Numerical Magnetohydrodynamic Model of Dark Filament Eruption and Arcade Flaring

Shigenobu HIROSE,[1] Yutaka UCHIDA,[1] Samuel B. CABLE,[2] Shuhei UEMURA,[1] and Tomotaka YAMAGUCHI[1]

[1] *Department of Physics, Science University of Tokyo, 1-3 Kagurazaka, Shinjuku-ku, Tokyo 162-8601, JAPAN*
[2] *Department of Physics, Auburn University, 206 Allison Laboratory, Auburn University, AL 36849, USA*
E-mail(SH): shirose@astro5.yy.kagu.sut.ac.jp

Abstract

We performed 2.5 dimensional magnetohydrodynamics numerical simulation based on the quadruple magnetic source model(Uchida 1980) to explain the dark filament eruption and the following arcade flaring consistently.

Key words:

1. Introduction

Now it is a popular idea that dark filament eruption (or plasmoid ejection) causes magnetic reconnection just above an "arcade" and the energy release through the reconnection finally results in arcade-type flaring.

In the quadruple magnetic source model proposed by Uchida(1980) the dark filament is supported in the energized neutral sheet between two magnetic loops and prevents the magnetic reconnection between them. Thus it can explain the features of an arcade-type flaring consistently.

Based on the quadruple magnetic source model, we performed 2.5 dimensional magnetohydrodymics numerical simulation. The first purpose is to obtain dark filament supported in the enegized neutral sheet of the quadruple magnetic source field. The second one is to investigate the dynamical evolution of the system through the magnetic reconnection caused by the dark filament erruption.

2. Numerical Results

2.1. Numerical Method

We solve the following basic equations of resistive magnetohydrodynamics numerically using two-step Lax-Wendroff scheme. We adopt an anomalous resistivity model in which the resistivity is a function of the current density.

2.2. Structure of Quasi-static Dark Filament

For the initial condition, we adopt a current-free field of quadruple magnetic source superposed by uniform field in the direction of the arcade.

We set a photospheric motion which brings two magnetic loops close to each other. The speed of the motion is 1% of the coronal sound speed. Then the magnetic energy is accumulated in the neutral sheet at the interface between two magnetic loops.

On the other hand, we put a gas blob above the neutral sheet. The density of the blob is 10 times as large as that of the background corona. Then the gas flows into the narrow space of the neutral sheet by the gravity, and we finally obtain *quasi*-static dark filament supported above the arcade. Figure 1 shows the curtain-like dark filament and the surrounding magnetic fields. We can see that the dark filament containing helical magnetic islands prevents the magnetic reconnection and thus contributes to the accumulation of the magnetic energy in the neutral sheet. The dark filament gas extends to the photosphere along the arcade, which may correspond to the "barbs" observed in H_α (Martin et al. 1994).

