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The high transverse velocity stars in Gaia-LAMOST

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Abstract. Although the stellar halo accounts for just ~1% of the total stellar mass of the Milky Way, the kinematics of halo stars can tell us a lot about the origins and evolution of our Galaxy. It has been shown that the high transverse velocity stars in Gaia DR2 reveal a double sequence in the Hertzsprung-Russell (HR) diagram, indicating a duality in the local halo within 1 kpc. We fit these stars by updating the popular Besançon/Galaxia model, incorporating the latest observational results for the stellar halo. We are able to obtain a good match to the Gaia data and provide new constraints on the properties of the disc and halo. In particular, we show that the thick disc contribution to this high velocity tail is small, but not negligible, and likely has an influence on the red sequence of the HR diagram.

Keywords. Galaxy: halo – Galaxy: disc – Galaxy: kinematics and dynamics

1. Introduction

Gaia Collaboration *et al.* 2018 have given a taste of the good quality science it is possible to do with the analysis of HR diagrams drawn from Gaia DR2. In particular, by selecting all stars within 1 kpc from the Sun with high transverse velocity, $v_t > 200$ km/s, two distinct sequences are discernible in the colour-magnitude diagram. In principle, the aforementioned kinematic selection criteria would most-likely select a pure stellar halo sample. Therefore, the two distinct sequences could imply that the local stellar halo is composed of two different stellar populations. However, it is important to quantify the expected contamination from thick disc stars in the sample and how this affects the interpretation of the stellar halo's formation. For this analysis, the relative fractions of stellar halo and thick at the Solar Neighbourhood, f_h and f_{TD} respectively, are of a major importance. In the following section we briefly introduce a new modelling procedure which enables us to estimate the f_h and f_{TD} from the data and thus quantify the expected thick disc contamination. The full analysis of this sample, including its chemistry and dynamics, can be found in (Amarante *et al.* 2020).

2. Modelling and Results

In order to quantify the amount of thick disc contamination, we compared the observed data with the Gaia DR2 mock catalog presented by Rybizki *et al.* (2018), which is based on Galaxia model of Sharma *et al.* (2011). We apply the same selection criteria to the mock catalog and, as can be seen in Fig. 1 left panel, the canonical model (red) fails to reproduce the observed sample (black). Pursuing a better modelling of the data,

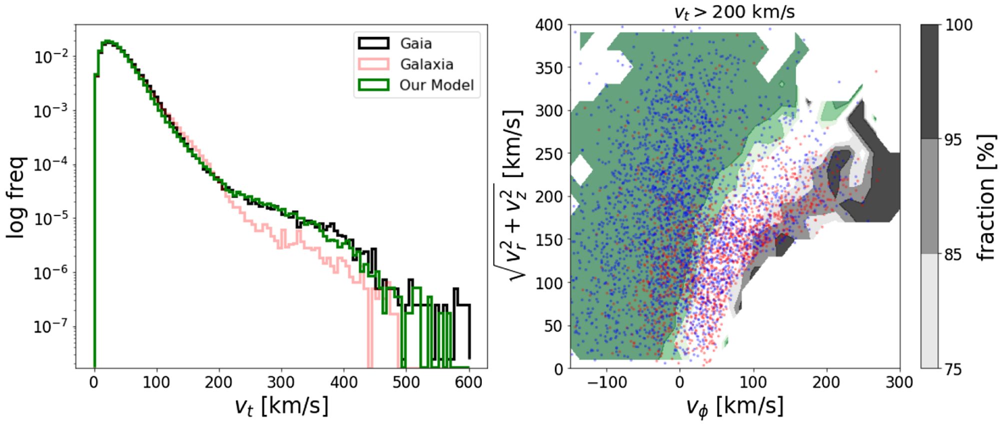

Figure 1. *Left panel:* The normalised distribution of v_t for Gaia data and our model, in black and green, respectively. The canonical Galaxia model, in red, is unable to describe the observed data for $v_t > 200$ km/s. *Right panel:* Toomre diagram for the Gaia high v_t sample, where the scatter points are colour coded based on the star's position in the HRD. The shaded areas are colour-coded based on the fraction of thick disc (gray) and stellar halo (green) according to our model.

we updated the kinematic description of the stellar halo using the results of Belokurov *et al.* (2018). The new halo kinematics are radially anisotropic and have a mild prograde rotation, $v_\phi \sim 30$ km/s. Moreover, we have also adopted a more physically motivated description for the thick disc's rotation velocity distribution (Schönrich & Binney 2012), which takes into account the asymmetric drift of the disc.

With these updated kinematics, we re-sample the mock stars' velocities and calculate their new v_t. We compare their distribution to the observed distribution in the range $v_t >$ 200 km/s by taking bins of width 10 km/s. Then we calculate the maximum likelihood using a standard χ^2 technique, where we have two free parameters corresponding to the re-weighting factors for the thick disc and stellar halo. We can see in the left panel of Fig. 1 that our model (green line) significantly improves the fit to the tail of the observed distribution. Moreover, even though the fit was made using only the tail of the distribution, our model also provides good agreement over the entire range of v_t.

From our model we can now calculate the updated fraction for the thick disc and stellar halo within 1 kpc from the Sun. We find that $f_{TD} = 6.52\%$ and $f_h = 0.42\%$. It is important to stress that this is a new methodology to obtain the fractions for these two populations and it is independent of the stars' chemistry. We find that the predicted thick disc contamination in the Gaia high v_t sample is $\sim 15\%$, which cannot be ignored if we are to infer the origin of the two sequences. We also expect the majority of these thick disc stars to lie in the red sequence and this is indeed borne out by our model, which predicts that the red sequence contains 36% thick-disc stars while the blue sequence contains less than 1%.

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