CHEOPS and TESS view of the ultra-short-period super-Earth TOI-561 b

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Some facts about TOI-561 b

TOI-561 b is the inner most planet in a multi-planetary system with at least other three other planets. Its orbital period is ~11 hr, with Rp ~1.4Re and Mp ~2.2 Me. It is the lowest density planet observed till the date (Lacedelli et al. 2022).

1. Introduction

Orbiting a metal-poor star TOI-561, TOI-561 b has a unique place in temperature-surface gravity - host star metallicity space (Fig. 1). We wanted to study its internal structure by updating its bulk properties and explore the possibility of it having an atmosphere.

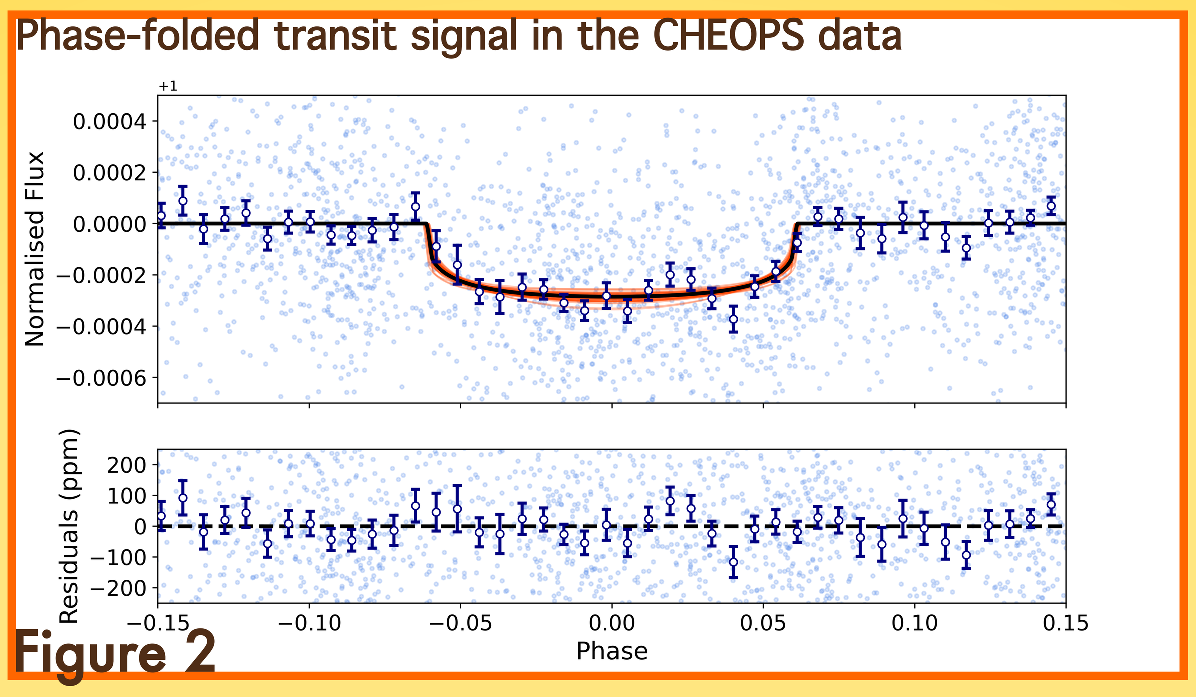

Figure 2

2. Observations (Fig. 2, 3 & 4)

The exquisite precision of CHEOPS and TESS allowed us to constrain planetary radius at 2%. Additionally, we tentatively detected an occultation signal in the TESS data (depth 27 +/- 11 ppm). We could not detect occultation in the CHEOPS data (3σ upper limit at 99 ppm).

