Discovering Young Eclipsing Binary Systems with TESS

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Why look for young EBs with TESS?

Finding young eclipsing binaries (EBs) and determining their properties can allow us to better understand and model how stars evolve before they reach the main sequence. At low masses, current pre-main-sequence (PMS) models do not agree with one another [1] and are not always consistent with measured stellar properties [2]. Stellar parameters of EB systems can be measured from observations with very few assumptions, making them ideal targets for constraining models of PMS stars. In this project, we aim to identify previously unknown young EBs using TESS data, determine their properties, and compare them to PMS models in order to help enhance the current understanding of young stellar evolution.

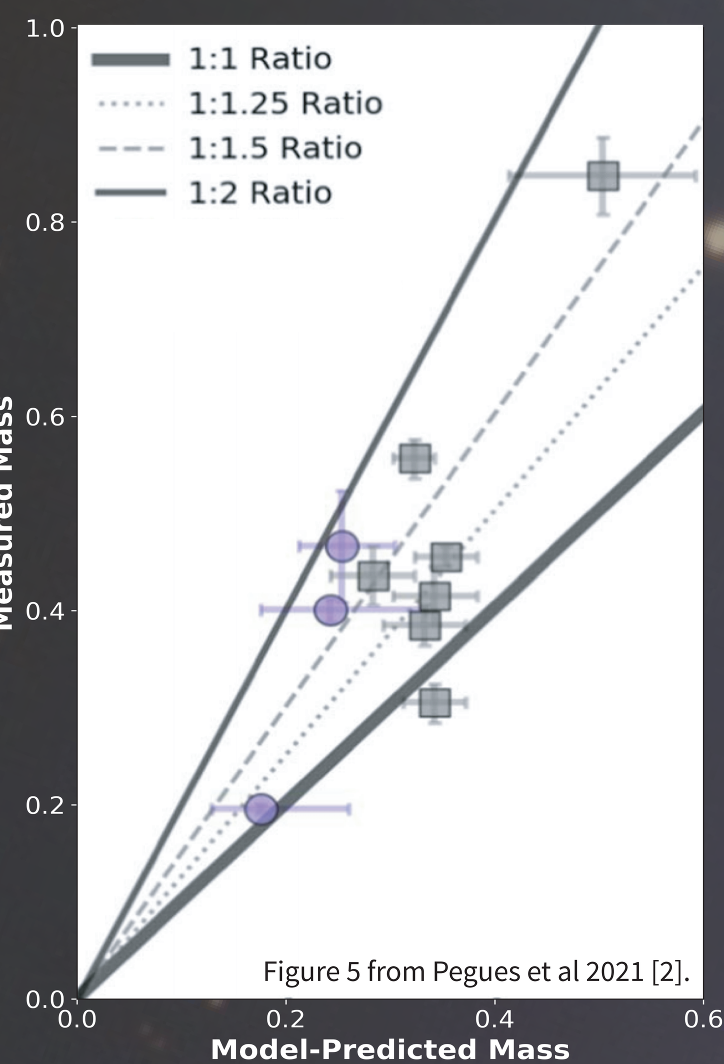

Figure 1: Plot of measured masses for a set of PMS stars as a function of mass predicted by PMS evolutionary models. The points systematically fall above the 1:1 ratio line, showing disagreement between the measured and predicted masses.

Sample Selection

We began our search for young, low-mass EBs using a set of 5007 young stellar objects (YSOs) with masses of ~0.05-1.5 $M_\odot$ identified from the APOGEE-2 spectroscopic survey [3]. To optimize our chances of finding EBs, we first examined two subsets of these YSOs: those flagged as double-lined spectroscopic binaries and those identified as radial velocity variables. For each of these 398 targets, we used the `Lightkurve` package to produce cutouts of TESS full frame images and perform aperture photometry to create a series of light curves and field plots. We inspected the light curves by eye to identify potential EB systems. From these plots, we compiled a sample of potential young, low-mass EBs.

References

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[3] Marina Kounkel et al 2019 AJ 157 196
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Acknowledgements

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Our Sample

We have identified nine targets that may be young, low-mass EB systems. Eight of these targets were found in star forming regions of Orion; the other in IC 348. Their periods vary from 1.7 to 15.9 days, and many exhibit non-eclipsing variability, likely caused by rotation. At least two-thirds of these targets are double-lined spectroscopic binaries.

