STOKED with TESS

I. Empirical limb-darkening coefficients & transit parameters of known exoplanets with TESS

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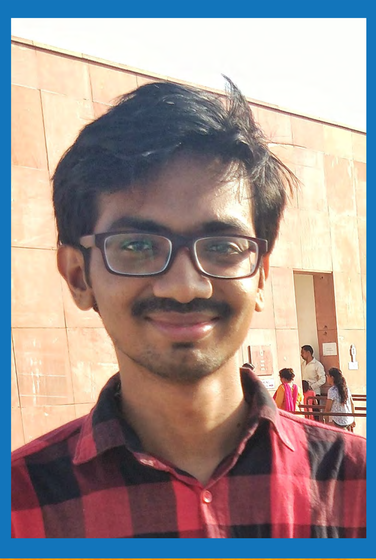

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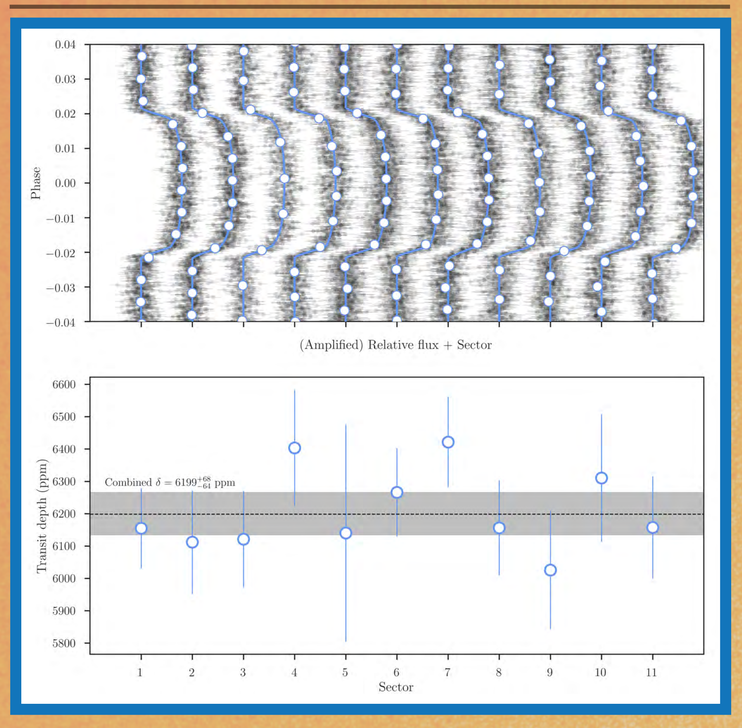
1. What is STOKED with TESS?

The **ST**udy **O**f **K**nown **E**xoplanet re-**D**iscoveries (STOKED) with TESS is a project aimed at the study of known transiting exoplanets observed by TESS. The project aims to perform a systematic study of known exoplanets observed by the mission in order to **extract and interpret stellar and planetary atmospheric and bulk properties**, along with **updated ephemerides** for the systems. The project is being led by Nestor Espinoza (MPIA) & Max Guenther (MIT).

Figure 1. Example transit light-curve fits (top) for WASP-126b, which was observed in the first 11 TESS sectors. The retrieved transit depths for each sector (bottom) match very well between sectors, providing a very precise combined depth.



2. What's with limb-darkening and TESS?

Suppose you had to fit a transit lightcurve from TESS: **how would you treat limb-darkening?** Typically one parametrizes the effect through so-called limb-darkening "*laws*", with the quadratic law (parametrized via two coefficients, u_1 and u_2) being the most popular. Here you have to options: you either believe stellar model atmospheres and fix the coefficients to theoretical predictions or you fit those parameters directly along with the other transit parameters (see, e.g., Cizmadia et al., 2013; Espinoza & Jordan, 2015, 2016). **Here fitted the limb-darkening coefficients for 70+ known exoplanetary systems observed by TESS and compared them to theoretical predictions** obtained from **ATLAS** and **PHOENIX** model atmospheres. The results for the most precise data in our sample (for exoplanets that have data for multiple sectors) are already very interesting:

Figure 2. Limb-darkening coefficients obtained form transit lightcurve fits to WASP-126b (see Figure1) for different sectors. This showcases the repeatability of the limb-darkening coefficients across sectors.

