Study of the April 20, 2007 CME-Comet interaction event with an MHD model

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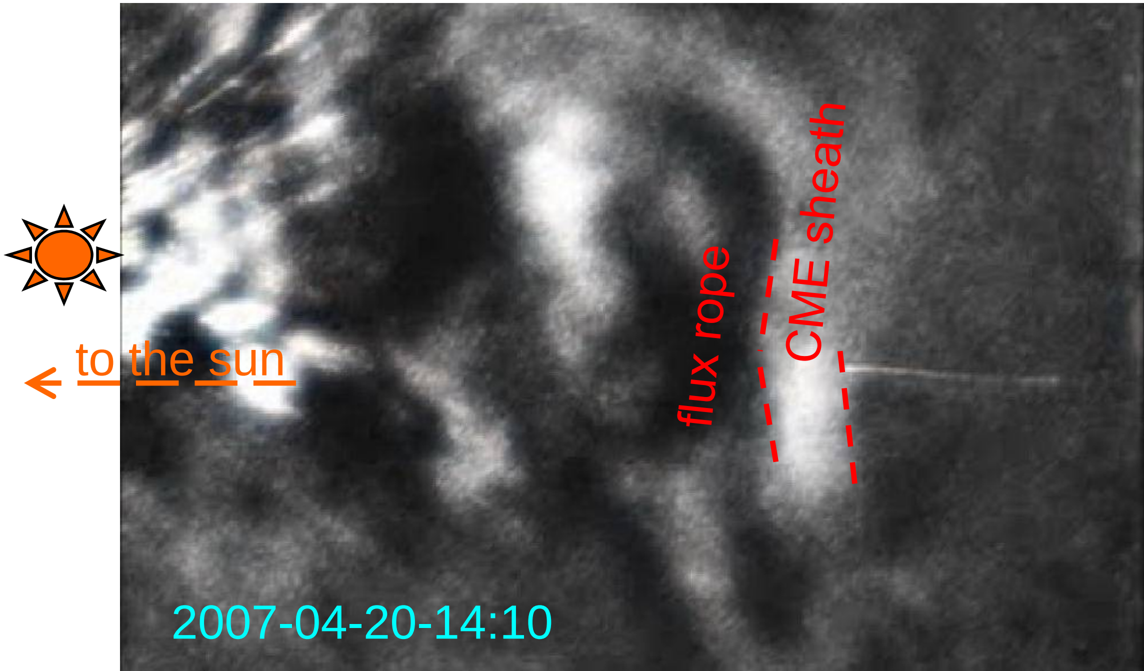
Introduction

- Disconnection events (DEs) are a class of violent disturbances in the cometary tails that can reveal dynamic information of the solar wind.
- In the past, only two types of structures are associated with DE triggering: Heliospheric current sheets (HCS) or shocks.
- In recent years, some CMEs are seen interacting with comets and causing DEs but never been fully understood.
- On April 20, 2007, STEREO SECCHI captured an outstanding event when a CME hit comet 2P/Encke at 0.34AU.
- This work is part of large-scale solar wind-comet interaction modeling effort as a cooperation between the Michigan CSEM and IGPP at UCLA.

