Chemical Abundances in Hydrus I & Defining our UFDs

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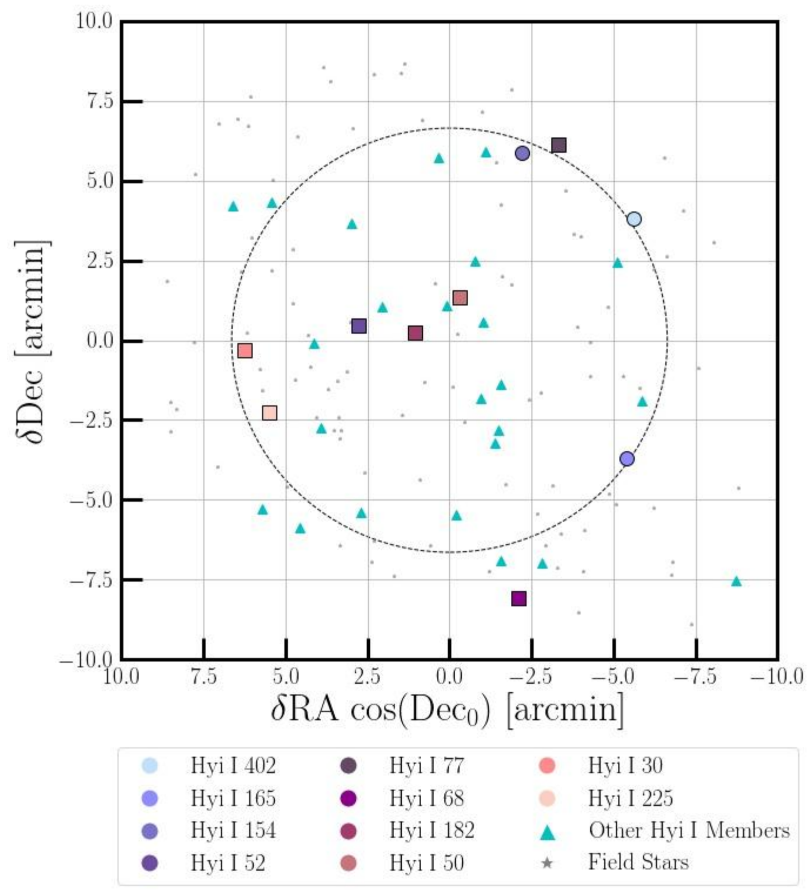
Recreating the metallicities of our ultra-faint dwarf galaxies (UFDs) is a persistent tension between observations and theory even though counts and kinematics of observed UFDs roughly match what is seen in simulations and semi-analytic models. Simulations predict a strong scaling between M_* and [Fe/H] – thought to be a result of star formation proceeding mostly in-situ and polluting the ISM proportionally to the number of stars formed. Instead, observations suggest that there is a "flattening" or plateau at the UFD scale, hinting at a decoupling between M_* and [Fe/H]. This disagreement has profound implications: **Are UFDs just tidally stripped remnants of more massive galaxies? Is there a minimum mass threshold for galaxy formation? Are many ultrafaints actually stellar clusters, indicating a lack of understanding of dark matter halo occupation fractions?** Metallicity and detailed chemical abundance measurements assist in sorting these possibilities.



