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# HIGH-SPEED PHOTOMETRY OF LUMINOSITY-VARIABLE DA DWARFS: R808, GD 99, AND G117–B15A

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## ABSTRACT

GD 99 and R808 are shown to be luminosity variable white dwarfs of the same type as HL Tau 76. The variability of G117–B15A is also confirmed. We show that the luminosity-variable white dwarfs make up a homogeneous and definable class of variable stars with the following characteristics: (1) The spectral type is DA. (2) The colors lie in the range $0.16 \leq (B - V) \leq 0.20$. (3) Power spectra of the light curves indicate that the variations are periodic or pseudo-periodic and have periods in the range of 200–1000 s. We suggest that the variations are caused by pulsations, and that the pulsations are driven by the classical Cepheid ionization zone mechanism.

*Subject headings:* stars: pulsation — stars: variable — stars: white dwarf

## I. INTRODUCTION

A small group of DA white dwarfs have displayed luminosity variations: HL Tau 76 (Landolt 1968), R548 (Lasker and Hesser 1971), G29-38 (Shulov and Kopatskaya 1973), G117–B15A, and G169-34 (Richer and Ulrych 1974, hereafter referred to as RU). The light curves show quasi-regular variations with amplitudes between 0.01 and 0.3 mag, depending on the star. Power spectra of the light curves have a complex low-frequency structure which appears to be nonstationary on time scales of both hours and days. The periods corresponding to the strongest peaks in the power spectra are typically 5–15 min, and thus are several orders of magnitude too long to be radial pulsations of white dwarfs (cf. Osaki and Hansen 1973). With the exceptions of G169-34 which has a color of $(B - V) = +0.24$, all of the variables have colors near $(B - V) = +0.20$.

We are presently engaged in a program of observations of the variable white dwarfs which has the immediate goals of confirming the known variables, of finding new variables, and of clarifying the photometric properties of the variables. The results given in an earlier paper (McGraw and Robinson 1975, hereafter referred to as Paper I) confirmed the variability of G29-38, and showed that G38-29 is also a variable white dwarf. This *Letter* presents further results. The DA white dwarfs R808 and GD 99 are shown to be variables, and the variability of G117–B15A is confirmed. We do not, however, concur with RU that G169-34 is a variable. We suggest that the remarkably homogeneous characteristics of the confirmed variable DA white dwarfs indicate that the physical mechanism which produces the variations is the same for all the variables. The most likely mechanism is nonradial white dwarf pulsations.

## II. THE LIGHT CURVES AND SPECTRAL ANALYSIS

All observations were made at McDonald Observatory using either the 2 m or the 92 cm telescope. A computer-controlled two-channel pulse-counting photometer (Nather and Warner 1971) was used to obtain the data. The observational techniques were similar to those described in Paper I. Figure 1 shows portions of the light curves of R808, GD 99, G117–B15A, and G169-34 expressed in detected photons per second reduced to outside the atmosphere.

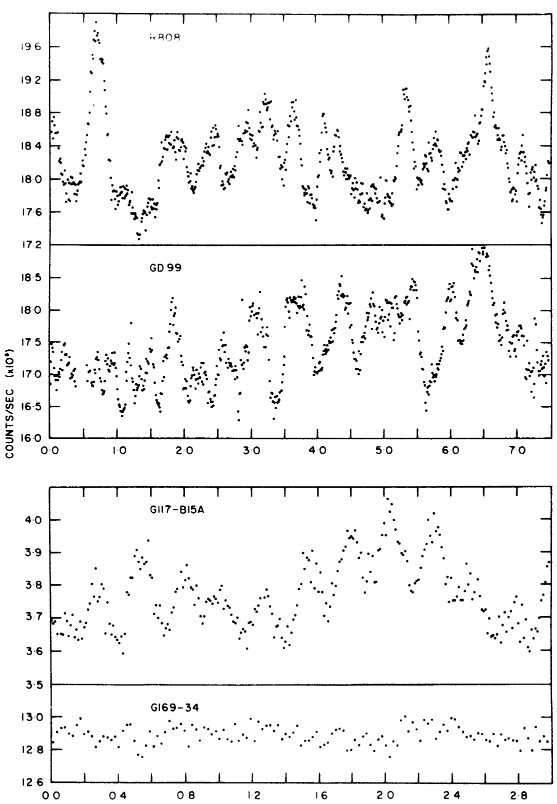


FIG. 1.—Segments of the light curves of R808, GD 99, G117–B15A, and G169-34. Abscissae are expressed in days and ordinates in detected photons outside the atmosphere.

