Gaia-era inner halo decomposition

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26.3.26.

Milky Way - current view

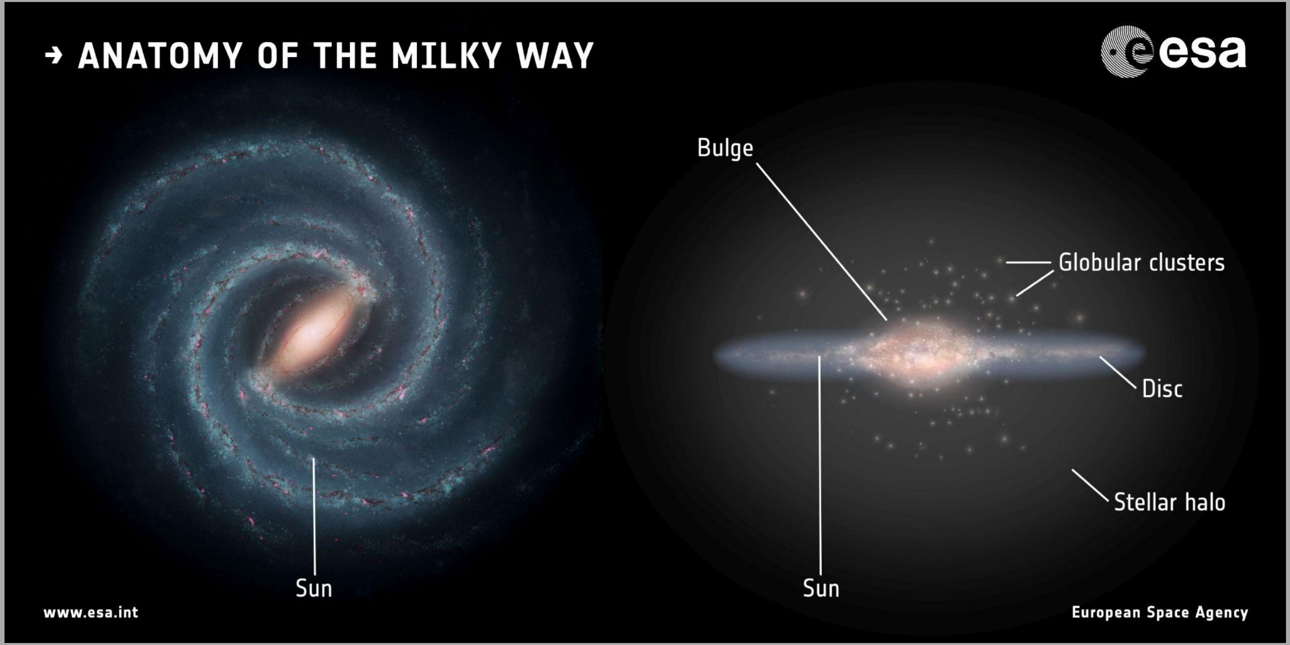


Figure 1. Anatomy of the Milky Way. Credit: Left: NASA/JPL-Caltech; right: ESA; layout: ESA/ATG medialab

- Studies in the **Gaia** era probe deeper into the **stellar halo**
- Further decomposition through **proper motions** and **metallicity**
- **Inner** (<20kpc) and **outer** halo with accreted and in-situ components

Mass of the Milky Way stellar halo (Deason et al., 2019)

- **Deason et al., 2019 - The total stellar halo mass of the Milky Way**

- **Motivation:** previous mass estimates are not robust and inconsistent with current picture of Milky Way evolution

- **Aim**: halo stellar mass within 100 kpc measured through red giant branch (RGB) stars
  - RGB stars: intrinsically bright, numerous and present at all ages and metallicites

- **Sample selection:** GDR2 RGB stars
  - stars at high latitude (|b| > 30°)
  - with parallax <0.2
  - colour $1.0 < G_{BP} - G_{RP} < 1.6$ and
  - apparent magnitude $14 < G < 17$

