Pruning Candidate Metal-Poor Stars with Gaia

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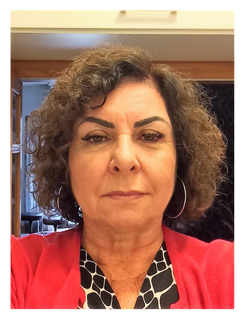

Introduction

Objective prism surveys from the past few decades have been the source of the majority of very metal-poor (VMP; [Fe/H] < -2.0) and extremely metal-poor (EMP; [Fe/H] < -3.0) stars known to exist in the halo of the Galaxy.

Since stars were selected based on ultra low-resolution spectroscopy, and often incomplete photometric information, they have collectively struggled to reach success rates, defined as SR = (Number of stars below [Fe/H] $= -2.0$)/(Number of candidates selected), greater than 15-20 %. Moreover, the difficulty of successful identification increases with decreasing temperature, which accounts for the dominance of main-sequence turnoff stars in their samples. The primary "contaminants" in these efforts are large numbers of foreground metal-rich or only moderately metal-poor stars in the disk system of the Milky Way.

We carry out empirical tests of what the SR might have been had this pruning been carried out prior to medium-resolution follow-up spectroscopy, using data for stars with this information available. It appears that we can double or triple the SR, encouraging application of this technique to other samples of VMP/EMP candidates in the near future. We note that all of the HK survey (V $<$ 15.5) and most of the HES metal-poor candidates (V $<$ 16.5) will have distance and proper-motion information available in Gala DR2, to be released in early 2018.

Main Objectives

- Improve the search for the best metal-poor candidates from HK and HES surveys based on astrometric information from Gaia DR1, even though still partial analysis.
- The basic idea is very simple: when we call a star a metal-poor candidate, we have SR $\approx$ 20% for getting a star below [Fe/H] < -2.0.
- *Why?* There are many more stars in the disk in the foreground for many different reasons: stars are a little warmer or little cooler, they present core emission feature in CaII K $\rightarrow$ objective prism resolution smooths these features, and makes the star appear to have a weak or absent CaII K line.
- That combination means that we select a lot of stars which are not metal-poor.

- Increase SR's
  $\rightarrow$ Elimination of those contaminants.
- *How?* Cross matching of HK data with Gaia data take the geometric distances for all the metal-poor candidates from the HK survey that are found in Gaia DR1.
- Presented as Santucci Diagrams: X-axis are the tangential velocities from proper motions + vertical distances (Gaia) and Y-axis are the distances from the Galactic plane, also from Gaia.
- With this experiment $\rightarrow$ Cross-match the databases and extract kinematic and distance information from the targets before the spectroscopic follow-up result is known.
- By evaluating distances and proper motions it is possible to locate the positions of the stars in the Galaxy and also to provide part of their kinematic component.

Data

- The data are bright metal-poor candidates from the HK survey that had matches to Gaia DR1.
- Only a partial subset has estimates of metallicities (marked with red star symbols in the plot).
- HK prism plates had all coordinates re-measured $\rightarrow$ Improvement.

Analyses

Matching data with revised coordinates from HK and Gaia DR1 $\Rightarrow$ Astrometric parameters for a subset of the sample.

- d (in kpc) $= 1/parallax$ (in mas)

- $V_T = 4.74 \times M \times d$ (in km/s)
  where M is the total proper motion of the star in mas and d is the distance in kpc.
  $M^2 = (\mu_\delta{}^2 + \mu_\alpha{}^2 \times \cos(\delta)^2)$
  μ_δ = proper motion in declination
  μ_α = proper motion in right ascension

Partial Results

The so called "Santucci Diagrams" can be seen below Figure 1 shows the distribution of the metal-poor candidates from the HK survey that have already been observed, and hence have known metallicities, while Fig. 2 shows the targets according to V_T $vs.$ Z for metal-poor candidates that have not yet been observed.

The colored regions were selected according to the following criteria:

- green: Stars that are in the halo ($|Z| > 0.5$ kpc) but have disk-like tangential velocities (V_T <100 km/s);
- gray: Stars that are in the halo and have star velocities that are halo-like (V_T >100 km/s);
- yellow:Stars that are in the disk and have disk-like tangential velocities;
- blue: Stars that are in the disk and have halo-like tangential star velocities;
- red: Stars that are on the disk and have tangential velocities between what is normally seen for the disk and for the halo).

