TOPOLOGICAL CATASTROPHE IN MASSIVE CURRENT SHEETS

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ABSTRACT. A two-dimensional sheet model for solar filaments (Kippenhahn and Schlüter configuration) is considered. We investigate the quasi-static evolution of gravito-magnetohydrostatic equilibria in exploring the response of massive current sheets to a slow continuous variation of the mass/flux ratio with fixed boundary conditions. A catastrophic behavior of the field topology is found to occur in the sequence following the formation of a cusp point (bifurcation).

## THE MODEL

Current sheets are guessed to play an important part in the general study of magnetohydrostatic equilibria. The occurence of critical points in current sheets has been discussed by many authors in the case of force-free-fields (schindler, 1986; Aly, 1986)

We study the series of quasistatic equilibria of a massive current sheet , where boundary conditions are maintained through the sequence (cf fig.1).

The main assumptions of the model are:

. Translational invariance

. Potential magnetic field ($\vec{B}=\overrightarrow{Rot}$ ($\psi$ (x, y) $\vec{e}_z$))

. The solar atmosphere considered as a perfect conductor

. Low value of the coronal plasma $\beta$

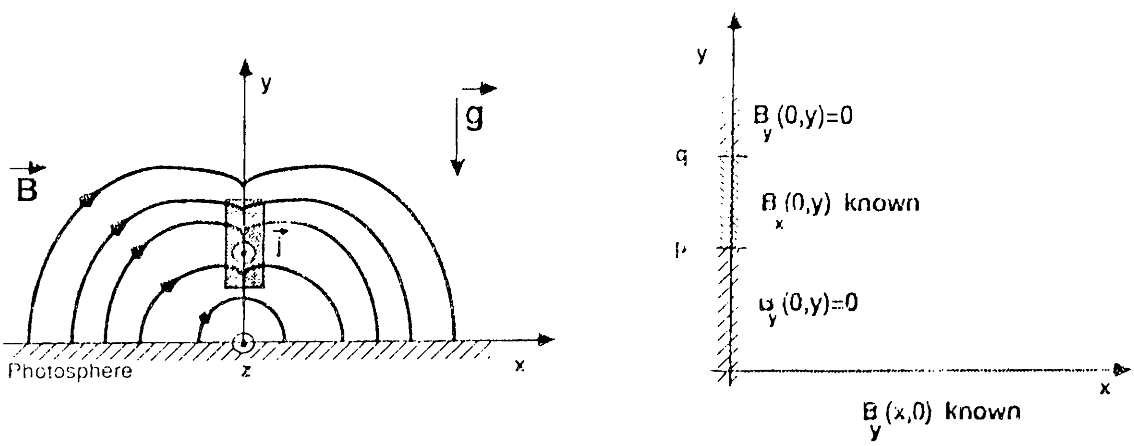


Figure 1. Schematic representation of the prominence (initial condition) and the boundary value problem.



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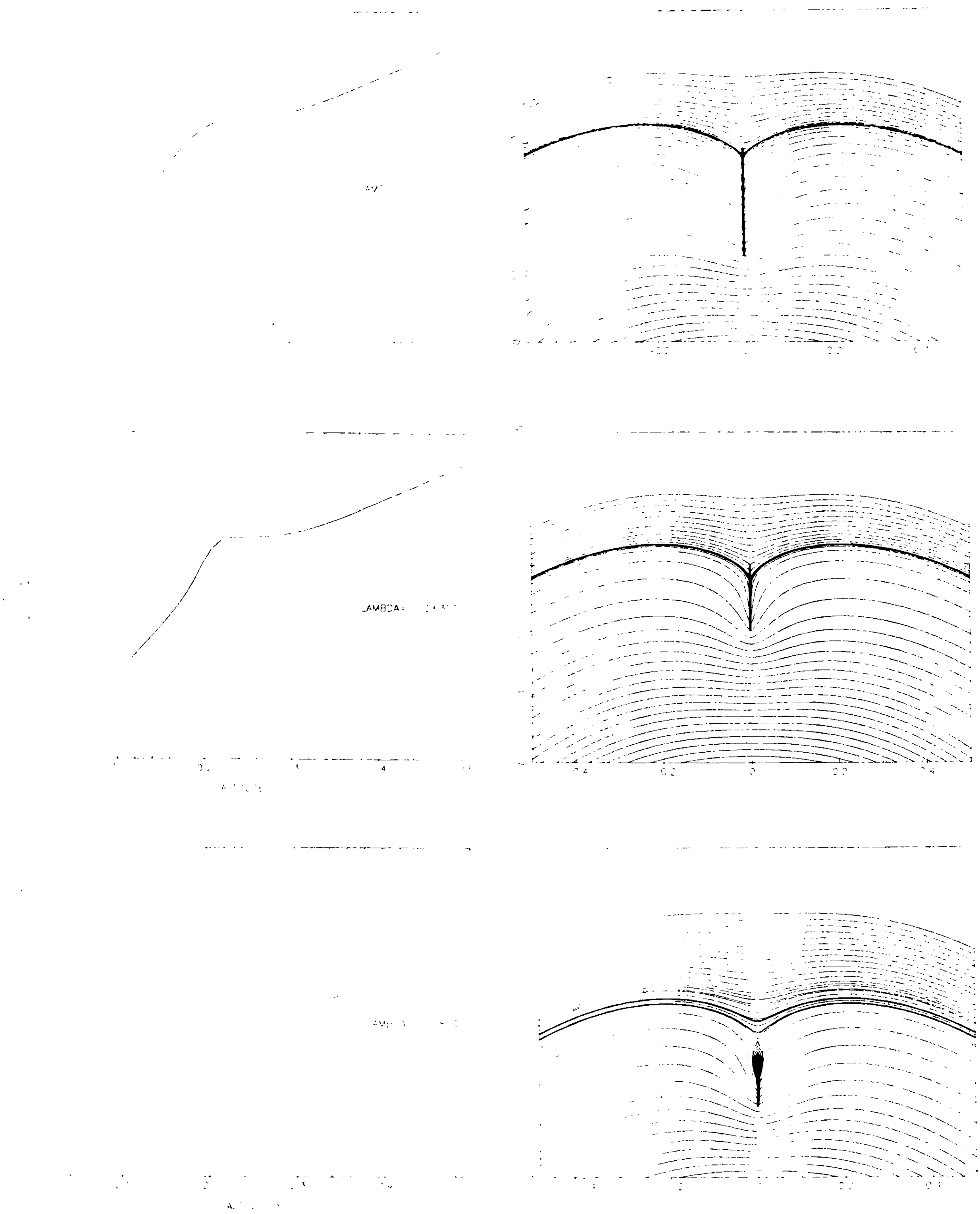

