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WHITE LIGHT FLARE AT THE SOLAR LIMB

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ABSTRACT

A white light flare was observed at the limb on 16 August 1989 in He 10830 Å spectra, Hα slit jaw photo-grams, and white light filter-grams of λ=5600 Å ±800 Å . The kernels of the white light flare are not spatially related with Hα brightenings, suggesting that the flare energy would be released at the photosphere.

Key words : Sun: white light flare—Sun: He 10830Å–Sun: limb flare

I. INTRODUCTION

A WLF (white light flare) is a brightening event at the photosphere /lower chromosphere, associated with a large X-class flare. WLFs, observed on the disk, are easily compared with the location of Hα brightenings and soft/hard X-ray bright points on the disk observation, while WLFs, observed at the limb, show their side views.

WLFs observed at the limb are rather rare, but fortunately a WLF just at the limb was simultaneously observed on 16 August 1989 in both Japan and China. It was one of the largest X-class flare (X20) observed in the solar cycle 22. White light images were observed in Japan (Hiei et al. 1992), and their line profiles of He 10830 Å and their slit jaw photographs of Hα images in China (You et al. 1998). It is found from the comparison of the WLF kernels with Hα brightenings, as shown in Fig. 3 in Hiei et al.'s paper (Hiei et al. 1992) was wrong, and the positions of the WLF kernels do not coincide with those of Hα brightenings.

II. OBSERVATIONS AND DATA

Observation and data reduction are briefly described here and their detail description is referred to the other papers (Hiei et al. 1992; You et al. 1998).

The WLF was photographed with a 15cm-aperture equatorial telescope on Fuji mini-copy film by using Y48 sharp cut filter. The filter transmits a longer wavelength than λ=4800 Å , while the film does not have a sensitivity longer than λ=6500 Å . Therefore the solar images were effectively taken at a wavelength of λ=5600Å with a half-band width of 800 Å . Total 23 images of a solar diameter 218mm were obtained with exposure times 1/2-1/250 s.

The He 10830Å line observations were made with a one-dimensional Reticon system mounted on the multi-channel spectrograph at Purple Mountain Observatory. The spatial resolution is $0.5'' \times 3''$, and the linear dispersion is about 1.94 Å /mm, corresponding to a sampling interval 1.3 km/s per pixel with the integration time of 10 s. The flaring region was scanned once every 30-90 s. The solar image around the slit was monitored and photographed simultaneously with He 10830Å in Hα images (0.5Å pass band) with a slit -jaw system.

III. CLASSIFICATION OF WLF

A direct image of WLFs is classified into four types from their appearance: 1) impulsive, 2) gradual, 3) moving, and 4) spray (Hiei 1986, 1993). The impulsive type shows a rapid intensity fluctuation with changing its brightened region nearby. This is in good correlation with a time change of hard X-ray flux(Fang & Ding 1994). This brightening would be due to the precipitation of accelerated particles. The gradual type shows a gradual increase in intensity, and the brightened region shows a slow movement in the same direction as an Hα bright strand of a two-ribbon flare. This type of brightening appears both at an impulsive phase and also even at a later phase of a flare. This might be related to a phenomenon of heat conduction/irradiation of an original energy release site to the chromosphere / the photosphere. The moving type is diffusely seen on the photosphere and moves toward the sunspot nearby or in the opposite direction (Zirin & Tanaka 1973; Machado & Rust 1974; Hiei 1986). The spray type shows a quite similar as a spray of a prominence, and sometimes outside the solar limb (Notuki et al. 1956; Hiei 1986).

Spectroscopic observations show that there are three types of spectral distributions (Machado et al. 1986; Hiei 1986; Fang & Ding 1994); type I) Balmer jump and Paschen jump are appeared, type II) almost flat spectrum without Balmer/Paschen jump, and type III) bluish color. Type I or II spectral feature is explained by considering the emission sources of bound-free transition of hydrogen, free-free transition of hydrogen, negative hydrogen, Thomson scattering, and electron scattering (Machado & Rust 1974; Hiei 1982; Neidig 1983;

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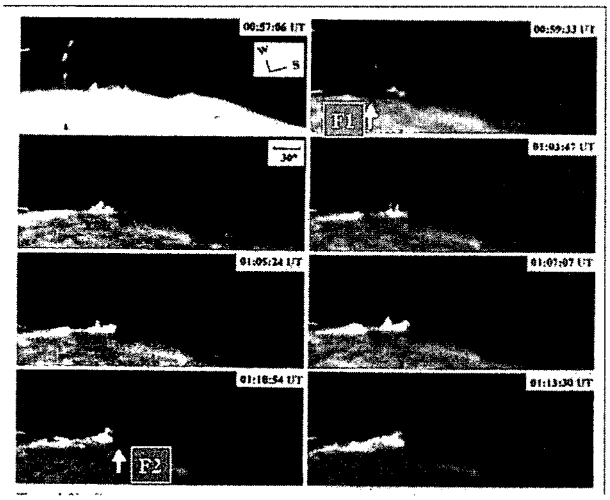

Fig. 1.— Hα filtergrams observed by the slit jaw system at Purple Mountain Observatory. The arrows F1 and F2 show the position of white light bright knots F1 and F2, respectively.

Donati-Falchi et al. 1985; Hénoux et al. 1993; Fang, et al. 1993; Fang & Ding 1995; Ding, Fang, & Yun 1999) It is concluded that type I spectrum is mainly due to bound-free emission of hydrogen and negative hydrogen, and type II due to negative hydrogen without bound-free emission.

