UNIVERSITY OF SURREY

Modelling the velocity dispersion of binary-rich dwarf galaxies

NATIONAL ASTRONOMY MEETING 2025 (ILLUMINATING THE FAINTEST GALAXIES)

10 July 2025

Amery Gration

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Ultrafaint dwarf galaxies

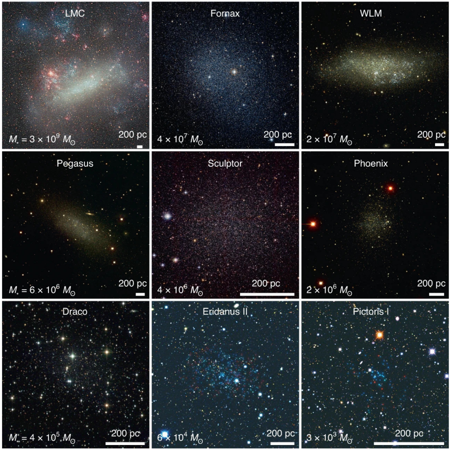

Figure 1. Some Local Group dwarf galaxies: stellar mass and size (Bullock and Boylan-Kolchin 2017).

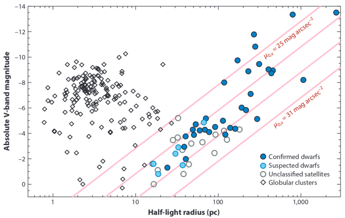

Figure 2. The Milky Way's satellites: size and brightness (Simon 2019).

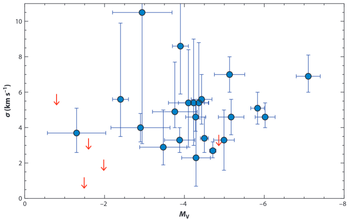

Figure 3. The Milky Way's satellites: reported LOS velocity dispersions (Simon 2019).

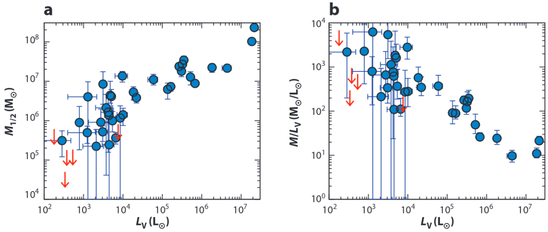

Figure 4. The Milky Way's satellites: dynamical mass and mass-to-light ratio (Simon 2019).

A mixture model

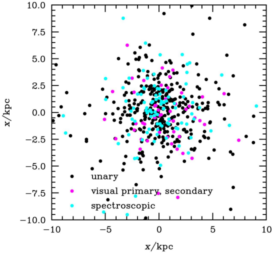

Figure 5. Unary, visual, and spectroscopic binary systems.

The **PDF** for observed LOS velocity,

$$
\begin{aligned}
f_{V_z}(v_z) = p_\mathrm{u} f_{V_{\mathrm{u},z}}(v_z) & \quad \text{(unary systems)} \\
+ p_1 f_{V_{\mathrm{v}_1,z}}(v_z) & \quad \text{(primary stars of visual binary systems)} \\
+ p_2 f_{V_{\mathrm{v}_2,z}}(v_z) & \quad \text{(secondary stars of visual binary systems)} \\
+ p_\mathrm{s} f_{V_{\mathrm{s},z}}(v_z) & \quad \text{(spectroscopic binary systems).}
\end{aligned}
$$

The additional LOS velocity dispersion

Stellar **velocity dispersion**,

$$\sigma^2_{V_z} = \sigma^2_{V_{\mathrm{u},z}} + \delta\sigma^2_{V_z}$$

for **additional velocity dispersion**

$$\delta\sigma^2_{V_z} = \frac{1}{1+\alpha(1-\beta)}\left(2\alpha(1-\beta)\sigma^2_{V'_{\mathrm{v},z}} + \alpha\beta\sigma^2_{V'_{\mathrm{s},z}}\right).$$

binary fraction (α)

spectroscopic fraction (β)

visual inner dispersion ($\sigma^2_{V'_{\mathrm{v},z}}$)

spectroscopic inner dispersion ($\sigma^2_{V'_{\mathrm{s},z}}$)

Warning

Mass segregation not allowed!

The velocity of stars in a binary systems

Visual binary systems

The **LOS velocity**,

$$v'_{1,z} = \frac{q}{1+q}\left(\frac{\mathrm{G}m_1(1+q)}{a_1(1-e^2)}\right)^{1/2}\sin(i)\big(\cos(\nu+\omega)+e\cos(\omega)\big)$$

and

$$v'_{2,z} = -\frac{v'_{1,z}}{q}$$

(e.g. Tremaine 2023).

Spectroscopic binary systems

The **LOS velocity**,

$$v'_{s,z} = \frac{L_1 v'_{1,z} + L_2 v'_{2,z}}{L_1 + L_2}$$

(Rastello, Carraro, and Capuzzo-Dolcetta 2020).

