithms and build prototypes for advanced analysis of **extended sources** in **1) denoising** (point source subtraction, internal BKG characterization, best strategies to filter out noise); **2) super-resolution** (enhance the spatial resolution of the system, sub-pixel event repositioning); **3) visualization of data cubes** (prompt visualization of data cubes by projecting in one, two or three dimensions); **4) maps of physical quantities** (semi-automatic production of maps of physical quantities (Temperature, Abundances, Velocity, etc)). Prototypes will be tested on simulated X-IFU and WFI data, and on real data (Chandra, XMM, XRISM).

CHEX-MATE gallery *2021, A&A, 650, 104*



Pipeline output

@Lovisari



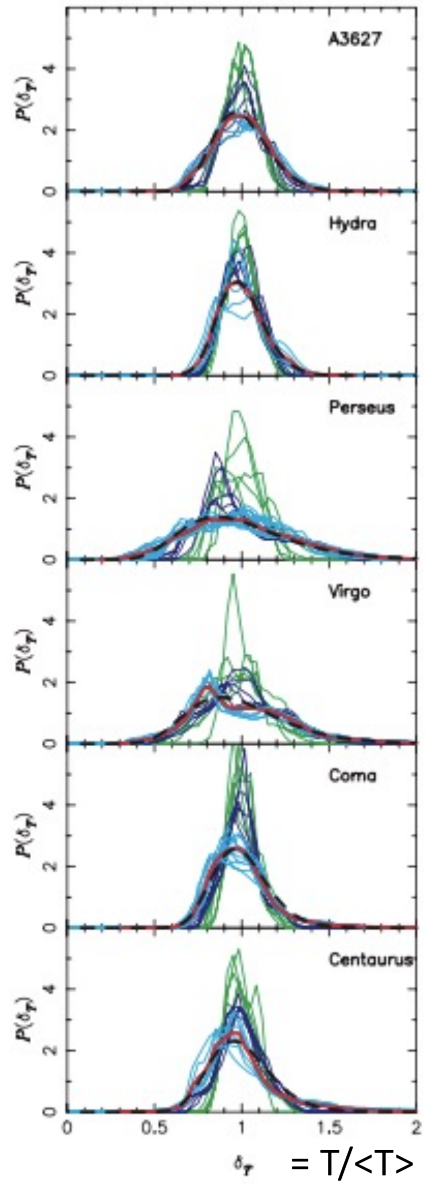
+ a Nr of other maps (currently not used) and all the profiles

2D maps of T measurements

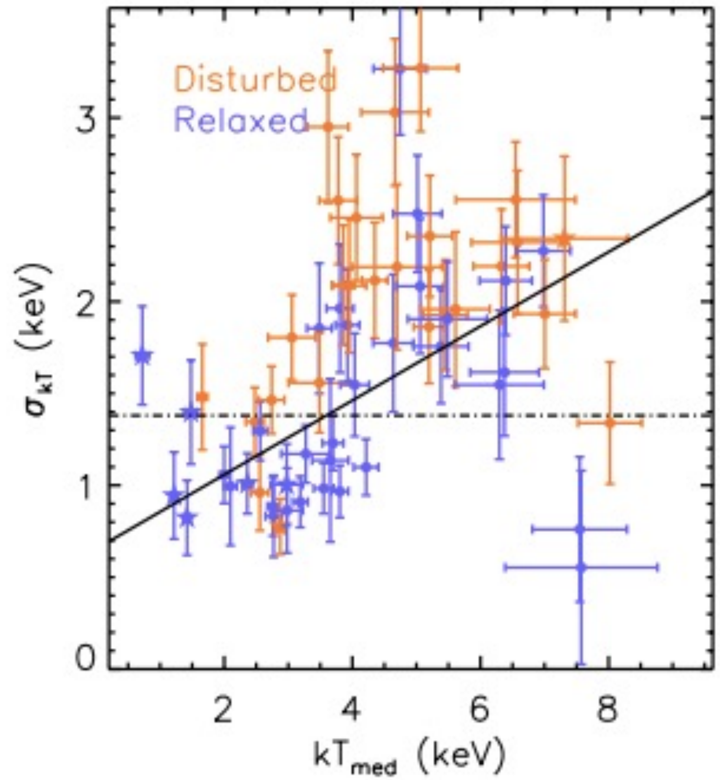
Kawahara+07: “we have shown for the first time that the probability distribution functions of the local inhomogeneities approximately follow a lognormal distribution. Based on a simple analytical model, we have demonstrated that not only the radial profiles but also the local inhomogeneities are largely responsible for the bias in the cluster temperatures.” (see also Khedekar+13)

