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Metal-Rich SX Phe Stars in the *Kepler* Field

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Abstract. High-resolution spectroscopic observations have been made for 32 of the 34 candidate SX Phe stars identified in the *Kepler* field by Balona & Nemec (2012). All available long- and short-cadence Q0-Q17 *Kepler* photometry has been analyzed for the 34 candidates. Radial velocities (RVs), space motions (U, V, W), projected rotation velocities ($v \sin i$), spectral types, and atmospheric characteristics ($T_{\rm eff}$, $\log g$, [M/H], $v_{\rm mic}$, etc.) were derived from ~160 spectra taken with the ESPaDOnS spectrograph on the Canada-France-Hawaii 3.6-m telescope and with the ARCES spectrograph on the Apache Point Observatory 3.5-m telescope. Two thirds of the stars are fast rotators with $v \sin i > 50$ km/s, including four stars with $v \sin i > 200$ km/s. Three of the stars have (negative) RVs > 250 km/s and retrograde space motions, and seven stars have total space motions > 400 km/s. All the spectroscopically measured SX Phe candidates have positions in a Toomre diagram that are consistent with being *bona fide* halo and thick-disk stars. Although several stars show a marked metal weakness, the mean [Fe/H] of the sample is near 0.0 dex ($\sigma \sim 0.25$ dex), which is considerably more metal-rich than is normally expected for a sample of Pop. II stars. Observed pulsation frequency modulations and optical time delays suggest that at least eight of the SX Phe stars are in binary systems, some of which show significant RV variations. Six of the time-delay binaries have secondary masses ranging from 0.05 to 0.70 $M_\odot$ and orbital periods in the range 9 to 1570 days. Another star appears to be an ellipsoidal variable with a 2.3-day orbital period; and two other systems have orbital periods longer than the ~4-year sampling interval of the *Kepler* data.

1 Introduction

Traditionally, field SX Phe stars have been identified by their Population II kinematics, asymmetric and (often) large-amplitude light curves, and low metallicities (Nemec & Mateo 1990). The Balona & Nemec (2012) candidates in the *Kepler* field were found by cross-referencing a list of 1424 *Kepler*-field δ Scuti stars with the UCAC3 proper motion catalog and selecting those stars with high proper motions ($\mu > 30$ milliarcsec/year) and large tangential velocities ($V_t > 120$ Km/s). That several of the stars are located more than 500 pc above the galactic plane strengthened the conclusion that the sample consists of halo and thick-disk stars.

In this investigation follow-up spectroscopic observations have been made for 32 of the 34 candidate SX Phe stars in order to better define their kinematics (radial velocities and space motions), to

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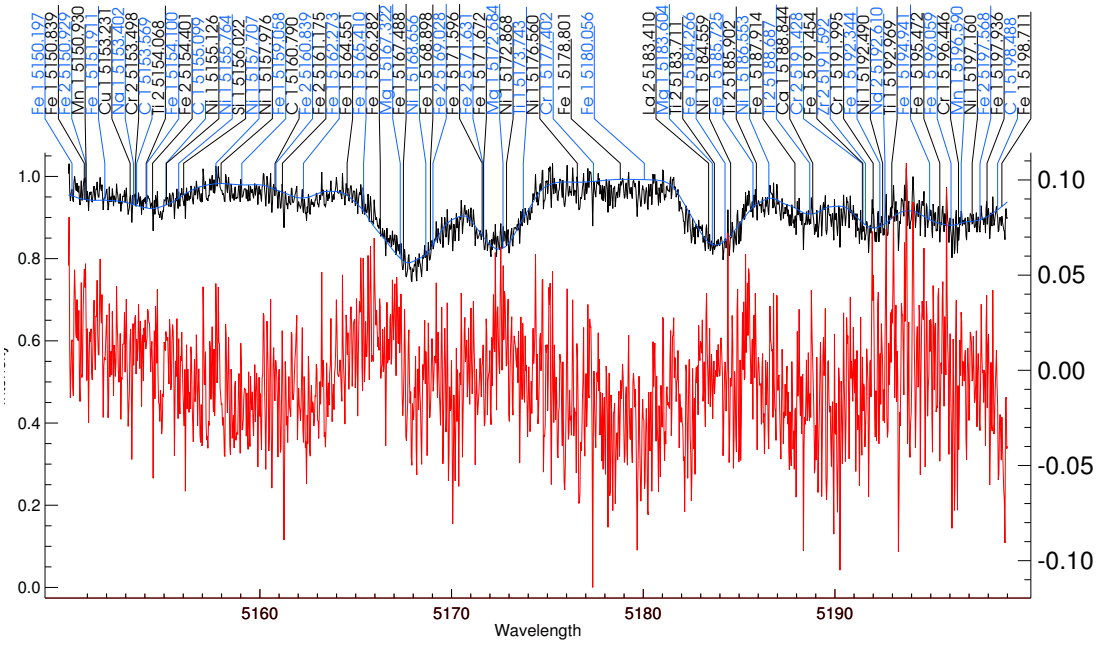

Fig. 1. Comparing a coadded CFHT ESPaDOnS spectrum (black) for KIC 7020707 (= CFHT star number 16), one of the rapidly rotating stars ($v \sin i$ = 105.3 km/s), with a synthesized spectrum (blue) - the residuals are shown in red. The wavelength region shown here is 5150-5200 Å. For this star the derived metal abundance was [M/H]= −0.21 ± 0.20 dex, and the barycentric radial velocity was RV= −0.32 ± 2.29 Km/s.

characterise their atmospheric characteristics (effective temperatures, surface gravities, spectral types, metal abundances, microturbulent velocities, etc.), and to better establish the stellar population to which each star belongs. In addition, all the available long-and short-cadence Q0-Q17 Kepler photometry for the complete sample of 34 candidates has also been analyzed; this has allowed the identification of numerous photometric binary systems and the derivation of their orbital characteristics (see Murphy *et al.* 2014; Balona 2014). Several of the stars are found to exhibit RV variations.

2 Discussion and Results

A sample spectrum comparing one of the coadded spectra with a synthetic spectrum calculated with the 'Spectroscopy Made Easy' (SME) program (Valenti & Piskunov 1996), is shown in Figure 1. Similar spectral fits have revealed that the metallicity distribution of the sample stars is approximately gaussian with a mean of –0.02 dex and a standard deviation of 0.24 dex. Such a distribution is even more metal-rich than that of the so-called 'metal-rich' globular clusters (see Fig.9 of Nemec & Linnell Nemec, 1991). Other results are summarized in the Abstract.

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