H\textalpha{} RED ASYMMETRY OF SOLAR FLARES*

K. ICHIMOTO and H. KUROKAWA
Kwasan and Hida Observatories, University of Kyoto, Kamitakara, Gifu, 506-13, Japan

(Received 12 December, 1983; in revised form 30 March, 1984)

Abstract. The evolutional characteristics of the red asymmetry of H\textalpha{} flare line profiles were studied by means of a quantitative analysis of H\textalpha{} flare spectra obtained with the Domeless Solar Telescope at Hida Observatory. Red-shifted emission streaks of H\textalpha{} line are found at the initial phase of almost all flares which occur near the disk center, and are considered to be substantial features of the red asymmetry. It is found that a downward motion in the flare chromospheric region is the cause of the red-shifted emission streak. The downward motion abruptly increases at the onset of a flare, attains its maximum velocity of about 40 to 100 km s\textsuperscript{-1} shortly before the impulsive peak of the microwave burst, and rapidly decreases before the intensity of H\textalpha{} line reaches its maximum. Referring to the numerical simulations made by Livshits et al. (1981) and Somov et al. (1982), we conclude that the conspicuous red-asymmetry or the red-shifted emission streak of H\textalpha{} line is due to the downward motion of the compressed chromospheric flare region produced by the impulsive heating by energetic electron beam or thermal conduction.

1. Introduction

The red asymmetry of the H\textalpha{} line profile of flares is one of the most conspicuous and common features in flare spectra; in their statistical study of 244 spectra of 92 flares Švestka et al. (1962) found that 80\% of flares have at least one region with red asymmetry. Tang (1983) has also reported that 92\% of 60 flares show red asymmetry in the study of H\textalpha{} monochromatic images of flares. Therefore we can expect that the red asymmetric profiles of H\textalpha{} flares imply a substantial information of thermodynamic structures in chromospheric flares. Though several models have been proposed, we have not yet settled upon the proper explanation for this important feature (Švestka, 1976).

For the solution of this problem it may be essential to study the evolutional changes of H\textalpha{} line profiles through every developing stage of a flare. There have been, however, only a few published observations which can show the time history of H\textalpha{} profiles from the start of a flare because of the difficulty in setting and holding correctly an identical flare point on the spectrograph slit. In their most extensive study on the temporal variations of H\textalpha{} profiles for 24 flares, Schoolmann and Ganz (1981) described that all of the H\textalpha{} emissions which show significant shift are shifted toward longer wavelengths and asymmetries tend to diminish with time. But they did not make any further quantitative analysis for their data.

In 1982, using the 60 cm Domeless Solar Telescope at Hida Observatory of Kyoto University, we obtained many H\textalpha{} spectra of flares with fairly high spatial and temporal resolutions. We quantitatively analyzed the H\textalpha{} profiles of selected events and studied the evolutional characteristics of the red asymmetry referring to the development of the corresponding microwave burst flux which should be a manifestation of the impulsive flare energy release. These results are given in Sections 2, 3, and 4. In Section 5 we

* Contributions from the Kwasan and Hida Observatories, University of Kyoto, No. 258.

discuss the possible reasons for the red asymmetric profiles in connection with the chromospheric heating mechanisms of a flare.

2. Observation and General Results

Observations were made in 1982 with the vertical spectrograph of the 60 cm Domeless Solar Telescope at Hida Observatory of University of Kyoto. The image size of the Sun is 30 cm in diameter on the slit of the spectrograph and the applied slit width of 100 μm corresponds to about 0.7 arc sec on the Sun. Since it is essential to reduce the exposure time in order to get a high spatial resolution, we adopted a fairly low dispersion of the spectrum i.e. 0.9 mm Å⁻¹ at Hα line; the exposure time for Hα spectra was 1/30 s with the Kodak 2415 film. In consequence, the average spatial resolution along the Hα spectral lines of flares was 0.7 to 2 arc sec depending on the seeing condition. The temporal resolution of our flare observation is also better than those which have ever been published; in the rising phase of flares, a Hα spectrum was taken every 2 or 3 s.

Since the primary aim of our observations is to study the evolutional change of Hα line profile of a flare at every developing stage of it, we intended to catch the flare kernels from the very beginning of a flare and keep them constantly on the spectrograph slit throughout their lives. These attempts, however, are not always successful because of the difficulties in predicting the precise location where the flare occurs and inevitable random motion of the solar image due to the atmospheric scintillation.

We obtained Hα spectra of 30 flares in 1982. Examining these spectra, we found no evidence for the predominancy of the blue asymmetry noted by Švestka et al. (1962) and Severny (1968) at the onset of a flare. On the contrary, almost all Hα flare spectra observed in this study show a striking dominance of the red wing over the blue wing from onset of the flare. This result agrees with that of Tang (1983) obtained with the Hα filtergram observations. The typical examples of Hα spectra and slit-monitoring pictures at the flash phase of the flares are given in Figure 1 where broad Hα emission streaks (A), (B), (C), and (D) can be clearly seen to shift toward the longer wavelength from Hα line center. Since these red shifted emission streaks are very often observed at the initial phase of flares, we came to the tentative conclusion that such a red shifted emission must be the very substantial feature in the red-asymmetric profiles of Hα flares.

We can summarize the general characteristics of red-shifted Hα emission streaks, which will be simply called red streaks hereafter, as follows: (1) Red streaks correspond to some spatially confined small flare points successively brightening in so-called Hα flare kernels which may be identified with foot points of flaring loops. The size of a flare point is smaller than the average spatial resolution in this study or less than 1 arc sec. (2) The red streak is a common and substantial feature at the initial phase of almost all flares which occur near the disk center of the Sun, though it can not always be correctly observed for small flares without a good seeing condition. (3) Conspicuous red streaks appear at the initial phase of a flare. We studied the temporal correlation between the appearance of Hα red streaks and microwave burst flux in 3750 MHz observed at Toyokawa Observatory in Figure 2 where the typical examples of this correlation are