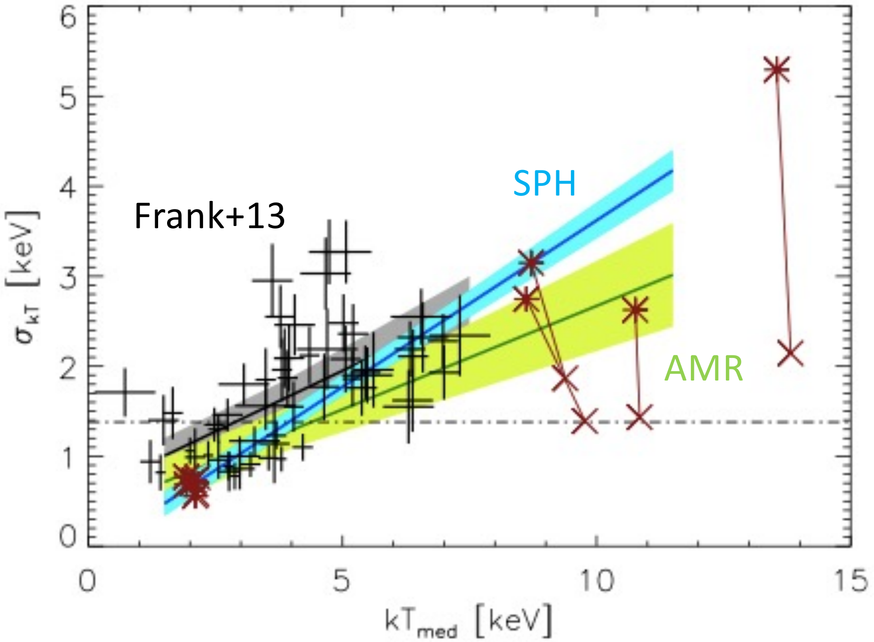
$$P_{\rm LN}(\delta_x)d\delta_x = \frac{1}{\sqrt{2\pi}\sigma_{{\rm LN},x}} \exp\left[\frac{-(\log \delta_x + \frac{1}{2}\sigma^2_{{\rm LN},x})^2}{2\sigma^2_{{\rm LN},x}}\right]\frac{d\delta_x}{\delta_x}$$

NB the mean μ is here defined as $\mu = -\sigma^2/2$;
by definition, $E(X) = \exp(\mu + \sigma^2/2) = 1 \rightarrow \mu = -\sigma^2/2$



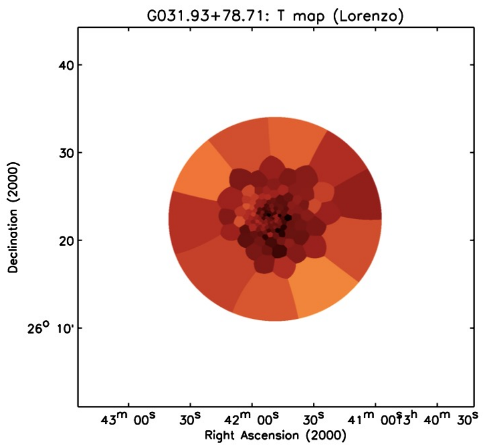
Frank+13: "We have used the smoothed particle inference method of (Peterson et al. 2007) to measure the temperature distributions of the HIFLUGCS sample of galaxy clusters. …We search for correlations between the width of the temperature distributions and other cluster properties, including median cluster temperature, luminosity, size, presence of a cool core, AGN activity, and dynamical state. … ***We find that none of the clusters have a temperature width consistent with isothermality***. Counterintuitively, we also find that the temperature distribution widths of disturbed, non-cool-core, and AGN-free clusters tend to be wider than in other clusters. A linear fit to $\sigma_{kT} - kT_{med}$ finds $\sigma_{kT} \sim 0.20\ kT_{med} + 1.08$, with an estimated intrinsic scatter of ~ 0.55 keV, demonstrating a large range in ICM thermal histories."