*a*) *G117–B15A*. G117–B15A was observed on 1974 December 16 and 1975 March 6. It is one of the most regular of the white-dwarf variables discovered thus far. The light curve is nearly sinusoidal and has a constant peak-to-peak amplitude of about 0.08 mag. Changes in the mean light level are small, 0.05 mag at most. A period of about 216 s can be derived directly from the light curve. The power spectra of the light curves of G117–B15A are shown in Figure 2, and confirm that the variations are nearly sinusoidal. There is only one strong peak in each power spectrum, and in each spectrum the peak is at a frequency of $4.63 \times 10^{-3}$ Hz. There are, however, two secondary peaks which also reproduce in each spectrum: one at $3.25 \times 10^{-3}$ Hz, and one at $3.68 \times 10^{3}$ Hz. Thus, G117–B15A is similar to R548 in the morphological simplicity of its luminosity variations.

*b*) *R808*. R808 was observed on four nights in March and April of 1975. The variations of R808 are similar to the variations of HL Tau 76, G29-38, and G38-29. The variations have a peak-to-peak amplitude of about 0.15 mag. The light pulses typically have a rapid rise to a sharp maximum followed by a slower decline to a somewhat broader minimum. The light curve appears to be more irregular than that of HL Tau 76, however. Power spectra of the light curves of R808 have been calculated. The principal peaks in the power spectra always lie in the frequency range $0.8 \times 10^{-3}$ and $1.3 \times 10^{-3}$ Hz. The structure of the power spectrum in this range is complex, and varies both over the course of a night and from night to night. The only peak in the power spectra which reproduces even approximately from night to night is at a frequency of about $1.2 \times 10^{-3}$ Hz. There are no stable frequency spacings which which might indicate rotational splitting of modes of nonradial oscillations such as were found in G29-38 (Paper I). Nor is there any convincing evidence that nonlinear coupling of the various frequencies is occurring, an effect found in HL Tau 76 (Page 1972; Fitch 1973), G29-38, and G38-29 (Paper I).

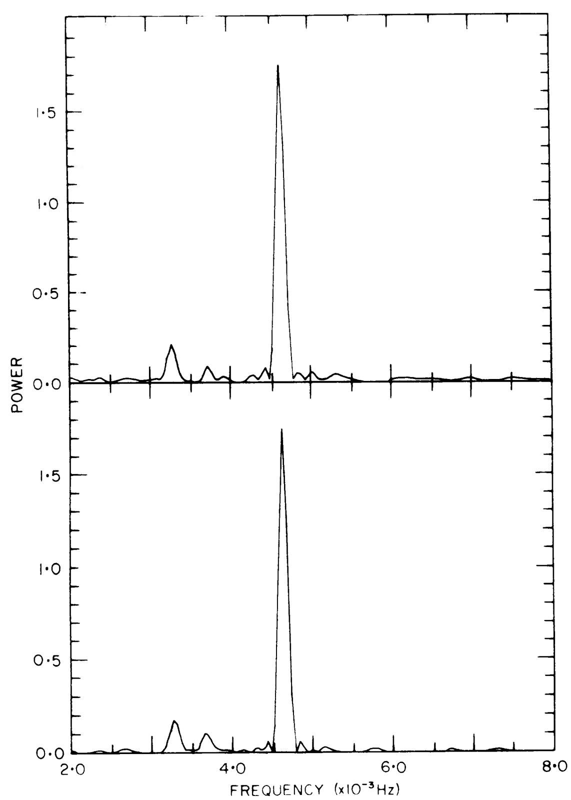


FIG. 2.—*Upper curve*, power spectrum of the light curve of G117–B15A in 1974 December. *Lower curve*, power spectrum of the light curve in 1975 March.

*c*) *GD 99*. GD 99 was observed on four nights in March and April of 1975. GD 99 has the most irregular light curve of any of the DA variables yet discovered. The light curve only occasionally shows distinct pulsations. Variations in the mean light level, sometimes mimicking transparency variations, often occur. Peak-to-peak amplitudes of distinct pulses range from about 0.05 to 0.15 mag. The light curve of GD 99 is the best example of an effect we have occasionally noted in the other variable white dwarfs: the light curve can become almost totally quiescent for intervals of up to about an hour. The power spectra of the light curves of GD 99 are exceedingly complex and exceedingly variable. It is virtually impossible to define even a restricted bandpass within which the bulk of the power occurs. The lower limit to the frequencies at which we detect power is limited by the length of our light curves, not by the star itself. Significant power can occur at frequencies as high as $1.0 \times 10^{-2}$ Hz. We have not found any regularities in the power spectrum.

