GALFOR

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant Agreement No. 101034319 and from the European Union – NextGenerationEU.

Kinematics of Multiple Stellar Populations in Globular Clusters with JWST

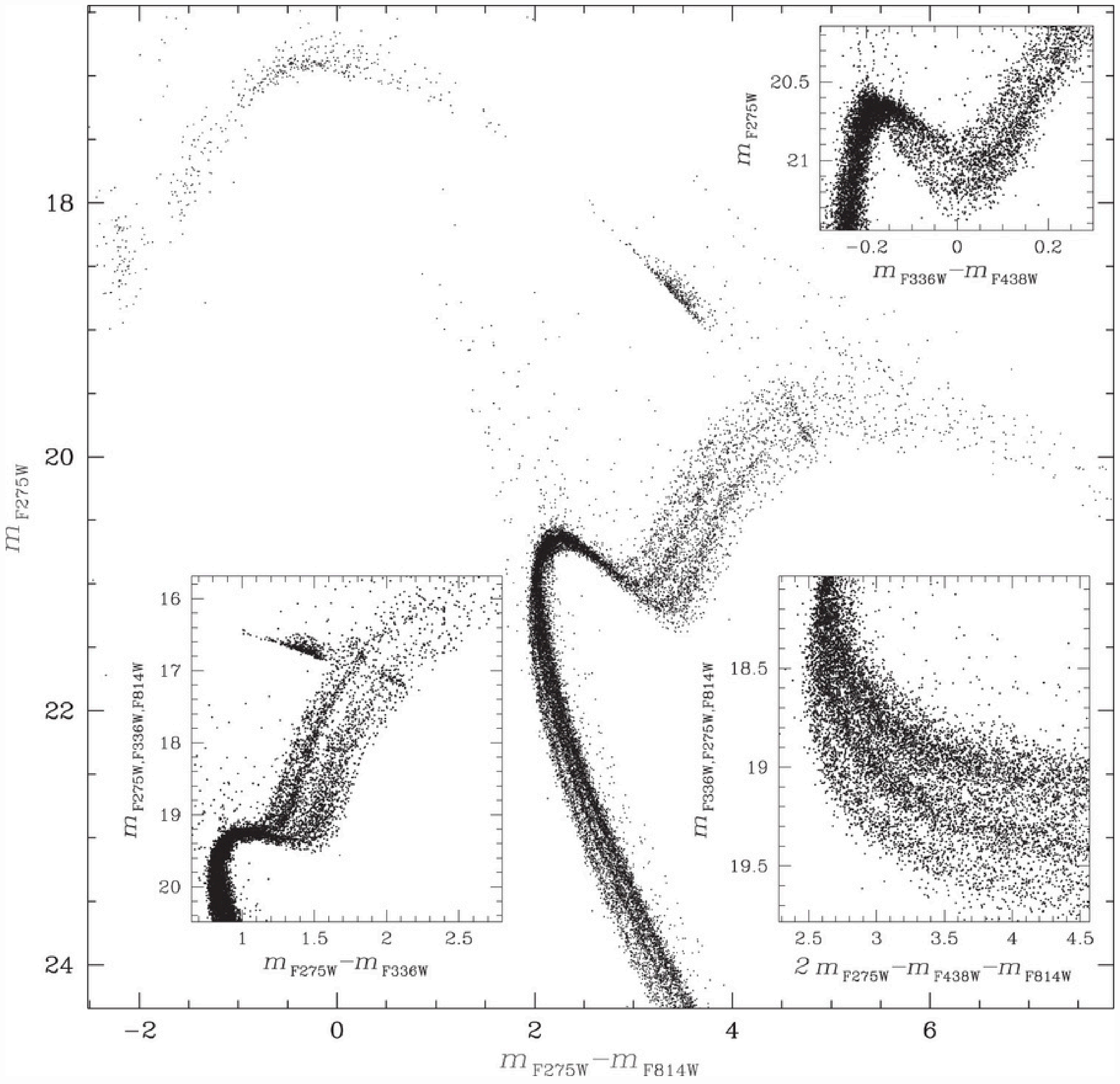
TUILA ZILIOTTO

UNIVERSITÀ DEGLI STUDI DI PADOVA

Introduction

Globular clusters host **multiple stellar populations**:

- **First stellar population**: same chemical composition as halo field stars.
- **Second stellar population(s)**: enhanced in He, N and Na, and depleted in C and O.

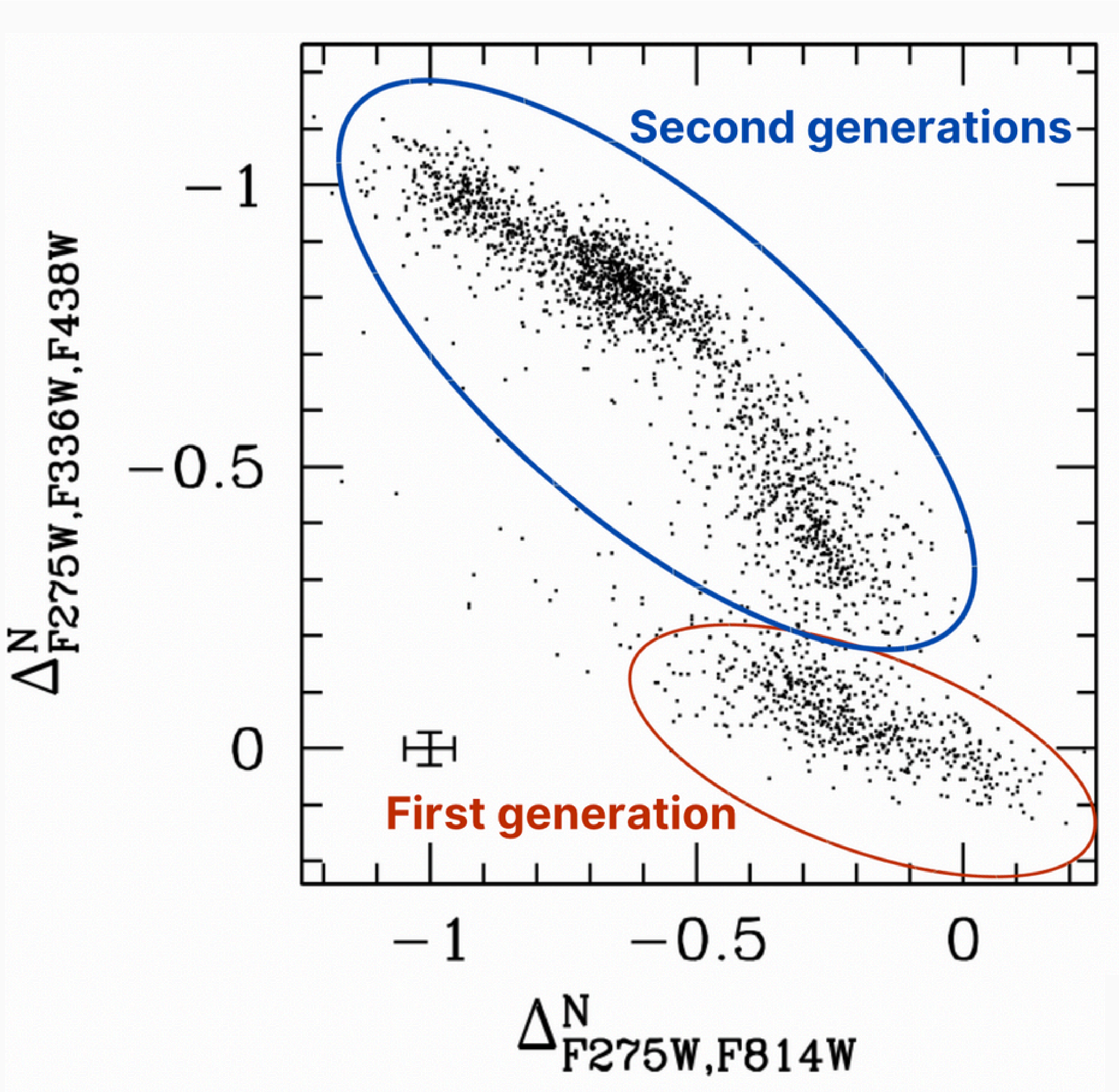


(MILONE ET AL. 2015)

