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OBSERVATIONS OF VARIABLE WHITE DWARFS: ONE NEW VARIABLE AND 35 NONVARIABLES

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ABSTRACT

We report additional results of a survey for luminosity variations in white dwarfs. G207–9 is shown to be variable, and a list of the 35 nonvariable white dwarfs which have been observed thus far is presented. We show that the amplitude of the luminosity variations of a white dwarf is correlated with the morphology of the power spectrum of its light curve. The lower-amplitude variables have simpler and more stable power spectra, and have shorter periods of variation.

Subject headings: stars: variables — stars: white dwarfs

I. INTRODUCTION

The first variable white dwarfs which were discovered, HL Tau–76 (Landolt 1968), R548 (Lasker and Hesser 1971), and G29-38 (Schulov and Kopatskaya 1973), had similar properties: all were DA white dwarfs, all had colors near $(B - V) = +0.20$, and all were multiply periodic with periods of 200–1000 s. Prompted by the similarity of these properties, we have undertaken a survey for variability in other DA white dwarfs with colors near $B - V = +0.20$. Results given in two previous papers (McGraw and Robinson 1975, 1976) include confirmation of the variability of G117–B15A, first discovered by Richer and Ulrych (1974), and of G29–38; and the addition of three new variables: G38–29, GD99, and R808.

Heretofore we have neither described our survey technique nor given a list of the nonvariable white dwarfs which we have observed. The first purpose of this communication is to provide this information. The second purpose is to report that the DA white dwarf G207–9 is also a variable, thus increasing the number of known variable white dwarfs to 8. In the final section we compare the variable white dwarfs to the nonvariable white dwarfs, and then show that among the variable white dwarfs there is a strong correlation between the amplitude of their variations and the structure of the power spectrum of their light curves.

II. DESCRIPTION OF THE SURVEY AND NULL RESULTS

The objective of our survey was to answer a highly specific question: Is there an homogeneous and definable class of variable white dwarfs with characteristics similar to those of HL Tau–76? This objective is sufficiently specific that the techniques used in this survey differed in several respects from the earlier and more general surveys for variable white dwarfs (Hesser and Lasker 1972; Richer and Ulrych 1974). The first difference was in the choice of stars. Only DA white dwarfs with color indices in the range $+0.15 \leq B - V \leq +0.25$ were observed. Since prior knowledge of both the spectral type and color of the white dwarf was required, the choice of candidate stars for the survey was made from among members of the various lists of white dwarfs published by Greenstein and Eggen.

A second difference in this survey was in the method used to measure the light curves of the candidate stars. Considerable care was taken to produce a low-noise light curve. In order to minimize scatter in the light curve due to atmospheric scintillation and photon counting statistics, the observations were made in white light, the integration times were fairly long—typically 5–10 s—and with the exception of several of the brightest white dwarfs, each star was observed at least once with the 204 cm Struve reflector. The observations were made with the McDonald Observatory two-channel high-speed photometer (Nather 1973). The light curve of the white dwarf is measured with the first channel, while the light curve of a nearby field star is measured simultaneously with the second channel. The aperture of the second channel is slightly smaller than that of the first channel. Comparison of the first and second channels made it possible to estimate the effect on the light curves of guiding errors and rapid variations in atmospheric transparency, both of which can mimic the periodic and quasi-periodic luminosity variations in the variable white dwarfs.

The final difference in this survey was in the technique used to decide whether or not a white dwarf was variable. The survey was begun under the mistaken assumption that only a power spectrum of the light curve could adequately test for variability. Therefore, the white dwarfs were observed for a sufficiently long interval of time—typically 4–6 hr—that the power spectrum would be statistically stable at the low frequencies at which variations were to be expected. However, it soon became apparent that in every case in which variations were detected, they were *first* detected by simple visual inspection of the light curve. The power spectrum did no more than confirm the variations. Therefore, the interval of time over which the candidate stars were observed was reduced to 1–2 hr; that is, an interval of time only long enough to define the light curve. There-

after, we acquired longer light curves and calculated power spectra only if we had already detected variability, or if visual inspection of the light curve left us uncertain as to whether a star was variable. The primary example of the latter case was G169–34 (McGraw and Robinson 1976). It should be noted that this technique reduced the total telescope time required for the survey by a factor of about 2 or 3.

