2. MOTION PICTURES AND PHOTOMETRIC STUDIES OF SOLAR FLARES

By HELEN W. DODSON

The projection of lapse-time photography of solar flares permits those who have not had the privilege of extensive observation of this type of solar activity to gain some insight into the overall aspect of the flare phenomenon. In addition, motion pictures of Hα flares taken with relatively high magnification show very clearly the inherent difficulties of trying to codify flares by single numbers in an importance scale, or by single measures of area or intensity. Some flares are relatively simple, but most are complex in both form and activity. Often there are many separate parts to the flare; some brighten simultaneously and others successively in time. Although flares are usually brightenings of a previously existing plage, the motion pictures depict vividly the intimate relationships in both location and motions between certain bright flares and the dark filaments.

The prevalence and vast extent of active dark flocculi at the time of flares is made evident by the film. Sometimes previously existing dark filaments are disturbed by an adjacent flare and become active. In other cases the bright flares are accompanied by the formation of ephemeral dark flocculi. On the film some of these resemble small 'puffs of smoke'. Other dark flocculi travel far across the disk and become prominences beyond the limb.

Although the motion pictures indicate that caution must accompany efforts to represent the complex flare phenomenon by relatively simple measured quantities, such efforts have been made at the McMath-Hulbert Observatory. Light curves and areas have been derived for many parts of 194 flares and sub-flares. The light curve for the brightest part of the flare and the area at the time of maximum intensity have been chosen to represent the phenomenon. On the basis of these measurements certain relationships have been examined.

There is no clear-cut relation between the rate of increase in brightness and the maximum intensity attained. However, there is some evidence that very bright maxima are favoured by a fast rate of rise and discouraged by a slow rate of increase in intensity. Certain flares decline in brightness as fast as others rise to maximum, but for any one flare the decrease in intensity is slower than the rate of increase. The position of the flare on the disk plays some part in the observed rates of change of Hα intensity. The slowest rates of both rise and decline were observed only for flares in the central part of the solar disk. The fastest rates of decline occurred only with flares near the limb of the Sun.

In addition, the position of the flare on the disk influences in some degree the observed maximum intensity of the flare. In units of the local continuous spectrum near Hα, the average maximum intensity of the 194 flares and sub-flares increased from centre to limb. In units of the central continuous spectrum, the average intensity diminished with increasing distance of the flares from the centre. 'Limb darkening' in the centre of Hα appears to be less for flares than for the undisturbed parts of the solar disk. It is also less than for the continuous spectrum near Hα. Linear equations expressing 'limb darkening' in the centre of Hα for flares and sub-flares are:

$$\text{Flares: } I_c = 0{\cdot}63 + 0{\cdot}34 \cos\theta$$

$$\text{Sub-flares: } I_c = 0{\cdot}36 + 0{\cdot}26 \cos\theta$$

where θ is the angular distance of the flare from the centre of the solar disk.

The highest intensities measured for flares in the photographic programme were 1·9 times the local continuum for a flare at CMD 72°, and 1·6 times the central continuum for a flare at CMD 15°. It had been hoped that careful measurement of photographic data would confirm and sharpen the often-suggested relationship between area and maximum intensity of flares. Such is not the case. It can be said that, in general, flare intensity and area increase together, but for the 194 flares in our study the correlation coefficient of area and intensity was only 0·58. Furthermore, for flares in the study with area as large as 200 millionths of the solar hemisphere the correlation coefficient between area and intensity in units of the local continuum was only 0·30. For flares with areas as great as 300 millionths, it was reduced to 0·03, or no systematic increase of intensity with area. Area and duration of the flare appear to be more closely associated than do area and maximum intensity. On the average, large flares continue for a longer period of time than do small flares.

Comparison of the photometric light curves for flares with the times of associated sudden ionospheric disturbances, as reported by or through the Central Radio Propagation Laboratory of the United States National Bureau of Standards, indicates that generally the S.I.D. starts during the ascending branch of the flare light curve and before maximum intensity has been attained. Flare-durations based on light curves measure the period of changing Hα intensity and tend to be considerably longer than flare-durations based on visual observations. According to the durations as shown by light curves, flares near the central part of the solar disk and their associated S.I.D.'s cover very nearly the same time interval. On the other hand, S.I.D.'s accompanying flares near the limb tend to last considerably longer than the observed Hα event.

The above results have been confirmed by direct examination of records of the 5 Mc./sec. WWV signal as obtained by the School of Electrical Engineering at Cornell University. Furthermore, examination of the Cornell records has indicated that there are numerous, well-defined, flare-associated disturbances of the ionosphere that have not hitherto been reported. This stems in part from the fact that some of the disturbances start more gradually than the usually recognized Dellinger effects. The validity of these flare-associated 'gradual ionospheric disturbances' has been confirmed by comparison with the ionospheric records of the National Bureau of Standards by members of their ionospheric staff.

3. OPTICAL OBSERVATIONS OF SOLAR FLARES

By M. A. Ellison

1. Flares on the Disk

A flare is a catastrophic event occurring on the Sun which has immediate repercussions on the Earth.

Let me illustrate some of the properties of flares by reference to three of the greatest which have been fully recorded in recent times:

(*a*) 1942, February 28; time of flash, 12^h00^m; duration, $>3^h{\cdot}5$; area of emission filaments, 2200 m.; long. E. 04°, lat. N. 07°. It was this flare which led to the discovery of solar radio noise by J. S. Hey, and it also enabled the writer to detect the asymmetry in the emission Hα line (this effect having been noted independently by M. Waldmeier in 1941). Sudden ionospheric disturbances (an intense crochet and a radio fadeout of duration $>8^h$) coincided with the time of the flash. A magnetic storm, classified as great (G), began $19^h{\cdot}4$ later. This flare also gave rise to the first recorded burst of cosmic radiation (+7% at Cheltenham) which reached maximum intensity 1^h after the maximum of the flare (1, 2).

(*b*) 1946, July 25; time of flash, 16^h27^m; duration, $>4^h{\cdot}3$; area of emission filaments, 2500 m. and overall length 550,000 km.; long. E. 15°, lat. N. 22°. Spectra photographed at Sherborne showed the Hα emission line 16 Å wide at maximum with central intensity 300% of the continuum. The continuous spectrum of the flare (intensity 10% of the adjacent continuum at λ 6000) was recorded at the same time. Accompanied by intense S.I.D.'s of long duration (fadeout $>5^h{\cdot}5$). The burst of radio noise on 72 Mc./s. (maximum $16^h24^m - 16^h27^m{\cdot}5$), as recorded by Lovell and Banwell, surpassed the solar black body value by a factor of 10^8. The associated cosmic ray burst reached its maximum intensity (+20% at Cheltenham) $2^h{\cdot}5$ after the flare flash. A magnetic storm, classified as very great (V.G.), began $26^h{\cdot}4$ after the peak intensity of the flare (3, 4).

(*c*) 1949, November 19; time of flash, 10^h32^m; duration, 1^h40^m; area of emission, 2120 m.; long. W. 70°, lat. S. 02°. This flare was noted for a great blow off of chromo-