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SPECTROSCOPIC SURVEYS UNVEALING THE GALACTIC STELLAR HALO

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Observatoire de la CÔTE d'AZUR

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INSTITUTO DE ASTROFISICA DE CANARIAS · IAC

esa

gaia

SDSS

GALACTIC ARCHAEOLOGY

Chemistry and kinematical and dynamical properties of the stars:

- Accurate chemical abundance determination (high-resolution spectra)
- Accurate distance and velocity measurements.

Up to now:

- Inner halo with high-resolution spectra and accurate astrometry (e.g., APOGEE, Gaia)
- Outer halo with low-resolution spectra (e.g., SEGUE,

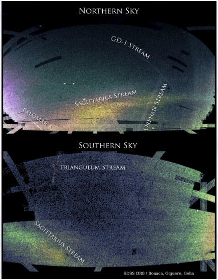
THE GALACTIC STELLAR HALO BEFORE GAIA

- Lambda - Cold Dark Matter model: galaxies formed from the accretion of smaller subsystems: several observational evidences.

' Different spatial, kinematical and chemical properties as a function of distance: inner and outer halo (r ~ 15-20 kpc):

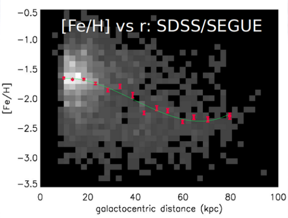
Different formation scenario.

(e.g., Carollo et al. 2007, 2010)

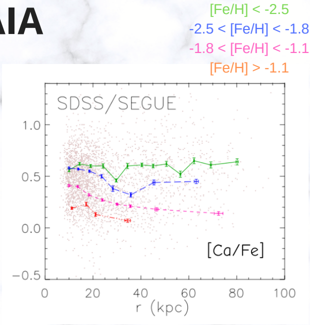


Bonaca et al. 2012

THE GALACTIC STELLAR HALO BEFORE GAIA



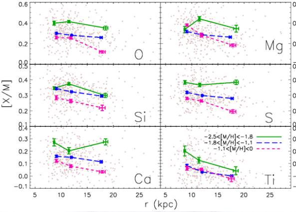
Fernández-Alvar et al. 2015

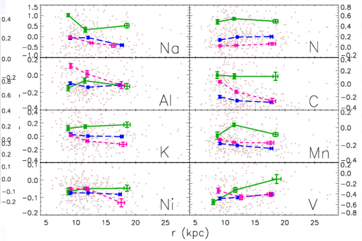


Distant surveys limited to low-resolution spectra

Chemical gradients with distance from the Galactic center, depending on metallicity.

THE GALACTIC STELLAR HALO BEFORE GAIA



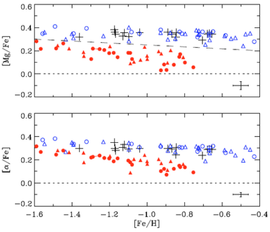


Fernández-Alvar et al. 2017

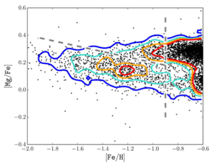
Lack of accurate chemical abundances to explore the outer halo.

Gradients confirmed in high-resolution spectra (APOGEE DR12) in several chemical species.

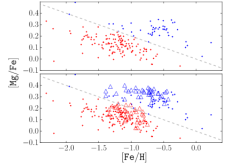
TWO DIFFERENT STELLAR POPULATIONS IN FIELD STARS



Nissen & Schuster 2010

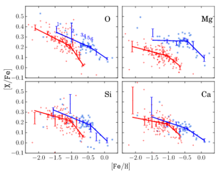


Hayes et al.



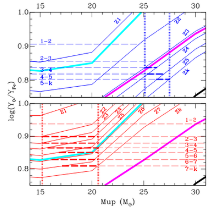
Fernández-Alvar et al. 2018

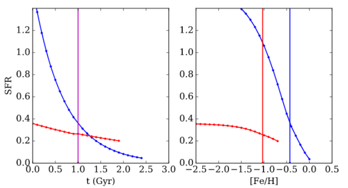
TWO DIFFERENT STELLAR POPULATIONS IN FIELD STARS



Fernández-Alvar et al. 2018

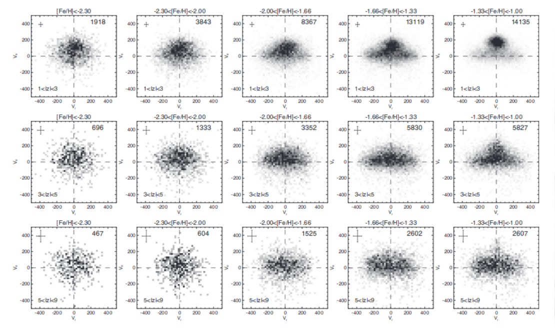
Comparison with chemical evolution models to infer the upper mass limit of the IMF and the SFR.





