Project Presentation

The Art of Astrometry and Computation

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MWGaiaDN

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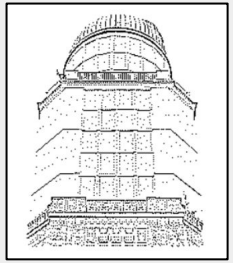
TECHNISCHE UNIVERSITÄT DRESDEN



Astrometric Properties of Gaia Quasars

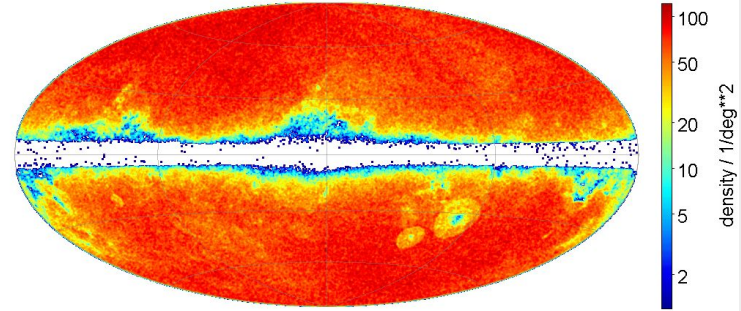
Motivation:

- QSOs are used to fix the orientation and rotational state of motion of the Gaia catalogue (Gaia-CRF).

- Can be used to trace the systematic errors of Gaia astrometry.

Research Objectives:

- To investigate possible problems in the astrometry of Gaia quasars.



Sky distribution of the Gaia-DR3 (~1.9 million) QSOs.

- Introduce an astrometric source quality index for each QSO candidate.

Present work

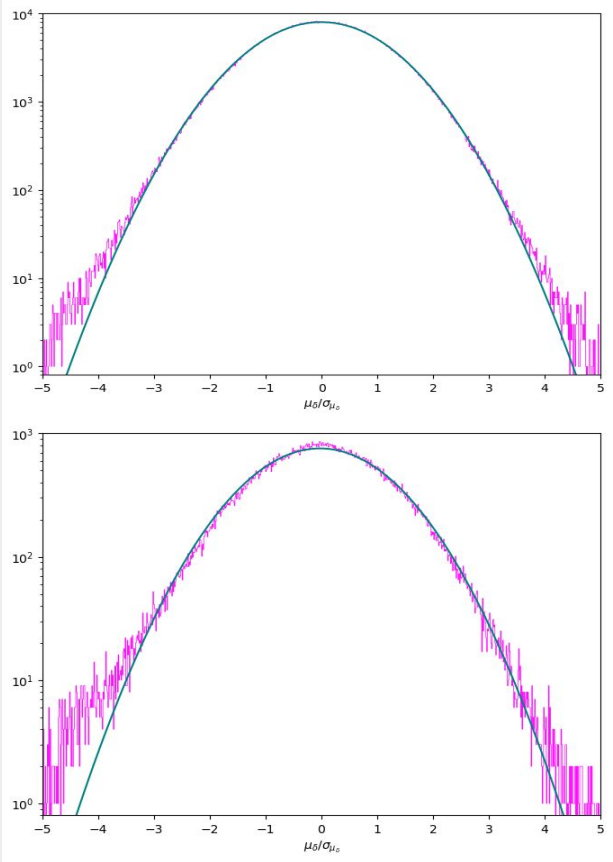
- Identify the subsamples of lower astrometric quality of QSOs from the 1.9 million astrometrically well-behaving QSOs (astrometric selection) found in Gaia DR3 based on source parameters.

Assumptions:

- The true parallaxes and proper motions of the QSOs are statistically zero.

Results:

- The statistical distribution of the normalized parallaxes and proper motion components of various subsamples of QSO candidates characterize possible stellar contamination and problems with Gaia astrometry.



Distributions of the normalized proper motion in declination for a sample of Gaia DR3 QSO candidates that :
i. are classified as quasars by the Gaia modules.
ii. are not classified as quasars by the Gaia modules.

