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TOI-682: two mini-Neptunes, one transiting

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TESS spots a transiting mini-Neptune

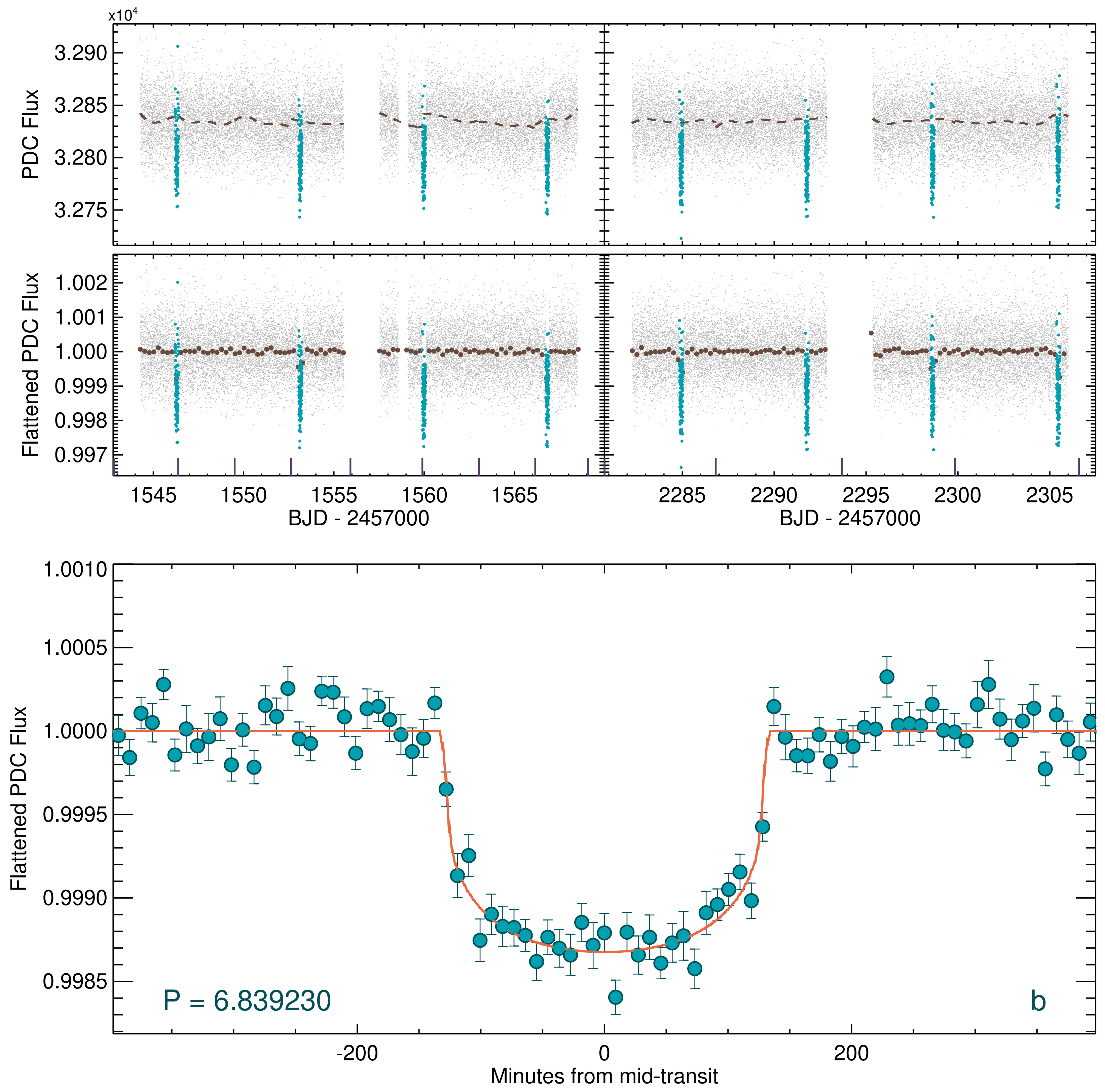

Figure 1. The TESS light curve of TOI-682, which was observed in Sectors 9 and 36. **Top**: PDCSAP flux processed by the SPOC pipeline. The individual 2-minute cadence fluxes are shown in gray, and the in-transit cadences are highlighted in blue. The brown dashed line is the spline model used to detrend the data. The times of spacecraft pointing corrections are denoted by purple tick marks on the bottom x axis. Note the 740-day break between sectors. **Middle**: The flattened light curve after dividing out the spline model. Binned out of transit data are shown in brown. **Bottom**: The phase-folded, binned, TESS light curve (blue circles) along with the best-fit transit model (orange) from our EXOFASTv2 (Eastman et al. 2019) global fit.

