Digging through the Galactic Graveyard: Chemistry and Ages of "Dead" Milky Way Satellite Galaxies

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STELLAR AGES

Accurately determining the ages of individual stars is a critical step in the ongoing efforts to understand how the Milky Way formed and evolved over time. Determining ages for stars that are not a member of a cluster has proven to be a challenge. The OCCAM team has worked to derive a new diagnostic tool to determine the ages of field stars utilizing the star's ratio between carbon and nitrogen abundances (Spoo et al. 2022 and references therein). This relationship has recently been extended and is now usable in the metallicity range -1.2 ≤ [Fe/H] ≤ +0.3 dex.

[C/N]-AGE CALIBRATION

The [C/N]-Age relationship utilized in this work uses APOGEE DR17 (Abdurro'uf et al. 2022) giant star chemical abundances and was calibrated using a uniform sample of open clusters. The recent work to extend the relationship into lower metallicity ranges (Spoo et al. in prep) was done with globular clusters and resulted in the relationship:

$$\log[Age(yr)] = 2.41(\pm.20)[C/N] + 10.20(\pm.08)$$

Which can now be applied to hundreds of thousands of giant stars across the galaxy from the SDSS-IV DR17 catalog as well as future SDSS-V (Kollmeier 2019) observations.

ESA *Gaia* Sub-structure	Horta 2023 stars	([Fe/H]>= −1.2) stars	([Fe/H]>= −1.5) stars
Arjuna	132	26 (20%)	85 (64%)
GES	2353	514 (22%)	1360 (58%)
HelmiStream	85	21 (25%)	29 (34%)
Heracles	303	81 (27%)	189 (62%)
Nyx	589	151 (26%)	467 (79%)
Sagittarius	266	22 (8%)	84 (32%)
Sequoia(M19)	116	27 (23%)	52 (45%)
Sequoia(N20)	61	22 (36%)	52 (85%)
Thamnos	121	33 (27%)	64 (53%)

Table 1: The nine halo sub-structures with the total number of identified member stars, the number of member stars used in this analysis and the number of usable stars once the calibration has been extended.

MILKY WAY SUB-STRUCTURES

Determining the ages of stars that are members of halo sub-structures is of particular interest. Accurate ages will help paint a more coherent picture of the original galaxies that were disrupted and absorbed by the Milky Way to form its halo. Horta et al. (2023) identified DR17 members of 11 sub-structures, nine of which were analyzed in this study: Arjuna, GES, HelmiStream, Heracles, Nyx, Sagittarius, Sequoia(M19), Sequoia(N20) and Thamnos. The total number of member stars as well as the number of stars analyzed here are presented in table 1 and a histogram of their log(age)'s is presented in figure 1 below. A surface gravity cut was made to ensure a clean sample of giant stars without extra mixing effects for this analysis.

