The General Assembly of Galaxy Halos: Structure, Origin and Evolution
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The Dynamical Evolution of Galactic X-ray Coronae in Clusters

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Abstract. Galaxies in group and cluster environments are subject to ram pressure stripping by the hot intracluster medium, resulting in gas loss and the eventual suppression of star formation. Recent *Chandra* observations of galaxies in group and cluster environments show that 60 - 80% of these galaxies have compact (1-4 kpc), hot (~ 1 keV) X-ray coronae centered on their cores. These coronae have survived stripping and evaporation in the cluster, and their long-term survival poses a test of our understanding of the physical processes in the ICM. In this poster, I summarize results from Vijayaraghavan & Ricker (2015), where we simulated the evolution of populations of galaxies and their hot coronal gas in group and cluster environments, and evaluated their detectability with existing and future X-ray catalogs.

Keywords. hydrodynamics, methods: numerical, X-rays:galaxies:clusters, galaxies:clusters:general, galaxies:halos, galaxies:evolution

1. Background

The dominant baryonic component in clusters of galaxies is the hot (10^7 K) intracluster medium (ICM) plasma, composing about 15% of the total mass in these systems. Orbiting cluster galaxies are subject to ram pressure by the ICM, which can remove most of their hot and cold interstellar medium (ISM) gas. Evidence for ram pressure stripping of galactic gas has been observed in the form of stripped tails that trail cluster galaxies. Ram pressure stripping in addition to tidal stripping and thermal conduction can remove all the gas bound to galaxies. The eventual consequence of gas loss from cluster galaxies is that these galaxies have significantly lower gas fractions and star formation rates compared to field galaxies. *Chandra* observations of galaxies in cluster and group environments (e.g. Sun *et al.* 2007, Jeltema *et al.* 2008) show that $60 - 80\%$ of these galaxies have compact ($1 - 4$ kpc), hot (~ 1 keV) X-ray emitting circumgalactic coronae centered on their cores. These coronae have survived ram pressure and tidal stripping, harassment, and evaporation due to thermal conduction in the cluster for many dynamical times. Their survival for timescales comparable to the Hubble time therefore poses a test of our understanding of the physical processes in the ICM. In Vijayaraghavan & Ricker (2015), we attempted to understand the behavior of these coronae under gravitational and hydrodynamic physical processes alone. We simulated the evolution of populations of galaxies and their hot coronal gas in group and cluster environments and evaluated their detectability with existing and future X-ray catalogs.

2. Results & Conclusions

In Vijayaraghavan & Ricker (2015), we present the results of N-body + hydrodynamic simulations of 26 galaxies in an isolated group of mass $3.2 \times 10^{13}\ M_\odot$ and 152 galaxies in an isolated cluster of mass $1.2 \times 10^{14}\ M_\odot$. These simulations were performed with the FLASH code with minimum spatial resolution of up to 1.6 kpc and $10^6\ M_\odot$

