Insights into the **Rotation** and Eruption of Magnetic Flux Ropes Influenced by **External Toroidal Magnetic Fields**

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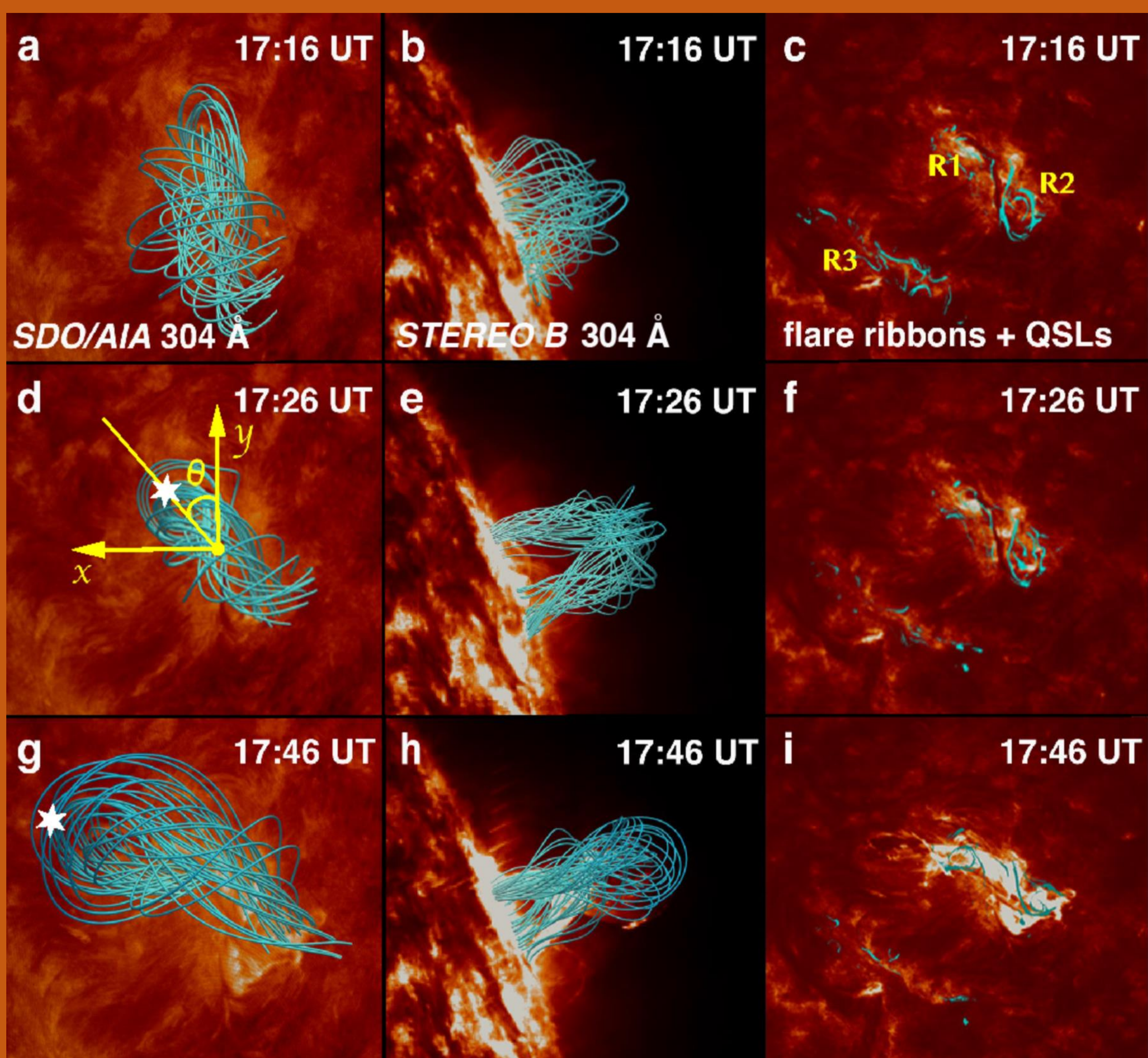
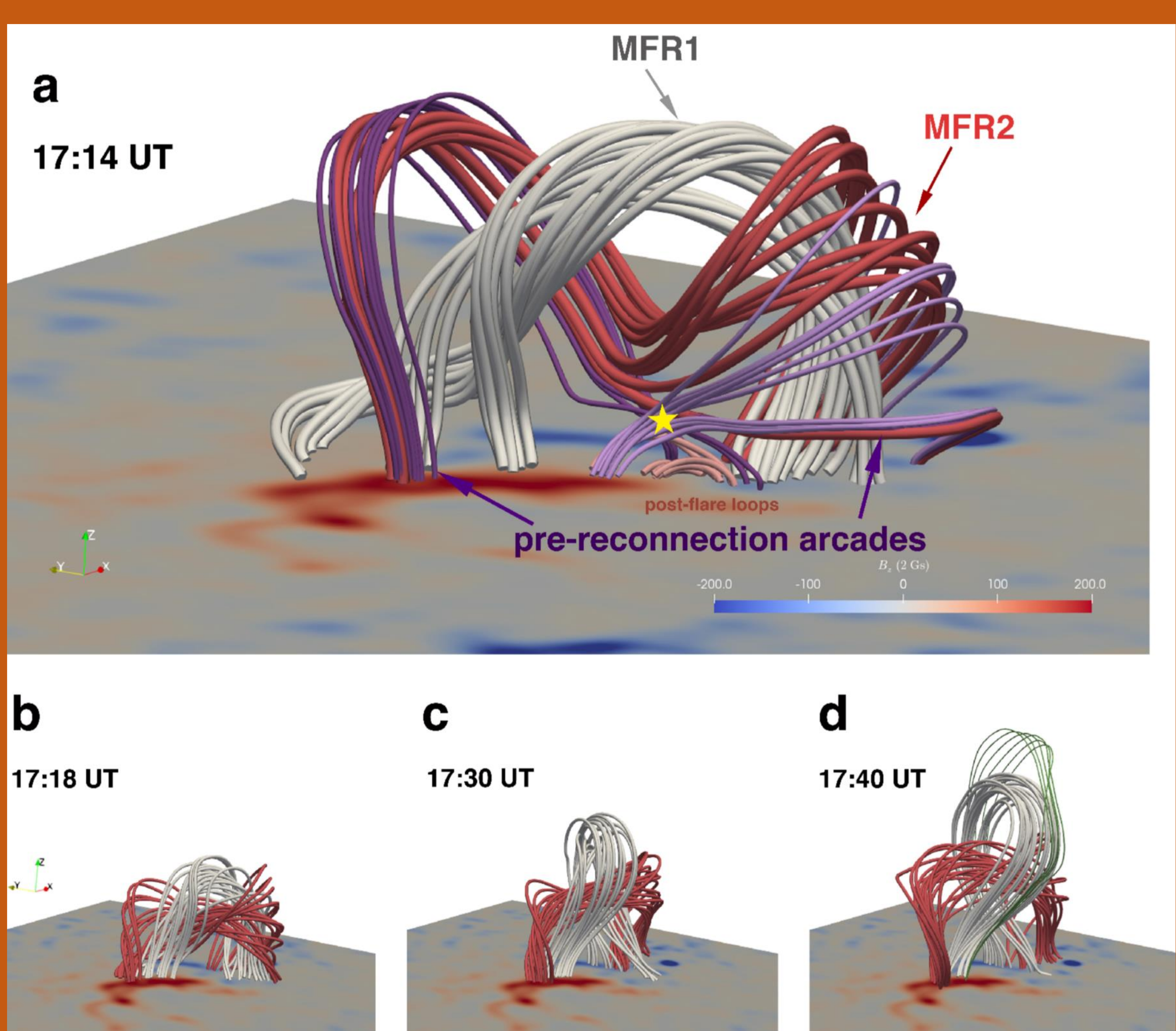
We perform a data-constrained simulation with the zero-beta assumption to study the mechanisms of rotation and failed eruption of a filament in active region 11474 on 2012 May 5. We discover two flux ropes in the sigmoid system, an upper flux rope (MFR1) and a lower flux rope (MFR2) grows by tether-cutting reconnection during the eruptions. The rotation of MFR1 is related to the shear-field component along the axis. The toroidal field tension force and the non-axisymmetry forces confine the eruption of MFR1. We also suggest that the mutual interaction between MFR1 and MFR2 contributes to the large-angle rotation and the eruption failure. (Paper I)



