EXOSAT OBSERVATIONS OF AM HER OBJECTS - PRELIMINARY RESULTS

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ABSTRACT

We present preliminary EXOSAT soft X-ray light curves of the AM HER objects VV Puppis, E2003+225, AN UMa and E1405-451. These are the first X-ray light curves with continuous and complete orbital coverage. For the last three objects these light curves show remarkable similarities each having two short eclipses per orbit. Only E1405-451 was detected in the medium energy experiment, a folded light curve is presented.

INTRODUCTION

AM Her objects (Polars) are cataclysmic variables in which the magnetic field of the accreting white dwarfs is strong enough to completely dominate the accretion flow. (See Liebert and Stockman (1984) for a review of these objects). Models of radial accretion onto a white dwarf (e.g. Kylafis and Lamb, 1982) suggest AM Her objects should produce hard X-rays from a shocked region above the accreting magnetic pole(s) and soft X-rays from the heated white dwarf photosphere. Previous determinations of the blackbody temperature of the soft X-ray component in the class of nearby objects (e.g. Hearn and Marshall, 1979; Heise, 1982) suggested that they would be bright in the low energy telescopes of EXOSAT.

We present here the preliminary results from the EXOSAT observatory observations of four of these objects. See Turner et al. (1981) and de Korte et al. (1984) for a description of the instruments used. The low energy telescopes were generally used with the 3000 lexan filter and the CMA, giving an energy range of 0.06-1.8 KeV.

VV PUPPIS

Two 100 minute orbital cycles of VV Pup were observed mainly with the 3000 lexan filter on Feb 4, 1984, although a short exposure with the Al/p was also made. The light curve is similar to that seen by Einstein (Patterson et.al. 1984), although in the second bright phase of our observation there appears to be virtually no flaring. VV Pup was in an intermediate optical state ($m \sim 15.6$-16.3) around the time of this observation. During the 'eclipse' interval marked by the bar in Fig.1 VV Pup was detected at a count rate level 3×10^{-4} times that of the peak, with a possibility that this was a background fluctuation of 1.6×10^{-4} (corresponding to a 3.6 σ detection)). VV Puppis was not seen in the ME, for a 10 KeV unabsorbed thermal bremsstrahlung spectrum, the 2-10 keV flux upper limit is $f_{2-10} < 1.4 \times 10^{-12}$ erg/cm^2/s.

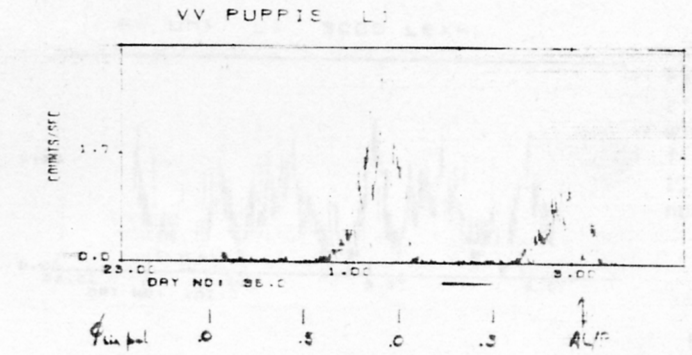

Fig.1 Soft X-ray light curve of VV Pup obtained with the 3000 lexan filter starting on 4 Feb. 1984 covering 2 orbital periods. Times are hours of UT. For symbols see text. Linear polarisation phases are derived from Walker (1965), Liebert & Stockman (1969) & Tapia (1977)

E2003+225

Fig. 2 shows one orbital cycle (3.7 hours) of this long period system obtained by EXOSAT with the 3000 lexan filter during 1983. A 12.5 minute eclipse is visible. The feature at ϕ =0.4 has analogues in the light curves of AN UMa and E1405-451. Comparison of the count rates in the 3000 lexan and Al/p filters from the same phase interval (ϕ =0.32-0.82) from adjacent orbital periods constrains an assumed blackbody spectrum to have kT< 0.03 keV and $N_H > 10^{19}$ cm^{-2} (assuming that orbit to orbit variations is less than 5%). The implied 0.05-2.5 keV flux is 1.0×10^{-11} erg/cm^2/s. This source was not seen in the ME. The 2σ flux limit is $f_{2-10} < 2.8 \times 10^{-12}$ erg/cm^2/s.

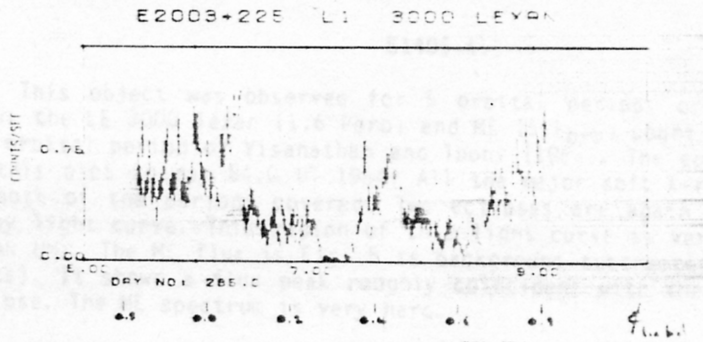

Fig.2. Soft X-ray light curve of E2003+225 covering one orbital period in 10.10.83. Linear polarisation phases are from the ephemeris of Nousek et al. (1984). Times are hours of UT.

