XMM-Newton Observations of the Super Soft Source CAL87

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Abstract

CAL87 is a Super Soft X-ray Source discovered in the Large Magellanic Cloud by the Einstein Observatory (Long et al. 1981). It is an eclipsing white-dwarf binary system with a period of about 10.6 hours (Alcock et al. 1997). Its soft X-ray spectrum with a moderately high spectral resolution was observed with the ASCA satellite. The analysis of the light curve obtained by ASCA suggests that CAL87 has an ionized corona, making it an Accretion Disc Corona (ADC) source (Ebisawa et al. 2001).

We observed CAL87 (exposure time 79 ksec) with the XMM-Newton satellite on April 18th, 2003. We obtained a RGS spectrum (R=100-500) and have identified many emission lines from O, N, and Fe, which were not evident in the ASCA observation. It is likely that the line emission arises from the thin plasma of the ADC. This is corroborated by high-S/N light curves obtained by EPIC exhibiting a broadened dip which is characteristic for ADC sources. The X-ray eclipse is time-shifted from the optical one by about 0.022 orbital phases. We present the results of a spectral analysis with an ADC model based on the XMM-Newton observation.

1. Introduction

CAL87 is an eclipsing white-dwarf binary, and Figure 1 shows a model of the system. Mass accretion from the companion star fuels hydrogen burning on the white dwarf surface. The spectrum is very soft, with almost all photons below 2 keV. Therefore, it is called "Super Soft X-ray Source".

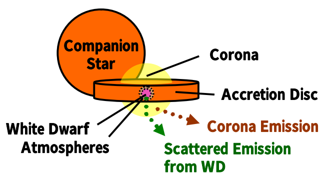

Fig.1. CAL87 model

2. Observation

Table 1. CAL87 observation log.

Project	Obs.ID	Obs. Date	Duration (s)
ASCA	44012000	1996-09-06	183407
Chandra	1896	2001-08-13	97760
XMM-Newton	153250101	2003-04-18	78614

3. Analysis and Results

3-1. Light Curve

Figure 3 is a EPIC background-subtracted light curve with regions shown in Figure 2. A source region is the circle of a radius of ~1.2 arcmin, which is determined to have the best signal-to-noise ratio. We used the orbital ephemeris reported by Alcock et al. (1997). The lower two panels show the visible light curve from Alcock et al. (1997). It has a broadened and shallow dip which is characteristic of ADC sources. The eclipse is time-shifted from the optical one by about 0.022 orbital phases.

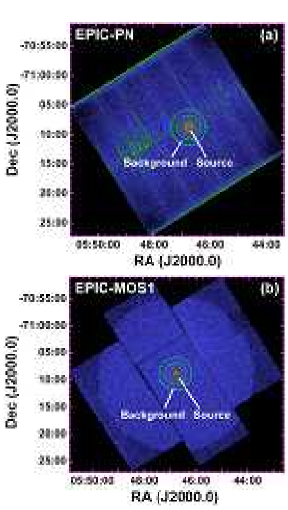

Fig.2. X-ray image of (a) EPIC-PN and (b) EPIC-MOS1. Solid circle is source region and the annulus region enclosed by dashed circles is background region.

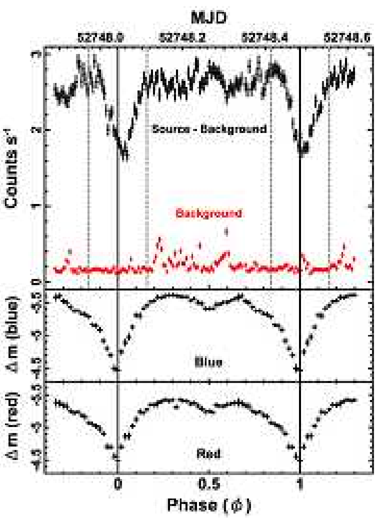

Fig.3. X-ray (This work) and Visible light curve (Alcock et al. 1997). The orbital ephemeris is referred from Alcock et al. (1997).