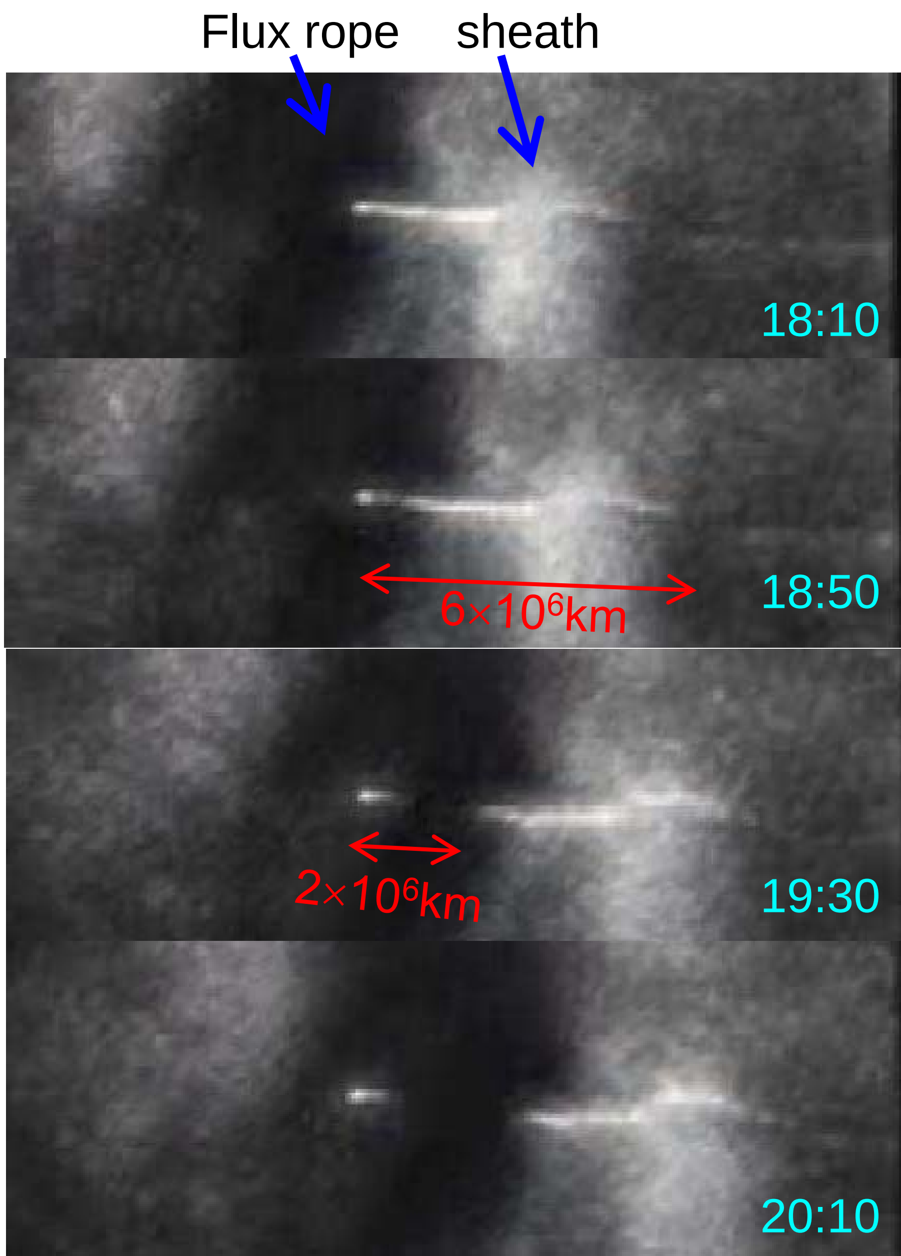


The April 20, 2007 Event

The following reasons has made this event puzzling:

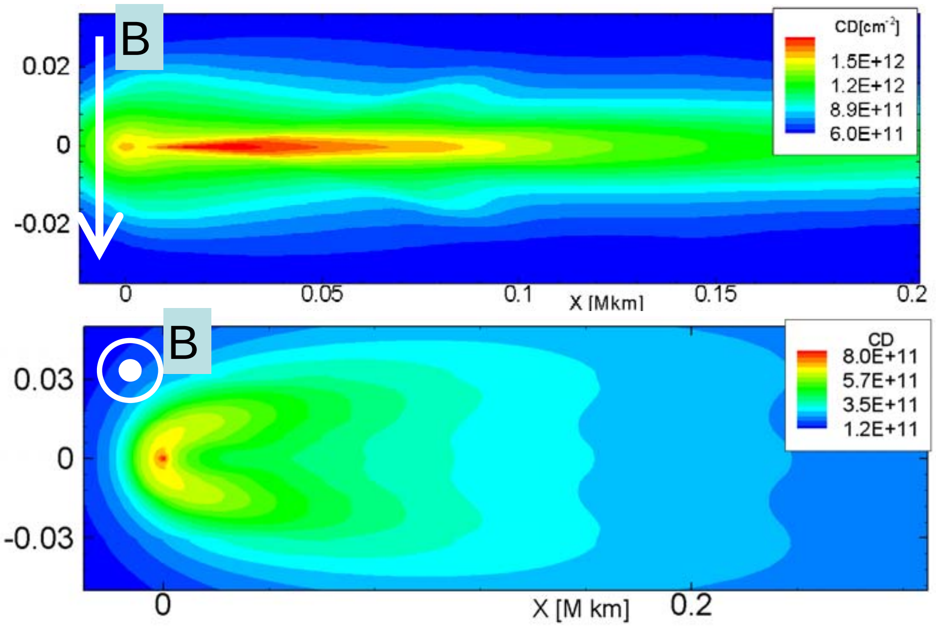
- Appear differently:
  - – Evolve faster than most DEs, which lasts half a day
  - – Show a longer gap between new and disconnected old tail.
  - – Tail elongation with no tail rays
- Caused differently:
  - – The dynamic pressure in this CME is not largely different from the ambient solar wind (<20%).
  - – There are neither HCS crossings nor shocks associated [Vourlidas et al., 2007]

HOW did this CME cause a tail disconnection?

