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New approach to galaxy clusters: substructure identification through morphology parameters

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Abstract. Recent spectral and spatial X-ray observations of galaxy clusters suggest subclustering and merging are common phenomena. Galaxy clusters can therefore be grouped into two categories: relaxed and non-relaxed. Investigating cluster dynamical states is vital because it is linked with the evolution of galaxy clusters on cosmic time scales. It affects cluster global properties such as the virial temperature, metal distribution, luminosity, and mass calculation. We have investigated the use of a number of morphological parameters (Gini, Asymmetry, M_{20}, Concentration, Ellipticity, Smoothness and Gini 2^{nd} order) to differentiate between relaxed and non-relaxed scenarios. We initially simulated different relaxed and non-relaxed morphologies with multiple beta profiles. Finally, we applied our method to a different redshift sample of clusters from the Chandra archive and studied correlations between parameters and X-ray gas properties. In this proceding, we will show the promising results from the quantitative study of morphology parameters and its possible application to study the morphology of radio halos and relics clusters.

Keywords : galaxies: X-ray clusters: substructure - merger: radio halo: radio relic

1. Introduction

There are various morphology parameters that trace the cluster surface brightness distribution within a given aperture size. Our primary goal is to separate relaxed and non-relaxed clusters using morphology parameters and we therefore investigated a range of parameters (Gini, M_{20}, Concentration, Asymmetry, Smoothness, Ellipticity and

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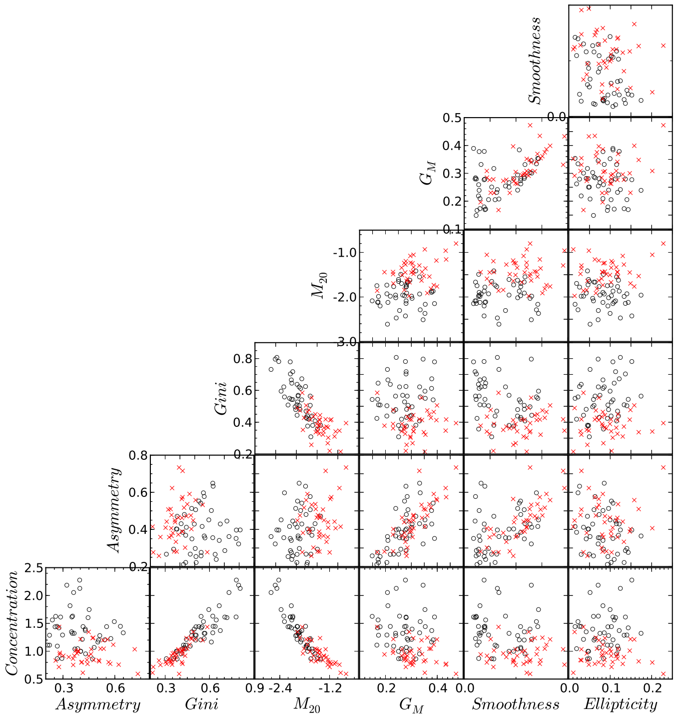

Figure 1. Seven morphology parameters plotted in the parameter-parameter plane. ○ = relaxed cluster and × = non-relaxed cluster. Galaxy cluster separation is based on the V09.

Gini 2^{nd} order moment) (Bershady, Jangren & Conselice 2000; Conselice 2003; Lotz, Primack & Madau 2004) to assess their capability in evaluating the degree of sub-clustering and distortion in any given cluster image. Individual parameter describes the particular class of morphology and hence dynamical state of galaxy clusters. Our sample (Vikhlinin et al. 2009, hearafter V09) includes low- and high-z clusters to completely characterize cluster dynamical states over a large redshift range. We have carried out calculations using aperture sizes of 200 and 500 kpc physical radii. We used a 200 kpc radius for nearby clusters and 500 kpc radius for high-z clusters. This is because the angular extent of nearby cluster ($z < 0.05$, cluster linear size is less than 2 kpc/pix) are larger than the Chandra FOV. The large variation in aperture size can affect the results (because they are related to surface brightness), so care should be taken when assessing the results. In addition, we also studied dynamical activity of clusters hosting diffuse radio sources. Current results suggest a strong link between the presence of diffuse intra-cluster radio emission and cluster mergers (Ferrari et al. 2008; Feretti et al. 2012, and references therein). Similarly to what done by Cassano et al. (2010), but using our new X-ray morphological parameters, we analyzed the X-ray morphology of relaxed clusters and non-relaxed clusters (which includes both radio-quiet mergers and radio-loud mergers).

2. Data and results

We downloaded the cluster data (a sample of 84 clusters) (V09) from the Chandra archival system and applied the standard data reduction procedures. We removed point sources and normalized each image by its exposure map in order to avoid artifacts and ccd gap. We then smoothed each cluster image by a 5" Gaussian width. Subsequently we calculated the morphology parameters and separated relaxed and non-relaxed clusters according to the V09 classification to check the potential of our parameters. In Fig. 1 we plot our results in parameter-parameter planes. Three parameters, Gini coefficient, Concentration and M_{20}, show a correlation and are very useful to differentiate non-relaxed clusters from relaxed within our sample. In our analysis we have not seen any correlation between cluster morphology and Ellipticity or Smoothness. As seen in Fig. 1, the galaxy clusters in our sample show a range of different morphologies and are not concentrated in particular positions in the parameter-parameter space. This is probably because of the hierarchical cluster formation process and indicates that clusters pass through multiple phases in their evolution. Each phase is dynamically important and tracing the cluster properties can help to understand complex structure formation in the standard cosmological model. We have extensively studied systematics and possible biases which might affect our results. We find that morphological parameters are quite robust over low exposure time (and high Poissonian noise) and small angular bin size which scale with higher redshift.

3. Conclusion and outlook

We have shown how we can use morphology parameters to study cluster dynamical states and trace physical properties. In principal, Gini, Concentration and M_{20} are very promising to detect disturbances in clusters at any scale. Other parameters might still be useful to trace or study other physical properties of galaxy clusters. These parameters are robust in various physical conditions and help to understand cluster morphology with sufficient extent. We are also investigating properties of radio halo and relic clusters to understand (cluster) merger-halo connection. These morphology parameters are also useful to compare with radio properties to establish any connection between high energy processes and synchrotron emission.

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