DYNAMICS OF CORONAL TRANSIENTS: TWO-DIMENSIONAL NON-PLANE MHD MODELS

Y. Nakagawa
Space Sciences Laboratory/NASA
Marshall Space Flight Center, AL 35812, U.S.A.

S. T. Wu and S. M. Han
The University of Alabama in Huntsville
Huntsville, AL 35807, U. S. A.

ABSTRACT

Numerical results are obtained for non-plane MHD responses to a sudden energy release in a stratified model atmosphere. In agreement with observations, it is shown that after the energy release, the magnetic field affected by the energy release relaxes toward the potential configuration while the outer atmospheric fields increase its shear. Additional results suggest a new way of interpreting the energy storage and release in repeated flares.

INTRODUCTION

It was shown (Nakagawa et al., 1978a; Wu et al., 1978) that some observed characteristics of the coronal transients (Hildner et al., 1975) can be reproduced by two dimensional plane MHD models. However, the plane analyses (confined within a meridional plane) were limited to the initial configurations of magnetic field to be potential, also to the exclusion of transverse waves (often called the Alfven waves).

In the present non-plane analyses, transverse waves are included together with the out-of-meridional component of magnetic field. The initial magnetic field is represented by a global constant α force-free field (Nakagawa et al., 1978b), and numerical computations are initiated with an introduction of a short temperature pulse simulating the energy release by a flare.

RESULTS AND DISCUSSION

Two distinct initial magnetic configurations (shown in Figures 1a and 2a) are considered. These configurations correspond to the open and closed configurations of the previous study (Nakagawa et al., 1978a).

M. Dryer and E. Tandberg-Hanssen (eds.), Solar and Interplanetary Dynamics, 495-498.

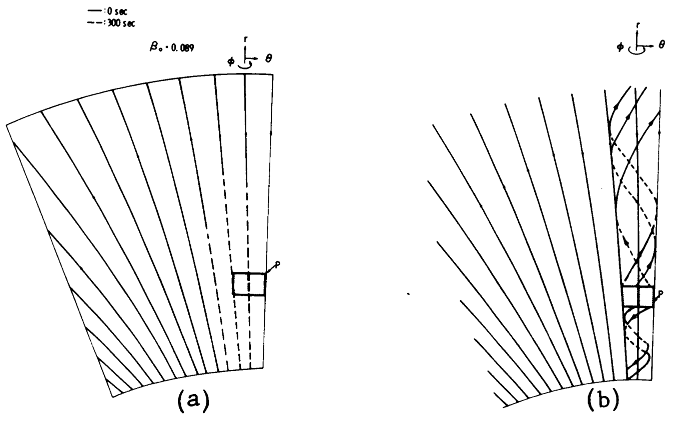

Figure 1. (a) The initial (solid) and disturbed (dashed) magnetic fields.
(b) The resultant material motions, p the position of energy release.

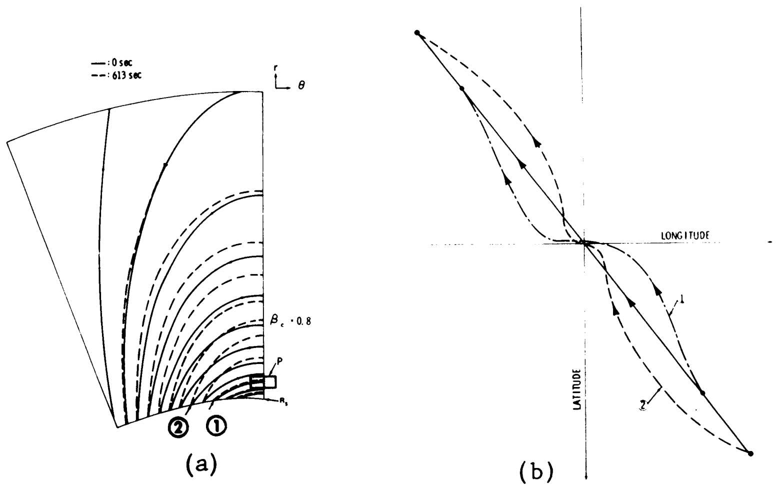

Figure 2. (a) The initial (solid) and disturbed (dashed) magnetic fields.
(b) The schematic changes of θ-ϕ projection of field configuration after energy release.

https://doi.org/10.1017/S0074180900068029 Published online by Cambridge University Press

In the open configuration, with a small value of $\beta = 0.089$ (where β is the ratio of the gas pressure to the magnetic pressure), it is found that the typical coronal response is a spiralling up or down motion confined around the axis as shown in Figure 1b: such spiralling motions are known with flare sprays (Tandberg-Hanssen et al., 1980).

With the values of β similar to those in previous studies (Nakagawa et al., 1978a; Wu et al., 1978), the general responses appear almost identical in the meridional plane projection. However, the velocities of expansion are reduced reflecting the fact that the presence of an additional degree of freedom, namely, the presence of transverse waves which carry away some of the energy released.

The most striking results are the difference in the responses of magnetic field in the closed configuration shown in Figure 2b. In the θ-ϕ projection (where θ is the co-latitude and ϕ the longitude), the initial field lines are straight lines, and the foot-points of different field lines are located along this line at different distances from the center of symmetry (Nakagawa et al., 1978b). With the energy release, the field lines expand away from the point of energy release. Physically this expansion corresponds to the reduction of local shear, i.e., electric currents. Thus, the initial configuration relaxes toward the potential configuration. In other words, after the energy release, the initially sheared magnetic field appears to relax toward the potential configuration as shown by Tanaka and Nakagawa (1973).

In addition, the expanding field lines, particularly in the radially outward direction, increase the shear. This sheared field leads to the appearance of flat-top topology as shown with larger values of α by Nakagawa et al. (1978b) in interpreting the observed characteristics of coronal transient by Hildner et al. (1975).

Finally, by pursuing the computation long after the energy release, it is found that the heated atmosphere (in a form of a bubble) gradually moves out of the domain of computation yielding the field lines to return toward the initial configuration. This result implies that repeated flares are possible in a sheared magnetic field without apparent shearing motions at the photospheric level after the first flare. Further details of the analyses will be published elsewhere.

One of the authors (YN) is supported by the National Research Council Senior Research Associateship. STW and SMH are supported by a NSF Grant ATM77-22484.

REFERENCES

Hildner, E., Gosling, J. T., MacQueen, R. M., Munro, R. H., Poland, A. I., and Ross, C. L.: 1975, Solar Phys., 42, p. 163.

Nakagawa, Y., Wu, S. T., and Han, S. M.: 1978a, Astrophys. J., 219, p. 314.

Nakagawa, Y., Wu, S. T., and Tandberg-Hanssen, E.: 1978b, Astron. Astrophys., 69, p. 43.
Tanaka, K., and Nakagawa, Y.: 1973, Solar Phys., 33, p. 187.
Tandberg-Hanssen, E., Martin, S. F., and Hanssen, R. T.: 1980, Solar Phys. 65, 357.
Wu, S. T., Dryer, M., Nakagawa, Y., and Han, S. M.: 1978, Astrophys. J., 219, p. 324.

DISCUSSION

Stix: What is the reason for the helical motion in the open field case?

Nakagawa: The helical motion is the consequence of inclusion of the transverse waves in this non-plane study, which has never been treated previously in one- or two-dimensional planar studies.

Kuperus: Why do you put your disturbance at some altitude above the boundary instead of perturbing the field at the boundary?

Nakagawa: To introduce disturbance on the boundary leads to the MHD initial-boundary value problem. Such a formulation is available now, however, we have not tried it in this paper.