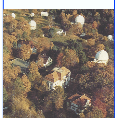
Coronae of Stars and Accretion Discs

Hamburger Sternwarte



Magnetic field variations and a giant flare

Multiwavelength observations of the active M dwarf CN Leo

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Abstract

The M5.5 dwarf CN Leo has been observed simultaneously with *XMM-Newton* and VLT/UVES on three nights in May 2006. Nightly variations of its magnetic field are deduced from FeH lines in the UVES spectra. A giant flare occurred at 23:47 UT on 19 May and is covered in total by all instruments. Photometry in high time resolution is provided by *XMM*'s EPIC instruments in X-rays, in the U band by the Optical Monitor, and by the UVES blue and red exposuremeters. Time-resolved spectroscopy in X-rays demonstrates the development of temperature and emission measure of the coronal flaring plasma. Coronal densities $\log n_e > 12$ are derived during the flare from the O VII triplet. The UVES spectra simultaneously trace the behaviour of chromospheric and transition region plasmas. Large increases in the fluxes of chromospheric emission lines are accompanied by a strong enhancement of the continuum level. The Balmer lines show strong broadening and lines of the hydrogen Paschen series are observed in emission during the flare.

Observations

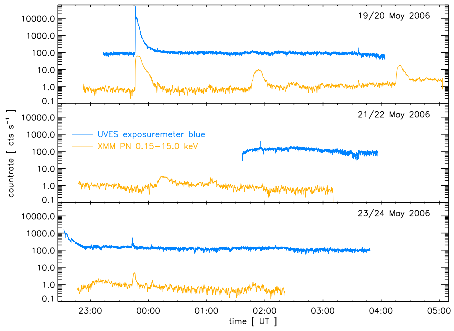

Figure 1: Time coverage of the nights of $19^{th}/20^{th}$, $21^{th}/22^{th}$ and $23^{th}/24^{th}$ May 2006 with *XMM-Newton* and VLT/UVES. Exposure times for UVES varied according to seeing conditions from 100 s to 300 s in the red arm and from 1000 s to 1500 s in the blue arm, resulting in 68, 24 and 89 red spectra and in 16, 5 and 11 blue spectra in the three nights respectively.

Magnetic flux variations

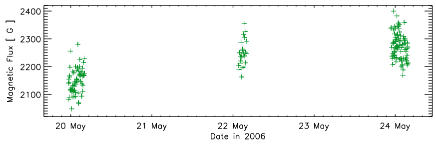

Figure 2: Following the method of Reiners & Basri (2006) we determined the magnetic field of CN Leo from the FeH band located around 9950 Å in the red UVES spectra. The average magnetic flux varies by ≈ 100 G from 1^{st} to 2^{nd} night and by ≈ 25 G from 2^{nd} to 3^{rd} night.

Flare lightcurves

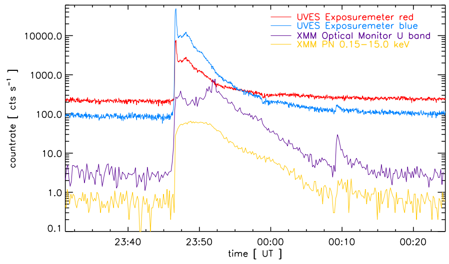

Figure 3: Lightcurves of the giant flare in different spectral bands. The optical lightcurves show an impulsive outburst followed by a secondary peak, while in X-rays the countrate stays constant for about five minutes. The decrease in countrate in the red and blue bands is initially very fast and then slows down, while the decay rate seems to be constant in X-rays and in the U band. Note that the EPIC instruments are affected by pile-up (up to 30% during the flare peak) and the OM lightcurve is corrupted by disproportionate dead-time and coincidence loss corrections for countrates higher than ≈ 500 cts s^{-1}.

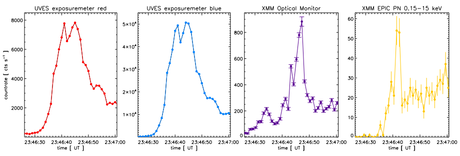

Figure 4: Zoom into the lightcurves for the first 30 seconds of the flare, showing the impulsive outburst. Blue and red look very similar apart from the different amplitude, while the U band lightcurve shows a precursing event followed by the main outburst. A very short outburst is visible in X-rays, the adjacent rise to the flat peak countrate is outside the plotting range.

Time series of chromospheric lines

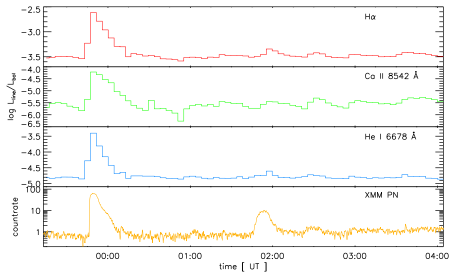

Figure 5: Temporally resolved behavior of Hα, Ca II at 8542 Å and He I at 6678 Å during the night of 19/20 May 2006. The three lines demonstrate that they make good tracers of the X-ray lightcurve also for smaller variations, but note the different cooling timescales during the giant flare.

