The Characterization of the Metal-rich Stellar Halo with Gaia DR2 and APOGEE

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Stellar Halos Across the Cosmos
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Stellar populations in the halo

- Halo stars: larger kinematical energy comparing to disk stars

- Within samples of halo stars: detection of different chemical trends → formed by distinct formation channels:

  In situ
  Accreted

(Steve Majewski’s talk)
A dual formation scenario for the Galactic halo

- Inner and outer halo differences:
  - spatial (Deason, Belokurov & Evans 2011),
  - chemical (Fernández-Alvar et al. 2015,2017)
  - and kinematical (Carollo et al. 2007, 2010; Belokurov et al. 2018; several talks here)

Fernández-Alvar et al. (2015)
The two alpha pop in the metal-rich halo

(In the solar neighbourhood)

Nissen and Schuster (2010)
The two alpha pop in the metal-rich halo

Hayes et al. (2018a): APOGEE database, much larger halo sample
The two alpha pop in the metal-rich halo

Fernández-Alvar et al. (2018)

\[ V_{\text{rad}} > 180 \text{ km s}^{-1} \]
The two alpha pop in the metal-rich halo

(In the solar neighbourhood)

Bonaca et al. (2017): in situ origin
Helmi et al. (2018): accreted origin

Haywood et al. (2018)
Our halo sample in APOGEE

- $|z| > 5$ kpc
- $4000 < \text{Teff} < 6500$ K
- $1.5 < \log g < 3.5$

- Chemical abundances by ASPCAP
- Orbital parameters: GravPot16 (Fernández-Trincado et al. 2017)
  - $V_{\text{rad}}$ APOGEE ($\sigma \sim 0.1$ km/s)
  - Gaia DR2 proper motions
  - StarHorse Distances (Santiago et al. (in prep.) bayesian method from spectroscopic stellar parameters and Gaia parallaxes priors).
Metallicity Distribution Function

Fernández-Alvar et al. (in prep.)
Orbital Parameters

Fernández-Alvar et al. (in prep.)
Orbital Parameters

See Hayes et al. (2018b)
Fernández-Alvar et al (in prep.)
Fernández-Alvar et al. (in prep.)
Fernández-Alvar et al. (in prep.)
Conclusions

- Metal-rich halo detected at $|z| > 5 \text{kpc}$
  Splits in three $[\text{Mg/Fe}]$ vs. $[\text{Fe/H}]$ sequences

- Intermediate $\text{Mg/Fe}$ stars:
  - KNEE of the high-alpha population
  - Triangulum/Andromeda candidates

- Low-$[\text{Mg/Fe}]$ stars follow the chemical trend of the bulk of metal-poor halo stars, $V$ distributed in 0 rotation, orbits less bound and reach larger $z_{\text{max}}$, $r_{\text{max}}$ and $r_{\text{min}}$: accreted origin

- High-$[\text{Mg/Fe}]$ stars $V$ distribution with primarily prograde rotation (although some in retrograde orbits). More bound and closer to the Galactic plane: disk heated origin, by a massive merger able to heat stars at such high $z$