1-M OBSERVATORY
EMBRY-RIDDLE AERONAUTICAL UNIVERSITY
OBSERVING TIME REQUEST

Proposal Title: Monitoring the Cooling of a ZZ Ceti Variable White Dwarf GD 99

Abstract

Images of ZZ Ceti variable white dwarf GD 99 will be taken between dates March 2, 2022 and April 30, 2022, using the CCD camera in the filter r. GD 99 is known to have unusual pulsation periods of 1058.1, 228.7, 1026.1 and 223.9s with an amplitude of 7.0, 5.8, 4.0, and 2.4 mmag, respectively. We want to replicate and confirm the known periods and amplitudes. We will use AstroImageJ to perform the photometry data reduction to obtain a light curve and Period04 to find the pulsation and amplitude of GD 99. Variable white dwarfs' brightness variations are due to temperature variations on the star's surfaces, ultimately, we want to create an O-C diagram to monitor the cooling of GD 99.

Observing Request Summary

Observer Pseudonym:	Team Ted
Total **Hours** Requested:	20
Telescope & Observing Mode:	1-meter
Instrument Requested:	SBIG STX-16803
Specific Dates Requested:	March 2nd, April 1st, April 30th

Special Constraints

Time Critical Observations:	Yes
Target of Opportunity Observations:	No
Lunar Constraints:	Yes
Other Constraints (Dates you cannot observe):	Cannot observe on March 18th or April 16th

Observer Information

Observer Pseudonym:	Team Ted

Science Justification

The life of a star is similar to that of a human in the sense that they both go through a certain process, birth, life, and death. Here on Earth, we have used fossils to determine our history and try to pinpoint the beginning of evolution. Overtime astronomers discovered the life of a star and found the end point of most stars is to become a white dwarf. It is because of this we consider white dwarfs to be the fossils of the sky, which provides a perfect celestial object to study. White dwarfs provide a life history, this contains answers to the final stages of a star's evolution. Pulsating variable white dwarfs, or DAV, are believed to be an evolutionary process that can assist in filling the blanks of stellar evolution. These white dwarfs occur due to non-radial gravity wave pulsations and the period of the pulsation is found to be correlated with the cooling of the star itself [3]. Therefore, analyzing white dwarfs will help us connect the history and future evolution of the Milky Way Galaxy.

It is important to gather as much information as possible from white dwarfs since they are potentially the answer key to multiple stellar evolution questions. These cosmic laboratories contain an abundance of information that we haven't fully collected. For instance, there are multiple DAVs with different pulsation periods. The varying periods can come from the different sizes or temperatures of the DAV. The cooler DAVs have a longer pulsation period than that of the hotter DAVs. Monitoring the pulsation periods can feasibly attain a number of discoveries, but the one we would like to focus on is the cooling rate of a DAV named GD 99.

We are proposing to observe this ZZ Ceti variable white dwarf, GD 99, in order to relate the pulsation period to the cooling rate. Once we have gathered enough data, we will relate the pulsation period we found to previously recorded data on the GD 99. After obtaining all of this information, we would like to create an O-C Diagram that would describe the changes in GD 99. This process would begin by taking a series of images of GD 99 and observing the pulsation periods found. We would put our findings into AstroImageJ (AIJ) and use the photometry process to produce a light curve. The data we collect would then be entered into Period04 where it would take a 4-year analysis of calibrated data that we used in AIJ. This will then present us with the pulsation period, frequency and amplitude. With this collected data we would then create an O-C diagram for the GD 99 that would provide the rate at which our variable white dwarf is cooling, which gives us an insight to the evolutionary state of the star.

References

[1] McGraw, J. T., and E. L. Robinson. "High-Speed Photometry of Luminosity-Variable Da Dwarfs : R 808, GD 99,and G 117-B15A." The Astrophysical Journal, vol. 205, 1 May 1976, pp. 1–2., https://doi.org/10.1086/182112.\

[2] Dalessio, James, et al. "Periodic Variations in the O-C Diagrams of Five Pulsation Frequencies of the DB White Dwarf EC 20058-5234." The Astrophysical Journal, vol. 765, no. 5, 8 Feb. 2013, pp. 1–28., https://doi.org/ https://doi.org/10.1088/0004-637X/765/1/5.

[3] Córsico, Alejandro H., et al. "Pulsating White Dwarfs: New Insights." The Astronomy and Astrophysics Review, vol. 27, no. 1, 2 July 2019, pp. 1–105., https://doi.org/10.1007/s0159-019-0118-4

[4] Bognár et al., Zs. "GD 99 - an Unusual, Rarely Observed DAV White Dwarf." Communications in Asteroseismology, vol. 150, 1 Aug. 2007, pp. 251–252., https://doi.org/10.1553/cia150s251.

