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Recurrent mass ejections associated with flare behind the limb on 1978 December 20

Rajmal Jain, A. Bhatnagar and R. N. Shelke
Udaipur Solar Observatory, 11 Vidya Marg, Udaipur 313 001

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Abstract. An interesting solar flare occurred on 1978 December 20 behind the north-west limb, in the McMath active region no. 15700, as inferred from the observed associated energetic mass ejections, strong x-rays, decimetric and metric type II radio bursts. In this paper a detailed study of the spray and surge activities associated with this flare is presented. A possible explanation for the observed recurring tendency of surges with a quasi-periodicity of 5–30 min is suggested as due to additional small magnetic flux brought out by buoyancy in or near a satellite spot which could provide enough collimating energy to squeeze out the surge material at a quasi-periodic time interval.

Another interesting surge phenomenon was observed which showed up and down motion of a small surge material between 11.00–11.30 UT, with a velocity of about 20 km s^{-1}. To explain this event a qualitative model is presented based on 'jumping bean effect'.

Key words : solar flare—mass ejection—surge and spray

1. Introduction

An interesting solar flare occurred on 1978 December 20 at 06.40 UT, about 10° behind the NW-limb in the McMath active region no. 15700. Over an interval of nearly 6 hours, 06.00–12.00 UT, recurrent surge mass ejections (homologous surges) were observed from this active region. During this period at least 14 distinct 'pulses' of activity took place, among which a fast spray like mass ejection at 06.43–06.50 UT was also observed. This spray was associated with the flare behind the limb at 06.40 UT, which in turn gave rise to type II, type III bursts, x-rays and sudden ionospheric disturbances. In this paper an analysis of the rccurring mass ejections and observations of radio and x-ray emissions are presented. The H-alpha time lapse observations were made at the Udaipur Solar Observatory, while the radio burst data were obtained from the Culgoora Radio Observatory, and x-ray data from Solrad 11.

2. Observations

2.1. H-alpha optical observations

Time lapse H-alpha observations of mass ejections on 1978 December 20 at the west limb were made at a rate of 5 to 20s with the 15 cm solar spar telescope, in conjunction with an Halle H-alpha filter of 0.5 Å passband. To measure the velocity in the sky plane of the various surge and spray features, the H-alpha films were projected to yield a linear scale of 800 km mm^{-1}. The outline of the features were drawn for a number of frames and the distance was measured from the solar limb along the radial direction. From the height *versus* time plots, we obtained the velocity of the ejected material. The H-alpha observations were started at 06.09.32 UT, at this moment a surge-like spike A_1 had already ejected outwards to 16,000 km above the west limb. Three different features A_1, B_1 and C_1 are identified in this first surge. The average velocity of these features ranges between 15 to 50 km s^{-1}. The height *versus* time plot of this surge is given in figure 1. About 4 min later another spike A_2 was observed ejecting out from the same location and with the same shape as the earlier surge. The height *versus* time plot for various features A_2, B_2 and C_2 identified in this surge is also shown in figure 1.

Before the spike C_2 faded completely, a huge spray ejection was observed at 06.42.39 UT from the same active region behind the limb. In figure 2 is shown the

