Outskirts of Galaxy Clusters: Intense Life in the Suburbs
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Application of the Voronoi tessellation technique for galaxy cluster search in the Münster Red Sky Survey

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Abstract. We present the preliminary result of our project, consisting in studying the properties of a large sample of galaxy clusters. The Münster Red Sky Survey, which is a large galaxy catalogue covering an area of about 5000 square degrees in the southern hemisphere, serves as our observational basis. It is complete up to $r_F = 18^m.3$. Creation of a cluster catalogue is the first step of our investigation. We propose to use the 2D Voronoi tessellation technique for identifying galaxy clusters in this 2D catalogue. Points with high values of the inverse Voronoi tessel area will be regarded as galaxy cluster centroids. We show that this approach works correctly.

1. Introduction

In this paper we present the first element of our project. It consists in studying the properties of a large sample of galaxy clusters. In order to perform such studies, we need a sample of clusters extracted in a uniform manner from a homogeneous set of data. Therefore, we chose the Münster Red Sky Survey as our observational basis. The first step of investigation is to create the catalogue of galaxy clusters. There are three basic cluster detection algorithms: the matched filter algorithm (Postman et al. 1996), the adaptive matched filter algorithm (Kepner et al. 1999) and the Voronoi tessellation technique (Icke & van de Weygaert 1987, Zaninetti 1989, Ramella et al. 1999, 2001). Kim et al. (2002) made a comparison of these cluster-finding algorithms, using a Monte Carlo experiment with simulated clusters. We decided to apply the Voronoi tessellation technique for cluster detection. The Voronoi tessellation technique is completely non-parametric, and therefore sensitive to both symmetric and elongated clusters, allowing correct studies of non-spherically symmetric structures. For a distribution of seeds, the Voronoi tessellation creates polygonal cells containing one seed each and enclosing the whole area closest to its seed. This is the definition of a Voronoi cell in 2D. This natural partitioning of space by the Voronoi tessellation has been used to model the large-scale distribution of galaxies.

2. Observational data

The Münster Red Sky Survey constitutes the observational basis of our work. It contains scans of 217 adjoining plates of the ESO Southern Sky Atlas R covering more than 5000 degrees squared. Plates were scanned using two PDS 2020 GM^{plus} microdensitometers of the Astronomical Institute in Münster. The star/galaxy classification was performed by an automatic procedure using effective radius, central intensity and

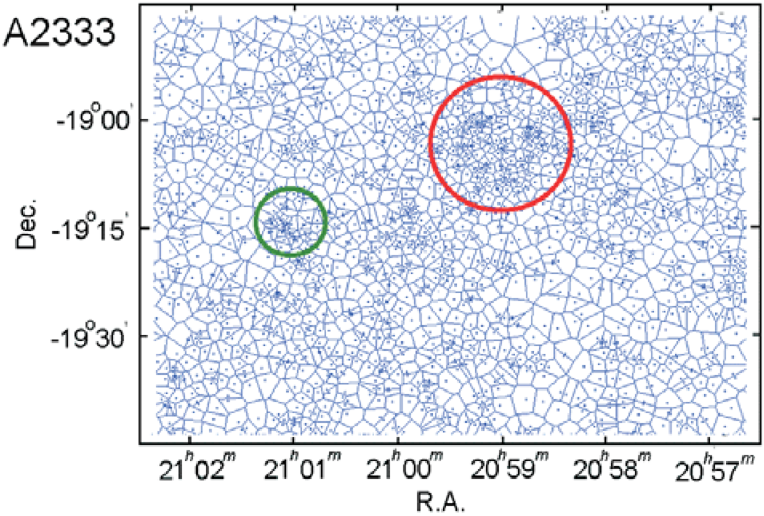

Figure 1. The region containing the A2333 after Voronoi tessellation. Each Voronoi cell encloses one galaxy. At least one more dense region is clearly seen.

surface brightness profiles. After that, visual inspection of over 2,775,000 objects was performed, allowing their re-classification. Uniformity of the whole catalogue was obtained through careful corrections of magnitudes across each plate. The overlapping regions of neighbouring plates allowed us to obtain a uniform instrumental system over the whole investigated region. The CCD photometry for 1037 galaxies and 1085 stars in 92 fields allowed one to establish the r_F magnitudes for each galaxy in the survey. The catalogue includes 5.5 million galaxies and is complete up to $18^m.3$ (Ungruhe 1999).

3. Analysis and result

We selected a fragment of the ESO/SERC 598 field with Abell cluster 2333. The A2333 cluster has 75 members, while in the field from $20^h56^m.4$ to $21^h02^m.4$ (R.A.) and from $-18°45'$ to $-19°45'$ (Dec.) there are 1781 galaxies. In the first stage of our investigation, we performed an analysis taking into account galaxy positions only. The galaxy positions provide input as seeds for the 2D Voronoi tessellation, and the Voronoi cell around each galaxy is interpreted as the effective area that each galaxy occupies in the projection plane. The result is shown in Fig. 1. Taking the inverse of these areas will be the next step of our procedure. In such a manner, the 2D local density of galaxies is determined at each point containing a galaxy. This information is then used to select galaxy members that live in highly overdense regions, which we identify as clusters. We do so by calculating the density contrast at each galaxy position as: $\Delta = (\rho - \langle\rho\rangle)/\langle\rho\rangle = (\langle\sigma\rangle - \sigma)/\sigma$, where σ is the area of the Voronoi cells, and $\langle\sigma\rangle$ is the mean area of all the cells.

4. Discussion and summary

We show that the Voronoi tessellation allows us to find the overdense regions. The main point of a further step in the search of galaxy clusters is the determination of the contrast level. This is crucial for finding real clusters. This can be done using various methods. One of them consists in using the number overdensity with respect to the average background. Another possibility is to use the colour-magnitude relation combining the data from the

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Münster Red Sky Survey with those from the APM catalogues. The determination of photometric redshifts can be considered as well. At present, we are able to conclude that the applied analysis allows us to find correctly the overdense regions in two-dimensional data.

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