PARTICLE ACCELERATION IN THE PROCESS OF ERUPTIVE OPENING AND RECONNECTION OF MAGNETIC FIELDS

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In a series of papers on the flare of 29 July 1973 (Nolte et al., 1979; Martin, 1979; Švestka et al., 1979) it has been shown that Hα "post-flare" loops are the cooled aftermath of previously hot coronal loops which were visible in x-rays in the same position earlier in the flare. Kopp and Pneuman (1976) have proposed that these post-flare loops are formed by a process of successive magnetic field reconnections of previously distended magnetic field lines as illustrated in Figure 1. Each successive reconnection of the magnetic field yields a closed magnetic loop that forms above and concentric with previously formed loops. A shock wave created during each sudden reconnection travels down both legs of each loop and provides energy for ionizing chromospheric mass at the footpoints of the loop. Subsequent condensation of the ionized mass at the tops of the loops renders them visible as this mass falls to the chromosphere.

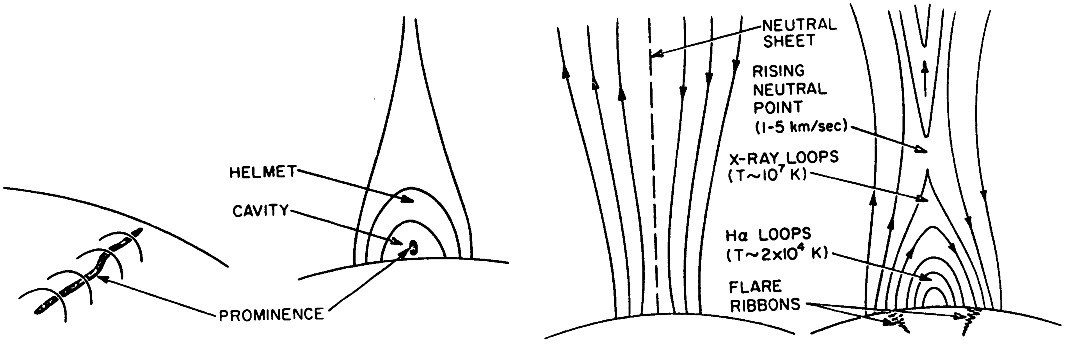

Figure 1. Kopp and Pneuman model for post-flare loops.

M. Dryer and E. Tandberg-Hanssen (eds.), Solar and Interplanetary Dynamics, 217-221.

The 29 July 1973 flare observations show that the Kopp and Pneuman model is entirely consistent with the observations of both the cool Hα flare loops and the hotter x-ray loops since both the cool and hot loop events are actually the successive formation of individual loops at increasingly greater heights. Therefore, we suggest, as already discussed in Švestka (1979), Martin (1979), Pneuman (1979) and Švestka et al. (1979), that the Kopp and Pneuman model is applicable to the early phases of flare loop development as well as to the later phase .

The Kopp and Pneuman model has several key features in common with some other reconnection models which make it an attractive model for two-ribbon flares in general. First, it yields loops. As illustrated in Figure 2, Skylab observations have shown that loops are the fundamental form of the coronal part of EUV and x-ray flares. Secondly, when reconnection occurs, high energy particles and/or thermal waves would be accelerated along the lower half of the reconnected magnetic field. The impact of such particles and/or heat waves with the chromosphere can produce the typical two-ribbon flare.