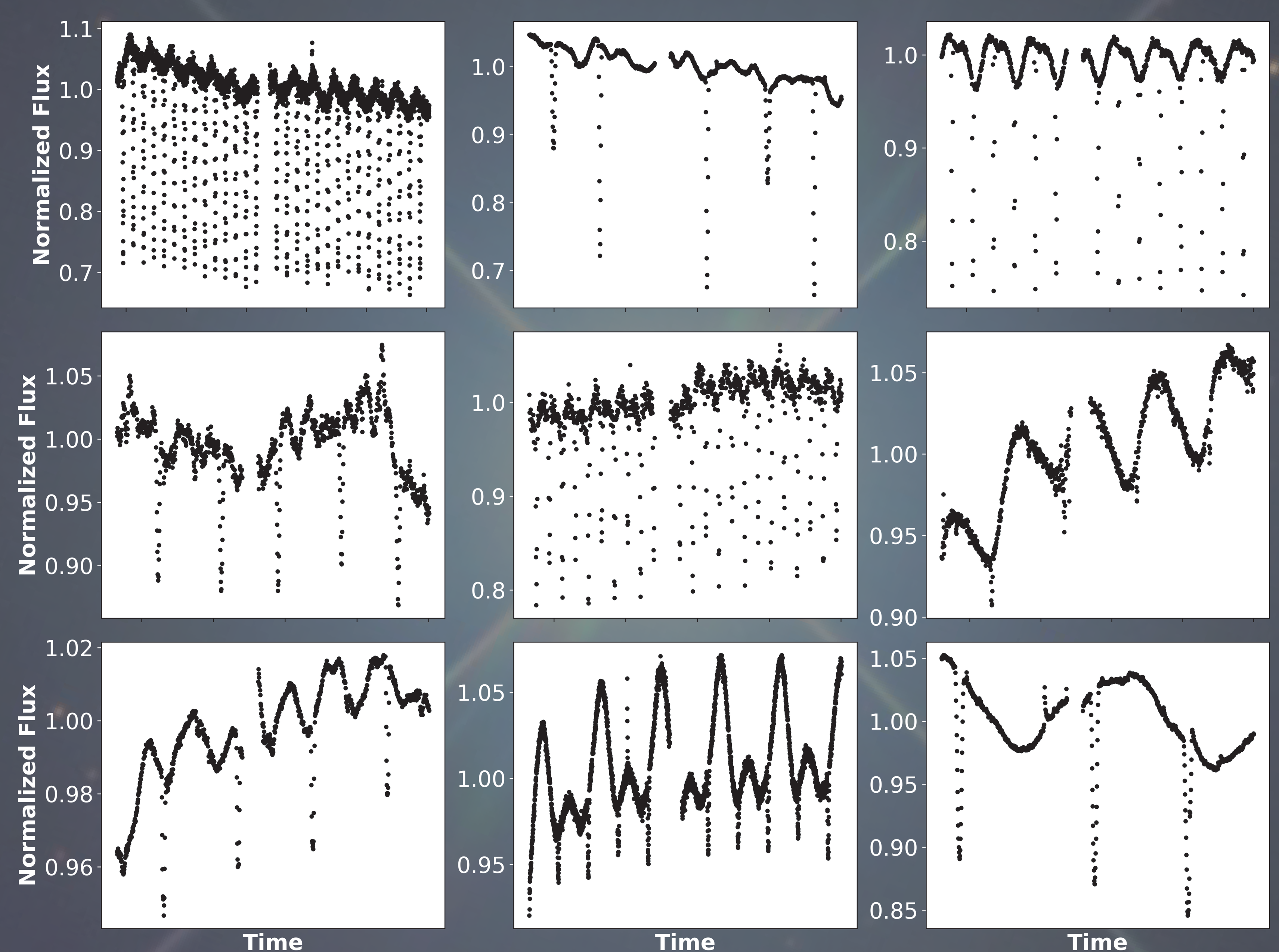

Figure 2: Normalized light curves generated from one sector of TESS data for each of the nine EBs currently in our sample.