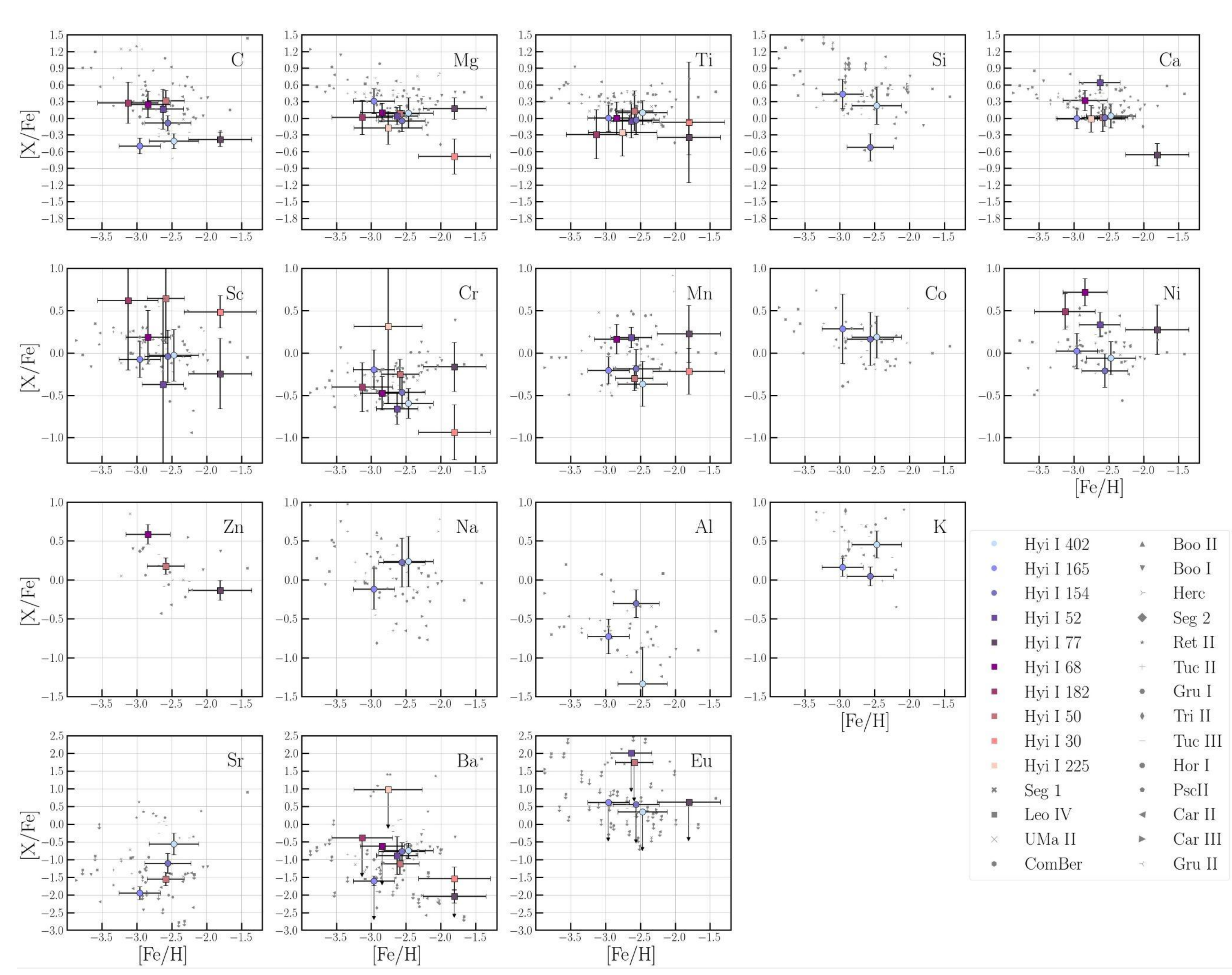
Hydrus I

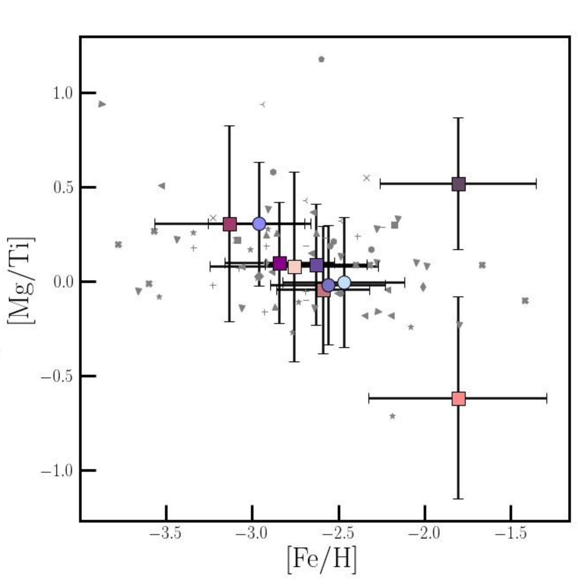
- Distance: 27.6±0.5 kpc
- M_V: -4.71±0.08
- $M_\star$: ~10^4 M_sun
- R_h: 53±4 pc
- V_{helio}: +80.4±0.6 km/s
- σ: 2.7±0.45 km/s
- ([Fe/H]): - 2.52±0.9

