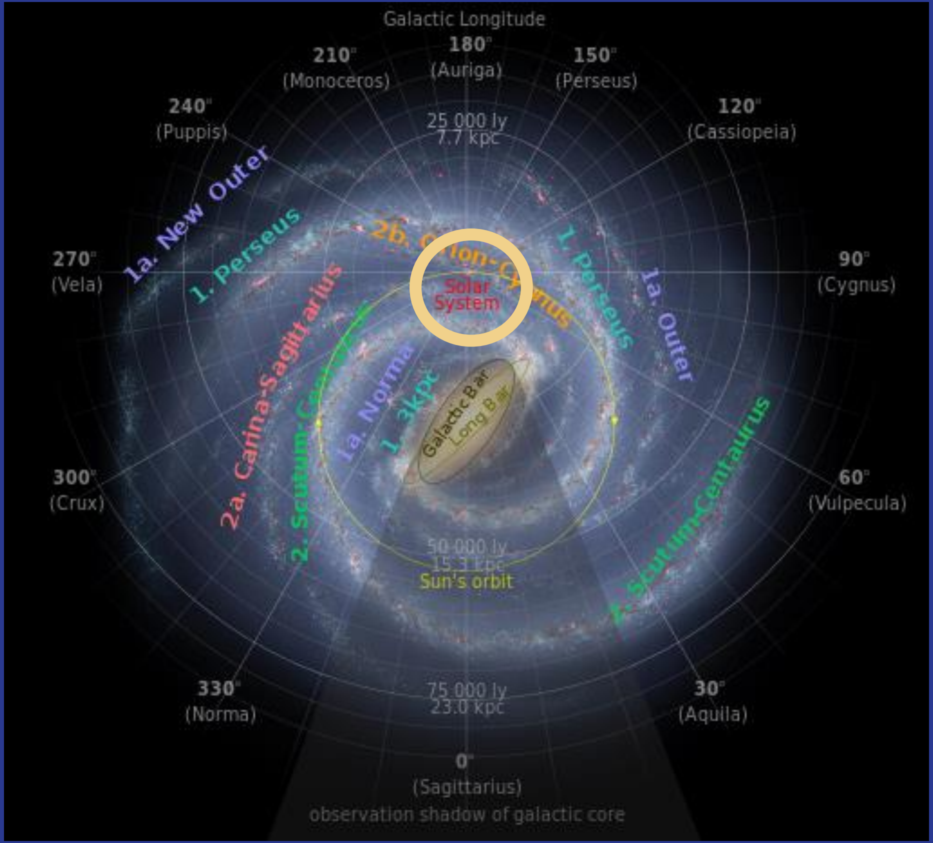
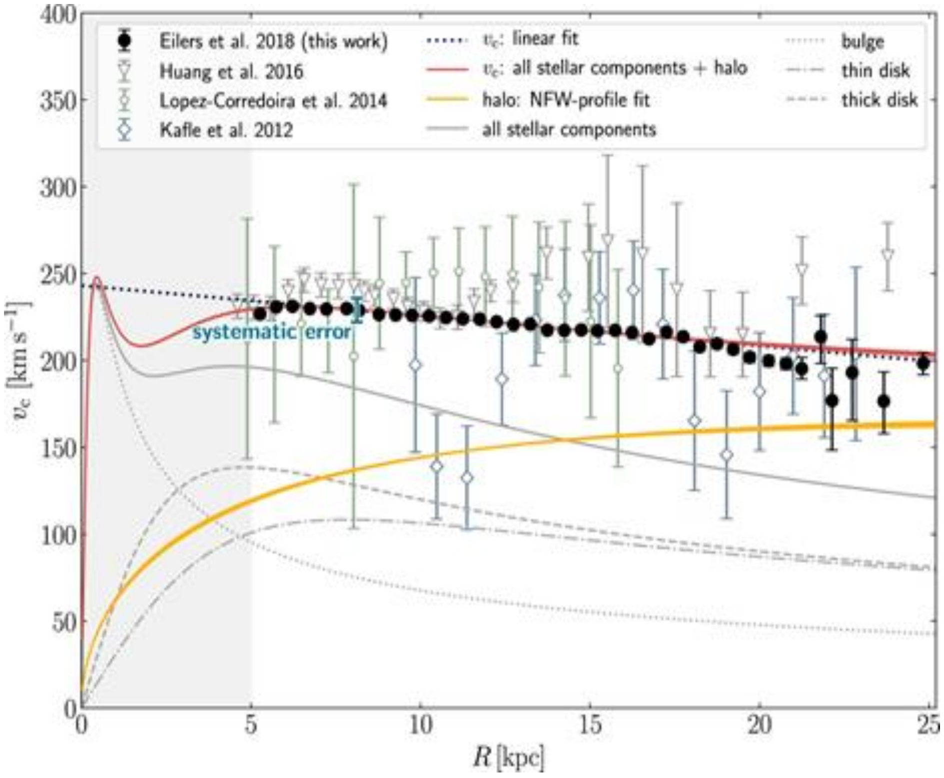


Deriving the Galactic Oort Constants from Observational Data

Shufan Xia
Advised by Karen Masters (Haverford)
& Zhaoyu Li (Shanghai Jiaotong University)



The red line shows the overall rotation curve

The Milky Way rotation curve tells us a lot about our Galaxy.

