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BPM 31594: A NEW SOUTHERN-HEMISPHERE VARIABLE WHITE DWARF

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ABSTRACT

The results to date of a Southern Hemisphere search for new members of the ZZ Ceti class of variable stars are presented. BPM 31594 was found to be variable and is a probable member of this class. This star exhibited a change in period by a factor of 2 in one day, and this change is discussed with respect to mode changes in nonradially oscillating white dwarf models. It is found that mode changes do not easily give a factor of 2 change in the observed period.

Subject headings: stars: variable — stars: white dwarfs

I. INTRODUCTION

There are, to date, nine known variable DA white dwarfs, all of which have similar properties. The photoelectric colors are all near $(B - V) = +0.20$ and all the variables show multiply periodic or pseudo-periodic light curves with amplitudes from a few hundredths to a few tenths of a magnitude. The period structure, which in general is not perfectly stable, leads to shifts in frequency and amplitude of peaks in the power spectra of light curves of these stars, though the primary periodicities all fall within the range 200–1000 s.

Of the known variables, four, R808, GD 99, G38-29, and G207-9, were discovered as part of a systematic search for variability in DA dwarfs with appropriate colors. The search program is described by Robinson and McGraw (1976 [Paper III]) and previous results are detailed in that paper and in McGraw and Robinson (1975 [Paper I], 1976 [Paper II]). The colors of the variables cluster in a well-defined group near the cool end of the DA sequence, and on this basis it has been proposed (Paper II) that the variables form a homogeneous group of single stars identified as the ZZ Ceti class and that the excitation mechanism may be related to a partial ionization zone. From examination of the light curves and their power spectra it has been suggested (Papers I, II, and III) that the variables are oscillating in nonradial pulsation modes since the observed periodicities are more than two orders of magnitude longer than those predicted for radial oscillations on white dwarfs (cf. Osaki and Hansen 1973).

Our search has now been extended into the Southern Hemisphere, and in this *Letter* we report the discovery of a new variable, BPM 31594, and discuss its unique period structure. The null results to date of the Southern Hemisphere variability survey are also presented.

II. OBSERVATIONS

All observations were made at Sutherland Astronomical Observatory using either the 0.76 m or 1.02 m reflectors. The data were obtained using the observing techniques described in Paper III with a computer controlled two-channel pulse-counting photometer (Nather 1973) virtually identical to that used in the Northern Hemisphere.

Twenty-one white dwarfs found to be nonvariable are listed, along with their $(B - V)$ colors and spectral types (when known), in Table 1. The colors and spectral types are from Eggen (1968, 1969), Eggen and Greenstein (1965, 1967), Greenstein (1969), or Wegner (1973). The JL stars are taken from the catalog of Jaidee and Lyngå (1969) with colors from Wegner (private communication). The integration time used for these stars was 10 s, and each star was observed for approximately 1 hour. Thus, it is claimed only that the star is constant to about 0.01 mag on a time scale from 20 s to about 30 minutes. LTT 7873, noted by Greenstein (1969) as a possible variable, was found to be constant. A DB dwarf, BPM 18164, and a C_2 dwarf, BPM 18615, were also observed and found to be constant.

BPM 31594, with colors $B - V = +0.21$ and $U -$

TABLE 1

CONSTANT-LUMINOSITY WHITE DWARFS

Name	$(B-V)$	Sp
G155-34	+0.15	DAs
JL 123	+0.20	
L79	+0.25	DAs
JL 219	+0.23	
L48-15	+0.16	DAwk
JL 22	+0.16	
G93-53	+0.26	DAs
L4	+0.17	DAwk
G67-23*	+0.20	DA
GD 31*	+0.21	DA
HZ 4*	+0.15	DA
JL 76	+0.13	
BPM 2819	+0.23	DA
LTT 7873*	+0.2	DA
BPM 19738	+0.20	DA
GD 133	+0.19	
BPM 37093	+0.18	DA
BPM 18164	−0.09	DB
BPM 19738	+0.20	DA
BPM 18615	−0.16	C_2
HZ 10*	+0.17	DA

* Independently observed from the northern hemisphere.

$B = -0.66$ (Eggen 1969), was found to be a variable, thus bringing the total of known variables to 10. The Journal of Observations of BPM 31594 is given in Table 2. On the discovery night this star exhibited a basically sinusoidal light curve with a period of about 314 s and a peak-to-peak amplitude of about 0.18 mag. On the next night, and on all subsequent nights when this star was observed, the mean luminosity and amplitude of variation remained about the same, but the period of the variation had increased to about 617 s and the light curve was not nearly so sinusoidal, with individual pulses showing definite sharp peaks. The light curve of run S2216 is shown in Figure 1.