A complement to existing transmission spectroscopy

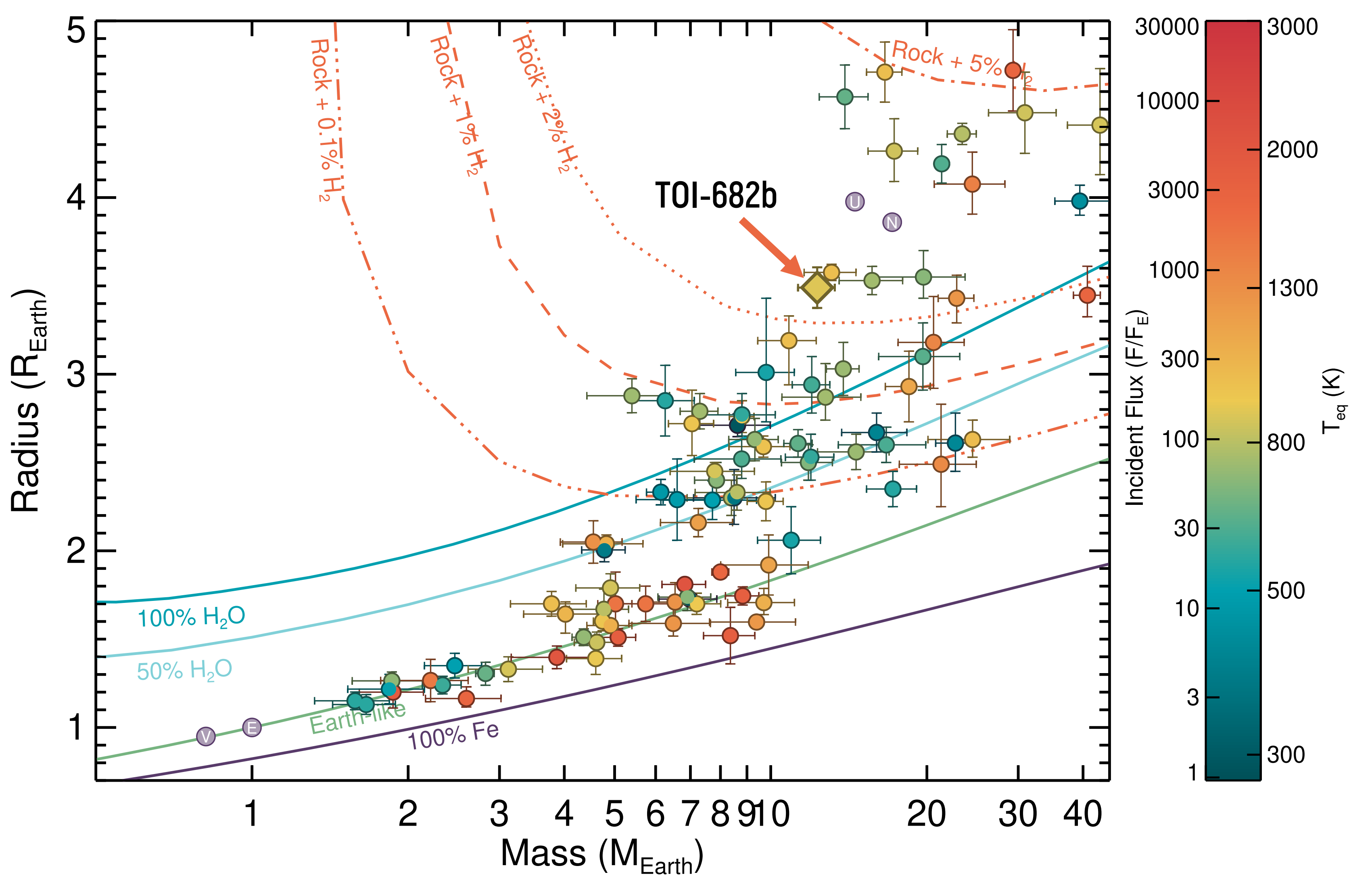

Figure 3. A mass-radius diagram showing RV masses with better than 5-sigma precision. Models are from Zeng et al. 2019. TOI-682b (large diamond) lies along the low-density upper envelope of mini-Neptunes. Its density (1.58 g/cm^3), reasonably deep transit (1.3 mmag), and host star's relative brightness (J=8.5) make it a promising target for transmission spectroscopy.

