PROMPT HIGH-ENERGY PARTICLE ACCELERATION DURING TWO-CURRENT-LOOP COLLISIONS

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Abstract. We present a model of prompt high-energy particle acceleration during two-current-loop collisions. By investigating test proton and test electron motions in the electromagnetic field derived from the MHD equations, we found that high-energy particle acceleration occurs only in the case of Y-type, loop–loop collisions. The results depend strongly on the plasma β and initial position of the test particle. When the plasma β increases, the particle acceleration rate decreases. The particles near the edge of the collision region can be accelerated to higher energy than the ones inside it. It has been shown that both protons and electrons can be accelerated to ~ 10 GeV within 0.001 s and ~ 5 MeV within 10⁻⁶ s, respectively. In the case of Y-type loop–loop collisions, one may expect that high-energy gamma-ray and neutrons will be generated from interaction between high-energy particles and the low atmospheric plasma.

1. Introduction

The high-energy particle acceleration mechanism during the impulsive phases of solar flares is one of the important subjects in the understanding of various features of solar flares. From previous solar maximum observations (SMM, HINOTORI), it became clear that both protons and electrons can be promptly accelerated to relativistic energies within 1 s during impulsive phases (Chupp, 1984; Rieger, 1989; Yoshimori, 1989). A physical mechanism to explain this prompt acceleration was investigated by Sakai (1990a, b), based on the current loop coalescence model for solar flares (Tajima, Brunel, and Sakai, 1982; Tajima et al., 1987; for a review, see Sakai and Ohsawa, 1987). Recent studies about the current loop coalescence model of solar flares (Sakai and de Jager, 1989a, b, 1991; de Jager and Sakai, 1991) have provided an opportunity to explain many characteristics of solar flares, such as coronal explosions discovered by de Jager and Boelee (1984), and high-energy particle acceleration and elementary flare bursts (Van Beek, De Feiter, and de Jager, 1974; de Jager and De Jonge, 1978). It has been shown that the loop coalescence processes have different characteristics, depending on the geometry of the region containing the two interacting current loops.

From recent YOHKOH soft X-ray images, Shimizu et al. (1992) pointed out that there were 61 single-loop events, 69 multiple-loop events, and 14 point-like events when observing 144 transient brightening events. Furthermore, in the multiple-loop events, 30% are of the X-type configuration, 57% of the Y-type configuration, and 13% are others. The final results of such loop–loop interaction depend on the magnetic field geometry and mutual positions of the interacting current loops.

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Sakai and Koide (1992) classified magnetic reconnection during two-current-loop coalescence. Chargeishvili, Zhao, and Sakai (1993, Paper I) developed a model of two-current-loop collisions to explain the impulsive nature of solar flares, following previous work done by Sakai (1989). They divided configurations of loop–loop collisions into three types (as shown in Figure 1 of Paper I). The case of \( X \)-type collisions is defined by \( L_x/L_z \gg 1 \), the case of \( Y \)-type collisions is defined by \( L_x/L_z = 1 \), the case of \( I \)-type collisions is contrary to the case of \( X \)-type, where \( L_x = |(1/p)(\partial p/\partial r)|^{-1} \) and

![Fig. 1. Time history of amplitudes of magnetic field components.](image-url)