Traceback Age of the Tucana-Horologium Association

Dominic Couture

May 7th, 2024

ESO/Digitized Sky Survey 2

Institut Trottier de recherche sur les exoplanètes
Trottier Institute for Research on Exoplanets

espace pour la vie planétarium montréal

CRAQ
Comprendre l'Univers
Understanding the Universe

Université de Montréal

Nearby Young Associations (NYAs)

- Stellar associations formed by the collapse of a molecular cloud
- Members are the same age, and have similar chemical composition and kinematics
- Gravitationally unbound, members follow independent galactic orbits

ESO / APEX

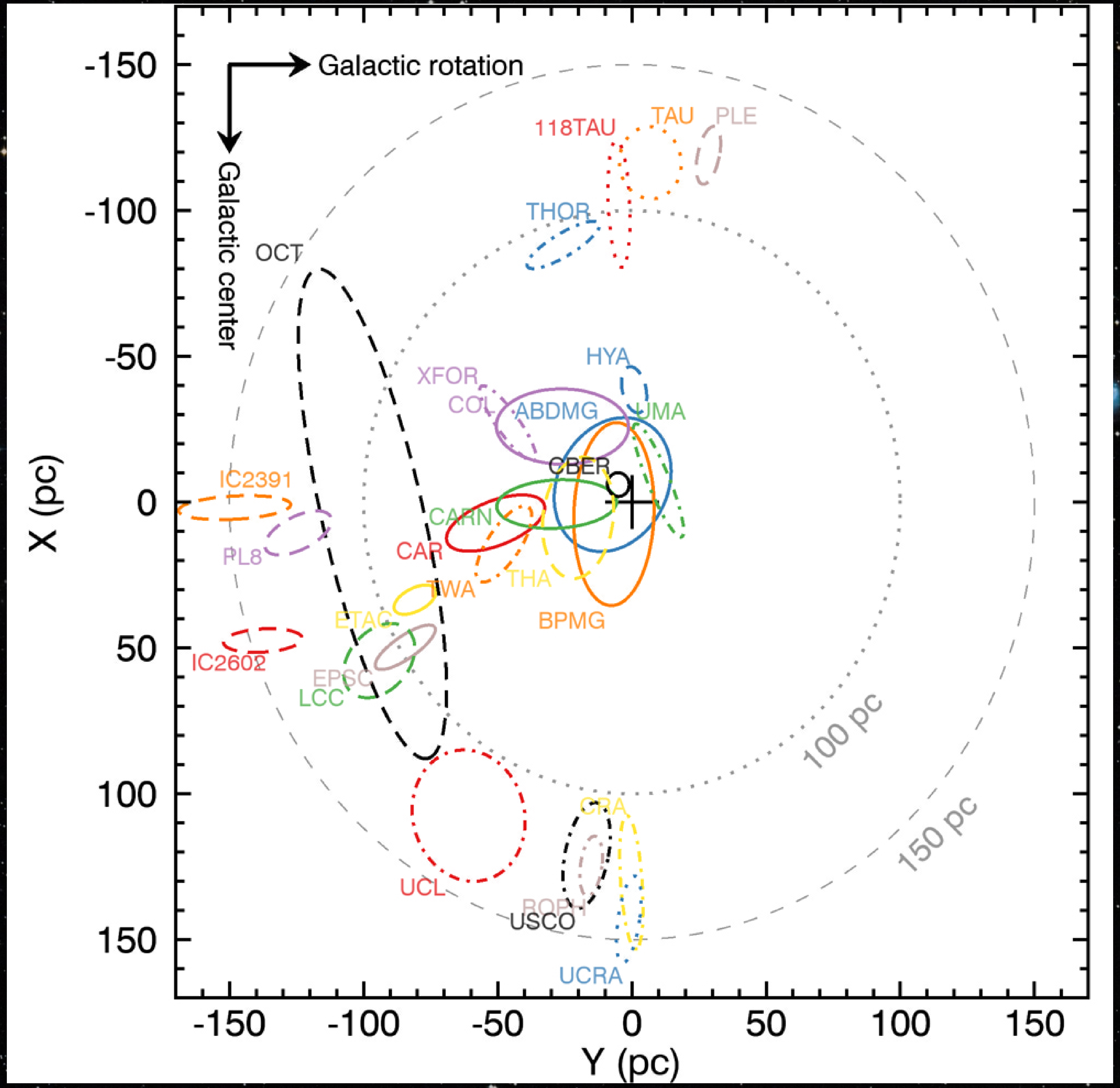
Nearby Young Associations (NYAs)

- Nearby (< 150 pc) and young (< 150 Myr)

- Young M dwarfs with known age are prime targets for the search and characterization of exoplanets

  - Better contrast and seperation for direct imaging for young planets around nearby dim stars

  - Stronger planetary transit signal for M dwarfs



Gagné et al. 2018

Tucana-Horologium Association (THA)

