CME Initiation

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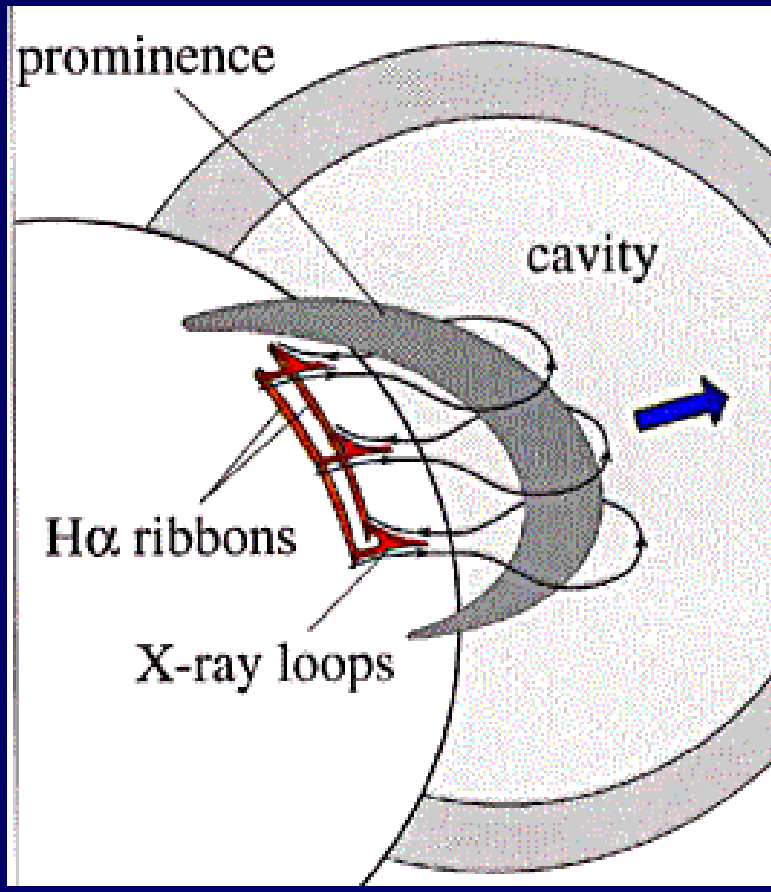
- TRACE observations of 06/16/2005 event

Observed CME Initiation and Evolution

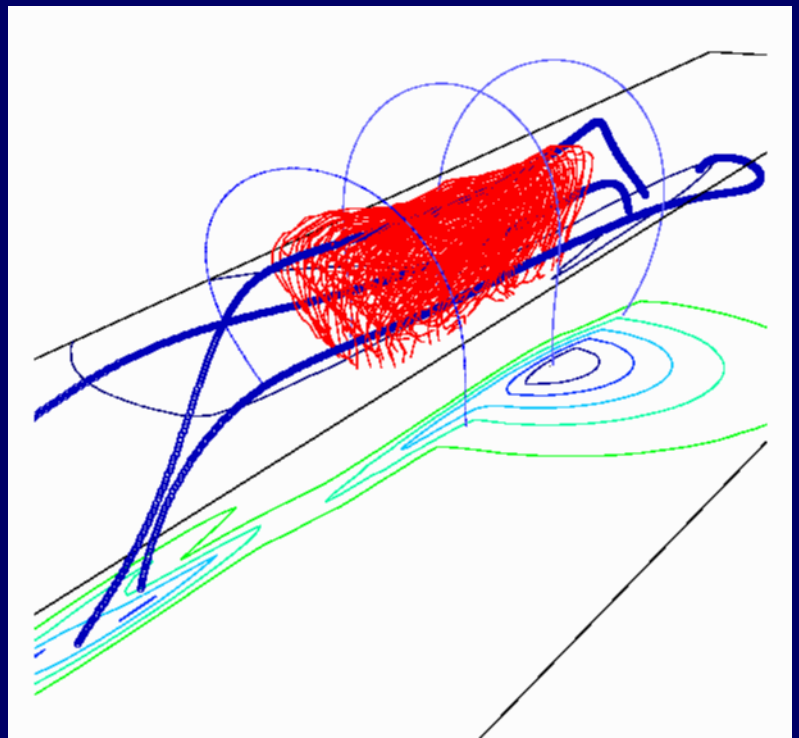
- Strongly sheared flux forms along a PIL (~ days)
- Origin and topology still debated
- B pressure of sheared flux contained by B tension of overlying unsheared coronal field
- Provides pre-CME energy source and force balance
- For some reason, force balance breaks down and field expands outward explosively
- Field reconnects below eruption yielding flare and fills in dimming region (~ 10 hours)

