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FIRST CCD OBSERVATIONS OF A FLARE IN Hϵ AND Ca-II(H)

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Abstract

The dynamic evolution of the chromospheric electron density during solar flares is fundamental for the testing of solar flare models. For this purpose we built an imaging spectrograph to observe optically thin Balmerlines below 400 nm with a time resolution of 1 s. On January 5, 1992 we observed a M1 / 1N flare in H_α, H_ϵ and Ca-II (H) and determined the temporal evolution of the electron density.

1. Introduction

Observations of various chromospheric lines with high temporal (1 second), spatial and spectral resolution provides a wealth of diagnostic information on the chromospheric response of solar flares. The chromospheric electron density and the plasma velocity at various heights are important physical parameters for testing the chromospheric condensation. The electron density can be determined from the line shape of optically thin hydrogen Balmer lines. With Doppler shift measurements of lines formed at different heights in the chromosphere the evolution of the condensation can be modelled. Previous observations were either based on the spatially and spectrally resolved H_α line (e.g. Graeter 1993, Wülser *et al.* 1992) or on other lines with no spatial resolution (e.g. Donati-Falchi *et al.* 1985, Lemaire *et al.* 1984). However, for a better understanding of the chromospheric response of solar flares we need observations of various optically thin chromospheric lines with high temporal, spatial and spectral resolution.

2. Observation

On January 5, 1992 we observed around 13:16 UT a M1 / 1N flare in H_α, H_ϵ and Ca-II (H) (NOAA active region 6993), with our imaging spectrographs at Locarno-Monti. The images of the active region were scanned every 2.3 s for the H_α and every 1.1 s for the H_ϵ and Ca-II (H) lines. A summary of the instrumentation is given in Table 1 (for more details see Wülser and Marti, 1989; Rolli and Magun, 1994).

