

The Kink Instability in Solar Eruptions

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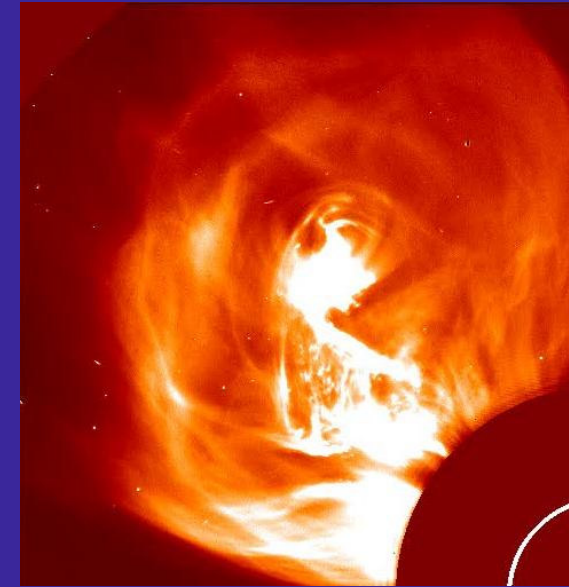
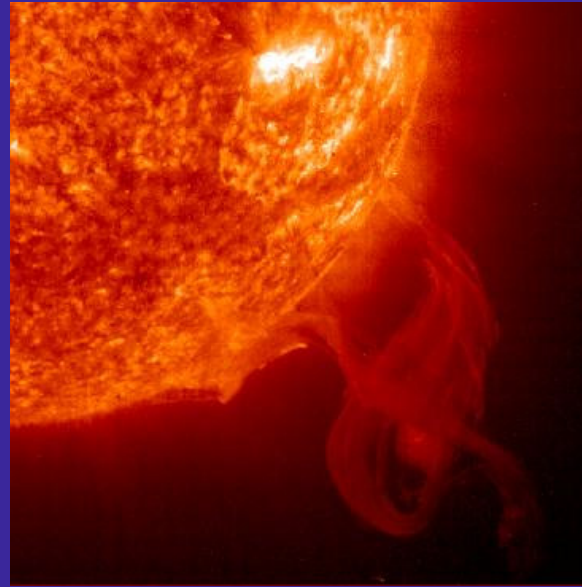
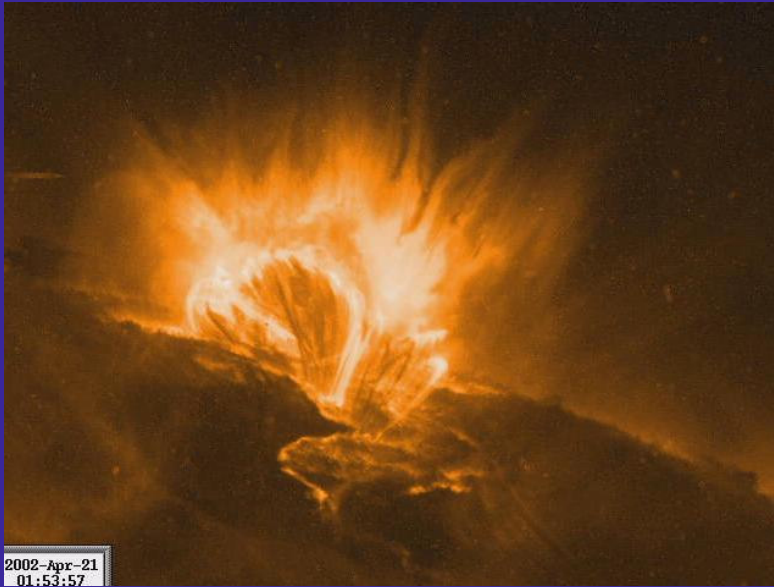
in collaboration with

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Thomas Neukirch (University of St. Andrews)