Formation scenarios

- A proposed explanation for this phenomenon is **multiple episodes of star formation within the same cluster**;

- **Mass budget problem**: the cluster should have lost most of its 1G stars to the Galactic Halo.



(MILONE ET AL. 2015)

Multiple population kinematics

(For results involving chemistry, check *Ziliotto et al. 2023*).

- Multiple stellar populations differ not only in their chemical properties, but also in their **initial structure** and **kinematic** properties.
- 2G stars may form in a sub-system more spatially concentrated and more rapidly rotating than 1G stars

Globular cluster kinematics

- Globular clusters are old, collisional systems;
- Stars interact: energy exchange;
- If you wait long enough, energy starts to equalize, evolving towards a state of energy equipartition.

Energy equipartition

Stellar mass

$$\sigma \sim m^{-\eta}$$

Velocity dispersion

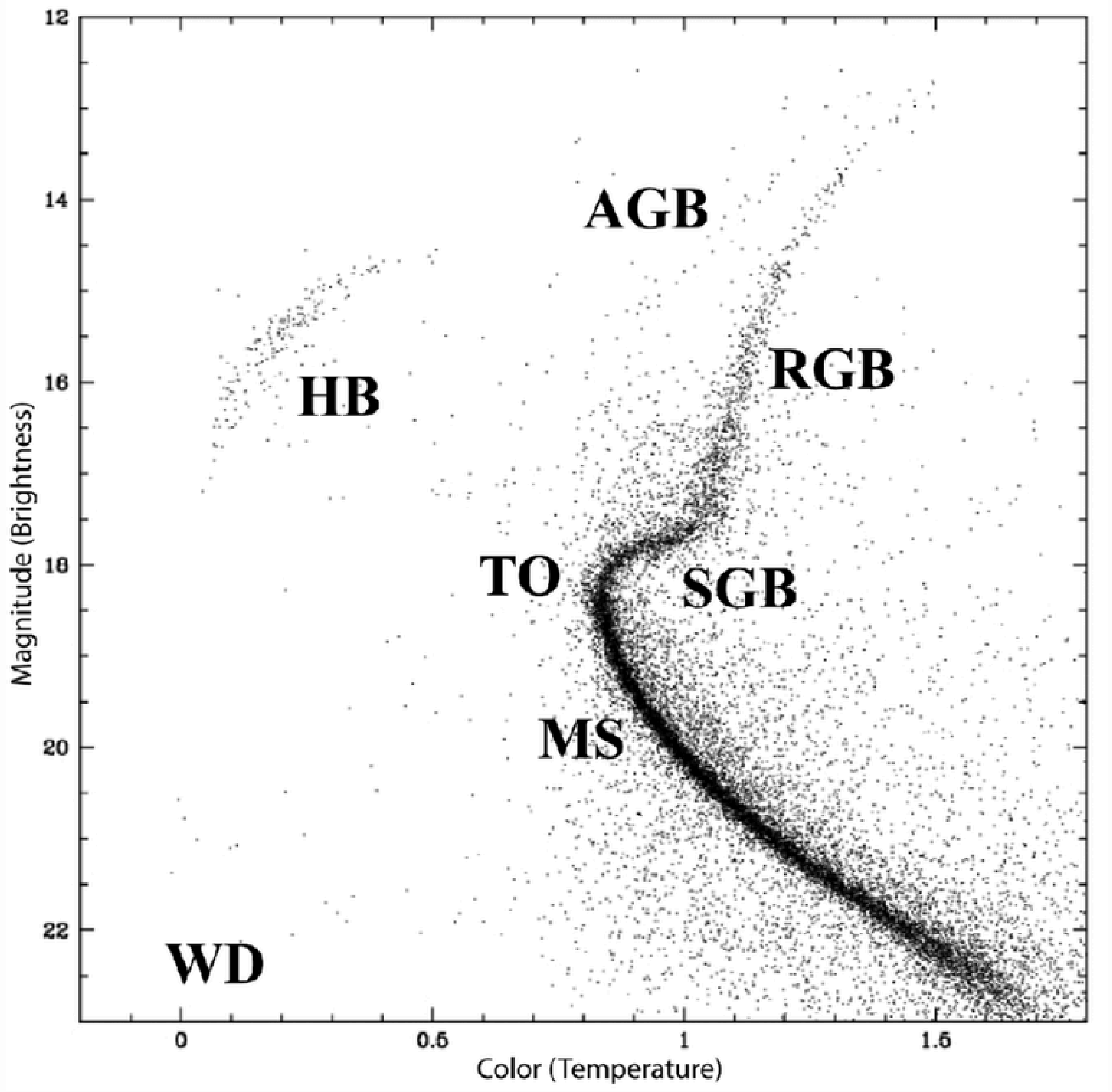
Amount of equipartition:

$\eta = 0$: None
$\eta = 0.5$: Full equipartition

Energy equipartition

Brighter stars: small mass range

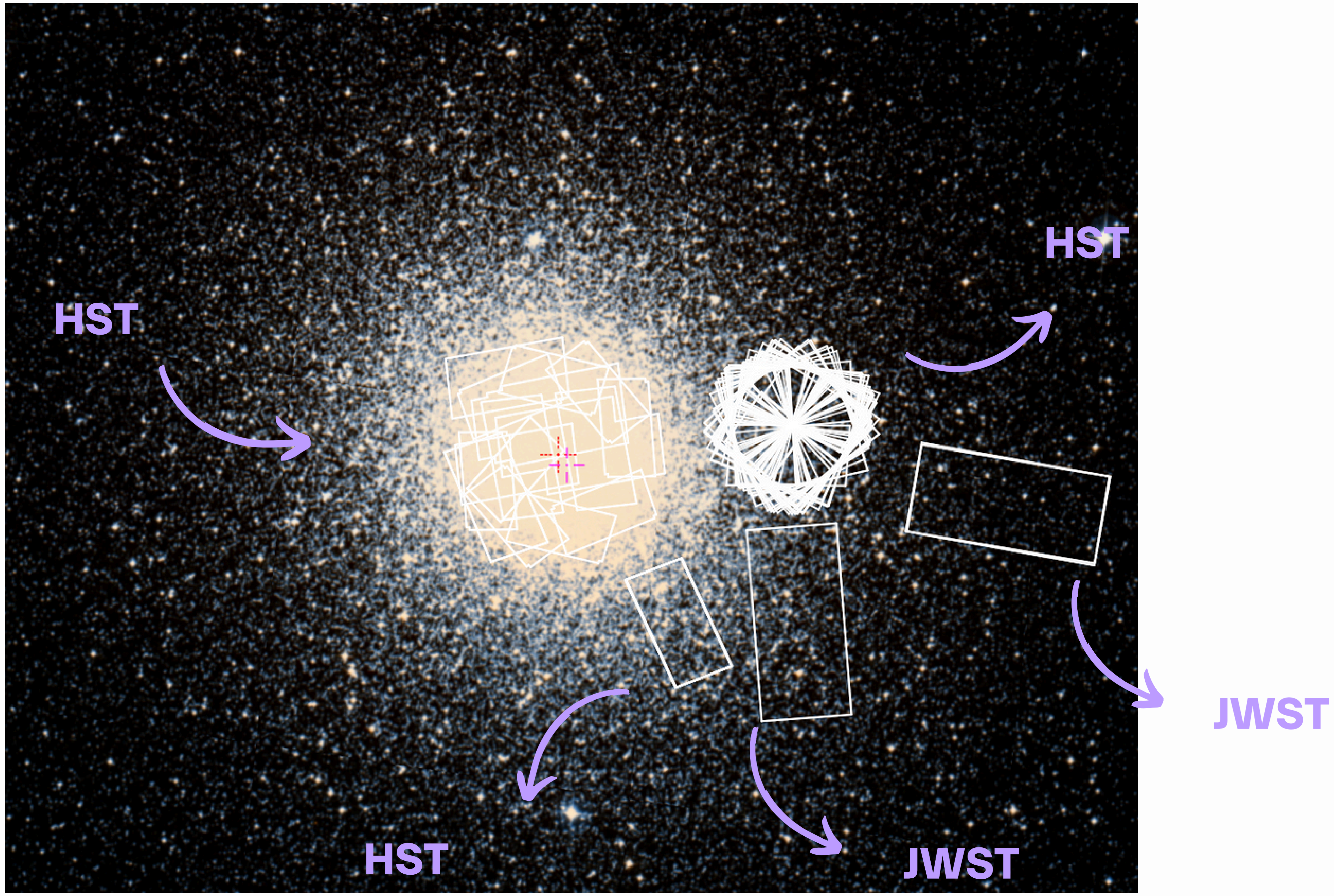
Main sequence stars: wide mass range,
but more challenges in obtaining kinematic data



Data: NGC 104

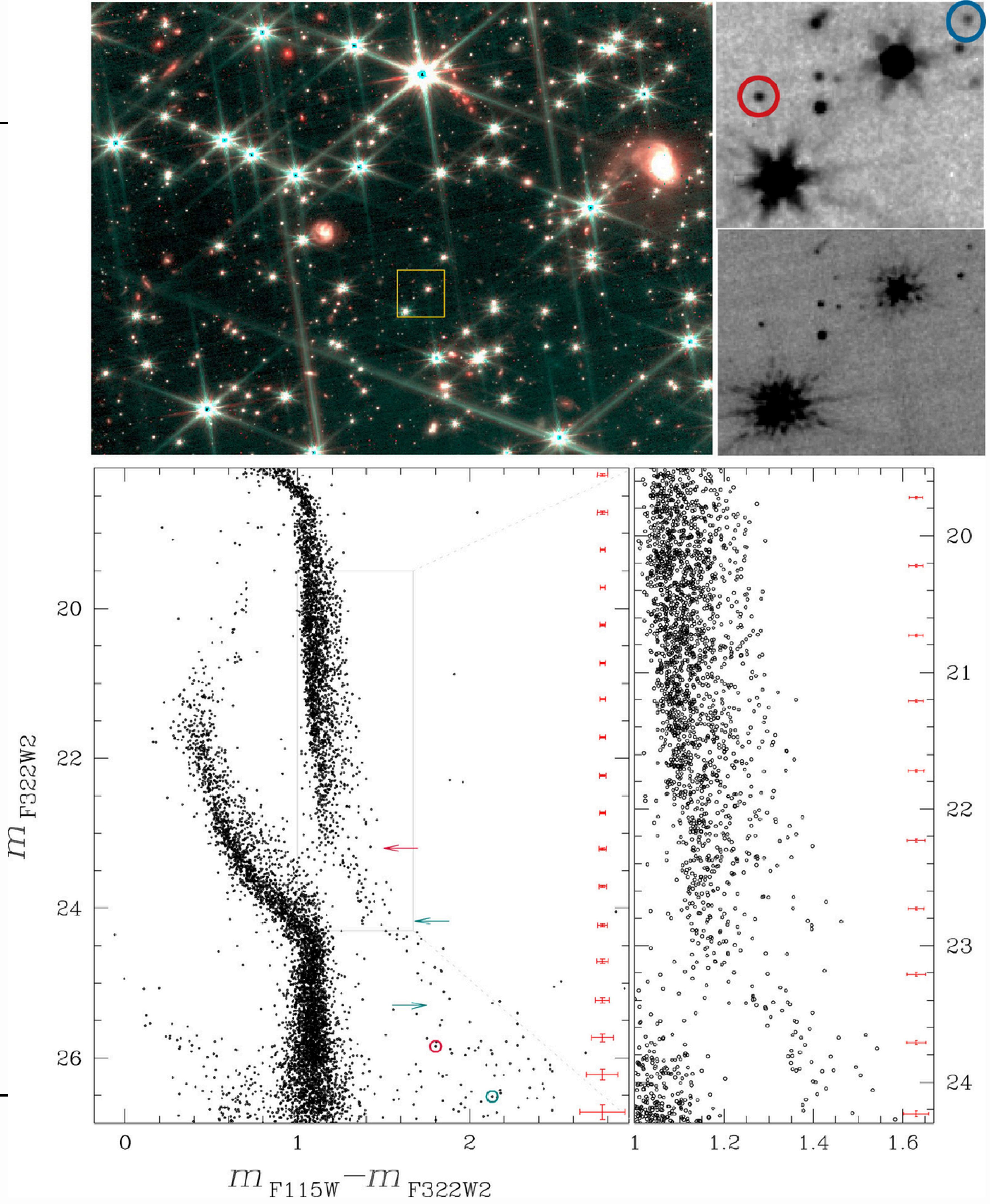
- **HST** and **JWST IR** data are very efficient to characterize multiple populations in the **low-mass regime**;

- **Gaia** provides proper motions for RGB stars, providing a **wide mass and radial range.**



