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G29-38 AND G38-29: TWO NEW LARGE-AMPLITUDE VARIABLE WHITE DWARFS

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ABSTRACT

G29-38 and G38-29 are shown to be luminosity-variable white dwarfs whose characteristics are similar to those of HL Tau–76. Power spectrum analysis shows that the light curves of both stars have a complex low-frequency structure that is variable with time. It is suggested that many but not all of the features in the power spectra of these two stars could result from nonradial pulsations in a rotating white dwarf.

Subject headings: variable stars — white dwarf stars

I. INTRODUCTION

Several luminosity variable DA white dwarfs are now known: HL Tau–76 (Landolt 1968), R548 (Lasker and Hesser 1971), G117–B15A, and G169-34 (Richer and Ulrych 1974). HL Tau–76, which may be considered the prototype of this class of variables, was discovered by Landolt (1968), who found it to have a photometric period of 12.5 min and an amplitude of about 0.3 mag, both of which appeared to be unstable. By examining the power spectrum of the light curve, Warner and Robinson (1972), Page (1972), and Fitch (1973) found a period structure of considerable complexity. Fitch isolated three periodicities, $P_0 \approx 12.436$ min, $P_1 \approx 8.237$ min, and $P_L \approx 0^d.135$, which he suggested were nonlinearly coupled to produce the variations.

In this paper, we show that G38-29 is a variable white dwarf and also confirm the variability of G29-38, originally discovered by Shulov and Kopatskaya (1973). Both are similar to HL Tau–76, thus raising the total to six known variable DA white dwarfs.

II. OBSERVATIONS

Table 1 gives the Journal of Observations for G29-38 and G38-29. All data were obtained with a computer-controlled two-channel pulse-counting photometer (Nather and Warner 1971). The diameter of the aperture of the primary channel was 15″. The second channel, with an aperture about 10 percent smaller than the primary channel, was used to monitor a constant star near the variable to ensure that variations in sky transparency or guiding errors did not contaminate the observations. An RCA 31034A photomultiplier with a copper sulfate filter was used except for run 1591 for which an EMI 9658 photomultiplier with no filter was used. All runs were obtained using the 2.08-m Struve telescope at McDonald Observatory except for run 1585 which was obtained on the 0.92-m telescope.

Portions of light curves of G29-38 and G38-29, expressed in number of detected photons per second reduced to outside the atmosphere, are shown in Figure 1. The light curves bear a striking resemblance to the light curve of HL Tau–76 (c.f. Warner and Nather 1972). The pulse shape is asymmetric and usually has a rapid rise to a sharp maximum and a slower decline followed by a broad minimum. The time scale of the variations is about 1000 s, but the light curves are not regular in either pulse shape or amplitude, and there is no obvious periodicity. The peak to peak amplitude of the variations is about 0.23 mag for G29-38, and about 0.20 mag for G38-29. The colors and spectral types of G29-38 and G38-29 along with those of the other known variable white dwarfs are collected in Table 2 (Eggen and Greenstein 1965, 1967; Greenstein 1969). The similarity of the colors, which cluster about $(B-V) = 0.20$ and $(U-B) = 0.55$, and the similarity of the spectral types, all of which are DA, testifies to the homogeneity of the group.

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TABLE 1

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Run No.	Date (UT)	Starting Time (UT)	Integration Time (s)	Number of Points
		G29-38		
1427....	1974 Oct. 16	03:27:57	5	3696
1431....	1974 Oct. 17	02:24:39	5	2978
1439....	1974 Oct. 21	01:34:50	2	6671
		G38-29		
1585....	1975 Jan. 7	02:45:09	10	3264
1591....	1975 Jan. 21	03:12:19	10	2720

TABLE 2

LUMINOSITY-VARIABLE WHITE DWARFS

EG	Name	Sp	$(B-V)$	$(U-B)$
10.....	R548	DA	+0.20	−0.54
34.....	G38-29	DAs	+0.16	−0.53
65.....	G117–B15A	DA	+0.20	−0.56
159.....	G29-38	DA	+0.20	−0.65
197.....	G169-34	DAss	+0.24	−0.62
265.....	HL Tau–76	DA	+0.20	−0.50