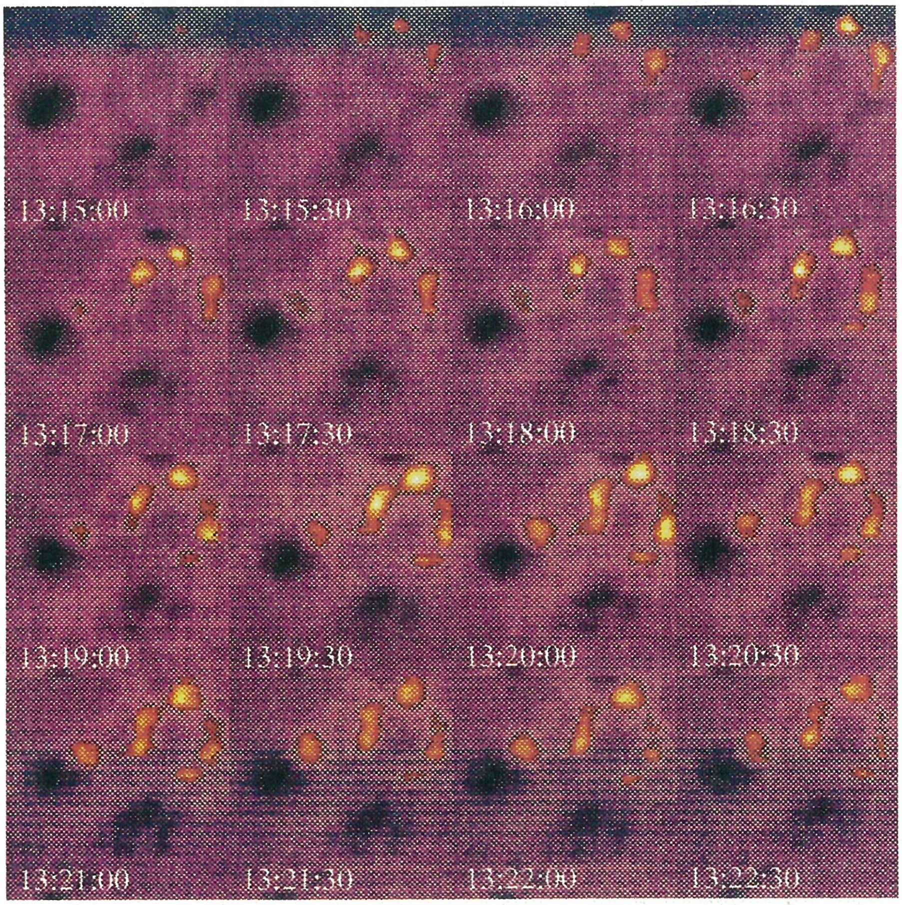

Fig. 1. H_ϵ line center images of the January 5, 1992 flare, with times in UT. Each image covers an area of $3' \times 3'$. **Bright areas represent flare kernels, dark areas sunspots. The orientation of the images is the same as in Figure 2.**

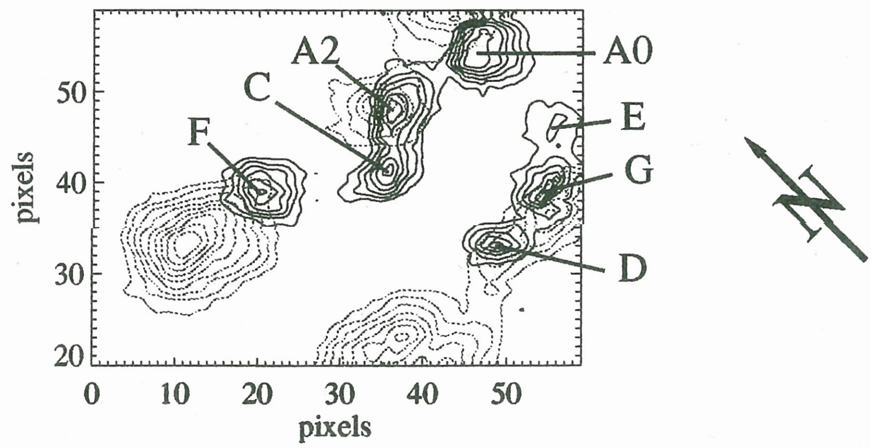

Fig. 2. **Contour map of the flare kernels (solid lines) and sunspots (dashed lines) in H_ϵ line center, at 13:21:00 UT.**

	H_α	H_ϵ & Ca-II (H)
time resolution	2.3 s	1.1 s
spectral resolution	0.26 Å to 1 Å	0.11 Å to 0.44 Å
total bandwidth	10 Å	16 Å
spatial resolution	3.1″ × 3.6″	2.8″ × 3.1″
image size	3.7′ × 3.6′	2.8′ × 3.1′

Table 1. Main features of the imaging spectrographs.

The flare was also observed in X-rays by the YOHKOH spacecraft (Doschek *et al.*, 1993). A time sequence of the flare images in H_ϵ line center is shown in Figure 1. Each image is 60 × 60 pixels (2.8′ × 3.1′) in size. The different flare kernels are identified on the contour map of Figure 2 (solid lines for kernels, dashed lines for sunspots). With the exception of the new label G, they are marked according to the main features in the SXT images (Doschek *et al.*, 1993).

3. Temporal evolution of the electron density

Between the possible broadening mechanisms for the hydrogen Balmer lines, the Stark broadening is the most efficient (Švestka, 1976). Very detailed calculations of the Stark broadening as a function of the electron density have been presented by Griem (1962). They show contributions from both electrons and ions, the latter being described with the quasi-static approximation with a Holtsmark distribution. For simplicity we assumed that the electrons and ions have an equal contribution to the Stark broadening. The observed spectra were fitted with a voigt profile, depending on electron density and a Doppler broadening due to an assumed constant chromospheric temperature of 10^4 K.