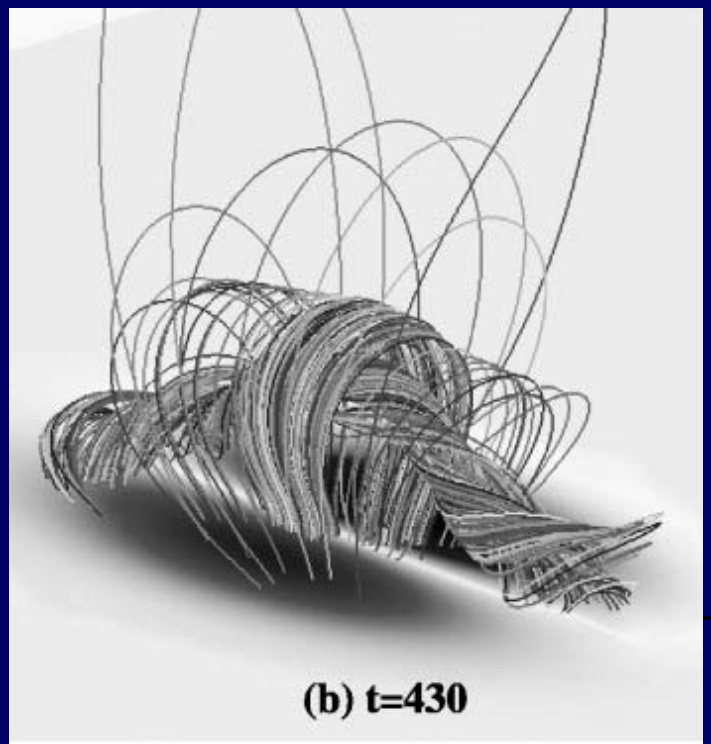
(Forbes)



Filament Magnetic Topology

- 2 general topologies: sheared arcade and twisted flux rope
  - Both have strong shear component
  - Amount of twist critical for CME initiation models
  - Key objective for Hinode: determine correct model
  - Berger: AR filament motions show little twist
    - DeRosa: Photospheric extrapolations??



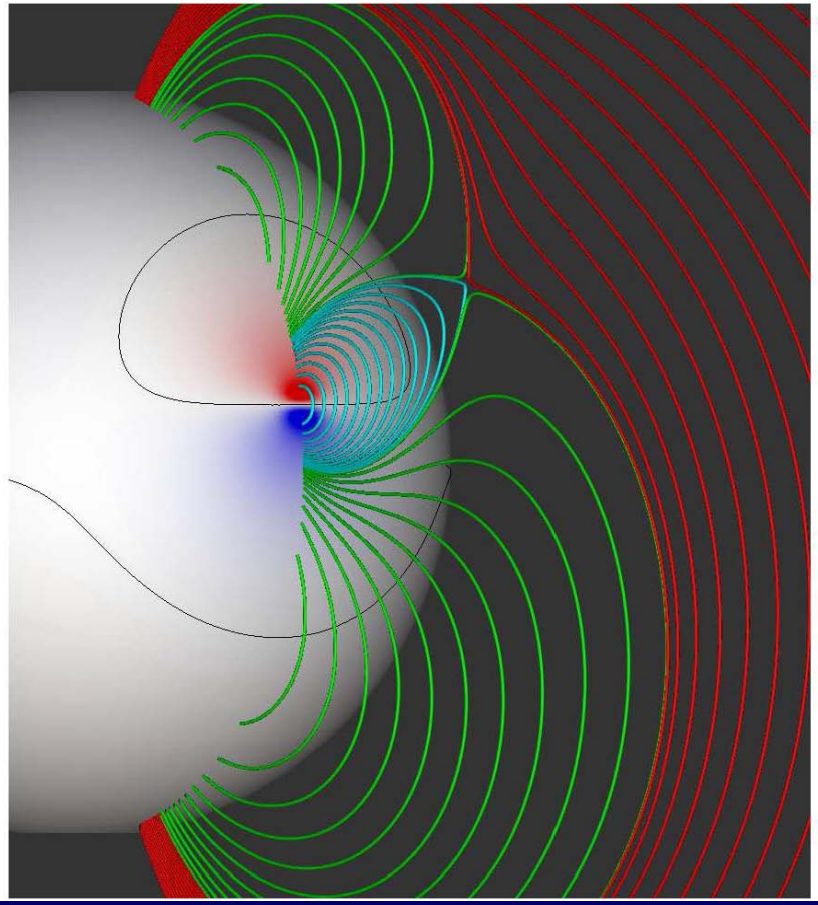


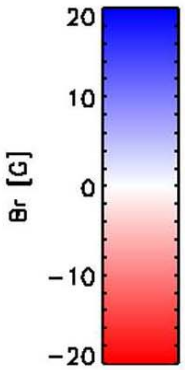
What Initiates Eruption?

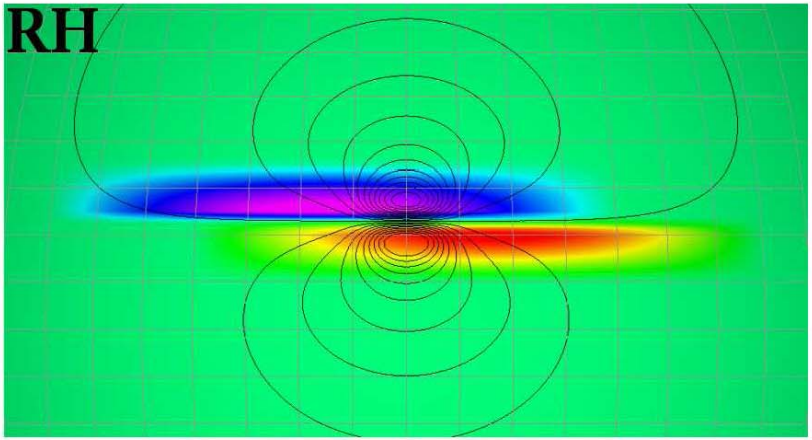
Must remove overlying tension suddenly!

