Uncovering the birth of the Milky Way through accurate stellar ages with Gaia

C. Gallart; E.J. Bernard; C. Brook; T. Ruiz-Lara; S. Cassisi; V. Hill; M. Monelli

Accurate distances to individual Milky Way stars provided by Gaia have allowed us to derive stellar age distributions from colour–magnitude diagrams (CMD) representative of the thick disc and the local halo. The CMD for the kinematically selected halo stars showed an **enigmatic double main sequence**. The blue sequence had been linked to a major accretion event, Gaia-Enceladus, whereas debate existed about the nature of the redder stars. We showed that both halo sequences share identical old age distributions, owing their difference in colour to the higher metallicity of the stars in the red sequence. These age distributions, together with cosmological simulations of galaxy formation, allowed us to identify the red sequence stars as the first stars formed in our Galaxy (the long-sought in-situ halo), and date the accretion of Gaia-Enceladus ~10 Gyr ago.

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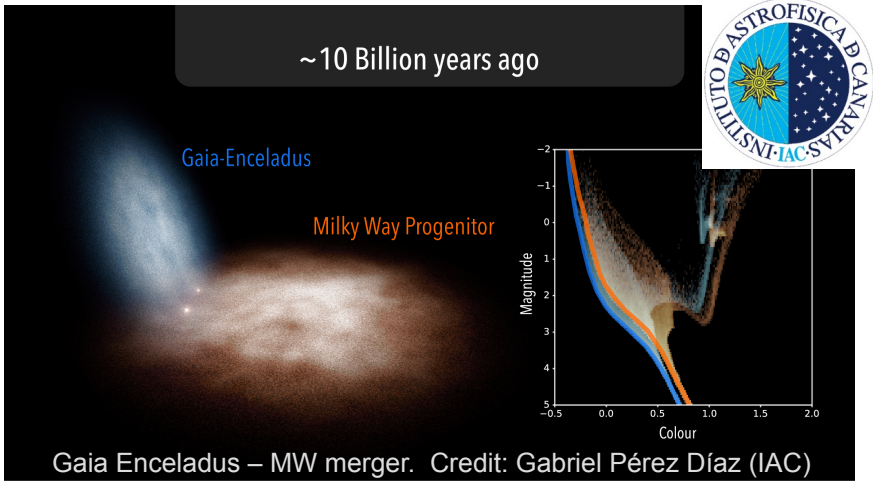
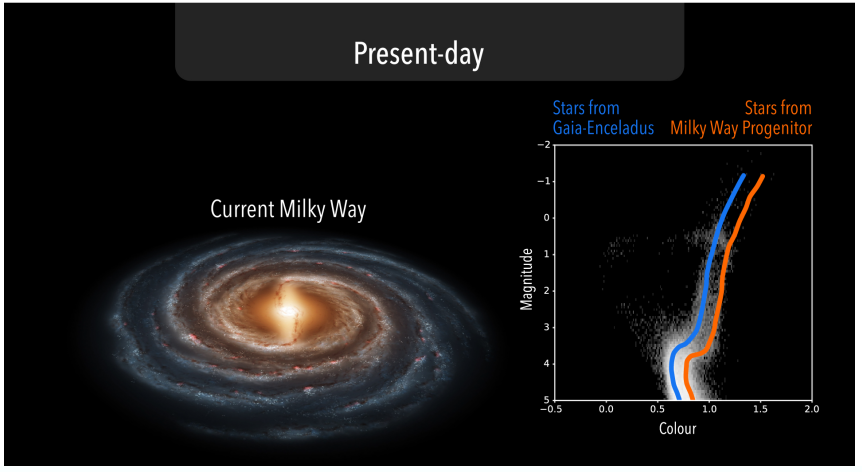
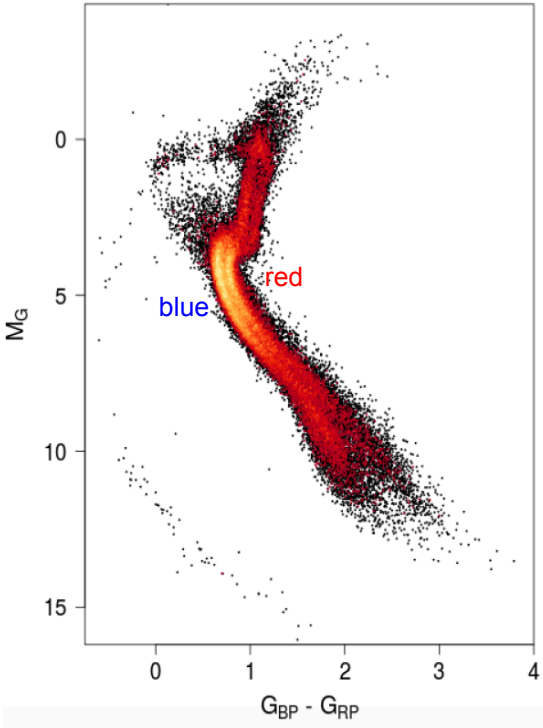


