The Photosphere & CME Initiation

"We would like us to give us your views on the application of vector field and photospheric flows data to the CME initiation problem.

"We will have heard from Bruce Lites, Tom Metcalf and Dick Shine on the various issues involved in determining these quantities and KD Leka will discuss how she has used the field information to explore flares and CMEs.

"You have a unique perspective from the MURI work about what it takes to do the problem properly. Other than that you have perfect freedom."

‘STORAGE & RELEASE’ PARADIGM

- Storage: Coronal field is prob'ly never at min. E:

  non-potential fields emerge; and high-β photosphere evolves, driving ‘line-tied’ coronal field.

- ‘Background’ Release: Ubiquitous, weak (heats corona?)
- Impulsive Release: Episodically undergoes massive, violent restructuring: CME and/or flare, then post-eruption/ post-flare loops

Q: We know the camel carries a burden, but which straw will break its back?

Q: What does restructuring process reveal?

- Disturbances are GLOBAL!

  EIT 195, 12 May 1997

  Prominence Eruptions

- Reconnection plays post-eruption role.
- *Q*: Does reconnection play a pre-eruption role, as well?

Q: How do models address this issue?

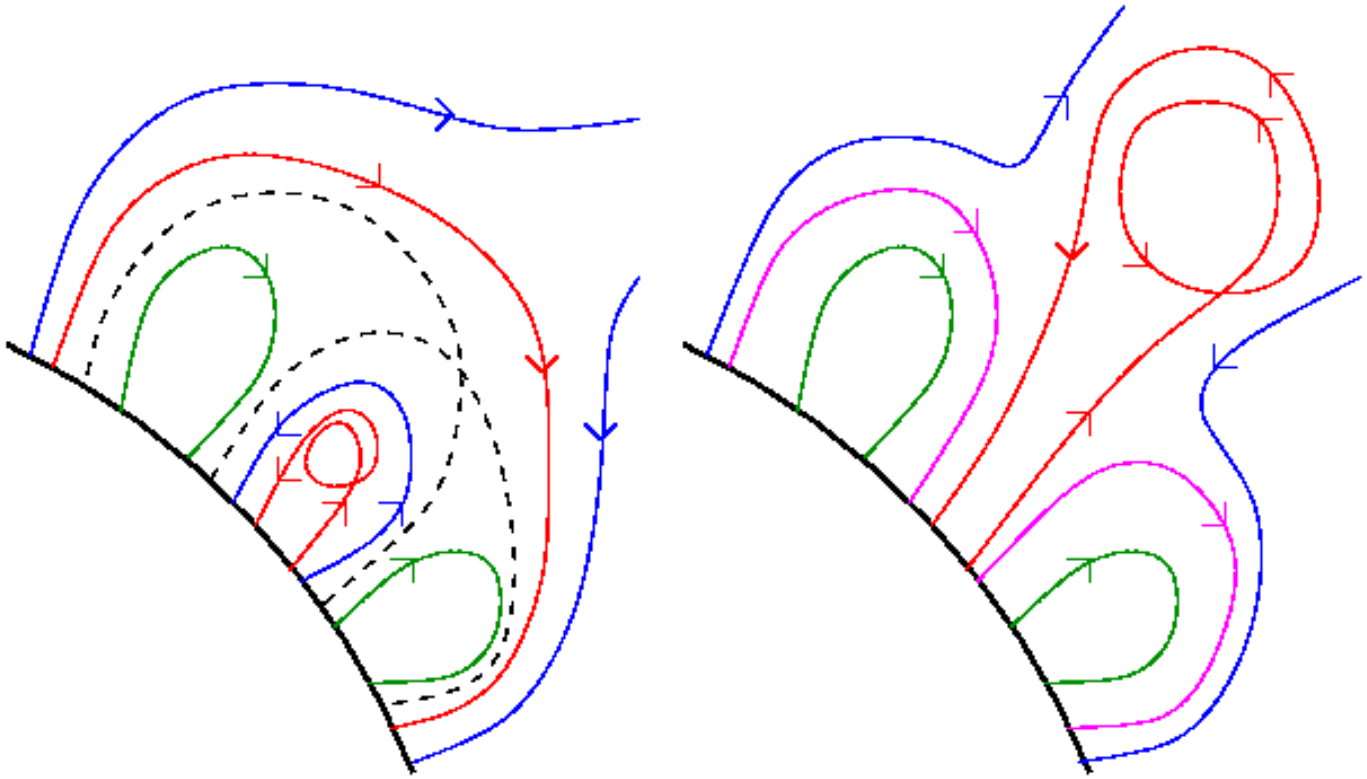
‘Tether Cutting’ ,

‘Breakout’ ,

‘Flux Rope’

Q: What does a CME *accomplish*?

Q: What changes?



NOT the flux distribution, perhaps!

NOT the open flux, perhaps!

Obvious change: TOPOLOGY!

Topology Paradigm

1. Irreducibly global property of coronal field

2. Determines sites of reconnection.

3. Determines "implications" of reconnection:

   - *Q*: Is reconnected flux now in an open field region?

   - *Q*: Is reconnected field far from equilibrium?

Similar events may have different effects in different topologies !

Relationship of Flares & CME's

1. "Flare" = "Reconnection"
   - Accelerated particles
   - EUV/SXR/HXR/radio signatures
   - Sometimes signatures are weak!

2. CME: Caused by reconnection between topologically significant field lines.

Same process – reconnection – sometimes leads to CME's, sometimes not.

Q: What is topology at a given instant?

- Observe it w/ EUV and SXR imagers.

  However, most field does not emit!

- Infer it: PF, LFFF, & NLFFF models.

  1. Separately inverting sequential mag'grams doesn't conserve topological constraints. (*)
  2. Inversions can't reproduce arbitrary topology.

Fundamentally, photospheric data underdetermines coronal topology.

