

# The discovery of 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 density  $\rho = 10.44 \pm 2.01 \text{ g cm}^{-3}$ ,  $M = 4.09 \pm 0.57 M_{\oplus}$  and  $R = 1.33 \pm 0.06 R_{\oplus}$ . Orbiting close to the host star ( $a/R_{\star} = 3.72 \pm 0.12$ ). 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 ( $P = 480 \pm 1.7 \text{ d}$ ), eccentric ( $e = 0.477 \pm 0.004$ ) non-transiting giant planet ( $M = 7.66 \pm 0.11 M_{\text{Jup}}$ ).

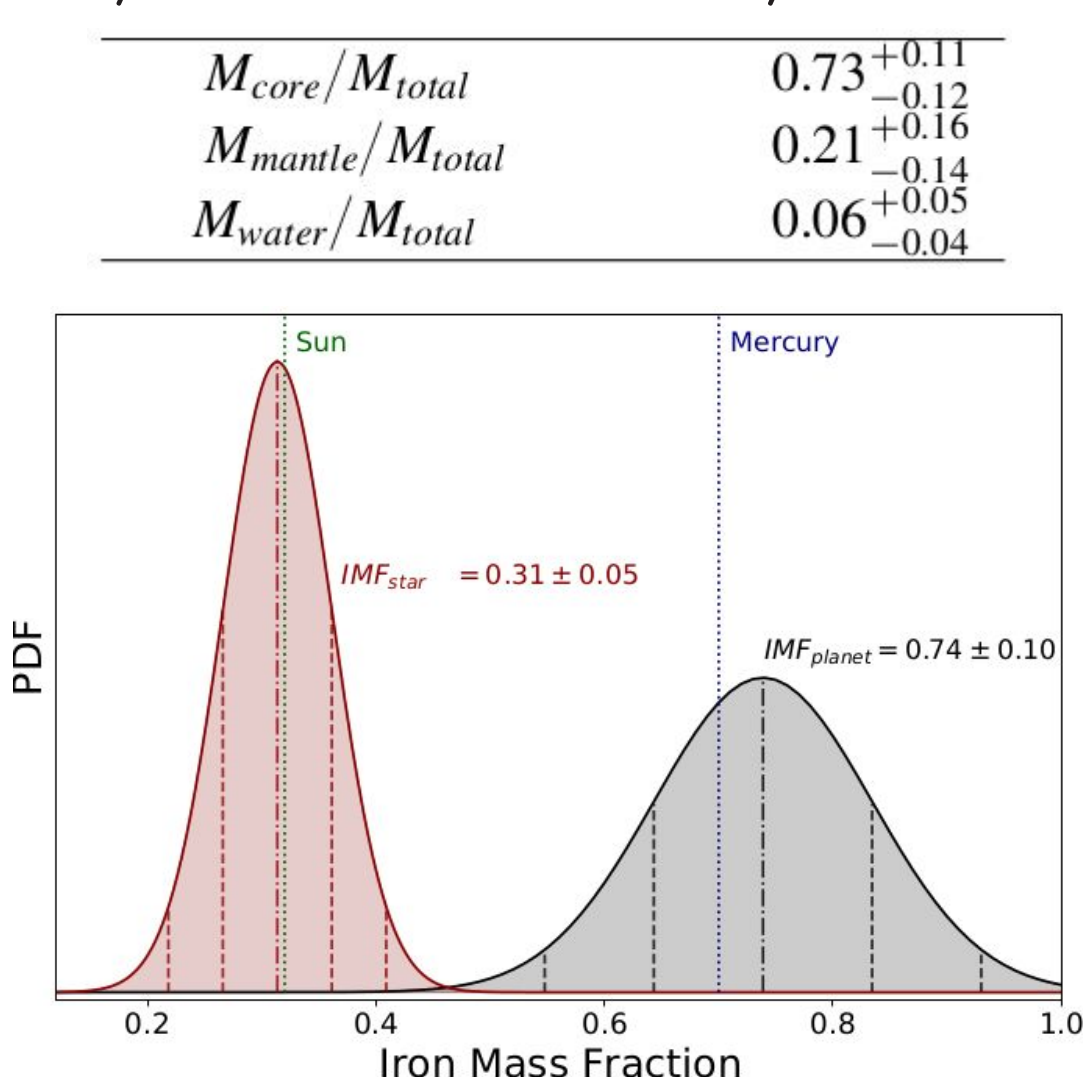
### Radial Velocities

We plot the Generalized Lomb-Scargle Periodogram (GLSP, Lomb 1976; Scargle 1982) of the RV timeseries and first notice that a high significance, low false alarm probability, peak is observed around a period of 500 days. After fitting a Keplerian to this signal and removing it from the RVs, the GLSP displays a significant peak at the period detected on K2 photometric data by the BLS,  $P = 1.62 \text{ days}$ .

