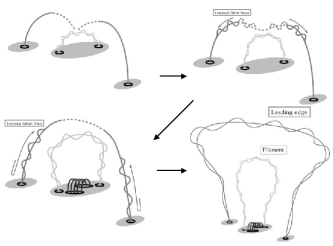
Investigation of Loop-Type CMEs with a 3D MHD Simulation}

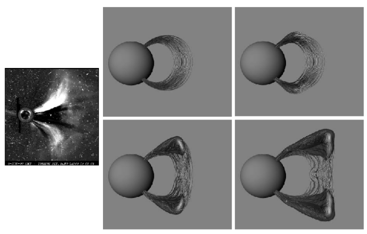
J. Kuwabara[1], Y. Uchida[2]

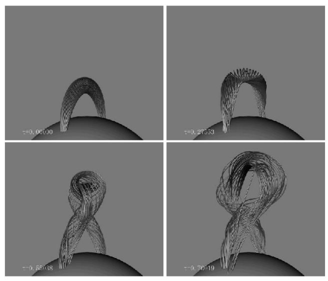
A Coronal Mass Ejection (CME) is a large-scale phenomenon which releases a huge mass into interplanetary space. Recently, we have came to understand the dynamics of CMEs and magnetic structures in the lower part of the corona. This understanding was driven by high sensitivity and high resolution satellites, "Yohkoh" and "SoHO". We now understand that CMEs are closely related to flares and filament eruptions. Hereafter we restrict our attention to those CMEs which have large flux loops. They have several characteristics: (i) They exhibit large flux loops containing core, leading edge, and cavity. (ii) During their time evolution, each of the two footpoints of CMEs are fixed at specific regions in the chromosphere. (iii) They release a huge mass to interplanetary space. (iv) Before they occur, there are magnetic flux loops connecting the footpoints of CMEs and the site where the (future) flare will occur. Moreover, Maia et al.1999 reports new subtype of loop-type CMEs, called "Coat hanger CMEs". These have extra characteristics: (v) They have a twisted structure along the loop (see Figure 1a). These structure, called "toroidal geometory", have also been reported by Dere et al 1997,1999, and (vi) They have the structure of a convex lens ("jutting out knots").

One model in which "flux loops are pushed by erupted filaments and expand upwards," explains characteristics (i) to (iv). We considered that (v) and (vi) are suggestive of Torsional Alfven Wave propagation. We therefore studied, via a 3D MHD simulation, how Torsional Alfven Wave propagation affects and deforms flux loops.

Flux loops which connecting the footpoints of CMEs and the future site of a flare exist before loop-type CMEs occur. Moreover, the magnetic field structure near the site of the flare (including the magnetic flux loops connecting the footpoints of CMEs) changes dramatically when a flare occurs. This suggests that when a flare occurs Torsional Alfven Wave packets must escape from the site of the flare and propagate along the magnetic loops to the footpoints of the associated CME. We propose that subsequent reflection and propagation of Torsional Alfven Waves from both footpoints of the loop produces the observed twisted magnetic flux tube in the both types of loop-type CME. More specifically TAWs escape from the site of a flare, propagate along the loop, and are reflected at the footpoints. The TAWs propagate back along the loop and collide at the loop top. (Figure: left)







Torsional Alfven Wave propagating from the footpoints up, along the large loop, can reproduce the observed twisted structure of Loop-Type CMEs. The TAWs carry high density gas from the high chromosphere outwards. The gas seems to drag magnetic field lines, apparently stretching them (Figure center). Moreover, Coat-Hanger CMEs have an elongated front propagating ahead of the twisted loop. If Torsional Alfven Wave are injected at both footpoints of the loop in opposite sense, the wave packets strengthen each other when they collide at loop top and magnetic force lines become tightly wound (Figure: right). We expect the morphological difference of these CMEs is caused by the sense of the injected Torsional Alfven Wave packets.

If the Torsional Alfven Wave packets escape freely from the site of the flare, this is the cause of characteristics (v) and (vi) that some CMEs have. On the other hand, if only a few Torsional Alfven Wave packets escape from the site of the flare, then non-twisted flux loops expand upwards. This scenario explains each of the cases of loop-type CMEs, namely those with properties (v),(vi) and those without. However, we don't yet know how Torsional Alfven Wave packets escape from the site of the flare. We expect these issues to be clarified in the future.

1, The Graduate University for Advanced Studies (Soukendai) / National Astronomical Observatory of Japan

2, Department of Physics, Faculty of Science, Science University of Tokyo, Japan