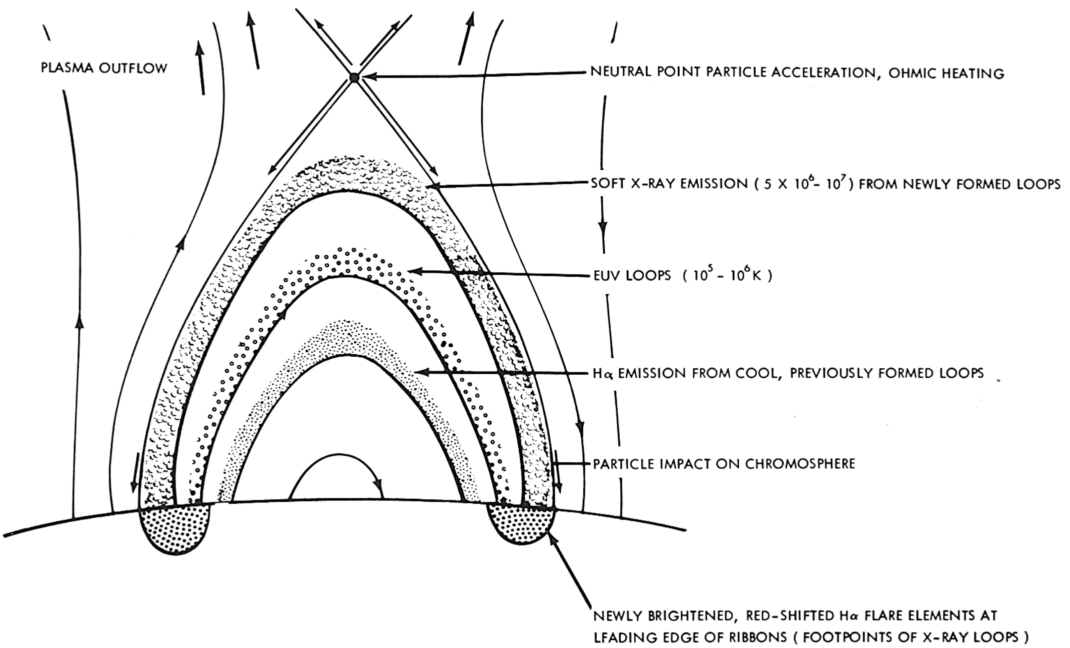

Figure 2. Interrelationship of various coronal flare loops and the chromospheric flare.

In support of this aspect of the model, we show in Figure 3a

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a two-ribbon flare photographed on 11 April 1973 from the slit-jaw images of the Hα multi-slit spectrograph at the Rye Canyon site of the Lockheed Solar Observatory. Figure 3b shows the corresponding Hα spectral lines below each slit in Figure 3a. Along only the outer border of such two-ribbon flares, the multi-slit spectra show very short-lived red-shifts in the flare profile whenever a slit is located on a newly formed flare element (3rd slit from the left).

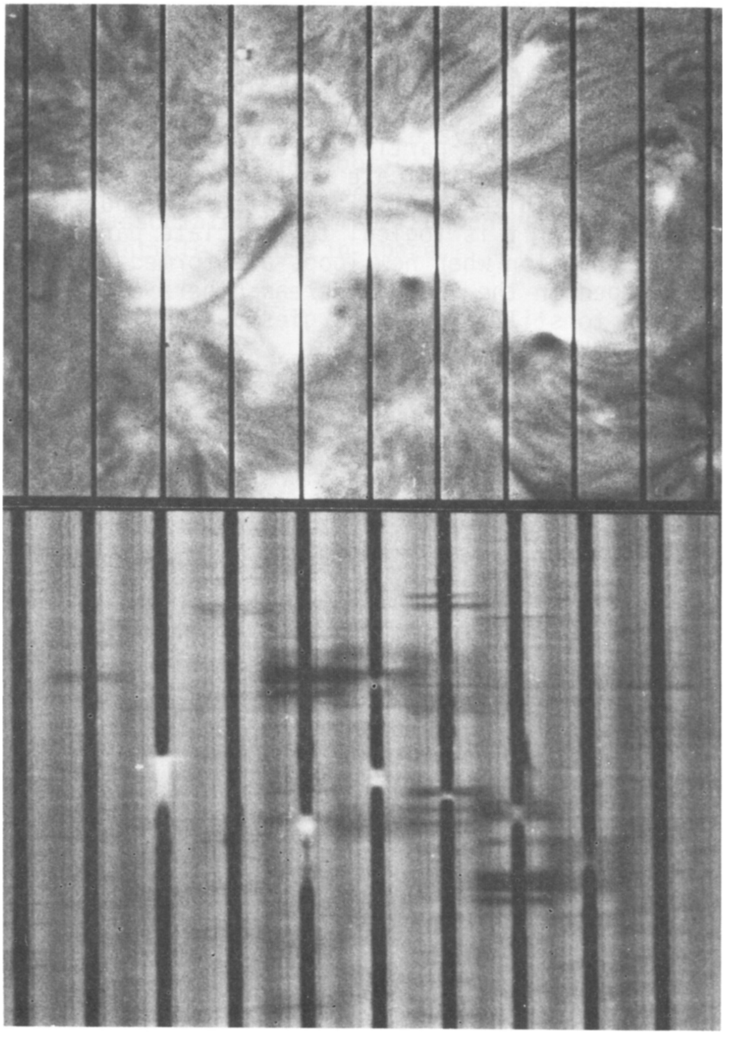

Figure 3a,3b. Slit-jaw image (upper half) allows the identification of a tiny, red-shifted flare element seen at the outer border of the flare in the 3rd slit from the left in the array of Hα spectra (lower half).

