Jeans equations in the Milky Way disc with Gaia DR3

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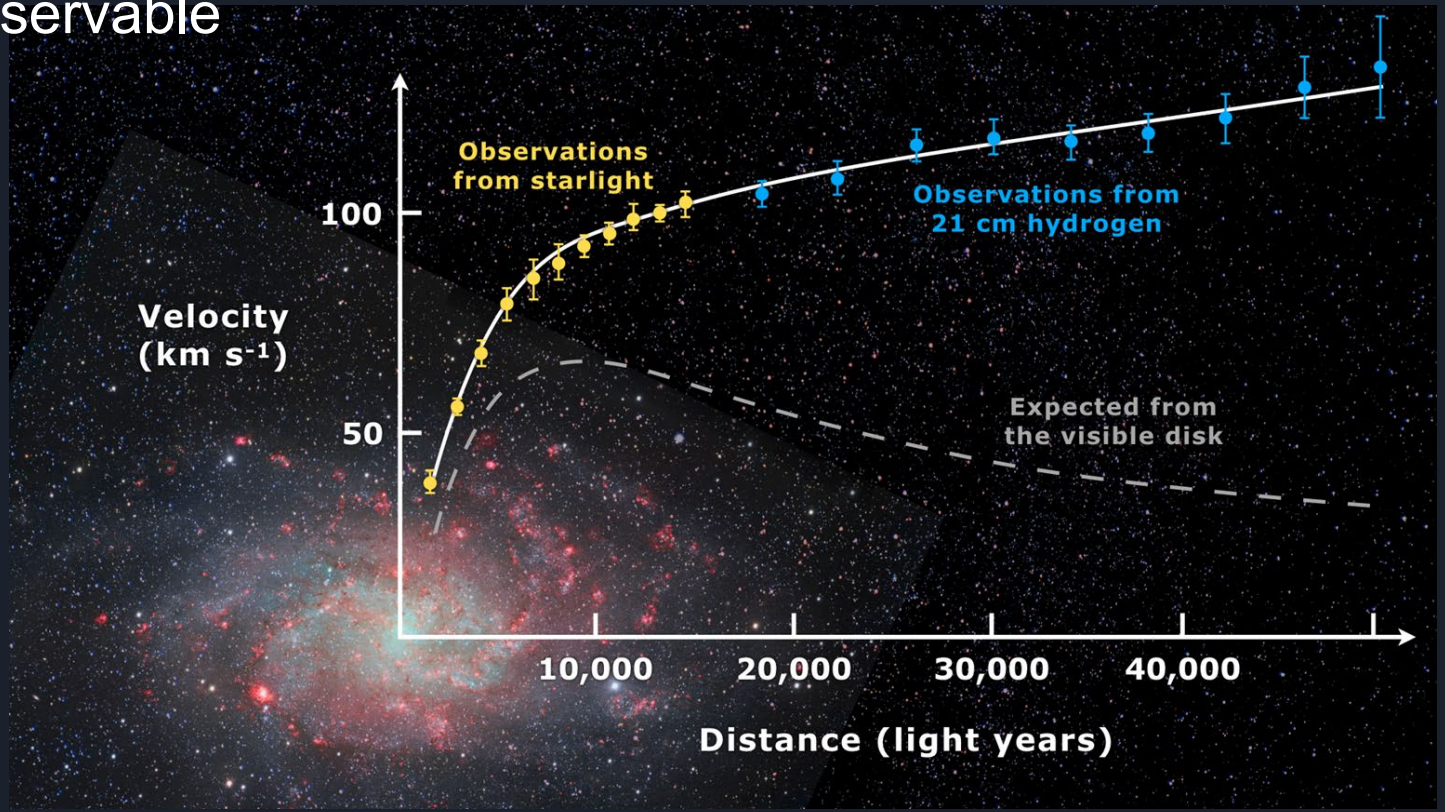
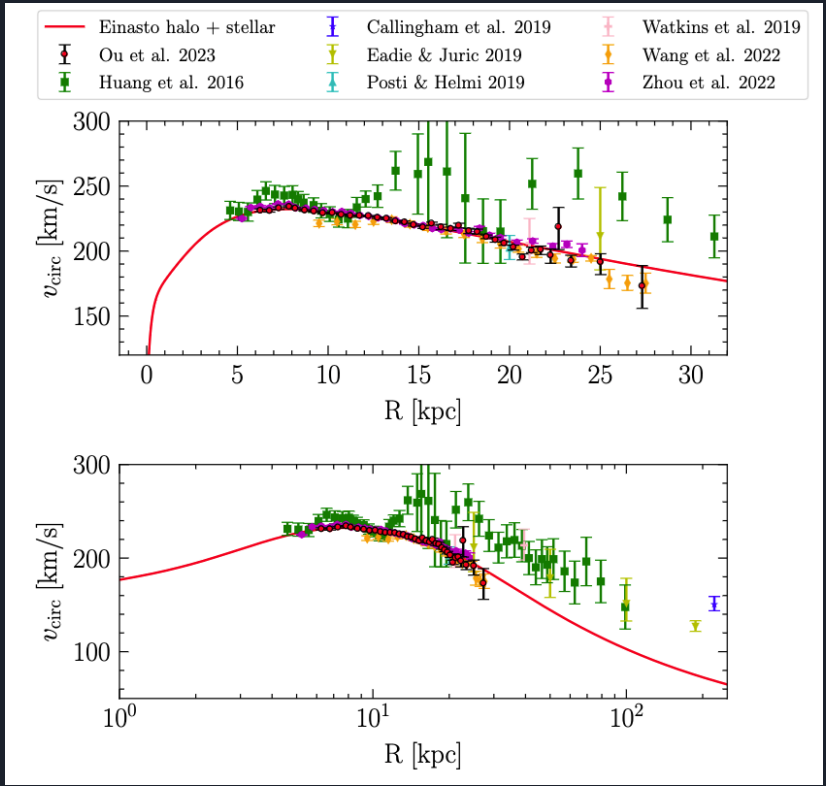
The Milky Way rotation curve is an important observable



