Astronomy and Astrophysics in the Gaia sky
Proceedings IAU Symposium No. 330, 2017
A. Recio-Blanco, P. de Laverny, A.G.A. Brown & T. Prusti, eds.

doi:10.1017/S1743921317005725

The kinematics and surface mass density in the solar neighbourhood using TGASxRAVE

Jorrit H. J. Hagen and Amina Helmi

Kapteyn Astronomical Institute, University of Groningen,
Landleven 12, 9747 AD, Groningen, The Netherlands
email: `hagen@astro.rug.nl`

Abstract. We investigate the kinematics of stars in the Solar neighbourhood by combining radial velocities from the latest data release of the RAVE survey with the Tycho-Gaia Astrometric Solution presented in Gaia Data Release 1. We use moments of the velocity distribution to characterise the kinematics over a radial distance range of 6-10 kpc and up to 1 kpc away from the plane. Our ultimate goal is to use these to put new constraints on the (local) distribution of mass using the Jeans Equations.

Keywords. (Galaxy:) solar neighborhood, Galaxy: disk, Galaxy: kinematics and dynamics, (cosmology:) dark matter

1. Introduction

With the launch of the Gaia satellite in December 2013 a wealth of new data is becoming available on the motions and positions of stars in the Milky Way and its satellite galaxies (Gaia Collaboration *et al.* 2016a,b). For example, the Tycho Gaia Astrometric Solution (TGAS) set provides significantly improved proper motions and parallaxes of nearby stars making it possible to derive new kinematic maps of the Solar neighbourhood by combining this data with spectroscopic surveys.

The improved kinematic maps of the Solar neighbourhood can be used for example, to obtain new, more precise estimates of the local dark matter density (Read 2014; McKee *et al.* 2015), as well as to establish the presence of asymmetries associated to spiral arms, the Galactic bar or even bending waves in the Galactic disk (e.g. Williams *et al.* 2013).

2. Data

We derive new kinematic maps of the vicinity of the Sun by combining TGAS with the fifth Data Release of the Radial Velocity Experiment (RAVE DR5 Kunder *et al.* 2017). RAVE is a southern hemisphere magnitude-limited ($9 < I < 12$) spectroscopic survey, which contains radial velocities, astrophysical parameters such as surface gravities, temperatures and metallicities, as well as a spectro-photometric parallaxes for ∼450000 stars.

There are ∼210000 stars in common between RAVE and TGAS, which thus have full phase-space information. From this sample we select the best relative parallax error measurement for each star from either TGAS (provided that the TGAS parallax is positive) or the RAVE survey, the latter being chosen only when the signal to noise ratio exceeds 20 and when the `ALGO_CONV` flag is not equal to 1.

After selecting the best parallax measurement for each star, we only keep those stars that have radial velocity measurements with a maximum uncertainty of 8 km/s, a

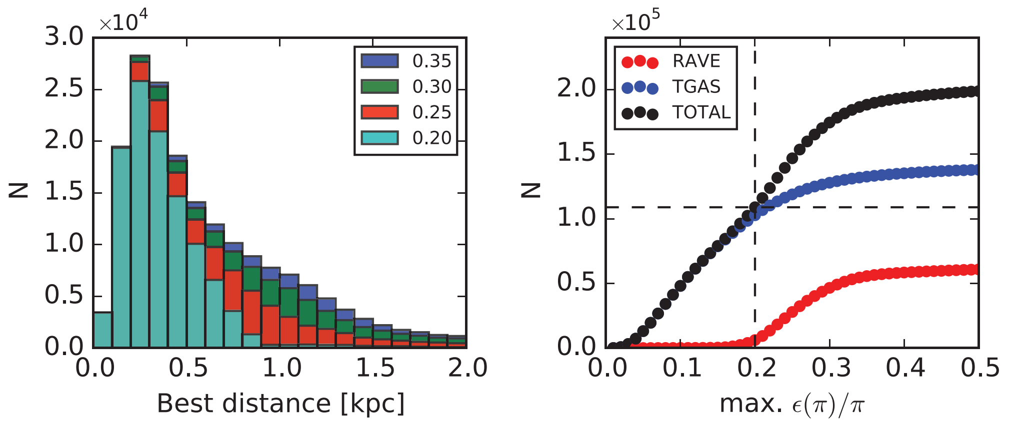

Figure 1. Left: Distance distribution of the stars with best distances determined from either RAVE or TGAS. We show the influence of varying the maximum relative parallax error on the final sample of stars. Right: The number of stars available as function of the maximum allowed relative parallax error. We also show the contribution of stars with TGAS and RAVE best parallaxes.