Gaia Enceladus – MW merger. Credit: Gabriel Pérez Díaz (IAC)



Context



Babusiaux et al. 2018

On the nature of the Galactic halo population

★ Existence of two distinct populations in the Galactic halo near the Sun has been long discussed (e.g.Brook+2003; Nissen&Schuster 2010)

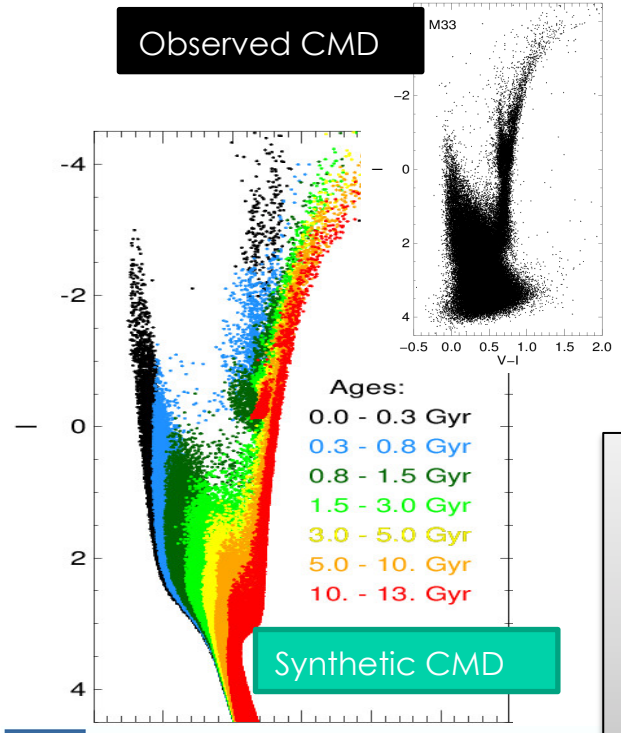
★The CMD of the **kinematically selected** halo stellar population from Gaia DR2 showed two enigmatic sequences that could correspond to these two distinct halo populations (Babusiaux+2018)

★**Blue sequence** → Accreted population: **Gaia-Enceladus**, contributing an important fraction of halo stars (Helmi+2018)

★**Red sequence** → Associated with the thick disc by the similar chemistry (Haywood+2018)

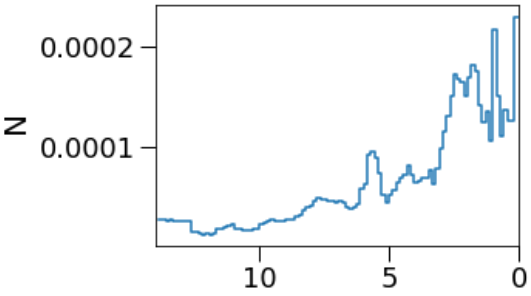
Due to the lack of accurate ages, the time of the merger and its role on the early evolution of the Galaxy remained unclear

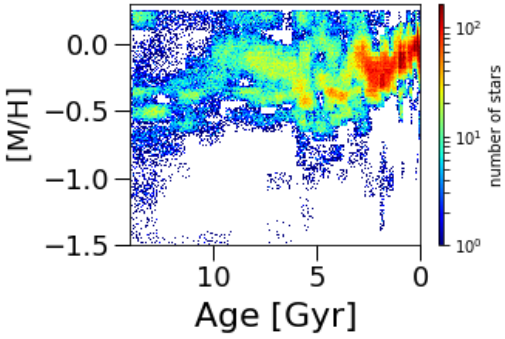
METHOD: CMD Fitting Technique



The distribution of stars across the observed CMD is compared with that in a synthetic CMD

