# A MODEL FLARE AND THE CONTINUED POST-FLARE MASS RELEASE FROM THE FLARE REGION

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## ABSTRACT

A mechanism for slow and enduring mass release well after the flare onset, which is inferred from the enduring enhancement in the interplanetary mass flux after flare activity, is discussed in the modified scheme of a "neutral sheet" model of flares. According to a possible new way of looking at the neutral sheet model as proposed by Uchida and Sakurai, it is argued that a slow and enduring mass release in the later phase of a flare may come from the reconnection in the region of interleaved opposite polarity fields produced in the interchange collapse which is proposed to be responsible for the highly dynamical phase at the start of a flare. Heated plasma, which is magnetically disconnected form the anchoring field in the photosphere through reconnection in this interleaved region, is continuously produced during the thermal phase, and is expelled from the flare region by the "buoyancy" in the gradient of the surrounding high magnetic pressure. The trajectory of this mass leakage will be along the steepest gradient of magnetic pressure, rather than along the field lines as expected in other picture, and this process can supply mass to the solar wind in open field regions.

## 1. A MODEL FLARE

Uchida and Sakurai ( 1976, 1979a ) have proposed a new way of looking at the neutral sheet model of solar flares. In brief, the proposal is to consider a general curved neutral sheet which itself is unstable to interchange instability <u>but</u> stabilized by the additional presence of a field component lying along the sheet which prevents the instability. The removal of this stabilizing field component, which is identified with the rise of a dark filament before the flare start, brings the configuration into an unstable one, and an interchange collapse takes place in a dynamical time scale which is $\sim 10^{1 \sim 2}$sec, rather than in a magnetic diffusion time scale which is intrinsically huge and many proposals have been made for mechanisms to make it shorter. The dynamical or transient behavior in the process of settling down of the configuration into a lower energy



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state as introduced in this model seems to explain the drastic and singular behavior around the flare start in a most natural way. Claimed presence of extraordinary high temperature region ( $\sim 10^8$K ) as observed in thermal hard X-ray component at around the flare start ( Ohki and Frost 1979 ) may be interpreted as due to the shocked high temperature region produced in the plasma ahead of the interleaving collapse. The hot small loop of $2 \times 10^7$K observed in soft X-ray and in FeXXIV line in EUV range may be interpreted as being the wishbone type structure below the "neutral" sheet, which is filled with the chromospheric plasma heated and expanded by the heat input from the extraordinary high temperature source thus produced above. The dynamical collapse also explains the emission of MHD shock wave from the flare region in the form of Moreton waves or type II burst shocks.

The interleaving property of the collapse is due to the characteristics of the instability that the growth rate is larger for smaller wavelength perturbation in the linear stage ( Bernstein et al. 1958, Uchida and Sakurai 1979b ). This trend, though suppressed in the shortest wavelength range, holds even in the non-linear stage ( Frieman 1954 ) in which the collapse is driven by the release of the stress in the global distortion of the field ( Uchida and Sakurai 1979b ), the stress having been piled up due to the footpoint motion in the presence of a stable "neutral sheet" which hinders the relaxation.

Now in our picture, the theoretical counterpart of the later thermal phase is as follows : As soon as the configuration settles down dynamically into the lower energy state, and we are left with an interleaved structure, the magnetic annihilation occurs all over the extended interface of the interleaved opposite polarity regions. The total area is $S_e \simeq 2hDN \simeq (2D/d)S_o$, where $S_o \simeq hL$ is the area of the unperturbed sheet with the height h and the length L, $N \simeq L/d$ is the number of leaves with the thickness d, and D is the distance of excursion in the non-linear stage of the interchange collapse, traversed by the outermost part of each polarity region. d and D are estimated to be $\simeq 10^5$cm and $\sim 3 \times 10^8$cm, respectively ( Uchida and Sakurai 1979b ), and therefore $S_e/S_o \sim 10^{3 \sim 4}$. The time scale of the annihilation, $\tau^* = 4\pi\sigma^*(d/2)^2/c^2$, is already as short as $10^{5 \sim 6}$sec with $\sigma^* = \sigma_n$, the classical conductivity, and can easily be shortened to $10^4$sec with assisting mechanisms which, eg., produce a rather weak anomalous resistivity effect, $\sigma^* \sim 10^{-1 \sim -2}\,\sigma_n$. The energy of the magnetic field which is involved in the annihilation in this later phase is $U \simeq (B^2/8\pi)S_e d/2 \sim (B^2/8\pi)DS_o$ and amounts to $10^{31 \sim 32}$ ergs for large flares. In small flares, L, and correspondingly U, is smaller, and the $2 \times 10^7$K region may have the appearance of a single loop.