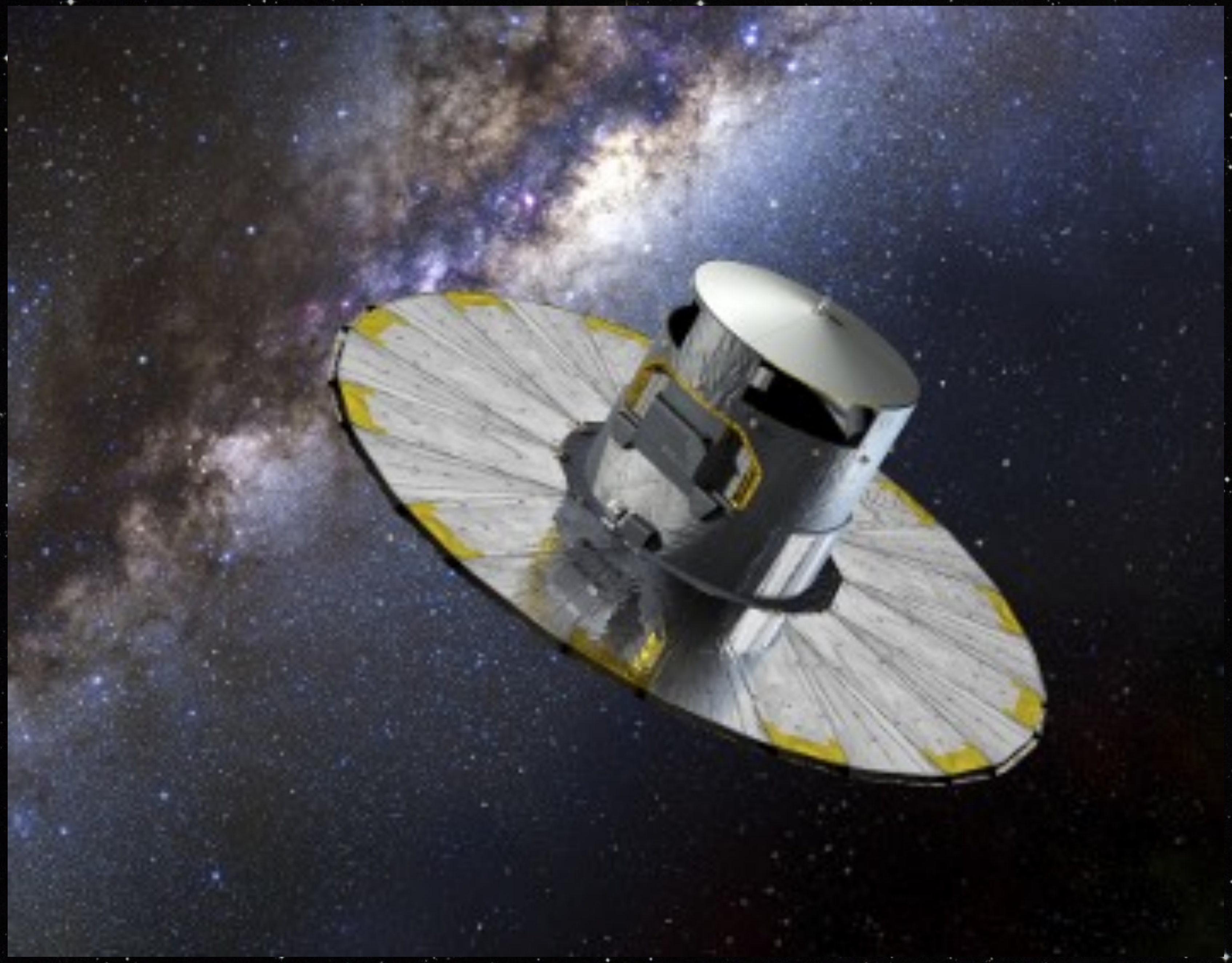
- Among the closest NYAs
- Exoplanets identified by direct imaging (Delorme et al., 2013; Artigau et al., 2015)
- Isochrones and LDB ages:
  - 51 ± 0.5 Myr (Galindo-Guil et al., 2022)
  - 45 ± 4 Myr (Bell et al., 2015)
  - 40 ± 3 Myr (Kraus et al., 2014).
- Dynamical ages:
  - $38.5_{-8.0}^{+1.6}$ Myr (Galli et al., 2023)
  - 55_{-0}^{+23} Myr (Miret-Roig et al., 2018)
  - 10 - 40 Myr (estimates)

Kanya (Kinematic Age for Nearby Young Associations)

- Stellar trajectories are traced back up to the point of minimal NYA size.
- Independent of stellar evolution models.
- Already used on the β Pictoris Moving Group in an earlier study.
- Our goal is to compute a traceback age for THA compatible with LDB and isochrones methods

Astrometric and kinematic data

- Gaia DR3 Catalog (Gaia Collaboration, 2022):
  - Parallax: ~ 0.02 - 1.2 mas
  - Proper motion: 0.02 - 1.2 mas/yr
  - Radial velocity: ~ 0.2 - 0.6 km/s
- Radial velocities remain the largest source of error.
- Dedicated radial velocity surveys can be used to complement Gaia DR3 data.

