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A new estimate of the Local Standard of Rest using *Gaia* Radial Velocity Survey

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1. INTRODUCTION

It is well known that as stars in the Galactic disk form from gas clouds orbiting in the gravitational field of the Galaxy, younger stars are more likely to be on approximately closed orbits like the gas. On the other hand, older stars follow more eccentric orbits with lower tangential velocities. The youngest stars in the solar neighborhood should be at the dynamical local standard of rest (LSR), which follows a notional closed orbit around the Galaxy (see e.g., Shu 1982). There are different methods for determination of the LSR, based on the general principle that since hotter stars have a shorter lifetime than colder ones, they are in average younger: i) Strömgren's method involving finding a relation between mean velocity and velocity dispersion for different stellar populations, and extrapolating to zero velocity dispersion (e.g., Ding et al. 2018), ii) determining nearly-circular orbits from 6D phase-space data of the stars (Francis & Anderson 2018), iii) specifically identifying young OB stars (Bobylev & Bajkova 2018), iv) fitting the position and velocity data to a model of the phase-space distribution function (Schönrich et al. 2009).

Since the amount of data provided by the *Gaia* mission (Gaia Collaboration et al. 2016) is significantly larger than previous data sets, another and very simple approach is also possible: examine the mean velocities in different effective-temperature bins, and if a high-temperature asymptote is evident, interpret is as the nearly-circular orbits of young stars.

2. DATA SELECTION & DATA TRANSFORMATION

Our analysis is based on the *Gaia* DR2 radial velocity survey.[1]. From this survey we extract stars within 100 pc of our Sun and fractional accuracies of $\sigma_{\mu_{\alpha^*}}/\mu_{\alpha^*}, \sigma_{\mu_\delta}/\mu_\delta, \sigma_{\bar{\omega}}/\bar{\omega} < 0.1$ and $\sigma_{v_{\rm rad}} \leq 5\,\mathrm{km\,s^{-1}}$.

To obtain the velocities in cartesian coordinates $\mu_{\alpha^*}, \mu_\delta, v_{\rm rad}$ are transformed using

$$\vec{v}_{\rm Equat} = \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} = \begin{pmatrix} rv\cos(\alpha)\cos(\delta) - dk\mu_{\alpha*}\cos(\alpha)\sin(\delta) - dk\mu_\delta\sin(\alpha) \\ rv\sin(\alpha)\cos(\delta) - dk\mu_\delta\sin(\alpha)\sin(\delta) + dk\mu_{\alpha*}\cos(\alpha) \\ rv\sin(\delta) + dk\mu_\delta\cos(\delta) \end{pmatrix}, \tag{1}$$

where $d = 1/\omega$ is the distance in au, and k is introduced to transform $\mathrm{au\,yr^{-1}}$ to $\mathrm{km\,s^{-1}}$. These velocities in Equatorial coordinates are transformed to Galactic coordinates (U, V, W) by multiplying with a rotation matrix

$$A'_G = R_z(-l_\Omega)\, R_x(90^\circ - \delta_G)\, R_z(\alpha_G + 90^\circ) \tag{2}$$

as given in equations (3.60) & (3.61) of the *Gaia* DR2 documentation (Gaia DR2 Documentation 2018).

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[1] http://cdn.gea.esac.esa.int/Gaia/gdr2/gaia_source_with_rv/csv/

3. LOCAL KINEMATICS AND THE LSR

The stars from the dataset were binned by temperature in steps of 200 K, with bins having less than 300 stars neglected. Then, the mean values for each component of (U, V, W) were calculated for each bin. The temperature-dependent behavior can be found in Figure 1.

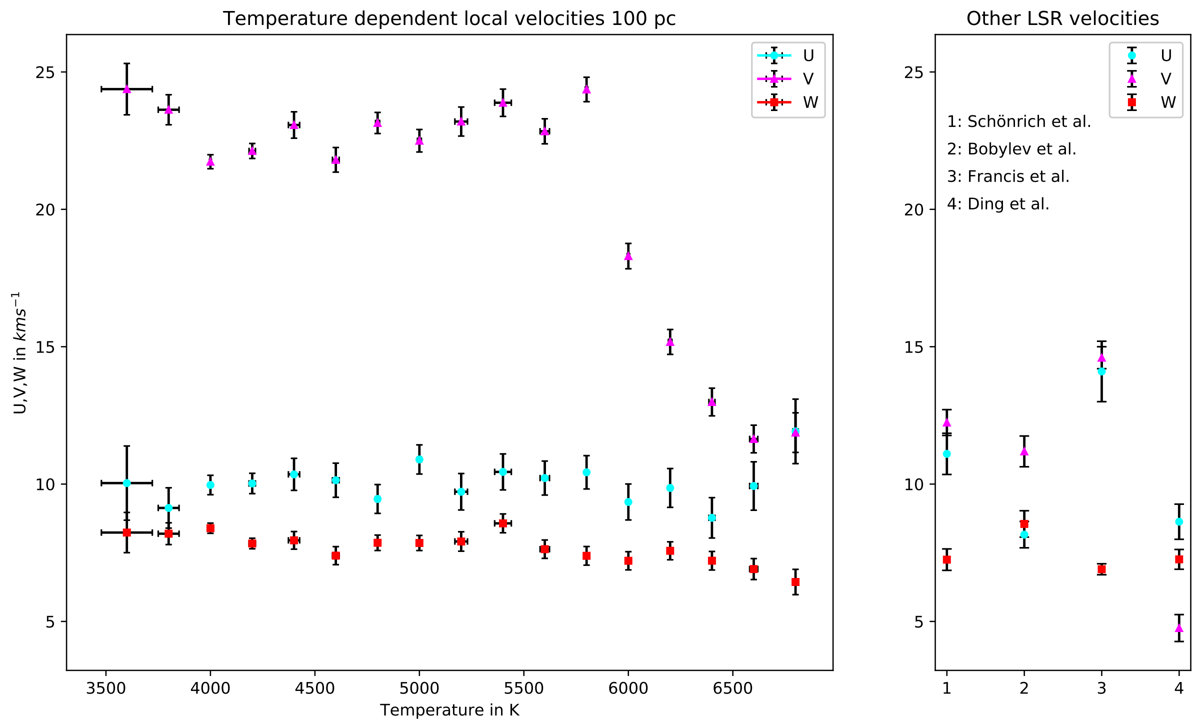

Figure 1. Heliocentric velocities U (radial), V (azimuthal), W (vertical) for stars with 100 pc of the Sun, as a function of effective temperature.

We see that the radial and vertical velocities have no evident trend with effective temperature. The azimuthal velocity also has no trend for stars cooler than the Sun, but for hotter stars the mean velocity drops, before levelling off again for $T > 6500$ K. As described in Section 1, we look at the velocities of high temperature stars. The highest temperature bin with more than 300 stars is 6800 K and has

$$(U, V, W)_\odot = (11.9 \pm 1.2, 11.9 \pm 0.7, 6.4 \pm 0.5) \text{ km s}^{-1}$$

. This is our estimate of the LSR velocity with respect to the Sun. Using median rather than mean values within temperature bins gives very similar results.

As also shown in Figure 1, this result is in general agreement with recent published values, and in particular is completely consistent with Schönrich et al. (2009). The velocity versus effective-temperature plot appears to be a simple but robust way to determine the LSR. It would be interesting to test our method again, once there is more data accessible for stars with temperatures above 6800 K.

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