Data: NGC 104

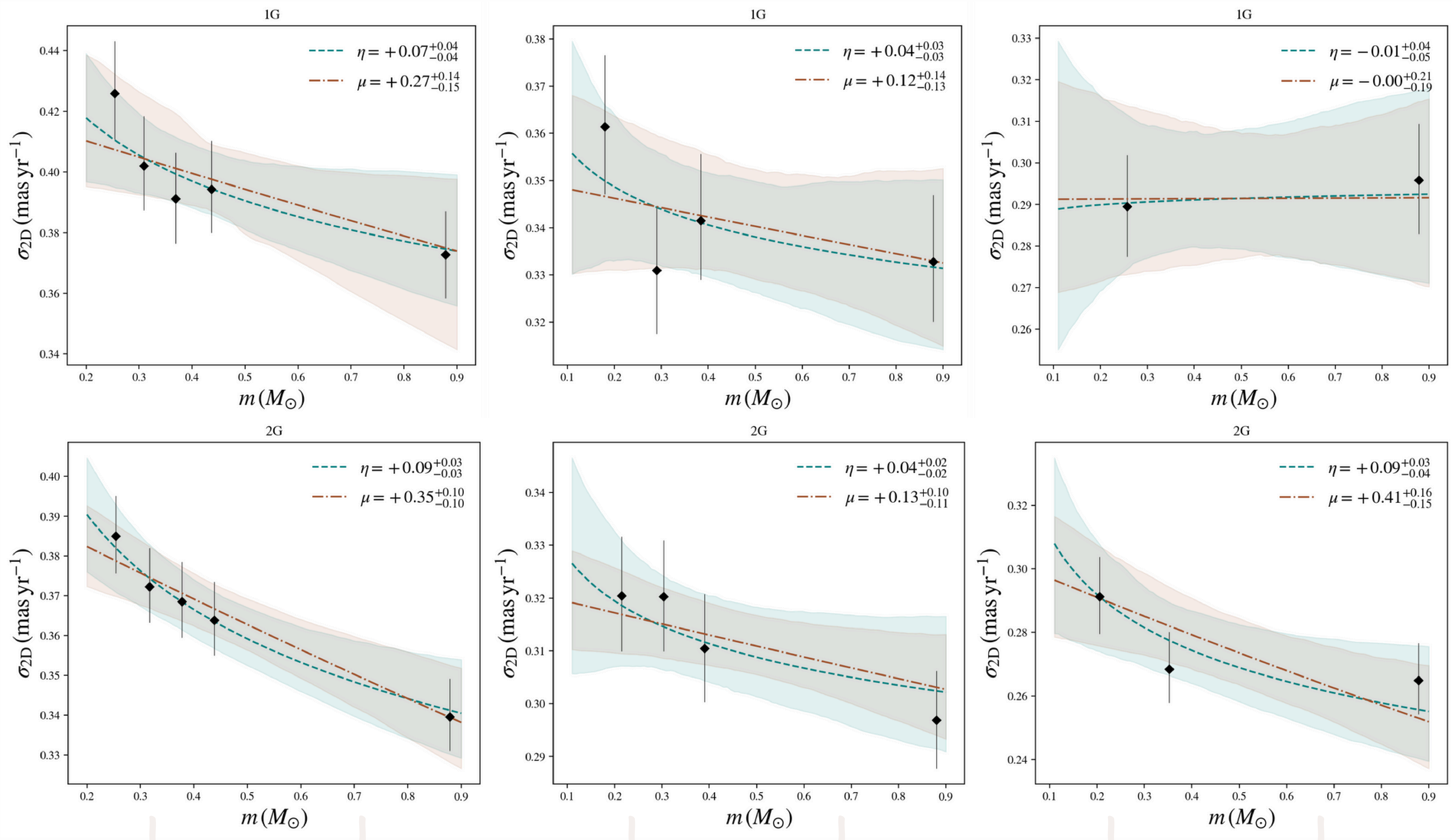
- **HST** and **JWST IR** data are very efficient to characterize multiple populations in the **low-mass regime**;
- **Gaia** provides proper motions for RGB stars, providing a **wide mass and radial range.**



