EXOSAT OBSERVATIONS OF H2252-035: PULSE PHASE AND ORBITAL PHASE DEPENDENT LOW ENERGY ABSORPTION AND IRON LINE EMISSION

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ABSTRACT

The 805 sec pulsing X-ray source H2252-035 has been observed for 7 h on September 14/15 and on September 17, 1983 in X-rays with the low energy telescope and the medium energy detectors of EXOSAT. While below 2 keV the semiamplitude of the 805 s pulses is ~ 100% in the 2.3-7.9 keV band it is only ~ 40%. X-ray dips that are more pronounced in low energies occur simultaneously with the orbital minimum of the optical light curve.

The medium energy spectra during dips with respect to the non dip spectrum can be explained by just enhanced cold gas absorption of an additional absorbing column of 2 10^{22} cm^{-2}. Model spectra for the 805 s minimum have to include a strong iron emission line at 6.55 keV with an equivalent width of 3 keV in addition to a reduced continuum intensity (radiating area) and enhanced low energy absorption.

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1. Introduction

In visual light the intermediate polar H2252-035/AO Psc shows three periods, the orbital period (3.6 h), the white dwarf rotation (805 s), and the beat period of the two (859 s). Before EXOSAT, only 805 s pulsations have been detected in X-rays. In addition, observations with the EXOSAT medium energy experiment (ME) on September 14/15 (night 1 = NT 1) and 17 (night 2 = NT 2), 1983 showed evidence for absorption dips that occurred simultaneously with the minimum of the orbital light curve in optical photometry. See Pietsch et al., 1985 (paper 1) for references on optical and X-ray observations and the simultaneous photometry and EXOSAT results.

While in X-rays the 805 s pulsations stayed in phase, simultaneous optical photometry showed a phase shift by about 180° between the two nights. During NT 2 the 805 s optical pulsations were in **antiphase** with the 859 s pulsations near orbital maximum and in antiphase with the 805 s X-ray pulsations. This is the "normal" behaviour of the source (Motch and Pakull, 1981; van der Woerd et al. 1984), during which reprocessed light from the inner parts of the accretion disk dominates the optical 805 s modulation. The phasing was wrongly stated in paper 1 and this led to some confusion (Warner 1986).

In this paper we report on the low energy X-ray 805 s and orbital light curve observed with the low energy telescope (LE) aboard EXOSAT during NT 1 and NT 2 and on phase dependent ME spectra during NT 1.

2. Observations

The LE observations were carried out with telescope 2 of EXOSAT using the channel multiplier array as focal plane detector (de Korte et al., 1981).

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The 3000 Å thick lexan filter (3000 Lx) was exchanged by the aluminium/parlene filter (Al/P) at 1h10m UT on September 15 and 7h55m UT on September 17, 1983. In NT 1 the average intensity of the source with the 3000 Lx and Al/P is the same within the errors. Since the transmission curves of the two filters strongly differ below 0.28 keV the dominant part of the observed flux has to originate above this energy. The ME spetrum of NT 1 (see below) supports this interpretation, showing a low energy cut off due to cold gas absorption ($N_H \sim 10^{22}$ cm^{-2}). During NT 2 the 3000 Lx rate increased and was about double the rate measured later with Al/P. If one assumes that the source spectrum and intensity did not change during NT 2 this would indicate a higher source intensity below 0.28 keV with respect to NT 1. The behaviour however may also just resemble source variability. Since 3000 Lx and Al/P in first approximation show the same rates and the flux seems to come from the same energy region, to improve the pure statistics we folded the data of the two filters together for the individual nights.

Details of the ME observations have been given in paper 1. ME count rates cover the energy range 2.3 - 7.9 keV and are given in counts per sec and half experiment, ME hardness ratio is defined as the count rate in the 4.7 - 7.9 keV band devided by the count rate in the 2.3 - 4.7 keV band. To improve statistics of folded data, source measurements of experiment half 1 and 2 have been added together. All times have been converted to solar system baricenter and for folding, epoch of September 15, 1983 0h baricenter corrected UT (BUT) was used.