Dynamical properties: ZAMS and present-day solar-type stars

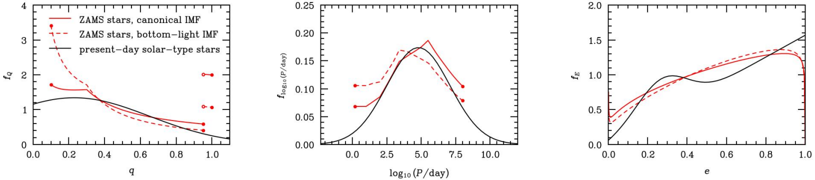

Figure 6. Dynamical properties for **ZAMS stars** (Moe and Stefano 2017) and **present-day solar-type stars** (Duquennoy and Mayor 1991).

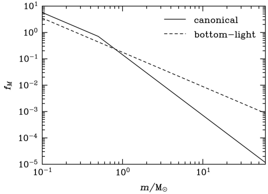

Figure 7. The **canonical IMF** (Kroupa 2002) and **bottom-light IMF** Geha et al. (2013).

The additional velocity dispersion

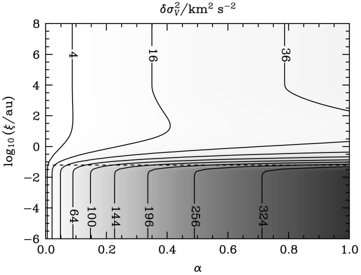

Figure 8. The additional LOS velocity dispersion for ZAMS stars and canonical IMF.

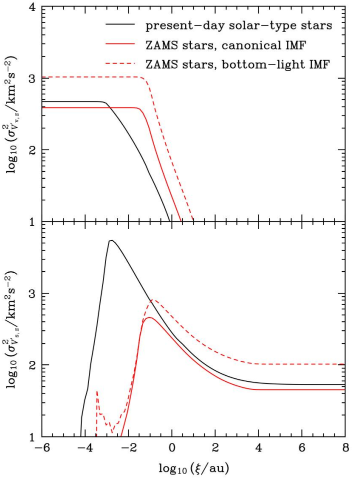

Figure 9. The additional LOS velocity dispersion for ZAMS stars and canonical IMF: visual and spectroscopic binary systems.

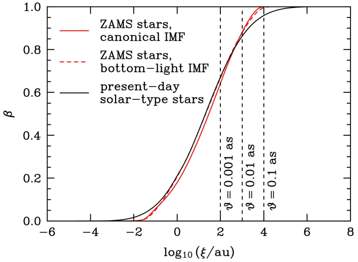

Figure 10. CDF for on-sky separation of binary system components.

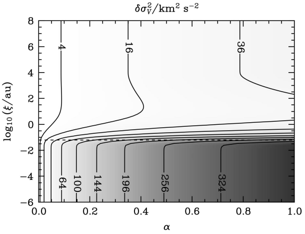

Figure 11. The additional LOS velocity dispersion for ZAMS stars and canonical IMF.

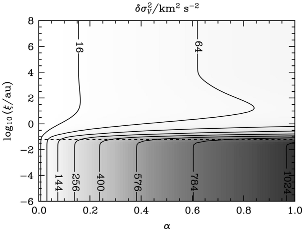

Figure 12. The additional LOS velocity dispersion for ZAMS stars and bottom-light IMF.

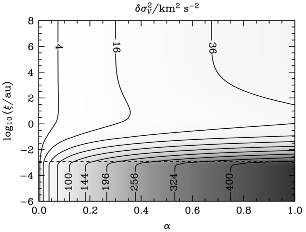

Figure 13. The additional LOS velocity dispersion for systems with RGB primary stars.

The fractional mass increase

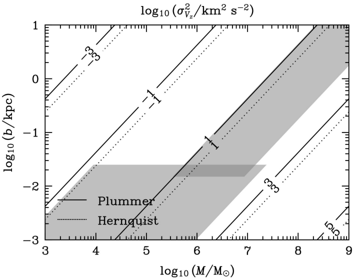

Figure 14. The LOS velocity dispersion for Plummer-type clusters and Hernquist-type galaxies.

The fractional mass increase

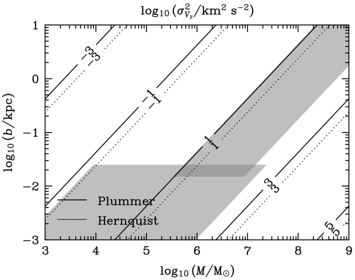

Figure 14. The LOS velocity dispersion for Plummer-type clusters and Hernquist-type galaxies.

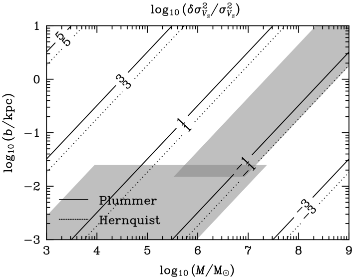

Figure 15. The fractional mass increase for Plummer-type clusters and Hernquist-type galaxies.

Summary

In summary:

- observations are alway in the **unresolved regime**,
- **additional velocity dispersion** $\sigma^2_{V_z} \gtrsim 10\,\mathrm{km}^2\,\mathrm{s}^{-2}$,
- **fractional mass increase** $\delta M/M \lesssim 1$.