Source: Wikipedia

Recent Work showed a declining (Keplerian) behaviour



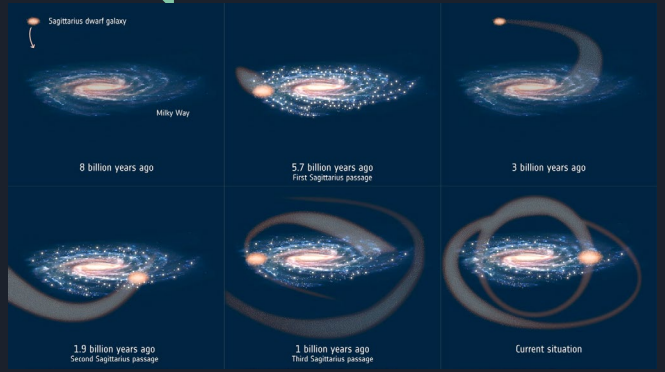
Source: Ou+23, see also Jiao+23

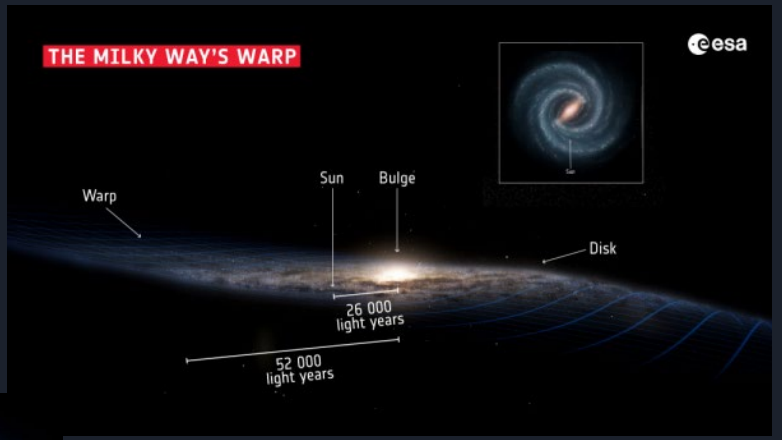
Jeans equations are used with assumptions