The 35 stars which have so far been observed in the survey and which have shown no sign of variability are listed, along with their $B - V$ magnitudes, in Table 1. From the nature of the survey, it is clear that the following cautionary notes must be added. (1) The survey would not normally have detected variations if the period of the variations were less than 20 s. (2) The survey would not detect variations with an amplitude less than 0.01 mag in stars brighter than magnitude 16, or less than 0.03 mag in stars fainter than magnitude 16. (3) Stars such as GD 99, in which the variations can disappear for perhaps an hour (McGraw and Robinson 1976), may have been judged to be constant. As a check on this problem, about 20 percent of the stars initially judged to be constant were reobserved. No additional variables were detected by the second observations.

TABLE 1

CONSTANT-LUMINOSITY DA WHITE DWARFS

EG	NAME	$(B-V)$
1	G130–49	+0.25
2	G31–35	+0.24
4	G1–8	+0.24
13	G94–9	+0.25
14	G71–B5B	+0.21
23	G37–44	+0.21
26	HZ 4	+0.15
30	HZ 10	+0.17
47	G105–B2 B	+0.21
69	G49–33	+0.25
73	TON 547	+0.16
84	L38	+0.23
92	G61–17	+0.22
112	G201–39	+0.23
117	G138–8	+0.23
120	...	+0.22
126	G21–16	+0.24
128	G141–54	+0.20
135	L79	+0.25
143	L85	+0.15
155	G67–23	+0.20
161	G128–72	+0.22
162	L93	+0.15
197	G169–34	+0.24
198	G181–B5B	+0.17
200	G155–24	+0.15
207	GD 31	+0.21
209	GD 64	+0.23
217	GD 91	+0.20
223	GD 189	+0.25
225	GD 215	+0.25
260	LTT–7873	+0.18
277	G185–32	+0.17
306	G172–4	+0.16
312	GD 25	+0.23

III. THE NEW VARIABLE: G207–9

The Journal of Observations of G207–9 is given in Table 2; and a portion of the light curve of G207–9, taken from run 1636, is displayed in Figure 1. Each point in Figure 1 is the mean photon counting rate averaged over 30 s, and corrected for atmospheric extinction. The maximum peak-to-peak variations are about 0.06 mag, but the mean amplitude of the variations is more nearly 0.04 mag. Even a cursory examination reveals a time scale of about 300 s for the variations.

A power spectrum of each light curve was calculated. Part of the power spectrum of run 1636 is shown in Figure 2. There are five features which recur in each power spectrum: Four large "spikes" at frequencies $f_1 = 1.354 \times 10^{-3}$ Hz, $f_2 = 1.794 \times 10^{-3}$ Hz, $f_3 = 3.145 \times 10^{-3}$ Hz, and $f_4 = 3.425 \times 10^{-3}$ Hz; and a small spike at about $f_5 = 3.860 \times 10^{-3}$ Hz. There are small changes in the amplitudes of each spike from run to run, but no detectable changes in their frequencies. The strong impression of a 300 s variation in the light curve appears to be due to frequencies f_3 and f_4, corresponding to periods of 318.0 s and 291.9 s, respectively.

