THE MAGNETIC PROPERTIES OF SOLAR SURGES

J.-RENÉ ROY

Department of Astronomy, University of Western Ontario,
London, Ontario, Canada

and

Sacramento Peak Observatory, Air Force Cambridge Research Laboratories,
Sunspot, N.M. 88349, U.S.A.

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Abstract. High resolution on- and off-band Hα filtergrams of disk solar surges obtained with the Vacuum Tower Telescope of the Sacramento Peak Observatory have been compared to magnetic data.

1. Surges constitute clusters of very fine dark (sometimes bright) filaments where each thread connects to an Ellerman bomb brightening. If the magnetic map reveals the existence of a satellite polarity as defined by Rust (1968), the bomb(s) lies over it.

2. Although a large fraction of surges is not associated with clearly detectable satellite polarities, events are strongly favored in regions of evolving magnetic features, characterized by dimensions of about 10000 km and significant flux change over a period of less than a day. A flux change rate of $3 \times 10^{13}$ Mx s$^{-1}$ has been measured along at least three homologous bomb-surge events in a satellite of region MW 18594. Surges appear to be related to rising flux of one polarity into a region of stronger opposite flux.

3. The trajectories of surges are matched by magnetic lines of force computed in the current-free approximation.

1. Introduction

Conventionally, the solar surge phenomenon describes the straight or arch-shaped collimated streamers of material stretching out from sunspot regions; they emerge as smooth threads or elongated knots of dark or bright gas and are often followed by an apparently gravity-induced return to the surface along the same trajectory. The main studies on surges are by Newton (1942), Ellison (1949), Giovanelli and McCabe (1958), Gopasyuk et al. (1963). Smith and Smith (1963), Bruzek (1969) and Westin (1969) have summarized the basic data about this transient solar phenomenon. The earliest workers were quick to point out the association of surges with sunspots, i.e. regions of strong magnetic field.

The question of the locus of origin of surges was examined by Gopasyuk et al. (1963) and Gopasyuk and Ogir (1963), who found that surges are ejected from the penumbra or even the umbra of spots; however, the Russian investigators were badly hampered by low resolution. A step forward in understanding surge origin was made by Rust (1968) who pointed out the importance of satellite spots; these smaller spots, imbedded at the boundary of a penumbra and the undisturbed photosphere, present a polarity opposite to that of their parent spot.

With the aid of high resolution Hα disk filtergrams, I have investigated the origin of surges by locating their bases on the magnetic maps and the sunspot pictures.
2. Observational

The observations for this investigation were taken with the large Vacuum Tower Telescope at the Sacramento Peak Observatory (New Mexico) during the summer and fall 1971. The 30-in 180-ft focal length telescope has been described by Dunn (1964, 1969, 1971a, b). As ancillary instrumentation, I used the tunable Hα Lyot birefringent filter built by the German firm Carl Zeiss; Haase and Gaenswein (1967) have given a description of this apparatus. Under excellent seeing, the telescope resolves physical lengths of about 200 km on the solar surface.

The filter bandpass can be stepped across the Hα profile to catch Doppler shifted material up to ±16 Å from line center; of the two bandpasses available, ⅟₄ and ⅟₂ Å, I used ⅟₂ Å. The scanning rate and position of the filter were controlled by computer. Since the observed velocities of surges reach about 100 km s⁻¹, I designed a sequence which swept the Hα profile by taking pictures on Kodak SO 392-35 mm film at -2, -1⅓, -⅗, -⅓, ±0, +⅓, +⅔, +1⅔ Å and came back to its starting position in 20 seconds. Such a sequence is shown in Figure 1 showing the flare-associated surge in Mount Wilson (MW) region 18468 on 29 June 1971. Other sequences, shorter or

![Sequence of images showing solar activity](image)