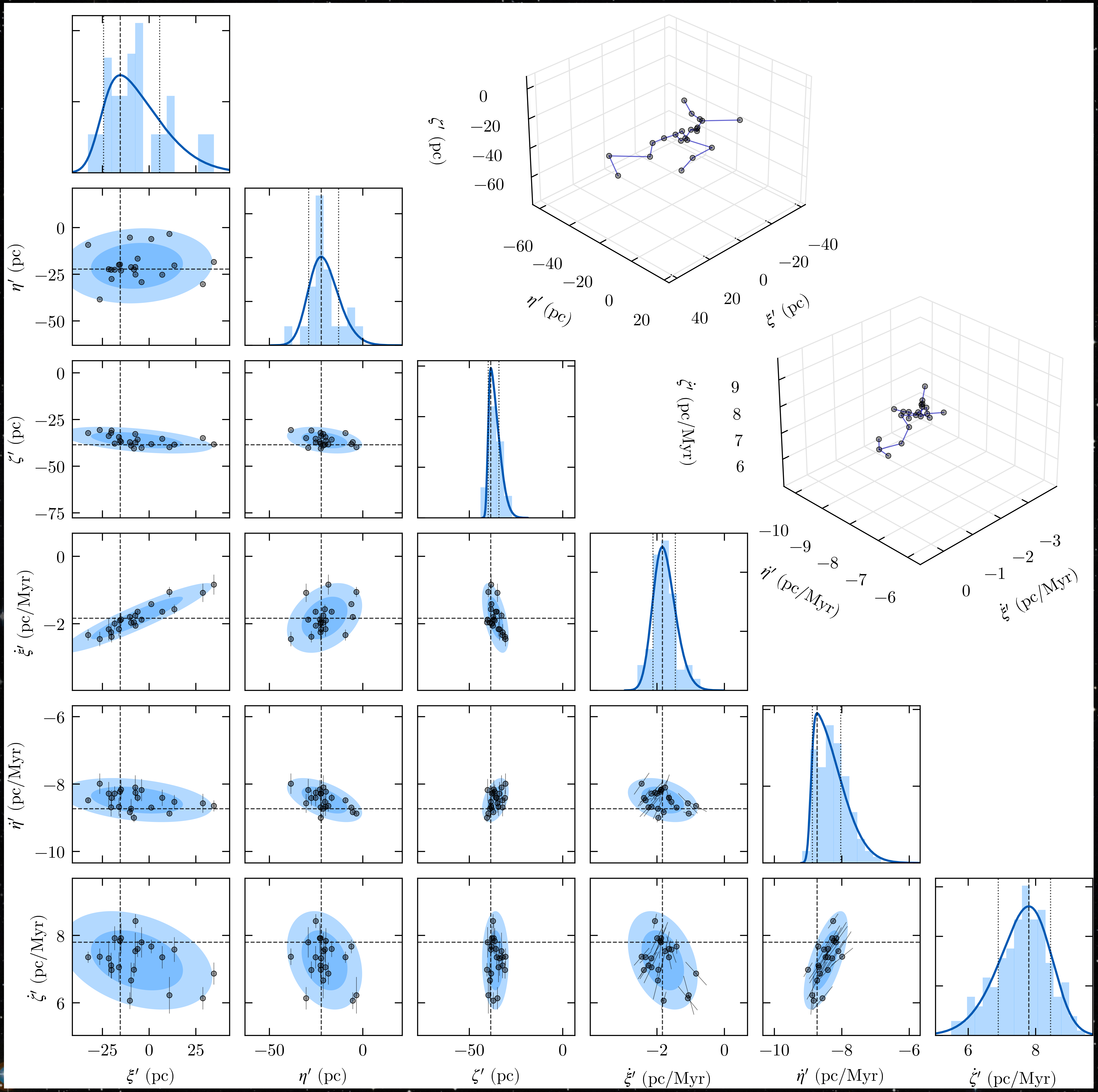


ESA

THA Sample

- 24 core members: identified in the Montreal Open Clusters and Associations (MOCA) database.

- To exclude binaries :
  - Gaia RUWE < 1.4
  - RV precision < 1.0 km/s
  - > 15 RV measurements
  - < 0.6 km/s RV variations
  - No excess brightness in the CMD