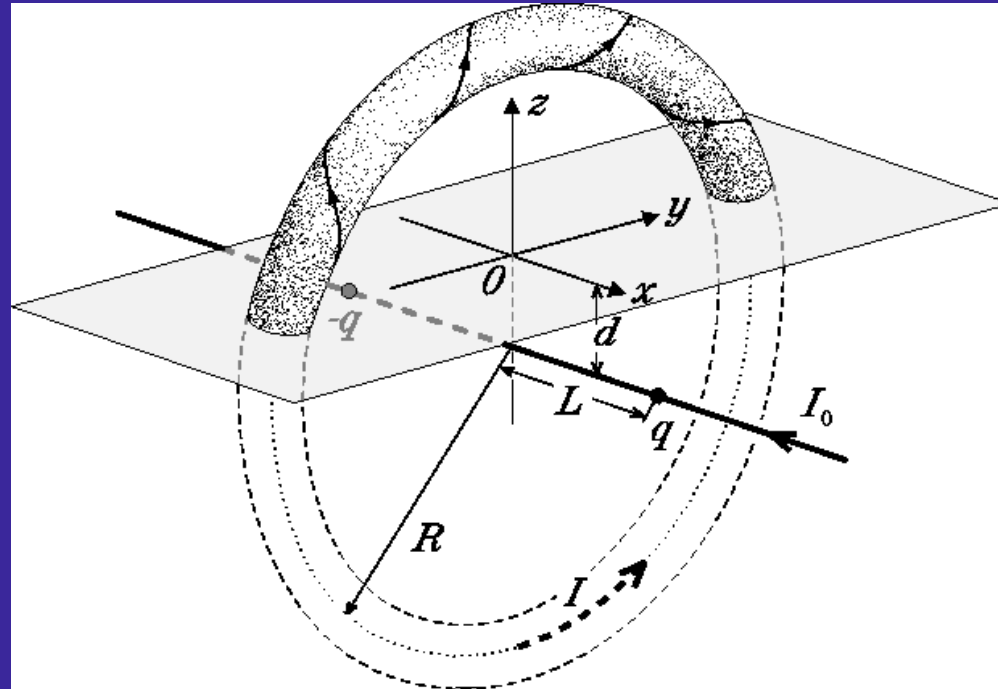
talk given at the SoHO 15 meeting, St. Andrews, 2004 September 6

large solar eruption



- flare, prominence eruption, and CME
- **main phase** quite well understood (“standard model”)
- **initiation process** remains unclear
 - different models considered:
e.g. **tether cutting, magnetic breakout, flux rope models**

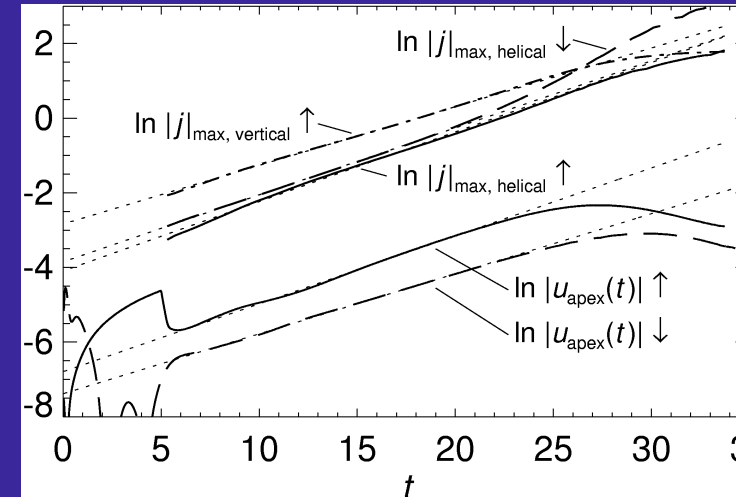
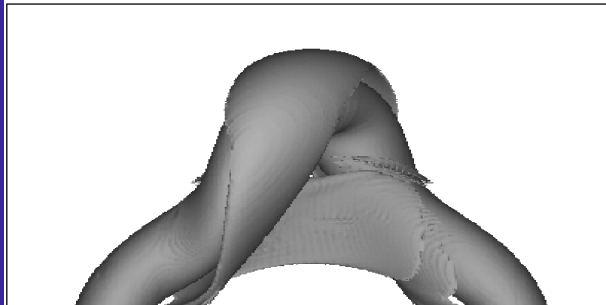
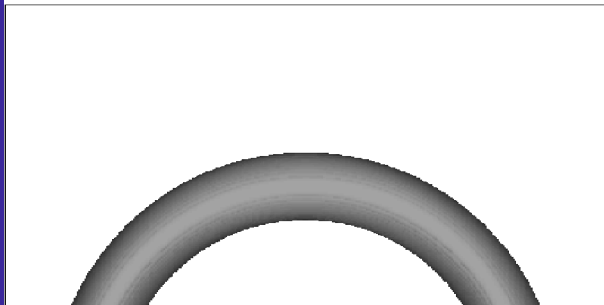
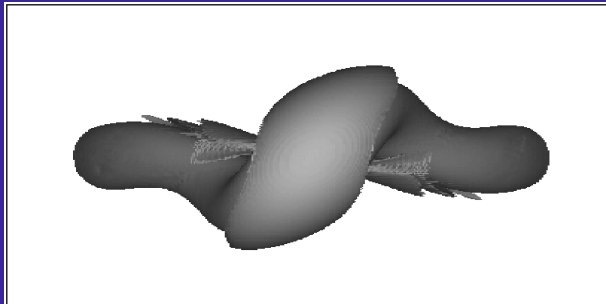
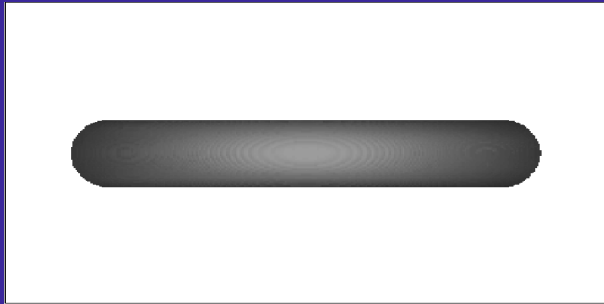
model of a coronal loop



