Part 3A

Accretion Plasma diagnostics - Observations

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Multiwavelength observations of eclipsing polars

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Abstract. Multiwavelength observations of polars are essential for developing the big picture of these systems, particularly to gain understanding of the relevant accretion-induced heating and cooling processes. Eclipsing polars are prime targets for such studies since different radiation processes can be disentangled by observations with high-time resolution. We present a preliminary combined analysis of space-based observations (*XMM-Newton*, *ROSAT*, *HST*) with ground-based high-speed photometry (MCCP, OPTIMA, ULTRACAM) of DP Leo, HU Aqr and UZ For. We determine the location and extent of different emission components and find secular and short-term changes in the accretion geometries. We find displaced optical and X-ray emission regions in DP Leo and HU Aqr as well as mini-bursts and accretion arcs of variable size in HU Aqr. We report marked changes in the X-ray eclipse length of UZ For between high and low states.

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1. Introduction

Polars are sources of electromagnetic radiation from the hard X-ray regime to the infrared (and in a few cases down to the radio regime). Most of the radiation is accretion-induced, being either primary plasma cooling radiation at hard X-rays or cyclotron radiation in the optical, or being reprocessed radiation from the accretion spot and its surroundings. The latter components are which originate from the white dwarf are detected at soft X-rays and in the ultraviolet. In addition, there is reprocessed radiation from the accretion stream. A discrimination and and differentiation of these components is greatly facilitated if the underlying geometrical structures can be resolved. This is best done in eclipsing systems. Among the presently known ~70 polars, a dozen show eclipses by the donor star. These are prime targets for high time-resolution observations with the aim to resolve structures and components at a given epoch. Some of the brighter polars have an observational history lasting for one or two decades. This allows us to uncover long-term trends in the accretion history and variations of the binaries geometry or asynchronism. Both aspects will be addressed in this review.

For the first time it is possible to obtain simultaneous optical/ultraviolet and soft/hard X-ray observations of polars from one spacecraft, *XMM-Newton*. In this paper we will discuss *XMM-Newton* observations of DP Leo, taken in the CalPV phase (calibration and performance verification, Pandel et al. 2002, Schwope et al. 2002), HU Aqr and UZ For, taken as part of the guaranteed time program of the AIP and Leicester University.

Some of the X-ray observations were accompanied by optical high-speed photometric observations. These were taken with the MCCP (Barwig et al. 1987), OPTIMA (Straubmeier et al. 2001), and with ULTRACAM (Dhillon et al. 2002). These cameras allow high-speed photometry with PMs, APDs or CCDs in the sub-second time domain. They differ in their capability of monitoring a comparison star and their ability or non-ability of dispersing the incoming light. For details the reader is referred to above mentioned publications. The ULTRACAM observations of HU Aqr were taken as part of the commissioning run of the instrument in 2002 May.

All timing data in this paper refer to the atomic time scale. The omission of, for example, leap seconds when referring to a barycentric time frame, leads to unacceptable inaccuracies.

2. DP Leo

DP Leo was observed in X-rays with EINSTEIN (1979 Dec), *EXOSAT* (1984 Jun, 1984 Dec), *ROSAT*-PSPC (1992 May, 1993 May) and most recently with *XMM-Newton* (2000 Nov). The *EXOSAT* observations did not reveal meaningful results as far as the eclipse parameters are concerned. At all other occasions the time of eclipse centre could be derived as well as the centroid of the bright phase. The latter indicates the stellar azimuth of the main of the two accretion spots. The observed time of the eclipse centre in X-rays does not correspond to inferior conjunction of the white dwarf, but is shifted by an amount determined in the first place by the azimuth (stellar longitude) of the accretion spot, but also by

