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Luminosity Functions of Nearby Groups of Galaxies

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Abstract

Galaxy luminosity functions, morphological analyses and light profiles of galaxies have been obtained for seventeen nearby groups of galaxies. The groups were categorised according to their velocity dispersion (σ) with clear differences evident:

1. The luminosity function of galaxies is bimodal for low-σ groups.
2. Light from low-σ groups is more centrally concentrated than high-σ groups.
3. Both categories contain large numbers of E/S0 galaxies in comparison with the field.

We suggest that the low-σ groups are more dynamically evolved than their high-σ counterparts, with rapid dynamical evolution occurring in these favourable sites.

1.1 Introduction

Most galaxies in the Universe are found in groups. They represent an important link between the field and clusters, yet the dominant physical processes operating in them are still poorly understood.

Luminosity Functions (LF) of galaxies are useful in comparing the populations of galaxies residing in different environments. The fitting of functional forms such as the Schechter function enables us to draw comparisons between the group or cluster environment and that of other regions of the Universe. The Schechter function drops sharply at bright magnitudes and rises at the faint end following a power law; however, features such as dips in the bright end or an excess of faint galaxies are sometimes found, making a single Schechter function a poor fit to the data (Binggeli *et al.* 1988).

The form of the luminosity function of galaxies in a group depends critically on its merger history. Major mergers between galaxies are more likely to occur in low-σ groups as the dynamical friction force is inversely proportional to the square of the relative velocity (V) of the interacting galaxies $F_{\rm dyn} \propto M^2\rho/V^2$ (Chandrasekhar 1943), where ρ is the density of galaxies and M is the mass of the interacting galaxies. Consideration of the collision time between galaxies indicates that large cross-sectional areas are conducive to merging activity ($\propto \mathrm{R}^{-2}$).

Determination of group LF, analysis of morphological differences between groups, and studying the light profiles of groups may help us to gain insight into some of the physics at work in the group environment.

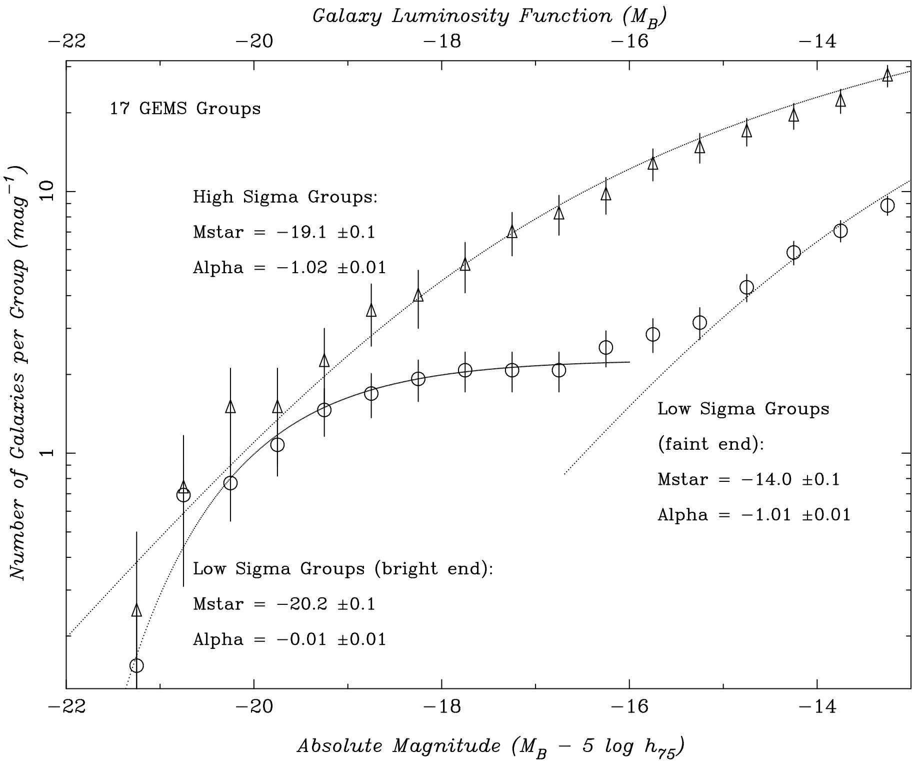

Fig. 1.1. The Cumulative Luminosity Function for 17 GEMS Groups, divided into two samples: high velocity dispersion (σ >350 km s^{-1}) and low velocity dispersion (σ <350 km s^{-1}) groups. There are clear differences between the two samples with a depletion or 'dip' in the number of galaxies having magnitudes between $M_B = -19$ and $M_B = -17$ present in the low velocity dispersion sample only.

