# A curious planetary system: A Dense Hot Super Mercury and a Cold Jupiter

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## The System We Found

In this work we report the detection and characterization of a new planetary system composed by:

- Slightly evolved Sun-like star
- Super-Mercury with a of density $\rho$ = 10.44 ± 2.01 g cm $^{-3}$, M = 4.09 ± 0.57 $M_{\oplus}$ and R = 1.33 ± 0.06 $R_{\oplus}$. Orbiting close to the host star (a/$R_*$= 3.72 ± 0.12).

  From the interior modeling analysis we find that the planet is composed mainly of iron, with the core representing over 70% of the planet's mass

- Distant (P = 480 ± 1.7 d), eccentric (e = 0.477 ± 0.004) non-transiting giant planet (M = 7.66 ± 0.11 $M_{Jup}$ ).

## Main Steps

Detection of a transit signal with the Box-fitting least squares.

Identification with radial velocities of the giant planet and the peak in the periodogram corresponding to the period of the smaller planet.

Using the HARPS data to evaluated correlations on the RVs with the activity of the star.

Performing a joint analysis by fitting simultaneously the K2 light curve and the RVs from HARPS and CORALIE.

Modeling of the internal structure of the Super-Mercury.

## Context

Most of the currently known planets are small planets with radii between that of the Earth and Neptune. The characterization of planets in this regime shows a large diversity in compositions and system architectures with distributions hinting at a multitude of formation and evolution scenarios.

Among the best characterized planets, there is only a handful of super-Mercury-type planets. Such objects are crucial for the understanding of the planetary formation environment and subsequent evolution.

## The Star

Stellar properties:

- $T_{eff}$ = 5799 ± 11 K
- log $g$ = 4.145 ± 0.022 cm s $^{-2}$
- $[Fe/H]$ = –0.027 ± 0.009 dex
- $v_{turb}$ = 1.165 ± 0.015 km s $^{-1}$
- $V$ ~ 10
- $M_*$ = 1.035 ± 0.022 $M_{\odot}$
- $R_*$ = 1.587 ± 0.028 $R_{\odot}$
- Age = 8.431 ± 0.70 Gyr

Spectroscopic parameters were derived using the standard method "ARES+MOOG" (for more details see Sousa 2014).

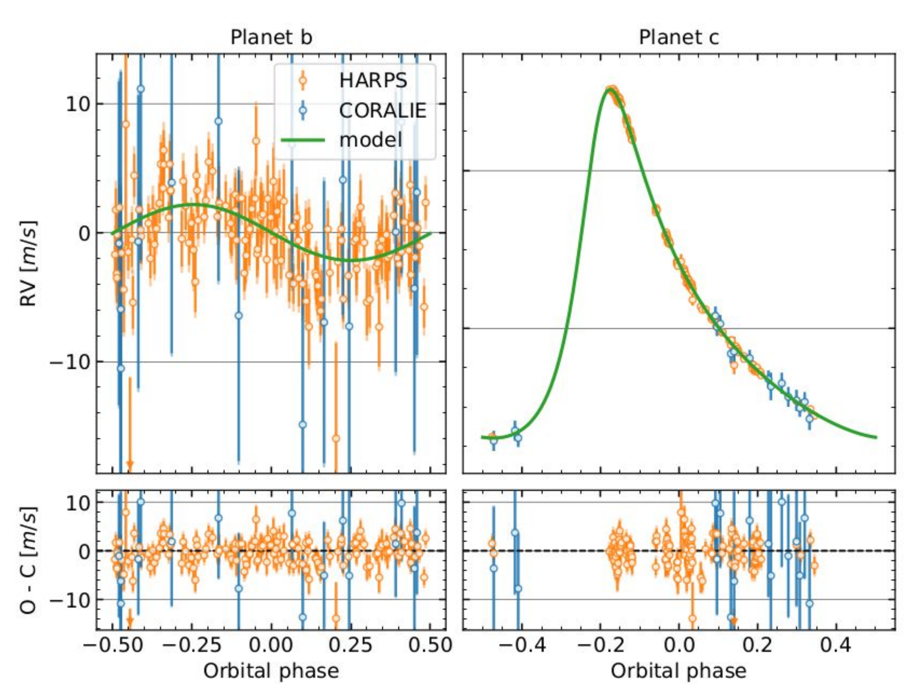
Mass, radius, age and extinction estimated through the use of the Bayesian tool PARAM v1.5 (Rodrigues et al. 2017).