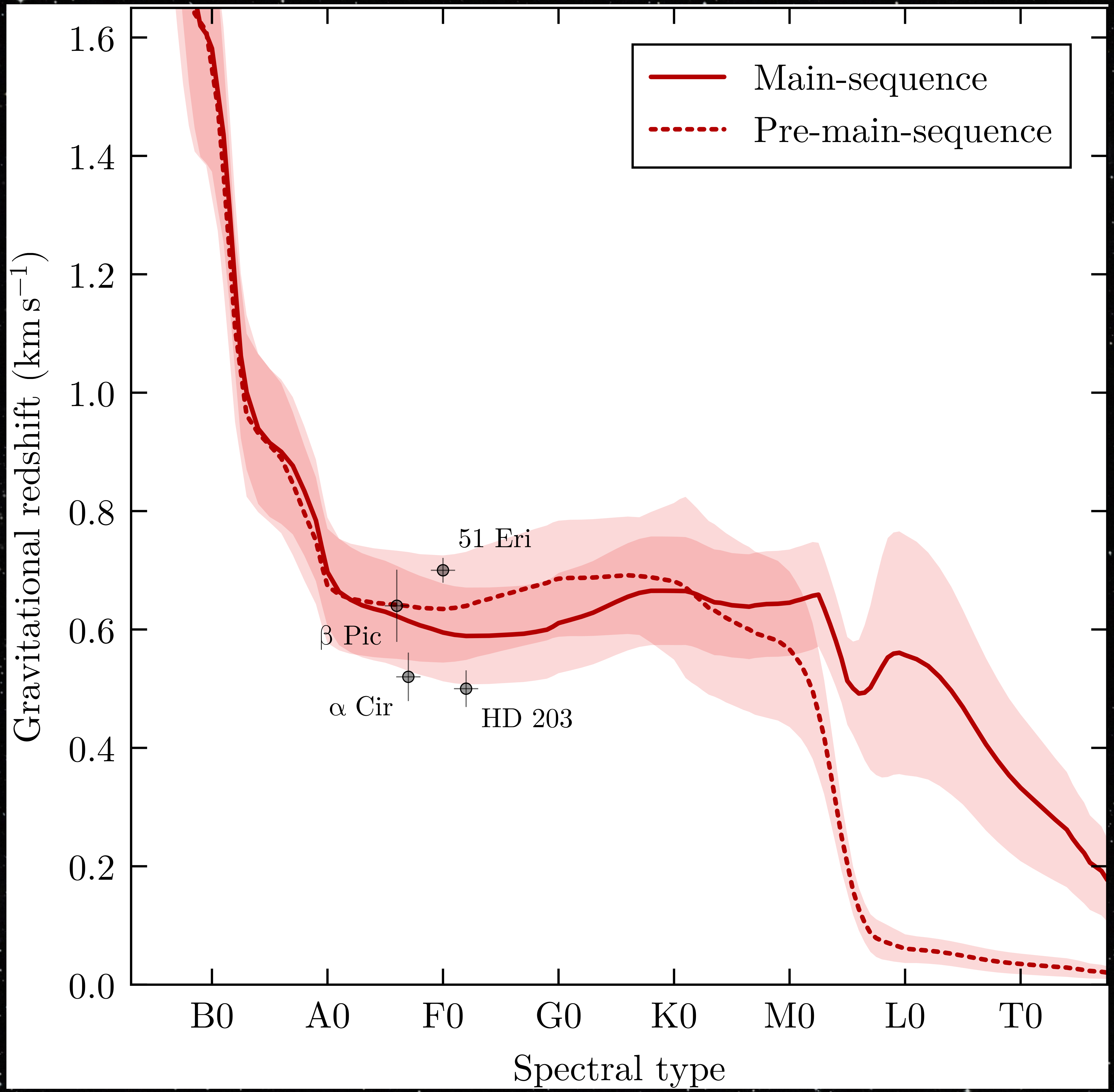
Gravitational Redshift

- Bias radial velocity measurement from Doppler shift

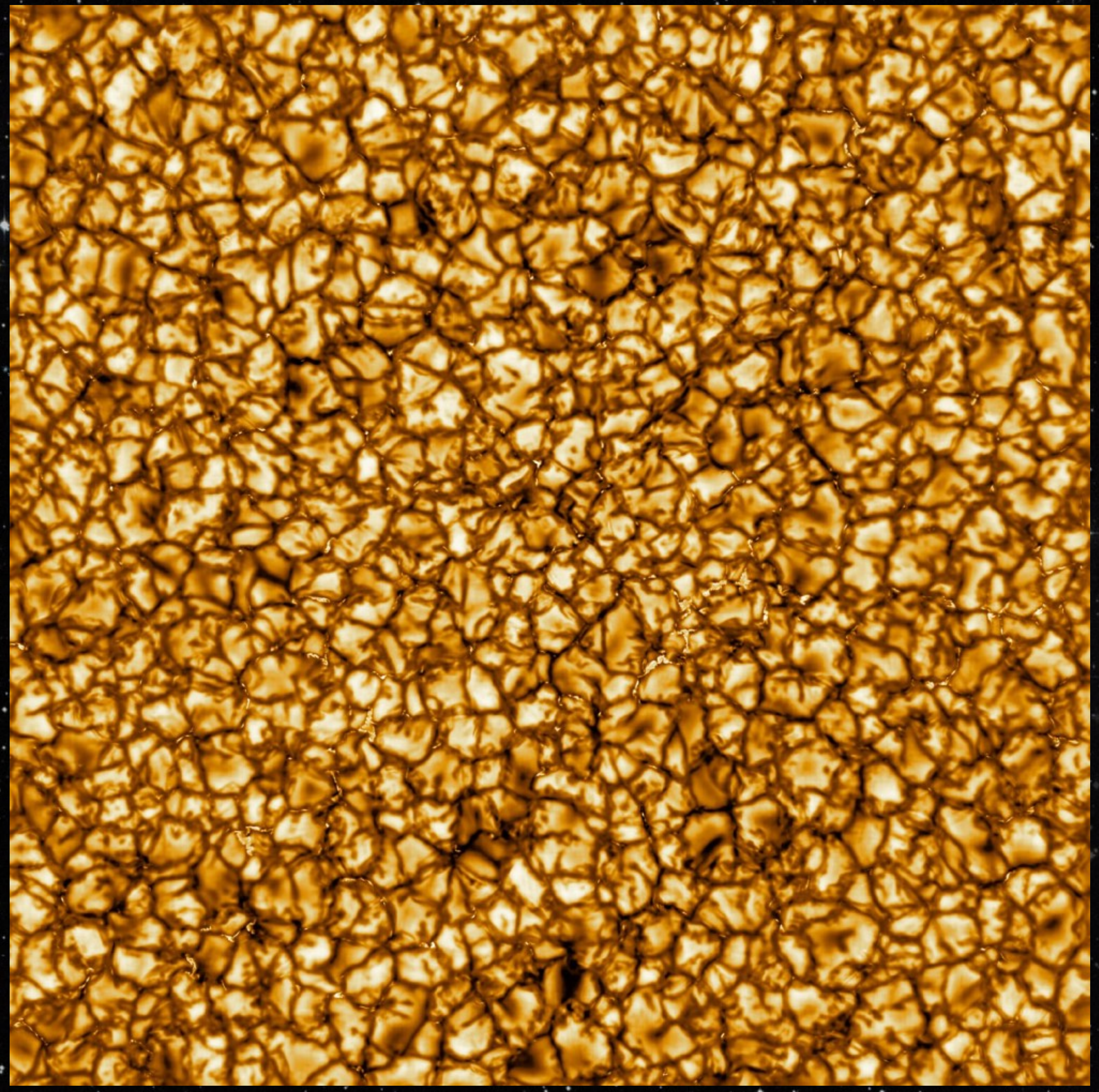
$$v_r = c\left(\left(1 - \frac{2Gm}{c^2 r}\right)^{-\frac{1}{2}} - 1\right)$$

- Adds about 0.5 km/s to radial velocity measurements (M dwarfs).

