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COORDINATED X-RAY AND ULTRAVIOLET OBSERVATIONS OF THE INTERMEDIATE POLAR H2215–086

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ABSTRACT

Quasi-simultaneous observations of H2215-086 (=FO Aqr), obtained with Exosat and IUE in 1983 and 1985 are reported. Secular variations in the X-ray flux and in the shape of the rotational light curve are observed. The modulation of the photoelectric absorption cutoff is studied by means of phase resolved X-ray spectra. A possible orbital modulation of the UV emission is also discussed.

INTRODUCTION

The HEAO-1 X-ray source H2215-086 /1/ was precisely located by means of an Einstein observation and identified with a cataclysmic variable /2/. The earliest photometric /2/ and spectroscopic /3/ observations led to the discovery of two clear periodicities (a 4-hr "orbital" one and a 21-min "rotational" one) and to the classification in the intermediate polar group. A refined ephemeris for the rotational period is given in /4/. The presence of a "sideband" period at 23 or 19 min is debated in /2/. A discussion about the nature of sidebands in intermediate polars is given in /5/.

The rotational periodicity has also been detected in the X-ray band with Exosat /6/. Here we report on Exosat and IUE observations obtained as part of an extensive program of multiwavelength observations of magnetic cataclysmic variables. Part of our X-ray and UV data have been preliminarily presented in /7/ and /8/.

OBSERVATIONS AND RESULTS

H2215-086 was observed with Exosat for 7 hrs in October 1983 and for 5.5 hrs in October 1985, hence for a duration substantially longer than the observation of /6/. On both occasions 8 quasi-simultaneous UV spectra were obtained with IUE.

A journal of observations is reported in Table 1.

A. X-rays

On both epochs the source was observed with the Medium Energy (ME) proportional counter array in an offset configuration, with one half of the experiment pointed at the target, and the other half monitoring the background. Due to the weakness of the source only data from the Argon chambers are used (there are 4 chambers for each experiment half). In both observations one set of spectra was collected every 10 sec. The source was not detected with the Channel Multiplier Array at the focus of the Low Energy (LE) telescope.

The ME background subtraction proved troublesome. No array swap was performed, therefore absolute background information had to be obtained using slew manoeuvre data. Unfortunately in both occasions the background was varying during part of the manoeuvres, therefore we were compelled to use only a limited part of the slew data. In the case of 1983 the ingoing slew background was used as reference. For the 1985 data we were unable to select between the two (slightly different) manoeuvre data and were forced to use an average of the two slews as background reference. For light curves (Figure 1) and time resolved spectra (Figure 3) the instantaneous background in the offset half was subtracted first, and then the result was compensated for the intrinsic difference of the two halves, based on the mentioned reference background spectra. For the total and phase resolved spectra (see below) the background in the offset half, integrated over the whole period, was subtracted and then compensated as above.

Table 1
Journal of observations

X-rays (Exosat ME)

Notes	Epoch (UT)	exposure (sec)	Count rates (cts/s/half) 1-5 keV	6-10 keV	1-10 keV
1983 Oct 11					
Total spectrum	03:49-10:57	24670	0.83±0.04	1.04±0.04	2.01±0.05
High (phases 0.00-0.30)		6190	1.48±0.06	1.19±0.06	2.88±0.09
Low (phases 0.40-0.90)		11220	0.60±0.06	0.91±0.06	1.63±0.08
1985 Oct 22/23					
Total spectrum	19:54-01:33	20220	0.90±0.04	0.95±0.04	2.06±0.05
High (phases 0.95-0.45)		9720	1.14±0.05	1.03±0.06	2.48±0.08
Low (phases 0.50-0.85)		5880	0.55±0.06	0.71±0.06	1.40±0.09

Ultraviolet (IUE)

Camera & image no.	Start time	exposure (min)	Average flux[1] 1420-1520 A	Camera & image no.	Start time	exposure (min)	Average flux[1] 2500-2700 A
1983 Oct 11							
SWP 21272	16:00	63	3.29±0.08	LWR 16967	14:41	63	2.87±0.04
SWP 21273	18:01	63	4.26±0.10	LWP 2027	17:12	42	2.64±0.04
SWP 21274	18:56	42	3.14±0.10	LWP 2028	19:10	42	3.13±0.04
SWP 21275	21:10	31	3.81±0.13	LWP 2029	20:43	21	2.61±0.06
1985 Oct 22							
SWP 26965	15:02	42	3.13±0.12	LWP 6969	15:50	21	3.72±0.07
SWP 26966	16:20	42	4.85±0.12	LWP 6970	17:11	21	4.42±0.06
SWP 26967	17:38	42	5.44±0.13	LWP 6971	18:29	21	3.67±0.04
SWP 26968	19:29	42	3.22±0.12	LWP 6972	20:19	21	2.67±0.05

[1] UV average fluxes are in 10^{-14} erg/cm^2/s/A

Background subtracted light curves for both years in the PHA channel range 6-40 (1-10 keV ca.) are shown in Figure 1. The average intensity level was higher in 1983. The intensity in both years was substantially higher than the one reported in /6/ for August 1983. The 21-min rotational periodicity is clearly apparent. The 1983 light curve is more erratic than the 1985 one, and shows a mild rising trend over the observed period. On the other hand during the 1985 observation a fainter state of the source was seen, lasting for 3-4 rotational cycles, with reduced rotational modulation.

To gain a better insight, we have folded the X-ray light curves with the optical rotational period known from the ephemeris of /4/: the result is shown in Figure 2. The start times of the two observations, arbitrarily taken as phase 0 correspond to phases 0.06 ± 03 (1983) and 0.37 ± 0.06 (1985) respectively, according to the ephemeris and related errors given by /4/. According to such relative phasing the phases of the X-ray minima in the two years differ by 0.5. From Figure 2 one can clearly see a change in the shape of the light curve between the two epochs : this can be quantified as a change in the pulsed fraction , which is 36% in 1983 and 50% in 1985 in the 1-10 keV band.

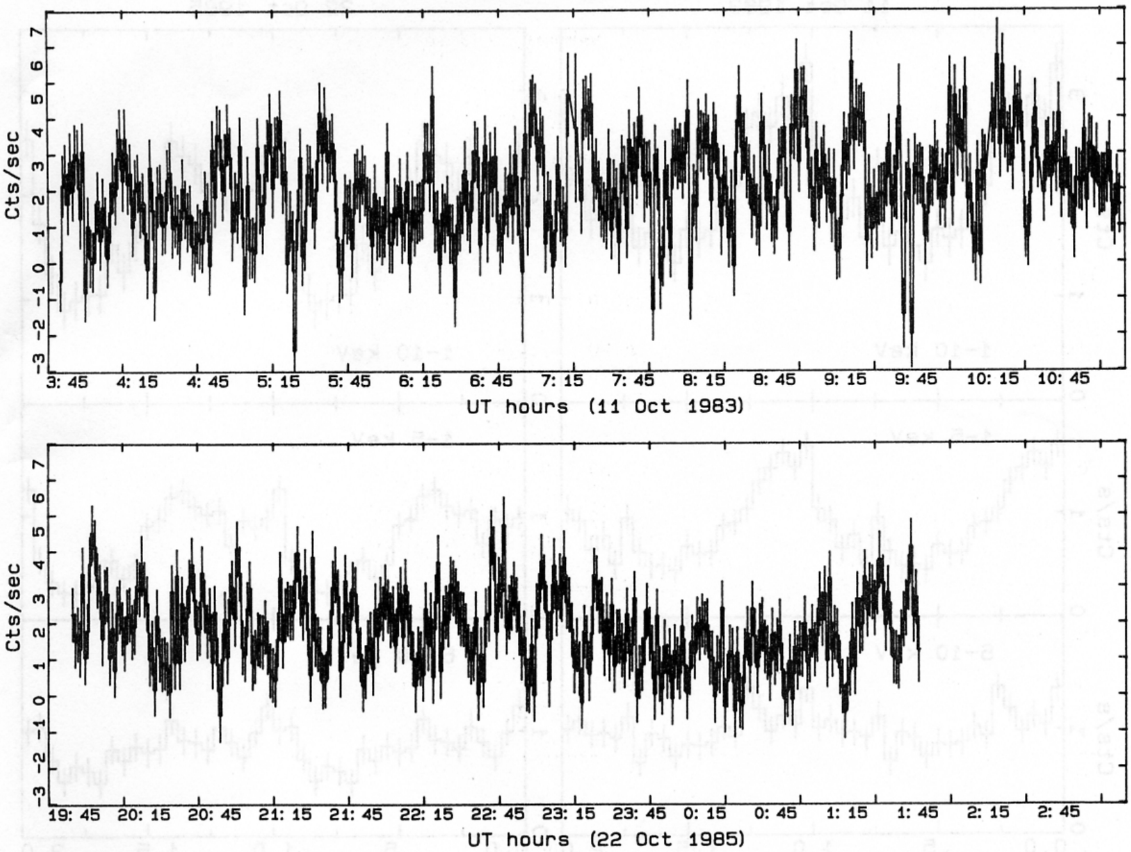

Fig. 1 Light curves of H2215-086 in the 1-10 keV range.

It is apparent from light curves in separate energy bands (1-5 and 6-10 keV) that the modulation is larger at lower energies, as could be expected if it is due to photoelectric absorption by cold material. A better way of looking at the energy dependence of the rotational modulation is shown in Figure 3, where folded light curves for individual PHA channels are presented in form of a gray-scale plot. One can see that, although the peak of the light curve is at a similar level on both epochs, the spectrum extends over a wider energy range (is flatter) in 1983. In the 1983 data one can also notice the strong sharp peak in the lower channels. One can see that the modulation extends up to quite high energies (8 keV).

We have also performed a period search in our data, using both a folding search method, and a discrete Fourier transform according to /9/. In the overall (1-10 keV) energy band the 21-min rotational period is clearly apparent; a sideband is visible at 19 min in 1983. If one restricts to the lower energy range (1-5 keV) the periodicity is much clearer, and the sideband is visible on both epochs in comparable position.

Finally we have divided each X-ray observation in 2 phase bins (as detailed in Table 1), corresponding to the high and low parts of the folded light curve, and accumulated a complete spectrum in each bin. These phase-resolved spectra have been best fitted with simple spectral forms in the energy range 2.5 to 10 keV. The results are summarized in Table 2. A thermal Bremsstrahlung model gives an ill defined, though high, temperature, due to the hardness of the spectra. The other two models give fits of comparable quality. The rotational modulation appears to be due to increased absorption without significant changes in the slope.

