The NOG Sample:
3D Reconstruction of the Real-Space Density Field

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Abstract. We discuss the real-space reconstruction of the optical galaxy density field in the local Universe (cz ≤ 6000 km/s) as derived from the 7076 galaxies of the Nearby Optical Galaxy (NOG) sample (see Giuricin et al. 1999 in the same volume). NOG is the currently best approximation to a homogeneous all-sky 3D optically selected galaxy sample that probes in great detail volumes of cosmological interest.

Our final goal is to construct a reliable, robust and unbiased field of density contrasts over a wide range of physical scales.

Exploring in detail the nature of the three dimensional galaxy distribution will provide us with invaluable qualitative cosmographical information about the topology and morphology of the local overdensities; but it also allows us to investigate on the z=0 cosmology, greatly increasing our quantitative understanding of physical parameters that constrain the evolution of structures and their clustering properties. Moreover, its near full-sky coverage and the large variety in galaxy content make the NOG ideal also for more specific tasks as the deconvolution of environmental effects from the properties and evolution history of the galaxies.

1. Introduction

Due to the high resolution with which NOG samples the dominating structures of the nearby Universe, this catalog is more suitable than IRAS-selected galaxy samples for mapping the galaxy density field on quite small scales (< 2 Mpc). However, high-density sampling rate, achieved with the NOG selection criteria (B_T ≤ 14, cz ≤ 6000, b ≥ |20°|), is counteracted by systematic effects arising from the cutoffs in the selection parameters or non-uniformities in the original catalogs which may have not been properly homogenized in our sample. So we have tried to correct and minimize these biases testing the sample completeness by means of a count-magnitude analysis and deriving the appropriate luminosity and redshift selection functions.

Historically, redshift surveys have provided the raw basis for investigating the three dimensional nature of the Universe. However, a large and complete sample of galaxy distances would represent a marked improvement over redshift surveys for measuring the properties of the galaxy 3D distribution since the density map in redshift space can be a systematically distorted version of the real picture. So we have carried out the task of replacing accurate “true distances” measurements for all the galaxies of the sample for which redshift information
Figure 1. Plots showing the velocity field in the CMB frame for the modified cluster dipole model (left) and the multi-attractor model fitted to the Mark III data set (right). The vector shown are projections of the 3D velocity field in the Supergalactic plane SGX, SGY. The contours correspond to the same velocity vector modulus; contour spacing is 100 km s$^{-1}$, the heavy contours marking 100 km s$^{-1}$ and 200 km s$^{-1}$ for the two models respectively.

was available. This has been carried out (Marinoni et al. 1998) by modelling the Doppler perturbations induced by peculiar motions and disentangling the cosmological component of the redshift which is the one acting as a distance indicator.

2. Distance reconstruction

In order to correct raw redshift-distances we used two basic models of the peculiar velocity field. These two models mean to be representative of the two competing and most popular pictures of the the $z=0$ kinematics. As a matter of fact, they describe the velocity field giving two opposite interpretations of the amplitude and the length scale coherence of the motions. The first model is the optical cluster 3D-dipole reconstruction scheme of Branchini & Plionis (1996) that we modify with the inclusion of a local model of Virgocentric infall. This model shows a region where the flow bifurcates towards the Great Attractor and towards the Perseus-Pisces complex.

The second description of the peculiar velocity field has been worked out using a multi-attractor model fitted to the Mark III peculiar velocity catalogue (Willick et al. 1997). This is a collection of homogeneized distances for a sample of galaxies of different morphological type and distributed in a nearly isotropic
way in the sky. In applying this reconstruction scheme we have adopted a King density profile for characterizing the mass distribution of each attractor (i.e. Virgo cluster, the Great Attractor, the Perseus-Pisces and Shapley superclusters) and a weakly non-linear series expansion by Regős & Geller (1989), to relate the peculiar velocity field and the mass fluctuations. The emerging picture is the one in which the principle feature of the velocity field in the PP region is a coherent streaming flows in the general direction of the GA and Shapley superclusters.

Inverting the non linear redshift–distance relations predicted by the above–mentioned velocity field models, we derive the distances of galaxies. The use of different velocity field models allows us to check to what extent differences in the description of the peculiar flows influences the estimate of galaxy distances in the nearby universe. We note that these differences turn out to be more prominent at the largest and smallest distances rather than for intermediate distances (i.e., for $2000 < r < 4000$ km/s, where $r$ is the distance expressed in km/s).

We have also studied the stability of the luminosity function and of the derived selection function against variations in the adopted peculiar velocity field models. Following the lines described in Marinoni et al. 1999, we found that peculiar motion effects are of the order of statistical uncertainties and cause at most variations of $1 \sigma$ in $\alpha$ and $2\sigma$ in $M_B^\ast$.

3. Density Reconstruction

The galaxy distribution is intrinsically a point process. The problem of reconstructing the density fluctuation $\delta(r)$ is connected with finding the best transformation scheme for diluting the point distribution into a continuous density field. After having devised an algorithm to infer real distances from measured redshifts, the remaining problems we have to overcome are:

- the number density of galaxies, in a flux-limited redshift sample, is a decreasing function of distance and a small error in the selection function, used to recover the real population of objects, causes a systematic error in the density field.

- the mean interparticle spacing of a redshift catalog is an increasing function of distance with corresponding ever increasing shot noise. Correcting for this effect introduce a lack of statistical similarity between the nearby and faraway parts of the catalog.

- there is a 34 % of the sky which is uncovered by the NOG catalog.

We address all these issues smoothing with a normalized Gaussian filter having a smoothing length which is a properly defined increasing function of distance. Moreover, we assign each galaxy a weight given by the inverse of the sample selection function in order to well calibrate the median value of the density.

The specific features of the galaxy distribution field are shown in figure 2 where we plot the 0.5 spaced contours of the galaxy density contrast $\delta$ in the Supergalactic Plane. It is clear how NOG can constrain the shape and dimensionality of high-amplitude, nearby structures as the so-called Supergalactic Plane.
Figure 2. The real space density field of NOG galaxies in the Supergalactic Plane. A Gaussian filter with an average smoothing length of 500 km/s has been applied. Dashed contours represent negative values of $\delta$ i.e. underdense regions with respect to the average density. Some prominent structures dominating the local volume such as the Hydra-Centaurus-GA complex, Virgo, Perseus-Pisces, Cetus Wall and Sculptor void are clearly visible.

It is also clear from a first visual impression how much irregulars are the shapes of the major structures and how much roughly symmetric is the distribution of high and low-density regions.

A full description of the density peaks and voids characterizing the whole volume of the catalog will be presented in a forthcoming paper.

References

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