A Search for Binary Stars at Low Metallicity

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Abstract. We present initial results measuring the companion fraction of metal-poor stars ([Fe/H] < −2.0). We are employing the Lick Observatory planet-finding system to make high-precision Doppler observations of these objects. The binary fraction of metal-poor stars provides important constraints on star formation in the early Galaxy [1]. Although it has been shown that a majority of solar metallicity stars are in binaries, it is not clear if this is the case for metal-poor stars. Is there a metallicity floor below which binary systems do not form or become rare? To test this we are determining binary fractions at metallicities below [Fe/H] = −2.0. Our measurements are not as precise as the planet finders’, but we are still finding errors of only 50 to 300 m/s, depending on the signal-to-noise of a spectrum and stellar atmosphere of the star. At this precision we can be much more complete than previous studies in our search for stellar companions.

Keywords: stars: binaries: spectroscopic, stars: Population II, techniques: radial velocities

PACS: 97.20.Tr, 97.80.Fk

INTRODUCTION

The observational study of multiple star systems has been carried out extensively by previous groups (e.g., [2, 3]). The general results have shown that among solar neighborhood F and G stars, there is a multiple star system fraction of approximately 65%. Carney et al. [4] recently discussed the incidence of binarity among metal-poor stars in the context of a deficiency of metal-poor binaries on galactic retrograde orbits. Lucatello et al. [5] also looked at binary frequency in metal-poor stars, but only in the subset of carbon-enhanced, s-process rich objects, finding a result that is consistent with 100% binarity.

As discussed above, much work has been done in determining the fraction of stars from solar down to low metallicities. But until only recently, have large enough number of metal-poor stars been discovered to begin exploring this regime systematically. What we are doing in this current study is extending this search into the very low metallicity with a new method. We are using the iodine cell radial velocity monitoring techniques developed for the planet finding group at Lick Observatory to get highly precise radial velocities for a number of very metal-poor stars.

METHOD

Our observational setup is very similar to the Lick Observatory Iodine Planet Search group [6]. We use a heated iodine cell placed into the light path of the Hamilton spectrometer to create a series of reference absorption lines. This enables us to obtain very precise radial velocities measurements, irrespective of the true zero-point radial velocity [7].

Although the observational setup and tools are the same as the planet search team, we face two unique challenges. The first is that our stars are generally faint, V = 8 and dimmer. This means we have much lower SNR spectra. The second challenge is that very metal-poor stars have fewer absorption lines, and therefore less radial velocity information than the near solar-metallicity stars of the planet searches.

Nevertheless, we have begun developing a technique that still gives very precise velocities and errors ranging from only 50 to 300 m/s.

DATA

In this ongoing project we have time baselines ranging from days up to almost 3 years. We are also observing both C-rich and C-normal metal-poor stars.

Our data so far is comprised of the following.

• 43 objects with 3 or more observations.
• 36 objects with 4 or more observations.
• 33 objects with 5 or more observations.
FIGURE 1. The known binary star BD+13-3683 ([Fe/H]~2.0). We show the data and orbital solution from Carney et al. [1] as the square points and dotted line. Our measurements are plotted as the black dots, and the error bars represent 2 times the actual error.

FIGURE 2. The radial velocity measurements for HD 4306. Preliminary results have been very encouraging. In figure 1 we show a test of our method. Figures 2 to 4 give examples of three results: a detection of a companion, a non-detection, and the detection of either a companion or an intrinsic velocity jitter.

Overall we have completed the first-pass analysis of 31 of our objects. The [Fe/H] distribution and E/I values are shown in figure 5. We find that 55% of our targets have detected radial velocity variation (defined here as E/I > 2).

If we eliminate stars with T eff < 4700K to minimize the potential effect of intrinsic stellar jitter, we are left with 26 stars, 12 of which have clear radial velocity variations. If these variations are assumed to be caused by a companion, the we find a spectroscopic binary fraction of 46%.

ACKNOWLEDGMENTS

We would like to acknowledge the National Science Foundation for their support under grant AST-060770.

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FIGURE 5. For each object, the rms of the velocity measurements, $E$, divided by the average radial velocity error for that object, $I$. The higher the value of $E/I$, the more likely it is a true radial velocity variable.

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