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RAM PRESSURE STRIPPING VERSUS TIDAL INTERACTIONS IN THE ABELL CLUSTERS A85 AND A496

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Abstract.
We have undertaken a multi-wavelength survey of several nearby clusters of galaxies to compare the effects of ram pressure stripping to those of gravitational interactions and their role in galaxy evolution. We present here preliminary results for Abell 85 and Abell 496, based on optical, near infrared and HI imaging, as well as X-ray temperature maps.

Keywords: galaxies: clusters: individual: A85, A496

1 Introduction

Galaxy evolution is known to be influenced by environment, and galaxies in clusters may evolve differently than isolated ones. In particular, ram pressure can strip galaxies from their HI gas, thus reducing the star formation rate of cluster spirals. Other phenomena such as single or multiple tidal interactions (galaxy harassment), may also modify galaxy properties in clusters, in particular transforming late type into early type galaxies.

We have selected a sample of nearby clusters (redshift $z \leq 0.2$) with different masses, X-ray luminosities and stages of relaxation, to see how the cluster environment influences the galaxies. Our data include imaging in the optical, near-infrared (NIR) and in the HI 21 cm line. These observations are then compared to X-ray emissivity, temperature and metallicity maps, which give informations on the overall cluster properties and history. We present here preliminary results on two very different clusters: Abell 85 (hereafter A85), at redshift $z = 0.055$, which is known to have undergone and still be undergoing mergers, and Abell 496 (A496), at $z = 0.033$, a typical relaxed cluster.

The basic hypothesis we want to test is the following: if the HI component is perturbed but the stellar disk is not, it is most probable that ram pressure stripping causes the perturbations in the gas distribution; on the other hand, if both the HI component and the stellar disk are perturbed, then gravitational mechanisms such as mergers or galaxy harassment are most probably at stake.

2 The data

• In A85, we observed 68 galaxies in NIR (JHK') within 26 fields; ten of these fields cover HI detections reported by Bravo-Alfaro et al. (2009), and other zones containing pairs or groups of galaxies. Details on the observations and data reduction can be found in Venkatapathy et al. (2017). These data were combined with images in the ultraviolet (GALEX) and g band (CFHT/Megacam). HI data cubes were obtained with the NRAO-VLA.
• For A496, the HI images were also obtained with the NRAO-VLA. Optical imaging was obtained with the CFHT/Megacam in several bands and NIR with the CFHT/WIRCam.

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We developed a new asymmetry index $\alpha_{\rm An}$ and applied it to our NIR images (Venkatapathy et al. 2017), showing that out of 41 bright galaxies 10 show mild to strong asymmetries. This suggests that tidal interactions must be playing an important role driving galaxy evolution in A85.

3 Results

3.1 The cluster A85

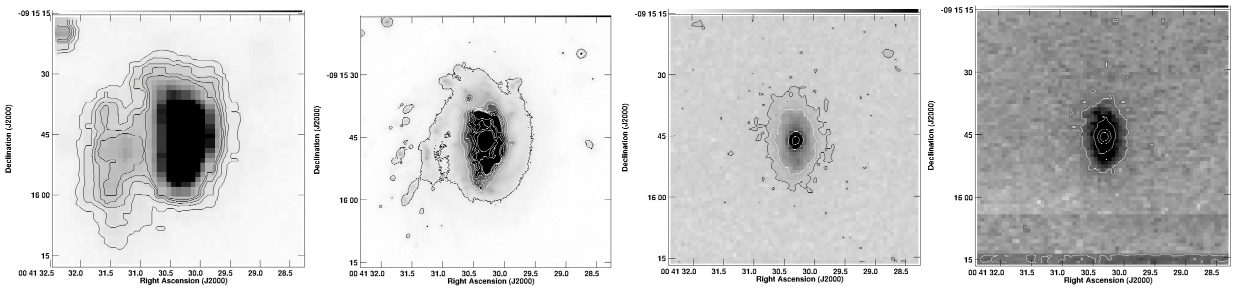

Fig. 1. From left to right: NUV, g, J and H band images of one of the jellyfish galaxies we observed, KAZ 364. The disrupted arms seen in the UV and blue bands are depleted of old stars (see the J and H bands), suggesting that ram pressure stripping is the mechanism responsible for the disruption (see text).

Among the galaxies studied in NIR in A85, three display long filaments in the blue bands; two of them are reported as "jellyfish" galaxies (see e.g. Poggianti et al. 2016). Interestingly, no old stars are found in our deep NIR images along the filaments, implying that the blue stars in these structures must be formed *in situ* and that ram pressure stripping is very active in A85 too. The most extreme case of a jellyfish galaxy (KAZ 364) is shown in Fig. 1.

