Environmental effects on HI–rich dwarf galaxies in the Hydra and Hercules clusters

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Abstract

We present H I, optical and near-infrared photometric and spectroscopic data of two samples of H I-selected dwarf galaxies in the Hydra I and Hercules clusters. We study in particular the environmental effects on dwarf galaxies in these clusters, in particular the role of interactions between them and either the intracluster-medium or companion galaxies, hitherto studied mainly in massive galaxies. The atomic gas is supposed to react very rapidly to any external perturbation. Therefore H I–rich dwarfs are ideal tools to probe the environment. The H I-selected dwarfs in Hydra tend to have massive H I–rich companions. They show a large diversity in their morphologies, surface brightness and star formation rates, as do dwarfs in the field. Our surveys have disclosed a few galaxies with some unusual morphological and spectrophotometric properties such as disk truncations or unexpected high metallicities. These oddities might be due to the particular environment of clusters. Deviant objects could also be recycled galaxies made out of material stripped from the giant galaxies in the cluster, a mechanism at the origin of tidal dwarf galaxies.

1 Introduction

Because of their low mass, dwarf galaxies in clusters should be very sensitive to their environment. They appear as ideal laboratories to probe environmental effects such as gravitational interactions and ram pressure by the intracluster medium. Gas rich dwarfs are particularly attractive since their gas, which usually extends far beyond the optical radius, should be easily stripped, as have been the H I-deficient spirals discovered in the X–ray core of several clusters. In this respect, the discovery of H I rich dwarf galaxies in H I surveys of nearby clusters (e.g. Cayatte et al., 1990; McMahon, 1993, Dickey 1997) is puzzling. Had they ventured in the cluster core or encountered a companion, they should have lost most of their gas content. The survival of their H I puts constraints on their location in the clusters – i.e. they could belong to sub-clusters seen in projection – and/or on their origin. We investigate the hypothesis that some gas–rich dwarfs in clusters are actually recycled galaxies made out of the material stripped from giant galaxies. As such, they would be the very result of environmental effects.

2 Samples of HI–selected dwarfs in Hydra-I and Hercules

We have collected multi-wavelength data of complete samples of gas–rich dwarf galaxies in the Hydra I and Hercules clusters which are located at a distance of resp. 45 and 150 Mpc. They have

"Dwarf Galaxies and their Environment"; Bad Honnef, Germany, 23-27 January 2001; Eds. K.S. de Boer, R.-J.Dettmar, U. Klein; Shaker Verlag

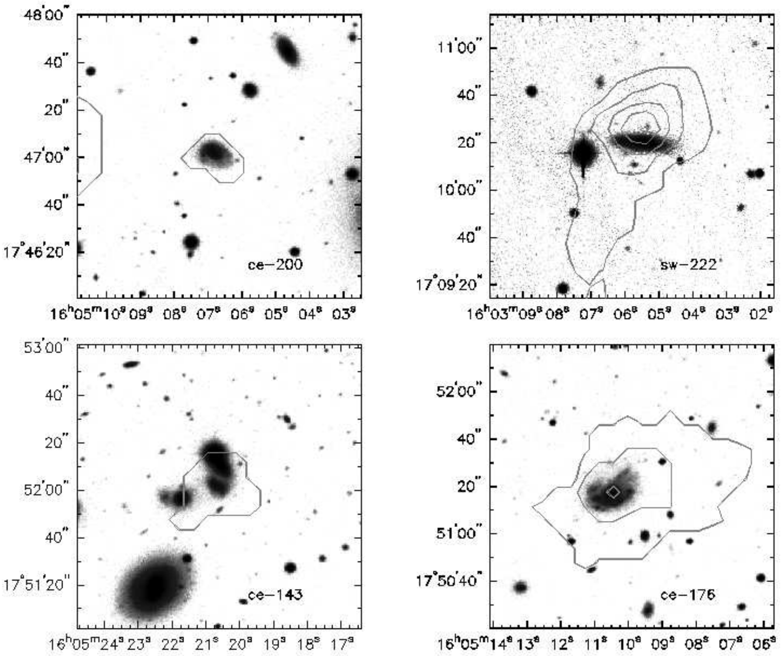

Figure 1: Examples of H I–rich dwarf galaxies in the Hercules cluster. The VLA H I contours (courtesy of J. Dickey) are superimposed on optical images of the cluster obtained with the Wide Field Camera on the Isaac Newton Telescope.