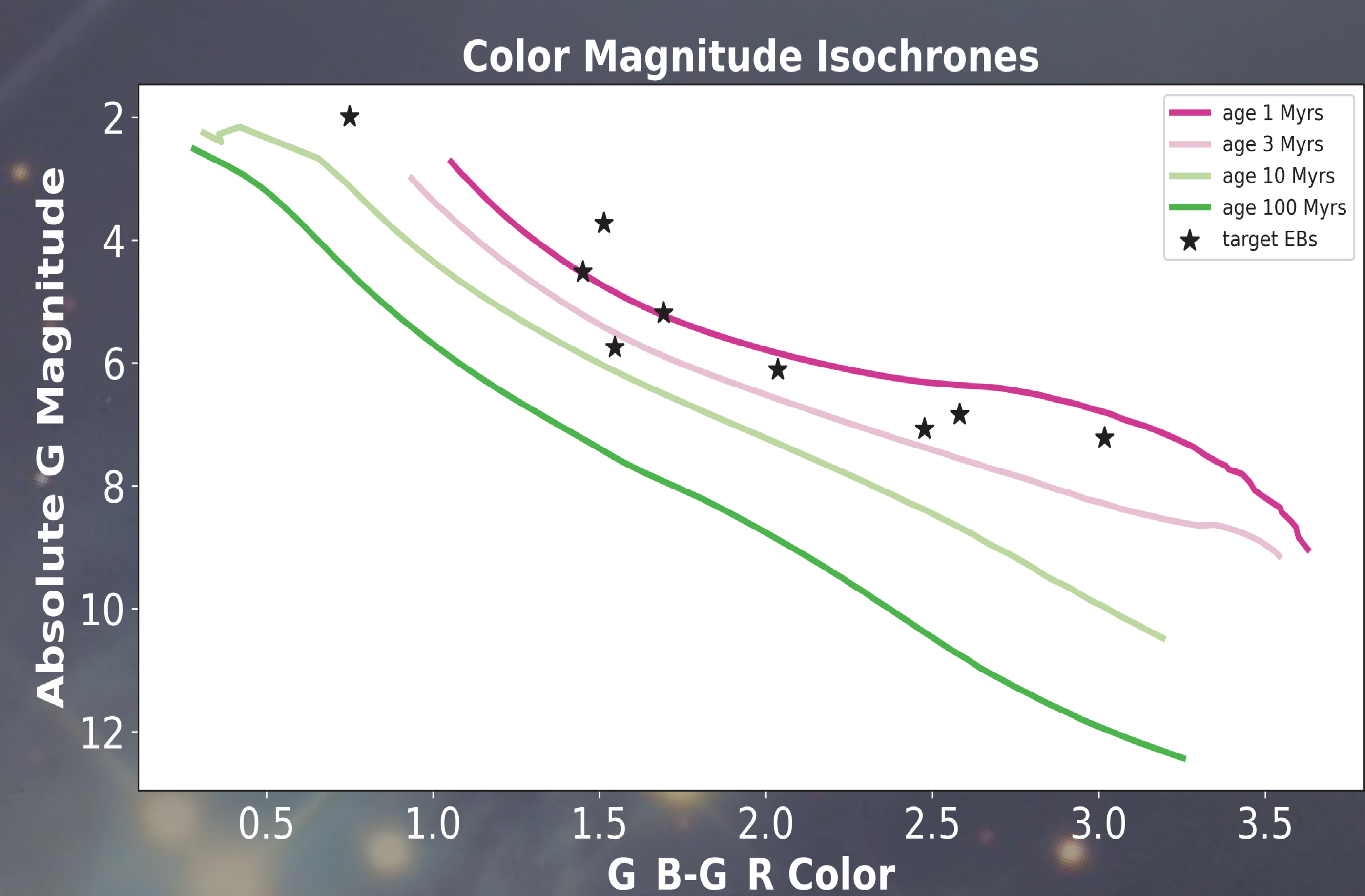

Figure 3: A color-magnitude diagram showing the targets in our sample, with PMS stellar isochrones [4]. To account for the two components in each system, the targets are plotted at half of their observed flux. All nine targets fall well above the 10 Myr isochrone, supporting their status as YSOs.

Next Steps

While we have performed initial model fits for the systems in our sample, we need radial velocity measurements and multi-wavelength observations of the targets to accurately determine their stellar parameters. We plan to take ground-based follow-up observations of the systems this fall and winter. Once we have these supplementary data, we will use the measurements to model each system and find its properties. We also want to extend our search to include all 5007 YSOs in the original dataset. Ultimately, we hope to use our findings to better constrain models of PMS stellar evolution.

Modeling and OriNTT 429

We flattened each light curve in our sample to eliminate any non-eclipse variation. Using the `exoplanet` package, we fit preliminary models to the flattened light curves. We employed Markov chain Monte Carlo (MCMC) sampling to find the distribution of possible values for each system's stellar parameters, with a focus on fine-tuning the eclipse times and periods that will inform follow-up observations.

