IS KO VEL (E1013-477) AN INTERMEDIATE POLAR ?

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ABSTRACT

We report X-ray observations (0.1-9 keV) of the cataclysmic variable KO Vel (E1013-477) made with *EXOSAT* in 1984. We found in our data no obvious evidence for any of the periods proposed for this source from optical observations. We are able to obtain an estimate of the spectrum as a flat (photon index $\alpha \sim 1$) power law with low interstellar absorption ($< 10^{21}$ cm^{-2}). Our results are discussed in the framework of the classification of the object as a magnetic cataclysmic variable (AM Her or intermediate polar type).

Keywords: Cataclysmic variables, stars: individual (KO Vel), X-rays: sources (E1013-477), X-rays: binaries.

1. INTRODUCTION

The X-ray source E1013-477, first detected with the *HEAO-1* A2 experiment and subsequently better located by means of an *Einstein* IPC observation, was identified (Refs. 1-2) with a 17 mag blue star (KO Vel).

Mason *et al.* (Ref. 2) also report optical and UV observations and propose a classification as an AM Her cataclysmic variable on the ground of its spectral characteristics and of the presence of strong flickering. They also propose an orbital period of 103 min, based on the recurrence of dips in photometric observations taken in June 1981 and January 1982 (but not confirmed by observations in April 1982).

After the earlier observations the source faded to 19 mag and no observations in a bright state have since then been reported.

Polarimetric observations (in the low state) yield only an upper limit of 1.0 ± 1.3 % circular polarization, which throws doubt on the AM Her classification, unless the source is an AM Her in quiescence (Ref. 3, see also Refs. 4-5)

Further photometry and time-resolved spectroscopy do not confirm the 103 min period (Ref. 6). Later photometry in the I band (Ref. 7) gives evidences for periodicities at 6.4 hrs and 71 min and the authors advance the possibility of a classification as an intermediate polar system.

More arguments in favour of such a classification are given by the detection in the optical (Ref. 8) of three coherent periods at 4.9 hrs, 68 and 89 min (interpreted respectively as the orbital, rotational and beat period as typically seen in intermediate polars, see Ref. 9).

2. OBSERVATIONS

E1013-477 was observed by the *EXOSAT* satellite (see Ref. 10 for a description of the payload) on 23 March 1984 between 10:32 and 14:24 UT.

We collected data with the Low Energy (LE) telescope with the Channel Multiplier Array in the focus and the 3000 Å Lexan filter interposed in the beam (0.02-2.5 keV) and with the Medium Energy (ME) proportional counter array (Argon chambers: 1-15 keV). The ME was used in an offset configuration, with one half of the experiment pointed at the source, and the other half monitoring the background.

For the LE experiment, we measured the counts in a 5×5 pixel (1 pixel = 4 arcsec) box around the source position and subtracted the background determined in an outer region. The net counts are 42.7 ± 9.4 in an effective exposure time of 9462 s. The count rate, after correction for dead time, point spread function, background disuniformity and vignetting, is $(4.5 \pm 0.9)\times10^{-3}$ cts/s.

For the ME experiment there is signal from the source in the PHA channel range 10-35 (2-9 keV), amounting to 0.46 ± 0.05 cts/s/half with an exposure time of 14780 s. We have verified the significance of the detection, computing the chance probability of measuring the observed number of net counts over the measured background, in the pointed and in the offset half, in the individual 4 detectors which constitute each half, and also in the PHA channel range 60-128 where only background should be present.

3. RESULTS

3.1 Temporal analysis

In fig. 1 we report the ME light curve in the 2-9 keV energy range. The low statistics forbids any splitting in further energy ranges for e.g. hardness ratio analysis.

We have first applied Fourier analysis (Ref. 11) to our light curve (before background subtraction and also to the background alone for reference). We are able to exclude the presence of any of the proposed optical periods, as well as of any other coherent

