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LOCAL KINEMATICS FOR A GAIA SAMPLE OF STARS

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Abstract. A sample of stars from the Solar neighbourhood which are within 100 pc from the Sun is formed. For all of them the newest astrometric data, products of the GAIA Mission, and line-of-sight velocities are available. The objective is to examine the local kinematics bearing in mind the usual classification into thin disc, thick disc and halo. For this purpose a catalogue of galactocentric orbits is formed. The preliminary results, among others, indicate a sufficiently significant rotation of the halo at the Sun.

1. INTRODUCTION

The local kinematics of stars, or study of the stars from the Solar neighbourhood has a long a history (e. g. Binney & Merrifield 1998 - pp. 624-642). It is usual to classify the local stars, according to their kinematics, into those belonging to thin disc, thick disc or halo. Though the approaches are different, the domination of thin disc stars in the Solar neighbourhood is indisputable. However, some problems are still present, for instance the rotation of the halo, the Solar motion component along the direction of the Milky Way (MW) rotation, etc. We have taken part in a study of the local kinematics with stress on the elements of their galactocentric orbits (Cubarsí et al. 2017, Cubarsí et al. 2021a, Cubarsí et al. 2021b, Stojanović et al. 2021). It was important to form a catalogue of orbits which comprises nearby stars. The criterion was the heliocentric distance to be less than 100 pc. The GAIA DR3 catalogue offers nice possibilities, because for a very large number stars high quality astrometric data are available. A limitation is that only for a sufficiently low fraction of them line-of-sight velocities are available. Nevertheless, the number of stars satisfying the mentioned criterion attains a very high value, in total 169,741 stars.

The present authors have calculated galactocentric orbits for these stars. Bearing in mind their elements they establish a partition of stars which contains thin disc, thick disc and halo. The orbital elements can be compared to the initial conditions, more precisely to their current velocity components with respect to both the Milky Way centre and the Sun. Since the values of the random velocities do not depend on the reference point (MW centre or Sun), it is possible to obtain the so-called velocity ellipsoids for each partition component. These data can further indicate the quality of the partition.

2. METHODS

In order to calculate an orbit around the Milky Way centre, in addition to the data about stars, one also needs a model of the Milky Way gravitational potential. As well known, in the first approximation the potential of the Milky Way is steady and axially symmetric. Our choice is a potential proposed by one of them (Ninković 1992). This potential is contributed by the bulge, (thin) disc and dark halo. The local circular speed is equal to 220 km s^{-1}, $R_{\odot} = 8.1$ kpc. Since the orbits are 3-dimensional, one may introduce the minimum and maximum distances to the rotation axis and maximum distance to the Galactic plane. In the case of the thin disc stars, which prevail, the influence of the distance to the Galactic plane on the extremal distances to the axis is negligible. This is, of course, due to the very small distances of these stars to the plane. In the case of the thick disc stars this influence is already noticeable, but not significant, as is the case with halo stars. As for the halo stars, some of them orbit the Galactic centre opposite to the rotation. However, among such stars there is no one which is all the time almost in the Galactic plane, i. e. has an orbit like a thin disc star, "but multiplied by -1".

3. RESULTS

The consideration of the obtained orbits and current velocity components with respect to the Sun - as usually U towards the Galactic centre, V along the Galactic rotation and W towards the North Galactic Pole - leads to the following results. For the thin disc we use:
$-110 < U < 90$, unit is km s^{-1},
$-80 < V < 40$; unit is km s^{-1},
maximum distance to the Galactic plane attained during the orbital motion under 0.5 kpc.
We obtained that percentage of stars that satisfy this criterium is 85.2%.
This results in a mean motion: $U_m = -9.8$, $V_m = -19.1$, $W_m = -6.8$.
The corresponding matrix of random velocity squares (velocity ellipsoid) is given in Table 1.

Table 1: Velocity ellipsoid for thin disc

1065.1	122.1	4.7
122.1	434.9	4.5
4.7	4.5	162.4

For the halo: any of the following conditions should be satisfied:
$U < -210$, $U > 190$, unit is km s^{-1},
$V < -130$, $V > 70$, unit is km s^{-1},
maximum distance to the plane exceeds 1.5 kpc.
Percentage of stars for halo is 1.45%.
Resulting mean motion $U_m = -12.6$, $V_m = -102.8$, $W_m = -14.7$.
Random velocity matrix is given in Table 2.

Table 2: Velocity ellipsoid for halo

10866.6	-761.8	-14.0
-761.8	10741.9	-619.7
-14.0	-619.7	7409.8

The remaining stars, with percentage of 13.35%, belong to the thick disc. Its mean motion: $U_m = -11.2$, $V_m = -34.5$, $W_m = -12.9$. Random velocity matrix is given in Table 3.