MARINO ET AL. 2024

Degree of energy equipartition: NGC 104

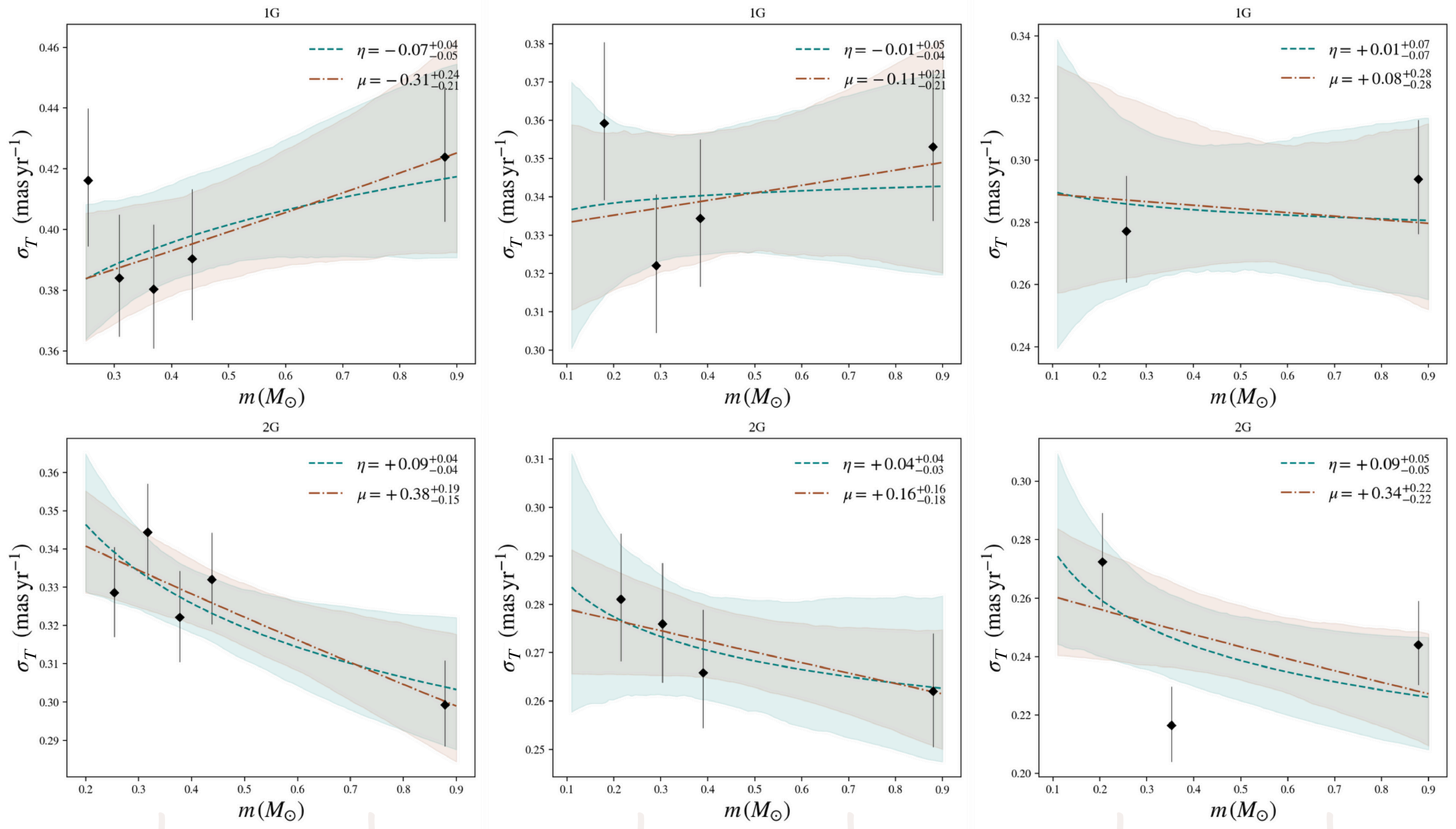
ZILIOTTO ET AL., IN PREP



2 Rh 3 Rh 4 Rh

Degree of energy equipartition: Tangential velocity dispersion

ZILIOTTO ET AL., IN PREP



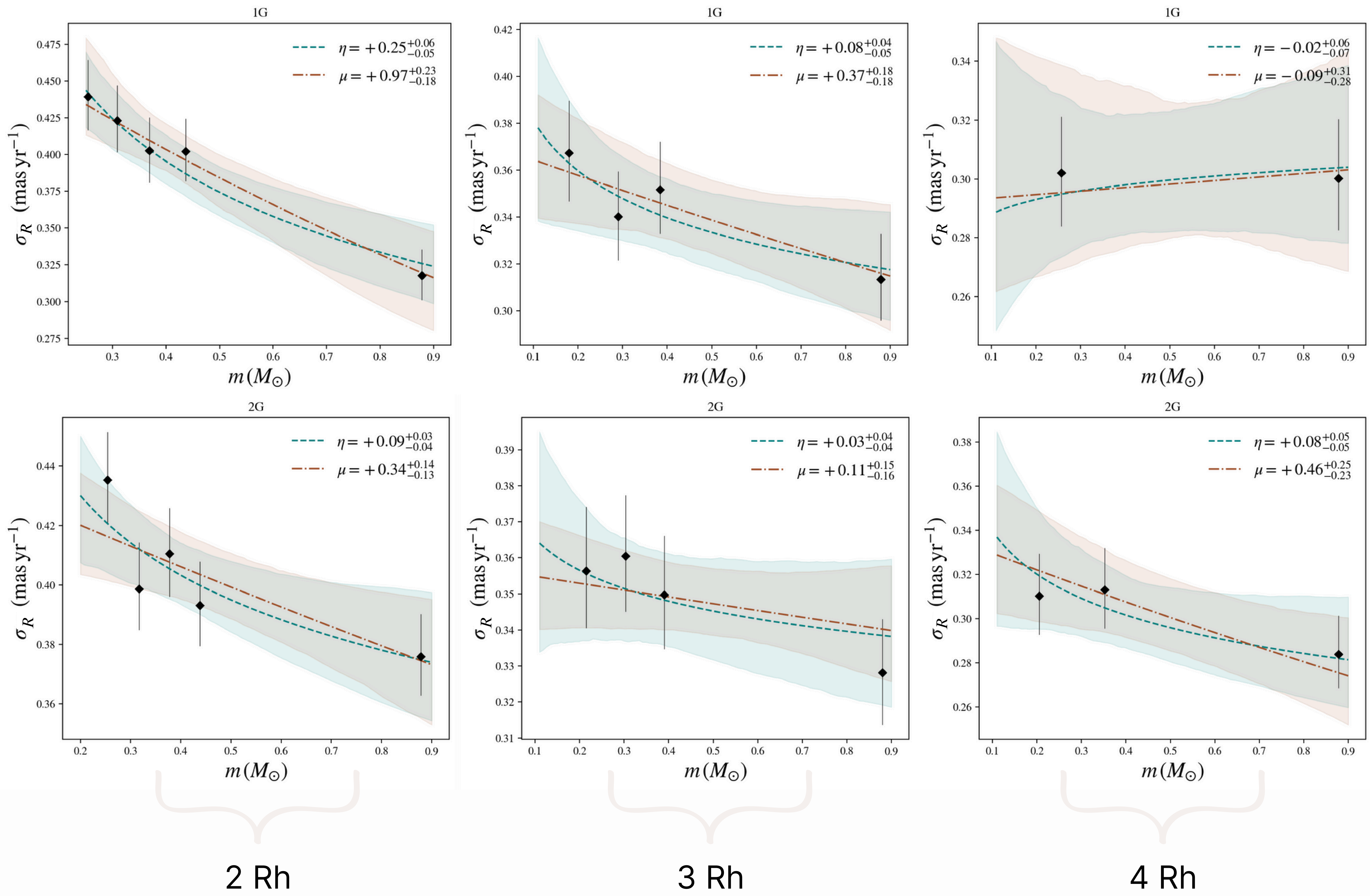
2 Rh

3 Rh

4 Rh

Degree of energy equipartition: Radial velocity dispersion

ZILIOTTO ET AL., IN PREP



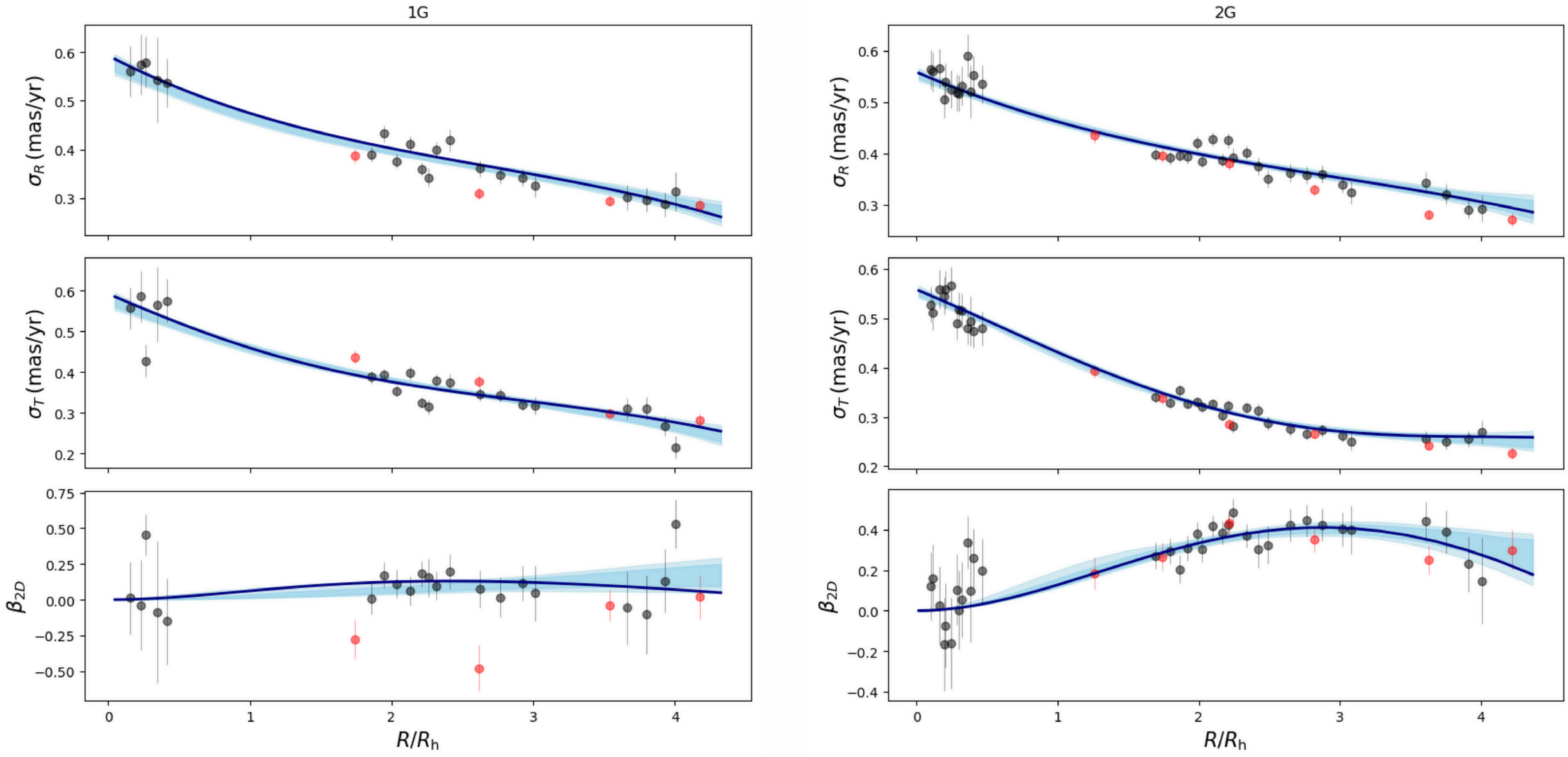
Anisotropy

- The anisotropy of the internal motion of first and second population stars can also provide information about the differences between these populations.

