CHANGES IN THE SOFT AND HARD X-RAY LIGHT CURVES OF THE AM HER OBJECT E1405-451

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ABSTRACT

The preliminary results of EXOSAT and contemporaneous optical observations of E1405-451 (V834 Cen) in 1985 and 1986 are presented. In the latter of the two observations the soft X-ray light curve was observed to be quite different to that seen in all previous observations, but similar to the optical light curve and the new soft X-ray light curve of E2003+225. A phase shift of the broad soft X-ray eclipse was also observed. The hard X-ray and optical light curves have also undergone small changes.

INTRODUCTION

The standard model of accretion in AM Her objects has magnetically confined accreting matter falling onto a single small spot on the white dwarf (Lamb & Masters 1979). The post shock region of the accretion column close to the white dwarf emits hard X-ray bremsstrahlung and optical/IR cyclotron radiation. The spot on the white dwarf illuminated by these spectral components reradiates the energy in a soft X-ray blackbody spectrum (see Lamb 1985 and Liebert & Stockman 1985 for reviews). The soft X-ray light curves of AM Her objects in which the spot is occulted by the body of the white dwarf

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are understood as due to its changing projected area as the white dwarf rotates (see Beuermann 1986 for an elaboration on this). However the soft X-ray light curves of the systems which do not occult are complex and less well understood (Mason 1985). Additionally, observations of AM Her, E2003+225 and H0139-68 have shown that major changes can occur in the soft X-ray light curves of AM Her objects with little or no change in the optical light curve (Osborne 1986; Mazeh, Kieboom & Heise 1986)

The AM Her object E1405-451 has an orbital period of 101.5 minutes. Polarisation studies show that the cyclotron emission region (which is close to the X-ray emission region) does not pass over the limb of the white dwarf (Wickramasinghe & Meggitt 1985 WM85; Cropper, Menzies & Tapia 1986 CMT86). The first X-ray light curve of E1405-451 was typical of such objects (Bonnet-Bidaud et al. 1985, BB85). This paper is a preliminary report of part of the later X-ray and optical observations, these show a major change in the form of the soft X-ray light curve similar to that seen in E2003+225.

OBSERVATIONS

The first EXOSAT observation of E1405-451 has been reported by BB85. Later EXOSAT observations took place on 2/8/85 at 0529 UT and on 5/3/86 at 1106 UT and lasted 11 hours and 27.3 hours respectively. The low energy and medium energy instruments used are described by de Korte et al. (1981) and Turner, Smith & Zimmerman (1981). CCD photometry using the ESO/MPI 2.2m telescope at la Silla was obtained on 3-4/8/85 (2347-0216 UT). High speed photometric data in the Johnson V band were obtained on 6/3/86 (1226-1630 UT) with the 40 inch telescope at Siding Spring using a two channel photometer.

