DW Cancri in X-rays

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Accepted 2019 January 9. Received 2019 January 9; in original form 2018 August 6

ABSTRACT

We report on the XMM–Newton observation of DW Cnc, a candidate intermediate polar candidate whose historical optical light curve shows the existence of periods at \( \simeq 38, \simeq 86 \), and \( \simeq 69 \) min, which were interpreted as the white dwarf spin, the orbital and the spin–orbit beat periodicities. By studying the 0.3–10 keV light curves, we confirm the existence of a period at \( \simeq 38 \) min and find in the OM light curve a signature for a period at 75 \( \pm 21 \) min, which is consistent with both the orbital and spin–orbit beat. These findings allow us to unveil without any doubt, the nature of DW Cnc as an accreting intermediate polar. The EPIC and RGS source spectra were analysed and a best-fitting model, consisting of a multitemperature plasma, was found. The maximum temperature found when fitting the data is \( kT_{\text{max}} \simeq 31 \) keV, which can be interpreted as an upper limit to the temperature of the shock.

Key words: novae, cataclysmic variables – white dwarfs – X-rays: binaries – X-rays: individual: DW Cancri.

1 INTRODUCTION

Cataclysmic variables (CVs) are binary systems with a white dwarf (WD) primary star accreting material from a donor (secondary) companion. Although the two stars interact principally via the formation of a Roche lobe (see e.g. Kuulkers et al. 2006 for a review), the accretion depends on several parameters as the strength of the magnetic field. In fact, depending on its value, CVs can be classified in non-magnetic systems, characterized by a weak field \( \lesssim 0.1 \) MG and an accretion disc, and, possibly, a boundary layer around the primary (see e.g. van Teeseling et al. 1996; Nucita et al. 2009a,b, 2011; Hoard et al. 2010; Balman 2011; Nucita et al. 2014; Mukai et al. 2017 to cite a few); intermediate polars (with magnetic field in the range 0.1–10 MG) where the accretion occurs via a mass flow directly pushed on to the WD poles.

In intermediate polars and polars the accretion flow (driven by the magnetic field) undergoes a strong shock close to the WD and releases X-rays to optical emission. Since the magnetic axis is offset from the WD spin one, the observed signal may show a modulation at the spin period and, in some cases, at lower time-scales depending whether parts of both poles are visible. Sometimes, a modulation in the X-rays light curves on the time-scale of the orbital period is also observed (Parker et al. 2005). These pulsations may be caused by a dependence of the accretion region view on the binary phase.

Another possibility could be the existence of a second emission component (caused by the interaction of the mass flow with an accretion disc or the WD magnetosphere) whose visibility changes with time. In alternative, if a non-axisymmetric disc exists, X-rays could suffer of a local absorption when the line of sight intersects the absorption structures. In the latter case, one would expect a decreasing of the modulation depth with increasing X-ray energy, thus suggesting photoelectric absorption as the main cause.

In this respect, DW Cancri (hereafter DW Cnc) is a variable binary identified as a CV from its Balmer emission lines (Stephanian 1982; Kopylov et al. 1988). Uemura (2002) reported kilosecond quasi-periodic oscillations (37 and 73 min) in the light curve, while Rodriguez-Gil et al. (2004), by performing radial velocity measurements, showed the existence of a period in the range 77–86 min. Finally, Patterson et al. (2004) reported the results of photometric and spectroscopic observations of the target. In particular, strong detection of the periods \( \simeq 86.1015(3) \) min and \( 38.58377(6) \) min were derived from radial-velocity measurements, showed the existence of a period in the range 77–86 min. Finally, Patterson et al. (2004) reported the results of photometric and spectroscopic observations of the target. In particular, strong detection of the periods \( \simeq 86.1015(3) \) min and \( 38.58377(6) \) min were derived from radial-velocity measurements and interpreted as, respectively, the orbital period \( P_{\text{orb}} \) of the binary (so that DW Cnc is a candidate CV below the period gap) and...
the spin period $P_{\text{spin}}$ of a magnetic WD. Further analysis on the DW Cnc light curve also showed the existence of a strong signal at spin 69.9133(10) min coinciding with the difference frequency $2\pi J2000 = 2\pi J2000 - 2\pi J2000$. 

