X-RAY ACTIVITY CYCLES IN STELLAR CORONAE

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ABSTRACT

We present first results from the XMM-Newton monitoring program of solar-like stars; here we report on the binary systems α Cen A/B and 61 Cyg A/B. During the last years both targets were observed in snapshot like exposures separated roughly by half a year each. We are able to resolve both stellar systems and to determine the X-ray luminosities and respective emission measure distributions of the individual components. We also investigate physical changes in the coronae during variability and activity cycles. An X-ray darkening of α Cen A is observed during this program for the first time, probably indicating a coronal cycle. 61 Cyg A exhibits a continuation of its cyclic activity as discovered with ROSAT in the 1990s, making it the first persistent coronal activity cycle observed on a star other than the Sun.

Key words: X-rays, stars, coronae, activity.

1. MONITORING THE TARGETS

α Cen is the nearest stellar system at a distance of 1.3 pc and we present six XMM-Newton observations of roughly two hours each, taken between 2003 – 2005. In all our observations the X-ray emission of the system is dominated by α Cen B, a K1V star. We investigate long-term variability and possible activity cycles of both stars and find the optically brighter component α Cen A, a G2V star very similar to our Sun, to have fainted in X-rays by at least an order of magnitude during the observation program. This behaviour was never observed before on α Cen A, but is rather similar to the X-ray behaviour observed with XMM-Newton on HD 81809 (Favata et al., 2004). Earlier spatially resolved observations of α Cen performed with *Einstein*, ROSAT and *Chandra* over the last 25 years always revealed a situation comparable to the beginning of our campaign in March 2003. We find that a coronal activity cycle with a duration of $\sim$ 3.4 years matches all observations, but an irregular event cannot be ruled out due to the absence of long-term chromospheric activity data.

61 Cyg, a K5V (A) and a K7V (B) star at a distance of 3.5 pc, was observed with XMM-Newton during the years 2002 – 2005 and we obtained seven exposures with durations about two to four hours. We find a continuation of the coronal activity cycle on 61 Cyg A, which was discovered with ROSAT in the 1990s and found to be tightly correlated with the chromospheric activity as measured in CaII H+K (Hempelmann et al., 2003). 61 Cyg A is the first example of a persistent coronal cycle observed on a star other than the Sun. The component 61 Cyg B exhibits a more chaotic behaviour and a cycle can be identified only as long-term trend. Results derived from the ROSAT monitoring are included to extend the time-base of the X-ray measurements.

2. DATA ANALYSIS

The data were reduced with the standard XMM-Newton Science Analysis System (SAS) software, version 6.0. Images, light curves and spectra were produced with standard SAS tools and standard selection criteria were applied for filtering the data. Spectral analysis was carried out with XSPEC V11.3.

The derived light curves of the program stars show variability on short timescales; flaring was observed on α Cen B, 61 Cyg A and strongest on 61 Cyg B. To investigate possible coronal activity cycles, only data from quasi-quiescent phases are considered, i.e., time periods free of strong activity or flares. To determine the X-ray brightness of our program stars, we use for α Cen a PSF (Point Spread Function) fitting algorithm which is applied to the event distribution in the sky-plane, while 61 Cyg is well resolved in the EPIC images which allows us to use individual extraction regions. X-ray luminosities are determined from spectral analysis, which uses multi-temperature APEC models and is performed in the energy range 0.2–5.0 keV, however, sufficient signal in quasi-quiescence is mostly present only up to 2.0 keV. Spectral analysis is performed for the α Cen system as a whole, but individual fits of spectra taken from small extraction regions around the respective component lead to comparable results for both components. Moreover, the determined X-ray luminosities L_X are nearly independent of the modelling details.

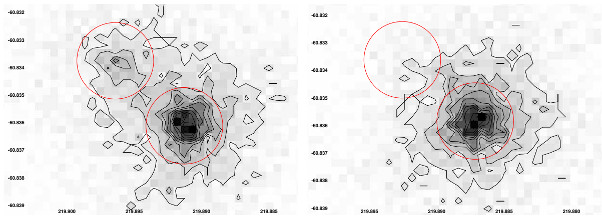

Figure 1. The α Cen system during March 2003 (left) and February 2005 (right); contours and 5″regions for the two components overlayed. Image creation is identical and the counts per image are comparable. The darkening of α Cen A at the upper left is striking and observed with XMM-Newton for the first time.

