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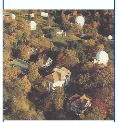

The many faces of a giant flare

Multiwavelength observations of CN Leo with high spectral and high time resolution

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Abstract

The M5.5 dwarf CN Leo has been observed simultaneously with *XMM-Newton* and VLT/UVES on 19/20 May 2006. 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 spectrograph, performing high-resolution spectroscopy in the UV and in the far red, simultaneously traces 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.

Coronal densities

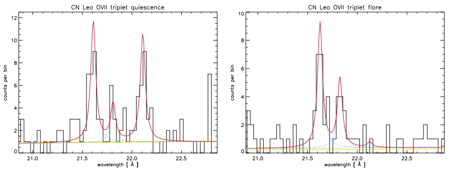

Figure 4: O VII triplet in RGS1 during quiescence (exposure time 20.8 ks, left) and flare (1.4 ks, right). In quiescence, the f/i ratio is 2.88 ± 1.53, indicating $\log n_e \approx 10$ but within the errors still consistent with the low-density limit, while during the flare the density increases to $\log n_e > 12$, 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.

Lightcurves

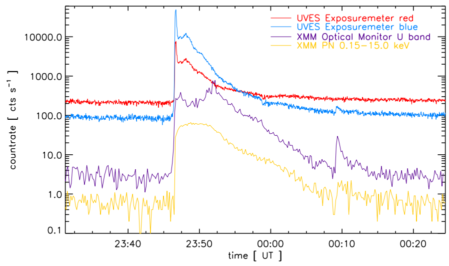

Figure 1: Lightcurves of the giant flare in different spectral bands. The optical lightcurves show an impulsive outburst followed by a secondary peak, while in X-rays the countrate stays constant for about five minutes. The decrease in countrate in the red and blue bands is initially very fast and then 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}.

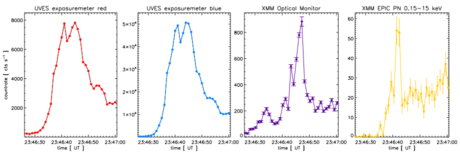

Figure 2: Zoom into the lightcurves for the first 30 seconds of the flare, showing the impulsive outburst. Blue and red look very similar apart from the different amplitude, while the U band lightcurve shows a precursing event followed by the main outburst. A very short outburst is visible in X-rays, the adjacent rise to the flat peak countrate is outside the plotting range.

EPIC spectra

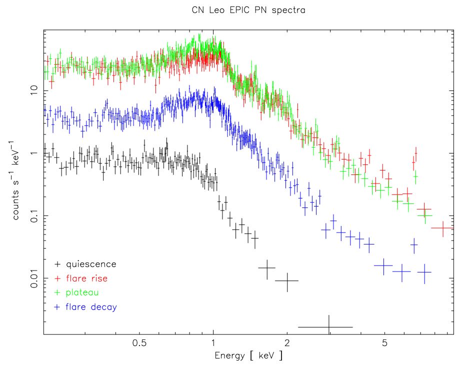

Figure 3: *XMM* EPIC PN spectra covering the initial rise phase, the "plateau" of constant countrate at the flare peak, and the decay phase of the flare. The spectra clearly demonstrate the development of the coronal plasma during the flare: The spectrum obtained during the quiescent phase is similar 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.

References

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Güdel, M., Audard, M., Skinner, S.L., & Horvath, M.I., 2002, ApJ, 580, L73
Houdebine, E.R. & Doyle, J.G., 1994, A&A, 289, 185

