Journal of the Southeastern Association for Research in Astronomy, 4, 52–54, 2010 July 1

OBSERVATIONS AND PRELIMINARY RESULTS OF POTENTIALLY PULSATING WHITE DWARFS

Andrew D. Colson[1] & Terry D. Oswalt
Department of Physics and Space Sciences & The SARA Observatory, Florida Institute of Technology, Melbourne, FL 32901

ABSTRACT

In this paper we present the observations and analysis of the DQ white dwarfs G 24-9 and LP 101-16. Our objective was to search for pulsations via variations in their light curves and recurrent frequencies in their discrete Fourier transform spectra.

Subject headings: stars: white dwarfs, stars: binaries: eclipsing

1. INTRODUCTION

White dwarfs are stars that have used all of their nuclear fuel and whose cores have become electron degenerate. They are essentially dead stars that lie below the main sequence on the Hertzsprung-Russell (HR) diagram. In several places along the cooling track for WDs it is possible for pulsations to occur which manifest themselves as small amplitude variations in light. Variable stars are categorized into two types: intrinsic due to physical changes, or extrinsic due to stellar properties. Pulsating variable stars change in magnitude due to expansion and contraction of their outer layers. Cepheid variables, Mira variables, RR Lyrae stars, and RV Tauri stars are all known to have radial pulsations (see Fontaine & Brassard 2008), i.e. periodic changes radius while maintaining a (mostly) spherical shape. White dwarf stars are non-radial pulsators.

Pulsating WDs lie within several distinct instability strips in the HR diagram. Most pulsations are driven by H or He ionization zones within the envelope of the star (DOV, DAV and DBV spectral classes. Recently, several white dwarfs with carbon rich atmospheres (DQV) have been shown to pulsate as well (Montgomery et al. 2008; Dufour et al. 2008; Barlow et al. 2008). These all have temperatures ranging from 18,000-24,000K (Córsico et al. 2009). The discovery of pulsations in much cooler (old) DQ stars would open a new means of testing models of these type of WDs via the method of asteroseismology (see Stobie et al. 1995).

2. OBSERVATIONS

All photometric observations of G 24-9 presented in this paper were made on three separate nights using the SARA 0.9-m telescope at the Kitt Peak National Observatory. Two nights of data were collected remotely from Florida Institute of Technology on 2009 October 26 UT and 2009 June 24 UT using a clear and Johnson B filter, respectively. On the other night observations were obtained on site on 2009 June 19 UT using a Johnson B filter. Regardless of the filter used, all images were obtained using an Apogee U42 CCD camera with 60-second integration times. LP 101-16 was observed on 2009 June 18 UT at KPNO using a B filter and a 50-second integration time.

Electronic address: acolson@fit.edu; toswalt@fit.edu
[1] Southeastern Association for Research in Astronomy (SARA) NSF-REU Summer Intern.

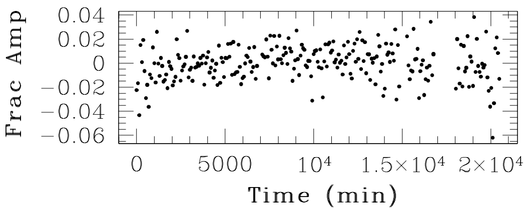

Fig. 1.— Light curve of G 24-9 observed on 2009 June 24 UT. See text for explanation.

3. DATA REDUCTION

All images from each night were bias, dark, and flat frame corrected using standard IRAF procedures. Next, time series photometry was performed on the WD and its companion stars using IRAF. The data extracted from this procedure include the number of counts in the WD, its companion stars, and the sky background.

3.1. *G 24-9: Results and Analysis*

We used SuperMongo to extract the star counts from the reduction process to generate a light curve (See Figure 1).

The light curve displayed in Figure 1 from observations on 2009 June 24 UT is the best data collected out of the 3 nights. Note that data were not collected between the time interval of 280 and 300 minutes due to a crash in the telescope control program. Although the counts in the target star and comparison two star dropped off due to clouds during various time intervals, the overall quality of the night was not seriously affected. This is evident from the low scatter (less than 0.002 percent) seen in the normalized ratio of the target star to comparison star. Small variations seen here may initially suggest that the WD is varying or pulsating on some level.