Titov and Démoulin, *A&A* 351, 707 (1999)

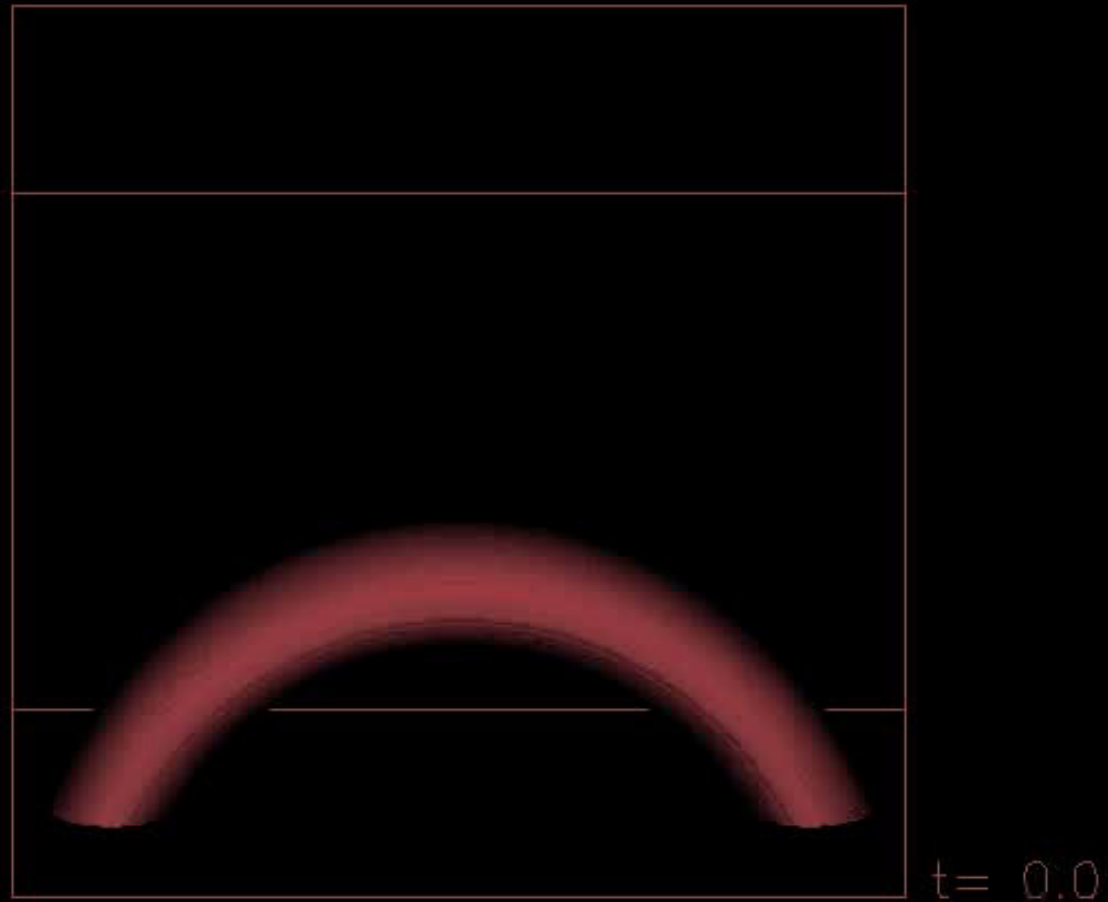
- approximate analytical force-free equilibrium
- arched line-tied twisted magnetic flux tube
- twist can be chosen within a wide range
- 3D ideal MHD simulations with $\beta = 0$