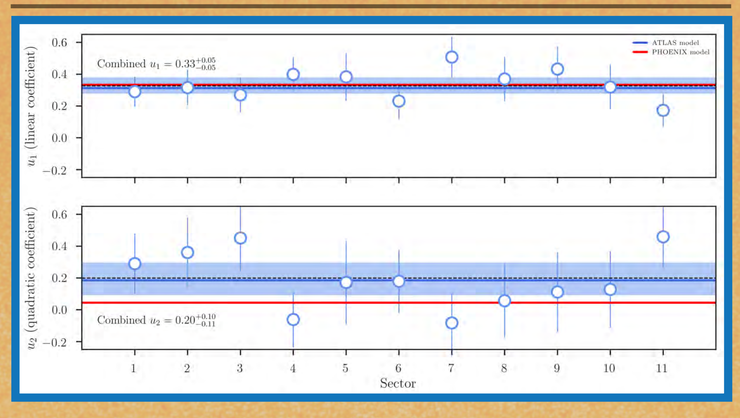
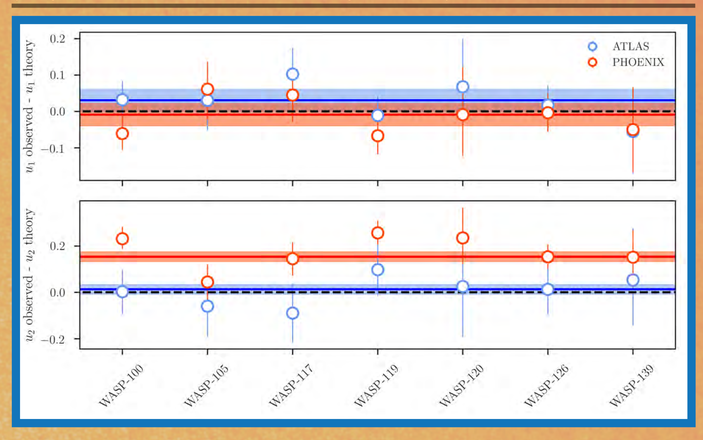


Figure 3. Difference between observed and theoretical limb-darkening coefficients obtained for the most precise datasets in our sample (exoplanets with observations in multiple sectors).

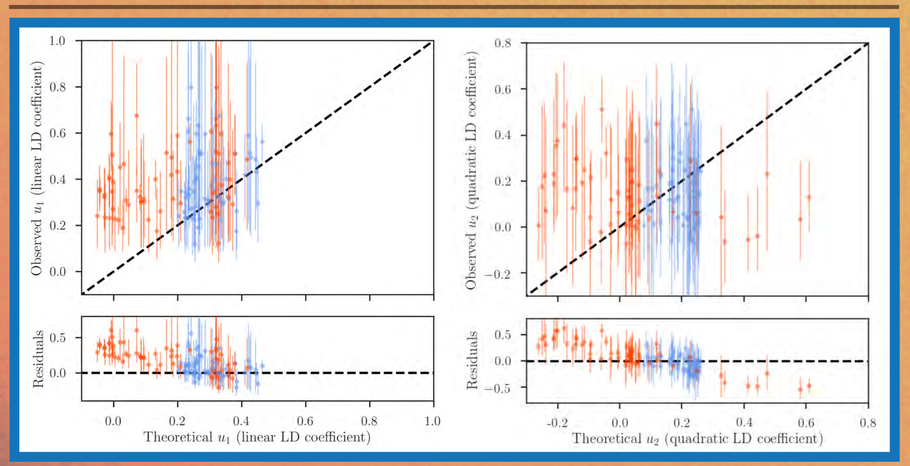


Empirical **limb-darkening coefficients are consistent between sectors for exoplanets observed in multiple sectors** (see e.g., WASP-126b in Figure 2). Results for a handful of the most precisesely characterized systems in this work (which are targets with multi-sector data) already show an **offset between theoretical and observed limb-darkening coefficients at least for PHOENIX model atmospheres** (Figure 3).

3. Results for the 70+ analyzed systems?

Observed TESS limb-darkening coefficients are **not well predicted by PHOENIX models** (Claret 2017, below). **Offsets exist, but are smaller for ATLAS models** (Claret 2017, below).

Figure 4. Comparison between observed, empirical limb-darkening coefficients and theoretical ones for the 70+ analyzed systems in this work (blue, **ATLAS** models; red, **PHOENIX** models).



4. What magic did you use to fit these TESS lightcurves?

Glad that you asked! We used ***juliet*** (Espinoza et al., 2018).This allowed us to take systematics present in TESS data into account in the errorbars of our retrieved transit parameters, as Gaussian Processes were simultaneously fit to the transit lightcurves along with the transit model. **To check out the code, use the QR code below or check the project's Github (http://www.github.com/nespinoza/juliet)!**

Joint analysis of exoplanetary transits & RVs

Juliet

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References
Cizmadia et al., 2013, A&A, 549, A9; Claret, 2017, A&A, 600, A30; Espinoza & Jordan, 2015, MNRAS, 450, 1879; Espinoza & Jordan, 2016, MNRAS, 457, 3573; Espinoza et al., 2018, arXiv e-print:1812.08549.