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GW Lib: a Unique Laboratory for White Dwarf Pulsations

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Abstract. Non-radial pulsations have been identified in a number of accreting white dwarfs in cataclysmic variables. These stars offer insight into the excitation of pulsation modes in mixed H/He/Z atmospheres, and the response of these modes to changes in the white dwarf temperature. Among all pulsating cataclysmic variable white dwarfs, GW Lib stands out by having a well-established observational record of three independent pulsation modes that were wiped out during its 2007 outburst. We have obtained new *HST* ultraviolet observations in May 2013 that show an unexpected behaviour: besides some activity near the ~280 s period that has been observed in the past, the white dwarf underwent a large-amplitude brightening. We demonstrate that the brightening is related to an increase of the photospheric temperature, argue against an accretion episode as explanation, and discuss this event in the context of non-radial pulsations on a rapidly rotating star.

1. Introduction

Dwarf Novae (DNe) are a subset of cataclysmic variables (CVs) with low accretion rates and thermally unstable accretion discs that lead to outburst events. The DN GW Lib is the prototypical CV white dwarf (WD) pulsator that underwent a large outburst in 2007 (Templeton et al. 2007). GW Lib was observed in quiescence on January 2002 during 4 orbits with the Space Telescope Imaging Spectrograph (STIS). The Discrete Fourier Transform of its light curve shows signals at 646, 376, and 237 s (Szkody et al. 2002). With the exception of the 230 s mode, they have remained detectable during a large campaign of ground based telescopes during 1997, 1998, and 2001 (van Zyl et al. 2004). Post outburst, new observations were performed with Cosmic Origin Spectrograph (COS) on April 2011. The data reveals an unresolved periodicity near 293 s (Szkody et al. 2012). If this period is the return of the pulsations after outburst, its structure and the changing frequency is likely related to the change in temperature induced by the 2007 outburst. The scenario turns even more complicated in 2013, as our new observations show a smooth large-amplitude variation of the UV flux spanning the three *HST* orbits, in addition some activity near the 280 s is detected (see Figure 1).

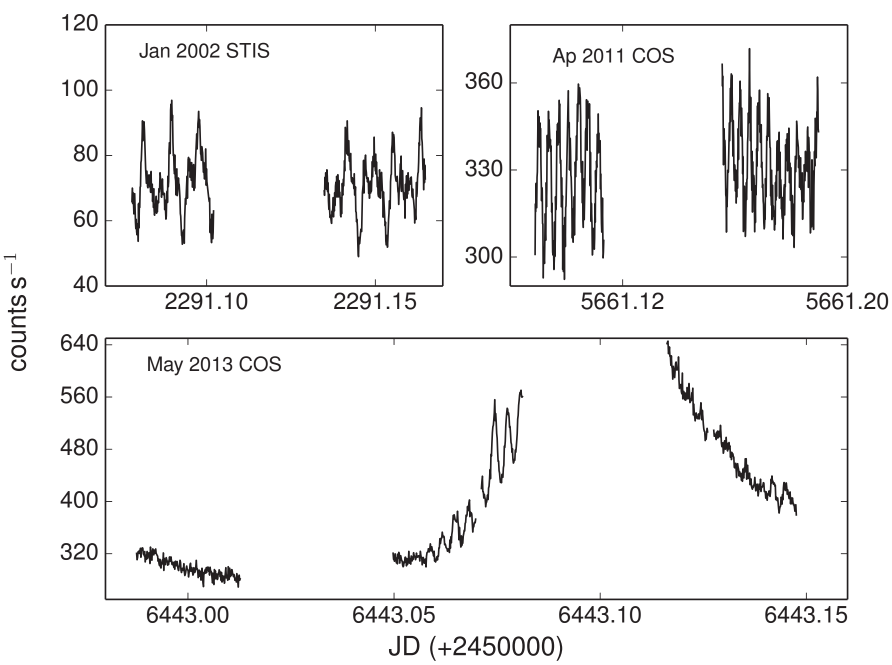

Figure 1. The *HST* light curves of GW Lib 2002, 2011, and 2013 are shown in solid black line (only the first two orbits of the STIS observations are displayed). The light curve in 2002 shows a multi-periodic behaviour while it is mono-periodic in 2011. A long 4-h modulation is detected in the observations of 2013 (bottom panel).