Background corrected count rates of H2252-035 for the LE and the aligned experiment halfs of the ME have been plotted for NT 1 and 2 in fig. 1. Both observations cover about two orbital cycles. While in ME the source count rate is high enough to resolve individual 805 s pulses (120 s integration

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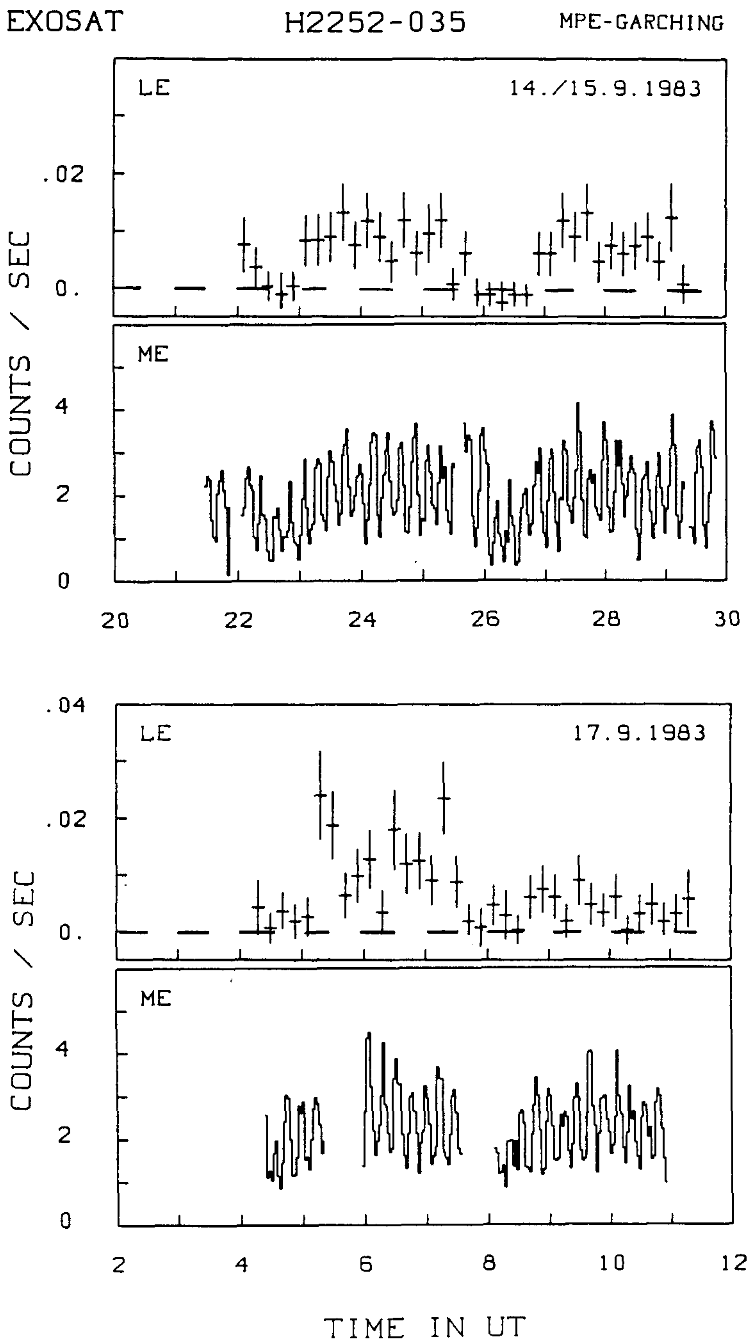

Figure 1: LE (< 2 keV) and ME (2.3-7.9 keV) count rates versus baricenter corrected UT for NT 1 and 2

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time per bin) in LE, due to the lower count rate, only variability on longer time scales can be seen (12 min integration time per bin). At the times of the orbital minima in the ME during NT 1 around 22h40m and 26h15m BUT extended dips of up to 1 h duration are clearly visible in the LE. Similar dips occur during NT 2 around 4h30m and 8h10m BUT. They are however masked by gaps in the ME plot that are caused by data reduction problems due to increased background and by time variability evident during the 3000 Lx observations as well as by the lower Al/P count rate.

