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Peculiarity of stellar kinematics in the solar vicinity

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The peculiar velocities of nearby stars are studied. We determine the solar velocity components from the radial velocities and proper motions of stars and open clusters. We show that nearby stars are not very suitable for the determination of the solar motion components because of peculiarities in their velocity distribution.

1 Introduction and sample

The velocity of solar motion is one of the key parameters of stellar kinematics. This parameter is very important for evaluating the kinematical properties of various structural components of the Galaxy. However, there are still significant discrepancies in the determination of solar velocity components (especially in the direction of galactic rotation). For example, Dehnen & Binney (1998) estimated the solar motion components in the commonly used coordinate system to be (U_0, V_0, W_0) = (10.0 ± 0.4, 5.2 ± 0.6, 7.2 ± 0.4) km s^{-1}, whereas Fehrenbach et al. (2001) obtained a different value, (U_0, V_0, W_0) = (2.9 ± 0.6, 10.4 ± 0.6, 4.8 ± 1.2) km s^{-1}.

The aim of this paper is to determine the components of solar velocity from radial velocities and proper motions of stars and open clusters (OCls) without relying on the immediate solar neighbourhood.

To this end, we use the proper motion data from the Hipparcos catalogue (van Leeuwen, 2007) and the the radial velocity data from the catalogue of Kharchenko et al. (2007) for stars. We use the catalogue of Dias et al. (2002) for OCls.

We use a sample of stars and OCls with heliocentric distances no greater than 300 pc and 1 kpc, respectively, and with fractional errors of parallaxes, proper motions and radial velocities not exceeding 30 %.

2 Determination of the solar velocity components from the data for stars

We subdivided all stars of the sample into six subsamples: subgiants (4190 stars), red giants (1454 stars), and four main-sequence subsamples: MS1 ($B - V \leq 0.2$) with 2475 stars, MS2 ($0.2 < B - V \leq 0.5$) with 5380 stars, MS3 ($0.5 < B - V \leq 0.8$) with 7736 stars, and MS4 ($B - V > 0.8$) with 1567 stars).

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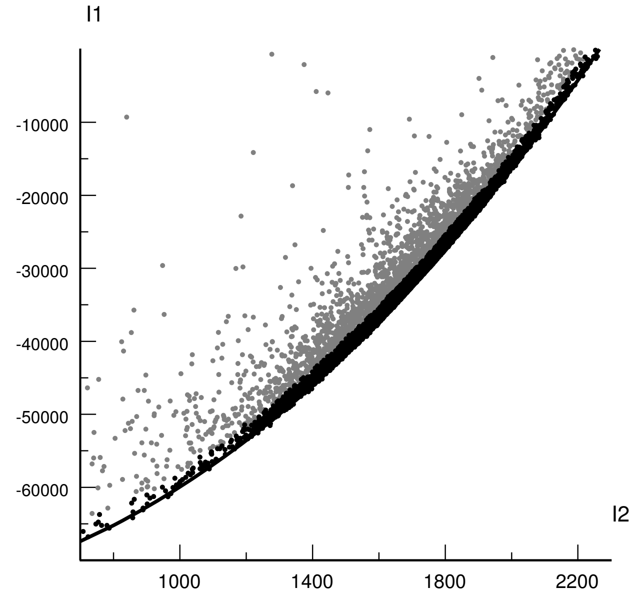

Fig. 1 Selection of stars using the Lindblad diagram (the grey and black dots show all stars and selected subsample stars, respectively).

Stars with low-eccentricity galactic orbits are better representative of the kinematical properties of the thin disc. To select such stars, we used the Lindblad diagram (Fig. 1), where $I1$ and $I2$ are the integrals of energy and momentum, respectively. We excluded high-eccentricity stars from our subsamples. We chose the optimum number of stars by setting the eccentricity cutoff so as to minimize the errors of the inferred solar velocity components. Figure 1 shows the Lindblad diagram for stars of MS3 group.

Figure 2 shows an example of the inferred solar velocity components for the central part of the main sequence. Table 1 gives the solar velocity components determined from the radial velocities and proper motions of all subsample stars.

Table 1 Components of the solar velocity.

