Simulating Rubin Observatory Light Curves of Eclipsing Binaries

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Introduction

Eclipsing binary star systems play a crucial role in our understanding of stellar evolution and Galactic dynamics. With the arrival of the Vera C. Rubin Observatory, astronomers will soon have access to an unprecedented volume of observational data.

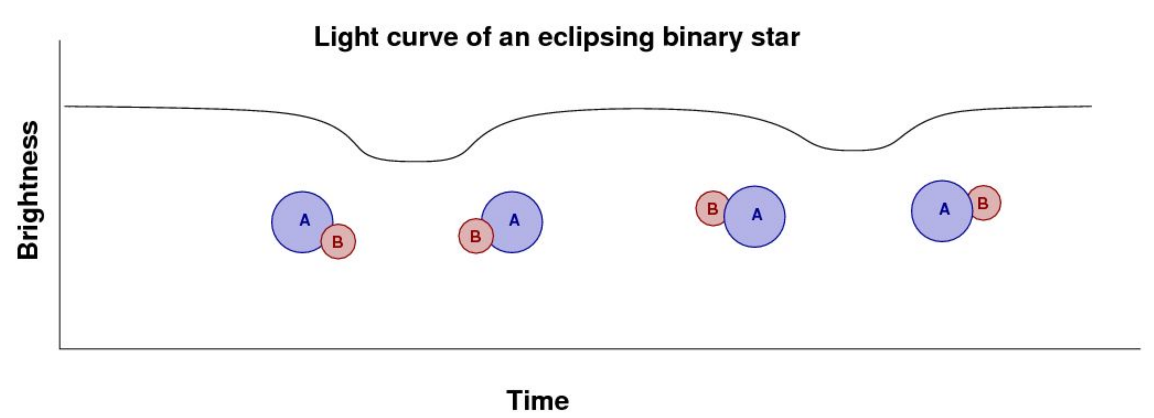


Image Credit: Copyright © Michael Richmond
http://spiff.rit.edu/classes/phys370/lectures/eclipse_1/eclipse_1.html

Objective

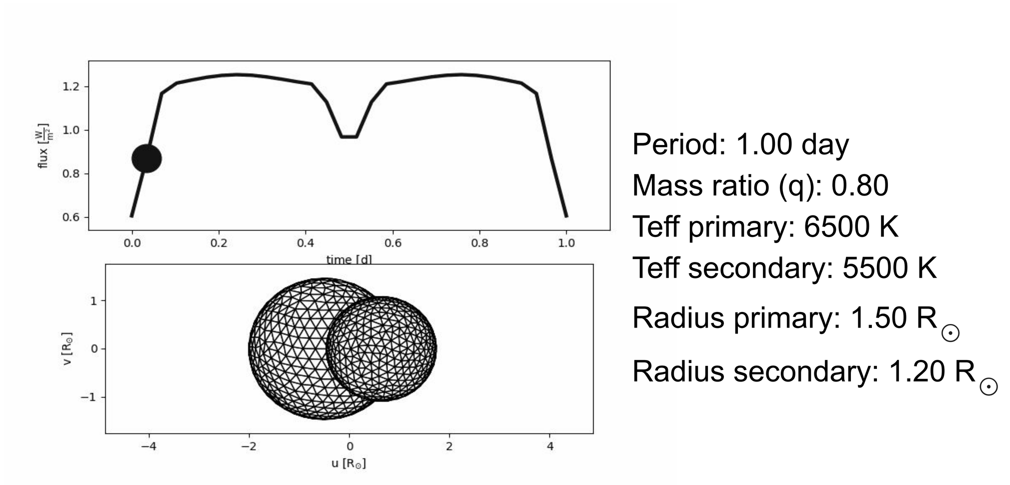
Our objective is to develop an algorithmic process to identify stellar properties from light curves of eclipsing binary star systems found in the Rubin Dataset.

Using our method, we should be able to interpret the light curve data and infer various parameters of each star (i.e. effective temperatures, mass ratio, eccentricity, etc.).