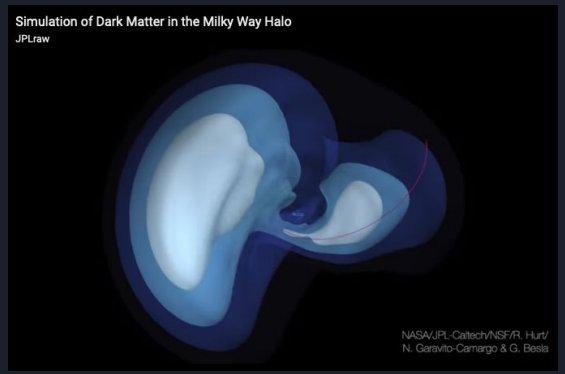
$$\frac{\partial \nu \langle v_R^2 \rangle}{\partial R} + \frac{\partial \nu \langle v_R v_z \rangle}{\partial z} + \nu \left(\frac{\langle v_R^2 \rangle - \langle v_\varphi^2 \rangle}{R} + \frac{\partial \Phi}{\partial R} \right) = 0,$$

$$v_c^2(R) = \langle v_\varphi^2 \rangle - \langle v_R^2 \rangle \left(1 + \frac{\partial \ln \nu}{\partial \ln R} + \frac{\partial \ln \langle v_R^2 \rangle}{\partial \ln R} \right).$$

The Milky Way is not symmetric nor stationary, as seen with DR3



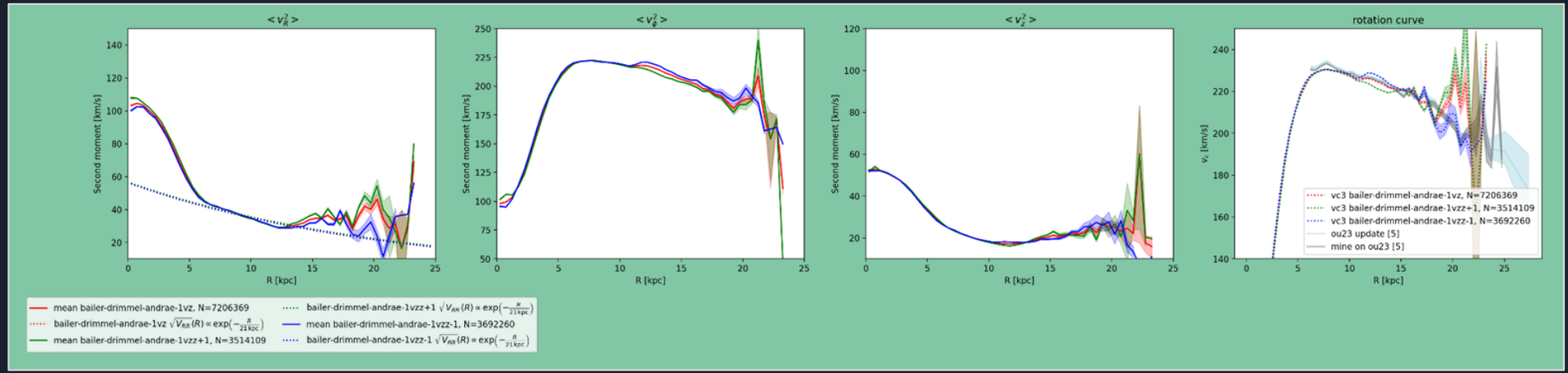




Our Goals

- Study the effect of asymmetry on Jeans equations
  - Improve on Antoja+21 and Eilers+19 with extended dataset from Gaia DR3
  - The second moments
    - Above vs Below the disk
    - Azimuthal slices
  - And through there on the rotation curve
    - Impact of neglecting the crossterm
    - Impact of other assumptions
  - Quantify the systematics
- Compare this to simulations
  - Auriga(ia)
  - Laporte+18 Sagittarius-like impact simulation
  - Quantify the offset between ‘true’ and Jeans-derived rotation curve

Gaia DR3 shows north -south asymmetry from R=11kpc



- Distances for stars from Bailer-Jones+21
- Relative error < 20%
- Only Giants (log(g) and Teff cut from Andrae+23)
- Radial bins of 0.5 kpc
- Spatial cut in |z| and azimuth as in Eilers+19 (and Ou+23)