From high resolution spectra, from MIKE and M2FS on the the Magellan/Clay Telescope, for 10 member RGB stars in Hyi I, see direct-left figure, we measured abundances for 17 elements, see figure left-below. The data was reduced using CarPy & M2FS Reduction Pipeline and chemical abundance measurements made with SMHR. Stellar parameters were *(mostly)* set spectroscopically. For 3 stars observed with M2FS (1030, 1077, & 1225), stellar parameters were set to the models: 13 Gyr Isochrones with DECam Photometry and metal poor halo stars from Barklem et al. (2005).

The abundances within Hyi I follow suit with measurements in other UFDs which suggests similar formation and evolutionary histories within this set of ancient galaxies. Additionally, as recently seen in other UFDs, there is a decreasing α-element ratio ([Mg/Ti]) trend across metallicity, see figure below-right. This trend suggests possible variations in the IMF at the smallest scales.

Chemical Abundances

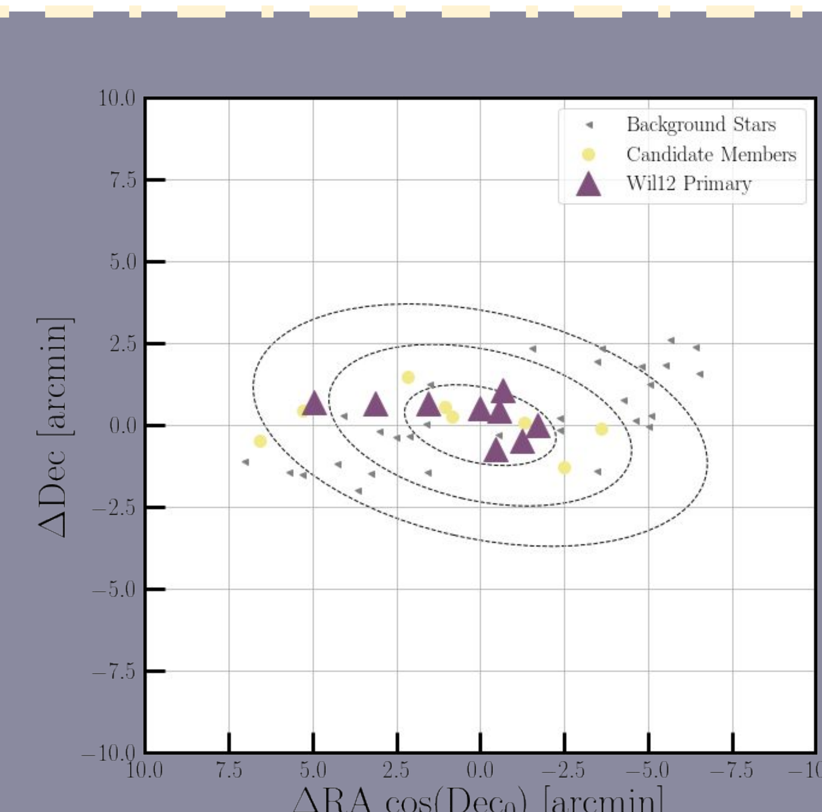


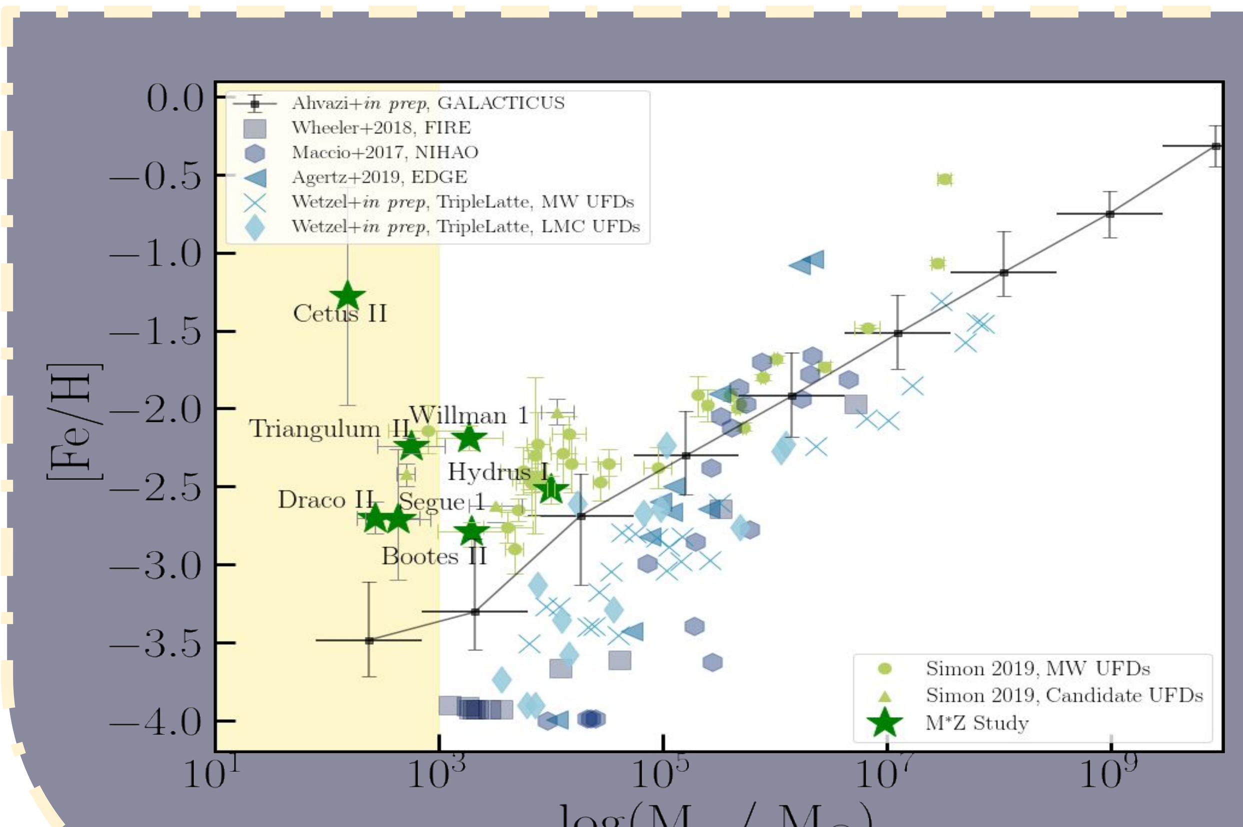


We are currently analyzing high resolution spectra, from Keck DEIMOS, for 10 members stars and 6 candidate member stars in Willman 1. Our goal is to measure the system's overall metallicity and characterize this stellar system (i.e. **is Willman 1 an UFD, a globular cluster, or a stripped remnant of a more massive galaxy?