Trigger process of coronal mass ejections caused by tearing mode instability

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Coronal mass ejections (CMEs) are magnetohydrodynamic (MHD) phenomena which are caused by loss of equilibrium of current containing coronal magnetic field. Coronal magnetic field are formed by the emergence from the solar interior of the current containing magnetic field which is generated and amplified by dynamo effect. Generally, such a field forms a force-free sheared arcade. Due to the evolution of tearing mode instability or small scale magnetic reconnection in the current of the arcade, an isolate flux rope is formed. When the equilibrium of the flux rope is suddenly lost by some mechanism, the flux rope is ejected as a CME.

In this study, we performed axisymmetric high resolution 2-dimensional MHD simulation of the whole initiation process of a CME; the formation of a flux rope, triggering and launching of the CME with flux cancellation model.

Generally, in MHD simulations of resistive phenmena such as tearing instability and magnetic reconnection, electric resistivity is limited by numerical diffusion of current density which depends on the grid resolution. However, in this study, we performed simulation with more than 10^4 grid resolution, by using the Earth Simulator, and succeeded to clarify the dependency of the evolution on the resistivity.

In the first phase in the simulation is a numerical build-up of force-free sheared arcade by introducing small velocity field of the azimuthal direction to the footpoints of potential field arcade at photosphere. In the next step, slow converging motion imposed on the arcade feets, causes a quasi-static evolution of the sheared arcade. Due to the velocity field, the feet interval shrinks, and current density of the arcade increases. Once the arcade satisfies the condition in which the growth rate of tearing mode instability is maximized, the instability quickly grows, and a flux rope is formed. After that the tearing mode instability in the current sheet repeatedly forms another flux rope. When the new flux rope is ejected and collides with the previously formed flux rope, they coalesces. It appears that the flux rope can be ejected as a CME when the momentum and total current of the flux rope exceed a critical value.