Patterson et al. (2004) also pointed out that the detected periods are at least over one year and, since the observed light curve resembles the behaviour of several members of the DQ Herculis subclass of CV (i.e. intermediate polar), DW Cnc might be considered as an intermediate polar CV as well. As noted by Patterson et al. (2004) (but see also Mukai 2005), a high-energy view of DW Cnc (with a confirmation of the pulse period) was lacking. This is of particular interest since the detection of any X-ray pulsation at the WD rotational period could be described in the framework of the model accretion model proposed by Hellier et al. (1991) and would be the signature of a channelled accretion in DW Cnc.

Hence, we present an $\approx 9.4$ ks $XMM–Newton$ observation of the intermediate polar candidate DW Cnc showing that its spin pulse is clearly detected in the X-ray band thus unveiling its nature as an intermediate polar object. We then discuss the spectral and timing analysis conducted on data collected by the EPIC and RGS cameras and the OM telescope interpreting the observed properties as possibly due to changes of view of the X-ray emitting region.

### 2 XMM–NEWTON VIEW OF DW CANCRI

#### 2.1 Data reduction

DW Cnc (with J2000 coordinates RA = 07h58m53.10s and Dec. = +16° 16’ 45.1”) was observed by the $XMM–Newton$ satellite in 2012 (Observation ID 0673140101) for $\approx 9.4$ ks during what appeared to be a normal quiescent state of the target. The observation started (ended) on 2012 April 02 at 09: 06: 03 (11: 43: 04) UT with the EPIC pn (MOS) camera operating in large (small) window mode. The medium filter was selected during the observation. RGS 1 and 2 data were also available. The optical monitor (OM) aboard the satellite also observed the target in fast mode (thus allowing a time resolution of 0.5 s) and with the UVM2 filter centred at $\approx 231$ nm.

The EPIC raw data files (ODFs) were processed using the $XMM–Science$ Analysis System (SAS version 17.0.0). The data were processed using the latest available calibration constituent files (CCFs) and the event lists for the three EPIC cameras obtained by running the EMCHAIN and EPCHAIN tasks, thus producing calibrated event files. We then searched for segments of the observation affected by soft proton flares and determined a list of good time intervals through which cleaned event files (suitable for the following analysis) were produced. The files were also corrected for the barycentre (via the BARYCEN SAS tool) so that the photon arrival times are in the barycentric dynamical time instead of spacecraft time.

The source (plus background) signals in the soft (0.3–2 keV), hard (2–10 keV), and full (0.3–10 keV) bands were extracted from circular regions centred on the nominal DW Cnc coordinates and with radii of 40 arcsec thus allowing a collection of $\approx 88$ per cent of the total energy. The background counts were extracted for the same energy bands as above) from surrounding circular regions with radii of 115 arcsec. For each EPIC camera and energy band, we produced synchronized source (plus background) and background light curves with bin size of 10 s. The background light curves were then scaled (mainly accounting for the source extraction area) and subtracted from the source light curves by using the EPICLCCORR task. Note that the soft, hard, and full X-ray light curves were also synchronized to each other so that they can be combined thus increasing the signal-to-noise ratio. As a result of the above procedure the EPIC soft, hard, and full (background corrected) light curves started (ended) at MJD = 56019.40173 (MJD = 56019.48471) and correspond to average count rate of 2.2 ± 0.5, 0.7 ± 0.5, and 2.9 ± 0.7 counts s$^{-1}$, respectively. The soft, hard, and full X-ray light curves are shown (from top to bottom) in the left-hand panels of Fig. 1.