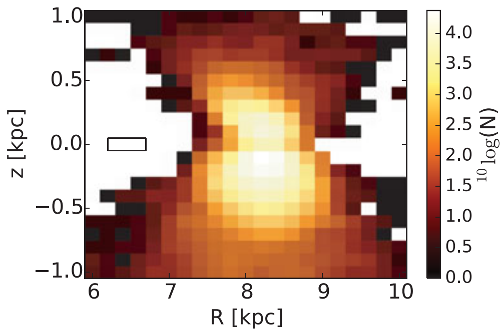

Figure 2. The spatial distribution of stars in our sample, where the colour coding indicates the number of stars found in each bin.

`CorrelationCoeff` > 10, and a maximum relative parallax error of 20%. Our final sample now contains 108916 stars and the majority of stars, 102738 stars, have best parallax measurements from TGAS.

In the left panel of Fig. 1 we show a histogram of the distances probed by varying the maximum allowed relative parallax error. Distances are obtained by taking the inverse of the parallax. In the right panel of Fig. 1 we show how varying the maximum allowed relative parallax error affects the number of stars in the sample, as well as the contribution from each of the surveys to the final sample. The spatial distribution of stars in our sample is shown in Fig. 2, where the colour coding indicates the number of stars in each bin.

When converting the observables to Galactocentric cylindrical coordinates and velocities, we assume $R_{\odot} = 8.3$ kpc (Schönrich 2012), $z_{\odot} = 0.014$ kpc (Binney *et al.* 1997), and $(U, V, W)_{\odot} = (11.1, 12.24, 7.25)$ km/s (Schönrich *et al.* 2010) for the peculiar velocity of the Sun. For the circular velocity at the Solar radius we adopt a value of 228.5 km/s.

3. Analysis and results

We sample the distribution of stars from $R = 6$ kpc to $R = 10$ kpc in bins of 0.25 kpc width and from $z = -1$ kpc to $z = 1$ kpc in bins of 0.05 kpc height. For

https://doi.org/10.1017/S1743921317005725 Published online by Cambridge University Press

