# White Dwarfs: Treasure Troves Waiting to be Discovered

## Review by Jacob Christensen

### I. Article Details

My review will be on an astrobite article named “Hunting for Variable White Dwarfs in the GALEX Archives”, which was written by Matthew Green and published on Dec 19, 2018. Matthew Green is a PhD student at University of Warwick, who specializes in white dwarf binary systems. The article was written in reference to the paper “Detections and Constraints on White Dwarf Variability from Time-Series GALEX Observations” written by Dominick M. Rowan et al (2018). This article caught my eye because I did my final project/paper on variable stars in Observational Astronomy.

### II. Article Summary

White dwarfs are anything but dormant, even though their days of nuclear fusion are over. Yes, they will eventually cool and become a black dwarf, the theoretical end of many stars, but they still hold onto enough heat to experience some stellar action. Variability in white dwarf apparent magnitude is of particular interest, and just like in fully-fledged younger stars, is caused by several different phenomena such as atmospheric instability and eclipsing binaries. Even planetary interactions can cause a white dwarf’s spectra to change from its predicted spectrum. To further explore and detect these factors affecting white dwarfs, the satellite GALEX was commissioned between 2003 and 2012 to capture data in the ultraviolet spectrum. It was highly effective, sweeping out as much as 77 percent of the sky.

In order to efficiently and effectively select stars that were of interest from the GALEX archives, the team of Rowan et al. (2018) first identified white dwarfs which were observed by GALEX. To further narrow down to variable white dwarfs, each star was pitted against four different measures of variability: Periodograms, which detect repeating patterns in the light curve of a star; Root-mean-square, a measure of dataset scatter; Instrumental noise, detected by comparing the same observation in different filters; and quality of data, determined by parameters such as signal-to-noise. All of this narrowed a total of 23,000 white dwarfs to 63 variables.

The variable white dwarfs were plotted on an HR diagram, color against absolute magnitude. The stars tended to clump together into two distinct groups, a reflection of the different kinds of white dwarfs that exist. In this case, HR diagram positioning highly correlates with the theoretical predictions for hydrogen dominated atmospheres (DA), or helium dominated atmospheres (DB), an indication that the team’s efforts to provide good data has paid off. The DB white dwarfs are good subjects of further study; it is not so clear as how they lost their hydrogen layers, but ideas include AGB thermal pulses or convective mixing. Figure 1 (Figure 2 in the astrobite article) shows all 63 variables and their designations on the HR diagram.

Additionally, 8 of the datapoints were found to be eclipsing systems, of which 7 were newly discovered. This is of particular interest because eclipsing systems give very precise measurements of stellar masses and radii. Figure 2 (Figure 3 in the astrobite article) displays the light curves generated by the team for these 8 systems.

