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LETTER

*Letter to the Editor*

# A new pulsating DA white dwarf: PG 2303+243*

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SUMMARY : We report the discovery of a new ZZ Ceti variable star. PG 2303+243 is a DA white dwarf from the Palomar-Green catalog, selected from its (G-R) color. The star has been found to vary with a main period of 794.5s and an amplitude as large as 5% of the mean stellar intensity. As many as 12 significant peaks are identified in the Fourier spectrum. Better time revolved data are necessary to confirm the reality of suspected rotationally split frequencies. The star fit the amplitude-period correlation known for the majority of the ZZ Ceti stars. This discovery raises to 20 the number of the ZZ Ceti variables presently known.
Keywords : ZZ Ceti stars, high speed photometry, white dwarfs.

## I- INTRODUCTION

As white dwarfs with hydrogen envelopes cool down along their cooling sequence, they cross a narrow instability strip in which they appear as ZZ Ceti variable stars. Linear non-adiabatic stability analyses have found that models of DA white dwarfs in the relevant effective temperature range do exhibit unstable gravity modes with the right periods ( Dolez and Vauclair 1981; Winget et al. 1982; Cox et al. 1986).

A detailed comparison of the theoretical work with the observations should, in principle, lead to the clarification of such questions as:

1) are all DA white dwarfs unstable in the instability strip, and what does this imply for our understanding of the stucture and evolution of white dwarfs ?

2) are the blue and red edges of the instability strip precisely enough determined to allow stronger constraint on the convection theory and to provide some insight on the pulsation-convection coupling?

3) is the linear analysis adequate for the description of the large amplitude variables and/or the sometime complex light curves and Fourier spectra?

Theses questions will not be answered untill a statistically significant sample of variable white dwarfs is known and well observed. For this reason, efforts have been devoted in the last few years to the discovery of new pulsating white dwarfs.

Our continuing program of high speed photometry is concentrated on DA white dwarfs with MCSP colors in or close to the instability strip. The ( G-R ) index was shown to be a good indicator of the effective temperature ( Fontaine et al. 1982; Greenstein 1982).

A systematical search for pulsating white dwarfs in the color range $-0.41 \leq$ G-R$\leq -0.29$ has been undertaken. This selection criterion has been successful in leading to the discovery of seven new ZZ Ceti variables: GD 385 (Fontaine et al. 1980), G191-16 and G185-32 ( McGraw et al. 1981), G255-2 ( Vauclair et al. 1981), G226-29 ( Kepler et al. 1983), GD 66 ( Dolez et al. 1983) and G238-53 ( Fontaine and Wesemael 1984). We report in the present Letter the discovery of one more ZZ Ceti variable selected according to the same criterion: PG 2303+243.

## II- OBSERVATIONS AND ANALYSIS

PG 2303+243 is a white dwarf from the Palomar-Green catalog (Green et al. 1986). The star ( $\alpha$= 23h 03m 50.9s, $\delta$=+24° 15' 49'' ), classified DA4 in the new classification scheme ( Sion et al. 1983), is rather faint ( V=15.5) and has published MCSP ( Green et al. 1986) and Stromgren photometry ( Wegner 1983). Color indices in both photometric systems place that star in the instability strip ( ( G-R)= -0.31; (b-y)= +0.09). For this reason, the star was put on our high speed photometry observing list. Finding chart is provided in the Palomar-Green catalog.

The high speed photometer used is a modified version of the photometer described by Vauclair and Bonazzola (1981) and Vauclair et al.(1981). It will be fully described separately. The new instrument is a three channel photon counting photometer. The photometer is attached to the Cassegrain focus of the 1.93m telescope at Haute Provence Observatory. The candidate star, a comparison star and the sky background are continuously and simultaneously measured. The data are stored on the HP21MX computer for immediate fast Fourier analysis, and on tapes.

Table 1 : High speed photometric observations of PG 2303+243

| Date UT | Start time UT | Resolution mHz |
|---|---|---|
| 1986 Nov. 27 | 17 40 | 0.110 |
| 1986 Nov. 28 | 17 47 | 0.115 |
| 1986 Nov. 30 | 17 48 | 0.098 |

* Based on observations collected at the Haute Provence Observatory (CNRS)

Three observing runs have been obtained of PG 2303+243. The star was discovered to be variable with a large amplitude on November 27, 1986. The variability was confirmed on two subsequent runs on November 28 and 30. The characteristics of the observations are summarized in Table 1.

Figure 1 shows the best light curve obtained on November 30. The light curve has the characteristic non-sinusoidal shape of large amplitude variables. This shape is reminiscent of those of two other large amplitude ZZ Ceti stars: G191-16 (McGraw et al. 1981) and G255-2 (Vauclair et al. 1981). Such a non-sinusoidal shape of the light curve is responsible for the occurence of linear combinations and harmonics of basic frequencies in the Fourier spectrum. The modulus of the Fourier transform (Figure 2) exhibits ∽12 significant peaks . Three of these peaks seem to correspond to independent frequencies, in the sense that most of the other significant peaks are combination of these three frequencies (Table 2) within the observational uncertainties. The dominant frequency is at 1.258 mHz ( period of 794.5 s ) , with an amplitude of 5.6%, one of the largest known.