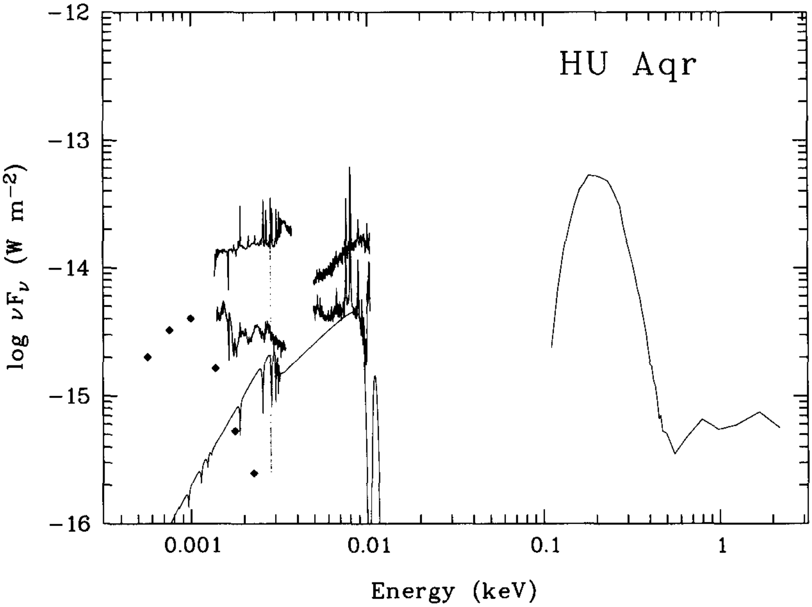

Figure 1. The broad-band spectral energy distribution of HU Aqr. The graph shows the spectral energy density from the infrared to hard X-rays obtained in high and low accretion states. In the optical, a bright-phase maximum and a mean low-state spectrum are plotted. In the ultraviolet, orbital minimum and maximum *HST*/FOS spectra in the 1996 intermediate accretion state are shown. The X-ray spectrum was obtained in the 1993 high state with the *ROSAT* PSPC. The contributions from the red and white dwarf stars are indicated with rhombs and solid lines, respectively.

the latitude, the orbital inclination and the white dwarf radius. The longitude is given by the centre of the bright phase, the latitude is constrained by the length of the bright phase, while the radius of the white dwarf and the inclination can be constrained from the length of the eclipse and from the length and shape of the eclipse in the ultraviolet, where the white dwarf dominates. Time of inferior conjunction of the white dwarf derived from the X-ray eclipse is then computed by applying small corrections to the observed times.

Ultraviolet observations with *HST*/FOS and optical observations with OPTIMA were analysed in order to determine further epochs of superior conjunction of the white dwarf and to compare the eclipse shapes. All timings of the white dwarf were used by Schwope et al. (2002) to determine an updated ephemeris of the system with a highly significant quadratic term (see Figure 2). The deviation is by two orders of magnitude larger than compatible with gravitational radiation. The cause for this large discrepancy is unknown, it could be for example due to either a third body in the system, or the magnetic field of the secondary. The general question arises whether this observation is unique for DP Leo, if it

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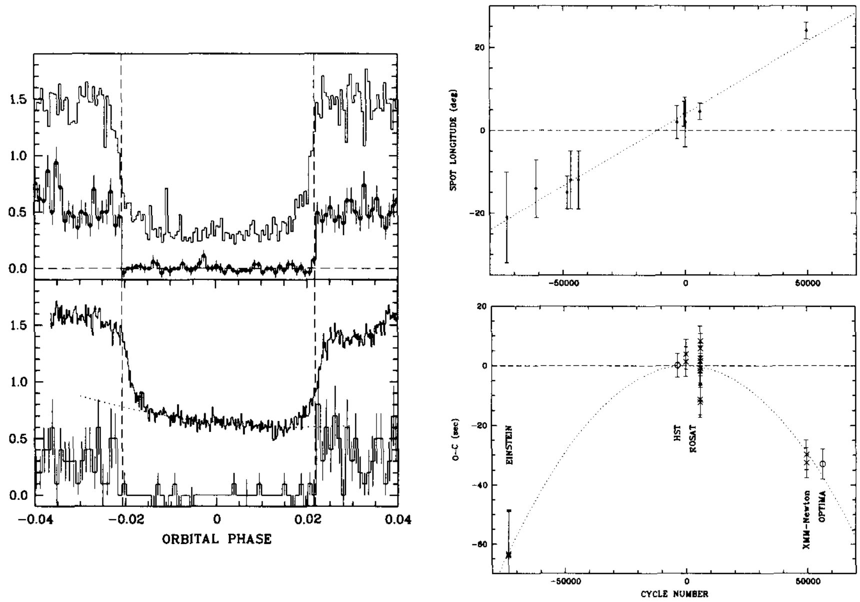

Figure 2. DP Leo: (left) Optical, ultraviolet and X-ray light curves obtained with, from top to bottom, *HST*/FOS (1340–2400 Å, binsize 2.7 s), *ROSAT* PSPC (5 s bins), OPTIMA in white light (1 s bins), and *XMM-Newton* with EPIC-PN (5 s bins). The units for the X-ray data along the ordinate are the count rate, the OPTIMA data are scaled arbitrarily and shifted by +0.5 units. The units for the *HST*-data are $10^{-15}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$, the data are shifted by 0.3 units. Vertical dashed lines indicate the soft X-ray eclipse, the dotted line matching the OPTIMA eclipse data approximates the contribution from the accretion stream at eclipse phase. Bin sizes are 1 s and 5 s, respectively. (top right) Long-term behavior of the accretion spot longitude. (bottom right) Residuals of eclipse timings with respect to a linear ephemeris.

is related to any other parameter of the binary (orbital period, magnetic field), if it is of relevance for other systems or to the class at all. The answer to these questions requires multi-epoch high-time resolution observations of as many as possible eclipsing polars, either at optical, ultraviolet or X-ray wavelengths.