been discovered in two low resolution H I VLA surveys that covered almost all the core volume and X-ray emitting regions (McMahon 1993; Dickey 1997). All sources with a low 21 cm line width were selected. Their line properties were afterwards checked with single dish telescopes at Nançay and Arecibo (in progress). Follow-up optical observations with the ESO/Danish 1.5m telescope and the Isaac Newton Telescope confirmed that almost all of the sources were indeed associated with dwarf galaxies (see Fig. 1). Our sample includes 15 H I–rich dwarfs in Hydra-I and 9 in Hercules. The database is presented in Duc et al., 1999 (Paper I) and Duc et al., 2001 (Paper II).

In the course of this study, we discovered several putative intracluster H I clouds without optical counterparts in deep optical images. One source in Hydra, situated at about 50 kpc from the gas–rich spiral ESO 436-G046, was confirmed at Nançay (Paper I). It could be a tidal debris, although its companion does not show any sign of a morphological perturbation. The H I sources in Hercules will be soon checked at Arecibo. Up to now, very few massive intergalactic H I clouds candidates have been found and, apart from the giant ring discovered by Schneider et al. (1983), all of them turned out to have faint optical counterparts. Low–mass intergalactic clouds are more commun, e.g. the gaseous companions of blue compact dwarf galaxies (Taylor et al., 1995).

The absolute blue magnitudes of the H I selected dwarfs range between −14 and −18.5. They have rather blue integrated colours and host one or several H II regions indicative of recent star formation. They exhibit a wide range of mean central surface brightness. Their brightness profiles can all be fitted by an exponential law with some deviations: truncation in the outer regions, flattening towards the nucleus. In general, judging from their global optical properties, the objects in our sample appear to form a quite heterogeneous class from blue compact dwarf galaxies to low surface brightness objects.

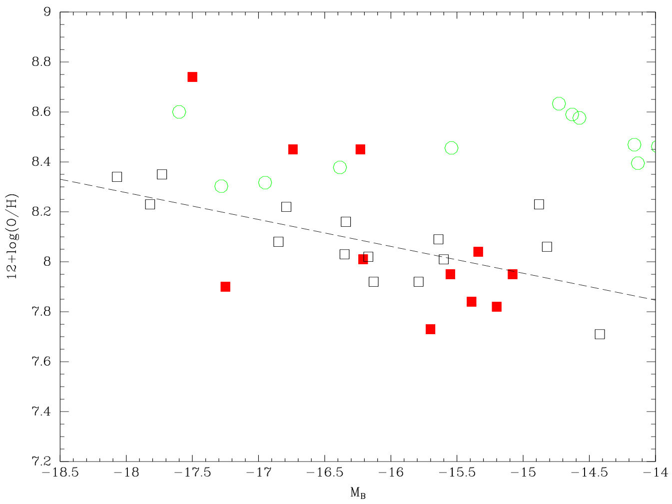

Figure 2: Oxygen abundance vs absolute blue magnitudes for the H I-selected dwarf galaxies in Hydra (filled squares), a sample of isolated dwarf irregular galaxies (open squares, Richer & McCall, 1995) and of tidal dwarf galaxies (circles, Duc et al., 2000).

3 Environmental effects and deviant properties

About 70% of the H I–selected dwarfs in Hydra have a more massive H I–rich companion. Only four objects are isolated (in linear distance and/or velocity). We found a weird effect: apparently, the H I/optical velocity of the dwarfs is systematically higher than that of their respective giant companions. We do not have any obvious explanation for such a property that incidently had been previously noted many times by H. Arp (e.g. Arp 1994; see also Szomoru et al. 1996). New H I maps of the Hydra dwarfs were recently obtained with the VLA at a higher spatial resolution than in the original surveys (J. van Gorkom, private communication). Their preliminary analysis reveal possibly large offsets between the clouds and the optical centers of several objects. If real, they could result from some stripping process or reveal a strong outflow activity in the star-bursting galaxies.