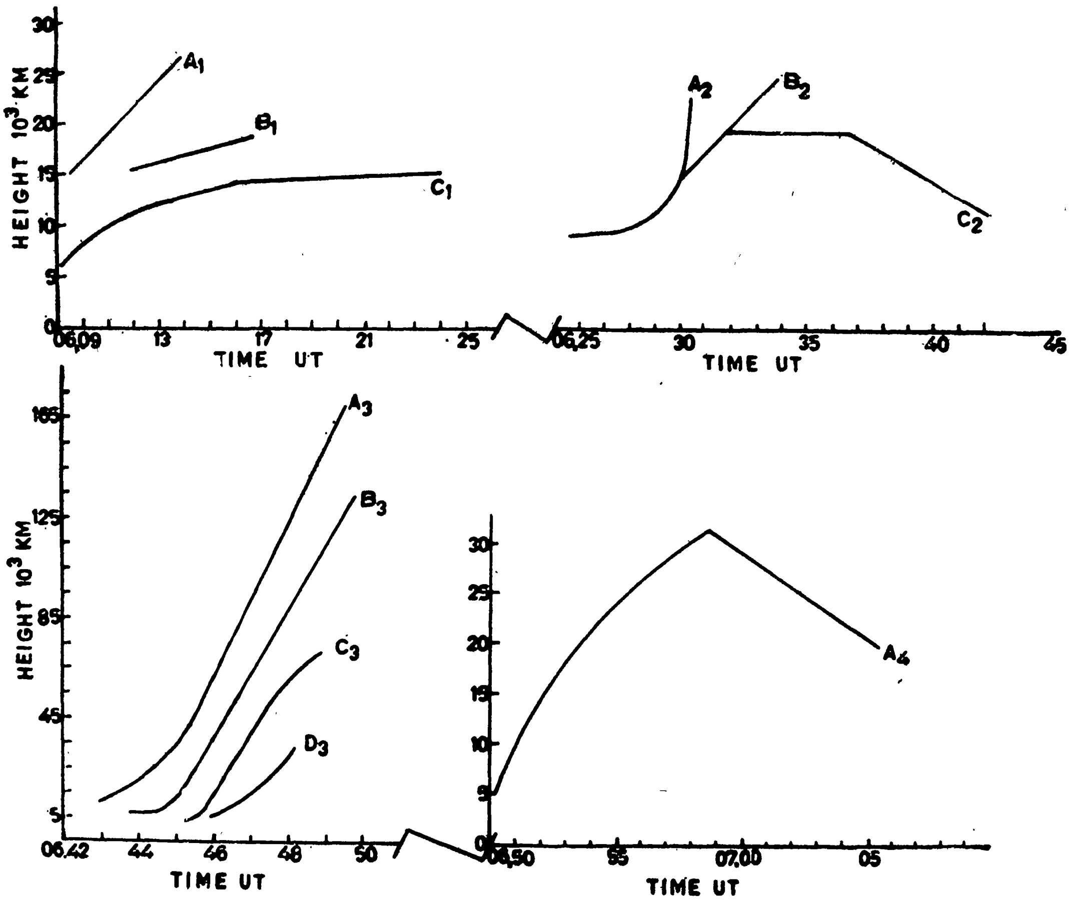

Figure 1. Height of surge and spray prominences above the limb plotted against time.

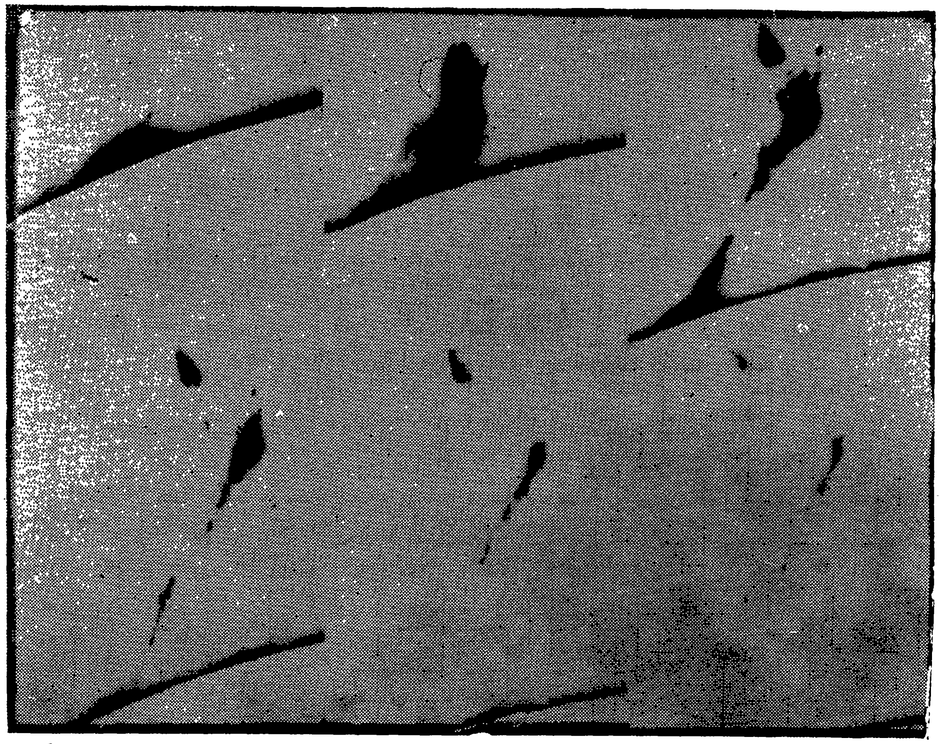

Figure 2. Development of spray prominence (negative print) in H-alpha line centre at (a) 06.43 UT, (b) 06.45 UT, (c) 06.46 UT, (d) 06.47 UT, (e) 06.48 UT, (f) 06.49 UT.

