Differential abundances of a planet-hosting star and its wide binary companion to explore planet formation

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ABSTRACT

We present a high-precision elemental abundance study of a recently discovered planet-hosting binary system based on high-quality spectra. From our strictly differential abundance analysis, we have detected significant differences in the chemical composition of their photospheres that correlate with the elements' dust condensation temperature. We found that the secondary component, which hosts a transiting gas-giant planet, is depleted in volatiles and enhanced in refractories relative to the primary stellar companion, in which no planets have been detected (Jofré et al. in prep).

CHEMICAL DIFFERENCES BETWEEN THE STELLAR COMPONENTS

From high-quality spectra, we derived precise stellar atmospheric parameters (effective temperature, surface gravity, metallicity, microturbulence) and chemical abundances of 25 elements using a strictly differential analysis as is detailed in Ramírez et al. (2015).

In **Figure 1**, we show differential abundances $\Delta[X/H]_{B-A}$ versus the 50% condensation temperatures (Tc) from Lodders (2003). **We note that the secondary component (*B*; which hosts a transiting gas-giant planet) is almost systematically depleted in volatiles (Tc ≲ 900 K) and enhanced in refractories (Tc > 900 K) relative to its stellar primary companion (*A*;** for **which no planets have been detected to date).**

Moreover, we find that the differential abundances as a function of Tc show a positive trend with a significance of the slope at the 7σ level considering both volatile and refractory elements.

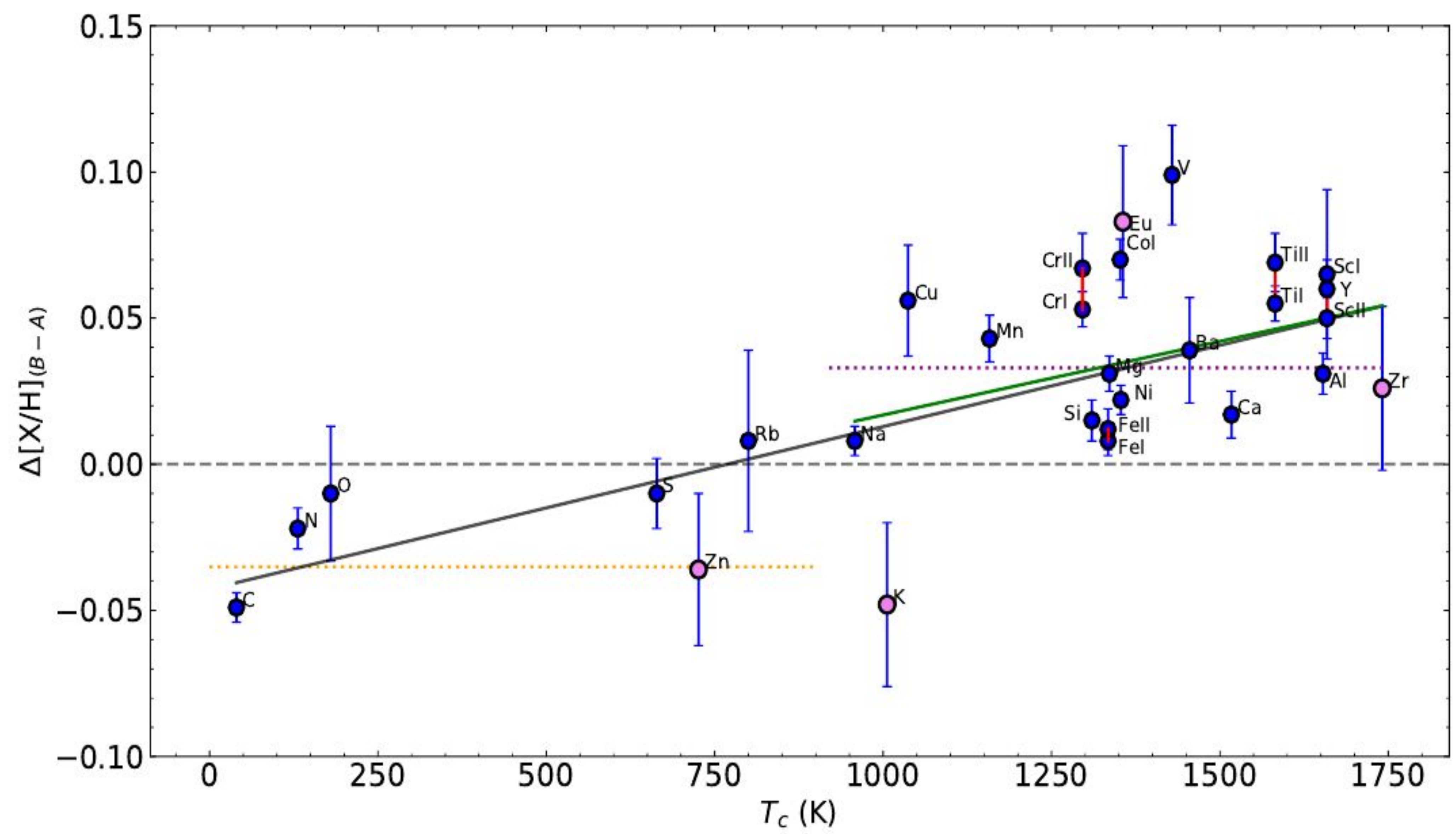

Figure 1. Differential abundances versus Tc. The solid black and green lines are the weighted linear least-squares fit to all the elements and refractory elements measured from more than one line, respectively. The horizontal dotted orange and violet lines represent the weighted average of the volatile (−0.035 ± 0.007 dex) and refractory (+0.033 ± 0.005 dex) elements, respectively. The dashed line corresponds to identical composition, the solid red vertical lines connect two species of the same chemical element, and violet circles show the species measured from one line only.