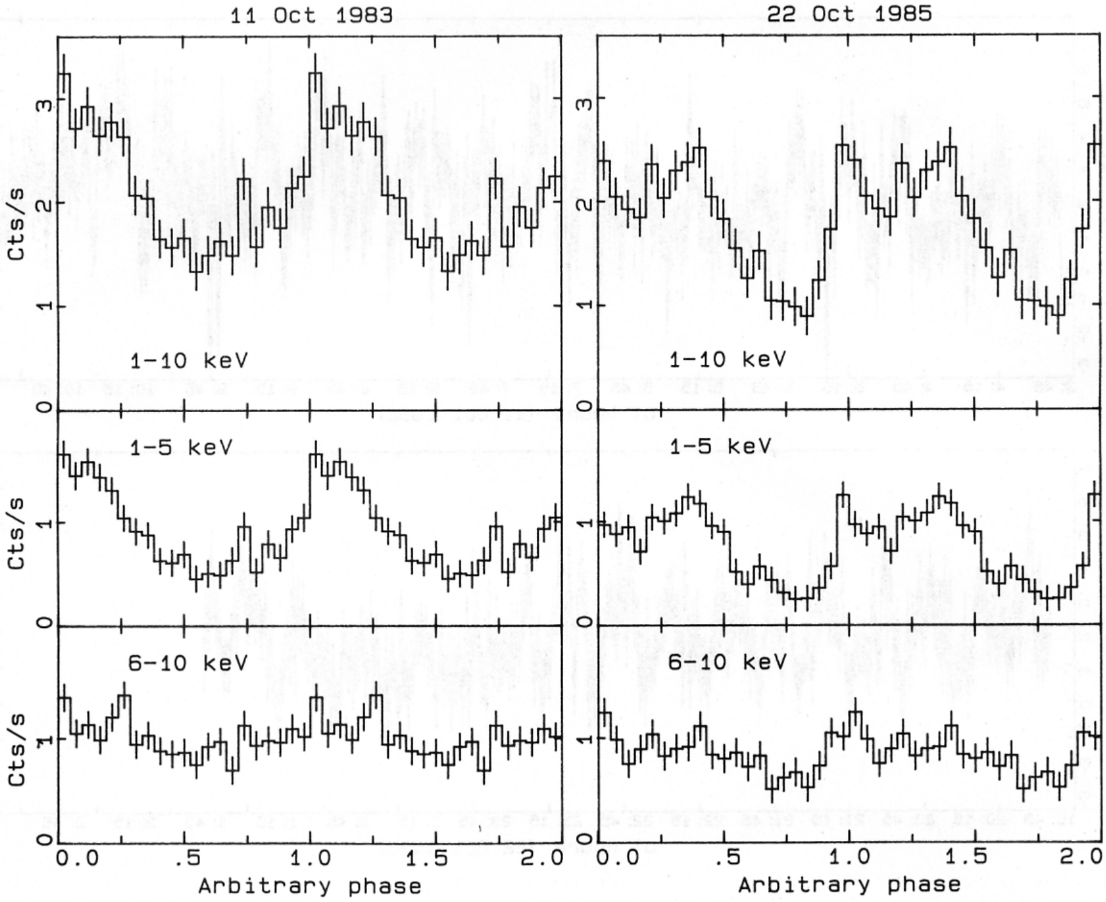

Fig. 2 Light curves of H2215-086, folded according to /4/. Arbitrary phase 0 refers to the start of each observation.

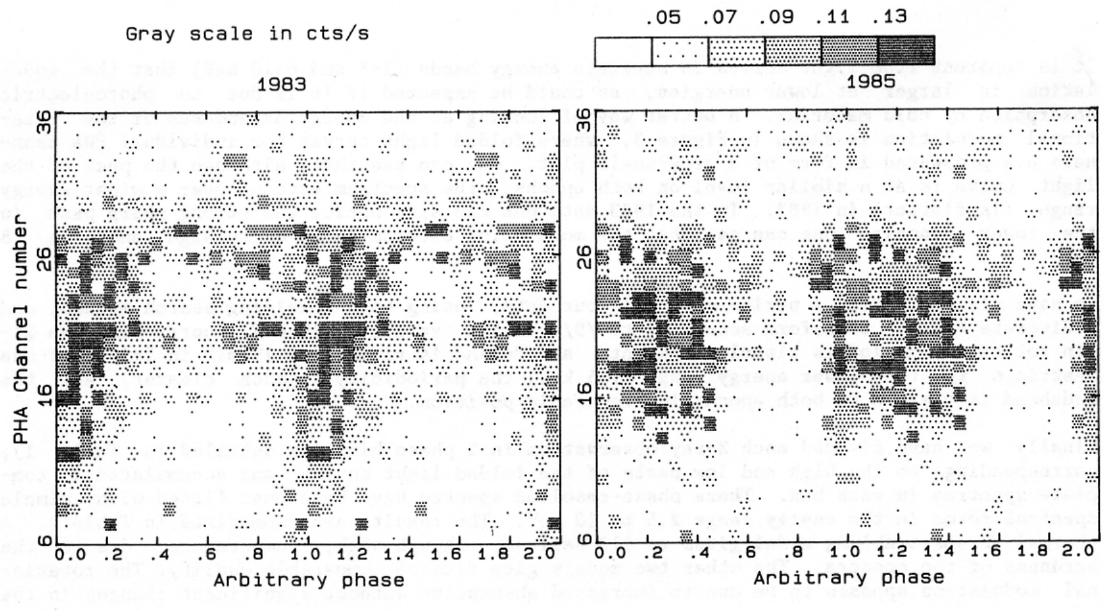

Fig. 3 Data folded in 1-minute phase bins with the period of /4/. Phase 0 is the observation start time. Two cycles are shown for clarity.

TABLE 2 Summary of Results

Epoch:	1983 Oct 11		1985 Oct 22	
Fit results	High phase	Low phase	High phase	Low phase
Degrees of freedom	21	14	19	11
Power law				
Column density	0.00 0.15 0.54	0.34 1.05 2.23	0.29 0.62 1.12	0.76 2.00 3.50
Photon index	0.19 0.54 1.00	-.10 0.48 1.35	0.55 0.98 1.50	0.27 1.35 2.27
2-10 keV flux	4.45 4.75 4.99	2.84 3.08 3.25	3.95 4.17 4.39	2.27 2.52 2.80
Chi-square	31.4	23.6	21.5	14.3
Blackbody				
Column density	0.00 0.00 0.15	0.13 0.60 1.50	0.00 0.19 0.31	0.21 1.00 2.29
kT (keV)	2.36 2.70 3.15	2.41 3.40 5.20	2.07 2.48 3.06	1.73 2.50 4.13
2-10 keV flux	4.34 4.59 4.80	2.88 3.08 3.27	3.91 4.20 4.46	2.28 2.53 2.80
Chi-square	28.6	21.5	18.8	13.4
Thermal Bremsstrahlung				
Column density	0.63 0.86 1.06	1.68 2.20 2.90	0.80 1.00 1.24	1.48 2.10 3.30
kT (keV)	> 37	> 19	> 25	> 11
2-10 keV flux	4.06 4.18 4.24	2.67 2.80 2.92	3.84 3.98 4.06	2.29 2.49 2.59
Chi-square	47.3	29.1	25.0	14.4

For each spectral fit parameter we give the best fit value, bracketed by the extrema of the 90% confidence range. The equivalent Hydrogen column density is in units of 10^{23} atom/cm^2. The fluxes given are at the source, in units of 10^{-11} erg/cm^2/s.

