Galaxy Merger in the Milky Way

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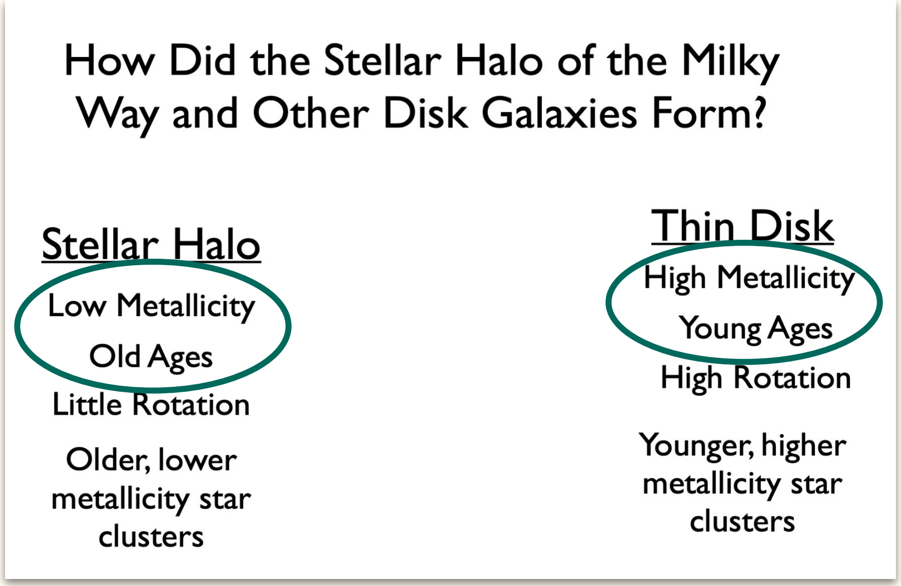
2 papers

Ancient Galaxy Mergers

- Gaia-Sausage
  (*Belokurov, 2018*)
- Gaia-Enceladus
  (*Helmi, 2018*)

Gaia-Sausage

Gaia-Sausage

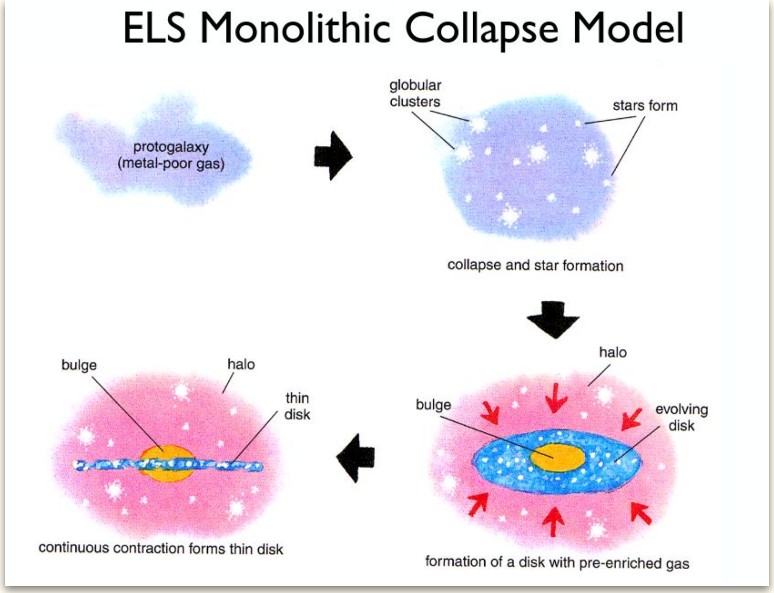


Galaxies: Structure, Dynamics and Evolution
Lecture 2. Bouwens

- Halo stars older than disk stars
  - Halo epoch formation still vague
  - 13 Gyr $< t_{ISF} <$ 8 Gyr
- Age t[Gyr] estimated by
  - cluster metallicity 13 $< t[\text{Gyr}] <$ 10
  - dwarf spheroidal galaxies host stars from $t \sim$ 13 Gyr
  - ultra-faint dwarfs formed most stellar pops. $t_H \sim$ 9.3 Gyr
- Observed Halo stars: 10 - 12 Gyr