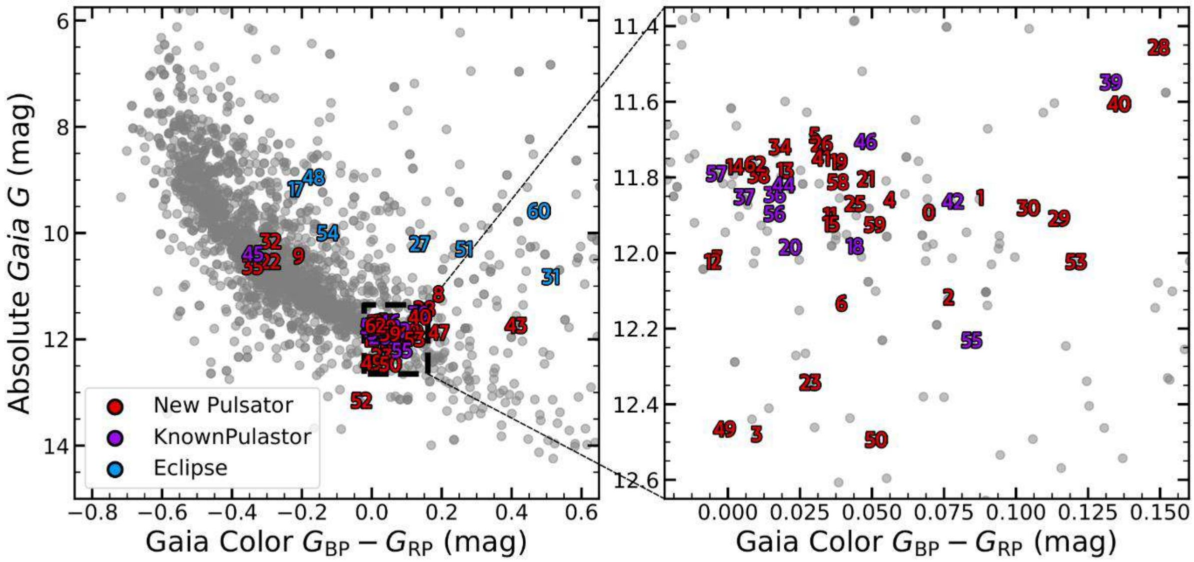


**Figure 1**: Taken from Figure 2 of Rowan et al. (2018). Notice that the pulsators clump into two groups along the sequence shown. As expected, eclipsing systems are generally higher in magnitude due to the presence of two stars.

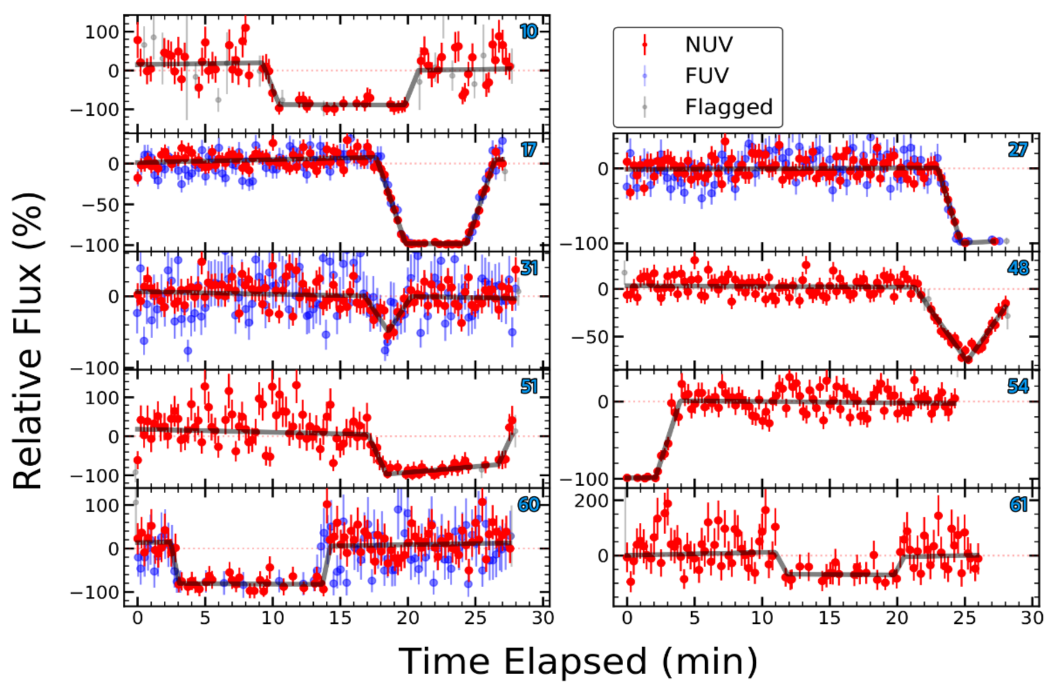

**Figure 2**: Taken from Figure 4 of Rowan et al. (2018). The first light curve shown was already known, with the others newly discovered. Red indicates near-ultraviolet, blue indicates far-ultraviolet. Each curve was generated using curve fitting software, showing the distinct drops in light.

Transiting exoplanets are not only highly effective ways of detecting planetary presence in a system, but also allow for in-depth study of the planet itself, including the size of the planet and even its atmospheric conditions. Unfortunately, no transiting planets showed up in the team's data. Previous estimates for the occurrence of such systems range between 1 to 10 percent chance of discovery. The team generated their own metric by manipulating their code to contain planetary transits, finding a probability of less than 0.5 percent that they would have seen the system if it were real. Even though this is lower than expected, it is in accordance with the rarity and thus value of searching for such systems in the future.

