A Catalog of 551,214 Low-Mass, Metal-Poor Stars in the Local Galactic Halo From Gaia EDR3

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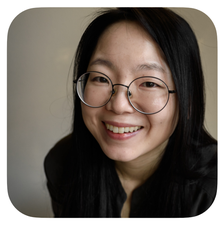
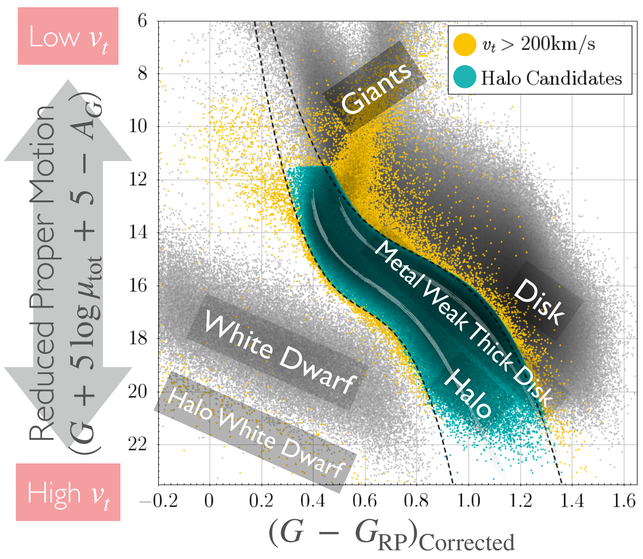
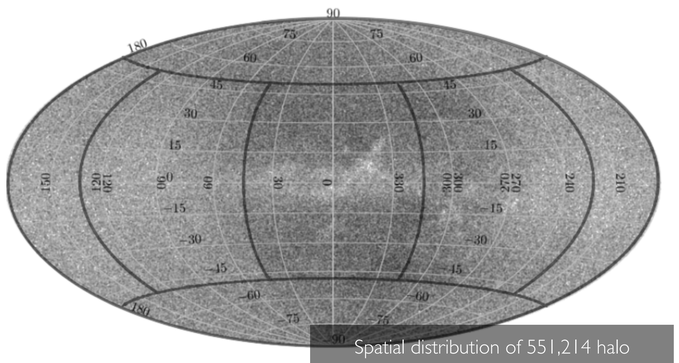


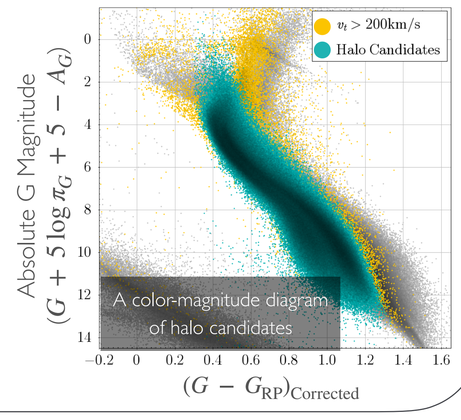
We present a census of the population of local (d < 2 kpc) Galactic halo stars, based on a search of stars with large proper motions (> 40 mas/yr) from the Gaia Early Data Release 3. From this we assemble a catalog of 551,214 low-mass halo stars, for which we also derive photometric metallicity estimates. We assembled 17,803 stars as a metallicity calibration subset from various large spectroscopic surveys, such as SDSS SEGUE/APOGEE, GALAH, LAMOST, and from Hejazi et al. (2020). We expand on these results to construct a color-magnitude-metallicity grid, which can be used to estimate metallicities for all the stars using their values of M_G and G_{RP}. We find that stars in our catalog share similar kinematics as reported in recent studies of more luminous Galactic halo stars. Our sample notably shows likely new members of Gaia-Enceladus Stream of which mean photometric metallicity estimate is around -1.2 dex. We further explore how the velocity-space distribution of low-mass M stars varies with metallicity, and tentatively identify possible chemically distinct sub-populations, which could potentially be revealed in greater detail with radial velocity measurements the full Gaia Data Release 3 and from large spectroscopic surveys like SDSS-V, DESI MW survey, WEAVE, and/or 4MOST.

I. Sample Selection

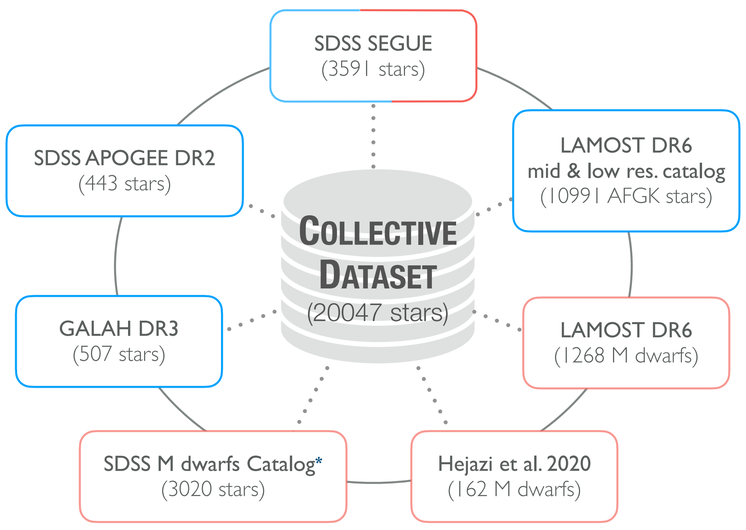
- Identified halo stars from a distribution of stars with high-tangential-velocities in a reduced proper motion diagram (right).
  - Performed reddening correction based on the 3D extinction map by Green et al. (2019).
  - Yellow points: stars with high-tangential velocities ($v_T > 200$ km/s).
  - Blue points: selected **551,214** main-sequence stars in the local Galactic halo ($d < 2$kpc).





