Environmental Effects on the Global Properties of Galaxies in the Cluster Abell 209

C. Haines, A. Mercurio, P. Merluzzi, F. La Barbera, G. Busarello, M. Capaccioli
INAF-Osservatorio Astronomico di Capodimonte

The effect of local environment on the formation and evolution of galaxies is one of the most pressing issues in cosmology today, with evidence that environmental processes affect the mass distribution of galaxies as well as their star-formation and morphological characteristics. Rich clusters provide a unique opportunity to study these environmental effects, providing large numbers of galaxies at the same redshifts which have been exposed to a wide variety of environments.

We have carried out a photometric study of the cluster Abell 209 at $z=0.21$ by using archive CFHT images covering a 42'x28' field centred on the cluster in both *B* and *R* bands. A209 is particularly rich (Abell class 3; $\sigma_v = 1394^{+88}_{-99}$ km s^{-1}), and shows significant substructure in optical (Fig. 1) and X-ray wavebands, as well as in the galaxy velocity distribution, indicating it has undergone a recent merger (Mercurio *et al.* 2003, A&A, 397, 431).

To measure the effect of cluster environment we have estimated the local surface density (Σ) of background-corrected $R<23$ galaxies across the CFHT field using the adaptive kernel method, and then split the galaxy catalogue into three subsets on the basis of their value of Σ, as shown in Fig. 1.