Methods

We employ a two-step approach utilizing the PHysics Of Eclipsing BinariEs (PHOEBE) Python library. First, we simulate a diverse range of binary system light curves to create a synthetic data set. This involved varying parameters such as stellar effective temperatures, mass ratios, and eccentricities. Second, we apply PHOEBE's fitting capabilities, specifically the EBAI and LC Geometry methods, to the simulated data to assess the reliability of PHOEBE's fitting algorithms. This research lays the groundwork for efficient identification and analysis of eclipsing binary systems in the forthcoming Rubin Observatory data.

Eric (left) and Sara (right) presenting their research during the Rubin Data Summit at SLAC on July 19, 2024.



An image of a full spectrum light curve of two stars with different temperatures, radii, and masses.

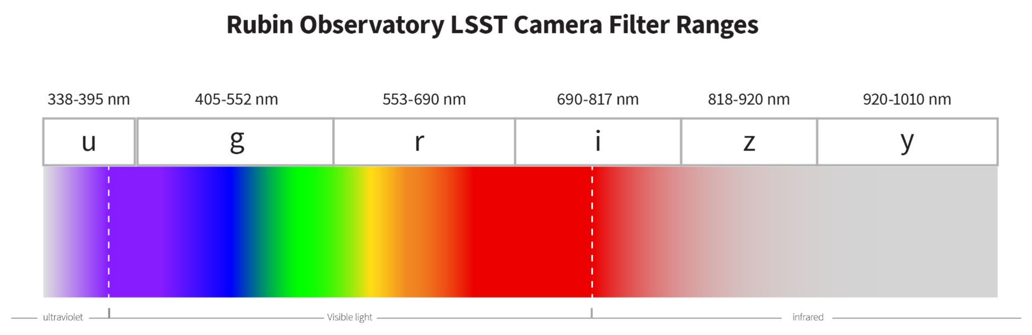
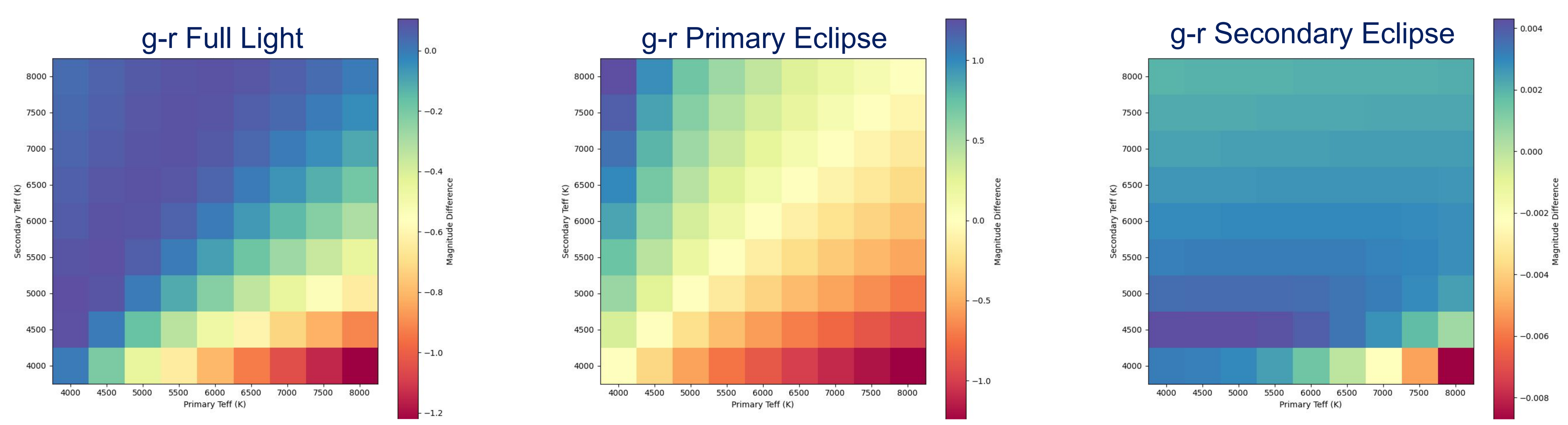