Gaia-Sausage

- **(Eggen, Lynden-Bell 1962)**:
  metallicity, eccentricity strongly correlated!
  - Criticism: unreliable; strong data selection bias



Galaxies: Structure, Dynamics and Evolution
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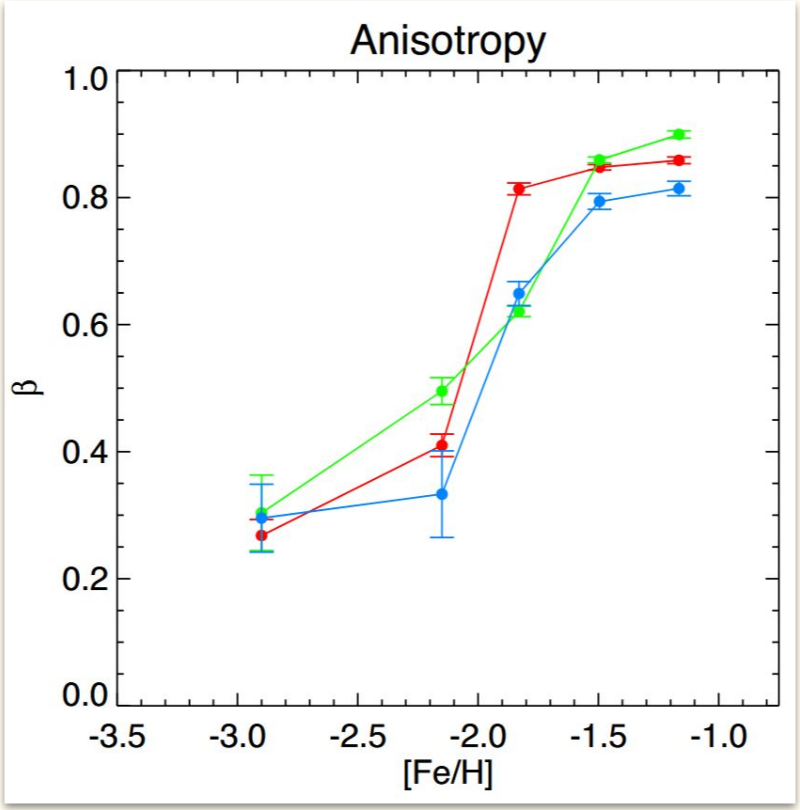
- **ELS Evolutionary Collapse Model**:
  1. Metal-deficient halo stars formed first in 1 sphere;
  2. Original gas cloud collapsed and new stars formed;
  3. Younger stars more circular orbits,
     but strongly affected shape of old stellar halo;
  4. Orbit of halo stars highly eccentric due to gas collapse.

Gaia-Sausage

- Kinematically invariant data
  - Prevent data selection bias

- Anisotropy β
  - $\beta \sim 1$ for radial orbits
  - $\beta \sim -\infty$ for circular orbits
  - $\beta \sim 0.5$ around the Sun ($<$ 15 kpc)

- *Figure 4:*
  Anisotropy vs. metallicity for halo stars
  - 'Knee' -> Massive progenitor