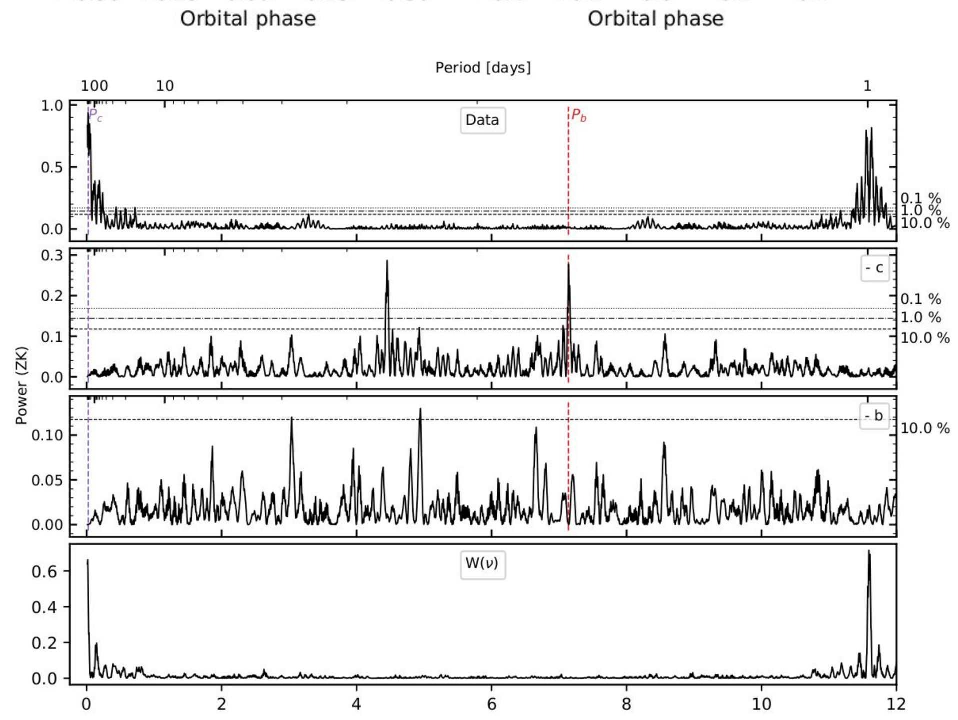
| Species | Value |
|---|---|
| Abundances | |
| [C I/H] | -0.104 ± 0.017 |
| [O I/H] | 0.045 ± 0.077 |
| [Na I/H] | -0.064 ± 0.013 |
| [Mg I/H] | 0.008 ± 0.016 |
| [Al I/H] | 0.018 ± 0.015 |
| [Si I/H] | -0.029 ± 0.025 |
| [Ca I/H] | -0.016 ± 0.041 |
| [Ti I/H] | -0.002 ± 0.022 |
| [Cr I/H] | -0.043 ± 0.029 |
| [Ni I/H] | -0.080 ± 0.014 |
| [Cu I/H] | -0.065 ± 0.027 |
| [Zn I/H] | -0.076 ± 0.020 |
| [Sr I/H] | -0.172 ± 0.077 |
| [Y I/H] | -0.134 ± 0.048 |
| [Zr I/H] | -0.143 ± 0.036 |
| [Ba I/H] | -0.081 ± 0.025 |
| [Ce I/H] | -0.058 ± 0.040 |
| [Nd I/H] | -0.063 ± 0.034 |
| [S I/H] | -0.16 ± 0.05 |
| A(Li) | 2.02 ± 0.04 |

## Radial Velocities

We plot the Generalized Lomb-Scargle periodogram (GLSP, Lomb 1976; Scargle 1982) of the RV timeseries. We notice that a high significance, low false alarm probability (FAP), peak is observed around a period of 200 days.. After fitting a Keplerian to this signal and removing it from the RVs, he GLSP displays a significant peak at the period detected in K2 photometric data by the BLS, P = 1.62 days.