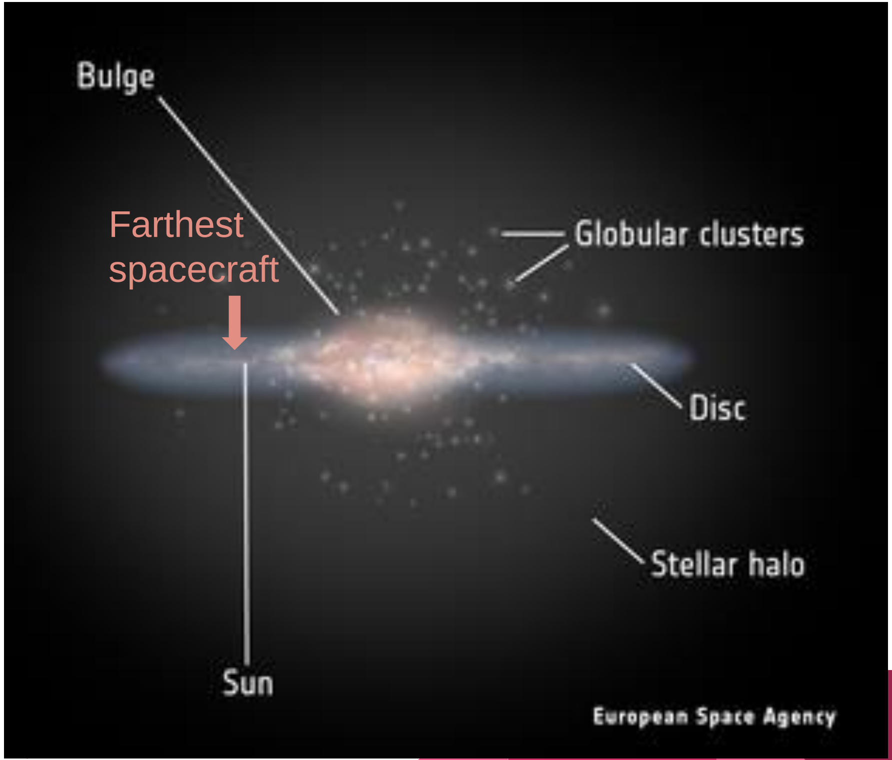
$$v_{circ}(R)$$

- Differential rotation
- MW potential
- Mass distribution: existence of dark matters

We have multiple methods to meaure the rotation curve, but it is hard due to observation constraints.

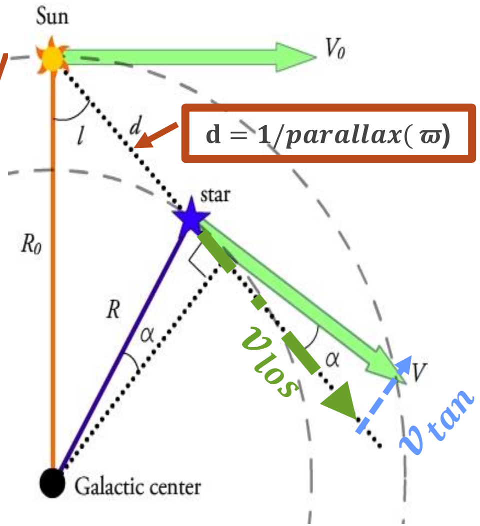
- Radial velocity of atomic hydrogen (HI) and CO emission (tangent point method); classical Cepheids; RR lyrae.

- Observation constraints because of our location in the MW:
    - 1) co-moving with MW;
    - 2) we can only see one side of the MW;
    - 3) dust and gas block our line of sight.



The Oort Constants are local traceres of the Galactic kinematics.

