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Measuring torque of galactic bar from Gaia DR2

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Abstract. Since past few decades, observations have improved so strongly that when modelling Milky Way (MW) dynamics it is required to include small perturbations to the modelling process. It is difficult task that we try to solve by selecting regions to model so small that the perturbation can be considered to give nearly constant effect. We use Solar Neighbourhood (SN) as our test sample and assume that the bar effects show more or less constant contribution to SN. By extrapolating and smoothing observed stars on their orbits, and requiring that smoothed and observed phase space are consistent we were able to deduce acceleration vector. We conclude from non-radial acceleration component that the bar must cause about one third of total acceleration near SN.

Keywords. Galaxy: kinematics and dynamics, Galaxy: fundamental parameters

1. Introduction

To determine fundamental parameters of MW (e.g. total mass), one makes a model of the MW, and fits its free parameters to observations as well as possible. The result of this modelling is a global model of MW. Its validity is as good as the proposed form of the model allows to describe MW. Another approach is to solve dynamical problems locally and repeatedly to get non-parametric acceleration field or, as in this case, the acceleration vector in SN. By finding acceleration vectors at different points we will be able to interpolate the results of each point into a global model.

2. Method and Data

The method of the present application is fully described in Kipper *et al.* (2019). As a short recap, we select a well defined region near SN. We choose all the stars in this region and consider their phase space coordinates as initial conditions to orbit calculation. To calculate the orbit we also need acceleration vector. We consider these acceleration vector components (and their gradients) as free parameters to model. In order to test, whether the acceleration vector was correct one, we assume that there is equal chance to observe star at each point on its orbit with respect to time (Han *et al.* 2016). This means that in case of true acceleration vector we are able to construct infinitely many equally probable realisations of the SN. Mathematically it is most desirable to smooth the star along its orbit and smooth the orbits into model phase space function. Based on the smoothed phase space function and observations we are able to calculate the likelihood to test the suitability of acceleration vector. Maximising the likelihood gives us the most probable acceleration vector in SN.

As initial conditions for orbit calculations are desired we considered only best quality data. We selected Gaia DR2 observation data that were morphed into distance and phase space parameters by Schönrich *et al.* (2019) (denoted as Sc in Figure 1) and Anders *et al.* (2019) (denoted as SH in Figure 1). We consider SN as an oblate ellipsoid with ~ 0.5 kpc

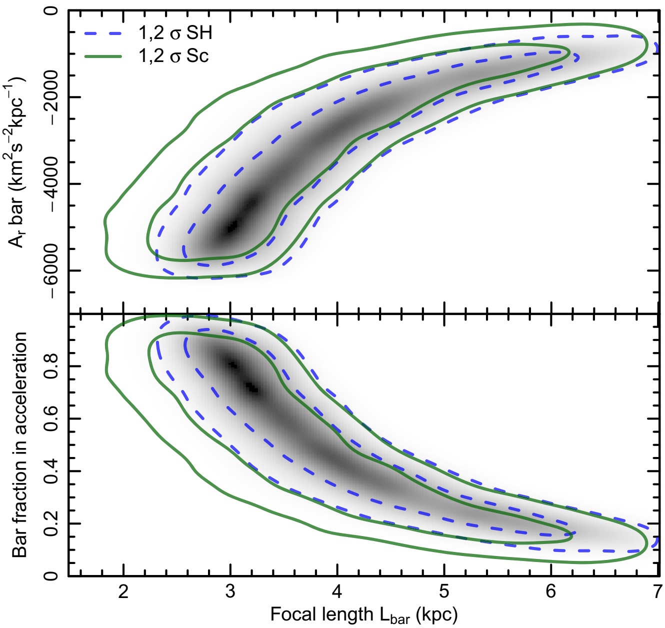

Figure 1. The acceleration caused by bar (top panel) and fraction of bar acceleration as a function of the length of the bar ($L_{\rm bar}$). The gray colors indicate the probability density.

radius and 0.2 kpc height. To tackle dust attenuation and Malmquist bias, the luminosity cuts to selection were considered based on near infrared luminosity data.

3. Implementation and Results

We considered the acceleration vector to represent an axisymmetric MW component, and additional bar component described as source of confocal ellipsoidally aligned isopotential lines. We assumed the angled between the bar and line connecting us with the MW centre is 30°. The focal points of the bar, that can be approximated with the length of the bar, is a free parameter.

Our modelling concluded that the acceleration function in SN is somewhat degenerated when considering this functional form (see fig 1), but we can conclude that when fixing the length of the bar to $\sim$4 kpc, the acceleration from the bar is about a third of the total acceleration in the MW plane. This can be caused by a bar that has mass about $1.6 \pm 0.3 \times 10^{10}$ M$_\odot$.

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