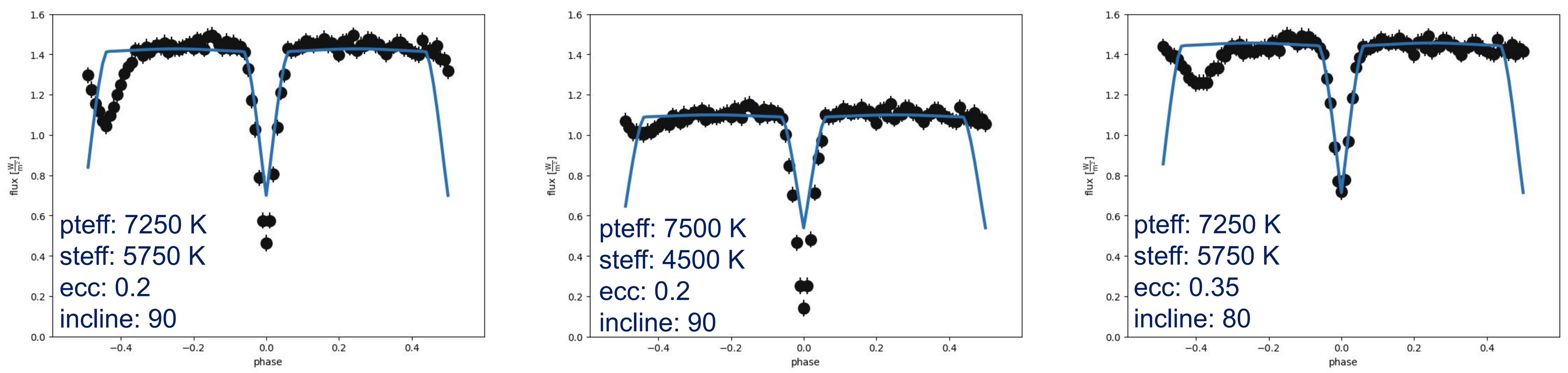
Image Credit: Rubin Obs/NSF/AURA

This image shows the frequency range of each light filter that will be used on the Rubin Observatory camera.

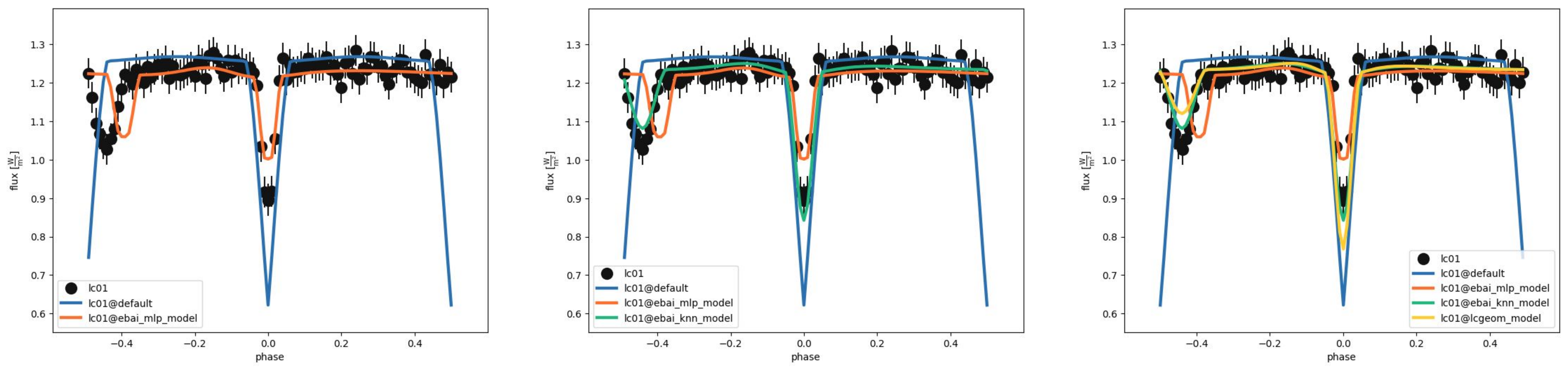
Results



These heatmaps all show simulated magnitude measurements of the same binary star system. The first image is simulated during full light (no eclipse), then during primary eclipse, and finally during secondary eclipse. Each column and row reflects a simulated change in a stellar temperature for each star. These maps show the difference in magnitude between two selected Rubin color filters ("g" and "r").



