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The surface mass density in the solar neighbourhood using red clumps stars in TGASxRAVE

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Abstract. We investigate the kinematics of red clump stars in the Solar neighbourhood by combining data from the RAVE survey with the TGAS dataset presented in Gaia DR1. Our goal is to put new constraints on the (local) distribution of mass using the Jeans Equations. Here we show the variation of the vertical velocity dispersion as function of height above the mid-plane for both a thin and a thick disk tracer sample and present preliminary results.

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

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1. Introduction and Dataset

With the launch of the Gaia satellite 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.* 2016). For example, the Tycho Gaia Astrometric Solution (TGAS) 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. These kinematic maps can be used to obtain new, more precise estimates of the local dark matter density (e.g. Read 2014).

We use red clump stars (RC) in the vicinity of the Sun to derive new kinematic maps by combining TGAS proper information with data from the RAVE survey (Kunder *et al.* 2017; McMillan *et al.* 2017, PJM2017). RAVE is a magnitude-limited ($9 < I < 12$) spectroscopic survey, which has measured radial velocities, astrophysical parameters, as well as a spectro-photometric parallaxes for ~450000 stars.

There are ~ 220000 stars in common between RAVE and TGAS for which PJM2017 derived new surface gravities using the TGAS parallaxes as priors. We select red clump stars on colour ($0.55 < (J-K)_{\rm 2MASS} < 0.8$) and surface gravity ($2.35 < \log(g)_{\rm PJM} < 2.6$). We only keep those stars that have radial velocity measurements with $\epsilon(v_{\rm los}) < 8$ km/s, $S/N > 20$, an `ALGO_CONV` flag equal to either 0 or 4 and `flag_any` = 0. The resulting sample contains 26650 stars.

2. Analysis and Results

We assume the mean RC absolute magnitude is $M_K^{\rm RC} = -1.59$ Mag (this value is derived for a sample of 3164 RC stars with a relative parallax error $\leqslant 10\%$). To derive a distance for each RC star we generate 1000 realizations sampled from a Gaussian with mean $M_K^{\rm RC}$ and dispersion 0.2 mag. The latter is a conservative estimate since our 10% parallax error sample has a dispersion of 0.08 mag. In each realization we also consider the errors of proper motion and radial velocity.

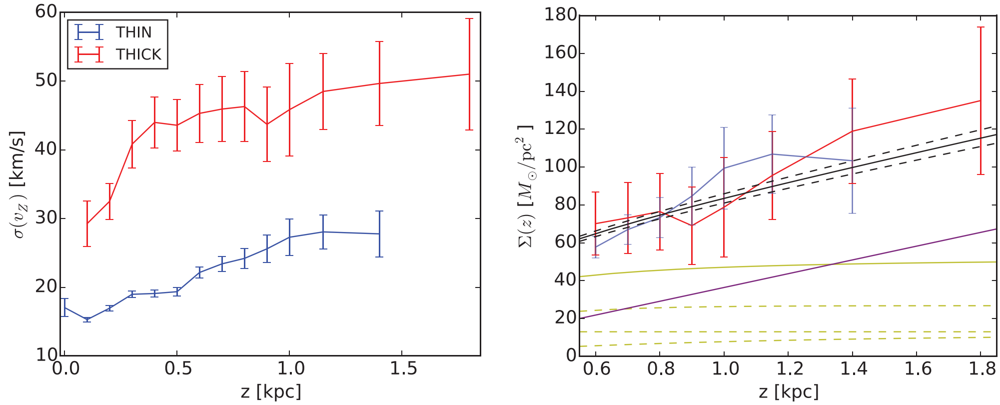

Figure 1. Left: The vertical velocity dispersion of RC stars as function of height for both a thin (blue) and thick (red) disk sample. Right: An example mass model. The data points with error bars indicate the surface mass density as implied from the Jeans analysis. The black line shows the mass model, which is the sum of the baryonic (solid yellow) components (thin, ISM and thick disks from top to bottom in dashed yellow) and the dark matter component (purple).

We then select RC stars in $7.8 \leqslant R \leqslant 8.8$ kpc (i.e. 0.5 kpc from the Solar radius). We further split the sample based on metallicity (i.e. Met_N_K > -0.25 and $-1.5 <$ Met_N_K < -0.5 for thin and thick disks respectively). We fold the data with respect to the $z = 0$ plane and compute their kinematics as function of z in bins with at least 40 stars. The left panel of Fig. 1 shows the (error deconvolved) vertical velocity dispersion of both samples, where error bars indicate the rms over all realizations. The figure shows that the velocity dispersion of the thin disk tracers increases with distance from the Galactic plane, whereas the thick disk tracer sample shows a more constant behaviour for $z > 0.4$ kpc (below this height there may still be contamination from the thin disk).

The variation of the vertical velocity dispersion with z is a key ingredient of Jeans modelling and can be used to compute the vertical gravitational force K_z, which is related to the total mass surface density $\Sigma(R, z)$ via $|K_z| \approx 2\pi G \Sigma(R, z)$ (Kuijken & Gilmore 1989). As an example we show in the right panel of Fig. 1 the result of applying the Jeans model to our data. We assumed a scale length of 2.5 kpc for both the thin and thick disk and scale heights of $h_Z^{\mathrm{thin}} = 0.25$ kpc and $h_Z^{\mathrm{thick}} = 0.9$ kpc. We assume that the stellar density at $z = 0$ is $\rho_\star(R_\odot, 0) = 0.06\ M_\odot/\mathrm{pc}^3$ and that here the thick to thin disk density ratio is 12%. The ISM contribution is $13 M_\odot/\mathrm{pc}^2$. Comparing to the surface mass density that we obtain by adding up the baryonic disks we can, if mass is missing, put new constraints on the local dark matter density. We find $\rho_{\mathrm{DM}}(R_\odot, 0) = 0.019 \pm 0.001\ M_\odot/\mathrm{pc}^3$, though we note that systematic errors are much larger than the uncertainty quoted here.

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