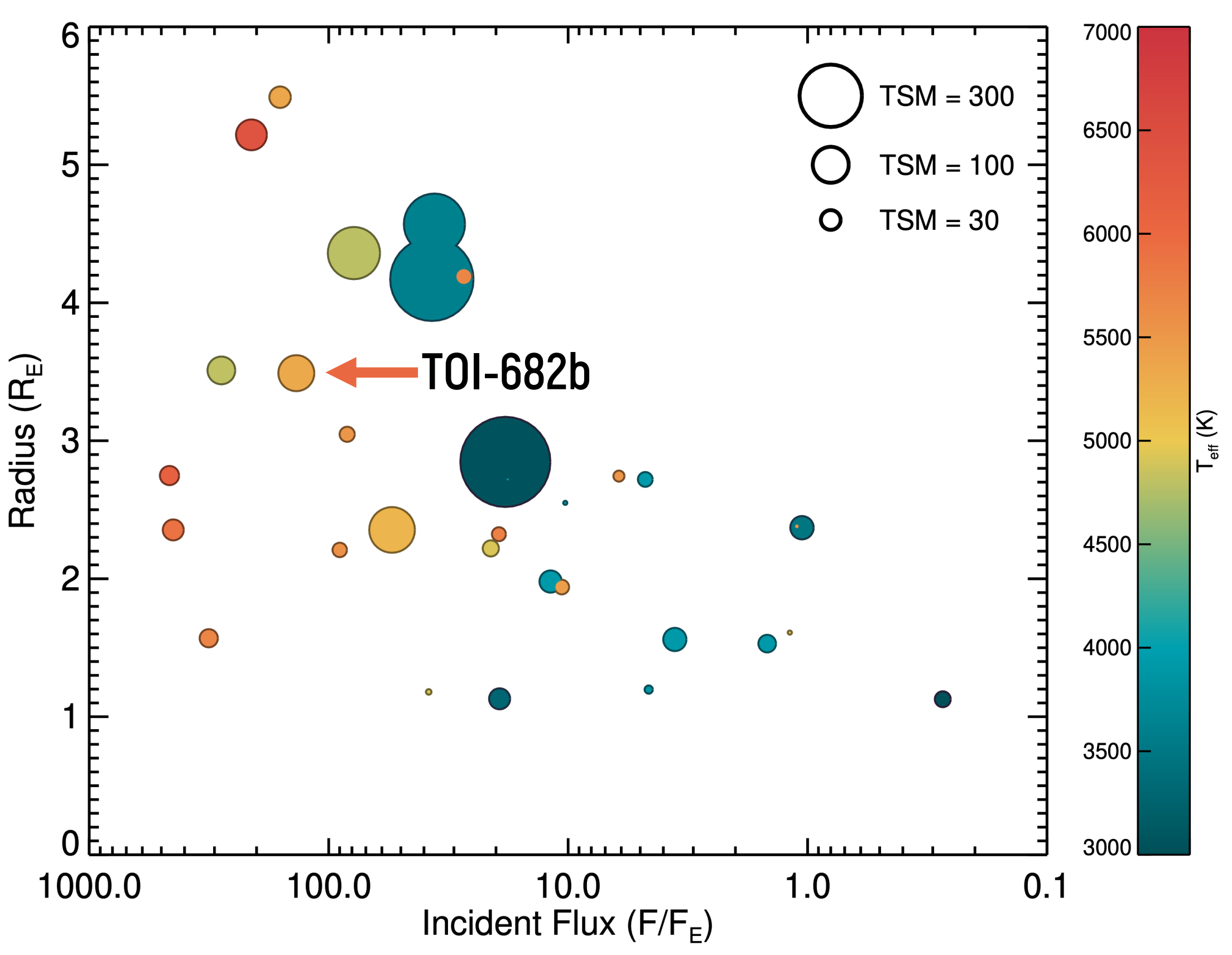

Figure 4. Planet radius vs incident flux, for planets with mass measurements and existing transmission spectroscopy listed in the NASA Exoplanet Archive. The area of each circle is proportional to the Transmission Spectroscopy Metric (TSM; Kempton et al. 2018) for that planet, and the color indicates the temperature of the host star. TOI-682 has a TSM of 90. While this is not among the absolute highest values, it is the best among highly irradiated mini-Neptunes. This is of particular interest given the observation of atmospheric hazes in cooler mini-Neptunes (e.g., Crossfield & Kreidberg 2017). Its size and temperature (950 K) therefore suggest that TOI-682b is a good candidate for observation of atmospheric features unobscured by haze, which would allow us to better understand this class of planet.

