

TESS Discovers A Short-Period Saturn-Mass Planet with an Inner Companion

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We discovered that the TOI-2000 system hosts a small planet ($2.7 R_E$, $8 M_E$) in a 3.10 day orbit interior to a hot Saturn-mass planet ($0.72 R_J$, $0.23 M_J$) in a 9.13 day orbit. We found this system through a systematic BLS search (see workflow on the right) for transiting inner companions to hot gas giants (impact parameter < 0.9) in TESS, Kepler, and K2 data.

Why study inner companions?

Studying the occurrence rate of hot gas giant inner companions informs us of the possible formation pathways for hot jupiters. Inner companions can only exist when the HJ did not undergo high eccentricity migration and instead formed in situ (Figure 1). To date, WASP-47e, Kepler-730c, and TOI-1130b have been the only such companions known. Quantifying this apparent scarcity is key to understanding the relative frequencies of these two pathways.

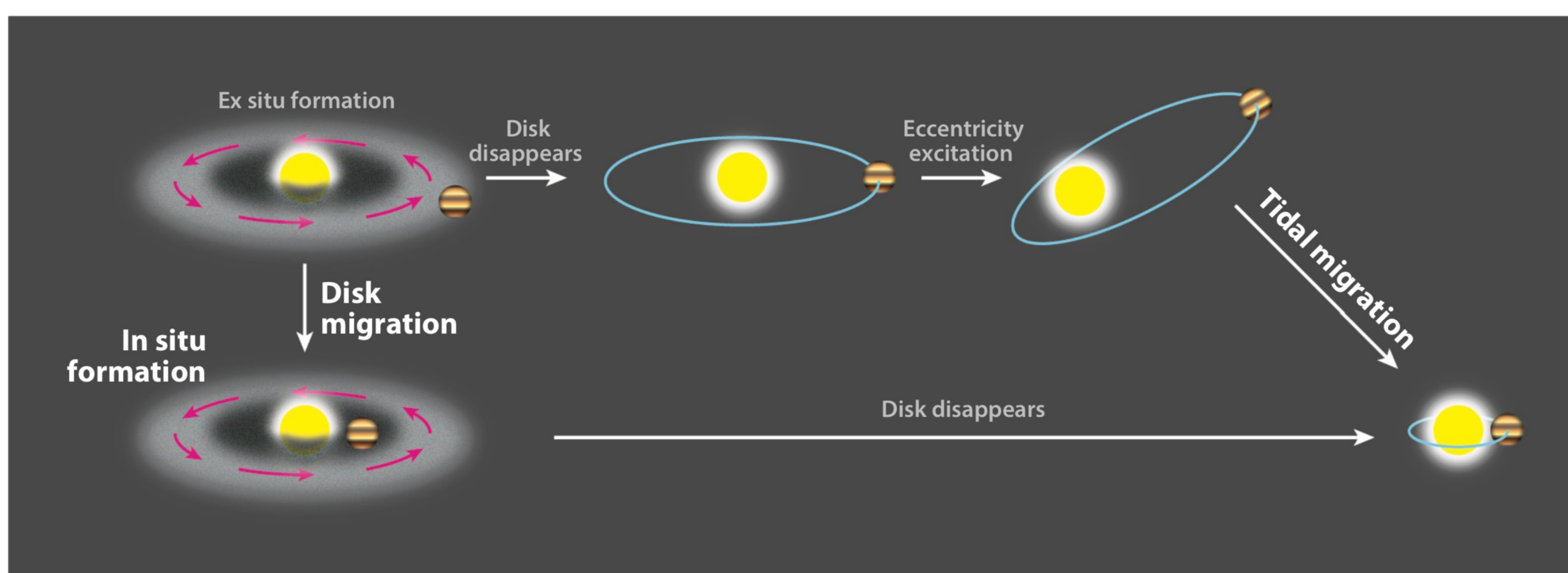


Figure 1. Hot Jupiter formation pathways (Dawson & Johnson 2018).

