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Coronal mass ejection experiment using internal current torus plasma
内部電流系トーラスを用いたコロナ質量放出模擬実験

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A new coronal mass ejection experiment was performed by using an expanding torus plasma (spheromak) in the TS-4 device in the University of Tokyo. Like an expanding plasmoid, its expansion is simulated by its own hoop force and attracted by poloidal coils located on the outboard side of the plasma. The pull mode reconnection with a significant asymmetrical outflows is successfully observed on the inboard side of the magnetic axis.

1. Introduction

1.1 *Reconnection experiment*

Magnetic reconnection has been studied by numerical simulations, satellite observations, and laboratory experiments. Conventional reconnection experiments using torus plasmas are classified into two types which are called push and pull modes [1]. The push mode reconnection has symmetrical inflow and asymmetrical outflow regions, while pull mode one has the counter combination. Recently, asymmetrical effects in the inflow and outflow region are widely noticed because of their importance [2-3].

1.2 *Coronal mass ejection*

Coronal mass ejection [4] is the phenomenon in which large number of particles and energy are released from the surface of the sun. Now it is understood as a reformation of the magnetic field in the corona loop through the magnetic reconnection. Shibata et al. [5] suggested the plasmoid ejection model in which the plasmoid ejection drives the reconnection outflow. The reconnection in CME is categorized into a pull mode, however, in the past pull mode experiments use a pair of poloidal coils to drive the symmetrical bi-directional outflow.

2. CME type Experiment

A CME experiment was performed by using the TS-4 device [6] in the University of Tokyo. In the device, one pair of flux cores, two pair of poloidal coils are installed. A pair of equilibrium field coils is settled outside the vacuum vessel.

After an initial small spheromak [7] is generated at the mid-plane, poloidal coils settled outside of the spheromak (called separation coil) are turned on, and their currents which have same direction to the plasma one attract the spheromak inducing magnetic reconnection at the inner side of its magnetic axis by eliminating the equilibrium field.

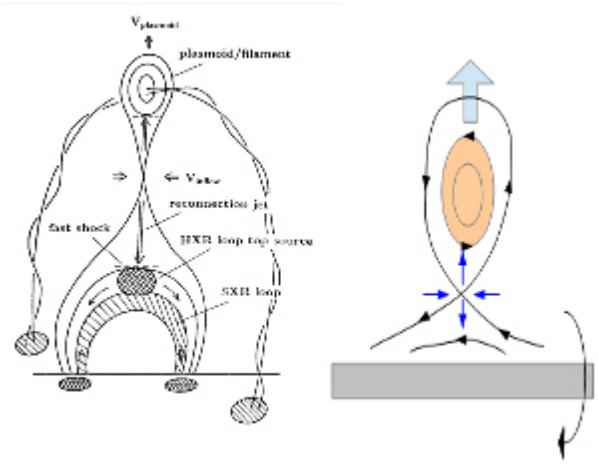

Fig.1. Schematic view of the poloidal cross section of the CME experiment and original plasmoid ejection model of coronal mass ejection[5].

In the experiment, plasmoid/filament which has two foot points on the sun is simulated by the initial spheromak. Both the plasmoid motion to theoutboard side of the device and the absorption of the magnetic flux into the separation coils drive the reconnection outflow, which means the reconnection is pull-mode like CME.

3. Experimental Setup

In the TS-4 device, 9×10 magnetic probe array which have two components (*Bt, Bz*) pickup coils on each measurement points is installed. Its resolution is about 8cm, and the array measures the global magnetic field structure. In the reconnection region, 4×9 3-component magnetic probe array which have 4cm resolution is installed to measure the fine structure of the local magnetic field around the

reconnection current sheet. On the mid-plane Langmuir probe is installed to measure the time evolution of the electron density and temperature.

A high speed visible camera which frame rate in the experiment is 200 kS/s is used to observe the temporal evolution of the global structures.

Working gas is Hydrogen which pressure is 1.5 ~ 2.0 mTorr.

4. Results

Fig.2 shows the time evolution of poloidal magnetic field of the experiment. To create the initial spheromak at the mid-plane, two spheromaks collide to annihilate their initial momentum given by the repulsive force to the flux core PF coil. After merging, separation coils attract the torus inducing reconnection at the inboard side of the magnetic axis. Before the reconnection starts, flux core PF coil current swing is stopped by the crowbar circuit, therefore, this reconnection is pure pull-mode.

Fig.3 shows the detailed magnetic field measured by the high resolution probe array. As the reconnection develops, positive toroidal magnetic field which is held by the initial spheromak is ejected from the reconnection region, and the reconnection changes from guide field reconnection to anti-parallel reconnection.

Just after the change to anti-parallel reconnection, reconnection rate increases and negative toroidal field is generated in the inboard right side of the X-point. It is understood as the switch on of Hall reconnection [8]. Existing pull mode reconnection experiment has symmetry downstream region in which electron flow makes quadrupole type out-plane field structure. However, this experiment has asymmetry downstream region. Although there is no obstacle in the inboard side, separation coil makes magnetic pressure in outboard side which stops the electron outflow and makes ions remagnetize to the coil field. As a result, out-plane field near X-point shows dipole structure, not quadrupole.

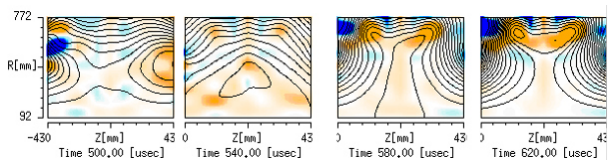

Fig.2. Time evolution of the poloidal cross section of the CME experiment. Merging of two spheromaks generate the initial steady spheromak at the mid plane. Then, separation coil attracts the plasma inducing reconnection.

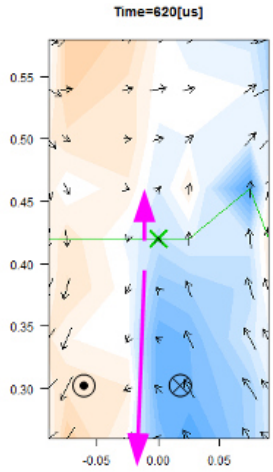

Fig.3. Magnetic field in the current sheet and X-point. Electron flow creates the dipole out-plane magnetic field at the inboard side of the X-point.

6. Summary

We demonstrate the novel experiment which has similar magnetic field configuration to CME to investigate the effects of asymmetry outflow region. Because of the Hall effects, asymmetry downstream region makes out-plane field dipole, not quadrupole often observed in past pull mode reconnection experiment.

Acknowledgements

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