Dwarf Galaxies: From the Deep Universe to the Present
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Dwarfs in the entourage of the Local Volume groups: flow tracers and cosmological probes

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Abstract. We consider a sample of dwarf galaxies with accurate distances and velocities around 14 massive groups in the Local Volume. We combine all the data into a single synthetic group, and then determine its radius of the zero-velocity surface, separating it against the global cosmic expansion. Our estimation is derived from fitting the the spherical infall model (including effects of the cosmological constant) to the observational data.

We found the optimal value of the radius to be 0.93 ± 0.02 Mpc. Assuming the Planck model parameters, it corresponds to the total mass of the synthetic group $(1.6 \pm 0.2) \times 10^{12} M_{\odot}$. Thus, we obtain the paradoxical result that the total mass of the synthetic group estimated on the scale of 3–4 its virial radius is only 60% of the virial mass estimate. Anyway, we conclude that wide outskirts of the nearby groups do not contain a large amount of hidden mass outside their virial radii.

Keywords. galaxies: distances and redshifts, cosmology: observations, (cosmology:) large-scale structure of universe, (cosmology:) cosmological parameters

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1. Introduction

Any overdense region in the Universe is driven by the competition between its self-gravity and the cosmic expansion, and therefore can be characterized by an idealized zero-velocity surface that separates these zones. The radius of this surface, R_0, is connected with the total mass of the overdensity, M_T, by the relation

$$M_T = (\pi^2/8G) \times R_0^3 \times H_0^2/f^2(\Omega_m), \tag{1.1}$$

where

$$f(\Omega_m) = (1-\Omega_m)^{-1} - \frac{\Omega_m}{2}(1-\Omega_m)^{-\frac{3}{2}} \cosh^{-1}(\frac{2}{\Omega_m} - 1) \tag{1.2}$$

changes in the range from 1 to 2/3 while varying Ω_m from 0 to 1. Taking the Planck model parameters $\Omega_m = 0.315, \Omega_\lambda = 0.685$ and $H_0 = 67.3$ (Planck Collaboration XVI 2014), we obtain the relation

$$(M_T/M_{\odot})_{0.315} = 1.95 \times 10^{12} (R_0/Mpc)^3. \tag{1.3}$$

2. Data and methods

In the past years, a significant number of new Local Volume dwarf galaxies with low luminosities and extremely low surface brightnesses has been discovered, in particular thanks to recent surveys of large sky areas (Abazajian *et al.* 2009, Tonry *et al.* 2012, Koposov *et al.* 2015). We use the most complete data on distances and radial velocities of the Local Volume galaxies to estimate the zero-velocity radius around 14 local massive galaxies.