Table 3: Velocity ellipsoid for thick disc

2848.2	218.8	-38.3
218.8	1444.9	-5.1
-38.3	-5.1	1399.6

As seen from the tables, the vertex deviation (UV correlation) is present for both discs. On the other hand, for the halo it is weaker, but there is another one in VW which is even stronger. Bearing in mind that the sample sizes significantly differ, it seems that the mean motion in U and W is rather similar, but, as well known, in V it shows a systematic increase in its modulus from the thin disc towards halo.

Our sample is shown in Fig. 1. This is another example where selection of stars that could be member of disc is done by using their velocities with respect to local standard of rest (LSR). This Toomre diagram shows nicely the distribution of stars, where color bar on the right shows density in this graph. One can notice that more than 75% of all thin disc stars in solar neighbourhood are contained within a sphere with radius of 80 km s^{-1} which is in accordance with result (Ninković et al., 2012).

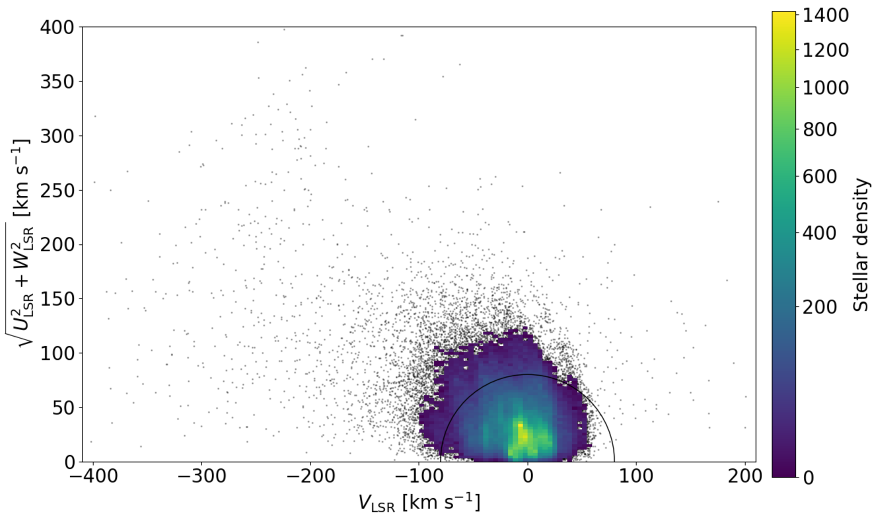

Figure 1: Toomre diagram showing the stars from our sample. Semicircle represent $|V_{LSR}|$ less than 80 km s^{-1}.

4. CONCLUSION

The present results, using Gaia DR3, are rather preliminary. Nevertheless, it is possible to conclude something. The mean motions in V of the two discs depend on the Solar motion in the same direction sufficiently strongly. If it exceeds 10 km s^{-1}, then the lags with respect to the circular speed are a few km s^{-1} for the thin disc, i. e.

about 20 km s^{-1} for the thick disc. It seems that the upper limits for the lag are somewhat greater than 10 km s^{-1} for the thin disc, i. e. greater than 25 km s^{-1} for the thick disc. The influence of the Solar motion is by far weaker for the halo. Therefore, its mean value in V suggests that at the Sun the halo rotates with a speed exceeding 100 km s^{-1} (clearly, speed with respect to Milky Way centre). The value of the mean random velocity square perpendicular to the Galactic plane (third row and matrix diagonal) in the case of the thin disc seems rather low compared to the corresponding value for the direction along the Galactic rotation (second row and matrix diagonal), i. e. sufficiently high in the case of the thick disc for the same comparison. This may be attributed to the maximum distance from the Galactic plane for the thin disc (0.5 kpc). It may be too low.

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References

Binney, J., Merrifield, M.: 1998, Galactic Astronomy, Princeton University Press, Princeton, New Jersey.
Cubarsí, R., Stojanović, M., Ninković, S.: 2017, *Serbian Astronomical Journal*, **194**, 33.
Cubarsí, R., Stojanović, M., Ninković, S.: 2021a, *Astronomy and Astrophysics*, **649**, A48.
Cubarsí, R., Stojanović, M., Ninković, S.: 2021b, *Astronomy and Astrophysics*, **652**, A58.
Ninković, S.: 1992, *Astronomische Nachrichten*, **313**, 83.
Ninković, S., Cvetković, Z. and Stojanović, M.: 2012, *Publ. Astron. Obs. Belgrade*, **91**, 163.
Stojanović, M., Cubarsí, R., Cvetković, Z., Pavlović, R., Ninković, S.: 2021, *Publ. Astron. Obs. Belgrade*, **100**, 351.