Internal dynamics of the Large Magellanic Cloud from *Gaia* DR2

Eugene Vasiliev

Institute of Astronomy, Cambridge

Abstract

We use the proper motions (PM) of half a million red giant stars in the Large Magellanic Cloud (LMC) measured by *Gaia* to construct a 2d kinematic map of mean PM and its dispersion across the galaxy, out to 7 Kpc from its centre. We then explore a range of dynamical models and measure the rotation curve, mean azimuthal velocity, velocity dispersion profiles, and the orientation of the galaxy. We find that the circular velocity reaches ~ 100 km/s at 5 Kpc, and that the velocity dispersion ranges from $\sim 40-50$ km/s in the galaxy centre to ~ 20 km/s at 7 Kpc.

1. Input data and sample selection

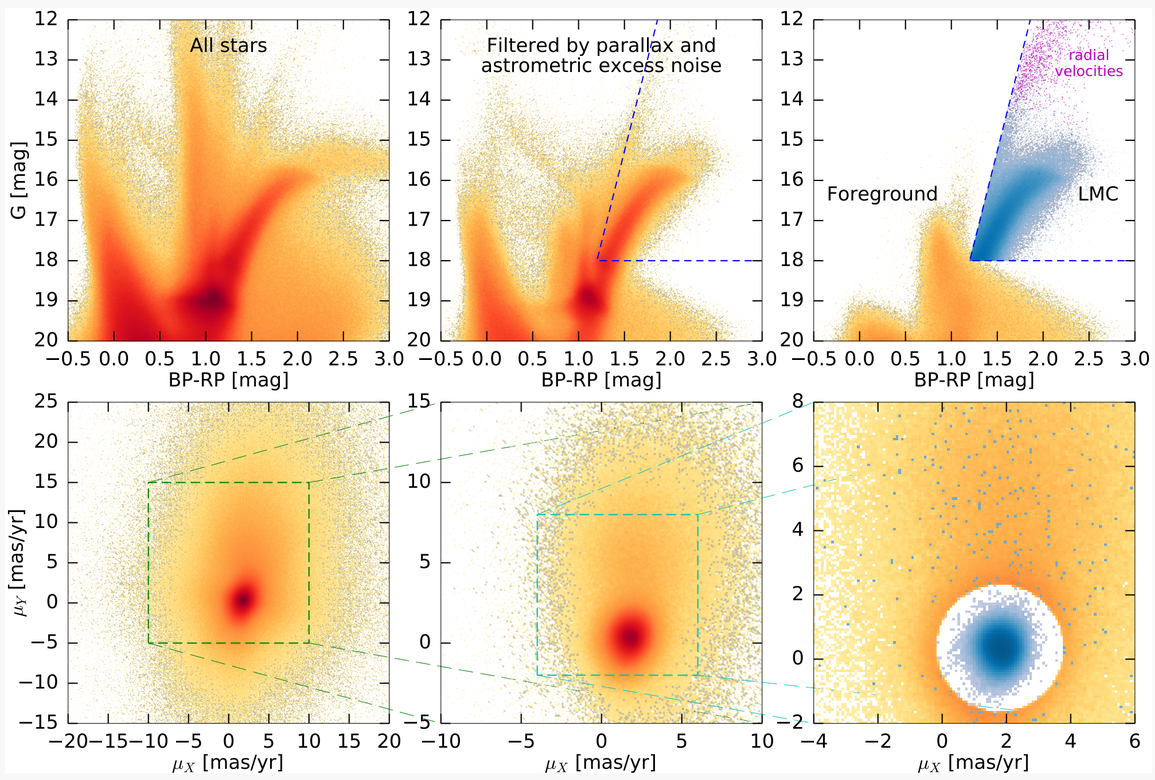

Figure 1: Obtaining a clean sample

- Select all sources within 8° from the LMC centre (left panels) – 10^7 sources.
- Retain only stars with parallax consistent with zero at 3σ level (eliminate obvious foreground contaminants).
- Reject stars with `astrometric_excess_noise` > 0.2 – possibly unresolved binaries or other sources with inaccurate astrometry.
- Remove stars with unreliable photometry: `phot_bp_rp_excess_factor` $> 1.3 + 0.06\,(G_{\rm BP} - G_{\rm RP})^2$ – preferentially faint sources in crowded regions, which are affected by nearby brighter stars (middle panels) – 3×10^6 sources.
- Select the region in the colour–magnitude diagram corresponding to red giants above the red clump (right panels – blue) – 5×10^5 sources.