3-2. Spectrum Analysis

The X-ray spectrum with CCD cameras (ASCA/SIS, XMM/EPIC) and grating spectrometers (XMM/RGS) are shown in Figure 4 and Figure 5. It was thought that the CAL87 spectra could be simulated by a blackbody radiation confirming the ASCA result. However, RGS spectrum revealed the existence of many emission and absorption lines. It is likely that the line emissions arise from the thin plasma of the ADC.

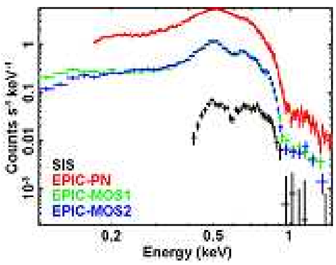

Fig.4. X-ray spectrum with CCD Cameras. (black; ASCA/SIS, red; XMM/EPIC-PN, green; XMM/EPIC-MOS1, blue; XMM/EPIC-MOS2)

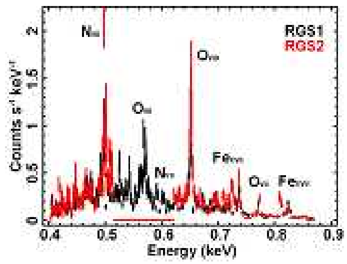

Fig.5. X-ray spectrum with Grating Spectrometer. (black; XMM/RGS1, red; XMM/RGS2)

We have identified some notable emission lines from O, N, and Fe (table 2), and fitted the spectrum with a thin thermal plasma model (VMEKAL). The fitting trials were conducted simultaneously for the set of RGSs and EPIC spectrum (Figure 6). The spectrum is fitted by thermal emission with a temperature of ~0.2 keV. We could not obtain an acceptable fit with the model. More detailed models are required.

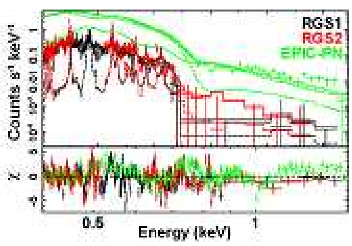

Fig.6. RGS and EPIC spectra with the compound of a blackbody and a thin thermal plasma model.

Table 2. Line emission.

Energy (eV)	Error (eV)	LineID	Eq. Width (eV)
423.7	11.5	N_{VI} ?	2.0
447.8	1.4	?	2.4
465.1	0.8	C_{VI} ?	3.4
471.1	4.7	C_{VI} ?	1.5
494.5	1.0	?	2.5
498.5	0.3	N_{VII}	8.6
501.3	0.5	N_{VII}	4.7
510.1	1.0	?	2.8
533.1	1.4	?	2.9
538.7	0.8	?	11.4
542.6	0.7	?	10.3
562.8	0.8	O_{VII}	9.2
567.5	0.5	O_{VII}	9.8
571.6	0.3	O_{VII}	15.8
592.7	2.0	N_{VII}	4.8
630.1	8.3	?	1.6
651.9	0.2	O_{VIII}	31.0
725.5	0.8	Fe_{XVII}	13.2
737.7	0.6	Fe_{XVII}	14.3
771.9	0.6	O_{VII}	37.2
810.2	0.8	Fe_{XVII}	44.2
822.7	0.8	Fe_{XVII}	29.6

4. Summary

- An X-ray eclipse of CAL87 is time-shifted from the optical eclipse by about 0.022 orbital phases.
- We have identified some emission lines from O, N, and Fe.
- CAL87 has a corona with a temperature of about 0.2 keV.

References

Long, K.S., et al. 1981, ApJ, 248, 925
Alcock, C., et al. 1997, MNRAS, 287, 699
Ebisawa, K., et al. 2001, ApJ, 550, 1007