PFS RVs reveal eccentricity and a non-transiting planet

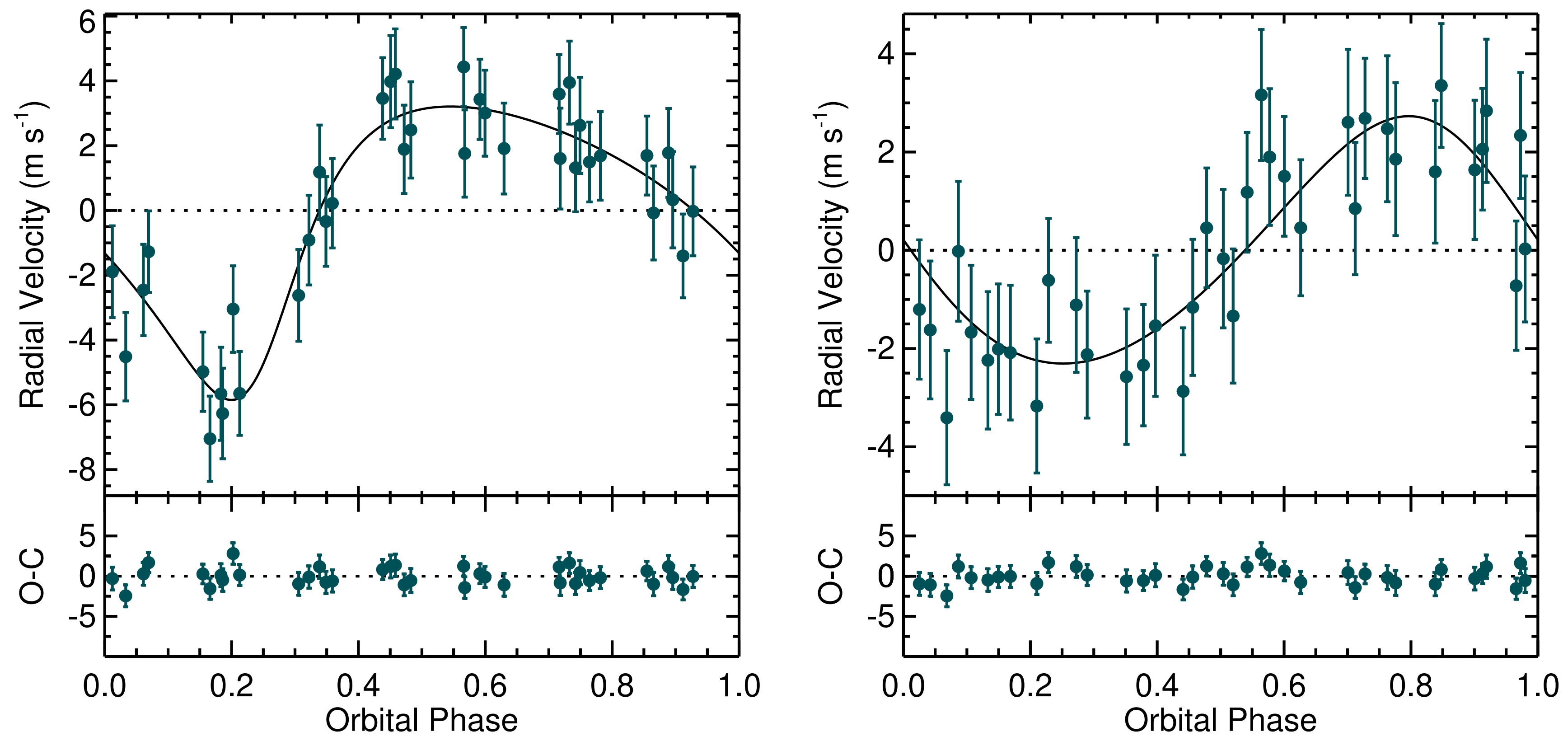

Figure 2. PFS radial velocities (RVs) of TOI-682, phased to the period of TOI-682b (**left**) and TOI-682c (**right**), after removing the model of the other planet in each case. We also simultaneously fit for activity-induced RVs variation, finding a strong correlation between the S-index and the RVs. Uncertainties related to this activity fit are propagated through the EXOFASTv2 global fit. The key stellar and planetary properties are displayed in the table below.

