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# Assembly of the Galactic Halo System Based on Carbon-Enhanced Metal-Poor Stars

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**Abstract.** There is growing evidence that, among the various subclasses of carbon-enhanced metal-poor (CEMP) stars, the outer halo of the Milky Way exhibits a higher frequency of CEMP-no stars (those having no over-abundances of heavy neutron-capture elements) compared with the CEMP-*s* stars (those with over-enhancements of the *s*-process elements), while the inner halo shows a higher frequency of CEMP-*s* stars. We map out fractions of CEMP-no and CEMP-*s* stars in the inner- and outer-halo populations, separated by their spatial distribution of carbonicity ([C/Fe]), a so-called "carbonicity map", based on a sample of over 100,000 main-sequence turnoff stars with available spectroscopy from the Sloan Digital Sky Survey. The CEMP-no and CEMP-*s* objects are classified by different levels of absolute carbon abundances for our sample, $A$(C). We also present kinematic and orbital characteristics of these subclasses for each population. The contrast appearing in these characteristics provides critical constraints on the assembly history of the two primary stellar components of the Galactic halo.

**Keywords.** Methods: data analysis, Galaxy: halo, stars: carbon abundances

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We investigated distributions of rotation velocities and orbital eccentricities for stars in four Galactic regions: the thick-disk region (TDR), the inner-halo region (IHR), the transition region (TrR), and the outer-halo region (OHR), separated by the level of [C/Fe] contrast, as shown in Figure 1 (see Lee *et al.* 2017 for more details). The distributions of rotation velocities and orbital eccentricities show a greater fraction of stars with retrograde motion and low eccentricity in the OHR, indicating that the Galactic halo consists of at least two distinct stellar populations, as recognized by Carollo et al. (2007, 2010).

We also followed Yoon *et al.* (2016) to separate CEMP stars into CEMP-*s* and CEMP-no stars by their absolute carbon abundance, $A$(C), to search for any distinct kinematic features between the two categories, as well as to map out the fractions of CEMP-no stars among CEMP stars. We found an increasing fraction of CEMP-no stars moving from the IHR to the OHR. We also noticed that, even based on small number statistics, there seems to be a subtle trend of and increasing fraction of stars with retrograde motion and low eccentricity among CEMP-no stars relative to CEMP-*s* stars, as shown in Figure 2. These characteristics imply that the outer halo has experienced a distinct assembly history from the inner halo, likely involving different progenitor masses.

## References

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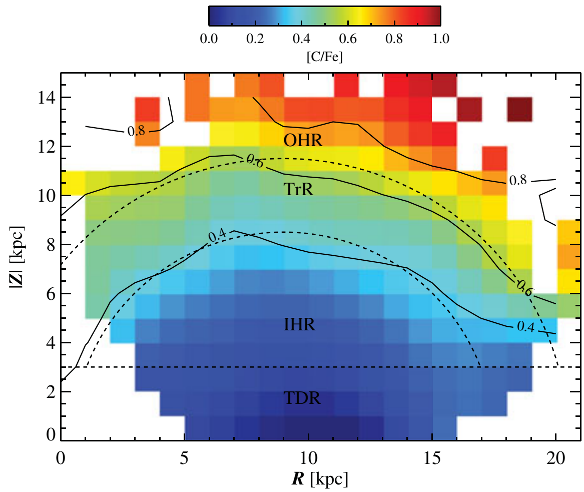
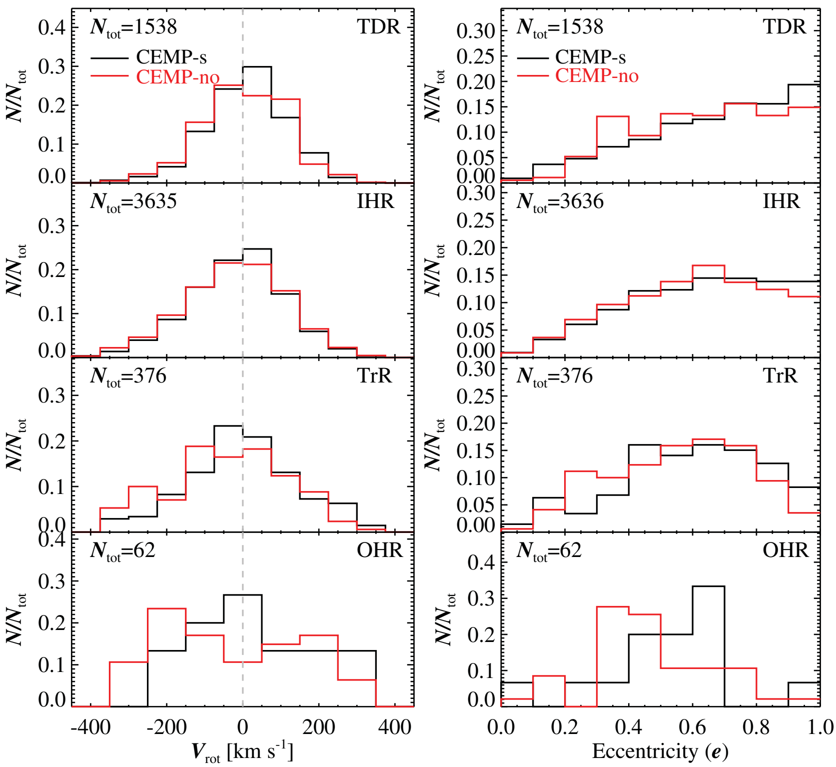



**Figure 1.** Map of carbonicity, [C/Fe], for our main sequence turnoff stars in the $|Z|$ versus $R$ plane. The bin size is 1×1 kpc; each pixel contains at least three stars. See Lee *et al.* (2017) for more detailed information on how to separate into four regions on the map.




(a) (b)

**Figure 2.** Distribution of rotation velocities (left panel) and orbital eccentricity (right panel) for CEMP-*s* (black) and CEMP-no (red) in each Galactic region. It appears that the portion of retrograde and low-eccentricity stars becomes larger as one moves from the IHR to OHR.

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