The Numerical Analysis on Characteristics of Plasma Temperature Variation about the Aug.17,25:58UT, 1992 Flare

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Abstract

The characteristics of plasma temperature variation during the collision of two current loops are described. It is revealed that the plasma temperature has an oscillatory feature with damping amplitude and growing quasi-period in the case of an I-type collision. In the case of a Y-type collision, if the initial current becomes strong enough, there also occurs pulsation of the temperature. The temperature profile of an X-type collision is characterized by the single pulse only. Based on the observatory phenomena, the Aug.17, 25:58UT, 1992 flare wave induced by the two loop interaction whose configuration was the I-type loop-loop interation. The numerical results agree with the observed one quite well.

1. Introduction

The solar flare phenomenon is a manifestation of the explosive release process of magnetic energy stored in the lower corona, including plasma heating and particle acceleration. Since the Smm and Hinotori satellites were launched, it has become clear that flares have a close correlation with current loop collisions. From Yohkoh's soft X-ray images, it is apparent that the interaction of coronal loops may be an important physical process for energy release in the solar corona (Shimizu 1992). Theories and simulations (see Sakai and Ohsawa 1987) have shown that, during the coalescence of two current loops through the magnetic reconnection process, magnetic energy stored in the current loops converts to plasma heating and production of high-energy particles. Such physical processes depend on the magnetic field geometry and the configuration of the interacting current loops (Sakai and de Jager 1991). Investigating the nonlinear coalescence instability of current loops, Tajima et al. (1987) paid attention to the double subpeak structure in quasi-periodic oscillations found in the time profiles of two solar flares on June 7, 1980 and Nov. 26, 1982. Chargeishvili et al. (1993) have classified loop-loop interactions into three types according to the ratio between the plasma pressure gradients in the Z and R directions, and pointed out the oscillatory character of physical quantities in the case of an I-type collision.

In this paper, we study the characteristics of plasma temperature near the interacting region in three types (X,Y,I) of loop-loop collisions by using a MHD approach developed by Chargeshivili[1]. Comparing the numerical results with Yohkoh data, we deduce that the flare of Aug.17, 23:58 UT, 1992 may correspond to the case of an I-type loop-loop interaction.

2. Characteristics of plasma temperature

Using MHD equations with gravity and resistivity effects, we get self-consistent expressions and a set of equations governing the behavior of all physical quantities (see Chargeishvili et al. 1993). From the numerical simulations, we found that the plasma β, the type of loop collision, and the initial current strength have significant effects on the characteristics of plasma temperature. Prescriptions of the physical parameters are given as follows. The case of an I-type loop-loop collisions is defined by $L_r/L_z \ll 1$, the case of a Y-type is defined by $L_r/L_z=1$, the case of an X-type is the opposite case of I-type, where $L_r=|(1/p)(\partial p/\partial r)|^{-1}$, $L_z=|(1/p)(\partial p/\partial z)|^{-1}$ and p is plasma pressure. The initial current strength is proportional to reverse of B_1, where $B_1=B_{r0}/B_{\varphi 0}$, B_{r0} and $B_{\varphi 0}$ are components of initial magnetic field in radial and azimuthal directions, respectively. Time is normalized by $\tau_A=(4\pi\rho_0)^{1/2}L_r/B_{\varphi 0}$. As for the time profile of plasma temperature, the case of an X-type has only one peak. In the case of a Y-type, there occurs pulsation. The case of an I-type shows oscillating character with damping amplitude and growing quasi-period.

First we consider the effect of the type of the collision on the time profile of plasma temperature. Figure 1, Figure 2 and Figure 3 show the different characters of the temperature profile for the different types of collisions. One can see that a pulsation phenomenon in the case of an I-type collision is more apparent than in the case of a Y-type. Next, considering the initial current strength, we found out that a stronger initial current leads to more evident oscillations in the temperature time profile (see Figure 1 and Figure 2). For a weak current case ($B_1=0.1$) that may correspond to a weak flare, the temperature is enhanced by a few times, while for a strong current case ($B_1=10^4$) which may correspond to a strong flare, the temperature can increase up to a hundred times. In the strongest current case, the Figure 2(d) shows that the time profile of plasma temperature of the Y-type collision has five peaks and that the third peak is much higher than the first one. However there is still a single pulse in the case of an X-type collision, even though the amplitude of the peak becomes higher (shown by Figure3(d)). As for the plasma β, an increase of it causes an increase of the first peak width and quasi-period and a decrease of the peak amplitude. Out of the range of the known values of β, the oscillation phenomenon disappears. In the weak current case, it happens near $\beta=0.02$.

3. Flare of Aug.17, 23:58 UT, 1992

The Aug.17, 23:58 UT, 1992 flare observed by Yohkoh showed double peaks in the soft X-ray flux. During the first peak, four brightening footpoints were located along a line, and they were divided into two pairs by the magnetic neutral line. No high energy particles were detected, only plasma heating occurred and small fraction of electron with energy about 20 KeV was observed before the first peak of soft X-ray flux (Takahashi et al. 1992). Comparing the numerical results with the time profile of the soft X-ray flux, we deduce that only the case of an I-type collision could provide such an event. The interval between the first and second peaks obtained from the simulation coincides well with the observed one, if the flare scale, plasma density and B_1 are about 10^9 cm, 10^{11} and 0.1, respectively. The enhanced maximum temperature in the first peak is about three times higher than the one in the second peak. By using a particle acceleration model (Zhao et al. 1993), we get results that particles can be accelerated to about 30 KeV within 1 second, which precedes the first temperature maximum. There is no particle acceleration near the second peak because electric field is not strong enough.

4. Conclusion

We describe characteristics of plasma temperature variation during loop-loop collisions for different initial conditions, such as plasma β, the type of the collision and initial current strength. Enhancement of plasma temperature is caused by adiabatic heating. Strong initial current strength leads to a strong flare and effective plasma heating. We suggest that comparing these characteristics with observed time profiles of physical quantities, one can conjecture the initial conditions of loop-loop interactions such as Alfven transient time, loop-loop configuration, current strength and so on.

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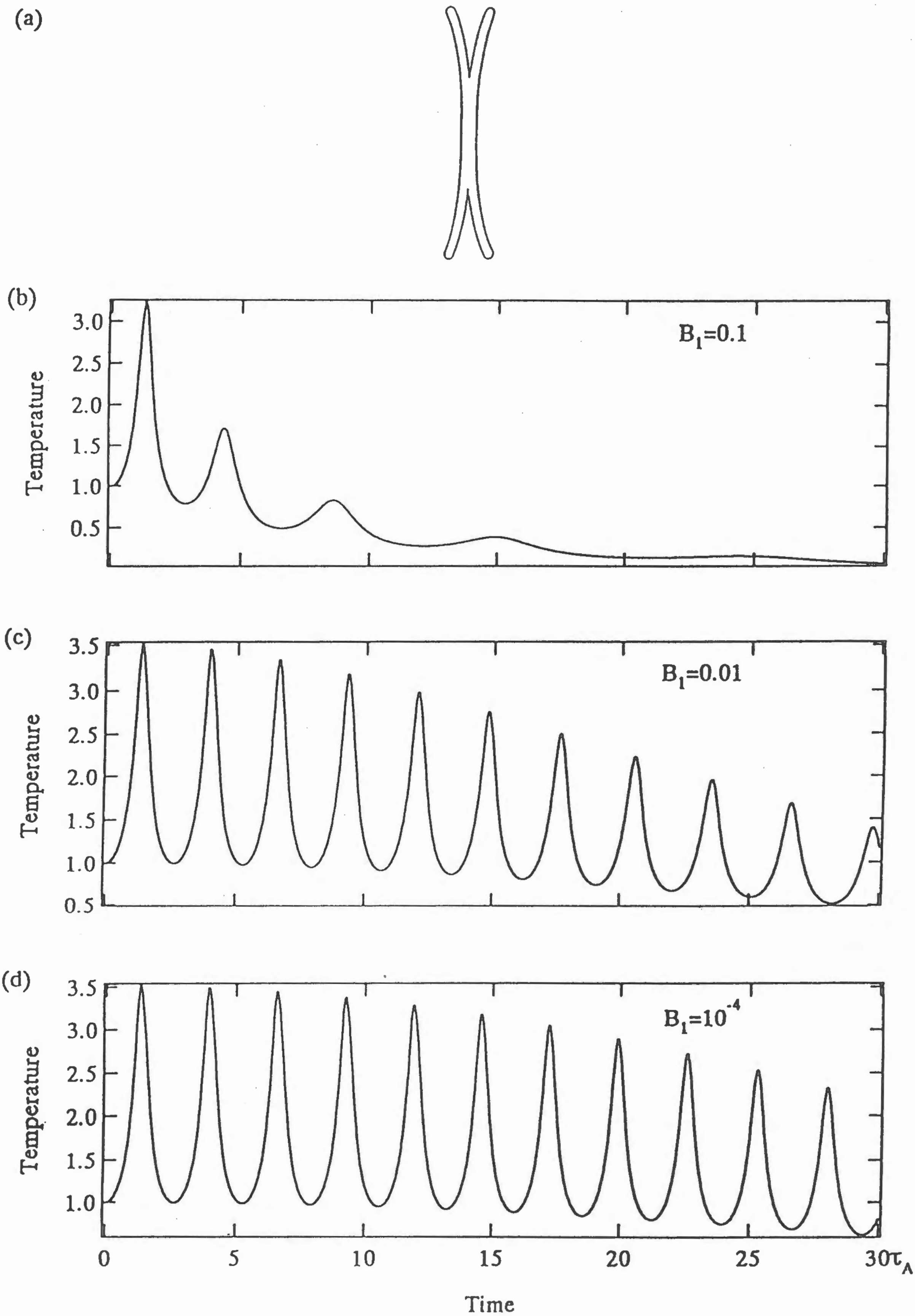

Figure1. The I-type of loop-loop collision and corresponding time profiles of plasma temperature for the different initial current strength

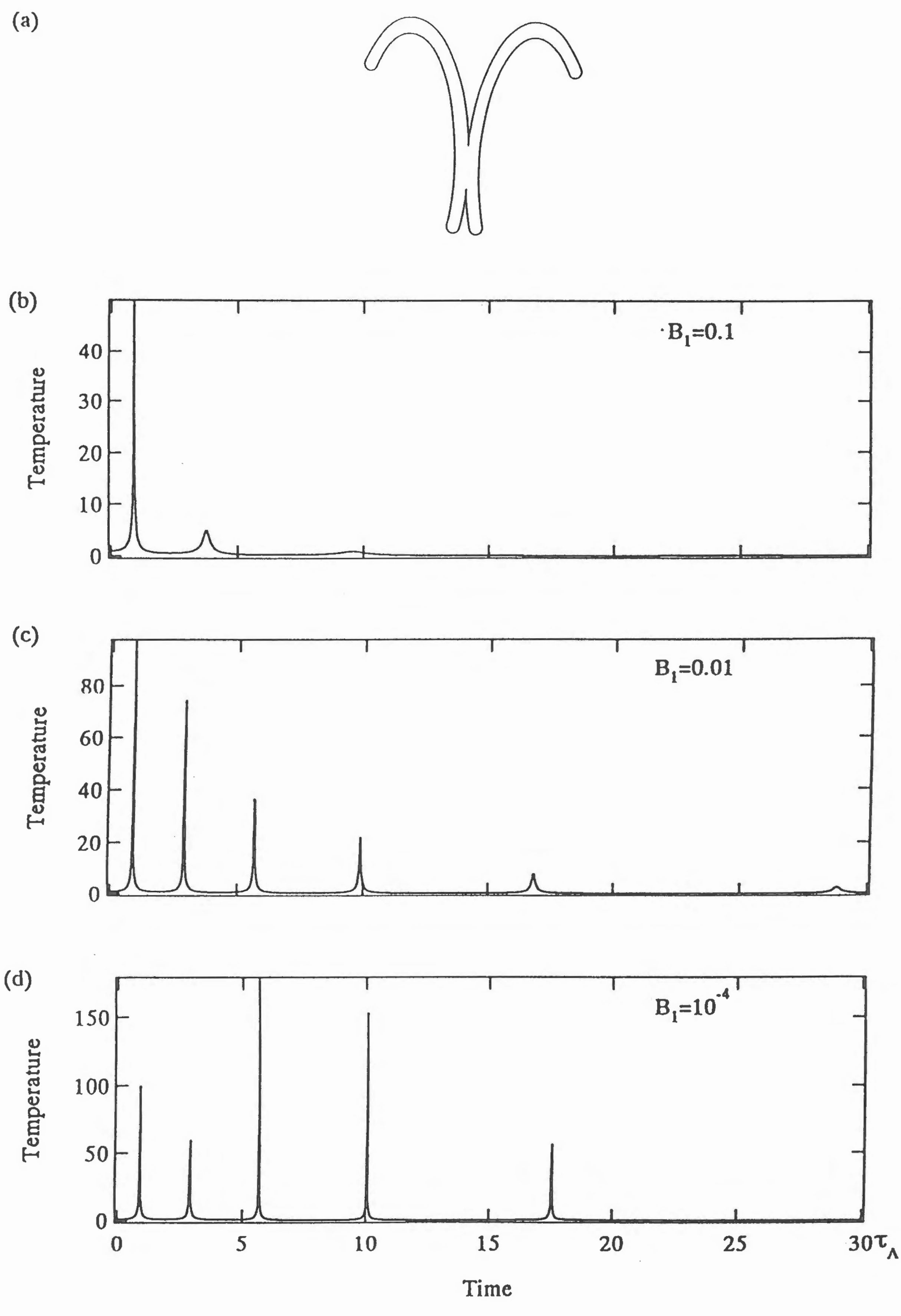

Figure2. The Y-type of loop-loop collision and corresponding time profiles of plasma temperature for the different initial current strength

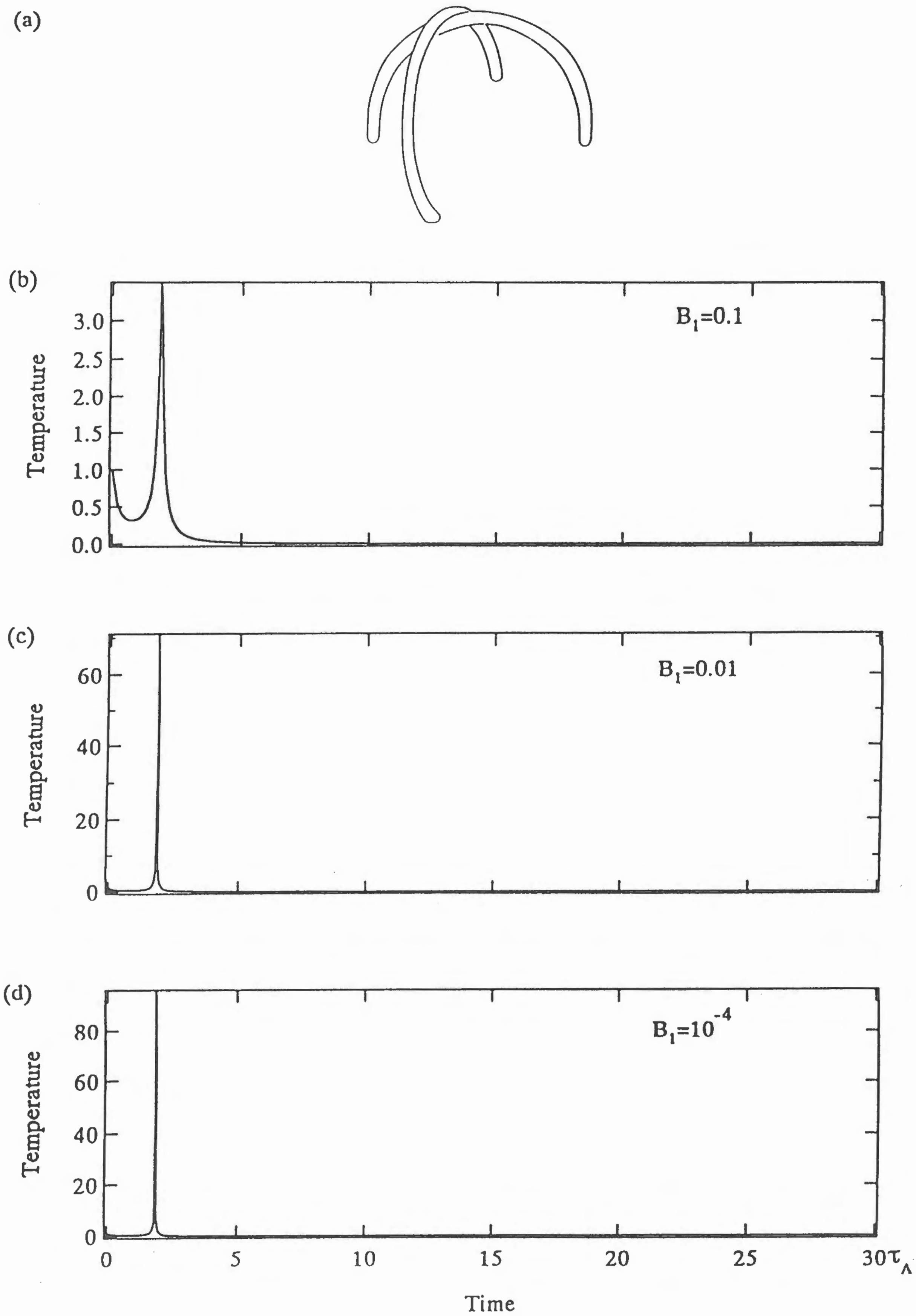

Figure3. The X-type of loop-loop collision and corresponding time profiles of plasma temperature for the different initial current strength