Evolution of Galaxy morphologies in Clusters*

Giovanni Fasano(1), Bianca Poggianti(1), Warrick Couch(2), Daniela Bettoni(1), Per Kjærgaard(3), Mariano Moles(4)
(1) Osservatorio Astronomico di Padova (IT)
(2) University of New South Wales (AU)
(3) Copenhagen University Observatory (DK)
(4) Instituto de Matematicas y Fisica Fundamental (ES)

August 15, 2000

Abstract.
We have studied the evolution of galaxian morphologies from ground-based, good-seeing images of 9 clusters at z=0.09-0.25. The comparison of our data with those relative to higher redshift clusters (Dressler et al. 1997, D97) allowed us to trace for the first time the evolution of the morphological mix at a look-back time of 2-4 Gyr, finding a dependence of the observed evolutionary trends on the cluster properties.

Keywords: Galaxies, Clusters of galaxies

1. Background

Over the past five years, thanks to the high spatial resolution imaging achieved with the HST, it has been established that the morphological properties of galaxies in rich clusters at intermediate redshift differ dramatically from those in nearby clusters. The most obvious difference is the overabundance of spirals in the cluster cores at $z = 0.3 - 0.5$. The second evidence for morphological evolution in clusters was uncovered only from post-refurbishment data, mainly thanks to the so called MORPHS collaboration (D97): coupled to the increase in the spiral fraction, the S0 galaxies at intermediate redshifts are found to be proportionately less abundant than in nearby clusters, while the fraction of ellipticals is already as large or larger.

Another proof of the changes occurring in clusters is the observed evolution of the morphology-density (MD) relation – the correlation between galaxy morphology and local projected density of galaxies – that Dressler (1980, D80) found in all types of clusters at low redshift, whereby the elliptical fraction increases and the spiral fraction decreases with increasing local density. A MD relation qualitatively similar to that found by D80 was discovered by the MORPHS to be present in regular clusters and absent in irregular ones at $z \sim 0.5$.

* Based on observations taken at the NOT and 1.5-Danish telescopes.
Overall, the available data seem to require a strong morphological evolution in clusters between $z = 0.4$ and $z = 0$. Still, it is worth keeping in mind that these conclusions are based on a small sample of distant clusters and on the comparison of a limited redshift range around $z \sim 0.4$ with the present-day cluster populations. The goal of the present work is to fill in the observational gap between the distant clusters observed with HST and the nearby clusters, and hence trace, for the first time, the evolution of the morphological mix at a look-back time of $2-4$ Gyr.

2. Observations and morphological classification

The data we used are part of a different project, for which 25 clusters spanning the redshift range $0.03 - 0.25$ have been observed. The observations were collected at the NOT and 1.5 Danish telescopes. To be consistent with previous morphological studies, among the 25 clusters observed, we have selected 9 clusters for which an acceptable coverage of the central 1 Mpc$^2$ has been imaged. As in D97, the analysis of the morphological types has been done for galaxies down to a visual absolute magnitude $M_V \sim -20.0$. In order to improve the morphological type estimates, besides the visual inspection of the images, we have used the luminosity and geometrical profiles obtained with the automatic surface photometry tool GASPHOT (Pignatelli and Fasano, 1999).

We have devised four different 'blind' tests to check the reliability of our morphological classifications both in an absolute sense and relative to the MORPHS scheme. In particular, the absolute accuracy of our classifications has been checked in two ways: (i) by means of 'toy' galaxies with bulge/disk luminosity and size ratios typical of E, S0 and Sp galaxies; (i) by producing redshifted versions of several galaxies of different morphological types belonging to the nearby galaxy imaging collection of Frei et al. (1996). In both tests the proper values of the observing parameters have been used to mimic our images and the resulting galaxies have been classified following the procedure used for our cluster galaxies.

3. Results

The clusters appear to be grouped in two different families, according to their S0/E ratios: a low S0/E family with ratio $\sim 0.8$, and a high S0/E family with ratio $\geq 1.6$. We have found that the only structural
Figure 1. Kolmogorov–Smirnov test applied to the overlapped radial distributions of galaxies of different types for low-S0/E and high-S0/E clusters.

difference between the low- and the high-S0/E clusters is the presence/absence of a high concentration of elliptical galaxies in the cluster centre (HEC/LEC clusters, respectively). A quantitative illustration of the difference in the galaxy spatial distribution between the low- and the high-S0/E clusters is given by the KS test shown in Fig. 1.

We have investigated the evolution of the galactic morphologies by comparing our results with other studies at lower and higher redshift. At higher redshifts, we have considered the MORPHS sample plus five additional clusters in the range $z = 0.2 - 0.3$, which we call the C98+ sample. The morphological fractions of all the clusters as a function of redshift are presented in Fig. 2. At low redshift, we refer to D80 as local benchmark for the HEC and LEC clusters (solid and open large squares in Fig. 2, respectively). We have also considered the values quoted by Oemler (1974) for different cluster types: spiral/elliptical/S0 -rich (S/E/L in Fig. 2, respectively). In spite of the large error bars, it is clear from this figure that there are systematic trends with the redshift: moving towards lower redshift the spiral fraction declines and the S0 fraction rises. The morphological fractions in our clusters are intermediate between the high and the low redshift values and seem to trace a continuous change of the abundances. In contrast, the elliptical fraction shows no particular trend with redshift, but rather a large scatter from cluster to cluster at any epoch.
Figure 2. Morphological fractions as a function of redshift. HEC and LEC clusters are displayed as solid and open symbols, respectively. The values from our sample are indicated by circles, whereas those from the MORPHS and C98+ samples are indicated with squares and triangles, respectively.

We have also analyzed the MD relation of our clusters. We found that, as in the higher redshift clusters, a morphology-density relation is present in highly concentrated clusters and absent in the low concentration ones. This suggests that the morphology-density relation in low concentration clusters was established in the last 1-2 Gyr.

References

Dressler, A., Oemler, A. Jr., Couch, W. J., Smail, I., Ellis, R. S., Barger, A., Butcher, H., Poggianti, B. M., Sharples, R. M. 1997 ApJ, 490, 577.
Dressler, A. 1980 ApJ, 236, 351.
Frei, Z., Guhathakurta, P., Gunn, J. E., Tyson, J. A. 1996 AJ, 111, 174.
Oemler, A. Jr. 1974 ApJ, 194, 1.
Pignatelli, E., Fasano, G. 1999
First Italian Workshop of the Network "Formazione ed evoluzione delle galassie".
http://www.brera.mi.astro.it/docB/galaxy/news.html.