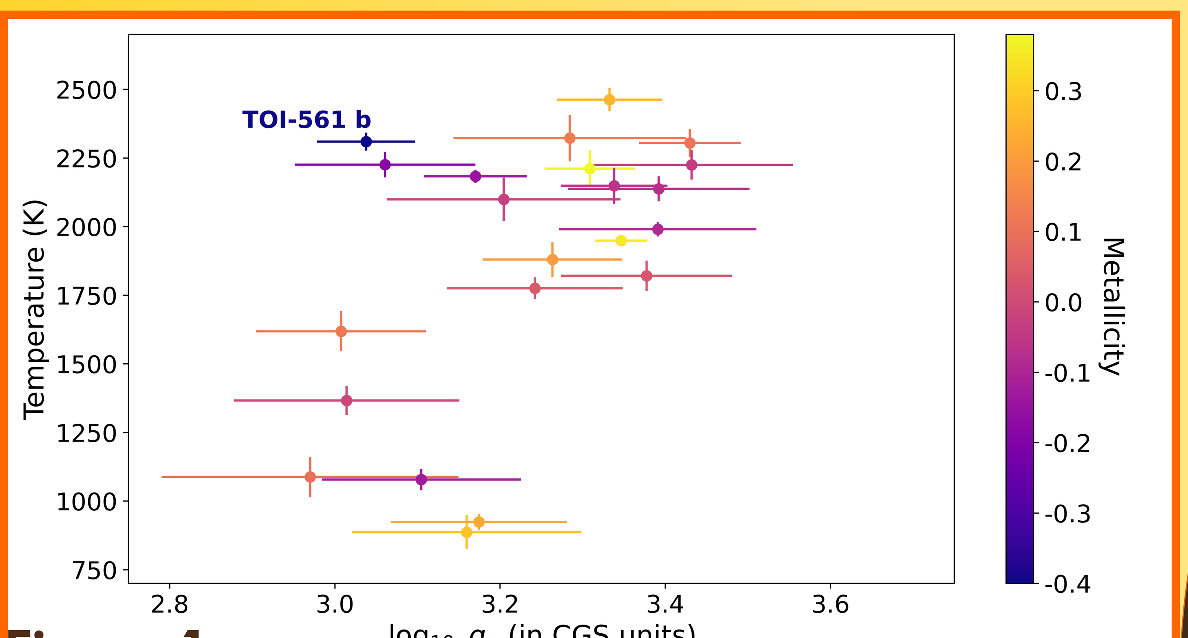

Figure 1

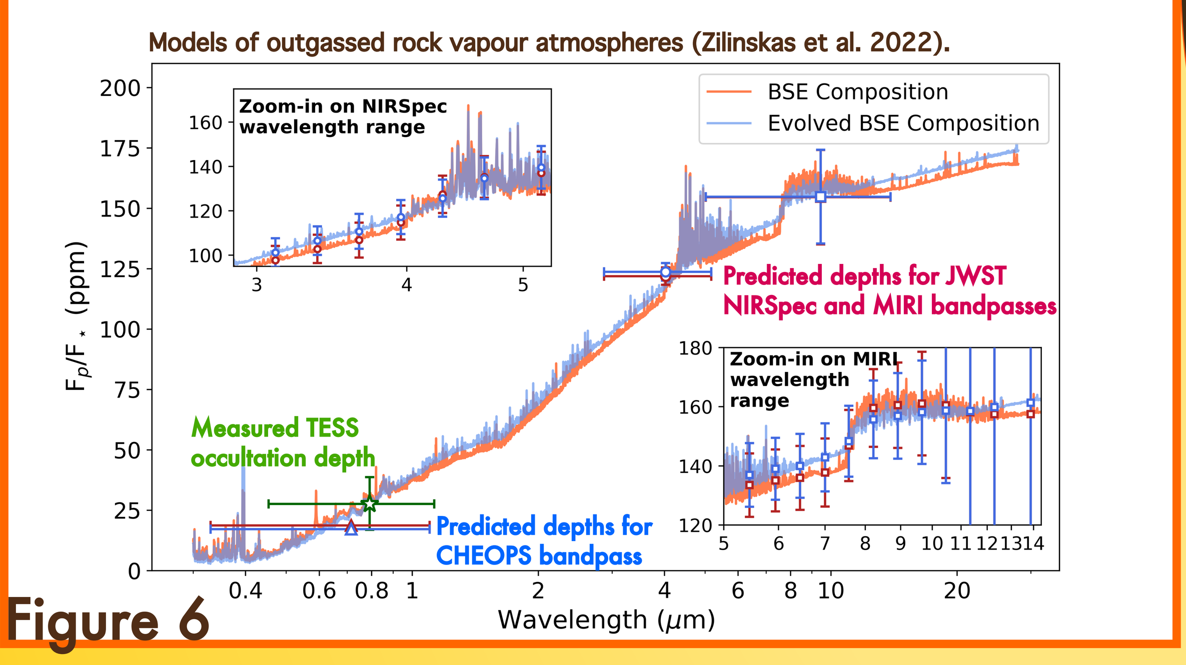

Figure 6

A quick summary

We observed the lowest density ultra-short-period planet TOI-561 b (P= 0.45 d, Rp=1.42 Re) with CHEOPS to study its internal structure & atmosphere. Using ultra-precision CHEOPS and TESS photometry, we constrain planetary radius at 2%. This constraint informed our internal structure modelling which shows that the observations are consistent with negligible H/He atmosphere; however, other lighter elements, in addition to the iron core and silicate mantle, are needed to explain the observed radius. We also find a tentative detection of an occultation signal (depth = 27 +/- 11 ppm) in the TESS data, which could be caused by thermal emission from silicate outgassed atmosphere.

