Chemical signatures of planetary formation and evolution in the WASP-160 binary system

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ABSTRACT **Wide binary stars with similar components hosting planets provide an interesting opportunity for exploring the star-planet chemical connection. Here, we present a detailed characterization of the solar-type stars in the WASP-160 binary system. No planet has been reported yet around WASP-160A while WASP-160B is known to host a transiting Saturn-mass planet, WASP-160B b. For this planet, we also derive updated properties from both literature and new observations. Furthermore, using TESS photometry, we constrain the presence of transiting planets around WASP-160A and additional ones around WASP-160B. The stellar characterization includes, for the first time, the computation of high-precision differential atmospheric and chemical abundances based on high-quality spectra. Our analysis reveals evidence of a correlation between the differential abundances and the condensation temperatures of the elements. In particular, we find both a small but significant deficit of volatiles and an enhancement of refractory elements in WASP-160B relative to WASP-160A. After WASP-94, this is the second stellar pair among the shortlist of planet-hosting binaries showing this kind of anomalous chemical pattern. We discuss that the formation of WASP-160B b and late accretion of rocky material by its host star, likely triggered by the inward migration of this giant planet, could explain the observed chemical pattern. Alternative scenarios involve the formation of additional giant planets around WASP-160B and rocky objects around WASP-160A. Full details about this work can be found in Jofré et al. (2021).**

CHEMICAL DIFFERENCES BETWEEN THE STELLAR COMPONENTS

From high-quality GEMINI-GRACES spectra, we derived precise stellar atmospheric parameters 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 WASP-160*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 WASP-160*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.**

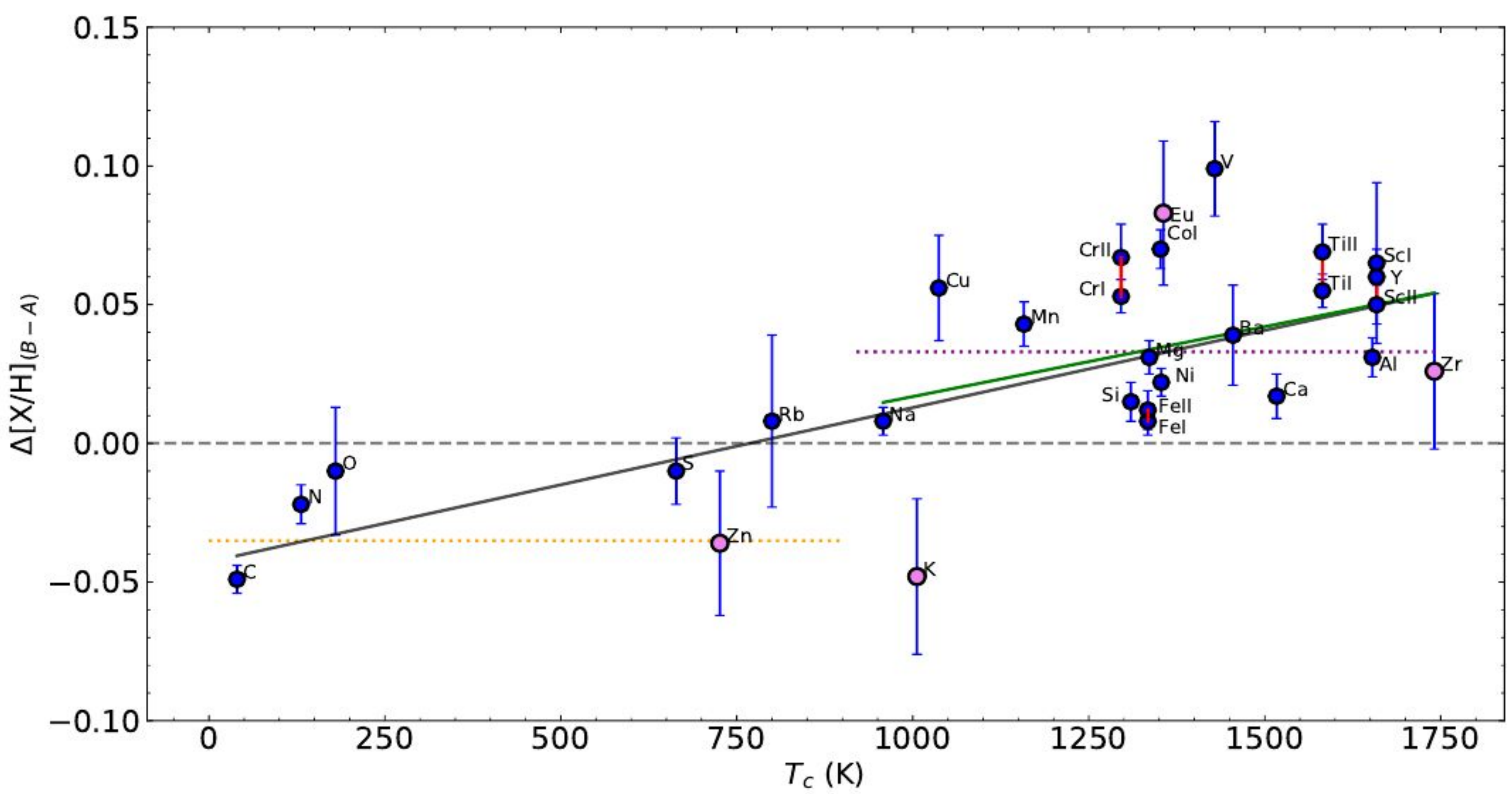

Figure 1. Differential abundances versus Tc. The solid black and green lines are the weighted linear least-squares fit to all the elements and refractory elements measured from more than one line, respectively. The horizontal dotted orange and violet lines represent the weighted average of the volatile (−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.