3. 805 s pulsation

ME and LE count rates and the ME hardness ratio have been folded modulo the 805 s period for NT 1 and 2 (fig.2). The ME pulse semiamplitude is about 40 %; the higher hardness ratio around the minimum of the pulse indicates a higher semiamplitude at lower energies. The shape of the pulse is sinusoidal with an indication of a flat top. The flat top may be explained, if for part of the pulse, all of the emitting region is visible (King and Shaviv, 1984). The pulse shapes are similar in both nights and minima and maxima occur at the same phase. For the LE the pulse semiamplitude is about 100% and the pulses are in phase with the ME. Similar semiamplitudes of the low energy pulses of the source have been reported by Patterson and Garcia (1980).

For NT 1 we generated ME spectra for the 805 s pulse maximum (phase 0.675 to 1.025) and minimum (phase 0.150 to 0.500) excluding the time of orbital dips (phase definition see below). Table 1 gives parameters fitting power law and thermal Bremsstrahlung models to the spectra. Both models give acceptable fits for the pulse maximum with similar parameters as given by White and Marshall (1981) for the average spectrum of the source. For the

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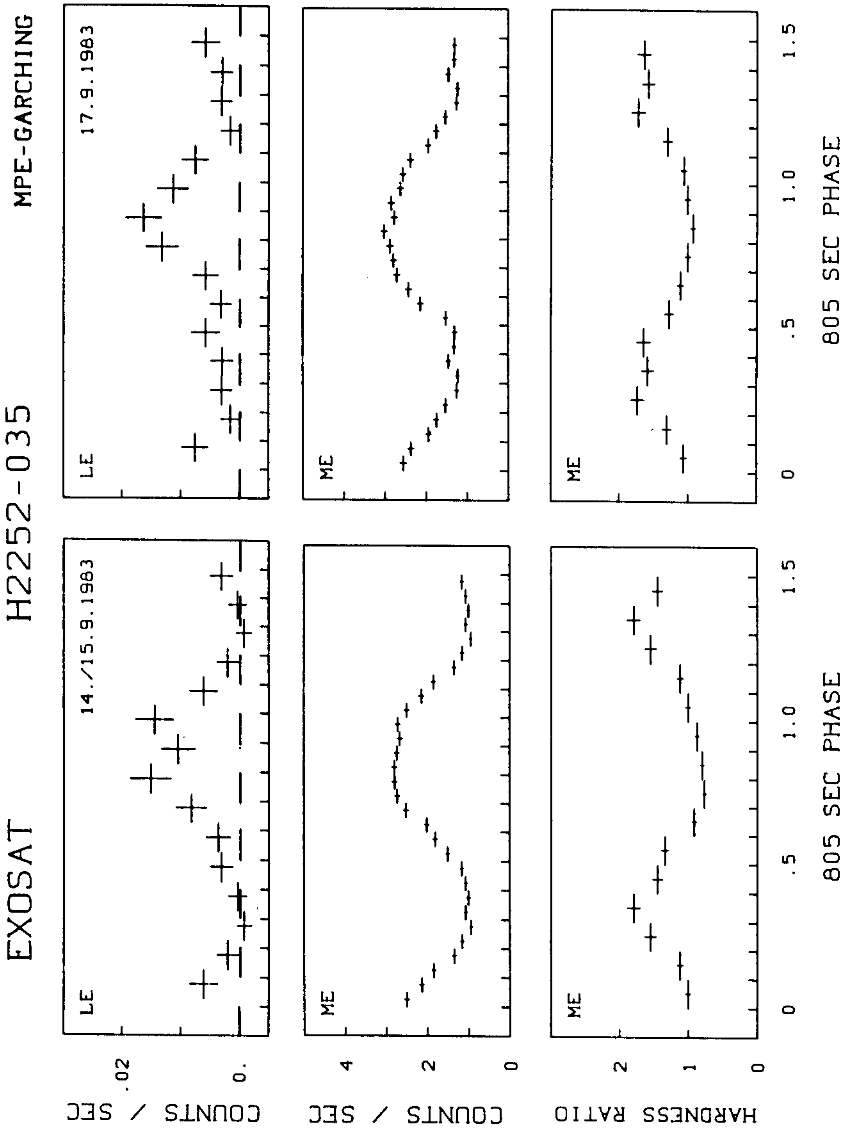

