<u>Preparing for TESS Planets in the Habitable Zone:</u>

Calibrating the Mass–Radius–Temperature–Metallicity Relationship for Late M dwarfs

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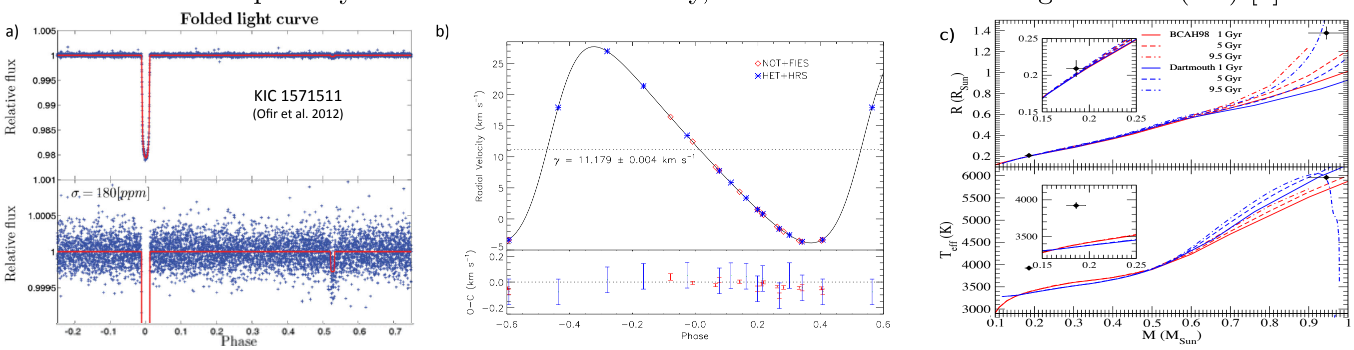
The goal of NASA's exoplanet mission TESS (launch 2017) is to detect transiting planets around bright dwarf stars. Due to the satellite's orbit, it will only be able to find potentially *habitable worlds* around the lowest mass M dwarfs ($M_\star \leq 0.2 M_\odot$). To fully understand these planets, it is paramount to accurately characterize their hosts (i.e., determine $M_\star$, $R_\star$, $T_{\rm eff}$, and [Fe/H]). The mass of a host star, which directly determines the planet mass, is typically derived by comparing measurable star properties (e.g., colors, $T_{\rm eff}$, L) to evolutionary models [e.g.,1] and/or empirical relationships [e.g.,2]. Our existing knowledge of the fundamental properties of low mass stars, necessary to calibrate these relationships, has primarily come from two types of systems: nearby, single stars with radii measured by interferometry [3] and M+M dwarf eclipsing binaries (EBs) [4]. Although M dwarfs compose most of the stars in our Galaxy, the relationships between their $M_\star$, $R_\star$, $T_{\rm eff}$, and [Fe/H] are not yet fully calibrated—particularly at the lowest mass. Our incomplete knowledge of M dwarf properties comes partially from the inherent deficiencies in these techniques. In particular, single interferrometric systems allow for measuring $T_{\rm eff}$, [Fe/H], and $R_\star$, but not $M_\star$ and M+M EBs provide direct measurements of $M_\star$ and $R_\star$ for both components, and their relative $T_{\rm eff}$s, but individual $T_{\rm eff}$ and [Fe/H] are difficult to derive from the complex spectra of two unresolved M dwarfs. In addition, very late M dwarfs for which these analyses can be done are extremely rare. For example, there are only 13 measurements of $M_\star$ and $R_\star$ of very late M dwarfs in the literature and of those, only 6 have $T_{\rm eff}$ [e.g.,6]. To address these defiencies, we have begun to use unequal mass ratio EBs to derive the properties of very late M dwarfs, [e.g.,5-7], hereafter EBLMs. EBLMs allow the spectroscopic derivation of $T_{\rm eff}$ and [Fe/H] for the primary and consequently the derivation of $M_\star$ and $R_\star$ for both components, as well as the M dwarf $T_{\rm eff}$. In addition, our sample of EBLMs is composed of ∼150 eclipsing binaries with a FGK primary and an M-dwarf secondary, discovered from WASP light curves (LC) [8].



Of the six late M dwarfs with $T_{\rm eff}$s, the only EBLM-like object is KIC1571511, discovered from its *Kepler* light curve (fig.-a). Its M dwarf has a 0.14 $M_\odot$ with a 0.18 $R_\odot$. From the eclipse depths, its $T_{\rm eff}$ is 4090K, higher than models expected by ∼900K [1]. More recently with the first full analysis of an EBLM [7], we find its M dwarf to be consistent with models for its given 0.18 $M_\odot$ and 0.21 $R_\odot$(fig.-c top). However, its $T_{\rm eff}$ is ∼600K too hot (fig.-c bottom). If the hotter M dwarf $T_{\rm eff}$ are typical, as suggested by these two objects, planets identified by TESS orbiting the lowest mass stars and thus the only planets in the habitable zone will not be accurately characterized. A hotter $T_{\rm eff}$would imply a higher $M_\star$ and consequently a higher mass for the planet.

We propose to obtain **K2 long-cadence** LCs for the **six** EBLMs in the C2/C3 fields. The targets are bright so that stellar characterization and radial velocities (RVs) are ameanable from the ground (fig.-b). We already have orbital periods for all EBLMs in our sample, and have been actively acquiring spectra. K2 is the only means to acquire the full LC for these objects, allowing us to measure radii precisely and determine the $T_{\rm eff}$ of the M dwarf secondary (not possible from their WASP LCs). Observations of the full orbit will determine the phase curve, which in turn constrains the M dwarf irradiation as a function of phase, providing information on whether hot spots could cause the apparent high $T_{\rm eff}$ measured for the two objects above. In the cases that the secondary eclipse depth is not measureable from the light curve, we will set upper limits for the $T_{\rm eff}$.

With TESS's expected launch only a few years away, it is now timely to invest in understanding the lowest mass M dwarfs and K2 has the unique capability of providing the much needed constraints for the mass-radius-temperature-metallicity relationship.

References: [1] Dotter et al. 2008,ApJS,178,89; [2] Torres et al. 2010,A&ARv,18,67; [3] Boyajian et al. 2012,ApJ,757,112; [4] Morales et al. 2009, ApJ, 691,1400; [5] Ofir et al. 2012, MNRAS,423,L1; [6] Zhou et al. 2014,MNRAS,437,2831; [7] Gómez Maqueo Chew et al. 2014, to be submitted to A&A; [8] Triaud et al. 2013 A&A, 549A, 18.