$$\beta_{2D}(R) = 1 - \frac{\sigma_T^2}{\sigma_R^2}$$

$\beta = 0$: isotropic
$\beta > 0$: radial anisotropy
$\beta < 0$: tangential anisotropy

Anisotropy

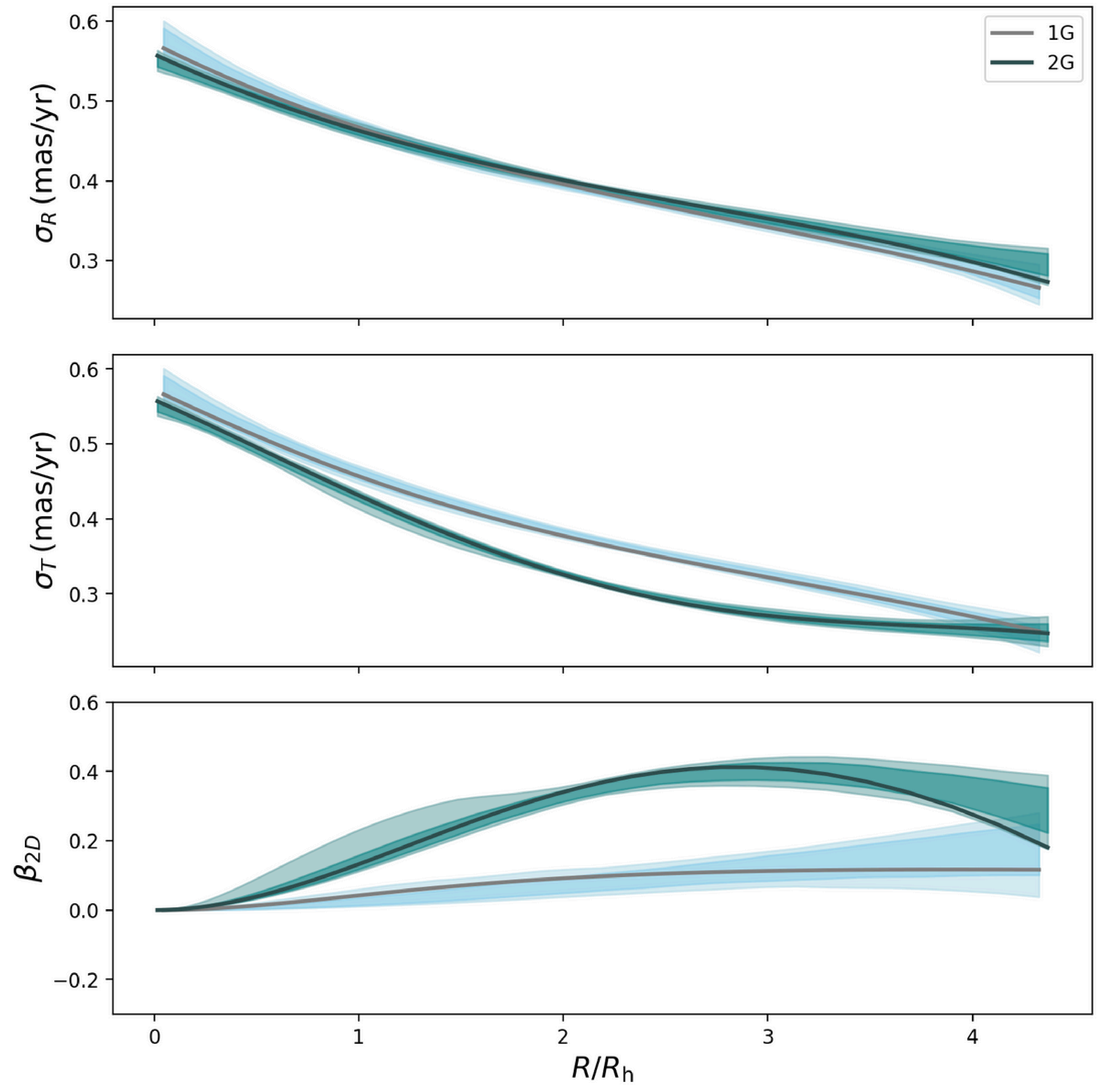


ZILIOTTO ET AL., IN PREP

Anisotropy

- Second generation stars present a significantly higher degree of radial anisotropy in comparison with first generation stars;