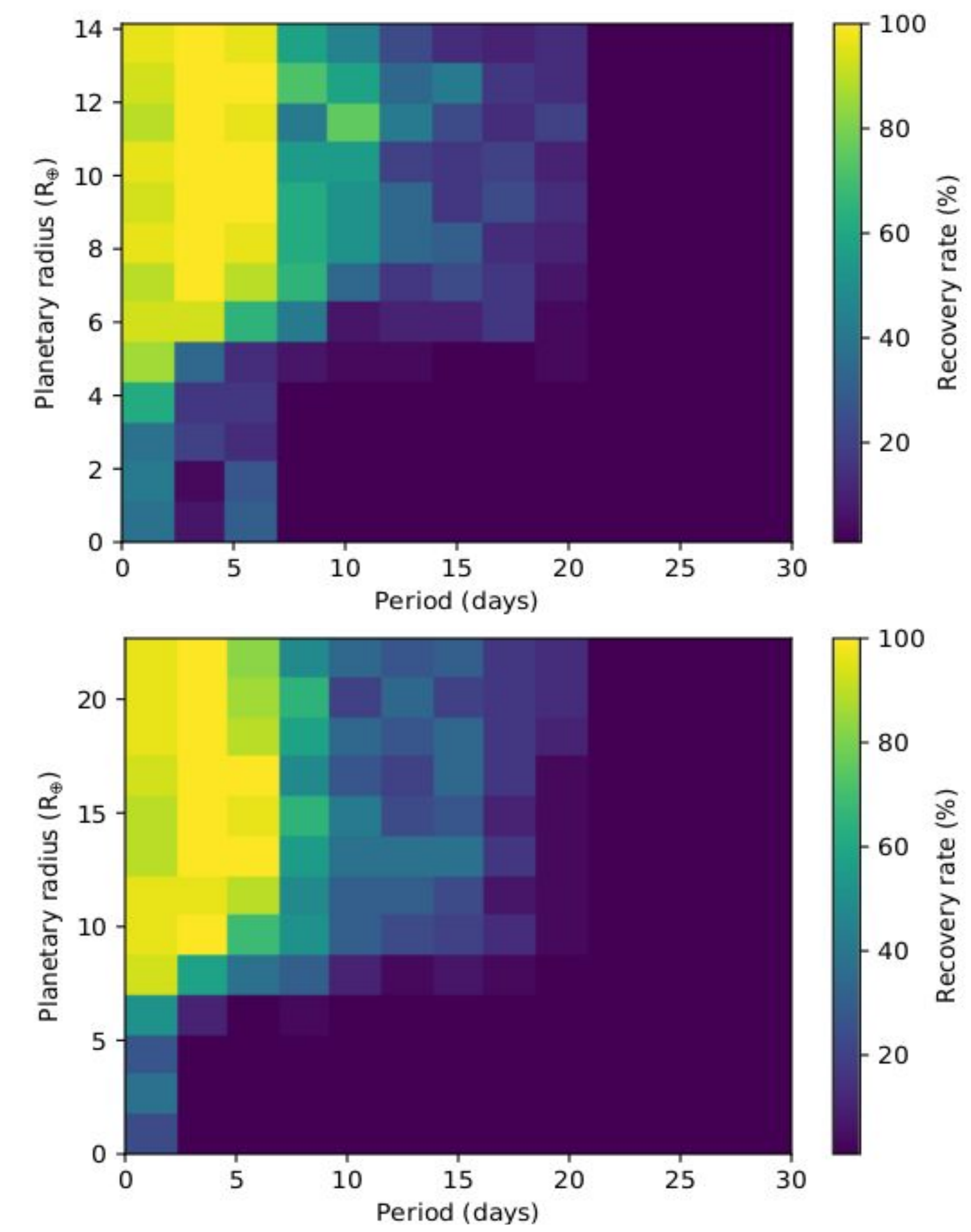

Figure 2. Injection-recovery tests performed on the TESS light curves of the primary (left) and secondary (right) stars. Light and dark colors indicate high and low recovery rates, respectively.

NO ADDITIONAL TRANSITING PLANETS FROM TESS DATA

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 $R_{\oplus}$ and from 0 to 30 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.

ORIGIN OF THE OBSERVED CHEMICAL PATTERN

The depletion of volatiles could be explained by the formation of the observed Saturn-mass planet WASP-160B b if we assume the present-day mass of the convective zone (Mcz) of the host star, but single or multiple additional planets (to add up to ~6 M_{Jup}) are required when adopting a larger Mcz. On the other hand, the refractory-difference could be explained by (i) the formation of rocky bodies (at least ~4.5 $M_{\oplus}$) around WASP-160A or (ii) the late accretion of at least ~6 $M_{\oplus}$ of planet-like material by WASP-160B.

The formation of the confirmed short-period giant planet orbiting WASP-160B and later accretion of planet-like material by this star, likely triggered by the inward migration of the giant planet, represents a tantalizing scenario to explain the observed anomalous chemical pattern. However, the detection limits provided by the current photometric and RV data along with the significant dependence on the assumed M cz prevent us from fully supporting this last hypothesis over the formation of additional (long period) giant planets in WASP-160B and those of the rocky kind around WASP-160A. Future high-precision photometric and spectroscopic follow-up, as well as high-contrast imaging observations, of WASP-160A and B, might provide further constraints on the origin of the detected chemical differences.

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