# H$\alpha$ AND X-RAY SIGNATURES OF CHROMOSPERIC HEATING OBSERVED IN SOLAR FLARES

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**Abstract**

We have studied the spatial and temporal relationship between thermal and non-thermal energy transport, and the chromospheric response in solar flares. H$\alpha$ imaging spectra from Mees Solar Observatory provided the information on the heating and dynamics in the chromosphere, soft X-ray images from Yohkoh provided the conditions of the thermal plasma in the corona, and hard X-ray data from Yohkoh provided the diagnostics of the non-thermal particles. We present some preliminary results for several large flares, and discuss their implications for the chromospheric flare heating mechanism.

## 1. Introduction

The mechanism heating the chromosphere during a flare is still an issue of debate. Two heating mechanisms have been studied theoretically in considerable detail (e.g., Fisher 1989): heating by a beam of non-thermal electrons and conductive heating from a hot corona. Combined H$\alpha$ and X-ray spectroscopy observations, in conjunction with theoretical modelling are a powerful tool to analyse the chromospheric heating mechanisms. We have previously shown that during the early impulsive phase such observations can successfully distinguish between the different heating mechanisms (Wülser et al. 1994). Later in the flare, the thermodynamical state of the plasma becomes more complicated and a quantitative analysis of the heating mechanism, in particular the comparison with theoretical modelling becomes more difficult. However, the temporal evolution of various observational parameters that reflect the heating rate and the chromospheric response can show us how the relative importance of the different heating mechanisms vary during later phases of the flare.

This paper presents some preliminary results of such an analysis on three large flares. We will define the key observational parameters and show some examples on what we can

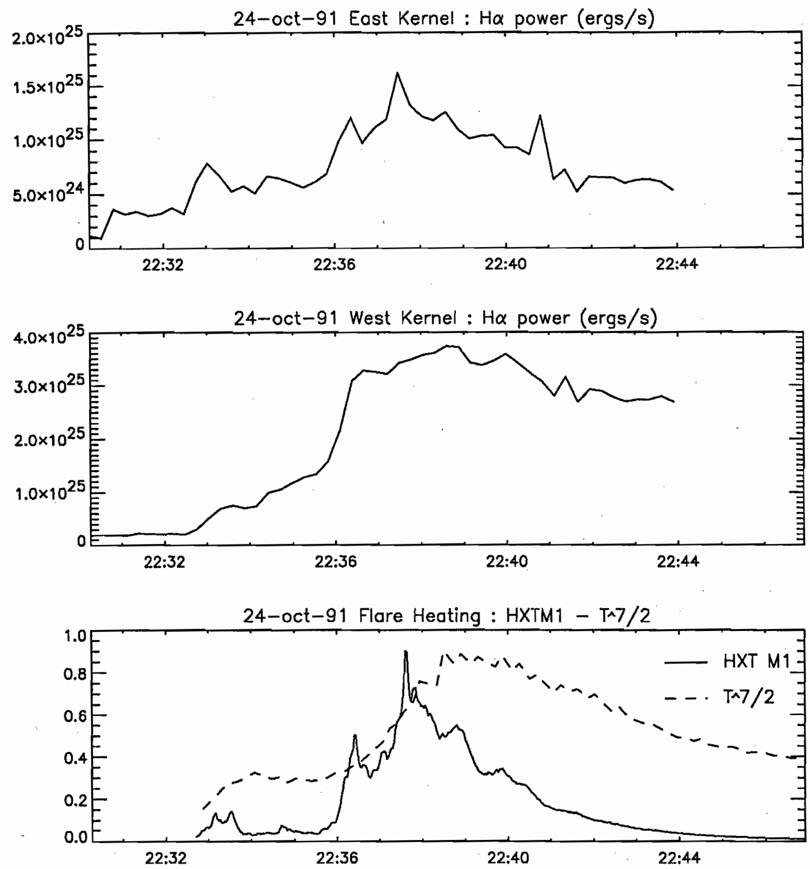


Fig. 1. Chromospheric response and flare heating in the 1991 October 24 flare. Top and middle panels: temporal evolution of the Hα power in two kernels. Bottom panel: Hard X-ray count rate between 23 and 33 keV observed by HXT (solid line), and $T_{fl}^{7/2}$ deduced from SXT observations (dashed line). The hard X-ray count rate serves as an indicator of non-thermal heating, and $T_{fl}^{7/2}$ serves as a measure of the conductive heat flux from the corona to the chromosphere (see text).

learn from a comparison of their temporal evolution during the flare.