Fig. 1. Region MW 18468 (W13 N15) at 1551 UT on 29 June 1971. The bandpass is ⅟₂ Å given by a tunable Lyot Hα filter as in all the filtergrams of this paper. This is a typical eight-frame sequence obtained by stepping the filter bandpass across the Hα profile through -2, -1⅓, -⅗, -⅓, ±0, +⅓, +⅔ and 1⅔ Å in 20 s. The sequence shows the complex differential dynamics of the surge constituent threads. North is at top; east is at left.
longer in time, were used. Each frame covers an area of $18 \times 24$ mm of a solar image 215 mm in diam. By printing on 16 mm film the $-2$ Å frames, then the $-1.5$ Å, etc., I obtained cinematographic sequences at given wavelength shifts, corresponding to known line-of-sight velocities. At Hα 6563 Å, a shift of 1 Å corresponds to a velocity of 47 km s$^{-1}$.

The magnetic maps of active regions were taken with the Sacramento Peak Doppler-Zeeman Analyzer (DZA). The DZA has been described by Evans (1966) and its renovated version by Dunn (1971c). Rust (1972) describes the procedure and problems of obtaining magnetic maps of evolving active centers with the DZA and his discussion is entirely applicable to this work. Magnetograms were taken in the lines of Fe I 6302.5 Å, Fe I 5250.2 Å and Fe I 6336.8 Å and were supplemented by recordings from Mount Wilson in the form of large scale magnetograms and visual Zeeman measurements in sunspots.

3. The Surge Magnetic Environment

The spike of dark or bright material of a surge tends to grow out rapidly from a small compact knot with a diameter of a few seconds of arc or less. The knot may reach flare intensity within 5–10 mins. These bright knots or bombs (Ellerman, 1917), whose spectral properties are of the same kind as ‘moustaches’ investigated by Severny and Koval (1961) and by Koval (1964, 1965a, b, 1967), form the basis and possibly the source of the surge (Brueck, 1969). This is confirmed by the fact that every one of the thirty surges I studied extends from bomb brightenings which appear at the initial phase of the surge. The identification of brightenings at the surge basis to Ellerman bombs is done by looking at the Hα profile behavior of the brightening as revealed by the eight filtergrams taken across Hα every 20 s or so. At Hα ± 0 Å the brightening is generally invisible throughout its history, while it has its maximum brightness between 0.5–2.0 Å off the core (Engvold and Maltby, 1968). The brightening presents the characteristic compactness of bombs not found in subflares. Surge generating bombs may be solitary or develop as a chain. Curves showing how surges develop just after bombs or subflare appear in Figure 2.

Unlike flares, the broad-wing Hα emission associated with surge appears to occur very near the seat of energy release. This makes the task of relating any peculiarity in the field to surge activity easier. In the following paragraphs, I display various photospheric sunspot patterns and magnetic configurations associated with surges. Most configurations fulfill, although on a smaller scale, the criterion of ‘structures magnétiques évolutives’ or evolving magnetic features (EMF) introduced by Martres et al. (1968).

A. SURGES AND SATELLITE POLARITIES

The best known type of surge-generating region is the satellite spot imbedded near the penumbra of a larger opposite polarity spot (Gopasyuk et al., 1963; Rust, 1968). However, because most magnetograms have relatively poor ($\approx 10''$) resolution,
satellite spots often remain invisible. The only clue for some disturbing agent is the vanishing penumbral structure or the complexity of the penumbral filament alinement. See the areas indicated by arrows on the Hα = 2 Å picture of Figure 4 and the Hα = 1 3/8 Å frame of Figure 3. In the latter case, the penumbral filaments are parallel to the spot border instead of being oriented radially; it indicates some perturbing magnetic structure perhaps related to the activity. Figure 4 shows the large region MW 18538, a prolific producer of surges on 19 August 1971; the surges apparently do not coincide with any visible satellite spot. Conversely, not every satellite spot shows activity. Some of them in Figure 5, region E for example, are relatively inactive, indicating that a peaceful equilibrium has been established with the master polarity. Therefore, the existence of a satellite is not a sufficient condition for bomb and surge activity. Change in the surface flux is required in the form of evolving magnetic features. Naturally, young developing regions provide ideal conditions, explaining their well known association with surge production. In the arch filament system (AFS) of MW
Fig. 3. Region MW 18538 (E42 S13) on 20 August 1971 around 1634 UT. The views are at Hα — 1° and — 1° Å. The arrow points to penumbral filaments with an orientation making a sharp angle to the undisturbed radial direction.