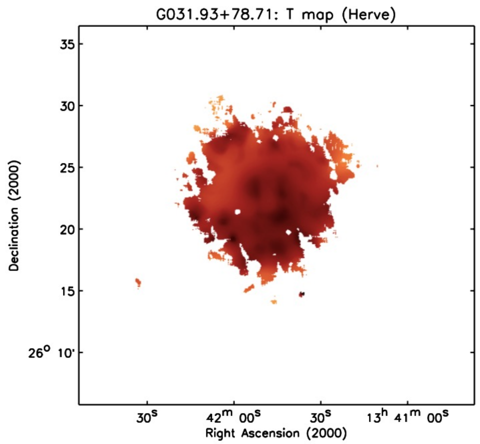


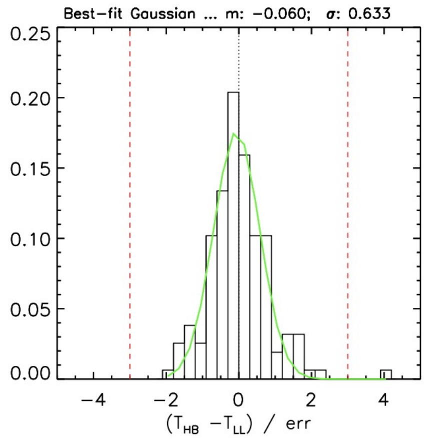


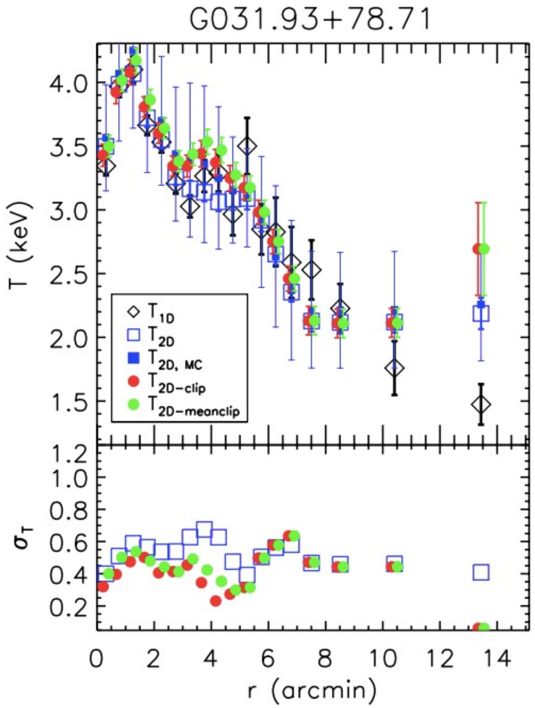
Rasia+14: "We find that the SPH simulations produce larger temperature variations connected to the persistence of both substructures and their stripped cold gas. This difference is more evident in nonradiative simulations, whereas it is reduced in the presence of radiative cooling. ***We also find that the temperature variation in radiative cluster simulations is generally in agreement with that observed in the central regions of clusters.*** Around R500 the temperature inhomogeneities of the SPH simulations can generate twice the typical HE mass bias of the AMR sample."