**). Chemical abundance analysis will focus on α-elements and r-process elements. Ba abundances will allow us to determine how common events such as core-collapse and Type Ia supernovae are within UFDs, providing insight into the duration of star formation (Frebel & Norris 2015, Ji et al. 2019). Eu and Sr abundances can trace rare events like neutron star mergers which illuminates the evolutionary history of the UFD (Ji et al. 2016, 2019). Characterizing Willman 1 is our first step in exploring the potential stellar mass – metallicity plateau, seen in the figure below.

Willman 1

- Distance: 45.0±10.0 kpc
- M_V: -2.9±0.74
- $M_\star$: ≥10^3 M_sun
- R_h: 33±8 pc
- V_{helio}: -14.1±1.0km/s
- σ: 4.0±0.8 km/s
- ([Fe/H]): - 2.19±0.08





$M_\star$-Z Plateau?

Work is underway to refine the low-mass and faint end of the Stellar Mass-Metallicity Relation (MZR). As seen in the MZR figure, to the right, observational data scatters and seems to plateau in the UFD regime. To begin to determine if this indicative of a minimum mass threshold for galaxy formation, we are examining the MZR to answer the question **"Is there a physical plateau in the stellar mass to metallicity relation in the ultrafaint dwarf galaxy regime?"** A Z plateau as UFD $M_\star$ continues to drop hints at a decoupling between the stellar mass and metal production. Using low resolution spectroscopic data from Keck LRIS, we are examining Bootes II, Draco II, Cetus II and Triangulum II to measure CaK-based metallicities, and potentially metallicity dispersions.

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