Chemical characterization of ultra-faint dwarf galaxies using SkyMapper photometry

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Introduction

Ultra-faint dwarf galaxies (UFDs) are some of the oldest systems (~13 Gyr) in the Milky Way halo. By extension, the study of the metal content (or "metallicity") of their stars can place strong constraints on models of early chemical enrichment. However, spectroscopy, the primary observational technique to study the chemical content of stars, only permits the chemical characterization of at best ~10-20 stars per system due to the faintness of these stars and associated prohibitively long observing times.

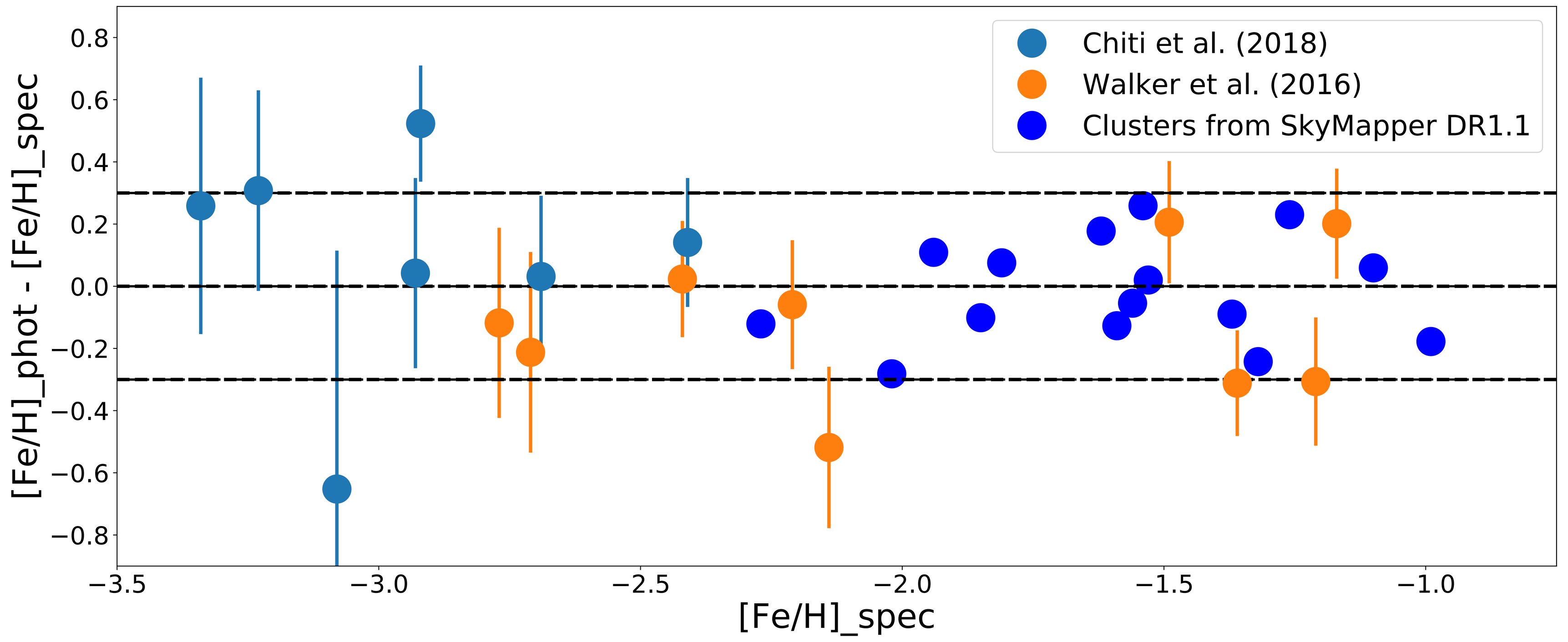
Here, we present a metallicity analysis of the Tucana II ultra-faint dwarf galaxy using deep SkyMapper photometry. With the SkyMapper filter system, we can:

1) Use the intermediate-band 'v' filter images to discriminate metallicities solely based on photometry rather than spectroscopy.
2) Use the SkyMapper 'u' and 'v' filters to derive surface gravities of stars, since these filters bracket the Balmer Jump. Brighter member stars (g < 21) of UFDs are generally on the red giant branch and thus have lower surface gravities

This way, we can retrieve information on the metallicities of more stars, more efficiently than is typically permitted by spectroscopy. We have thus characterized the metal content of stars out to several half-light radii of several UFDs and have found multiple new members.

