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An Intensive HST/COS Study of 31 CV WDs

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Abstract. Accretion is the key ingredient in the evolution of white dwarfs (WDs) in cataclysmic variables (CVs), with important implications for their potential as progenitors for Type Ia Supernovae. The effective temperature ($T_{\rm eff}$) gives a direct measure of the average accretion rate and we report here the $T_{\rm eff}$ measurement for 31 CV WDs, observed as a part of a 122 orbit HST program. The HST spectra alone cannot resolve the degeneracy between $T_{\rm eff}$ and the surface gravity $\log g$, and we will use phase-resolved X-Shooter observations to (i) measure the mass ratio of the CVs from the reflex motion of both the WD and the donor star (ii) to establish the spectral energy distribution (SED), which constrains both $T_{\rm eff}$ and $\log g$. Combining the X-Shooter and HST data, we can measure the WD masses to a few percent, and will be able to answer the question whether accreting CV WDs grow in mass.

1. Introduction

Cataclysmic variables are close interacting binaries containing a white dwarf accreting from a Roche-lobe filling low-mass companion. It has been observed that, on long time scales, the accretion process is stable, therefore angular momentum loss (AML) is needed in order to maintain the secondary in touch with its Roche lobe (Knigge 2011). The evolution of CVs is driven by AML and, as shown by Townsley & Bildsten (2003), the T_{eff} provides a mean to constrain the mean accretion rate $\langle \dot{M} \rangle$ in CVs. At present, among all the CVs known, only 43 have reliable T_{eff} measurements (Townsley & Gänsicke 2009). We have been awarded a large HST program in Cycle 20 (122 orbits, PI Gänsicke), in which we obtained high-resolution COS ultraviolet spectroscopy of 31 CV white dwarfs. Following the method from Long et al. (2009), we measured the T_{eff} of each object assuming $\log g = 8$, and accounting in this way for the degeneracy among the two quantities. Thanks to this HST/COS survey, we doubled the number of accreting white dwarf with accurate T_{eff}, thereby measuring their mean secular accretion rates. We report here the T_{eff} measurement for these 31 CV WDs.

2. Method

We fitted the HST data using a grid of synthetic WD spectra, calculated with TLUSTY and SYNSPEC (Hubeny & Lanz 1995). Through a χ^2 minimization routine, we determined the WD T_{eff} assuming $\log g = 8$ (Table 1). However the observed flux level significantly exceeds that of the model spectrum in the core of Lyα (1180-1250 Å) revealing the contribution from another component in the system (the disk, the bright spot or a boundary layer). We improved the fits allowing for either a blackbody (BB), or a power law (PL), or a constant (CONST) in addition to the WD (Figure 1).

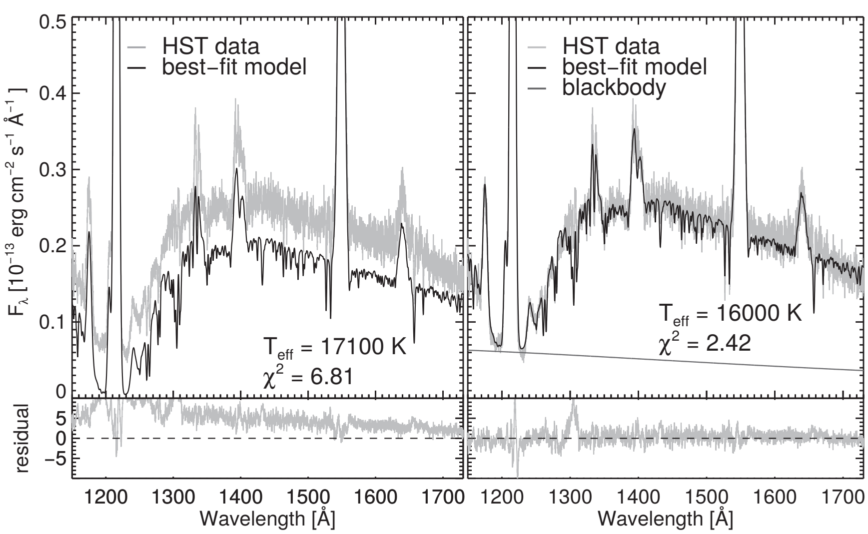

Figure 1. *Left:* HST/COS spectrum (light grey) of OT J213806.6+261957 with the best-fitting model (black) which is composed of a WD atmosphere model and Gaussian emission lines. The core of the Lyα profile is poorly fitted. *Right:* the fit is significantly improved by including an additional continuum component (blackbody, dark grey).