Star formation history **(SFH)** and thus **age and [M/H] distributions** are derived

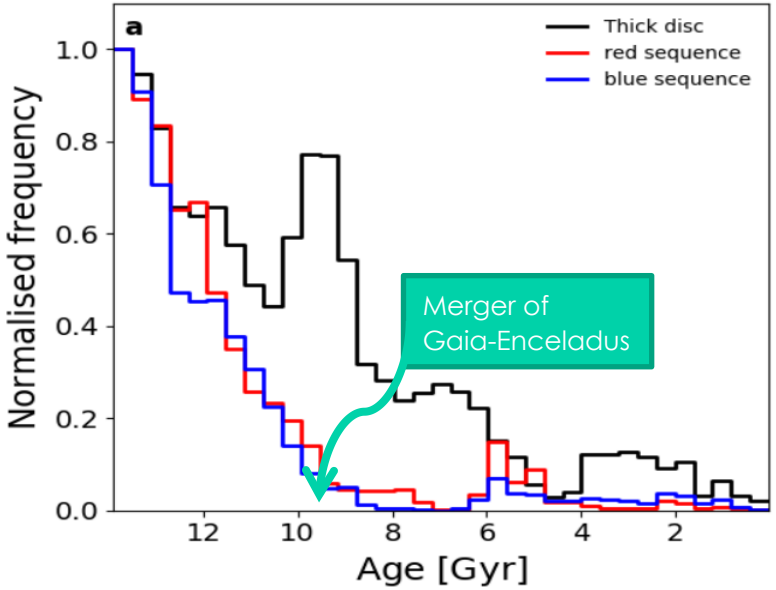




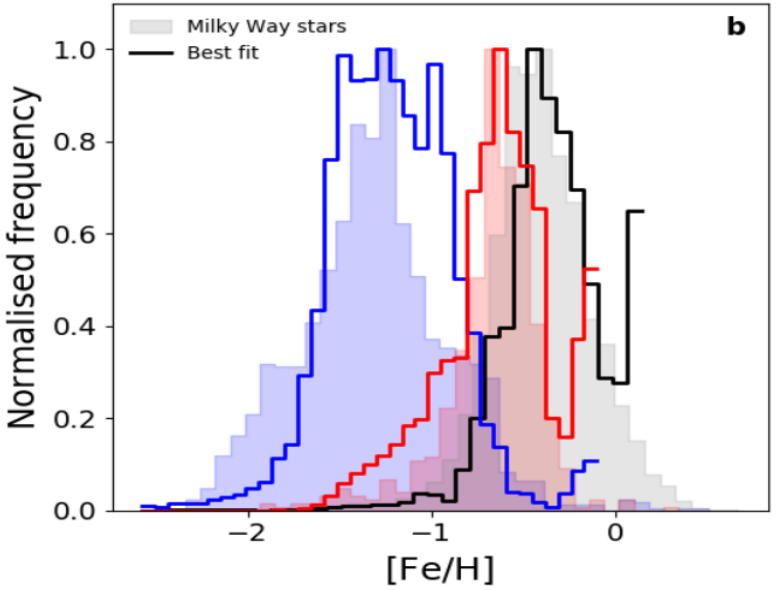
Obtaining SFHs from CMD fitting is a technique applied to study the evolution of Local Group galaxies

Pioneer works: Bertelli+1992; Gallart+1999; Hernández+1999; Dolphin 2002; Aparicio&Gallart 2004; Cignoni &Tosi 2010

