THE ASYMMETRIC DRIFT AND THE ROTATION CURVE OF THE GALAXY

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ABSTRACT. Asymmetric drift in the solar neighbourhood is studied by the means of the RAVE data. The asymmetric drift correction is applied to the SDSS data to measure the rotation curve of the Milky Way in the extended solar neighbourhood. The rotation curve is flat between 7 and 10 kpc. Via fitting this flat rotation curve, and the inner rotation curve determined through tangent point method, density model of the Milky Way is constructed.

Key words: Galaxy: dynamics – Galaxy: disk

1. Introduction

The rotation curve of the Milky Way provides a powerful tool for constraining the density model of our galaxy.

Here for our studies we use two data samples: over 600,000 stars from RAdial Velocity Experiment, or RAVE (Siebert et al. 2011) and over 20,000 stars from Sloan Digital Sky Survey, or SDSS (Lee et al. 2011). For both samples we have spectroscopic data, which allow to reconstruct stellar models and thus to measure distances to the stars via photometric parallaxes. Knowing also radial velocities from spectroscopy, coordinates on the celestial sphere and proper motions, we have all 3 spatial coordinates and all 3 components of velocity necessary for our analysis.

In Section 2 we discuss the asymmetric drift, which must be accounted for to construct the rotation curve. In this analysis we use the RAVE data sample. In Section 4 we apply the asymmetric drift correction to the SDSS data to construct the rotation curve of the Milky Way in the extended solar neighbourhood. In Section 5 we use the rotation curve to get the density model of the Milky Way. Finally, in Section 6 we outline the major results of our work.

2. Asymmetric Drift

The asymmetric drift is the difference between the mean rotation velocity v_φ of a stellar population and the actual circular velocity v_c. It is governed by the Jeans equation

$$v_c^2 = \bar{v}_\phi^2 + \sigma_\phi^2 - \sigma_R^2 - \frac{R}{\rho}\frac{\partial\left(\rho\sigma_R^2\right)}{\partial R} - R\frac{\partial\left(\overline{v_R v_z}\right)}{\partial z} \quad (1)$$

where R, φ, and z are cylindrical coordinates, v_R, v_φ, and v_z are corresponding velocities, σ_R, σ_φ, and σ_z are velocity dispersions, and ρ is stellar density.

To simplify the equation, we use several assumptions:

1. Exponential disc with the radial scale length R_d;
2. Constant shape of the velocity ellipsoid, $\sigma_R \sim \sigma_\varphi \sim \sigma_z$;
3. Stellar density proportional to squared velocity dispersion, $\rho \sim \sigma_R^2$, which together with the former assumption corresponds to constant thickness of the stellar disc;
4. Alignment of principal axes of velocity ellipsoid with coordinate directions of spherical coordinates.
5. The asymmetric drift is small, $\left|v_c - \bar{v}_\varphi\right| << v_c$.

These assumptions allow to re-write Eq. (1) in the following way

$$\bar{v}_\varphi = v_c - \left(\frac{2R}{R_d} - 2 + \frac{\sigma_\varphi^2}{\sigma_R^2} + \frac{\sigma_z^2}{\sigma_R^2}\right)\frac{\sigma_R^2}{2v_c} \quad (2)$$

According to our assumptions, the term in the brackets does not depend on σ_R. Thus if we plot $\bar{v}_\varphi$ as function of σ_R^2, we must get a linear dependence.

Equation (2) was applied by Golubov et al. (2013) to the RAVE data sample. The data were binned in metallicities, and each metallicity had its own dependence of the asymmetric drift on σ_R^2. All these dependences were consistent with the linear law Eq. (2) with different scalelengths R_d for different metallicities. The best fit local standard of rest velocity was in a good agreement with Dehnen & Binney (1998). If we assumed the local standard of rest by Schönrich et al. (2010) instead, the scalelengths R_d appeared to depend on σ_R^2.

3. Rotation Curve

The asymmetric drift correction studied in Section 2 is applied to the SDSS data sample from Lee et al. (2011). The applicability of this correction is checked via comparing the asymmetric drift measured for three different metallicity bins of the SDSS sample to the corresponding metallicity bins of RAVE. The asymmetric drift follows the same trend, which justifies the same asymmetric drift correction.

This results into a rotation curve at Galactocentric radii 7 kpc < R < 10 kpc. The rotation curves built for three populations of different metallicities are consistent with each other. The rotation curve is flat (Golubov & Just 2013a, Golubov et al. 2012), and does not demonstrate any dips similar to the ones assumed by Sofue et al. (2009).

4. Density Model

We apply the rotation curve to construct the density model of the Milky Way. When fitting the density model, we constrain ourselves with the local stellar density and dark matter density in the solar neighbourhood, as they were determined by Just & Jahreiß (2010). The rotation curve used for fitting is composed of the inner rotation curve determined via tangent point method, supplemented by flat rotation curve in the extended solar neighbourhood (Golubov & Just 2013a).

As the result of such fitting we get a density model of the Milky Way, consisting of Dehnen bulge, exponential disc with a hole, and flattened cored isothermal dark matter halo. Using NFW profile instead of cored isothermal halo is also consistent with the data, although provides a slightly worse fit (Golubov & Just 2013b).

5. Results

RAVE data were used to study the asymmetric drift. They were consistent with the linear dependence of $\bar{v}_\phi$ on σ_R^2, and better consistent with the old local standard of rest by Dehnen & Binney (1998), than with the new one by Schönrich et al. (2010). Dependence of the asymmetric drift on metallicity was also analysed, resulting into smaller radial scalelength for more metal-poor populations.

The rotation curve turned to be flat in the extended solar neighbourhood.

We have built a density model of the Milky Way, which was flat in the extended solar neighbourhood, consistent with the inner rotation curve derived by tangent-point method, and with the local density constraints.

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