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A new large-amplitude variable white dwarf

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ABSTRACT

A new large-amplitude ZZ Ceti star has been discovered in the Edinburgh–Cape Blue Object Survey. The light curve is non-sinusoidal, with a peak-to-peak variation ranging from 0.06 to 0.24 mag in white light. Six nights of observation show a multiple-period structure, with periods of between 800 and 1000 s. The principal frequency at $f = 1.101$ mHz is present on most nights observed with variable amplitude, probably caused by the presence of multiple close frequencies.

Key words: stars: oscillations – white dwarfs.

1 INTRODUCTION

The ZZ Ceti stars are a class of pulsating DA white dwarf stars. The light variations result from non-radial gravity-mode pulsations driven by an instability in the hydrogen partial ionization zone. The instability strip is delineated by a narrow temperature range of $11\,000 < T_e < 13\,000$ K on the white dwarf sequence, and it is suspected that most hydrogen-rich DA white dwarfs as they evolve to cooler temperatures will pulsate as they pass through this temperature range. The properties of the ZZ Ceti stars have been well described by Fontaine et al. (1982) and Winget (1988).

The majority of these ZZ Ceti stars were discovered in the 1970s and 1980s. Only 22 such stars are presently known, the most recent of which (having the lowest amplitude, with a semi-amplitude of 4 mmag) was discovered by searching for new variables that have a temperature determination from *IUE* observations placing them in the instability strip (Kanaan, Kepler & Giovannini 1992). It is important to discover new members of this class, especially in the south where few are known, as they are ideal laboratories for asteroseismological investigations of degenerate stars (Winget 1988). A good example of the wealth of information that can be obtained from detailed and concerted campaigns on an individual star is the study of PG 1159 – 035 (Winget et al. 1991).

The Edinburgh–Cape Blue Object Survey is a potential source of candidate degenerate pulsators (Stobie et al. 1992). The blue stellar objects are identified from COSMOS scans of U and B plates taken with the UK Schmidt Telescope. Follow-up photometry and spectroscopy is being obtained at the South African Astronomical Observatory (SAAO) to classify and determine the nature of each blue stellar object. Currently, over 190 DA white dwarfs have been identified, of which the majority are not in existing catalogues (O'Donoghue et al. 1993). From these white dwarfs, we have selected stars with $B-V$ colours near or within the range $0.15 \le B-V \le 0.25$ to monitor for variability. This paper describes the results of the discovery of the 23rd ZZ Ceti star known, and the first to be found in the Edinburgh–Cape Survey.

2 OBSERVATIONS

EC 23487 – 2424 has 1950 coordinates $23^h48^m47\overset{s}{.}0$, $-24°24'55''$, accurate to 1 arcsec. Its magnitude and colours are $V = 15.33$, $B-V = 0.19$ and $U-B = -0.57$. It is not in the catalogue of spectroscopically identified white dwarfs (McCook & Sion 1987). Spectra taken using the SAAO 1.9-m telescope, with the Unit Spectrograph and Reticon Photon Counting System at a dispersion of 100 Å mm^{-1} at λ460 nm, clearly identify EC 23487 – 2424 as a classical DA white dwarf. Use of the above photometry and the scale defined by McCook & Sion (1987) gives it a classification of DAV4.

Intensive photometry was obtained with the SAAO 1.0-m telescope, using the University of Cape Town (UCT) photometer. The observing log is listed in Table 1. Observations were obtained in white light with a blue-sensitive photomulti-

Table 1. Observing log.

run number	starting time HJD 2440000+	integration time (s)	length of run (d)
S5414	8596.33417	10	0.06146
S5418	8599.33002	10	0.05810
S5532	8895.48831	10	0.08958
S5535	8896.47710	10	0.07812
S5536	8897.33125	10	0.20127
S5539	8898.32774	10	0.12720

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plier tube and with a time resolution of 10 s. An offset guiding system was used so that observations only needed to be interrupted to obtain sky readings. A cubic spline fitted to the sky values was interpolated to subtract the sky from the star readings. The data were then corrected for mean extinction coefficients applicable to Sutherland. The intensity data were normalized by the mean intensity for each night to give the fractional intensity changes. The resultant light curves for the six nights of observations are plotted in Fig. 1.

The photometric quality of the data varied from night to night. Typically, the number of counts in a 10-s integration in white light was ~9500. Run S5536 was the best-quality night and the nature of the light curve is most clearly seen here, with the non-sinusoidal variation evident from the very peaked maxima and broader minima. The existence of multiple periodicities is also apparent from the variation in amplitude ('beating') of the pulsation as a function of time.