kink instability

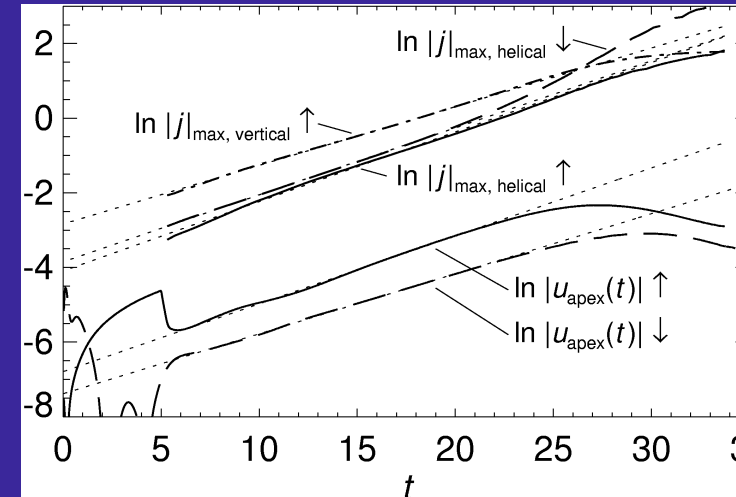
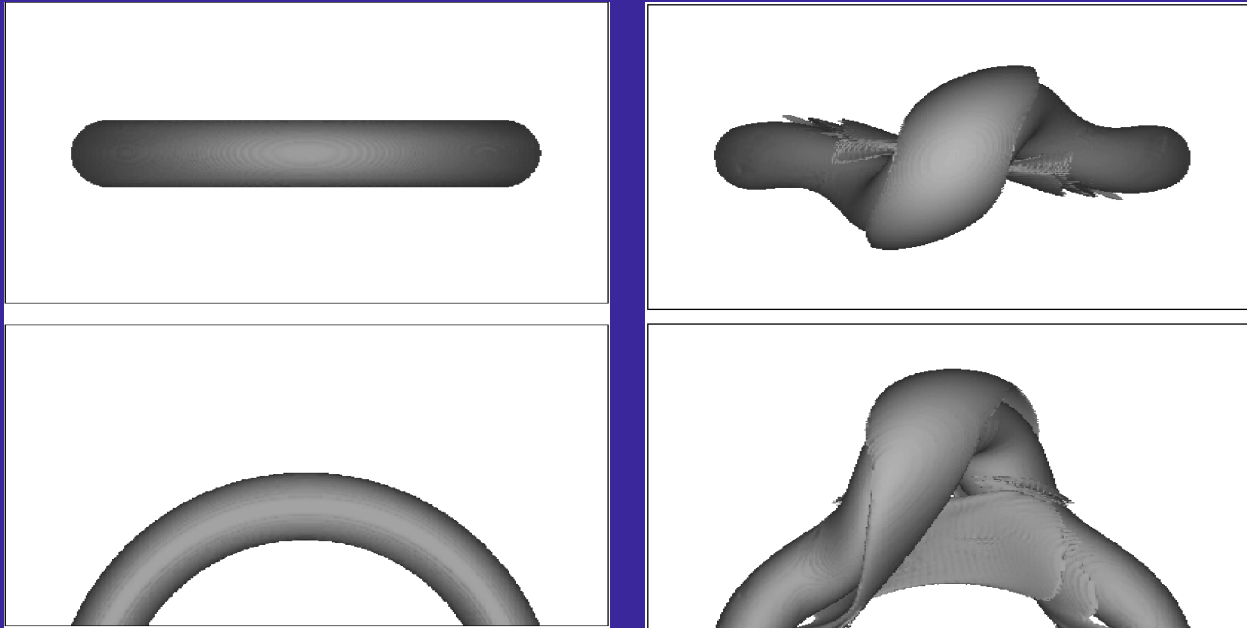


- kink develops at supercritical twist
- instability saturates (**no eruption**)
- indications of eruption:
 - **vertical current sheet** below rising flux rope
 - substantial **displacement** of rope apex

