A transiting super-Earth in the radius valley and an outer planet candidate around HD 307842

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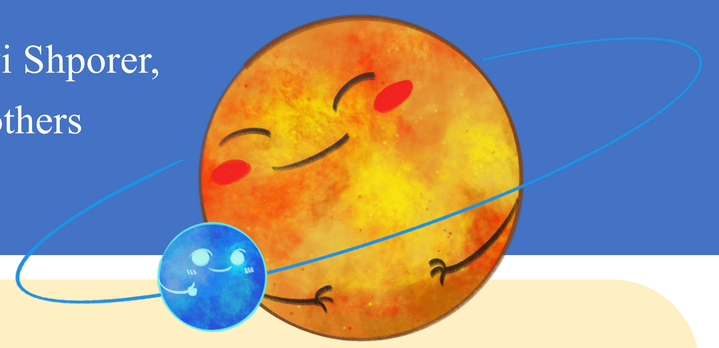
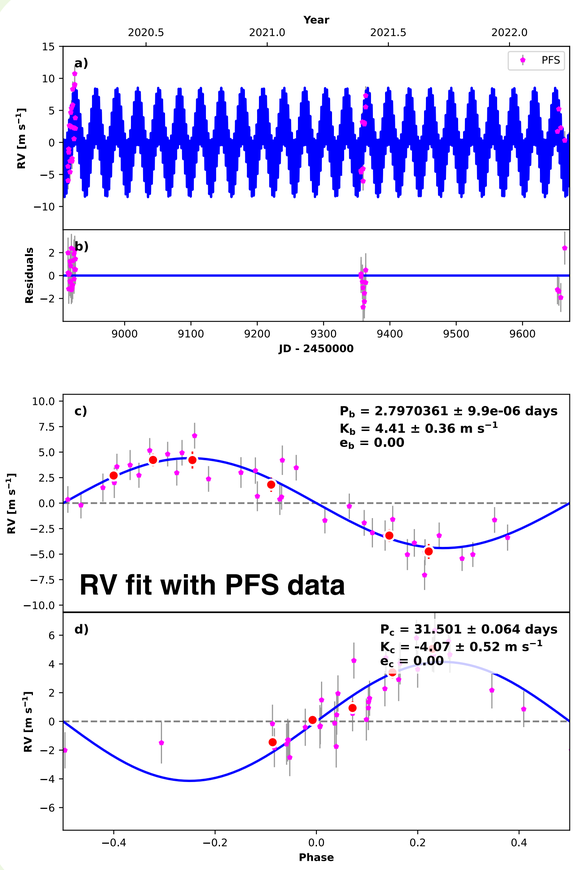