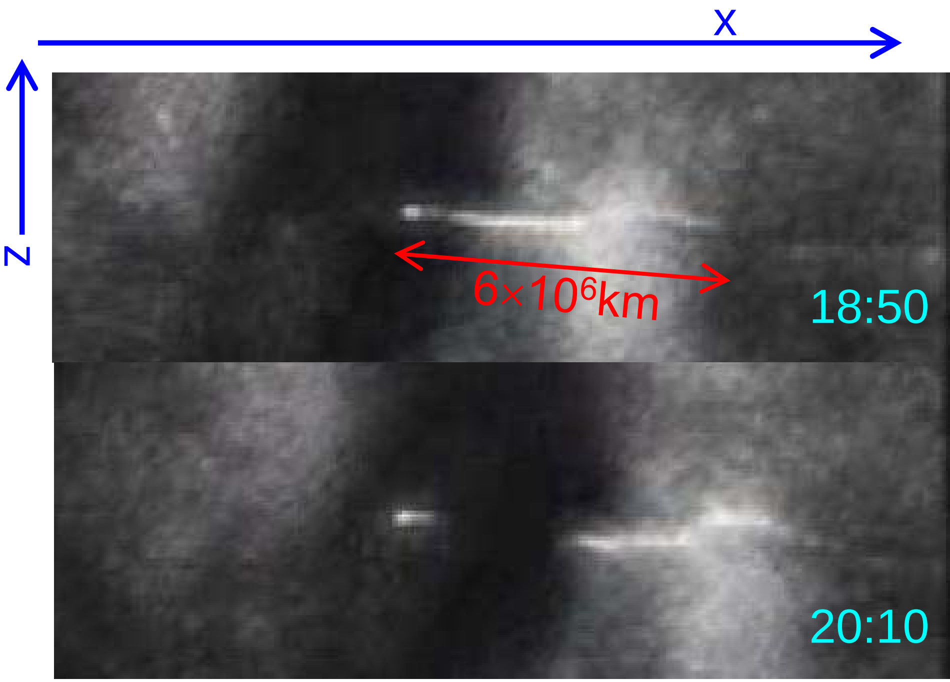


Understanding the Appearances

- The long tail before this event suggest that the IMF vector is close to the x-z plane.
- The DE is initiated by a reversal of IMF primarily in the z direction.
- The new short tail is interpreted as caused by IMF turning into the x-y plane.

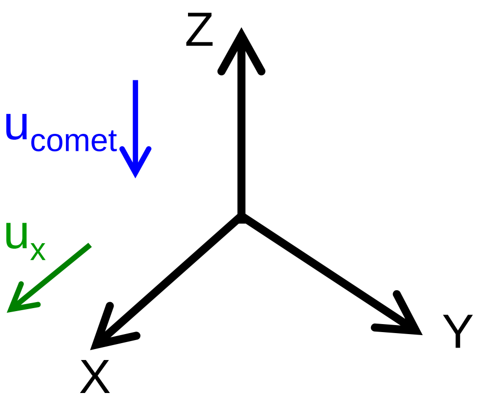


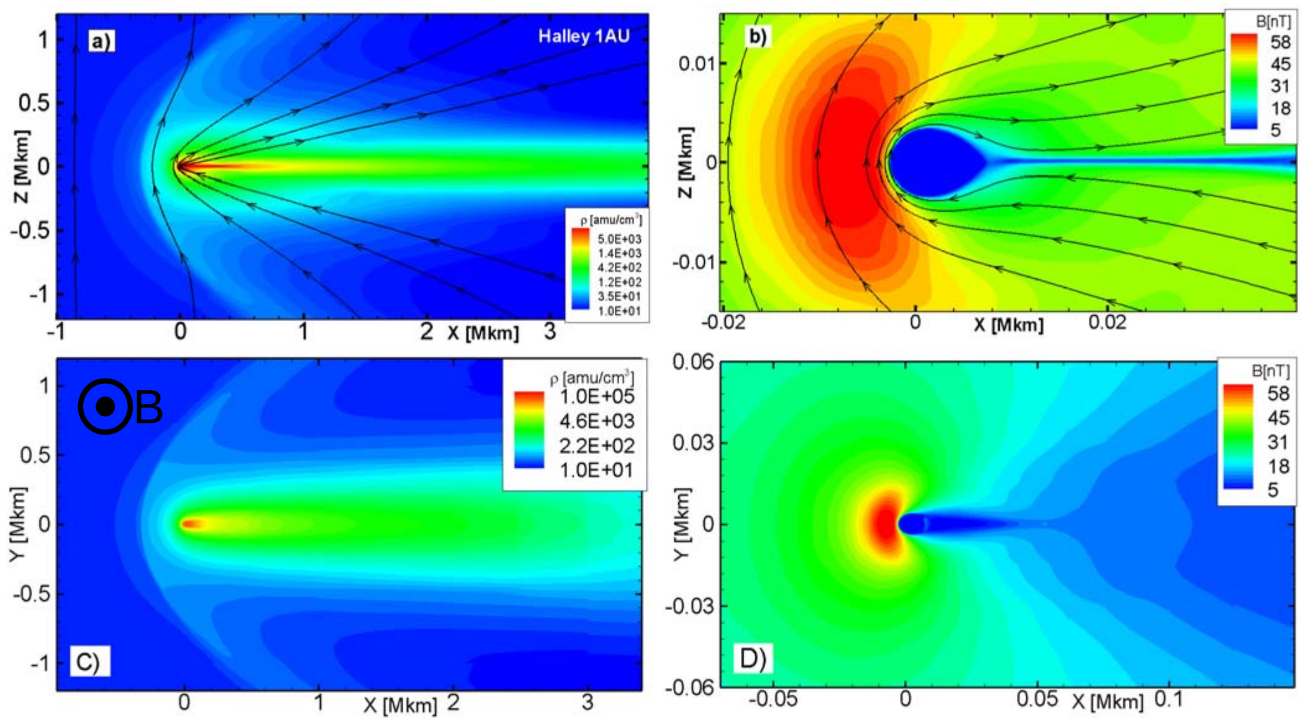
Contour plots show typical appearances of a Halley sized comet [Jia et al., 2007]. Top: column density integrated perpendicular to the IMF place during a DE. Bottom: column density along the IMF direction.