1.1.1 Group Evolution Multi-wavelength Study (GEMS)

Here we present results of the photometric analysis of a subset of 17 groups of galaxies from the 60 forming the GEMS (group evolution multi-wavelength study) sample (Osmond *et al.* 2003), selected to incorporate a wide variety of groups representing a wide spectrum of evolutionary stages. We compiled a list of 4320 groups from 14 optical catalogues and compared it to the ROSAT PSPC observation log selecting on the basis that the group position was within 20′ of the pointing co-ordinates and the groups all have a ROSAT exposure time in excess of 10000 seconds. Further details of the group selection and calculation of virial radius may be found in Osmond *et al.* 2003.

1.1.2 Observations

Seventeen GEMS groups were observed at the 2.5m Isaac Newton telescope (INT) at the Roque de Los Muchachos Observatory, La Palma. The detector used was the Wide Field Camera (WFC), which is an array of four thinned EEV CCDs situated at the f/3.29 prime focus. Each CCD thus can image an area of 22.5 × 11.3 arcmin of sky, together covering 1017 square arcmin.

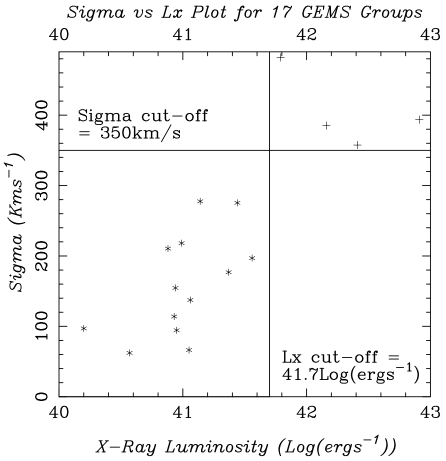

Fig. 1.2. The relation between velocity dispersion and X-Ray Luminosity for seventeen GEMS Groups. The sample is divided into two subsets: Low Sigma Groups σ <350 km s^{-1} and High Sigma Groups σ >350 km s^{-1}.

Reliable photometry with broadband B, R and I filters was obtained for galaxies down to M_B = 21, M_R = 20 and M_I = 19 for all groups. Further details may be found in Miles *et al.* 2003.

1.2 Results

In order to examine the dependence of the LF on the probability of merger, the group sample was split into two subsets: low velocity dispersion groups (σ <350 km s^{-1}) and high velocity dispersion groups (σ >350 km s^{-1}) (see Fig. 1.2).

The initial results show a difference between the LF of groups possessing low velocity dispersion (σ) and those with high-σ (see Fig. 1.1). Low-σ groups showed a dip at an absolute B-band magnitude of $M_B = -17$, high-σ groups did not display this feature.

The LF was then broken down into its component morphological types (Fig. 1.3). An excess of elliptical and S0 galaxies was found in our sample when compared to the field. However, the number of elliptical and S0 galaxies appears to be peaked toward the bright end of the spectrum M_B = –20.75 for the low-σ groups.

The total luminosity of galaxies in low-σ groups was added together and binned as a function of radius; the mean was taken to illustrate the average group in the sample (Fig. 1.4). The light distribution in low velocity dispersion groups was found to be more centrally peaked than high sigma groups and different from large clusters of galaxies where the light profile is expected to fall-off exponentially.

1.3 Conclusions

If we accept the hypothesis that, in non-cluster environments, large elliptical galaxies are formed through a major merger event, then we find evidence of more rapid evolution taking place within the low velocity dispersion environment.

There is evidence that the complete merging of groups to form massive elliptical galaxies has occurred and is observed in the form of fossil groups (isolated massive ellipticals with X-