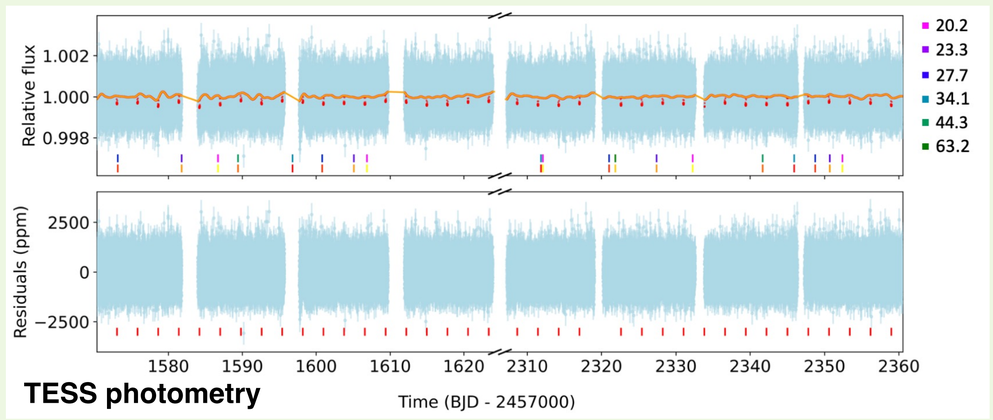
❖ Abstract

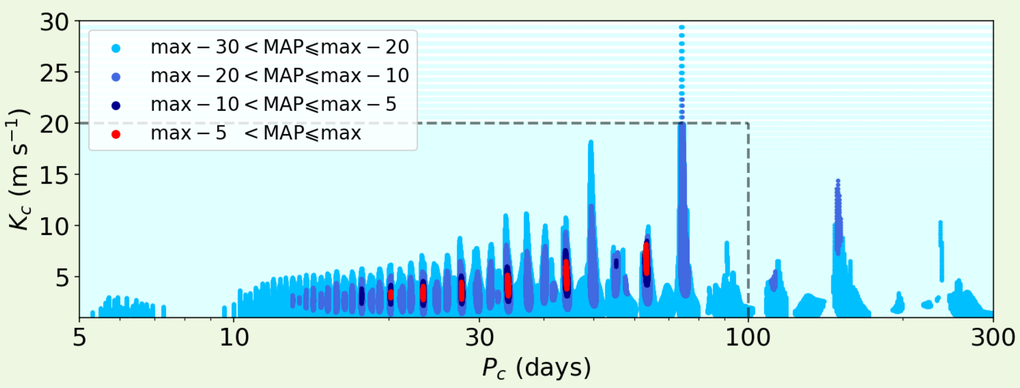
We report the confirmation of a *TESS*-discovered transiting super-Earth planet orbiting a mid-G star, HD 307842 (TOI-784). The planet has a period of 2.8 days, and the radial velocity (RV) measurements constrain the mass to be $9.67^{+0.83}_{-0.82}$ $M_\oplus$. We also report the discovery of an additional planet candidate on an outer orbit that is most likely non-transiting. The possible periods of the planet candidate are approximately 20 to 63 days, with the corresponding RV semi-amplitudes expected to range from 3.2 to 5.4 m/s and minimum masses from 12.6 to 31.1 $M_\oplus$. The radius of the transiting planet (planet b) is $1.93^{+0.11}_{-0.09}$ $R_\oplus$, which results in a mean density of $7.4^{+1.4}_{-1.2}$ g/cm^3, suggesting that TOI-784b is likely to be a rocky planet though it has a comparable radius to a sub-Neptune. We found TOI-784b is located at the lower edge of the so-called ``radius valley'' in the radius vs. insolation plane, which is consistent with the photoevaporation or core-powered mass loss prediction. The *TESS* data did not reveal any significant transit signal of the planet candidate, and our analysis shows that the orbital inclinations of planet b and the planet candidate are $88.6^{\circ}{}^{+0.84}_{-0.86}$ and $\leq 88.3^{\circ} - 89.2^{\circ}$. More RV observations are needed to determine the period and mass of the second object and search for additional planets in this system.

❖ Analysis

We obtained RV data from three different facilities: Magellan-PFS, LCO-NRES and CTIO-CHIRON.



