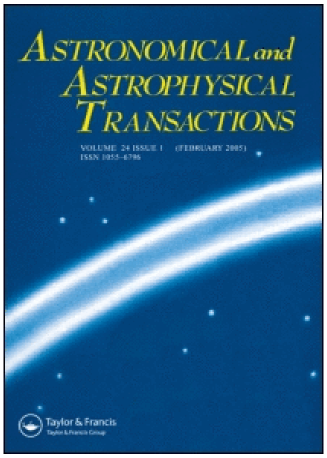

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Distribution of substructures in clusters of galaxies

J. Krywult [a]
[a] Institute of Physics, Pedagogical University, Kielce, Poland

Online Publication Date: 01 December 2003
To cite this Article: Krywult, J. (2003) 'Distribution of substructures in clusters of galaxies', Astronomical & Astrophysical Transactions, 22:6, 851 - 854
To link to this article: DOI: 10.1080/10556790310001644873
URL: http://dx.doi.org/10.1080/10556790310001644873

Astronomical and Astrophysical Transactions
Vol. 22, No. 6, December 2003, pp. 851–854

DISTRIBUTION OF SUBSTRUCTURES IN CLUSTERS OF GALAXIES

J. KRYWULT*

Institute of Physics, Pedagogical University, ul. Swietokrzyska 15, 25-406 Kielce, Poland

(Received 3 February 2003)

Wavelet analysis has been applied to the positional data of galaxies in the 117 Abell clusters. The calculations used allowed us to obtain coordinates of the centres substructures detected and to estimate the number of galaxies belonging to them. This study has shown that substructures are present in 45 clusters. Moreover, the analysis of the distribution of substructures within clusters shows that small substructures have a higher projected density than large substructures do and, for each applied wavelet scale a, the number of substructures increases towards the cluster centre.

Keywords: Clusters of galaxies; Substructures

1 INTRODUCTION

The presence or absence of substructures in clusters of galaxies is very important for the study of their evolution and formation. The frequency of substructures in clusters has been used in the past to evaluate the density parameter Ω_0 (Richstone *et al.*, 1992; Kauffmann and White, 1993). Moreover, the properties of galaxies in the clusters depend on their environment. In clusters, morphology segregation is found among galaxies both in substructures and outside them (Biviano *et al.*, 2002). Based on the APM cluster sample, similar results has been obtained by Plionis (2001). Moreover, he found that in the analysed sample of data, dynamically young clusters are much more spatially clustered.

In the present study the analysis of the distribution of the statistically significant substructures within Abell clusters was performed.

2 OBSERVATIONAL DATA

Three sources of data have been analysed; all the photographic material came from 48 in Schmidt telescopes. The catalogues of galaxies in Abell clusters were obtained from the DSS using the FOCAS package (Jarvis and Tyson, 1981), from scans performed at the Rome Observatory (Tevese *et al.*, 1992, 1997; Flin *et al.*, 1995, 2000) and from the COSMOS