DP Leo displays another interesting long-term variability, a continuous shift of the accretion spot longitude by $2.1° - 2.5°$/year. One may reasonably assume that the magnetic axis rotates at a similar rate. The reason for the implied asynchonism between the orbital and the spin period of the white dwarf of order 10^{-6} is presently unclear. No nova explosion as in the case of V1500 Cyg was reported for DP Leo. Patient observing of the spot longitude over the next years or even decades will help to decide whether the white dwarf in DP Leo rotates asynchronously in reality or if the observed motion is part of the predicted

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synchronization oscillations. Such oscillations of the magnetic axis around an equilibrium position were predicted to occur on time-scales of several tens of years (Campbell 1983, King & Whitehurst 1990) but could not be observed so far. The comparison between observation and theory is hampered by the simple fact that no prediction about the amplitude of the oscillations was made.

The optical, ultraviolet and X-ray light curves displayed in Figure 2 clearly show the different sizes of the emission regions. The count rates obtained with *XMM-Newton* and *ROSAT* were too low in order to resolve the eclipse ingress and egress. An upper limit of about 5 sec could be derived from the 1993 *ROSAT* observation, when the source was detected at the highest X-ray count rate so far. In the X-rays we detect emission from the accretion spot only. The ultraviolet is dominated by the different parts of the white dwarf's atmosphere (accretion-heated and quiescent). Radiation in the optical domain consists of a cyclotron component from an accretion arc or spot, a photospheric component and radiation from the accretion stream. The latter is detected as residual emission in the centre of the eclipse when the white dwarf is occulted by the donor star. The comparison between eclipse ingress-egress in the OPTIMA (cyclotron-dominated) and the X-ray light curves suggests that both emission regions lie slightly separated or adjacent to each other. This is similar to HU Aqr, where the soft X-ray emitting spot lies, at least occasionally, at the far end of an accretion arc. However, a slight caveat has to be made, since the observations which are compared in Figure 2 were not obtained simultaneously and a migration of the emission regions between the different epochs cannot be excluded completely.

3. HU Aqr

3.1. The optical, UV and soft X-ray eclipse

Figure 3 summarizes the knowledge on the structure of the eclipse in HU Aqr gained in the 1990s. It is a 45 sec cut-out of phase-averaged light curves centred on eclipse ingress and egress. In soft X-rays the eclipse ingress is strongly affected by absorption in an accretion curtain. The determination of the eclipse length in soft X-rays is, therefore, somewhat uncertain. The same structures as discussed briefly in the previous section on DP Leo can be recognized: the photosphere of the white dwarf in the ultraviolet, cyclotron radiation in the optical and soft X-rays from the accretion spot. Optical MCCP and *ROSAT* X-ray observations were obtained in the 1993 high state, whereas the *HST*/FOS data were obtained in the 1996 low accretion state. In Figure 3 only the R-band MCCP-data are shown, since these cover the 5th cyclotron harmonic almost exclusively. Cyclotron radiation originates from a 5-10 keV hot accretion plasma. Therefore the difference, particularly in the length of the eclipse egress at soft X-rays and in the optical is striking. The size of the cyclotron emission region is much larger than the size of the soft X-ray emission spot, which had a temperature corresponding to about 25 eV. The former takes most likely the shape of an accretion arc with an extent of some $20°$, while the latter is a rather small structure of about $3° - 4°$ (Schwope et al. 2001). Surprisingly, the hot cyclotron region is not a prominent emitter of hard X-ray radiation: such a component is undetected in the eclipse.

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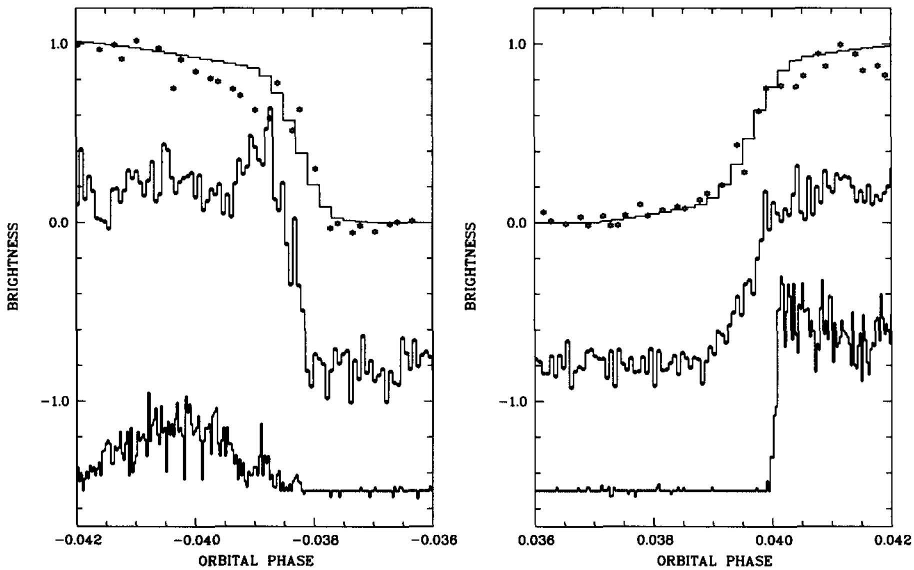