The energy source of WLFs is not completely known. According to a conventional flare model, its energy is initially released in the low corona, and the chromosphere is then heated by penetration of non-thermal electron/proton, by conduction, or by irradiation, and the photosphere is also heated if its energy is strong enough. WLFs of type I could be explained by the conventional flare model, but WLFs of type II has a problem. If the energy release site is in the low corona, then the energy will heat both the chromosphere and the photosphere. It would be difficult for the energy to reach to the photosphere without any affect to the chromosphere unless some special mechanism will work, for example, the chromosphere above the kernel of WLF on the photosphere will disappear during the flare, which would be unrealistic.

The explanation of type II spectrum is tried (Fang & Ding 1995; Ding, Fang, & Yun 1999; Matthews, Brown, & van Driel-Gesztelyi 1996). They consider that the energy is released in situ: lower chromosphere/ the photosphere. Recently Shibasaki (2001) proposed high-beta instability, which might supply enough energy to a flare, but in this case mass motion in the photosphere/the low chromosphere will be observed.

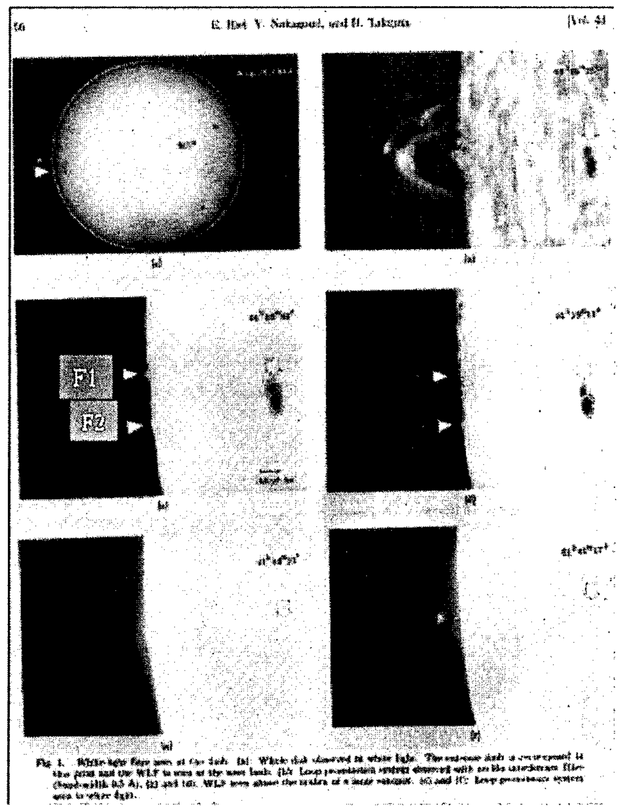

Fig. 2.— Bright knots, F1 and F2, of white light flare on 16 August 1989.

IV. COMPARISON OF WLF KNOTS WITH Hα BRIGHTENINGS

The WLF brightening (F1), observed on 16 August 1989, was of a mound shape with 4000 km width at the bottom and 1000 km height, appeared just at the limb. The height difference of the Hα chromospheric limb above the limb of the photosphere is about 3000 km, as seen in Fig.1 (b) and Fig.1(c)- (f) in Hiei et al.'s paper (1992). The WLF knots are surely located under the Hα chromosphere.

Hα flares observed at the limb show different brightening; i) bright knots, lying just on the Hα chromospheric limb before the onset of the flare, rapidly rise up and brighten up as a flare, ii) bright matter swells from plage region, suggesting that the flare energy comes from above iii) pre-existing thin Hα cloud makes bright.

In the case of the limb flare of 16 August 1989 event, two bright points of plage evolved to be flare kernels at 00:59. Almost at the same time 3 cm radio burst shows peak intensity (You et al. 1998). White light knot, F1 in Hiei et al.'s paper, was first detected at 01:02 and seen until 01:25, and F2 was seen from 01:11 to 01:18 (Hiei et al. 1992). Both white light knots (F1 and F2) at the onset do not correspond to Hα brightenings on the slit jaw photographs.

If such a purely photospheric brightening could be spectroscopically observed, flat continuum of the flare spectrum, type II, would be expected.

V. He 10830Å LINES

Essential property of He 10830 Å lines is described in You et al.'s paper (1998), and here brief characteristics are mentioned. At some region the intensity of He 10830 Å line emission shows maximum, but its back ground continuum is not so high, and vice versa, the intensity of the continuum shows maximum at the other region, but not high in the intensity of He 10830 Å line emission. This may suggest that the higher temperature region and the higher density region are not the same, in order to explain He 10830 Å line emission and the continuum.

It is interesting to note that the emission always shows blue asymmetry, but the absorption lines of He triplets do show at the original wavelengths, which suggests that the absorbing matter of the He 10830 Å gas surrounding the flare region is stationary.

VI. CONCLUDING DISCUSSION

Since Carrington (1859) and Hodgson (1859) found WLF on 1 September 1859, there accumulated many data on the images and spectra of WLFs, and we know that the brightened region of WLFs is in the low chromosphere/the photosphere. But there remains the problem of the energy supply, which is not solved yet. WLFs of type I may be understood by the conventional flare model, but WLFs of type II are not known. The ground-based observation, collaborated with space observation will make clear the energy problem.

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