Fig. 4. Region MW 18538 (E58 S13) on 19 August 1971. (a) Hα — 1° Å, 1655 UT; (b) Hα — 2 Å, 1655 UT; (c) Hα + $\frac{1}{2}$ Å, 1515 UT. North is at right; east is at top. Surges in their initial phase originating from the penumbral region in the leading spot (a) and at the end of a light bridge in the following spot (c). There is hardly any sign of satellite spots at Hα — 2 Å (b).
18468, I detected 14 sporadic little surges along the same trajectories as the AFS over 48 min on 29 June and seven over 34 min on 30 June 1971.

Region MW 18594

Nevertheless, the best breeding ground for surges remains at evolving satellite polarity coinciding with compact spots or pores. The magnetic fjord of opposite negative (−) polarity intruding in the following parent positive (+) polarity of MW 18594 (Figure 5) was the site of many homologous surges on 23 October 1971. Figure 6 displays phases of the activity observed in Hα between 1412 UT and 2100 UT. Some magnetograms for the same period are also included in Figure 7; these maps are enlarged sections of more complete maps such as the one of Figure 5. The satellite (−) pole south of the big (+) spot corresponds to the seat of bomb and surge activity. This island of (−) flux coincides with pores which have materialized in the photospheric pattern earlier, between 1500 UT and 1900 UT. Hα filtergrams obtained around 1412 UT show some activity indicating that (−) flux has started to emerge, but none of the pores is visible (Figure 6a). The materialization of pores may indicate change in the local field distribution.

The recording of magnetic changes associated with activity through photoelectric

Fig. 5. Magnetogram of region MW 18594 (W19 N05) at 1918 UT on 23 October 1971. Contours levels are ±10 G, ±20 G, ±40 G, .... Solid contours enclose positive field; dashed contours enclose negative field. The box encloses the region shown at successive times in Figure 7. Circle D indicates the satellite polarity associated with bomb and surge activity (Figure 6). A, B, C and E represent regions used as comparisons in order to compare their flux time behavior with region D. Magnetograms shown in this paper were taken by D. M. Rust of Sacramento Peak.
Fig. 6. Bomb and surge activity in region MW 18594 on 23 October 1971. North is at top; east is at left. (a) Hα + 1/2 Å, 1412 UT; notice the absence of the two tiny pores which have become visible in the later filtergrams at the seat of the bomb activity. (b) Hα – 2, – 1/2 and + 0 Å, 1913 UT, after ignition of a bomb which develops into a surge. (c) Hα – 1 1/2, – 1/2, + 1/2 Å, 2046 UT in the later phase of a successive event. A third pore (arrow) may have appeared in the interval following the preceding filtergram.

devices has proved to be an extremely difficult task due to seeing effects which easily mimic field variations; see recent comments by Michard (1971) and Rust (1972). Moreover, Sweet (1971) remarked that it is possible for the emerging and reentering flux to change connectivity without changing the observed longitudinal field. Despite these problems, I propose that the series of magnetograms of Figure 8 is a fair candidate for a relationship between activity and magnetic flux variation, where one sees the size and strength of the (−) satellite pole D (Figure 5) dwindling with time. Figure 8 gives the value of the (−) flux with respect to time of the satellite pole D located at the bomb site in MW 18594; as comparison, the fluxes of four other poles identified as A (+), B (−), C (−) and E (+) on the magnetic map of Figure 5 are given. These apparently stable comparisons were chosen because the magnitude of their perturbation in the surrounding field is similar to region D (−).
Fig. 7. Time sequence of magnetograms of MW 18594 on 23 October 1971 showing the boxed region of Figure 5 where activity is concentrated. Notice the weakening of the negative magnetic flux of the satellite polarity. Contours follow the same conventions as Figure 5.

