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Bulk Motion of Galaxies and Hubble Flow Anisotropy on a Scale of 100 Mpc

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Abstract. We study a large-scale bulk motion of thin edge-on spiral galaxies from the RFGC catalogue using a multipole decomposition of velocity field. The quadrupole and octupole components are statistically significant. The first one corresponds to the Hubble flow anisotropy, the second one leads to decrease of modulus of dipole component due to the strong dipole-octupole interaction.

The Flat Galaxy Catalogue (Karachentsev et al. 1993) and its revised version RFGC (Karachentsev et al. 1999) were carried out to study the bulk motion of galaxies on distances up to 100 Mpc. The Catalogue covers the entire sky and contains flat edge-on spirals with apparent axial ratios $a/b \geq 7$ and angular diameters $a \geq 0.6$ arcmin. We use the compiled data on radial velocities in the CMB frame, V_r, and corrected HI line widths at 50% level, w, for 1327 RFGC galaxies (Karachentsev et al. 2000).

The first 3 terms in the bulk motion velocity field expansion are $V_i = V_i^{(0)} + A_{ij}r_j + O_{ijk}r_jr_k$. Considering a tensor A as a sum of the unit matrix multiplied by Hubble constant and a traceless shear tensor Q, we get the equation for radial velocity

$$V_r = Hr + V_j^{(0)}n_j + rQ_{ij}n_in_j + r^2O_{ijk}n_in_jn_k.$$

By simplifying this DQO (dipole + quadrupole + octupole) model we get the DQ model without the last term and the D model without two last terms, i.e. $V_r = Hr + V_i^{(0)}n_i$.

For each galaxy a distance $R = rH$ (expressed in km/s) can be obtained from the generalized Tully-Fisher 6-parametric relation as

$$R = \frac{w}{a_r}(C_1 + C_2B + C_3BT) + C_4\frac{w}{a_b} + C_5\frac{w^2}{a_r^2} + \frac{C_6}{a_r},$$

where a_b, a_r, B and T are "blue" and "red" corrected diameters, surface brightness index and type index. We consider the set of subsamples with different $R_{max} = 6000, 7000, 8000, 9000, 1000$ km/s.

The symmetrical tensors Q_{ij} and O_{ijk} have 5 and 10 parameters correspondingly. Using the least squares method we obtain simultaneously values and errors for all parameters, namely 9 C_i and $V_i^{(0)}$ parameters for D model, 14 ones for DQ model and 24 parameters for DQO model.

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The values of parameters C_i of the generalized Tully-Fisher relation as well as the location of the apex for dipole component remain practically the same for three models and all subsamples.

In the CMB frame $\vec{V}^{(0)}$ points towards the direction $(l = 320°, b = 0°) \pm 15°$. The values of velocity are quite different for different models and subsamples. A quadrupole component could be considered either as an anisotropy of the Hubble expansion or as a nonuniformity of the bulk motion field. Its statistical significance is greater than 99%. It could be united with the ordinary Hubble expansion by introducing a "Hubble constant" varying over the sky $H(l, b) = H + Q_{ij}n_in_j$. A minimum of this "constant" is lesser than the average value by $(6.7 \pm 2.1)\%$ and corresponds to the direction $l = 270°, b = 0°$. The directions of maxima for different subsamples are not so stable. They change from $l = 10°, b = 70°$ for subsamples with $R_{max} > 9000$ km/s to $l = 190°, b = 65°$ for subsample with $R_{max} = 8000$ km/s. The values of excess lie between $(6.1 \pm 1.5)\%$ and $(3.9 \pm 1.8)\%$. The whole bulk motion velocity field for DQO model has a sharp minimum and a more flat maximum on the celestial sphere in galactic coordinates.

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