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# The luminosity function of galaxies in compact groups

A. L. B. Ribeiro,[1] R. R. de Carvalho[1,2]★ and S. E. Zepf[1,3,4]†

[1] *Divisão de Astrofísica, INPE/MCT, CP 515, São José dos Campos, SP 12201-970, Brazil*
[2] *Instituto Astronômico e Geofísico – USP, Av. Miguel Stéfano, 4200 Água Funda–São Paulo, CEP 04301-904, SP, Brazil*
[3] *Department of Physics, University of Durham, South Road, Durham DH1 3LE*
[4] *Department of Astronomy, University of California, Berkeley, CA 94720, USA*

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## ABSTRACT

We use counts of faint galaxies in the regions of compact groups to extend the study of the luminosity function of galaxies in compact groups to absolute magnitudes as faint as $M_B = -14.5 + 5 \log h$. We find a slope of the faint end of the luminosity function of approximately $\alpha = -0.8$, with a formal uncertainty of 0.15. This slope is not significantly different from that found for galaxies in other environments. Our results do not support previous suggestions of a dramatic underabundance of intrinsically faint galaxies in compact groups, which were based on extrapolations from fits at brighter magnitudes. The normal faint-end slope of the luminosity function in compact groups is in agreement with previous evidence that most galaxies in compact groups have not been dramatically affected by recent merging.

**Key words:** galaxies: clustering – galaxies: luminosity function, mass function.

## 1 INTRODUCTION

The luminosity function of galaxies is one of the most frequently used observational constraints on models of galaxy formation and evolution. This has led to a variety of studies comparing the luminosity functions of galaxies in different regions, in order to learn about environmental influences on the properties of galaxies. The conclusion of these studies is that the luminosity function of galaxies seems to be mostly independent of environment (Binggeli, Sandage & Tammann 1988), with some evidence for modest effects at faint magnitudes [$M_B > -16$, for $H_0 = 50$ km s$^{-1}$ Mpc$^{-1}$ (assumed hereafter)] (Vader & Sandage 1991; Ferguson & Sandage 1991).

Recently, Mendes de Oliveira & Hickson (1991, hereafter MOH) attempted to determine the luminosity function of galaxies in the Hickson compact groups (hereafter HCGs). Their study was based on the original Hickson catalogue (Hickson 1982), which only includes galaxies that are within 3 mag of the brightest group member. MOH were therefore forced to develop detailed models of the Hickson selection criteria in order to study the luminosity function. They concluded that compact groups are strongly deficient in intrinsically faint galaxies. Parametrizing the galaxy luminosity function in the usual Schechter form, they found $\alpha = -0.2^{+0.8}_{-0.9}$, where the limits are at 99 per cent confidence. Although HCGs are expected to be favourable sites for merging (e.g. White 1990), such a large effect is surprising since a wide variety of other observations indicate more modest differences between galaxies in HCGs and those in other environments (e.g. Whitmore 1993; Zepf 1994).

Because of the implications of an absence of intrinsically faint galaxies in compact groups, it is important to make further observational tests of MOH's suggestion. In this context, the critical feature of the Hickson catalogue is that it only includes galaxies within 3 mag of the brightest galaxy in the group. Because of this selection criterion, there are few galaxies in the catalogue fainter than $M_B > -19.0$. MOH attempted to correct for this bias through detailed modelling of the selection effects. However, the final results are very sensitive to the accuracy of the modelling of the selection effects present in the catalogue.

The ultimate goal of this paper is to address the question of the faint end of the luminosity function of galaxies in compact groups through a direct determination of the number of intrinsically faint galaxies in and around the groups. By carrying out our study at magnitudes fainter than those considered in the creation of the Hickson catalogue, we measure the faint galaxies directly without a need for detailed models of the selection procedure for the bright galaxies in the group. The direct study of these faint galaxies is now possible because of our recently completed work on deep counts of galaxies in the regions of compact groups (de Carvalho, Ribeiro & Zepf 1994, hereafter Paper I).

★ On leave of absence from Observatório Nacional – CNPq – DAF.
† Hubble Fellow.

The data used in this work and the methodology employed to estimate the luminosity function of galaxies in HCGs are described in Section 2. The preliminary results from current data are presented in Section 3. The analysis is discussed in Section 4.

## 2 LUMINOSITY FUNCTION OF COMPACT GROUPS

The data used in this paper to estimate the luminosity function of galaxies in HCGs come from deep counts of galaxies around 22 groups (see Paper I for details). Our basic technique is to compare the numbers of galaxies of a given magnitude inside and outside the groups. An excess of galaxies within the area of the group is taken as indicating the presence of galaxies at that magnitude that are members of the group. Such a technique is inherently statistical and cannot identify individual galaxies as members of the group or background objects. Since our goal is the determination of statistical quantities, however, such as the faint end of the luminosity function, the method is expected to be both powerful and reliable.