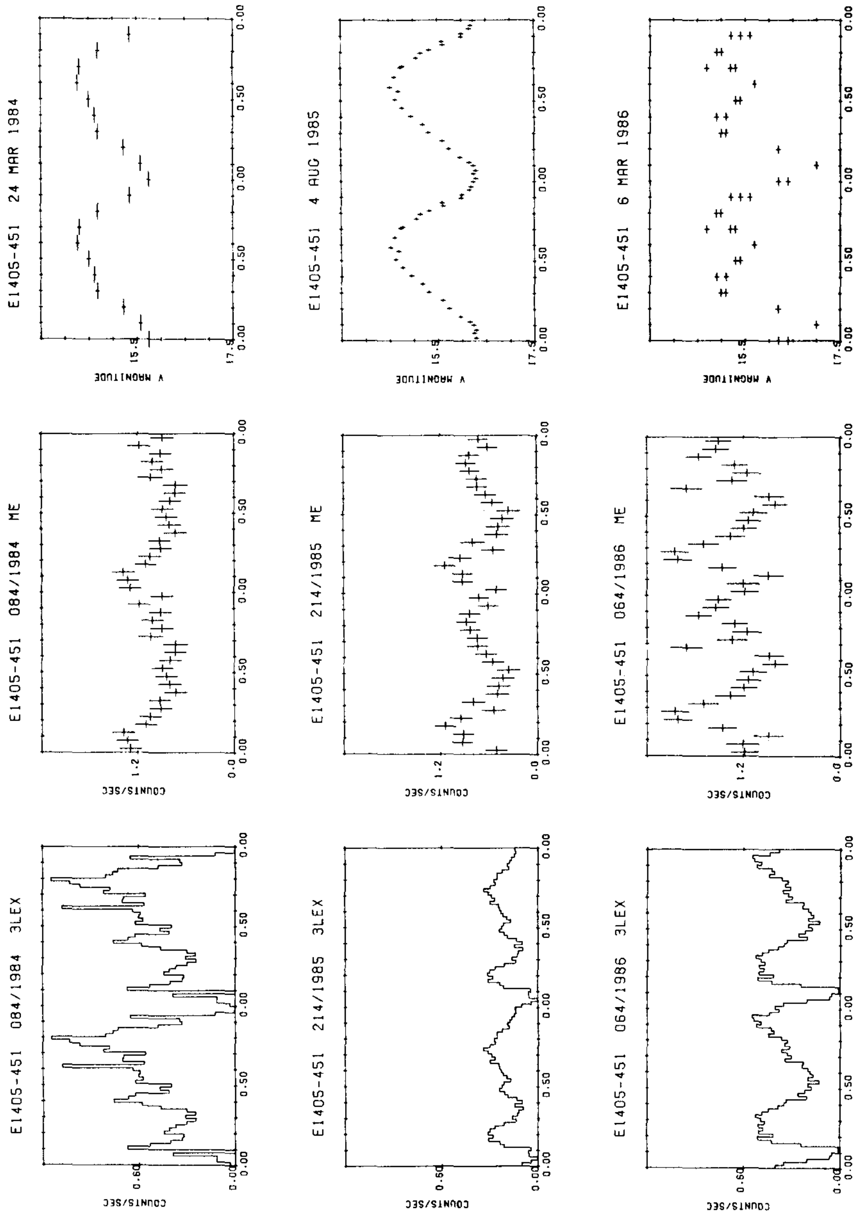

Figure. 1. Light curves of the AM Her object E1405-451.

The folded light curves, including the 1984 data of BB85, are shown in figure 1. The optical minimum ephemeris of CMT86 is used throughout (the linear polarisation pulse occurs at ϕ=0.55). The soft X-ray light curves taken with the 3000 lexan filter (0.05-2.0 keV), are shown on the left in 2 minute bins. The 1984 plot shows 1.8P_{orb} of data repeated for clarity (as are all the plots). An observation 5 hours later with the 4000 lexan filter (which has the same X-ray transmission curve but lower overall area) shows less flux around ϕ~0.8, similar to the light curve seen in the second panel. The lower panels show 5.7 and 10.2P_{orb} of data. The hard X-ray (1.0-7.5 keV) light curves are shown in the center panels in five minute bins. They show 4.9, 6.2 and 3.8P_{orb} of data respectively. The absolute intensities in these plots should be regarded as preliminary. The visual magnitude plots, shown on the right, are sampled from higher time resolution data (not 1985). The top panel shows average magnitudes from an observation of 2.8P_{orb}.

DISCUSSION

The double dip pattern, a characteristic of the soft X-ray light curves of these objects, was seen in both the 3000 and 4000 lexan observations in 1984. It was also seen in 1985 although it is not clear in this plot because of the coarse binning and weakness of the inter-dip flux. At least one, and possibly both, of these soft X-ray dips is probably due to photoelectric absorption in the accretion column as it passes through our line of sight. This follows from orbital inclination being greater than the co-latitude of the accreting pole, the phase of the (dilution corrected) circular polarisation maximum being zero, the radial velocity studies of Mouchet et al. (1986) and Rosen, Mason & Cordova (1986) which put the broad emission line region closest to our line of sight at $\phi\sim0.0$, and the low energy of the photons that make up the light curve. In this object the accretion flow near maximum altitude above the orbit plane would be responsible for the dips. The column density through this region is apparently variable, as the 1985 and 1986 hard X-ray light curves show a dip at this phase, the 1984 data do not.

The 1986 soft X-ray observation shows a new form of soft X-ray light curve together with a delay of $\sim0.1P_{orb}$ in the eclipse. This new light curve form is easily understandable as the variation of the projected area of the illuminated spot as the white dwarf rotates, interupted by the accretion flow as it passes through our line of sight. The projected area minimum occurs at phase 0.55, when the accreting pole is on the limb.

The gross shape of the hard X-ray light curves is similar to those seen in soft X-rays in the later observations. They are all surprising as the hard X-rays are thought to be due to optically thin emission from a small region. In a non-occulting system the hard X-ray light curve should be flat apart from any eclipse due to the accretion stream. Possible reasons for the minimum around phase 0.5 are that the X-ray emission region is embedded in a ring of absorbing/scattering material, or that the emission region is extended and part of it passes over the limb as the white dwarf rotates. An X-ray emission region embedded in a ring of cooler material has also been proposed for this source by Wickramasinghe, Tuohy & Visvanathan (1986) to explain observed phase dependant Zeeman absorption features.

The full range of high state V band light curve types seen from this object are illustrated by our observations, although the most recent light curve shows much deeper primary and secondary minima than previously seen. The maximum magnitude is a normal high state value. The minima in the optical light curve of this object have been ascribed to angle dependant optical depth effects in the cyclotron emission region (WM85). That is, it is optically thin when viewed close to the magnetic axis and thus has a low intensity, and it is optically thick but has a low projected area when viewed at high angles. However the eclipse by the accretion stream may also play a part in the formation of the primary minimum. The depth variations in the secondary minimum seen here could be due to shock height/radius ratio changes (WM85) or, if the emission region is extended as suggested by Schmidt, Stockman & Grandi (1986), due to a variable fraction of it passing over the limb of the white dwarf.

We have observed a new form of soft X-ray light curve from E1405-451. It is simple and very similar to that seen in E2003+225 (E1405-451 has a narrower eclipse). The change in the form of the soft X-ray light curve in E2003+225 coincided with a $0.1P_{orb}$ phase retardation of the eclipse due to the accretion column (Osborne 1986). A similar coincidence is seen in E1405-451, suggesting that the precise magnetic azimuth of the accretion stream high above the orbit plane is important in determining the soft X-ray light curve at all phases.

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