Figure 3. Eclipse details of HU Aqr observed (from top to bottom) in 1996 September with the *HST*/FOS, in 1993 August with the MCCP and in 1993 October with the *ROSAT*-PSPC. The binsize is 3 sec, 0.5 sec, and 0.5 sec, the data were scaled to a common stepsize at egress of 1 unit and plotted with vertical shifts of 0.0, −0.8, and −1.5 units, respectively. The histogram curve is a fit to the *HST*-data assuming a white dwarf of 13000 K, a spot with a central temperature of 80000 K (linearly decreasing) and a radius of 22°.

3.2. High-speed photometry with OPTIMA and ULTRACAM

Figures 4 compares optical light curves of HU Aqr obtained with high time resolution during high and low accretion states. They show some common features as well as striking dissimilarities. For comparison the reader is refered to recent high-state WHT/S-Cam observations (Bridge et al. 2002) or the collection of light curves in different accretion states in Schwope et al. (2001). Well-known features in the light curves of Figure 4 are the pronounced pre-eclipse dip in the high state which always turns out to be almost undetectable in the low accretion state. As with previous light curves found in the literature, the bright phase is much more pronounced in the low state than in the high state, when the stream contributes much more to the optical. The novel features in the high state light curve presented here are optical bursts or flares of extreme short duration. They last only a few seconds and the system's brightness may be doubled during this short time interval. The phasing of the few observed flares and their shape suggest that they originate from the main accretion spot and are thus reflecting accretion events (rather than, for example, flares from the donor star).

The novel features in the ULTRACAM low-state light curves are best visible in cut-outs of the data streams centred on the eclipses. These are shown in Figure 5 in comparison with 1993 high-state MCCP observations. The high- and

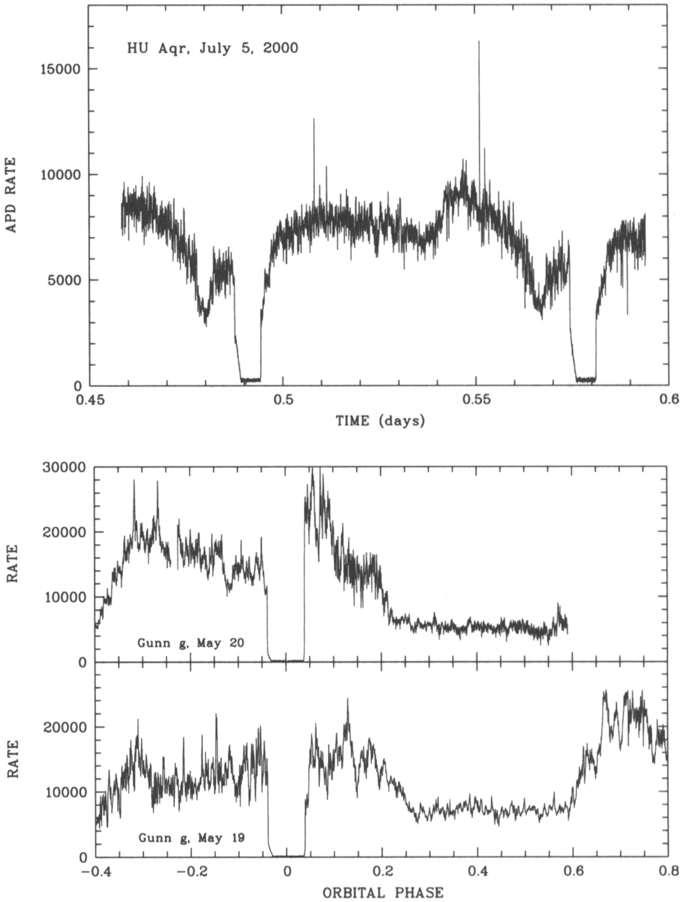

Figure 4. Top: White-light OPTIMA observation of HU Aqr in a high accretion state obtained at the 1.3m telescope at Mt. Skinakas, Greece (Kanbach et al., in preparation). Bottom: ULTRACAM observations of HU Aqr obtained 2002 May at the WHT in a low accretion state, quasi-simultaneously with the *XMM-Newton* observations.

low-state data were scaled in a way that the white dwarf, which is detectable only in the short phase interval 0.037–0.039 with minimal contamination, matches. In the low-state ULTRACAM data the stream ingress lasts considerably shorter than in the high state, 70 s vs. 120 s. This is expected but contrary to what was observed in all former low states (see Hakala et al. 1993., Schwope et al. 1993, Schwope et al. 2002), where the ingress of the stream lasted up to 5 min. The long stream ingress in the low state was always puzzling, since the standard accretion picture – ballistic stream, dipolar field line, early coupling in the low state – predicts a short stream ingress. In this respect HU Aqr behaves normally