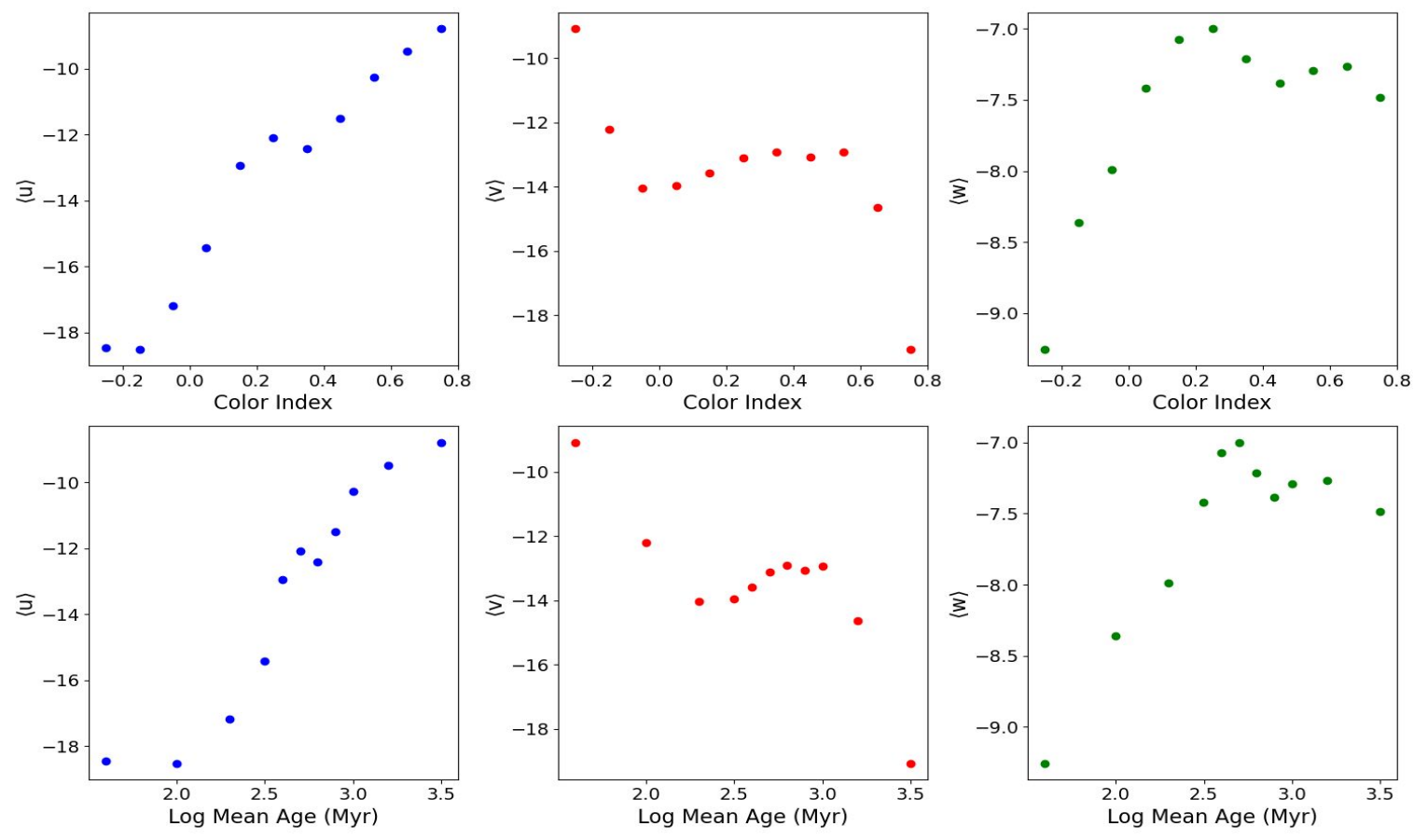
Project 1

Purpose:

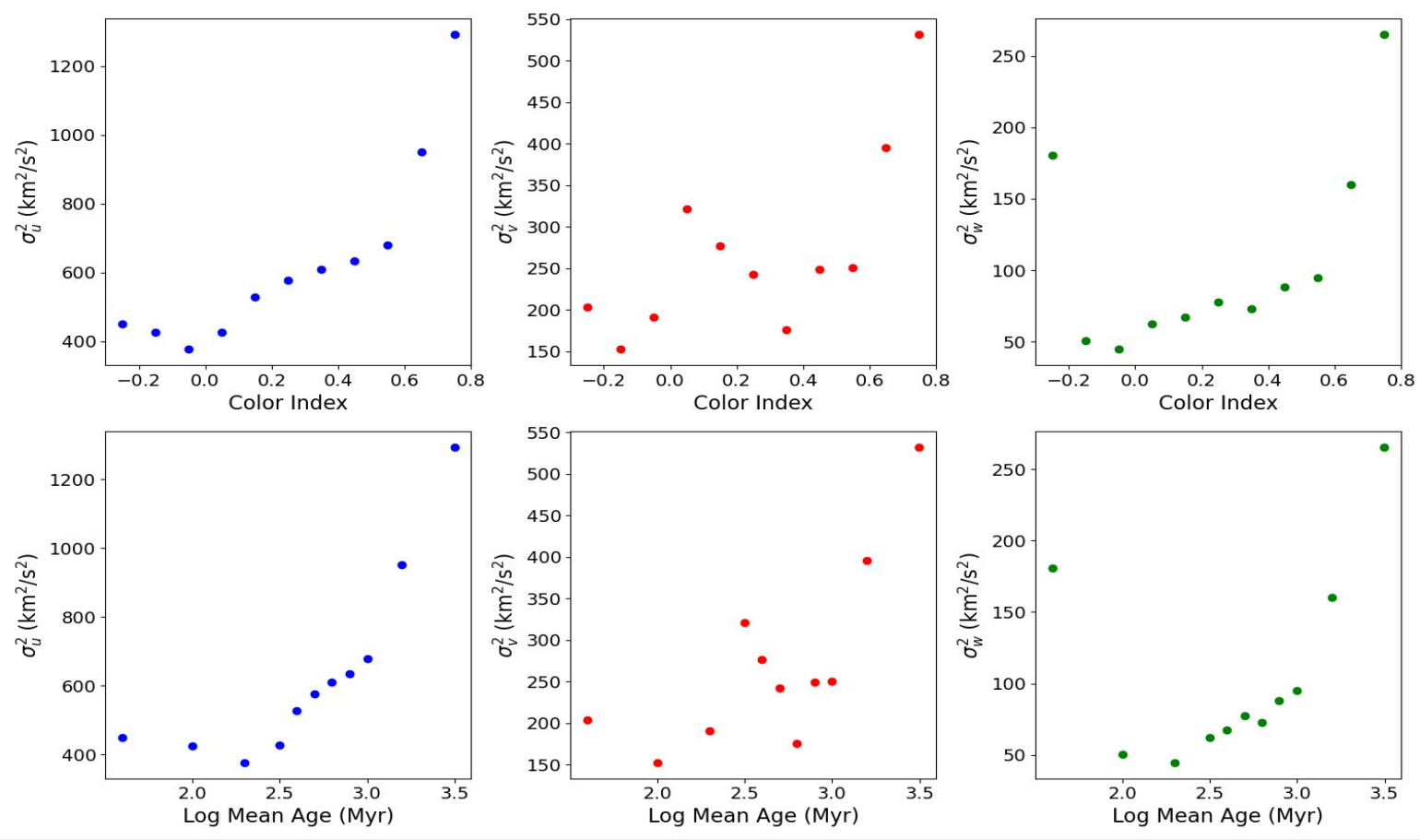
- Estimate the mean velocity and velocity dispersion of nearby stars as functions of their ages, and derive the velocity of the Sun relative to the Local Standard of Rest (LSR).
- Draw some conclusions about disk kinematics and properties of the galactic potential.
- Use data from the Gaia catalogue.

Results

Plot 1 Mean Velocities and Velocity Dispersions as Functions of Color Index and Log Mean Age



Plot 2 Velocity Dispersions as Functions of Color Index and Log Mean Age



Discussion

The plots provide insights into how the mean velocities (u, v, w) and velocity dispersions vary with color index and log of mean age.