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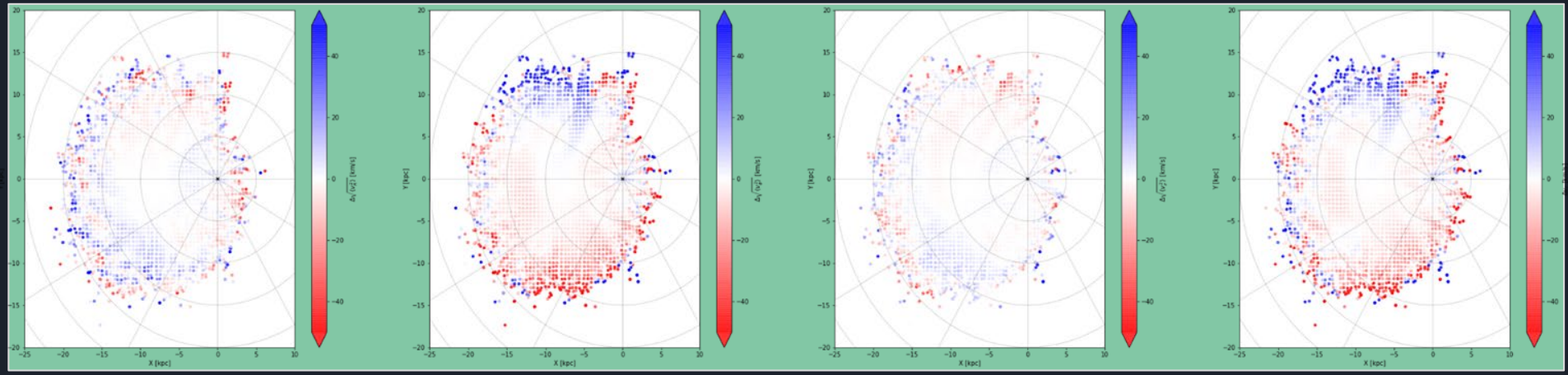

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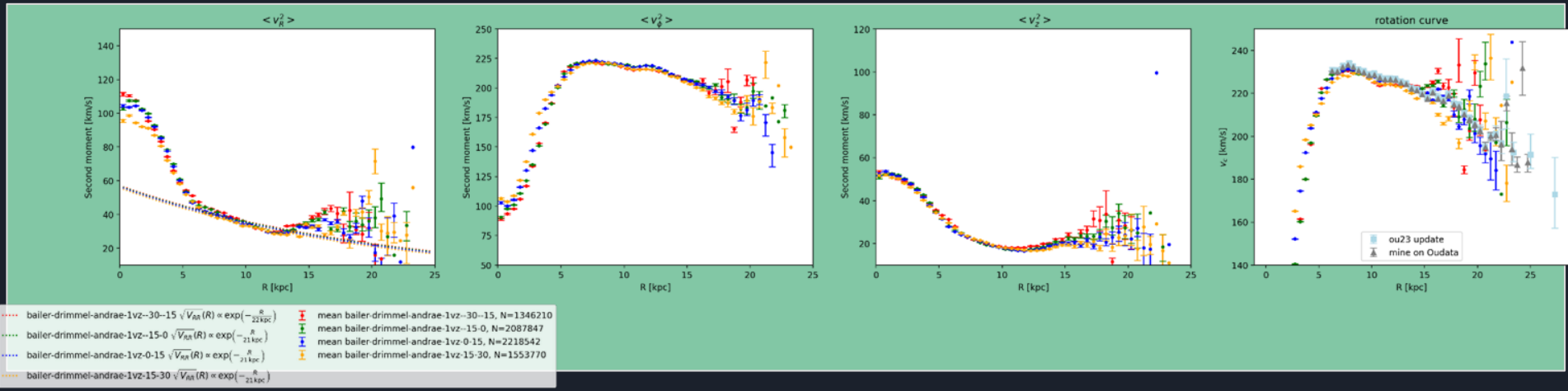
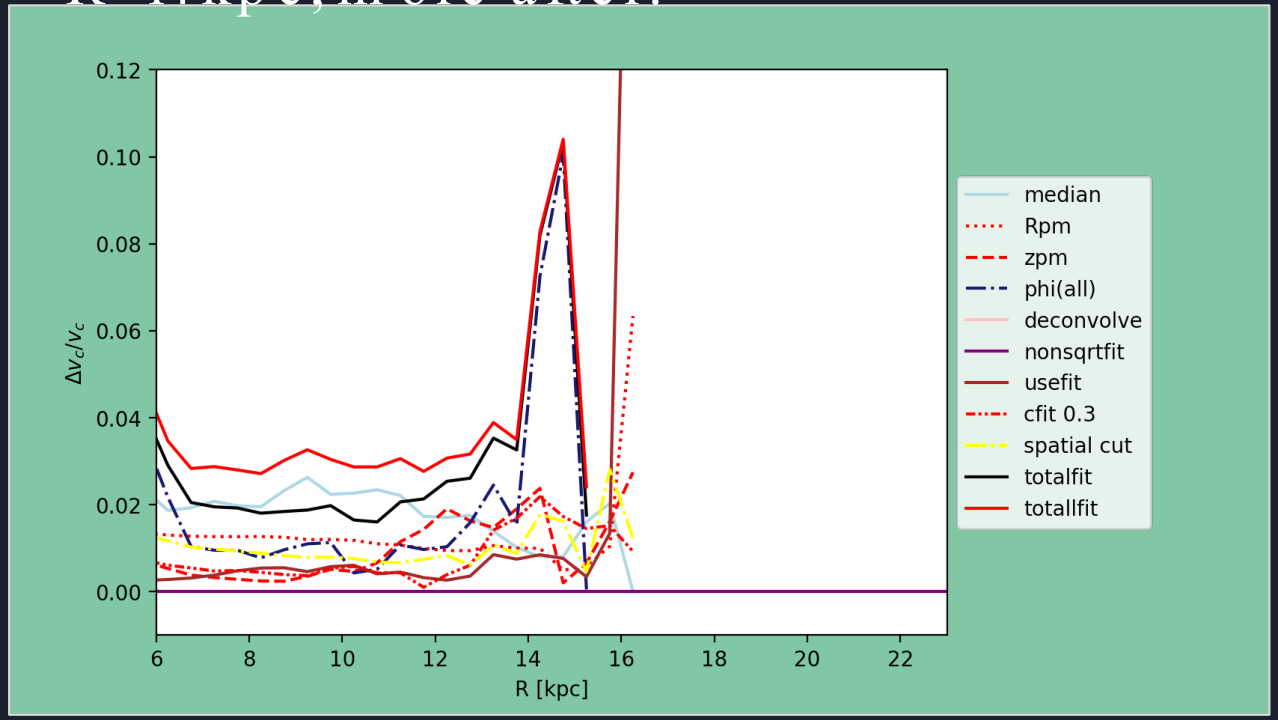
Gaia DR3 shows azimuthal asymmetry outside R=15 kpc



