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RAPID CHANGES IN Hα-FLARES CORRELATED WITH MICROWAVES

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Abstract. We have studied the time evolution of several flares in Hα with a time resolution of 1.4 seconds. The time profiles of the linecenter intensity show fast fluctuations and spikes. During the impulsive phase, prominent spikes occur in different kernels and they are correlated with microwave and Hard X-ray spikes. Spectrally resolved observations show major changes of the ratio between Hα line width and Hα linecenter intensity at time scales in the order of 1 minute. No significant fluctuations occured at shorter time scales.

1. Introduction

By studying the chromosphere with a sufficiently high temporal resolution and comparing the results with microwave and hard X-ray data one can draw conclusions about the flare heating mechanism in the chromosphere. Different energy transport mechanisms show different time delays between the initial energy release in the corona and the chromospheric response. Conductive flux results in a significant time delay in the order of some ten seconds. Non-thermal electrons, on the other hand, imply time delays of much less than a second, and fast fluctuations (order of seconds) in the primary energy release should also be seen in the chromospheric response.

We have studied the time evolution of several flares in Hα. Microwave observations from Bern (in the range of 3.1 to 35 GHz) and hard X-ray data from the HXRBS on SMM have been used for correlation purposes. Hα linecenter observations, which can be done with high temporal resolution are important for the measurement of fast fluctuations and small delays between the time profiles in different spectral regions. Spectrally resolved observations are limited in the temporal resolution because of the higher amount of data to be observed and stored. However, lineprofiles contain more physical information on the low-temperature flare plasma than does the intensity in the linecenter alone. Because Hα is optically thick, the lineprofiles reflect the dependence with height of the physical parameters in the chromosphere. Furthermore, they seem to be sensitive to the flare heating mechanisms (non-thermal electrons, conductive flux). Recently, theoretical lineprofile calculations have been carried out (Dinh, 1980; Canfield, Gunkler and Ricchiazzi, 1984) which may be used for quantitative comparisons with observed lineprofiles.

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2. Hα Observations

Hα linecenter observations have been done with a digital CCD camera taking images at a rate of 1 frame per 1.4 seconds (Kämpfer and Schöchlin, 1982). Before analysis the raw data has been calibrated for CCD inhomogeneities.

The lineprofile observations have been carried out with an imaging spectrograph equipped with a CCD array sensor (Wülser, 1984). The instrument scans an active region every 5.4 seconds, acquiring images in 15 spectral channels simultaneously.

The analysis of the time evolution of the lineprofile as a whole is rather difficult. It is more adequate to use single spectral signatures instead, e.g. linewidth, line shift, or total power in Hα. In this paper we concentrate on the analysis of the linewidth because it is supposed to be sensitive to the flare heating mechanism. Canfield, Gunkler and Ricchiazzi (1984) have theoretically found that broad Stark emission wings of obviously non-Gaussian form are produced by non-thermal electrons.

In order to get a parameter which is most sensitive to changes in the line wings, we measured the effective linewidth at those points where the flare profile exceeds the intensity of the adjacent continuum by 10 percent (Fritzova, 1964). As a consequence of this definition, linewidth and intensity at linecenter are not independent. Therefore, we looked for relative changes of linewidth and linecenter intensity. Figure 4b shows the time evolution of the linewidth of a flare on November 20, 1982, and Figure 4a its intensity at linecenter. The different evolution of the two parameters can be seen on a correlation diagram where linewidth is plotted as a function of linecenter intensity and time as free parameter (Figure 5).

3. Discussion

a) linecenter observations. Figure 1 shows the light curves for two individual kernels of the flare on December 17, 1980. The two kernels develop quite differently. Kernel A starts earlier and peaks later than kernel B, which shows a rather fast rise. Both kernels have spikes in their light curve but most fluctuations are prominent in only one of the kernels. As an example, consider the spike at 12h07m48s. It is a major feature in kernel A but not in B. The same spike is clearly seen in the light curve of the whole flare, in the microwave regions and in X-rays at 29keV (Figure 2). The close temporal coincidence between Hα and microwaves indicates a rapid energy transfer by electrons from the microwave source down to the chromosphere. Besides the rapid fluctuations this event also shows a close correspondence of the impulsive phase in the two spectral regions.