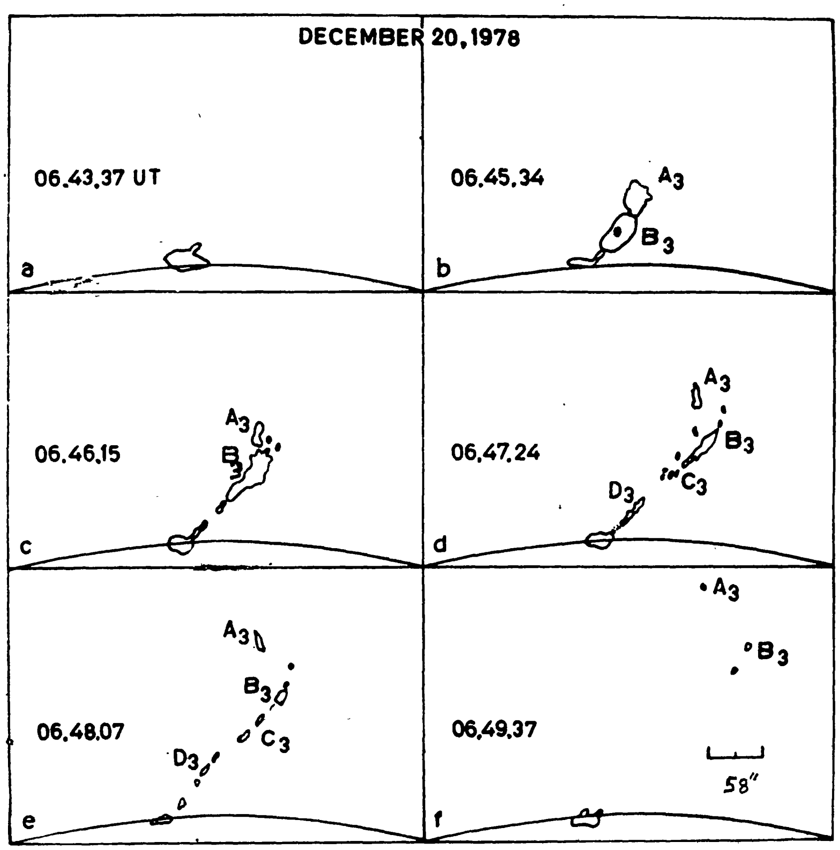

Figure 3. Line drawings of the development of spray prominence.

development of this spray prominence in H-alpha line centre, and the line drawings are given in figure 3. At 06.44.45 UT a blob of material rose up to 22,300 km and split into two parts (features A_3 and B_3). Both these features moved until 06.45.45 along a common trajectory, thereafter they started to move along independent trajectories. Following the feature B_3, a fast moving elongated feature C_3 was identified at 06.45.25 UT. Another feature D_3 observed at 06.46.05, was seen only for 3 min. The height and velocity plots of the spray features are shown in figure 4. Both features C_3 and D_3 attained velocities of more than the escape velocity (618 km s^{-1})

