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ON THE UNIVERSALITY OF DENSITY PROFILES IN CLUSTERS OF GALAXIES

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RESUMEN. Se ha analizado una muestra de cúmulos por medio de nuevos métodos de determinación de perfiles. A pesar del escaso número de objetos en cada cúmulo se pueden calcular perfiles individuales y la comparación entre ellos permite examinar sus características generales.

ABSTRACT. Using new methods for profile determination, a sample of clusters for which positions and velocities of its galaxies are known is analyzed. Even with the few numbers of objects per cluster individual profiles can be calculated and compared among them allowing general properties to be examined.

Key words: CLUSTERS-GALAXIES

I. NEW METHODS FOR PROFILE DETERMINATION

We have developed new analytical tools for determining the structure of groups and clusters of galaxies (Sanromà and Salvador-Solé 1989. Salvador-Solé and Sanromà 1989). They are based on the use of direotly observable quantities such as the histogram of intergalactic separations P(s) and the number of galaxies at radii greater than s, N(s). As a result two new methods for determining different profiles have been worked out:

1) To obtain the number density profile (and others such as luminosity density, kinetic energy density, velocity dispersion and the l.o.s. velocity distribution function) through a deconvolution process involving P(s) (see Sanromà and Salvador-Solé 1989 and Salvador-Solé and Sanromà 1989 for details).

2) To obtain the same profiles through an integral transform of N(s). It can be demonstrated (Sanromà and Salvador-Solé 1989) that the number density profile σ and N(s) are related through

$$\mathbf{F}\cdot\mathbf{A}(\sigma) = \mathbf{A}\cdot\mathbf{F}^{-1}(N)$$

where **A** and **F** stand respectively for an Abel and Fourier transformations. This method is shown to constitute a generalized binning, where the bin size no longer depends on the number of galaxies of the structure under study. Furthermore, combined use of both methods can be a useful tool for determining the presence and importance of substructure in clusters of galaxies (see Salvador-Solé and Sanromà 1980 for details)

The new methods eliminate many problems which plagued older methods (such as the classical binning, Avni and Bahcall 1976, and maximum likelihood, Sarazin 1980) and affords the advantage of being able to yield reliable results for structures with a small (say a few dozen) galaxies. Therefore they are particularly suited for determining profiles which are not thoroughly studied (such as number density) or even poorly known (such as velocity dispersion).

II. DENSITY PROFILES

Though number density profiles of clusters of galaxies have been studied extensively there is no agreement neither on the general shape of these profiles (see for instance Oemler 1974, Yahil 1974, Dressler 1978 Materne et al. 1982, Beers and Tonry 1986, hereafter BT) nor on the characteristic parameters for a given shape (see for instance Bahcall 1975 Dressler 1978). West et al. (1987) have reviewed the body of the literature on number density profiles and they have concluded that only 27 clusters can be considered to have reliable determined profiles. Both classical methods mentioned above (in fact binning most often) have been used to derive these profiles. They can hardly be expected to give reliable results for structures with less than about 200 galaxies and this fact ultimately explains our incomplete knowledge of number density profiles of clusters of galaxies.

Beers and Tonry (1986) and more recently Merrifield and Kent (1989 hereafter MK) have tried to overcome this limitation of classical methods by stacking the galaxy position from 48 (BT) and 29 Abell clusters (MK) so to obtain a mean profile up to 2 h^{-1} Mpc (BT) and 0.25 h^{-1} Mpc (MK). They obtain two different shapes (which again implies a disagreement for the inner part) but both argue for the universal validity of these profiles. However there is a drawback, inherent to this stacking technique, which casts some doubts on the validity of their results. Indeed, one must chose a normalization scale-length in order to be able to add all clusters together, and there is no a priori reason for such a parameter to be chosen unambiguously.

With our new methods we are able to calculate individual profiles for clusters with a number of galaxies of the order of those in the studies of BT and MK. Here we present preliminary results of the study of the sample of Dressler and Shectman (1988a; hereafter DS). These authors give positions types, magnitudes and velocities for galaxies in 14 clusters of Dressler's (1980) sample of rich clusters. We have focused on those clusters which show no sign of substructure, namely A754, A1631, A1983, DC0428-453, DC0559-40 DC0608-33, A1644, A1656 and DC0247-31.

In figure 1 we show normalized density profiles (continuous lines calculated with method 1 for all but the three last clusters. Only those galaxies constituting a complete sample (in this case up to V = 15) have been included in the analysis. Due to different redshifts of clusters in DS sample plates cover different scales and for sake of comparison with theoretical profiles we have chosen to plot only those clusters covered up to an intermediate scale range (and so we have excluded the two last clusters). We have also excluded A1644 for which the resolution (i.e. scale of radial symmetry, see original references) turned up to be much too large. All profiles are convolved down to the same resolution, as well as three theoretical profiles (dotted lines) corresponding, from top to bottom. to modified Hubble laws with core radius 0.25 Mpc and slopes 1, 2 and 3 respectively.