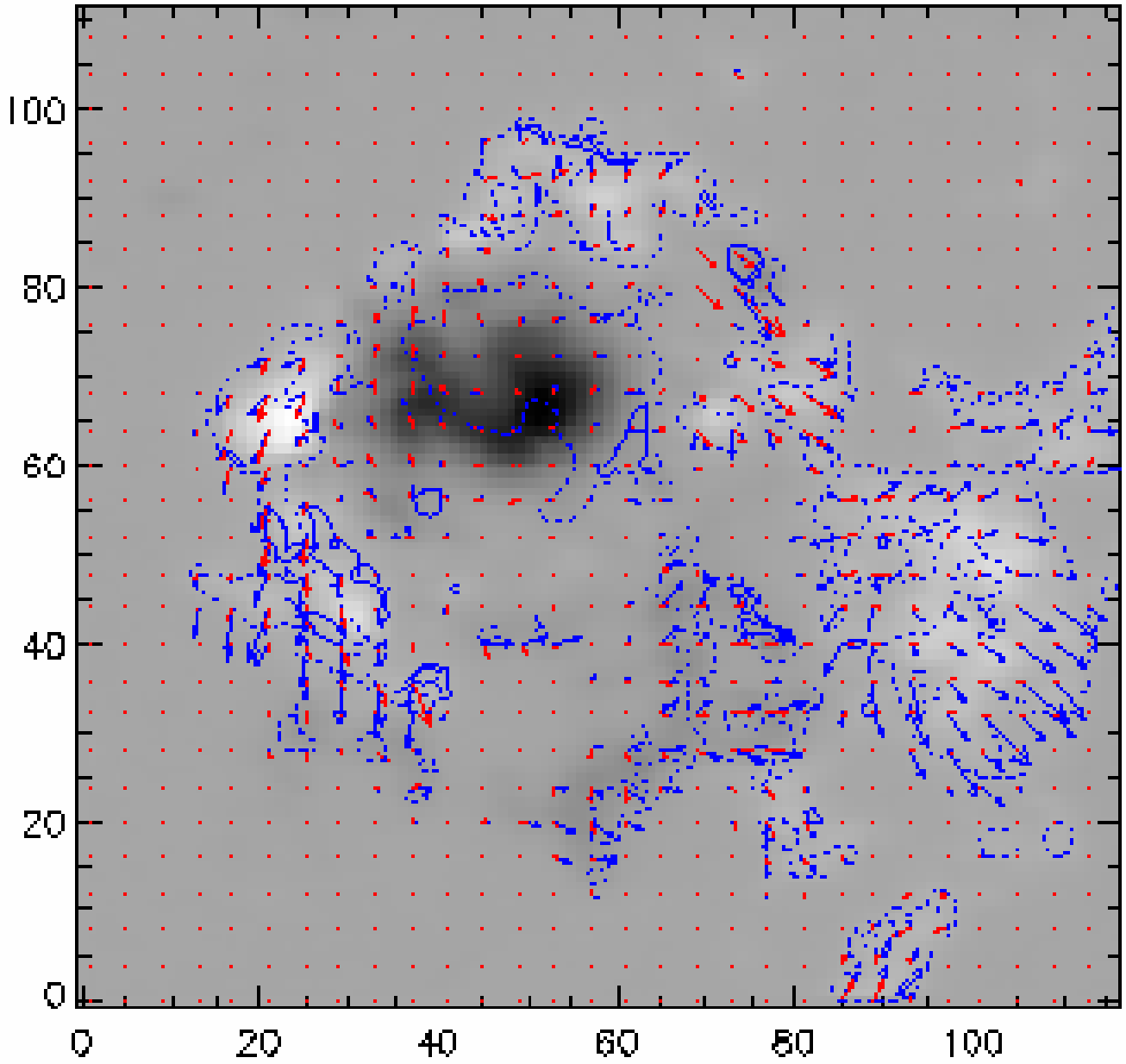
Q: What's MURI's approach?

1. Start with photospheric mag'gram and best guess at field topology.

vector mag'gram, **NLFF**

2. Evolve with (MHD) simulations, consistent w/photospheric evolution, conserving topology along the way

velocities, ***ZEUS* code**


100
80
60
40
20
0
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Q: How's it going?

Still in its infancy!

- **B**(*x*,*y*,*z*) and **v**(*x*,*y*,*z* = 0) are determined independently – can be inconsistent!
- Velocity inversion not unique! Consistent with:

$$\frac{\partial B_z}{\partial t} = \nabla \bullet (v_z \vec{B}_\perp - \vec{v}_\perp B_z)$$

- Stay tuned!

Q: Which photospheric events might be triggers?

1. Cancellation (reconnection? submergence?): indicates evolution of coronal topology.

2. Emergence: important change in bound. cond.

3. Vertical current, if Sun acts as current driver, evolves on wrong timescale.

4. Twisting/shearing inject **E** & **H**, but timescales are wrong, again.

Q: Where to go from here?

- More of same: multi-wavelength studies.
- Code coupling: low corona, high corona, solar wind – underway!
- Improved field reconstruction:
  1. non-zero flux through boxes' sides
  2. larger boxes!
- Data assimilation: update code's state w/data from arbitrary points in domain.

  (not MURI's approach – yet!)
- East Limb Mission!

HOLY GRAIL: Whole Sun magnetic evolution code!

Conclusions, I.

1. Global-scale topological restructuring of coronal field leads to CME's.

2. Reconnection plays a role!

3. Understanding CME initiation requires understanding coronal topology.

4. Coupling (line tying) of coronal field to p'sphere permits some inferences of coronal topology from p'spheric data.

Conclusions, II.

5. CME's, however, are synonymous with violation of this coupling!

6. Sequences of inversions of coronal fields from photospheric data cannot capture continuous topological evolution leading to an eruption.

