Local redshift surveys and galaxy evolution

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Abstract. We present observations of galaxy environmental dependencies using data from the 2dF Galaxy Redshift Survey. From a combined analysis of the luminosity function, Butcher-Oemler effect and trends in Hα line strengths we find support for a model where galaxy properties are mainly set by initial conditions at the time of their formation.

1 Introduction

Local redshift surveys, undertaken to map the three-dimensional distribution of galaxies and therefore address topics in cosmology, are also useful to derive a sample of local galaxies and analyze their properties, such as luminosity functions and star formation rates. Although the current generation of surveys is too local to be useful for galaxy evolution studies (but see descriptions of the DEEP2 and VIMOS surveys in the present volume), the 2dF and SDSS are adequate to obtain an in-depth description of the local world of galaxies.

2 The galaxy luminosity function

This is sometimes regarded as a 0^{th} order statistics, the simplest characterization of galaxy populations. It is essential to reproduce its shape as a first step towards a consistent model of galaxy formation. A review of this topic is presented in Driver & De Propris (2003). Here we compare luminosity functions for the field, clusters and as a function of local density from the 2dF galaxy redshift survey: since these luminosity functions are derived from the same catalogue of redshifts and photometry, they should share most of the selection biases and therefore should be fairly comparable to gain a picture of environmental effects on galaxy luminosities.

Figure 1 shows a schematic view of the behaviour of the two relevant parameters of the luminosity function as a function of density, δ_8, which is the density, for each galaxy, measured within an 8 Mpc sphere. We see that:

- M^* becomes brighter in higher density regions
- α becomes steeper in these regions

- This is essentially due to evolution in the M^* and α of early-type galaxies (i.e. spectroscopically quiescent objects)
- There is little or no evolution among late-type galaxies

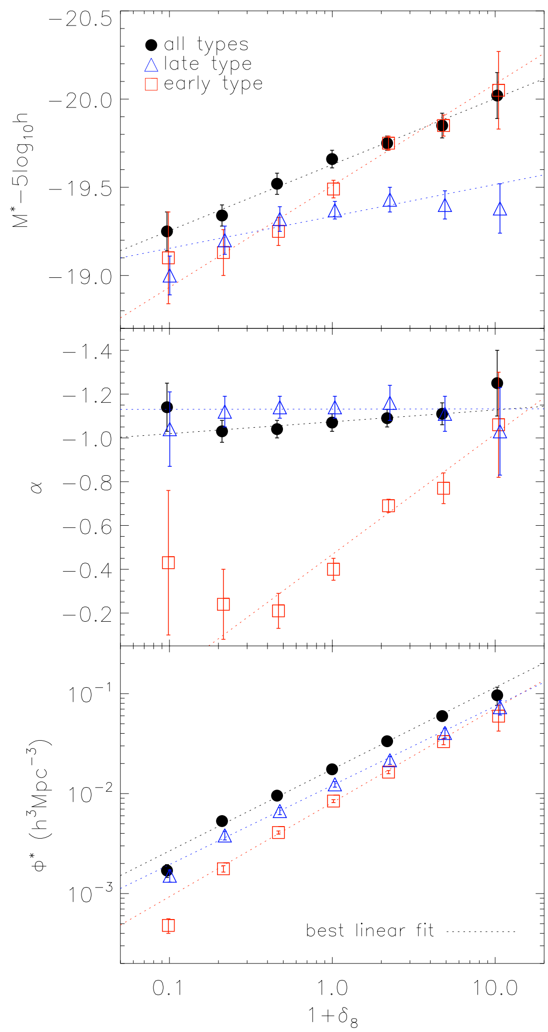

Fig. 1. The best Schechter fit parameters to the luminosity functions in the density regimes considered by Croton et al. (2003) for early-type galaxies (squares) and late-type galaxies (triangles),

This is reminiscent of the simple model for galaxy evolution presented in De Propris et al. (2003), where galaxies were simply assumed to move from star-forming to quiescent with little luminosity or density evolution. Although this is a very simplistic scenario, it appears to reproduce the observations to a good degree. If this is correct, (i) mergers are not necessary to form galaxies; suppression of star formation suffices and (ii) even the blue luminosity of most massive galaxies is dominated by the underlying old population.

