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AN HI SURVEY OF CLUSTERS IN THE LOCAL UNIVERSE:

Outlining the Project

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Abstract. We outline the project of multifrequency observation of five clusters of galaxies spanning a redshift between 0.05 and 0.2. The core of the project is an HI survey of clusters accomplished with the VLA in its C configuration, and complemented with GMRT data. The 21 cm imaging is being combined with optical spectroscopy and deep NIR imaging with the aim to obtain a database on galaxy evolution in the nearby universe. We choose a sample of clusters with different degrees of dynamical evolution, some containing an important population of starburst or/and post-starburst galaxies, and a hot intracluster medium with emission in X-ray.

Keywords: Clusters of galaxies: structure, Galaxies: evolution, Galaxies: spiral, Radio lines: galaxies

1. Introduction

It is generally accepted that galaxies in clusters differ systematically from field galaxies, both in morphology and in stellar population and gas properties. The observed differences within local clusters and those at redshifts 0.4 suggest that the cluster environment plays a fundamental role in galaxy evolution. Therefore, studying galaxies within clusters spanning a range of physical properties and over a moderate range of redshifts should provide the possibility to observe galaxies being transformed from normal to starburst, to post-starburst and to gas poor objects.

Paradoxally, this hypothesis is being studied more actively at intermediate redshifts than in the local universe (e.g. the MORPHS collaboration, Dressler et al., 1999; Poggianti et al., 1999). So far, observations confirm at least two evidences

of evolution: the trigger and halt of star formation activity, and the morphological transformation from spiral to S0. However, it is not yet clear which mechanisms are responsible for each phenomena.

Concerning theoretical work on environmental effects in clusters, there are at least three mechanisms being actively proved: galaxy harassment (Moore et al., 1996), gravitational effects by subgroups merging (Bekki 1999), and ram pressure stripping (Abadi et al., 1999). Most of these studies show that more than one process is at work. The key component to understand what physical mechanisms are playing a role is the gas supply in individual galaxies: HI imaging provides detailed information on environmental effects and by comparing it with the stellar component it is possible to distinguish if a dynamical or a gravitational process is at work.

2. Previous HI Imaging of Clusters

By the 80's, technical limitations only enabled to map the HI in clusters of galaxies with the aid of single dish telescopes. However, since the early 90's a big step forward has been achieved with synthesis imaging arrays such as the VLA, WSRT, ATCA, and the GMRT. Almost ten clusters have already been mapped in HI spanning a range of z between 0 and 0.08. In few cases the survey has been almost complete in volume, as in Hydra (McMahon, 1993) and Hercules (Dickey, 1997). In the remaining cases detailed mapping has been made on spiral galaxies: Virgo (Warmels 1988, Cayatte et al., 1990, 1994), A 262 (Bravo-Alfaro et al., 1997), Coma (Bravo-Alfaro et al., 2000, 2001), and Ursa Major (Verheijen et al., 2001).

For those clusters with a hostile intracluster medium (ICM), the HI imaging not only confirmed the gas deficiency previously observed with single dish telescopes, but it also shows how the morphology of the HI disks of central cluster galaxies differ from those in the field: they appear shrunken and/or asymmetric. At the extreme, some of the central galaxies in Coma present an important shift in position between the HI and the stellar disk. In this cluster the position of several HI non-detected spirals gives lots of information on the dynamics of different subclumps.

Oppositely, Hydra and Ursa Major are systems with a less aggressive ICM and few (if any) HI deficiency. In Hydra the HI properties and the velocity of more than 50 detected galaxies give precious information on the superposition of three substructures along the line of sight. At the extreme we find the Ursa Major system, which lacks of central condensation and is free from an X-ray emitting ICM. The HI strongly suggests that Ursa Major is in its earliest stage of formation.

3. Goals of the Project

One of the key questions concerning clusters of galaxies is to what extent the galaxy evolution within clusters is related to dynamical cluster evolution. In order to address this question we are on the way to enlarge the sample of clusters imaged in HI, aiming at the first one near a redshift of 0.2. This will enable to quantify the process of accretion of subclumps and the evolution of spirals as they move inside the system, all this as a function of redshift and physical properties of clusters.