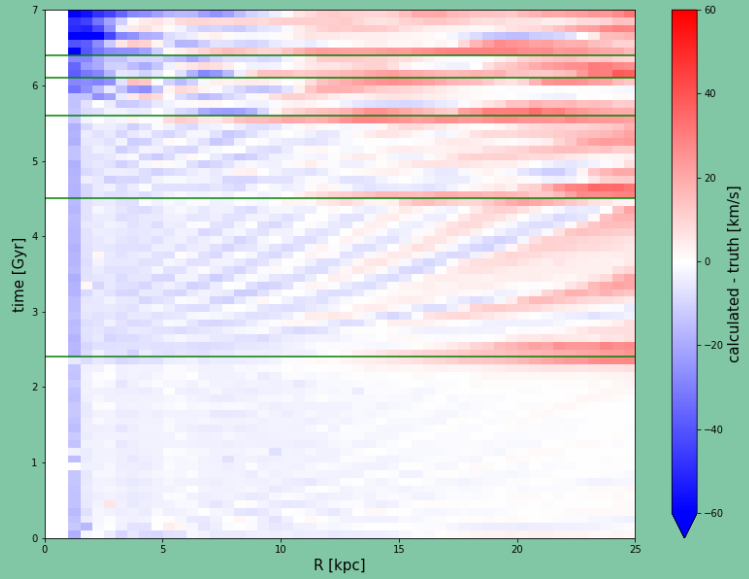
- Distances for stars from Bailer-Jones+21
- Relative error < 20%
- Only Giants (log(g) and Teff cut from Andrae+23)
- Cartesian bins of 0.5 kpc width
- Spatial cut in |z| and azimuth as in Eilers+19 (and Ou+23)