The OM UVM2 data were extracted by using the standard OMCHAIN task with time resolution set to 10 s. This resulted in a count rate light curve that was corrected for the Solar system barycentre and converted into magnitude assuming a zero-point of $\approx 15.77$. Hence the baseline magnitude (see also Fig. 2 where the start of the observation corresponds to MJD = 56019.38789) is $13.93 \pm 0.25$ during the $XMM–Newton$ observation. As one can note, the OM observation (lasting for $\approx 146.6$ min) is characterized by a small gap ($\approx 318$ s) as the maximum allowed integration time for an exposure in fast mode is $\approx 4.4$ ks.

As far as the spectral data are concerned, the EPIC source and background spectra were extracted in the same regions as above. Furthermore, high-resolution spectra from the RGS1 and RGS2 cameras were obtained (together with the corresponding ancillary files) by running SAS task RGSPROC. Then, the epic source (background corrected) spectra (one for each camera) were first re-binned to ensure that there were at least 25 counts per energy bin and then imported (together with all the relevant quantities as the response matrix and ancillary file) within the XSPEC package (version 12.9.0) for the spectral analysis and fitting procedure (see Section 2.3).

#### 2.2 Timing analysis

As described in the previous section, the barycentric/background corrected light curves (lasting for $\approx 119.5$ min) were extracted in the soft (0.3–2 keV) and hard (2–10 keV) bands with bin size of 10 s. The X-ray light curves and the associated hardness ratio were used to perform a blind search for periodicities in the range between twice the bin size and half the observational window with the well-known Lomb–Scargle technique (Scargle 1982). This search resulted in the identification of a periodic feature as indicated by the dashed vertical lines in the left-hand panels of Fig. 1, being the red horizontal lines the false alarm probability thresholds at 68 per cent (solid), 90 per cent (dotted), and 99 per cent (dashed) level, respectively. The average position of the feature corresponds to the periodicity of $37.7 \pm 4.5$ min, i.e. consistent with spin period ($P_{\text{spin}}$) of the WD already identified by Uemura (2002) and Patterson et al. (2004), thus confirming this signature in the high-energy data from DW Cnc. Note that the duration of the X-ray light curve limits our capability in any clear detection via the Lomb–Scargle periodogram technique of the orbital period (expected to be at $\approx 86$ min) or the periodicity associated with the different frequency ($\omega_{\text{spin}} - \omega_{\text{orb}} = 2\pi P_{\text{spin}} - 2\pi P_{\text{orb}}$) at $\approx 69$ min. This is also confirmed when using other analysis tools as the epoch folding technique. We also point to the fact that the timing analysis reveals powers at harmonics of the WD period as, in particular, $P_{\text{spin}}^2 \approx 19$ min (although at $\approx 3120$ A. A. Nucita, L. Conversi and D. Licchelli

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$^1$The historical AAVSO (The American Association of Variable Star Observers, https://www.aavso.org/) shows that DW Cnc is stable on a baseline of several years.
Figure 1. Left-hand panel: the DW Cnc Epic (background subtracted and synchronized) light curves in the 0.3–2, 2–10, and 0.3–10 keV bands and the hardness ratio together with the best-fitting sinusoidal function, respectively. Each light curve has a bin size of 10 s and the start of the observation corresponds to MJD = 56019.40173 d. Right-hand panel: the associated Lomb–Scargle periodograms with the identification of the WD spin period.

Figure 2. The OM light curve (in the UVM2 filter centred at 231 nm) is shown with a bin size of 10 s. The start of the observation corresponds to MJD = 56019.38789 d with the full light curve lasting for ∼2.44 h.

The general smooth and nearly sinusoidal light curves observed in different bands (2) and the fact that the soft and hard fractional modulations are consistent within the quoted errors, possibly imply that the rotational pulses could have their origin in a low confidence level) and $P_{\text{soft}}/3 \approx 14$ min. More interestingly, we noted in the power spectrum (see Fig. 1) the existence of a peak at ∼26 min which resembles the sideband feature ($\omega_{\text{spin}} + \omega_{\text{orb}} = 2\pi/P_{\text{spin}} + 2\pi/P_{\text{orb}}$) expected from $2\omega_{\text{orb}}$ modulation (see e.g. Norton, Beardmore & Taylor 1996).

