

## Pulsating white dwarfs in cataclysmic variables: The marriage of ZZ Cet and dwarf nova

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**Abstract.** There are now four dwarf novae known with white dwarf primaries that show large amplitude non-radial oscillations of the kind seen in ZZ Cet stars. We compare the properties of these stars and point out that by the end of the Sloan Digital Sky Survey more than 30 should be known.

### 1. Introduction

The DA white dwarf non-radially pulsating stars, known as ZZ Cet stars, have traditionally been found as isolated field objects. Until recently 34 were known (Fontaine et al. 2003), but a further tranche of 34 was just announced (Sullivan, these proceedings). The ZZ Cet pulsation strip in the HR diagram roughly extends over the range  $11\,000 \text{ K} < T_{\text{eff}} < 12\,000 \text{ K}$  (Bergeron et al. 1995), so it is of interest to see whether cataclysmic variables (CVs) with temperatures in that range also show pulsations (though the width and centre of gravity of the instability strip may be modified in the presence of accretion (Townsley & Bildsten 2003).

Until recently only one such hybrid CV/ZZ system was known: GW Lib (Warner & van Zyl 1998), which has a measured  $T_{\text{eff}}$  of 14 700 K (Szkody et al. 2002a) – though this may be affected by non-allowance for the mysterious emission source that adds a 2.08-h photometric modulation independent of the 1.28-h orbital period (Woudt & Warner 2002). The principal periods in GW Lib are near 650 s, 376 s and 236 s.

A second CV/ZZ system, SDSS J161033.64-010223.3 (SDSS 1610 hereafter), was discovered in 2003 June (Woudt & Warner 2003) and was selected as a candidate on the basis of its spectrum as published in the first release of CVs in the Sloan Digital Sky Survey (Szkody et al. 2002b). SDSS 1610 resembles GW Lib in clearly showing absorption lines of the underlying white dwarf primary, as well as the emission lines characteristic of an accreting system. Its light curve is shown in Fig. 1 (top panel). Its periodicities are near 607 s, 345 s and 221 s, with a harmonic at 304 s.

There is evidently a window of opportunity among the CVs of low rate of accretion ( $\dot{M}$ ): the  $T_{\text{eff}}$  of the white dwarf is determined by  $\dot{M}$ , largely through compressional heating in the interior (Sion 2003; Townsley & Bildsten 2003), and it happens that an  $\dot{M}$  that maintains  $T_{\text{eff}}$  in the instability strip is sufficient to produce Balmer emission lines but not too large to give the accretion disc

a luminosity large enough to hide the flux from the white dwarf. From the observed depth of, e.g., H $\beta$ , the fraction of flux contributed by the white dwarf can be estimated; for GW Lib this is  $\sim 50\%$  and in SDSS 1610 it is even greater.

The low  $\dot{M}$  in these systems automatically leads to the expectation that they will be dwarf novae of very long outburst interval  $T_{out}$  (see, e.g., Warner 1995). Comparison with Z Cha, which has  $T_{out} \sim 50$  d, shows that although the latter's primary is visible in the spectrum, it is far more covered by accretion disc flux than in the known CV/ZZ stars. At the other end of the  $T_{out}$  range, GW Lib has only had one observed outburst (in 1983) and SDSS 1610 has had none. Because the low  $\dot{M}$  systems are intrinsically faint they will in general be apparently faint – it is the ability of the SDSS to find CVs to faint limits that has opened the possibility of increasing the number of known CV/ZZ stars.

## 2. Pulsation frequencies

Some of the ZZ Cet stars show frequency patterns that have been ascribed to direct resonance between the principal driving modes and the wealth of other available modes (O'Donoghue, Warner & Cropper 1992). Thus in VY Hor, GD 154 and PG 1351+489 the eigenfrequencies are almost completely described by the sequence  $nf$  and  $(m + \frac{1}{2} + \epsilon)f$ , where  $n = 1, 2, \dots$ ,  $m = 0, 1, 2, \dots$  and  $\epsilon$  is a small quantity (O'Donoghue, Warner & Cropper 1992; Robinson et al. 1978; Winget, Nather & Hill 1987). For VY Hor  $\epsilon = 0.037$ , for GD 154  $\epsilon = -0.03$  and for PG 1351  $\epsilon = -0.03$ . In GW Lib and SDSS 1610, with the still rather limited observational data for the latter, we find a similar situation, but with the sequences  $nf$  and  $(m + \frac{3}{4} + \epsilon)f$ , where  $\epsilon \approx -0.03$  for GW Lib and  $\epsilon \approx 0.00$  for SDSS 1610. This may be a coincidence, but it could indicate that a different resonance condition is operating in accreting ZZ Cet stars.

