

Against the Planetary Interpretation of PTFO 8-8695b

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ABSTRACT

PTFO 8-8695b could be the youngest, shortest-period hot Jupiter known. However it has not been shown to be a planet. TESS recently observed PTFO 8-8695 for one month. The TESS light-curve shows that the dominant variability in this system is a sinusoidal modulation with a “long” period P_ℓ of 11.96 hours, likely caused by stellar rotation. Also present is a complex signal, previously identified as the planet candidate, that repeats with a “short” period P_s of 10.74 hours. The “long” and “short” signals show the expected beat every 4.48 days. There is a dip in the complex, short-period signal. However ground-based photometry from the past decade shows that the orbital phase of the dip seems to have instantaneously jumped, at least twice. The TESS epoch of the dip is consistent with recent observations by Tanimoto et al., and differs from the discovery epoch by 5.14 hours. Planets do not “jump” in orbital phase. PTFO 8-8695 therefore seems broadly consistent with the “transient dipping” phenomenology observed in many young M dwarfs, and seems unlikely to be a planet.

1. INTRODUCTION

If it were a planet, PTFO 8-8695b would be exceptional. A transiting hot Jupiter, orbiting a ≈ 3 Myr old M dwarf in ORION would make it the youngest hot Jupiter known. Its orbital period of only 12 HOURS would also make it the shortest period hot Jupiter known.

2. OBSERVATIONS

2.1. Blend considerations

The TESS pixels are $\approx 21''$ per side, and so we need to consider whether light from neighboring stars could affect the photometry. The scene is shown in Figure 3. The pixels used to measure the background level are indicated with an ‘X’ hatch, and the pixels used for the final light-curve are shown with the ‘/’ hatch.

The target star, PTFO 8-8605 (TIC 264461976), has a T -band magnitude of 14.0, and its position is shown with a star. The other (unlabeled) star inside the target aperture, TIC 264461979, has $T = 16.8$ and so cannot contribute a signal with relative amplitude 10%. The only neighbor that is sufficiently close and bright that its light might contaminate the target star is TIC 264461980, with $T = 14.8$, which we denote “Star A”. Star A is $23.6''$ NW of our target, and based on the magnitude difference could contribute up to 48% the flux of our target star, PTFO 8-8695.

Because PTFO 8-8695 has previously been identified to have periodicity consistent with our measurement of P_s , our

main concern regarding blending is the degree to which we can be certain that the long-period signal at P_ℓ also originates from PTFO 8-8695. We took two approaches towards determining the source of the long-period signal.

First, we examined the CDIPS full frame image light-curves of the target, which are available on MAST (Bouma et al. 2019). The maximal peak-to-peak beat amplitude is consistently $\approx 10\%$ across apertures of radii 1, 1.5, and 2.25 pixels. If Star A were the source of the long-period variability, we would expect the peak variability amplitude to be smallest in the 1 pixel aperture, based on the separation of the sources (Figure 3, bottom). From this test alone, it seems unlikely that Star A is the source of the long-period signal.

Second, we examined the light-curve of each pixel in the scene individually. We opted to use the interactive tools implemented in `lightcurve` (Lightcurve Collaboration et al. 2018). If Star A were the source of the long-period variability, we would expect the pixels nearest to Star A to show a sinusoidal signal with amplitude exceeding 10%. We find no evidence for this being the case. The pixel directly below Star A does not clearly show the sinusoidal variability, and the peak-to-peak variability in that pixel is $\lesssim 8\%$. In contrast, the south-easternmost pixel within PTFO 8-8695’s aperture (the pixel furthest from Star A that was used in the optimal aperture) shows the P_ℓ sinusoidal variability signal at $\approx 10\%$ amplitude.

As there is no evidence in favor of a blend scenario, we conclude that both the P_s and P_ℓ signals originate from PTFO 8-8695.