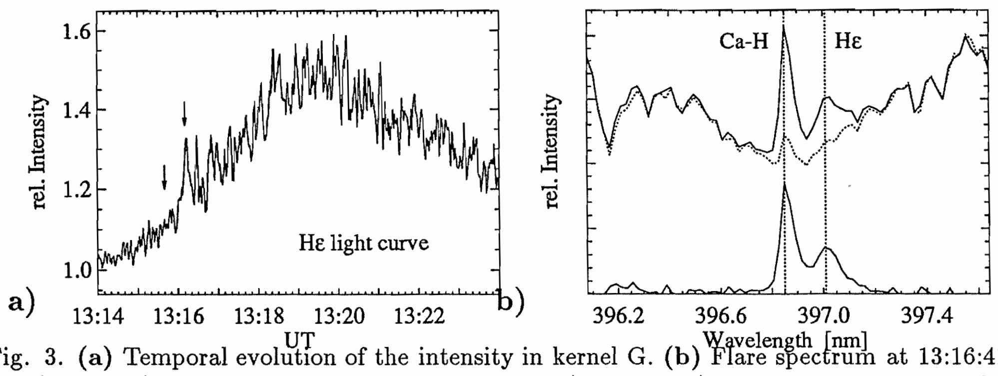

Fig. 3. **(a)** Temporal evolution of the intensity in kernel G. **(b)** Flare spectrum at 13:16:41 UT (solid line) and preflare spectrum at 13:14 UT (dashed line). The bottom curve is the flare spectrum with the preflare spectrum subtracted.

We computed the temporal evolution of the electron density derived from the H_ϵ line spectra observed in kernel G, which showed the strongest hard X-ray emission during the first peak around 13:16:10 UT. Figure 3a shows the H_ϵ light curve in kernel G and Figure 3b a sample spectrum of the Ca-H and the H_ϵ emission at 13:16:41 UT. In order to isolate the H_ϵ profile the Ca emission line was removed by fitting a gaussian profile to the Ca emission and substracting it.

4. Results and Conclusions

Figure 4a shows the electron density variation in kernel G during the flare with error bars. We observed a steep rise of the chromospheric electron density right at the onset of the flare, well correlated with the first hard X-ray rise (first arrow in Fig. 3a and Fig. 4). Simultaneously with the main hard X-ray peak (second arrow) and coinciding with the intensity peak in H_ϵ at 13:16:10 UT (Fig. 3a) we see a second rise of the electron density up to $8 \cdot 10^{19} m^{-3}$.

The evolution of the electron density in kernel G follows quite well the hard X-ray rise. This good correlation is strong evidence that the chromospheric plasma in kernel G is heated by an electron beam which leads to an enhanced H_ϵ emission.

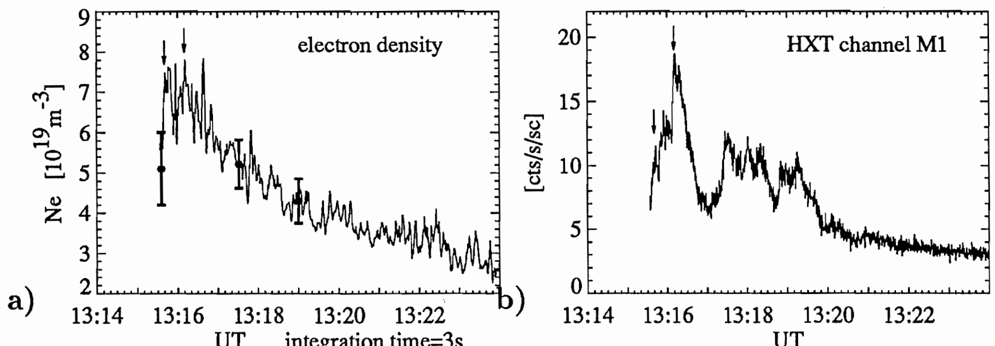

Fig. 4. **(a)** Temporal evolution of the electron density in kernel G, with typical error bars during the rise and the decay phase. **(b)** hard X-ray light curve for 22.7 - 32.7 keV (HXT channel M1).

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