MHD model

- 3-D simulation with the Michigan Block Adaptive-Tree Solar-wind Roe-type Upwind Scheme (BATS-R-US) code solving the ideal MHD equations.
- Photoionization, charge exchange, and dissociative recombinations are considered in the solar wind-comet interactions.
- 2.4×0.4×0.4 million km Cartesian grid based on the comet rest frame, x-axis points to the solar wind flow direction. Finest grid resolution is 25km, with a tail resolution of 2500km.





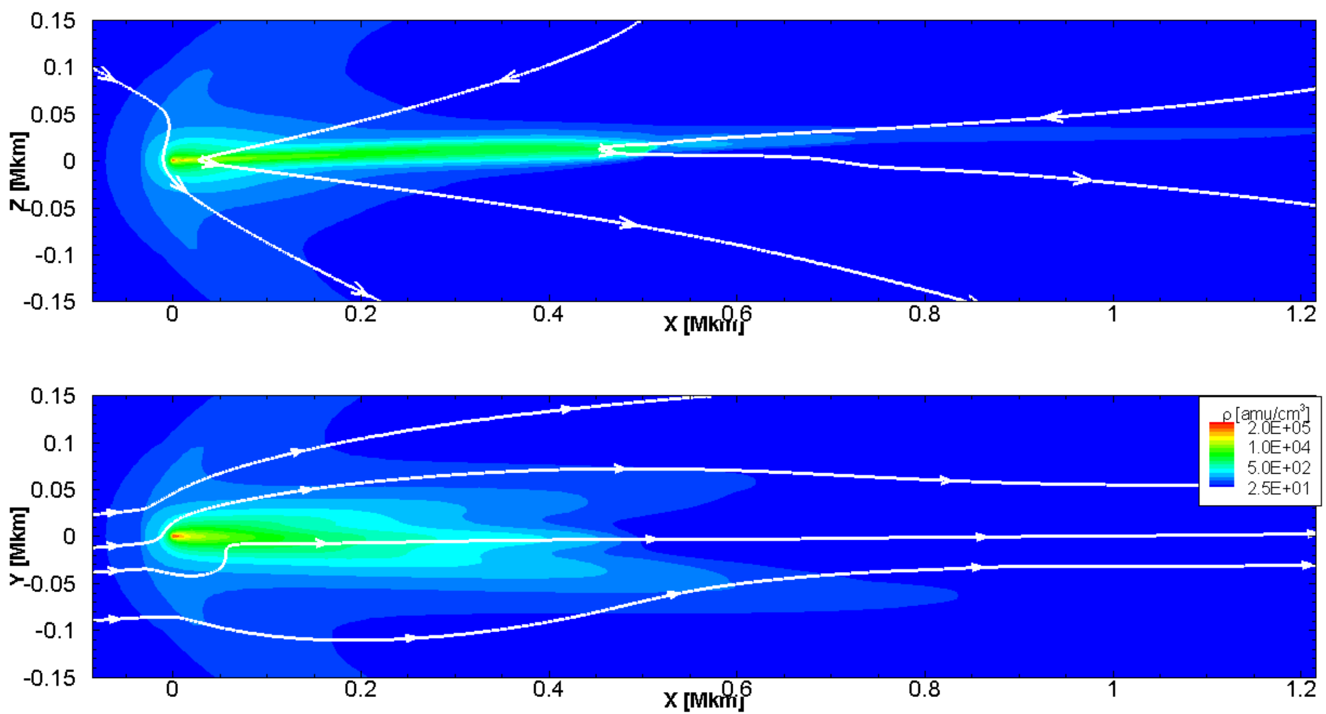
Steady State

- Solar wind values propagated from the magnetogram data at 2.5 solar radii using an MHD model [Cohen et al., 2008]

	Solar distance	Gas production rate Q(#/s)	B_x (nT)	B_y (nT)	B_z (nT)	u_{sw} (km/s)	n_{sw} (#/cc)	Ionization rate (s^{-1})
2P/Encke	0.34AU	2.0×10^{28}	14	1	-6	420	65	8×10^{-6}
1P/Halley	1AU	7.0×10^{29}	3.4	-3.4	0	400	8	1×10^{-6}