EXOFASTv2 stellar and planetary properties

	TOI-682b	TOI-682c
P (days)	$6.83968^{+0.00096}_{-0.00100}$	$16.134^{+0.041}_{-0.040}$
R_P ($R_\oplus$)	$3.49^{+0.12}_{-0.11}$	...
$M_p\sin(i)$ ($M_\oplus$)	$12.29^{+1.00}_{-0.99}$	$9.6^{+1.3}_{-1.4}$
e	$0.411^{+0.033}_{-0.031}$	$0.072^{+0.061}_{-0.050}$
T_{eq} (K)	952 ± 10	$715.6^{+7.6}_{-7.8}$
i (deg)	$89.41^{+0.40}_{-0.51}$	$\lesssim 87.8$
	TOI-682	
$M_\star$ ($M_\odot$)	$0.969^{+0.055}_{-0.048}$	
$R_\star$ ($R_\odot$)	$0.966^{+0.027}_{-0.026}$	
[Fe/H]	$+0.440^{+0.060}_{-0.069}$	
T_{eff} (K)	5309^{+73}_{-75}	

TOI-682 b and c: highly, or just slightly, misaligned?

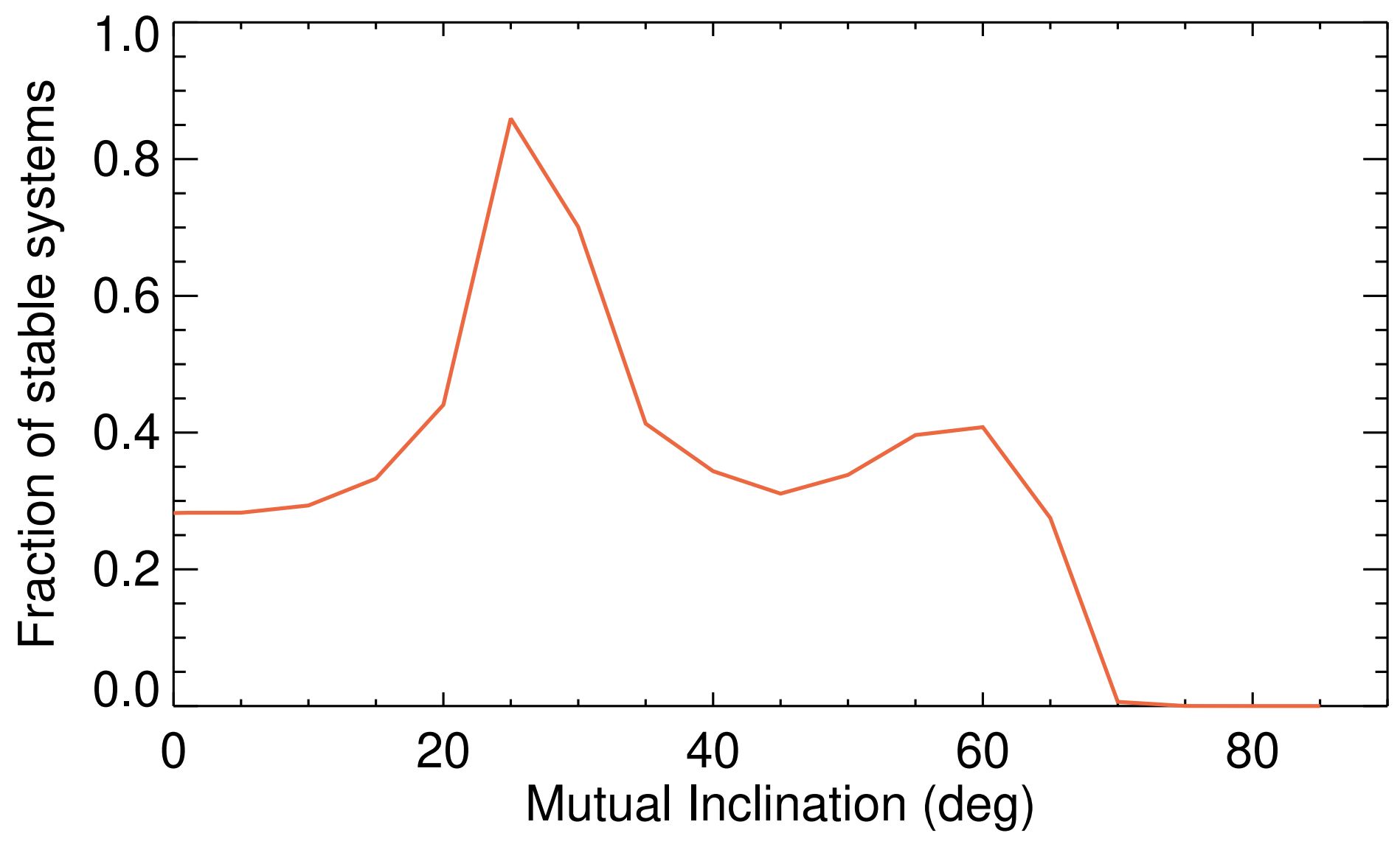

