Structure and dynamics or rich galaxy clusters: an ESO key-programme

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STRUCTURE AND DYNAMICS OF RICH GALAXY CLUSTERS: AN ESO KEY-PROGRAMME

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ABSTRACT. We describe the progress of the ESO key-program survey of rich nearby clusters of galaxies. We give a short description of the general properties of these clusters. First preliminary results are presented.

1. Introduction

The ESO Key-program "Nearby Clusters of Galaxies" started in 1989 with the aim of obtaining redshifts and magnitudes for $\sim$ 100 galaxies in each of 20 cluster fields, and for $\sim$ 20 galaxies in each of 100 cluster fields.

Spectra of objects have been obtained using the OPTOPUS Multi Object Spectrograph at ESO. Redshifts and their errors are then measured via the Tonry & Davis (1979) technique using a template spectrum of M31, and other templates for checking the results. Average errors on the velocities are around 60 km s^{-1}; similar values are obtained via the comparison of double measurements of the same galaxies, and comparison with data from the literature.

During the preparations of the spectroscopical observations, the plates of the candidate cluster fields are scanned with the *Leiden Astroscan* automatic plate-measuring

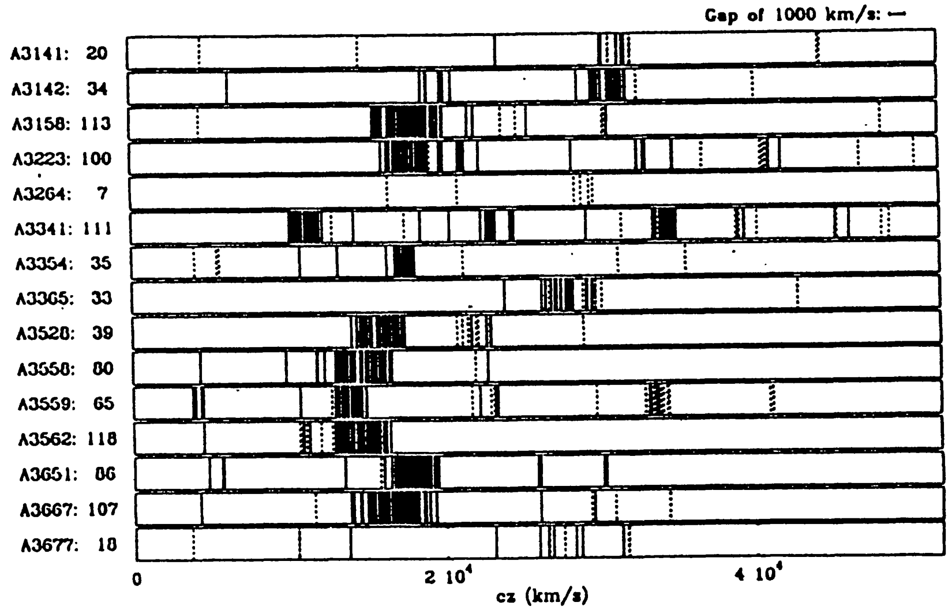

Fig. 1. Some line-of-sights in the redshift space. Each vertical bar represents a galaxy.

machine. These measurements yield positions and a photometric parameter for each object detected. The photometric parameter is converted to a magnitude after suitable calibration with CCD photometry, obtained with the Danish 1.54m telescope at La Silla.

More detailed descriptions of this program can be found in Mazure et al. (1989, 1991).

So far, 25 out of 32 observing runs have been reduced, yielding ~ 4000 galaxy spectra, in 80 fields. Of these, ~ 3000 are judged to be reliable, i.e. 75 %.

2. Finding the clusters

The line-of-sights we observed were chosen in the direction of rich (richness class $R \geq 1$) Abell clusters extracted from the catalog of Abell, Corwin, & Olowin (1989, ACO in the following). In figure 1 we show the galaxies found along some of these line-of-sights in the redshift space (each bar corresponds to a galaxy with measured redshift). In most fields, there is not a single system of galaxies, but two or three groups (or clusters) projected along the same line-of-sight. So, although we find clusters in the redshift space which correspond to ACO's clusters, their richness class assignements are wrong (compare, e.g., the field of A3562, an $R = 2$ cluster, with the field of A3559, an $R = 3$ cluster, which nonetheless appears less rich than the former in the redshift space).