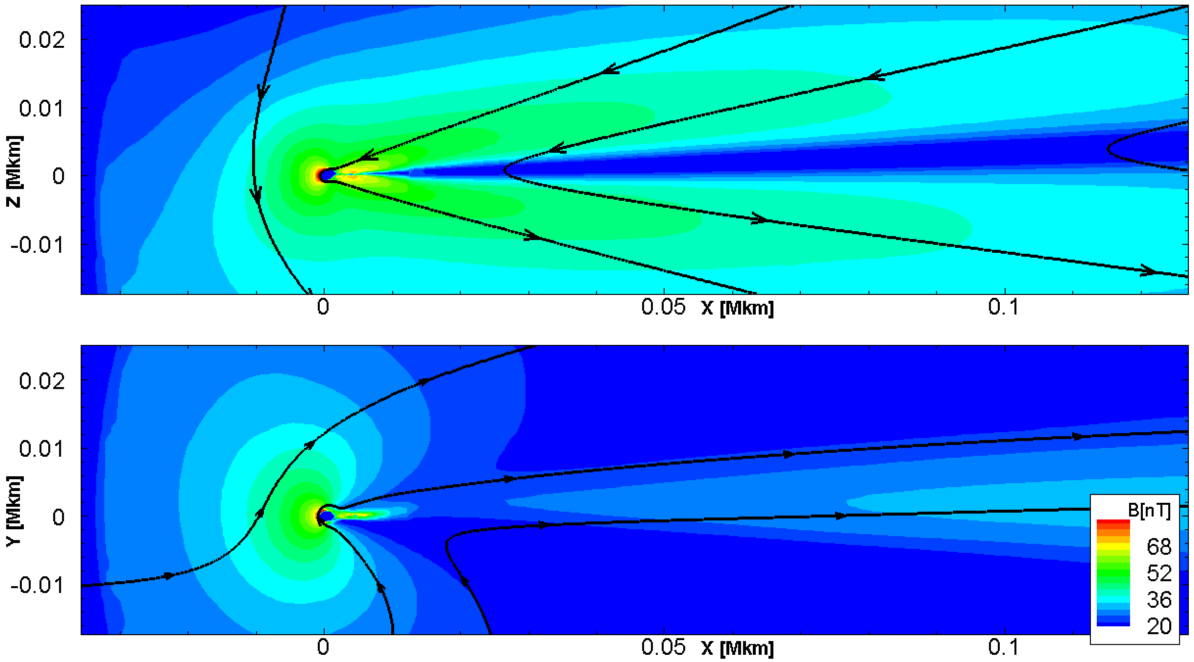
Subsolar distances of the bow shock and contact surface