7. Instead, dynamic magnetic evolution codes (MHD, or ???) are needed to follow topological development & disruption of coronal fields.

Q: What aspects of the photospheric and coronal evolution are necessary and/or sufficient for an eruption[?]

A: Don't know about 'sufficient,' but regarding 'necessary:'
Reconnection in corona.

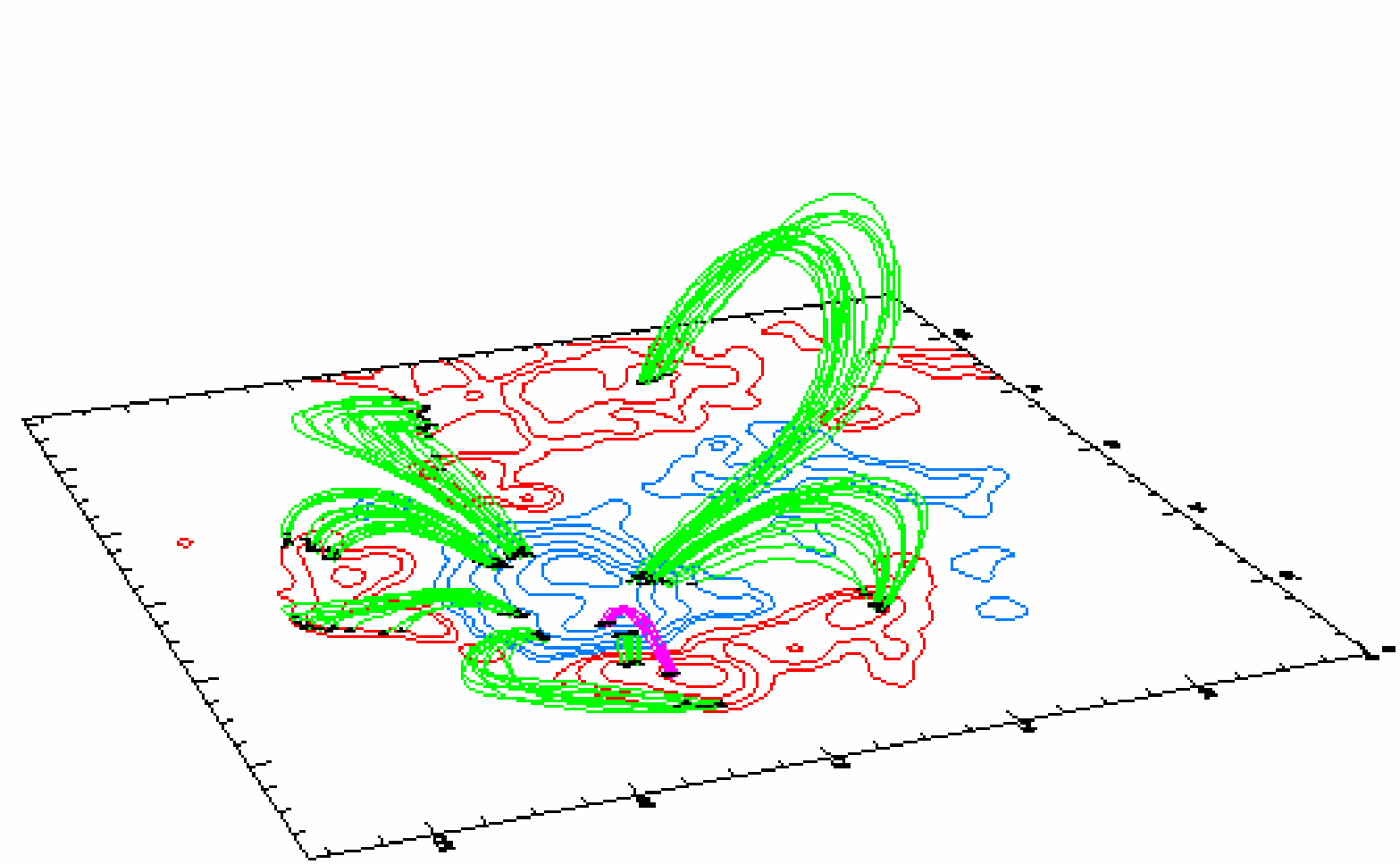
Q: Is magnetic complexity crucial to CME production?

