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A search for LSB dwarf galaxies in various environments

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Abstract. The varying dwarf galaxy populations in different environments pose a problem for Cold Dark Matter (CDM) hierarchical clustering models. In this paper we present results from a survey conducted in different environments to search for low surface brightness (LSB) dwarf galaxies.

1. Introduction

According to standard Cold Dark Matter (CDM) hierarchical clustering theory, there should be numerous low mass dark matter halos present in the Universe today. If these halos contain sufficient stars, they should be detectable as dwarf galaxies. Observationally this appears to be true for clusters of galaxies where the galactic density is high, but not so for the lower density environments. We conducted a search for these objects in the Millennium galaxy strip which runs along the celestial equator in the field, passing through filaments and voids. It is therefore an excellent data set for studies into the influence of the environment on dwarf galaxy populations. We compare these results with those from similar surveys carried out in the Virgo and Ursa Major (UMa) clusters. Our results are unique as the three surveys were conducted using the same instrument, same technique (exposure time, filter band) and same selection criteria, thus we can be sure that we are comparing "like with like".

Low surface brightness (LSB) galaxies are difficult to detect as their surface brightnesses are below that of the sky (≥ 23 mag arcsec^{-2}). The detection algorithm that we developed for this project is optimised for the detection of faint, diffuse objects on CCD frames (see Sabatini et al. 2003). To ensure that the objects picked out by the algorithm are actually dwarf galaxies and not background contamination, selection criteria based on morphology and magnitude are applied to the objects. These criteria were chosen following simulations of a cone of the universe randomly populated with galaxies, as detailed in Roberts et al (2003).

2. Results and Discussion

We have presented the results obtained for 3 surveys carried out in very different environments (Table 1). We find a DGR[1] in the field of 6:1, compared to a value

[1]We define a dwarf to giant ratio (DGR) as the number of dwarfs with $-10 \geq M_B \geq -14$ divided by the number of giants with $M_B \leq -19$.

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Table 1. Summary of results for the three surveys, compared with predictions from CDM

Environment	*Description*	*DGR*
MGS	Passes through regions of high and low density	6:1
UMa	Low density cluster	-
Virgo	High density cluster	20:1
2dF LF ($\alpha = -1.2$)	2dF survey results (Norberg et al. 2002)	7:1
CDM ($\alpha = -1.6$)	Schechter LF integration	370:1
CDM ($\alpha = -2.0$)	Schechter LF integration	8500:1

of 20:1 in the Virgo cluster. This very large ratio of dwarf to giant galaxies found in the Virgo cluster indicates that this region is very different to lower density clusters such as UMa, and the field where we find relatively few dwarfs.

Our results for the DGR of the MGS are consistent with those derived from the recent redshift survey determinations of the field LF made by 2dF (Norberg et al. 2002) even though we sample to some two magnitudes fainter in central surface brightness and magnitude. There is no hidden population of dwarf galaxies that has been missed by the redshift surveys.

These observational results are in disagreement with most predictions made by CDM models, commonly referred to as the "substructure" problem. The models predict far more small dark matter halos than observations detect (Kauffman et al. 1993). A number of theories have been put forward to explain the apparent difference in the observed number of dwarf galaxies in different environments. These range from those which try and explain how more dwarfs may form in rich environments, such as galaxy harassment (Moore et al. 1996) or the external pressure confining the ejected galaxy gas (Babul & Rees 1992), to those ideas which emphasise the suppression of dwarf galaxy formation in the field such as supernovae wind expulsion and galaxy squelching (Tully et al. 2002). Detailed observations of dwarf galaxies provide a challenge to the "concordance" cosmological model to which CDM is central. Dwarf galaxies are found in large numbers in rich clusters, but not in less dense galactic environments. For the CDM model to remain viable it has to provide a satisfactory solution to this problem. At present, it is not clear which, if any, of the mechanisms described above would be the best to help provide this solution.

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