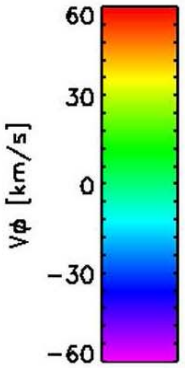
- Sheared arcade models:
  - "Breakout & tether-cutting"
    - Do not exclude twist, but not required
  - Reconnection removes/disconnects overlying field
- Twisted rope models:
  - "Flux cancellation & kink"
    - Must have sufficient twist
  - Loss-of-equilibrium/ideal instability moves aside or leads to reconnection of overlying field

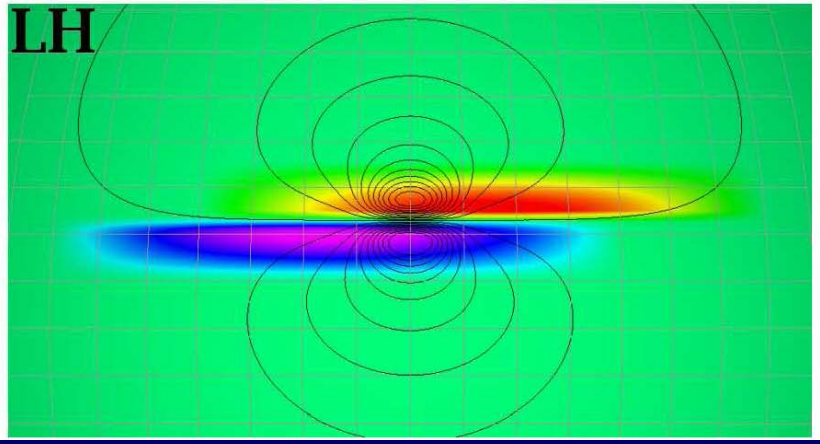