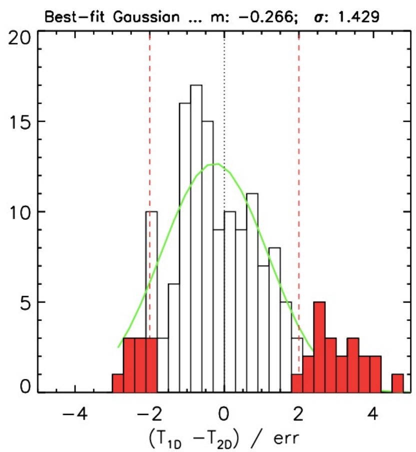
Results: 29 clusters

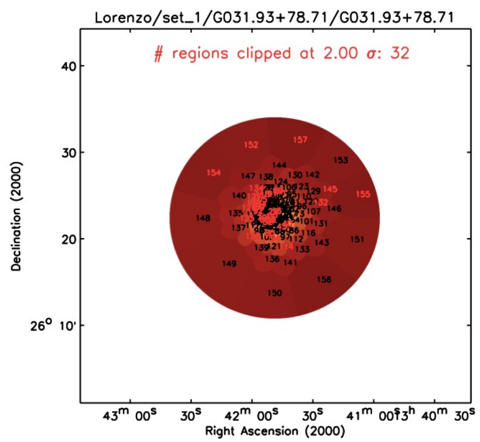


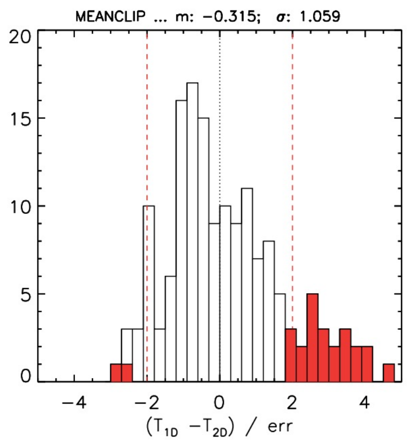


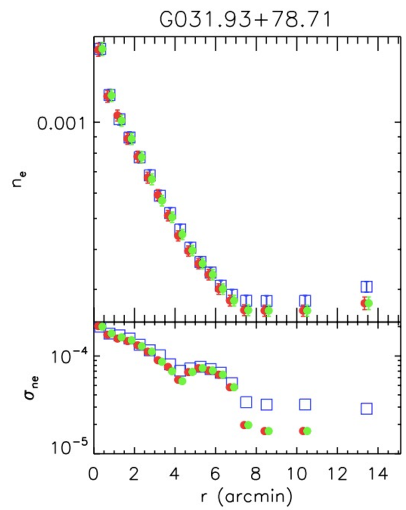




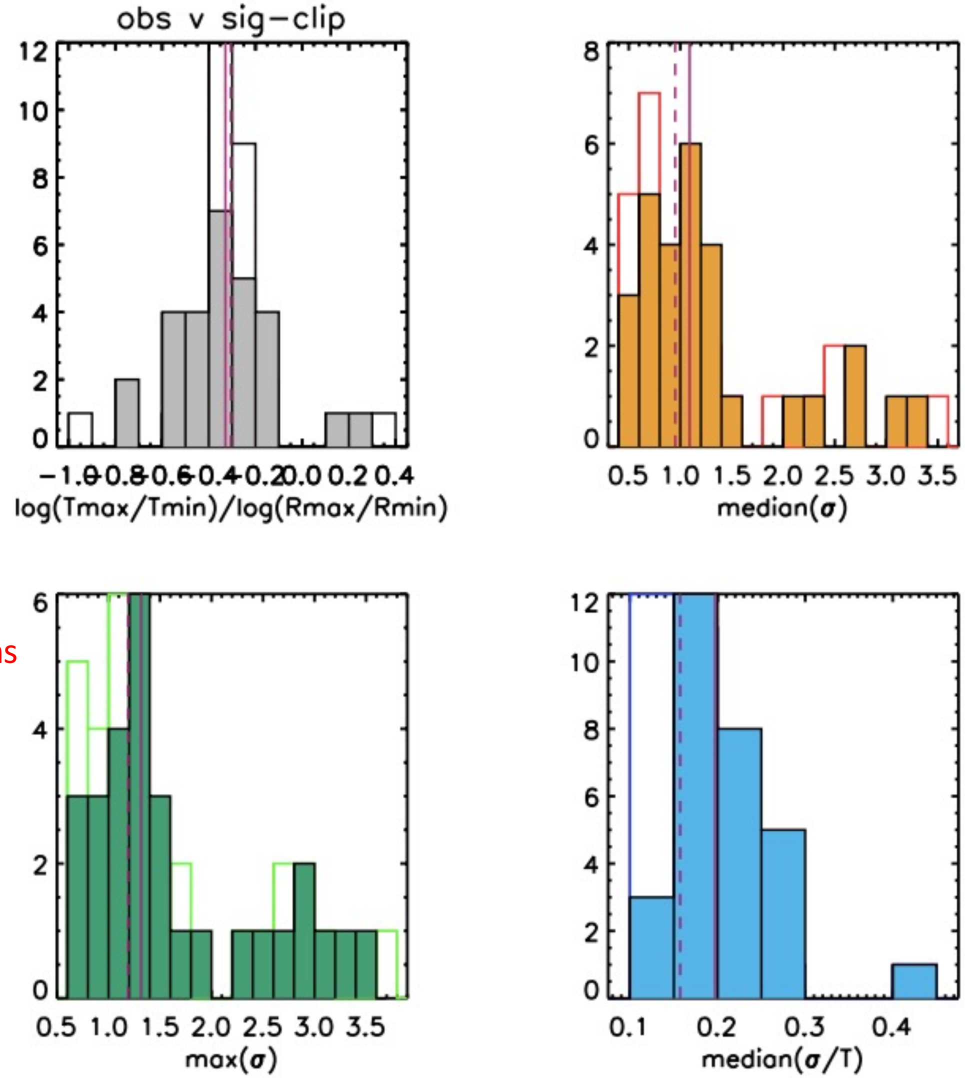