Subsamples	U_0 (km s^{-1})	V_0 (km s^{-1})	W_0 (km s^{-1})	Number of selected stars
Subgiants	10.7 ± 1.9	13.1 ± 2.2	6.9 ± 0.6	3129
Red giants	9.5 ± 0.8	17.0 ± 2.7	5.1 ± 1.2	1054
MS 1	11.0 ± 1.5	15.1 ± 1.2	7.9 ± 0.6	1391
MS 2	11.8 ± 0.9	10.6 ± 1.2	7.6 ± 0.4	3799
MS 3	10.6 ± 1.4	15.5 ± 2.0	6.9 ± 0.5	5519
MS 4	14.1 ± 1.6	19.1 ± 1.0	6.5 ± 1.3	1015
Average	11.1 ± 0.6	15.1 ± 1.3	7.1 ± 0.3	

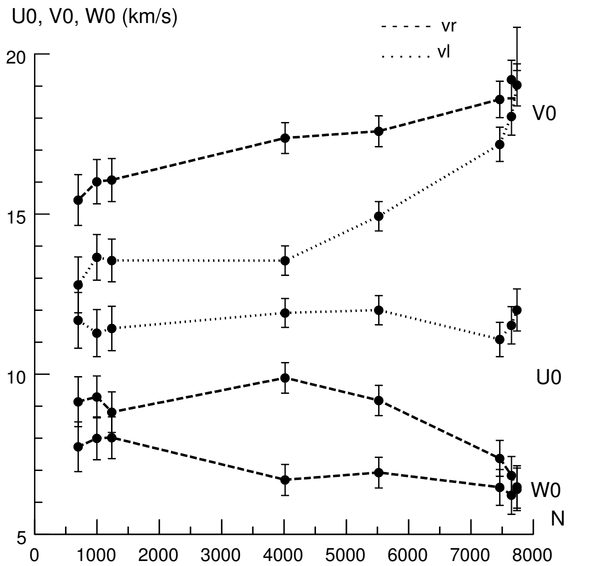

Fig. 2 Solar velocity components determined from the radial velocities and proper motions of stars of MS3 group.

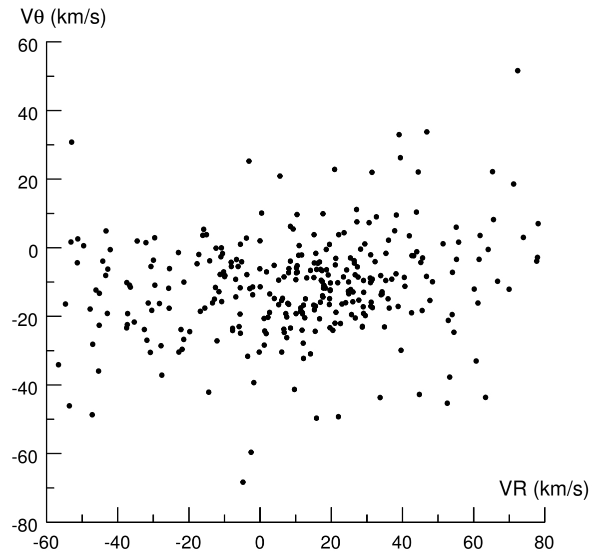

Fig. 3 Peculiar velocities field of OCls. Hereafter $V_R > 0$ and and $V_\Theta > 0$ in the direction of galactic anticentre and galactic rotation, respectively.

We conclude that selection of stars by the eccentricities of their galactic orbits does not reliably suppress the Stromberg asymmetry in subsamples (especially for the V_0 component). We believe this to be due to the fact that the adopted method assumes that the distribution of peculiar velocities is free from local features. In reality, the distribution of stellar velocities is highly structured. Large errors (especially in V_0) are therefore due to local effects in the distribution of peculiar velocities of stars. Hence objects should be selected within a greater volume of the Galaxy, and open clusters are very convenient tracers for this purpose especially given that most of them are quite young and move in almost circular orbits.

3 The determination of the solar velocity components from OCls data

As is evident from Fig. 3, the peculiar velocities field of OCLs is quite smooth because of the large space volume they sample and because the OCl sample contains practically no identifiable kinematical groups. Open clusters are therefore very convenient objects for the determination of the solar velocity components.

Figure 4 shows the distribution of OCls and their peculiar velocities projected on the galactic plane. We use only OCls with $r \leq 1$ kpc to estimate the solar velocity components, because UCAC-2 and UCAC-3 proper motions of faint stars are likely to be fraught with significant systematic errors. OCls with large eccentricities, which are mostly due to large proper-motion errors, were removed. A selection performed using the Lindblad diagram leaves us with a total of 220 OCls.

Figure 5 shows the components of solar velocity (U_0 and V_0) determined from the radial velocities and proper motions of OCls. Because of the low galactic latitudes of OCls we adopt the W_0 component determined from the data for stars. The resulting solar velocity components based on OCls data are $U_0 = 9.4 \pm 0.2$ km s^{-1}, $V_0 = 11.0 \pm 0.5$ km s^{-1}.