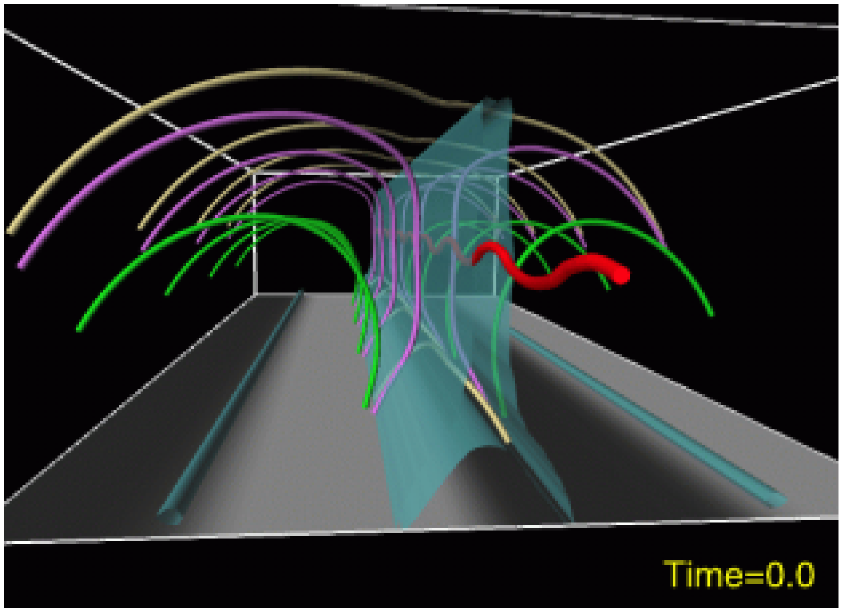

Fig. 1.. Structure of the quasi-static dark filament. Tubes and semitransparent surface represent magnetic lines of force and iso-density surface, respectively. Gray-scale at the bottom corresponds to z component of the magnetic field.

2.3. Dynamical Evolution caused by the Dark Filament Eruption

We further continued the photospheric motion after we obtained the quasi-static dark filament in the neutral sheet. Figure 2 shows the dynamical evolution of the system. The neutral sheet is compressed and thus the dark filament gas is expelled both upward and downward. Then anti-paralleled magnetic lines of force contact each other and the magnetic reconnection occurs. The dark filament gas ejected upward contains helical magnetic islands and is further accelerated upward by the magnetic reconnection.

Figure 3 shows the current density distribution and magnetic lines of force in a cross section of the "arcade". We can see that through the magnetic reconnection the current density or the stored magnetic energy in the neutral sheet decreases and the magnetic field approaches to the current-free field.

Most of the magnetic energy released through the magnetic reconnection is first converted into the energy of bulk motion both upward and downward. We can see from the velocity field in figure 4 that the kinetic energy of upward motion is much larger than that of downward motion. This is because the configuration of the magnetic field is asymmetry in the vertical direction.

Figure 5 shows the current density distribution in a lower β case. The value of β is about 5 around the neutral point and this is the half of the value in the typical case. We can clearly see the wave front of slow-mode in an "X"-shape where the magnetic energy is converted into the kinetic energy. This is because the compressibility is higher in the lower β case.

3. Discussion

The kinetic energy of downward motion will be finally converted into the flaring energy. So, in our model, only a small fraction of the magnetic energy released through the magnetic reconnection is finally converted into the flaring energy, and most of the released energy is converted into the erergy of the upward bulk motion. This energetic upward bulk motion may have some relation to mass loss phenomena such as CME.

References

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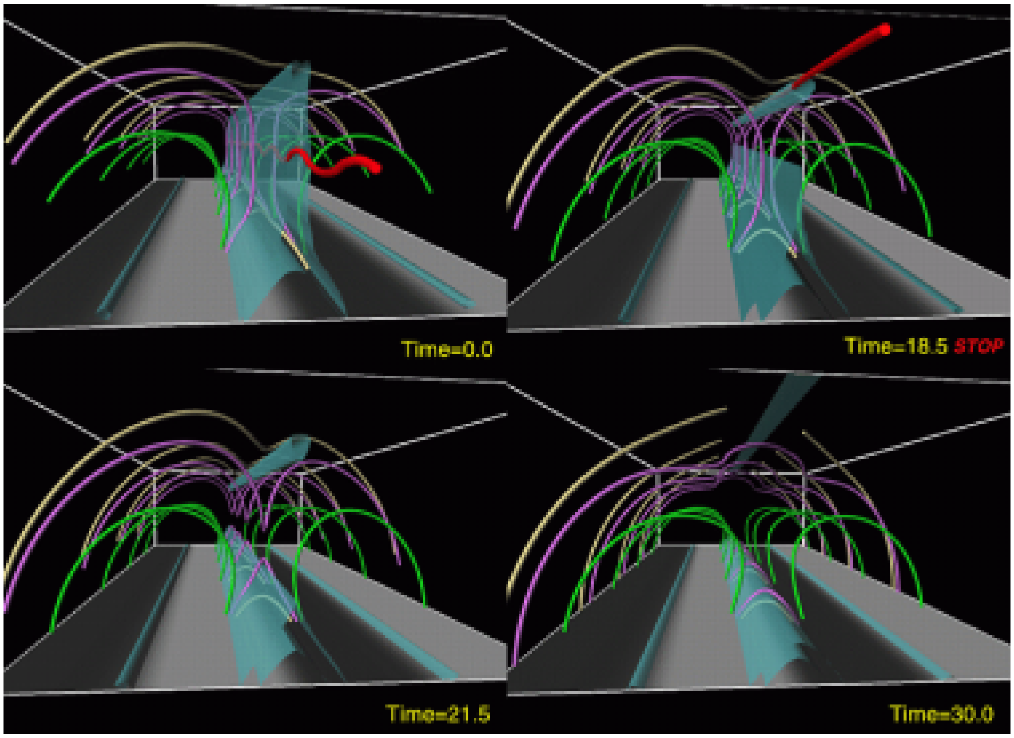