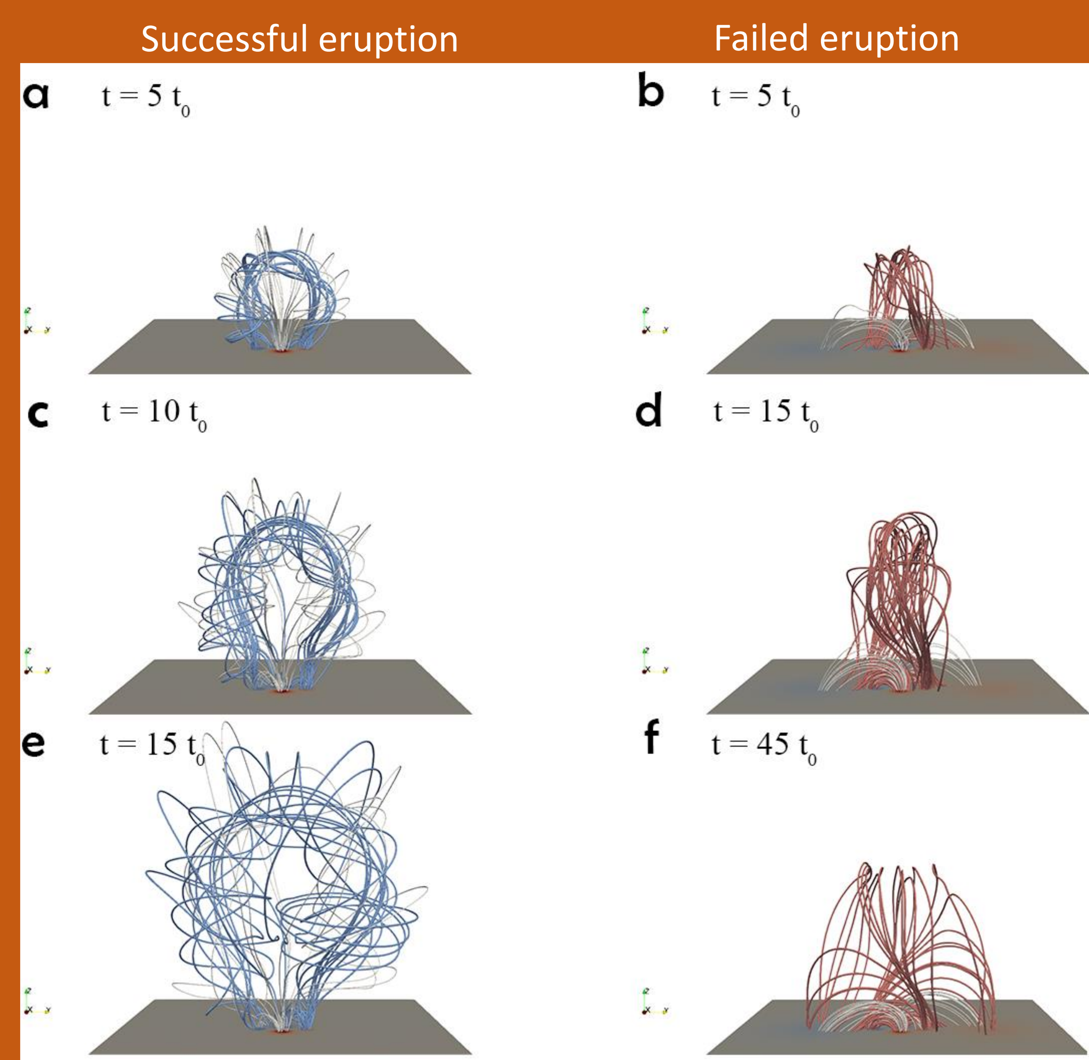
Comparisons between simulation results and observations

