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HIGH RESOLUTION OBSERVATIONS OF A M5.4 FLARE

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Abstract. Hα observations of a M5.4 flare taken in the active region NOAA 10646 with the Vacuum Tower Telescope at Observatório del Teide, Tenerife, on July 13, 2004 are presented. The temporal evolution of the area of the flare and its morphological changes are investigated and discussed. Simultaneous observations of the flare in EUV lines taken with CDS/SOHO instrument are shown and additional data from GOES-10 instrument are compared.

Key words: Sun: flare, Hα observations, EUV spectra

1. Introduction

During the observations at the Vacuum Tower Telescope at Observatório del Teide, Tenerife in July 2004 we observed under very good conditions all phases of an energetic flare M5.4. High spatial resolution of the telescope gave us the possibility to investigate the time development of the area of the flare in Hα emission. This contribution is a short preliminary work on this topic. First we tested the sensitivity of the method used for estimation of the relative flare area. Then we estimated the basic characteristics of the flare, namely the gradual phase of the flare and its duration and compared them with GOES data.

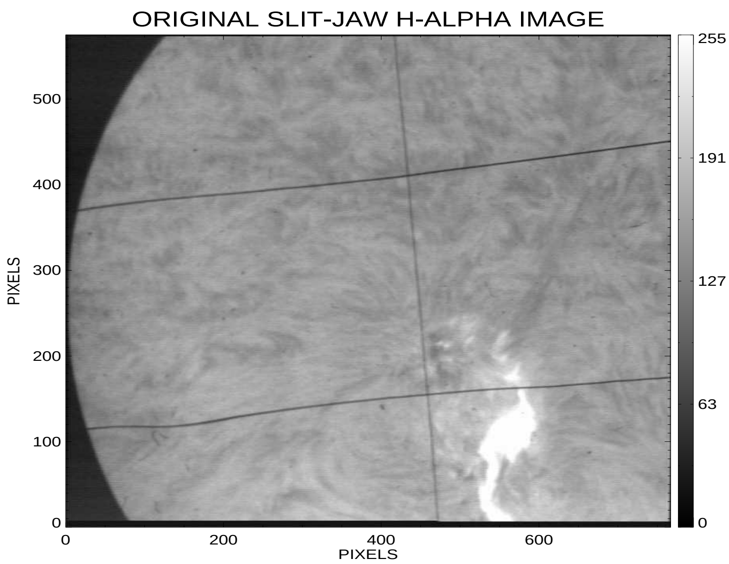

Figure 1: The full field of view of the slit-jaw system of the Vacuum Tower Telescope in Hα. The vertical line is the slit, the two horizontal wires are used to mark the area of spectral investigations. The color bar units are expressed in Arbitrary Intensity Units (AIU).

2. Observations and data reduction

VTT Hα observations: Observations were performed with the Vacuum Tower Telescope (Schröter et al. 1985) at Observatório del Teide, Tenerife. Active region AR 10646 in north-west part on the Sun (N12, W43, $\mu = 0.54$) was observed. Series of slit-jaw images were taken with the slit-jaw video system mainly in the Hα channel (Kentischer 1995). An example of the field of view is shown in Figure 1. Several short series of images were recorded in white-light channel to have a record of the sunspot configuration. A total number of 643 VTT CCD images of 768 $\times$ 576 pixels each was stored on disk in 8 bits/pix resolution. Additional calibration images were recorded at the beginning and at the end of the series for dark current and flat-field corrections. The series of the images started at 08:31:13 UT and lasted up to 09:15:30 UT. The energetic flare classified as M5.4 occurred in the observed target between 08:36 UT and 09:15 UT. The images were recorded every 4 seconds with an exposure time 1/24 sec. The Hα slit-jaw images