kink instability

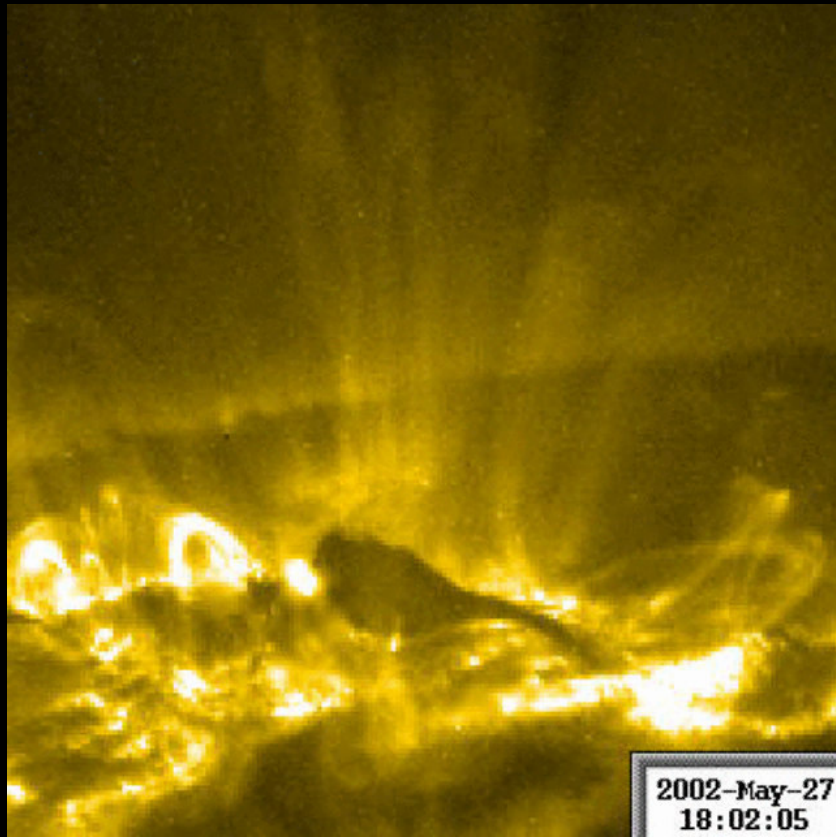


kink instability

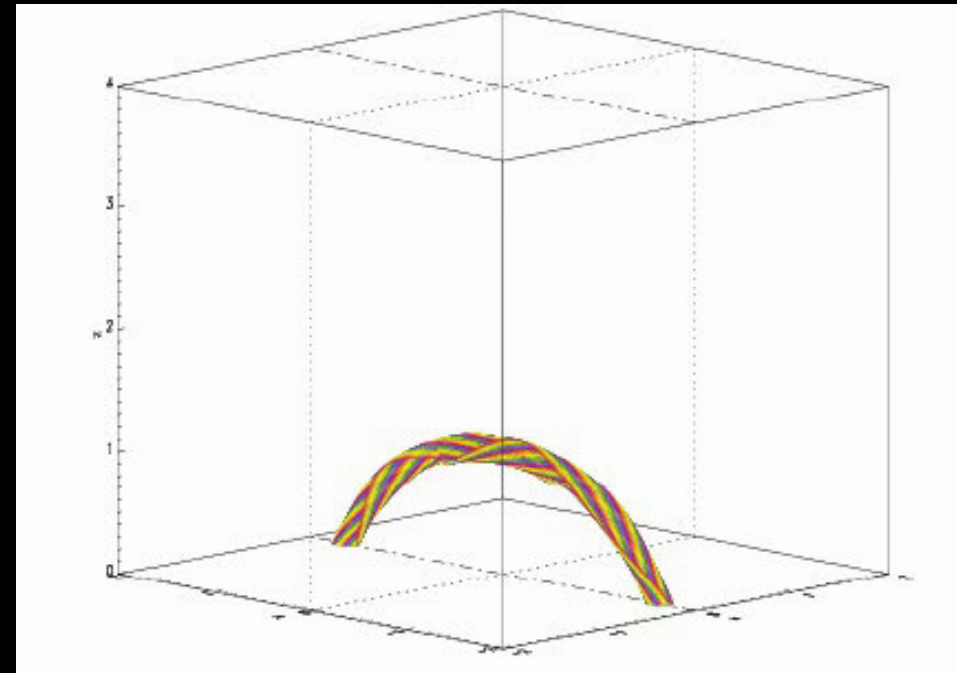


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“failed” filament eruption

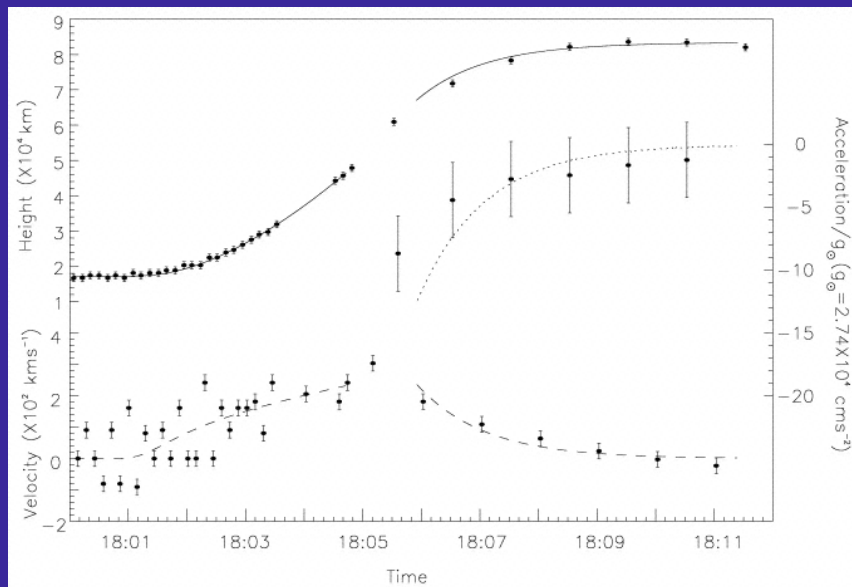


TRACE (195 Å)