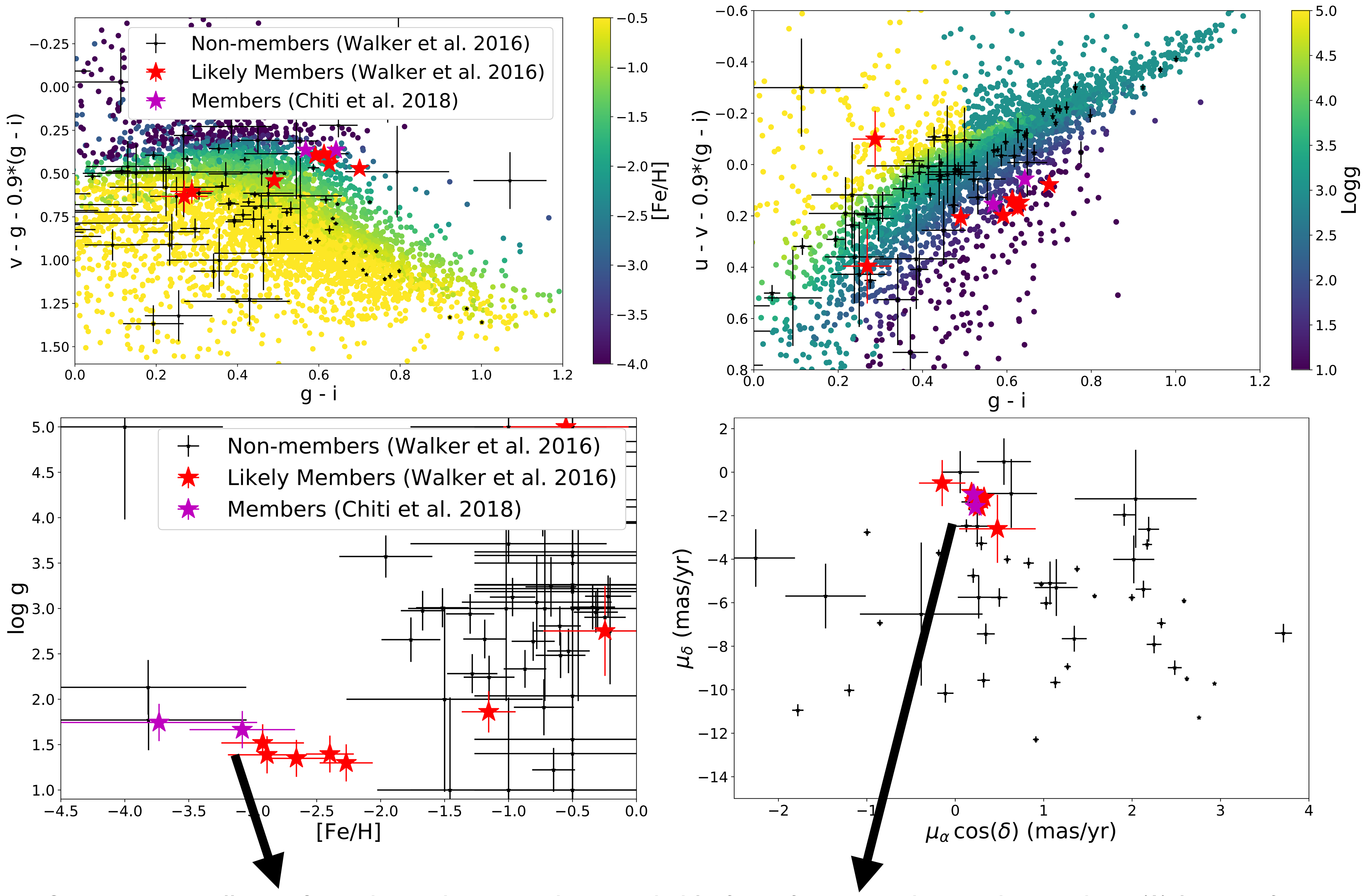
Methods & Validation

- To quantitatively relate fluxes to a metallicity, we computed two grids of synthetic SkyMapper *u,v,g,i* photometry using the Turbospectrum code spanning:
  (4000 < Teff (K) < 5700; 1.0 < logg < 3.0; -4.0 < [Fe/H] < -0.5)
  (5600 < Teff (K) < 6700; 3.0 < logg < 5.0; -4.0 < [Fe/H] < -0.5)
- By computing synthetic metallicities for stars with spectroscopic metallicity measurements in Tucana II (Walker et al. 2016; Chiti et al. 2018) and for globular clusters in the footprint of SkyMapper DR1.1 (Wolf et al. 2018) with spectroscopic measurements in Carretta et al. (2009), **we find that we can discriminate metallicities down to at least [Fe/H] = -3.5**