Low-frequency power spectra for runs S2209 and

TABLE 2

JOURNAL OF OBSERVATIONS OF BPM 31594

Run No.	Date (UT)	Starting Time (UT)	Telescope (m)	Integration Time (s)	Number of Integrations	Period (s) ±1.5 s
S2209......	1975 Nov. 11	22:37:00	1.02	10	670	314
S2211......	1975 Nov. 12	21:07:08	1.02	5	1520	617
S2216......	1975 Nov. 14	19:59:29	1.02	10	2250	614
S2267......	1976 Jan. 7	20:58:08	0.76	5	1670	619

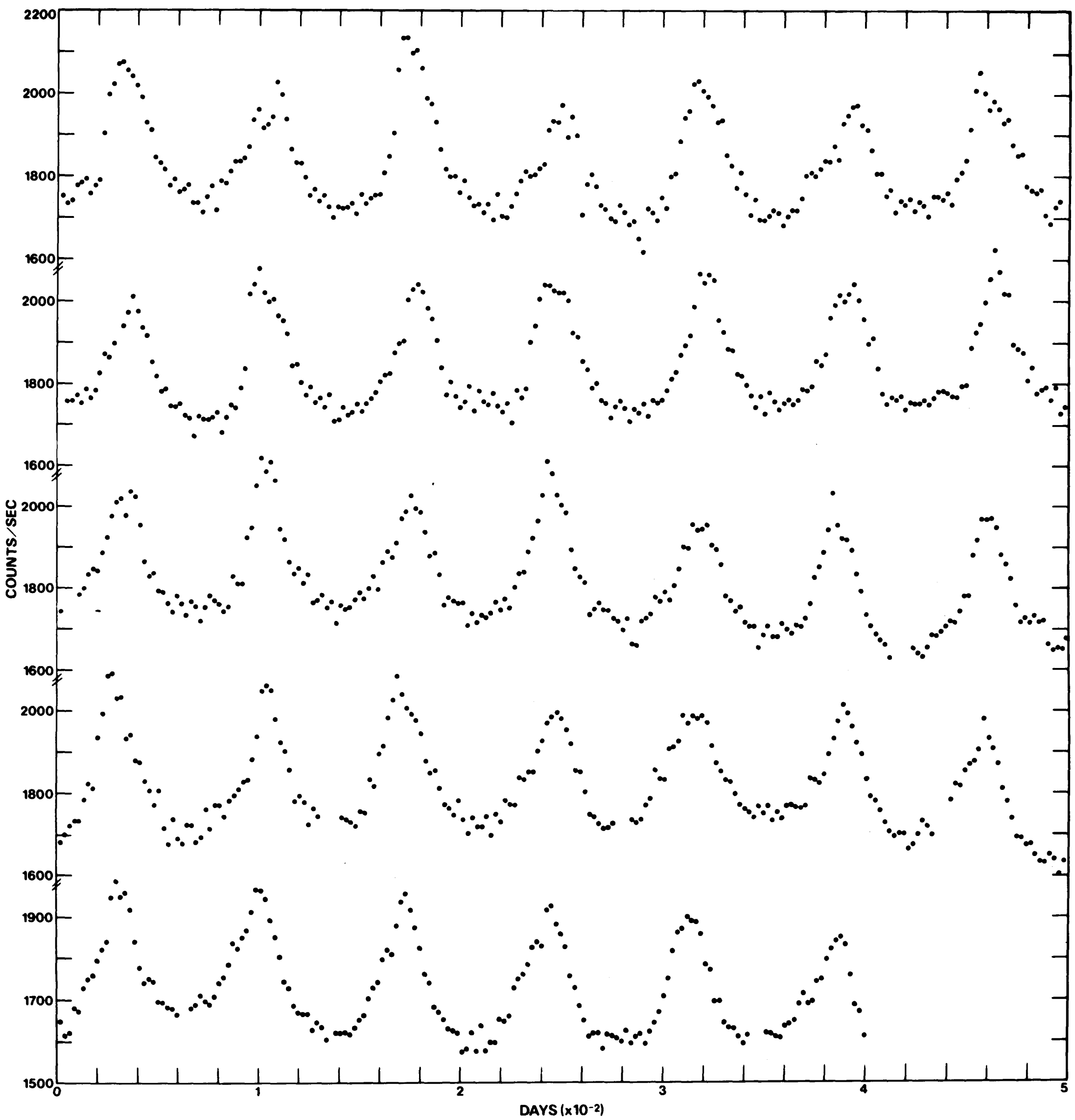

FIG. 1.—The light curve of BPM 31594, run S2216, expressed in detected photons per second reduced to outside the atmosphere. The light curve is continuous starting at upper left, and each plotted point is the mean of two 10 s integrations.