*d*) *G169-34*. G169-34 was observed on two nights in 1975 March. The light curve deviated in no manner from the light curve of the comparison star simultaneously observed with the second channel. There was no low-level photometric activity which might indicate that we had fortuitously observed this star during periods of relative inactivity. Power spectra of the light curves have been calculated and are entirely consistent with white noise. Succinctly, G169-34 was a constant star when we observed it. It is possible, of course, that the character of G169-34 has changed since it was observed by RU.

## III. DISCUSSION

R808 and GD 99 are new variable DA white dwarfs of the same class as HL Tau 76. G117–B15A is also confirmed as a variable of this type, but the period structure of the star is completely different from that reported by RU. They give a period of 1311 s as opposed to the period of 216 s derived in this work. The confirmed DA variables and their colors are given in Table 1.

Using the photometry of Eggen and Greenstein (1965*a*, *b*, 1967) and Greenstein (1969, 1970, 1974), we have plotted in Figure 3 the two-color diagram for DA white dwarfs showing the locus of the confirmed variables. They form a close group in this plane, all of

TABLE 1

LUMINOSITY-VARIABLE DA WHITE DWARFS

| EG | Name | SP | $(B-V)$ | $(U-B)$ | $T_e\,(U-V)$ |
|---|---|---|---|---|---|
| 10 | R548 | DA | +0.20 | −0.54 | 9510 |
| 34 | G38-29 | DAs | +0.16 | −0.53 | 10285 |
| 65 | G117–B15A | DA | +0.20 | −0.56 | 9980 |
| 115 | R808 | DA | +0.17 | −0.56 | 10900 |
| 159 | G29-38 | DA | +0.20 | −0.65 | 13260 |
| 219 | GD 99 | DA | +0.19 | −0.59 | 11200 |
| 265 | HL Tau 76 | DA | +0.20 | −0.50 | 8690 |

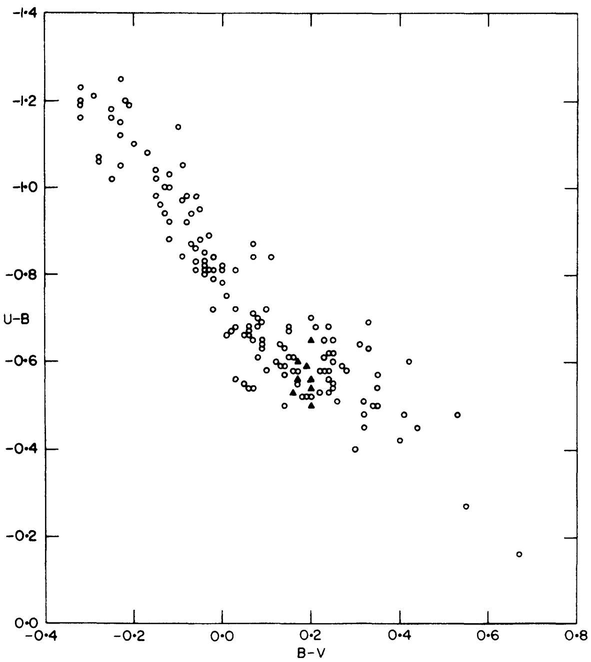


FIG. 3.—The two-color diagram for the EG DA white dwarfs. *Filled triangles*, the confirmed variable DA dwarfs.

them lying in the range $+0.16 \leq (B - V) \leq +0.20$. The DA variables are obviously different from other known white-dwarf variables of spectral type DB such as G61-29 and AM CVn which appear to be binaries whose rapid variations are probably due to helium mass transfer (cf. Warner 1972; Warner and Robinson 1972; Robinson and Faulkner 1975). We suggest that the recently proposed ZZ Ceti class of variable stars (Kukarkin *et al.* 1971) be reserved for the DA variables in Table 1 and specifically exclude the DB variables since the mechanism of variation is almost certainly different.

As was found in Paper I, the power spectra of the two new variables indicate a nonstationary process is responsible for the luminosity variations. The periodicities indicated are about two orders of magnitude longer than theory predicts for radial pulsations in white dwarfs and about a factor of 2 longer than predicted periods of *g*-mode nonradial pulsations (Ostriker 1971; Osaki and Hansen 1973; Brickhill 1975). Nevertheless, since the periodicities are not stable in frequency or amplitude, orbital revolution and rotation can be ruled out as direct contributors to the observed variations, and pulsation remains the most viable mechanism for producing the variations.