2. Observations

GW Lib was observed during the *HST* Cycle 20 for three orbits on May 2013. Five spectra were acquired using the far ultraviolet channel of COS. The G140L grating provides wavelength coverage of 1105-2253 Å.

3. Markov Chain Monte Carlo (MCMC)

We perform spectroscopic fits to investigate how the atmospheric parameters vary during this 4-h episode (bottom panel in Figure 1). We proceed as the follow. We split every COS observation into two chunks with the same exposure time. The data was reduced and recalibrated using CALCOS v2.21. The 10 spectra were fitted assuming 10% of solar metallicity and adopting a flux model as,

$$F_{\rm mod} = S \times [F_{\rm WD}(T_{\rm eff}, \log {\rm g} = 8.3) + k], \quad (1)$$

where S is the scaling factor, k is a constant representing an extra flux in addition to the flux that the WD model contributes, the latter is represented by $F_{\rm WD}$ in equation 1. The WD model grid was computed with TLUSTY45/SYNSPEC195 (Hubeny & Lanz 1995). The fit were performed using MCMC simulations. The parameter space was sampled by 100 walkers in a total of 2000 iterations.

4. Results and Discussions

Our results are illustrated in Figure 2. The top panel shows that significant changes in the effective temperature are evident. In the middle panel the apparent WD radius anticorrelates with the effective temperature. The WD radius can be derived using the distance estimated by Thorstensen (2003) and the flux scaling factor. The bottom panel shows that the flux of C IV emission line has remained constant.

The simultaneous increase of the WD temperature and decrease of its apparent radius implies that we are detecting heating and cooling of a fraction of the WD surface throughout the ∼231 min covered by the 2013 *HST* observation. Two possible explanations are:

1. A brief accretion episode. We would expect a variation in the accretion rate onto the WD to be accompanied with flickering, and a change in the flux of the C IV emission line, which are not observed. In addition, heating by accretion would have to be extremely symmetric with respect to the rotation axis, as it would otherwise result in a modulation of the UV flux at the WD spin period.

2. Non-radial pulsations in a rapidly rotating WD. A retrograde travelling pulsation mode will be slowed down in the observer's frame. If the period of this mode is close to the spin period of the WD, the observed flux variation can be very slow. However, our *HST* observations were too short to demonstrate that we detected a periodic signal.

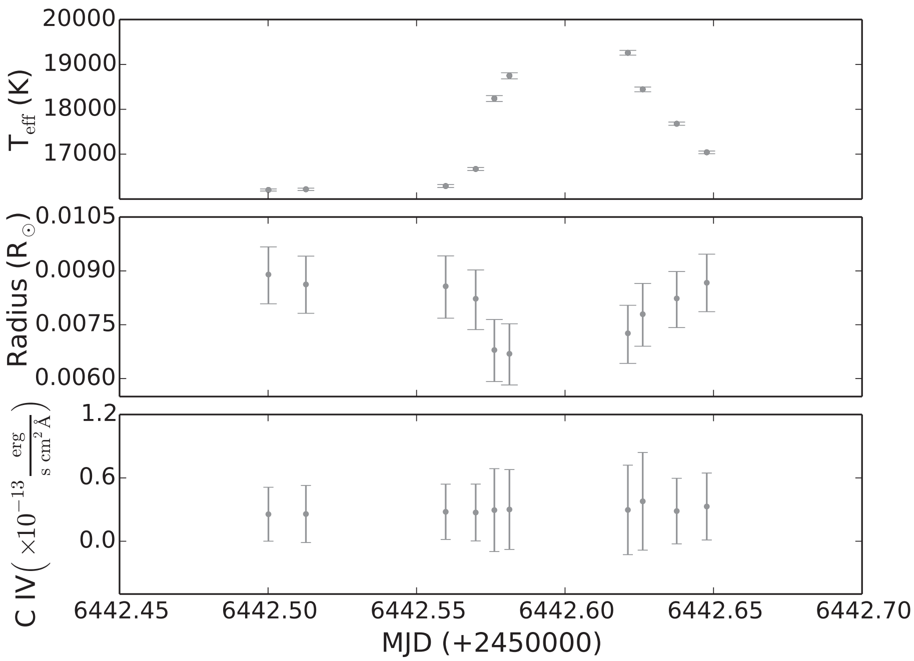

Figure 2. From top to bottom the effective temperature and the apparent radius of the WD, and the integrated flux of the C IV emission line during the *HST* observations in 2013.

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