TITLE
ASP Conference Series, Vol. **VOLUME**, **PUBLICATION YEAR**
EDITORS

Non–Gaussian morphology on large scales: Minkowski functionals of the REFLEX clusters of galaxies

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1. Methods

The spatial distribution of galaxy clusters poses important constraints on cosmological models. To quantify the large–scale structures traced by the galaxy clusters we have to go beyond the number density. At each cluster we attach a sphere (see Fig. 1). The union set of these spheres is characterized by the

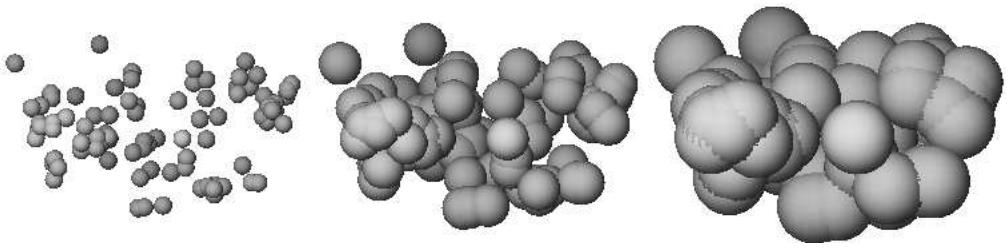

Figure 1. Spheres of varying radius attached to a sample of galaxy cluster from the REFLEX survey.

four Minkowski functionals (Mecke, Buchert, & Wagner 1994): the volume, the surface area, the integral mean curvature and the Euler characteristic. The ra-

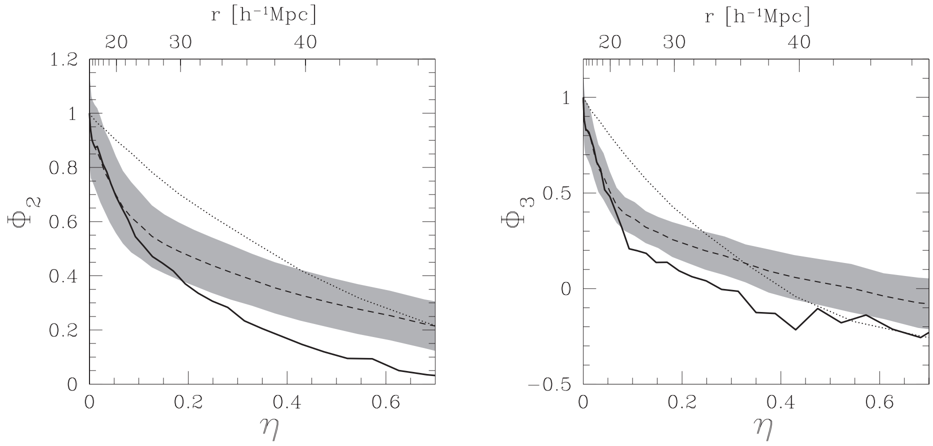

Figure 2. The normalized integral mean curvature Φ_2 and the normalized Euler Characteristic Φ_3 of the Reflex cluster sample (solid line). The shaded area is determined from simulated Gaussian point distributions with the same two–point correlation function as the Reflex sample. The dotted line is for Poisson distributed points.

dius of the spheres is used as a diagnostic parameter. Minkowski functionals can be expressed in terms of integrals of n–point correlation functions. Specifically, we derive analytical expressions for a Gaussian point distribution. They can be compared with the Minkowski functionals measured from the Reflex survey (Kerscher et al. 2001).

2. The Non–Gaussian distribution of REFLEX clusters

We calculate the Minkowski functionals of volume limited subsamples from the Reflex catalogue of galaxy clusters and compare them with a Gaussian point distributions with the same two–point correlation function as determined from the Reflex sample. As seen in Fig. 2 the Minkowski functionals of the observed cluster distribution deviate from the Gaussian case. A method to generate Gaussian point sets for a given two–point correlation function allows us to quantify the significance of these deviations. We find that the large–scale distribution of galaxy clusters in the Reflex survey is incompatible with a Gaussian point distribution at a significance level of 95%. A non–Gaussian cluster distribution could still be compatible with an initially Gaussian mass density field. However, in such a case biasing and/or non–linear structure formation processes are important.

References

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Kerscher, M., Mecke, K. R., Schuecker, P., Böhringer, H., Guzzo, L., Collins, C.A., Schindler, S., De Grandi, S., & Cruddace, R. 2001, A&A, 377, 1