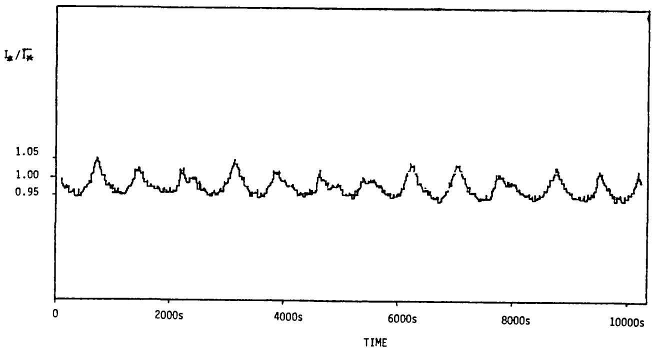


Figure 1 : Light curve of PG 2303+243, run of November 30, 1986. The light curve is normalized after sky substraction.

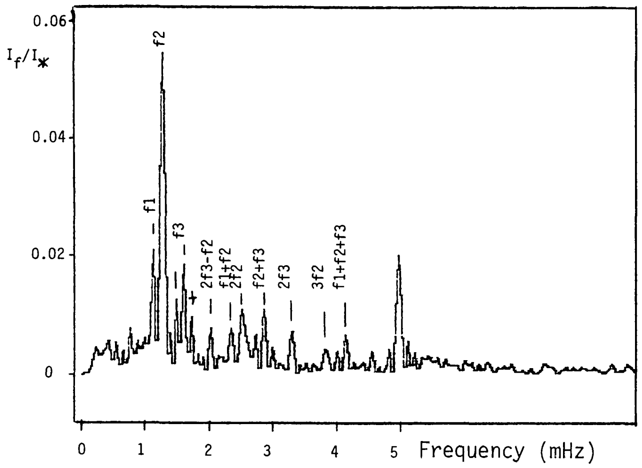


Figure 2 : Fourier transform modulus of the light curve shown in Figure 1. The amplitude, expressed as a fraction of the mean stellar intensity ($I_f/I_*$) is plotted vs. the frequency in milliherz. Significant peaks are labelled according to Table 2. The peak at 5 mHz is a 2% sinusoidal tracer added to the data for calibration.

The interpretation of the Fourier spectrum is not straightforward. A first possible interpretation could be that the frequencies $f_1$,$f_2$ and $f_3$ are the basic independent modes of the star. However, a second interpretation is also possible based on the following remarks: there is one peak on each side of $f_3$ ( $f_3^-$ and $f_3^+$ in Table 2, -and + in Figure 2), almost equidistant from $f_3$ ( $f_3 - f_3^-$ = 0.124 mHz; $f_3^+$ - $f_3$ = 0.148 mHz). Noting furthermore that the frequency difference between $f_3$ and its two satellites is equal, within the uncertainties, to $f_2$-$f_1$ ( 0.148 mHz), one is led to the conclusion that rotational splitting could be responsible for these equally spaced frequencies. The missing high frequency rotationally split satellite of $f_2$ could be too small to be detected ( a small peak is barely visible in Figure 2 and was not considered to be distinguishable from noise in our analysis). Such rotational splitting has been invoked to explain equally spaced frequencies in the Fourier spectrum of BPM 30551 ( McGraw 1977) and of GD 66 ( Fontaine et al. 1985). The time resolution of the data presented here for PG 2303+243 may be marginally significant to clearly identify the effect of the rotational splitting. Better time resolution should settled the question of its reality . Would this second interpretation be true, this would imply that the star is pulsating on only two basic modes of azimuthal number l=1, and that the white dwarf is rotating with a period of ∽ 1.9 h. The frequencies which are combinations or harmonics of the basic frequencies do not appear as rotationally split because of their small amplitude.

Table 2 : Frequencies identified in the Fourier spectrum of PG 2303+243

| Ident. | Frequency (mHz) | Period (s) | Amplitude (%) |
|---|---|---|---|
| $f_1$ | 1.110 | 900.5 | 1.6 |
| $f_2$ | 1.258 | 794.5 | 5.6 |
| $f_3^-$ | 1.480 | 675.4 | 0.8 |
| $f_3$ | 1.604 | 623.4 | 1.5 |
| $f_3^+$ | 1.752 | 570.7 | 0.8 |
| $2f_3-f_2$ | 2.023 | 494.1 | 0.8 |
| $f_1+f_2$ | 2.356 | 424.3 | 0.8 |
| $2f_2$ | 2.517 | 397.3 | 1.1 |
| $f_2+f_3$ | 2.862 | 349.3 | 1.1 |
| $2f_3$ | 3.282 | 304.7 | 0.8 |
| $3f_2$ | 3.726 | 268.3 | 0.4 |
| $f_1+f_2+f_3$ | 3.972 | 251.7 | 0.6 |

## III - CONCLUDING REMARKS

With a ( G-R ) color index of -0.31, PG 2303+243 lies in the ZZ Ceti instability strip, close to the red edge. High speed photometry conducted at the Haute Provence Observatory 1.93m telescope confirms that the star is a ZZ Ceti variable of large amplitude (5.6%). With a main period of 794.5s, PG 2303+243 satisfies the period-amplitude correlation established for the ZZ Ceti variables, according to which large amplitude variables have longer periods. Better time resolved data are necessary to interpret the Fourier spectrum. With the data discussed in the present Letter, the interpretation could be that the star is pulsating either on three basic modes of unknown l and k, or on only two basic frequencies of l=1, each being rotationally split in three components. In the latter case, the inferred rotation period of the white dwarf is ∽ 1.9 h. The discovery of the variability of PG

2303+243 raises to 20 the number of known ZZ Ceti pulsating white dwarfs.

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