In order to separate different groups (clusters) of galaxies in the same field, we have tried several techniques, mostly based on the gaps in the distribution of redshifts. All these techniques produced very similar results as the simple one here described: one system is splitted into two groups when these groups are separated by a gap of 900 km s^{-1} in the velocity space. This group definition is adopted in this preliminary analysis.

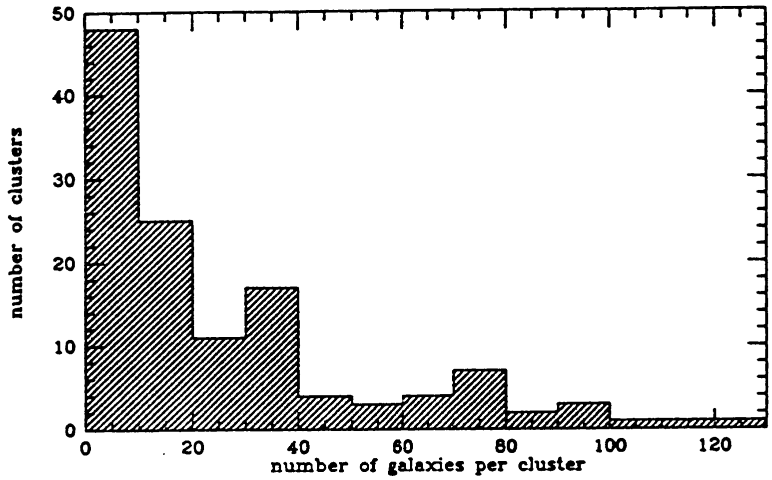

Fig. 2. Histogram of the number of member galaxies per cluster.

With this definition, we have found 127 groups (clusters) of galaxies in our data-set, each containing at least 3 galaxies. In figure 2, the histogram of the number of galaxy members in our groups is shown. There are 79 clusters with more than 10 galaxy members (at least 10 galaxies are needed for an estimate of the cluster velocity dispersion, when using robust estimators, see Girardi et al. 1993); there are 22 clusters with more than 50 members (at least 50 galaxies are needed for a study of the internal structure of clusters, see, e.g., Escalera et al. 1994).

3. General cluster properties

Most of our clusters are sampled out to more than 1/2 an Abell radius ($0.75\,h^{-1}\,Mpc$). All Bautz-Morgan types (Bautz & Morgan 1970) are equally represented and the richness class distribution follows that of ACO for $R \geq 1$ (only two $R = 0$ clusters are present in our sample).

In figure 3 we show the histogram of cluster velocity dispersions, σ_v, obtained using the biweight estimator (Beers, Flynn, & Gebhardt 1990). Only clusters with at least 10 members have been considered. The average value is 661 ± 21 km s^{-1}; this value is somewhat lower than the median value quoted by Zabludoff, Huchra, & Geller (1990), and considerably lower than the average value quoted by Girardi et al. (1993). In figure 4 we compare our σ_v distribution to the model predictions of Frenk et al. (1990), in the framework of the Cold Dark Matter theory, with different biasing parameters, b. Frenk et al. (1990) found inconsistency between their theoretical distributions and the observed distribution of σ_v. They claimed this inconsistency to come from a wrong membership assignement of galaxies to clusters in the real data. It is evident from figure 3 that this inconsistency is no longer present in our data, probably because our selection of cluster members and our estimation of σ_v are more efficient than ancient methods used so far in the literature. However, the CDM model which best fits our distribution has b $\simeq$ 2, and this model conflicts with results from COBE (Wright et al. 1992).