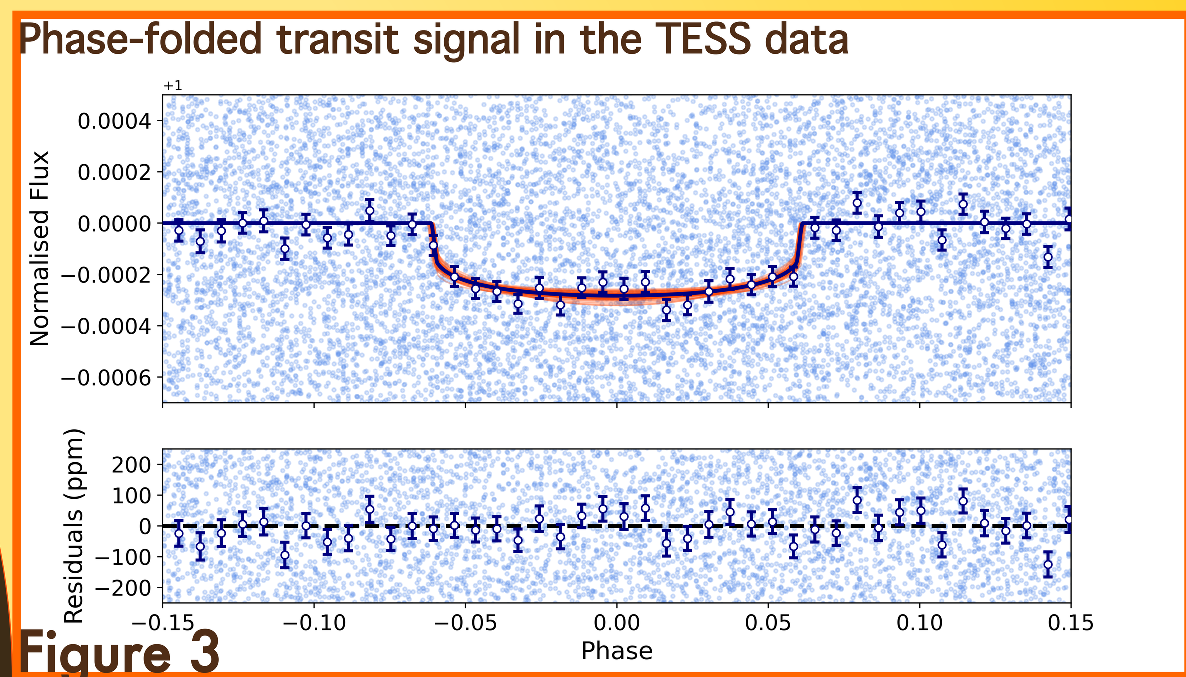

Figure 3

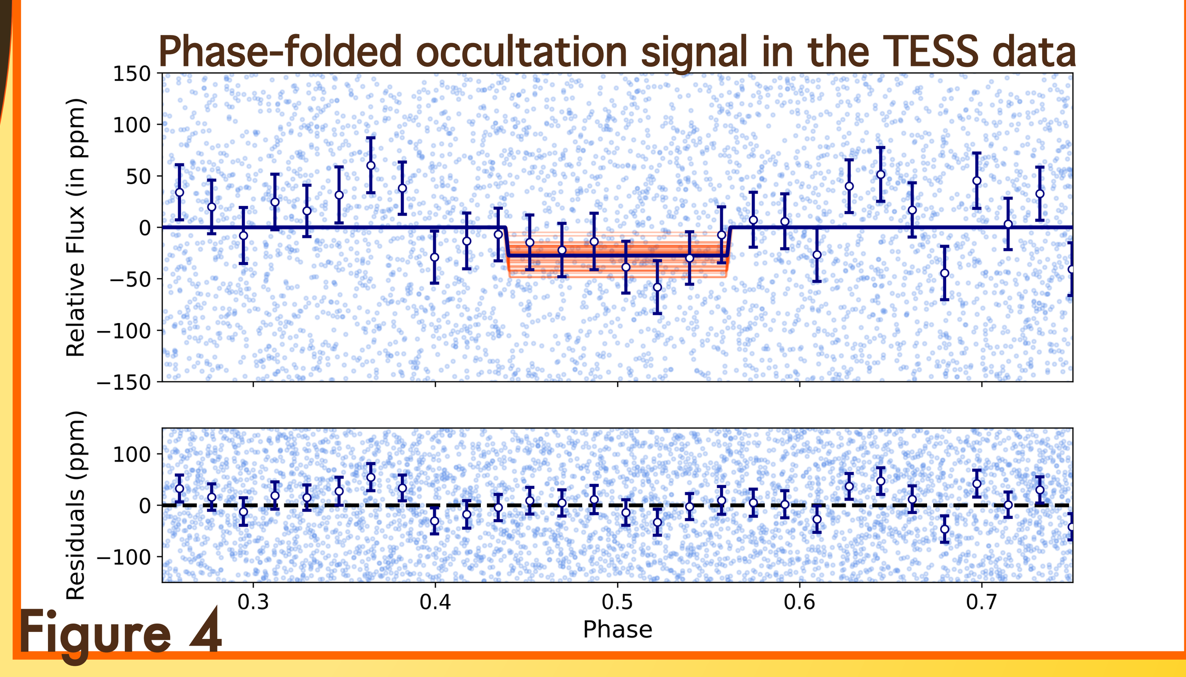

Figure 4

4. Prospects of an atmosphere

We compared the TESS occultation depth with theoretical models of outgassed rock vapour atmospheres from the literature (Fig. 6). They can fully explain the obs. occultation signal. The JWST simulations using these models shows that JWST should be able to detect silicate species if there is indeed any.

3. Internal Structure Modelling

Internal structure modelling with updated planetary parameters shows that the planet has a negligible H/He layer (Fig. 5). However, other lighter elements are needed to explain the observed radius, so, we included a water layer in the model for this purpose. A grid of forward models with water-enriched atmosphere demonstrate that such an atmosphere with a range of water fractions could indeed explain the observed radius.

