OBSERVATION OF A NEW TYPE OF FLARE*

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Introduction

The importance of chromospheric flares from both the astrophysical and geophysical points of view is now generally recognized, but, in spite of the extensive observational material collected by Ellison, Dodson, and others, it must be admitted that the mechanism of their origin is still little understood. In this paper we present observations of a hitherto unobserved phenomenon, namely, the ejection of a mass of very bright material from a flare some 28° from the limb of the Sun. The ejection occurred several minutes before flare maximum. It was approximately 10,000 by 30,000 km in size and moved outwards with a velocity across the line-of-sight of 300 km/sec. As it did so,

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it brightened appreciably, reaching maximum intensity $3\frac{1}{2}$ min after expulsion, its height then being 25,000 km. The ejection was quite unlike the dark surge prominences often emitted from flares, and in fact, except for its motion, possessed all the properties of a small flare.

Observations

The observations were made with the Hα-patrol camera of the C.S.I.R.O. Division of Physics in Sydney. The apparatus consists of a 5 in. horizontal telescope fed by a conventional coelostat and equipped with a $0 \cdot 7$ Å Lyot filter. Photoelectric guiding is employed, and exposures are automatically controlled by a rotating sector-disk shutter whose speed of rotation is regulated by a photo-

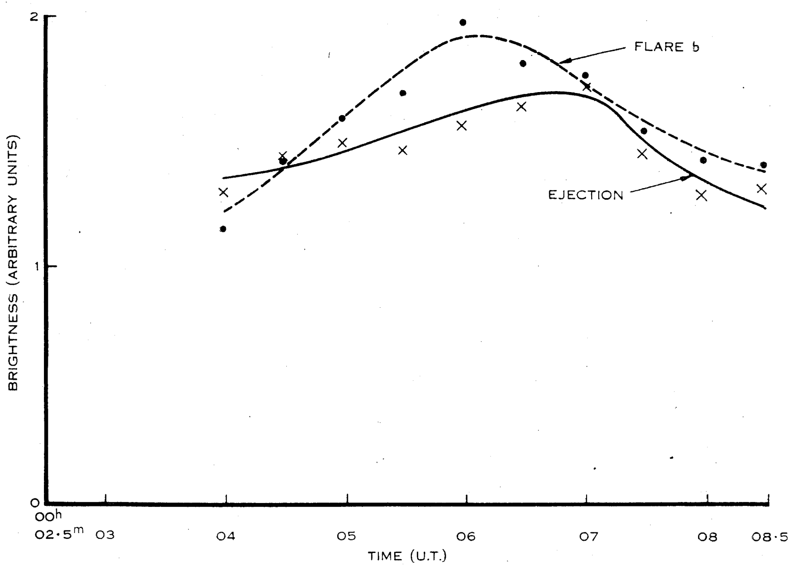

Fig. 1.—Light curve of ejection. For comparison the light curve of a small flare somewhat to the right of the ejection (cf. Plate 1) is also shown.

cell. On Kodak IV E film, and with an image diameter of 15 mm, the exposure time is about 1/30 sec. The equipment is in daily use for 35 mm cinematography of the Sun in light centred on Hα, usually on a 30 sec cycle.

Plate 1 shows a portion of the east limb for the period $00^{h}\ 02^{m}\cdot 5$ to $00^{h}\ 17^{m}\cdot 5$ U.T. on November 12, 1956. At $00^{h}\ 02^{m}\cdot 5$ a Class 2 flare is seen to be developing 28° from the limb ; one minute later a small portion begins to detach itself, and by $00^{h}\ 04^{m}\cdot 5$ has become completely detached. The ejected portion continues to move outwards, at the same time becoming elongated and brightening perceptibly. At $00^{h}\ 06^{m}\cdot 5$ a bright core is visible in the ejection; this can also be seen at $00^{h}\ 07^{m}$ where, however, the definition is poor. Maximum brightness is reached at $00^{h}\ 07^{m}$; thereafter the ejection fades somewhat, meanwhile continuing to elongate. Eventually it splits up into two nearly separated components which reach the limb at $00^{h}\ 08^{m}\cdot 5$. The last three photographs, taken 3 min apart, show the ejection after crossing the limb.