## III. Personal Reflection

I am highly interested in learning more about how the team who studied these white dwarfs picked out the best candidates for analysis. I studied my own multi-period variable star in Physics 329, using Period04 software to analyze which frequencies were real or spurious. I wonder if they used similar software but implemented into scripts which could automate the process, seeing they had over 23,000 stars to test. I can understand the effort that goes into such a task; making sure your science is good in astronomy can be very complicated since there are so many sources of error and noise in data—for instance, even the Earth's own rotation adds frequencies to a variable star you are observing. Also, one must consider the limitations of the equipment they use to observe, which the team did by comparing near and far ultraviolet data to ensure patterns were not instrumental. In my case, I worked with data from both a 12 and 8-inch telescope; the difference in quality of data was day and night. A truth of any astronomical investigation is that improvements can always be made, such as more data over longer periods of time, larger sample sizes, and often the addition of spectroscopic data to existing photometry, something the team lacked in this case.

It was exciting to be able to relate with the work done by a professional team of researchers, particularly with the physics of eclipsing binary systems. In Physics 228, we learned about how to measure a plethora of information from binaries such as stellar masses and radii. In our assignments, we used Kepler's Third Law along with radial velocity measurements to find individual masses, something made possible by inclination angle being guaranteed by the eclipse. Then, the eclipse time/velocity determined the radius of each star. Even though this paper did not delve into these physical parameters, it is very cool to see this team acknowledge the information we have learned in class—a confirmation of its relevancy. The other source of variable light discussed in the paper was pulsation. Upon reflection, I realized how well these two kinds of variability compliment each other. Pulsation gives us clues into the internal structure of the white dwarf, like how DA and DB dwarfs vary from a partially ionized zone of hydrogen or helium. A system with both eclipses and pulsation is like a jackpot of information.

In Physics 228 we learned about the classifications of white dwarfs based on their spectral lines, with the presence of metal lines being the defining feature of DZ white dwarfs. But how does a white dwarf, with its high surface gravity that pulls heavier materials beneath the surface, exhibit metal lines? Although the team found no transiting exoplanets around their stars, it is a well-known possibility that white dwarfs are orbited by debris and even planets which have survived their evolution. As the article mentions, such objects can even pollute a white dwarf's atmosphere, causing heavier materials to show up in its spectrum. This provides clues into what this alien solar system's heyday might have been like, back when planets were intact. Beyond studying white dwarfs to understand stellar evolution, we can learn the possible fate of our own solar system by looking at how these remaining planets interact with their parent star, now a white dwarf.

## IV. Conclusion

The team of Rowan et al. (2018) have primed the astronomy community for yet another investigation into the nature of stellar evolution. Using both high-quality technology and sophisticated data reduction processes, they ensured the quality of their observations, which goes a long way in increasing potential impact. White dwarfs are an interesting case study, they are stars exhibiting exciting physics that we still have much to learn about. From these newly discovered pulsator and binary systems, we will be able to study how well our mathematical relationships model real white dwarfs, such as the mass-volume relationship for degeneracy pressure. We can test our theories on the final stages of stellar lives seeing that white dwarfs record such information in their structure and composition. Indeed, white dwarfs can act as a link between the past and future of galaxies; other stars are formed with material thrown off of white dwarf planetary nebulae, and older stars inch ever closer to a fate possibly like the white dwarfs discovered by the team. Perhaps these white dwarfs will even aid in the effort to understanding the chemical evolution of our own Milky Way Galaxy. There is much information contained within white dwarfs that remains untapped, and this reason alone merits an astrobite article about the subject.

## V. References

*Detections and Constraints on White Dwarf Variability from Time-Series GALEX Observations,* Dominick M. Rowan, Michael A. Tucker, Benjamin J. Shappee, et al. 2019, Monthly Notices of the Royal Astronomical Society, vol. 486, no. 4, pp. 4574-4589

*Hunting for Variable White Dwarfs in the GALEX Archives*, astrobite review article by Matthew Green, Dec 19, 2018: https://astrobites.org/2018/12/19/galex_wds/