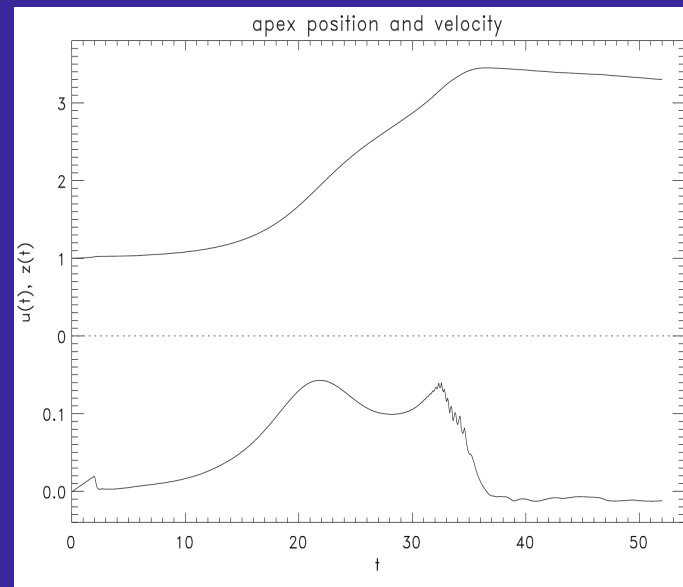


simulation ($\Phi \approx 5\pi$)

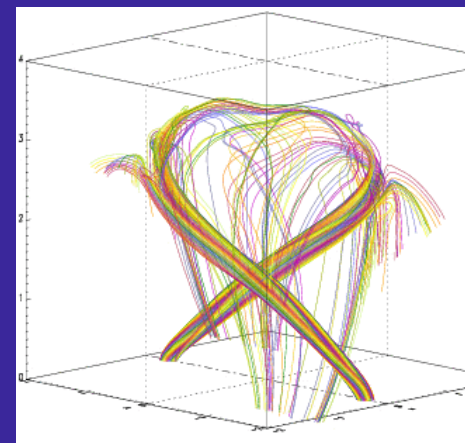
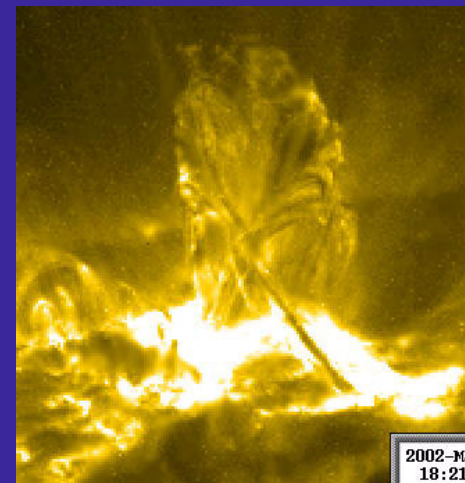
“failed” filament eruption



Ji et al., ApJ 595, L135
(2003)