EPIC spectra

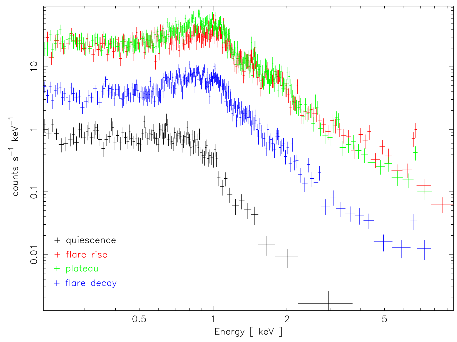

Figure 6: *XMM* EPIC PN spectra covering the initial rise phase, the "plateau" of constant countrate at the flare peak, and the decay phase of the giant flare. The spectra clearly demonstrate the development of the coronal plasma during the flare: The spectrum during the quiescent phase is similar to a previously obtained one from May 2004 (Fuhrmeister et al.). During the flare rise a strong increase in temperature and emission measure compared to the quiescent state is obvious. At flare peak enhanced line emission between 0.6 an 1.1 keV sets in, during the decay phase the emission measure slowly decreases with the temperatures still at high levels.

Coronal densities

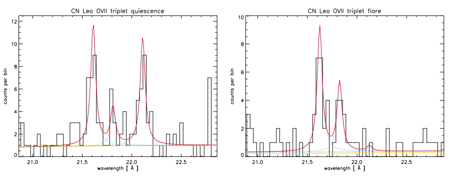

Figure 7: O VII triplet in RGS1, extracted from the quiescent part of the first X-ray observation (exposure time 20.8 ks, left) and covering the giant flare (1.4 ks, right). In quiescence, the f/i ratio is 2.88 ± 1.53, indicating $\log n_e \approx 10$ but within the errors still consistent with the low-density limit, while during the flare the density increases to $\log n_e > 12$, as determined by $f/i = 0.08 \pm 0.15$. The short duration of the flare prevents an analysis of density variations during different phases of the flare as performed by Güdel et al, 2002.

References

Fuhrmeister, B., Liefke, C., & Schmitt, J.H.M.M., submitted to A&A
Güdel, M., Audard, M., Skinner, S.L., & Horvath, M.I., 2002, ApJ, 580, L73
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UVES spectra: development of chromospheric lines and continuum enhancement during the giant flare

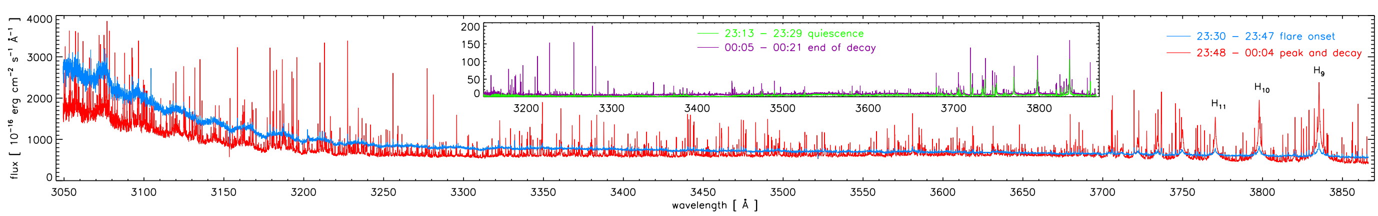

Figure 8: Continuum enhancement in the UV during the flare, and the development of chromospheric emission lines in the blue part of the spectra during the flare. Outside the flare continuum emission in the blue part of the spectra is almost absent. Note the delay between continuum enhancement and the onset of strong line emission and broadening of the Balmer lines.

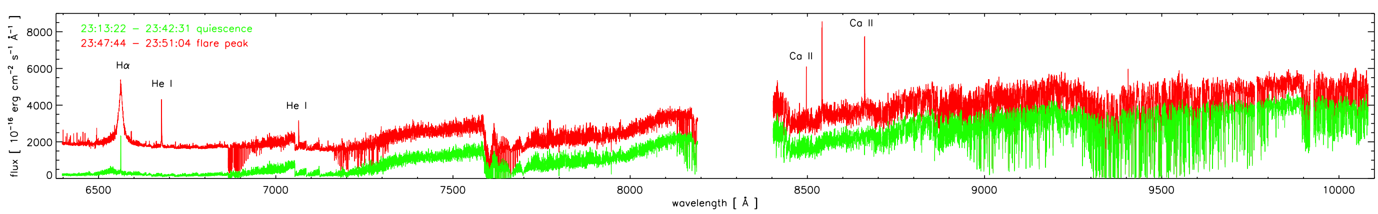

Figure 9: Broadening of Hα and continuum enhancement in the red part of the spectra during the initial phase of the flare. Ca II at 8498 Å, 8542 Å and 8662 Å as well as He I at 6678 Å and 7065 Å are observed in emission during the flare. The quiescent spectrum has been averaged from 7 spectra preceding the flare.