Evidence for dark matter in different scales from the KLUN galaxy sample

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1. Introduction

The KLUN (Kinematics of the Local UNiverse) sample of 6600 spiral galaxies is used in studying dark matter in different scales:

- Type dependence of the zero-point of Tully-Fisher relation indicates $M/L \approx 9 - 16$ in galactic scale
- Preliminary results from a study of selection effect influencing double galaxies give a larger value $M/L \approx 30 - 50$
- Study of the Perseus-Pisces supercluster, using Malmquist bias corrected TF distances and Tolman-Bondi solutions indicates $M/L \approx 200 - 600$ for the large clusters. Similar results were obtained in our previous work on Virgo galaxies
- Application of developed version of Sandage-Tammann-Hardy test of the linearity of Hubble law inside the observed hierarchical (fractal) galaxy distribution up to 200 Mpc suggests that either Ω_0 is very small (0.01) or major part of the matter is uniformly distributed dark matter.

2. KLUN

The KLUN sample currently contains 6600 spiral galaxies having measurements of isophotal diameter (D_{25}), HI line width, radial velocity, and B-magnitude. The sample is selected according to apparent diameter and is complete downt to $D_{25} = 1.6$ arcmin. Morphological type range from Sa to Sdm is covered ($T = 1$–8). The data are extracted from the homogenized compilation catalogue LEDA

(Lyon-Meudon Extragalactic database, http://www-obs.univ-lyon1.fr/leda) and complemented with redshift and HI spectrum measurements. Previously the KLUN sample has been used for the determination of the Hubble parameter with the Tully-Fisher (TF) relation. After taking properly into account the Malmquist selection and calibrator sample biases, and using the type dependent TF relation we obtained $H_0 \approx 55$ km s^{-1} Mpc^{-1} with both the direct (Theureau et al. 1997b) and the inverse (Ekholm et al. 1999) TF relation.

3. Type dependence in the TF relation and disk + bulge + dark halo model

The revealed Hubble type dependence in the zero-point of the TF relation has been interpreted with a simple mass model (exponential disk + bulge + dark halo $\propto$ luminous mass, ref. Theureau et al. 1997a). The fraction of dark mass was found to be in the range 50 – 80 % within the radius that the TF measurements refer to. This corresponds to $M/L \approx 9 - 16$, depending on the type. A better evaluation is expected when one takes into account a luminosity dependent M/L ratio (Hanski & Teerikorpi, in prep.).

Table 1. The simple model described in Theureau et al. (1997a) uses a common $M/L = 3.72$ for the bulge, and type dependent M/L value for the disk component of spirals. Adding the gas masses and assuming constant dark mass fraction the total M/L of spirals can be estimated by fitting the observed TF zero points to the ones predicted by this model. The values below are from Table 3. in Theureau et al. (1997a).

T^a	$(M/L_B)_{\rm disk}{}^b$	$y_{\rm HI}{}^c$	$y_{\rm tot}{}^d$	$M/L(gr_0)^e$
1	1.44	0.03	0.05	15.8
2	1.37	0.04	0.06	15.2
3	1.08	0.06	0.08	14.3
4	0.96	0.07	0.09	12.7
5	0.87	0.09	0.11	12.6
6	0.64	0.10	0.12	9.9
7	0.64	0.12	0.12	8.8
8	0.76	0.14	0.14	13.2

[a] morphological type
[b] disc mass-to-light ratio
[c,d] HI and total gas masses
[e] mass-to-luminosity ratio inside TF measuring radius

Such values are somewhat larger than what is obtained from the double galaxy sample by Karachentsev, and a work is in progress to identify the reason for the inconsistency (Teerikorpi, in prep.). Preliminary results, taking into account the incompleteness in large separation distances, suggest that Karachentsev's sample gives evidence for $M/L \approx 30$ for spiral-spiral pairs.