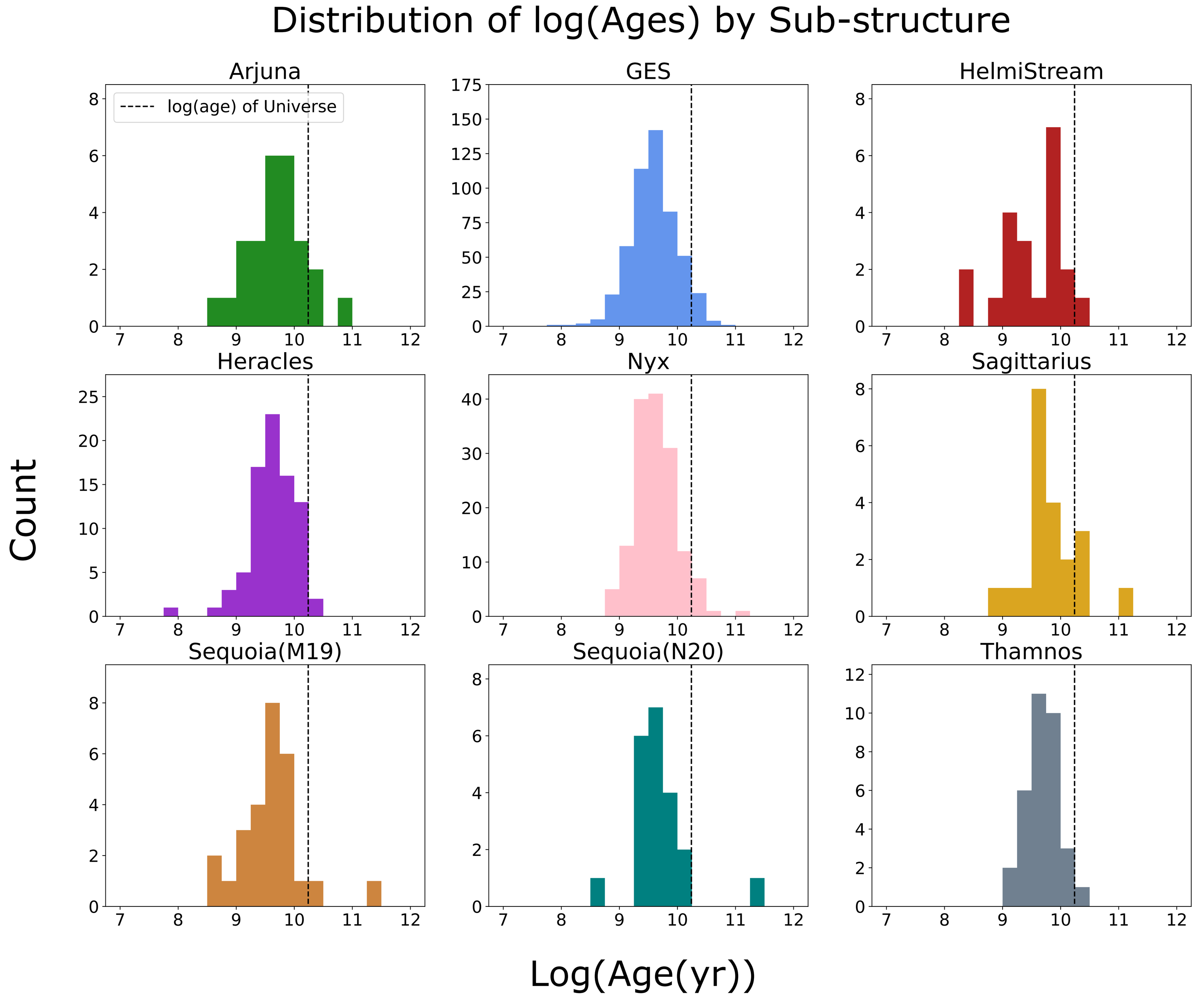

Figure 1: Histogram of the log(age) of stars in each of the nine sub-structures. Bin size varies by sub-structure to show more detail.

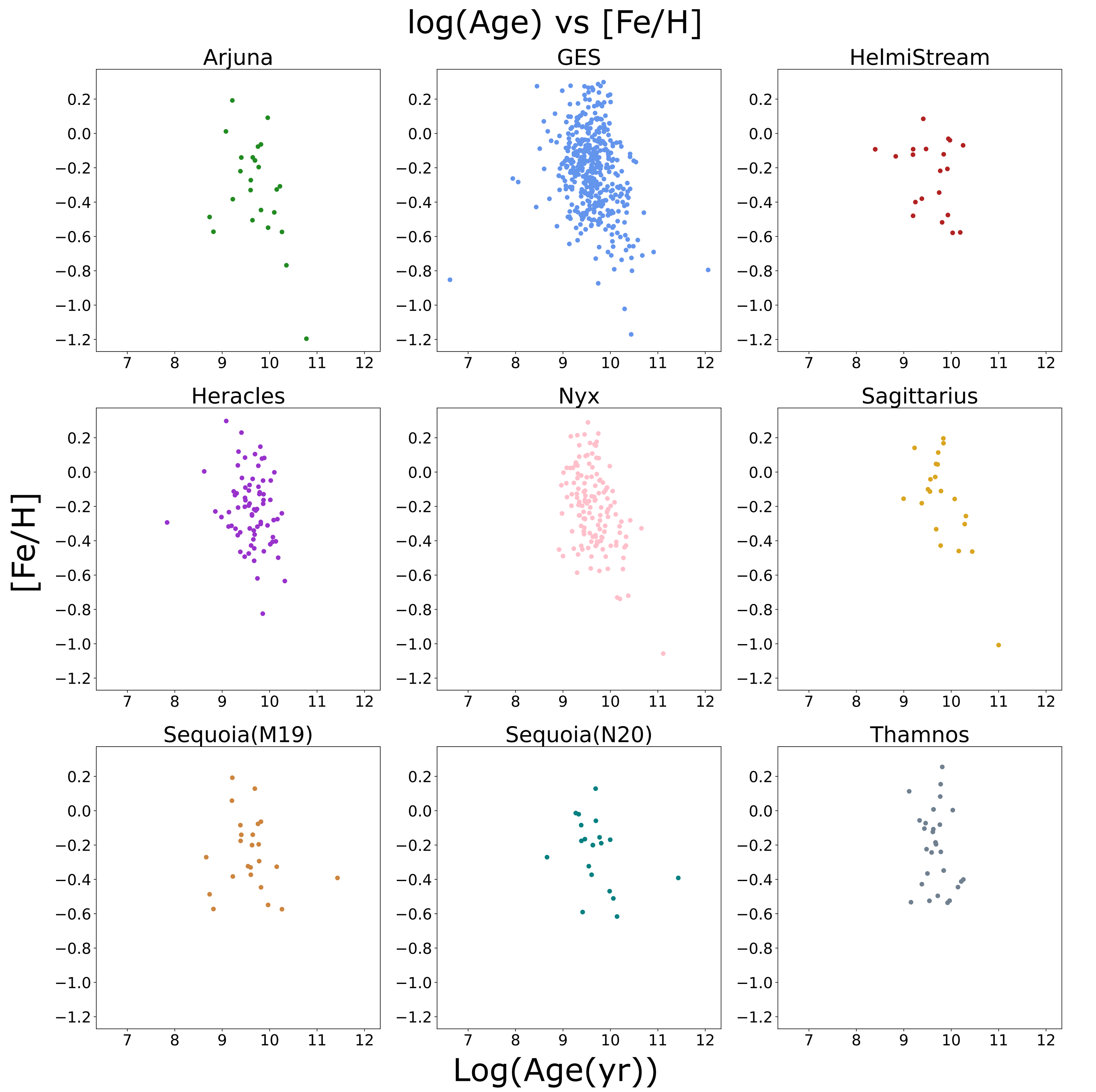

Figure 2: log(age) vs metallicity of each of the nine substructures. Colors are consistent with the histogram.

LINGERING QUESTIONS

1. Is there a trend in age and metallicity within the sub-structures?
2. What does the SFR look like in each sub-structure?
3. Does physical location within the Milky Way have an impact?
4. Will the extension to lower metallicities and additional stars from SDSS-V change the answer to either of the above 3 questions?

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