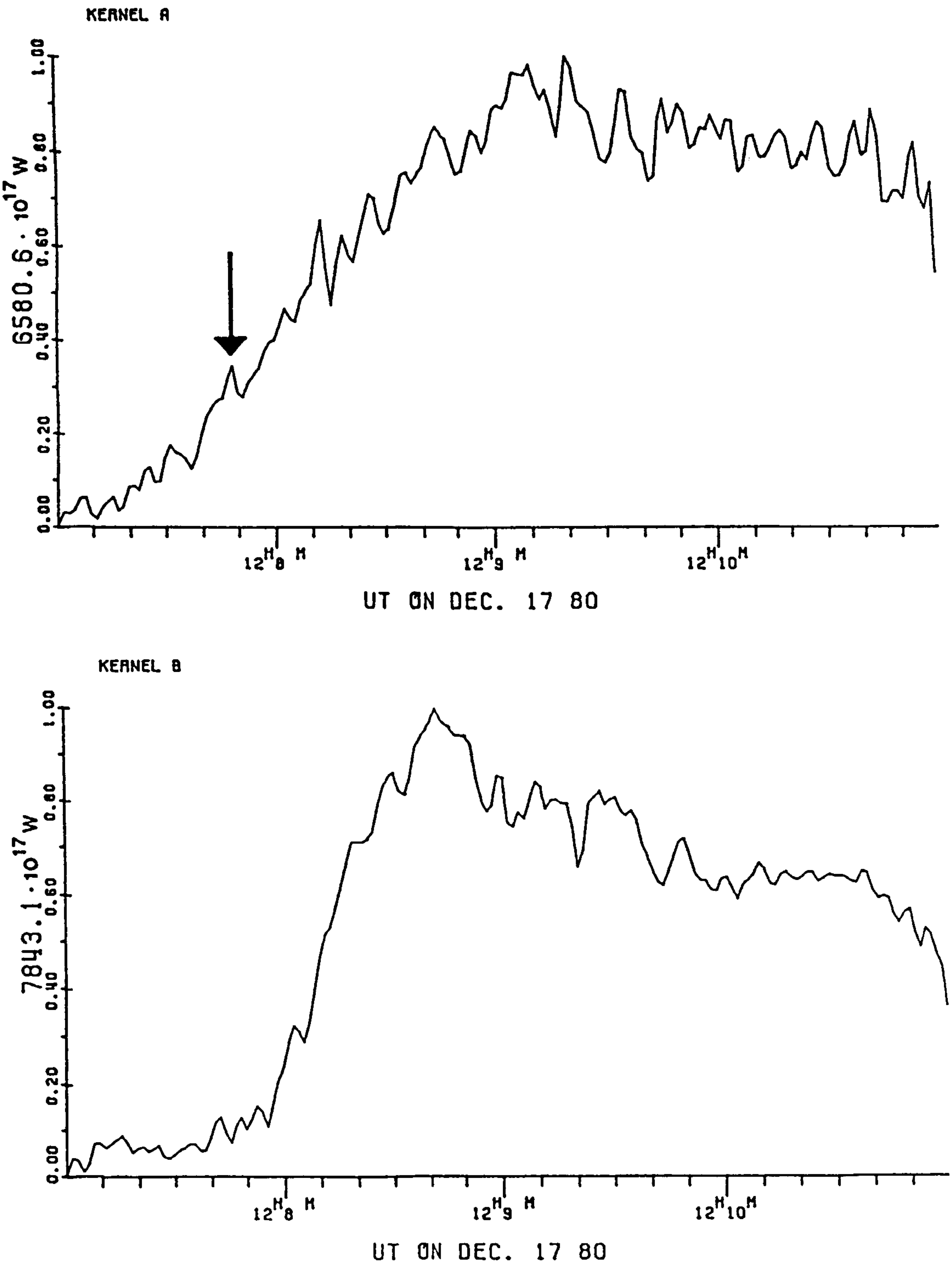


Fig. 1. Lightcurves for two individual kernels in Hα. The spike at 12h07m48s is very prominent in kernel A but not so much in kernel B.