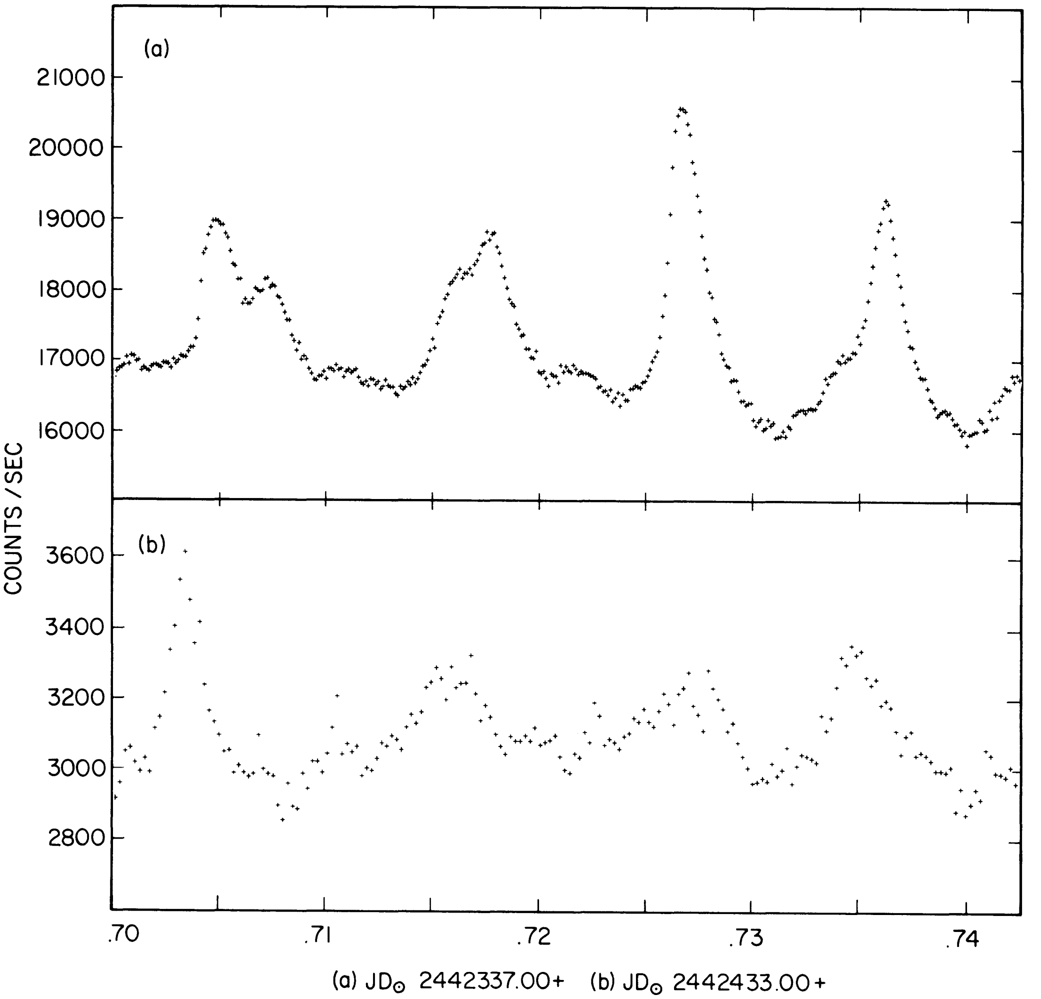

FIG. 1.—(*a*) A segment of the light curve of G29-38, run 1431. The abscissa is expressed in days, the ordinate in detected photons per second outside the atmosphere. Each plotted point is the average of two 5-s integrations. (*b*) A segment of the light curve of G38-29, run 1591. Two 10-s integrations were averaged to produce each plotted point.

III. POWER SPECTRUM ANALYSIS

A power spectrum of each run has been calculated in order to test for periodicities in the light curves. In each case the power spectrum is nearly flat from about 0.008 Hz to the Nyquist frequency, indicating that only white noise is present in this bandpass. But, as in HL Tau–76, a complex group of peaks appears in the power spectra at low frequencies. The low-frequency power spectra are shown in Figures 2 and 3. There is an obvious pattern to the major peaks in the spectra. In G29-38 there are always four and occasionally five major peaks confined within the bandpass 0.95×10^{-3} Hz to 1.7×10^{-3} Hz. In G38-29 one or two major peaks fall in the similar, but narrower, bandpass 0.95×10^{-3} Hz to 1.1×10^{-3} Hz. Closer inspection indicates that the peaks are variable in both amplitude and frequency not only from run to run (showing that the variations can occur on time scales of a day or longer), but also during the course of individual runs (showing that the variations can occur on time scales as short as a few hours). The frequencies of the major peaks in the power spectra of each run are listed in Table 3. The differences from run to run among the frequencies are too large to be accounted for either by measurement error or by systematic errors introduced in the calculation of the power spectra. The changes in the relative amplitudes of the peaks can be easily seen in Figures 2 and 3. Power spectra of the first and second halves of each run were calculated which showed that distinct changes in the amplitudes and frequencies of the major peaks occurred during the course of each run. The changes are of the same order of magnitude as those that occur between individual runs.