Completeness of inner companion detection

We performed a Monte Carlo simulation for each star, where planets of varying sizes, periods, and inclinations are generated and tested for our impact parameter and SNR criteria. The proportion of detectable planets is how much each star contributes to the total number of stars searched.

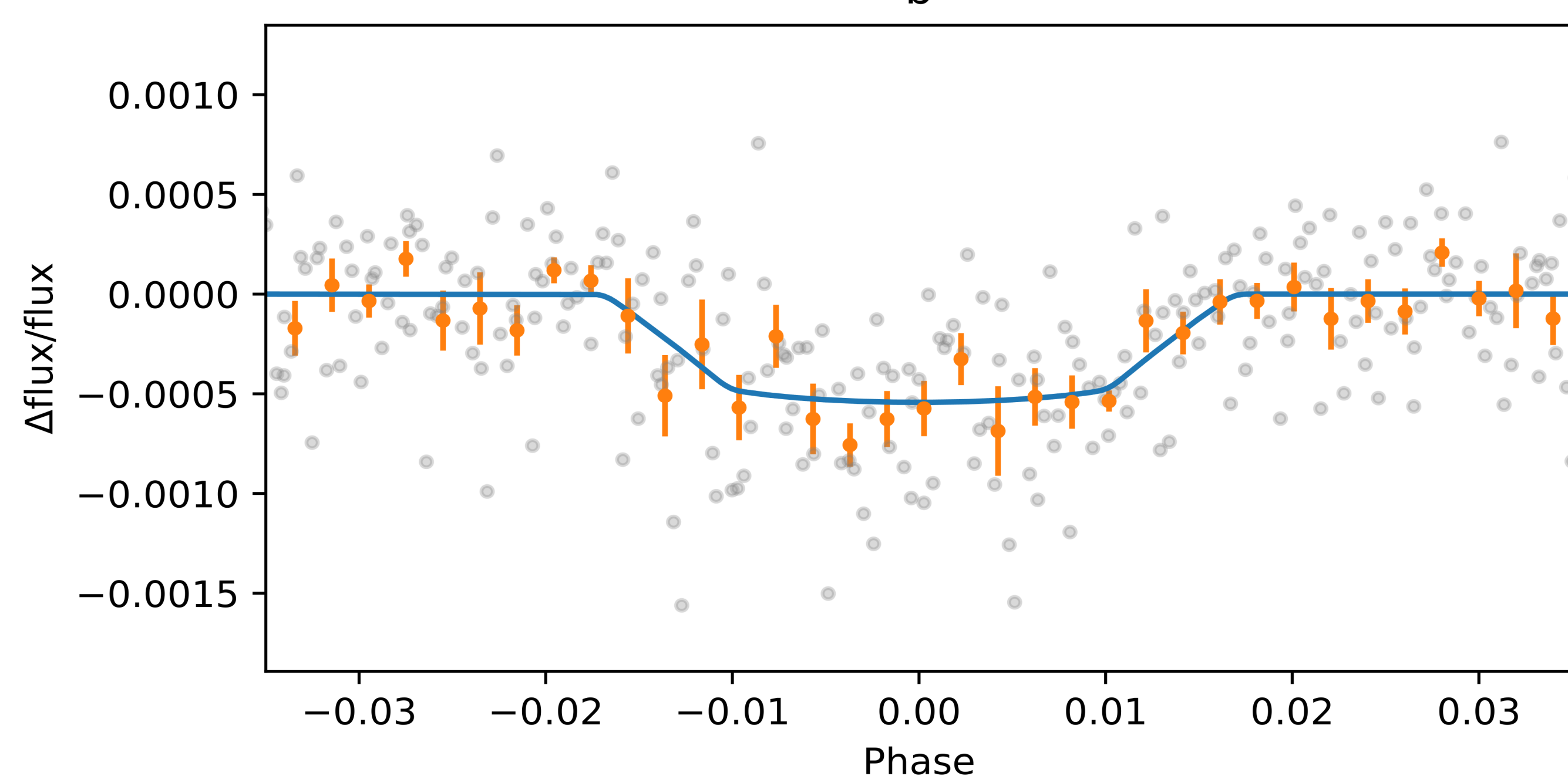
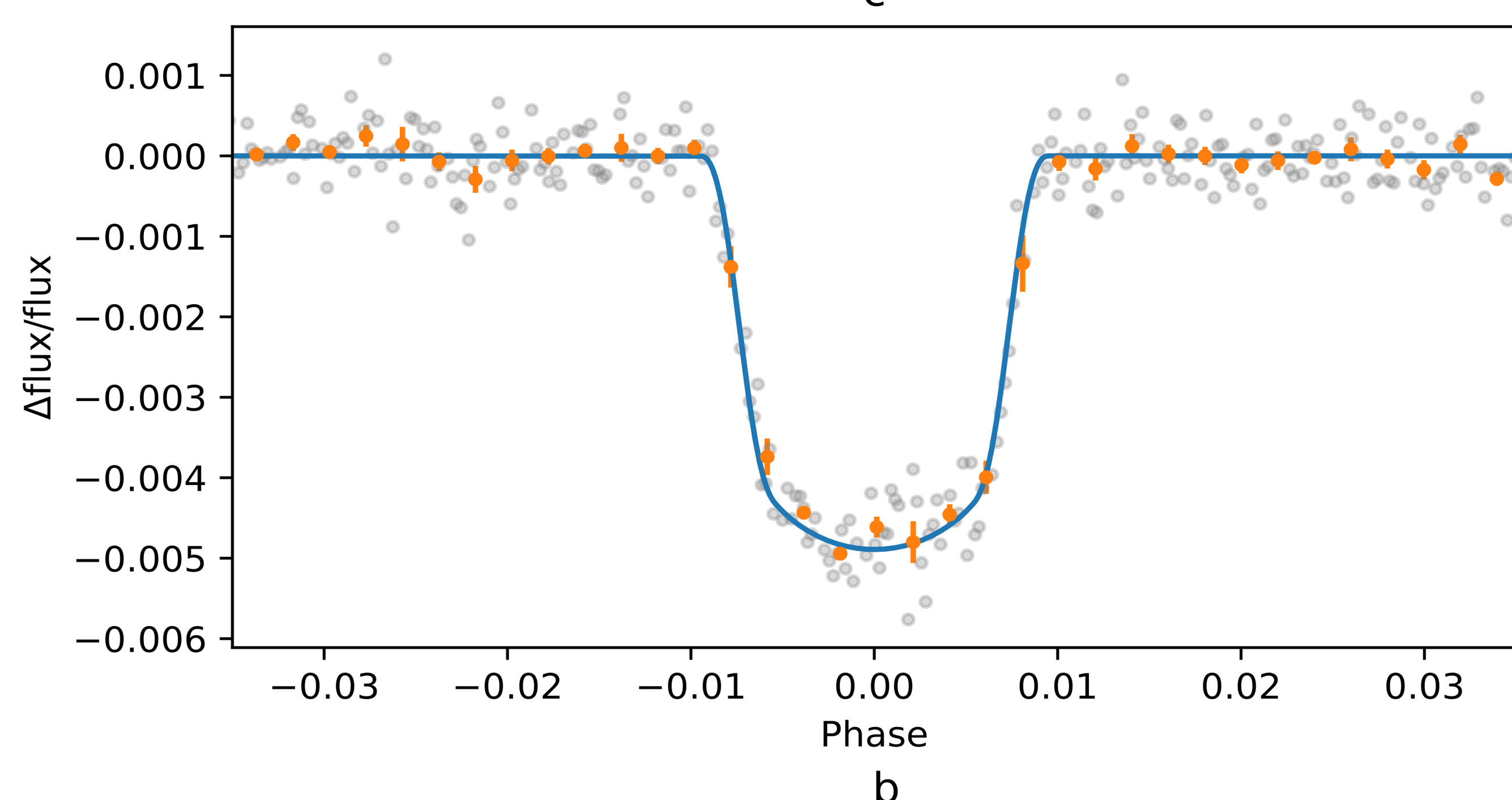


Figure 2. TESS light curve of TOI-2000, phase-folded for planets c and b.