All data points greater than 3σ away from the mean were removed to eliminate any outliers and to minimize spurious frequencies in the derived DFT spectra. After the outliers were removed, all remaining points were normalized to have a value of zero with respect to the mean differential ratio of target (T) to comparison (C1) star. The end result is the normalized light curve shown in Figure 2.

The normalized light curve shows each point's displacement from the zero line, which represents the mean T/C1 ratio for the night. As time increases in Julian Date (JD), small fluctuations of each point's displacement from zero are evident.

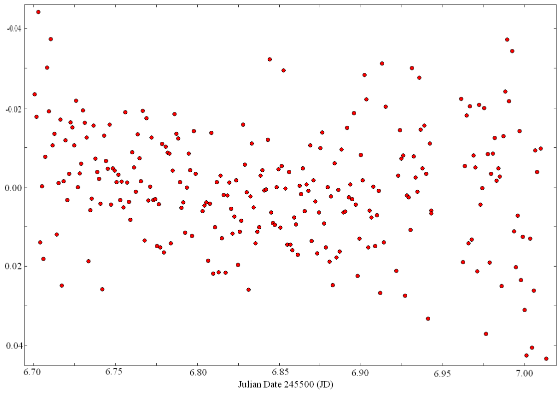

FIG. 2.— Normalized light curve of G 24-9 observed on 2009 June 24 UT. See text for explanation.

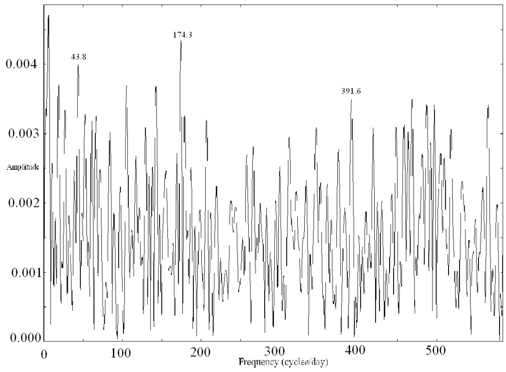

FIG. 3.— DFT of G 24-9 observed on 2009 June 24 UT. See text for explanation.

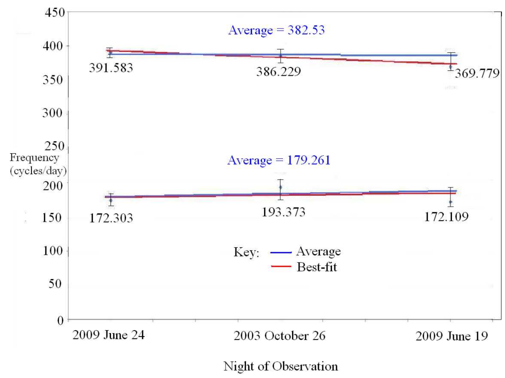

FIG. 4.— Frequency and errors of G 24-9 from all 3 nights observed. See text for explanation.

The construction of a Discrete Fourier Transform (DFT) spectrum helps reveal any significant frequencies present in the data. We adopted a threshold of significance of 4σ above the average amplitude, or noise level which is in accord with that used by other variable star observers to guard against false detections (see Breger et al. 1993).

The largest peak frequency in the DFT spectrum of G24-9 is at $\sim$6.0 cycles per day, but this can be ignored because it is an artifact resulting from the total time observed on this night. The largest significant amplitude peak of 0.0043 corresponds to a frequency of 174.3 cycles per day, or 8.3 minutes. This is within the expected time range for pulsations present in compact stars like WDs. However, the average amplitude or noise level is at 0.0016. Thus the suspected pulsation amplitude is only 2.7σ above the noise, and hence it does not meet our 4σ threshold for significance. The same procedure was used for the two highest amplitudes and corresponding frequencies to analyze each of the night's data. See Figure 4 for these results.

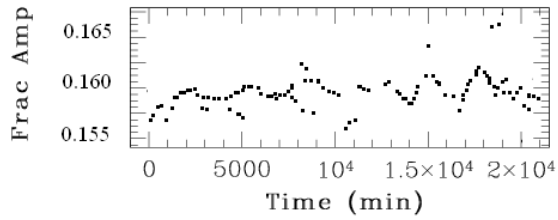

FIG. 5.— Normalized light curve of LP 101-16 observed on 2009 June 18 UT. See text for explanation.