Figure 2: 805 s light curves for NT 1 and 2 of LE (< 2 keV) and ME (2.3–7.9 keV) and ME hardness ratio ((4.7–7.9 keV)/(2.3–4.7 keV))

Table 1: ME Spectral fit parameters for H2252-035 September 14/15, 1983

Orbit		Maximum		Dip
805 s		Maximum	Minimum	Maximum
Photon Power Law				
Normalisation	1)	1.4 ± 0.1	0.56 ± 0.10	1.3 ± 0.2
Photon Index		$1.5 ^{+0.2}_{-0.1}$	0.6 ± 0.35	1.6 ± 0.3
N_H	2)	$15 ^{+6}_{-3}$	26 ± 9	41 ± 12
χ^2_r		0.89	1.48	1.03
Thermal Bremsstrahlung				
Normalisation	1)	1.4 ± 0.1	$0.75 ^{+0.08}_{-0.05}$	1.3 ± 0.2
kT (keV)	3)	> 24	> 80	> 14
N_H	2)	14 ± 4	$52 ^{+23}_{-7}$	$39 ^{+14}_{-11}$
χ^2_r		0.89	3.45	1.03
Thermal Bremsstrahlung and Iron Emission Line				
Normalisation	1)	1.41 ± 0.07	0.56 ± 0.09	1.25 ± 0.13
kT (keV)	5)	24	24	24
N_H	2)	14.8 ± 2.6	41 ± 13	$36 ^{+9}_{-8}$
Line				
- Normalis.	4)	2.5 ± 1.8	7.2 ± 2.0	$2.3 ^{+3.0}_{-2.3}$
- Energy (keV)	5)	6.55	6.55	6.55
- FWHM (keV)	5)	2.0	2.0	2.0
χ^2_r		0.71	0.71	0.94

1) Normalisation factor at 4 keV in units of 10^{-3} cm^{-2} sec^{-1} keV^{-1}

2) N_H in units of 10^{21} cm^{-2}

3) 2 σ limits

4) Line normalisation factor in units of 10^{-4} cm^{-2} sec^{-1}

5) Parameter has not been fitted

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pulse minimum however the simple models did not give acceptable fits and the inclusion of an iron emission line was needed. To compare the spectra we fitted a thermal Bremsstrahlung model with constant kT of 24 keV and an iron line at 6.55 keV with FWHM of 2 keV. The fit parameters are given in table 1 and the deconvoluted spectra in fig. 4.

The spectrum of the pulse maximum needs an N_H of 1.5 10^{22} cm^{-2} and an iron emission line with an equivalent width of (0.4 ± 0.35) keV (2 σ error).

The pulse minimum spectrum shows

(i) a reduced thermal Bremsstrahlung normalisation by a factor of 2.5,

(ii) enhanced low energy absorption (additional 2.6 10^{22} cm^{-2}),

(iii) strong iron line emission (EW (3.0 ± 1.0) keV, 2 σ error).

(i) can be explained by a partial obscuration of the X-ray emitting polar region (King and Shaviv, 1984) and (ii) possibly by the changed direction of the line of sight to this region.

4. Orbital light curve

LE and ME count rates and ME hardness ratio for NT 1 and 2 have been folded into 16 phase bins (1 bin approximately one pulse period) about the orbital period (fig.3). As has been stated in paper 1 in ME a dip occurs simultaneously with the minimum of the orbital light curve seen in optical photometry. During NT 2 one data point (around phase 0.53) has uncomplete pulse coverage and therefore shows lower count rate and high hardness ratio. During the dip the average count rate is reduced by ~ 40% and the hardness increase indicates that the dip is due to an absorption effect. In LE the dip is more extended in phase (~ 0.3 duration) and the source seems to be totally obscured.