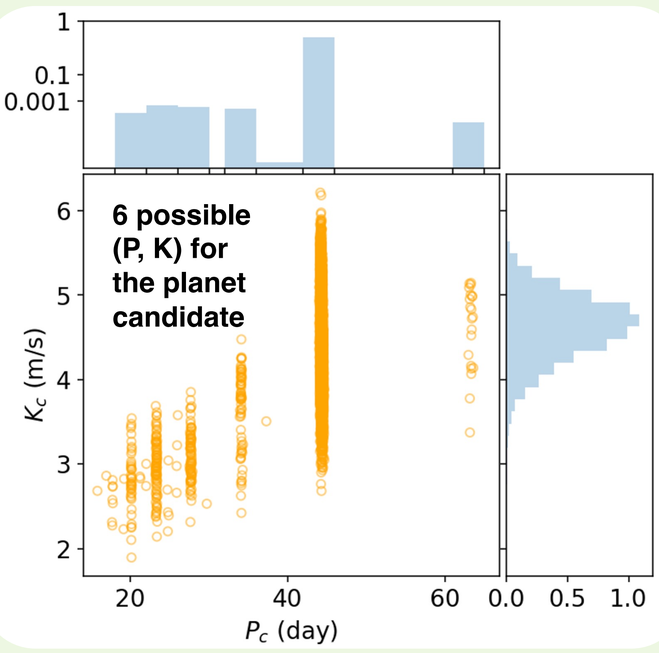




While the RV data is insufficient to fully map out the orbit of the second object, we conducted additional analyses to explore the parameter space of the period (P) and RV semi-amplitude (K) to constrain its orbital solution.

To accomplish this, we performed a grid search using a maximum a posteriori (MAP) fit in RadVel, with fixed input pairs of (P,K). This yielded 6 groups of the most probable (P,K) pairs with the highest MAP values. Additionally, we conducted a two-planet fit in Juliet with nested sampling, which also revealed 6 similar possible solutions: with periods of approximately 20, 23, 28, 34, 44, and 63 days.

To verify that the planet candidate is non-transiting, we conducted an injection-and-recovery test. The results suggest that it is an intrinsically non-transiting planet.



❖ Conclusion

TOI-784 b

Planet b is a transiting super-Earth with a period of 2.8 days and a radius of ~1.9 $R_\oplus$. The mass of planet b is ~9.7 ± 0.8 $M_\oplus$. The orbit is a circular orbit with an inclination of ~ 88.6°.

Planet candidate

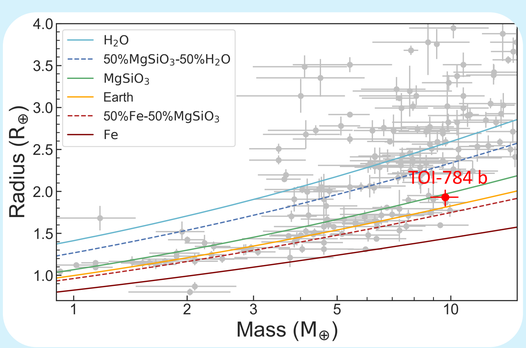
The planet candidate is likely non-transiting. In our work, we found that the most possible periods of the candidate are 20.2, 23.3, 27.7, 34.1, 44.3, and 63.2 days, which gives a mass within 12.6 – 31.1 $M_\oplus$.

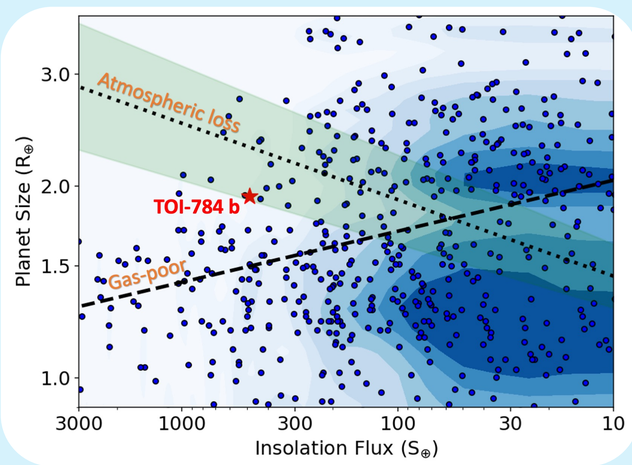
❖ Discussion

The estimated density of TOI-784b is roughly 7.4 g/cm^3, which would correspond to a rocky planet. In the M-R relation plot, TOI-784b (the red point) is between the green and orange lines representing a MgSiO3 core and Earth composition, respectively, which also implies that TOI-784b is a rocky planet, the same as our analyses.

Moreover, TOI-784b is located at the lower edge of the radius valley (in the Size-Insolation flux plane) predicted by photoevaporation or core-powered mass loss, which is consistent with the atmospheric loss formation scenario considering its rocky composition.

- The M-R relation
- Insolation vs. Planet Radius





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