RESULTS I

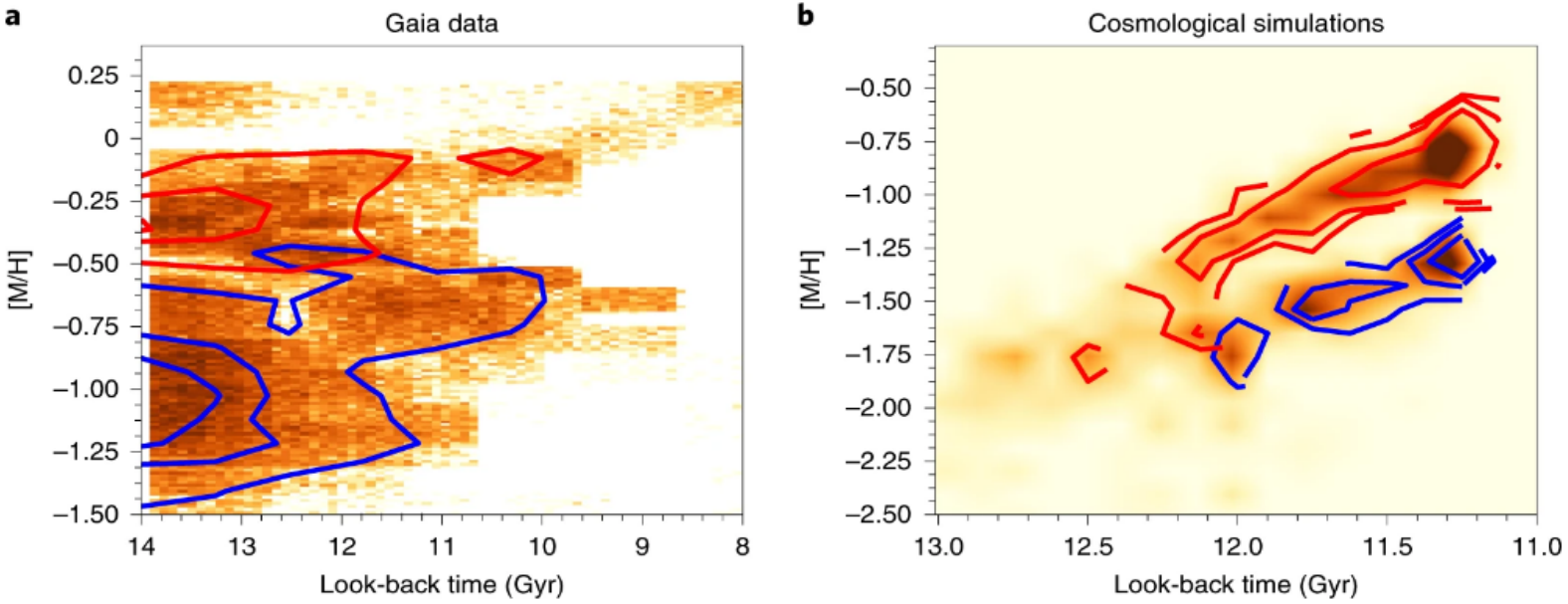


The two halo sequences have the same **OLD age distribution**, that is **older than** the age distribution of the **thick disk. Note the burst of star formation at the time of the merger.**



Sequence separation in the CMD due to **different metallicity distributions**. *Shaded histograms:* spectroscopic metallicity distribution of RGB stars. *Lines:* metallicity histograms derived from CMD fitting. Note the good agreement.

RESULTS II



The derived age-metallicity relation shows qualitatively similar features as those from cosmological simulations of Milky Way analogues experiencing an early massive merger. The two age-metallicity sequences correspond to the Milky Way progenitor and merged satellite. In these simulations, the thick disk formed at high redshift during a period characterized by gas-rich mergers (Brook+2004)

CONCLUSIONS

★ The availability of Gaia distances has allowed us to adapt the **CMD fitting technique** (commonly applied to dwarf galaxies in the Local Group) to analyze **Milky Way Gaia CMDs.**

★ This allows us to determine the **star formation histories and age distributions** in **large volumes** within the **Milky Way**

★ **This is a revolution in Galactic archaeology** as stellar age distributions are one of the main missing pieces of the puzzle → **possibility to obtain NOW chrono-chemo-dynamical maps** of the Milky Way

★ Blue and red halo sequences exhibit similar old age distributions, with the colour difference due to the difference in metallicity. Gaia-Enceladus was accreted by the Milky Way 10 Gyr ago, causing a burst of star formation in the thick disk