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

### 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.



### Main Steps

#### Datasets

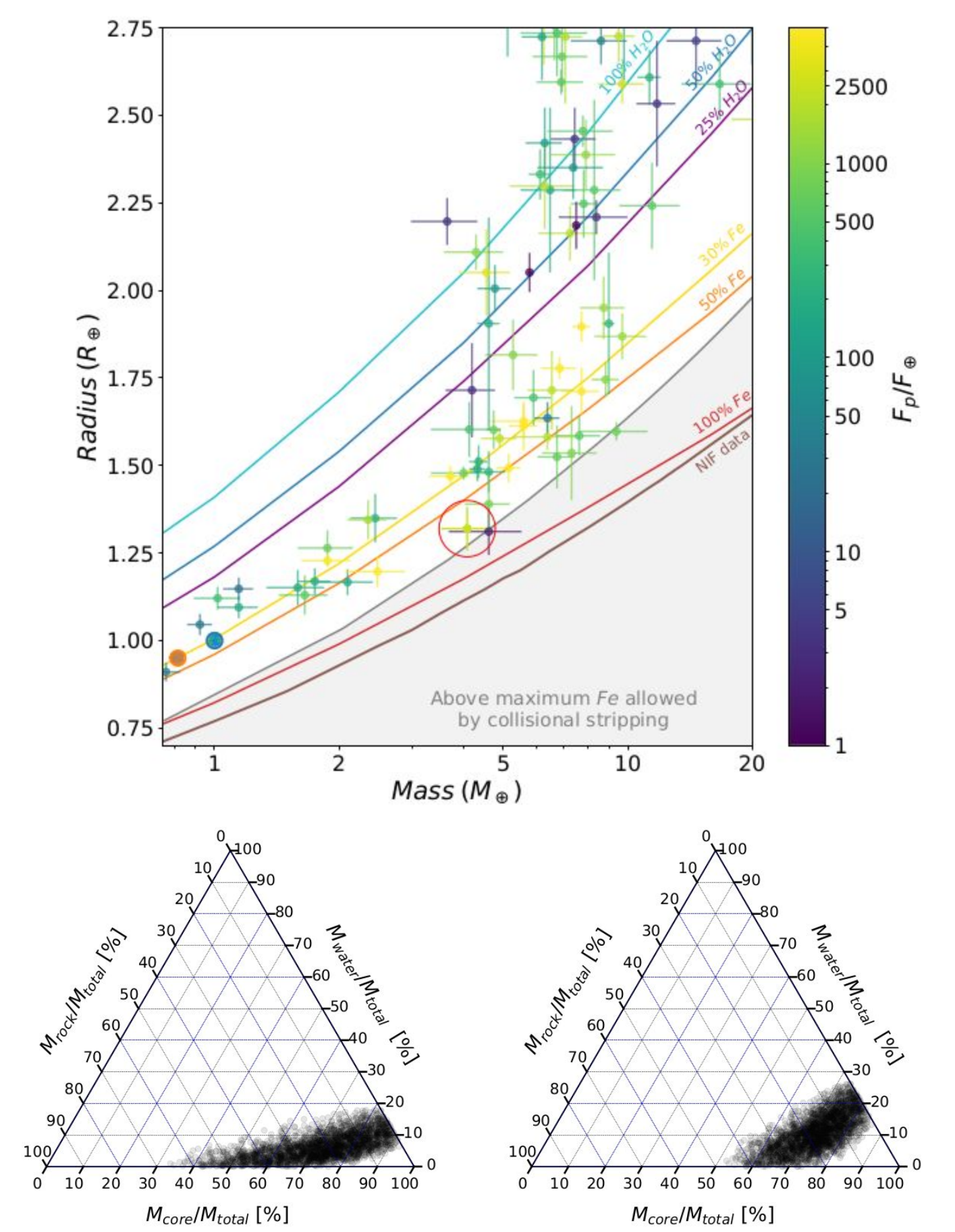
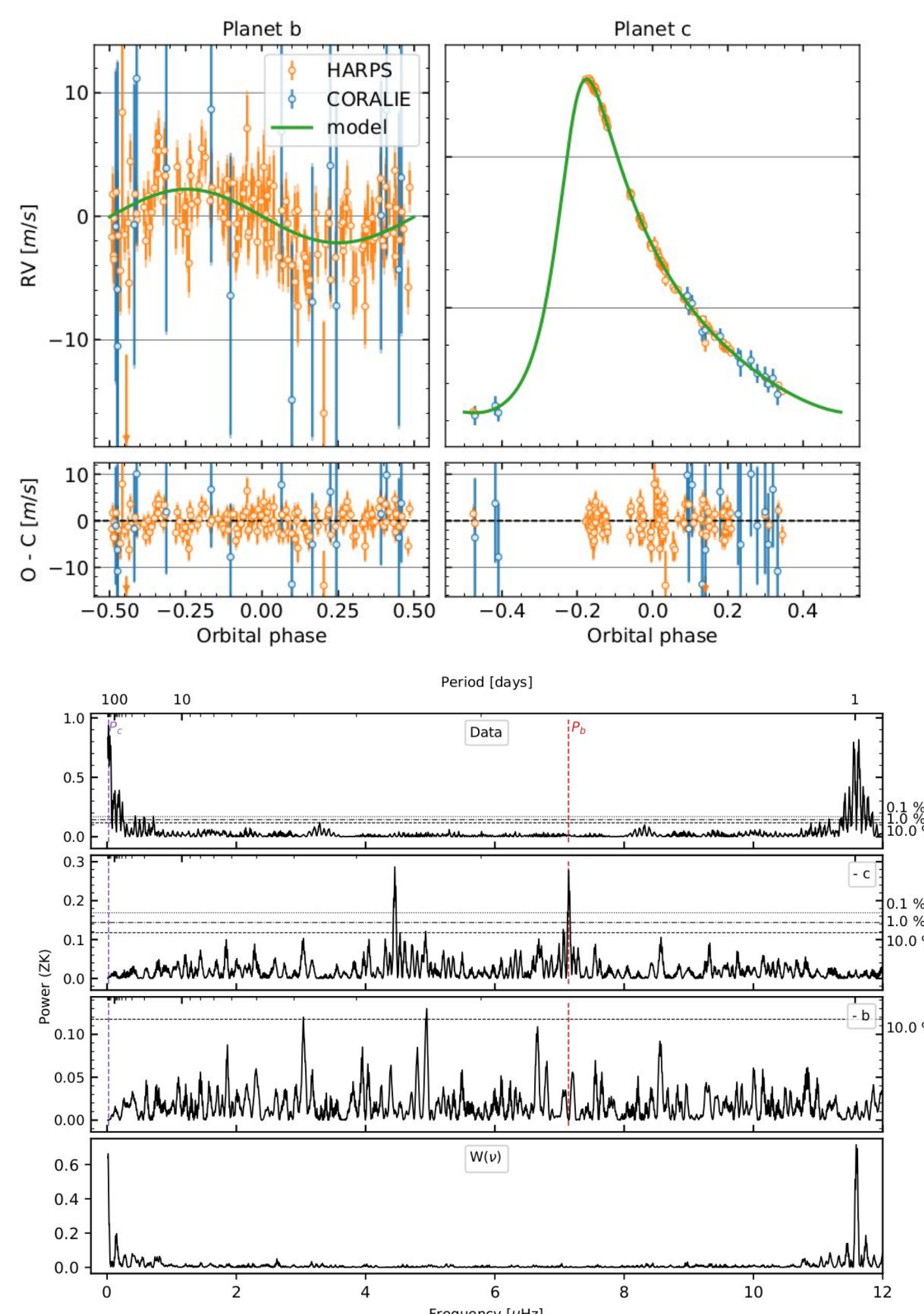
Lightcurve : K2  
Radial velocities : HARPS + CORALIE

