Period Analyses of Variable Stars Alpha Orionis and Beta Lyrae

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Abstract

Variable stars change in brightness over regular or semiregular periods of time. Causes of variability include pulsation (changes in size) or the presence of a companion star or planet that eclipses part of the stellar surface. We examine period changes of the bright variable stars Alpha Orionis (Betelgeuse) and Beta Lyrae using data from the American Association of Variable Star Observers (AAVSO). Periods were analyzed by applying Fourier and weighted wavelet z-transforms to the light curves of each star over a 30-year time span. Our analyses showed that both the short and long secondary periods of Betelgeuse changed with time. The long period decreased at a nearly constant rate, and the short period increased in sudden “jumps” before suddenly decreasing. The period of Beta Lyrae had only small variations surrounding the expected period, with the exception of a sudden 3-day decrease which immediately increased back to the expected period again. The AAVSO database contains contributions from amateur and student observers: our ultimate goal is to use an older DSLR to contribute to the AAVSO database of bright variable stars.

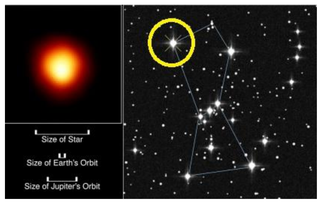

Figure 1. Alpha Orionis or Betelguese is a famous variable star.Image from AAVSO.

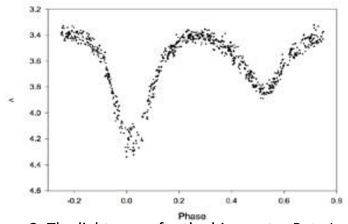

Figure 2. The light curve for the binary star Beta Lyrae. The variation of observed brightness results because the two stars alternately eclipse each other. Image Credit: AAVSO.

Introduction

Variable stars are stars that exhibit changes in brightness over a regular or semiregular period of time. Stars vary in brightness by either extrinsic factors such as an eclipse by a companion star or nearby exoplanet or intrinsic factors such as a change in size. Stellar variability reveals critical information about stellar evolution and binary star interactions and also leads to discoveries of exoplanets.

The study of variable stars requires consistent observations over long periods of time. Due to the large amount of information required, variable star data is often collected by amateur astronomers. This can be through visual or digital observations. Visual data is collected by observing the target star with the unaided human eye: this is accomplished by comparing it with stars of constant brightness (or magnitudes). These data can be subject to human visual acuity and some subjectivity, which leads to slightly more uncertainty in individual data point. However, there is usually a larger amount of such data as it is easy to collect and requires no expensive instrumentation. More recently, amateur astronomers have collected data using Digital Single Lens Reflex (DSLR) cameras: such data is more accurate and fairly easy to acquire. In this study, we use archival amateur observations from the American Association of Variable Star Observers (AAVSO) to examine the variable stars Alpha Orionis and Beta Lyra. The AAVSO data and analysis software is available free of charge to students and the organization has an extensive library of educational products for students and faculty to learn about variable stars. This study serves as a feasibility test to begin variable star observing/analysis program with students in the astrophysics program at MSU.

Observations & Analysis

We examined data for the two stars collected over a 30 year period. For Alpha Orionis we used digitally collected data in the visual Johnson V band. Visual observations collected with the unaided human eye were used for Beta Lyrae, as other types were too sparse. Analysis was conducted using the AAVSO VStar software package. First, the potential period for each star was found using a Data Compensated Discrete Fourier Transform (DCDFT) over a light curve during the 30 year period. Then, several long and short period candidates were tested to find the best fit. Finally, a Weighted Wavelet-Z (WWZ) analysis was conducted to see how the periods have changed with time.

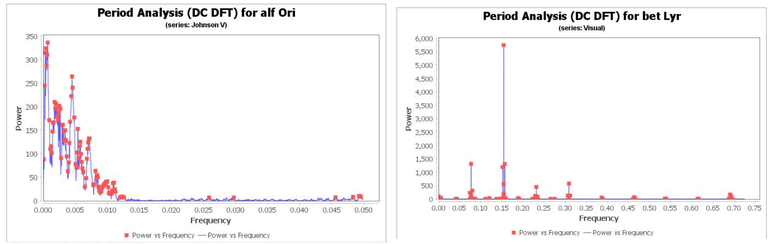

Figure 3. A DCDFT analysis graphs sine waves of different frequencies to a light curve to see which best represents the variability. These graphs show a range of frequencies and their likelihoods of being the true frequency of the star.

Results

According to the AAVSO’s Variable Star Index, Alpha Orionis has a short period of 423 days, and a long period of approximately 2100 days. We found the best fitting short period to be 443.46 days, while the best fitting long period was 3273.55 days. (4.72% and 43.68% difference, respectively). One of the other long periods tested was 2291.49 days, which did not seem to fit as well, but is closer to the official value (8.72% difference). However, the light curve diagrams for both tested and known periods were irregular, implying that they are likely changing. From the WWZ, we found the long period to be steadily decreasing, while the short period “jumped” from lower to higher values.