Table 1. Effective temperatures for the 31 CV WDs

object	*period* (min)	*second component*	*T* (K)
V485 Cen	59.03	BB	16400 (15300 - 17900)
GW Lib	77.90	BB	16600 (15500 - 18200)
SDSS J143544.02+233638.7	78.05	BB	12400 (11600 - 14200)
OT J213806.6+261957	78.10	BB	16000 (15000 - 17200)
SDSS J013701.06-091234.8	79.69	BB	14600 (13600 - 15400)
SDSS J123813.73-033932.9	80.52	BB	18800 (17500 - 20200)
ASAS J002511+1217.2	80.70	BB	12600 (12400 - 14000)
V1108 Her	82.08	PL	13300 (12600 - 14200)
SDSS J103533.02+055158.4	82.22	BB	12600 (12400 - 13600)
CC Scl	84.53	PL	19200 (18100 - 24400)
SDSS J075507.70+143547.6	84.67	BB	15700 (14500 - 16800)
1RXS J105010.8-140436	88.60	BB	11800 (11000 - 12400)
QZ Lib	91.60	BB	11200 (10000 - 11800)
SDSS J153817.35+512338.0	93.10	BB	24800 (22200 - 26600)
MR UMa	93.80	CONST	15100 (13600 - 15700)
1RXS J023238.8-371812	95.33	BB	13200 (12600 - 14000)
BB Ari	103.97	BB	15000 (13800 - 16000)
IY UMa	106.43	BB	16300 (15100 - 16900)
SDSS J100515.38+191107.9	111.60	BB	16000 (14900 - 16900)
CU Vel	113.04	BB	14800 (13800 - 15600)
SDSS J164248.52+134751.4	113.04	BB	19900 (18600 - 20600)
AX For	116.93	PL	16300 (14800 - 17300)
RZ Leo	119.50	BB	15300 (14200 - 16700)
QZ Ser	119.66	PL	15300 (14400 - 16700)
IR Com	125.34	BB	16900 (15500 - 17800)
SDSS J001153.08-064739.2	155.52	CONST	13800 (12200 - 14800)
OR And	195.70	CONST	26600 (26600 - 27000)
SDSS J040714.78-064425.1	244.94	BB	20300 (17700 - 20600)
HS 2214+2845	258.05	PL	24700 (23000 - 25000)
BD Pav	258.20	-	19500 (18100 - 20300)
HS 0218+3229	462.50	CONST	18400 (16700 - 19800)

3. Results

Adding our results to the 43 CVs from Townsley & Gänsicke (2009), we almost doubled the number of objects with an accurate temperature measurement. Since the $T_{\rm eff}$ is set by accretion heating, the $T_{\rm eff}$-$P_{\rm orb}$ distribution (Figure 2, top) should broadly reflect the accretion rate ($\dot{M}$)-$P_{\rm orb}$ distribution (Figure 2, bottom) predicted by CV evolution theory. The general trend in the $T_{\rm eff}$-$P_{\rm orb}$ plane agrees well with the theoretical prediction, with the average $\dot{M}$ above the period gap greater than that below. However, the systems with $P_{\rm orb} \sim 180$ min show an anomalous behaviour with a $T_{\rm eff}$ being about ten times higher than the value predicted by the evolution theory. Finally, the absence of systems with $T_{\rm eff} < 10000$ K suggests that none of them are strong candidate as "period bouncer”, showing that a major component of the predicted CV population remains still elusive to observations.

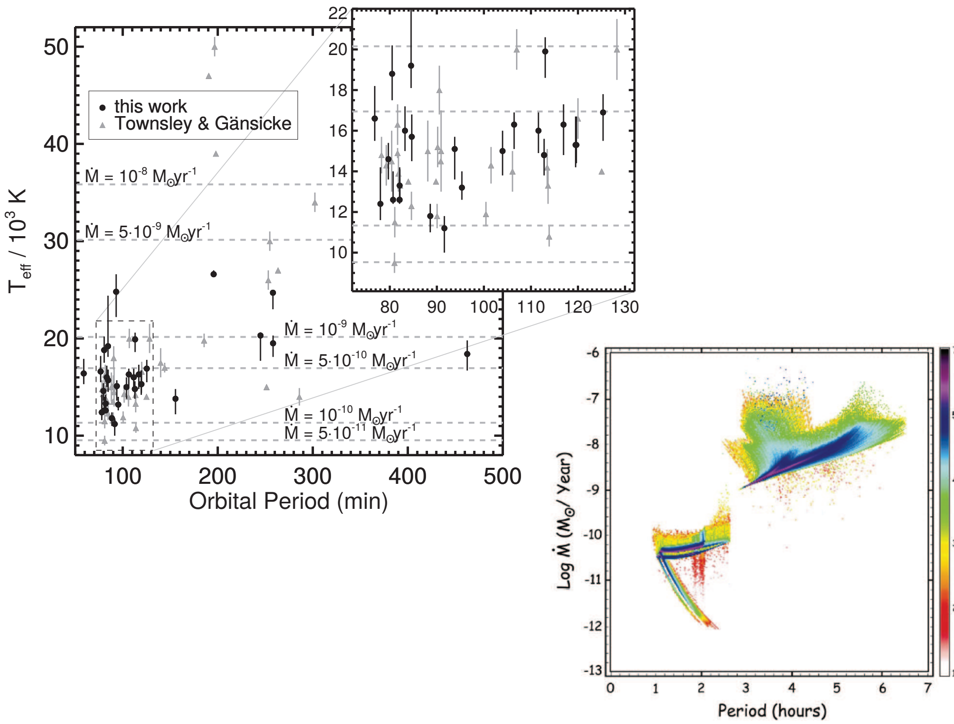

Figure 2. *Top:* effective temperature as function of the orbital period from this work (black) and from Townsley & Gänsicke (2009, grey). *Bottom:* present day CV population from Howell et al. (2001). The colour scale gives the logarithm of the system number density. (See online version for a colour figure).

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References

Howell, S. B., Nelson, L. A., & Rappaport, S. 2001, ApJ, 550, 897

Hubeny, I., & Lanz, T. 1995, ApJ, 439, 875

Knigge, C. 2011, in Evolution of Compact Binaries, edited by L. Schmidtobreick, M. R. Schreiber, & C. Tappert, vol. 447 of Astronomical Society of the Pacific Conference Series, 3

Long, K. S., Gänsicke, B. T., Knigge, C., Froning, C. S., & Monard, B. 2009, ApJ, 697, 1512

Townsley, D. M., & Bildsten, L. 2003, ApJ, 596, L227

Townsley, D. M., & Gänsicke, B. T. 2009, ApJ, 693, 1007