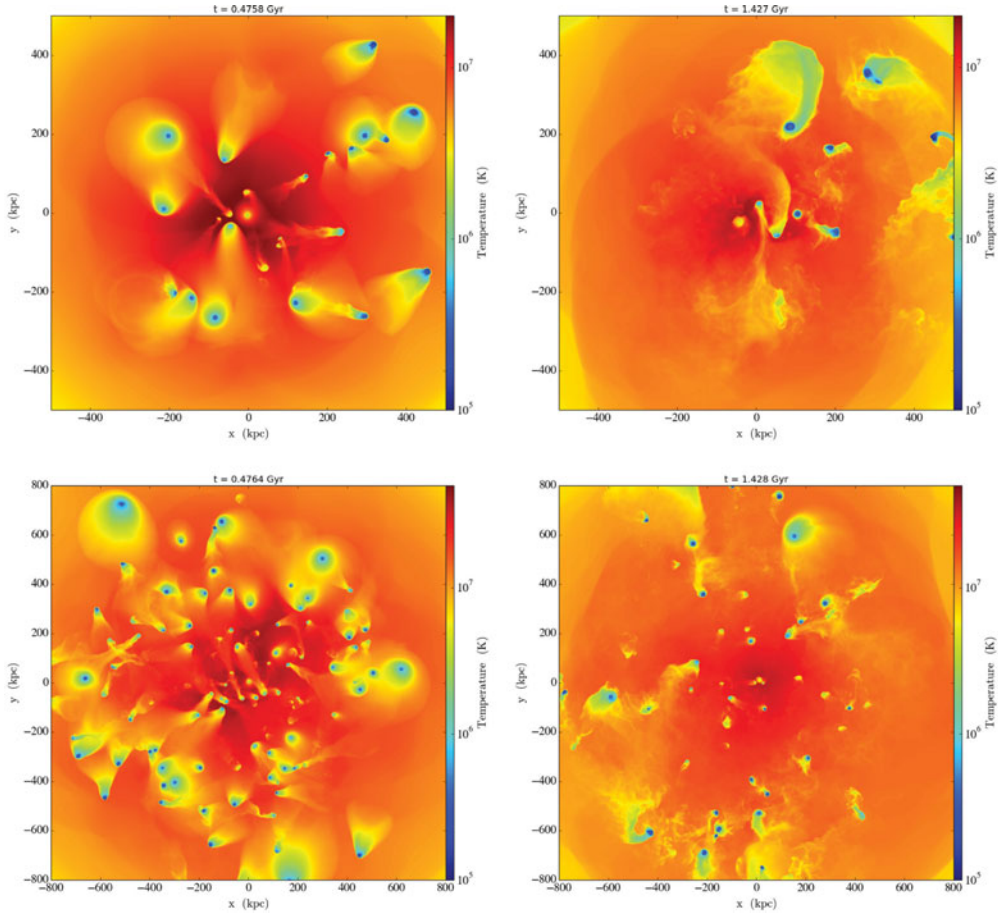

Figure 1. The evolution of gas in the group and cluster galaxies, as seen in maps of emission measure-weighted temperature. Galaxies are stripped of their gas by the ICM, and the stripped gas trails galaxies in their orbits in the form of wakes before mixing with the ICM.

particles. Galaxies in these simulations are NFW spheres with a collisionless dark matter component and hot gas component with 10% of the total mass of the galaxy.

Figure 1 shows ram pressure stripping in action for a range of group and cluster galaxies. Ram pressure is a drag force that removes gas when the local gravitational restoring force is not strong enough to overcome the opposing force of ram pressure. Stripped gas trails galaxies in their orbits, forming shear instabilities at the ISM-ICM interface, before eventually dissipating within the ICM. By ~ 3 Gyr, most galaxies have lost all their gas. The amount of gas removed depends on the mass of the galaxy and the host. Galaxies in the less massive group have smaller velocities and experience weaker ram pressure compared to galaxies in the massive, high velocity dispersion cluster. Group galaxies therefore lose gas at a slower rate than cluster galaxies. In a given environment, more massive galaxies are more resistant to ram pressure stripping due to their higher gravitational restoring forces.

We generated synthetic *Chandra* X-ray observations with 40 ks and 400 ks exposure times of the simulated group and cluster, including their galaxies. Galaxy wakes and tails are visible up to ~ 1 Gyr in the 40 ks image, and their surviving central coronae up to ~ 2 Gyr, albeit at low significance levels above the cluster background. Galac-

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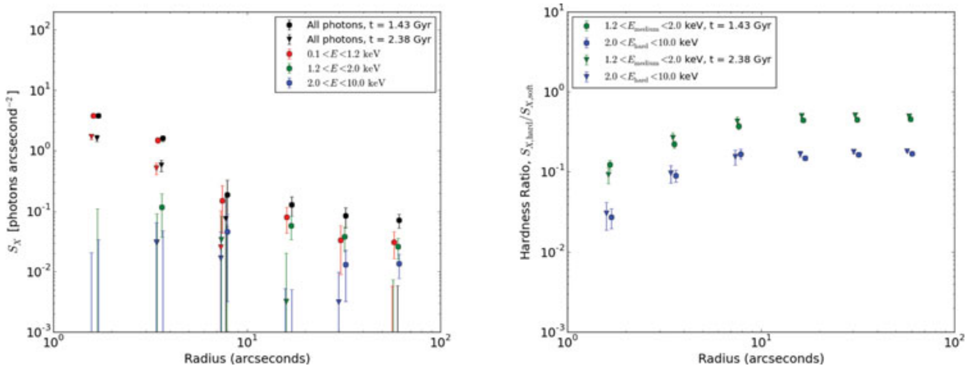

Figure 2. Left: Stacked , background subtracted radial profile for cluster galaxies (that are at least 200 kpc from the cluster center in projection). Right: Hardness radio profile.

tic tails are visible up to 2 Gyr in the 400 ks images. Galactic coronal emission can be detected observationally in short exposure observations by stacking regions around individual cluster galaxies identified in other wavebands. There is an excess in stacked galactic surface brightness profiles at $r \lesssim 10$ arcsec in group and cluster galaxies up to 2.38 Gyr in the low energy $0.1 < E < 1.2$ keV band. This excess persists on subtracting the correspondingly stacked emission centered on points diametrically opposite known galaxy centers. The X-ray emission from cluster galaxies declines faster than that of group galaxies, since galaxies in massive clusters experience stronger ram pressure. Additionally, the emission from galaxies at small galaxy-centric radii manifests itself in measurements of the hardness ratio ($E_{\rm hard}/E_{\rm soft}$), as a noticeable decrease in hardness ratio in the regions with significant galactic emission. These results are illustrated in Figure 2.

References

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