	BS (Mkm)	CS (km)
Encke	0.04	200
Halley	0.3	3000

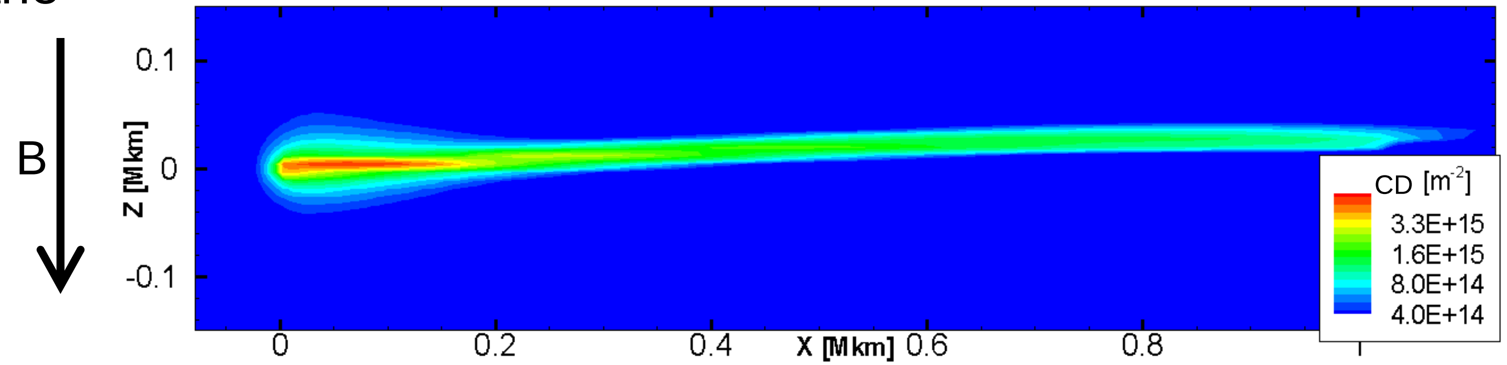


Steady State

- contact surface region

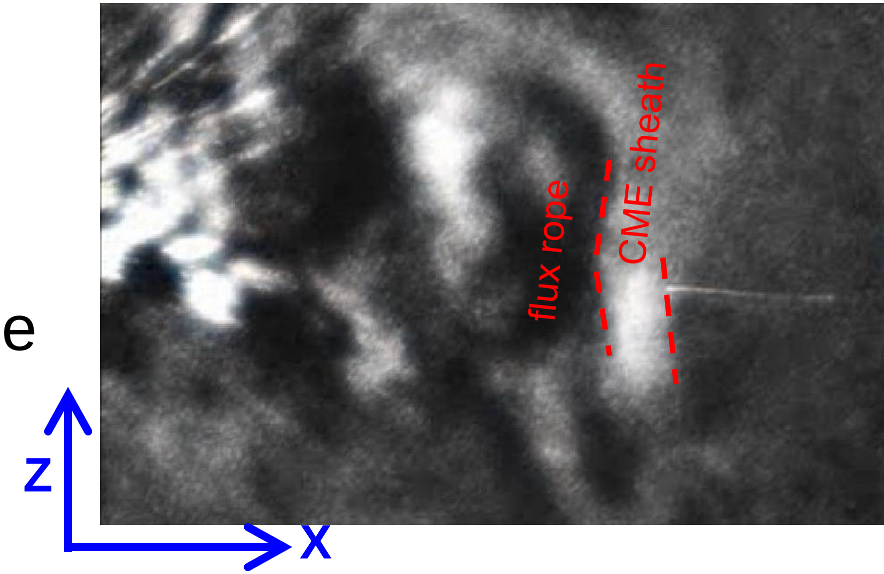


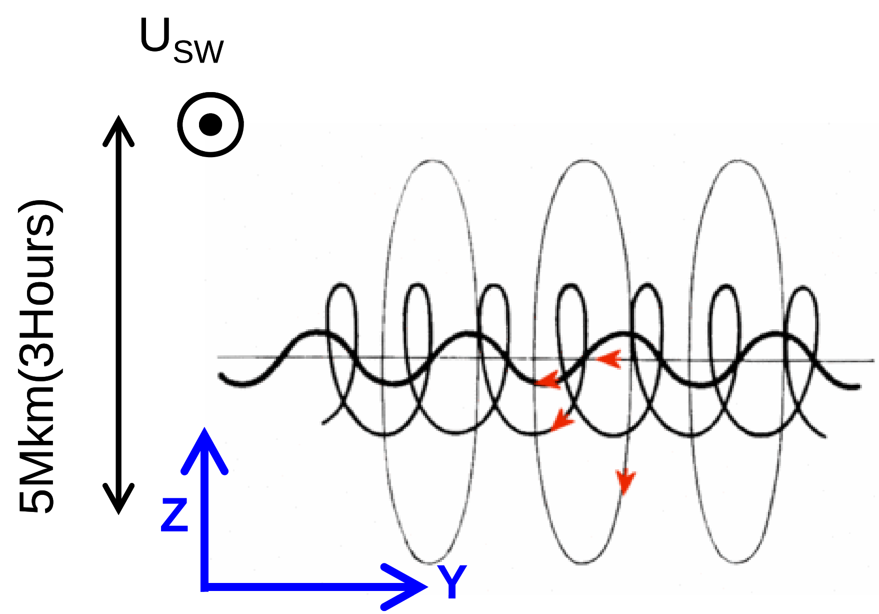
- column density integrated perpendicular to the solar wind flow in the ecliptic plane



Modeling the CME

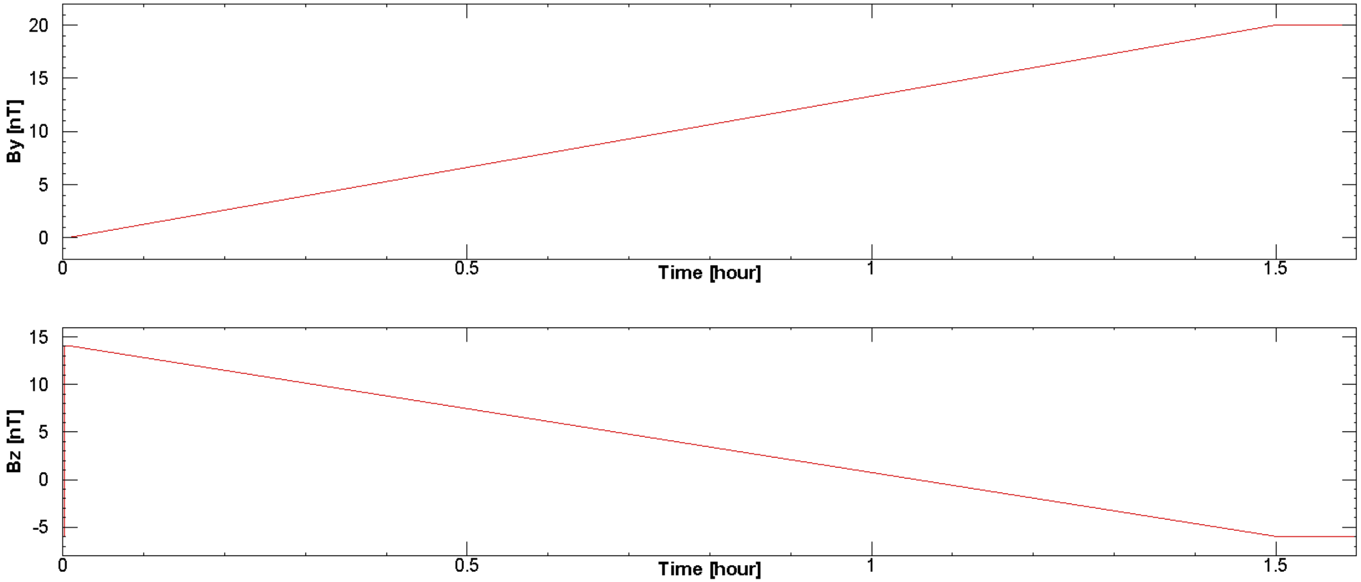
- This is a relatively weak CME.
- The possibility of a flux rope to trigger the tail disconnection is tested in this work.
- The cross section of the flux rope is 100 times larger than the comet bow shock