The Oort Constants describe the local rotation in the solar vicinity



Assume circular orbits and axis-symmetric potential

Expanding local velocity field for radial velocity(v_r) and proper motion ($\mu = \frac{v_{tan}}{d}$):

$$\boxed{\frac{v_r}{d} \propto sin(2l) \qquad \mu_l \propto cos(2l) \qquad \mu_b \propto sin(2l)}$$

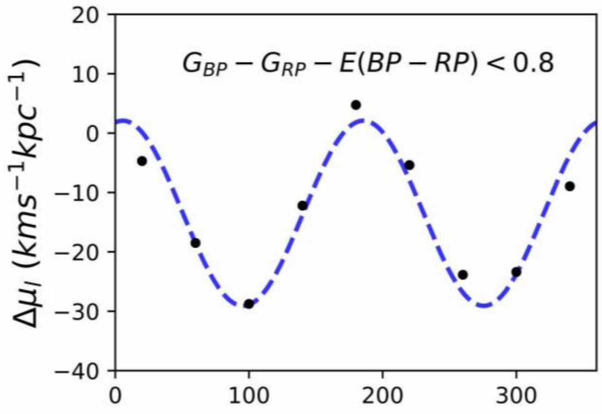
The full equations need 4 constants:

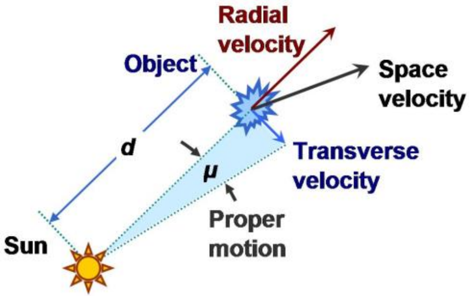
A -- azimuthal shearing, B-- vorticity,

C -- radial shearing, K-- divergence

Sun's non-circular motion adds single

sine (and cosine) terms





The Oort constants and the MW rotation curve

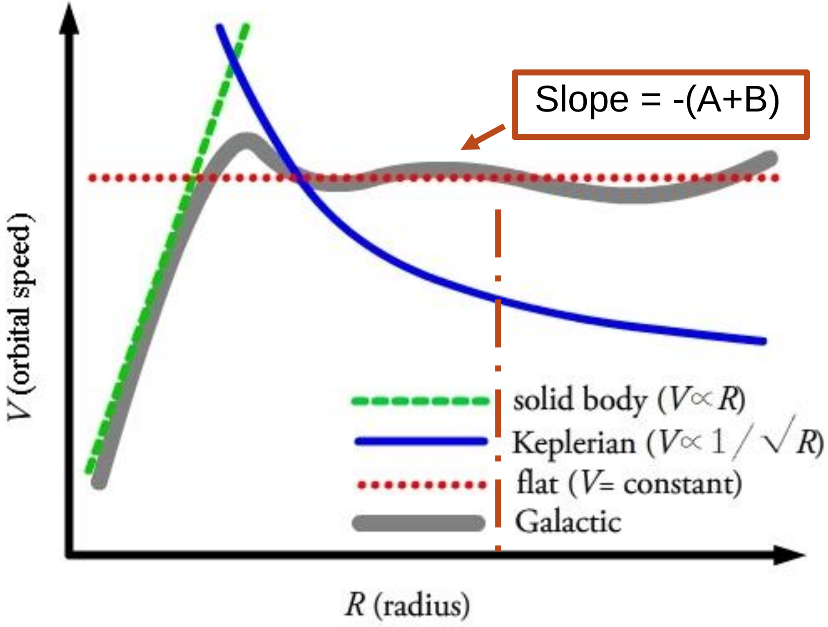
- The slope of the local rotation curve can be written in terms of A and B.

$$A = \frac{1}{2}\left(\frac{v_{circ}}{R_\odot} - \frac{dv_{circ}}{dr}\Big|_{R_\odot}\right)$$

$$B = -\frac{1}{2}\left(\frac{v_{circ}}{R_\odot} + \frac{dv_{circ}}{dr}\Big|_{R_\odot}\right)$$

- The Oort constants can be used to test different rotation models.

- The Oort constants give us $R_\odot, v_{circ\odot}$ and ellipticity

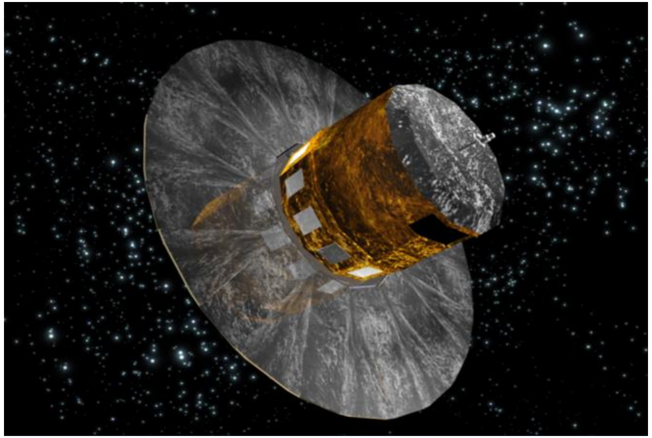


Constraints and influencing factors

- Requires a massive proper motion catalogue for stars just distant enough and enough sky coverage.
- Non-axisymmetric potential adds ellipticity to circular orbits.
- Spiral arms add streaming motions and random motions.
- Systematic error from non uniform distribution of parallax over longitudinal.