The average velocity dispersion does not increase significantly from $R = 1$ to $R = 2$ clusters, not surprisingly so, since the ACO richness class is not a good population

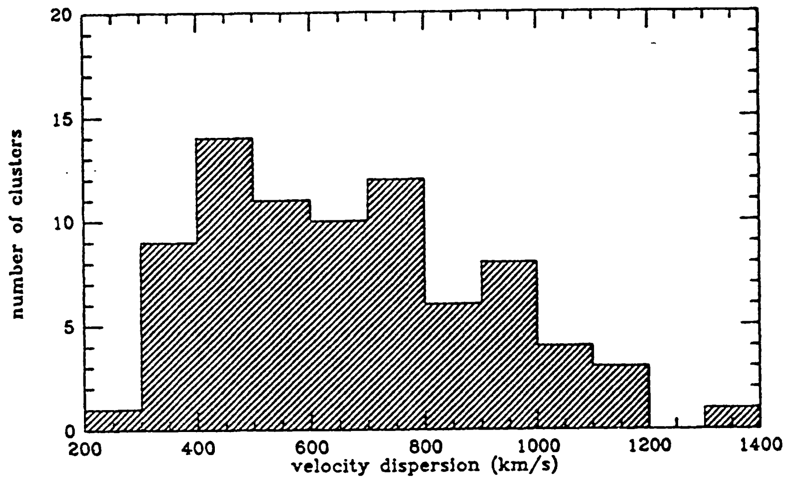

Fig. 3. Histogram of the velocity dispersions for clusters with at least 10 galaxy redshifts.

indicator (see previous section). On the other hand, clusters of Bautz-Morgan type I seem to have a larger value of σ_v with respect to the others (784 ± 106 vs. 644 ± 29 km s^{-1}), although the difference is only significant at the 92 % confidence level, according to a Kolmogorov-Smirnov test. As the Bautz-Morgan types are correlated with the difference in magnitude between the 1^{st} and 3^{rd} ranked galaxies in our clusters, we think that the Bautz-Morgan classification is correct. The reported difference in the velocity dispersions of the two classes of clusters may provide insight into the topic of cluster formation and evolution. In particular, the predominance in luminosity of one galaxy (characteristic of the Bautz-Morgan type I clusters) is thought to arise via merging processes, which are more efficient in low velocity encounters. It is then difficult to see how this scenario may have occurred in the high velocity dispersion Bautz-Morgan type I clusters, unless these merging processes took place before cluster virialization (as suggested by Merritt 1984).

Figures 5 shows the distributions of Kurtosis (panel a) and Skewness (panel b) of the velocity distributions in our clusters (with at least 20 members). Most of our clusters appear to have gaussian distributions of their galaxy velocities; the fraction of clusters with non-gaussian velocity distributions is only 10 % according to the W-test (Shapiro & Wilk 1965).

A preliminary analysis of the presence of substructures using the technique of Dressler & Shectman (1988) has been performed on our clusters (with at least 50 members). The percentage of clusters showing evidence of substructures according to this test is 35 %.

We have also identified the emission-line galaxies in our sample. The average fraction of emission-line galaxies in our clusters (with at least 10 members) is ~ 10 %, not surprisingly lower than in field galaxy samples (see, e.g., Vettolani et al. 1993). There are notable variations of the fraction of emission-line galaxies from cluster to cluster (in particular, we note that A 548, a highly structured cluster, has a fraction as high as 31 %).