S2216 are shown in Figure 2. The most striking change between them is the shift of the major peak in the spectra from a frequency of 3.22×10^{-3} Hz in S2209 to about 1.62×10^{-3} Hz in all subsequent runs. Though nonstationary, the spectra of this star are, in general, simpler than those for most other DA variables in that there is only one major peak and a relatively small number of subsidiary peaks. In the power spectrum of S2209 there is but one peak, which bears out the impression obtained from the light curve that the variation is basically sinusoidal. In the spectra of the latter three runs, two harmonics of the primary frequency f_0 are clearly visible—a circumstance which is expected, since the light curve is no longer sinusoidal. In addition, in the latter spectra there is always significant power at about 2.45–2.50×10^{-3} Hz which is very nearly $(3/2) f_0$. The remaining peaks in the power spectra are nonlinear combinations of these frequencies. This phenomenon has also been noted in other of the DA variables (Papers I and II).

III. DISCUSSION

Though BPM 31594 does not yet have a spectral classification, from the colors and light curve of the star it is most probable that it is DA and that this star should be assigned to the ZZ Ceti class of variables. Spectra of this star will be obtained at the earliest possible date.

Assuming this star to be a ZZ Ceti variable, the change in period by almost exactly a factor of 2 in one day should be regarded as an important clue in deciphering the pulsation modes of these stars. The long periods and rather intricate period structure of BPM 31594 indicate that this star is not varying in radial pulsation modes. It is worthwhile, however, to consider the effects on the observed periods of a white dwarf of changing nonradial pulsation modes. We assume the dwarf supports gravity mode oscillations with period P_{kl}, where the index k specifies the number of wavelengths interior to the star and l is the particular harmonic, that is, the number of node lines on the surface of the star. The surface perturbation of the star is then described by the spherical harmonic, Y_l^m, where m is the number of l node lines passing through a symmetry pole and can have any (integer) value from $+l$ to $-l$. Changes in any of the three indices klm can cause changes in the observed period.

Brickhill (1975) has investigated the gravity mode pulsations in a series of white dwarf models with temperatures and masses appropriate for the ZZ Ceti stars. For a given l, the variation of P_{kl} with k is approximated by:

$$P_{kl} = P_{1l}[1 + (k - 1)/h]\,,$$

where h has a value between 3 and 4. Requiring $P_{k'l}/P_{kl} = 2$ implies k must increase by at least 3, skipping intermediate modes, to achieve a period change of a factor 2. Though not impossible, this mechanism implies a change in excitation energy in a short period of time which makes it unattractive.

For changes in l with fixed k,

$$\frac{P_{k'l}}{P_{kl}} = \left[\frac{l(l+1)}{l'(l'+1)}\right]^{1/2};$$

and requiring $P_{k'l}/P_{kl} = 2$ gives $l'(l'+1) = \frac{1}{4}l(l+1)$. Thus, to increase the period l must decrease; but for reasonable values of l the above equation has no real, positive, integer solution. We therefore discard changes in l as the cause of the observed factor 2 period change.