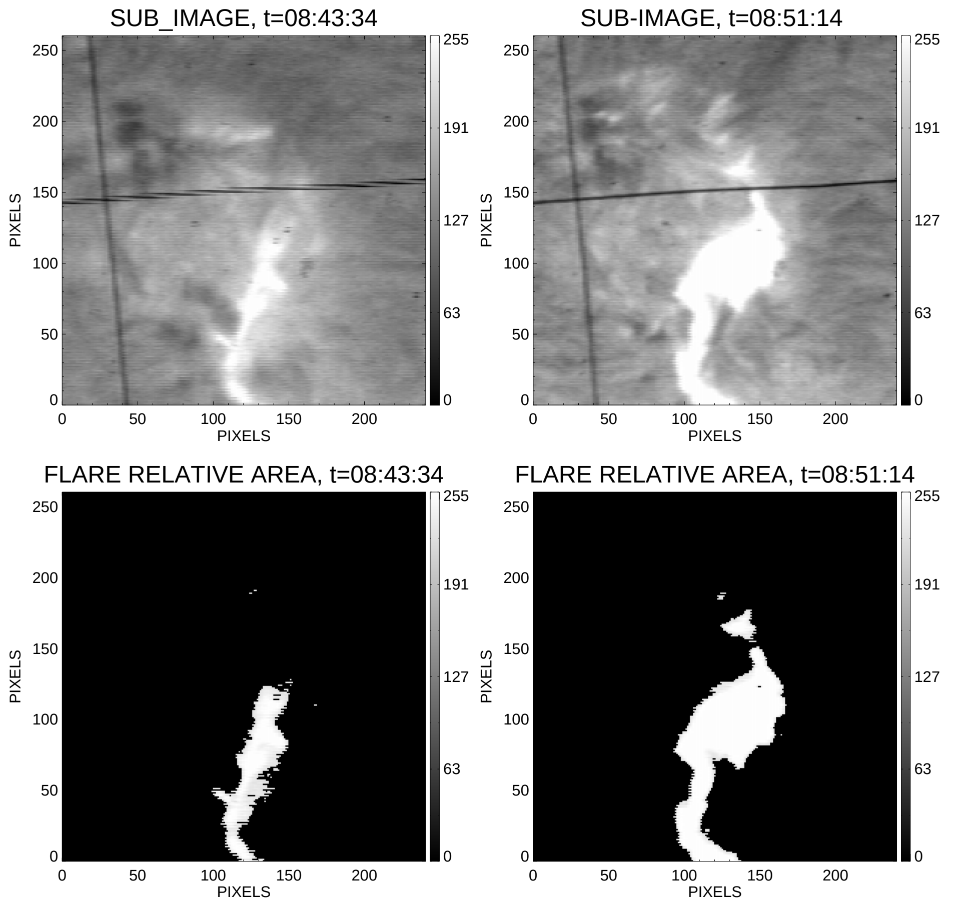

Figure 2: An example of two Hα sub-images with the M5.4 flare for the moments 08:43:34 UT and 08:51:14 UT (upper panels) and two *relative flare areas* estimated for the same sub-images using the threshold limit of 225 AIU (lower panels). The color bar units are expressed in AIU

were corrected for the dark current and flat-field intensity influences. The correction by the flat-field was not as good as expected due to some temporal changes of the dust covering the window of the camera. This did not influence the results obtained from the slit-jaw images. Then the following method for estimation of the area of the flare was applied small sub-images of 240 $\times$ 260 pixels each around the flare were cut from each slit-jaw image. An examples of two sub-images for the times 08:43:34 and 08:51:14 UT are given in Figure 2 on the upper panels. Eight threshold levels of intensity were chosen for tests of the area of the flare. Namely 215, 220, 225, 230, 235, 240, 245 and 250 arbitrary intensity units (AIU) of the whole range of 0 - 255 AIU were used. Each pixel of the sub-image of intensity higher than the threshold limit was considered as the area of the flare. Number of all pixels which fulfilled the criterion was adopted as the *relative flare area* in the particular sub-image for the particular time. Thus 643 *relative flare areas* were found for each threshold limit for the time interval 08:31:13 – 09:15:30 UT. Two particular *relative flare areas* calculated for above mentioned sub-images for the threshold limit of 225 AIU are shown in Figure 2 in the lower panels. *CDS/SOHO observations*: Simultaneous observations of the same active region AR 10646 were performed also with CDS/SOHO instrument using its NIS spectrometer in 'sit and stare' mode, i.e. the slit position was fixed and the solar rotation was not compensated. The width of the slit was 4 arcseconds and its length was 141 arcseconds. Sets of 6 EUV spectra images were recorded simultaneously. Namely the spectral lines of He I 584.33 Å ($2\text{x}10^4$ K), O III 599.59 Å ($8\text{x}10^4$ K), O V 629.73 Å ($2.5\text{x}10^5$ K), Ne VI 562.80 Å ($4\text{x}10^5$ K), Mg IX 386.04 Å ($1\text{x}10^6$ K), Si XII 520.67 Å ($2\text{x}10^6$ K) were recorded. The exposure time of the spectra images was 10 seconds and the sets of six spectra were recorded every 15 seconds. A total number of 290 sets of the six spectral lines was recorded during the observation. The period of the registration of the spectra started at 08:12 UT and lasted up to 09:25 UT. An example of time-space maps of intensities of three EUV lines is shown in Figure 5. No special reduction of data was made for CDS/SOHO observations, because of delay of the delivery of the raw data to our disposal. Only overview data provided on-line during the observations are used in this work.

