VISUALIZATION OF THE STRUCTURE OF THE MHD-SINGULARITY IN 3D MAGNETIC CONFIGURATIONS

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In the space plasmas magnetic fields play an important role in the formation of structures that are bursty in character. Such phenomena are often attributed to rapid dissipation of magnetic energy in highly conducting plasmas during reconnection of the magnetic field lines in the vicinities of the critical points of the magnetic configurations.

The problem of magnetic lines reconnection is closely related to the problem of the structurally stability of vector field. The structurally stable dynamic system is defined as a system whose state remains topologically equivalent to the initial state for any sufficiently small perturbation of the vector field. Since the magnetic field topology changes during both spontaneous and induced magnetic reconnection[1,2].

We present the result of the MHD simulations of nonlinear dynamics of MHD perturbations in structurally unstable 3D magnetic with two 3D saddle points. The analysis of the process is a difficult problem due to self-consistent nonlinear interaction between two vector fields: magnetic and velocity in the 3D geometry.

At the initial moment we consider the structurally unstable magnetic configuration with two null points connected by separator line embedded in the high electric conductivity plasmas, which is given by the magnetic field

$$\mathbf{B} = B_x\mathbf{e_x} + B_y\mathbf{e_y} + B_z\mathbf{e_z}, \tag{1}$$

$$\begin{aligned} B_x &= -2xy - z^2 + x^2 + \varepsilon, \\ B_y &= -2yz - x^2 + y^2 + \varepsilon, \\ B_z &= -2xz - y^2 + z^2 + \varepsilon, \end{aligned}$$

with $\varepsilon = 0.16$.

We solved the set of MHD equations numerically in a square computation region $(-1 \leq x \leq 1, -1 \leq y \leq 1)$. At the initial instant the plasma is rest in the magnetic field. The dimensionless MHD equations can be written as

$$\frac{\partial \rho}{\partial t} + div\, \rho \mathbf{v} = 0\,, \tag{2}$$

$$\rho \frac{d\mathbf{v}}{dt} = -\frac{\beta}{2}\nabla p + [rot\, rot\, \mathbf{A} \times rot \mathbf{A}]\ , \tag{3}$$

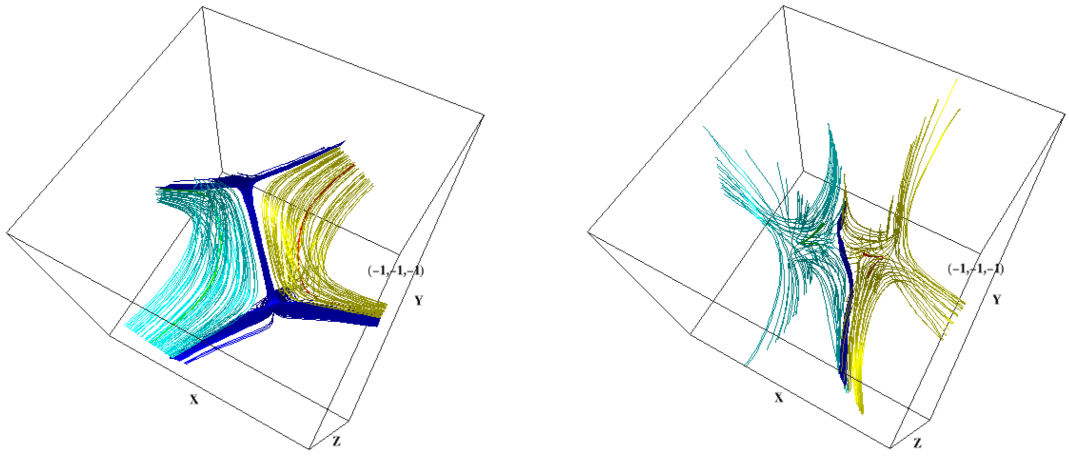
$$\frac{\rho}{\gamma - 1}\frac{dT}{dt} + p div \mathbf{v} = -k\Delta T + \frac{2\nu_m}{\beta}(rot\, rot\, \mathbf{A})^2\ , \tag{4}$$

$$p = \rho T\ , \tag{5}$$

$$\frac{\partial \mathbf{A}}{\partial t} = [\mathbf{v} \times rot \mathbf{A}] - \nu_m rot\, rot\, \mathbf{A}\,. \tag{6}$$

where **A** is a vector - potential of the magnetic field. All the results presented below were obtained for the magnetic diffusivity $\nu_m = 0.006$ and a pressure corresponding to $\beta = 0.012$. The dimensionless thermal conductivity and dimensionless electric field were chosen to be $k = 0.01$ and $E = 0.03$.

So Alfven and magneto-acoustic modes remain coupled in the linear approximation, we considered the boundary conditions which corresponding to excitation of nonlinear MHD waves. The boundary conditions for the remaining quantities were imposed in accordance with MHD equations. At the boundary regions through which the plasma enters the calculation domain we specified the plasma density and pressure $\rho = 1$ and $p = 1$. At the remaining boundary regions the boundary conditions assumed a free plasma outflow out of the calculation domain[3].



(a) initial configuration

(b) separatrix disappearance

Figure 1: Magnetic field visualization by illuminated streamlines

At the results of modeling of evolution of a MHD perturbation we can see that the structurally unstable magnetic configuration becomes structurally stable. The initial configuration is demonstrated on Fig.1(a). From Fig. 1(b) we can see the separatrix between the two null points disappears (time = 5 Alfen time). MHD perturbations break the symmetry of the initial magnetic configuration and lead to the final magnetic field with another symmetric type.

Two visualization methods was used to display the magnetic fields. First method is a modification of an illuminated streamlines' method. It was used to produce above images. The idea of the method is to use a pregenerated texture to simulate a lightning computations for modified illumination model. Main difference between that model and the standard one is a replacement of a surface normal vector (undefined in 1D case of streamlines) by the uniquely defined normal vector which is coplanar with tangential vector and vector towards the viewer. Thus light intensity can be computed for the points of a streamline. Resulting image contains a natural lightning which greatly improves the geometric perception. For the same purpose we apply the second method. It is an original version of a 'streamballs' method. Basic method operates with exponential type blobby object or convolution surfaces of the same type. An isosuface of the additional scalar field defined by those objects are used to display the streamlines. If one distributes sufficient number of blobs along the lines, and if each blob have a small influence, than the resulting isosurface will look like the tiny tube, and since that is a 'real' surface one can use a standard illumination model. We propose to use a blobs of special polynomial type along with octree-based space partitioning, which can greatly decrease the computational cost. Additionally we propose to use a propagation algorithm to construct a fast polygonal approximation, with initial cells set defined by skeleton consisted of streamlines and a line which connects the initial points and one point on a practical infinity[4]. Used together those methods allows us to create an informative and efficient visualization and animation of current sheet formation and explore the structure of the magnetic fields near MDH-singularities in 3D magnetic configurations.

REFERENCES

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