No significant peak is observed in the GLSP of the activity indicators at the period of the suspected planet b or c. We also evaluated the correlation between these indicators and the radial velocities and found none.

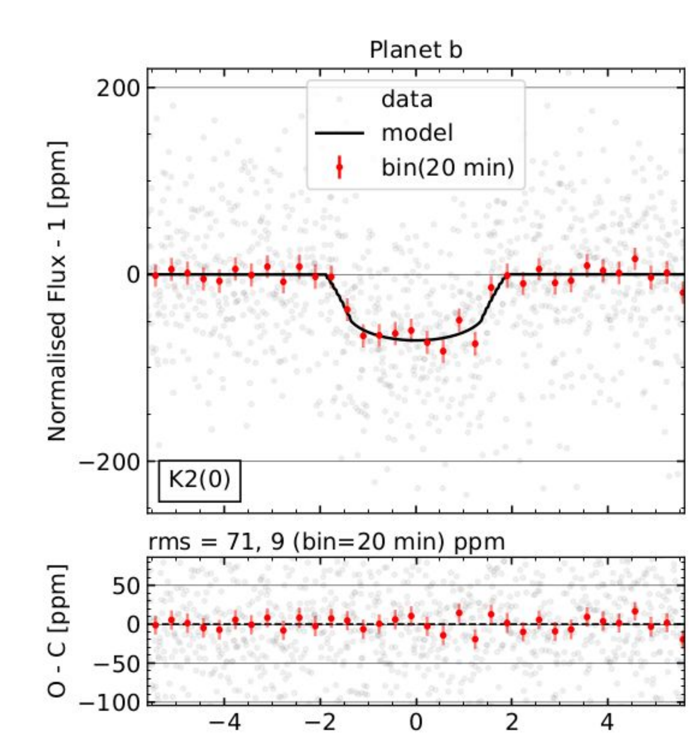



## Photometry

Small planet identified with (BLS; Kovács et al. 2002) implemented within the POLAR pipeline (see Barros et al. 2016, for more details).

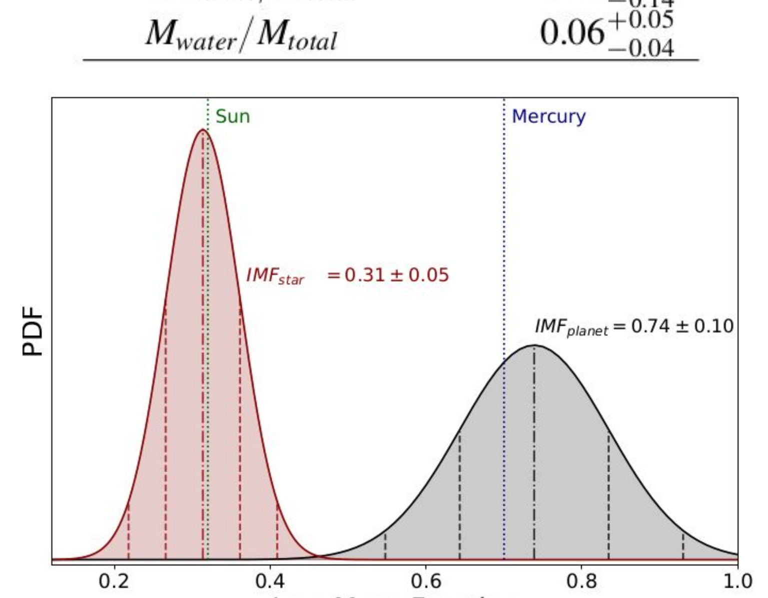
We analysed the data with three different software: POLAR , K2SFF and EVEREST founding consistent results.