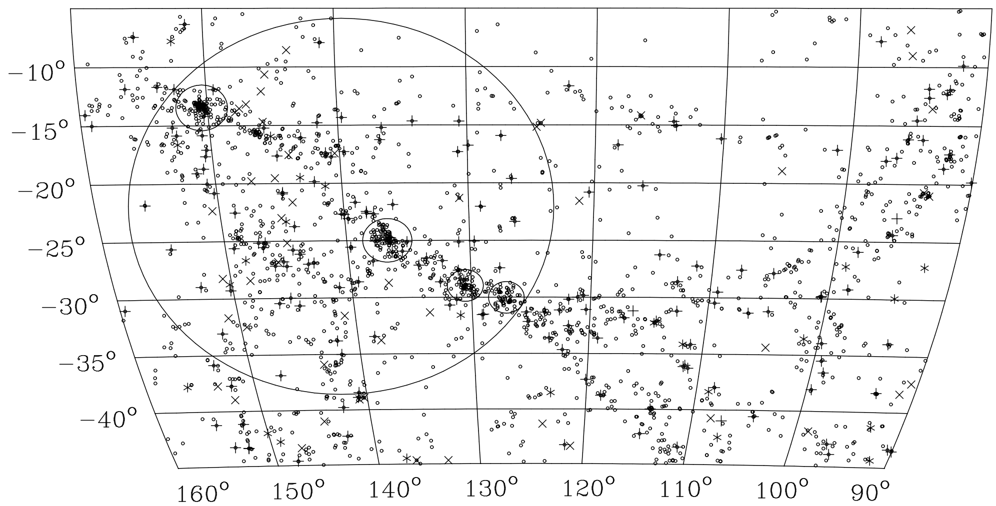

Figure 1. LEDA (o) and KLUN galaxies (+, ∗ and ×) in the PP region. Large circle is the 15 h^{-1} Mpc sphere at $(140.2^o, -22.0^o)$ containing the main concentration. Small circles are the four densest clusters, Perseus, A262, 0122+3305 and Pisces, from up left to down right. Using virial and other estimators by Heisler et al. (1985) we calculated M/L ratios of 280–540, 200–390, 250–550, and 260–590 for these four clusters. See Hanski et al. (1999) for details.

4. Masses of the Virgo and Perseus-Pisces superclusters and the Tolman-Bondi model

We have studied the Perseus-Pisces supercluster (Hanski et al., 1999) using Malmquist-bias corrected TF distances and the Tolman-Bondi solutions. Virial masses indicate $M/L = 200 - 600$ for the largest PP clusters (Fig. 1). Using matter distribution with an excess density $\propto r^{-2}$, where r is distance from PP, and a void between PP and the Local Group, we get a good fit between Tolman-Bondi model and KLUN data points. If the M/L values are valid elsewhere in the Universe, we obtain $\Omega_0 = 0.1 - 0.3$. The difference between zero and non-zero cosmological constant was found negligible in the Tolman-Bondi calculations.

The applicability of Tolman-Bondi solution even in regions where the luminous matter distribution is not spherically symmetric has been evidenced in our previous and new work on the Virgo supercluster (Teerikorpi et al. 1992, Ekholm et al., 1999). This suggests that the dark matter may be more symmetrically distributed.

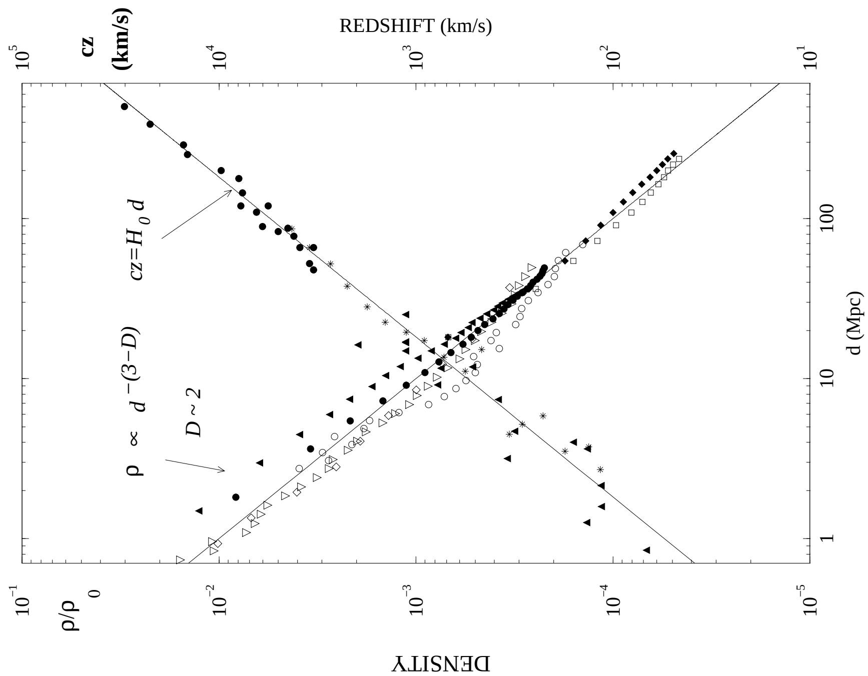

Figure 2. Hubble law vs. galaxy distribution.

5. Linearity of the Hubble law inside fractal galaxy distribution

We have applied a developed version of the Sandage-Tammann-Hardy test of the linearity of the Hubble law inside a hierarchical (fractal) galaxy distribution using a linear perturbation approximation for the velocity-distance law (Baryshev et al., 1998). If fractality with dimension $D \approx 2$ extends up to 200 Mpc, as suggested by certain studies, including our own using KLUN (Teerikorpi et al., 1998), a small Ω_0 (≤ 0.01) is required to produce the good Hubble law. A large Ω_0 is possible if the dark matter uniformly fills the space. E.g. with $\Omega_0 = 1$, one derives $\Omega_{\rm dark} = 0.99$, and the fractality is restricted to luminous matter.

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