New Results from an Intracluster Light Imaging Survey

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Introduction

Intracluster stars – stars outside of individual galaxies are a sensitive measure of the poorly understood processes of galactic mergers, cluster accretion and tidal stripping that occur in galaxy clusters (Dressler 1984, Mihos 2000). Although intracluster light (ICL) was first detected over fifty years ago (Zwicky 1951), progress has been slow due to its extremely low optical surface brightness (5-8 magnitudes fainter than the night sky).

We have recently completed an imaging survey of representative galaxy clusters to search for ICL, and compare how its properties relate to well-known galaxy cluster properties (richness, Bautz-Morgan and Roelofs-Sastry types, and X-ray properties). We supplement this deep imaging survey with high resolution N-body simulations of galaxy clusters (Mihos et al 2005, in prep) which we use to obtain predictions of the ICL structure.

We report new results from our deep imaging survey of galaxy clusters, designed to search for intracluster starlight (ICL). We have found a new intracluster tidal plume in Abell 84, and investigate the intracluster “starpile” previously found in Abell 545. These new findings are consistent with our previous results, which find that ICL is a common feature of galaxy clusters, and is produced by ongoing tidal stripping between galaxies.

ICL has differing spatial distributions

Abell 84 tidal debris

Although our analysis is just beginning on Abell 84, we have already found another example of intracluster tidal debris. The feature extends along a chain of galaxies near the cluster core. The size of this feature is large, 150 kpc by 40 kpc, and has a mean surface brightness of $\mu_v = 26.0$. This implies a large luminosity, $V \sim 20.5$, equal to a luminous galaxy.

Figure 1 – An image from one of our recent N-body simulations of a galaxy cluster. The simulated image is 3.2 Mpc on a side, and the ICL can be easily seen as the red, pink and green emission surrounding the cluster galaxies. The pink features have a surface brightness of $\mu_v \sim 29$ mag/arcsec$^2$, assuming a stellar mass-to-light ratio of five.

Figure 2 – Images of two of our program clusters, with Abell 801 on the left, and Abell 1914 on the right. The data has been bin and the colors denote different surface brightnesses: black is $\mu_v = 24$, green is $25 - 26$ and blue is $27 - 28$. There is a definite difference between the two clusters: in Abell 801 the ICL closely follows the galaxy light, while in Abell 1914, there is a noticeable spatial offset between the two components.

Figure 3 – Images of two of our program clusters, with Abell 801 on the left, and Abell 1914 on the right. After stellar objects have been masked, and the data has been binned to improve signal-to-noise. The colors denote different surface brightnesses: black is $\mu_v = 24$, green is $25 - 26$ and blue is $27 - 28$.

Figure 4 – On the left is our image of the center of MKW 7, with the brightest cluster galaxy partially subtracted. A tidal plume is clearly visible going up and to the right from the cluster center. The absolute magnitude of this plume is $V \sim -17$, comparable to a small galaxy. On the right is a binned-up image of Abell 1914 that shows a large (60 x 30 kpc) plume, that is very luminous $V \sim -21$. This feature is also seen in the weak lensing maps of Dohle et al. (2000).

Abell 545 and the “starpile”

Abell 545 was first studied in detail by Struble (1988), who found a low surface brightness feature in the central core of the cluster. The feature appears to have multiple nuclei, and is surrounded by E/S0 galaxies. Struble argued that this feature was created from infall from cluster galaxies, and dubbed it a “star pile”, that is, a cD halo without the accompanying galaxy.

With our deep images, we can analyze this feature in more detail. We confirm the earlier results, but find that the feature is contained within the surrounding galaxies, and may be much smaller in angular size than originally thought due to the contamination of a nearby star. From the angular sizes of the surrounding galaxies, we suggest that the redshift of this source and the cluster has been underestimated, and we may only be seeing the brightest portion of the feature due to cosmological dimming.

Observations and Data Reduction

For good sky subtraction, this survey focuses on Abell clusters of distance class 5-6 ($z \approx 0.1 - 0.2$). We observe at the KPNO 2.1m using the Washington M filter, which is similar to V but contains fewer sky lines.

We use the ultra-deep surface photometry techniques of Marron, Boroson & Harding (1994) for our observations and data reduction. We spend half of our telescope time constructing our sky flats (see Fig 2 below), and the other half observing the clusters. We carefully mask out all objects in our frames, using a combination of DAOPHOT/SEXTRACTOR and our own software. We construct an error model for each cluster that includes all sources of error, both random and systematic. Our data has a signal-to-noise of live from $\mu_v = 26.5$ to 27.3, depending on the cluster.

I CL is 10 – 20% of all starlight in clusters

Figure 5 – On the left is a comparison of the intracluster luminosity fractions for four of our clusters as a function of the photometric cutoff. The red data is from Abell 801, blue Abell 1234, green Abell 1553, and black Abell 1914. These measurements are compared to models of the galaxy NGC 3379 (dashed line), and a tidally truncated model of NGC 3379, suitable for galaxy clusters (dotted line).

Figure 6 – A 4 x 4 arcminute image of the central region of Abell 84. The plume is clearly visible extending from the bright galaxy at the bottom of the image up and to the left.

Figure 7 – A 2 x 2 arcminute region in Abell 545, centered over the “star pile” feature first detected by Struble (1988). On the left is the image with a normal image stretch, which shows the large number of elliptical galaxies. On the right is the same image, but binned up 3 x 3 to improve the signal-to-noise. The feature does not extend beyond the galaxies, and is likely to be much smaller due to contamination of the bright star immediately nearby.