3 FREQUENCY ANALYSIS

The time series of fractional intensities were analysed for their component frequencies using the Fourier periodogram technique of Deeming (1975) over the range of frequencies 0 to 10 mHz. Initially, the data for each night were analysed separately. The highest amplitude frequency was identified and the best-fitting sinusoid at this frequency was subtracted from the data (pre-whitening). The residuals were then searched for further frequencies and this procedure repeated until the noise level was reached, as judged by the highest amplitude peak in the periodogram not being significantly above the noise level. The frequencies identified for each night are listed in Table 2 and the periodograms shown in Fig. 2. It can be seen that most of the power resides in two peaks, one near 1.010 mHz and the other at a frequency in the range 1.20–1.25 mHz. The peak near 1.010 mHz is present on the last four nights, although of variable amplitude. Of the lower amplitude terms, we note that some are harmonics of the main frequency and are thus caused by the non-sinusoidal shape of the variation (e.g. on run S5414: $f_3 = 2f_1$; on run S5536: $f_4 = 2f_1$).

To obtain higher frequency resolution, we analysed the data in groups of nights. The first group,

Table 2. Frequencies present on individual nights. The amplitude is in fractional intensity units.

run number	f_1 (mHz)	a_1	f_2 (mHz)	a_2	f_3 (mHz)	a_3	f_4 (mHz)	a_4
S5414	1.199 3	0.063	1.684 10	0.020	2.428 9	0.020	-	-
S5418	1.238 6	0.044	1.070 10	0.025	1.686 11	0.022	-	-
S5532	1.229 3	0.034	1.018 4	0.023	1.138 8	0.011	-	-
S5535	1.013 3	0.050	1.215 4	0.027	2.245 10	0.012	-	-
S5536	1.010 1	0.049	1.149 2	0.014	1.249 2	0.015	2.022 2	0.010
S5539	1.015 2	0.024	1.201 2	0.022	-	-	-	-

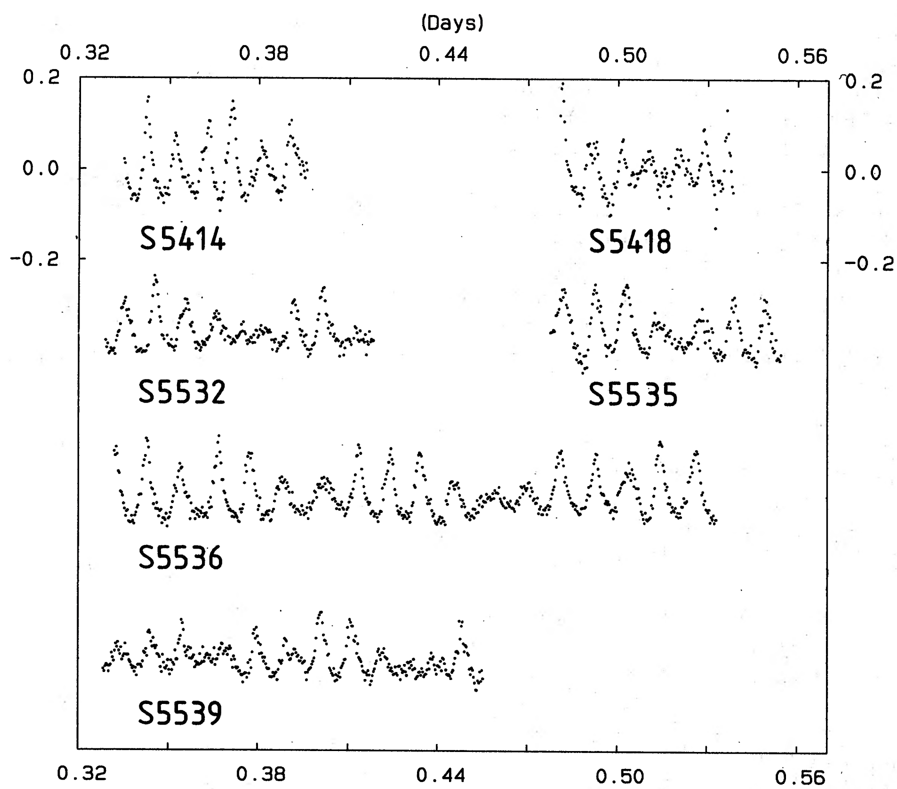

Figure 1. White light observations of EC 23487 − 2424 on six nights. The 10-s data points have been binned at 30-s time resolution for the purposes of this plot. Each night is identified by its run number. The abscissa scale is in fractional intensity units. The JD scale applies to run S5536, but otherwise has arbitrary zero-point shifts.