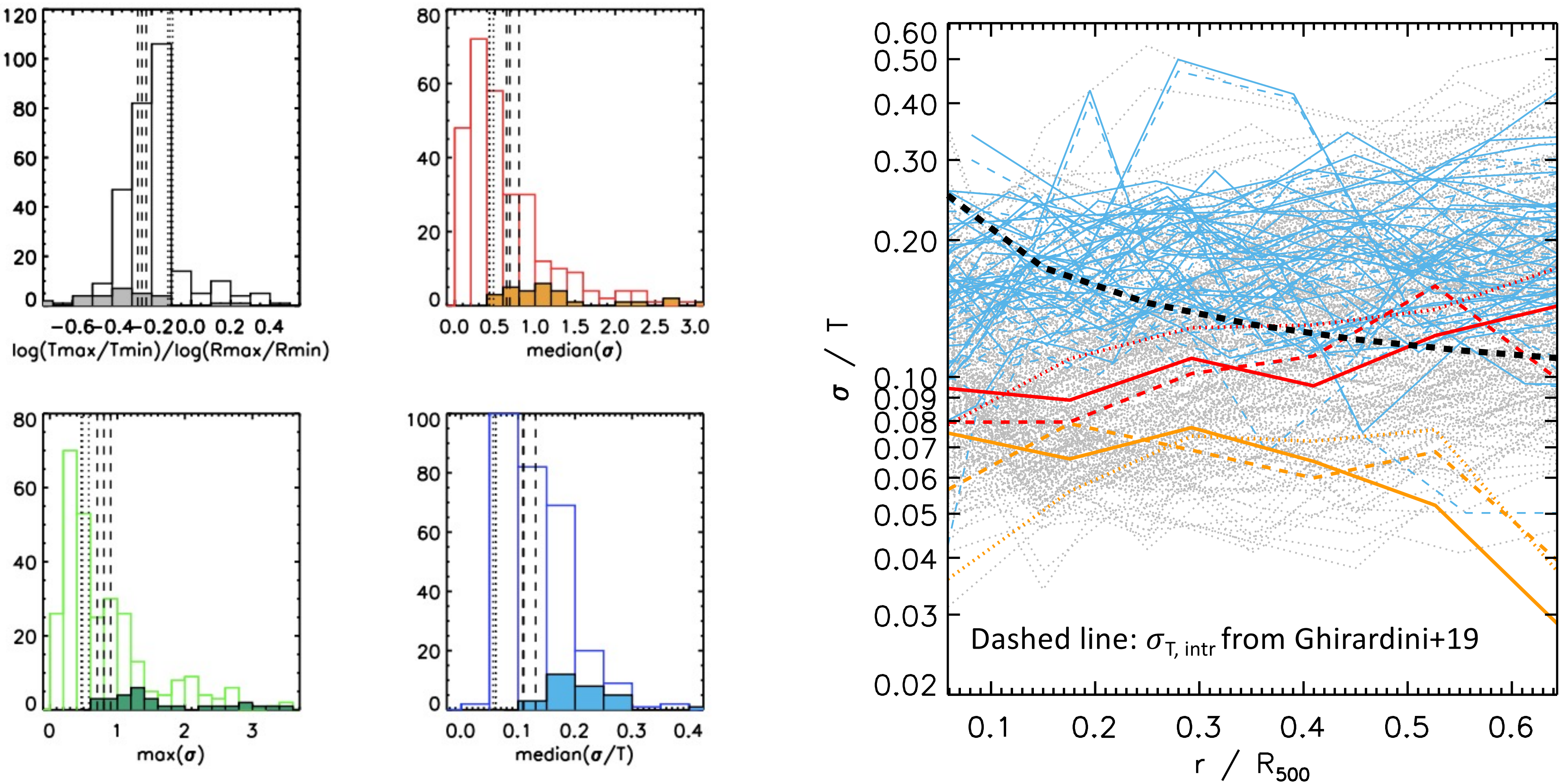
Results: 29 clusters



Filled: no cleaned data (ver line: median)
Empty: sig-clipped data (dashed line)

Sig-clipped data show lower values of $\sigma^2_{T,\,rms}$

Results: *29 clusters vs hydro-sims* (GADGET-X/the300; FLASH)