THE GAIA REVOLUTION

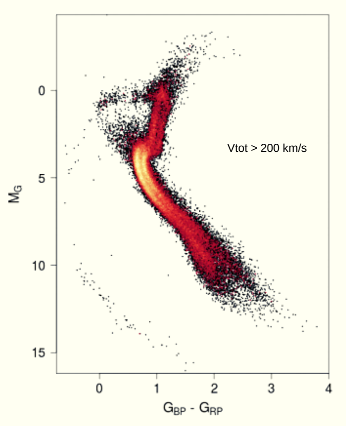
GAIA SAUSAGE (GAIA DR1 + TGAS)



Belokurov et al. (2018)

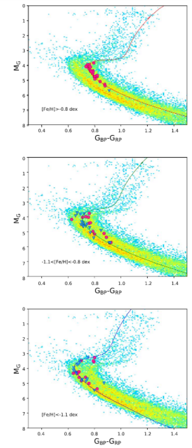
[Fe/H] > -1.7

orbital anisotropy: major merger event at the epoch of the disc formation



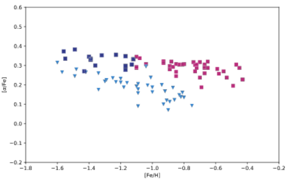
Gaia collaboration, Babusiaux et al. 2018a

Inner halo distributed in two populations (sequences in the HR diagram).



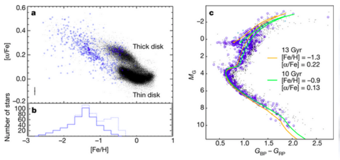
Haywood et al. 2018

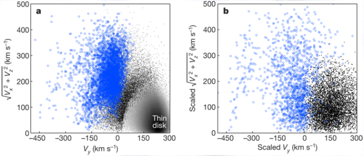
Nissen & Schuster 2010 sample
APOGEE DR14
high-alpha and low-alpha populations
indistinguishable at [Fe/H] < -1.1

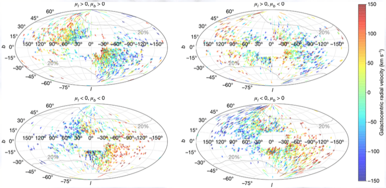


GAIA ENCELADUS (GAIA DR2)

Helmi et al. (2018)







Mass of 6x10^8 Msun, inferred from Fernández-Alvar et al. 2018 SFR estimates.

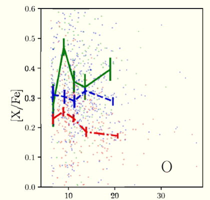
WHAT IS THE ORIGIN OF THE RED SEQUENCE WITH DISK-LIKE CHEMISTRY BUT HALO-LIKE KINEMATICS?

WHICH POPULATION (IN-SITU OR ACCRETED) DOMINATES THE INNER HALO?

WHAT IS THE CONTRIBUTION OF EACH POPULATION TO THE RADIAL GRADIENTS?

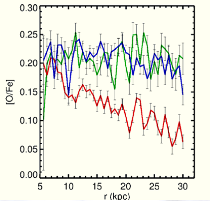
OBSERVATIONS AND COSMOLOGICAL SIMULATIONS

Fernández-Alvar et al. (2019a)

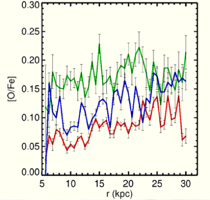


[O/FE] OBSERVATIONS

APOGEE
DR14

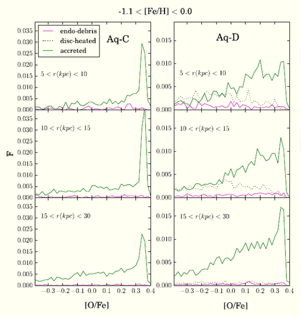


[O/FE] SIMULATION AQ-C



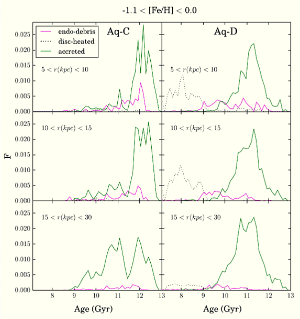
[O/FE] SIMULATION AQ-D

Aquarius hydrodynamical simulations



[O/FE] DISTRIBUTION AS A FUNCTION OF THEIR ACCRETED OR IN-SITU ORIGIN

Gradient caused by accreted stars

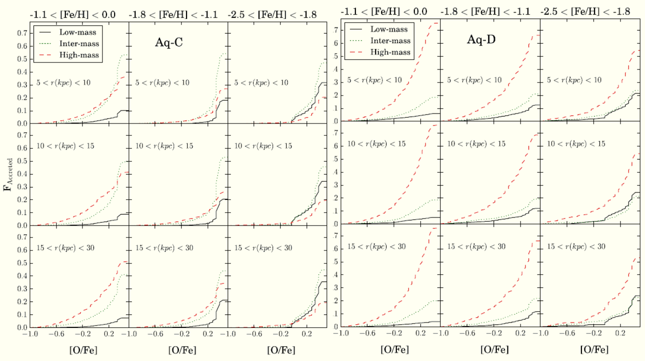


AGE DISTRIBUTION

Second star burst of star formation at distances larger than 15 kpc due to a massive satellite