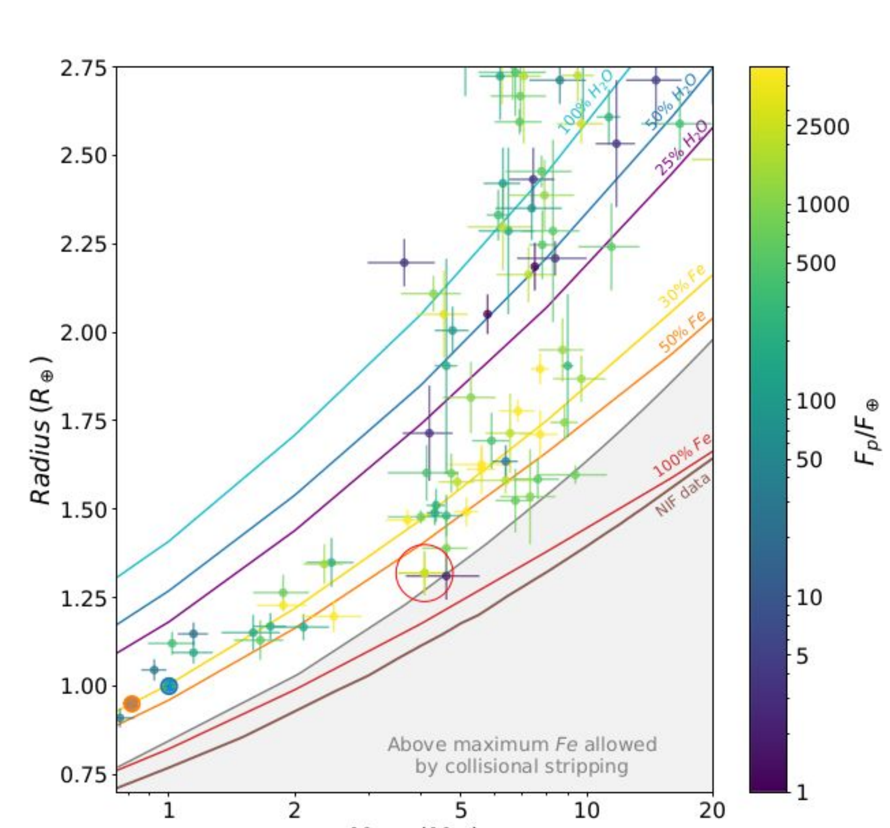


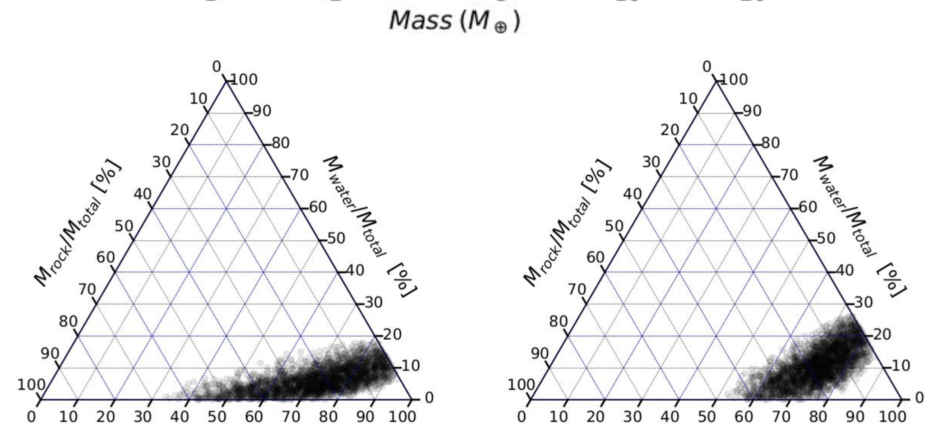

## Interior analysis

We characterize the internal structure of the transiting planet considering a pure-iron core, a silicate mantle and a pure-water layer and using a Bayesian inference analysis.

| | |
|---|---|
| $M_{core}/M_{total}$ | $0.73^{+0.11}_{-0.12}$ |
| $M_{mantle}/M_{total}$ | $0.21^{+0.16}_{-0.14}$ |
| $M_{water}/M_{total}$ | $0.06^{+0.05}_{-0.04}$ |



## Discussion

If we assume that the ratios of Fe/Si and Mg/Si measured in the host star reflect the planetary ratios we are not able to match the observed mass and radius. the probability that the planet reflects the stellar refractory abundances is less than 0.04%.

With well characterized bulk properties and host star abundances, this target is ideal to study planetary formation and evolution scenarios.

The small distance to the star together with an internal structure that resembles that of Mercury creates the conditions for an exospheric emission of the heavy refractory elements present at the planet's surface.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