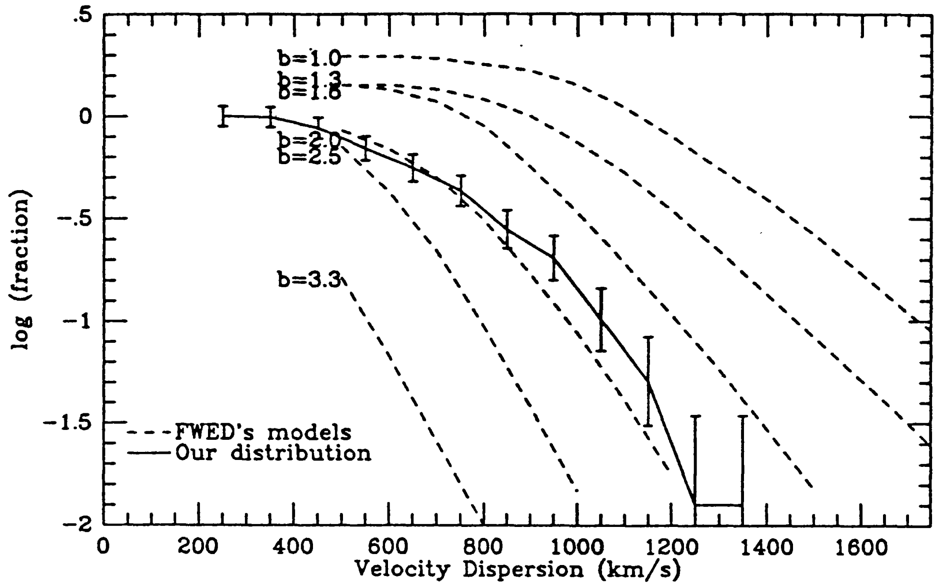

Fig. 4. Cumulative (logarithmic) distribution of velocity dispersions: our observational distribution (solid line) with 1σ error-bars is compared to the model distributions obtained by Frenk et al. (1990), labeled by the values of the biasing parameter, b.

4. Conclusions

The large amount of data on galaxy clusters obtained during this ESO key-program is going to provide new results both on cluster internal structure and dynamics, and on the Large Scale Structure of the Universe as probed by galaxy clusters. In this contribution we have given a progress report of the observational program and some preliminary general properties of our key-program clusters.

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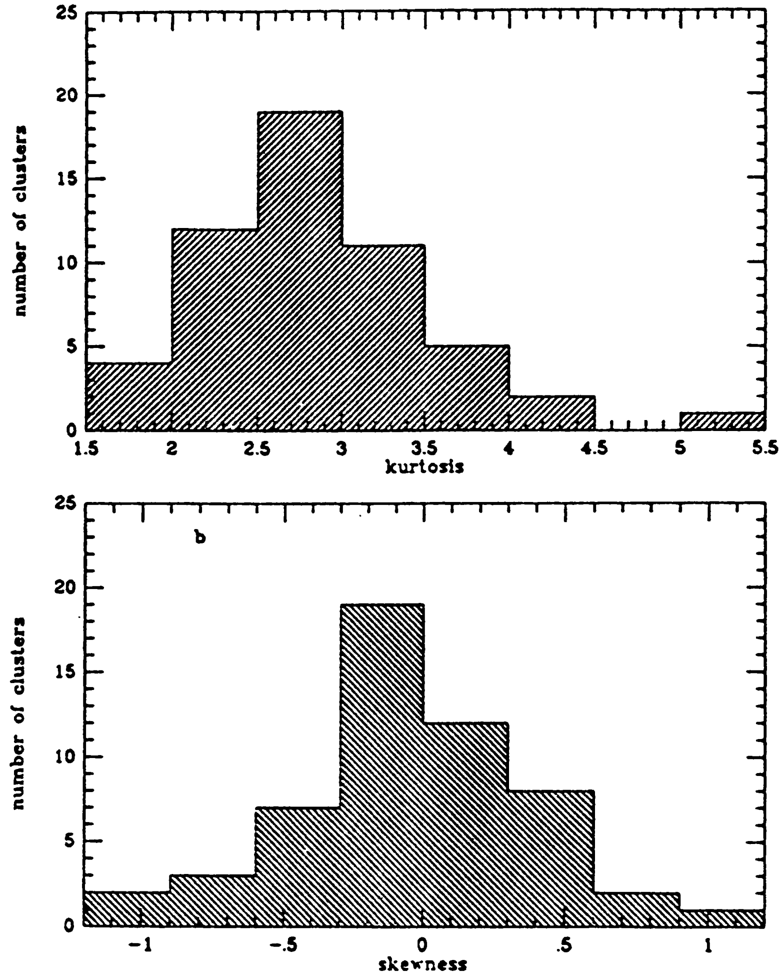

Fig. 5. Histograms of kurtosis (panel a) and skewness (panel b) of the galaxy velocities in our clusters with at least 20 galaxy redshifts.