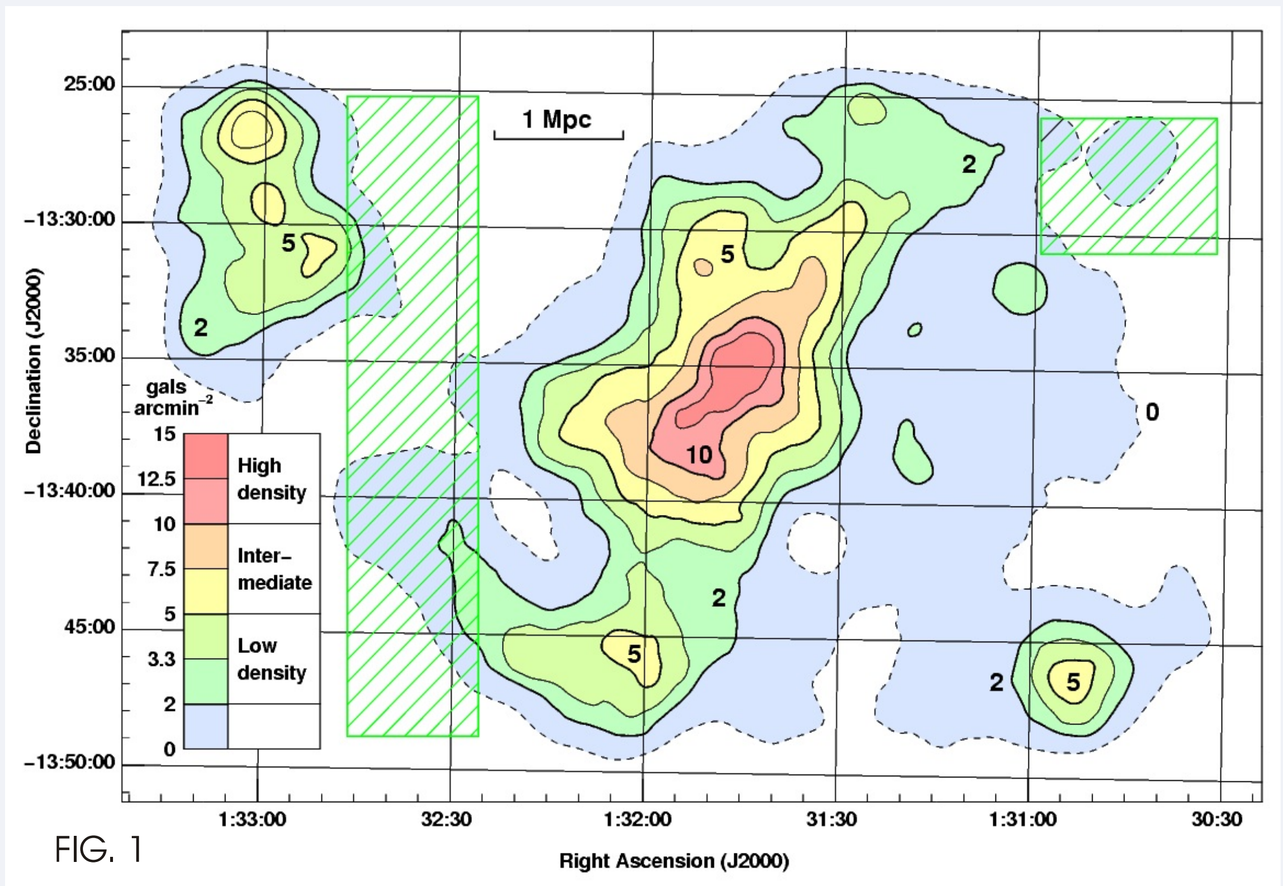

FIG. 1

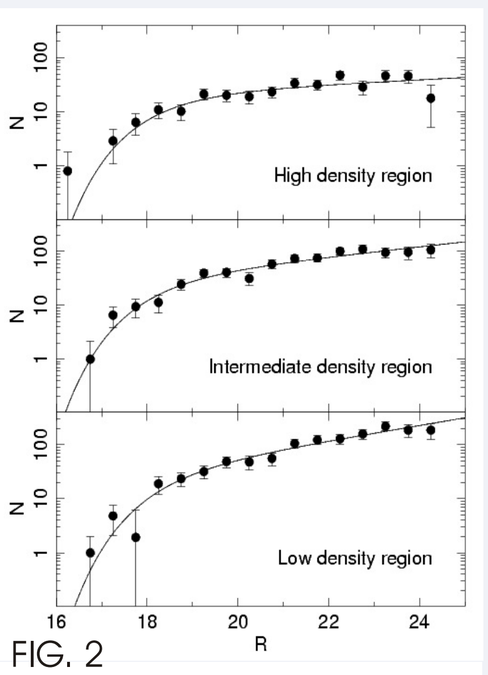

FIG. 2

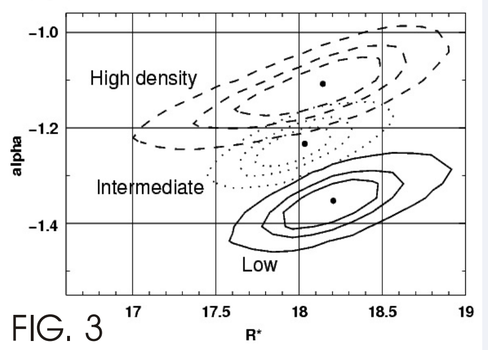

FIG. 3

Background galaxies are subtracted statistically, using two regions towards the edge of the CFHT images (see shaded regions in Fig. 1), whose number counts are similar to those from the ESO-Sculptor survey (Arnouts *et al.* 1997, A&AS, 124, 163). For each galaxy, the probability that it is a field galaxy is estimated from its *R* magnitude and *B-R* colour, and these probabilities used to produce numerous Monte-Carlo realisations of the cluster population using the prescription of Kodama & Bower (2001, MNRAS, 321, 18).

Fig. 2 shows the *R*-band galaxy luminosity functions for each of the three cluster environments, along with their best-fitting Schechter functions, whose faint-end slope (α) and characteristic-magnitude R^* are shown in Fig. 3 along with their confidence limits. **The faint-end slope becomes systematically shallower with increasing density, a result which is repeated if only galaxies belonging to the C-M relation are considered. We interpret these results as being due to the disruption and / or cannibalisation of dwarf galaxies by the cD galaxy and ICM in the cluster core.**

We have measured the effect of environment on the colour and slope of the colour-magnitude relation, and find no evidence for a change of slope with density. However, **we find that the relation is 0.0217 ± 0.0136 mag redder in *B-R* for the high-density region than the intermediate-density region. Considering an early-type galaxy that is 10 Gyr old, to reproduce this effect requires an increase in age of ~ 0.5 Gyr or $\sim$20% in metallicity.** Such an effect has been observed before for clusters in the SDSS (Hogg *et al.* 2004, ApJL, 601, 29), and is consistent with galaxies forming first or having their star-formation truncated earliest in the highest overdensities.