Even though we do not explicitly filter on proper motions, the final sample is very clean (μ_X, μ_Y clustered around the mean value for LMC stars), while the foreground stars with PM inconsistent with LMC by more than 2 mas/yr (right paneld – red) have very little overlap with LMC stars in CMD; their spatial distribution is nearly uniform across the area of interest.

2. Error deconvolution

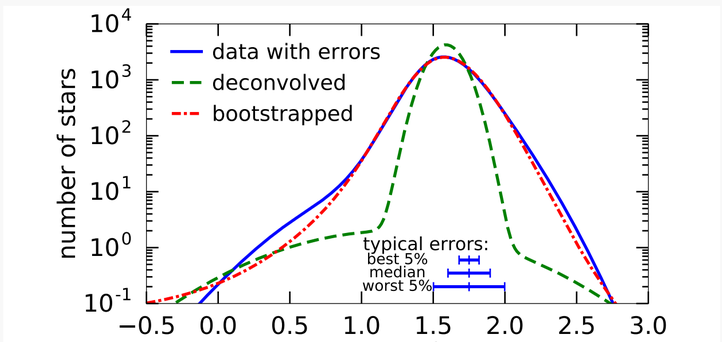

Figure 2: Obtaining the intrinsic distribution of PM

Use the *Extreme Deconvolution* approach [Bovy et al. 2011] to infer the intrinsic distribution of PM represented as a sum of two 2d Gaussians (the main sample and a small admixture of contaminants), which matches the observed distribution after being convolved with measurement errors.

3. Kinematic maps

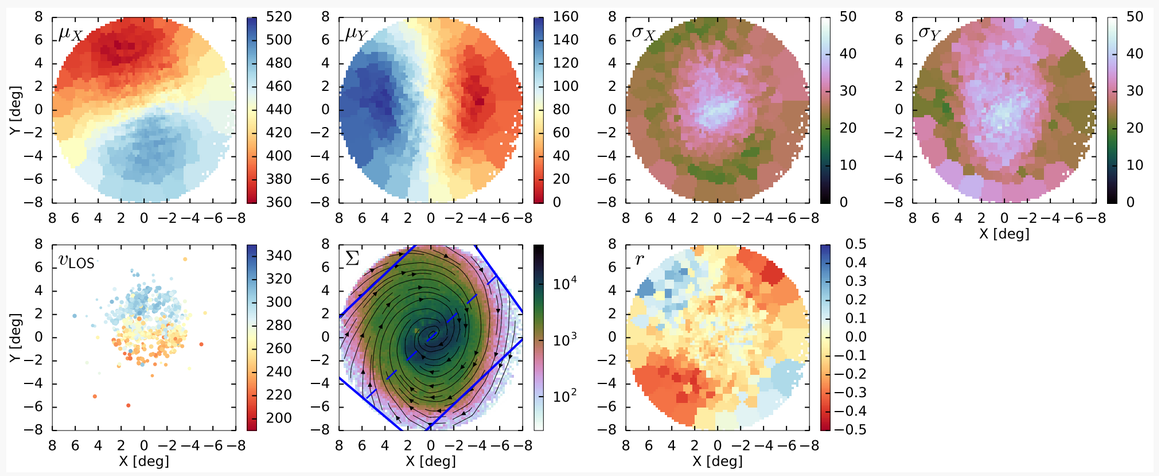

Figure 3: Kinematic maps of LMC from *Gaia* data

Top row: mean PM and its dispersion (measured in km/s; 1 mas/yr = 237 km/s assuming the distance $D = 50$ Kpc). Bottom left: individual radial velocity measurements. Bottom centre: density of sources per square degree, and streamlines of PM illustrating the effect of perspective shrinking due to the LMC line-of-sight motion away from the observer; the blue rectangle shows the orbital plane orientation, with the top-left corner being nearer. Bottom right: correlation coefficient for PM dispersions. The sources are binned into ~ 500 Voronoi bins [Cappellari&Copin 2001].

