STUDY OF THE FLARE-SURGE EVENT OF SEPTEMBER 7, 1958*†

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Giovanelli and McCabe (1958) indicate that, while most flare-surges appear dark against the solar disk throughout the greater part of their existence, it is not uncommon for a surge in its earliest stages, just as it leaves the flare, to be bright. Rapidly moving material that remains bright against the solar disk for a longer time is much less frequently observed. Of the cases of longer lasting bright surges that have been reported as exceptional events by Dodson and Hedeman (1949, 1952), Ellison (1950), Dodson and McMath (1952), Bray, Loughhead, Burgess, and McCabe (1957), and Reid (1959), those reported by Dodson and McMath, by Bray *et al.*, and by Reid appear to be detached and rapidly moving portions of flares, whereas the remainder did not attain flare brightness.

The surge event of September 7, 1958 remained bright against the solar disk for several minutes, but was clearly less bright than the flare from which it appeared to originate. A somewhat unusual programme of filming rate and exposure times used by the Climax observers contributed significantly to the detail with which the progress of the surge could be followed. During the early stages of the surge, four photographs were made per minute with an exposure time adapted to bring out the features on the solar disk, while a fifth exposure each minute was sufficiently long to show prominence features beyond the limb. About 4 min after flare maximum the exposure rate was increased to two frames every 2 sec, one timed to bring out disk features, the other to bring out limb features. There were several frames that were exposed for an extra-long time, probably as a result of faulty shutter operation. On these very long exposures faint features in the surge could be detected that otherwise would have gone unnoticed.

Immediately after flare maximum, bright surge material was observed tracing a path across the Sun's disk, from the edge of the flare to the limb, then beyond the limb. Some material seemed to part from the main mass and drift more nearly radially toward the limb, while the main body of the surge intersected a tangent to the limb at an angle of approximately 50°.

In order to study the motion of the surge, we measured the radial distance of the leading edge of the surge from the limb, both before and after it crossed the limb. These measurements of radial distance, plotted against time, are shown in Figure 1, the velocity in the early stages being 470 km/sec.

* The research reported in this paper was supported by the National Academy of Sciences as part of the International Geophysical Year Programme, with the assistance of a grant from the Ford Foundation.

† Manuscript received December 23, 1959.

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The surge crossed the limb at 1452 U.T. through a low prominence which had appeared on the limb about 1 hr earlier. Figure 2, which is a composite of 29 sketches of the leading edge of the surge, chosen at 30 sec intervals, gives a representation of the trajectory of the surge. Preceding the main body of the

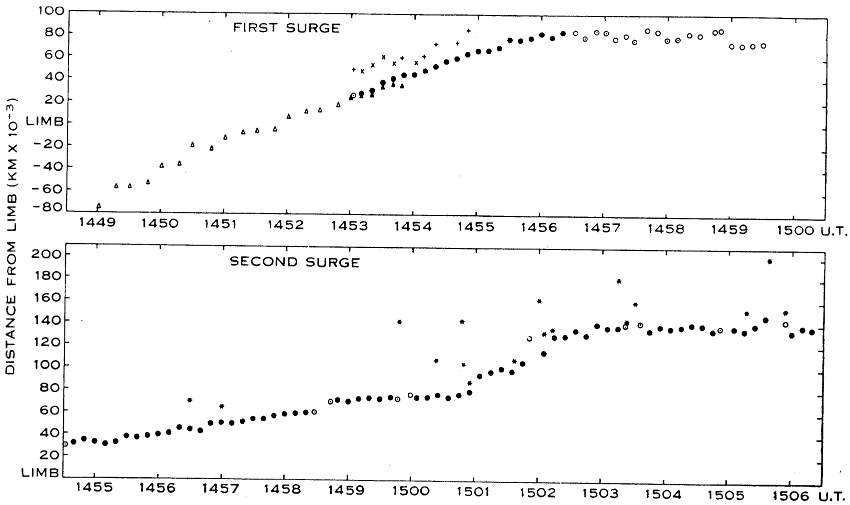

Fig. 1.—Variation of surge position with time ; surge of September 7, 1958, at P.A. 72°.

Number of exposures on which point is based :	1	2 or 3	4 or 5
Intense feature seen on normal (disk) exposures	△		▲
Intense feature seen beyond limb	○	⊙	●
Diffuse forerunner seen beyond limb	*	+	×

surge was a more diffuse and less well defined, slightly slower-moving mass of material which rose even higher, to over 100,000 km beyond the limb.

