PROBING THE ORBITAL DYNAMICS AND ATMOSPHERIC PROPERTIES OF THE TRAPPIST-1 PLANETS WITH JWST.

R. Luger[1,2,3], J. Lustig-Yaeger[1,2,3] and E. Agol[1,2,3], [1]Astronomy Department, University of Washington, Box 951580, Seattle, WA 98195, USA, [2]Astrobiology Program, University of Washington, Box 351580, Seattle, WA 98195, USA, [3]NASA Astrobiology Institute – Virtual Planetary Laboratory Lead Team, USA.

Introduction: The TRAPPIST-1 system hosts seven transiting terrestrial-size planets in orbits with periods under 20 days [1, 2]. At a distance of only 12 pc, these planets are ideal candidates for transmission and secondary eclipse spectroscopy follow-up with the James Webb Space Telescope (JWST), particularly because three of the planets lie within the star's habitable zone. While these observations will yield valuable information about these planets' atmospheres, the proximity of the system and the compactness of its planetary orbits opens a door to a novel characterization technique that has not previously been possible for exoplanetary systems: the detection of planet-planet occultations (PPOs). During a PPO, a planet is occulted by another planet in the same system, resulting in a slight dimming of the total flux received at Earth [3]. Although analogous to a transit, the signal from a PPO is typically orders of magnitude weaker because of the large star/planet contrast. However, in extremely coplanar systems such as TRAPPIST-1, PPO depths are comparable to secondary eclipse depths and should therefore be observable.

Methods: We develop a general photodynamical model for predicting and computing PPOs and apply it to the TRAPPIST-1 system. We first estimate the probability of PPOs in this system based on estimates of the system parameters, including the coplanarity of the planets, which we show are aligned to < 0.3° at 90% confidence. We predict the probability of events as a function of the phases, durations, and impact parameters for pairs of planets. We further develop a fast integration scheme to compute PPO light curves under different assumptions about the planets' atmospheres.

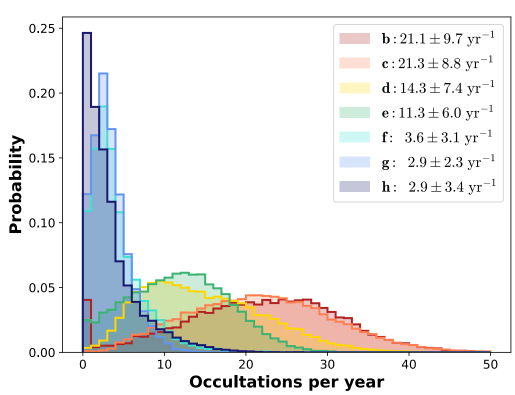

Figure 1 Number of potentially observable planet-planet occultations for each of the TRAPPIST-1 planets in one year. Planets b and c undergo ~20 significant occultations per (Earth) year.

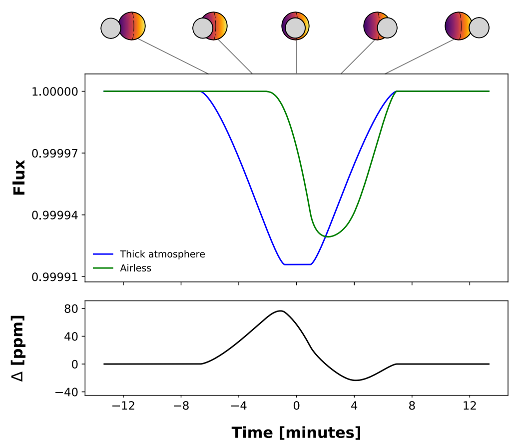

Figure 2 Occultation of c by d, assuming an atmosphere with strong recirculation (blue) and one with negligible recirculation to the nightside (green). The asymmetry in the latter case is a powerful diagnostic of the day/night temperature contrast of the inner TRAPPIST-1 planets.

Results: Marginalizing over all current uncertainties on the orbital parameters of the TRAPPIST-1 planets, we find that of order one PPO should occur per (Earth) day, while 80 PPOs should occur per year with the potential for detection (Figure 1). We find that dynamical analysis of the timing of these PPOs can be used to strongly constrain the planet eccentricities and masses and to break TTV degeneracies. We also show how PPOs can be used to constrain a planet's day-night temperature contrast (Figure 2) and construct crude surface maps. Finally, we investigate the prospects for detection of PPOs in TRAPPIST-1 with JWST, which looks promising if several events can be be observed and stacked at 12-15 µm. The proposed Origins Space Telescope shows even better promise at longer wavelengths.

References: [1] Gillon, M. et al. (2017) *Nature, 542,* 456. [2] Luger, R. et al. (2017) *Nature Astronomy, 1,* 0129. [3] Ragozzine, D. and Holman, M. (2010) *Arxiv e-prints*.