Fig. 2.. Dynamical evolution of the system: the dark filament eruption and the following magnetic reconnection. The notations are the same as in figure1.

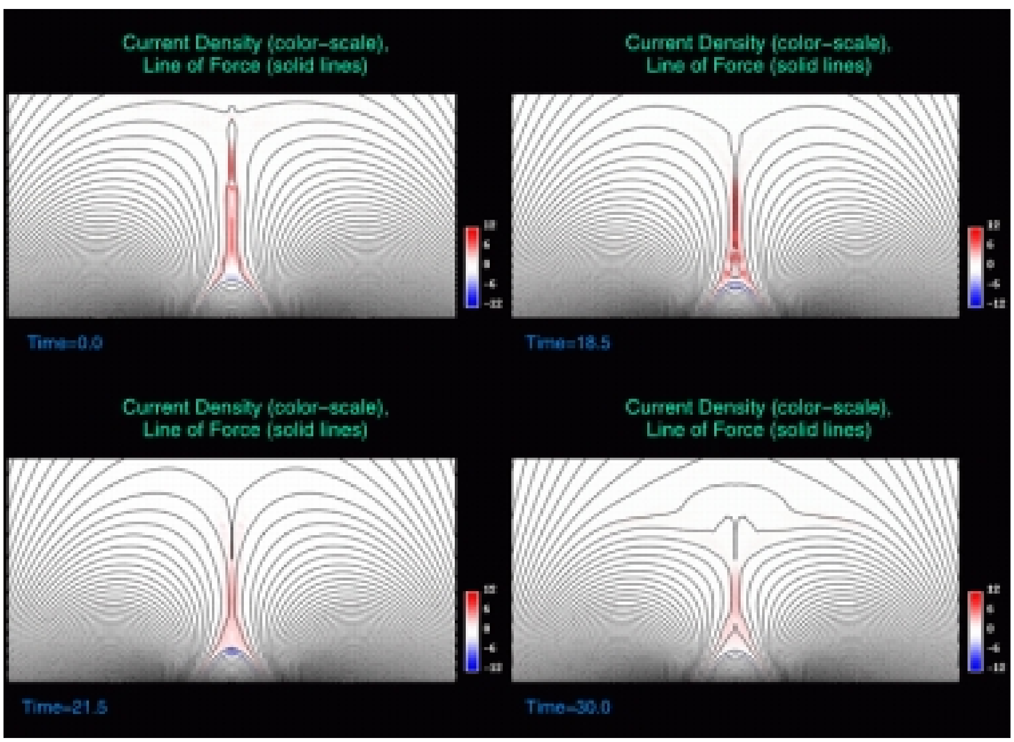

Fig. 3.. Current density distribution and magnetic lines of force in a cross section of arcade. Gray-scale and solid lines represent current density and magnetic lines of force, respectively.