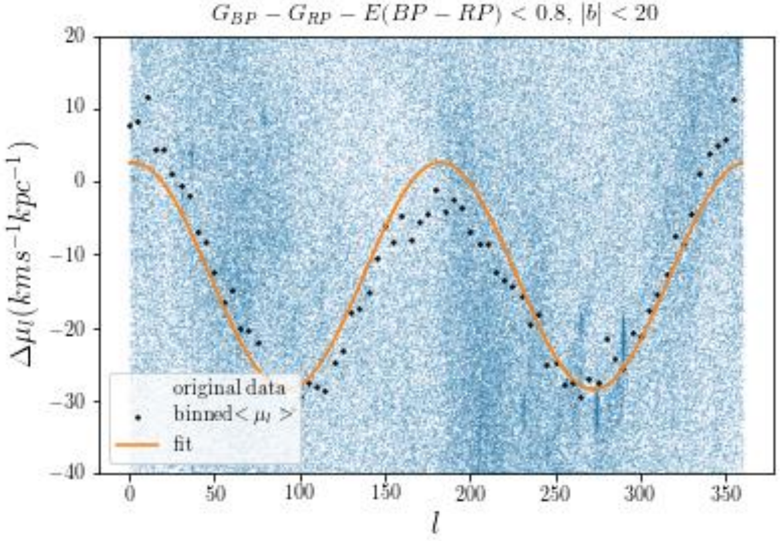
Gaia DR 2 has proper motion measurements of nearly 1.7 billion stars

- Gaia makes it possible to look at fine local kinematic features
- Previous studies of Oort constants: radial velocity unused, patterns due to individual sample not included, sampling limits without much justification.



*This December, *Gaia EDR3,* >1.8 billion stars

Preliminary result of μ_l using Gaia DR2 shows interesting over-dense regions and lower than expected peak at 180degree.



My plan

Goal:

- What is the best sample of stars to carry out Oort constants derivation
- Determine the deviation of Gaia observational results from theoretical model

How:

- Derive Oort constants from ***Gaia*** DR2
- Study the overdense regions and deviation from double sine curves
- Use a toy model simulation to find at what latitude and parallax the Oort constants analysis is appropriate

Summary

- Rotation curve tells us about the potential and mass distribution of the MW.
- It is not easy to measure rotation curve.
- Oort constants describe local rotation motion, but can be used to test rotation models and determine other galactic parameters.
- Gaia makes it possible to determine Oort constants to higher precision
- I wil derive the Oort constants from ***Gaia*** data and examine the sampling limits.

Acknowledgement

- Prof. Karen Masters
- Dr. Zhaoyu Li and Dr. Juntai Shen from Shanghaijiaotong Univeristy

Image Sources

Artist’s impression of the Milky Way: NASA/JPL-Caltech/R. Hurt (SSC/Caltech), https://solarsystem.nasa.gov/resources/285/the-milky-way-galaxy/
Artist’s impression of Gaia:European Space Agenecy, https://www.esa.int/ESA_Multimedia/Images/2006/05/Artist_s_impression_of_the_Gaia_satellite
Rotation curve: Eilers, A.-C., Hogg, D. W., Rix, H.-W., & Ness, M. K.2019, ApJ, 871, 120, doi: 10.3847/1538-4357/aaf648
Galactic coordinate: COSMOS - The SAO Encyclopedia of Astronomy
Geometry of a differentially rotating disc: Wikipedia – Oort constants
Different rotation curve: Wikipedia - Oort constants
Proper motion: Wikipedia – proper motion
Longitude proper motion: Li, C., Zhao, G., & Yang, C. 2019, ApJ, 872, 205, doi: 10.3847/1538-4357/ab0104

Key equations

Rotational velocity and radial velocity:

$$v_r = (v_{circ} - v_{circ})R_{\odot} sinl$$

$$\begin{cases} v_r = d(K + Ccos2l + Asin2l) \\ \mu_l = (Acos2l - Csin2l + B)cosb + \boxed{\varpi(u_0 sinl - v_0 cosl)} \\ \mu_b = -(Asin2l + Ccos2l + K)sinbcosb \\ \qquad \boxed{+\varpi((u_0 sinl + v_0 cosl)sinb - w_0 cosb)} \end{cases}$$

Correction for Sun’s random motion (u0,v0,w0) deviated from circular orbit