III. VELOCITY DISPERSION PROFILES

In their paper on cluster profiles, West et al. (1987) find only five clusters for which calculated velocity dispersion profiles can be relied upon, namely Coma, Perseus, Fornax, Hydra and Abell 194. It is clear that our knowledge on this profile is rather poor. No analytical shape has been proposed for this profile and there is even no agreement on whether its general characteristics differ from each other (see for instance Kent and Sargent 1983). The reason for this situation lies again on the practical impossibility of calculating this profile with classical methods for clusters with a small number of galaxies.

We have calculated velocity dispersion profiles for the same clusters as in section II. We have also excluded A1644. As before. only galaxies up to V= 15 have been considered. In figure 2 we show the 8 normalized profiles. In this figure no attempt of comparison has been made and each profile has been calculated up to its outer limits on the plate. The number of galaxies involved in the calculation of each profile ranges between 25 and 50 (except in the case of A1656 which is 86).

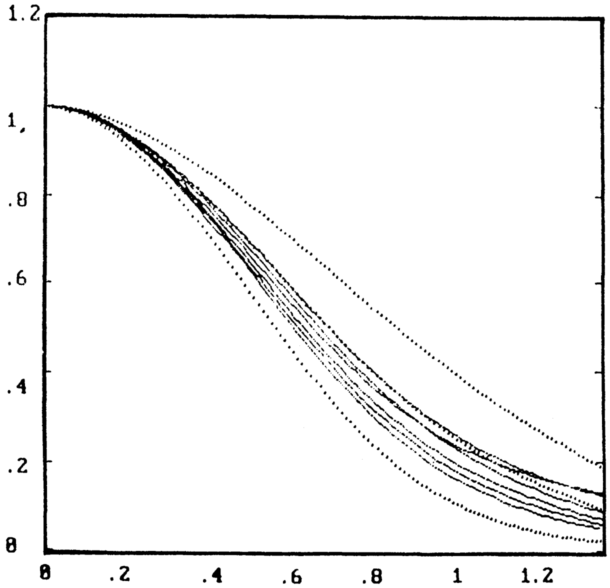

Fig. 1. Density profiles (abscissae are Mpc).

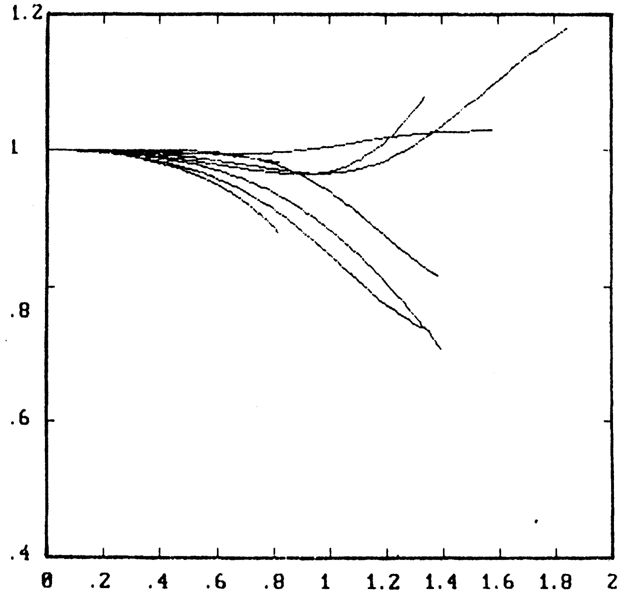

Fig. 2. Velocity dispersion profiles (abscissae are Mpc).

With this significant amount of new information at hand (as compared to the above mentioned 5 known profiles) some comments are of order. First it is apparent that three profiles (A754, A1631 and DC0608-33) seem to be rising in the outer regions. While this behaviour was already suggested by a rough binning performed by Dressler and Shectman (1988b) we have verified that. at least in the case of DC0608-33. This is due to an only galaxy. Since our method is both powerful for analysing small data sets and sensible to singular values, as in the case mentioned, it will be worth analysing in detail this behaviour. Second, we have tried to compare the rest of the profiles, which show very similar general trends, with different theoretical shapes (for instance modified Hubble laws) but none of those tried so far seem to follow the behaviour of the experimental profiles.

IV. CONCLUSIONS

While study of velocity dispersion profiles is still at its very early stages, some conclusions can be drawn from the analysis of density profiles.

The general behaviour of density profiles is the same (as it was already known) and this gives some support to claims of universality. However our results also show that small apparent differences can be due to significantly different profiles. Moreover, proposed parameters (BT; core radius 0.25 Mpc, slope 1) for this supposed "universal density profile" seem to be ruled out by these results.

Since both density and velocity dispersion profiles are closely relaxed through equations describing the dynamics of clusters and the possible universality of one has consequences on the behaviour of the other it will be worth following up a detailed study of these profiles. In particular, for the density profile it is necessary to reexamine our knowledge both in an individual and statistical basis. The new tools described above will no doubt give us new insight on the characteristics of this important part of our observational knowledge on clusters of galaxies.

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