We folded the soft, hard, and full light curves at the WD spin period (see Fig. 3) using 50 bins and note that the data show a quasi-sinusoidal behaviour with a broad maximum. In order to evaluate the degree of X-ray spin modulation, we define the percentage fractional modulation as $100*(M - m)/(M)$, where $M$ and $m$ are the maximum and minimum flux in the binned (both soft and hard) light curves. This resulted in fractional modulations resulted to be $43 \pm 4$ per cent (soft band) and $48 \pm 5$ per cent (hard band), respectively.

Figure 3. The EPIC light soft, hard, and full curves folded in 50 bins (each corresponding to ∼45.04 s) at the spin period of the WD.
the aspect changes (i.e. occultations) of the X-ray emitting region (a polar cap) as the WD rotates.\footnote{Furthermore, since the X-ray source never suffers of complete occultations (and no important spectral changes are observed, see Section (2.3) implies that the oblique rotator is observed at low inclination.}

Note however that the hardness ratio curve is characterized by a modulation with the WD spin period. This is clear from the bottom panel in Fig. 1 where, as usual, we define the hardness ratio HR as

\[
HR = (H - S)/(H + S),
\]

where \(S\) and \(H\) represents the count rates in the soft and hard bands, respectively. Inspection of this figure shows that the hardness ratio remains negative (due to an average emission in the soft band larger than the harder one) and has a sinusoidal behaviour as shown by the best-fitting sinusoidal function (obtained fixing the period to that derived by the Lomb–Scargle periodogram) superimposed to the data. This behaviour could arise (in part or totally) from the existence of a complex, partial covering absorption column as observed in other intermediate polars. We investigate this issue in Section 2.3 by performing a phase resolved spectral analysis.

The OM data in the UVM2 filter cover a total length of \(\pm 146.6\) min so that one could in principle detect any feature (if present) with periodicity of \(\pm 69–86\) min as these signal would be present with at least \(\pm 2\) full cycles. The periodicity was searched for by constructing the corresponding Lomb–Scargle periodogram.\footnote{We note here that, as discussed in Belanger (2016), the presence of gaps in the data introduces structures in the periodogram (including the Lomb–Scargle one) and, in particular, a sort of reddening effect appears. Hence, we filled the OM gap by randomly selecting data points from the remaining part of the light curve thus preserving the overall characteristics as bin size, rms, and noise of the data. For each light curve, the periodicity was searched for by constructing the corresponding Lomb–Scargle periodogram and the results averaged.} This procedure resulted in a clear identification in the optical data of a period of \(75 \pm 21\) min which, within the quoted errors, is consistent with both the 69 and 86 min features previously reported. The large error is due to the peak broadening in the associated periodogram.

### 2.3 Spectral analysis

We first simultaneously fit the background subtracted MOS 1, MOS 2, and pn spectra (grouped on a minimum of 25 counts per energy channel) with a simple bremsstrahlung model absorbed by a neutral hydrogen foreground column and a constant of proportionality to account for any possible difference between the detector responses (within XSPEC the model is const\(\text{phabs}\)\(\text{mekal}\)). We fixed the hydrogen column density to the average value found in the direction of the target (\(nH = 3.52 \times 10^{20}\) cm\(^{-2}\); Kalberla et al. 2005). The resulting fit quality is very poor (\(\chi^2 = 4.05\) for 542 degrees of freedom) and large residuals appear in the energy range 0.7–1 keV s (possibly due to the, blended, iron L-shell complex around 1 keV) and at the K line locations of heavy elements, in particular the features at 6.65 and 6.69 keV, plus residuals corresponding to the fluorescence of iron at 6.4 keV. In this respect, when repeating the analysis by adding three thin Gaussian lines (at 6.4, 6.65, and 6.69 keV) and one broad Gaussian centred at \(\approx 0.8\) keV the quality of the fit dramatically improves (\(\chi^2 = 1.32\) for 535 degrees of freedom) but still remaining statistically unacceptable.