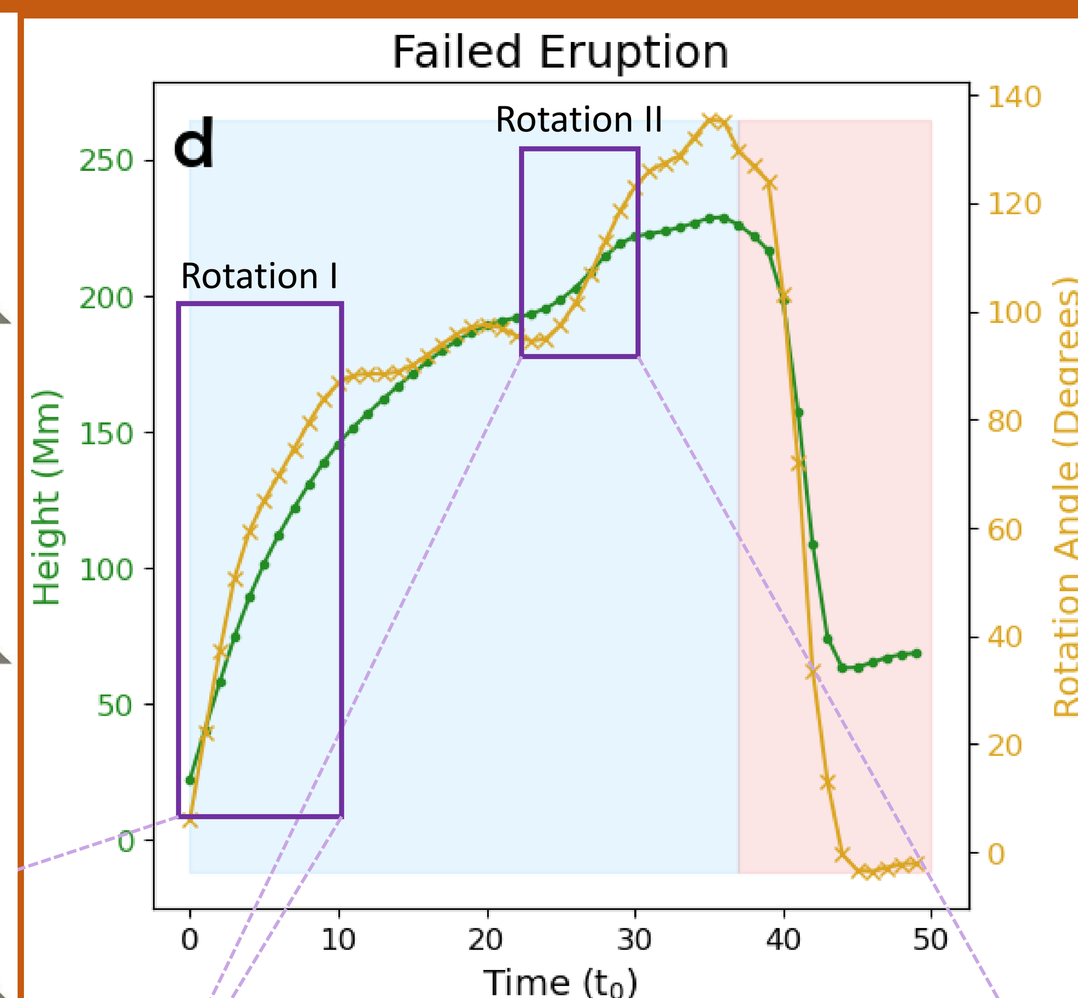


Evolution of the flux-rope system, where gray lines represent the inserted flux rope (MFR1), and red lines represent the flux rope formed during the eruption (MFR2). MFR1 exists before the eruption, which corresponds to the observed filament.
MFR2 grows gradually *by tether-cutting reconnection* between two adjacent sheared magnetic arcades during the eruption.

Confined reasons:
The toroidal field tension force and the non-axisymmetry forces confine the eruption of MFR1.
After a large-angle rotation of MFR1, its toroidal field is almost parallel with the overlaying field, which produces a surge of the strapping field and restricts the rising of MFR2.