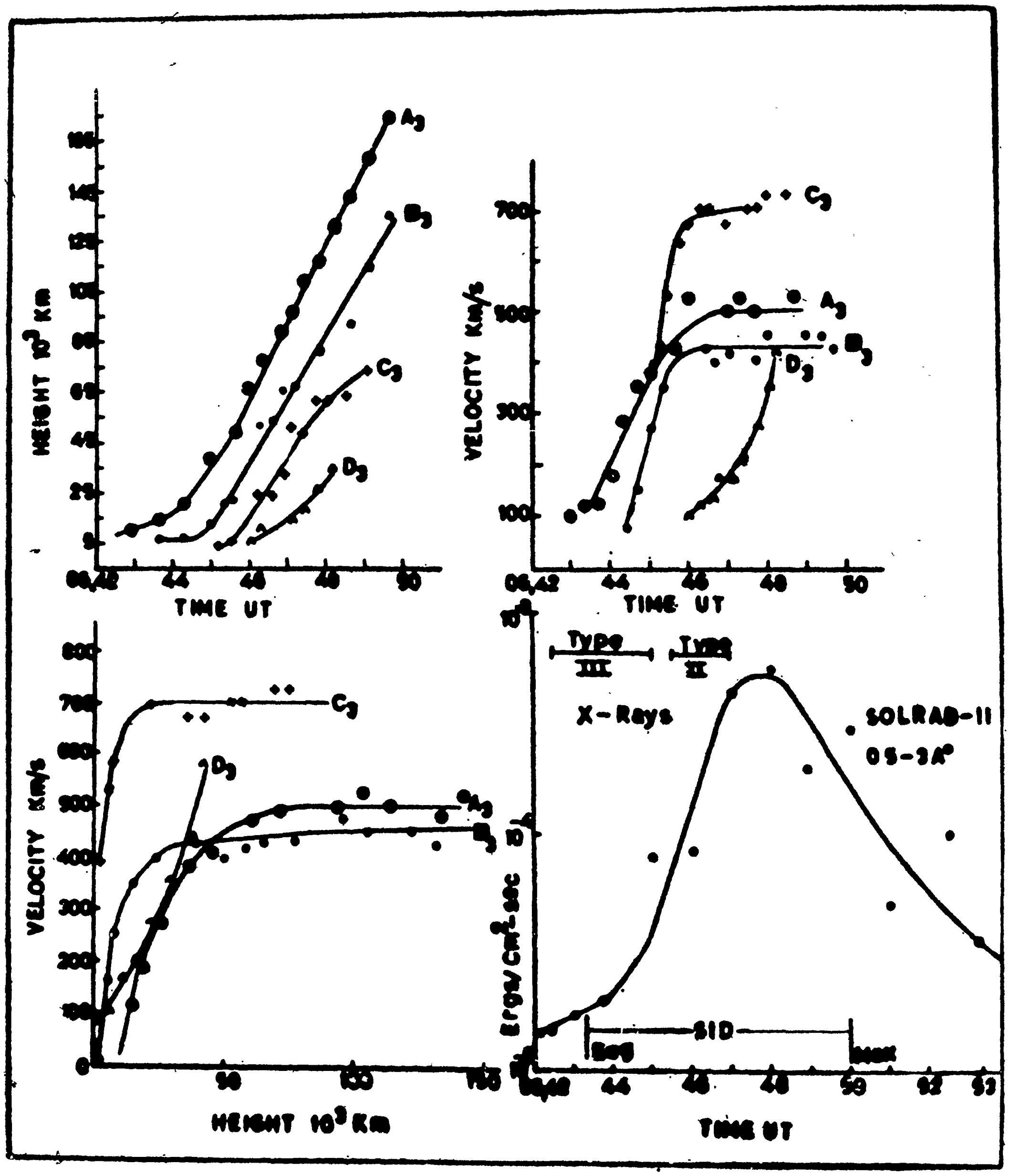

Figure 4. Top (left)—Height *versus* time plot of spray prominence. Top (right)—Velocity curves for spray ejections showing accelaration with time. Bottom (left)—Velocity-height relations for spray ejections. Bottom (right)—Flare-spray associated x-ray flux enhancement in 0.5–3 Å band as observed by Solrad 11. Times of associated radio bursts and SID are shown by horizontal bars.

in the chromosphere. Features A_3 and B_3 were also ejected out with velocities nearly 500 km s^{-1} and reached more than 100,000 km above the limb. The radio burst and x-ray emission associated with this spray event are discussed in the next section.

The third surge A_4 was observed at the same location at 06.50.03 UT about 10 min after the flare event. After about 80 min at 08.06.49 UT, another surge activity-started in the same location and was almost of the same shape. The height *versus* time plots of various surges are given in figures 5 and 6. The beginning time, maximum height and velocity of various surge features may be noted from figure 7. For over 30 min, 11.00–11.30, UT an interesting surge phenomenon was observed. A small surge spike A_{10} injecting out from the same location on the west limb showed thrice an up and down motion. The height *versus* time plot of this event is shown in figure 6. We call this phenomenon of surge motion jumping bean effect. During 06.00–11.30 UT, a total of 14 distinct 'pulses' of activity took place as inferred from figure 7.