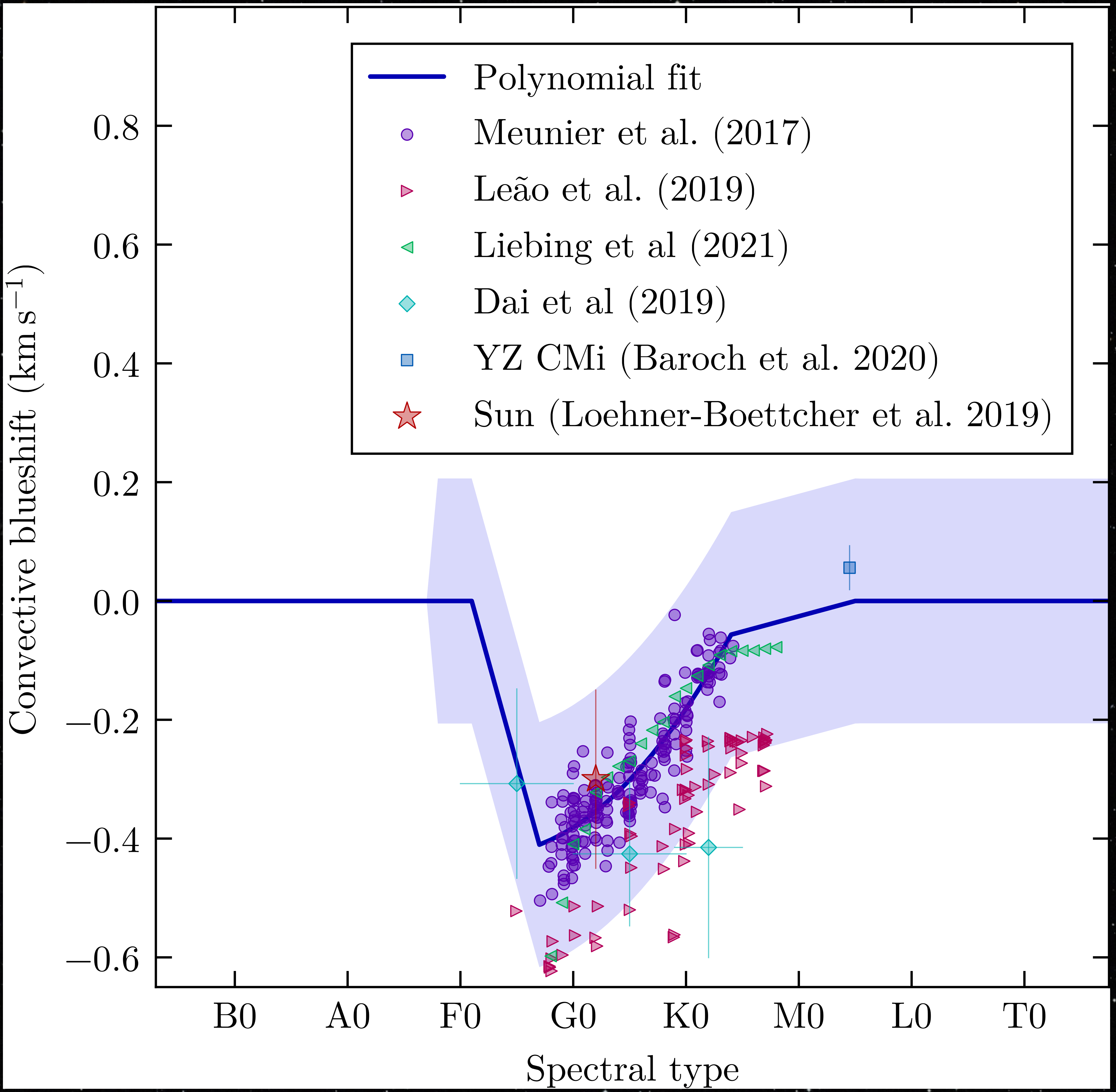
- We used sequences of stellar mass and radius as a function of spectral type for young stars (Pecaut & Mamajek 2013)



Convective Blueshift



NSO / AURA / NSF



- Convective blueshift: due to convection at the surface of the star, small effect, about -0.2 km/s (M dwarfs)

Measurement Error Bias

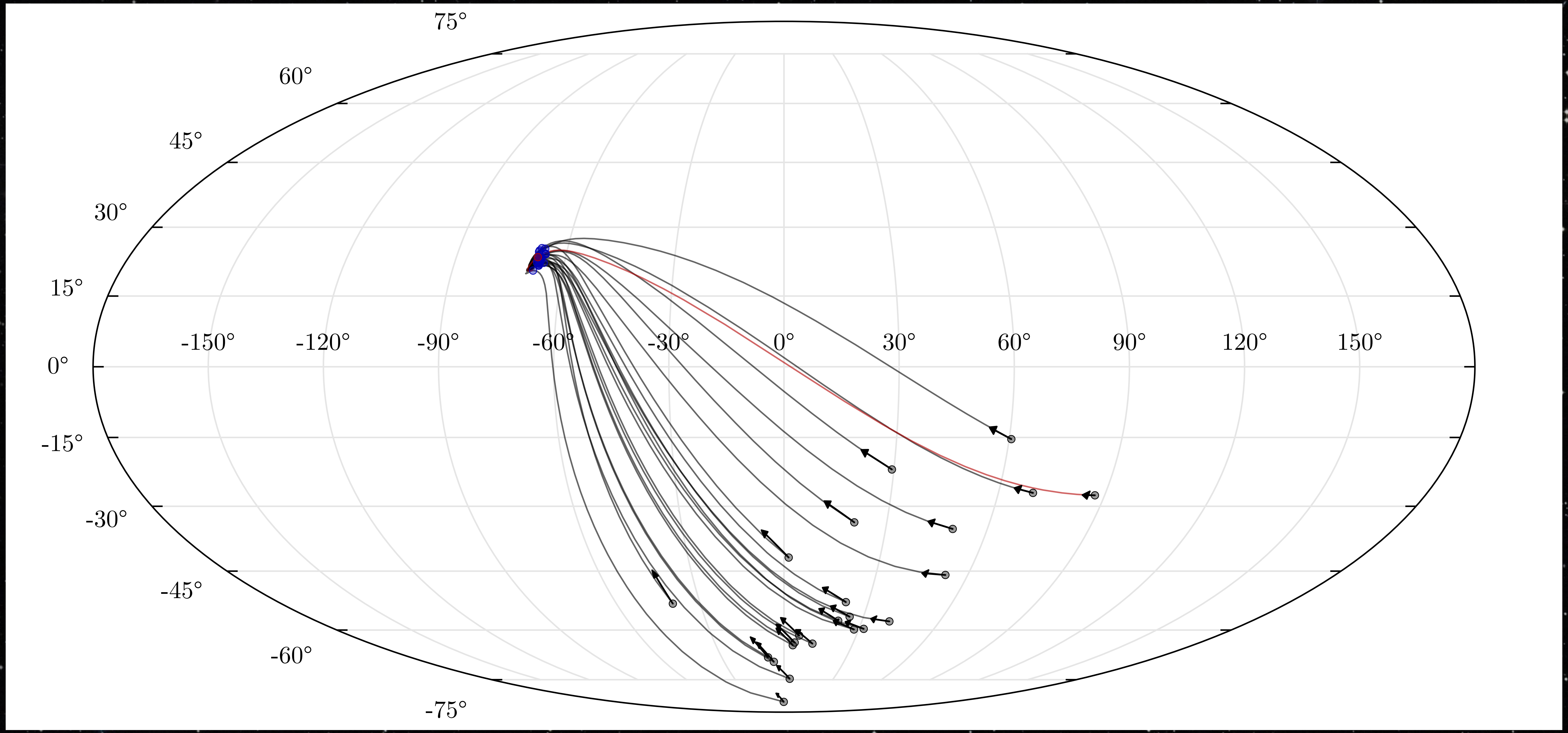
- Measurement errors add an artificial scatter (σ_{error}) to the actual scatter in position (σ_{real}):