3. ANALYSIS

3.1. Visual Inspection

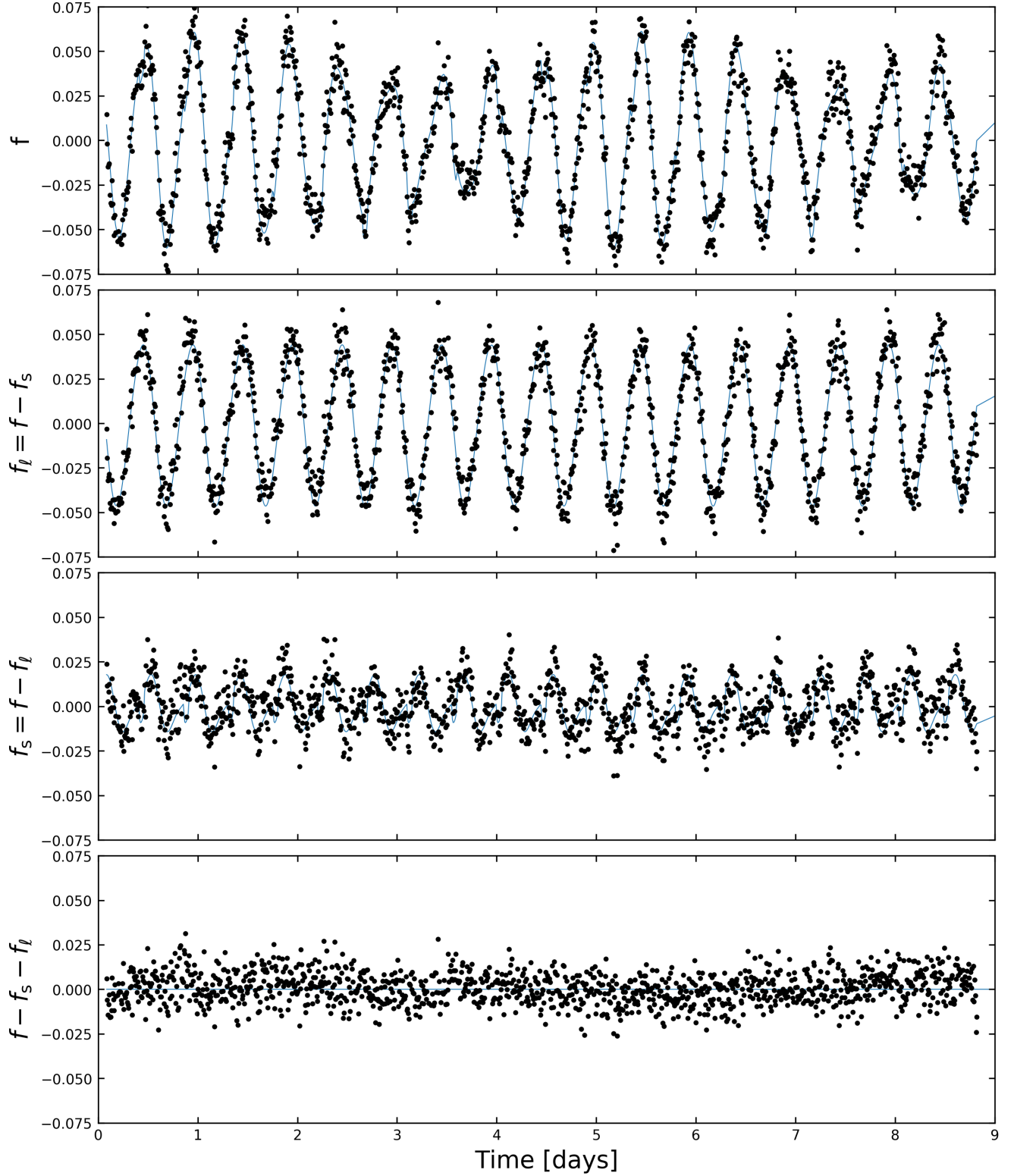


Figure 1. TESS light-curve of PTFO 8-8695 (Sector 6, Orbit 1). *Top:* “Raw” PDCSAP mean-subtracted relative flux versus time. The beat period of 4.48 days is visible by eye. The model plotted underneath the data includes 2 harmonics at the long period P_ℓ , plus 2 harmonics and a transit at the short period P_s . *Upper middle:* Long-period signal, equal to the raw signal minus the short-period signal. *Lower middle:* Short-period signal, equal to the raw signal minus the long-period signal. *Bottom:* residual. The data are binned from 2 to 10 minute cadence as a convenience for plotting and fitting.