These results led us to examine the spectrum with an emission model (as \textit{mekal}, Meew, Gronenschild & van den Oord 1985) of hot plasma in collisional ionization equilibrium able to simulate line emissions from different elements. A single temperature model (\textit{const\text{phabs}\text{mekal}} in XSPEC), with hydrogen column density as above and metal abundances set to the solar ones) resulted in plasma temperature of \(\approx 5.3\) keV but very poor from the statistical point of view (\(\chi^2 = 4.83\) for 543 degrees of freedom). Since, relaxing the assumption of the solar abundance did not improve the fit, this is a hint that a multitemperature plasma is acting. We found a reasonable fit by requiring a three-component plasma (\(\chi^2 = 1.05\) for 538 degrees of freedom) with temperatures \(kT_1 = 11.4^{+2.0}_{-1.0}\), \(kT_2 = 1.3^{+0.1}_{-0.0}\), and \(kT_3 = 0.6^{+0.4}_{-0.0}\) keV and neutral hydrogen column density \(nH = (1.9 \pm 0.4) \times 10^{20}\) cm\(^{-2}\). Note that the two previous models converge practically to the same values of temperatures (within the errors) regardless if the hydrogen column density is considered as a free fit parameter or fixed at its average Galactic value observed towards the target.

In the previous section, we showed that the hardness ratio light curve is characterized by a modulation with the WD spin period. Since most of the IP are characterized by strong and very complex absorption (see e.g. Mukai, Ishida & Osborne 1994), the observed modulation could be explained by a partial covering absorption column.

To test this hypothesis, we fit the data using, as above, three mekal components with equal abundances and absorbed by both simple and partial absorptions, i.e. \textit{const\text{phabs}\text{pcfabs}\text{mekal} + mekal} in XSPEC. The best fit resulted in a metal abundance of \(Z = 0.53^{+0.12}_{-0.09}\), temperatures \(kT_1 = 10.5^{+1.3}_{-1.0}\), \(kT_2 = 1.4^{+0.1}_{-0.0}\), and \(kT_3 = 0.6^{+0.4}_{-0.0}\) keV, neutral hydrogen column density \(nH = (2.2 \pm 0.5) \times 10^{20}\) cm\(^{-2}\), complex equivalent hydrogen column \(nH = (10.4^{+2.1}_{-1.0}) \times 10^{20}\) cm\(^{-2}\) (being this value similar – although with large uncertainties – to column density values found in other IP objects, see e.g. Evans et al. 2006) and with a partial dimensionless covering factor \(f = 0.11 \pm 0.08\).

Note that, although all the values of the interesting parameters remain practically unchanged with respect to the previous model, the associated \(\chi^2\) statistics (\(\chi^2 = 0.97\) for 535 degrees of freedom) and its negligible improvement does not justify the introduction of any complex partial covering thus favouring galactic absorption.

We further noted that the metal abundance sets to a relatively low value and, in addition, the simple three temperature plasma model (with all the parameters fixed to their best-fitting values except for the normalization constants) does not adapt to the RGS 1 and RGS 2 data failing in reproducing the overall shape and, in particular, the intensities of the transition lines as the He-like transitions of OVII (see Section 2.4). Hence, two possibilities are equally probable: the derived metal abundance is too low or a complex stratification of temperatures is required.

Observing that the accretion post-shock regions are expected to have a gradient in temperature deriving from the cooling of the gas when falling on to the WD surface (de Martino et al. 2005), we used in XSPEC a multitemperature scenario based on the \textit{cemekl} model (still intrinsically dependent on \textit{mekal}) absorbed by a neutral hydrogen distribution characterized by a column density. We remind that the \textit{cemekl} model is normally used to account for a gradient of temperature in post-shock regions around CVs. In
Figure 4. The best fit to the MOS 1, MOS 2, and pn data with the XSPEC model constxphabs(cemekl) (see text for details).

In particular, the emission measure gradient follows a power law as $d\text{EM} / dT = (T_{\text{max}})^{\alpha - 1} / T_{\text{max}}$. In this model, the free parameters are the neutral hydrogen column density, the maximum value of the plasma temperature $T_{\text{max}}$, the power-law index $\alpha$, the metal solar abundance $A_Z$ relative to the solar one, the model normalization, and a constant factor introduced for intercalibration issues among the instruments. The best-fitting converged towards the values ($\chi^2 = 1.04$ for 540 degrees of freedom) $n_H = (3.1 \pm 0.3) \times 10^{20}$ cm$^{-2}$, $kT_{\text{max}} = 31^{+1}_{-2}$ keV, $\alpha = 0.65^{+0.06}_{-0.05}$, and $A_Z = 0.9^{+0.1}_{-0.1}$, respectively.

Note that the low-hydrogen column density of the absorber is consistent with the value of the Galactic column density in the direction of the source so that, again, the introduction of any complex partial covering is not required. Differently to what happens in most of the observed IPs (Mukai et al. 1994), but in common with at least another IP object (HT Cam; de Martino et al. 2005), DW Cnc seems to be not characterized by complex local absorption, being this an hint that the X-ray source is not seen though variations due to aspect changes of the underlying X-ray emitting region as the WD rotates. In fact, in the scenario in which a polar cap never suffers of complete occultations (i.e. the oblique rotator is observed at a low inclination angle), changes in the observed projected area of the X-ray source naturally explains the observed modulation.

As a by product, this model reproduces much better the overall structure of the RGS 1 and RGS 2 spectra (see Section 2.4) when fixing all the parameters to the best-fitting results and adjusting only the normalizations.

In order to investigate the WD spin pulse profile and any possible dependence of the source spectral properties on the phase, we defined phases intervals (see Fig. 3) encompassing the regions around maxima (at phases 0–0.25 and 0.7–1) and minima (at phases 0.33–0.55) and extracted the corresponding spectra from the three XMM–Newton cameras. The spectra were then fitted separately with the same model consisting in an absorbed multitemperature plasma with all the interesting parameters free to vary but fixed metal abundance to the value obtained analysing the phase averaged spectrum. As a result, we obtained $kT_{\text{max}} = 28^{+4}_{-5}$ keV and $\alpha = 0.57^{+0.06}_{-0.05}$, and $kT_{\text{max}} = 35^{+7}_{-6}$ keV and $\alpha = 0.61^{+0.10}_{-0.05}$ for maxima and minima, respectively. Clearly, at different phases, the spectral properties of the source are consistent within the quoted uncertainties.

Table 1. Spectral parameters for the best-fitting model (constxphabs(cemekl)) in XSPEC, see text for details). We also give the 0.3–10 keV absorbed and unabsorbed fluxes.

| Parameter | Value |
|-----------|-------|
| $n_H$     | $(3.1 \pm 0.3) \times 10^{20}$ cm$^{-2}$ |
| $\alpha$  | $(0.65^{+0.06}_{-0.05})$ |
| $kT_{\text{max}}$ | $31^{+1}_{-2}$ keV |
| $A_Z$     | $0.9^{+0.1}_{-0.1}$ |
| $F_{0.3-10\text{keV}}^{\text{abs}}$ | $(1.59^{+0.02}_{-0.03}) \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ |
| $F_{0.3-10\text{keV}}^{\text{una}}$ | $(1.68^{+0.02}_{-0.03}) \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ |

The previous finding, and the fact that we do not find evidences for a local partial covering, pushes us in interpreting the observed variability due to aspect changes of the underlying X-ray emitting region as the WD rotates. In fact, in the scenario in which a polar cap never suffers of complete occultations (i.e. the oblique rotator is observed at a low inclination angle), changes in the observed projected area of the X-ray source naturally explains the observed modulation.

This model (see Fig. 4) resulted in absorbed and unabsorbed 0.3–10 keV band fluxes of $F_{0.3-10\text{keV}}^{\text{abs}} = (1.59^{+0.02}_{-0.03}) \times 10^{-11}$ and $F_{0.3-10\text{keV}}^{\text{una}} = (1.68^{+0.02}_{-0.03}) \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$, respectively, which correspond to luminosities of $\gtrsim 8.2 \times 10^{31}$ and $\gtrsim 8.7 \times 10^{31}$ erg s$^{-1}$ when a distance of $\gtrsim 208$ pc (as reported in the second Gaia data release; Brown et al. 2018) is assumed (see Table 1).

2.4 RGS data

Note that the same multitemperature model used for the EPIC spectral fit provides an adequate description of the RGS spectra when fixing all the parameters of the model to those derived above but adjusting consistently the model normalizations. In particular, inspecting Fig. 5 (where the best fit is superimposed to the RGS1 and RGS2 data re-binned in order to have at least a significance of 10$\sigma$ per bin), one can note the existence of the OVIII Ly$\alpha$ emission line at $\approx 0.65$ keV, and emission lines in the energy range 0.56–0.57 keV (21.6–22.1 Å) possibly associated with the He-like transitions of OVII, i.e. the resonance line $r$ (corresponding to the
transitions between the \( n = 2 \) shell and the \( n = 1 \) ground state), and the intercombination \((i)\) and the forbidden \((f)\) lines. In this respect, as shown by Porquet & Dubau (2000) the relative emission strength of the \( r, i, \) and \( f \) lines is a good indicator of the physical conditions of density and temperature of the gas.

In order to have a measure of the line fluxes, we followed the phenomenological spectral analysis method described in Nucita et al. (2010) and references therein. In particular, the unbinned RGS spectra are divided in intervals of 100 channels wide and Gaussians are fitted to all the identified emission lines. For each (single) emission line the centroid energy is free to vary and, when triplets are identified, the relative distance between the central energies was always modelled as a power law with a fixed photon index \( \Gamma \) frozen to the value predicted by atomic physics. The local continuum was always modelled as a power law with a fixed photon index \( \Gamma \) = 1 and normalization free to vary. Since we are dealing with the unbinned spectra, we estimated the goodness of the fit by using the C-statistic (see Cash 1979). We further consider the line (or triplet) detected at 68 per cent confidence level when, repeating the fit with the continuum only, we obtained a change in the C-statistic value \( (\Delta C) \) by at least 2.3. The result of this analysis (see also Table 2) showed that the OVII resonance line is much more weaker than the Ly\( \alpha \) line at 18.96 Å and the OVIII He-like triplet. However, due to the large uncertainties, further higher S/N observations are required in order to accurately determine the redshift and, possibly, to analyse any line modulation with the spin/orbital period of DW Cnc.

### Table 2. Line parameters as measured from the RGS 1 and RGS 2 spectra of DW Cnc. The expected centroid wavelength in the rest frame is extracted from the CHIANTI data base (Dere 2001).

| Line ID | \( \lambda_{\exp} (\text{Å}) \) | \( \lambda_{\text{obs}} (\text{Å}) \) | Flux \( \times 10^{14} \text{ erg s}^{-1} \text{ cm}^{-2} \) | \( \Delta C \) | R | L | G |
|---------|-----------------|-----------------|-----------------|-----------|---|---|---|
| OVII Ly\( \alpha \) | 18.969 | 18.966\,^{+0.009}_{-0.012} | 13.6\,^{+0.1}_{-0.1} | 16 | -- | -- | -- |
| OVII \((i)\) | 21.600 | 21.632\,^{+0.019}_{-0.008} | 5.5\,^{+3.2}_{-2.9} | 14 | \( \leq 1 \) | \( \leq 1.5 \) | \( \leq 5 \) |
| OVII \((i)\) | 21.790 | 21.835\,^{+0.019}_{-0.008} | 8.1\,^{+4.7}_{-4.6} | -- | -- | -- | -- |
| OVII \((f)\) | 22.101 | 22.135\,^{+0.019}_{-0.008} | 3.0\,^{+3.4}_{-2.6} | -- | -- | -- | -- |

3 DISCUSSION AND RESULTS

DW Cancri is a variable binary classified as a CV from its Balmer emission lines (Stepanian 1982; Kopylov et al. 1988). The source was intensively studied in the optical band and periods of \( \approx 38 \), \( \approx 86 \), and \( \approx 69 \) min (see e.g. Uemura 2002; Patterson et al. 2004; Rodriguez-Gil et al. 2004) were identified and explained as the WD spin period, the orbital period and spin–orbit beat, respectively.

Nevertheless, as suggested by Patterson et al. (2004), a confirmation of the DW Cnc spin period in the X-rays was necessary. Hence, analysing the 0.3–10 keV data acquired by the XMM–Newton telescope, we have shown the existence of a 37.7 ± 4.5 min periodicity consistent with the spin period of the WD thus allowing us to classify DW Cnc a member of the intermediate polar class. The timing analysis reveals powers at harmonics of the WD period,
i.e $P_{\text{spin}}/2 \approx 19$ min and $P_{\text{spin}}/3 \approx 14$ min, being the second feature more evident. Unfortunately, the duration of the X-ray light curve limited our capability to have any clear detection of the orbital and spin–orbit beat periodicity corresponding to the frequency $\omega_{\text{spin}} - \omega_{\text{orb}} = 2\pi P_{\text{spin}} - 2\pi P_{\text{orb}}$. However, a sideband at the beat period $\approx 26$ min possibly exists as originating from a $2\omega_{\text{orb}}$ modulation which could produce a feature at frequency $\omega_{\text{spin}} + \omega_{\text{orb}} = 2\pi P_{\text{spin}} + 2\pi P_{\text{orb}}$.

Note finally that the OM data in the UVMM filter cover a total length of $\approx 146.6$ min thus allowing us to identify a period of 75 ± 21 min which, within the quoted uncertainty, is consistent with both the 69 and 86 min features reported in literature.

We also performed a spectral analysis of the phase average spectrum finding that the EPIC data can be described by a multitemperature plasma model simply absorbed by the galactic neutral hydrogen column density. In particular, the best fit converged towards the values ($\chi^2 = 1.04$ for 540 degrees of freedom) $n_H = (3.1 \pm 0.3) \times 10^{20}$ cm$^{-2}$, $kT_{\text{max}} = 31^{+20}_{-5}$ keV, $\alpha = 0.65^{+0.08}_{-0.09}$, and $A_Z = 0.9^{+0.2}_{-0.4}$, respectively, which corresponds the unabsorbed 0.3–10 keV band flux of $F_{0.3–10\text{keV}} = (1.68^{+0.02}_{-0.02}) \times 10^{-11}$ erg s$^{-1}$ cm$^{-2}$. When assuming a distance of $\approx 208$ pc, the measured luminosity turns out to be $\approx 8.7 \times 10^{31}$ erg s$^{-1}$.

The best-fitting model provides an adequate description of the RGS spectra ($<0.3$ keV) as well. In addition, in the low-energy data, we noted the existence of a few emission lines (corresponding to the harder part of the mekal component embedded in the cvmekal model used here) could be unreliable [but not different from other similar findings as in the case of PQ Gem (Evans et al. 2006)] and possibly arising from the usage of a multitemperature model. Of course, further spectral observations extended to larger energies would allow to solve this issue.

We also remind that the spectral properties extracted in the phase intervals associated with the maxima and the minima of the source activity remain consistent (within the errors) with the values derived for the phase averaged spectrum. This fact, together with the absence of any evidence of a local partial covering, push us in interpreting the observed variability as due to aspect changes of the X-ray emitting region as the WD rotates. Also in this case, further and longer X-ray and/or optical observations are required in order to check the existence of periods other than that associated with the WD spin in the DW Cnc data. High-energy band X-ray data (see e.g. Landi et al. 2009) would also allow to firmly establish the spectral properties of DW Cnc.

ACKNOWLEDGEMENTS

This paper is based on observations from XMM–Newton, an ESA science mission with instruments and contributions directly funded by ESA Member States and NASA. We thank the anonymous referee for the suggestions that greatly improved the paper. We thank partial support from the INFN projects TaSP and EUCLID. We warmly acknowledge Berlinda Maiolo, Sara Nucita, and Matteo Nucita for reading the manuscript. We warmly acknowledge ESAC (ESA) for the facilities provided.

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