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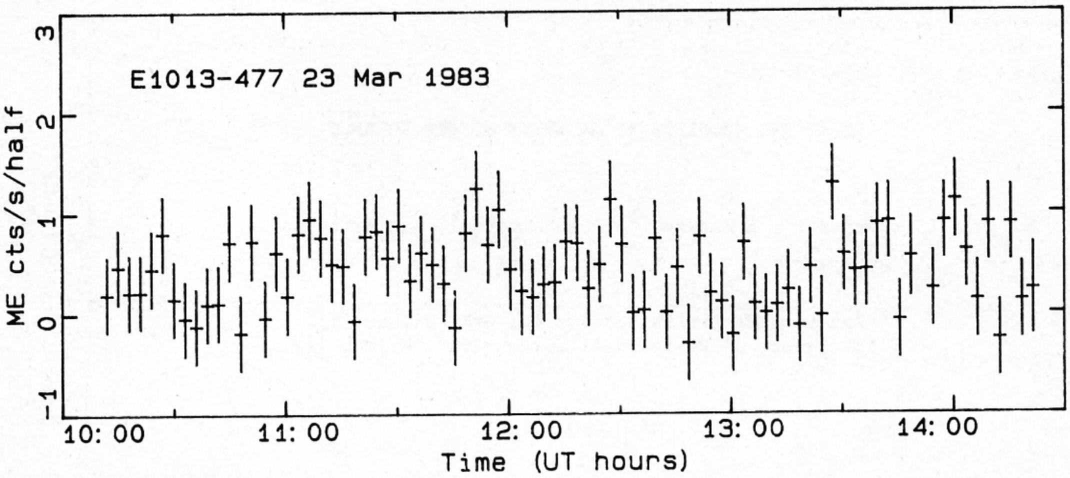

Fig.1 The net light curve of E1013-477 in the 2-9 keV band (the bin size is 180 s).

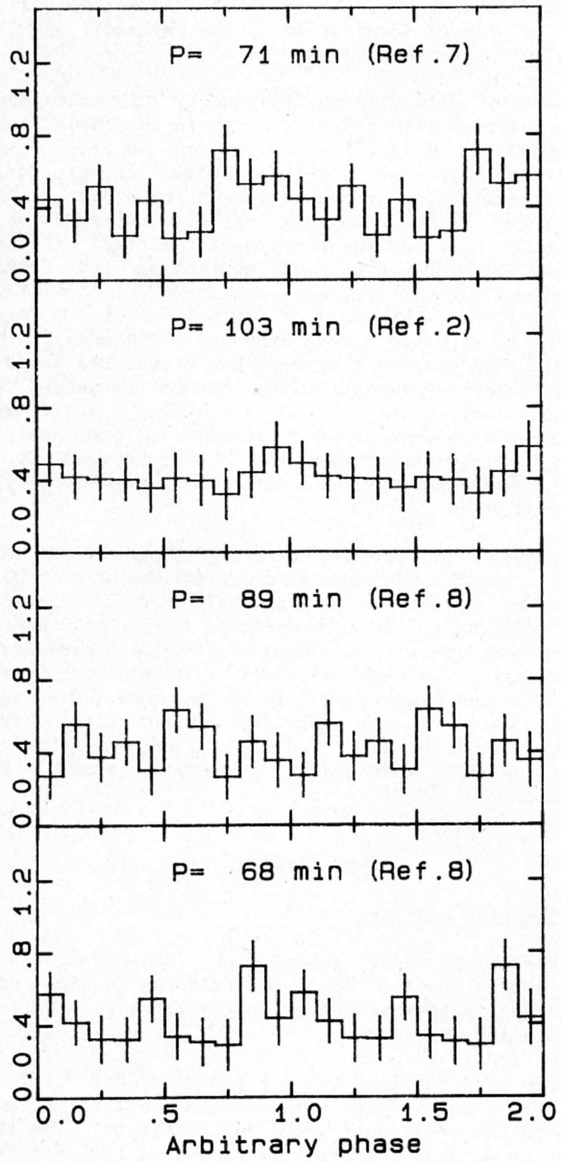

Fig.2 The light curves folded at some of the periods proposed in the literature.

periodicity with a chance probability smaller than 0.1 % (which is the value typical of background fluctuations).

We have also performed a folding analysis; a search in the range 60 to 120 min does not find any modulation. The light curves folded at the proposed periods are shown in Fig. 2, and do not contain any clear evidence of modulation.

In order to strengthen our conclusion, we have performed a simulation by Montecarlo techniques generating light curves with a similar background noise level and with a sinusoidal component of decreasing amplitude. We find that we would be able to detect the period at a significance greater than 0.999 up to an amplitude of 0.15 cts/s corresponding to a pulsed fraction greater than 30 %.

3.2 Spectral analysis

In order to perform a spectral fitting of our data, we have rebinned the ME spectrum in such a way that each energy bin contains a signal at least at the 3 σ level.

The fitting of the ME data alone, given the limited quality, is able to constrain the parameters of the fit only very poorly. However a power law (best fit and 90 % confidence limits on photon spectral index 0.9 (0.0-2.2) and $N_H < 5.5\times10^{22}$ cm^{-2}) is preferred with respect to a thermal Bremsstrahlung distribution (kT > 5.4 keV, $N_H < 7\times10^{22}$ cm^{-2})) on the ground of the better χ^2 (respectively 7.6 vs 9.4 for 7 degrees of freedom).