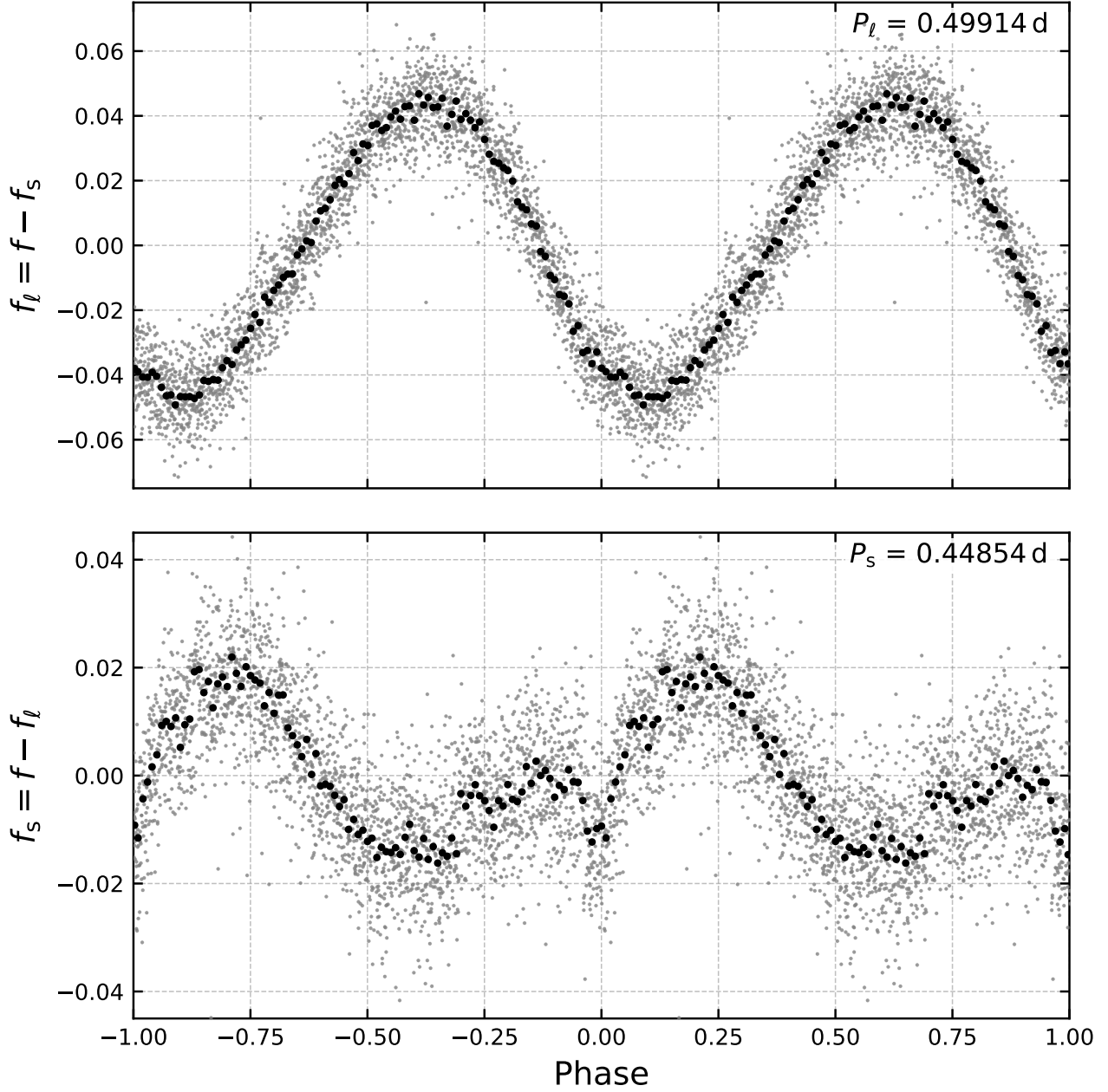


Figure 2. Phase-folded long and short-period signals. *Top:* Long-period signal, as in Figure 1. *Bottom:* Short-period signal. The reference phase is set to the most “planetary” dip. Gray points are the 10 minute cadence PDCSAP flux. Black points are binned to 100 points per period.