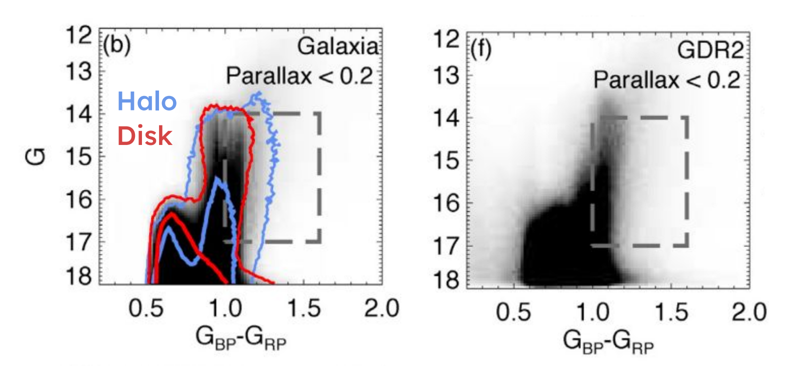
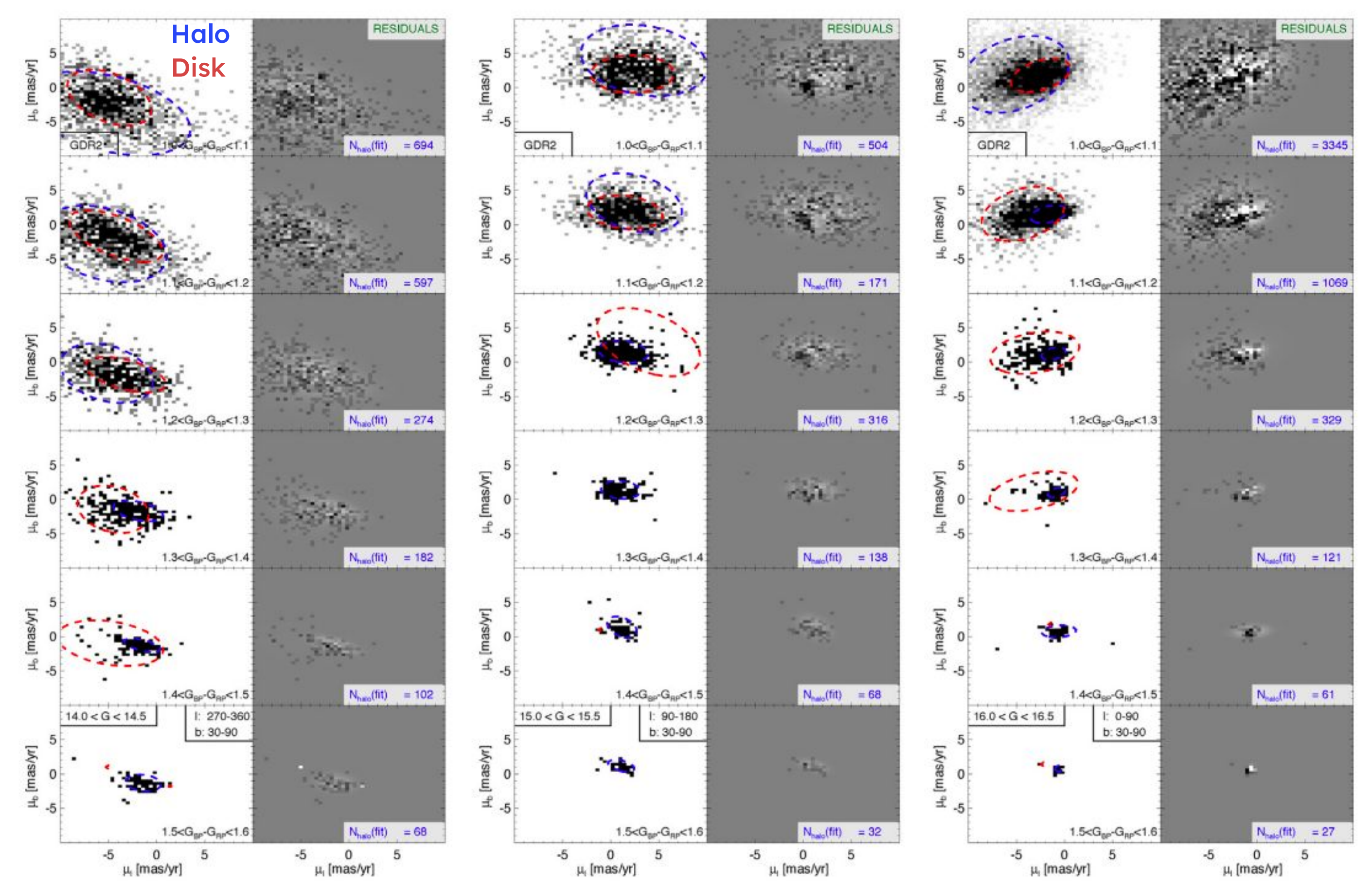


