The First Year of M Dwarf Exoplanets Discovered by TESS

William Waalkes[1], Zachory Berta-Thompson[1], Jessica Roberts[1], and Karen Collins[2]
[1]University of Colorado Boulder, [2]Harvard-Smithsonian Center for Astrophysics

Photometric Followup with the Las Cumbres Observatory (LCO)

The Las Cumbres Observatory is a global network of telescopes with sites throughout the northern and southern hemispheres. **We have been using the 1-m telescopes with the Sinistro camera to perform ground-based photometric followup of M dwarf TESS objects of interest (TOIs).**

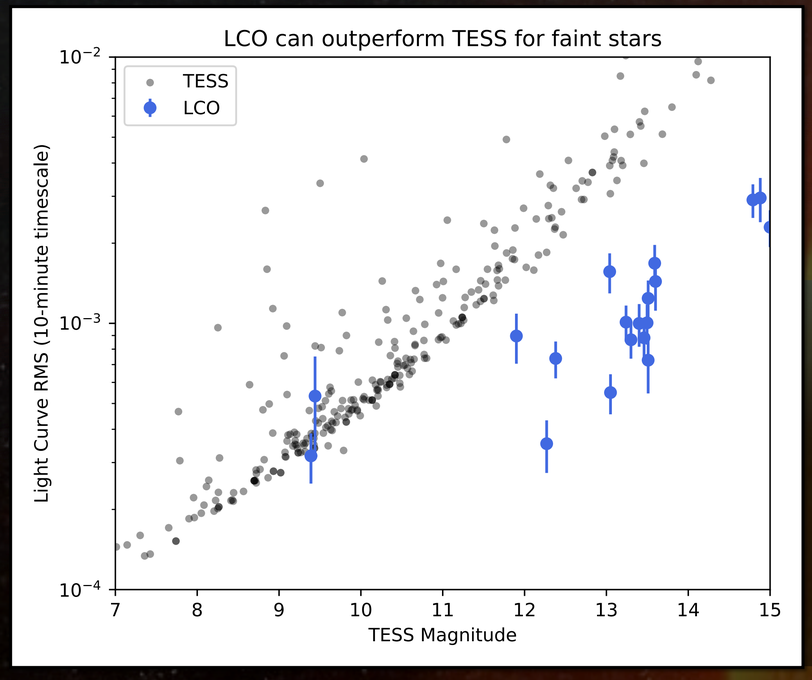

Figure 1: For Tmag > 10, LCO outperforms TESS for single transit detections. LCO has been a valuable resource in the ground-based followup of TESS planet candidates. RMS calculations were done with 10-minute binning of the light curves.

To date, we have acquired LCO data on 23 separate TOIs. Of these, we ruled out 3 as eclipsing binaries and 1 as a non-planet candidate. 15 of our targets have resulted in transit detections, which make up the sample of blue points in Fig. 3. **Our observations have helped validate 13 planets, including LHS 3844b[1] and the LP 791-18 system[2]**. Below are two examples of light curves from LCO data, shown with the TESS light curves on the left**. These two planets are TOI 237.01 and TOI 122.01 (Waalkes et al., in prep), two super-Earths on ~5 day orbits around .21 R_s and .33 R_s M dwarfs, with insolations of 3 I_E and 8 I_E, respectively.**

