1. Introduction

New observations suggest that dwarf galaxies pervade the universe, for they have been encountered in large numbers in the field (Marzke et al. 1998), groups (Côté et al. 1977), and clusters of galaxies (e.g. Trentham 1998). Some early studies encountered an over-abundance of dwarfs in clusters (e.g. Sandage et al. 1985) in the nearby universe. Studies at higher redshifts also suggested large numbers of dwarfs in clusters. The faint-end slope of the luminosity function (LF) has indicated the over-abundance of dwarf galaxies, having steep values of $-2.0 \leq \alpha \leq -1.4$. Even a pattern of universality in the steep slope has been suggested (Trentham 1998).

In the recent studies of clusters' LFs, a factor that has been often overlooked is the effect of the environment. For instance, the characteristics of cD galaxies have always suggested that their formation is due to processes pertaining to clusters, since no cD galaxy have been found in the field (Kormendy & Djorgovský 1989). In general cD clusters (Root-Sastry cD; Bautz-Morgan class I, I-II) are rich, massive, and dynamically evolved. In contrast non-cD clusters are often irregular, poorer, and with less hot gas in the intracluster medium (ICM). These cluster morphological and dynamical properties defined mainly by the giant galaxies should also be reflected in the dwarf population. López-Cruz & Yee (1995) encountered a class of clusters that they termed flat-LF clusters that challenged the idea that dwarf galaxies were very abundant in clusters' environments. Later López-Cruz et al. (1997) reported seven flat-LF clusters in a survey of 45 and suggested that the luminous halos of cD galaxies and a large fraction of the intracluster gas was formed by the disruption of dwarf galaxies. The results of López-Cruz et al. pointed out that the effects of the environment were detectable in the dwarf population easier than in the giant population.

The idea that the cluster environment is hostile to galaxies is strengthened by new high resolution numerical simulations showing that the cluster environment is able to strip gas and the outer halos of giant galaxies, even induce morphological changes (e.g., Moore et al. 1999). Dark matter dominated dwarfs should be susceptible to all the dynamical effects induced by the environment. In some cases the effects could be devastating, causing the disruption of a large number of dwarf galaxies, and hence the flat faint-end slopes. A plausible mech-
anism is that in rich clusters a dwarf galaxy could suffer multiple encounters with giant galaxies. Therefore, dwarf galaxies could be affected by tidal disruption and orbital heating. Alternatively, the lack of dwarf galaxies in rich environments has been interpreted in terms of the density-morphology relation: dwarf galaxies prefer low density environments (Phillipps et al. 1998). We argue that such an explanation cannot account for the relationship between the cD halo luminosity and the gas mass in the ICM, whereas the dwarf disruption scenario addresses this naturally (López-Cruz et al. 1997).

2. Observations

The observations come from the Low-Redshift Optical Survey (LOCOS) (see López-Cruz 1997, Ph.D. thesis). The LOCOS is a comprehensive multicolor photometric survey that includes a sample of 45 Abell clusters with \( z \) between \( \sim 0.4 \) to 0.15. The observations were carried out in Kron-Cousins \( I \), \( R \) and \( B \) bands at KPNO\(^1\) with the 0.9m telescope and the T2KA CCD (2048 \( \times \) 2048 pixels). The field covered by this combination is \( 23' \times 23.2' \) with a scale of 0.68/\("\)/pixel. The integration times varied from 900 to 2500 seconds, depending on the filter and the redshift of the cluster. The photometric calibrations were done using stars from Landolt (1992) compilation. Control fields are also an integral part of this survey, we observed 5 control fields (in \( R \) and \( B \)) chosen at random positions in the sky of 5° away from a cluster observation. Data preprocessing was done with IRAF, while the object finding, star/galaxy classification, photometry, and the generation of catalogues was done with PPP (Yee et al. 1996).

3. Results

López-Cruz & Yee (1995) pointed out that rich cD clusters had the tendency towards flatter LFs. More examples were presented in López-Cruz et al. (1997) and Driver et al. (1998). The Schechter function has been adopted almost universally to describe the behavior of the LFs. However, this approach has a number of problems. For example, in many cases there are not enough degrees of freedom. Hence to avoid degeneracy in the fits, it is necessary to restrict the parameter space, thereby resulting in an interdependence of the parameters. This makes the process model dependent. One can get around such problems using the data themselves and introducing a non-parametric dwarf-to-giant ratio (D/G) defined by summing the counts in the tabulated (in 0.5 mag bins) LFs in the following manner: the counts in the interval \(-20 < M_R \leq -17\) and the counts of galaxies brighter than \(-20\) are summed to give the number of dwarf and giant galaxies, respectively; i.e.,

\[
D/G = \frac{N(-20 < M_R \leq -17)}{N(M_R \leq -20)}.
\] (1)

\(^1\)KPNO, NOAO, is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the NSF.
In order to include the largest possible number of clusters to generate the D/Gs we have included clusters that were complete to \(M_R = -17.25\) by adding an extra bin centered on \(M_R = -17.0\) with the same counts as in the bin centered on \(M_R = -17.5\). Figure 1 shows the behavior of D/G versus the richness parameter \(B_{gc}\) (Yee & López-Cruz 1999). A clear trend towards lower D/Gs is seen as richness increases, a simple fit shows that \(D/G \approx 909B_{gc}^{-1} + 2\). It is also seen that cD clusters tend towards lower D/G than non-cD clusters. If the dwarfs are contributing to the gas in the cluster, then the D/G should correlate with the gas mass \((M_{gas};\) Jones & Forman 1999) of the ICM. Such a correlation is seen in Figure 2.

4. Discussion and Conclusion

We have disregarded low surface brightness (LSB) galaxies in our discussion, although they have been detected in large numbers in poor clusters such as Virgo (Impey et al. 1998). We claim that our results are independent of our efficiency to detect (LSB) galaxies since we have included fairly bright objects. Our 100 % completeness limit is 0.9 mag brighter than the 5σ stellar detection limit. Moreover, LSB galaxies are unlikely to survive in clusters (Moore et al. 1999). There are two main conclusions drawn from the present study. First that there is a range of D/G that seems to be correlated with the richness of the cluster. This is also indicative of a wide range in faint-end slopes in the LFs of cluster galaxies. If this trend of decreasing number of dwarfs with richness is extended to very poor regions, then we propose a D/G \(\sim 15\) for the field \((B_{gg} \approx 68)\). Second, the relationship between the gas mass of the ICM and the D/G supports the dwarf disruption scenario for the formation of the luminous halo of cD galaxies and the origin of the ICM. The alternative explanation of
Figure 2. The variation of D/G with the gas mass $M_{\text{gas}}[10^{14}M_\odot]$. The filled squares are cD clusters and the solid line is the fit $D/G \approx 1 \times 10^{14}M_{\text{gas}}^{-1} + 2$. If disrupted dwarfs have contributed to the gas in the ICM, then this correlation is expected.

the D/G behavior in terms of dwarf population density relation cannot account for the relationships between the ICM gas mass and the luminosity of the cD halo (López-Cruz et al. 1997). It also cannot account for the relationship with the D/G presented above.

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