3. Results

Our results are shown in Figures 3, 4 and 5. The changes of the *flare relative areas* (expressed by the number of pixels which exceed the threshold limits) are shown in Figure 3 for the threshold limits 215 - 230 AIU and in Figure 4 for the threshold limits 235 - 250 AIU. Several interruptions of the curves in Figures 3 and 4 belong to those short periods when the slit-jaw image system registered white-light images instead of Hα ones.

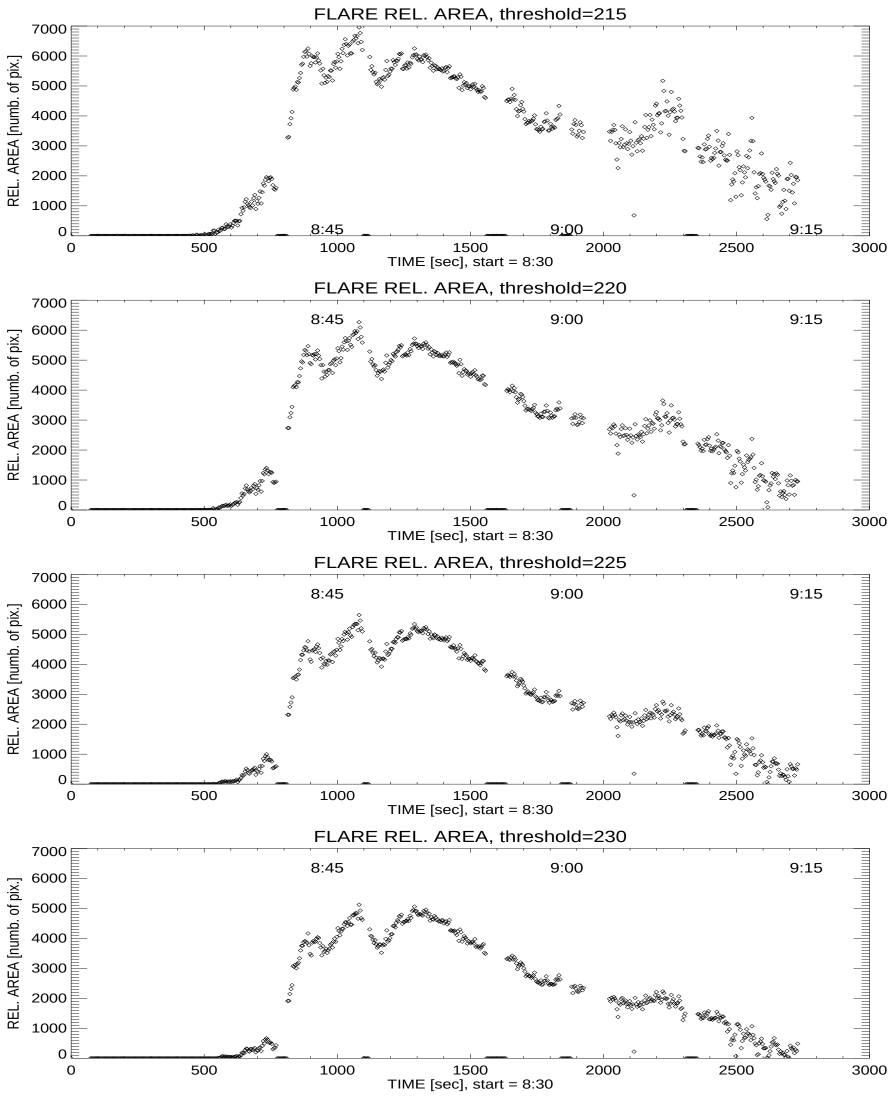

