Galaxy Cluster Substructure Study

The hot intracluster medium in galaxy clusters often shows significant two-dimensional structure generated by mergers and AGN feedback. We analyzed a sample of X-ray bright, nearby galaxy clusters, which have been observed for more than 100 ks with Chandra. Using the Chandra ACIS data, we mapped various properties of the intracluster medium, identifying substructure at high spatial resolution. These maps enabled us to study asymmetries in the projected pressure and density. We present the detailed analysis of these profiles for the best-observed clusters in our sample. From the Chandra data we derive 2D cluster models, which we use as input for eROSITA simulated observations. The aim of the simulations is to investigate possible bias in the determination of cluster properties such as temperature or mass, when a large sample of clusters are analyzed in the eROSITA cluster survey.

Chandra Cluster Sample

We defined a **Chandra Cluster Sample** by correlating all available observations from the Chandra Data Archive with known ROSAT clusters (NORAS, REFLEX, CIZA). We selected the most luminous clusters of galaxies ($L_X > 2x10^{44}$ erg/s in the 0.1-2.4 keV band) with more than 100 ks Chandra exposure time (~10 Ms overall) and above a redshift of about z > 0.03 (excluding extended clusters, too large for the ACIS field-of-view).

For this sample we derived 2D spatial-spectral maps (Fig.1) with a constant signal-to-noise ratio. In each spatial bin an APEC model is fitted to the emission of the intracluster medium (ICM) and we obtain the projected properties temperature, pressure, density, entropy and metallicity.

Asymmetries in the ICM are an important tracer of energy deposition in the medium and help us understand the influence of AGN feedback or minor and major mergers.

Gaspari et al. 2014 recently found, that their high-resolution hydrodynamic simulations of galaxy clusters showed relations between ICM properties such as Mach number or thermal conduction and fluctuations in the power spectrum of various observables.

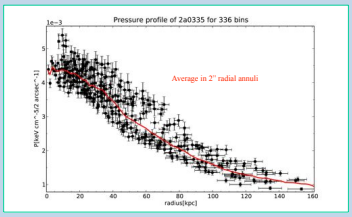

Fig.4: Radial projected pseudo pressure profile of 2a0335 derived from the spatial-spectral map with 336 bins.

We derived profiles for each cluster (Fig.4) and analyzed the spread of projected pressure and temperature at particular radii. Studying the spread in individual clusters and the sample (Fig.3) allows us to analyze the substructure in such a large sample of clusters of galaxies to unprecedented detail (Hofmann et al. in preparation).

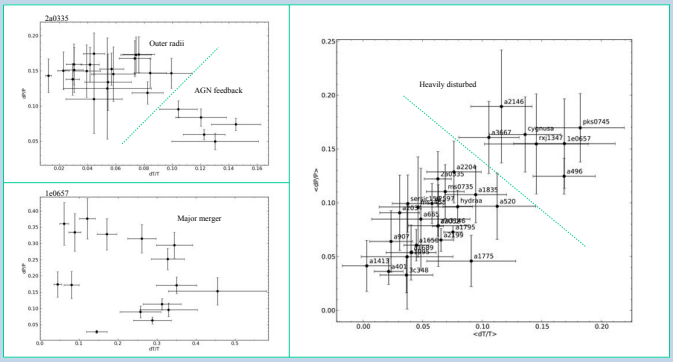

Fig.3: **Left**: Fractional fluctuations in pressure over fractional fluctuations in temperature for the sample clusters 2a0335 (top) and the Bullet Cluster (bottom). **Right**: Average fractional fluctuations in pressure over average fractional fluctuations in temperature for the whole sample of 30 clusters. Based on projected 2D ICM properties.

Citations:
F. Hofmann et al. in preparation.
A. Merloni, P. Predehl, W. Becker et al. 2012, eROSITA science book, arXiv:1209.3114.
J. S. Sanders 2006, MNRAS, Volume 371, Issue 2, pp. 829-842.
M. Gaspari, E. Churazov, D. Nagai et al. 2014, arXiv:1404.5302.
C. Schmid, M. Martin, J. Wilms et al. 2010, AIP Conf. Proc. 1248, 591.

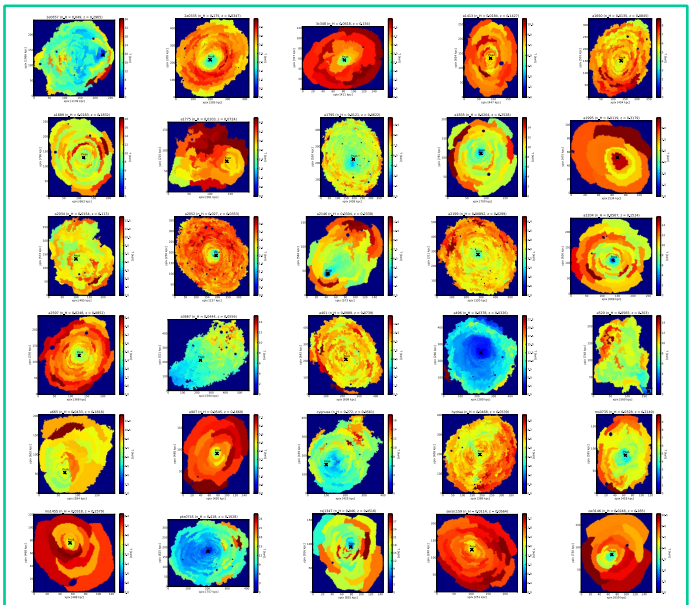

Fig.1: Temperature maps of 30 clusters in the >100 ks Chandra Cluster Sample. Binned with a signal-to-noise of 50 (using the *contbin* method by Sanders 2006). Temperatures in keV.

eROSITA

The upcoming **eROSITA** survey (starting 2016) will deliver the largest sample of X-ray observed clusters of galaxies (10^5 clusters, peak around z = 0.2, see Merloni et al. 2012). In order to investigate expected parameter bias due to substructure, we simulate observations of galaxy clusters in the survey (Fig.2). As input we use 2D models of the ICM emission, derived from the deep observations of the Chandra Cluster Sample (Fig.5). Event files are simulated with the Bamberg Simulator for X-ray observatories (Schmid et al. 2010). We run a source detection (CIAO tool *wavdetect*) to identify the cluster position and extract spectra with *srctool* (eROSITA eSASS package).

Comparison of the fitted properties to the Chandra study will prove important for the interpretation of eROSITA observations.

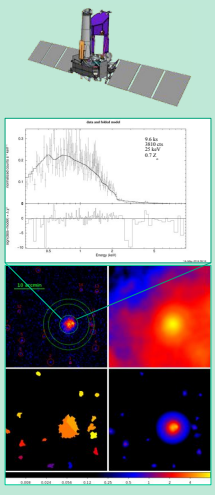

Fig.2: Simulated observation of the Bullet Cluster in the eROSITA survey. **Top**: Combined spectrum of the 7 eROSITA cameras with the best fit APEC model and Chi². **Top left to bottom right**: Count image and source regions, detection background, extraction regions, source image.

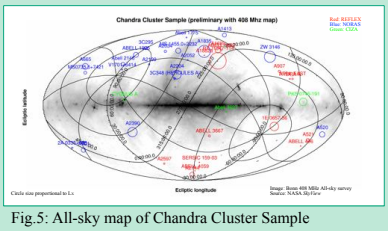

Fig.5: All-sky map of Chandra Cluster Sample

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