3D Breakout Model for CME Initiation





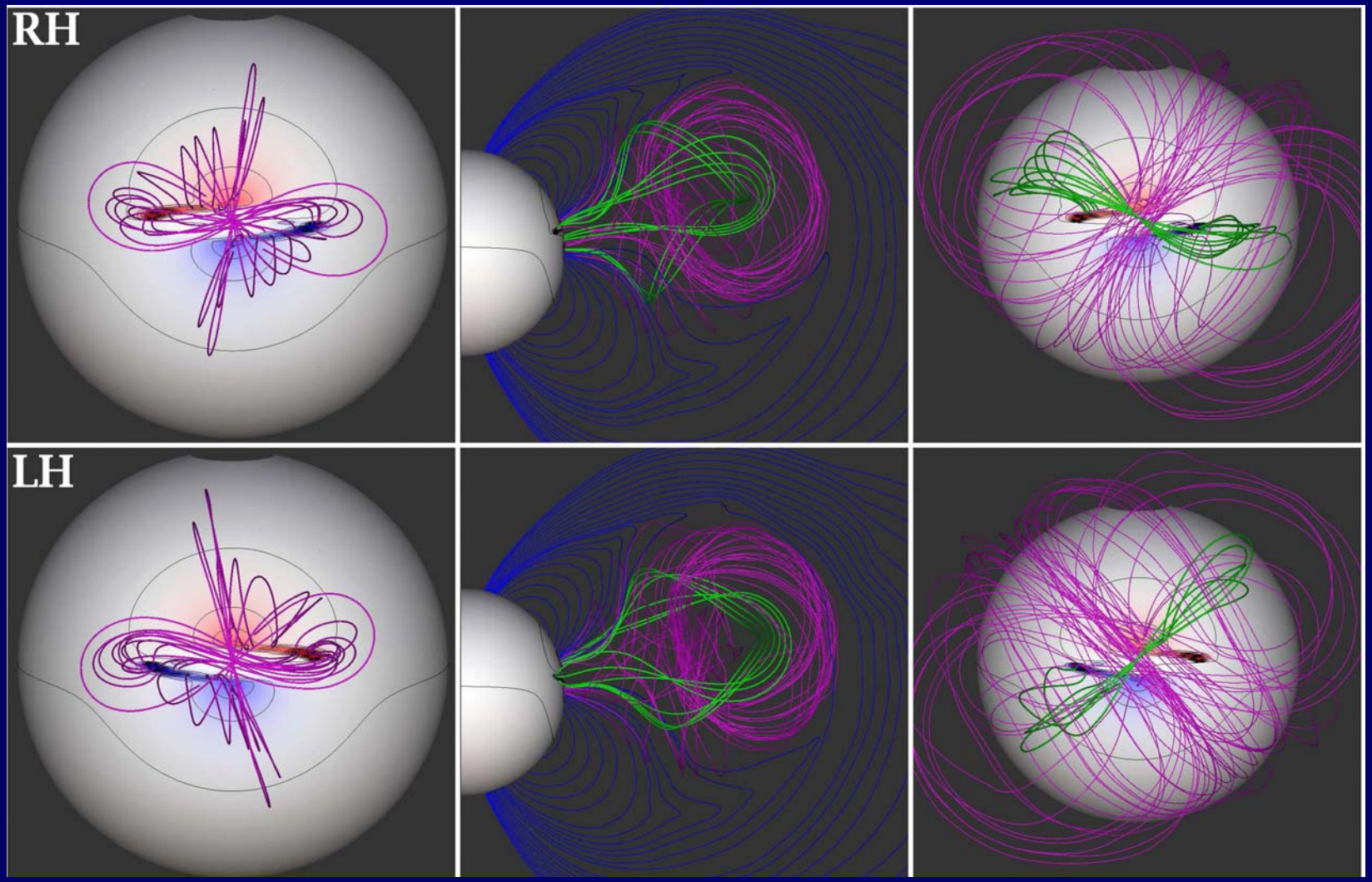






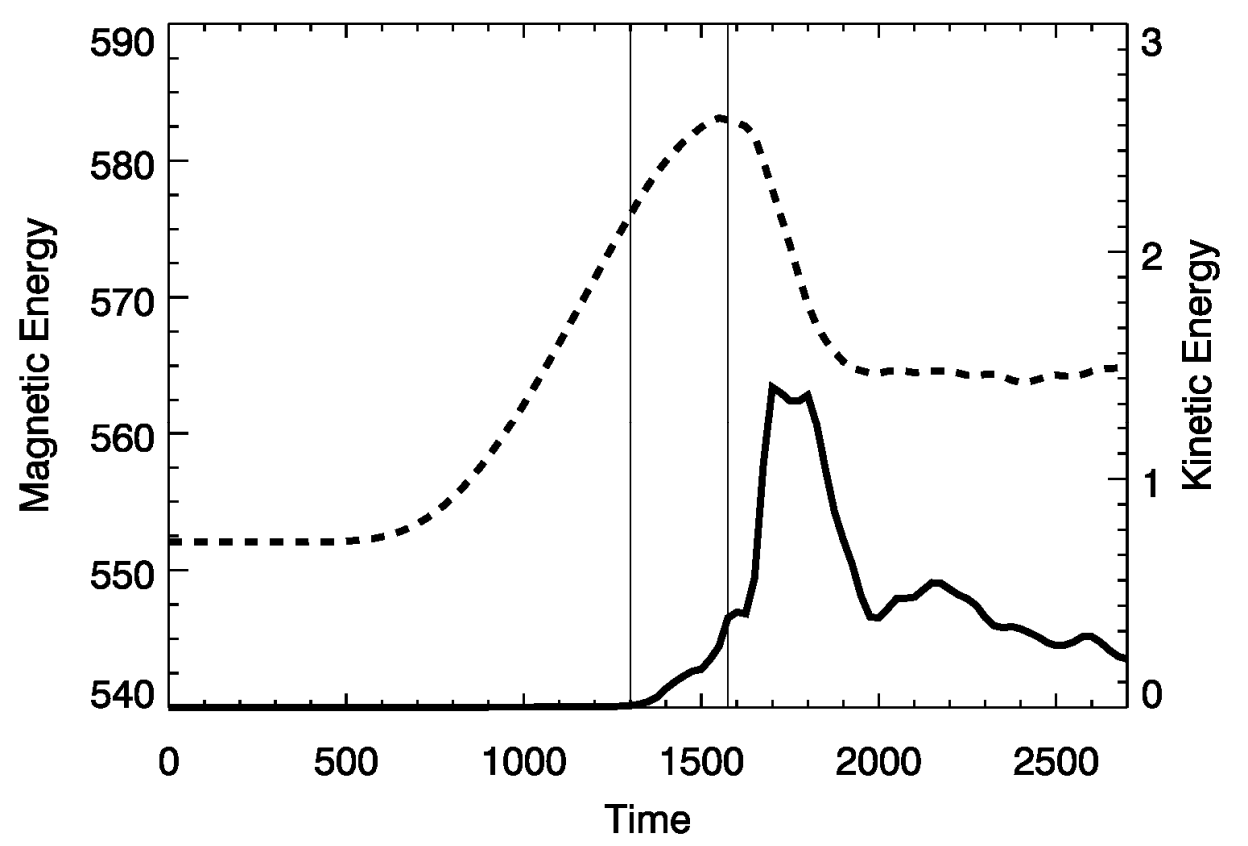
- Initial potential field in simplest multi-polar topology
  - Two flux system
- Photospheric flow fields (from Lynch et al, 2008)

Breakout Model for CME Initiation



- Pre-eruption stressed state
- Formation of twisted flux rope, as a result of flare reconnection
- Rotation of erupting field (from Lynch et al, 2008)