Gaia-Sausage - Results

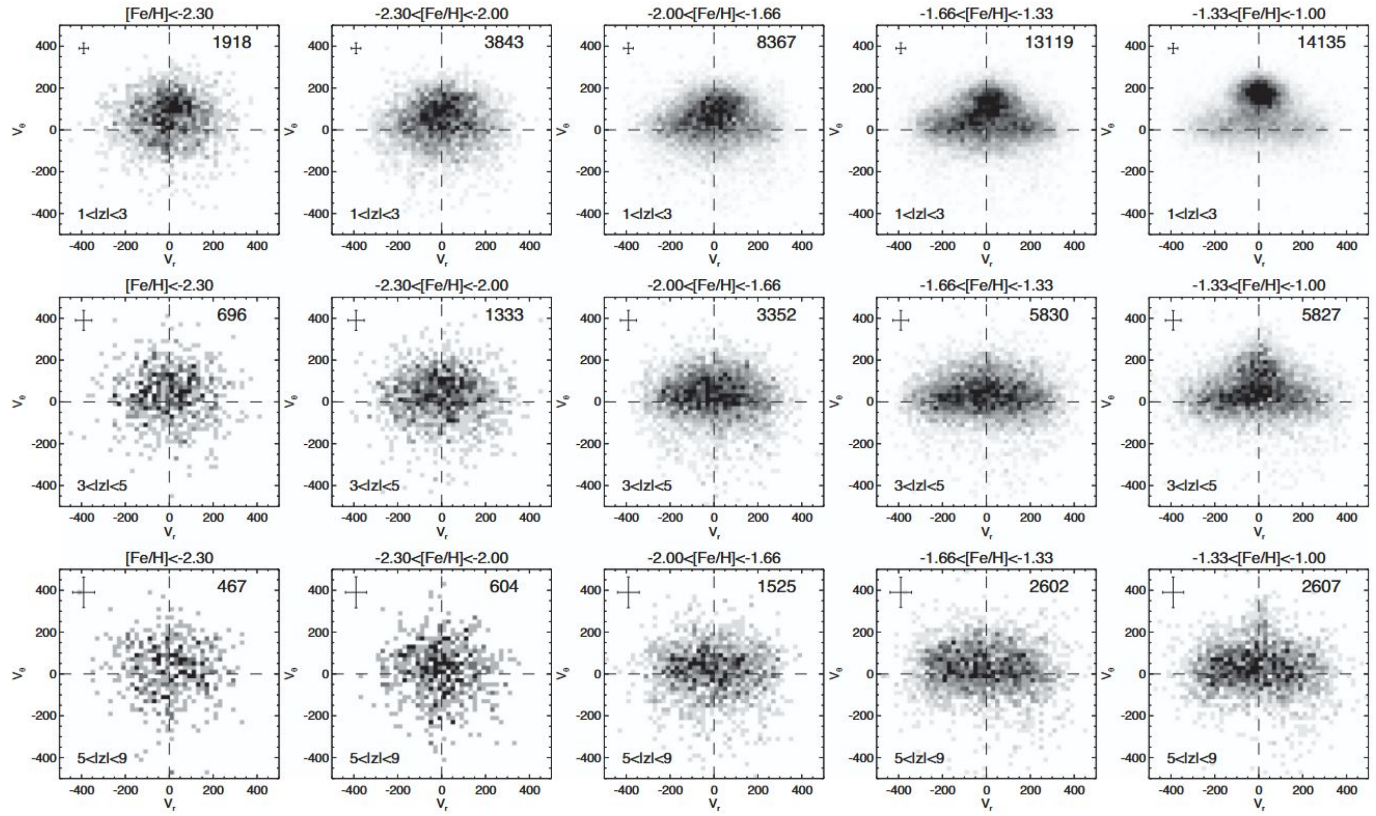


Figure 2:
Plotted data of the radial vs azimuthal velocity distribution

Gaia-Sausage

- Solid white: Disk
- Solid black: Halo
- Dashed white: another halo!