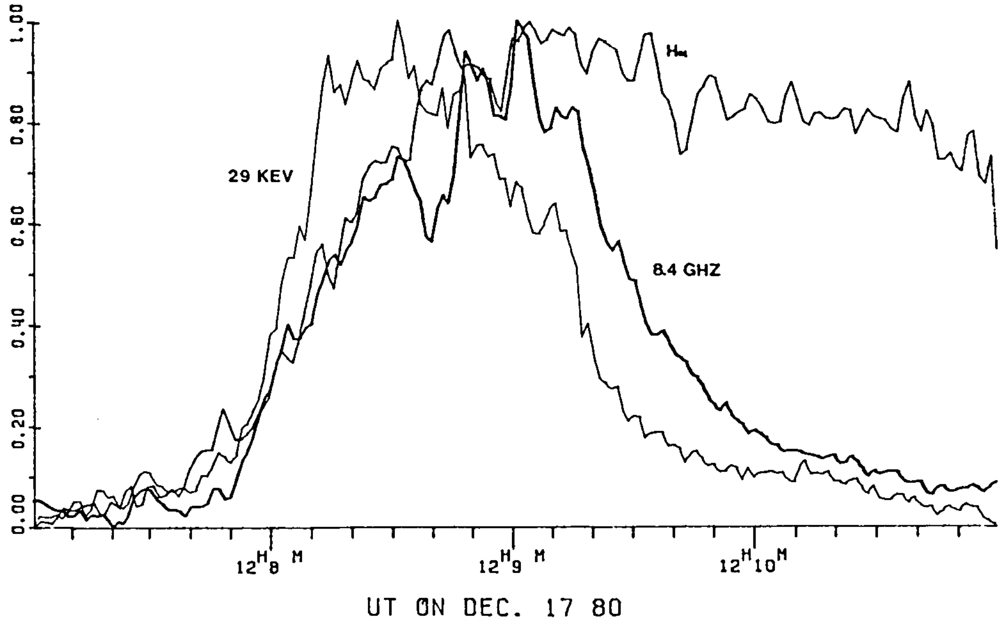


Fig. 2. The comparison of the Hα lightcurve with the corresponding event in the microwave region at 8.4 GHz and in hard X-rays at 29 keV clearly shows the close correspondence of some prominent spikes.

The flare of June 17, 1982, is an example of an another type of event where the development of the total Hα intensity is delayed compared with the microwave emission (Figure 3a). However, if the evolution of a specific kernel is considered, no time delay can be observed and there is a close correspondence between the individual spikes in Hα and microwaves during the impulsive phase (Figure 3b).

b) spectrally resolved observations. Figure 4 shows the time evolution of intensity and linewidth of the flare of November 20, 1982. The two time profiles show a spiky structure, but the ratio of both parameters does not change much on short timescales in the order of 10 seconds. On longer timescales, (some ten seconds to minutes) the ratio is changing significantly. By comparing intensity and linewidth (Figures 4a, 4b and 5), we can distinguish 3 phases: During the first phase until 10h13m15s, both parameters show a fast rise. The second phase lasts until about 10h15m and is characterised by a further increase of intensity, whereas the linewidth fluctuates around a constant value. In the third phase both parameters decrease. A comparison with microwaves (Figure 6) shows, that the first phase coincides with the impulsive burst. The fast increase of the Hα linewidth indicate a heating of the chromospheric flare by fast electrons. However, broad Hα emission wings as a clear indicator for massive electron heating do not exist. At the beginning of phase 2, a qualitative change occurs. The microwave flux begins to decrease substantially and the Hα linewidth remains at about a constant value. These facts suggest that the further increase of the Hα intensity is not primarily due to electron heating.