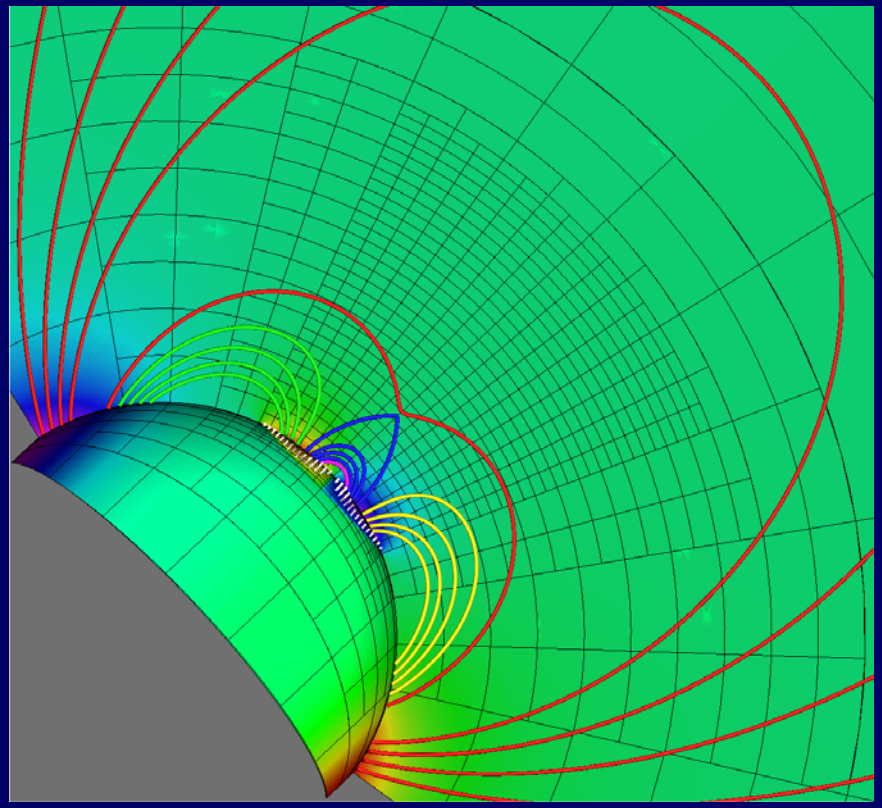
Breakout CME

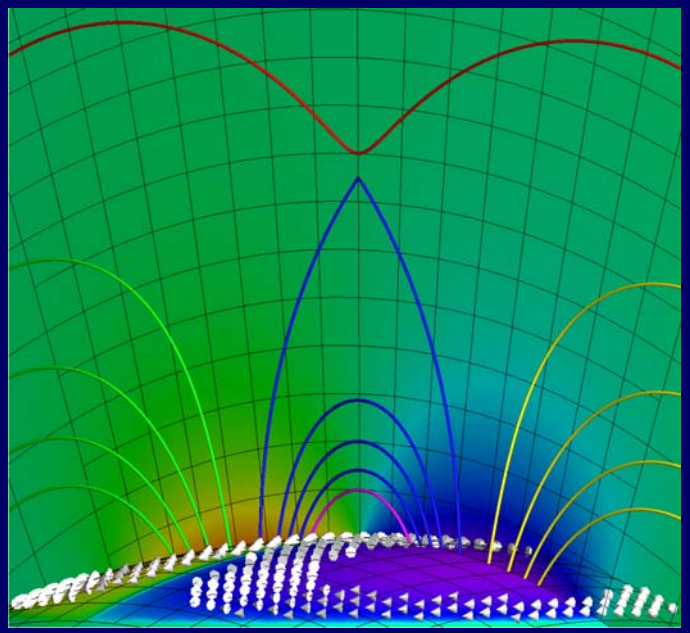


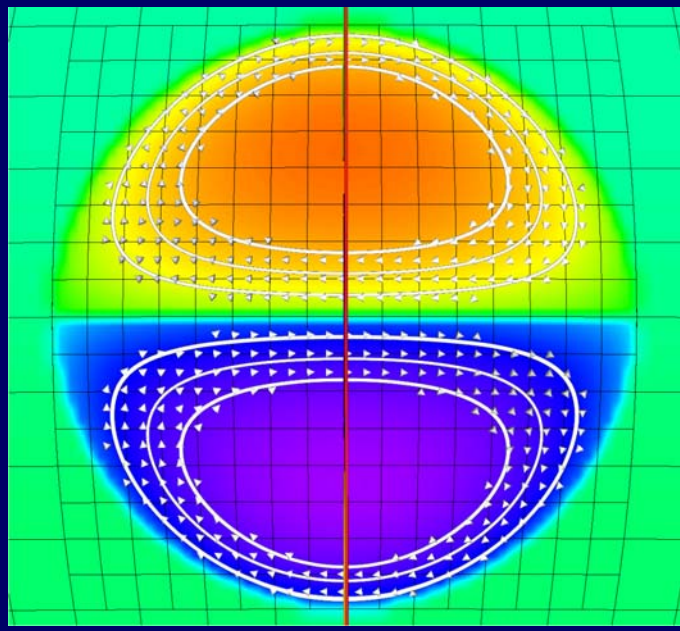
- Ejection initiated by breakout reconnection,
- Flare reconnection provides major boost (Lynch et al, 2008)
- Also seen in 2.5D simulations (MacNeice et al 2004)