One of the key questions on galaxy evolution concerns the star formation history, which we address by comparing gas content, optical spectra and colors. Analyzing the radio continuum images, which are a by-product of HI imaging, we expect to understand how does the cluster environment affect radio emission from individual galaxies, and if there appear to be merger induced star formation and/or AGN's.

HI imaging has proved to be useful in constraining cluster substructure (Bravo-Alfaro et al., 2000). If we combine this information with the star formation history outlined by optical spectra and colors, we will estimate the importance of the merging of subclumps and shocks with the ICM with the trigger of star formation. It is worth mentioning the substructures found in Hydra and Coma. In the former one, the clumps clearly have not gone through each other yet, and there is no evidence of starbursts or post-starbursts. At the other extreme, the HI non-detections in Coma strongly suggest that certain groups have crossed the cluster core, which is confirmed by the presence of an important population of starburst and post-starburst galaxies (Bothun and Dressler, 1986; Caldwell et al., 1993, 1999).

4. The Sample

We observed five clusters with the VLA enlarging the total number of clusters imaged in HI to about fifteen. Four of the clusters are on the redshift range between 0.03 and 0.06, and one is around $z=0.2$. Imaging in HI with the VLA at $z=0.06$ enables to cover almost one Abell radius in one single pointing ($\sim 30'$), while at $z=0.2$ a single pointing will image the cluster out to three Abell radii.

A 496 ($z=0.033$) is a cD cluster where substructure in its galaxy velocity distribution is not clearly determined. A 754 ($z=0.055$) and A 85 ($z=0.055$) are extremely interesting merging systems. Redshifts for several hundreds of galaxies in these systems are available, as well as X-ray data, optical imaging and spectroscopy. A 2670 ($z=0.077$) is classified in many studies as a rich dynamically relaxed cluster with a significant population of post-starburst and star-forming galaxies. We have Keck imaging of the central parts of the cluster and, at the distance of this cluster, we are able to study individual HI properties. The farthest system in our study is A 2192 ($z=0.187$), a rich cluster with a large spiral fraction.

Figure 1. Total HI image of the cluster A 2670. Contours indicate the HI and crosses are optically catalogued cluster members. The gas rich group to the NE is enlarged in the upper panel. Some of those galaxies have $10^{10} M_{\odot}$, and diameters up to 100 kpc.

5. The Project So Far

Between 2000 and 2002 some 500 hours of the VLA (in its C configuration) have been devoted to this project, reaching HI mass limits of about $10^8 M_{\odot}$. Clear detections are seen in almost every cluster. In A2670 we have 49 detections and in A496 at least 46. In A 85 and A 754 we detected so far 20 and 5 galaxies respectively. In A 2192 we report what can be the farthest galaxy ever detected in HI. Data reduction is still on the way, and final results will be shown by van Gorkom et al. (2003). In this work we show some results on A 2670 which displays contradictory evidence: many studies classify it as a dynamically relaxed cluster but it also shows segregation, both spatially and in velocity of the gas rich galaxies, as if they were falling to the main body from two different directions. The HI detection rate of post-starburst galaxies is only a few percent, and unlike distant clusters, in A 2670 we do not detect these galaxies in continuum. In the upper panel of Figure 1 we show the striking gas rich group to the NE of A 2670, with HI contours overlaid on a B-band DSS image. In the lower panel we show the total HI emission of the cluster, showing an absence of HI detections within a radius of about 250 kpc from the cluster center, i.e. a stripping radius 2–3 times bigger than in clusters like Virgo. HI observations are in good agreement with Bird's result (1994) who proposed the existence of three independent clumps. The case of A 2670 not only shows that a cluster apparently relaxed may display an important number of HI rich galaxies, but it also represents a proof of feasibility of mapping the HI in galaxies at intermediate redshifts.

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