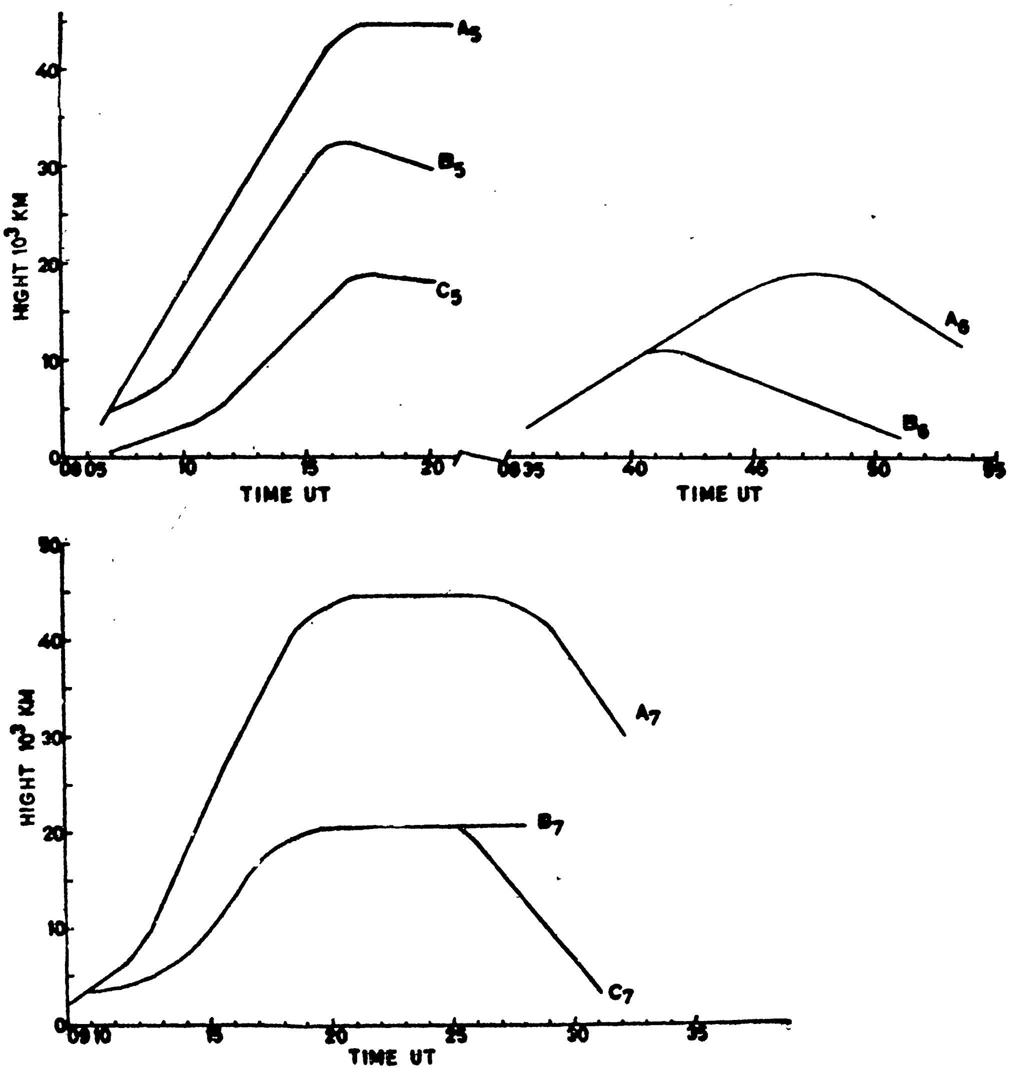

Figure 5. Height-time plots of surges observed during 0805–0935 UT.