* E-mail: krywult@pu.kielce.pl

ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/10556790310001644873

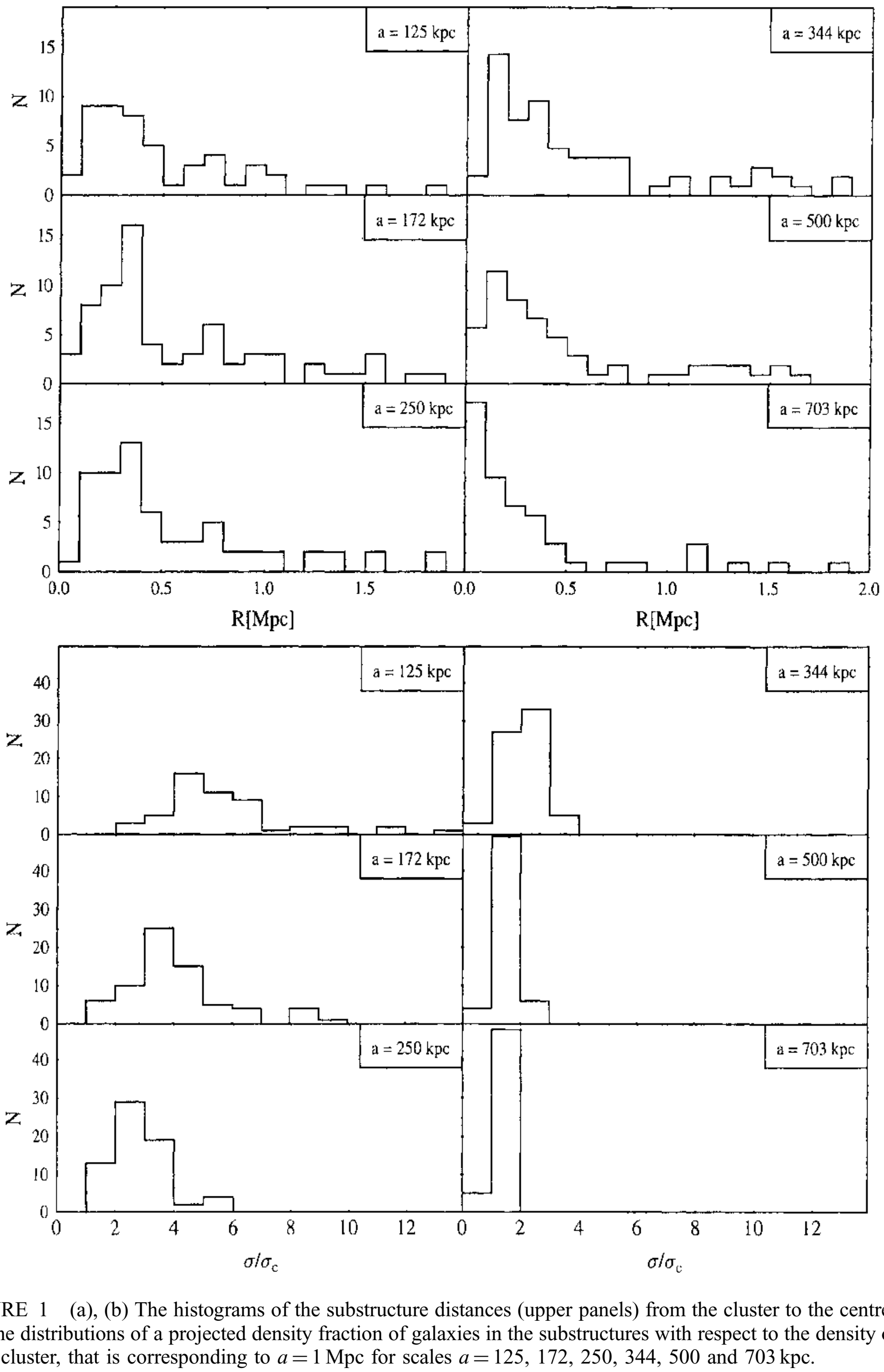

FIGURE 1 (a), (b) The histograms of the substructure distances (upper panels) from the cluster to the centre. (c), (d) The distributions of a projected density fraction of galaxies in the substructures with respect to the density of the main cluster, that is corresponding to $a = 1$ Mpc for scales $a = 125$, 172, 250, 344, 500 and 703 kpc.

machine at the Royal Observatory in Edinburgh (Yentis *et al.*, 1991). In the first two cases, additional visual inspection of images well below the accepted magnitude was carried out.

Each galaxy within the cluster regions 3 Mpc $\times$ 3 Mpc and with the brightness limit m_3, $m_3 + 3$, where m_3 is the magnitude of the third brightest galaxy was considered as the cluster member. It was accepted that $H = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $q = 0.5$.

