Eclipsing Binary Light Curve Synthesis and Brute Force Parameter Comparison for Automated Big Data Analysis

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Abstract

An eclipsing binary star system is comprised of two gravitationally bound stars that orbit a common center of mass, with an orbital plane aligned in such a way that the stars are observed eclipsing one another. We observe eclipsing binaries (EBs) via light curves made of data points of their total flux. Using MPI to take advantage of parallel computing power, and using PHOEBE2 modeling software, tens of thousands of light curves with a wide range of parameter values were synthesized. The parameters considered include temperature ratio, sum of fractional radii, inclination, and radial and tangential eccentricities. The goal of this project is to automatically compare the light curves of observed binary systems to synthetic light curves in order to approximate parameters of binary star data. This comparison can help us approximate the parameters of observed data. This allows us to understand how different physical and geometrical parameters of a star system affect light curves and thus how the physical properties of a star dictate their evolution.

Introduction

EBs play a crucial role in understanding stellar evolution. The immense amount of observed EB data allows us to study the formation methods and life cycles of stars. There is a massive amount of EB data being collected by large scale missions; Gaia alone is expected to observe 8 million EBs, and this data will allow for the testing of stellar evolution theories [1]. It would be near impossible for humans to process this amount of data, and therefore automation is crucial. Computing methods allow for large amounts of light curves to be processed effectively. These light curves can be synthesized with our own parameters and then compared to observed data, in order to best approximate the characteristics of stars in nature [2].

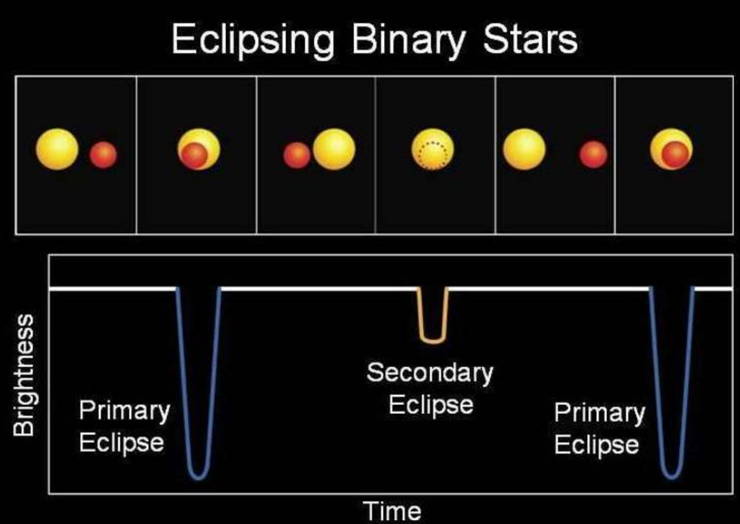

Fig. 1 Light curve of binary star Kepler-16, showing both primary and secondary eclipses. [3]. Eclipsing Binary Stars are observed through light curves. Their fluxes, or light emitted, will change when one star orbits in front of the other as observe them eclipse. In this diagram the secondary eclipse shows the smaller star travelling in front of the bigger star, this making a smaller dip in the flux.

Methods

The project synthesizes hundreds of thousands of light curves and compares them to observed data. Through this analysis we can find the parameters of given stars automatically rather than having human scientists find the parameters. The way we are generating hundreds of thousands of light curves is MPI4py. This Message Passing Interface (MPI) tool for python is very powerful as it allows for programs to run in parallel. Villanova University's cluster computer named 'Clusty' was used in running MPI for the project, the multiple nodes of Clusty were perfect for the MPI to have multiple sets of the program running in parallel and communicating with each other. This allowed for much more efficient light curve synthesis. The efficiency of the synthesis helps meet the goals of the project: to consider an immense number of parameters to find the best fit for observed data. An observed light curve is then compared to the set of synthetic light curves to find the best fit. The parameters of the observed curve can be determined through the parameters of the best fitting synthetic curve.

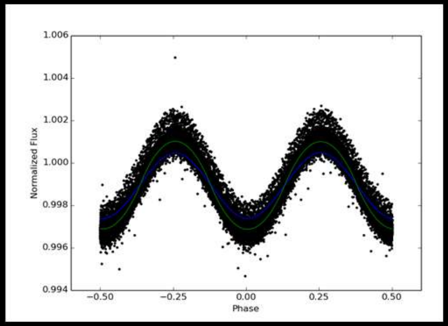

Fig 2. An observed light curve of binary star KIC 8912468

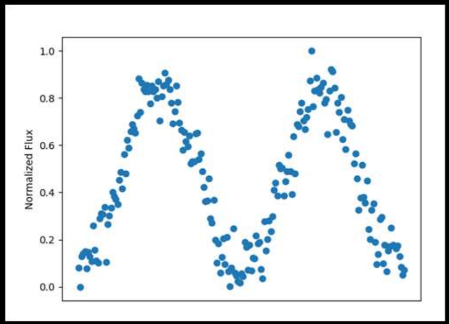

Fig 3. A synthesized light curve with similar parameters to binary star KIC 8912468

Conclusion/Future Work

The program written for the project was tested by using synthetic light curves slightly different from the ones in the synthetic set. This was to show that the best fitting parameters can still be found even with noise or light curves that differ from those in the synthetic set. The project will continue to evolve as we work on improving the efficiency of the synthesis and comparison methods. Currently, the comparison algorithm is strictly exhaustive brute force, but future work will implement methods that are more efficient, as well as compare more closely related light curves while improving the parameter determination. This project is important because of the increasing amount of data that needs to be analyzed in order to better understand the evolution of EBs and stars in general.

Acknowledgments

The authors would like to thank the Center for Research and Fellowships and NASA grant 4-20011 for their support in this project. The authors would also like to thank Tyler Kline for his computational contributions to the project.

References

[1] Devinney, E., Guinan, E., Bradstreet, D., DeGeorge, M., Giammarco, J., Alcock, C., & Engle, S. 2005, BAAS, 37, 1212.
[2] Prša, A., Guinan, E. F., Devinney, E. J., et al. 2008, ApJ, 687, 542
[3] Image Credit: NASA