4. Models

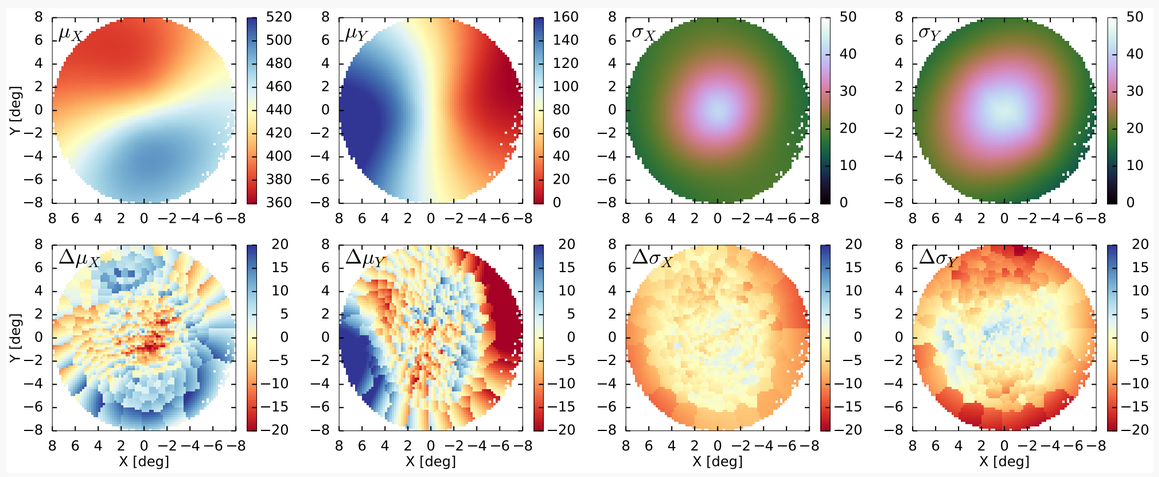

Figure 4: Kinematic maps of the best-fit JAM models (top row) and the residuals (bottom row)

- Use the Jeans anisotropic model (JAM) approach [Cappellari 2008, Watkins et al. 2013], in a new implementation allowing for arbitrary density/potential profiles and perspective corrections; exponential stellar disc + dark halo (7 free parameters).
- Complement with another approach – thin-disc models (no dynamical consistency or inference about the potential, just non-parametric velocity profiles).
- Extra 6 free parameters: distance, disc plane orientation, centre-of-mass velocity.
- Use the `emcee` code [Foreman-Mackey et al. 2013] to explore the parameter space.

5. Results: internal dynamics

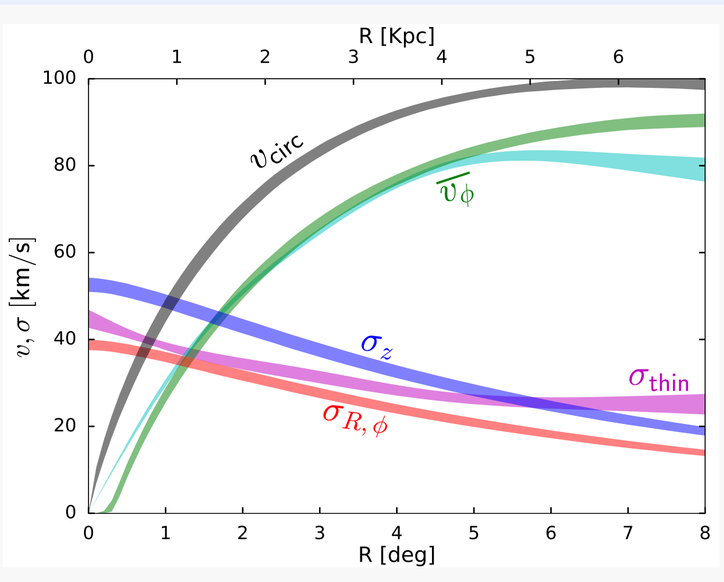

Figure 5: Internal dynamics of the models

Red and blue: radial and vertical velocity dispersion profiles in JAM; purple: isotropic velocity dispersion in thin-disc models; green and cyan: mean azimuthal velocity in JAM and thin-disc models; gray: rotation curve (circular velocity in equatorial plane) in JAM.

References

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This study: arXiv:1805.08157, submitted to MNRAS Letters.