$$\sigma^2_{total} = \sigma^2_{real} + \sigma^2_{error}$$

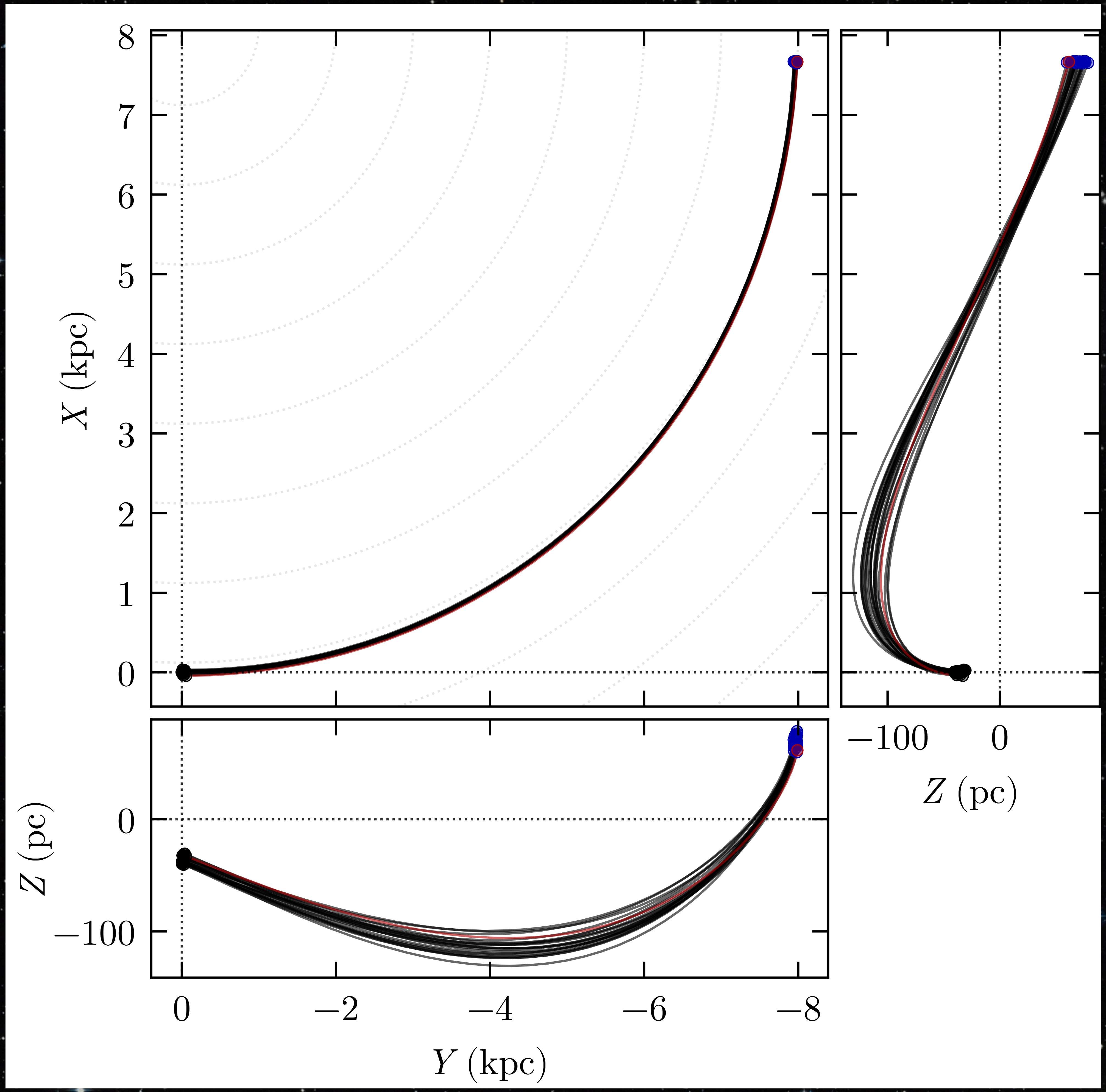
  - This artificial scatter is minimal at the current epoch.
  - The real scatter is minimal at the epoch of star formation.
- Ages are biased towards younger ages and must be corrected by a 1 to 2 Myr offset.