The above images depict simulated observational data points from different simulated binary star systems, measured in magnitude vs. time. The blue line represents the "default" binary system light curve generated by PHOEBE.



The above images depict the same simulated observational data points from the same simulated binary star system, measured in magnitude vs. time. The blue line represents the "default" binary system light curve generated by PHOEBE. The orange line is PHOEBE attempting to fit the simulated data with a line of best fit. The green line is PHOEBE attempting to fit the simulated data with a machine learning algorithm. The yellow line is PHOEBE assuming the geometry of an eclipsing binary light curve to help constrain the system's parameters.

Summary and Future Work

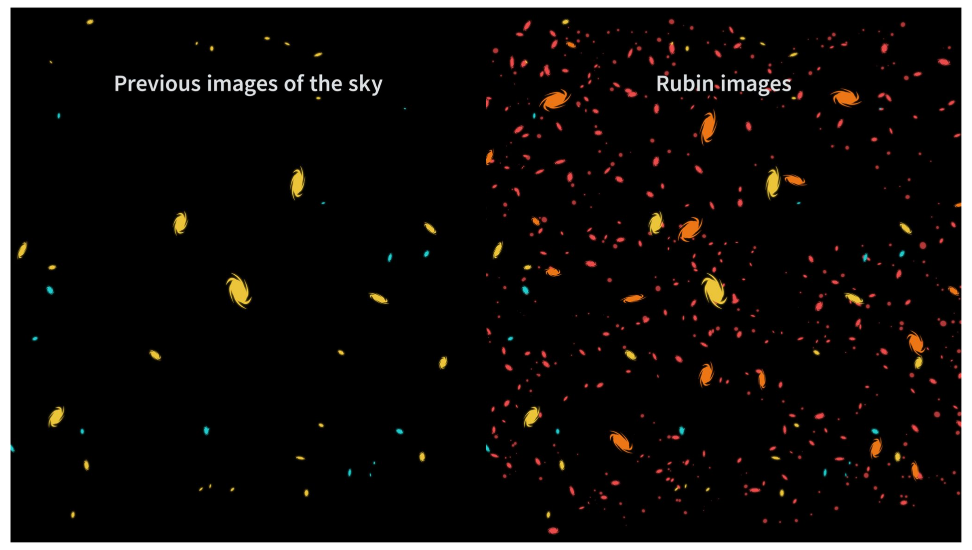


Image Credit: Rubin Obs/NSF/AURA

Every three days, The Rubin Observatory survey will capture one high resolution image of the night sky above the entire southern-hemisphere. This survey is called the Legacy Survey of Space and Time (LSST). The LSST project will repeat this process for a total of 10 years, ending with an estimated 60 petabytes of data.