## 2. MASS LIBERATION IN THE LATER PHASE

One point to be noticed is that the reconnection in three-dimension in our interleaved region of opposite polarity fields can produce magnetoplasma whose magnetic field is disconnected from their photospheric roots and is closed on itself ( Fig. 1 ). Only two leaves with the field of one polarity and the opposite polarity leaf sandwiched between them are shown in the figure, and only lines of force reconnected to those on the middle

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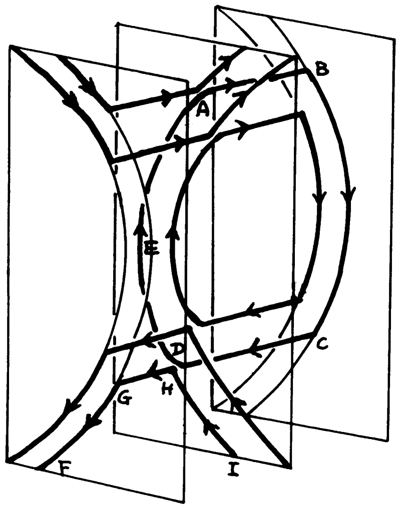


Fig. 1. Schematic picture for three-dimensional reconnection on interleaved structure

leaf are shown for the sake of clearness. The configuration will be composed of the repetition of such basic pattern, and closed loops of field lines disconnected from their photospheric roots are produced without entanglement. The reconnected field lines can not form such an isolated loops in conventional two-dimensional reconnection.

The plasma with isolated field lines like ABCDE in Fig. 1 can be squeezed out of this region by melon seed effect. The sum of the volume of the thus liberated plasma is V $\underset{\sim}{\sim}$ 2hDNd/2 $\sim$ $DS_o$ $\sim$ $10^{27.5}cm^3$, and the potential energy with which the plasma "rolls down" the hill of the magnetic pressure gradient ( which reduces essentially to $(B^2/8\pi)V$ according to Parker (1958) ) is estimated to be of the order of $10^{32}$ergs. It may be noted that this energy is due to the buoyancy of the diamagnetic blob created in the gradient of strong magnetic field of active region, rather than the kinetic energy given to the plasma directly by the flare effects.

Reconnected field lines like FGHI in Fig. 1, on the other hand, will be able to account for the formation of loop-prominence-system appearing after flares. In our model, those lines of force with distant footpoints are folded in the inner side of the "leaves" in the interchange collapse, and come into contact with the opposite polarity field later than those with closer footpoints, corresponding to the observation.

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*DISCUSSION*

*Kuperus:* How does the outward moving plasma cloud gain energy? Is it magnetic energy or gravitational energy that is converted into kinetic energy?

*Uchida:* The kinetic energy of the blob comes from the magnetic buoyancy (a diamagnetic blob is pushed out of the stronger magnetic region due to the difference of magnetic pressure on two sides). It may be stressed that, although this kinetic energy derives itself from the energy of active region, is is independent from the so-called "flare energy." The flare does not accelerate the blob in our picture, but simply produces a blob which is disanchored from the photosphere, and the existing magnetic pressure gradient takes care of its acceleration.

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