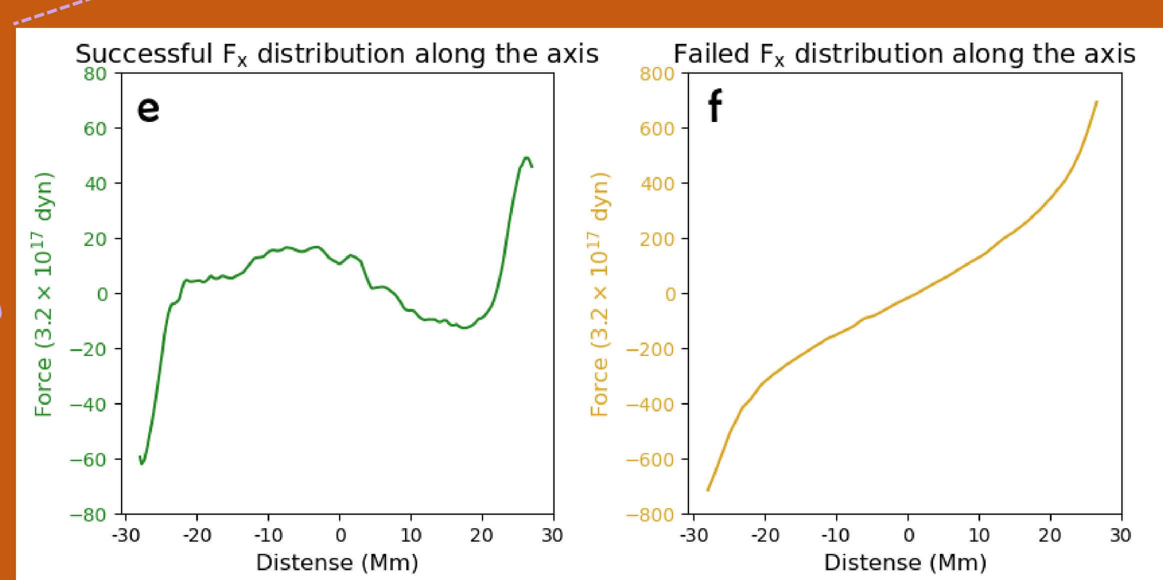
Rotation reason:
The shear-field component provided by MFR2 and the external toroidal field is the reason for the rotation of MFR1.





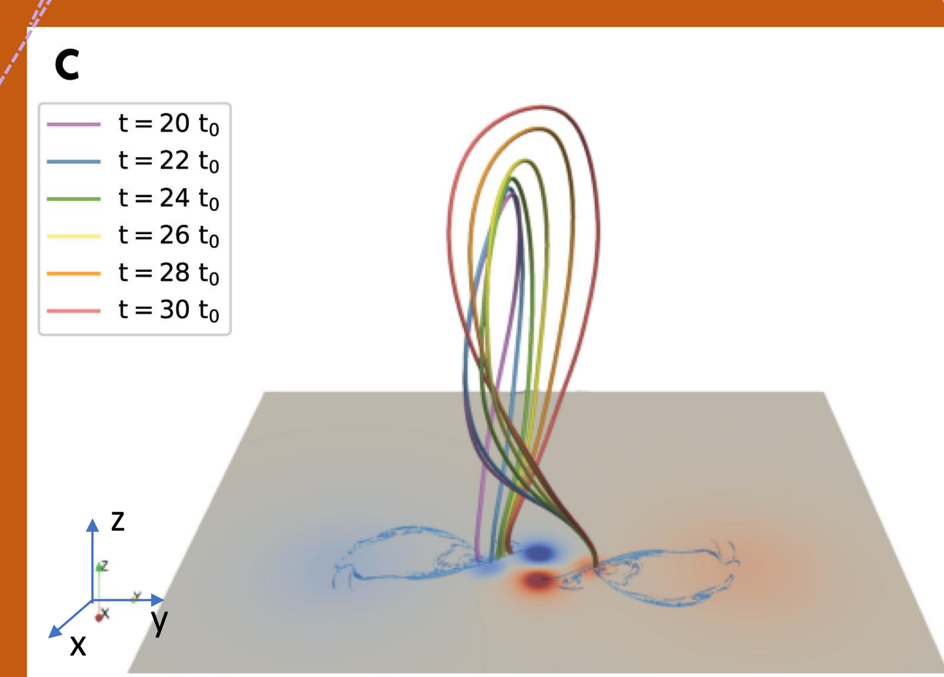
Global evolution of magnetic fields for both cases