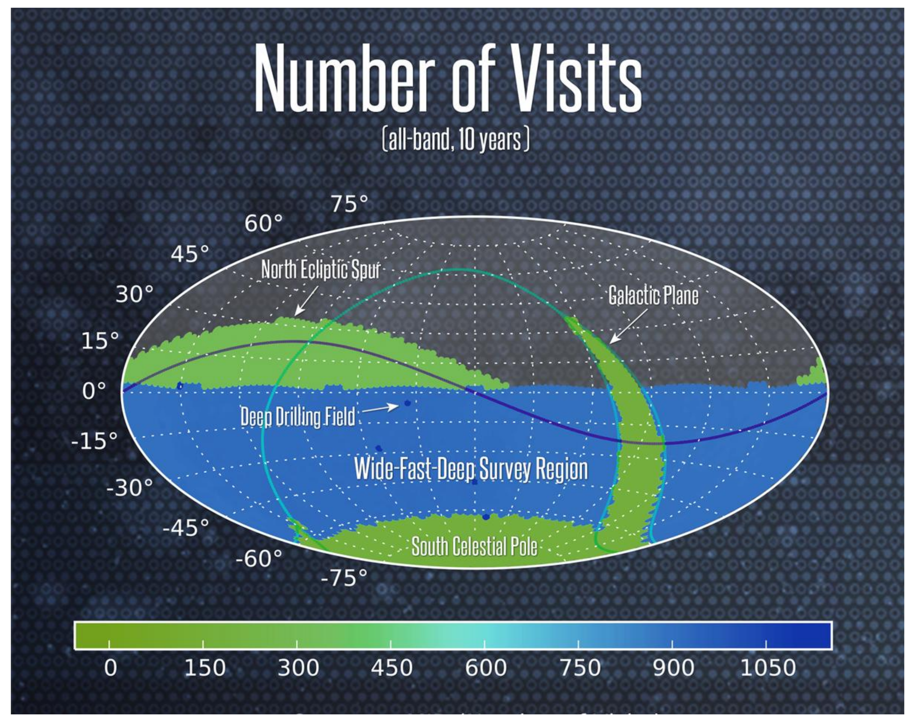


Image Credit: Rubin Obs/NSF/AURA

References

Gautam et al. (2024), ApJ, 964, 164
Geller et al. (2021), ApJ, 919, 83
Jones et al. (2020), ApJS, 247, 63
Rowan et al. (2022), MNRAS, 517, 2190
https://rubinobservatory.org
http://phoebe-project.org

Acknowledgments

This project was supported by National Science Foundation grants PAARE #2218943 (P.I: L. Edwards, Cal Poly San Luis Obispo) and LEAPS-MPS #213230 (P.I. B. Binder, Cal Poly Pomona).
We'd like to thank Louise Edwards for organizing the Rubin Data Summit hosted at SLAC. We would also like to thank the Cal Poly Pomona Office of Undergraduate Research for the opportunity to participate in the Student Success and Transfer Articulation through Research and Support Services (STARS) program.

Eric Hury

California Polytechnic State University Pomona

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Method: We employ a two-step approach utilizing the Physics Of Eclipsing Binaries (PHOEBE) Python library. First, we simulate a diverse range of binary system light curves to create a synthetic data set. This involved varying parameters such as stellar effective temperatures, mass ratios, and eccentricities. Second, we apply PHOEBE's fitting capabilities, specifically the EBAI and LC Geometry methods, to the simulated data to assess the reliability of PHOEBE's fitting algorithms. This research lays the groundwork for efficient identification and analysis of eclipsing binary systems in the forthcoming Rubin Observatory data.

(a) An image of a full spectrum light curve of two stars with different temperatures, radii, and masses.

(b) This image shows the frequency range of each light filter that will be used on the Rubin Observatory camera.

Results: These heatmaps all show simulated magnitude measurements of the same binary star system. The first image is simulated during full light (no eclipse), then during primary eclipse, and finally during secondary eclipse. Each column and row reflect a simulated change in a stellar temperature for each star. These maps show the difference in magnitude between two selected Rubin color filters ("g" and "r").

(a) The above images depict simulated observational data points from different simulated binary star systems, measured in magnitude vs. time. The blue line represents the "default" binary system light curve generated by PHOEBE.

(b) The above images depict the same simulated observational data points from the same simulated binary star system, measured in magnitude vs. time. The blue line represents the "default" binary system light curve generated by PHOEBE. The orange line is PHOEBE attempting to fit the simulated data with a line of best fit. The green line is PHOEBE attempting to fit the simulated data with a machine learning algorithm. The yellow line is PHOEBE assuming the geometry of an eclipsing binary light curve to help constrain the system's parameters.

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