Entropy Distributions in the Cores of Nearby X-ray Luminous Clusters of Galaxies

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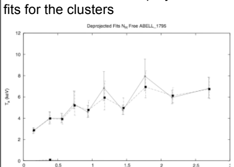
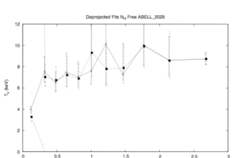
ABSTRACT

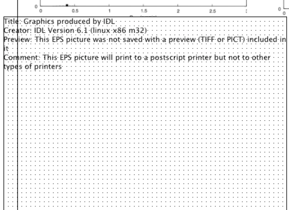
We present entropy distributions for 11 bright galaxy clusters from the Chandra public archives. For each cluster, we fit projected one and two temperature mekal models using XSPEC to annular regions of 20,000 counts each. We also derived one- and two-temperature deprojected profiles in order to estimate radial entropy profiles. We present temperature and entropy maps for these clusters. We discuss how well such maps may represent the "true" projected quantities by comparing theoretical models from the Virtual Cluster Exploratorium with maps derived in similar ways to our data. By studying the entropy distribution within clusters we quantify the effect of radiative cooling, supernovae feedback, and AGN feedback on cluster properties. We also discuss systematic uncertainties arising from assumptions made about geometric symmetry in deprojection models and the practice of fixing the absorption column density to the Galactic value and other systematics arising from treatment of the data.

DATA FITTING

- Data was processed using CIAO 3.1.2 and CALDB 2.28
- Fits were done with *Mekal* code within Xspec using several types of runs: N_H frozen or free combined with Fe free per annulus or free but tied to neighboring annuli
- With each new version of the CALDB our fits required fewer second, cooler temperature components for the cluster cores
- We also found that deprojection did not significantly change the temperature fits for the clusters

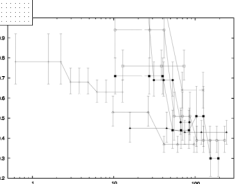


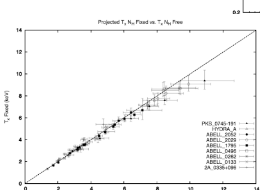




Fit temperature is plotted as a function of scaled virial radius. Average temperatures are those taken from ASCA. Fits extend to deep within most cluster cores.

Our clusters have pronounced metallicity gradients with the highest values in the cores. Based upon previous fits, we coupled annuli with similar metallicities to avoid fitting at a resolution higher than our data allowed.





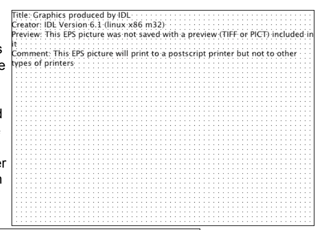
When NH was left free, the fit temperature was shifted to higher temperatures compared with a fixed NH. Does this indicate a need for higher resolution NH values or fine tuning of the ACIS calibration in the hard X-rays?

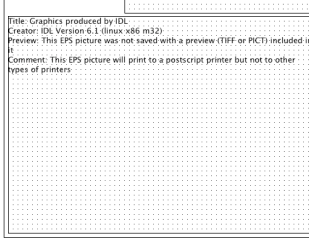
PROJECT SUMMARY

- The properties of a cluster's entropy distribution can be fully understood by looking at the X-ray structure of the cluster
- These cluster characteristics offer clues to better understanding the details of how large scale structure forms in the Universe
- Since the gravitational collapse of gas within a dark matter potential is adiabatic, the only mechanism by which entropy can be changed within the gas is by heating or cooling
- Hence, detailed study of a cluster's entropy distribution tells us about the feedback and cooling properties within the cluster
- For our purposes, entropy has been defined as $S=Tn_e^{-2/3}$
- By fitting a cluster's temperature and density as a function of radius, we derived a radial profile of the entropy within the cluster
- The profiles serve as the foundation of a library that will be used to compare with theory (such as the VCE) and other X-ray observations to help explain the similarity breaking of clusters and groups

ENTROPY PROFILES

Entropy profiles go as $R^{-1.3}$ in the core with a low central value. When extended deep within the core will the entropy turn over or flatten out an entropy floor?



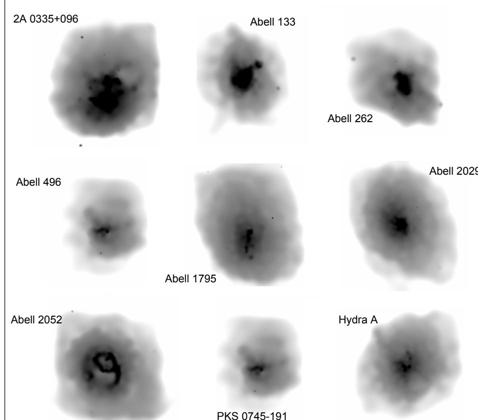


When scaled to average cluster temperature to the 2/3 power, the profiles steepen and tighten their grouping; this is indicative of…

CONCLUSIONS AND FUTURE WORK

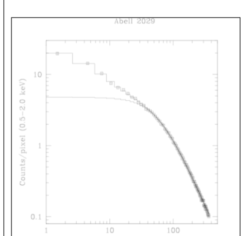
DATA SAMPLE

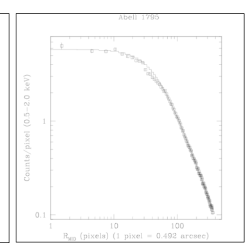
- Our sample of clusters is composed of seemingly relaxed clusters from the Chandra Public Archive
- We selected clusters without too much substructure but still with interesting core features



SURFACE BRIGHTNESS BETA MODELS

- The gas within a cluster can be modeled as a single phase plasma using Beta-model analysis of the X-ray surface brightness
- Clusters with core structure were fit over a region outside the cooling flow
- Our sample does not show decreasing Beta versus decreasing temperature, but we do not extend below 2keV where the trend shows up
- However, we do still find that Beta hovers around 0.4 and not the canonical value of 2/3
- A second Beta component was used to fit the clusters with excess soft emission in the core
- clusters with structure- no soft emission; without- lots of soft emission?
- Why only one Beta for cooling flows and two for "relaxed" systems?





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