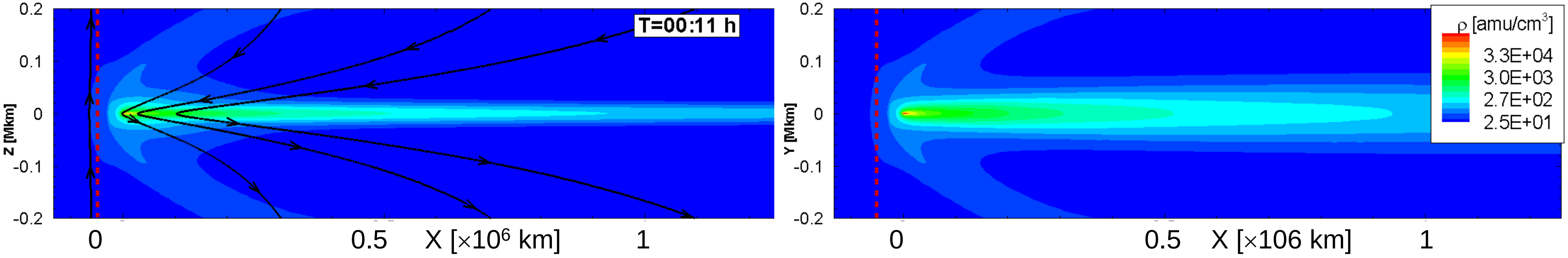


Simplified flux rope

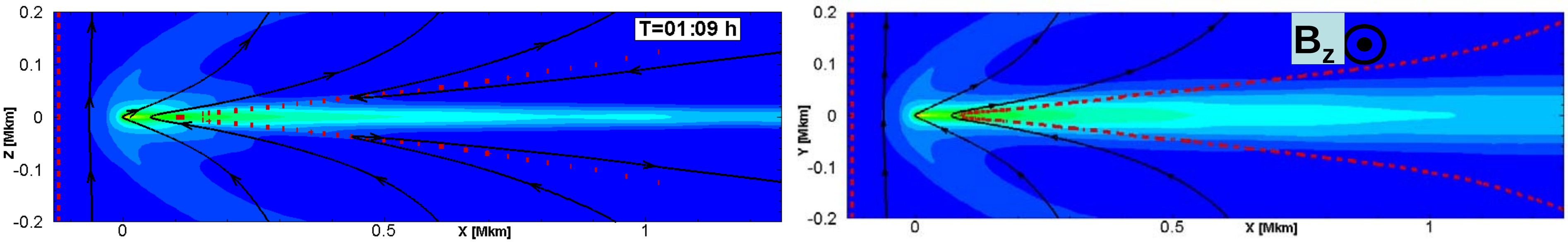
- The flux rope is represented by two stages of variations in the IMF: a reversal in B_z and then gradually rotated into B_y.
- The B_x background is not applied for this preliminary study.
- $B_{y\ max}$ in this flux rope is estimated as 20nT.



2-d Projected Evolution

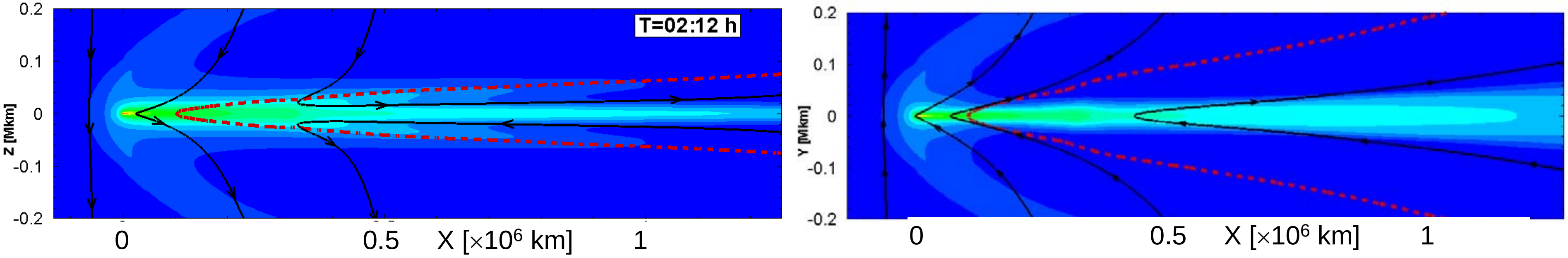


Left: x-z plane cut with x=(-0.2,1.4) Right: x-y plane. black lines are field lines. red dashed line is the leading front of the CME, which is about to hit the comet

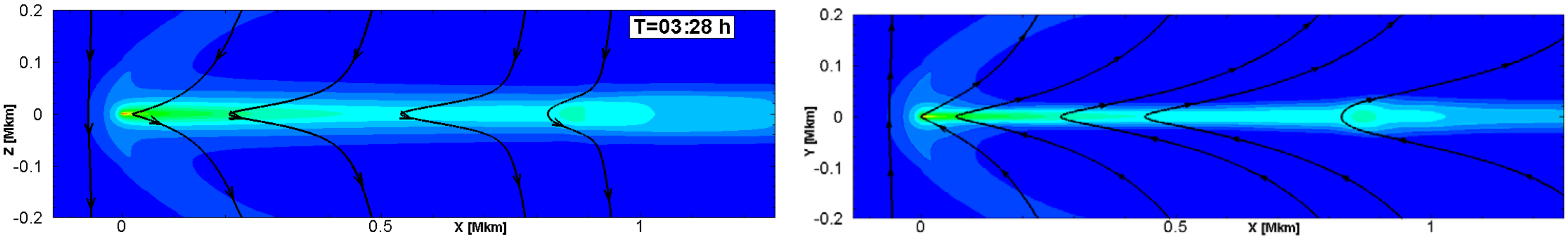


The leading side of the CME outside the tail (marked by the dotted right red line) has been pushed more than 1×10^6 km but its remnant field in the comet tail is lagged behind at T=1:09h. The upwind B_z start to drop below zero (left dotted red line)