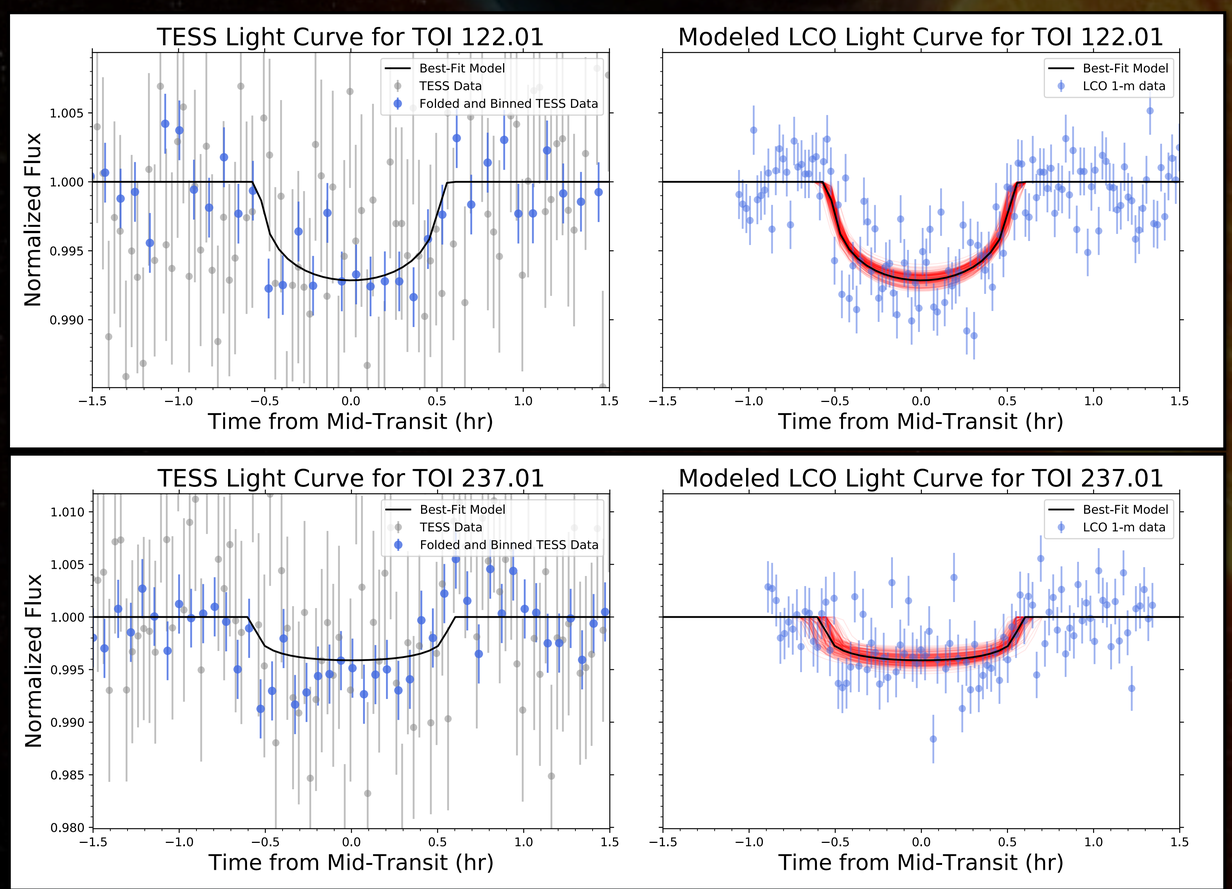

Figure 2: Light Curves for two temperate super-Earths, TOI 122.01 and TOI 237.01. The left panels show the PDCSAP TESS light curves with phase-folded and binned light curves overplotted. The right panels are LCO light curves with a best-fit model (black) and random MCMC sample models (red). Light curve modeling was done with the use of emcee[3] and BATMAN[4]. Photometry was performed with AstroImageJ[5].

TESS Planet Populations

There are now 800+ TESS Objects of interest, including false positives and fully validated systems**. We defined a subsample of TOIs to be M dwarf planet candidates if the stellar T_{eff} < 4000 K or R_s < 0.5 R_{sun}. We have scheduled LCO observations for this M dwarf sample, in search of low-insolation terrestrial planets**. The following plots show the total population of TOIs compared with our M dwarf sample and the sub-sample of systems for which we have transit observations.