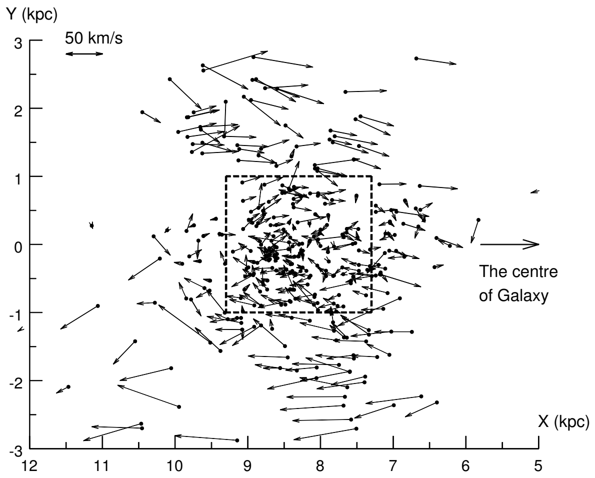

Fig. 4 Distribution of OCls and their peculiar velocities projected on the galactic plane (The Sun is at $X = 8.3$ kpc, $Y = 0.0$ kpc).

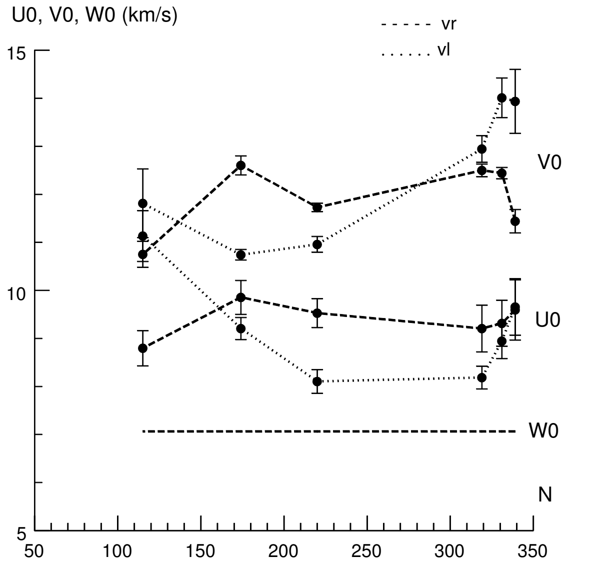

Fig. 5 Components of solar velocity (U_0 and V_0) determined from the radial velocities and proper motions of OCls.

4 The peculiar velocities field of the stars

The peculiar velocities field of stars is not smooth, unlike that of OCls, where kinematical groups are difficult to identify (see Fig. 6a). By applying the smoothing procedure to the velocity space, concentrations of stars with similar velocities – moving groups – can be clearly identified. Figure 6b shows the wavelet-smoothed field (see, for example, Loktin & Popova 2007) of peculiar stellar velocities. Moving groups appear to be of dynamical origin and are therefore convenient tools for the study of galactic dynamics.

Digital band filtering reveals numerous condensations of stars largely coincident with known stellar kinematic groups (Francis & Anderson 2009; Antoja et al. 2008; Famaey, Siebert & Jorissen 2008). The most complete distribution of moving groups can be found in the paper of Zhao, Zhao & Chen (2010) (the squares in Fig. 6b). Note that the moving group Stream 1 has been identified in none of the previous studies. Moving stellar groups are also well separated on the Lindblad diagram.

Figure 7 shows the HR-diagrams for moving groups (isochrones are adopted from Girardi et al. 2003). As is evident from the figure, the HR diagrams of moving groups located on the periphery of the peculiar velocity field are more similar to those of open clusters. This means that the age dispersion in moving groups located on the periphery on the diagram of the peculiar velocity field is not large.

5 Conclusions

1. The solar velocity components determined from the radial velocities and proper motions of stars are equal to $U_0 = 11.1 \pm 0.6$ km s^{-1}, $V_0 = 15.1 \pm 1.3$ km s^{-1}, $W_0 = 7.1$ km s^{-1}. Open cluster data yield the following velocity components: $U_0 = 9.4 \pm 0.2$ km s^{-1}, $V_0 = 11.0 \pm 0.5$ km s^{-1}. The differences between these results greatly exceed the error bars.
2. Nearby stars are not very suitable for the determination of solar velocity components because of the peculiarities in the velocity distribution. It is therefore more appropriate to choose objects from a larger galactic-disk volume. Kinematical groups make it impossible to unambiguously determine the velocity zero-point in the Galaxy.
3. The origin of moving groups is still unclear. The hypothesis that they are of purely dynamical origin (e.g., Famaey et al. 2008), which is based on the large age and metallicity scatter within each group, is not very justified, because group members are selected based on kinematic criteria exclusively.