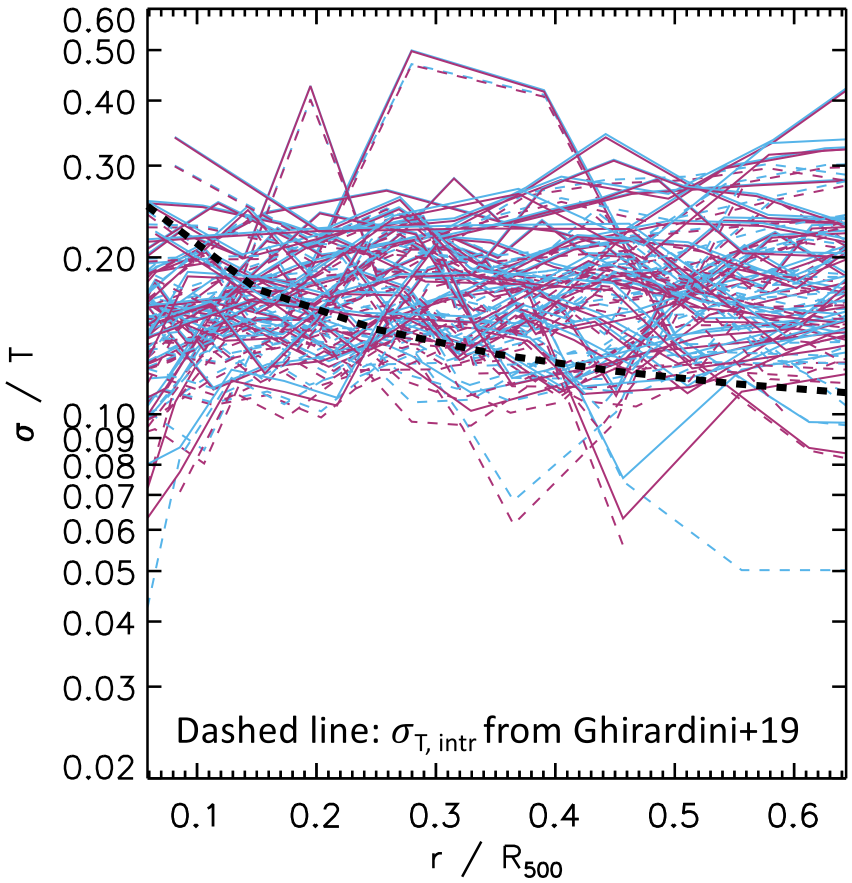
Results: *29 clusters (0.1-0.6 R_{500})*
$\sigma_{T,\,intr} = \mathrm{sqrt}(\sigma^2_{T,\,rms} - \varepsilon^2_{T,\,stat})$