NO ADDITIONAL TRANSITING PLANETS FROM TESS DATA

In order to further constrain possible scenarios that could account for the chemical pattern observed in Figure 1, **we searched for transiting planets around the primary stellar companion and for additional ones around the secondary star in the light curves (LCs) obtained from the publicly available TESS data.** We ran on each LC the Transit Least Squares code (Hippke & Heller 2019) and **did not detect any transit planetary signal.**

In addition, **we performed two injection-recovery tests to evaluate the detection limits of transiting planets in the TESS LCs of both stars in the system.** We explored the planet Radius-Period parameter space from 0 to 12.0 $R_\oplus$ and from 0 to 30.0 days. In **Figure 2**, we present the results of these tests, which can be summarized as follows:

i- Transiting planets larger than ~5.5 $R_\oplus$ and ~7 $R_\oplus$ with orbital periods shorter than ~7 days around both stars can be detected with high probability (> 80%).

ii- There is no chance of detection for planets at periods > 20 days or for small planets (R_p < 5.5 $R_\oplus$) with orbital periods longer than ~7 days in the case of the primary star, and small planets (R_p < 7 $R_\oplus$) with orbital periods longer than ~2.5 days for the secondary companion.

iii- The detection probabilities range from 20 to 80% for all the planets that occupied the parameter-space in between.

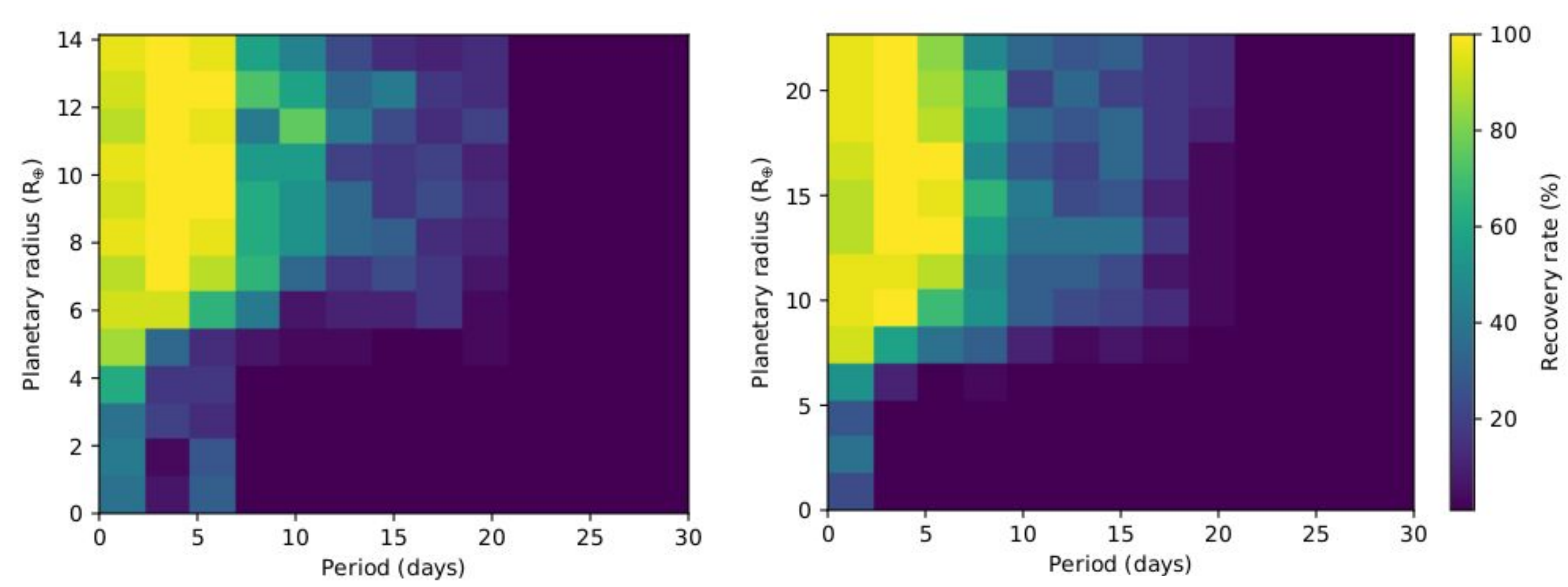

Figure 2. Injection-recovery tests performed on the TESS light curves of the primary (left) and secondary (right) stars. Light and dark colors indicate high and low recovery rates, respectively.

ORIGIN OF THE OBSERVED CHEMICAL PATTERN

The chemical difference between the stellar components of the binary system could be interpreted as:

I) A deficiency of refractory elements in the primary star associated with the formation of rocky planets (e.g., Meléndez et al. 2009) or the formation of a Jupiter analog planet (Booth & Owen 2020).

II) An enhancement of heavy elements in the secondary star due to the engulfment of planetesimals and/or terrestrial planets. These bodies could have been pushed or dragged onto the star during the inward migration of the short period gas-giant planet detected around this star (e.g., Saffe et al. 2017)

The lack of planetary signals in both the photometric and spectroscopic current data for the primary star would favor the last scenario. However, a precise radial velocity follow-up and/or additional photometric monitoring of this star might help to further constrain the cause of the elemental abundances difference.

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