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EXOSAT X-RAY LIGHT CURVES OF SS ARI[1]

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ABSTRACT

We construct the X-ray light curves of the W UMa type contact binary SS Arietis (HD12929) from the EXOSAT data in HEASARC data archive. The phase dependent X-ray light curves obtained by using the ephimeris of Kaluzny & Pojmanski (1984) have been presented. The resulting X-ray light curves show that the X-ray radiation of SS Ari is modulated on the orbital phase as in the case of other W UMa type binaries. Although a detailed analysis of these data is impossible because of the very low count rate of this star in the X-ray region, we try to find the physical explanation of the X-ray light curves in the context of the radiation in the corona region of W UMa type stars.

1. INTRODUCTION

X-rays from W UMa type systems provide important information about the high coronal activity of contact binaries. After the first detection of X-ray emission of a contact binary by HEAO 1 satellite (Carroll *et al.* 1980), many observations have been carried out by numerous X-ray satellites such as EINSTEIN, EXOSAT, ROSAT, ASCA, and GINGA, and it is now recognized that W UMa type star are suitable for the studies of the X-ray emission in the corona of the late type stars. Phase dependent studies of contact binaries with the EINSTEIN satellite (Cruddace & Duppree 1984) revealed complex coronal structures, and it was suggested that X-ray flux of W UMa systems comes from the chromosphere and corona of cooler companions. Vilhu & Heise (1986) observed contact binaries by using EXOSAT and found that X-ray emission could also come out from regions other than corona and chromosphere.

Photometry of SS Arietis, which is one of the W UMa-type eclipsing binary systems, provides much interesting information about the physics of mass accretion. Especially, X-ray photometry gives clues to the coronal structure of the contact binaries in the X-ray emission region. Therefore such systems have been observed by several X-ray satellites.

In this paper, we study the X-rays from SS Ari for the better understanding of X-ray emitting plasma in W UMa systems by analyzing unpublished EXOSAT X-ray data. Although the mean

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orbital period is 0.40599008 day, the period seems to be suffering from a sinusoidal variation (Kim *et al.* 1997). The spectral type of this star is reported as G0V (Kim *et al.* 1997) or K2III (Mullan & Stencel 1982). Previous works (Vilhu & Heise 1986) suggested characteristic features of the EXOSAT X-ray data for some W UMa type stars. We want at first to confirm the reported tendency of X-ray modulation reported by Vilhu & Heise (1986). We also analyze the X-ray data of SS Ari observed by other X-ray satellites for the better interpretation of the X-ray emission region of W UMa type binaries. Results of this study will be published elsewhere.

2. EXOSAT OBSERVATIONS

EXOSAT observed SS Ari on 1984 Aug. 19 21:57:58 for 13 hours, and the observational data can be retrieved from the High Energy Astrophysics Archive Research Center (HEASARC) of NASA. The observation fully covered the orbital period of this binary. The EXOSAT satellite equipped two low energy imaging telescope (LE), two medium energy proportional counter (ME), one grating scintillation proportonal counter (GSPC) and one transmission grating spectrometer (TGS) were on board, and carried out observation from May 1983 to Apr. 1986. For ME region, an argon proportional counter and a xenon proportional counter have been used for 1 - 20 keV and 5 - 50 keV respectively, while for low energy (LE) region position sensitive detector and channel multipler array have been used for 0.3 - 2 keV and 0.04 - 2 keV respectively.

Note that no previous ME and LE X-ray data of SS Ari have been published. We collected X-ray data in 0.8 - 3.6 keV and 3.6 - 8.9 keV and in 0.04 - 2.0 keV for X-ray light curves in 1 - 15 keV. The collected data from HEASARC are all background substracted.

3. DATA ANALYSIS

For the reduction of the collected data, the X-ray data analysis program packages, XRONOS and XSPEC, have been used. Since the collected X-ray data have already been substracted from the background radiation, we could directly use these data for the analysis. We construct X-ray light curves in 0.04 - 2.0 keV and 0.8 - 3.6 keV and 3.6 - 8.9 keV region. We then fit the X-ray spectrum by various models such as power law, black body, bremsstrahlung and gaussian model by using XSPEC, to obtain the possible X-ray plasma parameters. However, the observed count rate is too low to fit any significant model to this data. We failed to get any results from the spectral data.