Here the appearance suggests an ordinary surge prominence; the contrast between the disk and the limb in the last three prints has been artificially increased in order to show the detailed structure.

Figure 1 gives the light curve of the ejection (in arbitrary units) together with that of a small flare somewhat to the right of the ejection—visible on Plate 1—which began to brighten at $00^h\ 03^m$. The light curve was obtained by microphotometry of the negatives, using an effective scanning aperture of 3500 km, i.e. one-third the smaller dimension of the ejection. Photometric

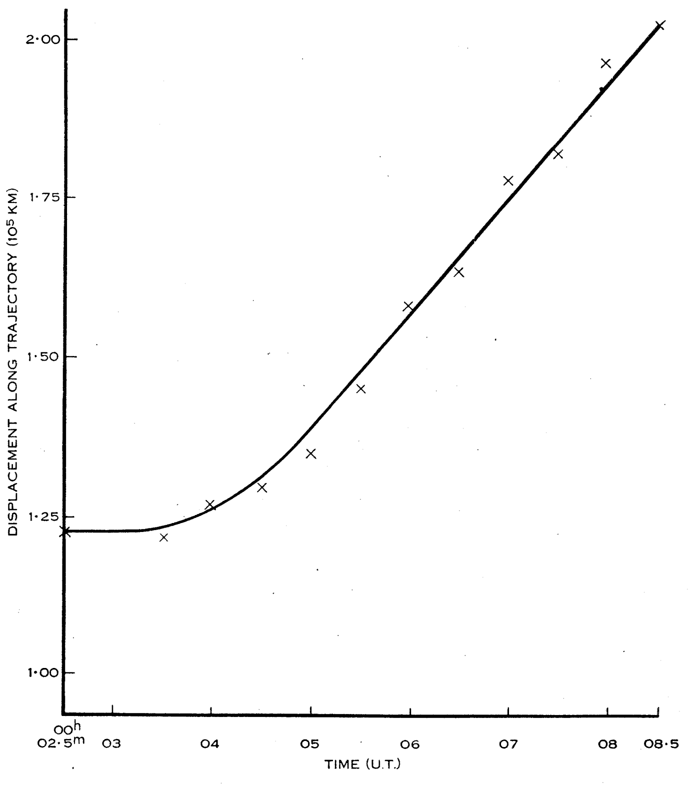

Fig. 2.—Displacement of the foremost point of the ejection along the trajectory, measured from an arbitrary reference point. The linear portion of the curve corresponds to a velocity across the line-of-sight of 300 km/sec.

calibration was provided by six out-of-focus exposures, taken through standardized filters, which are made on the daily films as a matter of routine. There was a significant increase in brightness as the ejection moved outwards, the maximum being attained at $00^h\ 07^m$, that is, $3\frac{1}{2}$ min after expulsion. At this time the brightness was only 14 per cent. less than that of the neighbouring small flare; this would seem to classify the ejection as a flare in its own right.

It must be emphasized that the time of maximum brightness—and indeed the whole light curve—is to some extent rendered uncertain by possible Doppler displacements of the Hα line from the centre of the pass-band of the Lyot filter.

The actual velocity in the trajectory is so large (300 km/sec) that quite a small change in the *direction* of motion is sufficient to shift the Hα line of the ejection by an amount comparable with the half-width of the filter, thus appreciably altering the apparent brightness. In the early phase of the expulsion, when the velocity was small or zero (cf. Fig. 2), the light curve gives the actual brightness of the ejection, but thereafter the measured values only represent lower limits to the brightness. It is clear that after expulsion a real increase in brightness, at least as great as that measured, must have occurred.