I have approximated the field over the area $A$ enclosed by two subsequent contours by $\frac{1}{2}(B_i + B_{i+1})$. The total flux through an area of one polarity is then

$$F = \sum_i A_{[(i+1)−i]} \times \frac{B_i + B_{i+1}}{2}.$$

While the absolute value of the magnetic flux in the comparisons stayed roughly the same at about $50 \times 10^{19}$ Maxwells (Mx) in region A, and about $16 \times 10^{19}$ Mx in regions B, C and E, it dropped from $25 \times 10^{18}$ Mx to almost nothing in region D within 3 hr. This corresponds to a changing rate of $3 \times 10^{15}$ Mx s$^{-1}$. Region MW 18594 produced bombs continuously at the location of the evolving (−) feature.

Is the recorded magnetic change real? From the quality of filtergrams made simultaneously to the magnetic maps, it appears that the seeing quality was fair over the observatory; off-band Hz views show the granulation implying that the seeing disk was then probably smaller than the magnetograph scanning aperture of $5'' \times 5''$. Figure 9 gives the value of the longitudinal field along a roughly north-south line going through the satellite polarity. The rather sharp (+) peak south of the satellite remains identical throughout the sequence, except for 5 maps (1725, 2010, 2024,
2042 and 2124 UT) where seeing might have smeared it. Since the indentation in the (+) region remains strong, it means that smaller unresolved tiny (−) features may still be present but weaker. The field gradient on the side of the big spot north of the satellite gets smoother with time. This reflects the weakening of the (−) inclusion followed by the straightening of the boundary neutral line. Strongest support for possible change comes from the modification in size and sharpness of pores seen at Hα−2 Å between 1400 and 2100 UT.

The following spot of MW 18594 shows a subflare accompanied by surge ejections on 19 October 1971 (Figure 10). Comparing together the magnetograms of 19 and 20 October, one sees that in the magnetic depression of the first day, new flux has made its way to the surface.
Fig. 9. Time behavior of the longitudinal field component versus position along a roughly north-south line crossing the evolving (−) satellite polarity south of the parent (+) spot in Figure 7. The shaded area represents the negative field of the satellite.

Region MW 18468

Although not related to any satellite spot as such, the disk surge which occurred in region MW 18468 on 29 June 1971 is typical of activity associated with evolving magnetic features. Figure 1 displays Hz filtergrams of the event, six minutes after the horseshoe-shaped subflare maximum. Though the flare encompasses a rather large area of the chromosphere, the most conspicuous ejective flow appears in the area of two (−) polarity pores. Most dark threads connect back to the surface at a small brightening much smaller than a granule and visible at least as far as 2 Å in the wing of Hz. The bright points are mostly located near the boundary between the pore umbra and the undisturbed photosphere. The movie also discloses tiny ejections above the eastern kernel of the flare, where the Hz−2 Å filtergram (Figure 11) shows five tiny pores of (+) polarity; the ejections look poorly contained and their flare brightness implies high densities or temperatures. Inspection of Mount Wilson
sunspot drawings of MW 18468 discloses interesting development between 29 and 30 June in the area where the flare and surge took place: the maximum flare brightness region on 29 June corresponds to an area of increasing (+) flux (1000 G up to 1800 G) while the two (−) pores between which most of the surge filaments were anchored, show sizable shrinking and drop in intensity (−1400 G down to −1000 G) (Figure 11).