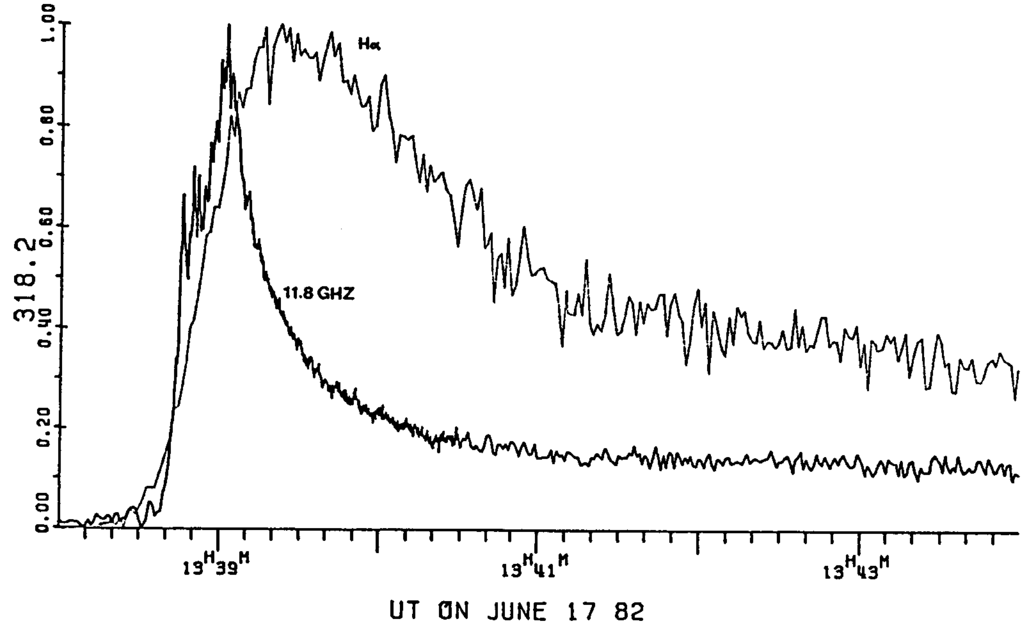


Fig. 3a. In this flare a time delay between the overall development of the Hα-intensity and the microwave region is present.

