Centroid Offsets in Simulated Clusters of Galaxies

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Abstract

Clusters of Galaxies are frequently used as cosmological probes and have been studied observationally through a variety of means; including the thermal Sunyaev-Zeldovich effect, through their X-ray emission as well as by weak gravitational lensing. These techniques sample, respectively, the projected thermal pressure of the ICM, the projected X-ray emissivity and the total surface density of the cluster material. In as much as clusters are dynamic systems, it is not clear that all three of these signals will have coincident maxima for a given cluster. Here, we investigate the frequency of centroid offsets (between thermal SZE, X-ray and total mass images) in a large catalog of simulated clusters of galaxies. We also investigate the role that centroid offsets may play in assessing the kinematic state of observed clusters as well as their interaction history.

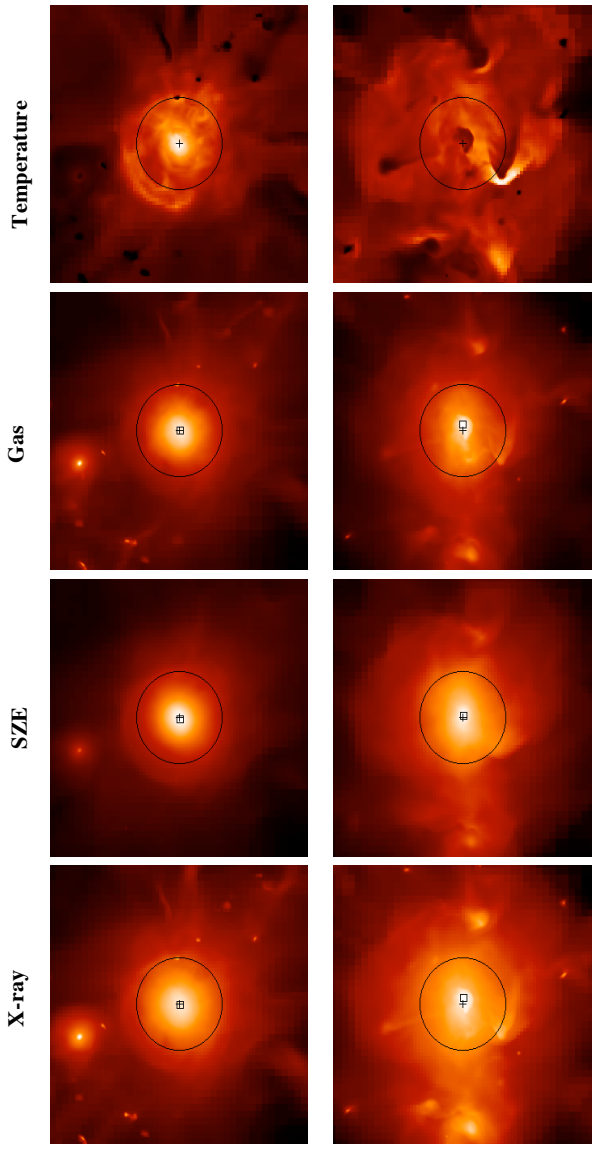

Figure 1 Images of a relaxed simulated cluster (left column) and a very disturbed cluster (right column) at the present epoch. The large circle marks the r_{500} radius, the cross marks the center of mass for the cluster and the square in the gas density, Sunyaev-Zeldovich effect (SZE), and X-ray images denote the peak location. For the relaxed cluster, the three peaks are nearly coincident with one another and lie within a few cells of the center of mass. For the interacting cluster, the X-ray and SZE peaks lie within ~80 kpc of each other and are each significantly offset from the center of mass.

SZE - X-ray Offsets

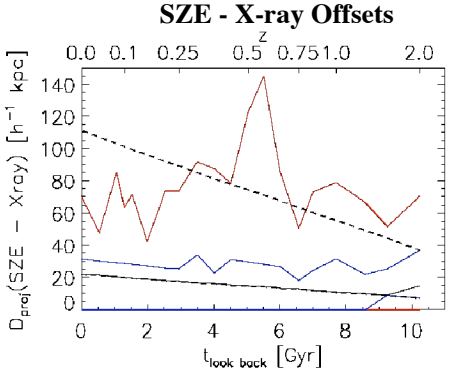

Figure 2 The distribution of projected distances between peak value of the Compton *y* parameter and X-ray emission as a function of redshift. The solid black line marks the median of the distribution while the blue lines denote the 25th and 75th percentile values, the red curves indicate the 10th and 90th percentile values. The dashed lines indicate the size of one and five grid cells.

Discussion and Conclusions

We have measured the location of peak X-ray and SZE emission in a large sample of simulated clusters of galaxies. The sample includes ~100 clusters at the present epoch and ~10 clusters at z = 2 with a mass $M_{200} \geq 10^{14}\ M_{\odot}$. We select the peak emission value within an aperture of r_{500}, centered on the cluster center of mass.

- The peaks of X-ray and SZE emission are frequently coincident. At observable redshifts, half of all sample clusters have centroids at the same projected location to within one grid cell. Only very disturbed clusters have widely separated SZE and X-ray peaks (see Figures 1 and 2).
- However, neither of these centroids are likely to coincide with the cluster center of mass (see Figure 3) - perhaps indicating that the gas sloshes within the dark matter potential.
- Because nearly all clusters show an offset between their emission peaks and the cluster center of mass, a peak is not a good proxy for the cluster barycenter nor are small offsets likely to serve as strong evidence for recent merger activity in a given cluster.

Offsets from Cluster Center of Mass

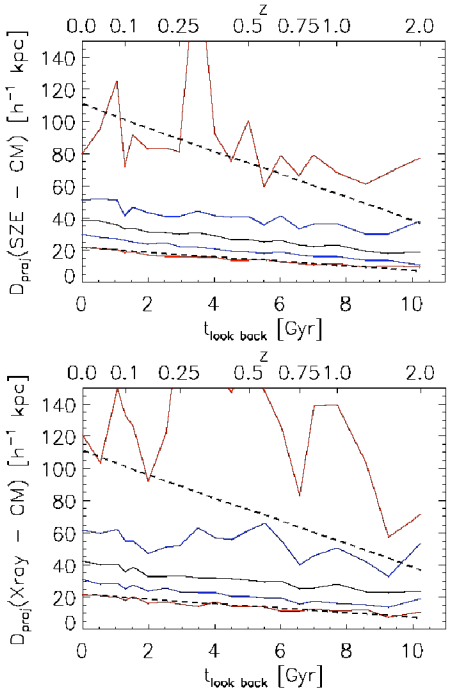

Figure 3 The distribution of projected distance between the peak SZE signal and the cluster center of mass (top panel) and the peak X-ray emission and cluster center of mass (bottom panel). The meaning of the curves is the same as in Figure 2.