At about 1454 : 30–1455 U.T., $2\frac{1}{2}$–3 min after the first surge crossed the limb, a second, somewhat larger and more spectacular surge began building up

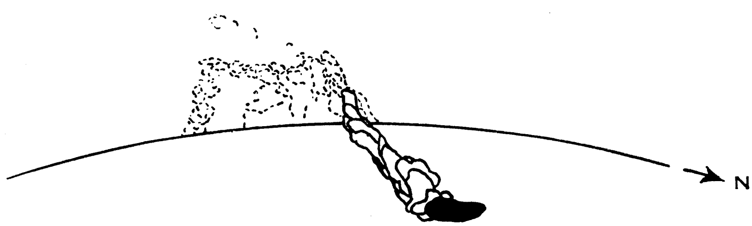

Fig. 2.—Composite sketch showing the flare at 1449 U.T. (black area) and the trajectory of the first surge from 1449 U.T. until 1502 U.T., with positions of the leading edge drawn at 30 second intervals. The solid outline is from normal exposures ; the dotted outline from longer exposures.

gradually beyond the limb, slightly north of the first, and rising essentially perpendicular to the limb.

The initial motion of this second surge was slow and the surge itself difficult to distinguish from a pre-existing prominence on the limb. In its earlier phase this surge was arch-shaped, with a strikingly bright knot of emission located within the centre of the top of the arch. The arch gradually took on a more columnar shape with an enlarged top containing the bright knot. This " column " rose between the above-mentioned prominence and the first surge. As it rose the arch-like characteristics of the lower levels disappeared and the prominence assumed its former outline on the limb.

Six minutes after the first suggestion of this slow-starting second surge, some very fast material seemed to break through it and speed upward with a velocity (between 1500 : 30 and 1502 : 19 U.T.) of nearly 520 km/sec. Thereafter,

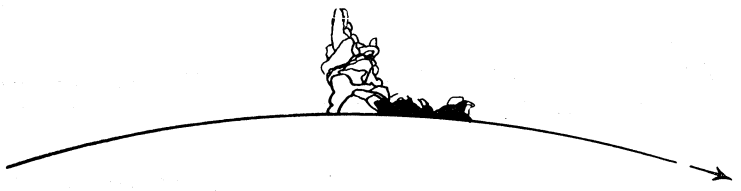

Fig. 3.—Composite sketch of the leading edge of the second surge at 60 second intervals, between 1452 and 1506 U.T. Darkened outline shows the initial stable prominence.

at about 130,000 km from the limb, it slowed down but continued to move, ultimately reaching a distance of more than 140,000 km. A few extra-long exposed frames of the film show material in the region between 170,000 and 200,000 km beyond the limb. Figure 3 is a composite of 15 sketches of the leading edge of the second surge, at 1-min intervals.

We next examined the flare around 1455 : 30 U.T., which should have been the time that material would have left the flare, at 520 km/sec, in order to appear at the limb at 1458 : 15 U.T. However, no noticeable special event within the

TABLE 1

DEDUCED ELECTRON DENSITIES

Height above the Chromosphere (km)	Electron Density (cm^{-3})
40,000 $\pm$ 10,000	$4 \cdot 2 \times 10^8$
70,000	$2 \cdot 5 \times 10^8$
80,000	$1 \cdot 9 \times 10^8$

flare could be found on the photographs. The only direct evidence found to connect this second surge with the flare were slight traces of dark and bright material apparently extending from the flare into the base of the surge.

Of the various solar radio noise emission features that were reported as beginning about the time of the maximum phase of the flare by Boulder, Cornell, Ottawa, and Fort Davis, an unclassified burst of intensity 1, having some features of a type II burst, and lasting from 1449·7–1455 U.T., appeared to be the most likely to be associable with either surge. This burst was recorded at Fort Davis in the 100–580 Mc/s frequency range, along with a small group of moderate intensity type III bursts at 1449–50 U.T. of the type described by Giovanelli (1958), and an unclassified burst of slight intensity at 1457 U.T.

By comparing Figure 1 with a reproduction of the Fort Davis sweep-frequency record kindly furnished us by Dr. Alan Maxwell, we have been able to deduce a rough correspondence between the optically determined position of the front of the first surge and the frequency of maximum emission in the simultaneous unclassified burst. Then, by equating the second harmonic of plasma frequency to the observed burst frequency, in accordance with the March 1, 1957 observation of Giovanelli and Roberts (1958), and estimating the height of the surge above the chromosphere by the distance, measured normal to the limb, from the centre of the flare to the front of the surge, we deduce the electron densities given in Table 1.

These densities, and the corresponding scale height of approximately 56,000 km, seem quite reasonable for a region in the corona overlying a large amount of solar activity.

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