The galaxy counts were binned in intervals of 0.5 mag. A luminosity function of the galaxies in each group was constructed, and the background was estimated in two different ways.

(i) Assuming that the background component has a uniform distribution, we measured the number of galaxies per square degree brighter than a given limiting magnitude. Defining $N(m)$ as the number of galaxies per square degree brighter than magnitude $m$, we have $N(m)=N_0\ 10^{0.6(m-m_0)}$, where the normalization constant is estimated from counts in surrounding areas to a magnitude limit of 18.5. This limit was chosen because all of the different fields examined in this work were complete to this limiting magnitude. The parameter $N_0$ was estimated individually for each field, and showed a standard deviation of $\sim 30$ per cent among the fields.

(ii) The second method to account for the background contamination was to use the histograms of the counts in the vicinity of each individual group, instead of assuming a uniform distribution for this component among all of the groups.

In the next section we will discuss how sensitive the parameters defining the luminosity function are to both methods.

The normalization of the luminosity function was determined using the same procedure as adopted by MOH. For a magnitude-limited sample we have to normalize the contribution of each group by its effective limiting volume, which is defined as the volume corresponding to the maximum distance at which the group would still be included in the sample. Although our sample of compact groups is taken from Hickson's whole catalogue, it is not a random subsample, but rather one cut at $z<0.03$. Thus the $m_0$ of the completeness function estimated by Hickson, Kindl & Auman (1989) is not necessarily appropriate for our subsample. In order to determine the best $m_0$ for our sample, we examined the cumulative distribution of the total magnitude of the 22 groups. The magnitude of each group was obtained from the uncorrected total magnitude of galaxies in the group (see Paper I for details of our definition of the groups). We found that our subsample follows equation (1) from Hickson et al. (1989), with $m_0=13.0$. This compares with $m_0=13.75$ found for the whole sample of 100 groups. If we use Hickson's group definition and magnitudes we obtain a similar cumulative distribution.

## 3 PRELIMINARY RESULTS

In order to test the robustness of the luminosity function of galaxies in compact groups, we defined different subsamples from our 22 groups under study. For case I we took the whole sample with the background corrected by a uniform distribution law (hereafter UNIF). For case II we took the whole sample but with the background corrected using the histogram of counts in the vicinity of each group (hereafter HIST). We then divided the sample into two halves according to the median projected separation. Case III involves the groups with projected separation smaller than the median, correcting the background as for UNIF. Case IV considers the groups with projected separation larger than the median, correcting the background as for UNIF. Cases V and VI are similar to cases III and IV, but with correction of the background as for HIST. The next step was to consider those groups with more than seven galaxies, for which we found a tendency for faint galaxies in compact groups to be more diffusely distributed than bright ones (Paper I). Cases VII and VIII consider this subsample, with the background corrected by UNIF and HIST, respectively. Finally, we removed from the total sample the three groups (HCG 21, 90, and 91) that have the characteristics of loose groups rather than of compact ones (Paper I). Cases IX and X take the 19 remaining compact groups with background corrections as for UNIF and HIST, respectively. The results for the luminosity functions for all these different subsets are presented in Table 1, where column 1 lists which case is being considered, column 2 gives a brief description of the case listed in column 1, column 3 specifies the method used to correct for the background counts, columns 4, 5, 6 and 7 present the parameters $M^*$ and $\alpha$ and their error estimates, column 8 gives the value of chi-squared per degree of freedom and column 9 lists the number of groups involved in each case. The errors listed in Table 1 for the fitted parameters are formal uncertainties obtained from the non-linear least-squares fits, and do not represent any systematic errors that may be present in our determination of the luminosity function.

Fig. 1 shows the luminosity function of the compact groups in our sample, with the background contribution taken out by method (i) (case I). The Schechter function is also plotted. The values of $\alpha$, $\phi^*$ and $M_*$ are obtained by a non-linear least-squares fit (Jefferys, Fitzpatrick & McArthur 1988). With this technique, we find $\alpha=-0.82\pm0.09$. In addition, we have used the $\chi^2$-test to estimate roughly the 99 per cent confidence limits for case I, and we find $\alpha=-0.82^{+0.38}_{-0.18}$. It is important to emphasize here that this error estimate gives only a crude measure of the true error involved in evaluating the luminosity function of galaxies in compact groups. The value of $\alpha$ in compact groups is not significantly different from that found in the galaxy survey of Loveday et al. (1992). Specifically, we do *not* confirm the claim of Mendes de Oliveira & Hickson (1991) that compact groups are dramatically deficient in faint galaxies. Instead, the luminosity function appears to be

**Table 1.** Parameters of the LF of galaxies in compact groups.

| Case | Descr. | Back-Corr | M* | ± | α | ± | $\chi_\nu$ | Number |
|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| I | All | U | -20.77 | 0.16 | -0.82 | 0.09 | 0.83 | 22 |
| II | All | H | -20.77 | 0.25 | -0.77 | 0.15 | 1.68 | 22 |
| III | Small R | U | -21.38 | 0.30 | -0.89 | 0.10 | 0.73 | 11 |
| IV | Large R | U | -21.08 | 1.36 | -0.85 | 0.28 | 3.07 | 11 |
| V | Small R | H | -20.88 | 0.49 | -0.89 | 0.12 | 0.43 | 11 |
| VI | Large R | H | -21.41 | 0.45 | -0.80 | 0.14 | 1.08 | 11 |
| VII | N>7 + Lseg | U | -20.93 | 0.17 | -0.92 | 0.08 | 0.62 | 17 |
| VIII | N>7 + Lseg | H | -20.88 | 0.26 | -0.83 | 0.14 | 1.65 | 17 |
| IX | 3LGs removed | U | -20.75 | 0.18 | -0.79 | 0.11 | 0.80 | 19 |
| X | 3LGs removed | H | -20.74 | 0.12 | -0.80 | 0.08 | 0.35 | 19 |

Notes. U: background corrected by a uniform distribution law; H: background corrected using the histogram of counts in the vicinity of the field; R: projected separation; N: number of galaxies in the group; Lseg: luminosity segregation (see Section 3 for more details); LGs: loose groups.

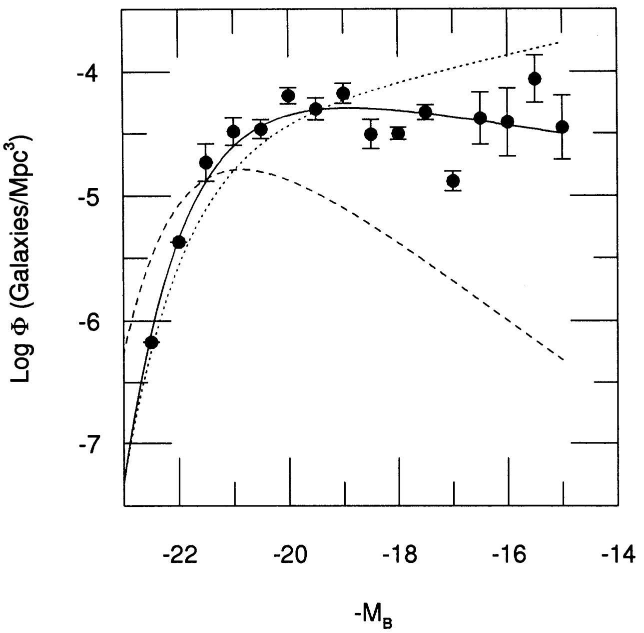


**Figure 1.** Comparison of the luminosity function of compact groups obtained in the present work (solid line) with that obtained by Mendes de Oliveira & Hickson (1991) (dashed line). We also plot the typical luminosity function for field galaxies (dotted line) (see Binggeli et al. 1988). 1$\sigma$ error bars are also shown.

roughly flat out to our completeness limit. Similar results are obtained if method (ii) is used to remove the background contribution.

## 4 DISCUSSION

We have determined the luminosity function of galaxies in compact groups by comparing counts of galaxies within 22 compact groups to counts in areas around each of these groups. We find a clear excess of galaxies within the groups, extending to a completeness limit of approximately $M_B = -14.5 + 5 \log h$. The counts are consistent with a luminosity function for galaxies in compact groups that is the same as that found for field galaxies. Although we do not yet have redshifts for the faint galaxies, the clear excess in the groups compared to the local background is difficult to explain except by the presence of intrinsically faint galaxies physically associated with the groups.

Our study directly probes faint magnitudes within the groups, and finds no support for the earlier suggestion of MOH that compact groups are very deficient in intrinsically faint galaxies. The MOH study was based only on the original Hickson list of galaxies, which was specifically limited to galaxies within 3 mag of the brightest one, resulting in a typical limit of $M_B = -19.0$. Although MOH attempted to model this effect, it is unsurprising that their sample did not give an accurate view of the population of intrinsically faint galaxies within compact groups. A second, less critical, effect is the greater central concentration within the groups of the brighter galaxies, relative to the fainter ones. This may be either the result of dynamical friction or a selection effect. Regardless of the reason for the effect, it leads to a small difference between the luminosity function determined only in the central area favoured by the brighter galaxies and that determined for the somewhat larger region delineated by the faint galaxies.

The similarity of the slopes of the faint ends of the luminosity functions in compact groups and in loose groups poses a new challenge to dynamical models of the evolution of compact groups. This similarity adds to the list of signatures of galaxy interactions and mergers, which appear to be only moderately enhanced in compact groups compared to other environments. The properties of galaxies that appear to be most dramatically affected by the compact group environment are those that are sensitive to dynamical perturbations, such as rotation curves and the isophotal shapes of galaxies. The challenge is to develop a model by which the wide variety of observations of galaxies in compact groups can be understood.

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