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These very tiny red-shifted flare elements are consistent with the idea that each successive magnetic reconnection provides sufficient particle or thermal-wave energy to temporarily depress the chromosphere at points along the outer, newly developing border of two-ribbon flares. Furthermore, the Hα multi-slit spectra also show that this red-shift at points along the outer border is a continuous characteristic throughout most of the lifetime of two-ribbon flares.

Two-ribbon flares have been shown to be powerful sources of particle acceleration (Švestka, 1976): Essentially all cosmic-ray and proton flares are of this type; out of 50 flares which were clearly identified as sources of protons in space from 1956 through 1969 (Švestka and Simon, 1976), 31 were definitely, and 14 most probably, two-ribbon flares. Thus one can suppose that the two-ribbon flare process is characteristic for particle acceleration on the Sun. Because several observations indicate that the acceleration is accomplished in loops (white-light flare patches, impulsive kernels, also see Hudson, 1979), it is logical to associate particle acceleration with magnetic reconnection when new loops are formed (Figure 4). Some particles are trapped in the loops, whereas others escape upwards and can be accelerated to still higher energies as passing through the shock wave that precedes the coronal transient.

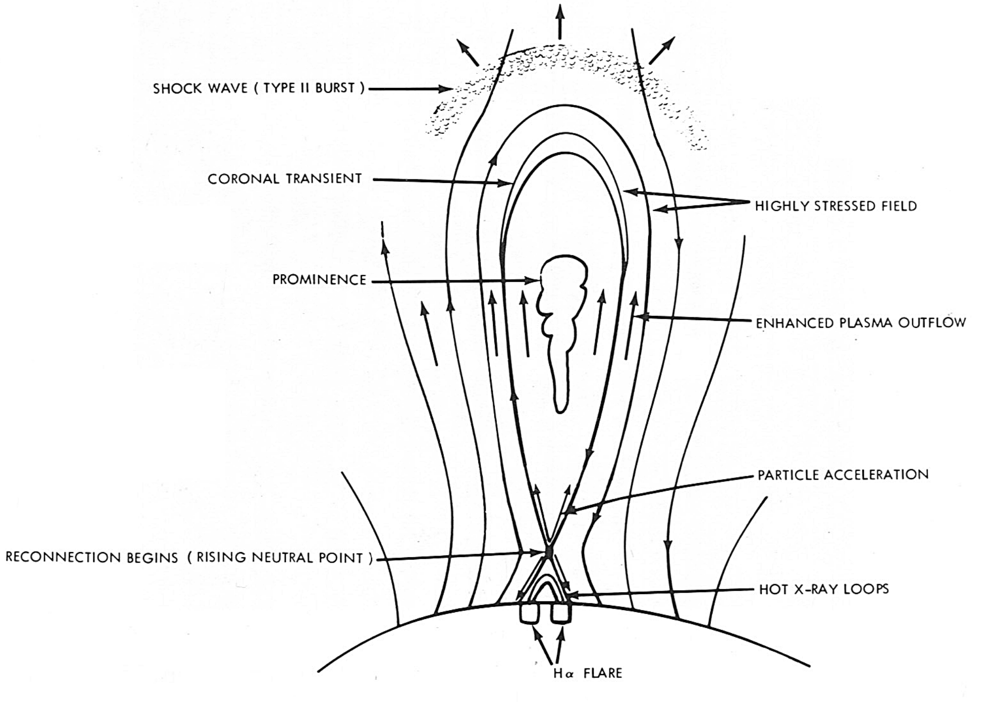

Figure 4. Flare onset.

An important feature of this model is that particle acceleration would be a long-enduring process with the most rapid acceleration occurring during the flash phase of the flares but with continued acceleration and injection occurring throughout the whole flare life. After the flash phase, the decreasing intensity and rate of growth of flare loops and chromospheric flare ribbons suggests that the reconnection rate gradually decreases, but theprocess continues for a very long period of time: The continuous formation of loops at the limb are often seen long after the Hα flare has faded, and in the flare of 29 July 1973, observed on Skylab, new loops were formed still 12 hours after the flare onset (Švestka et al., 1979).

A closely related result is that all disparition brusques, also without any obvious chromospheric flare, have been found by Rust and Webb (1977) to be followed by flare-like systems of X-ray loops. This suggests the possibility that non-optical X-ray loop flares may follow all disparition brusques. Hence, we are led to think that disparition brusques might be associated with the frequent occurrence of long-lived low-energy particle events in space.

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