B. SURGE ACTIVITY IN LIGHT BRIDGES

The only cases I have of surges originating from inside spots took place along light bridges. Although rarely giving rise to spectacular events, light bridges constitute rich producers of brightenings followed by ejections of all sizes. Table I summarizes the characteristics of surge generating regions with light bridges.
<table>
<thead>
<tr>
<th>Mt. Wilson region No.</th>
<th>Time of observation</th>
<th>Magnetic environment</th>
<th>Magnetic history</th>
<th>Surge activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>18511 E62 S15</td>
<td>25 July 1971 1502–1715 UT</td>
<td>Double-umbra unipolar (+) spot due to light bridge. 80% of bombs appear along edge of light bridge adjacent to umbra with strongest field.</td>
<td>Same double-umbra configuration for whole disk passage. On 26 July, three pores (−800 G) have emerged just east of the light bridge.</td>
<td>Veils of surges (Figure 12) from eastern edge of bridge following each of six bursts of arrowhead shaped bomb brightenings.</td>
</tr>
<tr>
<td>18538 E58 S13</td>
<td>19 Aug. 1971 1514–1724 UT</td>
<td>Large bipolar group. Light bridge crossing leading spot and largest of following spots.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18594 W80 N10</td>
<td>27 Oct. 1971 1403–1527 UT</td>
<td>Large bipolar group (same as Figure 5) with light bridge in leading spot.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE I**

Surge activity in light bridges
Fig. 11. Filtergrams of region MW 18468 on 29–30 June 1971 at Hα—2 Å. Magnetic field values are from Mount Wilson sunspot visual field measurements and refer to maximum intensity. 29 June (1551 UT) is at top; 30 June (1554 UT) is below.
C. A CASE OF ERUPTIVE FLARE

Region MW 18522

A most disturbing fact about explaining surge and spray production is provided by region MW 18522 which produced five flares on 3 August 1971: 1355, 1550, 1857, 1913 and 1928 UT. At Sacramento Peak I recorded completely the first event which occurred just ahead of the single visible sunspot of the region and which was accompanied by a spectacular eruption (Figure 13) fulfilling most of the characteristics of flare sprays stated by Smith (1968). Later events were similar although less grandiose. The point to stress is that absolutely nothing peculiar is noticeable in the spot on 3 and 4 August when the center produced eruptive flares like a machine gun! It implies that very small scale features (<200 km) may trigger major perturbations.

4. Lines of Force

I computed the magnetic lines of force in the current free approximation using the Schmidt analysis (Schmidt, 1964). The method has been described by Harvey (1969), Rust (1970) and Rust and Roy (1971). Footpoints for computed fieldlines are set on the magnetogram to coincide with the observed bases of surge filaments.

Computation I have done for surges in MW 18511 (25, 31 July 1971) and in MW 18594 (20, 21, 23 October, 1971) show that surge filaments follow closely trajectories determined by the magnetic lines of force computed from a potential field. (Figure 14 as an example.) This confirms the results of Rust (1968) and Harvey (1969) and indicates that the current-free analysis is an adequate tool to investigate coronal magnetic field. At low heights (<5000 km), calculated fieldlines fail to match the complex structure of the surge material which appears in emission. This is due to the
Fig. 13. Filtergram of a flare spray in its initial phase in region MW 18522 (E77 S10) on 3 August 1971 at 1407 UT (Hα ± 0 Å).

Fig. 14. Computed current-free fieldlines matching the surge veil of 25 July 1971 (Figure 12). I used a magnetogram of the region obtained by R. Sinha in the line of Fe i 6302.5 Å on 29 July 1971 (1758 UT).
low resolution of the magnetic maps and to the assumption of a flat distribution of monopoles situated at the photospheric level. In reality, one should expect to have sources in the chromosphere which violate the approximation. The obvious presence of dissipative processes taking place surrounding evolving satellite spots, as revealed by the rapidly changing bomb structure, suggests the presence of electric currents at chromospheric levels. At heights greater than 10000 km, the field configuration is mostly determined by the strongest features of the underlying spots (Rust and Roy, 1971) and agreement is fair.