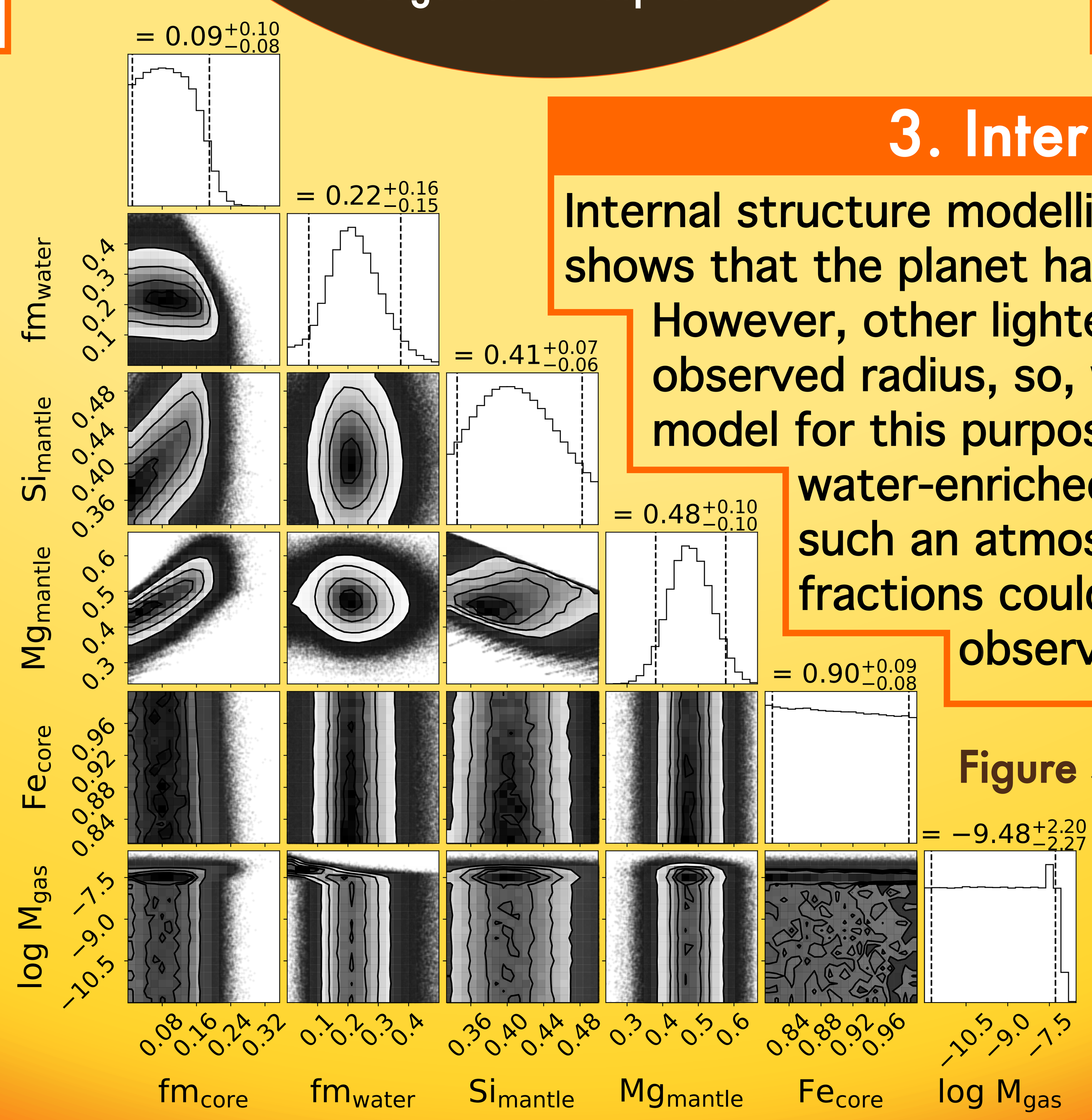

Figure 5: A corner plot of internal structure model parameters

References:

Lacedelli, G., Wilson, T. G., Malavolta, L., et al. 2022, MNRAS, 511, 4551

Zilinskas, M., van Buchem, C. P. A., Miguel, Y., et al. 2022, A&A, 661, A126

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