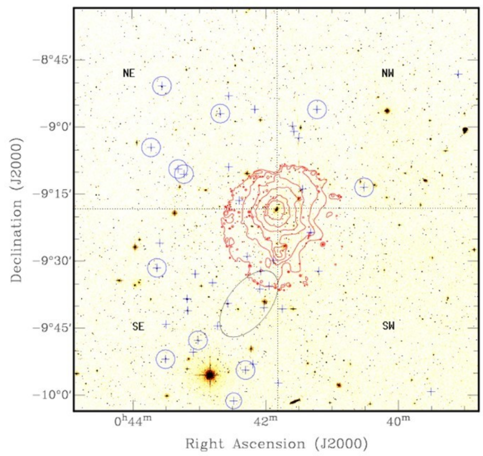

Fig. 2. Distribution of blue galaxies in A85 (crosses) superimposed on the optical image, with the galaxies detected in HI circled. The X-ray contours from ROSAT are in red. The blue ellipse southeast of the cluster shows the position of the X-ray filament (taken from Bravo-Alfaro et al. 2009).

The strong influence of ram pressure stripping in A85 is confirmed by the spatial distribution of the galaxies where HI is detected. As seen in Fig. 2, ten of them are in the east half of the cluster, while only two are detected in the west half. One hypothesis to explain this picture is that ram pressure stripping must have been much stronger in the west half of the cluster. X-ray maps allow to understand better what has happened, as explained below.

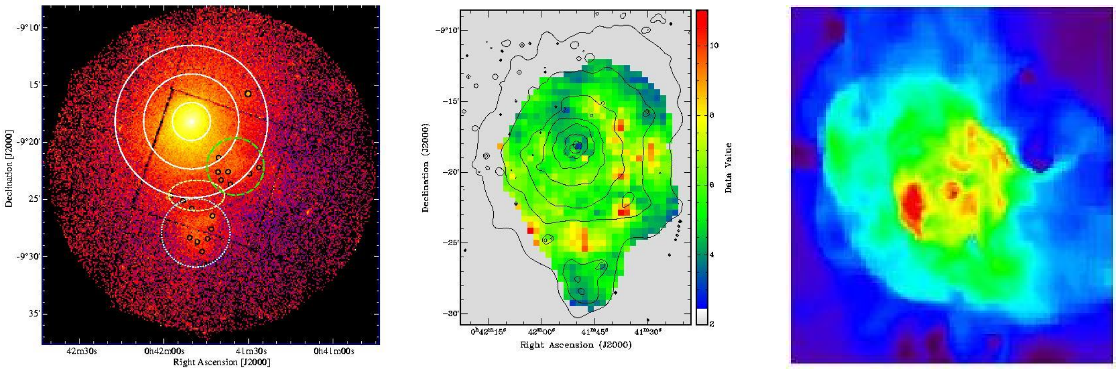

Fig. 3. From left to right: emissivity, temperature map of the X-ray gas in A85, and temperature map obtained from a hydrodynamical simulation by Bourdin et al. (2004).

In X-rays, A85 appears to be strongly perturbed. Figure 3 shows the emissivity and the temperature map of the X-ray gas in A85, derived from XMM-Newton observations (see Durret et al. 2005). This temperature map can be compared with that obtained from a hydrodynamical simulation by Bourdin et al. (2004) where a small cluster coming from the northwest has merged with the main cluster. The similarities between the temperature map observed for A85 and the simulation strongly suggest that a merger has taken place about 3–4 Gyr ago coming from the west or northwest. This can explain why ram pressure has been more efficient in the west half of the cluster, leading to a deficit of HI detections in this zone. An X-ray filament was also detected southeast of A85 and is believed to be made of groups falling onto the cluster, implying that a second merger is presently taking place, the impact region being hotter (Durret et al. 2003; Bravo-Alfaro et al. 2009).

3.2 The cluster A496

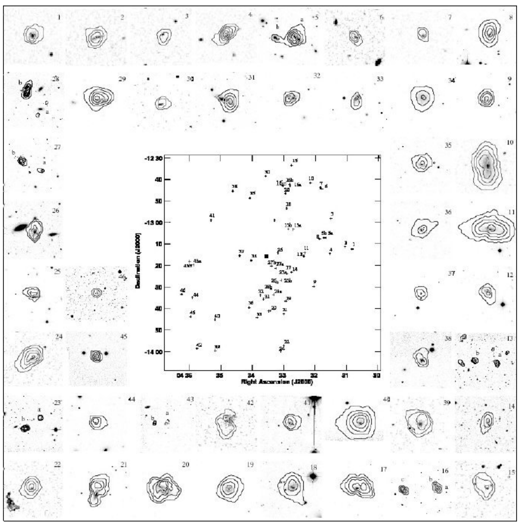

Fig. 4. Distribution of the galaxies detected in HI in A496 and corresponding individual HI maps (from Bravo-Alfaro et al., in preparation).