Figure 3: The changes of the *relative flare area* (expressed in the number of pixels which exceed the threshold limit) in slit-jaw Hα images, for time interval 08:31:13 – 09:15:30 UT for thresholds of 215, 220, 225 and 230 arbitrary intensity units (AIU), respectively. Several interruptions of the curves indicate periods when the slit-jaw system was used to record white-light images.

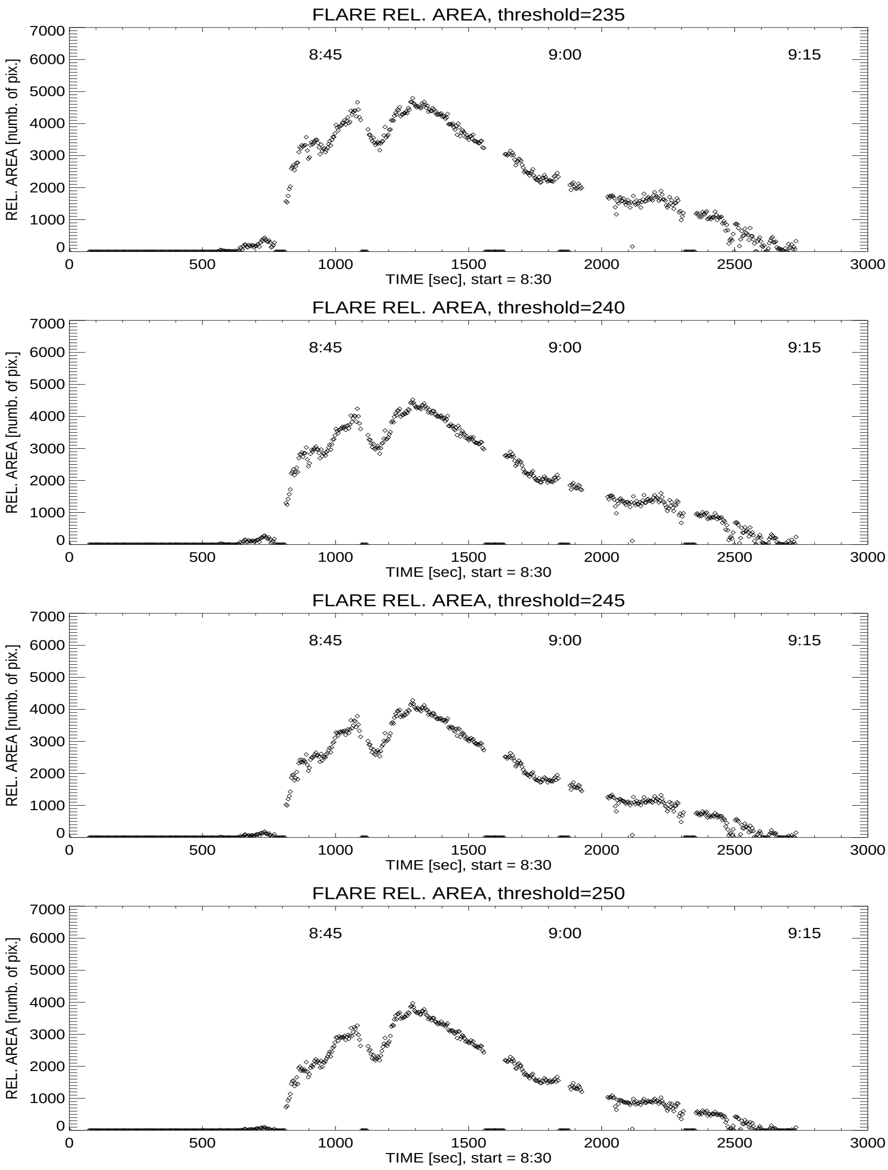

Figure 4: The same as in Figure 3 but for thresholds of 235, 240, 245 and 250 arbitrary intensity units (AIU) respectively.

