ON THE MEAN DENSITY OF GALAXIES AND IDENTIFICATION OF STRUCTURES

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ABSTRACT. We discuss the difficulty of detecting of galaxy structures when the Voronoi tessellation technique is applied to two dimensional data. The problem relates to the determination of the mean density of objects in an investigated field. For data originating from plates with different limiting magnitudes there are subregions with totally different galaxy densities in the different part of investigated field. As a result galaxy structures being more numerous in more populated regions. The described effect is a general one, since all wide-field optical surveys have been made from plates with different magnitude limits.

Key words: Galaxy clusters; data analysis – Voronoi tessellation.

1. Introduction

Our project is to study a large sample of galaxy structures (Panko,& Flin, 2005a) the observational basis for our work being the Münster Red Sky Survey, hereinafter MRSS (Ungruhe, 1999). The MRSS contains scans of 217 plates of adjoining fields in the ESO Southern Sky Atlas R covering more that 5000 square degrees. The resulting catalogue includes 5,524,245 galaxies, with all possible sources of systematic error having been carefully studied. The catalogue is complete down to $r_F = 18^m.3$, although in individual ESO fields the faintest recorded magnitude can reach $19^m.5$ and less. The MRSS covers almost exactly the same region of the sky as the APM, which is tied to observations in the B band.

We selected the Voronoi tessellation technique (hereinafter VTT) to search for galaxy structures (Icke & van de Weygaert, 1987; Zaninetti, 1989; Ramella et al., 1999, 2001). The VTT is completely nonparametric, and therefore sensitive to both symmetric and elongated clusters, allowing robust studies of non-spherically symmetric structures.

In the two-dimensional case, which is our approach, the VTT creates polygonal cells containing one seed each and enclosing the whole area closest to its seed. This natural partitioning of space by the VTT has been used to model the large-scale distribution of galaxies.

We performed a galaxy cluster search using the VGCF (Voronoi Galaxy Cluster Finder) program developed by Ramella et al. (2001); see also Ramella et al. (1999) for a description of the automatic procedure used for galaxy cluster identification in photometric galaxy catalogues. After some experimentation we selected appropriate values needed for suitable density contrast (Panko,& Flin, 2005b)

The application of the procedure yields the following parameters: the coordinates of the centre of the overdense region, the number of galaxies in the region, the estimated number of background galaxies, and the area of the structure. We have completed the identification of structures over the entire region investigated, taking into account all galaxies in the MRSS catalogue. We catalogue only structures having at least eight galaxies. There are 16,550 such structures.

2. Local density variations and structures search

For computational reasons the VTT analysis was performed after dividing the complete MRSS catalogue into separate portions. Each separate portion had the seven degree extension in declination of the survey, while the breadth in right ascension varied, depending on the declination of the investigated field. The values for the extent in right ascension ranged from 21 minutes through 36 minutes, up to 1 hour. Each region contains data from several ESO plates. The particular field discussed here is presented in Fig.1 The coordinates of the centre are: $23^h.65$ and $-22^o.5$, and it contains galaxies found on four adjoining ESO plates with very different limiting magnitudes.