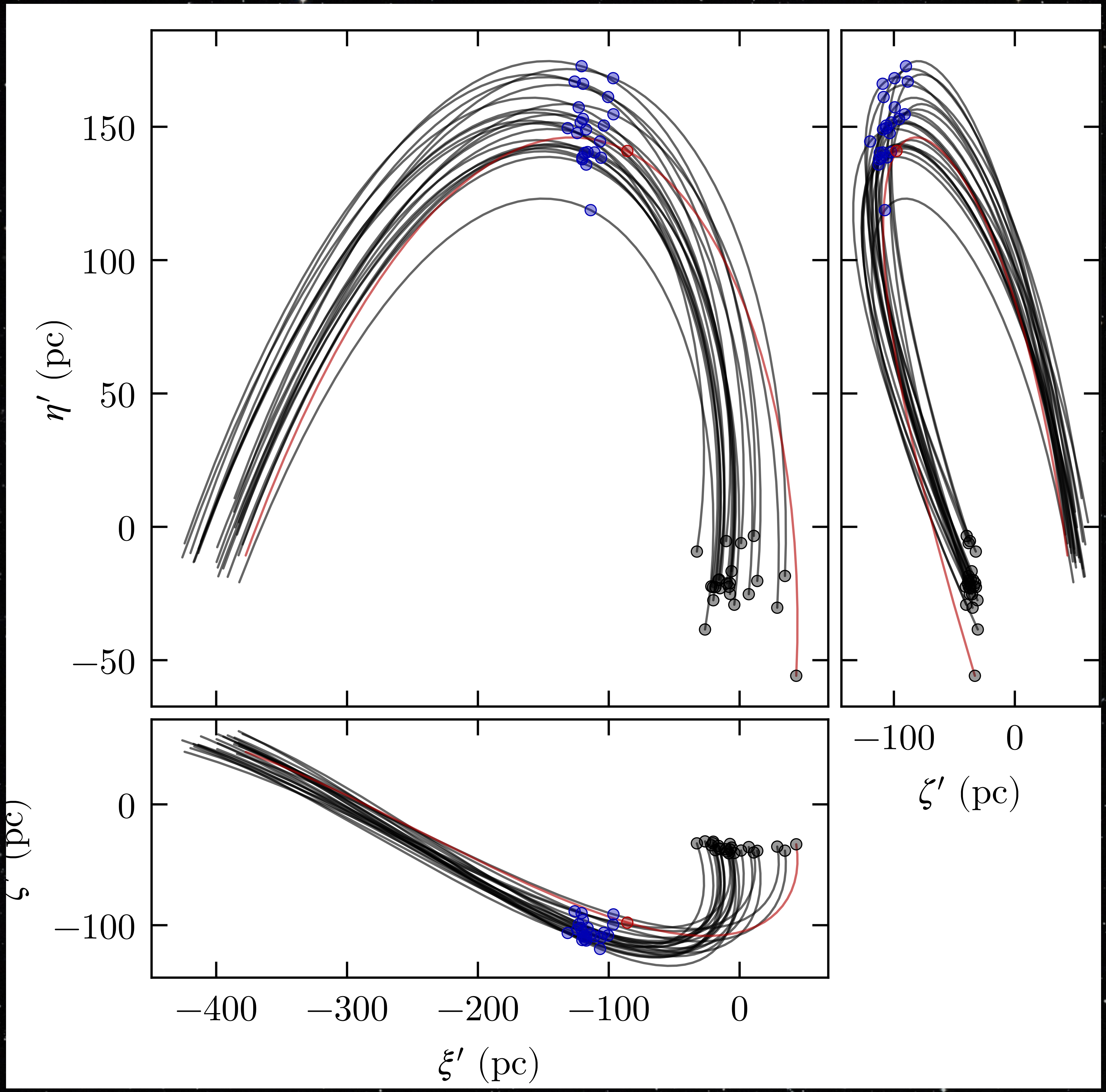
Tracing back THA

- Galpy Python Package
- Trajectories converge on the sky
- Gaia DR2 2904801835303287808 was excluded from the sample during the traceback
- Outliers will bias the traceback age toward younger values