Figure 2. Colour-magnitude diagrams for Galaxia model and GDR2 stars. Adapted from Fig. 1 of Deason et al., 2019

Disk and halo decomposition (Deason et al., 2019)



- Disk and halo stars are decomposed through 2D Gaussian fitting to **proper motion distributions**
- Method validated on simulated MW-like galaxies

Figure 3. Fits to GDR2 proper motions. Fig. 6 of Deason et al., 2019

From RGB star counts to luminosity (Deason et al., 2019)

- Use isochrones (with −2.5 < [M/H] < 0.0 and ages 10–14 Gyr) to get the number of stars per unit luminosity as a function of colour
- Weigh isochrones by age and metallicity, volume correct
- Combine all bins to give the total luminosity estimate

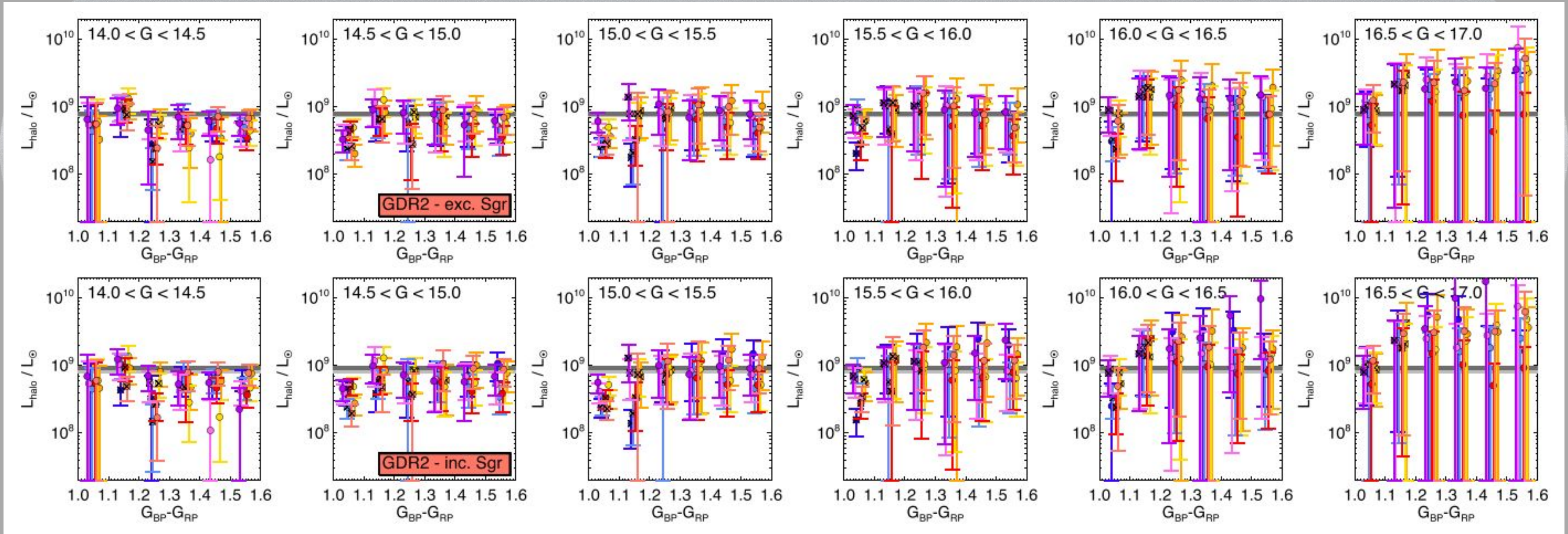


Figure 4. The estimated (total) stellar halo luminosity as a function of colour in different magnitude bins.
Fig. 11 of Deason et al., 2019.