A: Complexity (topological) in coronal field.
By extension, photospheric field?

Q: What photospheric motions, or emergence/submergence of flux are required for a CME to be initiated?

A: 1. In 'buildup' phase, some energy (and helicity?) input.
2. In initiation, perturbation that leads to reconnection.

NLFFF of AR 8210, from S.Regnier



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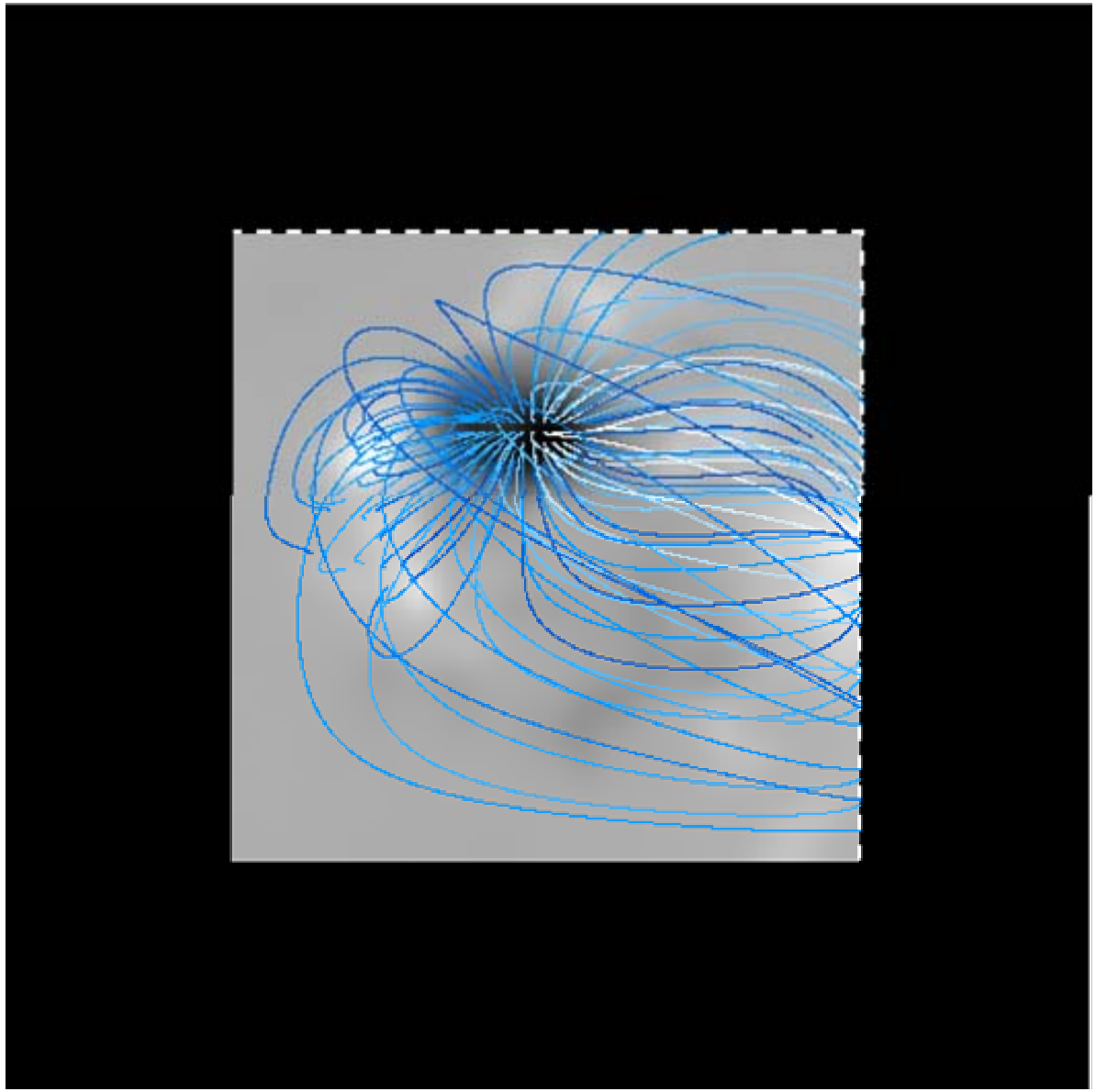
Data-driven *ZEUS* Run



