Individual Mass Determination of the HIFLUGCS Clusters

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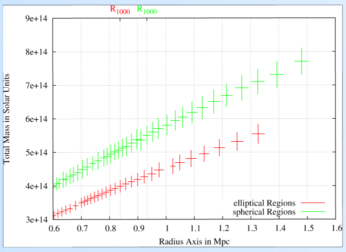
Abstract: Clusters of galaxies are the most massive gravitationally relaxed systems in the universe, so the observed cluster mass function is a sensitive probe of cosmological parameters. The greatest challenge in measuring the cluster mass function is obtaining sufficiently accurate mass estimates. We are in the process of deriving the mass function by the determination of the individual masses for the 64 objects of the HIFLUGCS (see the references below) sample using high quality data from Chandra. By studying the two dimensional cluster shape we can obtain more accurate masses and investigate the presence of substructure and the consequent impact on the determination of the cosmological parameters. Furthermore we will check systematic uncertainties in mass determination between all instruments (XMM EPIC and Chandra ACIS). As a first step we investigate the calibration uncertainty by determining the cluster temperature in specified regions. A similar study, but with a much smaller sample, was performed by Nevalainen et al. (2010), showing the same qualitative result.

Sample: The sample we use consists of the 64 X-Ray brightest galaxy clusters. High quality data for all of them is available in the XMM and Chandra archive. For this work we focus on the Chandra satellite because of its outstanding spatial resolution, the low fraction of solar flare contamination and the possibility to go to large radii. Due to the high flux and low redshift of the clusters the background treatment is crucial. After the particle background is subtracted, we model the three remaining background components (CXB, galactic halo, local hot bubble) from a simultaneous fit to Chandra and ROSAT All-Sky Survey data and subtract it afterwards.

2D Shape: In general galaxy clusters are not spherical and we analyze the cluster shape in detail by measuring its ellipticity and comparing spectra and resulting masses for spherical and elliptical annular regions. The Figures 1-5 show the difference between elliptical (axis ratio 1.1) and spherical treatment for Abell 2204. The elliptical regions are derived using the non-iterative algorithm from Buote et al. (1994) which is based on the calculation of the inertia tensor (Trumpler & Weaver 1953). The hydrostatic equation is modified as mentioned in Buote & Humphrey (2012).

Mass Determination: We derive the total mass using the hydrostatic equation. Monte Carlo simulations predict the uncertainty. The temperature profile is parameterised by two smoothed power-laws (Figure 5), the surface brightness profile by a triple-beta model (Figure 3+4), which is justified by the sufficiently high data quality. With this approach we want to parameterise the observations in more detail.
The gas mass is computed with the surface brightness profile and the calculated cooling function for each region by computing the emissivity. We get the cooling function by simulations including the temperature and metallicity information.



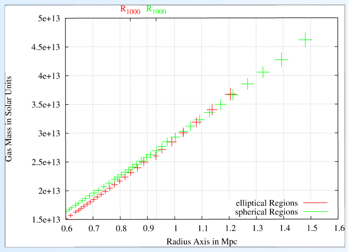
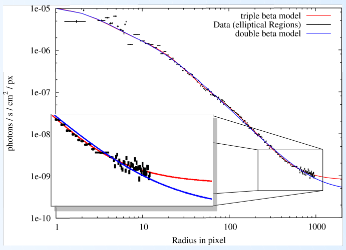


Figure 1+2: Total mass (left) and gas mass (right) of A2204 as a function of Radius or the minor axis in case of elliptical Regions (red)



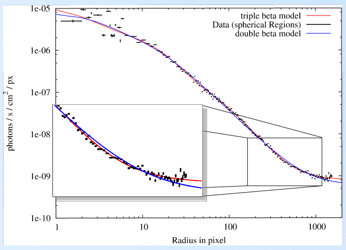


Figure 3+4: Surface Brightness Profile of A2204 using elliptical (left) and spherical (right) Regions. The window is a close-up of the behavior at large distances.

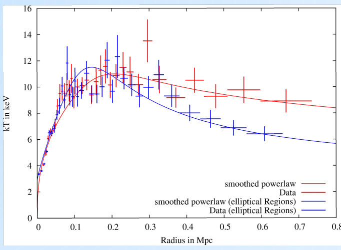


Figure 5: Temperature profiles of A2204 from elliptical (blue) and spherical (red) regions fitted with two smoothed power-laws. For the elliptical regions the radius is the average of the minor and major axis.

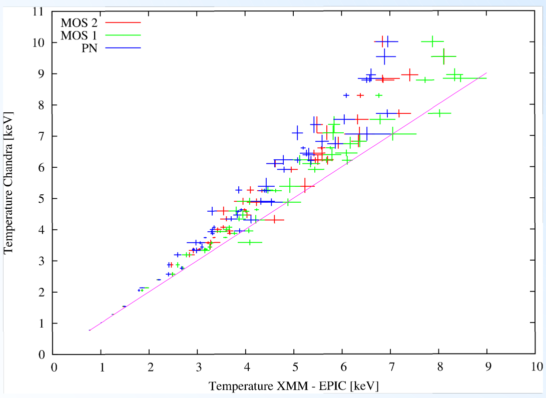


Figure 6: Comparison of the best-fit temperatures of 59 HIFGLUCS clusters for the 3 XMM EPIC detectors and Chandra ACIS.
The temperatures are determined inside 3.5' excluding the cool core if present. Non cool core clusters are only analyzed within the 3.5'.

Calibration uncertainties: The Chandra temperatures inside the central regions of the clusters are compared with the XMM-Newton results (see Figure 6). It turns out that on the one hand Chandra delivers usually higher temperatures than any EPIC detector, on the other hand MOS1, MOS2 and PN themselves have systematic discrepancies. The effect on the cluster masses are investigated.

Results and outlook: The data reduction pipeline is nearly finished and results for some clusters are already available (see Figures 1-5).
For the deprojection analysis we will use the dsdeproject code from Sanders & Fabian (2007). We will modify it to account for the ellipsoidal volume and tested several ellipsoids and inclination angles.
The final step will then be to establish the cluster mass function.

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