4. Discussion and conclusions

Sensitivity of the method: The method suggested and used for calculations of the *relative flare area* gives fully acceptable results almost for all threshold limits. It can be seen in Figures 3 and 4 that the period of the flare duration i.e. the appearance of no-zero area of the flare, is very similar for threshold limits ranged from 230 to 250. It means that the thresholds of 90%, 92%, 94%, 96% and 98% of the maximum intensity of the image are usable for the estimation of the *relative flare area*. The threshold of 225 = 88% of the maximum intensity of the image is on the lower limit of the correct estimation of the *relative flare area*. This pronounces well all temporal changes and duration of the *relative flare area* and still keeps small scattering of data. The thresholds of 240 = 94% of the maximum intensity seems to be the upper limit of the correct calculation of the *relative flare area* because the next two limits (245 = 96% and 250 = 98% of the maximum intensity) have already lost some features in the curves. (c.f. small enhancements of the *relative flare area* at the beginning at about 650 seconds, as well as the enhancement at 2200 seconds). The smaller number of pixels shows that only hot kernels of the flare were matched by this two highest threshold limits. The first two threshold limits (215 = 84% and 220 = 86% of the maximum intensity) give higher scattering of the data and express still same no-zero *relative flare area* in the end of flare duration. This is caused by matching of the hotter parts (rest of the flare) in the active region and including them to the *relative flare area* because of too low threshold limits. We can conclude that threshold limits from the interval of 84% - 98% of the maximum intensity of the Hα images are suitable for calculation of the *relative flare area*.

Flare results discussion: For an estimation of the basic parameters of the flare we used the results obtained for the threshold limit 225 = 88% of the maximum intensity. The duration of the Hα flare expressed as a *relative flare area* larger than zero was 35.8 min, c.f. Figure 3 the third panel from top. Duration of the gradual phase of the Hα flare was estimated to be 4.58 min. Two remarkable drops and one enhancement of the *relative flare area* were recognized in the flare duration. Namely the drops appeared at the time points 950 and 1150 seconds respectively and the enhancement appeared at the time point 2225 seconds. All these changes were modulated by dismiss and occurrence of flare kernels as it was found after careful in-