Chromospheric lines and continuum enhancement

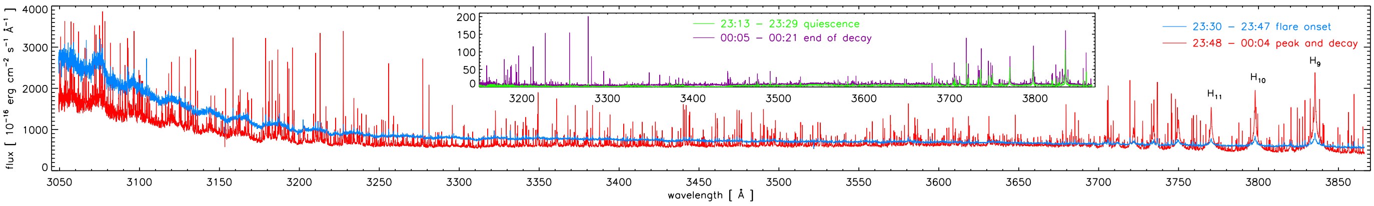

Figure 5: Continuum enhancement in the UV during the flare, and the development of chromospheric emission lines in the blue part of the spectra during the flare. Outside the flare continuum emission in the blue part of the spectra is almost absent. Note the delay between continuum enhancement and the onset of strong line emission and broadening of the Balmer lines.

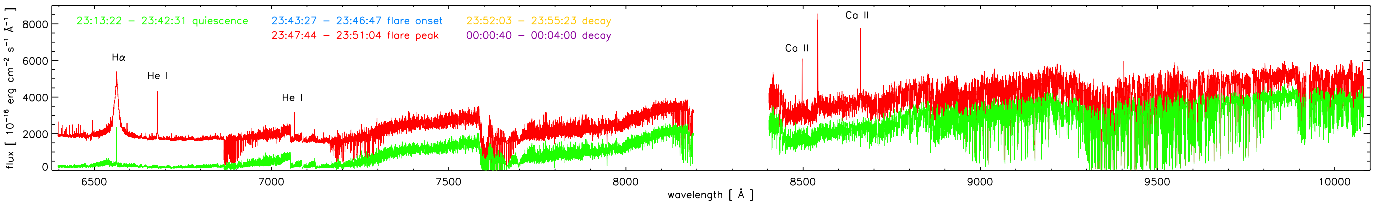

Figure 6: Broadening of Hα and continuum enhancement in the red part of the spectra during the initial phase of the flare. Ca II at 8498 Å, 8542 Å and 8662 Å as well as He I at 6678 Å and 7065 Å are observed in emission during the flare. Note that the central pixels of Hα and the Ca II lines enter saturation during the flare peak. The quiescent spectrum has been averaged from 7 spectra preceding the flare.

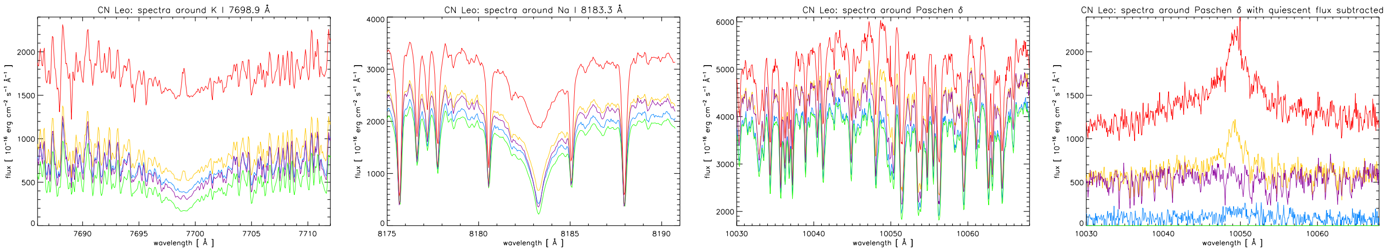

Figure 7: Evolution of individual lines during the flare. Left: The broad absorption lines of K I and Na I develop emission line cores or are filled up during the flare. While the second line of the K I dublet at 7664 Å shows the same behavior as the line at 7699 Å, Na I at 8195 Å falls into the gap between the two CCDs. Right: A disproportionately higher flux is visible during the flare around 10 049 Å at the wavelength position of Paschen δ. Assuming that the flare covers only a small part of the stellar surface we subtracted the quiescent spectrum from the spectra covering the flare to obtain the pure flare emission. In these spectra (amongst others) lines of the Paschen series from Paschen δ to Paschen 10 are clearly observed in emission, indicating extremely high densities in the lower chromosphere according to Houdebine & Doyle, while the Balmer lines trace the upper chromosphere. See Figure 6 for the meaning of the color coding.