If we assume that a single spectral component is responsible of the emission in the soft and hard X-ray bands, we can fit the LE and ME data together (see Fig. 3 for the photon spectrum and Fig. 4 for the confidence contours on the parameters). This allows to constrain the N_H to a very small value (nominal best fit at 10^{19} cm^{-2}) and in a narrower range (< 9×10^{20} cm^{-2}), while confirming the preference of a power law model (photon index 0.8 with a χ^2 of 7.6) over a thermal model (kT < 9.8 keV, N_H between 2×10^{20} and 1.3×10^{21} cm^{-2} with a χ^2 of 10.3 with 8 degrees of freedom).

We can use our LE+ME best fit to estimate a flux at the source of 7.6 (7.1-10.0) $\times10^{-12}$ erg/cm^2/s in the 0.1-9 keV energy band (values in parenthesis are 90% confidence limits).

The distance of KO Vel is presently unknown (observations of the secondary in the IR are missing). We could use our 90% upper limit of the hydrogen column density, and the map of the local distribution of hydrogen (Ref. 14) to place an upper limit of the distance at about 150 pc (the direction towards E1013-477 crosses a quite thick region in the galactic plane).

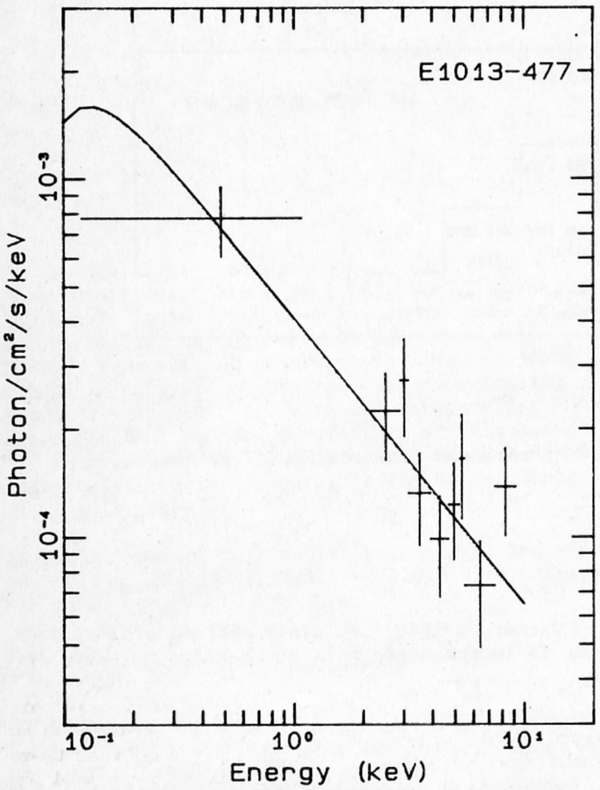

Fig.3 The photon spectrum of E1013-477 deconvolved with the best fit power law model (absorption cross sections according to Ref. 12). The first data point refers to the LE.

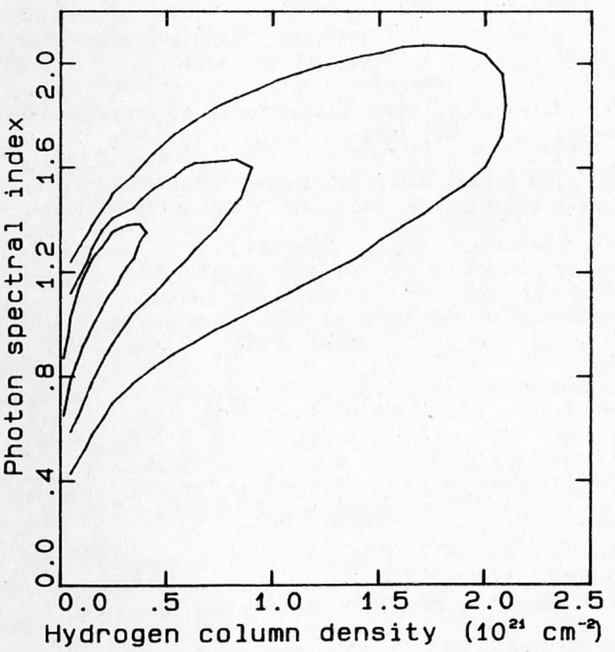

Fig.4 Confidence contours at 68, 90 and 99 % levels for the power law fit to the LE and ME data.

4. DISCUSSION

We can compare our intensity with the previous *HEAO-1* and *Einstein* observations (Ref. 2). Our data imply a flux at the Earth of 1.5×10^{-13} erg/cm^2/s in the *HEAO-1* 0.14-0.44 keV band, of 1.4×10^{-12} erg/cm^2/s in the *HEAO-1* 0.5-2.5 keV band, and of 2.8×10^{-12} erg/cm^2/s in the IPC 0.2-4 keV band.