In his comprehensive observational survey of active prominence magnetic fields, Harvey (1969) found the polarization signals of surges to be very noisy; he interpreted this as due to the complex nature of the field. I believe the field structure is no more complicated than in any other prominences; indeed it appears much more orderly. The successive surges of 25 July and 23 October 1971 followed exactly the same trajectories indicating that the main field responsible for collimating the ejected plasma remained unchanged. Curiously, Harvey (1969) measured different field strengths in three homologous surges, i.e. 87 ± 15, 40 ± 15 and 17 ± 6 G. An explanation is that Harvey may have measured different threads of a surge which appeared in the same projected position in the sky or that the surge differential dynamics may have affected his time-averaged polarization signal; I found that surge material often moves in completely opposite directions in adjacent channels separated by a few seconds of arc, a scale unresolved by the magnetograph. Stenflo (1968) has shown how 'multi-stream' models where streams are assigned different velocities, areas, intensities and magnetic fields, lead usually to observed average field strength smaller than the true average field strength.

I have been able to reproduce a set of fieldlines with a neutral point overlying the satellite polarity of MW 18594 on 23 October 1971. Obviously, the set of current-free fieldlines of Figure 15 has only a qualitative value. But it points out the relationship between intense bomb and surge activity and the existence of a neutral point suggested by Rust (1968).

5. Discussion

The occurrence of surges in sunspot light bridges and very close to the boundary penumbra-undisturbed photosphere implies that strong field (≤1000 G) and/or steep gradient are necessary for ejective flow to occur. If associated with any detectable magnetic feature, it is characterized by the presence of an evolving satellite polarity surrounded by flux of opposite polarity. Evidences from the events taking place in regions MW 18538, 18594, 18511 and 18235 indicate that surge activity is favored in regions where the magnetic flux of a satellite polarity changes significantly over a period shorter than a day; this local flux increase, if occurring near low strength poles, may be paralleled by the weakening of the opposite sign polarity (MW 18468). Because the relevant magnetic flux changes are small, they probably can be detected only if the ratio ΔF/F is significant, i.e. in relatively small flux regions like satellites. The common absence of visible strong opposite polarity at the origin of surges implies
Fig. 15. Computed current-free lines of force above satellite spot D of Figure 5 viewed through the plane of the region from a south-east direction. Due to obvious limitations of the current-free method, it produces very low closing fieldlines near the satellite spot; therefore, I reproduce them by expanding the vertical scale generously.

that their production does not require a high concentration of satellite flux but only enough magnetic 'fuel' to supply the surge kinetic and radiative energy. In order to provide the collimating force to squeeze out the energized flow, already present strong field is the needed matrix. After surge occurrence, one may notice a simplification of the boundary (neutral line) between the two regions of opposite polarity: MW 18235, 18468 and 18594 (23 October 1971). This apparent stabilization is not general. Because surge activity is an indicator of emerging flux, the resulting configuration may end up more complicated than before, e.g. MW 18594 on 19–20 October 1971 (Figure 10).

As new flux is brought to the surface by buoyancy, annihilation and reconnection probably occur. Due to a favorable geometrical arrangement around satellite polarity (Severny, 1964; Rust, 1968), annihilation heats very hot gas leading to the bomb flash. Perhaps a mechanism related to the reconnection of fieldlines or to a pressure gradient accelerates the hot material into a surge. The whole process is similar to the rocket nozzle. The bomb acts as the seat of highly random motion of hot plasma. Shortly above the chromosphere, the motion is converted into direct flow. The dominant surrounding field provides the containing force and perhaps the varying cross-section for the flow to expand and accelerate. Adapted versions of models for spicules might be worked out for surges.

Activity along light bridges in spots is apparently associated with very small
features. This view is strengthened if we accept the presence of bombs as evidence for small scale opposite polarity features. Magnetic buoyancy forces could bring up some flux right through the sunspot at a weak resistance point such as a light bridge; recall that Beckers and Schröter (1969) found that light bridges in a unipolar spot showed a smaller field than the neighboring umbra by more than 300 G.