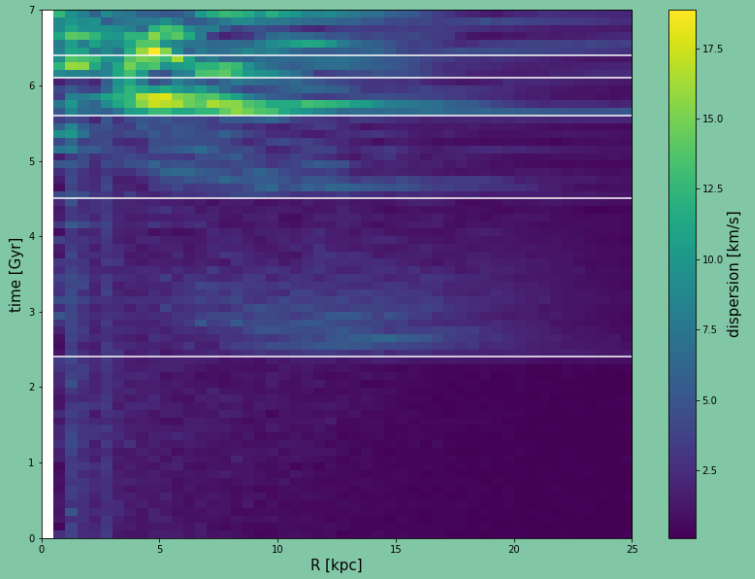
Sources of systematics add up to 5% before R=14 kpc, more after.



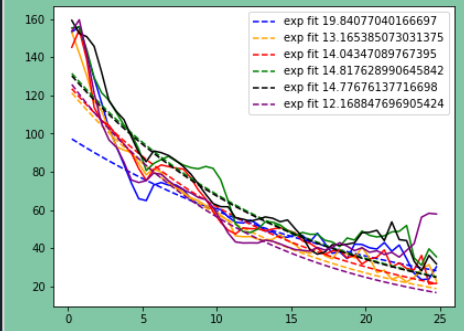
Simulation of Sagittarius -like interaction shows impact of pericenters

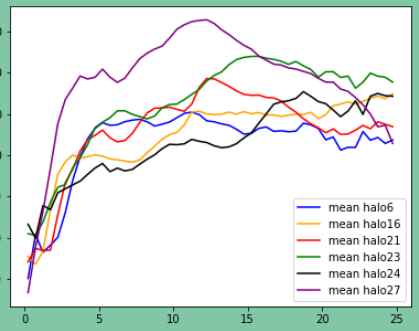
Mismatch between ‘true’ v_c and Jeans equation derived one, and intrinsic spread in v_c