Fig.1 presents the relation between the galaxy num-

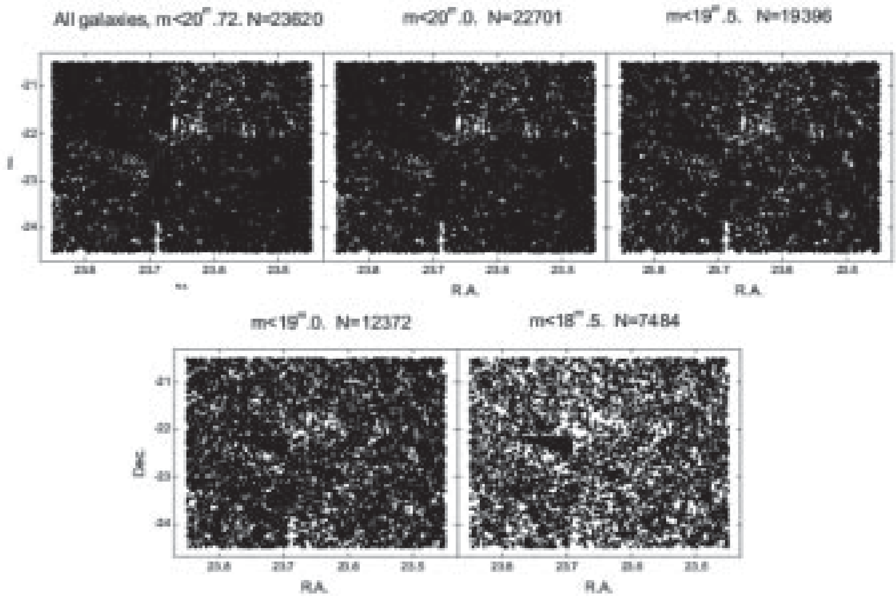

Figure 1: The variations in the local density of galaxies discussed here. In the upper part of the field the number density ratio from left and right is 1.78, 1.71, 1.23 0.95 and 0.85 respectively.

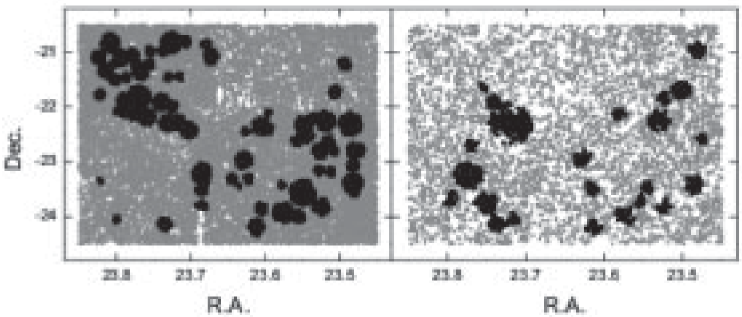

Figure 2: The galaxies which are identified as structure members (black dots). The limiting magnitude is 20.22 (left panel) and 18.5 (right panel). Background galaxies are shown as gray dots.

bers and the limiting magnitude considered. It is clearly seen that the number of objects detected on the plates is drastically different for a limiting magnitude of $20^m.22$ (Fig.1, first panel), although the plate boundaries are smoothed for a limiting magnitude of 18^m5 (Fig.1, last panel). Note that this limiting magnitude is very close to the completeness limit of the catalogue.

The application of the VTT is very sensitive to the mean density of galaxies in the field. When the sample containing all galaxies in the region considered was investigated, we found 69 structures located as shown in Fig.2 (left panel). They are located almost exclusively in the high density regions.

We repeated the analysis for the same region using a limiting magnitude for the galaxies of $18^m.5$. In this instance we found 23 structures (Fig.2, right panel), of which only 15 had been detected previously when a fainter magnitude limit was considered.

3. Conclusions

It is obvious that a cluster finding algorithm involving the VTT depends strongly on the general density of galaxies. The algorithm uses the mean density of objects in the area considered. But that is a feature not only of the VTT but also of other automated techniques that are based on mean density estimation. The small differences among the various techniques are connected with the size of the area in which the background density is estimated, as well as the manner of counting background objects. Both the global and the local galaxy density are considered. Our remarks are valid for all techniques in which the galaxy density is computed.

The strange situation presented in our Fig.2 occurred where nearby regions with very different densities were joined together. Simultaneous consideration of low and high density regions yields a greater number of structures detected in more populated regions than in less numerous ones. For technical reasons it is not possible to evaluate a large section of the sky simultaneously, so it is always necessary to divide the entire analyzed region into smaller pieces. In such smaller regions it is possible to have plates with very different magnitude limits. Therefore it is safer to work only with objects lying above the statistically complete magnitude limit.

In such manner a homogeneous set of data is obtained. Please note, that in our example when the completeness limit was applied, 15 of 23 detected structures had also been detected to a fainter limiting magnitude. In the APM there are no structures in the region, which can be attributed to the dissimilar spectral coverage of the two surveys and the different technique of cluster finding.

Because of the change in mean density level in denser regions, the size of a structure (radius of the structure and its area, both measured in square arcseconds) will be smaller. The number of galaxies inside the structure will also be smaller, so that in some structures the number of galaxies drops below the level that allows them to be counted as structures (in our case eight galaxies). That introduces an inhomogeneity in the structure catalogue. In our case, we stress that the same effect occurs in all algorithms where the mean density is counted. Presumably automated cluster finding techniques do not always give indisputable results, as some believe.

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