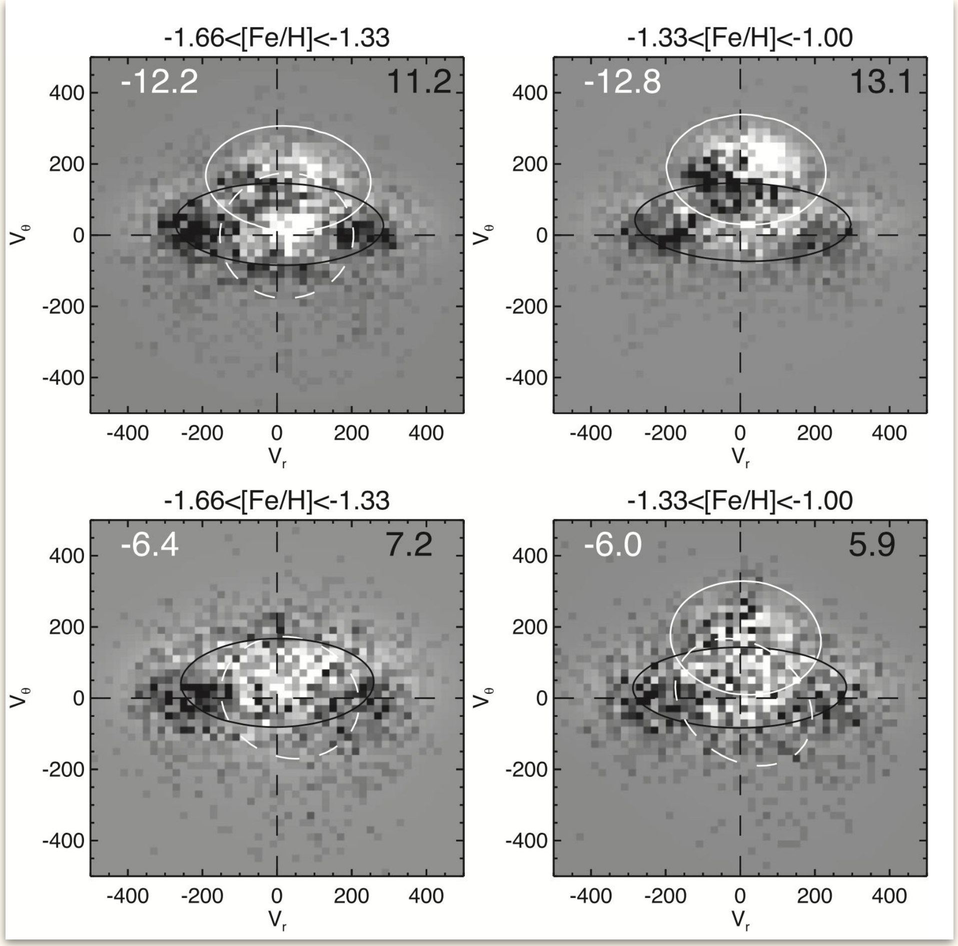
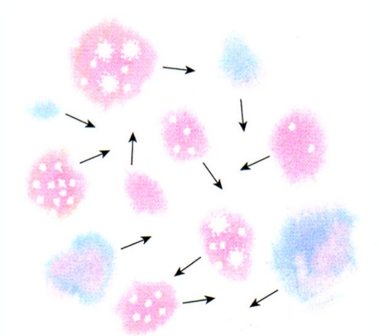


Figure 3:
Velocity residuals
with fit Gaussians

Gaia-Sausage - Conclusion

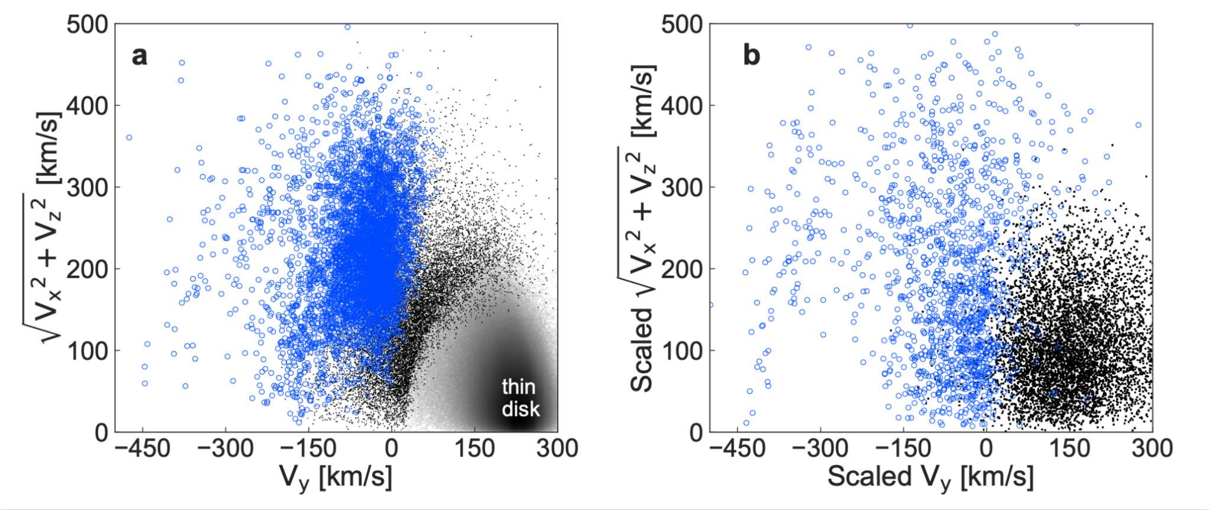
- Lecture shows that the disk has a high metallicity and the halo a low metallicity
  - The paper shows that is not entirely true
- One halo population has low metallicity and low radial velocity
- Second halo population has high metallicity and high radial velocity


protogalactic fragments in various stages of evolution

Gaia-Enceladus

Gaia-Enceladus

- Different method to show the possibility of a merger
- Plots velocity distribution
- Mass-ratio of 0.24