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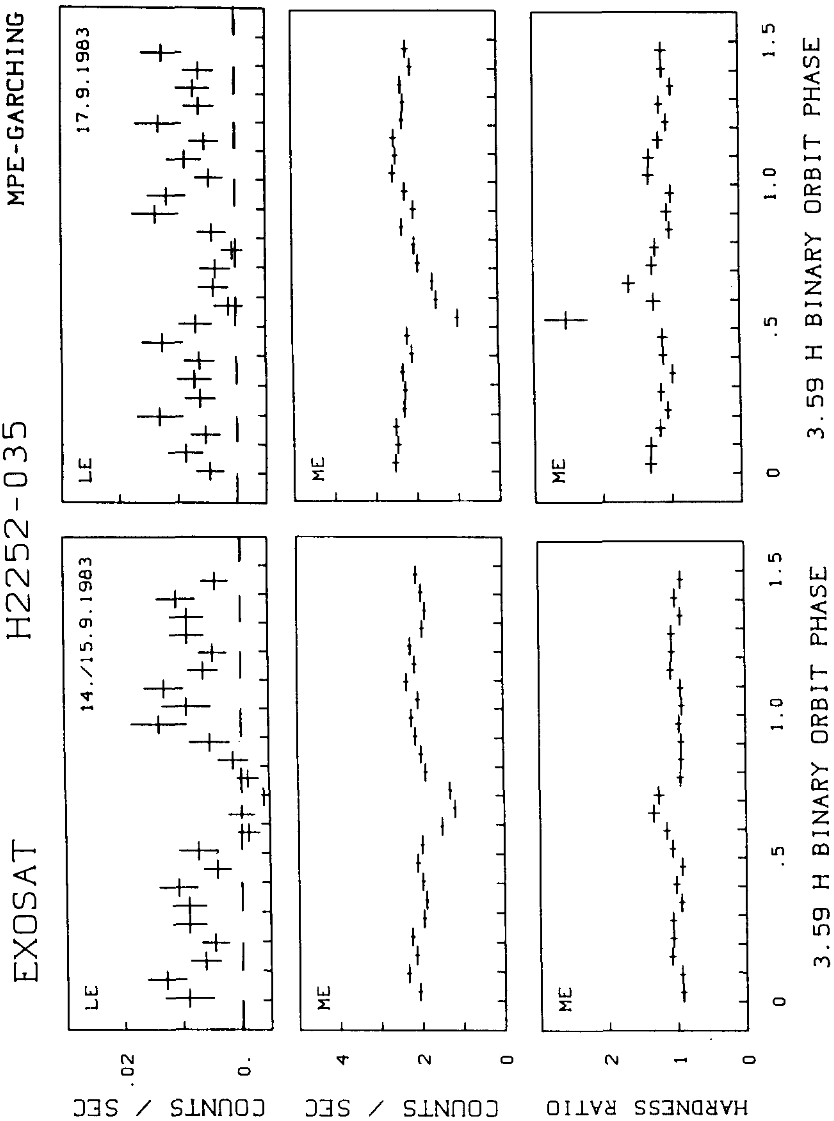

Figure 3: orbital light curves for NT 1 and 2 of LE (< 2 keV) and ME (2.3-7.9 keV) and ME hardness ratio ((4.7-7.9 keV)/(2.3-4.7 keV))