Rotation I



Fx along the axis at t = 0, where the abscissa represents the distance in y direction between the positive footpoint and the sample point on the axis

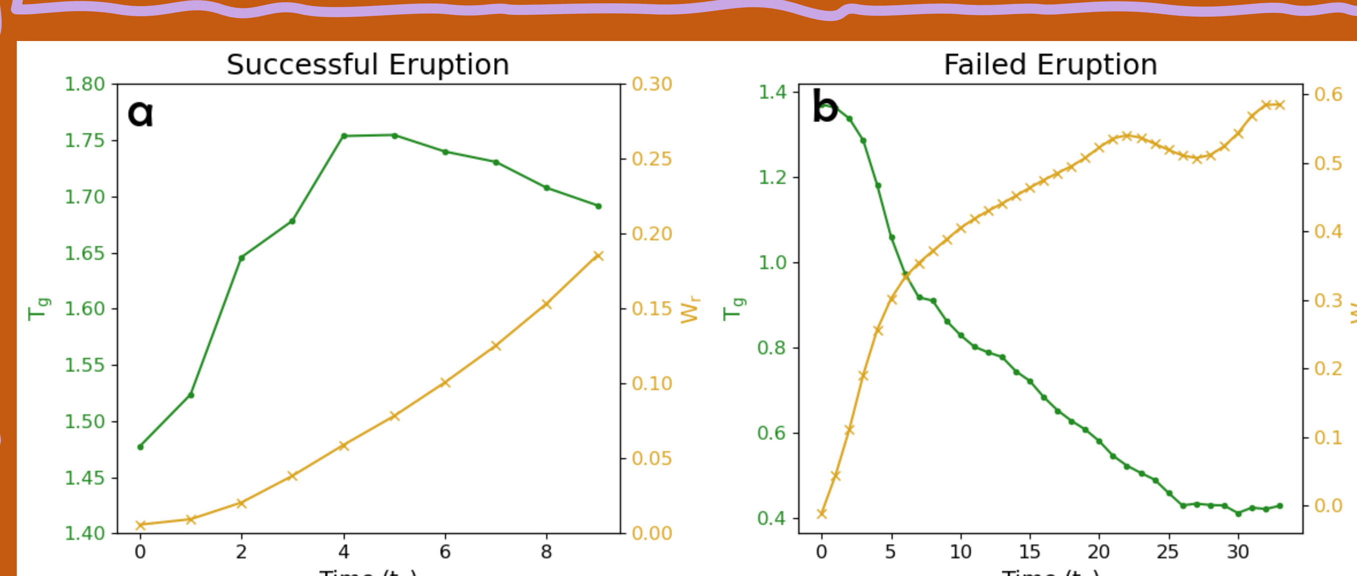
Rotation II



Footpoint drift: one of flux-rope fieldlines evolution during t = 20 ~30 t_0

Footpoint drift can alter the direction of the line connecting flux-rope footpoints as well as the direction of the MFR apex, which is a potential mechanism to promote the rotation.

We perform three-dimensional magnetohrdronamic simulations to model the eruption of magnetic flux ropes in the magnetic configuration with and without external toroidal magnetic fields, to examine the mechanisms by which the toroidal magnetic field facilitates flux-rope rotation, and in exploring potential alternative rotation mechanisms beyond the effects of sheared fields and kink instability. The behavior of flux ropes in two simulations exhibits significant contrasts. We indicate that external toroidal fields facilitate the flux-rope rotation by ***promoting the release of the initial twist***, ***amplifying the lateral Lorentz force*** exerted on the flux rope and ***promoting the formation of the lower MFR***, which can amplifying the aforementioned effects of external toroidal fields. In addition, ***slipping magnetic reconnection*** between flux-rope field lines and sheared-arcade field lines can also contribute to the rotation. (Paper II submitted)



Evolution of the twist and writhe of both cases

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