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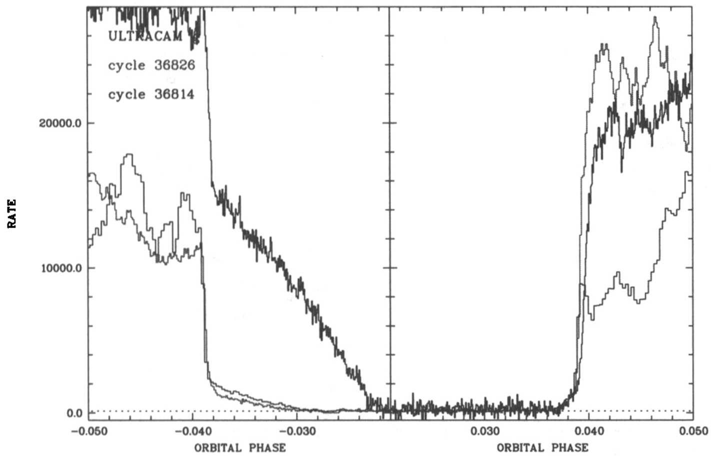

Figure 5. ULTRACAM $g-$band (2002 May 19 & 20) and MCCP $V-$band (1993 August 16-18) observations of HU Aqr in low and high states. The MCCP data are shown in black, the ULTRACAM data obtained in cycle 36814 and 36826 in dark and light grey (blue & red), respectively.

in the 2002 observations. A second remarkable feature in the ULTRACAM data is the standstill during eclipse egress of the accretion arc in cycle 36814 halfway up to maximum brightness. The halt lasts for about one minute. This feature can be caused by either structure in time or space, *i.e.* a cessation of accretion in general for a short time or a cessation of accretion in a part of the accretion arc. Since no real drop in intensity is observed but merely a standstill only, we regard the latter explanation as viable. Figure 5 clearly shows that the accretion arc is substantially more extended in the high state than in the low state. If the length of the accretion arc is determined by the length of the ballistic stream, this is a natural consequence of the early coupling onto field lines in the low state.

3.3. An *XMM-Newton* observation of HU Aqr

There are several science cases for an *XMM-Newton* observation of HU Aqr based on the results summarized in the previous paragraphs: the search for the eclipse of the hard X-ray component and its phasing with respect to the eclipse of the soft component; the search for X-ray emission in the centre of the eclipse, when the white dwarf is occulted; the search for the X-ray counterparts of the optical flares and the determination of its characteristic parameters (time scales and energy content); and the determination of the spectral parameters of the soft and the hard X-ray components.

XMM-Newton observations of HU Aqr with all three X-ray telescopes and with the OM took place on 2002 May 17, for a total of 36 ksec. The OM was used with the UVW2 filter, which has an observational passband of 2000–2800 Å and

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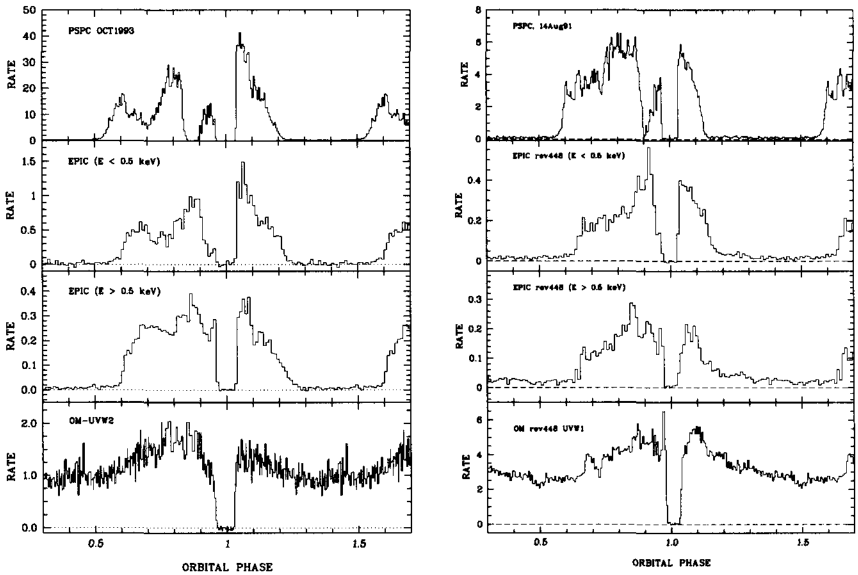

Figure 6. *ROSAT* and *XMM-Newton* observations of the twins HU Aqr (left) and UZ For (right). Shown are from top to bottom phase-folded light curves obtained with the *ROSAT*-PSPC, *XMM-Newton* (average count rate of all three EPIC cameras) in soft and hard bands ($E >< 0.5$ keV), and the optical monitor. HU Aqr was observed through the UVW2 filter(2000–2800 Å), UZ For was observed through the UVW1 filter (2400–3600 Å).

a maximum effective area of 20 cm^2 at about 2300 Å. Phase-folded light curves of the *XMM-Newton* observations are displayed in Figure 6. They are shown in two energy bands, thus sampling mainly the soft, blackbody-like and the hard bremsstrahlung components. These curves can be compared with a high-state *ROSAT*-PSPC observation performed in 1993 October. A further comparison in the same figure is done with the twin system UZ For, where *ROSAT* high-state and *XMM-Newton* low or intermediate state observations are also shown.