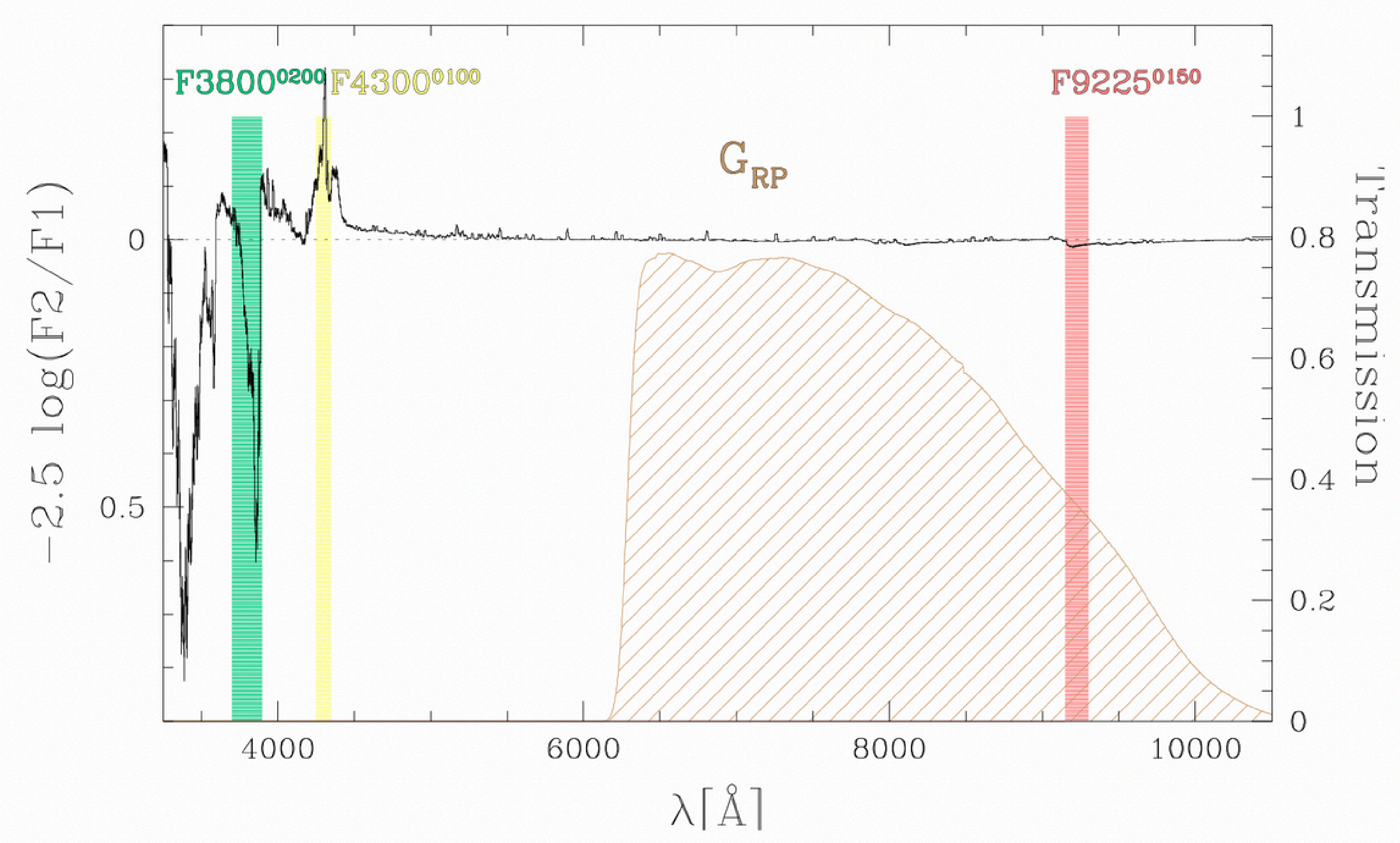
- This result agrees with simulations predicting multiple episodes of star formation, where second generation stars are form more centrally concentrated.