Figure 5. We explore the architecture of the system through N-body simulations by drawing orbital parameters and masses from our posteriors and varying the mutual inclinations between the planets. While we cannot rule out most inclinations – at least ~30% of simulated systems remain stable for mutual inclinations up to 65 degrees – >80% are stable for a 25 degree mutual inclination. In conjunction with a high eccentricity for TOI-682b, the mutual inclination can help constrain the system's formation pathway.

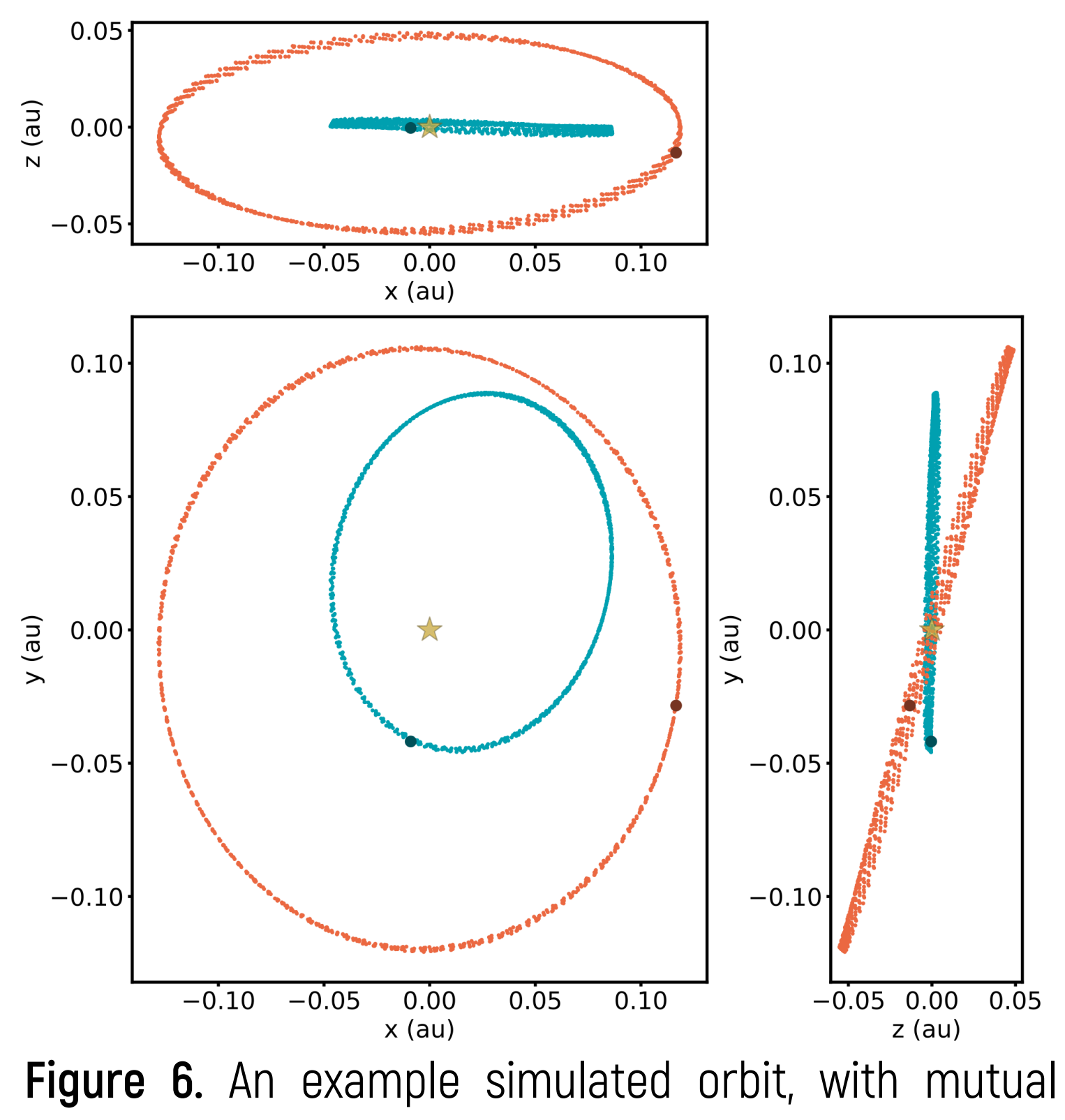

Figure 6. An example simulated orbit, with mutual inclination 25 degrees. The positions of the planets are plotted for 5 years after the first TESS transit, during which slight inclination variation is apparent.