simulation

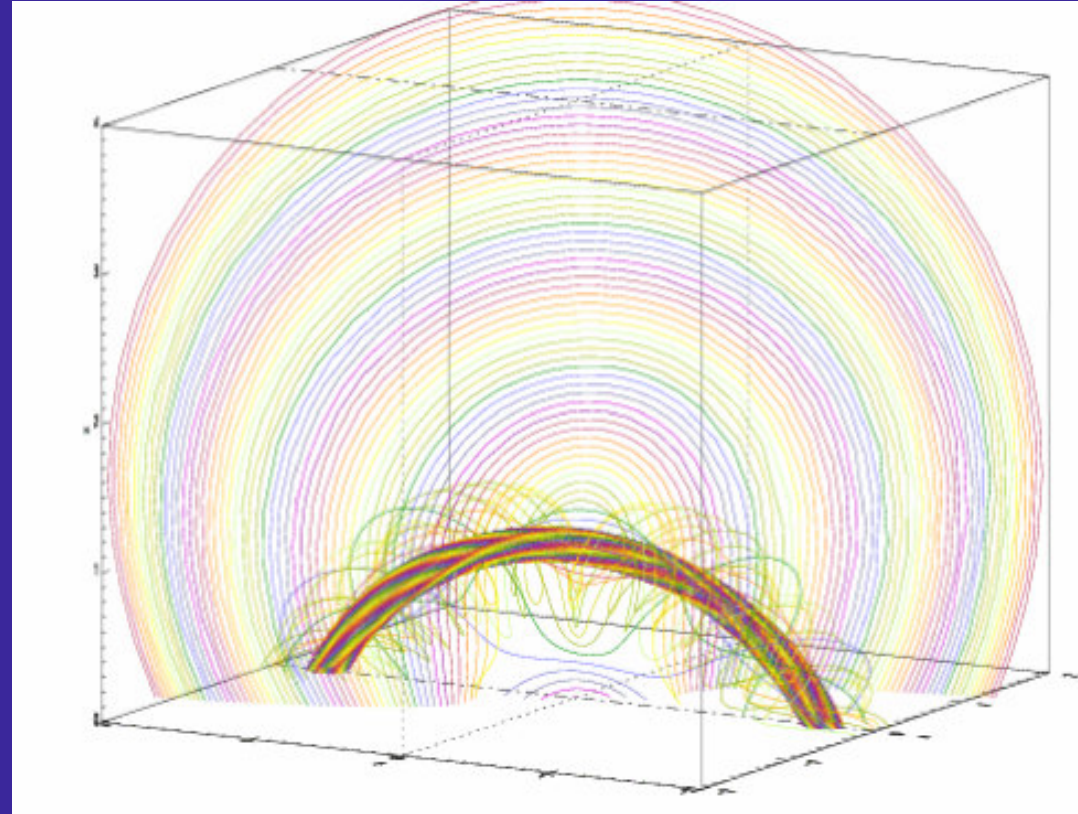
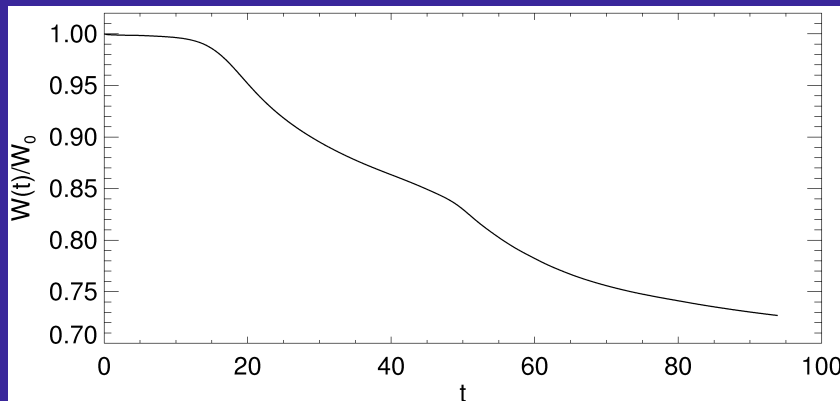
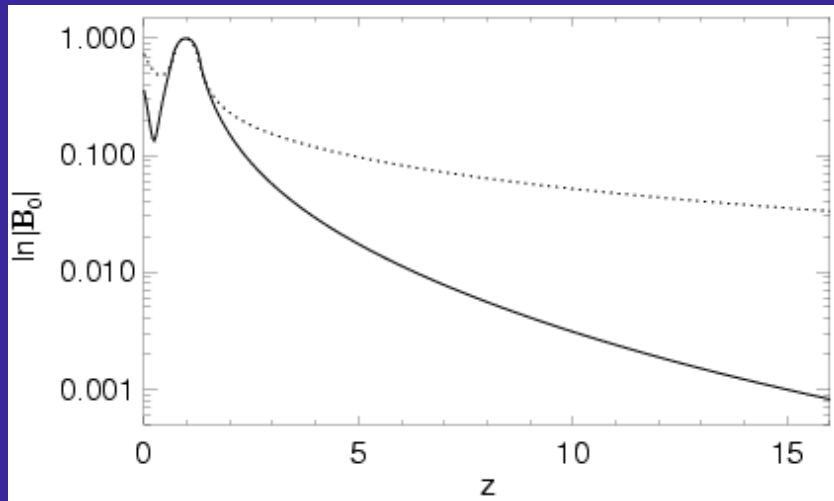