We obtained radial velocity measurements for our target OriNTT 429 (TIC 276662451) from spectra taken for a previous study of PMS binary systems [5]. These data allowed us to perform a full model fit on the target and more tightly constrain its stellar properties. This model fit yields primary and secondary masses of 1.15 ± 0.0180 and 1.07 ± 0.0164 $M_\odot$, respectively. We also find the system to have an elliptical orbit with an eccentricity of 0.287 ± 0.00114 and a period of 7.46 ± 5.52e-7 days.

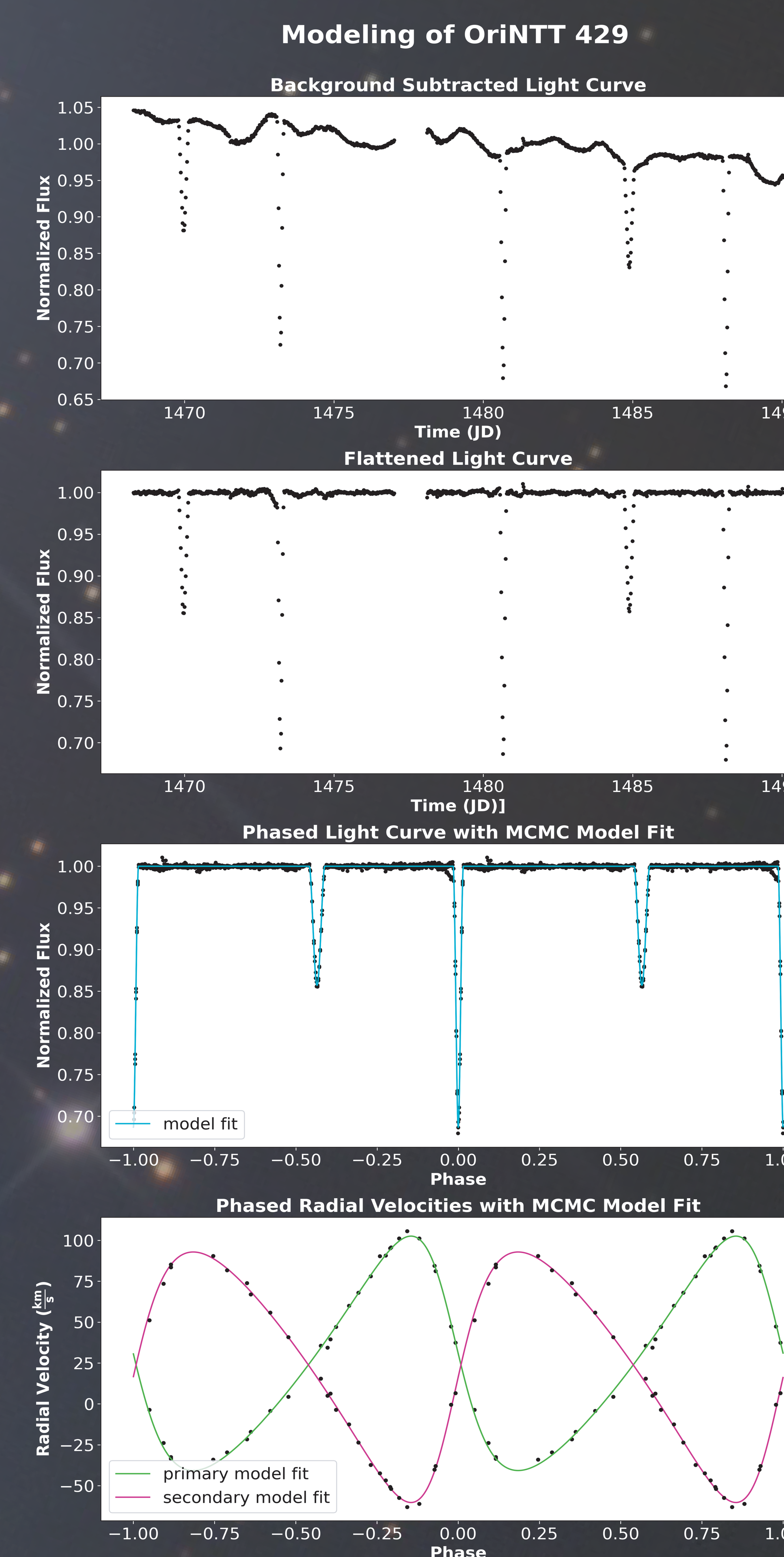

Figure 4: From top to bottom: the light curve for OriNTT 429 generated from its TESS cutout, the light curve after being flattened, the phased light curve with model fit overplotted, and the phased radial velocities with model fit overplotted. The difference in eclipse depths is interesting considering the mass ratio of ~0.94.