## 3. Further discoveries

The publication of the second SDSS CV release (Szkody et al. 2003) revealed at least three further candidate CV/ZZ stars. We have observed SDSS J013132.39-090122.3 and SDSS J220553.98+115553.7 (see also Fig. 1) and find that indeed both have ZZ Cet primaries. At the time of writing this leaves the strong candidate SDSS 1238 to be examined later in the observing season.

The Fourier transforms in Fig. 2 show that in SDSS 0131 the dominant periods are near 595 s and 335 s with weak oscillations also near 260 s; SDSS 2205 has strong oscillations near 575 s and 330 s, with weak oscillations near 475 s. In both cases the ratio of the stronger periods is  $\sim 1.75$ , as in GW Lib and SDSS 1610.

The total number of CVs in the first two SDSS releases is 60, of which we have found that probably  $\sim 8\%$  are CV/ZZ combinations. It is estimated that the final total of CVs found in the SDSS will be  $\sim 400$  (Szkody et al. 2002b), so in a few years we may expect to have more than 30 CV/ZZ stars to study in detail.

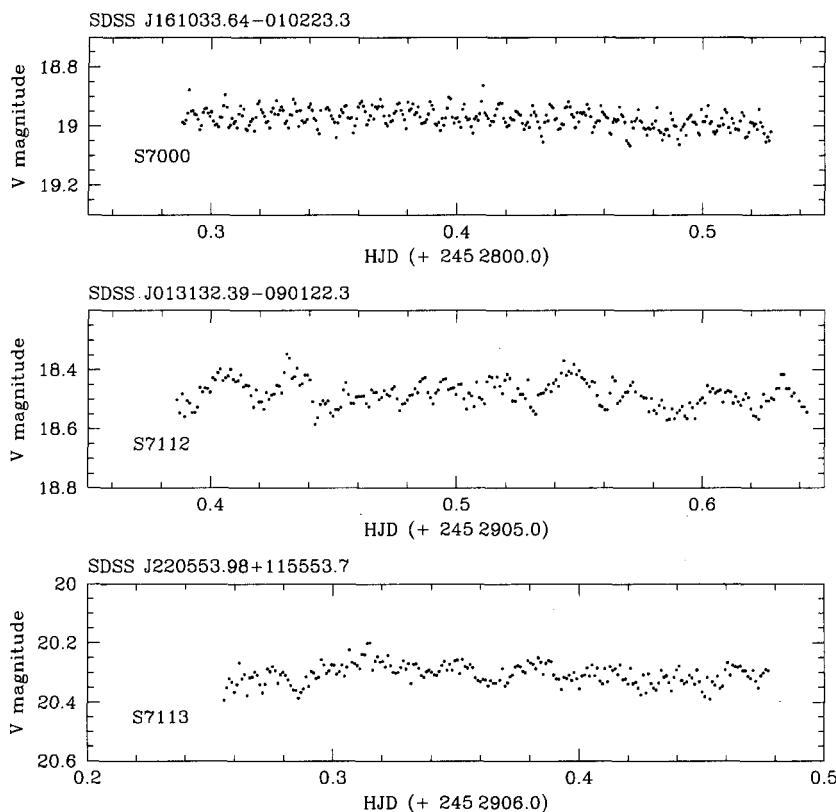


Figure 1. Light curves of the three new CV/ZZ stars, obtained with the University of Cape Town CCD and the 1.0-m and 1.9-m telescopes at the South African Astronomical Observatory.