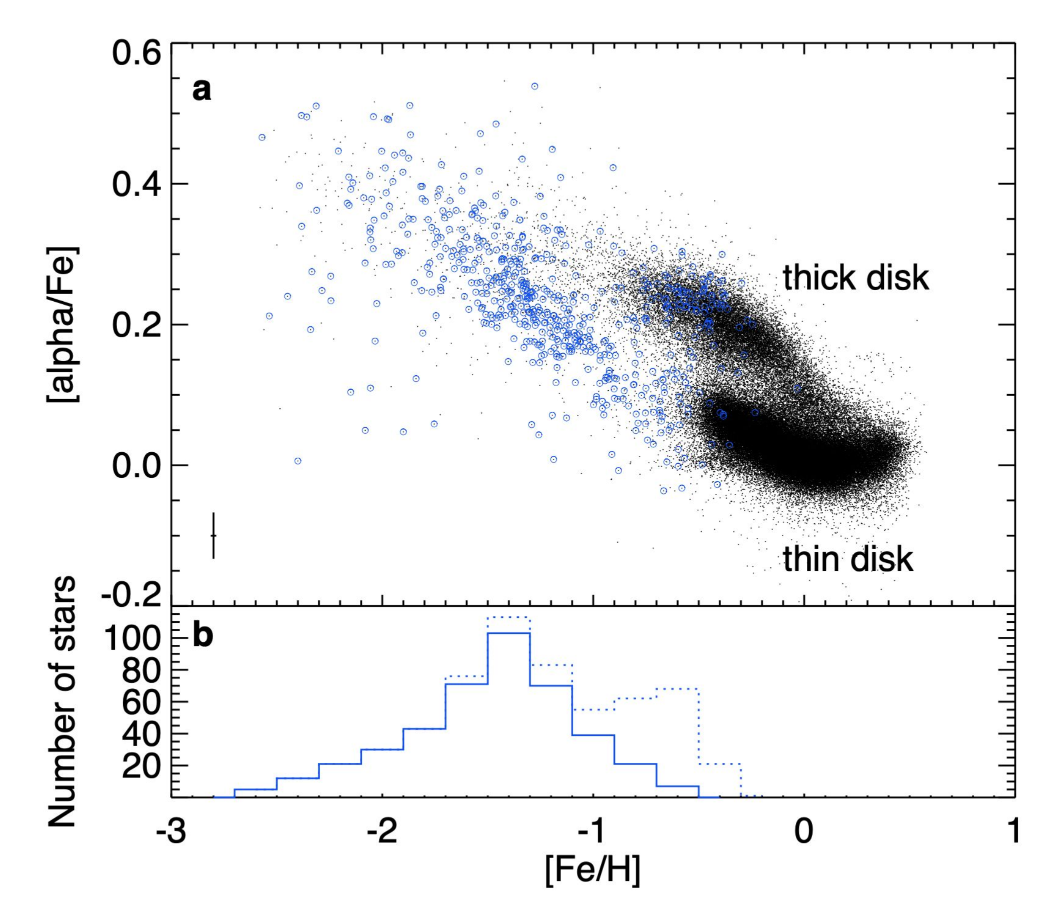


Velocity distribution of stars from the halo

Simulation of the velocity distribution in case of a merger

Gaia-Enceladus

- **b** shows high metallicity spread
- Properties of this merger
- Looks at [α/Fe] ratio vs [Fe/H] ratio
- α-elements are from massive stars that die fast
- [α/Fe] decreases as [Fe/H] increased
- Low [α/Fe] means low star formation rate
- **a** shows at -0.6 [Fe/H] the stars have lower [α/Fe] ratio
- Merger had lower star formation rate



Main results

Halo has 2 populations, probably caused by a merger	1 high metallicity and 1 low metallicity population
Merger has a mass-ratio of 0.24	Merger has low [α/Fe] ➡ low star formation rate