Conclusions:

- The increasing trends in velocity dispersions with both color index and log mean age indicate that older stars and stars with higher color index have higher velocity dispersions. This is consistent with the theory of disk heating where stars gain velocity dispersion over time due to gravitational interactions.

- The increase in mean velocities with age and color index might be attributed to the asymmetric drift and the kinematic heating processes in the Galactic disk.

Question 3

Predicted value:

Mean ratio of σ_v^2/σ_u^2: 0.4436142450489774

Theoretical value:

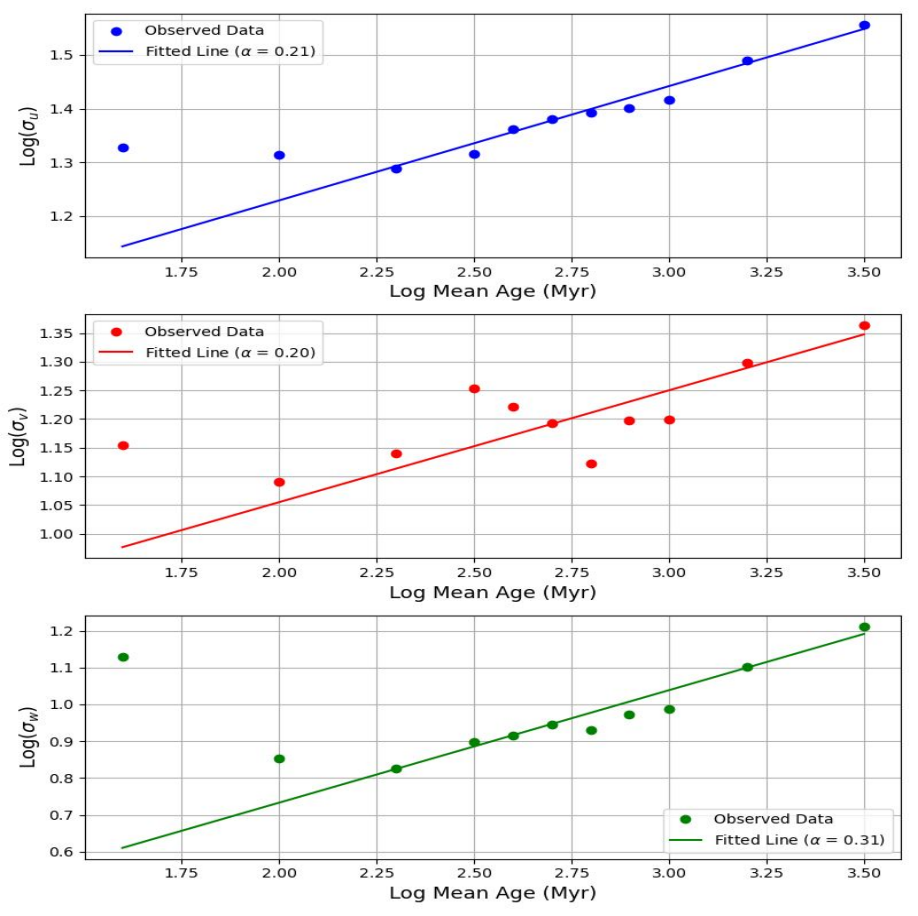
$$\frac{\sigma_v}{\sigma_u} = \sqrt{\frac{-B}{A-B}} \approx \frac{1}{1.47}$$

~ 0.6802721088435374

Relative error ~ 0.3478

The ratio obtained from the data should be close to the theoretical value to validate the epicycle theory.