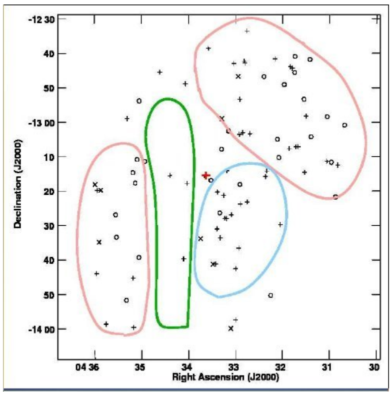

Fig. 5. Spatial distribution of the bright spiral galaxies ($B_T < 17.5$) in A496: in the pink zones, the galaxies are perturbed in HI but show a normal stellar disk in the NIR, while the blue zone is dominated by galaxies perturbed both in HI and NIR. The green region is unexpectedly depleted of spirals.

We fully mapped A496 in HI and detected 58 galaxies, many more than in A85 (Fig. 4). Out of those 58 galaxies between 20% and 30% show disruptions in HI, either with gas deficiency and/or asymmetries and offsets between HI and optical positions. Therefore, ram pressure stripping must play a less important role in A496 than in A85, as expected by the relaxed nature of A496. However, if we compare the distributions of the galaxies detected in HI with the galaxies showing asymmetries in the NIR, we find some surprising results: some galaxies appear somehow disrupted in HI but have rather normal stellar disks, and some are perturbed at both wavelengths. Interestingly, A496 does not display the expected pattern of HI-rich spirals projected at higher radius, and HI-deficient galaxies closer to the cluster core. Fig. 5 shows a rather complex spatial distribution of the brightest spiral galaxies and their various kinds of asymmetries. We can see that they are segregated spatially. It is very likely that the "pink" zones, where the galaxies are perturbed in HI but have a normal stellar disk, are zones where ram pressure stripping dominates. On the other hand, in the "blue" region, there are galaxies perturbed both in HI and NIR, where tidal interactions must dominate. The green zone appears nearly depleted of spirals. A detailed analysis of the HI properties of the A496 galaxies is under study (Bravo-Alfaro et al. in preparation).

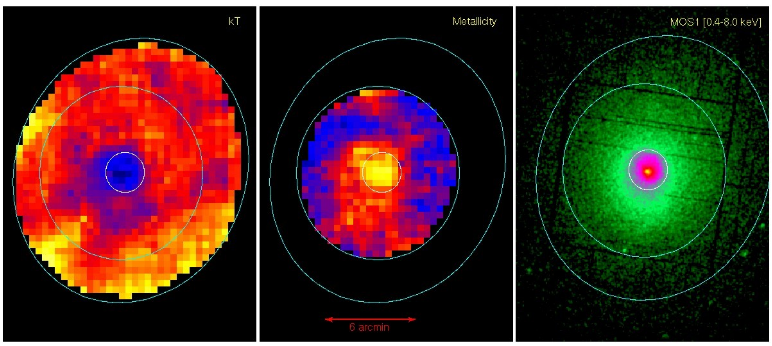

Fig. 6. From left to right: temperature, metallicity, and emissivity maps of the X-ray gas in A496. The two ellipses show the regions where the number of X-ray photons was sufficient to compute the temperature and metallicity maps.

The X-ray emissivity map of A496, which appears quite smooth and relaxed, contrary to A85, suggests that it is a relaxed cluster (Fig. 6). However, the temperature and metallicity maps are not perfectly symmetrical: the gas is hotter in the south part of the cluster, and a metallicity excess is also detected south of the cluster center. This suggests that a minor merger may have come from the south, the merging group or small cluster being of relatively small mass, since we do not see patches of hot gas in the temperature map as was the case in A85. However, this scenario is difficult to put together with the picture drawn by the very complex distribution of spiral galaxies and their HI content, that suggest recent falling of groups (or subclusters).

4 Conclusions

The study of asymmetries in the gas component (HI) and in the old stellar distribution (NIR) of spirals in A85 and A496, shows that in these clusters both mechanisms (ram pressure stripping and tidal interactions) are playing a role in galaxy evolution. By combining these techniques with X-ray maps we begin to disentangle the effects produced by each physical mechanism and we understand better the dynamical history of the clusters. In particular we link the cluster merger history with the zones where different physical mechanisms dominate the transformation of galaxy morphology.

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