It is possible that given sufficiently long light curves, the power spectra of the light curves of G29-38 and G38-29 would be independent of time. However, on the time scales we have considered, the power spectra are not independent of time, and the physical process which generates the light curves must be considered nonstationary. Thus, the spectra are amplitude-

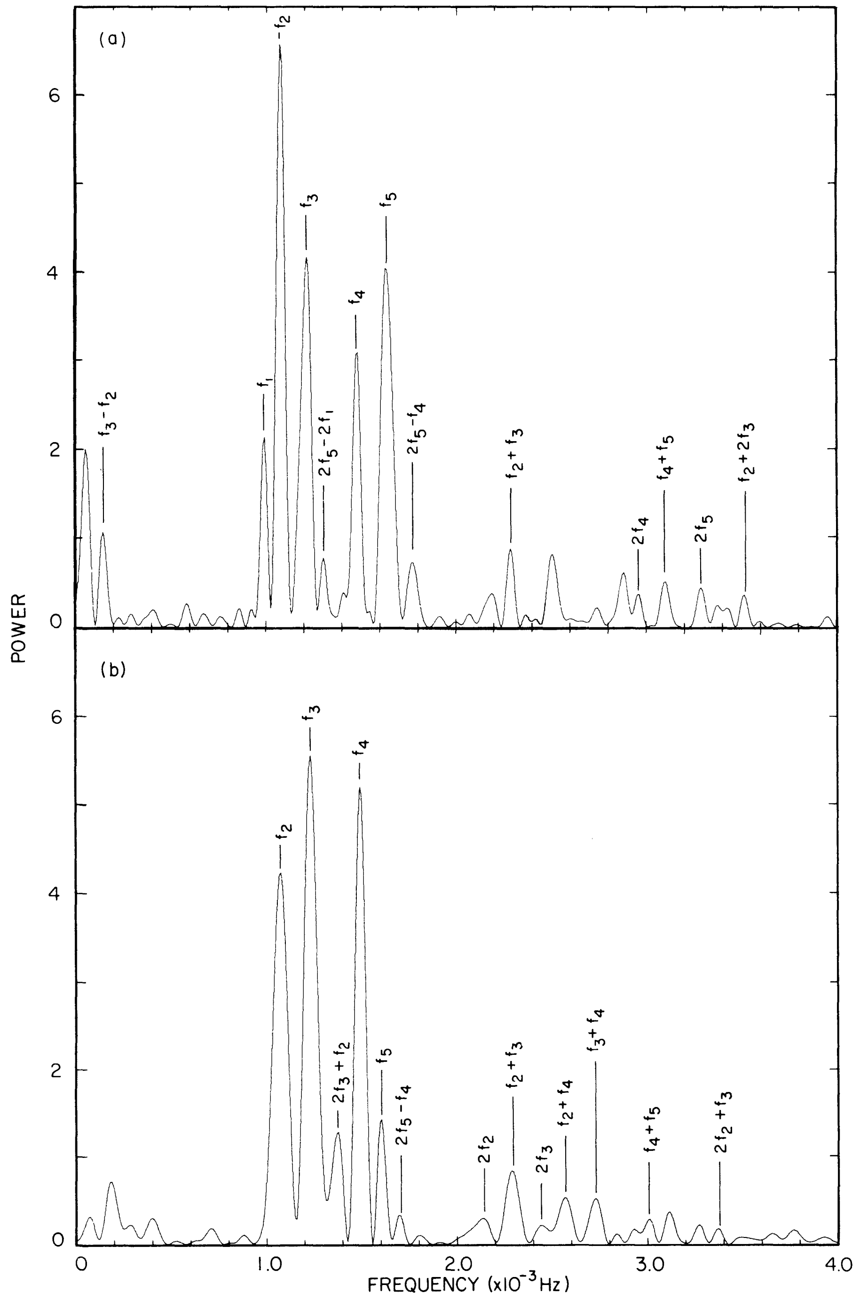

FIG. 2.—Two low-frequency power spectra of light curves of G29-38: (*a*) run 1427, (*b*) run 1431. Assuming a peak at frequency f represents a strictly periodic variation, the power of the peak $P(f)$ is related to one-half the peak-to-peak signal in the light curve by $\Delta m = -2.5 \log \{1 + [2P(f)/N\Delta t]^{1/2}\}$, where Δm is in magnitudes, Δt is the sampling interval, and N is the number of points in the transform. For all spectra in this paper, $N = 4096$ and $\Delta t = 30$ s. The noise level in the spectra is less than 10^{-3} in power. Major peaks and a few of the peaks identified with linear combinations of major peaks are indicated.

weighted mean representations of the light curves, and, in the absence of additional information, the peaks in the spectra must be literally interpreted as the power present at a given frequency, and not as an indicator of a strictly periodic component to the light curve. With this proviso in mind, we have searched for relationships among the frequencies at which peaks occur.