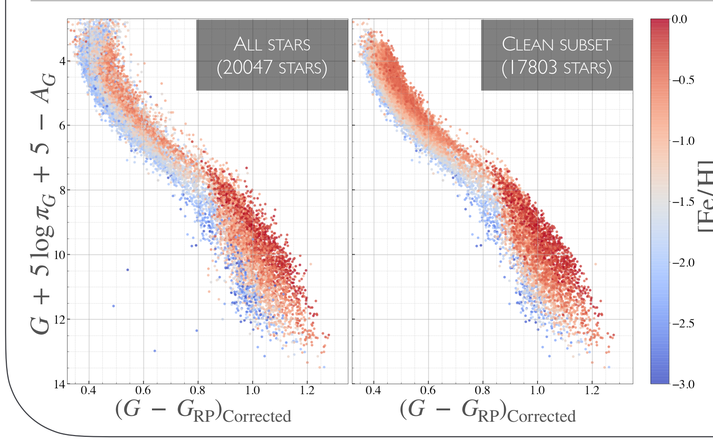


II. Collective Dataset



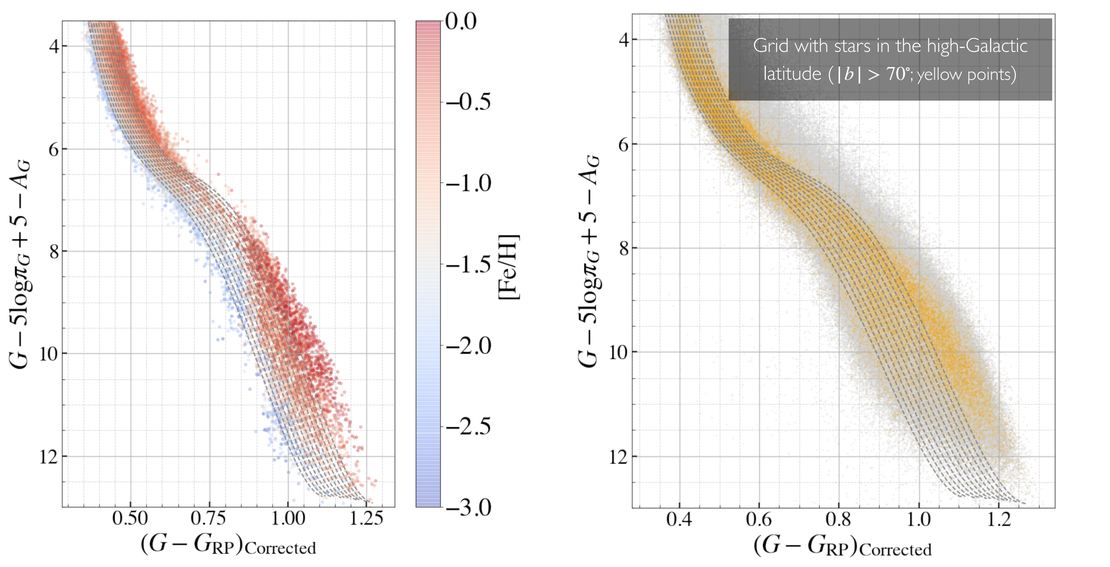
- We collected stellar metallicities precisely measured from large spectroscopic surveys:
  - $\sigma([Fe/H])/[Fe/H] < 0.15$
  - Blue boxes: AFGK dwarfs
  - Red boxes: M dwarfs

* **SDSS M dwarfs Catalog:** A list of M dwarf candidates assembled for the SDSS SEGUE survey. It only provides ***spectral types*** of M dwarfs, obtained from the spectral template. We assigned random metallicity values based on each spectral types, which reported from Woolf et al. (2009) and Hejazi et al. (2020):
- Dwarf (d): -0.34 ≤ [Fe/H] < 0.0
- Subdwarf (sd): -0.87 ≤ [Fe/H] < -0.34
- Extreme-subdwarf (esd): -1.36 ≤ [Fe/H] < -0.87
- Ultra-subdwarf (usd): -3.0 ≤ [Fe/H] < -1.36