Figures

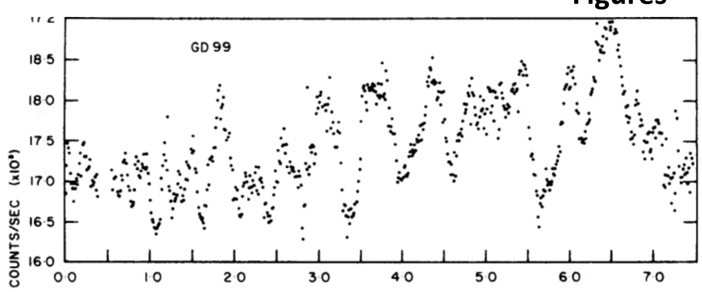

Figure 1: Light curve of GD 99 revealing unusual periods of 1058.1, 228.7, 1026.1 and 223.9s. This model will be used as a reference to reproduce. [1]

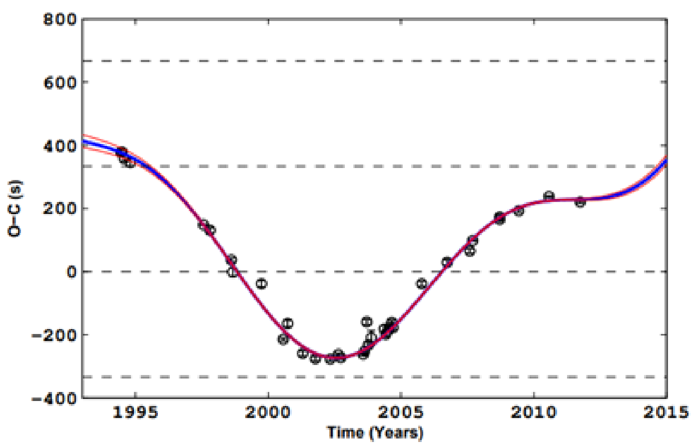

Figure 2: O-C Diagram of DB White Dwarf EC 20058-5234 [2]. Currently there are no O-C diagrams or relevant data produced for GC 99. Our goal is to create an O-C diagram for GD 99 with data taken throughout our observations.

Technical Justification

We intend to study GD 99, which is classified as a ZZ Ceti variable white dwarf in order to determine the cooling rate in relation to the object's pulsation period. We would utilize the SBIG STX-16803 CCD camera on the ERAU 1-meter telescope to image our object throughout the semester. The variable white dwarf we selected had to follow certain criteria and limits: short pulsation period of about 100-1400 seconds [3], the apparent magnitude must be within the limits of the ERAU 1-meter of 16-magnitudes with a long enough exposure to resolve our object, and the object's position in the sky must be available to observe during accessible telescope time, as well as not being affected by the moon.

GD 99 has an unusual pulsation period as four periods were identified (1058.1, 228.7, 1026.1 and 223.9s) with an amplitude of (7.0, 5.8, 4.0, and 2.4 mmag), respectively [4]. We are trying to replicate these results to confirm its unusual behavior, and ultimately create an O-C diagram to determine the cooling rate of our object. GD 99 will be observable anywhere between 7:30 pm to 3:30 am EST and has a right ascension of 09^h 01^m 48.6^s and declination of +36° 07¢ 7.7² from the dates February 24th to April 24th. GD 99 has a magnitude of 14.2, however, because DAV's have a surface composition of hydrogen [3], we will be using the R filter.

To obtain a reasonable SNR of about 850 per exposure for a 14.2-magnitude star, the exposure time will be 180 seconds with an estimated readout time of 10 seconds. We will need about 200-300 images in total to obtain this SNR, setting the observation time to 2 hours per night. We prefer to observe on dates where the moon is new to minimize any light interference due to our high magnitude star. Our object, due to how faint it is, would not be visible through our 1-meter because of the full moon and therefore we cannot observe on March 18 and April 16. Due to G 99's irregular pulsation behavior, a total of 20 hours is being requested to make sure the pulsation period is consistent with our observations.

A technical issue we foresee is the Daytona Beach light pollution playing a factor in our observation. Because we are imaging a 14-magnitude star with an irregular pulsation period at sea level in a humid climate, observation opportunities may be limited. In which case, we would like to utilize the SARA telescopes, specifically KPNO and CTIO, for their location advantage.