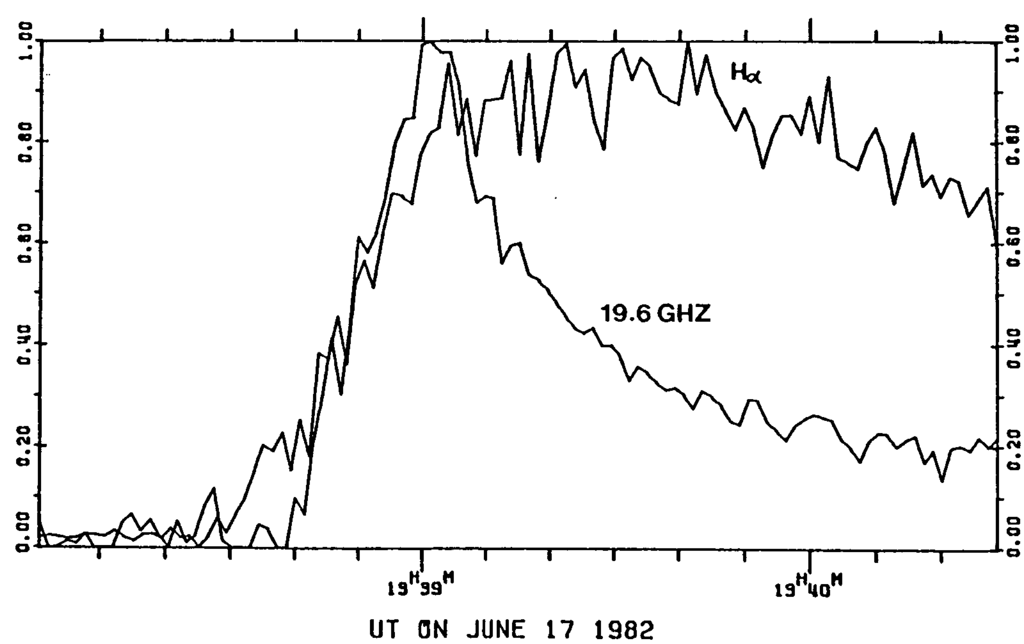
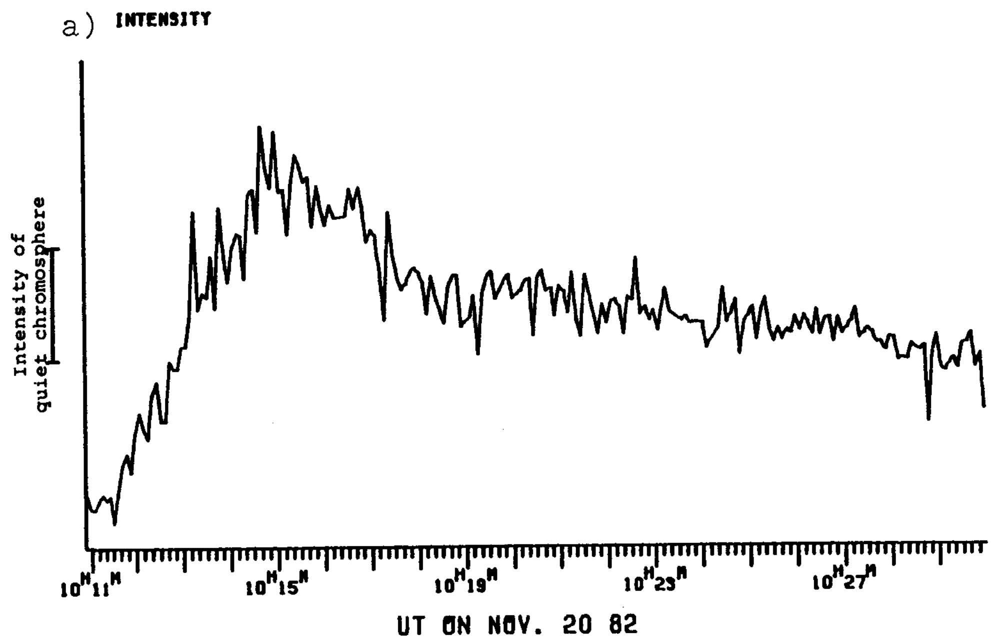


Fig. 3b. Temporal evolution of a specific kernel and the microwave event at 19.6 GHz which shows no time delay between the two spectral regions. Integration time in both cases is 1.4 sec.