● rise characteristics and morphology reproduced

→ filament is twisted flux tube

→ destabilization due to kink instability

modified model

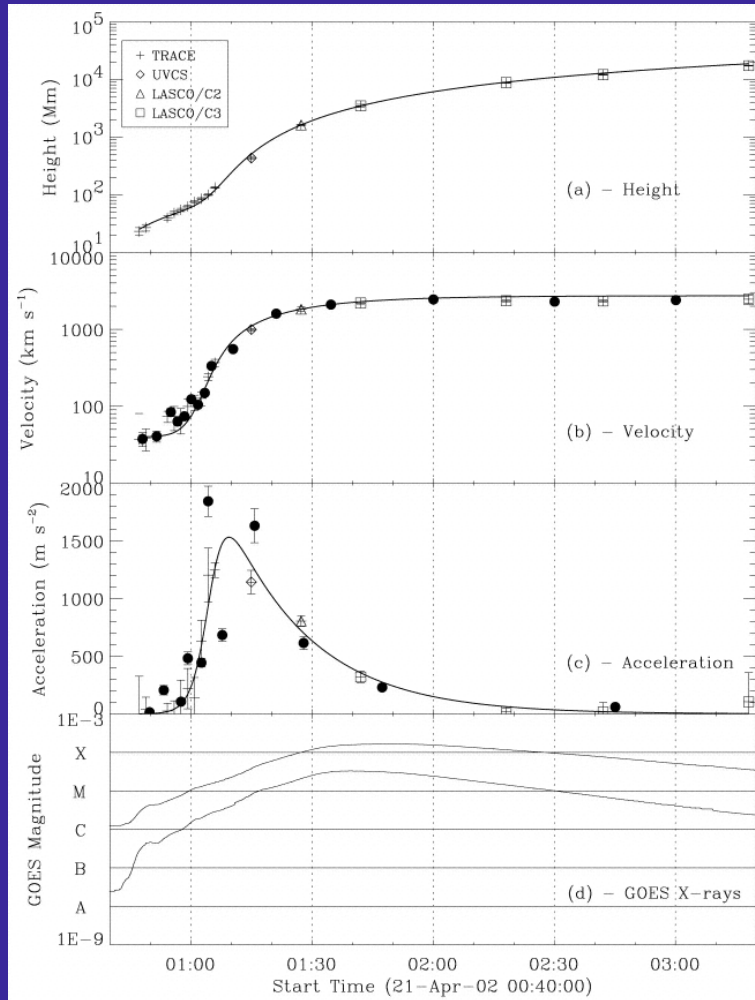


● eruption prevented by strong overlying field

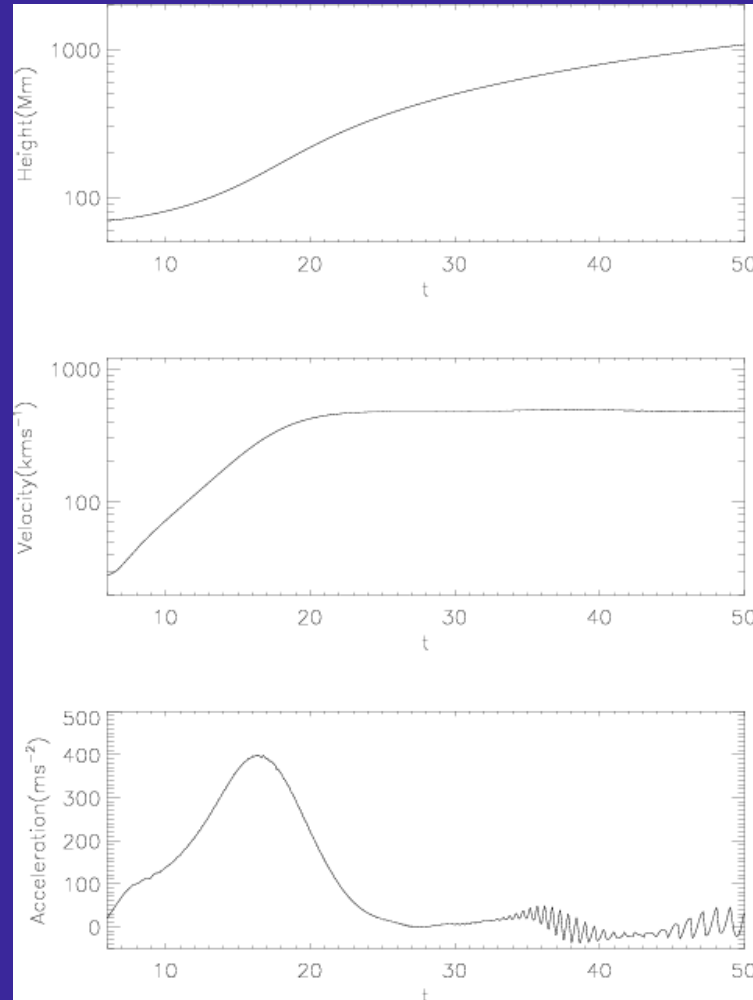
● replace line current by a pair of dipoles

→ flux rope erupts

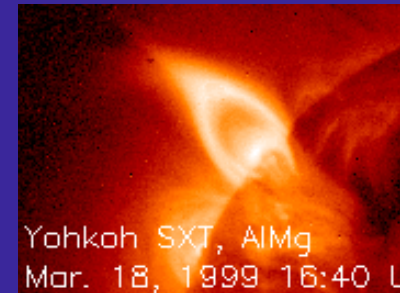
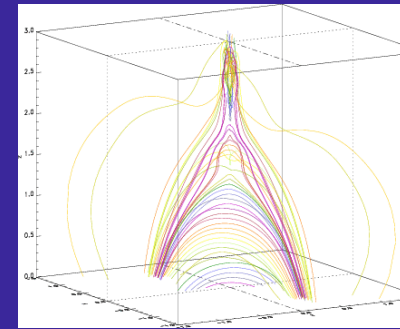
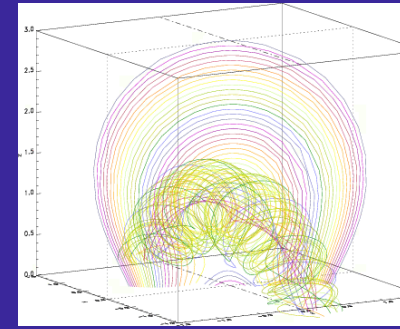
modified model



Gallagher et al.,
ApJ 588, L53 (2003)



simulation



- qualitative agreement with rise characteristics of CME
- reconnected field lines form cusp structure

summary & conclusions

- Titov & Démoulin equilibrium is kink-unstable for supercritical twist
- essential features of solar eruptions reproduced
- kink instability of a twisted flux tube is the initiation mechanism of a substantial fraction of solar eruptions
- overlying field important for “success” of eruption