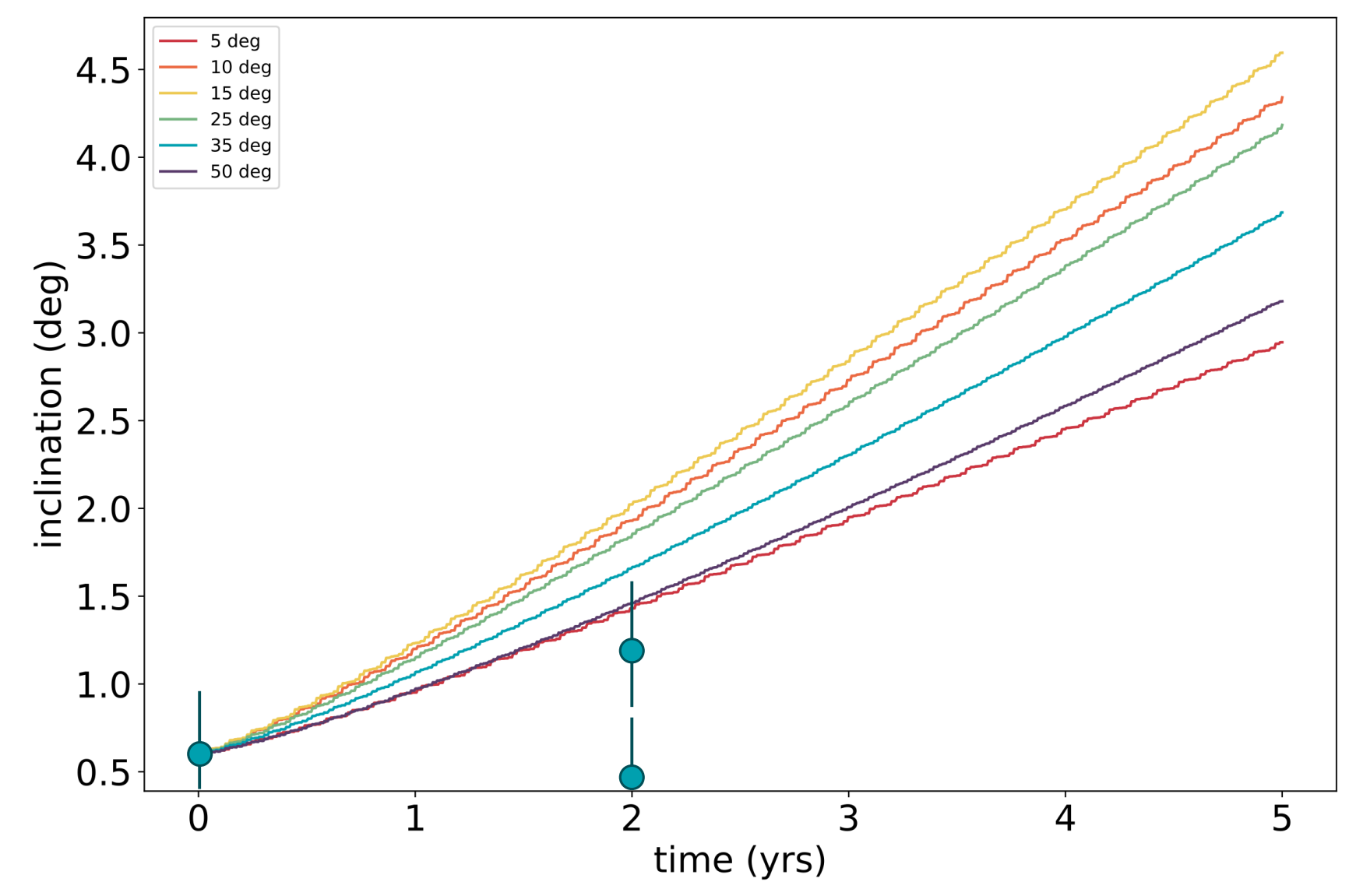

Figure 7. An inclination variation may be observable and would provide constraints on the mutual inclination. Example simulations are shown as colored lines for a series of mutual inclinations. The value derived from TESS Year 1 and Year 3 transits are plotted as blue circles. However, there is a |90 - i| degeneracy, so continued monitoring is necessary to constrain the evolution.