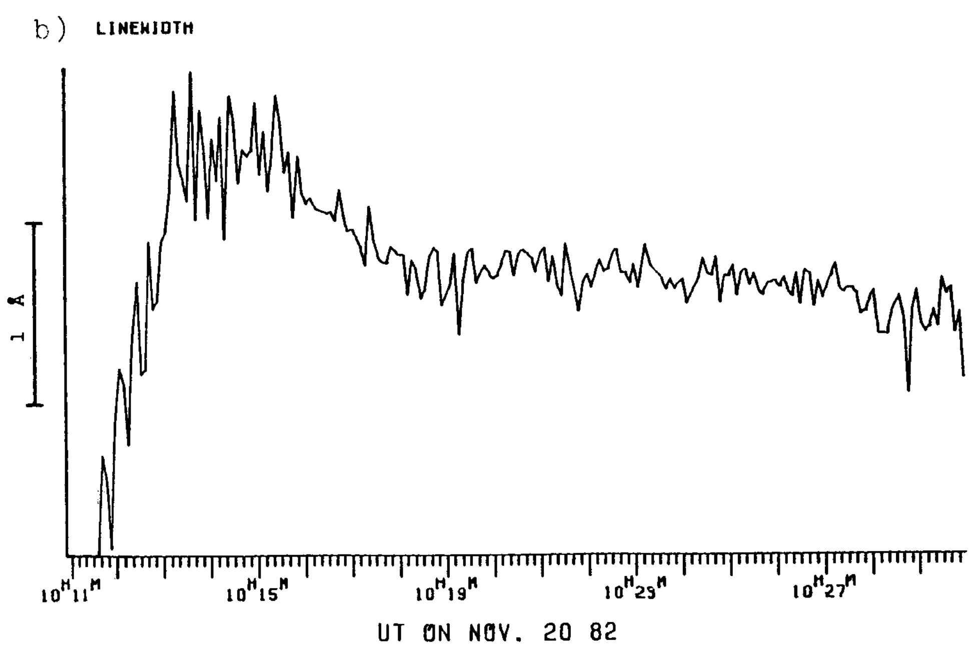


Fig. 4. Flare of Nov. 20, 1982: Time evolution of linecenter intensity (a) and linewidth (b) at the center of the strongest flare kernel.

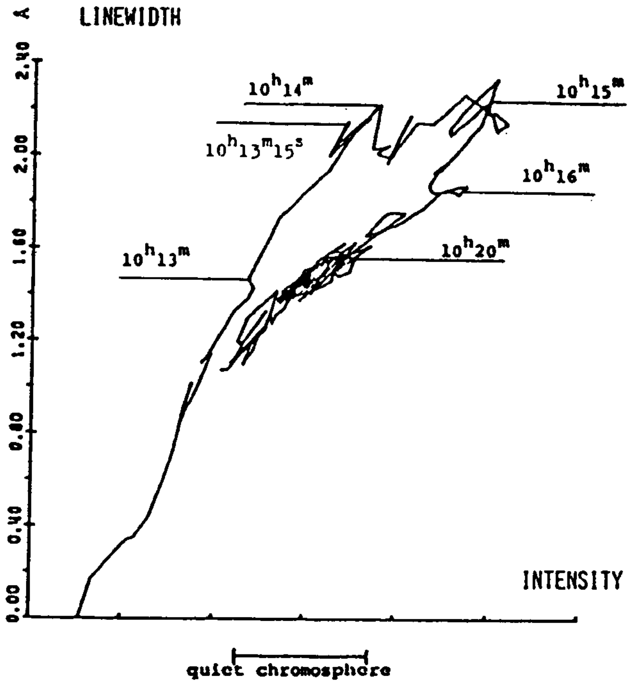


Fig. 5. Flare of November 20, 1982: Correlation diagram. Linewidth as a function of intensity at linecenter. Free parameter is time. Changes in the ratio of linewidth and intensity mainly occur between 10h14m and 10h15m.