In order to see any phase dependent features in X-ray energy region, we construct the X-ray light curve with the high integration time (274 seconds). From the resulting light curves we find a signifant variation of X-ray with time. Therefore, we perform the phase study by using epoch folding method of XRONOS package. The epoch and ephimeris have been adopted from Kaluzny & Pojmanski (1984). The folded X-ray light curves present the phase-dependent X-ray flux behaviour. In Figure 1 the phase dependent X-ray light curves of SS Ari are presented. In the following discussion, we use the phase dependent X-ray light curve in this X-ray region. Note that although one loses information of X-ray data if the integration time increase, we adopt the higher integration time because we want to see the tendency of the phase dependency of light curves.

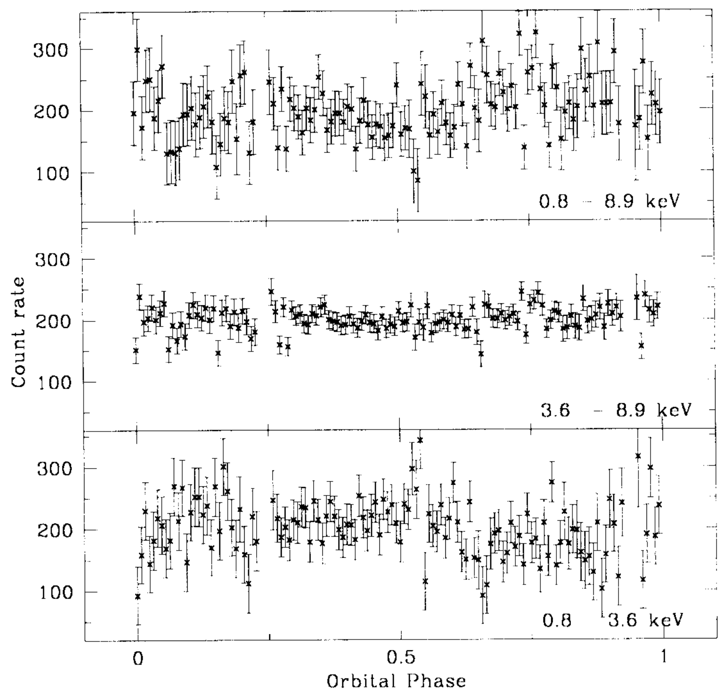

Figure 1. Phase dependent X-ray light curves of SS Ari. The upperest pannel is for 0.8 - 3.6 keV, the middle pannel is for 3.6 - 8.9, and the lowest pannel is for 0.8 - 8.9 keV. An arbitary unit of the count rate has been adopted in order to compare the modulation of the X-ray radiation.

4. DISCUSSION

Combined X-ray light curves shown in Figure 1 cover the full orbital phase. Vilhu & Heise (1986) pointed out that the X-ray light curve depends both on the orbital phase and the X-ray energy. They also suggested that there are many components for X-ray emission regions in the corona. They found that X-ray maxima occur at phases around 0.2 and 0.8, while broad X-ray maxima occur at phase around 0.5, and dips near 0.5. In our light curve in 0.04 - 2.0 keV of SS Ari we could not find these features. The light curve in this energy region has flare-like phenomenon, which has to be clarified in our future work (Kim & Choi 1998).

In the corona model of Cruddace & Duppree (1984), X-ray is expected to be radiated mainly from the vicinity (chromosphere and corona) of the cool star. At phase 0.0, the cooler star faces to the observer, and thus the main X-ray region is observed near this phase. Therefore, the main X-ray maxima at phases around 0.2 and 0.8 come from this corona model. Vilhu & Heise (1986) suggested also that an extra X-ray source exists near the Lagrangian point(L1). During the partial eclipse of this extra X-ray source, we observe a gradual increase and decrease of X-ray radiation near the phase 0.5. However, if this source is totally eclipsed by the atmosphere of the hotter star, one would observe a dip at this phase.

The X-ray light curves also cover the full orbital period. It is clear from Figure 1 that the X-ray light curve is more modulated in lower energy region than in higher energy region. This phenomenon is similar to the case of cataclysmic variables (Kim & Beuermann 1995), leading to an assumption that this modulation is caused by X-ray photoabsorption.

5. CONCLUDING REMARKS

We have investigated the unpublished X-ray data of SS Ari observed by EXOSAT. Our results confirm the coronal model suggested by Cruddace & Duppree (1984) and marginally the existance of another X-ray emission region near L1. The light curves can be considered more detail in further works in order to understand the X-rays of contact binaries in this X-ray region. It is also in progress to collect the X-ray data from other X-ray satellites such as GINGA, ROSAT, ASCA. Details of the study for the X-ray data from these satellites will be reported elsewhere.

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