Total halo mass and its implications (Deason et al., 2019)

- Total MW halo luminosity:

  $\mathbf{L_{halo} = 9.4 \pm 2.4 \times 10^8\ L_{solar}}$

  (exc. Sgr: $L_{halo} = 7.9 \pm 2.0 \times 10^8\ L_{solar}$)

- **Total halo stellar mass** computed by estimating the stellar mass to light ratio for the Kroupa IMF:

  $\mathbf{M^*_{halo} = 1.4 \pm 0.4 \times 10^9\ M_{solar}}$

  (exc. Sgr: $M^*_{halo} = 1.2 \pm 0.3 \times 10^9\ M_{solar}$)

  - order of magnitude higher than previous literature estimates

- **Significance:** Mass estimate supports the picture of a massive merger event with a single dwarf progenitor of mass $0.5–1 \times 10^9\ M_{solar}$ (Gaia-Enceladus)

  - directly accounts for the accreted stellar debris

- **Conclusion:** MW inner halo (<20kpc) is dominated by a single massive merger with contributions from

  - **accreted** metal-poor stars from smaller dwarfs
  - **in-situ** component

Milky Way in-situ stars (**Belokurov & Kravtsov, 2022**)

Aluminium to iron abundance => in-situ MW stars from:

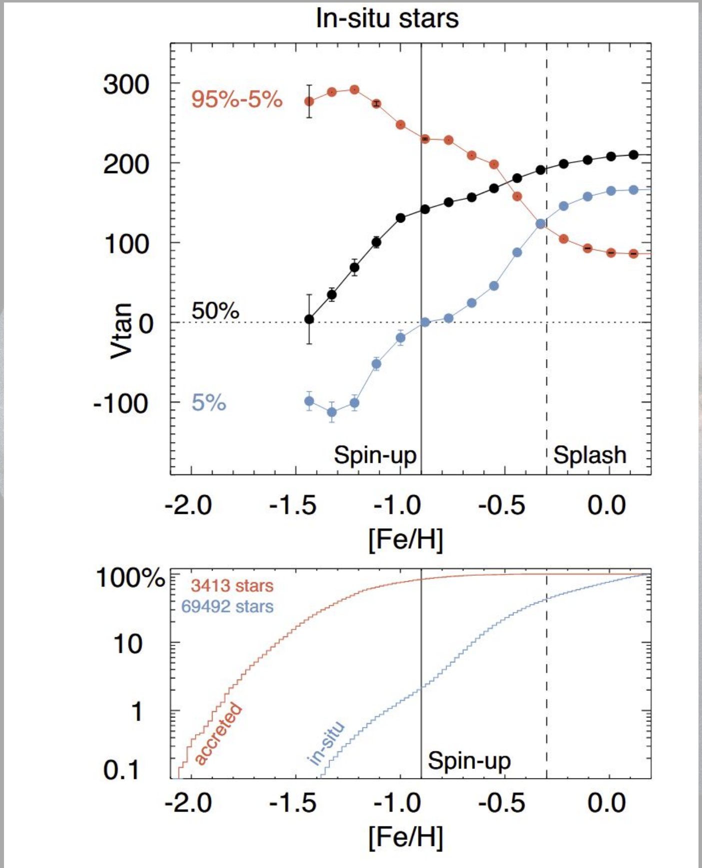
- Supernova II - Al and Fe enrichment
- Supernova Ia - iron peak enrichment

Data from:

- APOGEE DR17 - accurate Al estimates
- Gaia DR3 - accurate astrometry

=> Highly pure in-situ stars ($-1.5 < [Fe/H] < 0.5$)

Milky Way - Turbulent Youth (Belokurov & Kravtsov, 2022)