AN UMa

A chance observation by EXOSAT on March 31, 1984 showed that this object was active with a soft X-ray flux ~20 times that seen by Szkody et al. (1981). Osborne (1984) suggested that the object had returned to its high state, and subsequent photographic photometry showed it to be at B=15.5 (Argyle, 1984). This can be compared to the following magnitudes: high state (14.0-15.0), intermediate (16.5), low (20) (Liebert, 1982). AN UMa was reobserved on April 12, 1984 and it is this observation which is discussed here. Fig. 3 shows the 3000 lexan light curve covering 3 orbital periods (P_{orb} = 115 mins). It can be seen that the main features of the light curve occur in each cycle. These are seen more clearly in Fig. 4, which shows this data folded according to the linear polarisation ephemeris of Liebert et al.(1982). There are two eclipses. The shorter eclipse occurs half an orbital period from the peak of the broad maximum. The source was not seen in the ME, the 2-10 keV flux limit (2σ) is $f < 4 \times 10^{-12}$ erg/cm^2/s. SAS-3 observed AN UMa in its high state in 1975 (Hearn and Marshall, 1979).

Their light curve is broadly similar to ours, although of much lower quality. However, the main X-ray features apparently occur 0.3 earlier in phase in our observation.

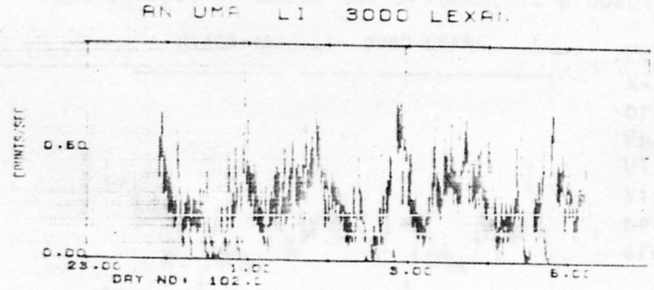

Fig.3. orbital cycles of AN UMa observed with 3000 lexan filter, starting on 11.4.84. Times are hours of UT.

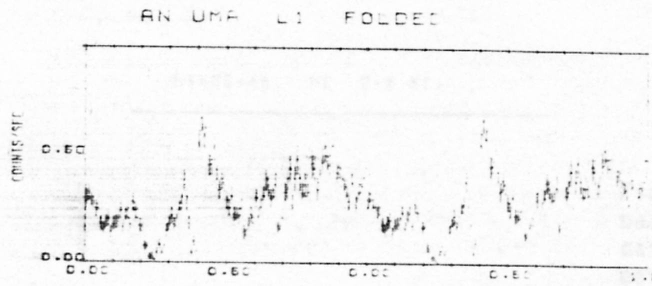

Fig.4. The data of fig.3 foled according to the linear polarisation ephemeris of Liebert et al. (1982). Note different phasing to that of Hearn & Marshall (1979). 2 periods are shown for clarity.

E1405-451

This object was observed for 5 orbital periods on 24/3/84. Fig. 5 shows the LE 3000 lexan (1.6 Porb) and ME (5 Porb) count rates folded with the orbital period of Visanathan and Tuohy (1983). The epoch of phase zero in this plot is day 84.0 UT 1984. All the major soft X-ray features occur in both of the periods covered. Two eclipses are again seen in the soft X-ray light curve. This region of this light curve is very similar to that of AN UMa. The ME flux is Fig. 5 is background subtracted (as are all the plots). It shows a flux peak roughly coincident with the short soft X-ray eclipse. The ME spectrum is very hard.

DISCUSSION

The system inclination ,i, and magnetic colatitude , δ , (the angle between the rotation axis and magnetic axis)of AN UMa and E1405-451 are the same within the errors (5^0 and 10^0) (Brainerd and Lamb, 1983), i.e. respectively 65° and 20°. These values suggest that both a grazing eclipse of the pole by the white dwarf, requiring $i + \delta \gtrsim 90°$, and an eclipse of the pole by the accretion stream, which requires $i > \delta$, are possible. These might be identified with the 'long' and 'short' eclipses. If this were so, then the peak of the hard flux in E1405-451 would be occurring when the line of sight was in the plane of the shock. E2003+225 may also have a similar geometry, that is $i + \delta \gtrsim 90^0$ and $\delta < i$, given the similarity of its light curve to AN UMa and E1405-451. This is not inconsistent with the results of Nousek et al.(1984), who give $46^0 < i < 80^0$ and $63^0 < \delta < 80^0$. The short (accretion column?) eclipse occurs at ϕ=0.4 for AN UMa and E2003+225 as it does for 2A0311-227 (Patterson, Williams and Hiltner. 1981). Note that the linear polarisation spike (ϕ =0) does not occur at the time of the long eclipse in these two systems, it probably does in E1405-451.

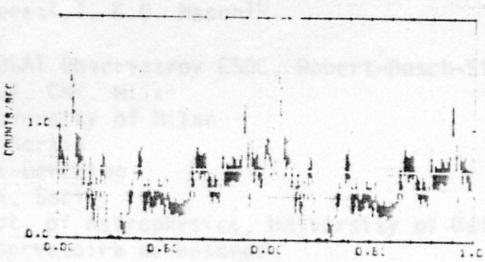

Fig.5a. Folded 3000 lexan soft X-ray light curve from 1.6 orbital periods of E1405-451. Phase zero is 1984, day 84.0 UT. Period = 102 mins. from Visvanathan and Tuohy (1983). 2 periods are shown. The eclipses are arrowed.

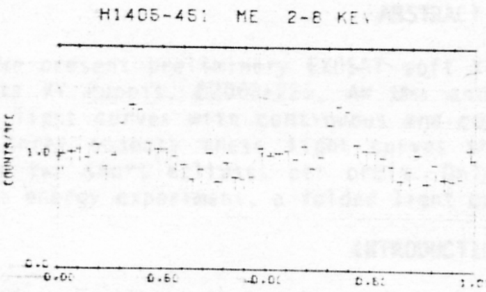

Fig.5b. 5 orbital periods of background subtracted 2-8 KeV data from the medium energy detectors folded according to the same ephemeris.

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