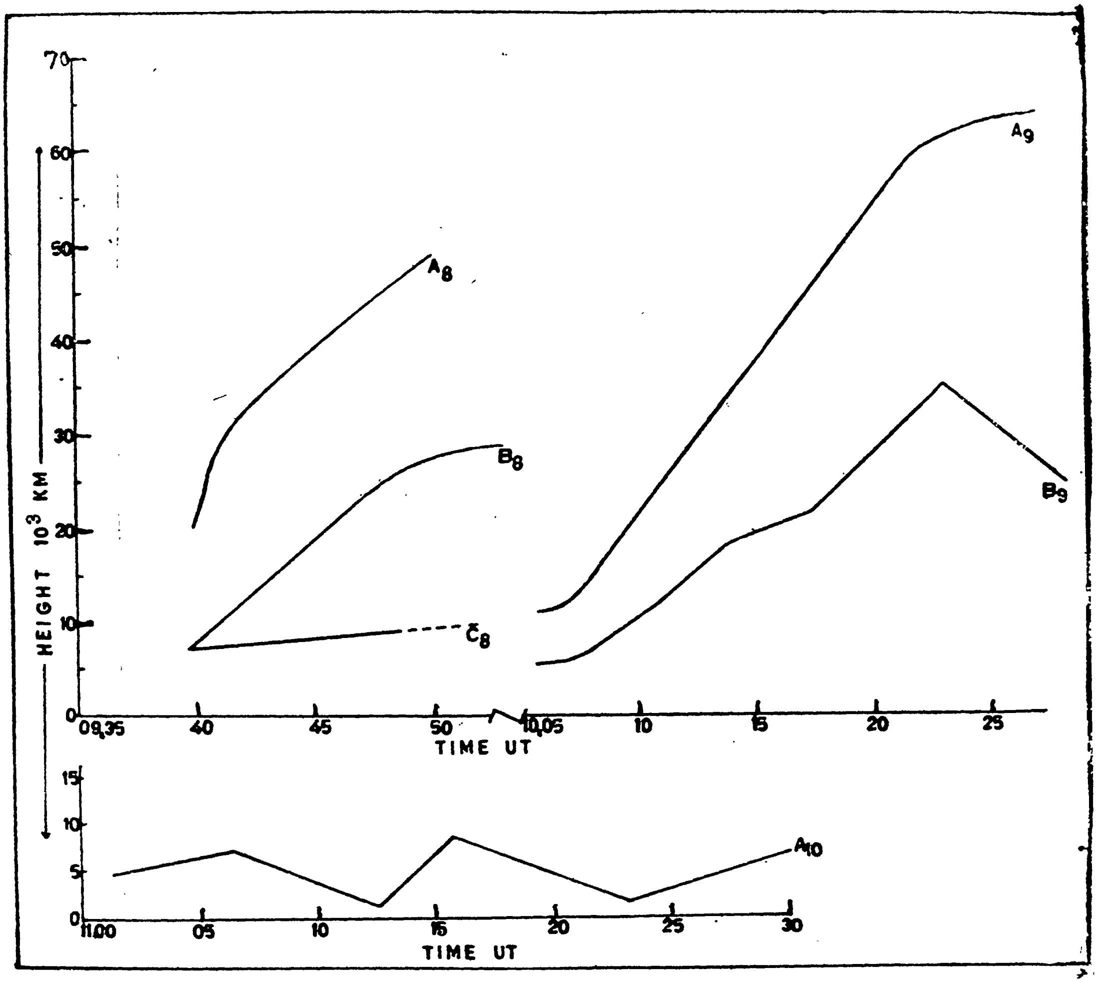

Figure 6. Height-time plots of surges observed during 0935–1130 UT. Note the curve of last surge displaying jumping bean effect.

2.2. *X-ray observations*

In figure 4 is shown the x-ray enhancement in the 0.5–3Å band as observed with Solrad 11 during the impulsive phase of the flare behind the limb, which triggered a huge spray ejection on the west limb around 06.43 UT. The enhancement in x-rays was observed about 3 min prior to the first appearnce of H-alpha mass ejection over the limb. If the spray ejection and the x-ray burst were simultaneous events corresponding to the flash phase, then the delay may imply that the spray took 3 min to appear above the limb from the active region (N22, W100), about 10° behind the limb. If these two events were simultaneous, the average ejection velocity of the spray would be nearly 60 km s^{-1} which is indeed very small as compared to the observed values. Thus we infer that the spray ejection occurred later after the flash phase of the flare and the x-ray emission. The x-ray enhancement associated with this flare produced ionospheric disturbances (SID). The sudden phase anomaly (SPA) was observed to begin at 06.43 UT and to attain a maximum at 0650 UT (figure 4) indicating 7 min duration of development time and relaxation time of about 2 min.