For a given k and l, the white dwarf must support a

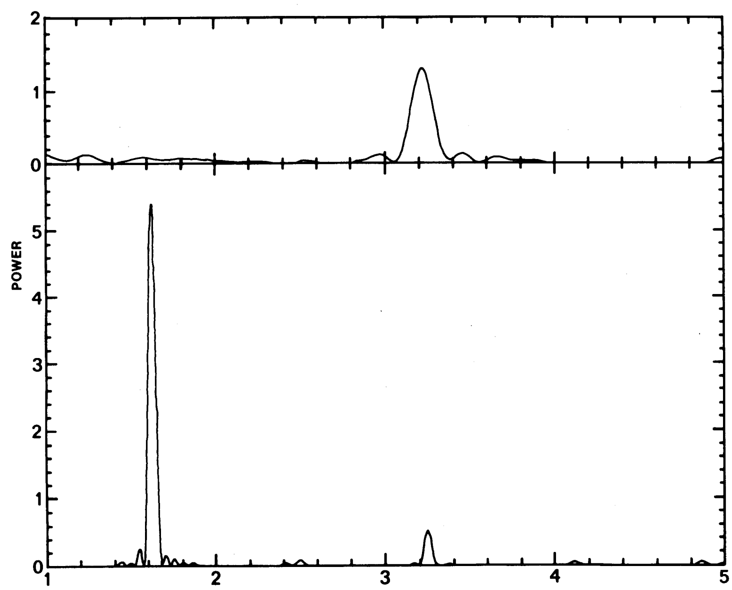

FIG. 2.—Power spectra of runs S2209 (*upper*) and S2216 (*lower*). The amplitude of a spectral peak, $P(f)$, at frequency f is related to one-half the peak-to-peak amplitude of a strictly periodic signal in the light curve by $\Delta m = 2.5 \log \{1 + [2P(f)/N\,\Delta t]^{1/2}\}$, where Δm is in magnitudes, Δt is the sampling interval, and N is the number of points in the transform. For these spectra $N = 4096$ and $\Delta t = 30$ s.

symmetry axis to have $m \neq 0$. The most obvious mechanism for achieving this is rotation, for which case Brickhill (eq. [13]) gives for the observed periods:

$$P_{klm} = 1/\sigma_{klm} = |\sigma_{kl} - m(1 - C_{kl})\Omega|^{-1}$$

where σ_{kl} is the frequency of the nonrotating star, Ω is the rotation frequency, and C_{kl} is a constant which can take values $0 \leq C_{kl} \leq [l(l+1)]^{-1}$. For $\sigma_{kl} \gg \Omega$ this equation describes a set of evenly spaced frequencies centered on σ_{kl}. This frequency structure was possibly observed in the power spectra of the light curves of G207-9 (Paper III) and G29-38 (Paper I) but is definitely not observed in the spectra of BPM 31594. A second case, $\Omega \gg \sigma_{kl}$, essentially a "spot" model for the white dwarf wherein the "spots" are attributed to the surface perturbations, may also be ruled out. If the 617 s period is associated with the rotation period, the g-mode oscillation period must be about two orders of magnitude longer than the periods calculated for white dwarf models. Also, the light curve is pseudo-periodic and nonsinusoidal, which is not expected from rotationally produced phenomena.

These results indicate that period changes by a factor 2 do not easily and naturally occur for mode changes of ± 1 in any of the indices describing nonradially oscillating stars. It appears that the most probable mechanism discussed here for producing the observed period change is a change in k by 3. This point deserves further attention. Also, in this discussion, important points such as the nonsinusoidal nature of the light curve following the period change have been avoided. In a more detailed investigation the effects of aspect, of interference of traveling waves on the surface of the star, and of the existence of multiple modes within the star must be taken into proper account.

Note added in proof.—A spectrum of BPM 31594 obtained by G. Wegner shows the star to have spectral type DA, thus confirming its membership in the ZZ Ceti class.

REFERENCES

Brickhill, A. J. 1975, *M.N.R.A.S.*, **170**, 405.
Eggen, O. J. 1968, *Ap. J. Suppl.*, **16**, 97.
———. 1969, *Ap. J.*, **157**, 287.
Eggen, O. J., and Greenstein, J. L. 1965, *Ap. J.*, **141**, 83.
———. 1967, *Ap. J.*, **150**, 927.
Greenstein, J. L. 1969, *Ap. J.*, **158**, 281.
Jaidee, S., and Lyngå, G. 1969, *Ark. f. Astr.*, **5**, No. 21, 345.
McGraw, J. T., and Robinson, E. L. 1975, *Ap. J.* (*Letters*), **200**, L89 (Paper I).
———. 1976, *Ap. J.* (*Letters*), **205**, L155 (Paper II).
Nather, R. E. 1973, *Vistas in Astronomy*, **15**, 91.
Osaki, Y., and Hansen, C. J. 1973, *Ap. J.*, **185**, 277.
Robinson, E. L., and McGraw, J. T. 1976, *Ap. J.* (*Letters*), **207**, L37 (Paper III).
Wegner, G. 1973, *M.N.R.A.S.*, **163**, 381.

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