G117–B15A appears to be an exception to these comments since the power spectra indicate a stationary process and the principal period is short enough to be interpreted as either an orbital or rotational period or a nonradial pulsation on a nonrotating star. Arguing against the first two explanations are the two small but significant repetitive peaks in the power spectra. An orbital period of 216 s implies a separation of only $5.4 \times 10^9$ cm or about 7.5 white-dwarf radii. If rotation produces this periodicity, the surface features modulating the light must persist virtually exactly for periods of about 3 months. On the other hand, since the colors of G117–B15A are similar to the colors for the other DA variables, it is not unreasonable to assume that its variations are also caused by pulsations.

Two mechanisms for producing pulsational instability in a white dwarf suggest themselves: hydrogen shell burning and the classical Cepheid ionization zone mechanism. The variables are at the cool end of the DA sequence. Using Shipman's (1972) $(U - V, T_e)$-calibration, we derive a mean $T_e$ of about 10,500 K for these stars, with individual effective temperatures given in Table 1. Vauclair (1971) has compared the relative instabilities to radial pulsations produced by shell burning and the Cepheid mechanism in a series of models in which the total luminosity derives from hydrogen burning. For the hotter models shell burning is important in producing the instability, but at $T_e =$ 11,040 K and cooler the Cepheid mechanism is most important, and these models would be unstable even without the shell-burning source. It would seem that the Cepheid mechanism may be important in producing the instabilities observed in the variable DA dwarfs; but if this is the case, how this manifests itself in the long, unstable observed periodicities has yet to be determined. Certainly the temperature boundaries for the onset of the Cepheid mechanism in white dwarfs deserves further attention.

In conclusion, the seven known variable white dwarfs make up a homogeneous class of variable stars with the following characteristics: (1) The spectral type is DA. (2) The colors lie in the range $+0.16 \leq B - V \leq +0.20$. (3) The light curves are periodic or pseudo-periodic and have periods in the range 200–1000 s. We have suggested that the variations are pulsations, and that the pulsations are driven by the classical Cepheid ionization zone mechanism.

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## REFERENCES


Brickhill, A. J. 1975, *M.N.R.A.S.*, **170**, 405.
Eggen, O. J., and Greenstein, J. L. 1965*a*, *Ap. J.*, **141**, 83.
———. 1965*b*, *ibid.*, **142**, 925.
———. 1967, *ibid.*, **150**, 927.
Fitch, W. S. 1973, *Ap. J. (Letters)*, **181**, L95.
Greenstein, J. L. 1969, *Ap. J.*, **158**, 281.
———. 1970, *Ap. J. (Letters)*, **162**, L55.
———. 1974, *ibid.*, **189**, L131.
Kukarkin, B. V., Kholopov, P. N., Pskovsky, Yu. P., Efremov, Yu. N., Kukarkina, N. P., Kurochkin, N. E., Medvedera, G. I., Perova, N. B., Fedorovich, V. P., and Frolov, M. S. 1971, *General Catalog of Variable Stars* (2d Suppl.; Moscow).
Landolt, A. U. 1968, *Ap. J.*, **153**, 151.
Lasker, B. M., and Hesser, J. E. 1971, *Ap. J.*, **163**, 289.
McGraw, J. T., and Robinson, E. L. 1975, *Ap. J. (Letters)*, **200**, L89 (Paper I).
Nather, R. E., and Warner, B. 1971, *M.N.R.A.S.*, **152**, 209.
Osaki, Y., and Hansen, C. J. 1973, *Ap. J.*, **185**, 277.
Ostriker, J. P. 1971, *Ann. Rev. Astr. and Ap.*, **9**, 353.
Page, C. G. 1972, *M.N.R.A.S.*, **159**, 25p.
Richer, H. B., and Ulrych, T. J. 1974, *Ap. J.*, **192**, 719 (RU).
Robinson, E. L., and Faulkner, J. 1975, *Ap. J. (Letters)*, **200**, L23.
Shulov, O. S., and Kopatskaya, E. N. 1973, *Astrophysica*, **10**, 117.
Shipman, H. L. 1972, *Ap. J.*, **177**, 723.
Vauclair, G. 1971, in *IAU Symposium 42, White Dwarfs*, ed. W. J. Luyten (Dordrecht: Reidel), p. 145.
Warner, B. 1972, *M.N.R.A.S.*, **159**, 315.
Warner, B., and Robinson, E. L. 1972, *M.N.R.A.S.*, **159**, 101.



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