## 2. Observations

We have analyzed soft and hard X-ray images from SXT and HXT on YOHKOH to determine the temporal evolution of the heating input into the chromosphere. We use the hard X-ray count rate in HXT channel M1 as a proxi for the variation of the non-thermal particle heating. We can also estimate the conductive heating input using the Spitzer expression $F \approx \kappa_0 T_{fl}^{7/2}/L$. As a first order approximation we assume that the loop length $L$ is constant with time and use the term $T_{fl}^{7/2}$ as a proxi of the variation of the conductive heating. We determine $T_{fl}$ from ratios of SXT images taken through the thick Aluminum and Beryllium filters. In addition, we have analyzed Hα imaging spectroscopy observations from Mees Solar Observatory to determine the chromospheric response during the flare. We use the total power in Hα as a proxi of the radiative output of the chromosphere, and the Hα redshift velocity as

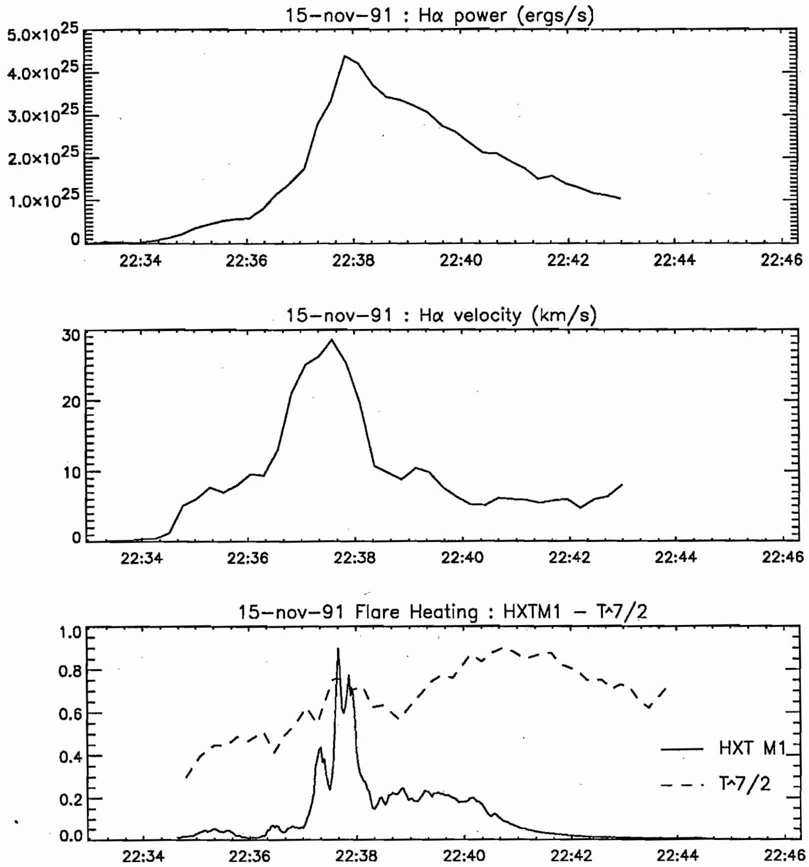


Fig. 2. Chromospheric response and flare heating in the 1991 November 15 flare. Top panel: temporal evolution of the Hα power. Middle panel: Hα downflow velocity. Bottom panel: Hard X-ray count rate between 23 and 33 keV observed by HXT (solid line), and $T_{fl}^{7/2}$ deduced from SXT observations (dashed line).

a signature of the dynamic response.

## 3. Discussion

Fig. 1. is a comparison of the Hα power with our flare heating proxis for the 1991 October 24 flare. The top and middle panels show the Hα power in two different kernels of the flare. The bottom panel shows the hard X-ray count rate in HXT channel M1 (solid line), and the $T_{fl}^{7/2}$ term of the Spitzer heat flux expression deduced from the SXT observations (dashed line). It is immediately obvious that the two Hα kernels respond very differently. The E kernel (top panel) has a temporal evolution that follows closely the temporal evolution of the hard X-rays. This suggests that this kernel is predominantly heated by non-thermal electrons. The W kernel (middle panel) shows a more smooth temporal evolution that is more similar to our conductive heating proxi $T_{fl}^{7/2}$. However, even in this kernel, the steepest rise of the Hα power coincides with the hard X-ray rise at 22:36 and not with the steepest rise in the conductive heating proxi which occurs more than a minute later. This suggests that the E kernel is heated by both heating mechanisms, with drastic changes in the relative importance of each mechanism during the course of the flare.

Fig. 2. compares the chromospheric response in the strongest H$\alpha$ kernel with flare heating proxies for the 1991 November 15 flare. The top and middle panel show the H$\alpha$ power and velocity, respectively, and the bottom panel again shows the hard X-ray count rate (from HXT) and $T_{fl}^{7/2}$ (from SXT). In this case, neither the H$\alpha$ power nor the H$\alpha$ downflow velocity show a clear one-to-one relationship with either the hard X-rays or the conductive heating proxi. However, we found several interesting relationships that generally appeared in all three flares we have analyzed so far. First, steep increases in the H$\alpha$ power and in the H$\alpha$ downflow velocity coincide with impulsive peaks in the hard X-rays. Second, the H$\alpha$ downflow velocity rises simultaneously with the H$\alpha$ power, but in the early flare it responds more strongly. Later in the flare, the downflow velocity responds less to heating than does the H$\alpha$ power. Third, in response to a decrease in the heating rate, the H$\alpha$ downflow velocity decreases faster than the H$\alpha$ power.

The above results are preliminary and we are currently expanding and repeating this study in a more quantitative manner. We will include a spectral analysis of the hard X-ray data to deduce the electron beam power, and we will calculate the conductive flux as a function of location in the flare. We will also extend our study to include all important H$\alpha$ kernels in each flare to obtain a more comprehensive view of the chromospheric heating mechanism.

## References

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