The *XMM-Newton* observations of HU Aqr were obtained when the system was in a rather low or intermediate accretion state. Bright-phase optical maximum in the high state may reach $V \simeq 14.5$; in 2002 May 19 and 20, *i.e.* around the time of the *XMM-Newton* observation, it reached only $g \simeq 16.0$, similar to what was observed in earlier low accretion states. An analysis of the *ROSAT* soft X-ray light curve is given by Schwope et al. (2002). Qualitatively, the *XMM-Newton* soft X-ray light curves show the same features as the *ROSAT* light curve, although they occur at different phases. The bright-phase centre is shifted from $\phi = 0.87$ to $\phi = 0.92$, corresponding to a longitudinal motion of the accretion spot by about 18° towards the donor star. The narrow pre-eclipse dip, caused by the transiting accretion stream that has just left the orbital plane, is shifted correspondingly. In the low state it usually merges with the stellar eclipse, hence the centre of this feature cannot be determined exactly. If one measures the phase of half intensity at dip ingress instead, one finds a shift by about 25°. The broad dip of uncertain origin is shifted from $\phi \simeq 0.69$ to $\phi = 0.75$. The hard X-ray light curve is clearly less affected by absorption, *i.e.* the centre of the bright phase is more or less flat-topped. This curve is remarkably asymmetric with a steep bright-phase ingress and a slow egress into the faint phase. The bright phase starts simultaneously in soft and hard X-rays, it lasts however longer in hard X-rays. This is indicative of the sought-for hard X-ray counterpart of the optical cyclotron accretion arc. A direct confirmation of this hypothesis by a comparison of the eclipse ingress and egress parts of the light curves in hard and soft X-rays is unfortunately inconclusive due to the low count rate in the hard spectral band. A meaningful comparison requires another observation in the high accretion state.

A preliminary spectral analysis of the bright phase with a cold absorbed blackbody plus bremsstrahlung plus Gaussian line for the iron line at 6.7 keV yields $kT_{\rm bb} = 30\,\rm eV$, $kT_{\rm br} \sim 15\,\rm keV$. The bolometric fluxes in the soft and the hard components are $F_{\rm bb} = 8.2 \times 10^{-12}\,\rm erg\,cm^{-2}\,s^{-1}$ and $F_{\rm tb} = 4.8 \times 10^{-13}\,\rm erg\,cm^{-2}\,s^{-1}$, respectively, *i.e.* despite the reduced accretion state the source showed a distinct soft excess. Contrary to the *ROSAT* PSPC observations, HU Aqr was not detected in the eclipse with *XMM-Newton*.

The OM light curve finally shows a smooth enhancement of the UV flux during the bright phase. It also displays the stream eclipse dip, visible as a smooth flux decrease prior to the stellar eclipse. We are going to model these data by folding white dwarf model atmospheric spectra through the response of the OM telescope/filter/detector combination. This will allow to derive the energy content in the reprocessed ultraviolet radiation and, together with the energy content in the X-ray and optical cyclotron components, will properly address the question of reprocessing and energy balance in a model polar in a low accretion state.

4. UZ For

UZ For received two exposures with *XMM-Newton* so far. The first was obtained in revolution 202 (2001 Jan 14) for ~22 ksec, when the source was encountered in a deep low state (Still & Mukai 2001). The source was not detected for the majority of the exposure apart for a ~1 ksec bursts with ~5 keV thermal emission soft X-ray counterpart. A timing analysis by Pandel & Córdova (2002) including the OM (UVW1) revealed an impacting blob of matter of $10^{17} - 10^{18}$ g in the main accretion region as likely cause of the burst. A smooth orbital modulation of the ultraviolet light curve, OM + UVW1, with maximum flux at $\phi = 0.88$ and modulation amplitude of ~30% was also found, which is likely to be remnant photospheric emission from the heated accreting spot. Whether accretion ceased completely or was just unobservable is difficult to decide, the rate of accretion, however, was estimated to be about a factor 1000 lower than during previous hight states.