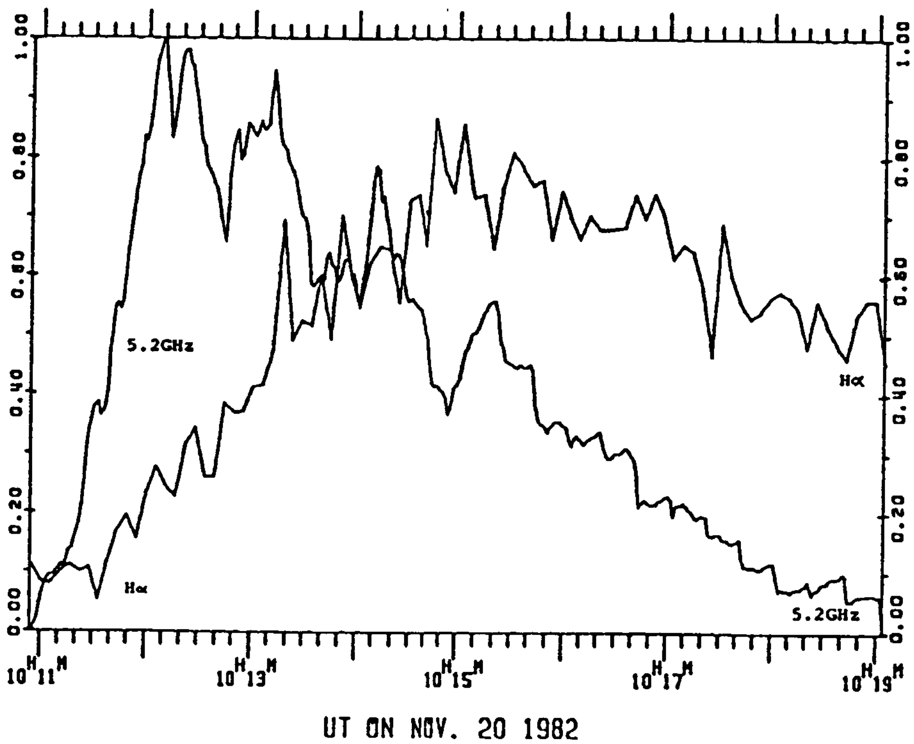


Fig. 6. Time evolution of microwaves at 5.2 GHz and Hα-intensity of the flare of November 20, 1982.

An other flare (November 21, 1982) did not show these 3 phases in Hα: There was no difference between the temporal evolution of linewidth and linecenter intensity. On the correlation diagram (Figure 7) the flare rises and falls along the same line of path. The absolute amplitudes of linewidth and Hα intensity were larger in this flare. It consisted of a single loop, in contrast to the previously discussed event of November 20, which showed a more complex structure (4 Hα kernels). Presently it is not clear to the authors wether the 3 phase evolution in Hα only occurs above some minimum value of released energy and loop size.

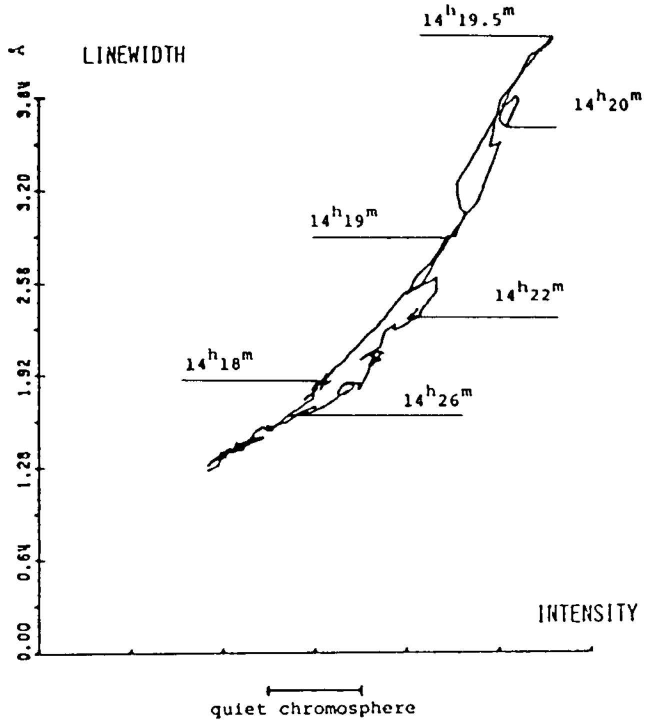


Fig. 7. Flare of November 21, 1982: Correlation diagram. This flare rises and falls along the same line of path.

4. Summary

The time evolution of the total Hα intensity during the impulsive phase shows fast fluctuations and spikes which are correlated with microwaves and hard X-rays. These spikes indicate chromospheric heating by fast electrons. Different peaks can originate from different kernels.

Spectrally resolved Hα observations showed no significant changes of the shape of the line profile during the spikes. However, the time resolution of the imaging spectrograph may have been too low to resolve the changes properly. On longer timescales, one of two investigated flares shows an enhanced linewidth during the impulsive phase, which is another indicator for electron heating of the chromosphere. We conclude, that Hα observations with high temporal resolution are a valuable tool for the analysis of the chromospheric flare. Together with microwave and hard X-ray measurements, they especially can give us additional information about the flare heating mechanism.

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