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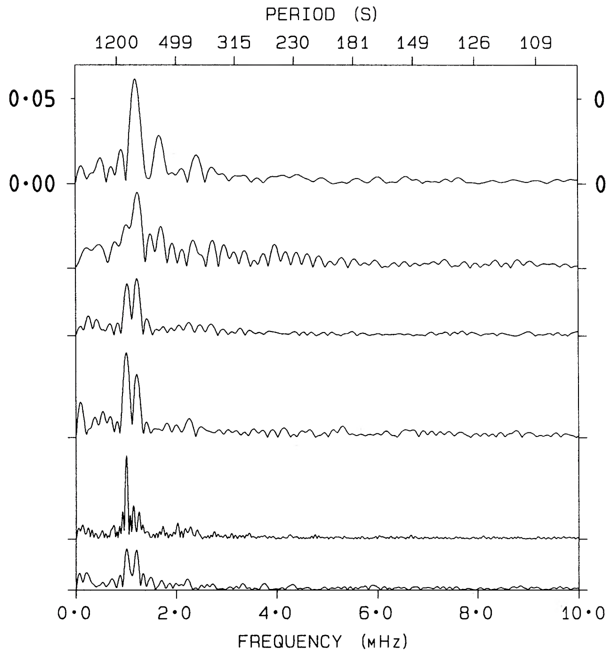

Figure 2. Periodograms of individual nights. The abscissa scale is amplitude in fractional intensity units.

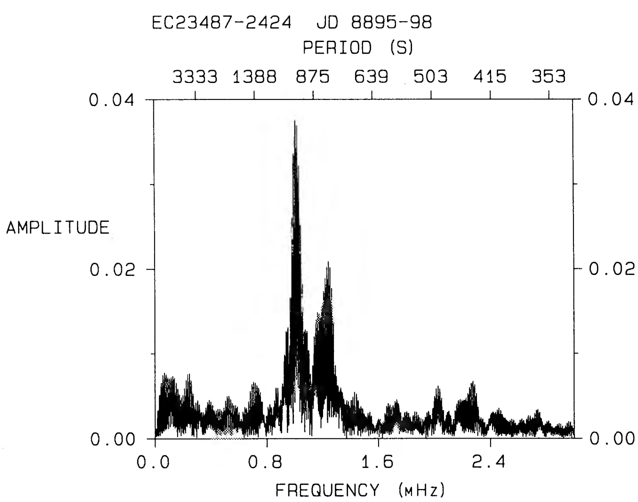

Figure 3. Periodogram of group of nights, JD 244 8895–8898. The abscissa is in fractional intensity units.

JD 244 8596 − 8599, was too sparse to obtain useful results. The second group, JD 244 8895 − 8898, however, consisted of four consecutive nights with longer duration runs. The periodogram of these data in Fig. 3 shows that there are two main groups of peaks, one near 1.0 mHz and the other near 1.2 mHz. The non-sinusoidal nature of these oscillations can be seen from the structure of harmonic peaks present at twice the main frequencies. Analysis of the periodogram in Fig. 3 was carried out in a similar manner to that of the individual nights. The frequency structure turned out to be complex, with many frequency peaks well above the noise level. The four highest amplitude terms are listed in Table 3. The original peak near 1.010 mHz now breaks up into a number of components, explaining the variable amplitude seen on different nights. Beyond these first four terms, it becomes increasingly difficult to identify a peak because of the 0.011 574-mHz alias structure (caused by the daily gaps in the data), and the other terms are not listed.

Table 3. Frequencies present on JD 244 8895–8898.

n	*f* (mHz)	*a*
1	1.00707 3	0.0377
2	1.24307 7	0.0193
3	1.15179 10	0.0128
4	1.01086 12	0.0110

4 CONCLUSION

EC 23487 − 2424 is the 23rd ZZ Ceti star to be discovered. With a maximum range of 0.24 mag, it is of relatively large amplitude in comparison to the range of amplitudes exhibited by known ZZ Ceti stars (0.004–0.3 mag). A number of frequencies have been identified in the pulsation, most of which are concentrated in the range 1.0–1.25 mHz, together with harmonics at twice the frequency in some cases. The nature of the light variation and frequencies present in EC 23487 − 2424 is complex, and a concerted multisite campaign would be needed to make progress with the frequency structure of this pulsating degenerate star.

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