A second observation with *XMM-Newton* took place on 2002 Aug 8, for a total of 29 ksec. The OM with the UVW1 filter was used in fast mode. Phase-

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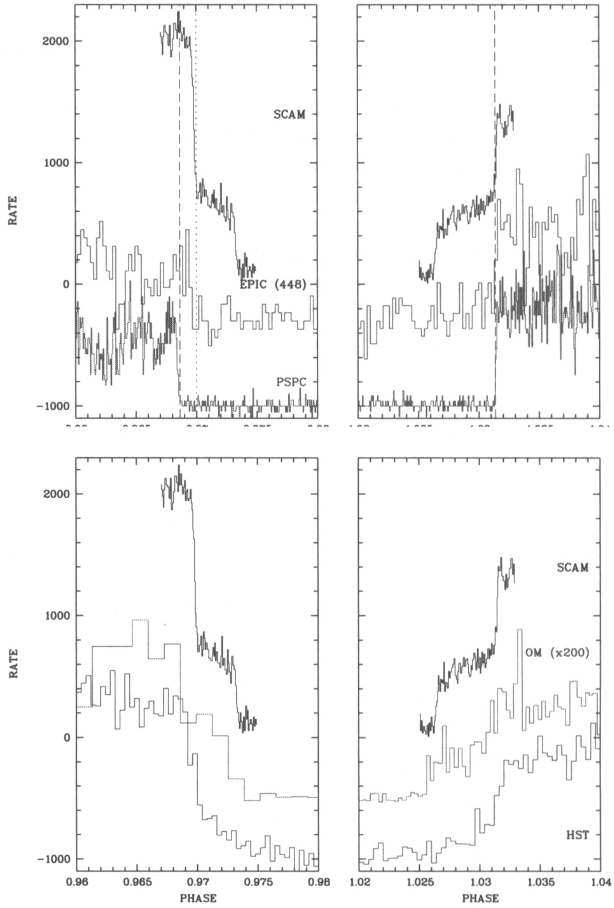

Figure 7. Details of the stellar eclipses in UZ For at different wavelengths and accretion states. As a reference for expected times of ingress and egress of the two accretion spots, S-Cam light curve of Perryman et al. (2001) are reproduced. In the upper panel *XMM-Newton* (binsize 2 s) and *ROSAT* PSPC (binsize 0.5 s) data obtained in low and high accretion states are shown with scaling factors of 1000 and 150, respectively. In the lower panel the OM data obtained in *XMM-Newton* revolution 448 (scaling factor 200, binsize 10 s) and with the *HST*/FOS (binsize 3 s, contribution of accretion stream subtracted, arbitrary scaling) are shown.

folded light curves in a soft X-ray band ($E < 0.5$ keV), a hard X-ray band ($E > 0.5$ keV) and the OM are reproduced in Figure 6. As for HU Aqr, a high state *ROSAT* PSPC light curve (obtained 1991 Aug 14), is also shown in the figure. The behaviour of UZ For is remarkably similar to that of HU Aqr.

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In the high state, as observed with *ROSAT*, *EXOSAT* and *EUVE*, UZ For displayed a pronounced soft X-ray dominated bright phase centred on phase $\phi = 0.865$, *i.e.* with a spot azimuth at about 50° (Osborne et al. 1988, Warren et al. 1995). In the state of reduced accretion in *XMM-Newton* revolution 448 the centre of the bright phase is shifted to phase $\phi = 0.9$, *i.e.* the spot moves to a longitude of ~35°. The length of the bright phase varied on different occasions, but no clear relation between accretion state and length of bright phase exists. As in HU Aqr, a pre-eclipse dip is observed with the phase of dip ingress being shifted from $\phi \simeq 0.87$ in the high to $\phi \simeq 0.93$ in the low state. Since the main accretion spot ('spot 1' in Perryman et al. 2001) lies at 'deep southern' latitudes, the mere existence of a pre-eclipse dip in high and low accretion states is a hint to a second accretion pole (spot 2) in the 'northern' hemisphere of the white dwarf in both accretion states. Perryman et al. located 'spot 2' at the rotational pole, and 'spot 1' at a co-latitude of about 150°. The observed shift of the spot and dip azimuth (or longitude) supports the idea, that the higher ram pressure of the accretion stream in the high state allows deeper penetration of the magnetosphere. The details, however, are subtle, since the observed spot longitude is that of 'spot 1' and the observed dip longitude is somehow related to 'spot 2'. It would be important to see how the longitude of 'spot 2' varies as a function of accretion rate. Since the second spot seems to be too weak in X-rays, this requires high time-resolution photometry of the optical eclipse in high and low states and a proper determination of the eclipse centre of the white dwarf at those epochs.

In revolution 448 'spot 1' is bright in X-rays between orbital phases 0.63 and 1.17. UZ For is detected in X-rays throughout the orbital phase (apart from the eclipse). The extra emission in the faint phase is particularly prominent at phase 0.2–0.3, in all wavebands at all occasions. The faint-phase emission is much harder than the bright-phase emission, and its origin is not completely clear. If (most of) the faint-phase emission is attributed to 'spot 2', one would expect 'spot 2' to be visible in the X-ray eclipse after ingress and before egress of 'spot 1', which is not or just marginally. The alternative explanation involves scattering of X-rays in the accretion column. Both explanations predict a harder faint-phase than bright-phase spectrum, the latter explanation due to absorption of soft X-rays in the column, the former due to a smaller soft X-ray excess at reduced accretion rate.