3.2. Model Fitting

4. DISCUSSION

5. CONCLUSIONS

Software: astrobases (Bhatti et al. 2018), astropy (Astropy Collaboration et al. 2018), astroquery (Ginsburg et al. 2018), corner (Foreman-Mackey 2016), emcee

(Foreman-Mackey et al. 2013), IPython (Pérez & Granger 2007), lightkurve (Lightkurve Collaboration et al. 2018), matplotlib (Hunter 2007), MESA (Paxton et al. 2011, 2013, 2015) numpy (Walt et al. 2011), pandas (McKinney 2010), radvel (Fulton et al. 2018), scipy (Jones et al. 2001).

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Bhatti, W., Bouma, L. G., & Wallace, J. 2018, *astrobases*, <https://doi.org/10.5281/zenodo.1469822>

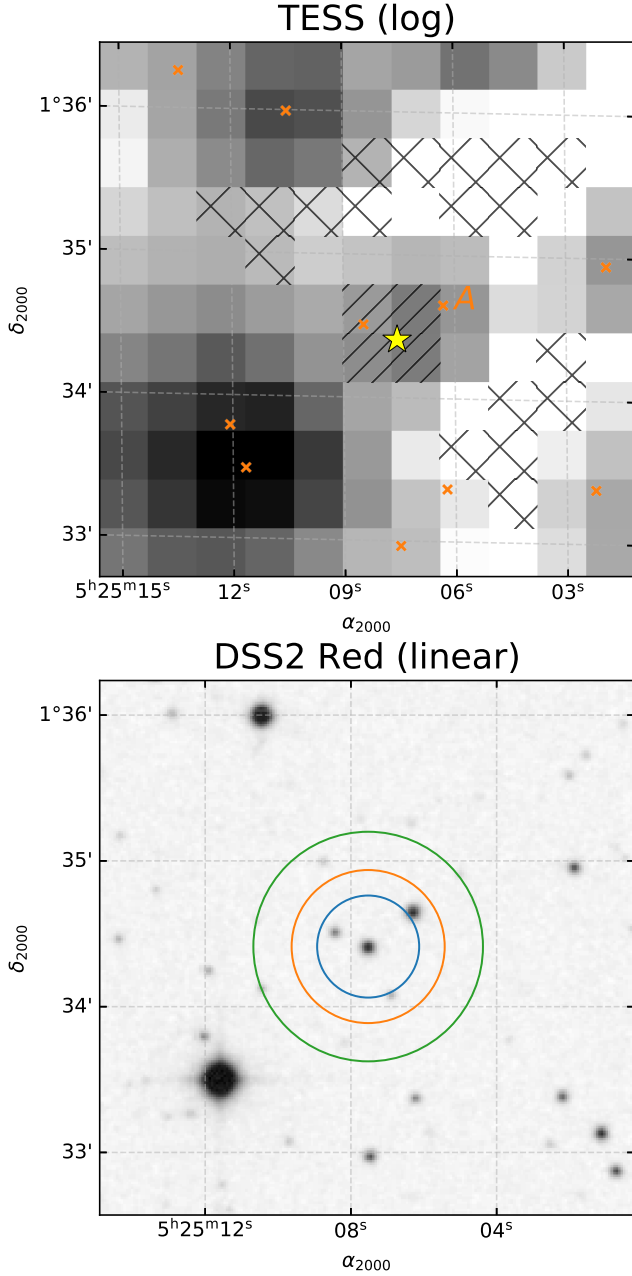


Figure 3. Scene used for blend analysis. *Top:* Mean TESS image of PTFO 8-8695 over Sector 6, with a log-stretch. The position of PTFO 8-8695 is shown with a yellow star. Neighbors with $T < 17$ are shown with red crosses. The apertures used to measure the background and target star flux are shown with \times and $/$ hatches, respectively. *Bottom:* DSS2 R -band image of the same field, with a linear stretch. The circles show apertures of radii 1, 1.5, and 2.25 pixels used in part of our blend analysis. The pixel level TESS data show that “Star A” does not contribute variability at either of the two observed periods (see Section 2.1).