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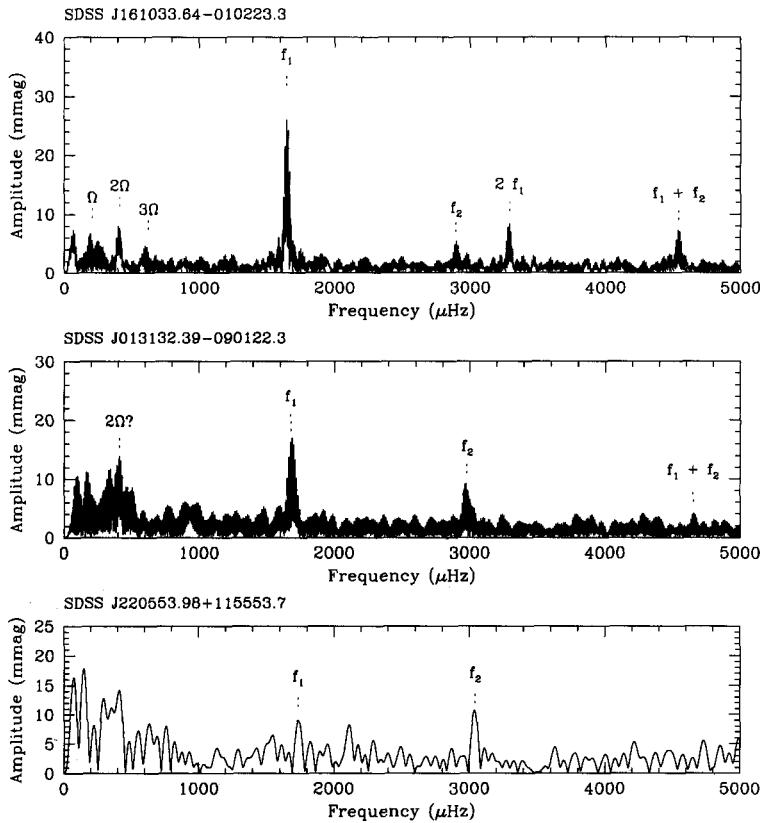


Figure 2. Fourier transforms of the three new CV/ZZ stars. The FTs of SDSS 1610 and SDSS 0131 are based on three (SDSS 1610) and four (SDSS 0131) nights of data, respectively; the FT of SDSS 2205 is based on a single 5.5-h observing run (run S7113 shown in Fig. 1), but the same frequencies are seen during other runs on other nights. The most prominent frequencies are labelled with  $f_1$  and  $f_2$ .

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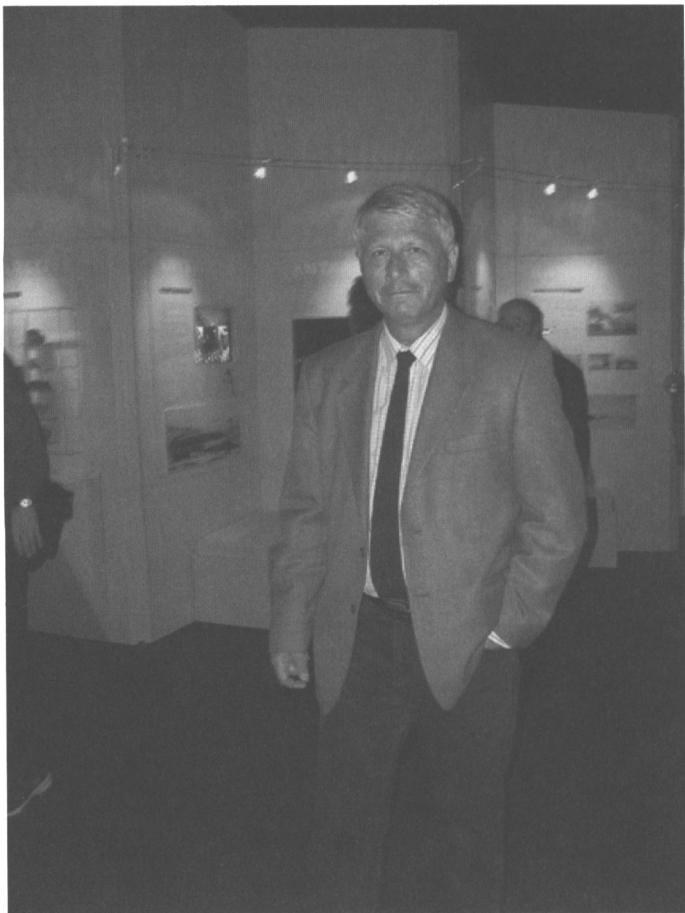
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## Discussion

*Handler:* I would like to point out the ZZ Ceti star HS0507+0434B, which seems to have evolved as a single star, shows period ratios of 3:4, 4:5 and 4:5 within a precision of a few  $10^{-4}$  between its four independent pulsation modes (Handler, Romero-Colmenares & Montgomery 2002, MNRAS).

*Warner:* Thank you.



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