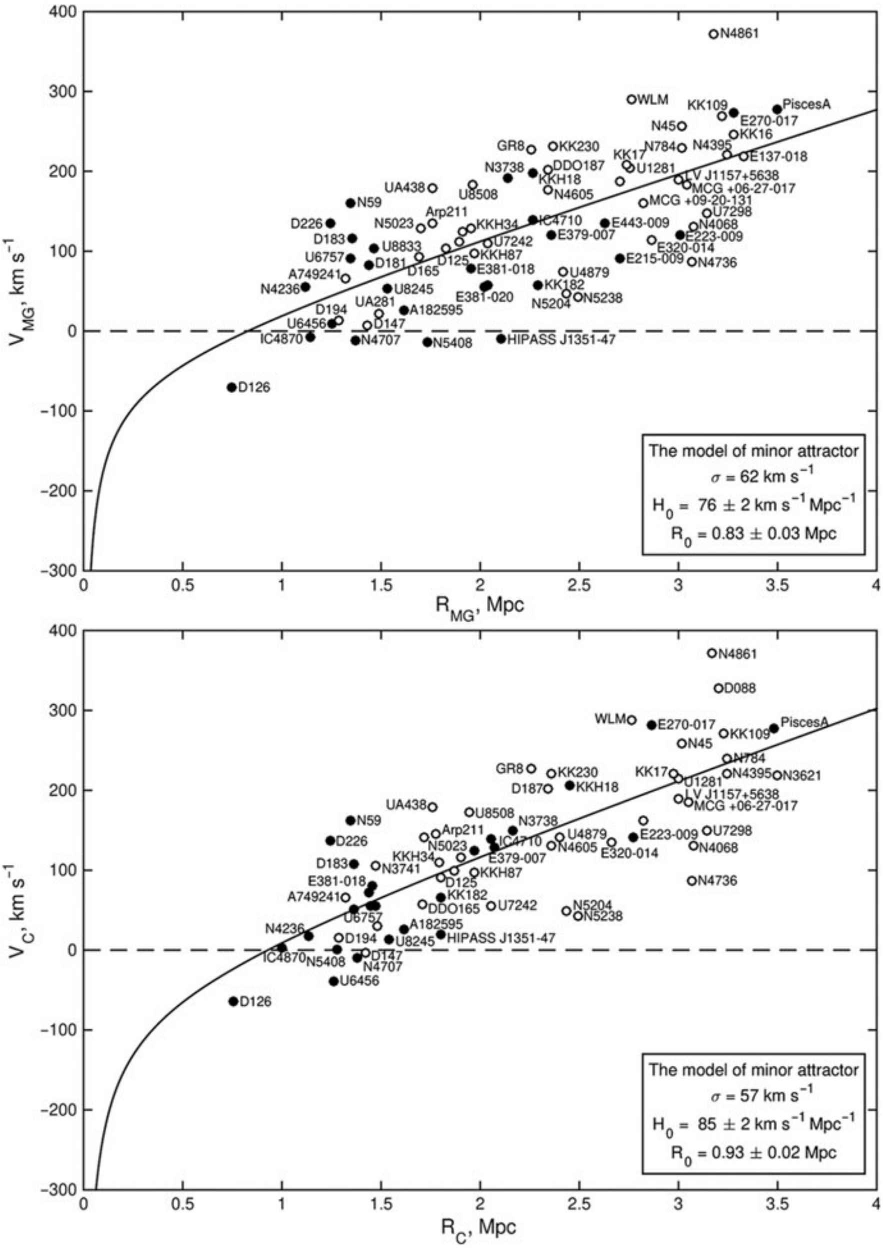

Figure 1. Hubble diagrams for the synthetic group of the Local Volume. Upper panel: The distances and velocities of satellites are calculated relative to the main galaxy in a group. Lower panel: The distances and velocities of satellites are calculated relative to the barycentre of a pair of the most massive galaxies in each group.

We combine all the data into a single synthetic Local Volume group. Our approach is based on a comparison of the observational data with the velocity field expected from the spherical infall model, including effects of the cosmological constant.

3. Discussion

To obtain the radius of the zero-velocity surface R_0, we test various assumptions about a location of the group barycentre. The resulting Hubble diagrams are presented at the Figure 1.

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We found the optimal value of the radius R_0 for the synthetic Local Volume group to be 0.93 ± 0.02 Mpc. It corresponds to the total mass of

$$M_T \simeq (1.6 \pm 0.2) \times 10^{12} M_\odot. \tag{3.1}$$

Averaging orbital mass estimates for 14 massive groups in the Local Volume and considering the representation of each group in the Hubble diagram, we obtain the mean logarithmic mass

$$M_{orb} \simeq (2.6 \pm 0.4) \times 10^{12} M_\odot. \tag{3.2}$$

So, the mass of the synthetic group derived from outer motions of surrounding galaxies (on the scale of 3–4 its virial radius) is only ~60% of the expected mass from inner orbital motions of satellites (the virial mass estimate). This paradoxical result can have several explanations.

• On the scale of virial radius, the contribution of the dark energy in the group mass does not exceed 1%, but in the sphere of R_0 radius, the role of this kind of a mass defect becomes significant, about 30% (Chernin, Bisnovatyi-Kogan, Teerikorpi *et al.* 2013).

• The discrepancy might be caused by the existence of unrelaxed (tidal) thin planar structures of satellites seen around the MW and M31, which are at variance with the assumption of spherical symmetry case (Kroupa 2014).

Anyway, we conclude that wide outskirts of the nearby groups do not contain a large amount of hidden mass outside their virial radius.

The work is presented in more details in Astronomy & Astrophysics, 609, A11 (2017).

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