Peculiar numerological relationships have been found among the frequencies of the variations of four of the previously known variable white dwarfs. The two frequencies of variation in R548 have a ratio of very

TABLE 2

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Run No.	Starting Time (JD 2,442,500.0+)	Integration Time (seconds)	No. of Integrations
1620	66.83295	5	1883
1626	68.78426	10	1024
1636 A & B	77.72623	10	1880

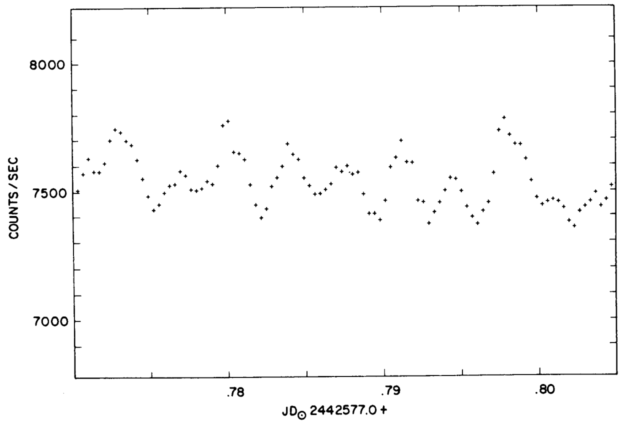

FIG. 1.—A portion of the light curve of G207–9 during run 1636. Each point is the mean photon counting rate averaged over 30 s and corrected for atmospheric extinction.

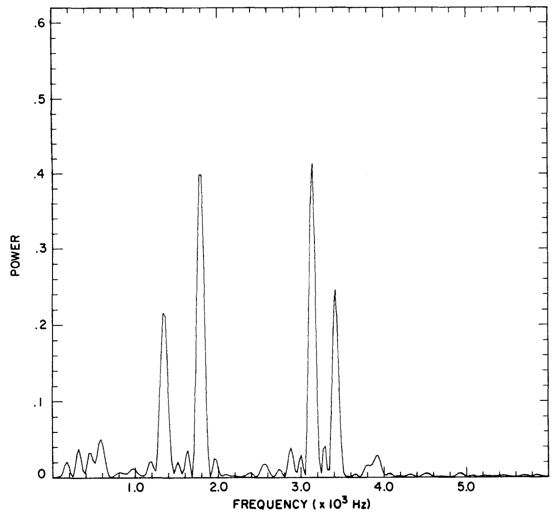

FIG. 2.—The power spectrum of the light curve of G207–9. In addition to the four major frequencies at 1.35×10^{-3} Hz, 1.794×10^{-3} Hz, 3.145×10^{-3} Hz, and 3.425×10^{-3} Hz, there is a significant minor frequency at 3.86×10^{-3} Hz. None of the remaining features are stable enough to recur in the power spectra of the other two runs.

nearly 5:4 (Lasker and Hesser 1971). In the case of HL Tau–76, G29–38, and G38–29, the multitudinous frequencies which occur in the power spectra can be shown to be simple pairwise linear combinations of just two to five basic frequencies (Fitch 1973; McGraw and Robinson 1975). G207–9 presents yet another example of these relationships: $f_5 - f_4 = f_2 - f_1 = 0.440 \times 10^{-3}$ Hz to within the limits of measurement. We found the identical relation among four of the five basic frequencies in G29–38 (McGraw and Robinson 1975), and suggested at that time that rotational splitting of a nonradial pulsation mode could account for such a relationship. The same physical mechanism could account for the relationship of the frequencies in G207–9.

IV. DISCUSSION

The eight variable white dwarfs are listed in Table 3 along with their spectral types and *UBV* colors. G207–9 conforms exactly to the characteristics which we have previously deduced for this class of variables (McGraw and Robinson 1976): (1) all are DA white dwarfs; (2) all have colors in the range $+0.16 \leq B - V \leq +0.20$; (3) all are multiply periodic with periods in the range of 200–1000 s. The narrowness of the instability strip in the color-color diagram must be deemed remarkable. Figure 3 is the color-color diagram of both the variables from Table 3 and the nonvariables from Table 1. The limits of the instability strip are sharply defined, and within the strip fully 50 percent of the white dwarfs are variable. The narrowness of the strip is even more remarkable since the faintness and intrinsic variability of the stars could produce large errors in the measurement of their colors. The observed width of the strip is not inconsistent with a true width of only 0.01–0.02 mag. Because of the potential for observational errors, it would be premature to conclude that both variables and nonvariables peacefully coexist within the instability strip.