2-d Projected Evolution

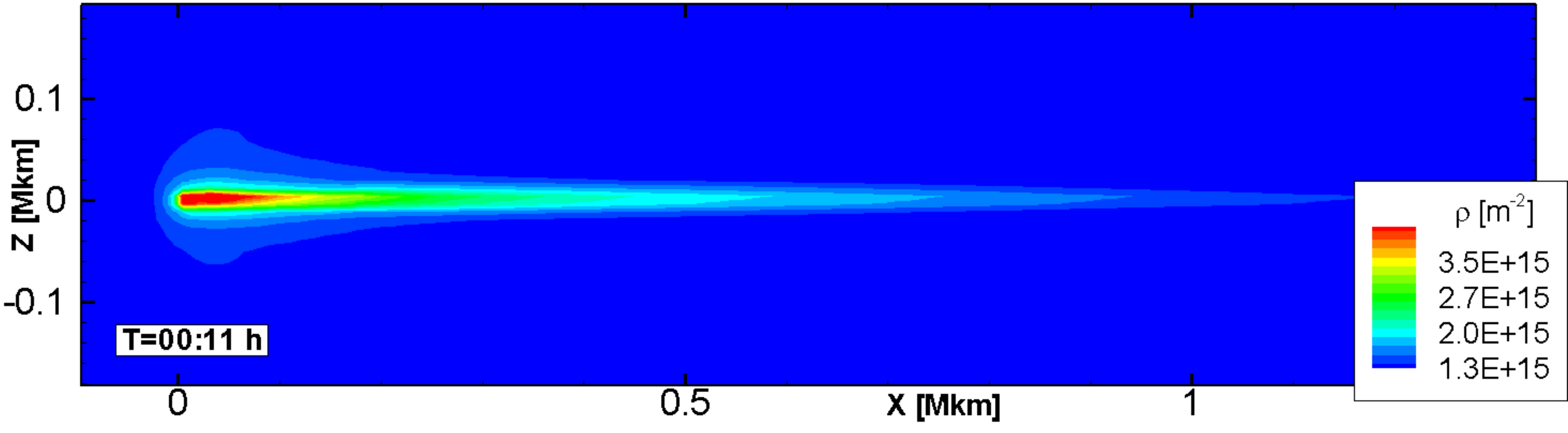


At 2:12h, the second reversal in B_z starts to generate a plasmoid at x=0.4×10^6 km, as the B_y component is decreasing the length of the tail in the x-z plane

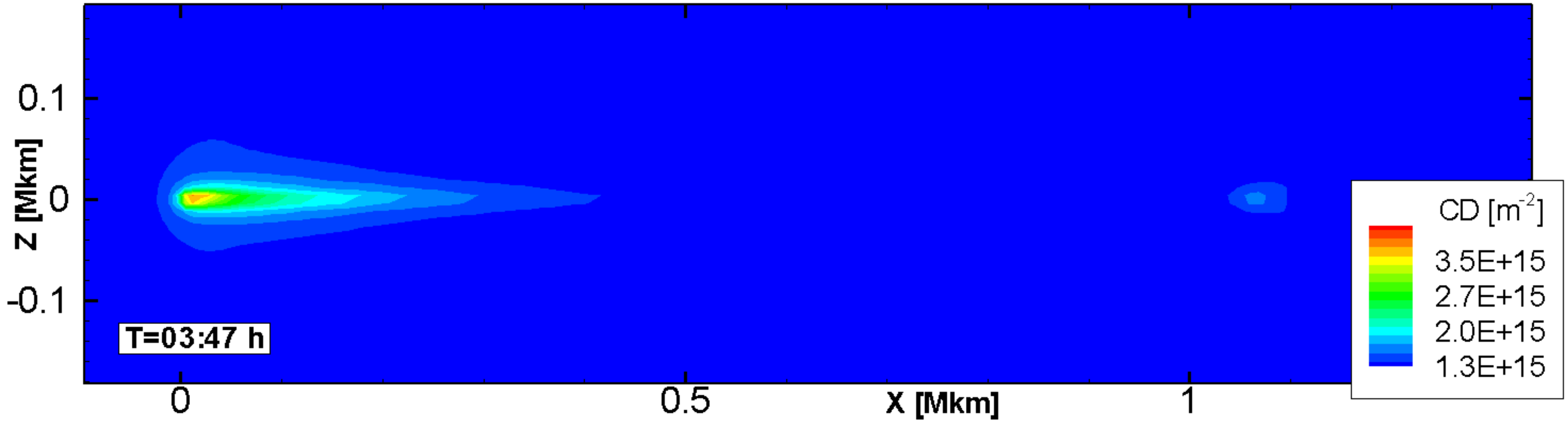


At 3:28 h, the plasmoid has been carried to x=0.9×10^6 km.

Reproducing the Appearances



Column density along the y axis. Total time: 3:40 h



Summary

- This disconnection event in the comet tail at 0.34 AU is the effect of a CME, which is different from most recorded events in the past.
- The flux rope in this CME is the primary cause of the tail disconnection.
- The field reversals in the flux rope have caused the tail to disconnect, while the axial field has caused the new tail to appear short.
- By reproducing this event, we are able to infer the magnetic field configuration of this CME at 0.34AU.