The most striking relationship is the nearly even spacing of four of the major peaks in G29-38. Averaged over the three runs, the spacings are $\langle f_3-f_2 \rangle \approx \langle f_5-f_4 \rangle \approx 0.14 \times 10^{-3}$ Hz, and $\langle f_4-f_3 \rangle \approx 0.26 \times 10^{-3} \approx$

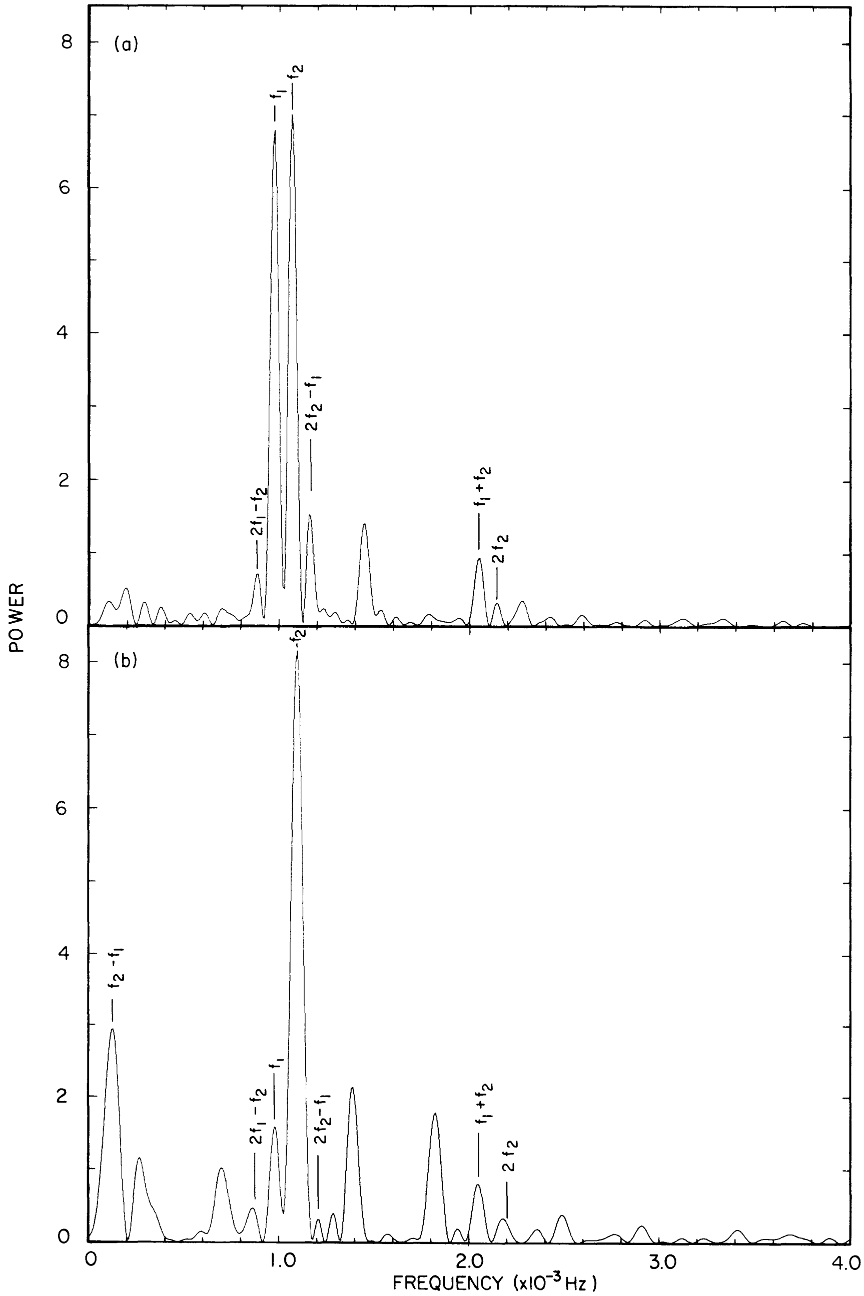

FIG. 3.—Low-frequency power spectra of light curves of G38-29: (*a*) run 1585, (*b*) run 1591. The noise level in these spectra is less than 10^{-2} in power. The two major frequencies and their linear combinations which appear in both spectra are labeled.