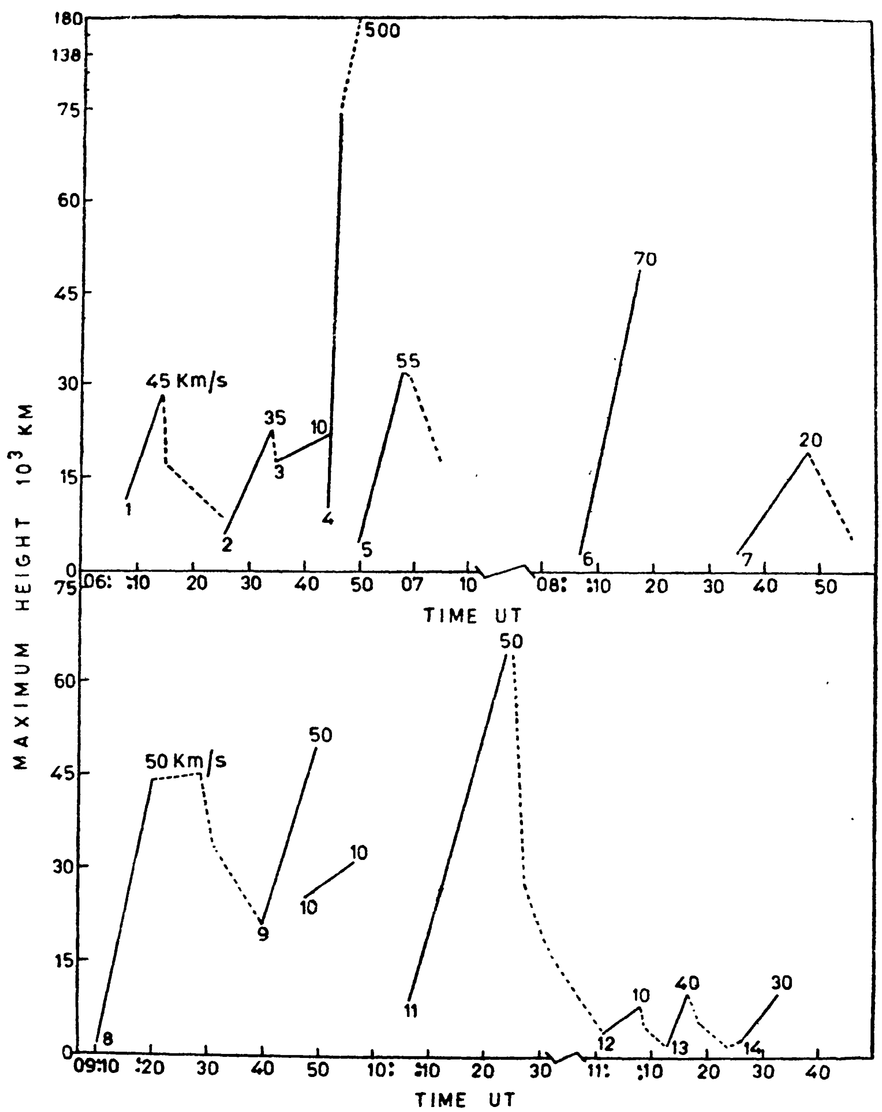

Figure 7. Maximum height *vs* time plot of various surge features showing pulses of activity. At the top of each pulse velocity is also indicated.

2.3. Radio dynamic spectra

This flare of 06.40 UT on 1978 December 20 gave rise to type II and type III radio bursts, as observed by the Culgoora radio observatory. A group of more than 10 type III bursts at decimetric and metric band of intensity 2 were observed between 06.42.5 and 06.45 UT. Type II bursts of intensity 2 were reported on decimetric and metric band during 06.45.5–06.47 and 06.45–06.56 UT respectively. The type II emission at metric band showed a negative frequency drift of 0.9 MHz s^{-1} from 200–80 MHz.

3. Discussion

The time-lapse observations of this interesting limb activity reveal two important aspects of mass ejecting prominence activities associated with flares and active regions:

(i) energetic spray activity following a major flare, and (ii) relatively low energy phenomena of quasi-periodic homologous surge activity.

The McMath active region no. 15700 on 1978 December 20 was observed injecting surge material from the beginning of our observations at 06.09 UT. Two homologous surges had already occurred 15 min before the major spray event took place at 06.43 UT. From the x-ray and radio emission data, it is obvious that this spray was associated with a major flare behind the limb. The observed explosion in this case, was extremely violent and the ejected spray material fragmented into bits and pieces and was thrown out with velocities greater than 600–700 km s^{-1}. It is also possible that the material might have dragged the magnetic field lines along with it to great heights.

Two surges were observed before the flare spray event and a small surge (A_4) about 10 min after the flare. Nearly 80 min after the occurrence of the flare spray, the quasi-periodic homologous surges restarted from the same location and almost along the same trajectory. Six homologous surge ejections were observed at interval ranging from 5 to 30 min. A total of 14 distinct pulses of activity were observed.

The recurring surge activity has been observed earlier by McMath & Pettit (1938) Rosseland & Tandberg-Hanssen (1957) and Loden (1958) at an interval of 1 hr and with a lifetime of 10–20 min. Homologous surge activity at shorter time interval has been also reported by Roy (1973). Gopasyuk *et al.* (1963) and Rust (1968) have shown that the satellite spots are generally surge generating regions, imbedded near the penumbra of a large opposite-polarity sunspot. Roy (1973) has shown that surge events strongly favour regions of evolving magnetic features. To explain the surge ejection Khoklova (1953) and Schluter (1957) have proposed a mechanism called melon seed effect.

Recently, Altschuler *et al.* (1968) have suggested a possible mechanism for surge ejection as due to changing magnetic and velocity fields. Plasma in a relatively cool and dense region tends to descend, the downward motion across magnetic field lines induces an electric current and this current distorts the dominent magnetic field. An 'island' with reversed polarity forms and if a perturbation of this dynamic status occurs, a disturbance is generated which propagates towards weaker magnetic field. This model places the surge exactly on the island of polarity reversals in the photosphere corresponding to the 'satellite spot' as observed by Rust (1968). In order to explain the recurring tendency of surges, it is essential that the original magnetic field configuration be easily restored.