Figure 2.The vector potential on the y-axis a(y) and the associated topology of magnetic field lines for different values of λ.



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The potential vector fulfilling the boundary conditions is represented by:

$$\Psi(x,y) = \Psi_0(x,y) + \widehat{\Psi}(x,y)$$

where $\Psi_0$ is the potential of subphotospheric currents ,and $\widehat{\Psi}$ the potential resulting from coronal currents along $\vec{e}_z$ and the mirror currents .
The evolution is asssumed to be driven by a "material pumping" along the field lines (only possible for arcades showing a sag part ) specified by the law:

$$S(a,\lambda) = S(a,0) \; . \; f(\lambda)$$

where $S(a)=dm/da$ characterizes the mass/flux distribution ;$\lambda$ is the "control parameter", linked to the injection of current in the prominence and $f(\lambda)$ is chosen equal to $\lambda$ with no loss of generality

We are lead to solve coupled equations for the evolution:

$$\begin{cases} B_y(0^+, y, \lambda) = (\mu_0 g/2) \; . S(a,\lambda) \\ a \; (y,\lambda) = \Psi_0(0, (y,\lambda)) \; - \; (1/\pi) \displaystyle\int_0^{\infty} dy' \; B_y(0^+, y,\lambda) \; (\ln |y'-y| / |y'+y| \;) \; \tau(y') \end{cases}$$

Deriving with respect to $\lambda$,we get a non-linear inhomogeneous integro-differential equation that we solve numerically, adopting an Eulerian description.
A *topological constraint* is considered ,to take into account the redistribution of matter during island formation.Matter settles to the lowest point (on y-axis) of the field.This condition is specified by $\tau(y)$ and determines in a non-linear and a non-local way the evolution of the field structure.

## RESULTS

Until the cusp point is reached at $\lambda=\lambda_c$ we notice in the field lines portraits an increase of the dips on the y-axis with the evolution .
At the critical point ,a topological catastrophe of the field occurs in the sequence of equilibria.Conditions for a bifurcation to take place have been derived,using theorems of integral equations theory (see Peterle and Heyvaerts,1988 for a more detailed discussion)

Some consequences of the observed equilibrium bifurcation :

. a transition from a topology initially line-tied towards a topology with magnetic islands.(cf. fig.2)
. a rapid fall of matter leading to a pinch-like state of the mass profile of the filament .
. a fragmentation of the sheet in some cases (for instance when the mass loading does not apply to the whole prominence).



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Besides, we have made the connection between our physical model and a simplified flow topology reproducing the same qualitative properties (cf fig.3). This dynamical system approach shows that the bifurcation is confirmed and is found to be doubly degenerate (in the terminology of the singularities theory). Beyond $\lambda=\lambda_c$, the cusp point, structurally unstable, splits up into one O-type critical point and a X-type one, involving a transition to non equivalent topologies. (Seehafer, 1986)

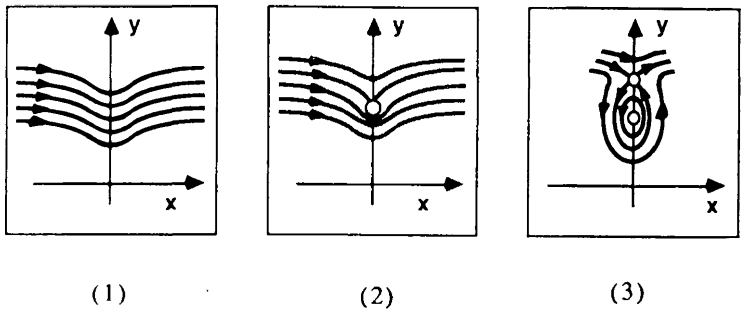


Figure 3. Schematic Field topology in the vicinity of the critical cusp point. (1) No critical points; (2) one cusp point ; (3) one center and a saddle point

## CONCLUDING REMARKS

We have developped a consistent calculation of the evolution at and past the cusp point of our sequence of equilibria ,paying due attention to matter redistribution in the structure.

The bifurcation found in our model is not a catastrophic turning point (S-shaped diagram) as it is often encountered in the study of field evolutions, through shearing motions (see Heyvaerts et al, 1982).

We modeled the mass loading process by an homothetical variation law. But the method is not restricted to the particular type of evolution considered and could be used as well to study variations due to a change of boundary conditions, or a mixture of both these problems.

We assume that the existence of a local dissipation mechanism in the neighborhood of neutral points will allow the transition between the two non-equivalent topologies to physically occur and produce a release of energy stored in this region inducing a solar flare.

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