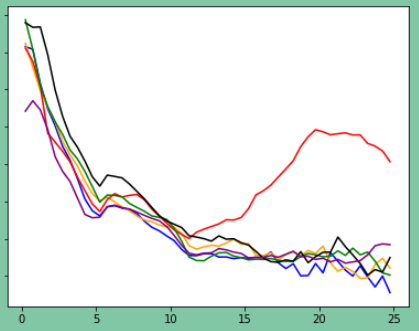


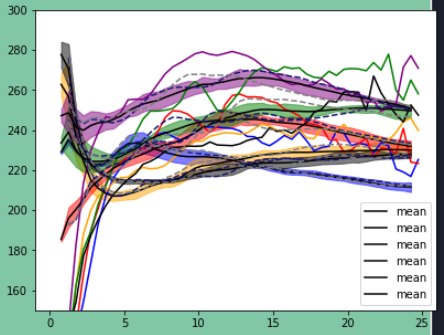


Aurigaia shows similarly perturbed profiles





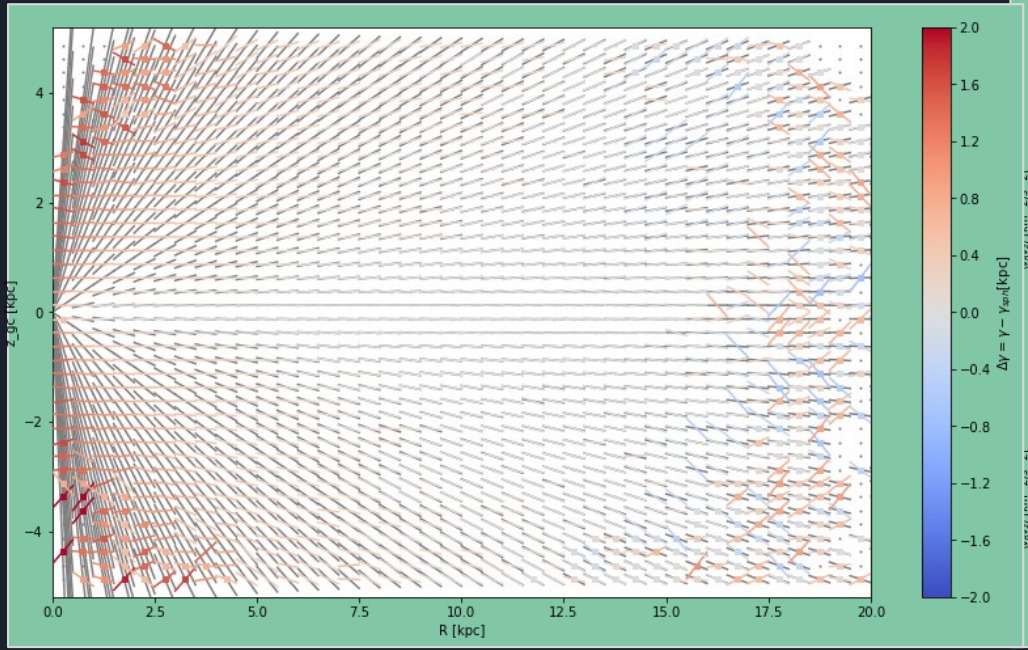


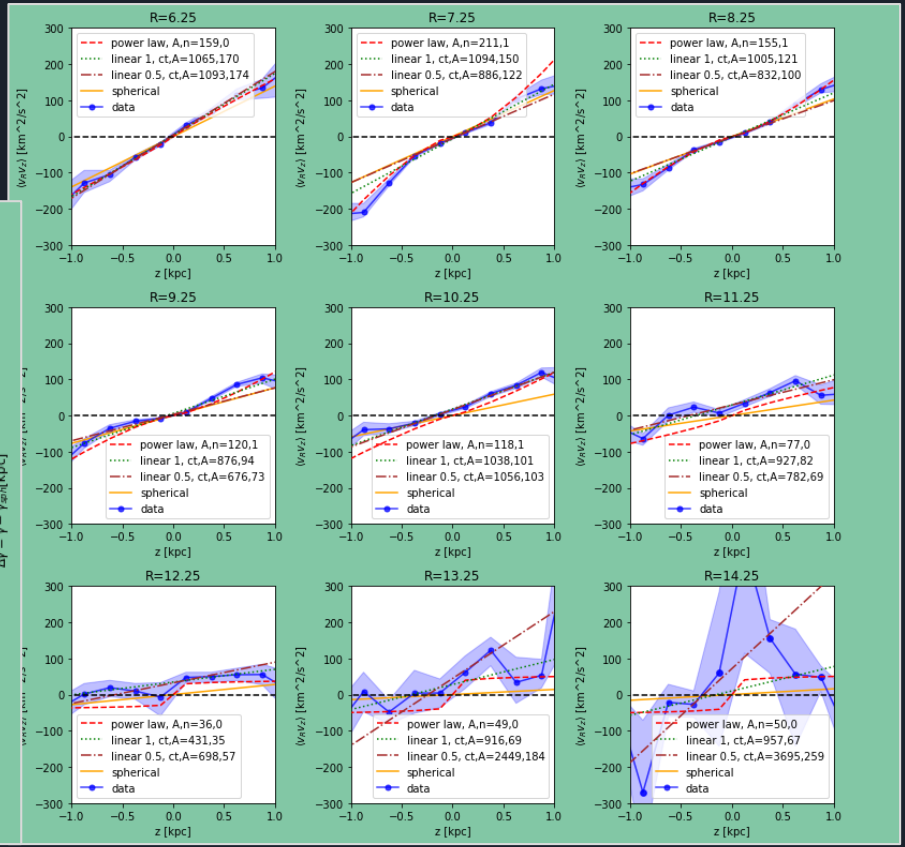


Conclusions

- Gaia DR3 data can reliably give dynamical information about the Milky Way disk within R=15kpc
  - Due to increasing measurement uncertainties, mainly in distance.
- There is asymmetry in above vs below the disk and azimuth up to 10% in the second moments
- This gives a systematic error on a Jeans-derived v_c of up to 5%.
  - V_c is also seen to be declining past R=15kpc.
  - Our v_c agrees within 2sigma with Ou+23 and Wang+22
- Similar behaviour is found in Simulations (N-body and Cosmological)
  - Pericenters of Sagittarius cause signatures like those in the observations
  - Auriga halo's also have perturbed radial profiles
  - Mismatch between 'truth' and Jeans-derived v_c can be up to 40%
  - Intrinsic variation in 'true' v_c based on azimuthal position can be up to 10%

The Crossterm





The Crossterm