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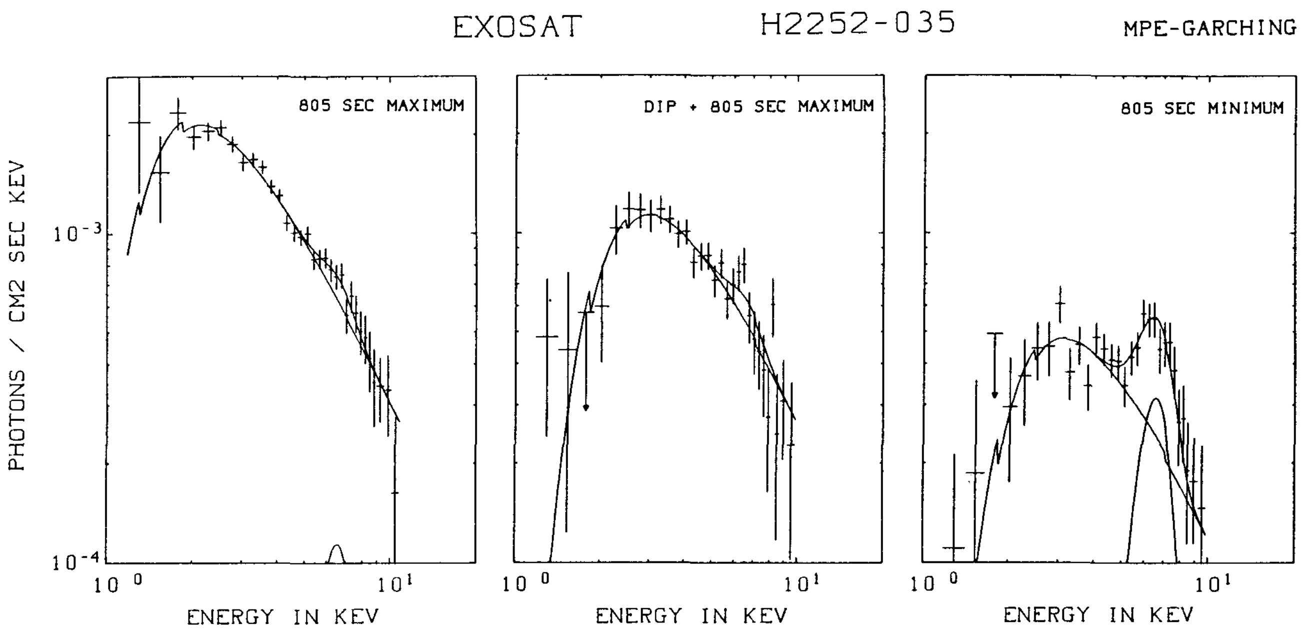

Figure 4: ME spectra for NT 1 using different phase regions of the orbital and 805 s period. The spectra have been deconvoluted assuming 24 keV thermal Bremsstrahlung spectra of variable intensity plus a 6.55 keV emission line (FWHM 2 keV) of variable strength and a variable hydrogen absorption column.

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An ME spectrum of the dip (phase 0.55 to 0.85) for NT 1 using only 805 s pulse maximum data (phase definition see above) was well fitted using the model spectra discussed above (tab.1, fig. 4). If one compares the thermal Bremsstrahlung plus iron emission line fit parameters found for non dip and dip spectrum of the pulse maximum the only significant change is enhanced low energy absorption (additional 2 10^{22} cm^{-2}). This means that the dip has to be caused by obscuration of the X-ray emitting region (the white dwarf) by cold gas. Since observations of similar sensitivity with the HEAO A2 experiment 1978 (White and Marshall, 1981) did not see orbital dips, the strength of the dips must be time variable. The absorbing gas may be located at the bright spot where the mass transfer stream impacts the disk edge and variability in this region is expected due to variations of the accretion rate. X-ray dips with changing intensity have also been observed in low mass X-ray binaries which are believed to have a lot of similarities to cataclysmic variables and where the compact object in the system is a neutron star instead of a white dwarf.

5. Conclusions

Our EXOSAT observations of H2252-035 show similar 805 s pulse shapes in ME and LE as the HEAO A2 and A3 experiments (White and Marshall, 1981; Patterson and Garcia, 1980). A model, that solely uses the occultation of the X-ray emission region by the body of the white dwarf during its rotation (King and Shaviv, 1984), explains most of the observed phenomena of the 805 s X-ray pulses. A flat top occurs in the average pulse profile because for this part of the pulse the whole X-ray emitting region is visible. The ME pulse amplitude and spectra of pulse maximum and minimum indicate that ~ 60% of the emitting region are occulted during pulse mini-

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mum. The enhanced low energy absorption during pulse minimum may be caused by the changing viewing angle to the emission region. The origin of the strong iron line, that is observed during pulse minimum, however remains unclear.

For the first time we observed orbital dips of the source that vary in intensity because HEAO A2 with similar sensitivity did not detect them. The dips can be explained by cold gas absorption that may have its origin where the mass transfer stream impacts the disk edge.

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