Comparative Study of Simulated and Observed Blended Light Curves for Unambiguous Stellar Rotation Period Determinations

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Abstract

Gyrochronology postulates that the age of stars similar in mass to our Sun can be approximated based on their rotational period. With this in mind, determining accurate rotation periods using photometry data from missions such as Kepler, K2, and TESS is vital for accurate stellar age estimates. Blended light curves pose a particular problem: When conducting simple aperture photometry, neighboring targets can taint the resulting light curve. In most cases, this issue makes the data unusable for unambiguous determination of stellar rotation periods. In this poster, we outline our research project, which aims to provide a solution to the issue of blended light curves. The project consists of computing a grid of simulated blended light curves and comparing them to observed blended photometric data from Kepler, K2, and TESS. Simulations will be computed using Butterpy, a Python package that yields the light curve of a particular model of starspots evolving through the stellar surface, as well as Fleck, which aids in generating photometric simulations with singular starspots. We expect to quantitatively match any simulation from the grid to any of the blended light curves in our sample. Success in the project results will significantly impact other fields of astronomy that also use photometric data by facilitating a new collection of previously unusable data.

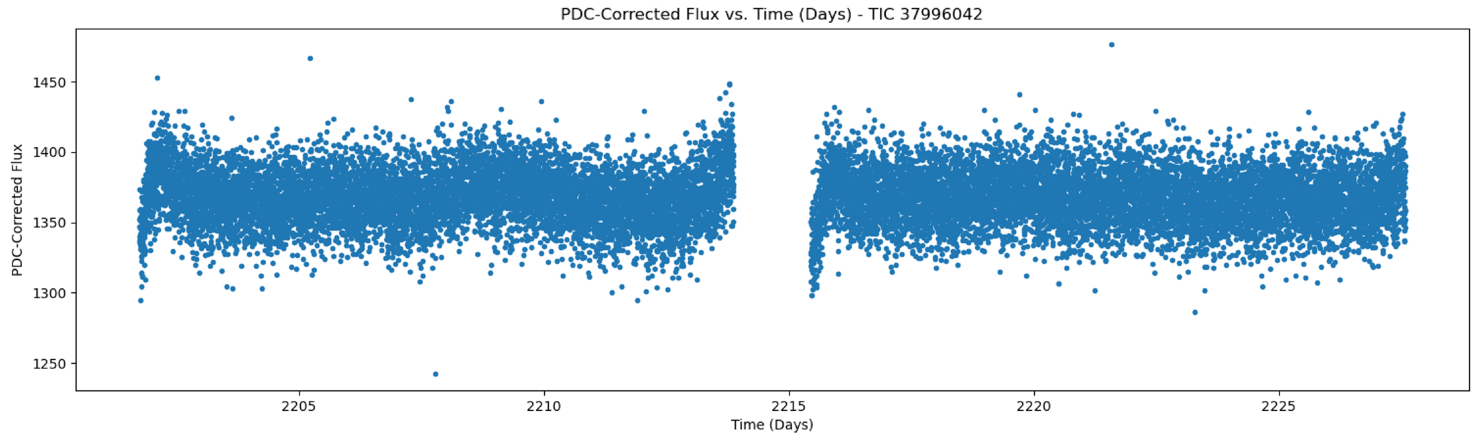
Goals

- Using user-input parameters to generate simulations of blended light curves, we aim to quantitatively compare these simulations to real blended light curves.
- We aim to do this by analyzing a real photometric blend, and altering the input parameters for Butterpy and Fleck light curves until we can obtain a simulation which matches the real blended data.

Given Data

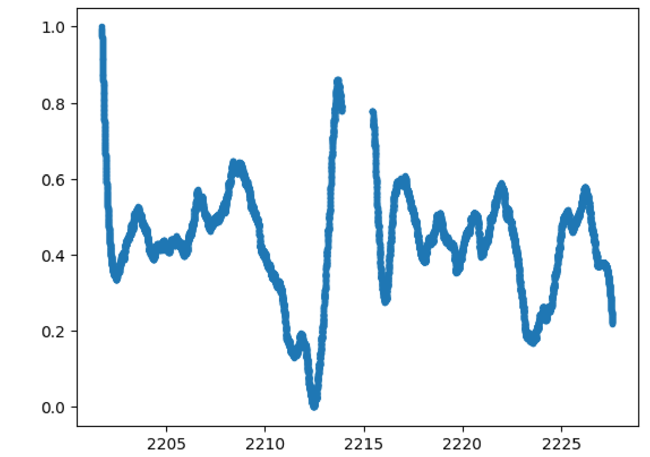
PDC-corrected light curve data was provided by Dr. Lares-Martiz

This data describes the blended photometry of two targets within the same TESS pixel, meaning that the light curve of each star is contaminated to some degree by the other.