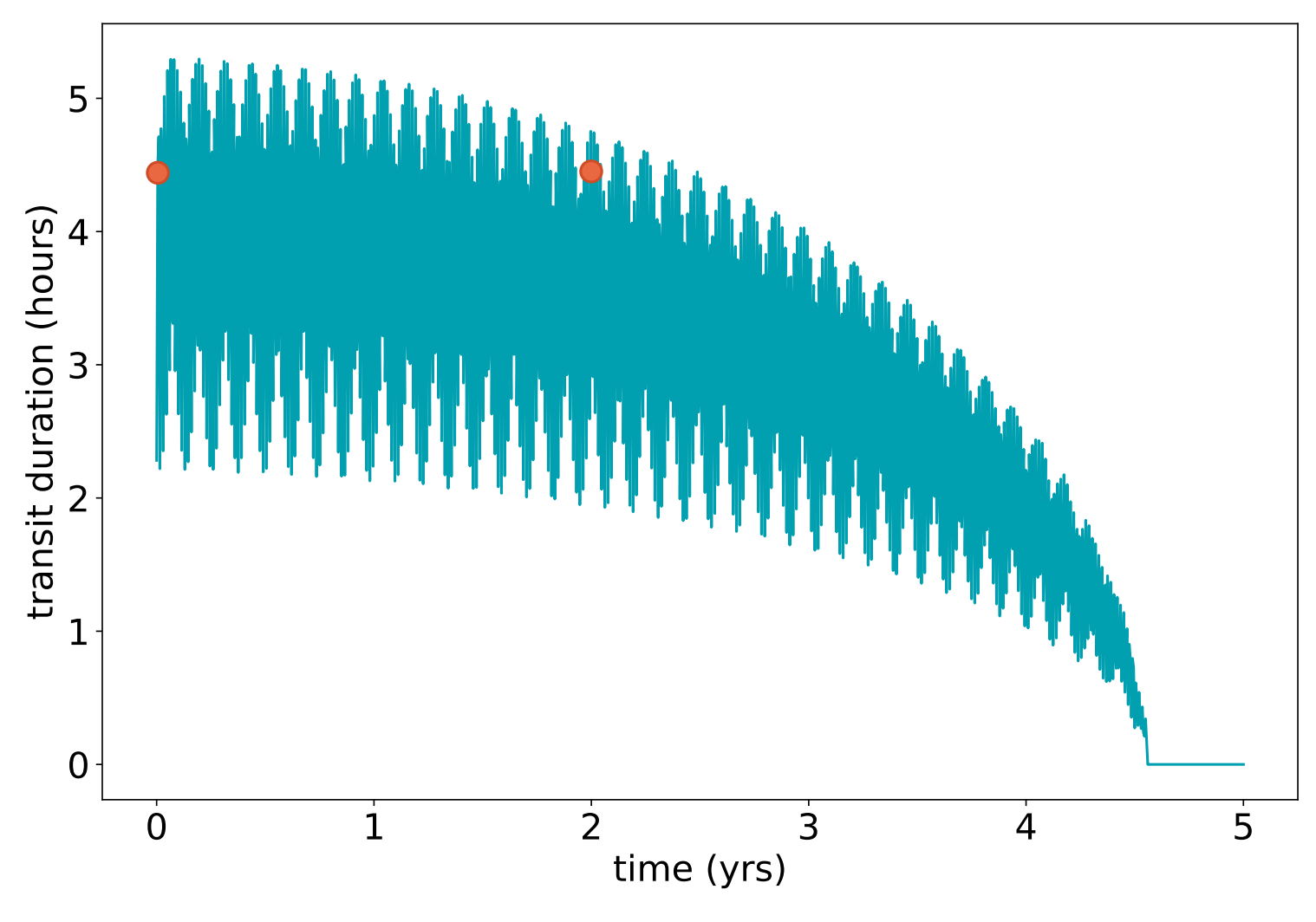

Figure 8. As the inclinations (and eccentricities) change, so too will the transit duration. Here we show the predicted transit duration for initial mutual inclination of 25 degrees (blue line). There is not yet strong evidence for transit duration variation (between Year 1 and Year 3), but the predicted variation grows in the coming years. The same is true for the eccentricity of TOI-682b.

References

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