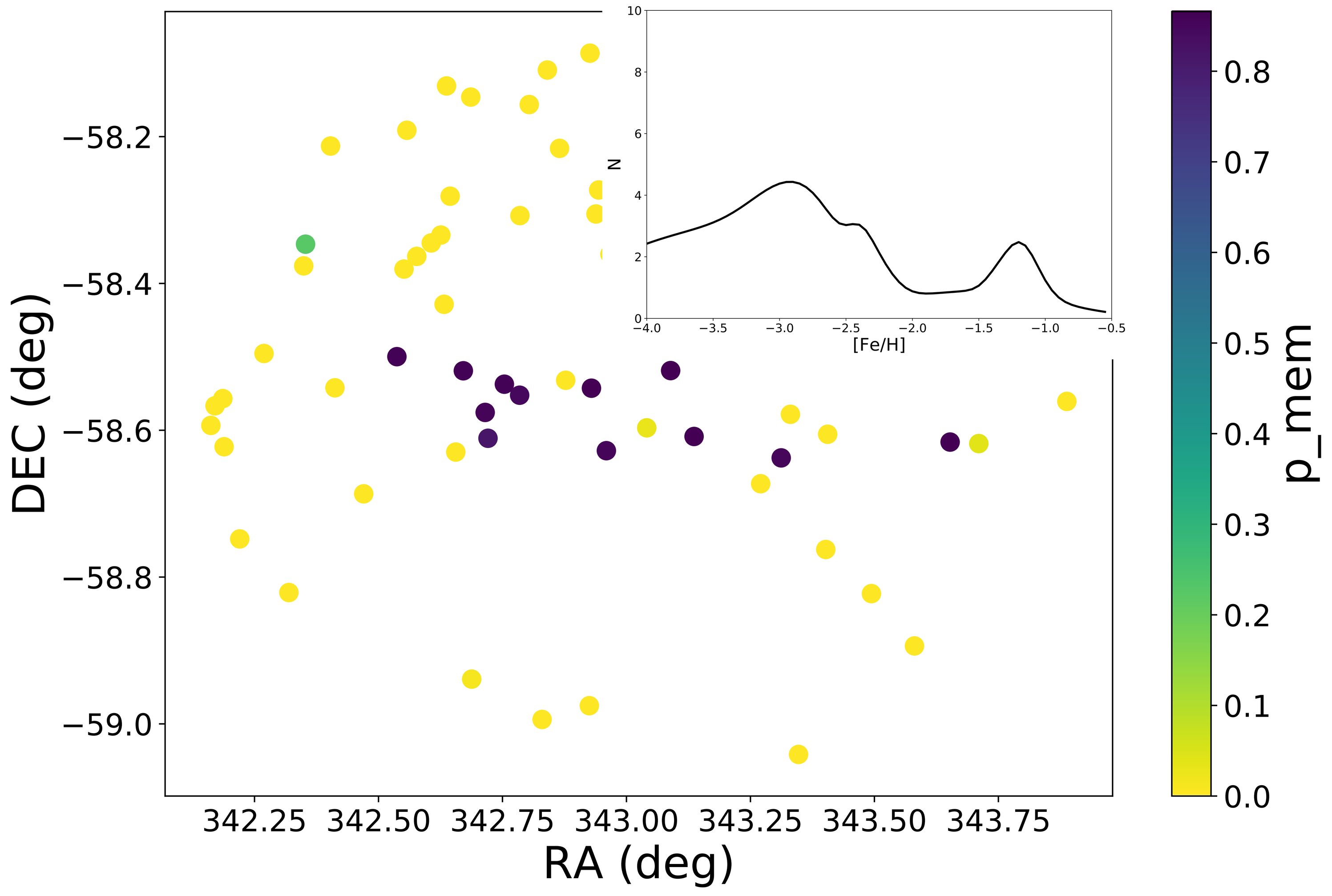
Identifying metal-poor members of UFDs using photometric metallicities, surface gravities, and *Gaia* proper motions

Every star in our deep SkyMapper photomery of Tucana II (down to g~21) is plotted in the below color-color plots, illustrating the discriminating power of the SkyMapper filters in deriving metallicities and surface gravities. Likely members and non-members from two spectroscopic studies of the system (Walker et al. 2016, Chiti et al. 2018) are over-plotted as well.



- Spectroscopically confirmed members are distinguishable from foreground stars due to their (1) low surface gravity (2) generally low metallicity and (3) systemic proper motion
- Incorporating photometric surface gravities and proper motions in membership selection allows us to identify more metal-rich ([Fe/H] ~ -1.5) candidate stars of the system, thereby leading to a more complete metallicity distribution
- **Thus, we can efficiently identify member stars of UFDs and calculate spatially unbiased, magnitude-limited metallicity distribution functions down to [Fe/H] = -4.0**

Results and Implications



We derive membership probabilities for each star using a mixture model analysis for foreground and Tucana II stars. With these membership probabilities, we derive a metallicity distribution function (MDF) for the system (inset in above figure).

The spread in the photometric MDF of Tucana II agrees with results from spectroscopy suggesting that Tucana II has undergone some chemical evolution (Ji et al. 2016; Chiti et al. 2018).

Implications that we can derive magnitude-limited, spatially unbiased MDFs of these systems to characterize the chemistry of these systems. We will apply this technique to other UFDs to derive more complete, spatially unbiased MDFs and also e.g., identify any possible metal-poor, low surface brightness features associated with these systems.

References

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