MASS DISTRIBUTION

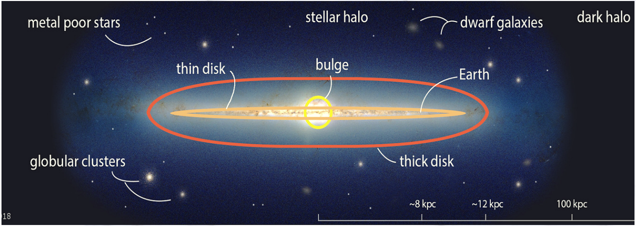
Intermediate mass satellites dominating at r < 15 kpc with high-[Mg/Fe] and massive satellites dominating at r > 15 kpc with low-[Mg/Fe]



low mass satellites: Mdyn < 10^9Msun

intermediate mass satellites: 10^9Msun<Mdyn<10^10Msun

massive satellites: Mdyn > 10^10Msun

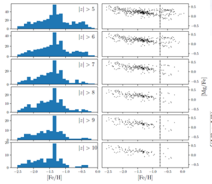


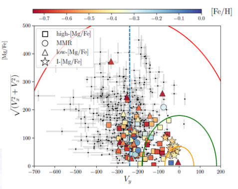
THE THICK-DISK AND THE HALO: THE METAL RICH HALO TAIL WITH Z

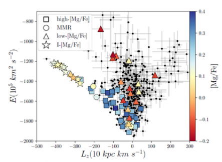
Fernández-Alvar et al. (2019b)

THE METAL-RICH HALO TAIL WITH Z

Fernández-Alvar et al. (2019b)







MDF

Metal-rich stars (high-[Mg/Fe], I-[Mg/Fe] and low-[Mg/Fe]) up to |z| ~ 10 kpc

TOOMRE DIAGRAM

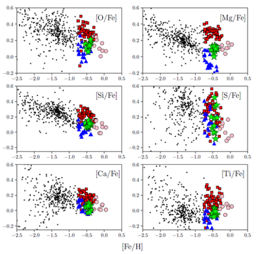
Halo-like kinematics, except for the I-[Mg/Fe] group

ACTION SPACE

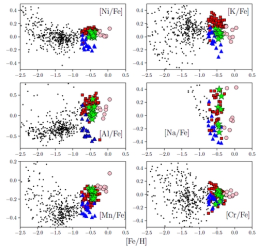
High-[Mg/Fe] with almost no rotation but a tail towards the disk locus

CHEMICALLY DISTINCT

ALPHA



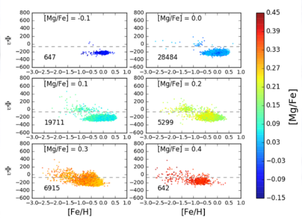
OTHERS



OLD THICK DISK OR IN-SITU HALO?

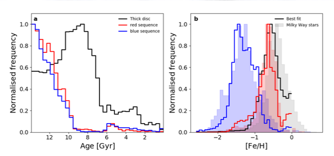
THE MILKY WAY HAS NO IN-SITU HALO BUT IT HAS A THICK DISC. COMPOSITION OF THE STELLAR HALO AND AGE-DATING THE LAST SIGNIFICANT MERGER WITH GAIA DR2 AND APOGEE

Di Matteo et al. 2018 (arXiv:1812.08232)



THE BIRTH OF THE MILKY WAY: THE IN-SITU HALO AND EARLY THICK DISK AS UNCOVERED BY ACCURATE STELLAR AGES WITH GAIA

Gallart et al. 2019 (arXiv:1901.02900)



FUTURE WORK: THE MAUNAKEA SPECTROSCOPIC EXPLORER

TARGET THE OUTER HALO

Accurate chemical abundances of millions of stars in the outer halo:
- Characterize the chemical gradients and compare with simulations.
- Identify distinct stellar populations and use chemical evolution models to infer IMF and SFH of the outer halo building blocks.
- Accretion history.

LOOFING FOR THE VERY FIRST STARS

Understand the first steps of Galaxy formation by the characterization of ver metal-poor stars [Fe/H] < -3 and their distribution accross the halo.

THANK YOU!