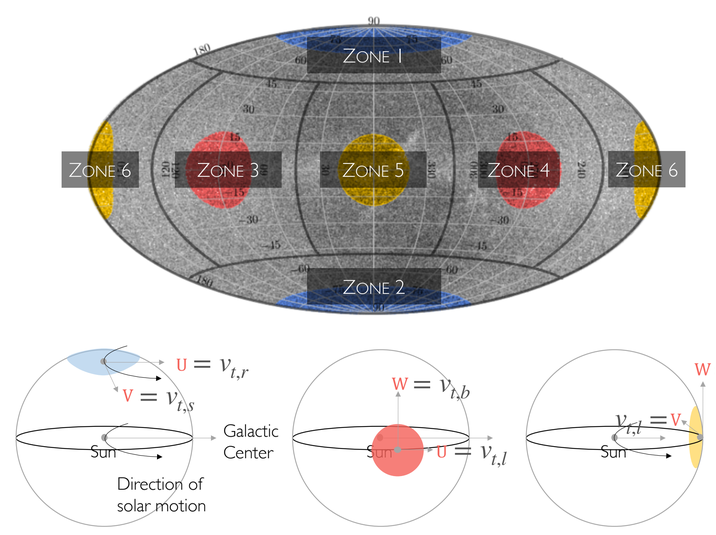
- Removed unresolved binaries from each groups of stars in the same metallicity bins (0.2 dex).
  - Since equal-mass binaries appear to be ~0.75 mag brighter than single stars, photometric metallicities of unresolved binaries tend to be overestimated in the color- magnitude diagram.

III. Photometric Metallicity Grid



- Built the photometric metallicity grid (gray lines in the plots above) based on the distribution of stars from the collective dataset in the color-magnitude diagram.
  - Group stars by absolute G magnitude: 3.5 < M_G < 13.0, binsize = 0.5 mag
  - Obtained linear relations between metallicities and G - G_{RP} colors.
  - Converted those to the color-magnitude relationships with linearly distributed metallicities:
    - Metallicity range: -2.2 ≤ [Fe/H] < -0.2
    - Binsize = 0.2 dex
    - We are currently working on improving better grid for M dwarfs (8.0 ≤ M_G, 0.85 ≤ G - G_{RP})

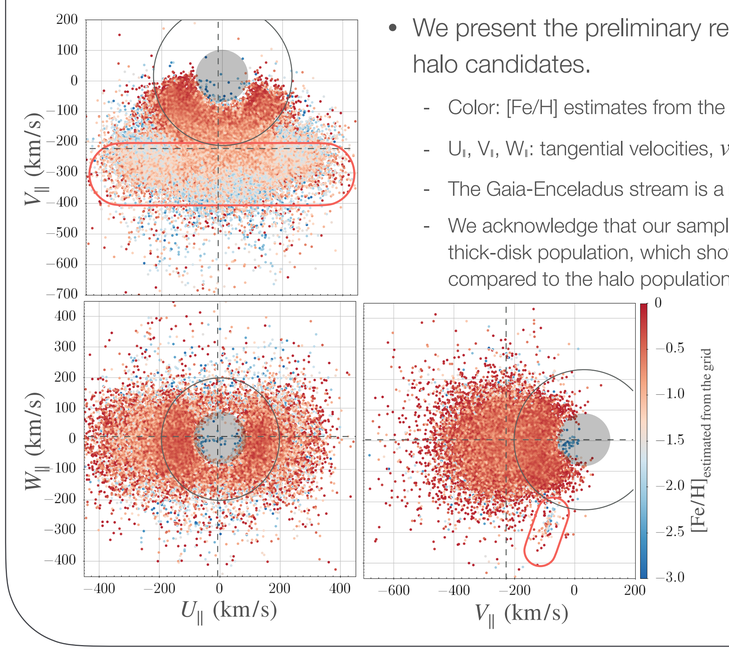
IV. Kinematics



- Zone 1 & 2 (Galactic North/South poles): projected U, V velocities
- Zone 3 & 4 (Solar apex/antapex): projected U, W velocities
- Zone 5 & 6 (Galactic center/anticenter): projected V, W velocities

- Tangential velocities of stars located in six spatial patches can correspond to the projected Galactic UVW velocities.

PROJECTED GALACTIC *UVW* VELOCITIES



- We present the preliminary result of the chemodynamic analysis of halo candidates.
  - Color: [Fe/H] estimates from the photometric metallicity grid (see Section III).
  - U_t, V_t, W_t: tangential velocities, $v_T = 4.74 \times \mu_{\rm tot} \times d$.
  - The Gaia-Enceladus stream is a main structure of the local Galactic halo.
  - We acknowledge that our sample experiences the contamination from the thick-disk population, which shows relatively metal-rich and slow kinematics compared to the halo population.

★ Chemical properties and radial velocities from future Gaia DR3 and from large spectroscopic surveys like SDSS-V, DESI MW survey, WEAVE, and 4MOST will provide more interesting aspect of the structure and evolutionary history in near Solar neighbourhood.

References

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