- [Fe/H] > 0.9 for in-situ stars
- Spin-up: rapid MW disc formation => V_{tan} increase
- Splash: violent head-on collision with Gaia sausage
- Post splash phase: slim V_{tan} spread
- Most in-situ stars have high [Fe/H]

Figure 4. (Top) Tangential velocity of in-situ stars as a function of metallicity.
(Bottom) Cumulative metallicity distribution accreted and in-situ stars

Milky Way - Turbulent Youth (Belokurov & Kravtsov, 2022)

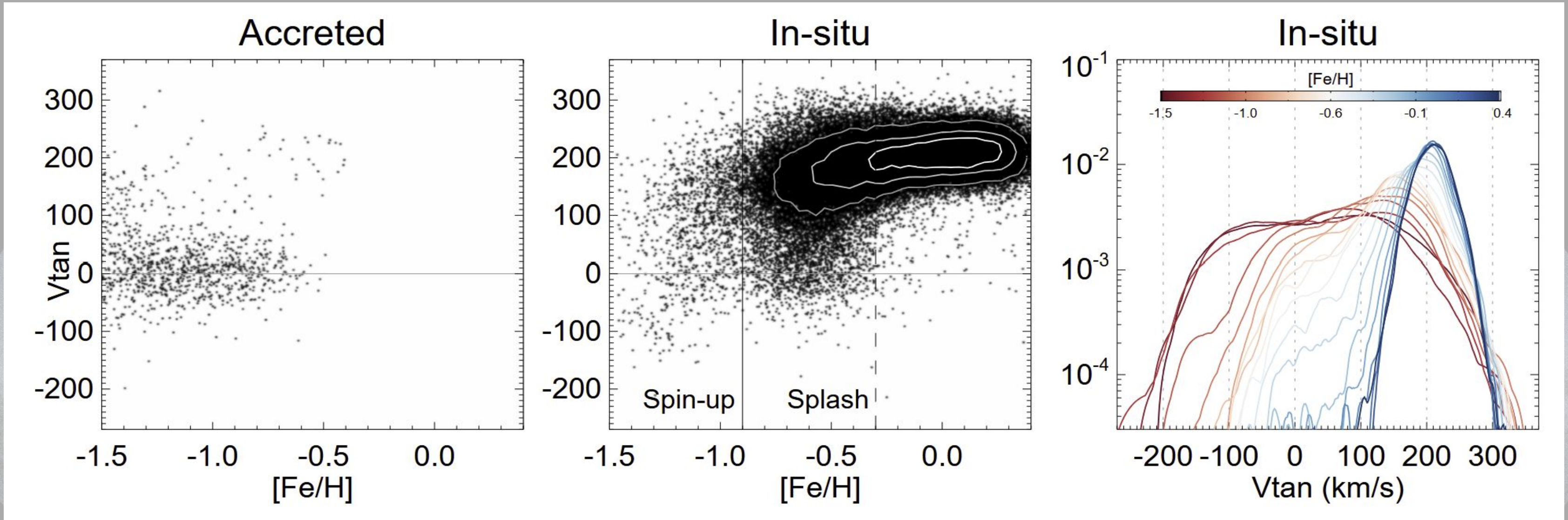


Figure 5. Tangnetial velocity as a function of metallicity for accreted (left) and in-situ stars (middle). (Right) PDF of tangential velocity in metallicity bins

- Vtan scatter of accreted and in-situ stars: similar story
- Slim Vtan PDF of high [Fe/H] stars
- Spin-up phase happens over a small metallicity range

Conclusion and other points

- **Belokurov & Kravtsov 2022**
  - Abundance ratios of Al, Mg, Si, Ni, C, N, O, Mn w.r.t. Fe, and slight focus on Mg
  - Stellar populations from FIRE-2 Latte simulation suite - chaotic spatial distribution at z = 3 - 4
  - ELVIS + zoom-in N-body FIRE-2 simulations -> constraints on formation of coherently rotating MW disc at lookback time of approx. 8 - 12 Gyr

- **Overall conclusion**: MW inner-halo is composed of both **accreted** and **in-situ** stellar populations