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

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

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

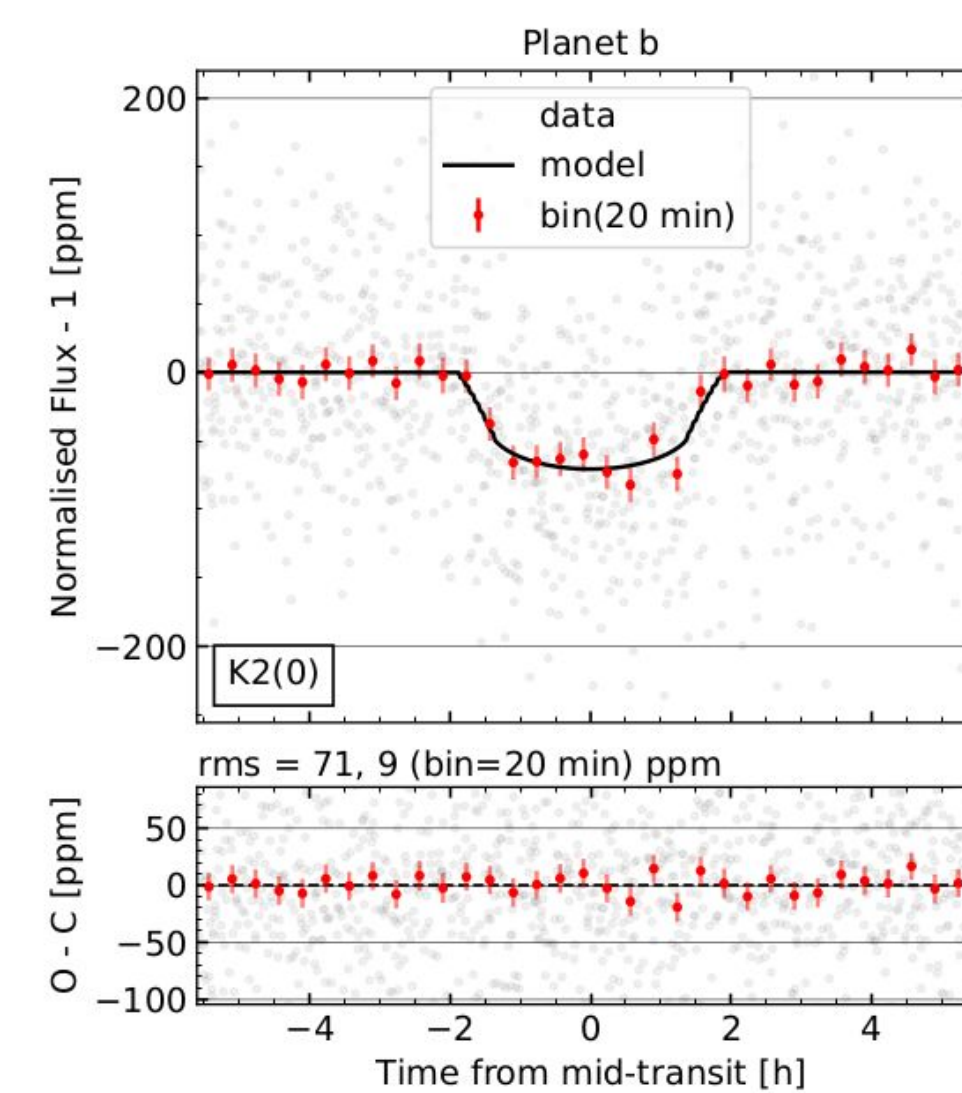
Most of the currently known planets are small planets with radii between that of the Earth and Neptune. The characterization of planets in this regime shows a large diversity in compositions and system architectures with distributions hinting at a multitude of formation and evolution scenarios.

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

### Photometry

A small planet was identified with the BLS (Kovács et al. 2002) implemented within the POLAR pipeline (see Barros et al. 2016) at  $P = 1.62 \text{ days}$ .

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



### Interesting takes

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 for the study of planetary formation and evolution scenarios.

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

### The Star

Stellar properties:

- $T_{\text{eff}} = 5799 \pm 61 \text{ K}$
- $\log g = 4.145 \pm 0.022 \text{ cm s}^{-2}$
- $[Fe/H] = -0.03 \pm 0.04 \text{ dex}$
- $v_{\text{turb}} = 1.165 \pm 0.015 \text{ km s}^{-1}$
- $V \sim 10$
- $M_{\star} = 1.035 \pm 0.022 M_{\odot}$
- $R_{\star} = 1.587 \pm 0.028 R_{\odot}$
- Age =  $8.431 \pm 0.70 \text{ Gyr}$

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

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