Plot 4


Observed Data
Fitted Line (α = 0.21)
Log(σ_U)
Log Mean Age (Myr)
Observed Data
Fitted Line (α = 0.20)
Log(σ_V)
Log Mean Age (Myr)
Observed Data
Fitted Line (α = 0.31)
Log(σ_W)
Log Mean Age (Myr)

Discussions

Stellar Disk Heating: Power Law Relation

- The velocity dispersions as functions of the mean age can be described by a power law:

$$\sigma \propto T^{\alpha}$$

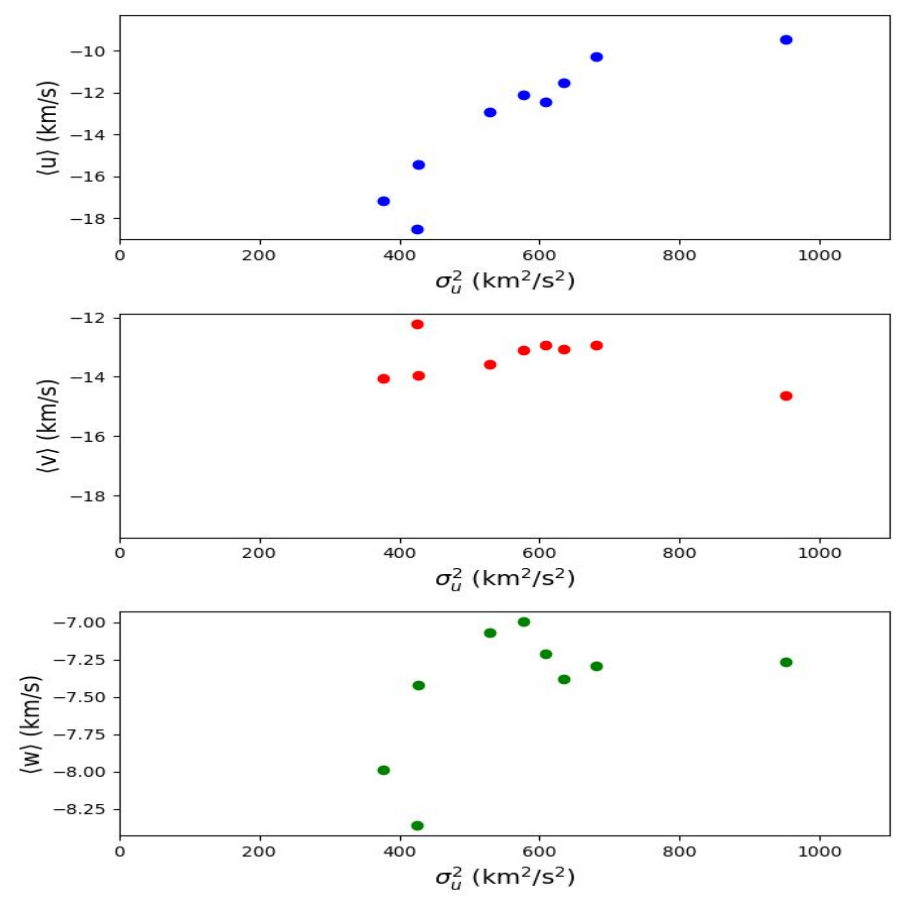
- From the log-log plots:
  - $\alpha \approx 0.21$
  - $\alpha \approx 0.20$
  - $\alpha \approx 0.31$