Confined Eruptions by Breakout Model

(DeVore & Antiochos, ApJ, 2008)

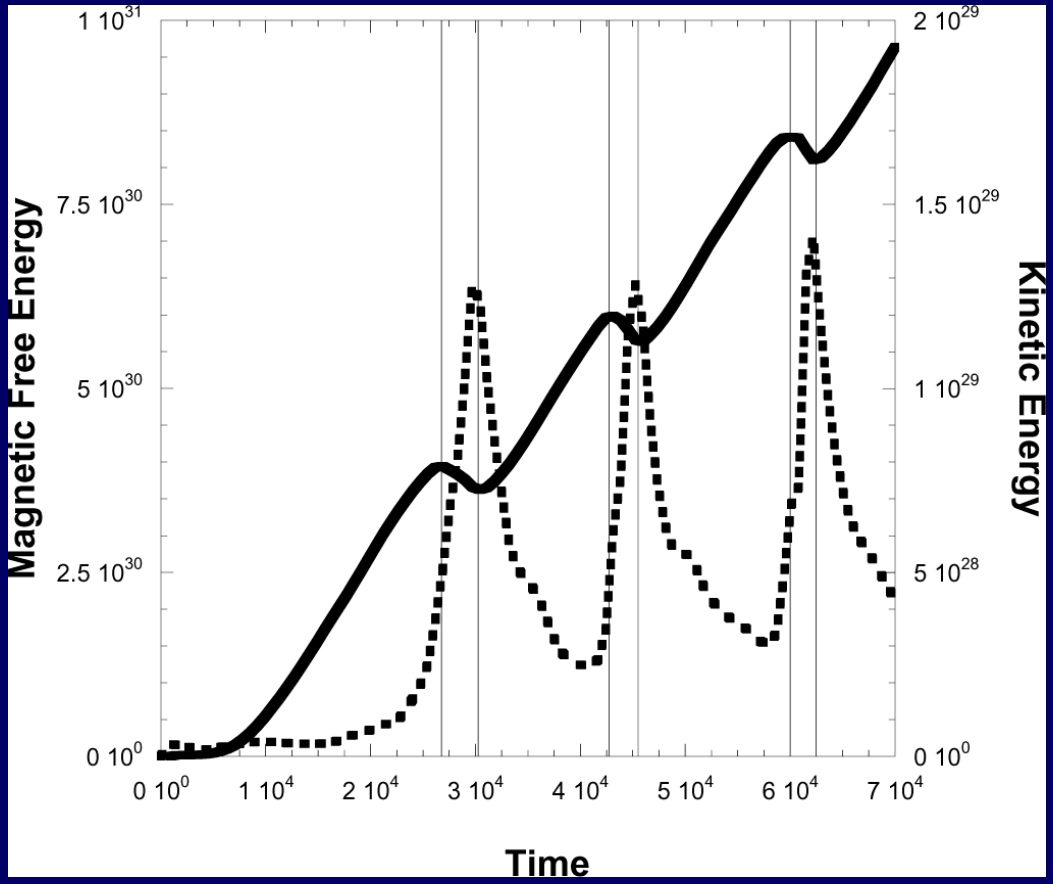




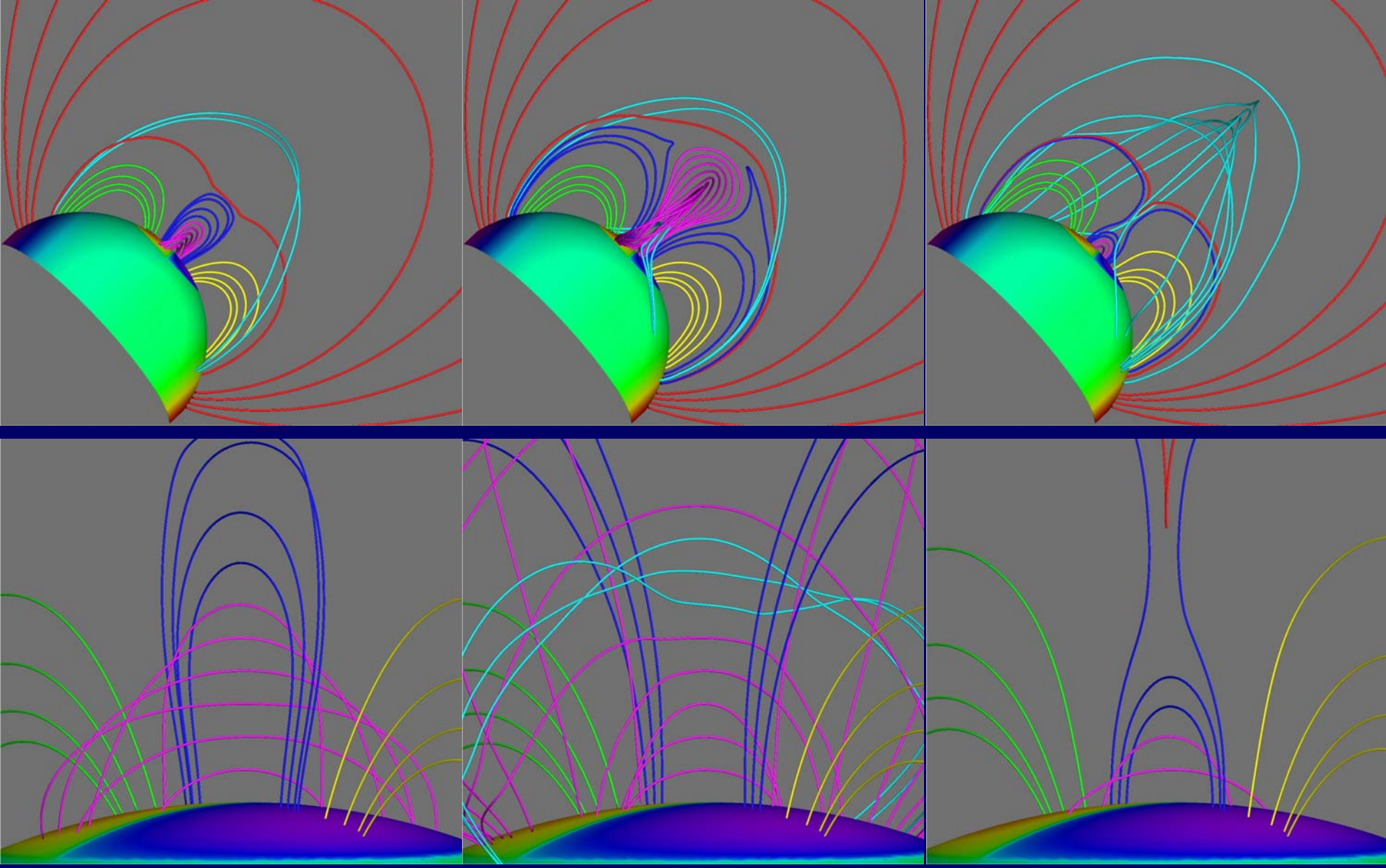


- Four-flux 3D topology driven by photospheric rotational flows

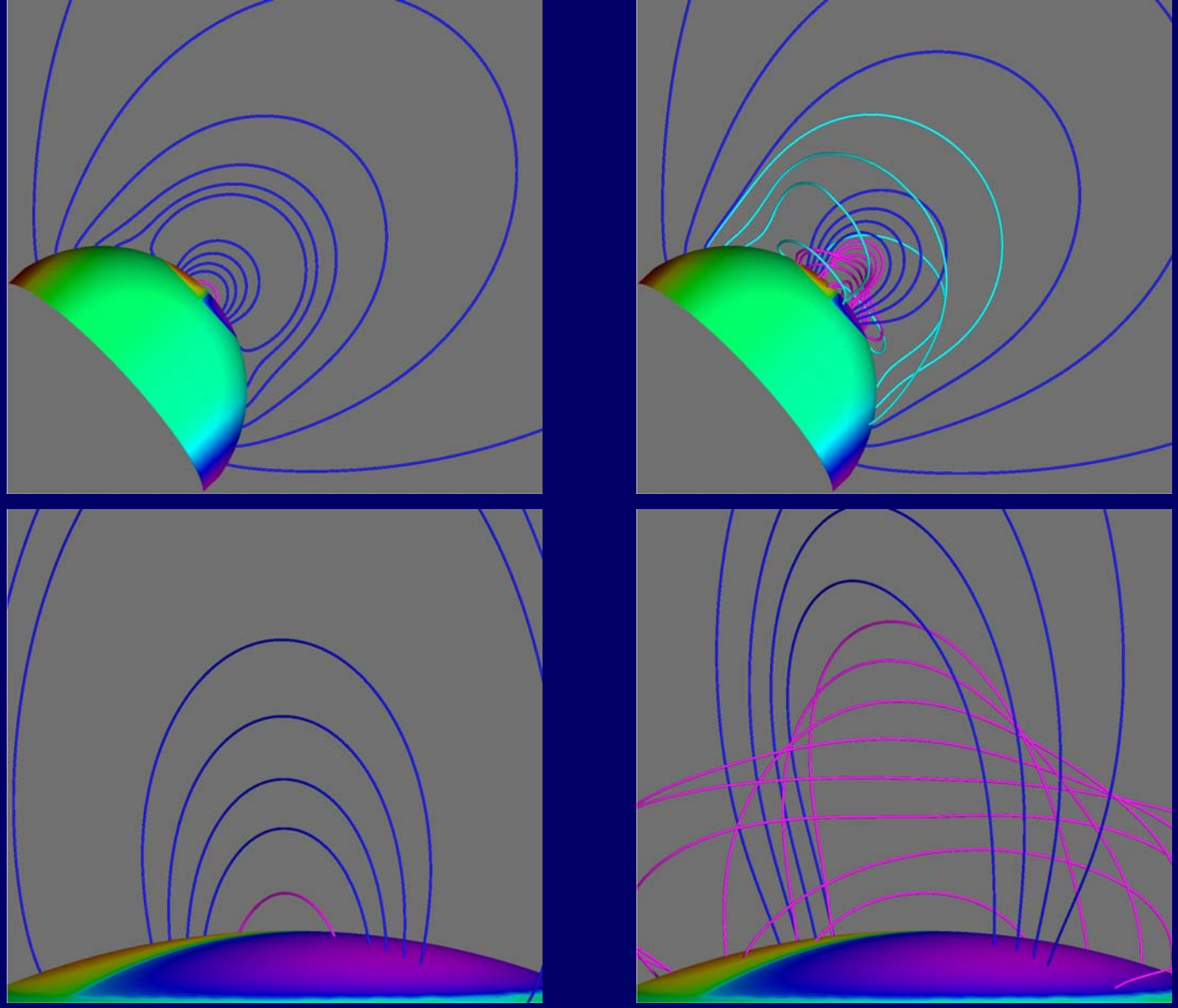
Confined Eruptions by Breakout Model



- Series of confined eruptions
  - ejection for stronger AR field