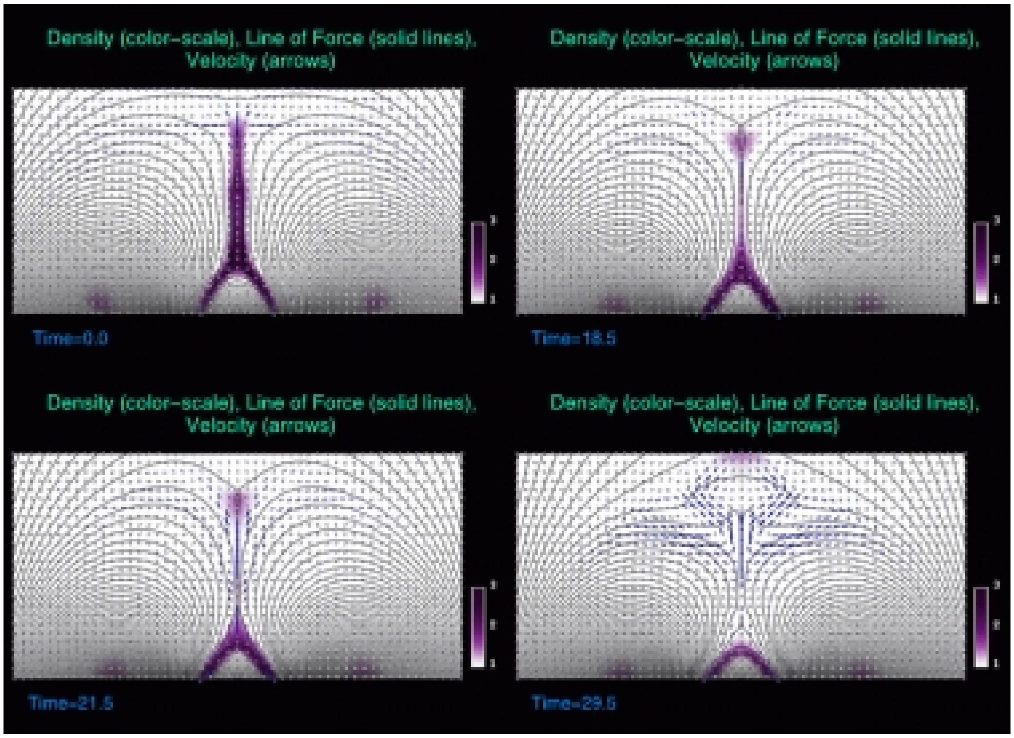

Fig. 4.. Density distribution, velocity field and magnetic lines of force in a cross section of arcade. Gray-scale, arrows and solid lines represent density, velocity vectors and magnetic lines of force, respectively.

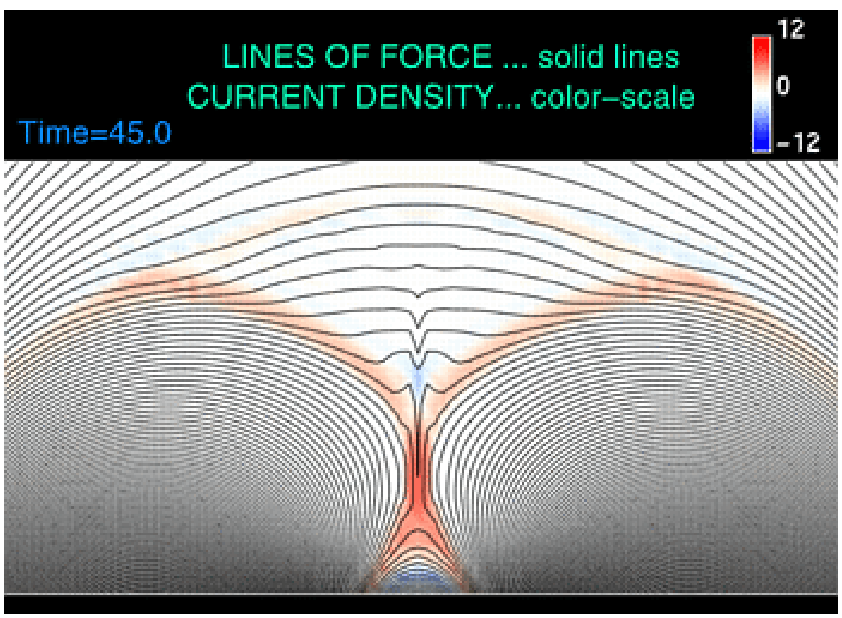

Fig. 5.. "X"-shape slow-mode wave front in a low β case. The notations are the same in figure 3.