ZILIOTTO ET AL., IN PREP

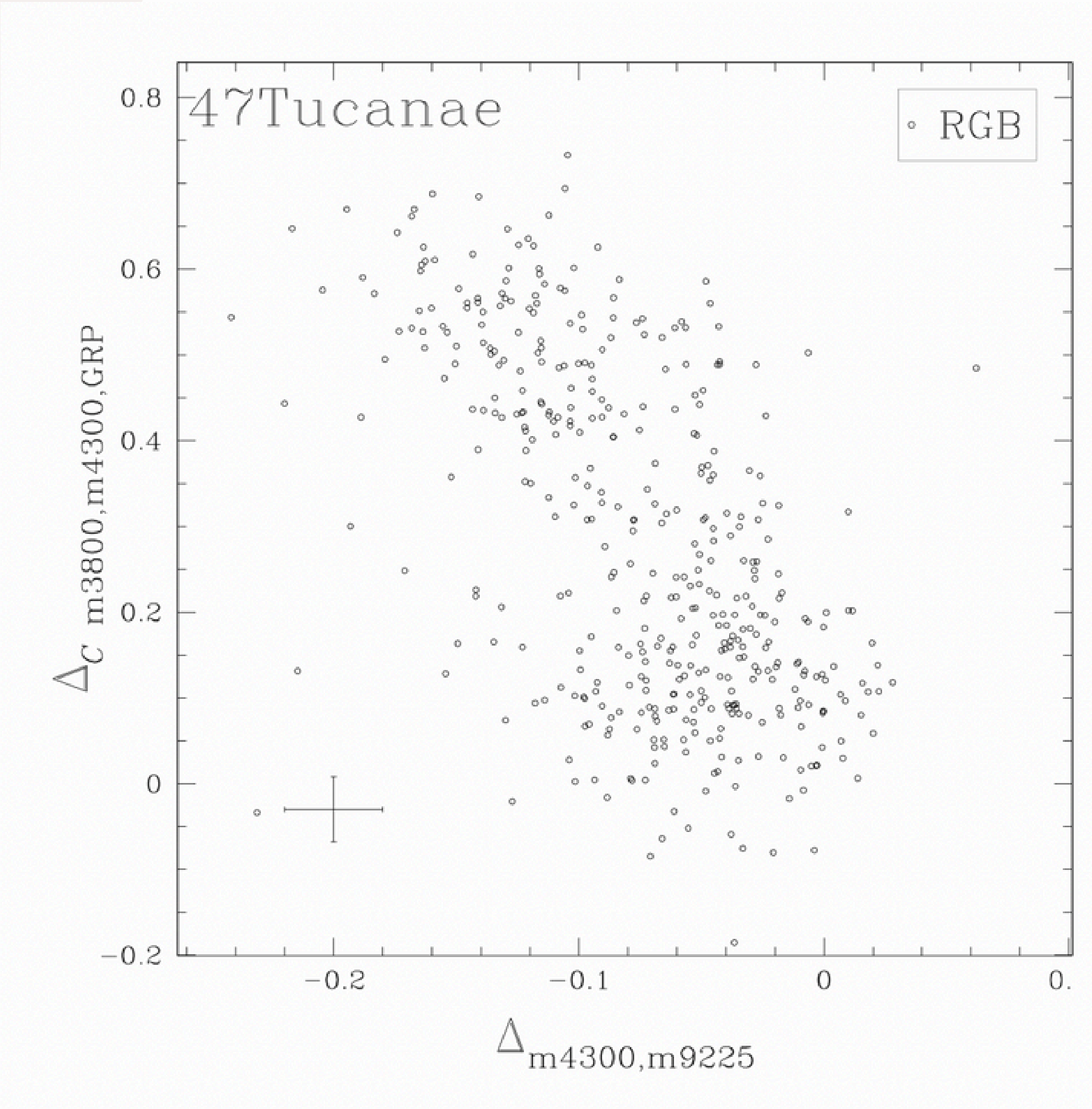
Spectro-photometry from Gaia XP spectra

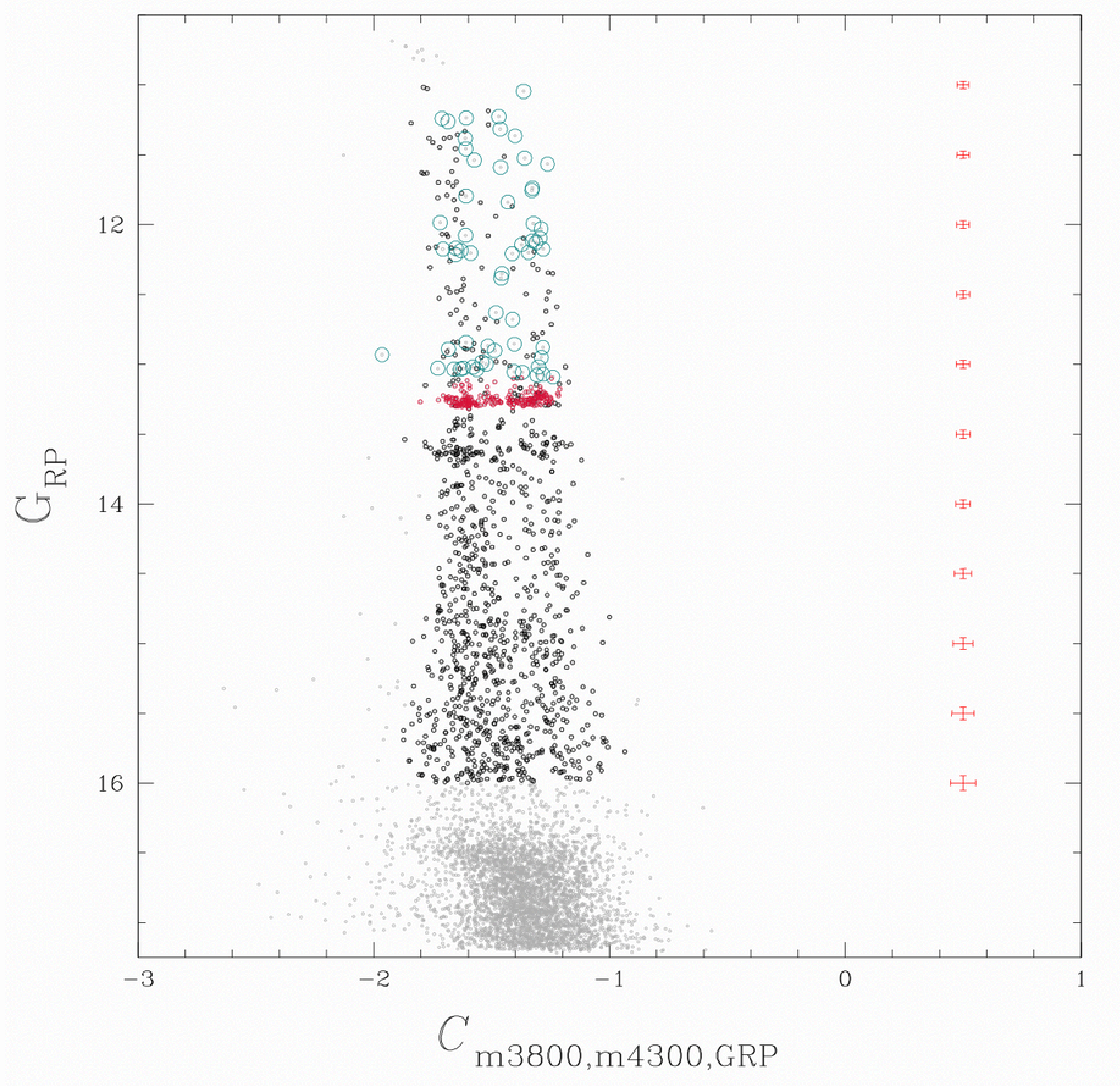
- We defined new photometric bands that are efficient to disentangle 1G and 2G giant stars from Gaia XP spectra in the outermost regions of the cluster and outside the tidal radius.



(MEHTA ET AL. 2024)

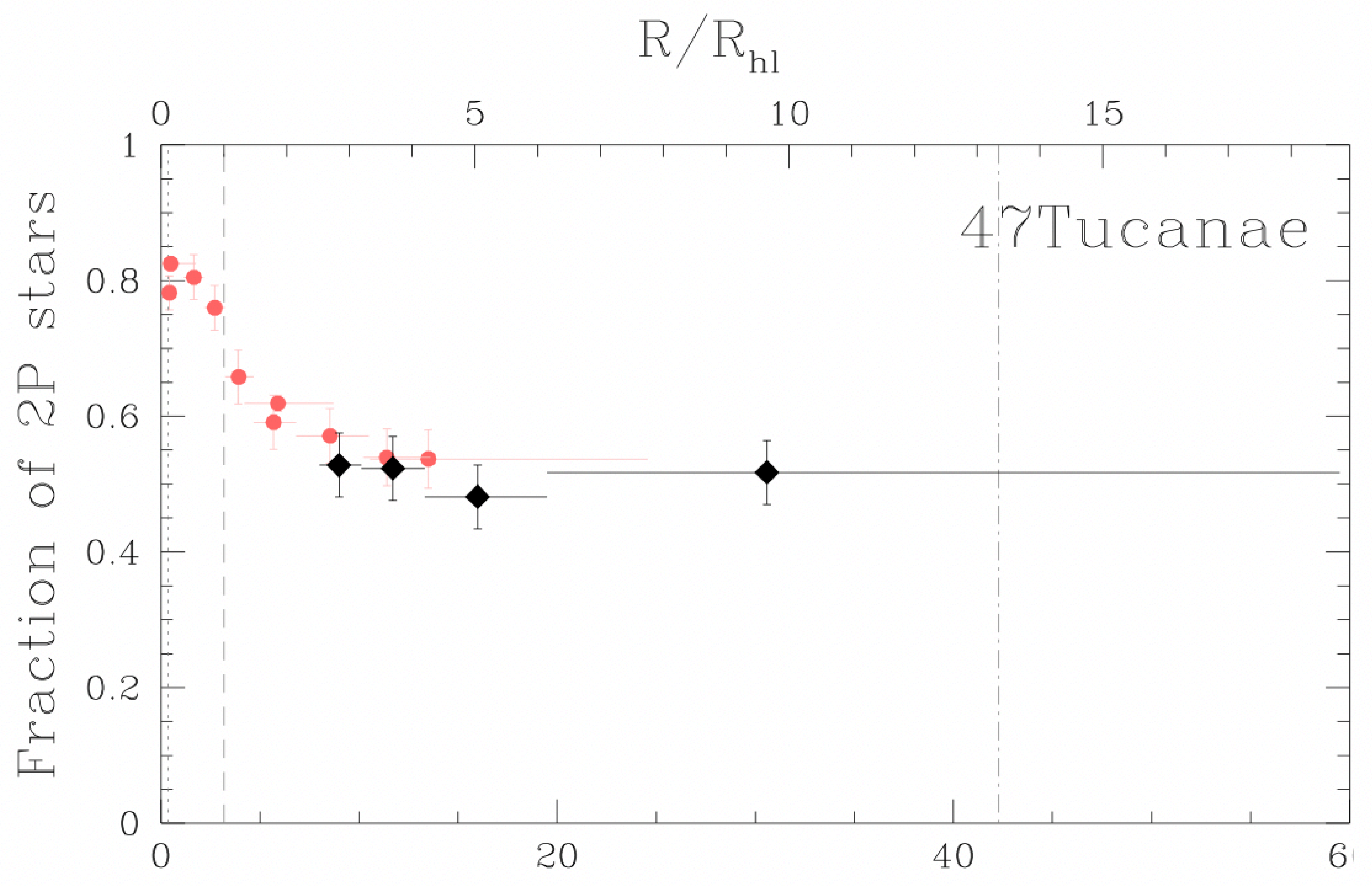
Spectro-photometry from Gaia XP spectra





(MEHTA ET AL. 2024)

Spectro-photometry from Gaia XP spectra



(MEHTA ET AL. 2024)

Conclusion

- The evolution towards energy equipartition is anisotropic and proceeds at different rates in the tangential and radial directions;
- Second generation stars are more radially anisotropic than first generation stars;
- Our results support scenarios involving multiple episodes of star formation within the same cluster;
- This could imply that Globular Clusters contributed substantially to the baryonic mass of the Galactic Halo and possibly played a significant role in reionization.

TUILA.ZILIOTTO@UNIPD.IT