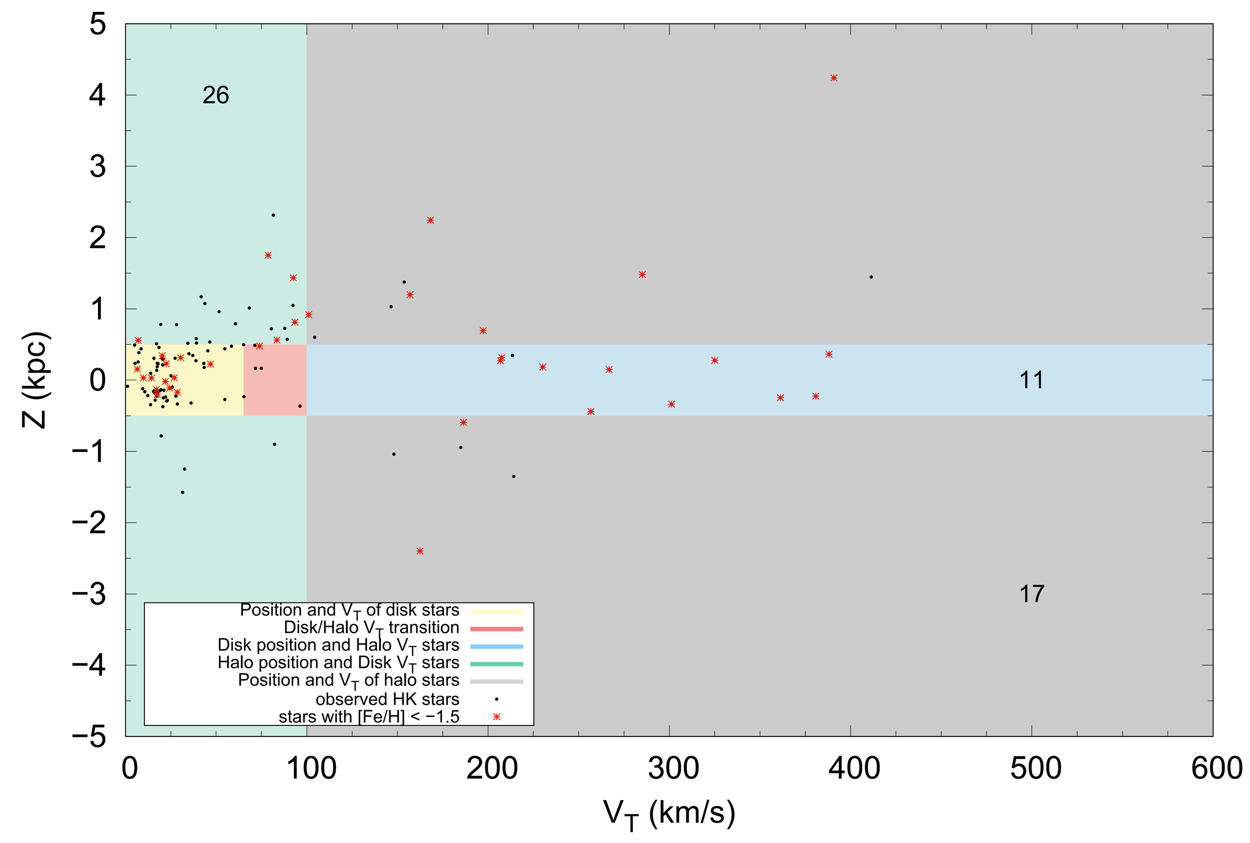

Figure 1: Distribution of observed metal-poor candidates from the HK survey. Red symbols corresponds to the stars with [Fe/H] ≤ -1.5.