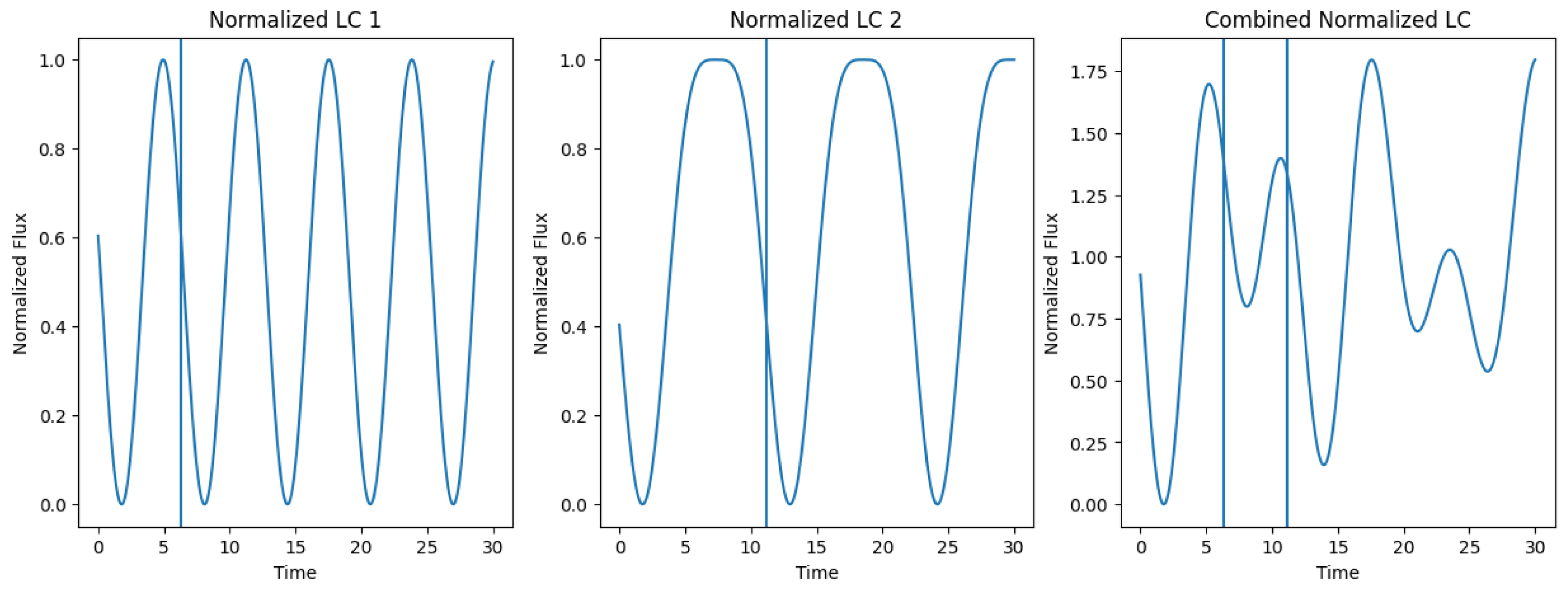
Data “Cleaning”

The data was cleaned using a Savgol filter with a window size of 501, and a polynomial of order 3. This removed outliers and allowed us to denoise the data, which was used to see the shape of the data. This could then be compared with our simulated light curve.



Fleck

In method 1, we used the python library know as Fleck. This library allows the the user to place star spots at specific longitude and latitudes of the star. Each spot and star can also have a variety of parameters, such as inclination, quadratic limb darkening, and spot radii. This allows for the effective searching of the optimal parameters to fit the simulated light curve to the real blended light curve.



Butterpy

Method 2 uses the python library ButterPy. This library allows for the user to simulate light curve of stars with specific inclinations, phases, periods, and activity levels. In comparison to Fleck which simulates light curves with small amounts of spots, ButterPy simulates bands of star spots within a given range of latitudes, which will then drift towards the equator. This allows for the better creation of realistic light curves, as it can capture attributes such as the non-sinusoidal nature found in real data.

Research into the quantitative comparison of real blended light curves and simulations generated via Butterpy is ongoing.

Current Focus

The Butterpy python package allows us to simulate light curves with starspot patterns that evolve over time, which manifests as a gradual change in the periodic flux changes of the generated light curve. As star spots grow, the average flux decreases gradually, and has the opposite effect when star spot bands shrink.

With Fleck, the evolution parameters of individual star spots can be input by the user, allowing for a more localized, yet more “personalizable” simulation of light curve data.

Both Butterpy and Fleck allow us to alter parameters beyond the evolution of starspots on each simulated star, including the rotational period, light curve duration (in days), and stellar inclination, among others. For our current investigation, we maintain a consistent observation period of ~30 days between the real blended curves and the simulated blends.

Future Work

We believe that this research has a massive amount of potential. Currently, this works as a proof of concept, to show that it is possible to infer the attributes of the stars composing a blended light curve by simulating a matching light curve with known parameters. This can be automated, allowing for the parameters to be optimized to fit the blended curve. This can be done using a method such as a grid search, where the algorithm tests different parameters until it creates a light curve with sufficiently low error.

Additionally, we plan to include simulation comparisons in which additional variables (such as the simulation time range and stellar inclination) are also altered, in order to broaden the applicable scope of this research.

Acknowledgements

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