The eclipse light curves of UZ For are shown in greater detail in Figure 7. In the upper and lower parts of that diagram we compare X-ray and ultraviolet light curves obtained with *XMM-Newton*, *ROSAT*, the OM-UVW1 and *HST*/FOS with the optical S-Cam data by Perryman et al. (2001). Although all timings of the eclipse were determined in the same atomic time frame, a linear regression of all timings of inferior conjunction of the white dwarf yielded unacceptable large deviations. The determination of the correct time of eclipse centre needs further investigation. For the time being we use as a reference the S-Cam light curve by Perryman at al. (2001) and we refer all phases to the eclipse egress of the main spot at phase $\phi = 1.0313$. The S-Cam data nicely resolves the eclipses of the two accretion spots and indicate the visibility of the two spots during the eclipse.

Simulations of high- and low-state eclipse light curves with the likely geometry of UZ For show that the migration of the spot by 15° from the high to the low state will shift the eclipse egress by only ~1.5 s, *i.e.* a very small amount on the scale along the abscissa in Figure 7. This justifies the relative scaling of all the data to be centred on eclipse egress.

The average soft X-ray eclipse observed with the *ROSAT* PSPC lasts 477 s (indicated by long dashes in Figure 7). The eclipse egress lasts ~1.5 s, while the ingress lasts about three times longer than the egress. In the state of reduced accretion in 2002 August (*XMM-Newton* revolution 448) the X-ray eclipse lasts only about 472 s, *i.e.* shorter by ~5 s than in the high state (ingress indicated by the dotted line). The count rate in the *XMM-Newton* observation was insufficient to resolve eclipse ingress or egress. Simulations of the *ROSAT*-PSPC light curve with the code presented in Schwope et al. (2001) revealed a full opening angle of the accretion spot of 5° in the high-state (with the following model parameters: mass ratio $Q = 5$, inclination $i = 81.3°$, co-latitude of 'spot 1' $\beta = 150°$). These models suggest that the asymmetry between ingress/egress can be explained by variable foreshortening of a flat accretion spot.

These models also show that the shorter eclipse length in the low state require a migration of the main accretion spot towards the equator. This contradicts simple-minded expectations, since in the low state coupling of matter to field lines happens at larger distance from the white dwarf, hence the foot point(s) of the accreting field line(s) should lie closer to the magnetic pole, *i.e.* typically at a larger co-latitude. Whether the locations of the likely coupling regions (for both accretion spots) and the spots themselves can be understood in the framework of a dipolar geometry needs more detailed modeling of the magnetic and accretion geometry.

As noted above, Figure 7 shows that X-rays from the second spot are not or just marginally detected. The second spot should be detectable between phases $\phi = 0.970 - 0.973$, and $\phi = 1.0265 - 1.031$, during the short phase intervals, when the main spot is already occulted by the donor star. One then may ask whether at all there were two accretion regions in UZ For at the time of the *XMM-Newton* observations. At the time of the *ROSAT* observations, the presence of a second accreting region became evident by optical high-speed photometric observations at the AAT (Watson 1994). There are other high- or low-state observations reported in the literature, which are either compatible with a one-pole or a two-pole accretion geometry (see Bailey & Cropper 1991, Schwope et al. 1990), Accretion at a second pole seems not to be triggered by a particular high accretion rate or similar. Hence, it is not known in advance, and it does not become evident from the shape of the X-ray light curve, whether a second pole in UZ For is active or not. The OM light curve, therefore, although obtained with a relative low count rate proved to be extremely useful in order to distinguish between a one-pole and a two-pole accretion geometry. The data obtained during *XMM-Newton* rev 448, plotted in greater detail in the lower panel of Figure 7, show emission at the time when the prime spot is occulted by the donor star. A light curve obtained with the *HST*/FOS depicted from the *HST* archive is also shown for comparison. The *HST* data do not show any clear sign for emission from 'spot 2' but, with their smooth gradual in-/decrease, are compatible with a single heated accretion spot. The OM data differ from this shape by showing a two step function at ingress and egress very much similar to the S-Cam data. This shape of the OM-UVW1 light curve is regarded as evidence for a second accretion spot. Clearly, both accretion regions are in completely different accretion modes, in high- and low-accretion states. 'Spot 2' is an extremely weak X-ray emitter. It also has a significantly higher magnetic field of 75 MG vs. 53 MG (Schwope et al. 1990). The likely plasma temperature was determined from the shape of the narrow cyclotron emission line to be of order 1–2 keV, *i.e.* similar to the recently discovered low-accretion rate polars from the Sloan or the Hamburg-Schmidt surveys. What makes UZ For interesting for further modeling is the presence of two distinctly different accretion regions on the same white dwarf, so that the parameter space $(B, \dot{m}, M_{\rm WD})$ can be reduced.

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