With the addition of G207–9 to the list of variable white dwarfs, a correlation between the amplitude of the variations and the structure of the power spectrum can be found. The variations in G117–B15 A, R548, and G207–9 have a low amplitude, and the power spectra are relatively simple. The variations in G117–B15 A have a maximum peak-to-peak amplitude of about 0.08 mag, and its power spectrum shows only one major frequency. The variations in R548 can have an amplitude of up to 0.03 mag, and its power spectrum shows two frequencies. The variations in G207–9 have an amplitude of up to 0.06 mag, and its power spectrum shows five frequencies. Furthermore, the power spectra of these three stars are relatively stable. The frequencies of variation are constant to within the errors of measurement; and although the amount of power in those frequencies varies, the variations are comparatively small. Finally, the periods of variation of the three low-amplitude variables are comparatively short, typically being in the range of 200–700 s.

TABLE 3

THE LUMINOSITY-VARIABLE DA WHITE DWARFS

EG	NAME	Sp	*V*	$(B-V)$	$(U-B)$
10.....	R548	DA	14.10	+0.20	−0.55
34.....	G38–29	DAs	15.63	+0.16	−0.53
65.....	G117–B15A	DA	15.52	+0.20	−0.56
115.....	R808	DA	14.36	+0.17	−0.56
127.....	G207–9	DAn	14.64	+0.17	−0.60
159.....	G29–38	DA	13.10	+0.20	−0.65
219.....	GD 99	DA	...	+0.19	−0.59
265.....	HL Tau–76	DA	15.2	+0.20	−0.50

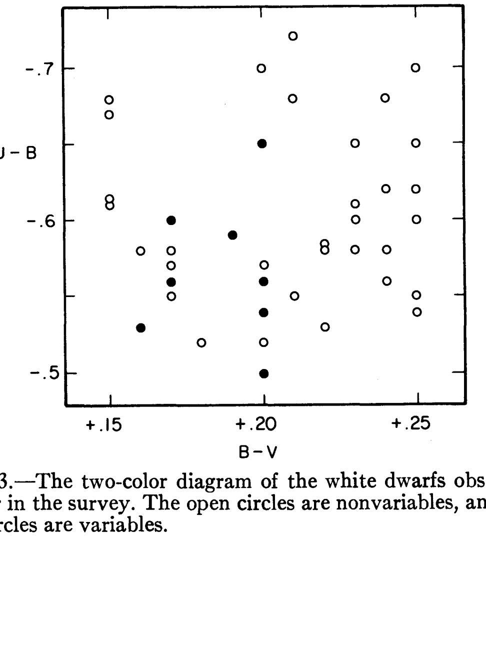

FIG. 3.—The two-color diagram of the white dwarfs observed thus far in the survey. The open circles are nonvariables, and the filled circles are variables.

The amplitudes of the variations in the other five white dwarfs are large, and range from perhaps 0.15 mag in GD 99 to 0.34 mag in HL Tau–76. The power spectra of these stars are very complex, and can have significant power at dozens of frequencies. Numerological regularities of the sort discussed in the previous section can be found in the power spectra of some of the variables (e.g., HL Tau–76, G29–38, and G38–29), but nearly as often the power spectrum is essentially unintelligible. The power spectra are extremely unstable and can show dramatic changes in both frequency and amplitude on time scales as short as a few hours. Finally, the periods of variation of the large-amplitude variables are very long, typically being 700–1000 s.

In summary, then, the correlation is that the low-amplitude variables have simple and stable power spectra and their periods of variation are short, whereas the large-amplitude variables have complex and unstable power spectra and the periods of variation are long.

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