3 METHODS OF ANALYSIS

The existence of substructures in galaxy clusters has been checked using wavelet analysis (Escalera *et al.*, 1992). In this work, following Escalera and Mazure (1992), the two-dimensional radial function called the Mexican hat has been applied:

$$g(r, a) = \left(2 - \frac{r^2}{a^2}\right) \exp\left(-\frac{r^2}{2a^2}\right), \tag{1}$$

where r is the distance between the position of a galaxy and a point (x, y) where the wavelet coefficient is calculated, and a is a scale length for the wavelet in order to form the corresponding set of wavelet coefficients.

For the analysis presented here, the discrete wavelet was computed on a grid of 256×256 pixels for seven scales increasing from $a = 8$ pixels to $a = 64$ pixels, namely 8, 11, 16, 22, 32, 45 and 64 pixels respectively. The corresponding distances are 125, 172, 250, 344, 500, 703 and 1000 kpc. In order to avoid any edge effects, areas larger than the cluster itself were analysed. The significance of the substructuring detected have been modelled using Monte Carlo simulations. For each cluster and each scale a, the wavelet analysis was carried out on a set of 1000 structureless distributions of galaxies containing the same number of points as in the true fields.

It was assumed that substructures are real if the probability that the detected substructure is due to random fluctuation is less than 0.5%. Furthermore, for each scale a, only substructures with more than four galaxy members in a circle of radius a are noted.

The result from wavelet analysis was applied to tests properties of detected substructures. For each scale a, Figures 1(a) and (b) show the histograms of the substructure distances from the cluster to the centre.

Moreover, the number density of galaxies in the detected substructures are computed. Figures 1(c) and (d) show the projected density fraction of galaxies in the substructures with respect to the density of the main structure, detected on the scale $a = 64$.

4 CONCLUSION

The method based on wavelet transform has been applied to detect substructures in the projected distribution of galaxies in 117 Abell clusters. The significance of substructuring detected has been calibrated using Monte Carlo modelling. This study shows that statistically significant substructures are present in 45 of the 117 cases.

Furthermore, as a result of wavelet analysis, the locations of substructures and the number of galaxies belonging to these substructures have been found. In the analysed sample of galaxy clusters, the distribution of detected substructures within clusters is not uniform. For each applied wavelet scale a, the number of substructures increases towards the cluster centre. Moreover, this study has shown that the small substructures have a higher projected number density of galaxies than large substructures do.

References

Biviano, A., Katgert, P., Thomas, T. and Adami, C. (2002) apstro-ph/0201540.
Escalera, E. and Mazure, A. (1992) *Astrophys. J.* **388**, 23.
Escalera, E., Slezak, E. and Mazure, A. (1992) *Astron. Astrophys.* **264**, 379.
Flin, P., Krywult, J., Trevese, D., Cirimele, G. and Hickson, P. (2000) *Astron. Astrophys., Suppl. Ser.* **146**, 373.
Flin, P., Trevese, D., Cirimele, G. and Hickson, P. (1995) *Astron. Astrophys., Suppl. Ser.* **110**, 313.

Jarvis, J.F. and Tyson, J.A. (1981) *Astron. J.* **86**, 476.
Kauffmann, G. and White, S.D.M. (1993) *Mon. Not. R. Astron. Soc.* **261**, 921.
Plionis, M. (2001) astro-ph/0110616.
Richstone, D., Loeb, A. and Turner, E.L. (1992) *Astrophys. J.* **393**, 477.
Trevese, D., Cirimele, G., Cenci, A., Appodia, B., Flin, P. and Hickson, P. (1997) *Astron. Astrophys., Suppl. Ser.* **125**, 459.
Trevese, D., Cirimele, G. and Flin, P. (1992) *Astron. J.* **104**, 935.
Yentis, D.J., Cruddace, R.G., Gursky, H., Stuart, B.V., Wallin, J.F., MacGillivray, H.T. and Collins, C.A. (1991) In: MacGillivray, H.T. and Thomson, E. (Eds.), *Digitized Optical Sky Surveys*, p. 67.