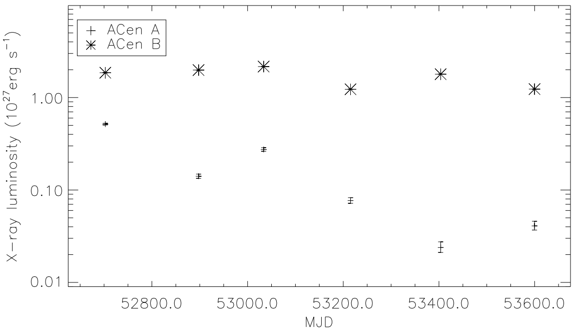

Figure 2. X-ray luminosity in the 0.2 – 2.0 keV band for α Cen A and B as determined from MOS1 data using PSF fitting algorithm and spectral modelling. Plotted errors are Poissonian derived from the PSF fitting.

3. ALPHA CENTAURI – THE DARKENING OF THE SOLAR TWIN

In Fig.1 we show two images of the system taken with the MOS1 detector during the March 2003 and the Feb. 2005 exposure. While the X-ray luminosity α Cen B is constant within a factor of two, a significant change, i.e. a strong dimming, is observed for α Cen A. To quantify these changes we determine the brightness of each component with a PSF fitting algorithm and subsequently its X-ray luminosity via spectral modelling.

In Fig. 2 we show the long-term light curve of α Cen A and B. The derived X-ray luminosities L_X (in 10^{27} erg/s) are given in Table 1 for the individual exposures. Spectral analysis shows both stars to have a rather cool (1.5 – 3 MK) and inactive corona with α Cen B being slightly hotter. The observed darkening of α Cen A is mainly due to a strong decrease in emission measure, comparable to the behaviour of the Sun as observed with Yohkoh (Acton, 1996). Comprehensive results including the data up to Feb. 2005 are published by Robrade et al. (2005).

Table 1. Derived X-ray luminosity for α Cen A/B.

Obs.	Mar. 03	Sept. 03	Jan. 04	July 04	Feb. 05	Aug. 05
L_X (A)	0.52	0.14	0.27	0.08	0.02	0.04
L_X (B)	1.86	1.98	2.16	1.22	1.79	1.23

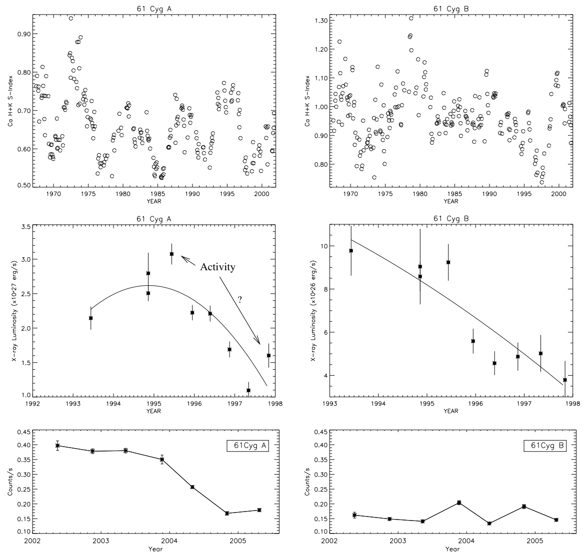

Figure 3. Long-term chromospheric activity up to 2001 (top) and ROSAT measurements (middle, from Hempelmann et al. (2003)) as well as preliminary results from the XMM-Newton program (bottom), here PN measurements (Robrade et al., in preparation) for 61 Cyg A (left column) and 61 Cyg B (right).

4. 61 CYGNI – THE PERSISTENT CORONAL CYCLE

In Fig. 3 we show that 61 Cyg A exhibits a very regular chromospheric activity cycle with a period of 7.3 years and a nearly symmetric rise and decay phase. Our X-ray measurements are well correlated and in phase with the previously observed cyclic activity as well as the ROSAT observations in the 1990s. In contrast, the chromospheric cycle of 61 Cyg B (11.7 yr) is more irregular, not symmetric and its activity index has a higher mean value. This is also reflected in its coronal behaviour. Although darker in X-rays, the corona is more active in the sense that flaring occurs more often and with larger amplitudes than on 61 Cyg A. Our X-ray light curve is rather constant and correlated variations are not detected over the three years. However, also in the ROSAT light curve as well as in chromospheric data, phases of rather constant activity are observed.

ACKNOWLEDGMENTS

J.R. acknowledges support from DLR under 50OR0105.

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