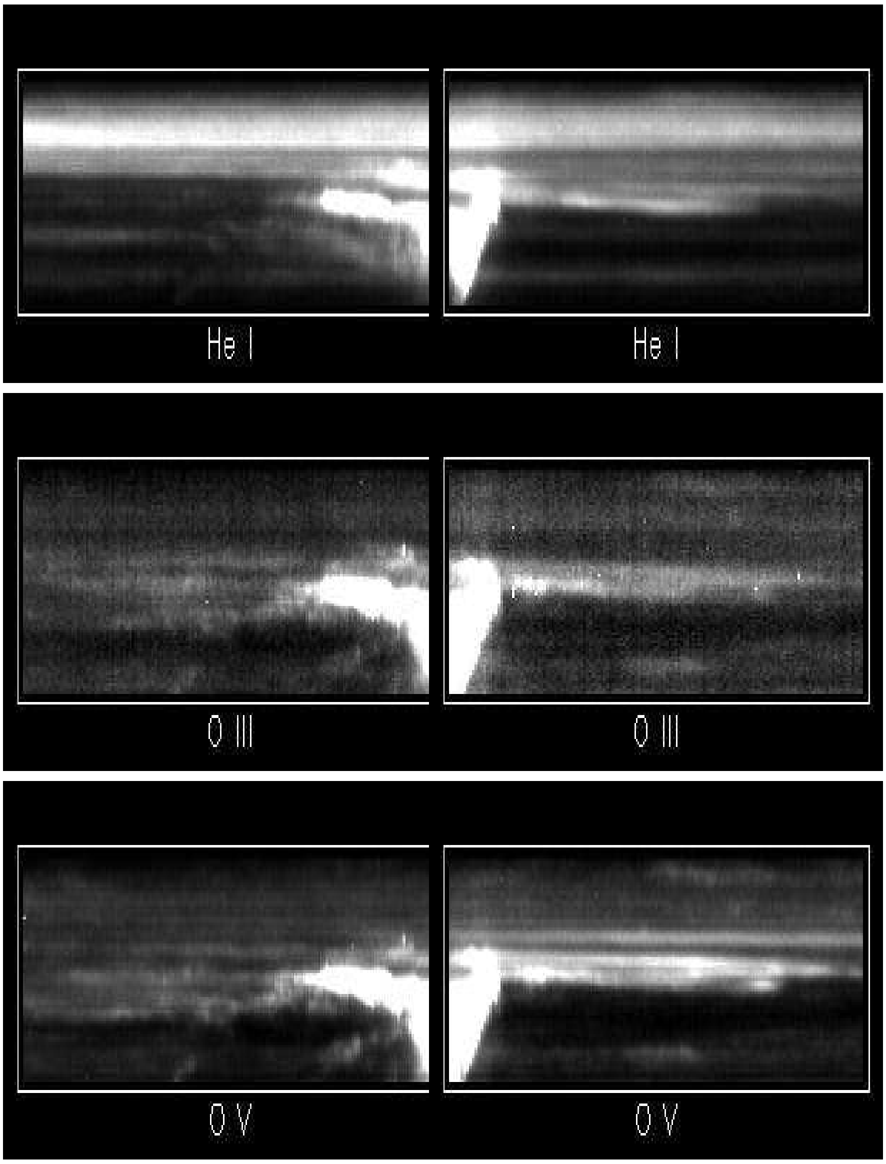

Figure 5: Composition of two sub-intervals of observations of time development of the intensities of three (chromosphere and transition region) EUV spectral lines (He I, O III and O V) with CDS/SOHO instrument. The x-axis of the whole composed double-image covers the time interval 08:12 – 09:25 UT and time is running from the right to the left. The y-axis represents 14 arcseconds i.e. the slit length.

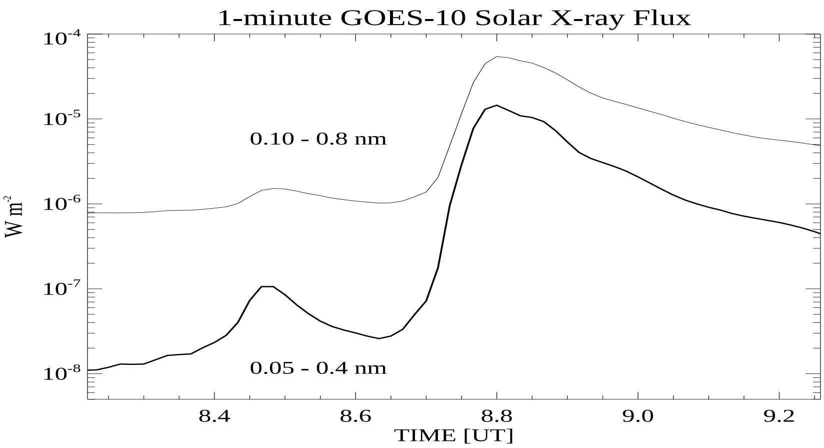

Figure 6: Solar X-ray flux measured in two channels for the period of the occurrence of the M5.4 flare.

spection of the original sub-images. Comparisons of the *relative flare area* changes and the GOES 10 solar X-ray flux data (Figures 3, 4 and 6) show that the moments of the start and of the maximum phase of the flare are almost identical in both the x-ray flux and in the *flare relative area* but the gradual phase is shifted forward in time in the case of the Hα flare development. This coincidence and possible small time shifts in corresponding phases of the flare will be case of further investigation. The EUV spectral observations gained with the CDS/SOHO instrument (c.f. an example is shown in Figure 5), which were taken simultaneously with the observations of the flare in Hα, will also be used for investigation of the coupling of the H alpha flare with higher parts of the solar atmosphere. The detailed comparison of the results will be made in near future, when the raw CDS data will be at our disposal.

References

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