The known period for Beta Lyrae is 12.944 days, while we found a period of 12.942 days (0.03% difference). The WWZ showed only small variations around the official value, except for one data point, which suddenly dropped to a period of 10 days, but this is visually collected data subject to uncertainties associated with observer experience and visual acuity.

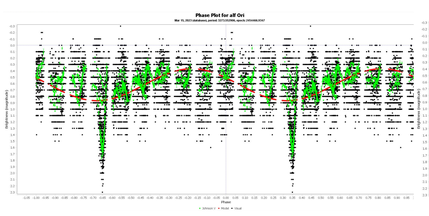

Figure 4. Phase plot for Betelgeuse with 3273.55 day period.

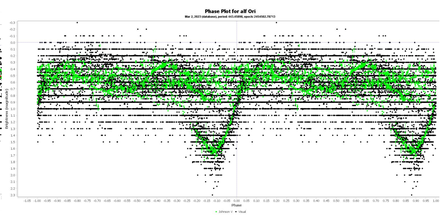

Figure 5. Phase plot for Betelgeuse with 443.46 day period.

Figure 6. Phase plot for the short period of Betelgeuse according to the VSX (423 days)

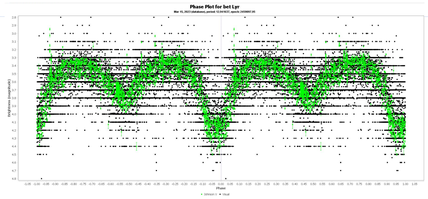

Figure 7. Phase plot for Beta Lyrae with 12.942 day period.

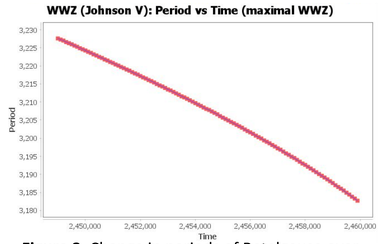

Figure 8. Change in periods of Betelgeuse over time with range of 3000-3500 days

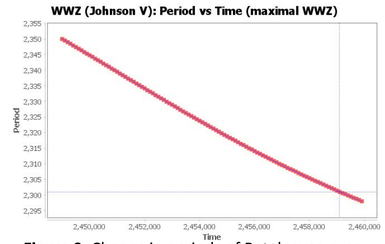

Figure 9. Change in periods of Betelgeuse over time with range of 2000-2500 days

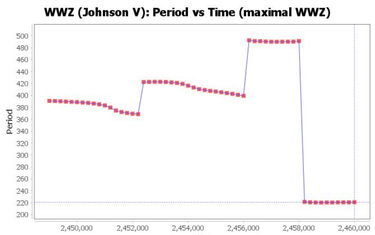

Figure 10. Change in periods of Betelgeuse over time with range of 400-450 days

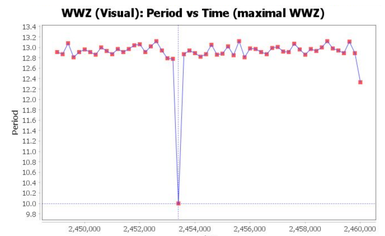

Figure 11. Change in periods of Beta Lyrae over time with range of 10-14 days

Discussion

The short period of Betelgeuse compared fairly well with other literature. Wasatonic (2022) found the period to be 439 ± 5 days, while others such as Percy *et al.* (2013) listed it as 388 days. However, given that the period was found to be changing with time, different researchers have found different periods within a 350-500 day range. The long period found by Wasatonic (2022) was 2209 ± 183 days, and other literature seems to be within this range as well. Polaksis (2020) mentions that the long period of Betelgeuse decreased while approaching a historically faint minimum in 2019, in agreement with our conclusion that it was decreasing during this time span.

The period of Beta Lyrae was more consistent in both our results and other literature. Researchers seem to agree on the AAVSO listed period of 12.944 days. Notably, Collins (2010) affirms the AAVSO period, while also suggesting a longer secondary period of approximately 280 days caused by intrinsic variability. Overall, our results are in agreement with other literature.

Conclusions & Future Plans

Our study demonstrates that analysis of variable star data from the AAVSO is well within the abilities of an undergraduate physics major. The learning curve for the project involves is not trivial: students must familiarize themselves with the AAVSO database, software package and the process of light curve analysis. There are a number of suggested projects on the AAVSO site for data analysis and for those who wish to collect and analyze.
Time series analysis, such as performed here, has applications in many areas of science, so the skills a student learns in such a project are transferable.

Our future plans are to work on using an older DSLR from the professor’s collection to obtain our own data for analysis. These data will be contributed to the AAVSO database.

References

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