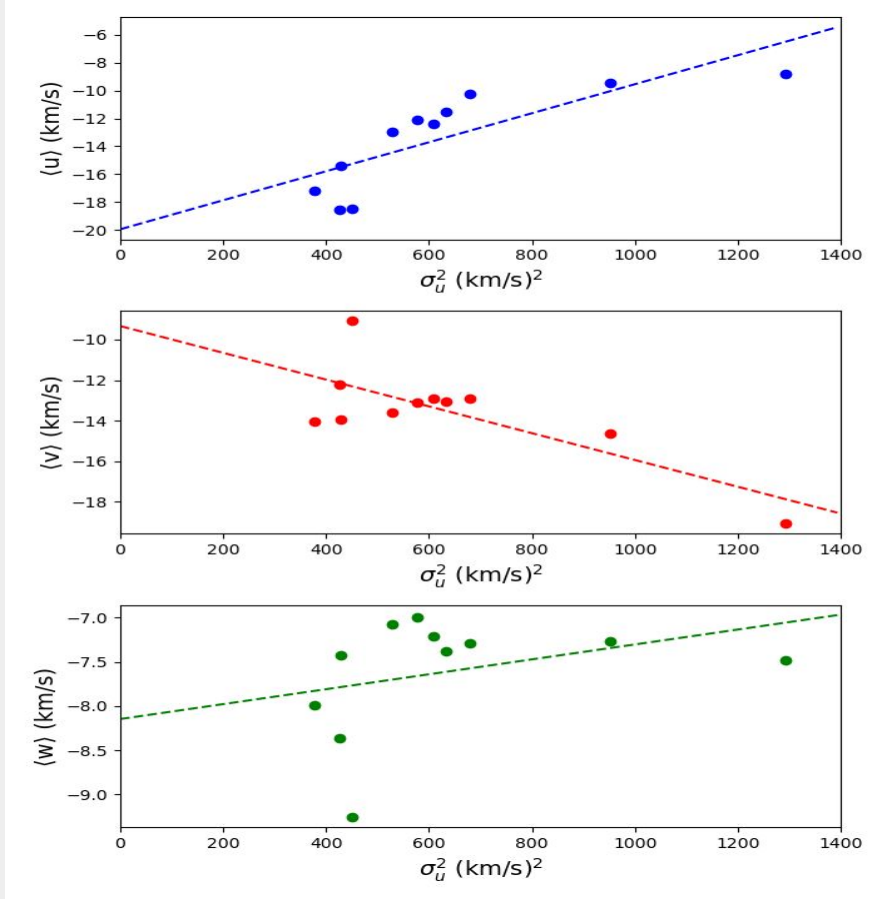
Conclusions:

- The values of α suggest that the heating mechanisms affect the velocity dispersions differently in different directions. The values are consistent with typical observations where α ranges between 0.2 to 0.4, indicating that disk heating occurs over time.

- The positive slopes indicate that the velocity dispersions increase with age. This is consistent with the theory that older stellar populations tend to have higher velocity dispersions due to accumulated perturbations and interactions over time.

Plot 5


⟨u⟩ (km/s)
−10
−12
−14
−16
−18
0
200
400
600
800
1000
σ_u^2 (km^2/s^2)
⟨v⟩ (km/s)
−12
−14
−16
−18
0
200
400
600
800
1000
σ_u^2 (km^2/s^2)
⟨w⟩ (km/s)
−7.00
−7.25
−7.50
−7.75
−8.00
−8.25
0
200
400
600
800
1000
σ_u^2 (km^2/s^2)


⟨u⟩ (km/s)
−6
−8
−10
−12
−14
−16
−18
−20
0
200
400
600
800
1000
1200
1400
σ_u^2 (km/s)^2
⟨v⟩ (km/s)
−10
−12
−14
−16
−18
0
200
400
600
800
1000
1200
1400
σ_u^2 (km/s)^2
⟨w⟩ (km/s)
−7.0
−7.5
−8.0
−8.5
−9.0
0
200
400
600
800
1000
1200
1400
σ_u^2 (km/s)^2

Discussions

- The asymmetric drift equation relates the mean velocities to the velocity dispersions:

Conclusions:

- The negative correlation of ⟨v⟩ with σu2 confirms the asymmetric drift theory.
- The velocities relative to the LSR can be derived from the intercepts of these relations.
- The Sun’s velocity relative to the LSR and the galactocentric velocity can be estimated using these values.

Calculated values

Heliocentric Velocity of the LSR:

$(-19.03, -10.25, -7.72)$ km/s

Sun's Velocity Relative to the LSR:

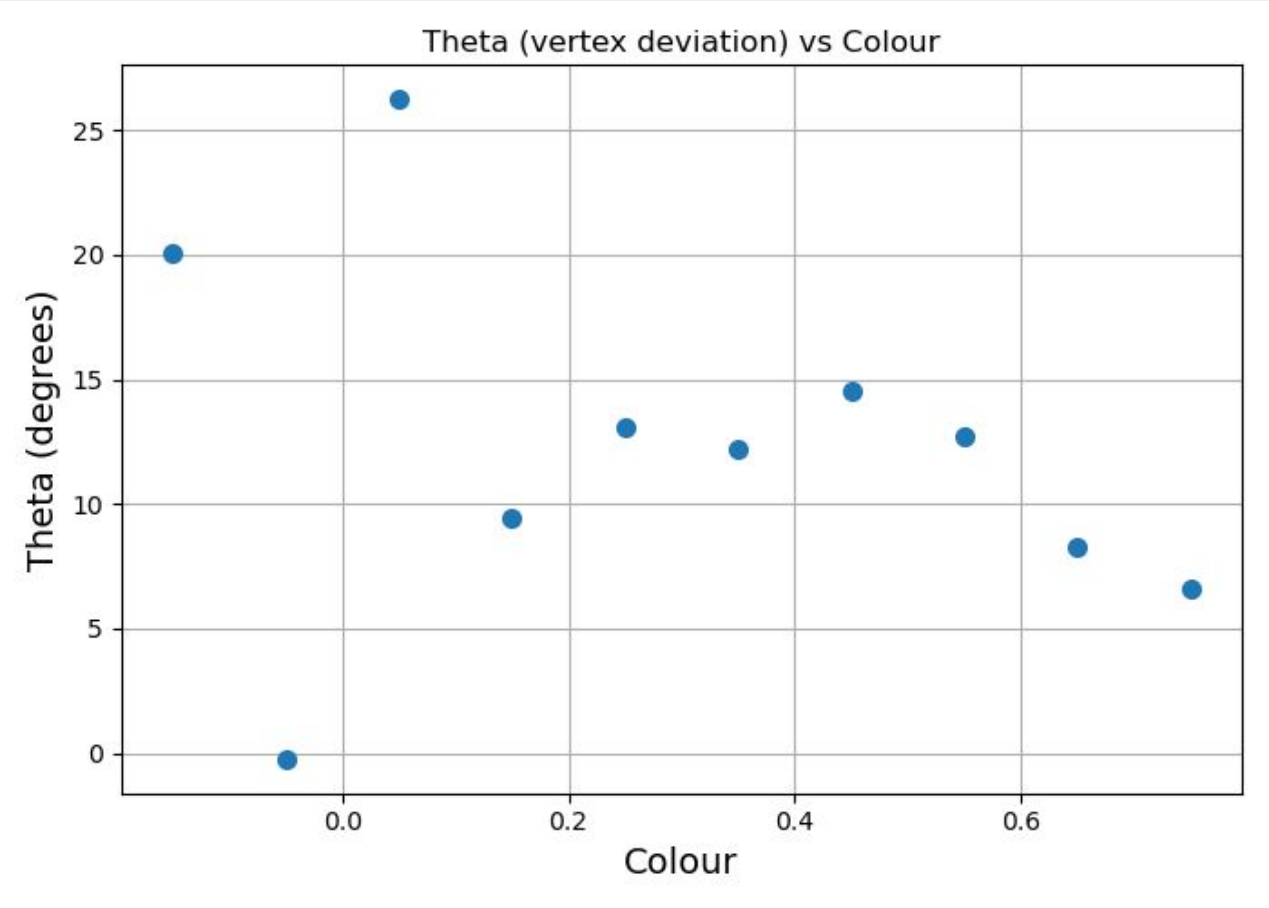
$(19.03, 10.25, 7.72)$ km/s

Galactocentric Velocity of the Sun:

$(19.03, 230.25, 7.72)$ km/s

The extrapolated values indicate a slightly different heliocentric velocity of the LSR and corresponding Sun's galactocentric velocity.

Plot 6


Theta (vertex deviation) vs Colour
Theta (degrees)
25
20
15
10
5
0
0.0
0.2
0.4
0.6
Colour

Discussions

Vertex Deviation as a Function of Color

- The vertex deviation θ is expected to be zero for an axisymmetric potential.
- The plot shows deviations from zero, indicating non-axisymmetric components in the galactic potential.

Conclusions:

- The consistent deviations from zero suggest that the Galactic potential is not perfectly axisymmetric and there are perturbations.
- The decrease in vertex deviation with redder colors indicates that older stars have more circular orbits, as younger, bluer stars show more deviation due to less settled orbits.

Exercise 1

Compute the orbits of M4 stars over a MW potential.