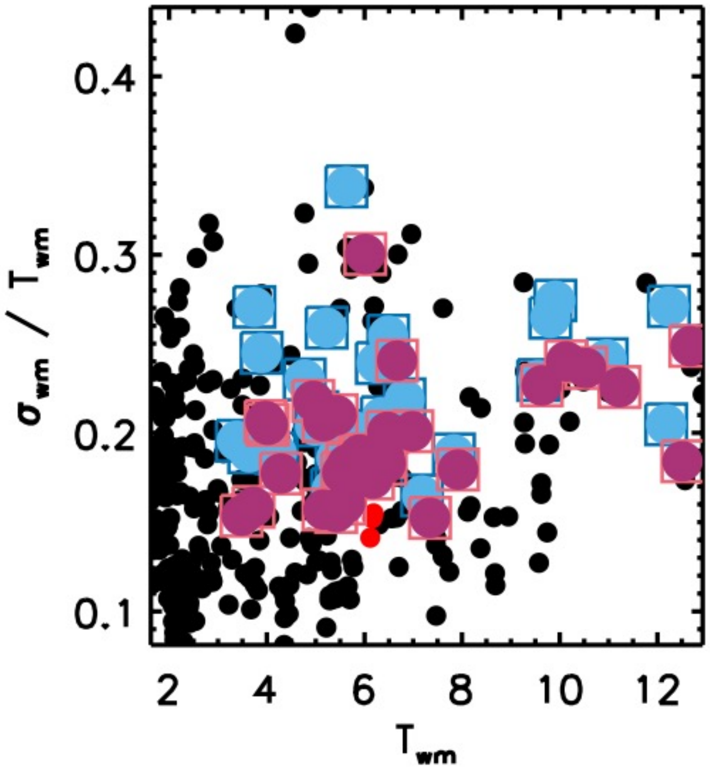
Cyan: XMM, all area

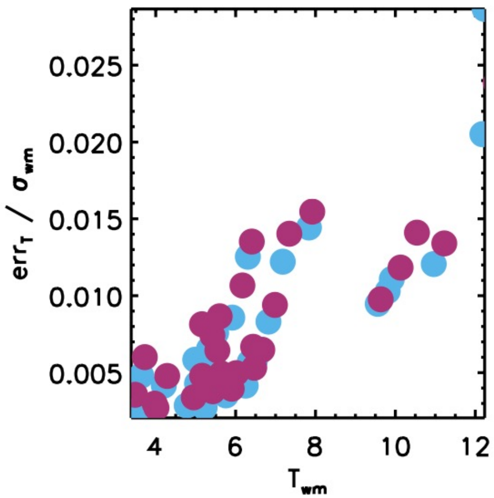
Purple: XMM, w/o clipped regions

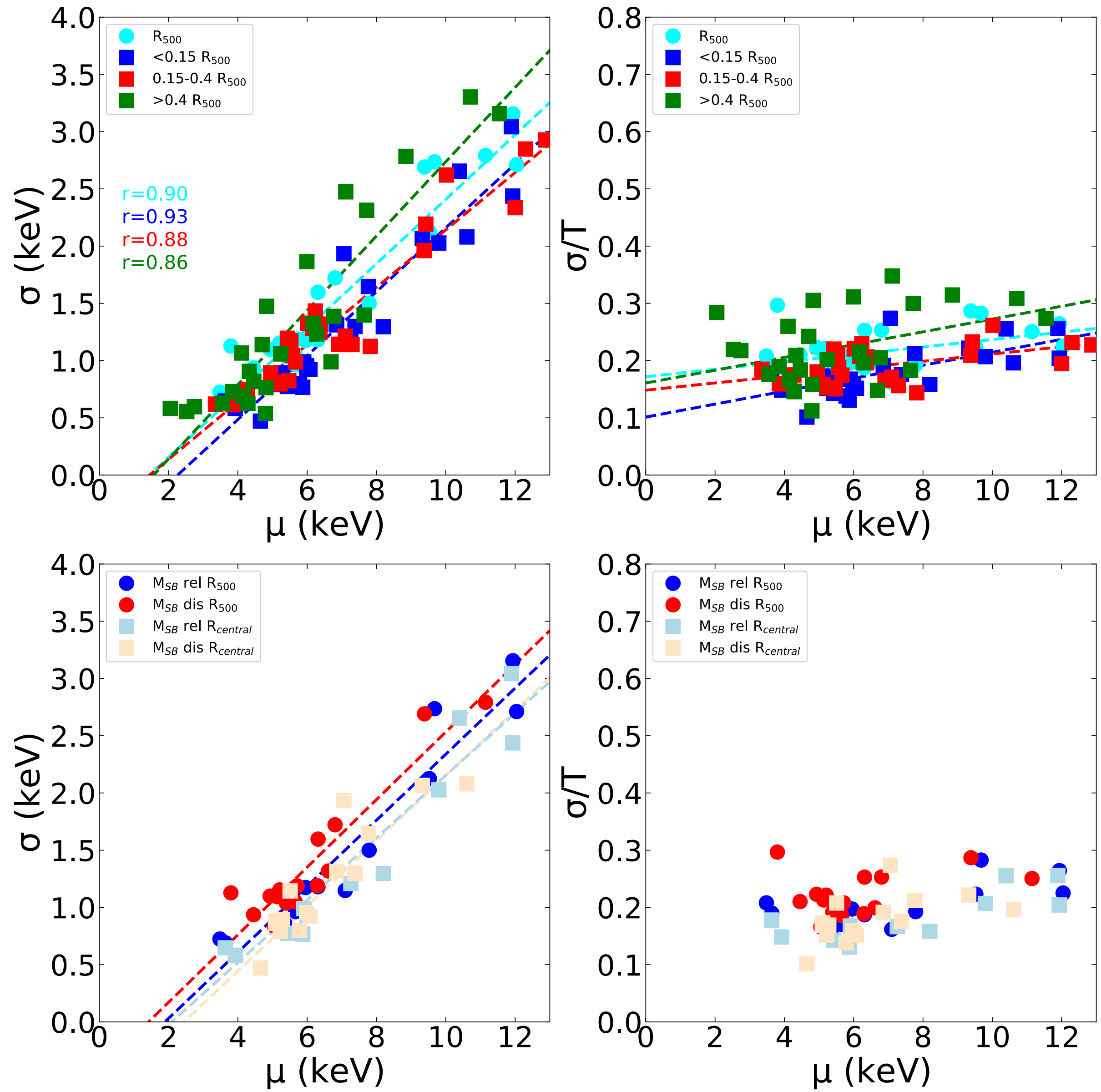
Black: GADGET-X/the300

Red: FLASH





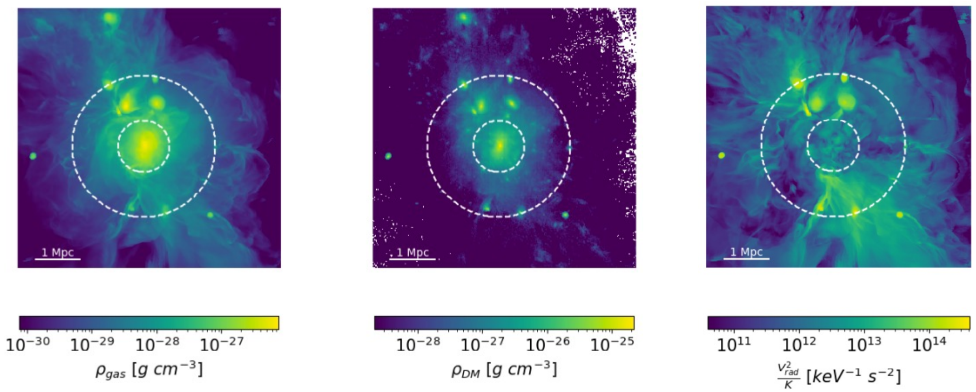


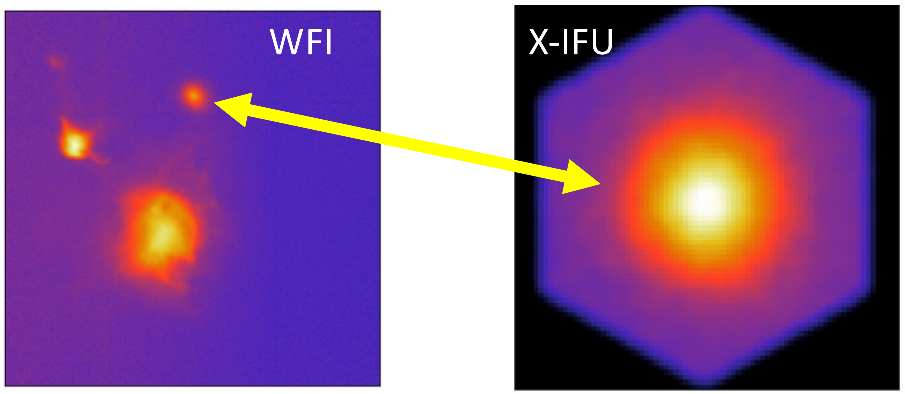


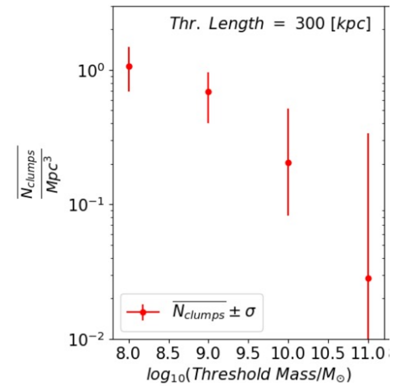
R_{500}
<0.15 R_{500}
0.15-0.4 R_{500}
>0.4 R_{500}
r=0.90
r=0.93
r=0.88
r=0.86
σ (keV)
μ (keV)
σ/T
M_{SB} rel R_{500}
M_{SB} dis R_{500}
M_{SB} rel $R_{central}$
M_{SB} dis $R_{central}$

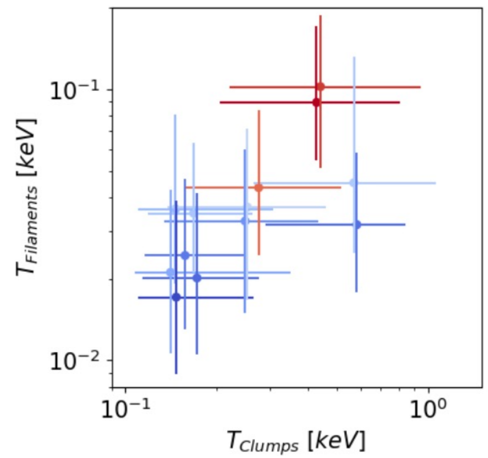
Clumps as proxies of dense WHIM

- **Properties of clumps & filaments in adiabatic ENZO simulations** (Angelinelli+ arXiv:2102.01096)
- ***Ongoing: Extending the analysis to the Gadget/Magneticum***
- *Final product: Cosmo-Hydro ⊗ SIXTE*, XSPEC for analysis
- For A&A special issue: use WFI to detect them & XIFU to characterize clumps & environment









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