Other questions naturally come up: if each thread of the surge connects to a tiny bomb somewhere in the chromosphere, what mechanism triggers their almost simultaneous flaring? Some threads are squeezed out of isolated bombs earlier or later as lonely ejected filaments, but most of the surge ejection occurs in phase. It explains why low resolution and wide bandpass filters tend to show surges as huge growing tongues which distend and retract coherently. A surge is actually a multitude of jets less than one arcsec across originating at a set of bright knots in the low chromosphere, triggered outward more or less simultaneously. Nevertheless, the chain reaction of bomb brightenings remains unexplained.

I have not been able to determine if the field or photospheric changes are progressive or sudden, nor if sudden changes correlate with bomb activity. It is interesting that the flux change rate recorded with the activity in MW 18594 on 23 October 1971 amounted to $3 \times 10^{15}$ Mx s$^{-1}$, a value also obtained by Ribes (1969) and Rust (1972) for flare activity associated to evolving magnetic features. Either this is fictitious because we are simply measuring noise inherent to magnetic recording, or more probably, as the quality of the observations indicates, the flux change represents real magnetic energy dissipation associated with evolving satellite spots. Since $1 \, V = 10^8$ CGSM, then according to Maxwell's equation the emf induced in region MW 18594 by the flux change rate $\Delta F/\Delta t = -3 \times 10^{15}$ Mx s$^{-1}$ is

$$\oint E \, ds = -10^{-8} \, \Delta F/\Delta t.$$

If $\Delta F/\Delta t$ is expressed in CGSM units (Mx s$^{-1}$), then

$$\oint E \, ds = 3 \times 10^7 \, V.$$

A similar value for $\Delta F/\Delta t$ in evolving satellite polarities may represent a threshold in the electric field for flaring breakdown to happen in the solar atmosphere. On the other hand, the given emf is an order of magnitude or more smaller than the values given by Zvereva and Severny (1970) for proton emitting regions. Those authors have concluded that the $10^7 \, V$ also calculated for small flares are below the critical value for generating hard particles. It explains why surge events are not associated with proton emission detectable at 1 AU.

The lesson taught by region MW 18522 which produced the flare spray of 3 August 1971, is that one should be very careful not to overinterpret or to rely heavily upon present longitudinal magnetic field data. The dynamics of spectacular phenomena must be determined by the evolution of very small scale magnetic features where the importance of dissipative processes is far from negligible.
Summary

This investigation leads to the following conclusions:

(1) All surges observed extend from roughly triangular shaped bombs ranging in size from a few hundreds to 5000 km; the surge follows the bomb evolution in a way suggesting that its material is squeezed out from the bomb.

(2) If the magnetic map reveals a satellite polarity, the surge-generating bomb lies over it. Nonetheless, the presence of visible satellite spot is not necessary for surges to occur.

(3) Surges occur very near locations where the photospheric field concentrations are larger than 1000 G.

(4) Surges are strongly favored in regions of evolving magnetic flux (increasing or decreasing). The region is characterized by dimensions of the order of 10^4 km and significant flux change over a period of less than a day. Surges appear to be related to new flux of one polarity rising into a region of stronger opposite flux already present at photospheric level. In the case of the homologous surges of region MW 18594 on 23 October 1971, the phase of bomb and surge activity coincides to weakening satellite flux; the measured change rate in the distribution of longitudinal field amounted to 3 \times 10^{15} \text{ Mx s}^{-1}. However, surge events occur as well during the phase of strengthening of satellite flux.

(5) When one evaluates the emf arising from $\Delta F/\Delta t$, the obtained value of about $10^{7}$ V is not sufficient to give rise to any proton event if one follows the criterion given by Zvereva and Severny (1970).

(6) Events arising in regions where nothing peculiar appears on the magnetic map or the photospheric pattern (surge from light bridge) implies that complex processes may be highly important on small scale. Small ejections extending from brightenings in light bridges are very common.

(7) The trajectories of surge threads are matched by fieldlines calculated in the current-free approximation.

(8) Theoretical models for surges based on the existence of a neutral point in the magnetic configuration of evolving satellite pole have an observational basis.

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