The fact that this high velocity ejection was visible at all suggests that the motion was substantially in a plane perpendicular to the line of sight so that, throughout its motion, its height above the Sun's surface steadily increased. It is very remarkable that the brightness was increasing while the ejection was actually in the corona, the maximum apparent brightness being attained at a height of 25,000 km at $00^{h}\ 07^{m}$.

Dr. J. A. Roberts of the Radiophysics Division, C.S.I.R.O., has kindly informed us that a cluster of normal type III bursts was recorded by the radio spectrometer at Dapto from $23^{h}\ 59^{m}$, November 11, 1956, to $00^{h}\ 01^{m}$, November 12, 1956. It thus preceded the flare by over two minutes but, as other flares were in progress at this time, the observed radio bursts are not necessarily correlated with the flare under discussion. Small bursts at 600 and 1420 Mc/sec were recorded at Potts Hill.

No sunspots were visible in the region of the flare until November 16, when a few small spots appeared; these were decaying on the 19th, and had disappeared by the following day.

TABLE 1

FLARE DATA

Areas are given in millionths of visible hemisphere, and are not corrected for foreshortening

Flare	Duration (U.T.)	Time of Maximum	Area	Radial Distance	Disk Longitude	Heliographic Coordinates
a	$00^{h}\ 01^{m}\cdot 5$–$00^{h}\ 28^{m}$	$00^{h}\ 06^{m}$	200	0·88	—62°	29 °N. 172 °W.
b	$00^{h}\ 03^{m}$ –$00^{h}\ 21^{m}$	$00^{h}\ 06^{m}$	30	0·93	—72°	32 °N. 162 °W.

To complete the description of the observations, Table 1 gives the durations, times of maximum brightness, areas, and heliographic coordinates of (*a*) the flare from which the ejection occurred, and (*b*) the small flare visible to the right of the ejection in Plate 1.

Discussion

The brightness of the ejection, its rise to a maximum, and its concentrated appearance suggest that it was actually a flare in its own right and, moreover, one moving with a relatively high velocity. The question of flare motions has been discussed by Ellison (1949, cf. p. 13), who believes the evidence is in favour of the stationary nature of flare emission regions. Thus from a study of 99 flares he finds no displacement of the Hα line greater than 0·4 Å which, on a Doppler interpretation, implies velocities of less than 18 km/sec. Ellison emphasizes (1949, cf. p. 5) that at the extreme limb care must be taken to distinguish between *flare surges* and flares; otherwise high velocities might falsely be attributed to the flare itself. On the disk no such confusion is possible, such flare surges appearing as dark streaks—quite unlike the bright, discrete mass observed here.* However, on the disk an additional source of confusion is possible: the impression of large velocities may be given by the "fading" and "lighting-up" of successive chromospheric filaments characteristic of flare development (Ellison 1949, cf. p. 14). In the present case, the absence of any chromospheric plage structure in the region traversed by the ejection (cf. Plate 1) and the constancy of its velocity make this explanation untenable.

In contradiction to Ellison, Severny and Shaposhnikova (1954) claim to have detected high velocity motions in flares. However, their published photographs do not reveal any cases of flare development which appear in any way unusual and provide no clear substantiation of their claims.

It seems, therefore, that the phenomenon described in this paper is rare if not unique; during the course of examination of our film records containing some 500 flares nothing else resembling it has ever been noticed. On the other hand it must be pointed out that, if any similar ejection should happen to possess a large component of its velocity in the line-of-sight, it would escape detection owing to the relatively narrow bandwidth of the monochromator.

Acknowledgment

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* Occasionally bright surges have been seen just within the limb (Ellison 1950; Dodson and Hedeman 1952); the brightness is always considerably less than that of a flare, however. The flare discussed in this paper is properly described as a disk flare, the distance from the limb being 28° of longitude.