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Local Kinematics and the Local Standard of Rest with *Gaia* Radial Velocity Survey

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1. INTRODUCTION

The amount of data provided by the *Gaia* mission (Gaia Collaboration et al. 2016) is significantly larger than previous data sets. Therefore, it makes sense to study stellar motions based on much more values with better statistics.
We want to answer two questions:

- What is the mean motion of stars in the solar neighborhood, and is there a temperature dependence?
- Can we determine the local standard of rest (LSR) with a very simple approach still obtaining satisfying results?

2. DATA SELECTION & DATA TRANSFORMATION

Our analysis is based on data from the *Gaia* DR2 radial velocity survey[1], closer than 100pc away from our Sun. Furthermore, all stars with either $\frac{\sigma_{\alpha*}}{\alpha^*}, \frac{\sigma_\delta}{\delta}$ or $\frac{\sigma_{\varpi}}{\varpi}$ larger than 0.1, and $\sigma_{v_{rad}} \leq |5|$ km s^{-1} are neglected.
To obtain the velocities μ_{α^*}, μ_δ and v_{rad} are transformed to Cartesian coordinates using

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

in km s^{-1} where d is the distance, and k is introduced to transform au yr^{-1} to km s^{-1}. These velocities in Equatorial coordinates are transformed to Galactic coordinates, following equations 3.60 & 3.61 of the *Gaia* DR2 documentation (Gaia DR2 Documentation 2018).

3. LOCAL KINEMATICS

Stars similar to our Sun are confined to a thin disk, orbiting the center of the Galaxy (Keel 2007). Because of gravitational potential of all objects in the Milky Way, stars cross the disk in an oscillating motion as well as they do in radial direction. Since all stars are assumed to follow such motions, this should result in a statistically steady state (Tayler 1993). The dataset only allowed to examine stars with a temperature between 3400K and 7600K. The stars were grouped by temperature $T_i = (3400 + i\cdot 200)$K, where each group contained all objects within $T_i - 100\text{K} < \mathrm{T_{star}} < \mathrm{T_i} + 100\text{K}$. Then, the mean values for each component of (U, V, W) were calculated for each temperature bin (see figure 3). U and W are approximately constant over almost the entire temperature range. We also note a significant decrease of V at 5800K, and that its values are less constant for temperatures below. However, the differences are less than 3km s^{-1}. It is interesting to see that the motions of the stars seem to have a temperature-independent behavior over 2400K. It would be interesting to see if the stars keep to change their velocities as they tend to for the highest temperatures once more data is available.

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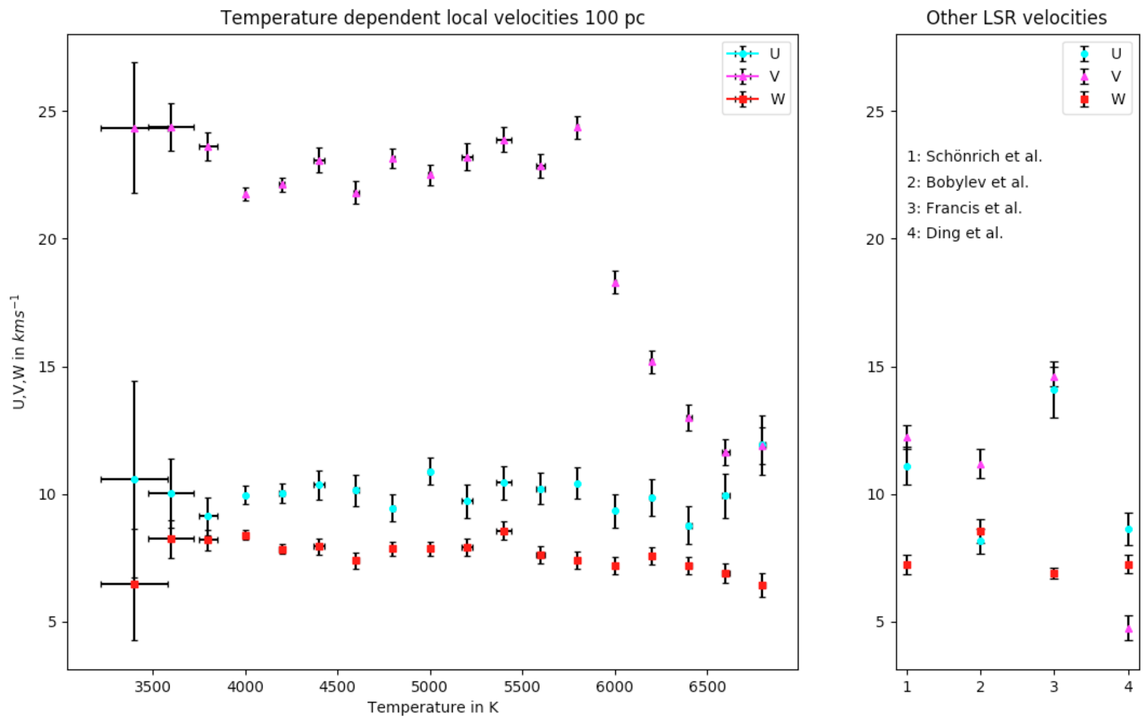
[1] http://cdn.gea.esac.esa.int/Gaia/gdr2/gaia_source_with_rv/csv/



4. LOCAL STANDARD OF REST

In this section we want to determine the LSR, which follows the mean motion of the disk material in the solar neighborhood (Shu 1982). Because this is not only stars, but also gas, and dust, we cannot just take the values found for the local kinematics. The idea for determining the LSR in a simple way is the following: Since hotter stars have a shorter lifetime than colder ones, we assume that they are in average younger. Because the stars in our sample are most likely created in gas clouds in the galactic disks, their mean velocities should be close to the velocity of the gas. Therefore, we look at the velocities of high temperature stars. As shown in table 2, the highest temperature with sufficient data is 6800K with $(U, V, W)_\odot = (11.92 \pm 1.17, 11.87 \pm 0.72, 6.44 \pm 0.46)\,\mathrm{km\ s^{-1}}$.