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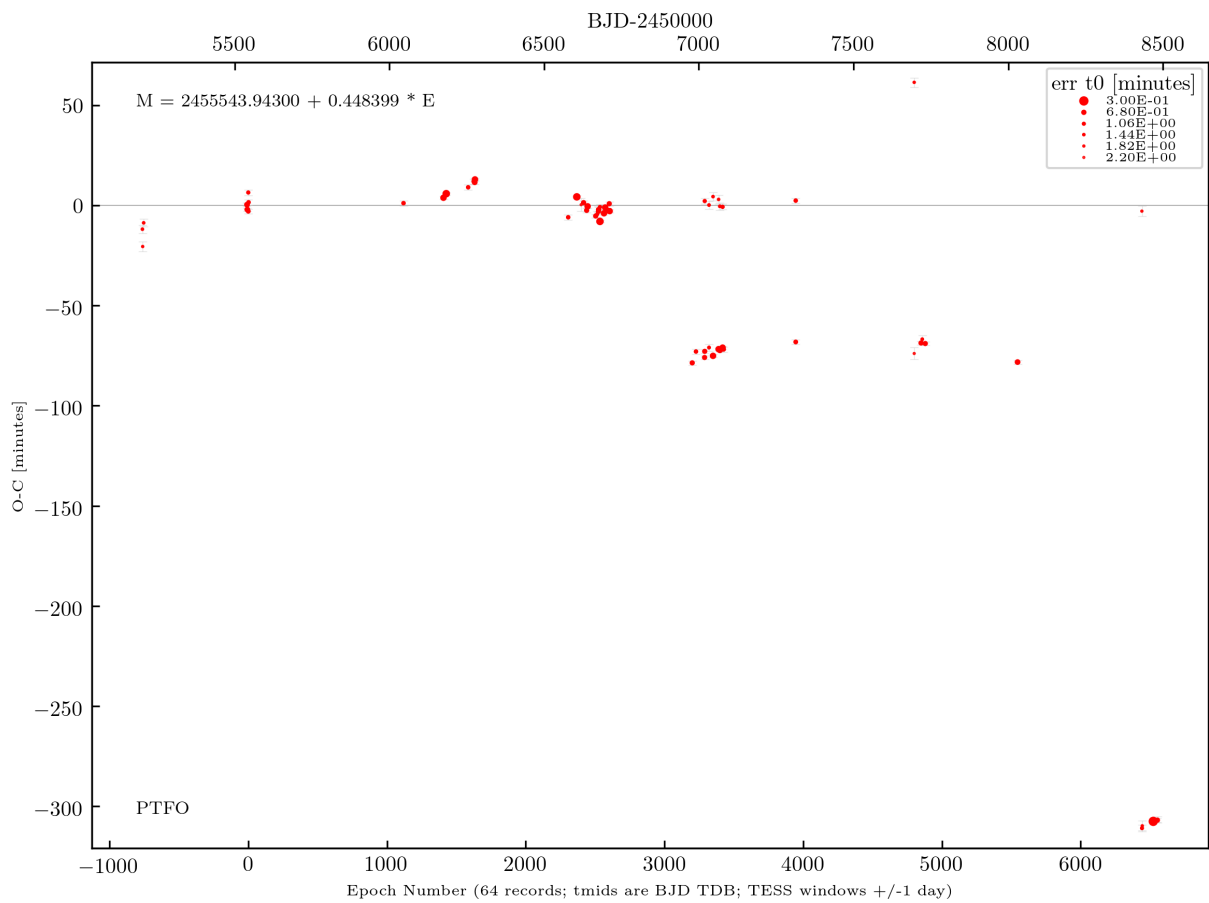


Figure 4. foo. bar