Select *TESS*, *Kepler*, and *K2* hot jupiters

BLS search for inner companions

Vet TCEs manually

Calculate occurrence rate upper limit

Calculating the occurrence rate

Calculating the occurrence rate from the number of stars observed is mathematically equivalent to determining the fairness of coin tosses. We calculate the posterior distribution analytically, assuming a flat prior, and compare the results with TOI-2000 and other TESS HJ systems to those without. Note that TOI-1130 is not counted due to the high impact parameter of its HJ.

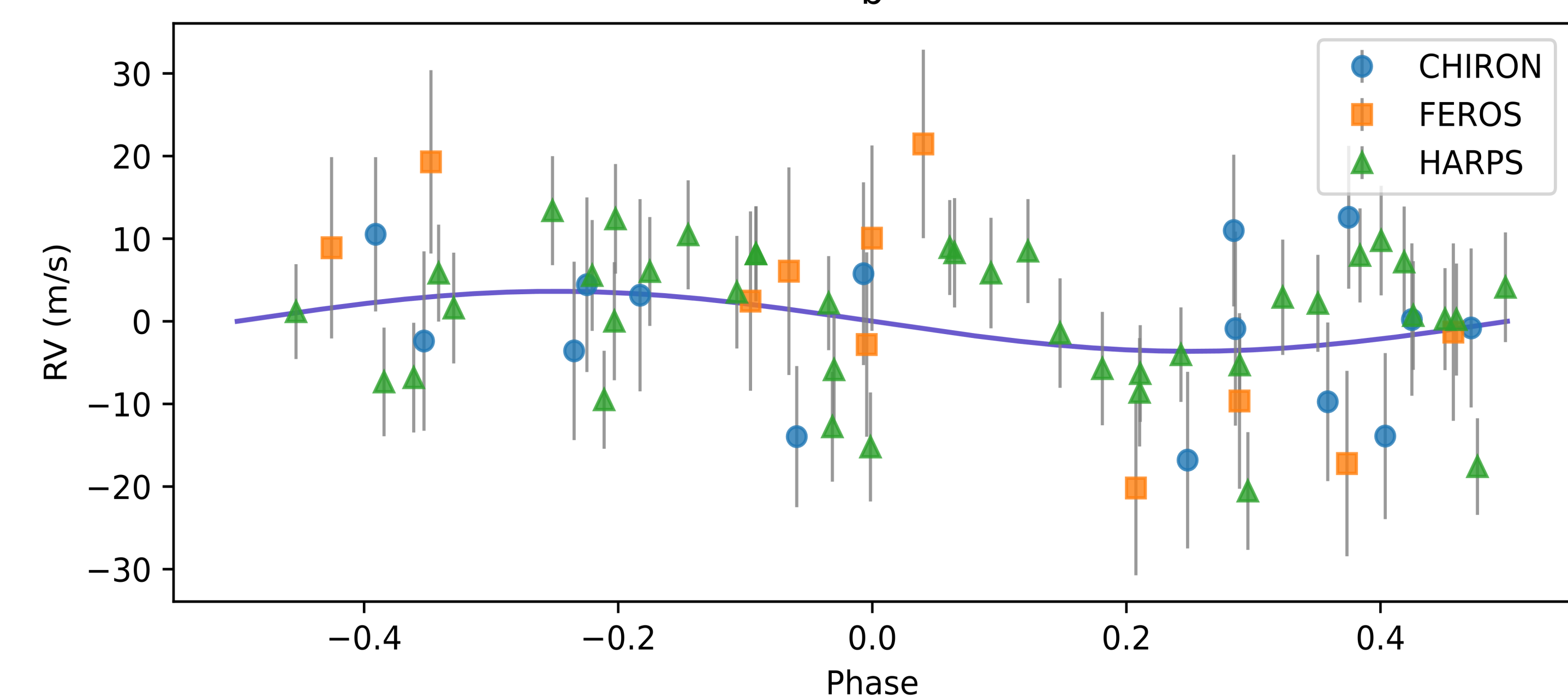
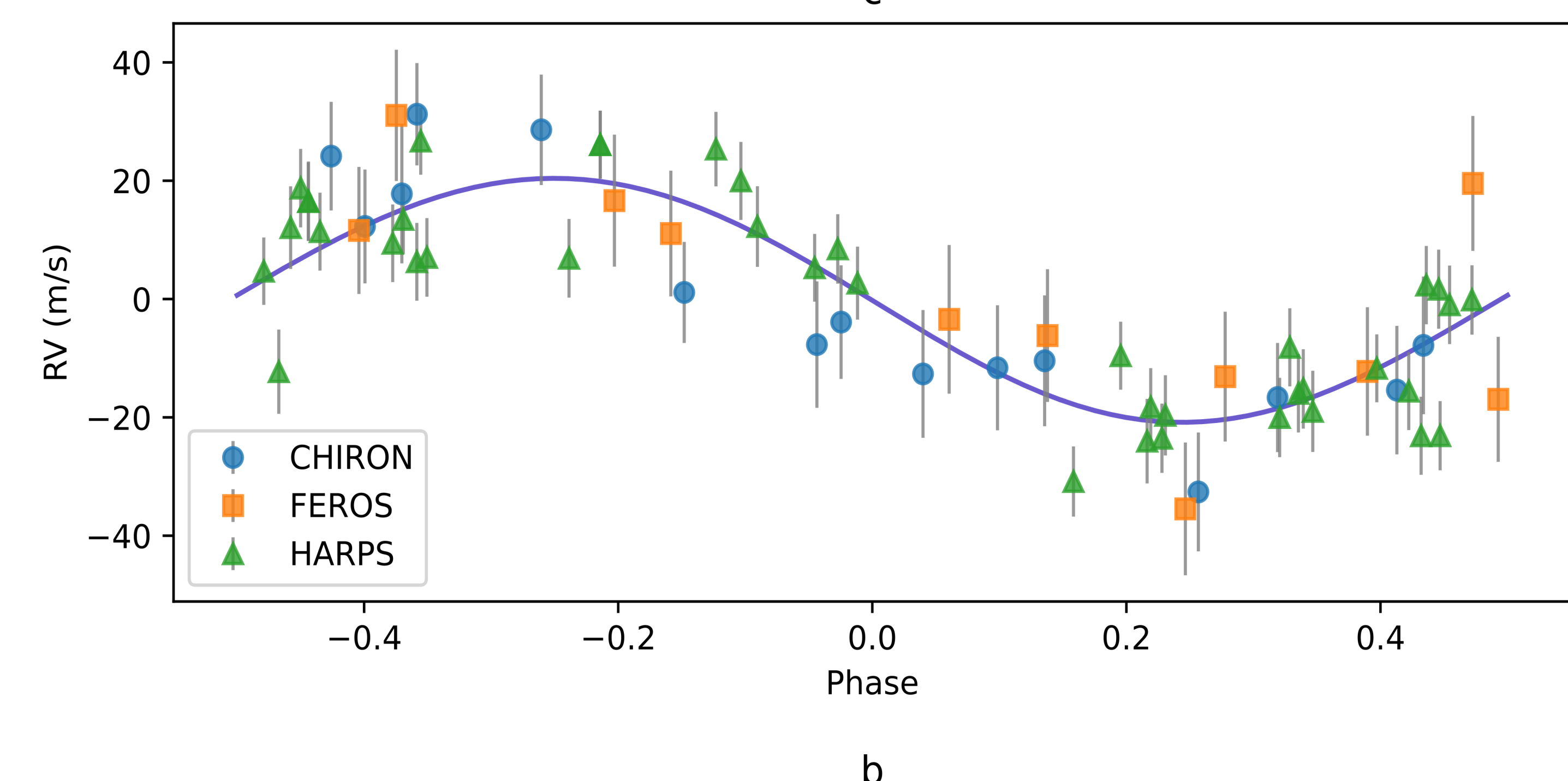
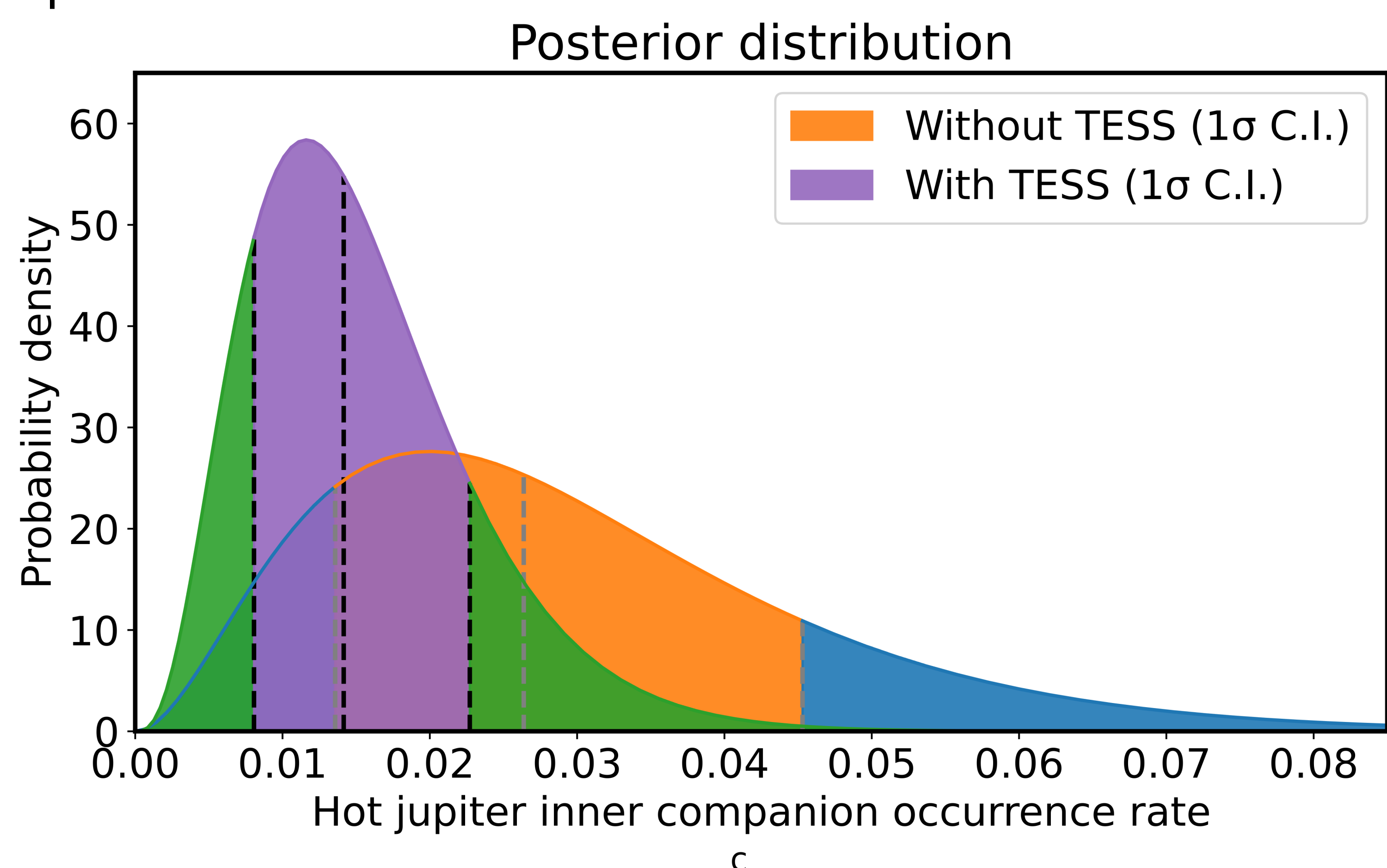


Figure 4. RVs of TOI-2000, phase-folded for planets c and b.