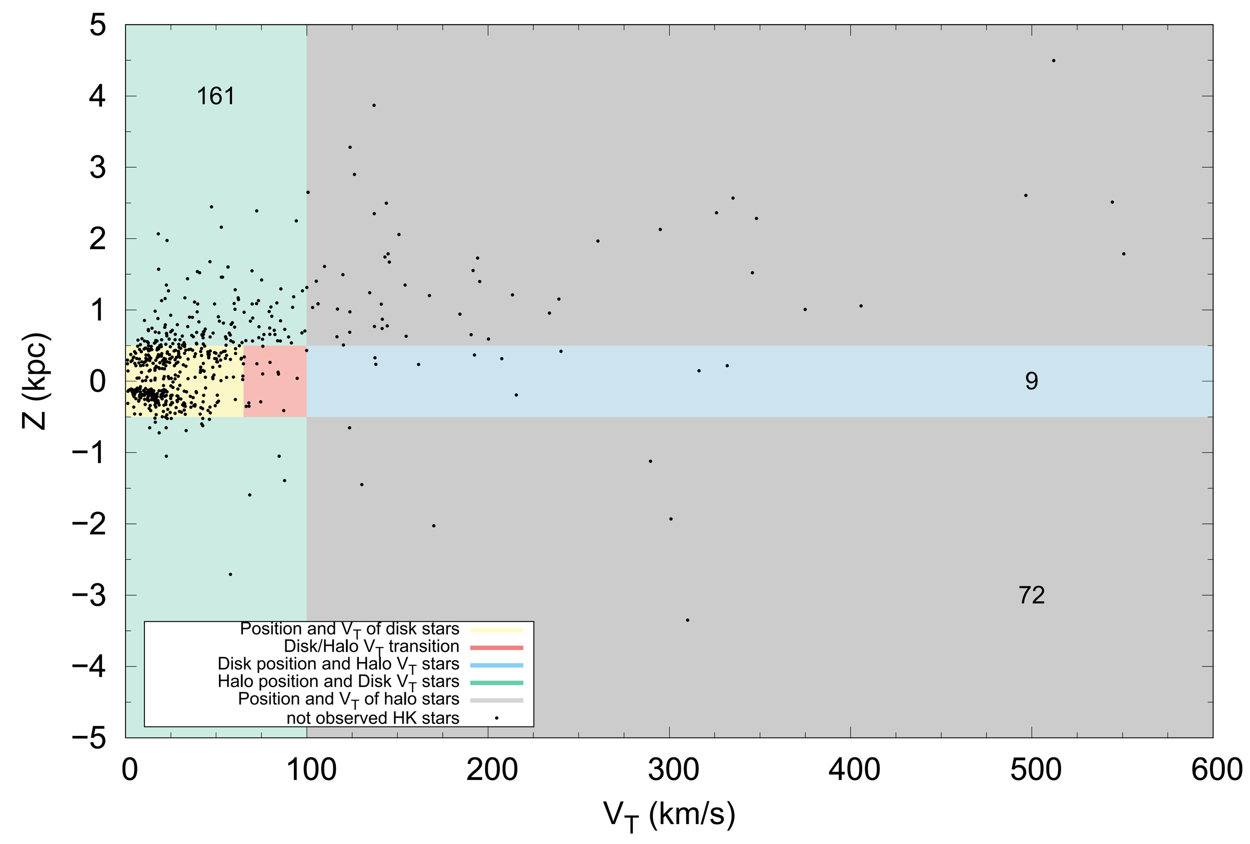

Figure 2: Distribution of the targets to be observed.

REGIONS	ALL STARS	MP STARS	SR(%)
PosDisk_VelHalo	11	10	91
PosHalo_VelDisk	26	6	19
PosHalo_VelHalo	17	10	59

Table 1: Success rates in different color regions of the Santucci Diagram for observed stars

Conclusions

- The previous success rate is $\sim$ 32% (39/123 = MP/Total Observed)
- If we consider just the stars in the blue and gray regions (meaning $V_T > 100$ km/s) $\Rightarrow$ best success rate of finding MP stars $\sim$ 75% $\Rightarrow$ SR of finding MP considering $V_T > 100$ km/s is more than two times greater than the previous SR.

Forthcoming Research

These are still partial (we can roughly double the number of observed stars once we have revised coordinates for the entire HK catalogue), but it is already encouraging. The ability of preventing mistakes from candidate catalogues (such as bad seeing, not good calibration, etc.) is a good way to improve the success rate for the follow-up metal-poor candidates.