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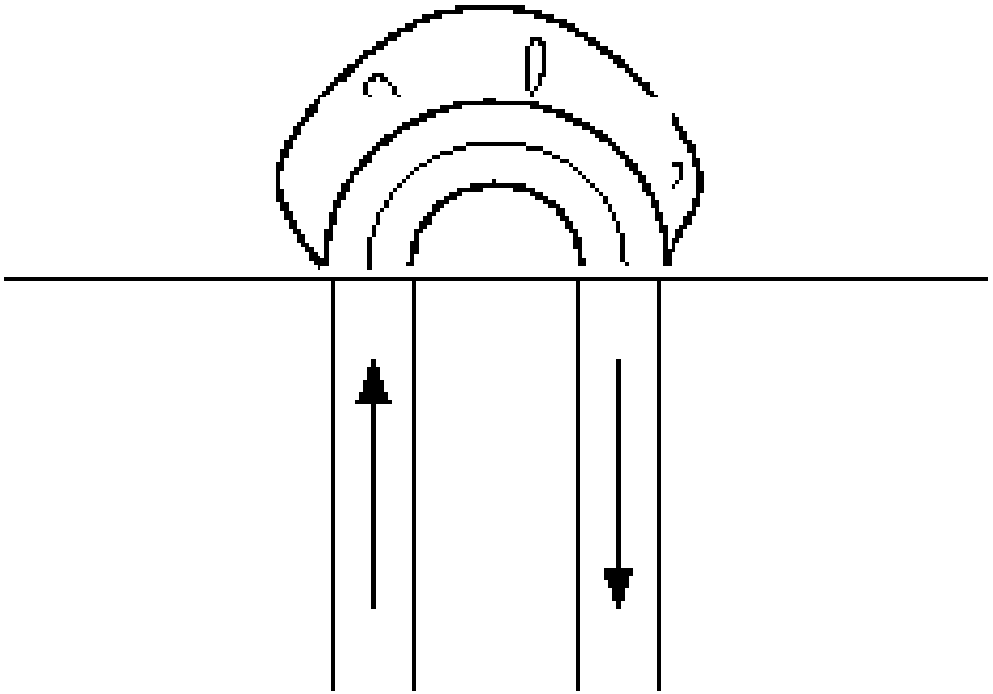
My simplistic mental picture:



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Q: Does prominence mass trigger eruption?

NO! Magnetic field moves prominence, and mass comes along for the ride!

TRACE prominence eruption movie.

Note how prominence rises, *then* mass drains, and field leaves TRACE FOV.

Notes

-- CENTRAL IDEA: reconnection allows previously restrained
sheared or twisted fields to expand upward toward new
equilibrium at higher altitude.

(Not a new idea! Tether Cutting, Breakout)

-- SUBTEXT: Different mechanisms trigger in different circumstances.
(worst possible scenario, right?)

III. -- Continued -- EXAMPLES:

- Photospheric data alone underdetermines situation.
    - Sometimes cancellation matters, sometimes not...
    - Sometimes shear matters, sometimes not...

- Coronal: Some reconnection is important, some not...
(Assuming impulsive SXR and EUV emission signatures of reconn.)