Ultra-Short-period planets, with periods of less than two days, are skirting right on the edge of destruction. For ultra-hot Jupiters (UHJs), the strongest challenge comes from tides: the closer these massive planets get to their stars, the faster the rate of orbital decay, and the eventual fate of some is to spiral into their stars. Tentative evidence for tidal disruption comes from the distribution of short-period orbits and the metallicities of stars hosting what may be the remnants of tidally disrupted gas giants. However, more direct evidence comes from long-baseline observations of short-period planets that may be undergoing orbital decay. Such is thought to be the case for WASP-12b (P=1.09 d), whose orbital period seems to be decreasing (Patra et al., 2017). Not surprisingly, planets that may be inspiraling are intrinsically rare, and there are also not many ultra-hot Jupiters known around bright stars that are easy to monitor from the ground over the decade+ that is required to determine the rate of orbital decay. TESS has already provided dozens of candidates ultra-hot Jupiters, many bright, that are good candidates for observing tidal effects. Unfortunately, ultra-hot Jupiters are accompanied by a high rate of false positives. We demonstrate a heuristic method solely on TESS photometry that can significantly improve planetary recovery for these massive, tidally-challenged planets, and demonstrate using WASP-18 b, (TESS 100100827, P = 0.94 d), showing how modeling the out-of-transit phase curve variability can be used to efficiently separate eclipsing binaries from ultra-hot Jupiters.

We have fit 110 candidate TOIs with P<2 days for phase variability. Our goal is to develop a heuristic test based on the values for $A_{\text{ellip}}$, $A_{\text{beam}}$ and $A_{\text{refl}}$ that can triage ultra-hot Jupiter candidates into three groups:

A: Promising candidates
B: Likely false positives
C: Everything else

Top: Full phase light curve. Bottom: phase variability from all components, with central transit remove. Model is plotted in red.

Good candidate traits:
- $q_{\text{beam}}$ x 10$^3$ and $q_{\text{ellip}}$ x 10$^4$ within order of magnitude of 1 (i.e., mass ratio is 10$^{-4}$, similar to Jupiter and the Sun)
- $A_{\text{refl}}$ positive, less than expected max
- $A_{\text{ellip}}$ and $A_{\text{beam}}$ positive

Figure 3. TIC 100100827, good candidate for followup. $A_{\text{refl}}$ is within expected range, and both mass ratios are consistent with planetary. This is WASP-18 b ($R_\text{p}$=13.6 $R_\text{J}$, $P$=0.94 d).

Figure 3. TIC 1129033, good candidate for followup. $A_{\text{refl}}$ is negative, but mass ratios are both consistent with planetary. This is WASP-77 A b ($R_\text{p}$=13.6 $R_\text{J}$, $P$=1.36 d).

How these plots were made
1. All TOIs with P<2 days and values for $P$, $R_\text{p}$, $M_\text{p}$, and $R_\text{p}$/$R_\star$ as of June 21, 2019 (110 objects) on the TESS ExoFOP (https://exofop.ipac.caltech.edu/tess/).
2. We used lightkurve (http://ascl.net/1812.013) to obtain the TESS target pixel files for each sector each target was observed.
3. For each target pixel file, we used the mission pipeline’s optimal aperture mask to create the light curve (https://docs-ascl.net/lightkurve/api/lightkurve.targetpixelfile.TessTargetPixelFile.html#lightkurve.targetpixelfile.TessTargetPixelFile.pipeline_mask).
4. Detrended light curve using 2nd-order Savitzky-Golay (i.e., polynomial fit to each point) filter with window size equal to 4 orbital periods for each target.
5. Dropped outliers (20 sigma).
6. Folded all sectors’ light curves onto the orbital period and bin 10 points at a time, using the bin median as the datum; per-point uncertainties initially estimated as median absolute deviation, with subsequent $\chi^2$ re-scaling after model fit.
7. Using binned data, fit Mandel-Agol transit model without limb-darkening using Levenberg-Marquardt to confirm the reported timing. (We did not check for transit-timing variations.)
8. Fit sinusoidal model for the reflection, beaming, and ellipsoidal components, rescaling parameter uncertainties by square root of resulting $\chi^2$ (Fig 5b, right, from Jackson et al. 2012, shows the different components)
9. Estimated the expected reflected component using the $A_{\text{ellip}}$ 1. We did not use the other scalings (Eqs. 2 and 3) to the estimate beaming and ellipsoidal signals, but we DID use them to convert the observed signals into a mass ratio, assuming the stellar parameters supplied by the table from the TESS ExoFOP.

References: