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The eclipsing AM Herculis binary V2301 Ophiuchi

I. ROSAT & IUE observations

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Abstract. We present X-ray and UV observations of the unique eclipsing cataclysmic variable V2301 Oph (1H1752+081). The X-ray eclipse of the primary star is total and corresponds in phase with the optical eclipse of the white dwarf. The X-ray light curve shows a quasi-sinusoidal orbital "hump" typical of AM Her systems. The orbital phase at which the hump has its peak has remained at ∼0.9 in all ROSAT observations taken over several years. We can rule out a 100% modulated spin-pulse signal with a period shorter than $P_{\rm orb}$. Thus, it is very unlikely that there is either a non-synchronously rotating white dwarf or an accretion disk in V2301 Oph. The relatively hard X-ray spectrum of this weakly-magnetic system does not change its shape during the orbit or around the eclipse and is consistent with that expected from a hot accretion column on a weakly magnetized white dwarf. The interstellar absorbing column density of $\sim 4 \cdot 10^{20}$ H-atoms cm^{-2} required by the X-ray spectral fits is capable of hiding any weak soft X-ray component. The lower limit to the relative contributions of a hard bremsstrahlung and a soft blackbody component is consistent with both the empirical relation for AM Hers and the theoretical expectations for a system with a low magnetic field strength. The irregular "dips" present in the light curve around phases 0.85-0.92 with depths up to 80% are not accompanied by significant changes in the hardness ratios and must be due to partial covering by a structured and blobby accretion stream which has been lifted out of the orbital plane by the magnetic field of the primary. The close agreement between the phasing of the dips and the peak of the X-ray light curves is expected in a synchronous magnetic accretor. The relative strengths of the NV, CIV, and HeII UV emission lines are typical for AM Her stars. Thus, the X-ray orbital light curves and the X-ray and UV spectra clearly identify V2301 Oph as an AM Her system.

Key words: stars: individual: V2301 Oph – stars: cataclysmic variables – stars: eclipsing binaries – stars: magnetic fields – X-rays: stars – UV: stars

1. Introduction

Cataclysmic variables (hereafter CV's) are close binary systems containing a white dwarf primary and a late-type secondary main-sequence star. The secondary fills its Roche lobe and transfers material via the inner Lagrangian point to the primary. If the primary is only weakly magnetic (a DQ Her system or Intermediate Polar) or non-magnetic, the specific angular momentum of the accretion stream results in the formation of an accretion disk, with a warm, shocked region – the "hot-spot" – where the stream hits the outer disk. In magnetic systems with large primary surface magnetic fields of typically 10-60 MG (the AM Her variables), the material in the accretion stream is eventually directed along the magnetic field lines of the primary, producing a very hot shock near the surface of the white dwarf.

The HEAO-1 Modulation Collimator Survey source V2301 Oph (1H1752+081) was identified as a deeply eclipsing CV with an orbital period of 113 minutes by Remillard et al. (1992). Silber (1992; Silber et al. 1994) obtained CCD photometry of the system which showed features reminiscent of the eclipses of a classical disk "hot spot" and a white dwarf. The derived disk radius was unusually small, with a radius roughly corresponding to the specific angular momentum of the accretion stream. However, no features attributable to a disk eclipse were seen, suggesting that V2301 Oph might be an AM Her. The main argument against the latter model was that V2301 Oph is a very hard X-ray source whereas most AM Her's are observed to be quite soft.

Barwig, Ritter & Bärnbantner (1994; hereafter BRB) obtained high-speed photoelectric photometry and higher-

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Table 1. Log of observations

Date	Instrument	$t_{\rm total}$	Comment
1993 Sep 10	ROSAT, PSPC	2773 s	
1993 Sep 11	”	2717 s	
1994 May 27	IUE LWP28277	35 min	out of eclipse
1994 May 28	IUE, SWP50920	4× 8 min	eclipse
”	”	2× 90 min	out of eclipse
”	IUE, LWP28278	90+13 min	out of eclipse
1995 Mar 25	ROSAT, HRI	1091 s	
”	”	1909 s	
”	”	2913 s	
1995 Mar 26	”	32 s	
”	”	3404 s	

resolution time-resolved spectroscopy of V2301 Oph (their ephemeris will be used in all analyses which follow). The variable ingress times of the “hot-spot” eclipse and the high amplitude radial velocity variations of the Balmer emission lines led them to identify V2301 Oph as an AM Her system. The duration of the “white dwarf” eclipse ingress lasted twice as long as the egress, implying that the accretion spot had some longitudinal structure on the face of the white dwarf. Despite the difference in the eclipse times, the amplitude of the eclipse was the same. This effect went away during the “low-state” seen in 1995, during which the eclipse times were the same (Barwig, private communication).

The magnetic nature of V2301 Oph was finally determined by Ferrario et al. (1995), who observed the Zeeman splitting of the Balmer absorption lines from the white dwarf during a low state. They determined a mean magnetic field strength of only 7 MG, significantly smaller than the next lowest magnetic fields in AM Hers (Beuermann & Burwitz 1995): about 12-14 MG in AM Her itself (Bailey et al. 1991), EF Eri (Östreicher et al. 1990), and RXJ1957-57 (Thomas et al. 1996). Thus, the polarized optical cyclotron lines seen in the intermediate-to-high states of other AM Hers are located in the near infrared in V2301 Oph, explaining not only why the classical signs of a magnetic accretor weren’t seen previously, but why Ramsay & Cropper (1994) and Ferrario et al. (1995) could only find an upper limit of about 1% to the optical broad-band circular polarisation – usually a sign of an intermediate polar. However, Šimić et al. (1997) show that the Balmer emission line and optical continuum light curves are more easily explained as begin due to emission from the accretion stream and the accreting poles rather than from a bright spot at the edge of a disk.

As the first part of a multi-wavelength study of V2301 Oph, we present X-ray and UV observations of V2301 Oph which enable us to shed further light on the nature of this unusual object. In a second paper, we will present phase-resolved spectroscopy of the optical emission lines and a tomographic analysis of the magnetospheric boundary layer.

2. X-ray observations

We obtained X-ray observations of V2301 Oph using the ROSAT satellite, both from the PSPC All-Sky Survey (RASS; Voges 1993) and from pointed PSPC and HRI observations (see the log of observations in Table 1). V2301 Oph is a fairly hard but bright X-ray source. All data were reduced using standard EXSAS procedures within the MIDAS data reduction environment.

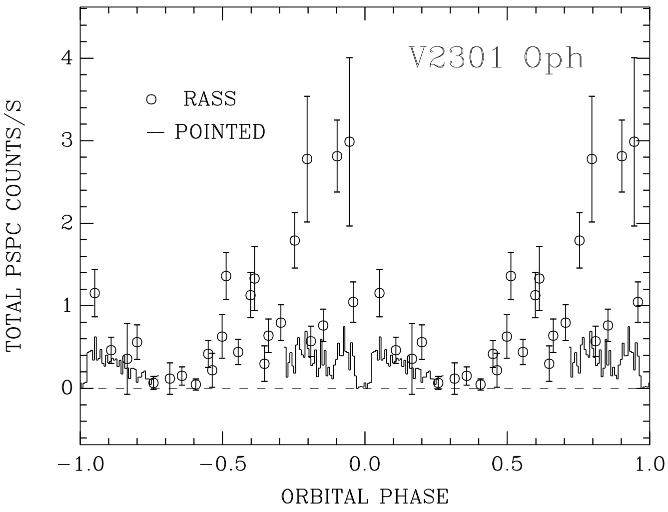

Fig. 1. Orbital light curve of V2301 Oph taken from the ROSAT survey data (circles) and the PSPC pointed data (solid line)

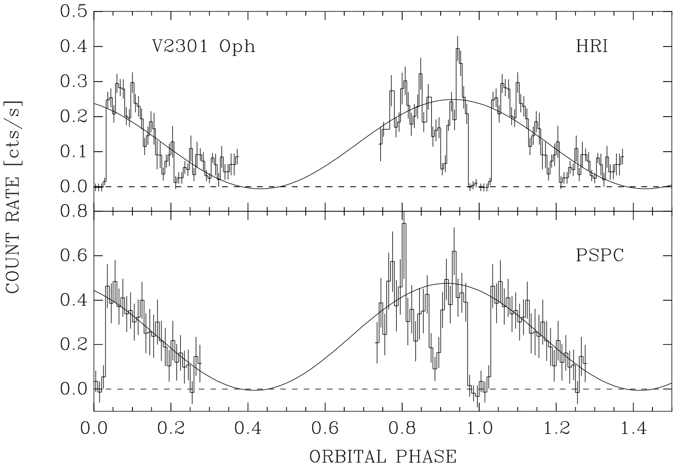

Fig. 2. Mean phased ROSAT PSPC and HRI light curves (histograms) showing the eclipse of the white dwarf, the orbital “hump” around phases 0.75-1.1, the variable “dips” around phases 0.8-0.9, and sinusoidal fits to the non-dip, non-eclipse light curves (solid lines).

2.1. ROSAT All-Sky Survey

The orbital light curve of V2301 Oph pieced together from the RASS data (Beuermann and Thomas 1993) is shown in Fig. 1 (circles with error bars). V2301 Oph was fairly hard during the RASS (HR1=+0.8) but still showed an unusually high 0.1-3 cts s^{-1} in the ROSAT PSPC, making it one of the brightest X-rays sources in the CV sky at the time. Unfortunately, no data were available during the eclipse. Although there is considerable variation from orbit to orbit, an orbital hump around phases 0.5-

1.1 can be seen. Most of the variation at a given orbital phase is due to orbit-to-orbit variations and the odd phase-coverage of the survey data rather than marked differences in count rates within an orbit. Thus, the orbital "hump" is real but its amplitude is variable. Similar orbital humps are seen in most AM Hers and are produced when the accretion shock on the white dwarf shows its maximal area ("bright phases"; King & Shaviv 1984).

2.2. ROSAT PSPC observations

We obtained ROSAT PSPC pointed observations centered on two eclipses on 1993 September 10 and 11 (Table 1). The maximum count-rate was smaller than that seen in the RASS data: roughly 0.6 cts s^{-1} in the pointed versus 2-3 cts s^{-1} in the survey data. The binned light curve constructed from a total of 5490 s of data using the orbital ephemeris of BRB is shown in Fig. 2 (lower graph). The eclipse of the X-ray emission region expected for the estimated inclination of 80° (BRB) is clearly visible and is total (the noise during mid-eclipse is due to the subtraction of the soft X-ray background). As in the RASS data, a broad orbital hump is apparent, but there is also a clear dip in the hump around orbital phase 0.87-0.90 which reaches down to about 20% of the hump level, presumedly due to photoelectric absorption by material along the line-of-sight to the emission region at that particular phase. The X-ray spectrum of V2301 Oph is hard and does not change in shape with orbital phase (Fig. 3). The weighted means of the standard ROSAT hardness-ratios HR1 and HR2 are $+0.89 \pm 0.04$ and $+0.31 \pm 0.03$, respectively. Thus, not only is there no sign of the optically thick soft spectrum component typical of most AM Hers, but there are also no spectral changes around the eclipse or during the dips.

2.3. ROSAT HRI observations

We obtained ROSAT HRI pointed observations on 1995 Mar 25 and 26. During 5 OBI's, a total of 9349 s of accepted time was obtained. The binned light curve constructed using the orbital ephemeris of BRB is shown in Fig. 2 (upper graph): as with the PSPC data, the total eclipse of the X-ray emission region and the dipping behavior (this time around phase 0.9) is obvious. Comparisons of the mean PSPC and HRI light curves as well as the individual unphased HRI light curves clearly show that the dips are due to individual absorption events scattered around phases 0.8-0.9.

3. IUE observations

We obtained three IUE UV spectra of V2301 Oph using the short (SWP) and long wavelength (LWP) cameras with the large aperture and in low dispersion (∼ 6Å) mode (see Table 1). In order to save read-out time and to achieve reasonable S/N, we exposed the SWP camera displacing V2301 Oph at two positions in the large aperture at an offset of 8" from each other, accumulating two segments of 90 minutes each during the out-eclipse phases at one position and four segments of 8 minutes each during the eclipse phases at the other. We also acquired two LWP spectra.

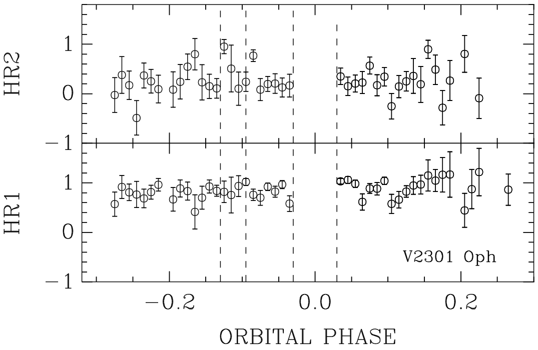

Fig. 3. The ROSAT PSPC hardness light curves showing that V2301 Oph is a hard source with practically no orbital spectrum modulation. Bottom: HR1, measuring the relative flux in the 0.1-0.4 and 0.4-2 keV bands. Top: HR2 (the 0.4-0.5 and 0.5-2 keV bands).

While the first exposure was very short (35 min.) and was used to check the centering procedure of the target for the multiple exposures, the second spectrum was a longer one and obtained accumulating two segments of 90 minutes and 13 minutes for a total of 103 minutes during out-of-eclipse phases.

The IUE spectra have been processed using the standard IUE software package (IUESIPS) at VILSPA. Since IUESIPS does not handle multiple exposures, we extracted the spectra from the the line-by-line IUESIPS processed images using standard MIDAS routines and applied IUESIPS camera sensitivity functions and time degradation corrections as it is currently done with the new software package (NEWSIPS). Before extraction, the images were inspected line-by-line for spurious features like cosmic rays.

The out-of-eclipse SWP spectrum shows a weak blue continuum and emission lines of NV λ1240, the SiIII/SiII/OI blend around 1300 Å, CII λ1335, SiIV λ1397, CIV λ1550, HeII λ1640, NIV λ1718, CIII λ1176, and Al III λ1855. In the longer exposure LWP spectrum a weak MgII λ2800 line is observed. During the eclipse phases no spectrum was detected. The average out-of-eclipse UV spectrum is shown in Fig. 4 with no evidence of any 2200 Å interstellar absorption feature.

While the strongest lines as NV, SiIV, CIV, HeII are typically observed in both non magnetic and magnetic CVs, the presence of a wide range of ionization states from CIV to CII, from NV to NIV and from SiIV to SiIII/SiII appears to be a characteristics of AM Her stars (de Martino 1995). Line flux ratios NV:SiIV:CIV:HeII ($1.4{:}3.8{:}13.5{:}2.0 \cdot 10^{-13}$ erg cm^{-2} s^{-1}) of V2301 Oph are typical for those observed in CVs (Mauche, Lee & Kallman 1997). The NV/SiIV ratio (0.36) fits into the range observed for AM Hers whereas all intermediate polars except EX Hya and FO Aqr have values greater than 1.0 (de Martino 1995; Szkody & Silber 1996).

4. The X-ray light curves

V2301 Oph must have been in a very similar state during the pointed PSPC and HRI observations – the ratio of the mean count rates roughly corresponds to that of the effective areas

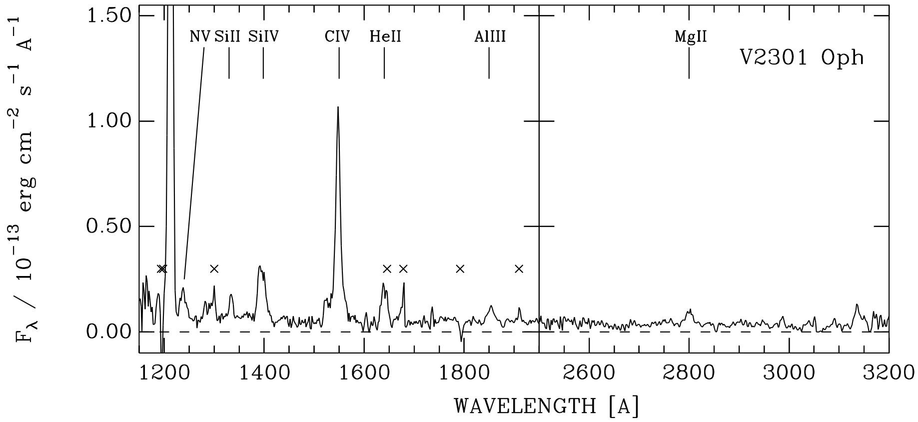

Fig. 4. IUE spectrum of V2301 Oph. The exes show the positions of cosmic ray events and reseaux marks.

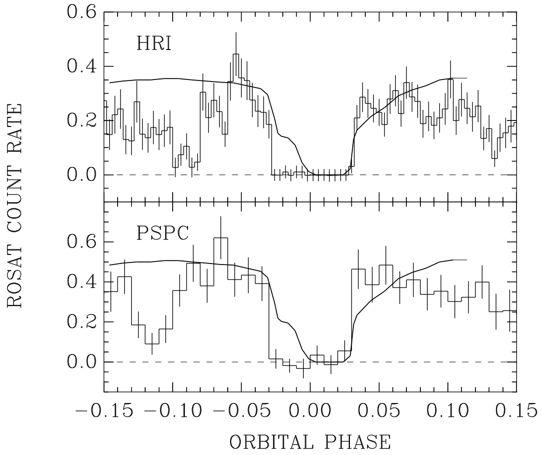

Fig. 5. The mean X-ray (histograms) and optical R-band (continuous line) eclipse light curves. The phase-resolution of the HRI light curve is twice as high as that of the PSPC light curve.

of the instruments for a hard spectrum and the light curves are very similar. The differences between the RASS and the pointed observations suggest that V2301 Oph shows several distinct X-ray states with different flux levels and degrees of light curve variability, presumeably related to the overall accretion rate: a minimum state during which the optical Zeeman lines from the white dwarf can be seen; a state with fairly steady accretion like that seen during the PSPC and HRI observations; and the high state with the irregular accretion seen in the RASS data.

When the eclipses in the PSPC and HRI mean light curves are compared with the smoothed mean R-band light curve from BRB (Fig. 5), it is clear that the X-ray eclipse is due to the eclipse of the accretion region on or around the white dwarf. The other major optical eclipse feature is not seen in the X-rays and is due to the accretion stream while or after it is deflected onto the magnetic field lines of the white dwarf. Unfortunately, the number of photons is not large enough to see if the lengths of the ingress and egress phases are equal (as would be expected for the simple eclipse of a small accretion region on the white dwarf) or not (as is observed in the optical during the normal photometric state of V2301 Oph; BRB).

The RASS data are too sparse to allow a precise determination of the hump position, but there is enough phase coverage in the PSPC and HRI data to permit a simple sinusoidal fit to the portions of the mean light curves uncontaminated by either the eclipse or the "dips". The fitted phase positions of the assumed sinusoidal peaks are 0.92 ± 0.02 and 0.93 ± 0.02 for the PSPC (taken in 1993) and HRI (1995) mean light curves, respectively. These results are consistent with the overall shape of the light curve in the RASS data taken in 1990/1991.

In order to search for a hypothetical spin-pulse, we pre-whitened the PSPC and HRI data using the fits to the orbital humps and then binned them into light curves with 40 sec time resolution. Analysis-of-Variance periodograms (AoV: Schwarzenburg-Czerny 1989) were then calculated, making sure to bin consecutive points falling in the same phase bin. No signal with periods greater than 150 sec are present above the expected noise level ($\theta_{AoV} \approx 1$). The spacing of the OBI's and the loss of the dip and eclipse phase data limit our sensitivity: only hypothetical pulses with semi-amplitudes of more than 0.1 and 0.08 counts s^{-1} for the PSPC and HRI data sets, respectively, would have been seen above the statistical noise level. Thus, we can only rule out the presence of a 100% modulated signal at the 95% confidence level.

5. The X-ray spectrum

Given the very low spectral resolution of the ROSAT PSPC and the modest number of observed photons, it is difficult to identify the source of the hard X-ray spectrum. The simplest measures of the shape of the spectrum are hardness ratios, which are measures of the relative number of hard versus soft photons. The standard ROSAT hardness ratio HR1 was between 0.6 and 0.9 during the RASS and pointed PSPC observations (Fig. 2), i.e. indicative of a relatively hard spectrum, and neither data set shows any sign of orbital variations in HR1.

Fitting the observed average spectrum with a single optically thin (Raymond-Smith) component yields a H column density $N_{\rm H}$ of $(4.0 \pm 1.5) \times 10^{20}$ cm^{-2} (consistent with the maximum expected galactic extinction of 10^{21} cm^{-2} and the absence of any 2200 Å interstellar absorption feature), and a very poorly determined temperature of (8 ± 12) keV. Though a high-temperature

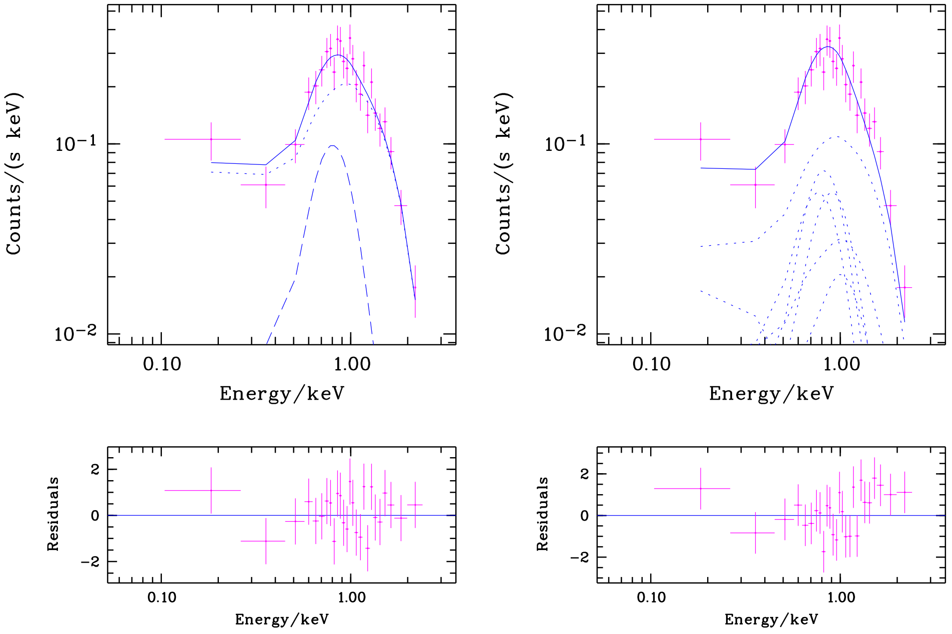

Fig. 6. Spectral fits to the ROSAT PSPC data (dashed lines are the sub-components). Left: a two-component Raymond-Smith model. Right: a constant pressure accretion column model. See the text for details.

component is needed to produce a hard X-ray spectrum, the fit has significant residuals around 0.6 to 1 keV, suggesting the presence of line emission from a much cooler gas. A meaningful two-component fit (with 5 parameters: one H column density, two emission measures, and two temperatures) is not possible. Therefore, we arbitrarily fixed the temperature of the hot component at 10 keV or 20 keV and fit the remaining 4 parameters: the results can be seen in Table 2 and Fig. 6 (left graph). The emission measures of the "warm" component are not significantly affected by the choice of $T_{\rm warm}$. A "banana diagram" showing the confidence region for the two parameters $N_{\rm H}$ and $T_{\rm warm}$ is shown in Fig. 7. An analysis of the (poorer) RASS data yielded similar results.

The relative difficulty in finding $T_{\rm warm}$ (and hence $N_{\rm H}$) is most easily explained by a wide spread in the temperatures of the X-ray emitting regions. The choice of a two- or more-component plasma is, however, very arbitrary. A much more meaningful model for the spectrum of an AM Her star is the radiation produced in a magnetic accretion column in which a wide range of temperatures naturally exists. In systems with low magnetic field strengths like V2301 Oph, bremsstrahlung emission should dominate the cooling, and the structure of the accretion column can be derived analytically (Hoshi 1973; Aizu 1973). We fit the PSPC spectrum using the simplest possible model: an accretion column with constant pressure (e.g. Frank, King, and Rayne 1992; pp. 142-144). The shock temperature

$$kT_{\rm sh} = \frac{3}{8}\frac{GM\mu m_{\rm H}}{R_*} \approx 46\,{\rm keV}\left(\frac{M_*}{0.9M_\odot}\right)^{5/3} \quad (1)$$

is held fixed, as is the (not particularly relevant) base temperature $T_{\rm eff} = 3\times10^{-4}\ T_{\rm sh}$. The column was split up into 9 sections (the maximum number allowed within EXSAS: a total of only 20 parameters can be used) with fixed mean relative emission measures and temperatures (weighted by the bremsstrahlung emissivities) ranging from 0.0083 to 0.6961 and 0.02 to 23 keV, respectively. The only fitted quantities are the interstellar absorption and the total emission measure (Table 2). With $N_{\rm H} = (4.5\pm0.9)\times10^{20}\,{\rm cm}^{-2}$ and $\chi^2/24 = 1.1$, this physically-motivated model for the X-ray spectrum not only yields similar results for the amount of interstellar absorption but is statistically as good as the two-component model (Fig. 6).

There are not enough photons in the narrow "dip" phases to make a formal fit to the covering factor and absorption column densities. The factor of $\sim$ 0.8 reduction in the flux could be explained by an additional column density of typically $8\times10^{21}\,{\rm cm}^{-2}$, but would have produced a more pronounced "glitch" in the HR2 hardness-ratio light curve (Fig. 3). A better explanation is partial covering by a very optically thick component which totally blocks out a fraction of the emission from the underlying X-ray source. The covering factor would then be roughly 0.5-0.8 and would require $N_{\rm H} > 10^{22}\,{\rm cm}^{-2}$.

6. Discussion

There are two reasons why V2301 Oph has been considered to be a potential intermediate polar candidate: (1) most (but not all) AM Hers are very soft X-ray sources while most (but not all) intermediate polars have hard spectra like V2301 Oph; and (2) given the observed very low mean magnetic field, it should be difficult to prevent the formation of a disk and, in turn, an intermediate polar.

The total number of known AM Her stars and intermediate polars has increased dramatically within the last 5 years, due largely to the RASS (Beuermann & Burwitz 1995), and it is now clear that the class of an object cannot be derived solely from its X-ray hardness. Beuermann & Schwope (1994) have shown that there is a tight, empirical relationship between the flux ratio of the optically thick, soft X-ray component and the optically

Table 2. Spectral fits to the PSPC data

Model	N_H (10^{20} cm^{-2})	kT_{hot} (keV)	EM_{hot} (*)	kTwarm (keV)	EMwarm or Fwarm (*)	χ^2/N_{free}
1-component	4.0 ± 1.5	8 ± 12	6.6 ± 2.2	-	-	1.4
2-component	4.0 ± 2.2	$\equiv 10$	5.6 ± 1.2	0.5 ± 0.8	0.22 ± 0.12	0.79
2-component	3.9 ± 2.0	$\equiv 20$	5.5 ± 1.2	0.5 ± 0.7	0.19 ± 0.10	0.77
Accretion shock†	4.5 ± 0.9	< 46 keV	5.3 ± 0.4	-	-	1.1
"Standard AM Her"‡	$\equiv 4.5$	$\equiv 20$	1.66 ± 0.11	$\equiv 0.025$	0.022 ± 0.041	1.4

* Bremsstrahlung emission measures are in units of 10^{53} cm^{-3} d_{100}^2, where d_{100} is the distance in units of 100 pc. Blackbody fluxes are in units of photons cm^{-2} s^{-1}.

† Constant pressure solution.

‡ Warm Blackbody and Hot Bremsstrahlung components.

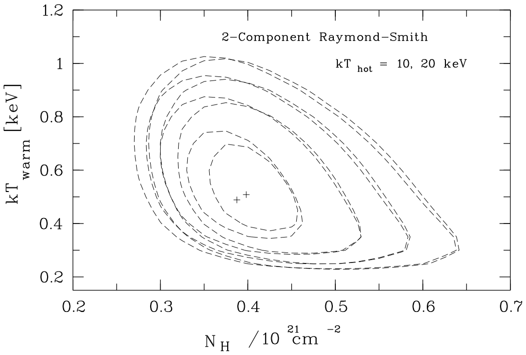

Fig. 7. "Banana" diagram showing the 50,60,70, and 80% probability contours for the interstellar H column density and the temperature of the cool component in a two-temperature Raymond-Smith fit to the ROSAT PSPC spectrum assuming a hot-component temperature of 10 (solid lines) or 20 keV (dashed lines). The plus marks show best-fit positions. See the text for details.

thin, hard X-ray component and the magnetic field strength in all AM Her systems (in the sense that higher magnetic fields imply more flux in the soft component). This effect is easily explained as being due to the increasing importance of cyclotron cooling in systems with higher magnetic field strengths (Beuermann 1997). The fitted spectral parameters for this "Standard AM Her Model" (kT_{ff} = 20 keV, kT_{BB}=25 ev) using our data and the H column density derived above are also shown in Table 2. No significant soft-component could be detected: the resulting 2-σ *lower limit* to the ratio of the hard Bremsstrahlung and the soft Blackbody component ROSAT fluxes F_{ff}/F_{BB} is 1.4. Thus, the X-ray emission from V2301 Oph fits the empirical relation and our theoretical expectations quite nicely: the bremsstrahlung component is dominant in the system with the smallest measured magnetic field (Ferrario et al. 1995).

The X-ray light curves clearly show that V2301 Oph is not an intermediate polar. Although we can only rule out a spin-pulse with nearly 100% amplitude, empirically, no intermediate polar has a mean quasi-sinusoidal orbital light curve which peaks near phase 0.9. While X-ray "dips" in the form of substantial phase-dependent absorption of the underlying X-ray flux are seen in a wide range of CVs with accretion disks, including a large number of intermediate polars (Hellier, Garlick & Mason 1993), the absorption is always strongest at orbital phases 0.6-0.8, whereas the dips in V2301 Oph occur later within a much narrower phase range (0.8-0.95). This latter type of dipping behavior is common in AM Her stars with large inclinations (Watson 1995) and is attributable to the passage of the accretion stream along the line-of-sight between the underlying X-ray source on the white dwarf and the observer. Since this can occur only if the stream has been vertically deflected from its trajectory in the orbital plane, the phase of the absorption dips roughly indicates where the magnetic threading of the stream occurs. The maximum dipping in V2301 Oph occurs at the same phase as the peak of the X-ray light curves, a situation expected for a synchronously rotating magnetic accretor.

The phasings of the PSPC and HRI light curves already suggest that $P_{beat} = (1/P_{spin} - 1/P_{orb})^{-1}$ must be greater than about 150 yr. If the white dwarf in V2301 Oph accretes from a Keplerian disk, it must be spinning up on a timescale (e.g. Wang 1987)

$$\begin{aligned} \tau_{spin-up} &\approx \left| P_{orb}/\dot{P} \right| \approx \frac{2\pi I}{n(\omega_s)\sqrt{G M_1 R_D}\dot{M}} \\ &\approx 8 \cdot 10^4\, yr \left(\frac{\dot{M}}{10^{-10}\, M_\odot yr^{-1}} \right)^{-6/7} \end{aligned} \qquad (2)$$

where $n(\omega_S)$ is the torque function of the fastness parameter ω_S, and where a white dwarf mass M_1 of 0.9 $M_\odot$, an inner disk radius R_D of 52% of the spherical Alv́en radius R_A, a moment of inertia I of 10^{50} g cm^2, and a surface field strength of 7 MG have been assumed (yielding $\omega_S \approx 0.09$ and $n(\omega_S) \approx 0.5$). Large variations in the mass-accretion rate on timescales of $\sim 10^6$ yr are certainly possible (King et al. 1996), so that V2301 Oph might have suffered a long period of nearly zero mass-transfer in the past, and have slowed down to nearly synchronous rotation. However, given the still small number of known magnetic CV systems, it seems very unlikely that we would catch a system like V2301 Oph just at the point where a major change in the accretion has occurred, even taking possible selection effects into consideration. Thus, the lack of a measureable spin period makes it very unlikely that an accretion disk is currently present in V2301 Oph.

The only remaining reason for believing that V2301 Oph could still be an intermediate polar – in spite of all the other evidence – is our expectation, that the very low mean magnetic field may not be strong enough to prevent the formation of a disk. The position and kinematics of the magnetospheric boundary layer – the region where the accretion stream threads the magnetic field of the white dwarf – provides us with a direct measure of the strength of the magnetic field. We will study this region in great detail and so address this final question in Paper II (Hessman et al., in preparation).

7. Conclusions

V2301 Oph shows a rich variety of features both in its X-ray light curves and its hard X-ray and UV spectrum which clearly indicates an origin in an AM Her system: an orbital "hump" due to the changing aspect of the central X-ray source which is fixed in the rotating frame of a synchronous binary; the lack of a measurable spin-pulse; "dips" in the light curve due to the passage of the accretion stream in front of the line-of-sight after it has been lifted out of the orbital plane; UV emission line-ratios more typical of a magnetic than a non-magnetic system; and an X-ray spectrum indicative of a non-isothermal optically thin emission region like that expected for a magnetic accretion column in an only moderately strong magnetic field.

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