Compared to other results, e.g. (Schönrich et al. 2009), (Bobylev & Bajkova 2018), (Francis & Anderson 2018) or (Ding et al. 2018), one can see that our values are within uncertainties with *Schönrich et al.* which probably enjoys the highest acceptance. However, as one can see there is not really a consensus for these velocities and it is not clear how the different results should be interpreted.

Table 1. Temperature dependent velocities

Temperature K	# of stars	U km s^{-1}	V km s^{-1}	W km s^{-1}
3400	114	10.59 ± 3.85	24.34 ± 2.55	6.46 ± 2.18
3600	857	10.04 ± 1.35	24.38 ± 0.93	8.24 ± 0.73
3800	2769	9.13 ± 0.73	23.63 ± 0.55	8.19 ± 0.4
4000	11519	9.97 ± 0.35	21.73 ± 0.25	8.39 ± 0.19
4200	10711	10.02 ± 0.37	22.12 ± 0.27	7.84 ± 0.19
4400	3992	10.35 ± 0.58	23.07 ± 0.48	7.95 ± 0.32
4600	3576	10.14 ± 0.62	21.8 ± 0.45	7.4 ± 0.33
4800	5271	9.46 ± 0.52	23.14 ± 0.38	7.86 ± 0.28
5000	5356	10.9 ± 0.53	22.5 ± 0.41	7.86 ± 0.28
5200	3191	9.72 ± 0.66	23.2 ± 0.53	7.91 ± 0.35
5400	3769	10.44 ± 0.66	23.88 ± 0.5	8.57 ± 0.34
5600	3777	10.22 ± 0.62	22.84 ± 0.46	7.63 ± 0.33
5800	4208	10.43 ± 0.61	24.36 ± 0.45	7.39 ± 0.34
6000	2822	9.35 ± 0.65	18.3 ± 0.46	7.21 ± 0.33
6200	2198	9.86 ± 0.71	15.17 ± 0.45	7.57 ± 0.33
6400	1461	8.77 ± 0.73	12.99 ± 0.5	7.21 ± 0.34
6600	886	9.93 ± 0.88	11.64 ± 0.5	6.91 ± 0.38
6800	375	11.92 ± 1.17	11.87 ± 0.72	6.44 ± 0.46
7000	21	5.63 ± 3.11	7.81 ± 2.71	11.0 ± 2.4

Table 2. Distance dependent LSR velocities for T = 6800 K

distance pc	# of stars	U km s^{-1}	V km s^{-1}	W km s^{-1}
100	375	11.92 ± 1.17	11.87 ± 0.72	6.44 ± 0.46
200	379	11.91 ± 1.16	11.92 ± 0.72	6.32 ± 0.47
400	381	11.71 ± 1.17	11.79 ± 0.72	6.98 ± 0.34
600	387	11.36 ± 1.18	11.86 ± 0.73	6.14 ± 0.51
1000	391	11.07 ± 1.24	11.67 ± 0.77	5.70 ± 0.58

5. CONCLUSION

It was shown that the motion of nearby stars is almost independent of temperature for stars with T$\leq$ 5800K. At this temperature, $V_\odot$ drops significantly. Since there is not enough data on the high-temperature area, it is not possible to make predictions how velocities change there.

As shown in section 4, recent results of the LSR are not consistent. Therefore, it is not clear if we really have found 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 6800K.

REFERENCES

Gaia Collaboration et al. 2016, Description of the Gaia mission (spacecraft, instruments, survey and measurement principles, and operations)

European Space Agency & Gaia Data Processing and Analysis Consortium, 2018, Documentation release 1.0

W.C. Keel, 2007, The Road to Galaxy Formation, Springer, Second edition

R. J. Tayler, Galaxies: structure and evolution, Cambridge University Press

F. H. Shu, 1982, The Physical Universe - An Introduction to Astronomy, University Science Books

R. Schönrich, J, Binney & W. Dehnen, 2009, Local Kinematics and the Local Standard of Rest, arXiv:0912.3693v1 [astro-ph.GA]

V. V. Bobylev & A. T. Bajkova, 2018, Kinematics of the Galaxy from OB Stars with Data from the Gaia DR2 Catalogue, arXiv:1809.10512v1 arXiv:1809.10512v1

C. Francis & E. Anderson, 2018, The local standard of rest and the well in the velocity distribution, arXiv:1311.2069v2 in paper: 2018, on arxiv since 2113!?

P.-J. Ding, Z. Zhu & J.-C. Liu, 2018, Local standard of rest based on Gaia DR2 catalog, Research in Astronomy and Astrophysics