3 The Butcher-Oemler effect

A traditional measure of star formation and its variation in clusters is the blue fraction as defined by Butcher & Oemler (1984). Our sample of clusters lies at $z < 0.11$ and is therefore unsuitable to study how the blue fraction evolves, but it allows us to explore how the blue fraction depends on cluster properties and therefore identify the mechanisms responsible, as well as control the selection effects present in cluster samples at higher redshift.

Figure 2 shows that the blue fraction does not strongly depend on cluster properties such as richness, velocity dispersion and Bautz-Morgan type. With proper accounting for errors, the blue fraction may not be significantly different from cluster to cluster. The only dependencies are with luminosity (the blue fraction is higher for lower luminosity limits), which argues that the blue galaxies are intrinsically faint, and with radius.

The above implies that the original claims for a trend in blue fraction with redshift may have resulted from a selection effect and an underestimate of the actual errors and that the cause for the suppression of star formation responsible for the trend in the luminosity function (and the Hα relations shown below) may not be associated with the effects of the cluster environment (e.g. ram stripping, tides, harassment).

We have explored the Butcher-Oemler effect as a function of the more general mean density and show that there is a clear relation between lower density and higher blue fraction, of which the clusters represent an extreme. Clusters are simply a continuation of field trends (Figure 3).

However, as shown in Figure 4, this is not due to star formation being suppressed, but simply to a changing fraction of red and blue galaxies, consistent with our simple model for instantaneous suppression of star formation with conservation of numbers and luminosity.

4 Galaxy ecology: The Hα-environment relation

Balogh et al. (2003) have carried this analysis a step further in their study of trends in Hα emission with local density from a combined 2dF and SDSS sample. Consistent with the previous findings, they show that:

- The population of galaxies is bimodal: one population shows star formation and the other is quiescent
- The star formation rate is largely independent of density: the numbers of star forming and quiescent galaxies vary smoothly and continuously with density.

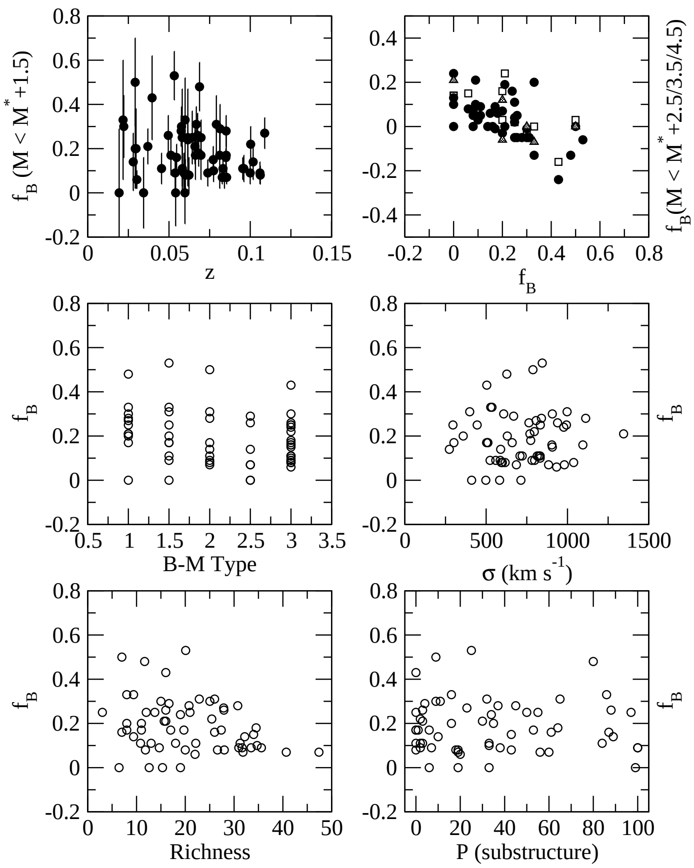

Fig. 2. Dependence of the blue fraction in clusters on redshift, luminosity and cluster properties. The top panel on the right shows the difference between the blue fraction measured to $M^* + 2.5$ (filled circles), +3.5 (open squares) and +4.5 (triangles) with respect to the blue fraction measured to $M^* + 1.5$ (which is the one used in all other panels. We omit error bars for clarity, but show them in the top left panel.