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References

Antoja, T., Figueras, F., Fernandez, D., & Torra, J. 2008, A&A, 490, 135
Dehnen, W., & Binney, J. 1998, MNRAS, 298, 387
Dias, W. S., Alessi, B. S., Moitinho, A., & Lépine, J. R. D. 2002, A&A, 389, 871
Famaey, B., Siebert, A., & Jorissen, A. 2008, A&A, 483, 453
Fehrenbach, Ch., Duflot, M., & Burnage, R. 2001, A&A, 369, 65
Francis, C., & Anderson, E. 2009, New A, 14, 615
Girardi, L., Bertelli, G., Bressan, A., et al. 2003, Mem. Soc. Astron. Ital., 74, 474
Kharchenko, N. V., Scholz, R.-D., Piskunov, A. E., Röser, S., & Schilbach, E. 2007, Astron. Nachr., 328, 889
Loktin, A. V., & Popova, V. E. 2007, Astron. Reports, 51, 364
van Leeuwen, F. 2007, A&A, 474, 653
Zhao, J., Zhao, G., & Chen, Y. 2009, ApJ, 692, L113

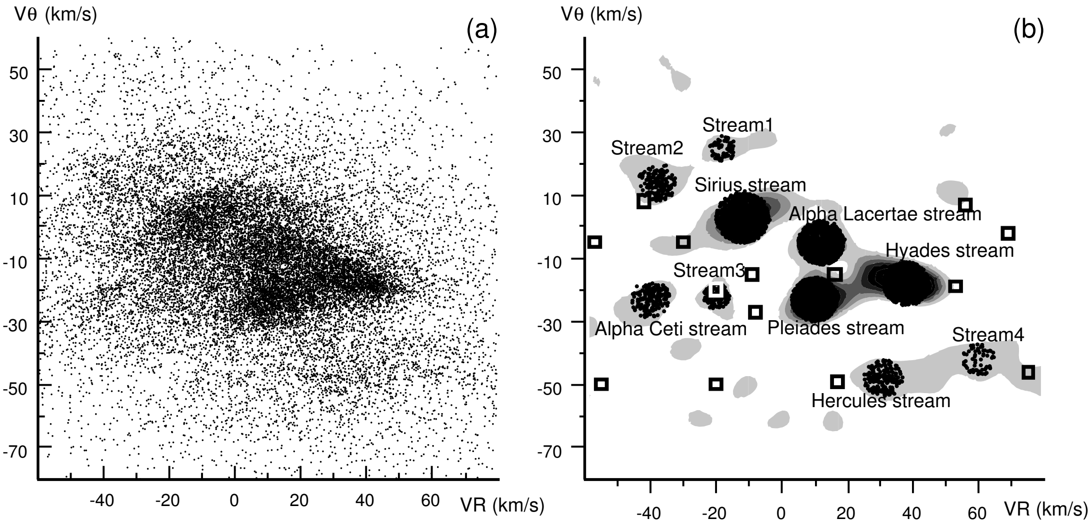

Fig. 6 The peculiar velocities of stars (*a*) and wavelet-smoothed velocity field with moving groups identified (*b*).

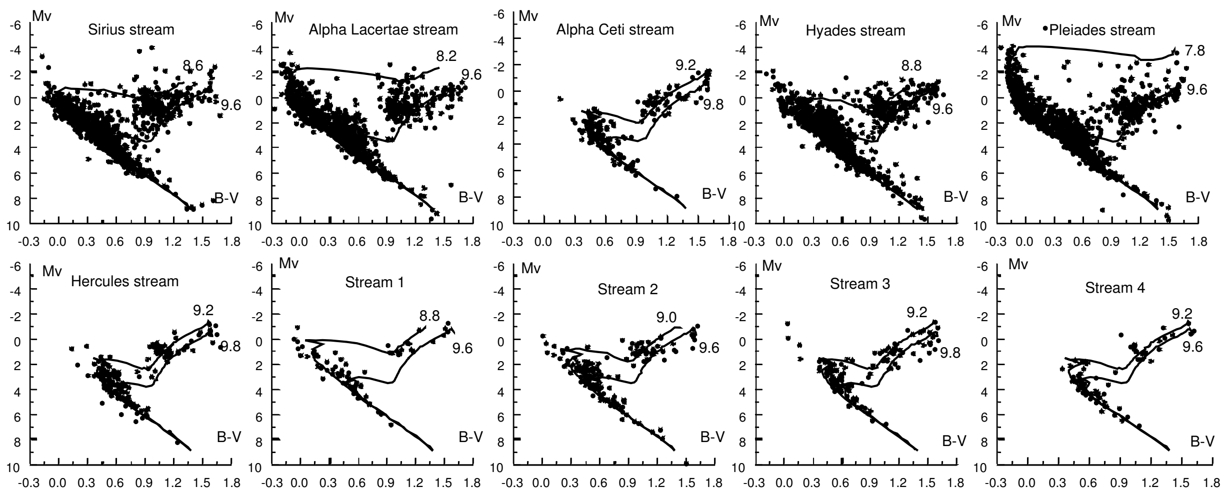

Fig. 7 HR-diagrams for moving groups (isochrones from Girardi et al. 2003).