We have examined how the cluster environment, and in particular the dynamical state of A209, affects star-formation, by measuring the mean *B-R* colour (after correcting for the effect of the C-M slope to remove the effect of the changing galaxy mass-distribution with Σ) of $R<21$ cluster galaxies as a function of spatial position, as shown in Fig. 4 by the coloured contours. **A clear overall trend with density (shown by black contours) is apparent, with galaxies in the high-density regions appearing $\approx$0.1 mag. redder than those in the low-density regions. This is due to the truncation of star-formation as galaxies fall into the cluster, a process which is also manifested by the decreasing blue galaxy fraction from low- to high-density regions.** Substructure in the mean *B-R* colours is also apparent, and appears related to the dynamical state of the system, with two regions of red galaxies on either side of the cluster core aligned with the direction of elongation of the cluster, whereas perpendicular to the axis of elongation appear regions close to the cluster centre containing bluer than average galaxies.

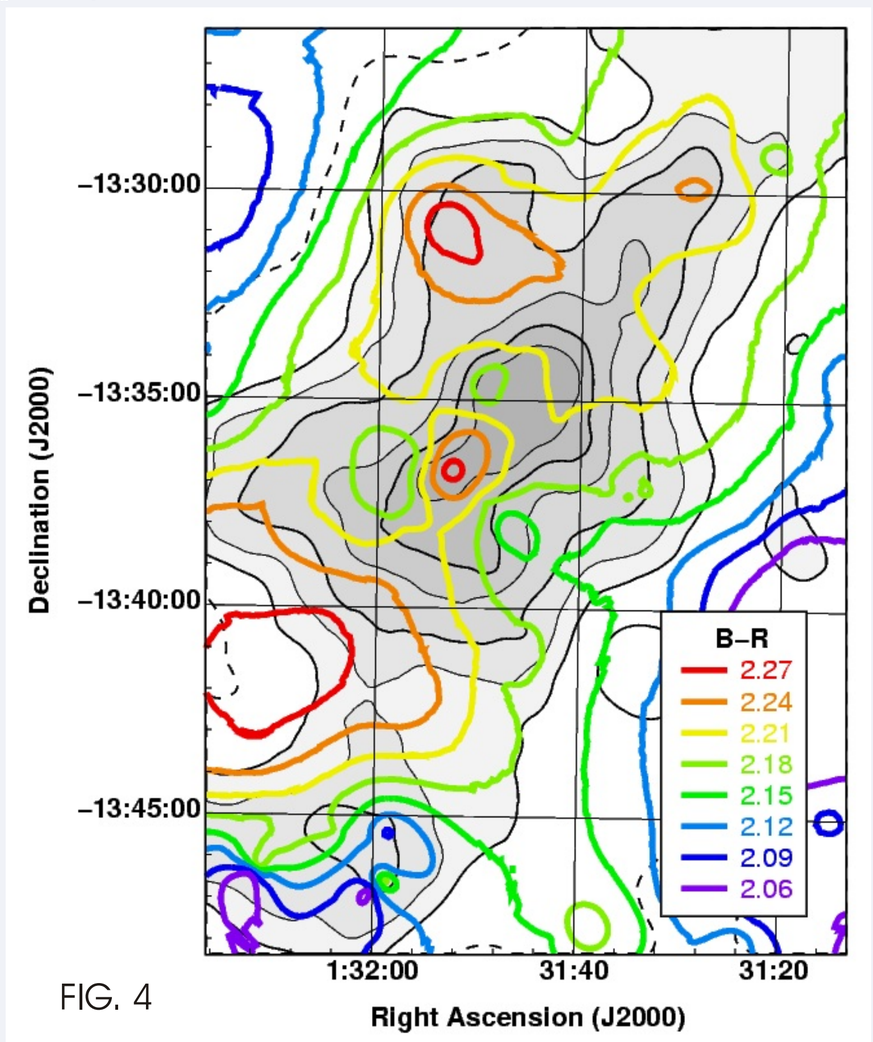

FIG. 4

Conclusions: The faint-end slope of the galaxy luminosity function becomes significantly shallower from low- to high-density environments in A209 due to the dwarf galaxy population disrupted and / or cannibalised by the cD galaxy and the ICM in the cluster core. The reddening of the C-M relation with density, is consistent with cosmological models of structure formation, in which galaxies form earliest in the highest-density regions corresponding to cluster cores, and have the bulk of their star-formation complete by $z\sim1$ at which point the ICM suppresses further formation of stars and galaxies.