B. Ultraviolet

In both observations a total of 8 spectra was obtained, exposing alternately in the SWP (1200-1900 A) and LWP (2000-3000 A) cameras. The first exposure of 1983 was in the LWR camera (same range as LWP). All spectra (with the exception of the last one of 1983) were exposed for a multiple of the rotational period (21, 42 or 63 minutes) in order to average out any rotational modulation effect.

The UV spectra /7/ show the typical emission lines (N V, Si IV, C IV, He II) above a well defined continuum. There is no indication of a dip around 2200 A, therefore we estimate E(B-V) < 0.05 and apply no reddening correction.

We present here measurements of broad band flux in selected line-free regions and of line intensities. The results are shown in Figure 4 as a function of time. The He II line (not shown), which is the second strongest line, shows a behaviour similar to C IV. Orbital phase according to /2/ is also reported, but the uncertainty in the ephemeris is such as to preclude definite conclusions on phase-related modulation. It is however apparent that in 1983 the UV flux is lower and less variable than in 1985. Comparing the fluxes in the different bands one can see that the X-ray looks higher in 1983, where the UV is lower.

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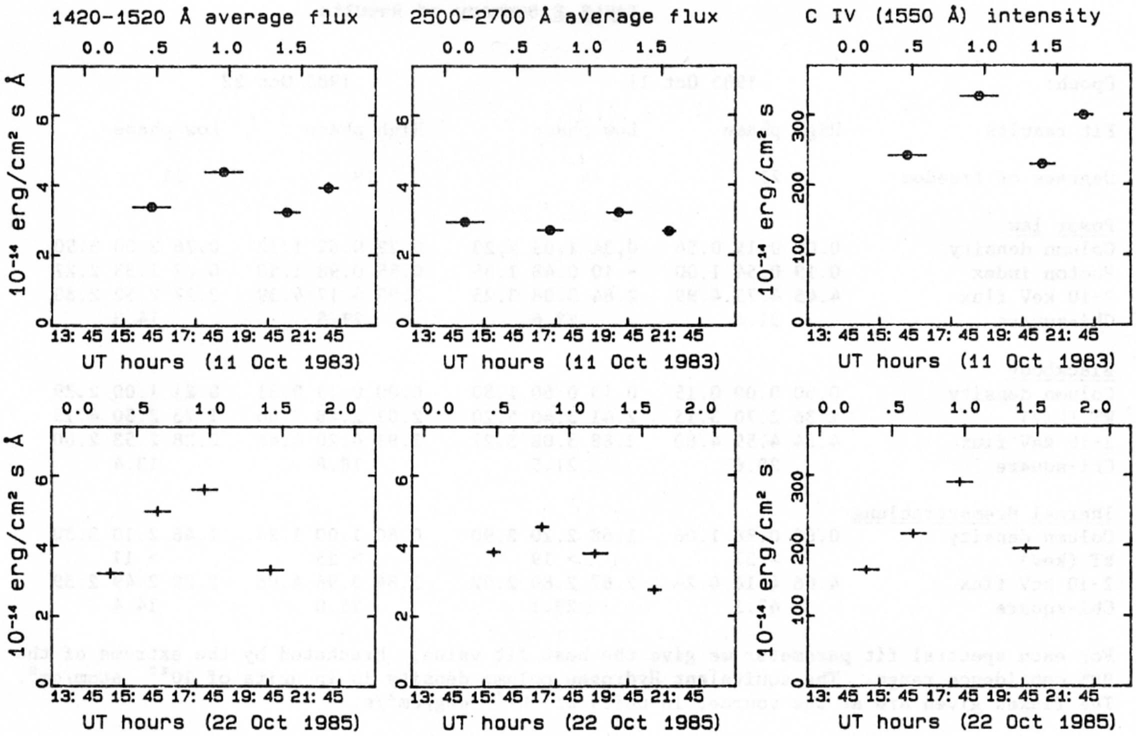

Fig. 4 Ultraviolet broad band fluxes and line intensities. The orbital phase according to /2/ is indicated on top of each frame.