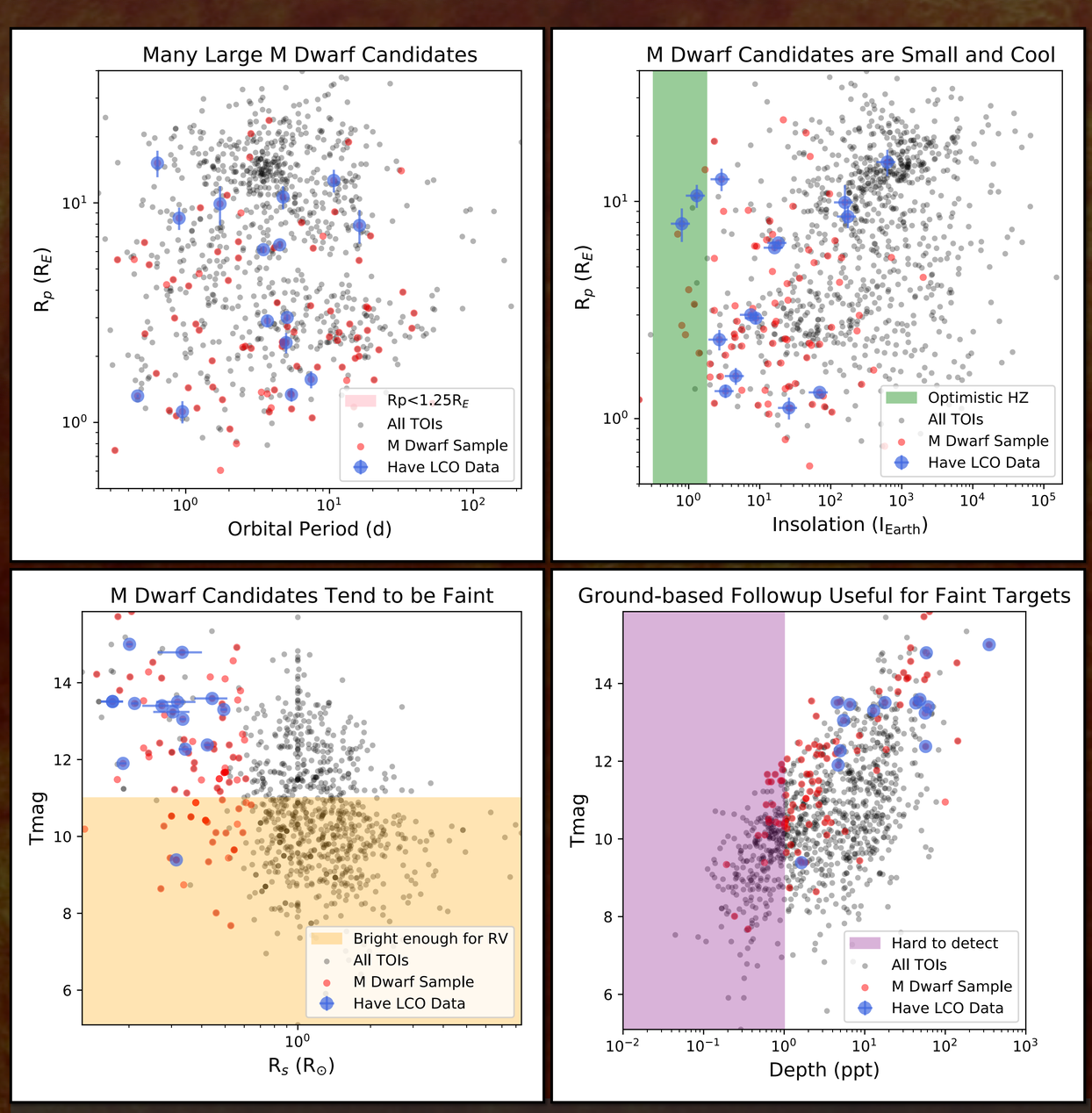

Figure 3: Population plots for all TOIs (gray), M dwarf TOIs (red), and the sub-sample of M dwarf TOIs for which we have acquired transit photometry with LCO (blue)**. Top Left:** M dwarf candidates have been found to have a large spread in radii**. Top Right:** We can see that planets orbiting M dwarfs occupy much of the low-insolation and small radius space. **Bottom Left**: The number of M dwarf TOIs drops off sharply at low magnitudes. **Bottom right:** Many of the small terrestrial planet candidates around M dwarfs have depths < 1ppt, which are very difficult to detect with meter-class ground based telescopes. The viable data we have been able to collect is clustered around dimmer stars with deeper transit depths. **Based on the TOI population, we can see that TESS followup is filling in interesting phase space for small, cool planets around small, dim stars.**

Comparison With Predictions

Overall Prediction	M Dwarf Sample
2 or more planets around 20% of stars[6]	12%
41 Earth-sized worlds (<1.25$R_\oplus$)[7]	13
46 planets within 50 pc[7]	38
69 planets with 0.32 $I_\oplus$ I <1.78 $I_\oplus$[7]	9

Table 1: Predictions of the overall TESS yield and planet distribution. It is worth noting that all predicted planets in the optimistic habitable zone orbit M dwarfs.

Of the various predictions for the TESS yield, we have decided to point out how the current statistics of the M dwarf sample compare to a few interesting metrics. For multiplicity, size, and proximity, the M dwarf sample is so far approaching expectations. However, there are far fewer low-insolation planets than we might expect to have found in the first year.

Citations: (1) Vanderspek+ 2018, (2) Crossfield+ (submitted), (3) Foreman-Mackey+ 2013, (4) Kreidberg 2015, (5) Collins+ 2017, (6) Ballard 2018, (7) Barclay+ 2018
Background Image: M Weiss/CfA

Questions? Feel free to find me at the conference or you can email me at:
William.waalkes@colorado.edu
Twitter - @astrowillwaal

NSF