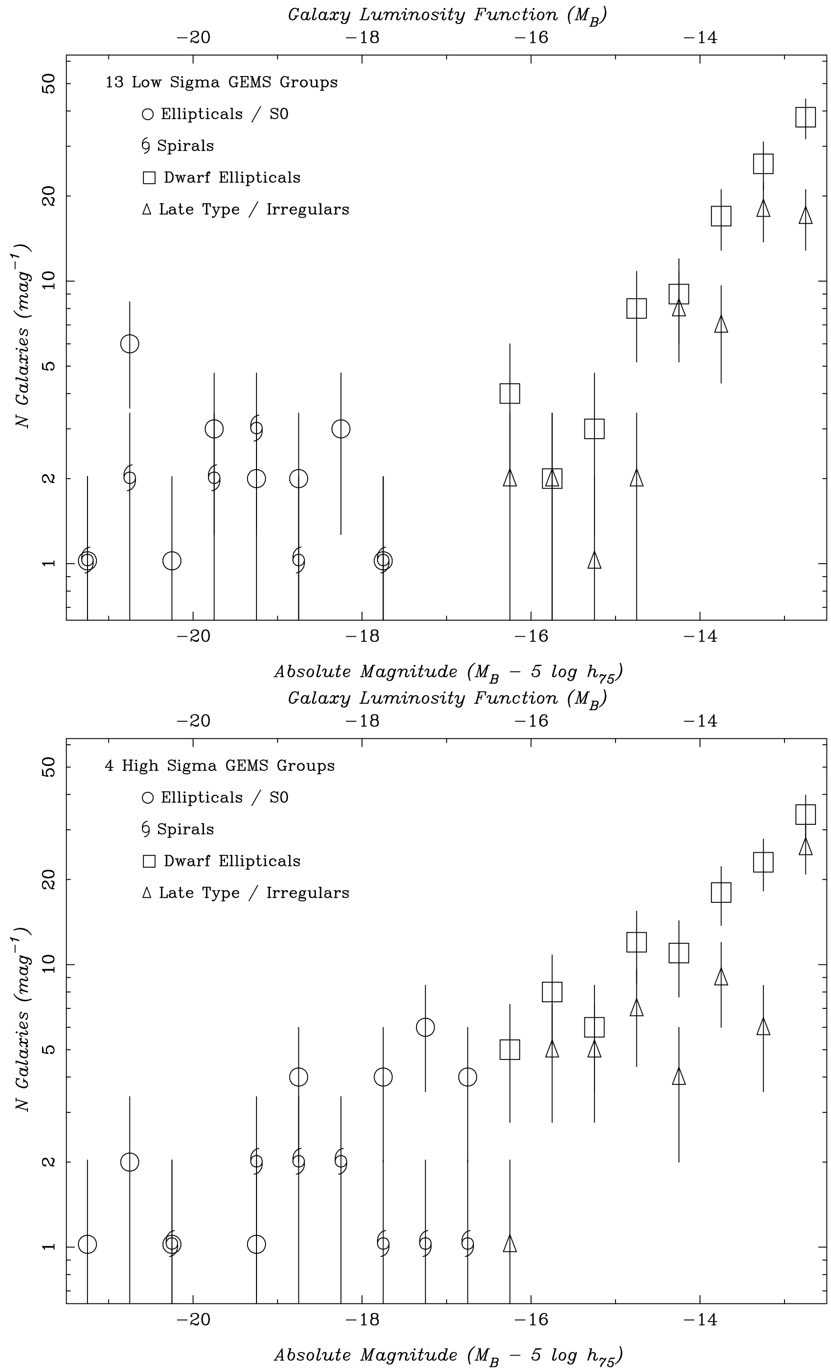

Fig. 1.3. The luminosity functions of groups separated into morphological types. The number of elliptical and S0 galaxies appears to be peaked towards the bright end of the spectrum $M_B = -20.75$ for the low-σ groups whereas the high-σ groups show no such peak.

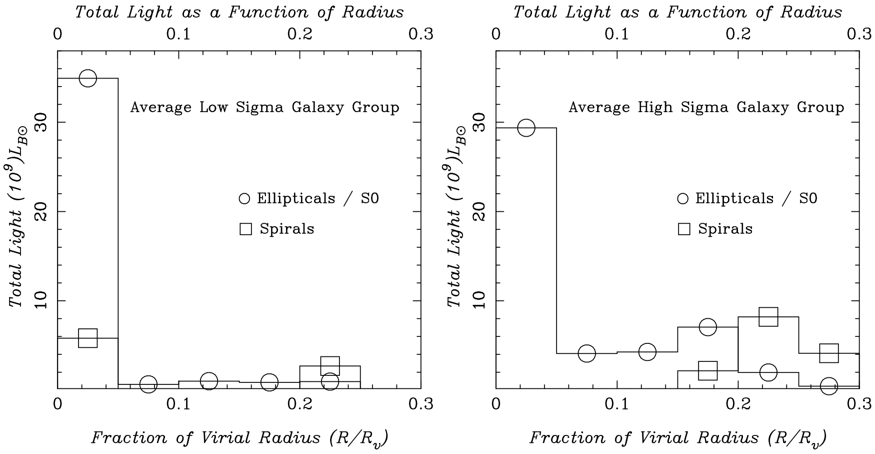

Fig. 1.4. The total luminosity of galaxies in low-σ and high-σ groups added together as a function of radius and the mean taken. The light distribution in low-σ groups was found to be more centrally peaked than high-σ groups and different from large clusters where the light distribution is expected to be a Hubble profile.

ray properties similar to groups of galaxies). These objects have been observed by Ponman *et al.* (1994) and Vikhlinin *et al.* (1999) who point out that the space density of luminous field ellipticals ($M_R <$ -22.5) is similar to identified fossil groups.

The present analysis would suggest that fossil groups are likely to form in the low-σ group environment. High-σ groups appear to be scaled-down versions of large clusters of galaxies with less evidence of advanced evolution and a more spread out light distribution.

Consideration of the total luminosity of galaxies in our groups provides support for this model. Rapid evolution resulting from mergers is likely to make the light more centrally concentrated. This is because stars are not destroyed during a merger but go to enhance the luminosity of the target galaxy. Fig. 1.4 shows the total light of an average low-σ group to be centrally peaked and different from large clusters, where light distribution follows an exponential fall-off (as a King or Hubble profile).

These results suggest that the low-σ groups are more dynamically evolved than their high-σ counterparts, with rapid evolution occurring in these favourable sites.

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