- The fraction of star forming galaxies is sensitive primarily to density over large scales

These results argue that the local environment does not influence galaxy star formation rates, and therefore that galaxy properties are set at high redshift via processes involving relatively short timescales. This obviously accounts for the lack of any correlation between the blue fraction and cluster properties.

5 A 'predestination' model of galaxy evolution

We present here a speculative scenario for galaxy formation and evolution, which attempts to account for the observations described above.

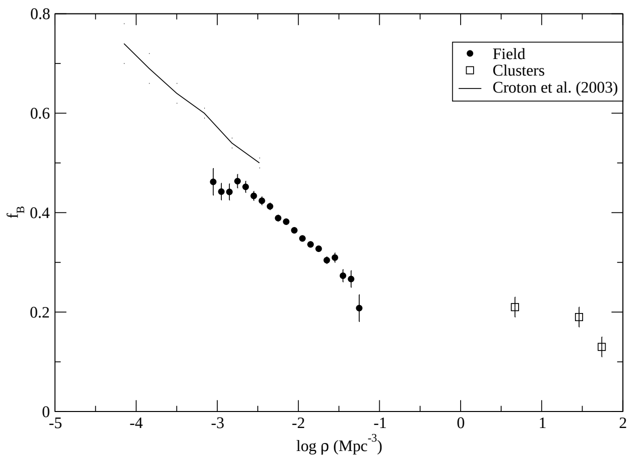

Fig. 3. Variation of the blue fraction with local density.

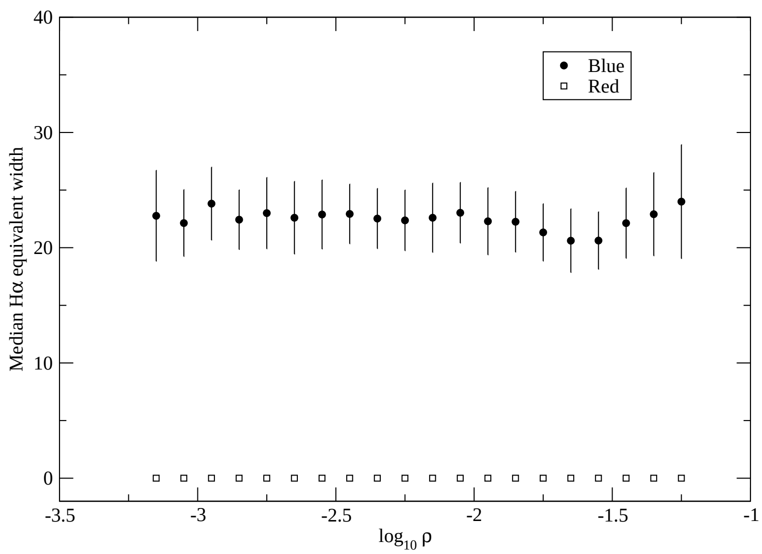

Fig. 4. Median Hα equivalent width for red and blue galaxies as a function of density.

In our model, the properties of galaxies are set by their initial conditions. Galaxies that form in the highest density regions evolve faster and burn all their gas quickly, therefore becoming ellipticals. Blue galaxies are a residual population of star-forming objects, which are therefore more prevalent in lower density regions. The fact that the U (Cortese et al. 2003) and B band luminosity functions for star-forming galaxies are identical in all environments (De Propris et al. 2003) is a necessary consequence of this mechanism.

Star formation may be triggered at high redshift in small groups, which evolve into the dense regions of today. The likely trigger is close interactions, which have been shown to induce star formation (Barton et al. 2003), or mergers between gas-rich galaxies. It is unlikely that these mergers have been important in forming galaxies to $z < 2$, as also shown by the results of the K20 survey described elsewhere in these proceedings.

The above scenario is remarkably similar to the original scenario of galaxy formation in Gaussian random peaks presented by Bardeen et al. (1986), where the main galaxy properties are set by the initial conditions at the time of their formation. The slow evolution detected in nearly all high redshift surveys (with the possible exception of the Combo-17 results presented elsewhere in this volume) is a strong pointer to this scenario.

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