Large-Scale Structure in the NIR-Selected MUNICS Survey

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Abstract. The Munich Near-IR Cluster Survey (MUNICS) is a wide-area, medium-deep, photometric survey selected in the K’ band. The project’s main scientific aims are the identification of galaxy clusters up to redshifts of unity and the selection of a large sample of field early-type galaxies up to \( z < 1.5 \) for evolutionary studies. We created a Large Scale Structure catalog, using a new structure finding technique specialized for photometric datasets, that we developed on the basis of a friends-of-friends algorithm. We tested the plausibility of the resulting galaxy group and cluster catalog with the help of Color-Magnitude Diagrams (CMD), as well as a likelihood- and Voronoi-approach.

Keywords: galaxies: photometric redshift, survey, cluster finding: friends-of-friends

1. Motivation

The MUNICS survey was created in order to identify clusters of galaxies at high redshifts by detecting their luminous early-type galaxy population and to use the resulting mass function of clusters for cosmological tests (Bahcall et al., 1997). Another aim of the survey was to utilize field- and cluster-galaxies over a wide range of redshifts as a laboratory for galaxy evolution (Drory et al., 2001a; Feulner et al., 2002).

2. MUNICS in Brief

Our survey covers an area of roughly 1 deg\(^2\) in the near-IR J and K’ bands, supplemented with 0.6 deg\(^2\) of V, R, and I band imaging. The galaxy catalog was selected in K’ with a 50\% completeness at K’ \( \sim 19.5^\alpha \) (Drory et al., 2001b). Redshifts were determined from V, R, I, J and K’ band photometry using a photometric redshift technique (Bender et al., 2001), that makes use of model SEDs (Maraston, 1998) and empirical templates, and was calibrated with \( \sim 500 \) spectroscopic redshifts (Feulner et al., 2002) (see Fig. 1, left panel). The catalog contains \( \sim 5000 \) galaxies with \( z \geq 0.4 \).
Figure 1. **left panel:** Histogram of the redshift errors. The rms scatter is consistent with a Gaussian (dotted line: best-fit Gaussian) of a width $\sigma = 0.075$ and an insignificant mean deviation from the unity relation of $\langle \Delta z \rangle = -0.006$. **right panel:** $J-K'$ vs. $K'$ color-magnitude diagram of one group at $\langle z \rangle = 0.77$. The filled boxes denote the galaxies that were found to be structure members by our FOF. The open squares denote all galaxies found within 5 core-radii ($r_c = 0.125 \, h_{100}^{-1} \, \text{Mpc}$) at $\langle z \rangle$ of the cluster center. The group members roughly trace a red-sequence.

3. The Extended Friends-of-Friends Algorithm

So far, friends-of-friends (FOF) algorithms (Huchra and Geller, 1982) were designed to find number density enhancements in spectroscopic redshift surveys or numerical simulations (Nolthenius and White, 1987). Due to the comparatively large uncertainties in the photometric redshifts, the original FOF-technique had to be modified for application to MUNICS, resulting in our “extended friends-of-friends” algorithm.

This modified algorithm takes the photometric redshift errors into account. It looks for friends compatible with an a priori redshift on a redshift grid, spanning the entire depth of the survey and finally unifies the structures found in individual redshift bins, if structures have at least one member in common.

We found 104 structures within $0.4 \leq z \leq 1.1$ in our survey field, which corresponds to a (flux-limited) number density of $\sim 8 \cdot 10^{-5}$ structures $\text{Mpc}^{-3}$ within $0.5 \leq z \leq 0.8$ for an $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, and $h_{100} = 0.7$ cosmology.
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4. Testing the Structures

4.1. Color-Magnitude Diagrams

In a J-K’ vs. K’ CMD, evolved members of a bound structure are expected to be lying roughly on a horizontal line, the “red sequence” (see Fig. 2, right panel). About 50% of our CMDs look reasonable for groups or clusters.

4.2. Voronoi Tessellation

The inverse of the area of a Voronoi cell around a galaxy is a measure for the local density of the galaxy distribution and can be used for finding accumulations of galaxies and finally clusters (Ramella et al., 2001).

We prepared Voronoi tessellations in preselected photometric redshift bins for our MUNICS dataset and compared the resulting density charts with the results of our FOF algorithm (see Fig. 2, left panel).
4.3. Likelihood Approach

We furthermore determined the probability that a given point on a uniform grid in redshift-space is the center of a galaxy cluster, taking into account the known distributions of galaxies in the MUNICS survey. To estimate this likelihood, we assumed Gaussian probability distributions for a typical cluster in redshift, projected position and J-K' color. We included empirical knowledge about typical cluster core radii ($r_c = 0.125 h_{100}^{-1}$ Mpc; Bahcall, 1977) and velocity dispersions ($\sigma_V = 10^3$ km s$^{-1}$), as well as the individual errors of the MUNICS galaxies and SSP model colors (Maraston, 1998) to define the rms of the distributions (see Fig. 2, right panel).

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