Figure 4 shows the frequencies of the two largest amplitudes in the DFT spectra of G24-9 are present on all three nights it was observed. Although none of the frequencies are identical, they are identical within each other's error bars. Identical frequencies from night-to-night would be an indicator that G24-9 is pulsating, albeit at a very low level of significance. The close, but not identical frequencies may be directly related to the quality of data, reduction process, or just a coincidence. In order to rule these out, more data must be collected on contiguous nights, or with larger telescope apertures to improve the signal-to-nose ratio.

3.2. *LP 101-16: Results and Analysis*

The previously outlined procedure was also used to analyze the light curves obtained for the WD component LP 101-16. Figure 5 displays the normalized light curve of LP 101-16 observed on 18 June 2009 UT.

As can be seen in the fractional amplitude panel, there is a large amount of scatter in the data, which may mask any pulsations that are present. Throughout the night some clouds were present, as evident in the sky panel, and this may have created the large scatter. Figure 6 is the corresponding DFT for LP 101-16.

The DFT spectrum for the normalized light curve of LP101-16 shows a peak frequency near 93.7 cycles per day, or 15.4 minutes, with an amplitude of 0.0152. This amplitude is only 3.3σ above the noise, still below our 4σ threshold for pulsation detections. Again, no definitive statement about pulsations in this object can be made, however, given only one night of data, the 3.3σ result is encouraging. Therefore, it is strongly urged to collect more data on LP 101-16.

4. CONCLUSION

Based on the preliminary results in this paper, it is not plausible that the WDs G 24-9 and LP 101-16 pulsate at a very low level. However at the moment we have inconclusive results. The frequency of G 24-9 lies within the accepted periods of known pulsations in WDs. However,

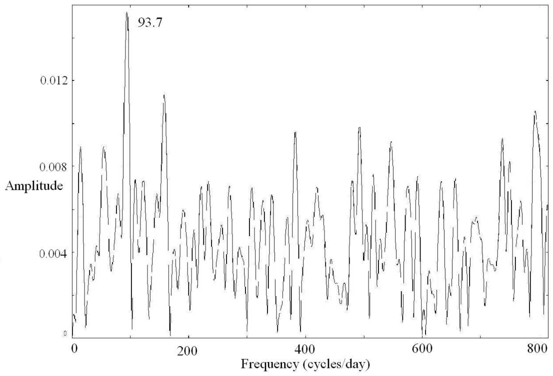

FIG. 6.— DFT of LP 101-16 observed on 2009 June 18 UT. See text for explanation

its SNR is well below our 4σ threshold for false detections. For LP 101-16, neither its frequency nor SNR are within the accepted standards, but the DFT from a single night cannot rule out pulsations in this object either.

We therefore recommend that follow up observations on both objects with telescopes of large apertures be undertaken to reduce the amount of noise. If peak frequencies of each night observed are consistent and between 8 to 15 minutes with a corresponding SNR greater than 4σ, then the objected should be seriously considered as a potential pulsating DQ WD.

This project was funded by a partnership between the National Science Foundation (NSF AST-0552798), Research Experiences for Undergraduates (REU), and the Department of Defense (DoD) ASSURE (Awards to Stimulate and Support Undergraduate Research Experiences) programs and NSF Major Research Instrumentation grant AST-0420753. This project was also funded in part by the NSF through grant AST-0807919 to the Florida Institute of Technology.

REFERENCES

Breger, M., et al. 1993, A&A, 271, 482
Córsico, A. H., Romero, A. D., Althaus, L. G., & García-Berro, E. 2009, A&A, 506, 835
Barlow, B.N., Dunlap, B.H., Rosen, R., Clemens, J.C. 2008, ApJ, 688, L95
Dufour, P., Fontaine, G., Liebert, J., Schmidt, G.D., Behara, N. 2008, ApJ, 683, 978
Fontaine, G., & Brassard, P. 2008, PASP, 120, 1043
Montgomery, M.H., Williams, K., Winget, D.E., Dufour, P. 2008, ApJ, 678, L51
Stobie, R. S., O'Donoghue, D., Ashley, R., Koen, C., Chen, A., & Kilkenny, D. 1995, MNRAS, 272, L21