This means that in 1983 the source was substantially fainter than in 1977 (*HEAO-1* observations), but stronger than in 1979-80 (*Einstein* observations). The existence of faint states for this source is known also in the optical (see section 1 above) and in the UV (compare the 1982 observation reported in Ref. 2 with the 1983 one reported in Ref. 3).

It is important to note that all fluxes given in Ref. 2 were computed assuming a kT ~ 1 keV, which is clearly inconsistent with our data. Little can be said about the spectrum based on the single *Einstein* IPC point. On the other hand the ratio of the count rates in the high- and low-energy *HEAO-1* bands given in Ref.2 (1.1) implies (see Fig. 7 of Ref. 13) for *whatever* value of the absorption, a spectrum *steeper* than α=1.5 (or a Bremsstrahlung temperature *lower* than 2 keV). Therefore we can conclude that the *HEAO-1* spectrum is definitely softer than ours. This softness might be due to the presence of an additional low-energy component (the blackbody component of an AM Her system ?).

The classification of E1013-477 as an AM Her object or as an intermediate polar is still uncertain.

While the observation of different orbital and rotational periods (and of their beat period, see Ref. 9) would be a clear signature of an intermediate polar, at least one of such periods should appear also in the X-rays. The present observations cannot therefore offer further support to such classification.

We have searched the *Exosat* database (Ref. 15) for the LE and ME countrates of all magnetic cataclysmic variables observed by *Exosat*. The dataset is not yet complete, as some of the observations have not yet been processed through the automatic analysis. We have retained only ME observations with a quality flag of 3 or greater (in a scale 0-5). The result is shown in Fig. 5. One can clearly see that the AM Her objects have LE/ME count rate ratios significantly larger (> 10^{-1}) than intermediate polars (< 10^{-2}), with the exception of the peculiar soft object SW UMa. The present observation of E1013-47, with a ratio of 0.01 falls into an intermediate region, close to the intermediate polar GK Per, and lower than EX Hya (the intermediate polar with the highest LE/ME ratio 0.04), than AM Her itself in the low state (0.05), and than BL Hyi (a polar in low state; 0.15).

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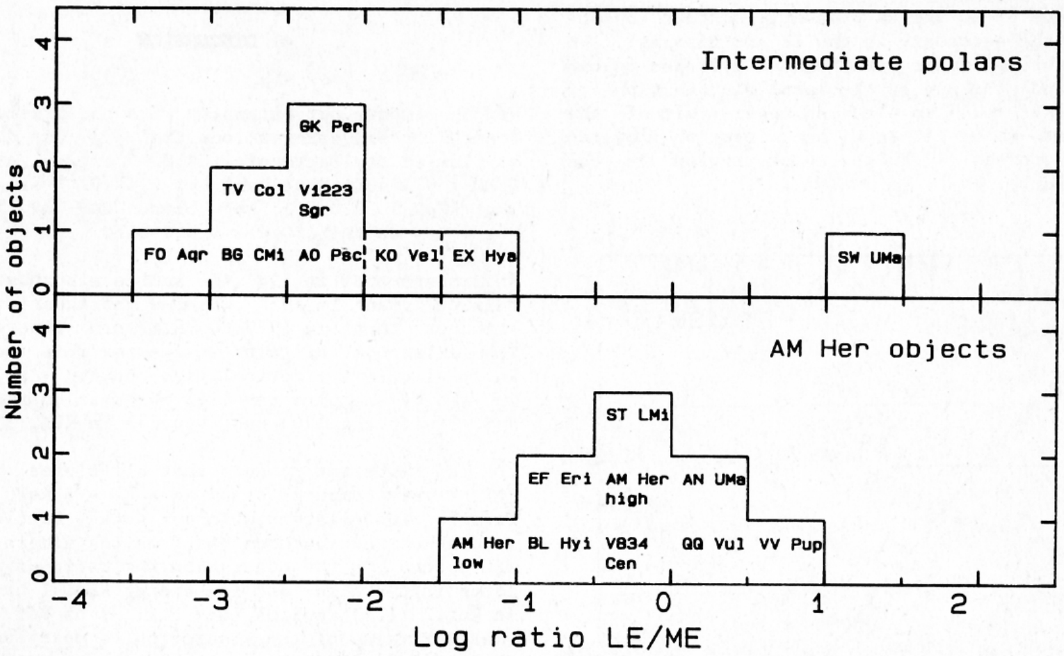

Fig. 5 The distribution of the LE/ME count rate ratio (as obtained from the EXOSAT database) for intermediate polars and AM Her objects.

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