The metallicity of galaxies could be affected by the environment too, as argued by Vilchez (1995). We have determined the oxygen abundance in the H II regions of the Hydra dwarfs (Paper II). A correlation between luminosity and metallicity has been well established for galaxies of different morphological types over several orders of magnitudes. The majority of the dwarfs in our sample do indeed follow this trend (see Fig. 2) . However, three of them (20%) appear to be too metallic for their luminosity. Hydra is not the only cluster where cases of over-abundances have been measured. In a study on the Fornax cluster, Rakos et al. (2001) noted that a few dwarf ellipticals had colours consistent with simultaneously a younger age and a rather higher metallicity than main stream dwarfs. In Coma, Secker (1996) measured a color gradient in the radial distribution of dEs which he interpreted as a metallicity increase towards the cluster center. It has been suggested that the pressure confinement exerted by the dense ICM in the core of clusters could prevent the escape of heavy elements from low-mass galaxies (Babul & Rees, 1992) and hence contribute to increase their metallicity. However, ram-pressure might at the same time strip the gas from the galaxies plunging into the cluster core, quench star formation and hence halt any further chemical enrichment (Murakami & Babul, 1999). Other explanations may be proposed. Systematic errors introduced by the empirical methods used to estimate the abundances in H II regions cannot be excluded a priori. With an oxygen abundance of 1/3 to 1/2 solar, the

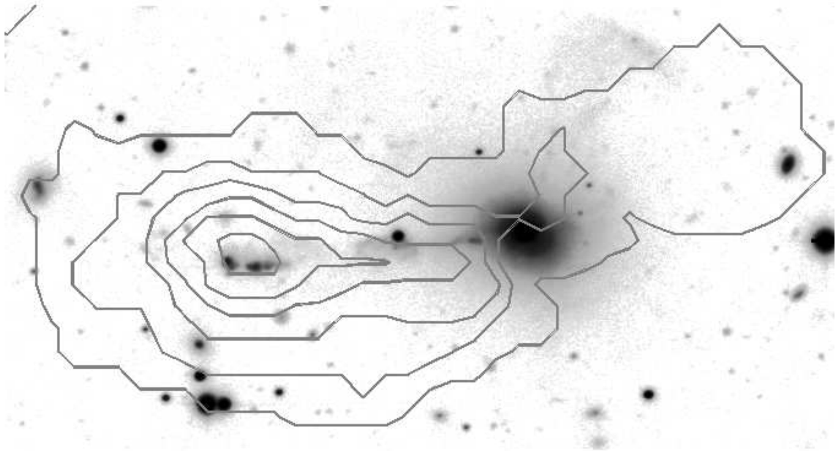

Figure 3: An H I-selected dwarf galaxy of tidal origin in the Hercules cluster. The compact object, to the left, lies at the tip of an H I tidal tail which emanates from IC 1182. Its colour and morphology would qualify it as a blue compact dwarf galaxy although its oxygen abundance is much higher than typical BCDGs.

deviant dwarfs in Hydra actually occupy the locus of Tidal Dwarf Galaxies (TDGs). TDGs are self-gravitating entities made out of gas and stars tidally pulled out from interacting galaxies (i.e. Duc et al, 2000; see also contributions by Peter Weilbacher and Ute Lisenfeld in this volume). The building material of TDGs has hence been pre-enriched in the disks of their parents. This peculiar "genetic" property provides a useful tool to identify old TDGs. Instances of dwarf galaxies of tidal origin have already been unambiguously identified in several clusters. For instance, one H I–selected dwarf in our Hercules survey is found at the tip of a tidal tail which emanates from the old merger IC 1182 (see Fig. 3). As long as the umbilical cord between the parent and the baby galaxy is not broken, it remains straitforward to identify a tidal formation. This is most probably the origin of the dwarf near IC 1182. In Hydra, we do not have any strong signs for past tidal interactions, contrary to Hercules where several interacting systems are clearly visible. In the former cluster, the putative recycled dwarfs could have been formed out of gaseous material stripped from spirals during a process involving ram pressure rather than tidal interactions. Whether genuine galaxies can really be formed that way is however still very speculative.

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