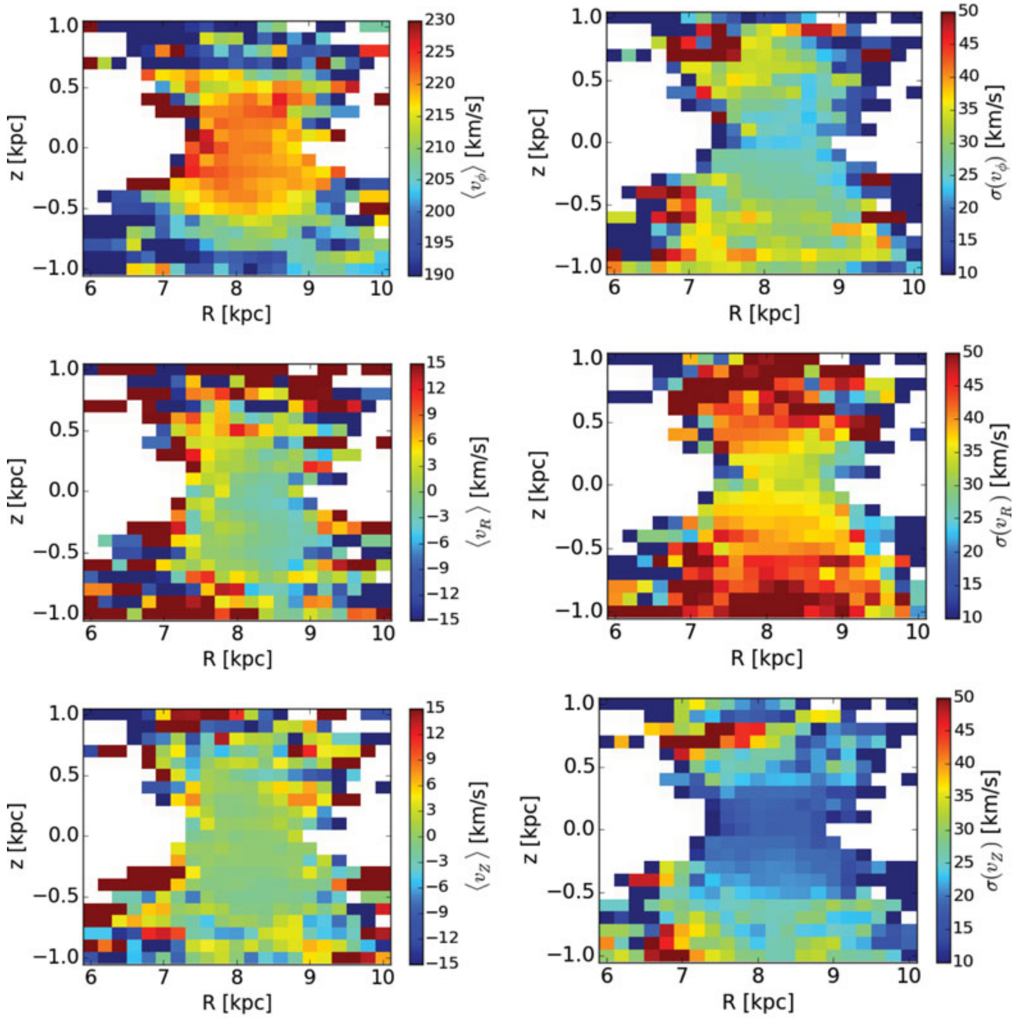

Figure 3. The means (left) and dispersions (right) of the cylindrical azimuthal, radial and vertical velocities in the meridional plane.

each bin we compute the first two velocity moments. The resulting kinematic maps are shown in Fig. 3. The asymmetric drift is clearly seen, as the mean rotational velocity decreases with increasing velocity dispersion. In these maps we do not see clear evidence for a wave-like behaviour in the vertical velocity component as reported in e.g. Williams *et al.* (2013).

In future work we plan to apply the Jeans equations to these data to compute the vertical gravitational force K_z. A key ingredient is the variation of the z-velocity dispersion in the vertical direction, which is shown in Fig. 4 for stars in our sample that are within 0.5 kpc in R from the Solar radius. In this case, we have folded the data with respect to the $z = 0$ plane. This figure shows that the velocity dispersion increases with distance from the Galactic plane as expected. The somewhat bumpy behaviour (e.g. at ~ 0.7 kpc) might be caused by the impact of distance errors at large galactic heights (McMillan, private communication).

https://doi.org/10.1017/S1743921317005725 Published online by Cambridge University Press

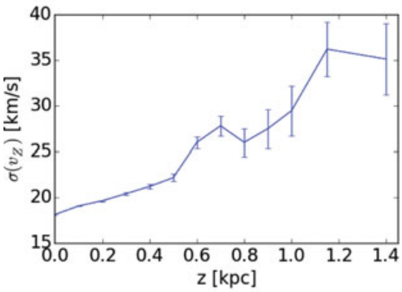

Figure 4. The vertical velocity dispersion of stars in our sample located within 0.5 kpc in R from the Solar circle.

It has been shown that to a good approximation $|K_z| \approx 2\pi G\Sigma(R, z)$, or that the relation at least gives a lower limit to the surface density $\Sigma(R, z)$ (Kuijken & Gilmore 1989; Bovy & Tremaine 2012). Comparing this quantity to the surface mass density that one would obtain by adding up the stellar contribution we can, if mass is missing, put new constraints on the local dark matter density.

Acknowledgements

We are grateful to Maarten Breddels and Jovan Veljanoski for many useful discussions and support when handling the datasets. This work has made use of data from the European Space Agency (ESA) mission *Gaia* (`https://www.cosmos.esa.int/gaia`), processed by the *Gaia* Data Processing and Analysis Consortium (DPAC, `https://www.cosmos.esa.int/web/gaia/dpac/consortium`). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the *Gaia* Multilateral Agreement.

References

Binney, J., Gerhard, O., & Spergel, D. 1997, *MNRAS*, 288, 365
Bovy, J. & Tremaine, S. 2012, *ApJ*, 756, 89
Gaia Collaboration, Brown, A. G. A., Vallenari, A., *et al.* 2016a, *A&A*, 595, A2
Gaia Collaboration, Prusti, T., de Bruijne, J. H. J., *et al.* 2016b, *A&A*, 595, A1
Kuijken, K. & Gilmore, G. 1989, *MNRAS*, 239, 571
Kunder, A., Kordopatis, G., Steinmetz, M., *et al.* 2017, *AJ*, 153, 75
McKee, C. F., Parravano, A., & Hollenbach, D. J. 2015, *ApJ*, 814, 13
Read, J. I. 2014, *Journal of Physics G Nuclear Physics*, 41, 063101
Schönrich, R. 2012, *MNRAS*, 427, 274
Schönrich, R., Binney, J., & Dehnen, W. 2010, *MNRAS*, 403, 1829
Williams, M. E. K., Steinmetz, M., Binney, J., *et al.* 2013, *MNRAS*, 436, 101

https://doi.org/10.1017/S1743921317005725 Published online by Cambridge University Press