$2 \times 0.14 \times 10^{-3}$ Hz. Exactly such spacings would be predicted for rotational splitting of a nonradial pulsation mode with $l = 2$. Using equation (13) given by Brickhill (1975), we find that these frequency spacings could be produced in a white dwarf with a rotation period of somewhat less than 2 hours, corresponding to an equatorial velocity of 1 to 2 km s^{-1}. While surprisingly low, this velocity is in qualitative agreement with the low rotational velocities of white dwarfs found by direct determinations (Greenstein and Peterson 1973).

A second relationship is suggested by Fitch's (1973) analysis of HL Tau–76. Fitch found that most but not all of the frequencies f of peaks in the power spectrum of the light curve could be calculated from pairwise linear combinations of three independent frequencies, the lowest of which did not appear in the spectrum. The same relationship, $f = mf_i \pm nf_j$, where m and n

TABLE 3

FREQUENCIES OF THE MAJOR PEAKS IN THE POWER SPECTRA OF G29-38 AND G38-29

STAR	RUN	FREQUENCY* (10^{-3} Hz)				
		f_1	f_2	f_3	f_4	f_5
G29-38............	1427	0.9847	1.0742	1.2126	1.4771	1.6317
	1431	......	1.0701	1.2288	1.4893	1.6032
	1439	1.0000†	1.0946	1.2248	1.4933	1.6317
G38-29............	1585	0.9766	1.0661			
	1591	0.9806	1.0986			

* Accuracy of measurement = $\pm$ 0.0041 $\times$ 10^{-3} Hz.

† Assumed.

are (small) integers and i and j specify the independent frequencies, was applied to the power spectra of G29-38 and G38-29. Reasonable fits to frequencies of peaks in the power spectra were achieved by adopting the frequencies of the largest and most stable peaks (those frequencies which are given in Table 3) as the independent frequencies. We find no need to invoke any unseen low frequencies to adequately represent the peaks in the power spectrum in this manner. Thus, pairwise combinations of four or five independent frequencies were used for G29-38, and just two independent frequencies for G38-29. In Figures 2 and 3 some of the secondary peaks in the power spectra are labeled with the linear combination of independent frequencies which best fits the position of the peak. Fitch suggested that the linear combinations of the three frequencies in HL Tau-76 could be produced if the three frequencies were caused by large-amplitude radial pulsations or by orbital motions which were nonlinearly coupled or superposed. With the exception that we believe that the independent frequencies may correspond to pulsations in nonradial modes, we invoke a similar nonlinear coupling to explain the cross-frequencies in G29-38 and G38-29.

IV. DISCUSSION

G29-38 and G38-29 clearly belong to the same class of variables as HL Tau-76. All three are DA white dwarfs, and all three have colors near $(B-V) = +0.20$ and $(U-B) = -0.55$. The light curves of all three show the same asymmetric pulse shape, which usually has a rapid rise to a sharp maximum followed by a slower decline and a broad minimum. The peak-to-peak amplitudes are similar, being about 0.23 mag for G29-38, about 0.20 mag for G38-29, and about 0.3 mag for HL Tau-76. The power spectra of all three have a complex structure at frequencies which are too low to be due to radial pulsations.

We suggest that it may be possible to interpret the power spectra of G29-38 and G38-29 in terms of a nonradial pulsation. The nonradial pulsation is first split into from two to five approximately evenly spaced frequencies by rotation of the white dwarf. These two to five frequencies are then nonlinearly coupled to produce a multitude of secondary frequencies. It should be noted, however, that against this suggestion must be weighed some severe objections:

1. The peaks in the power spectra are variable in both frequency and amplitude. Our interpretation does not account for the variations, nor is it clear that any interpretation can account for the variations if it includes only pulsation and rotation of a white dwarf.
2. Linear combinations of five frequencies were necessary to match the secondary peaks in the power spectra of G29-38. Even restricting m and n to less than or equal to 3 produces 179 cross-frequencies, of which only 62 appear in the power spectrum. Moreover, not all of the significant secondary peaks were matched even with 179 cross-frequencies, the peak at 2.51 $\times$ 10^{-3} Hz in Figure 2a being the most extreme example.
3. Our interpretation ignores theoretical studies of white dwarf pulsations which show that white dwarfs should be pulsationally stable, and that even the nonradial g-mode pulsations have periods which are usually too short by a factor of perhaps 2 to account for the observed time scales of the variations (Ostriker 1971; Osaki and Hansen 1973; Brickhill 1975).

Further observations of this class of stars are in progress. We expect that the observations will help to clarify these problems.

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