The observed recurring tendency of surges with quasi-periodicity of 5–30 min could possibly be explained by small additional magnetic flux which is brought out by buoyancy in the satellite spots or in the evolving magnetic region as suggested by Roy (1973). This flux, though small, could provide enough collimating force to squeeze out the surge ejection. Our observations indicate that in those cases when the surge velocity (kinetic energy) is higher, the time interval for the next surge to eject becomes much higher. This supports the conjecture that it is the magnetic flux, brought out by buoyancy, that is responsible for providing the collimating force to the surge and to provide higher energy it would take much longer time to build up.

An interesting phenomenon of jumping surge material was observed between 1100 and 11.30 UT. Distinctly three times smaller mass was observed to display up and down motion, with a velocity of about 20 km s^{-1}. We call this phenomenon jumping bean effect. To explain this event we propose a qualitative model (figure 8), according to which the plasma cloud was supported by the magnetic field lines of force over the active region. Because of a slight magnetic field change, the tension in the field lines would vary, resulting in an up and down motion of the plasma cloud. This is similar to a suggestion by Svestka (1976) that to explain the repetitive surges the initial situation must be restarted after the disturbance, similar to a jumper exercises on a trampoline.

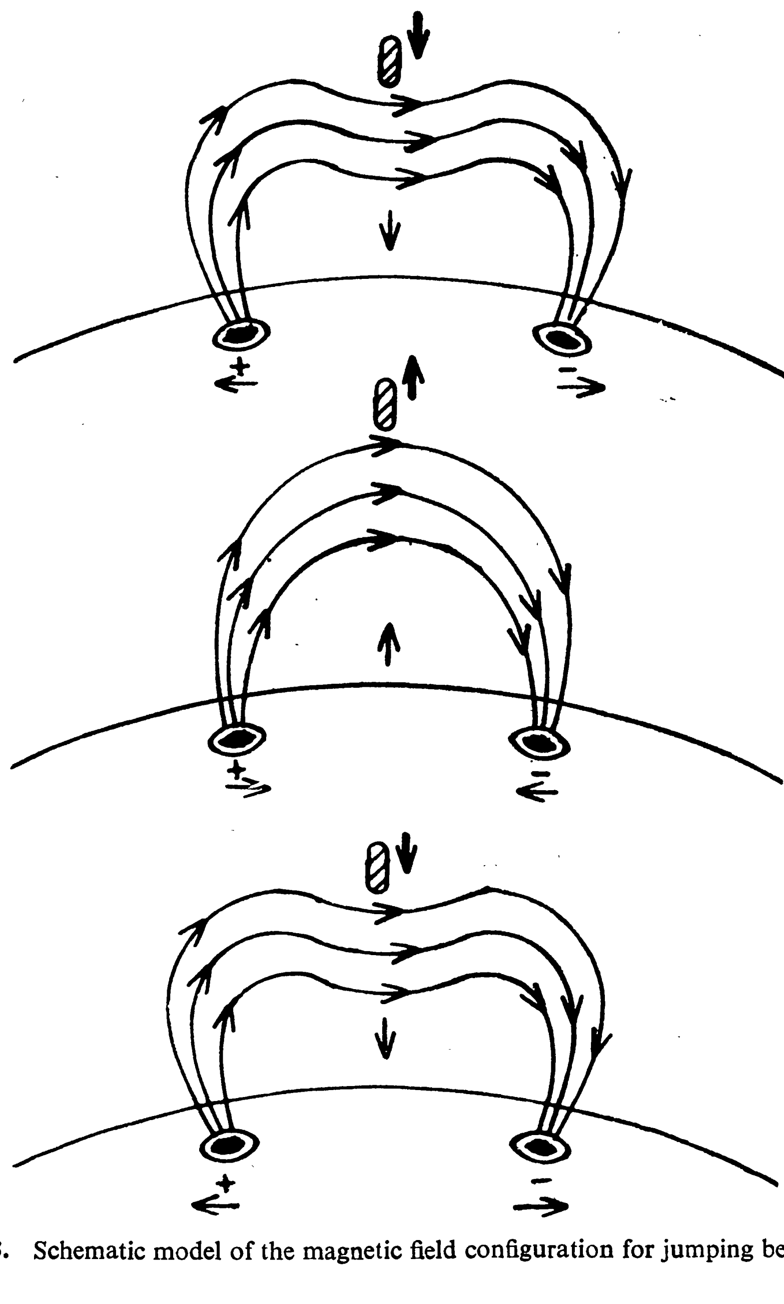

Figure 8. Schematic model of the magnetic field configuration for jumping bean effect.

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