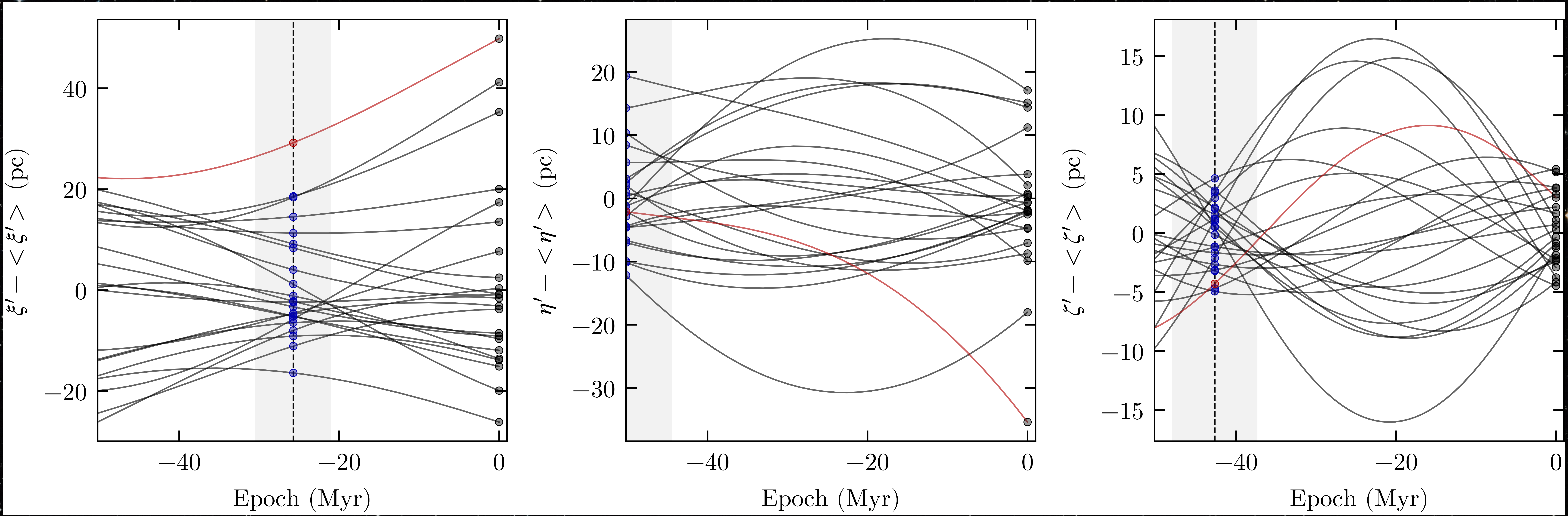


Galactic Orbits





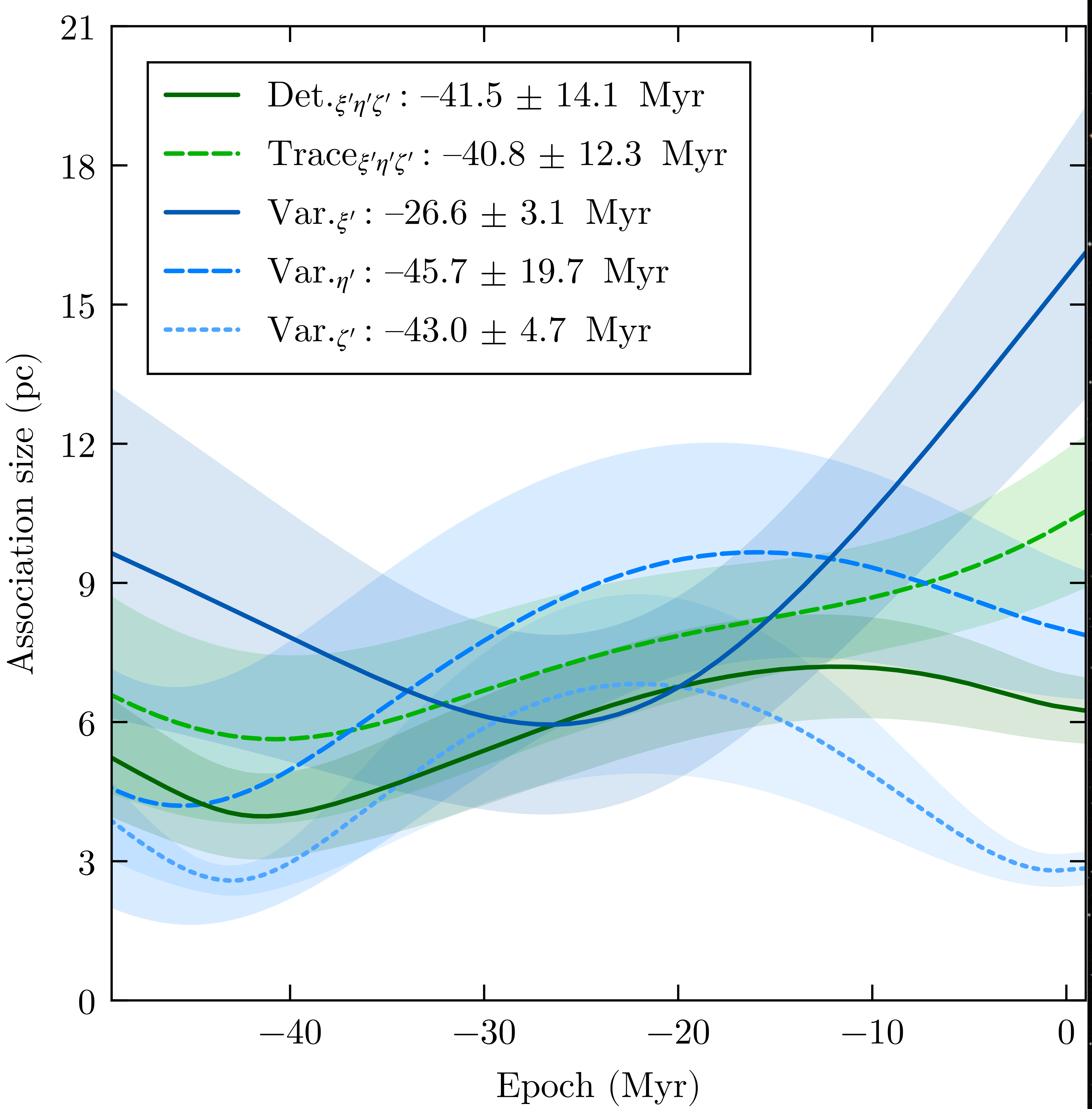
Galactic Orbits



Size metrics

Many association size metrics were investigated (~ 80 in total):

- XYZ and ξ'η'ζ' variances, trace and determinant of the:
  - Spatial covariance matrix
  - Spatial-velocity cross covariance matrix
- XYZ and ξ'η'ζ' median absolute deviations (MAD)



Minimum spanning trees

- Minimum Spanning Tree (MST): mean branch length and MAD, using a Kruskal algorithm (Kruskal, 1956)
- Total length of all branches: ~40 times faster and yields the same result

Kinematic age of THA

- Metrics along the ξ'-axis offer the least random and systematic errors due to the higher velocity dispersion along this axis.

- Metrics that use data along all axes reach a minimum value at an older epoch at the cost of inferior contrasts and higher errors on traceback ages.

- By correcting for gravitational redshift, convective blueshift and the bias due to measurement errors, and minimizing the ξ' variance, we find:

$$26.6 \pm 3.1 \text{ Myr}$$

Conclusions

- Our traceback age for THA doesn't match the results from isochrones and LDB methods:
    - Contamination of the THA sample
    - Challenge of finding an accurate and reliable metric to measure the size of an NYA
- Future work: Columba, Carina and more.