- Bursts of multi-polar (breakout) and bipolar (flare) reconnection

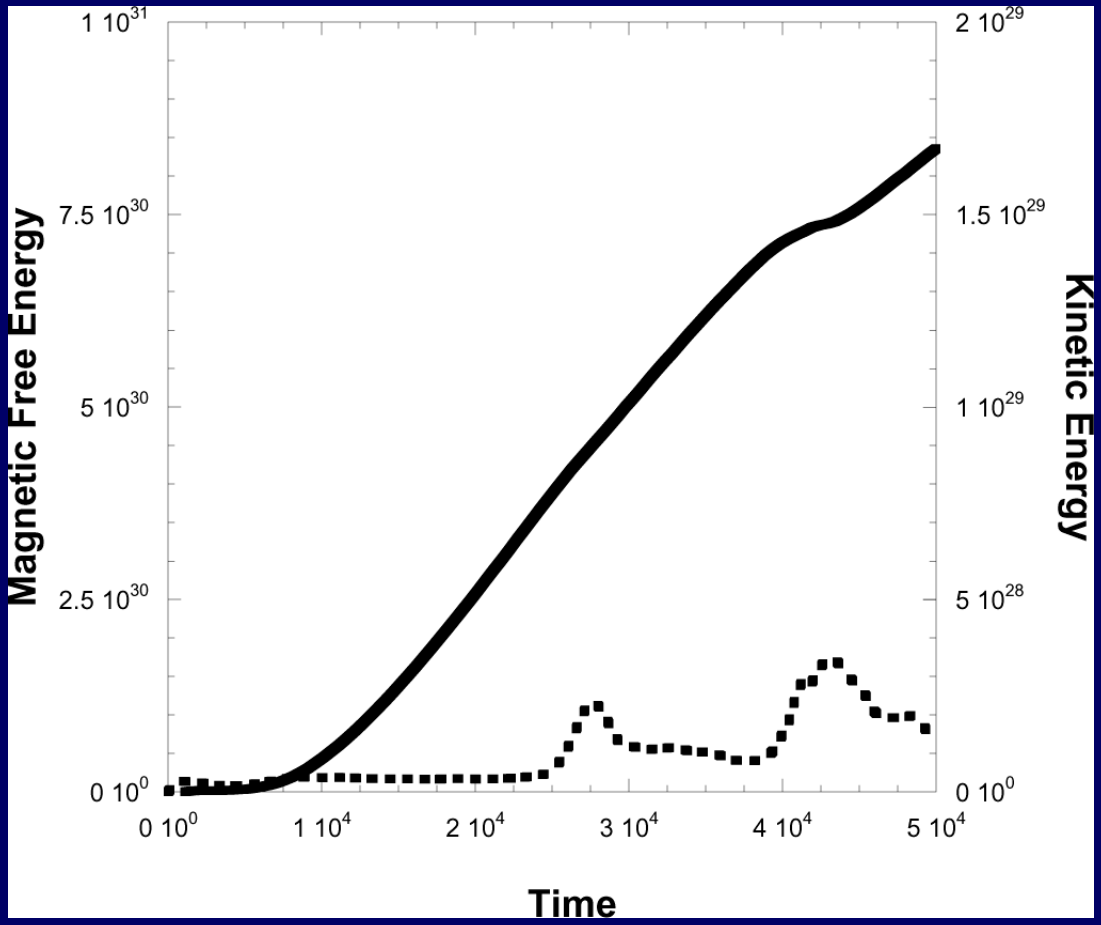


- Evolution of second eruption
- Helicity transferred to high-lying field – prediction for Hinode



- Twisting of bipolar topology
- Minor internal (tether-cutting) “reconnection”

Non-Eruption of Bipolar Topology



- Non-eruption of bipolar topology, similar result by Lynch for two-flux topology
- Breakout reconnection makes it all happen!

Conclusions

- Hinode needs to determine topology of pre-eruption field
  - All models produce post-eruption twisted flux rope
- Models do produce fast CMEs, but need more realistic physics for diffusivity
  - Incorporate kinetic reconnection results
- Validation with combined imaging and in situ measurements
  - Probe, Explorer, Solar-C, …