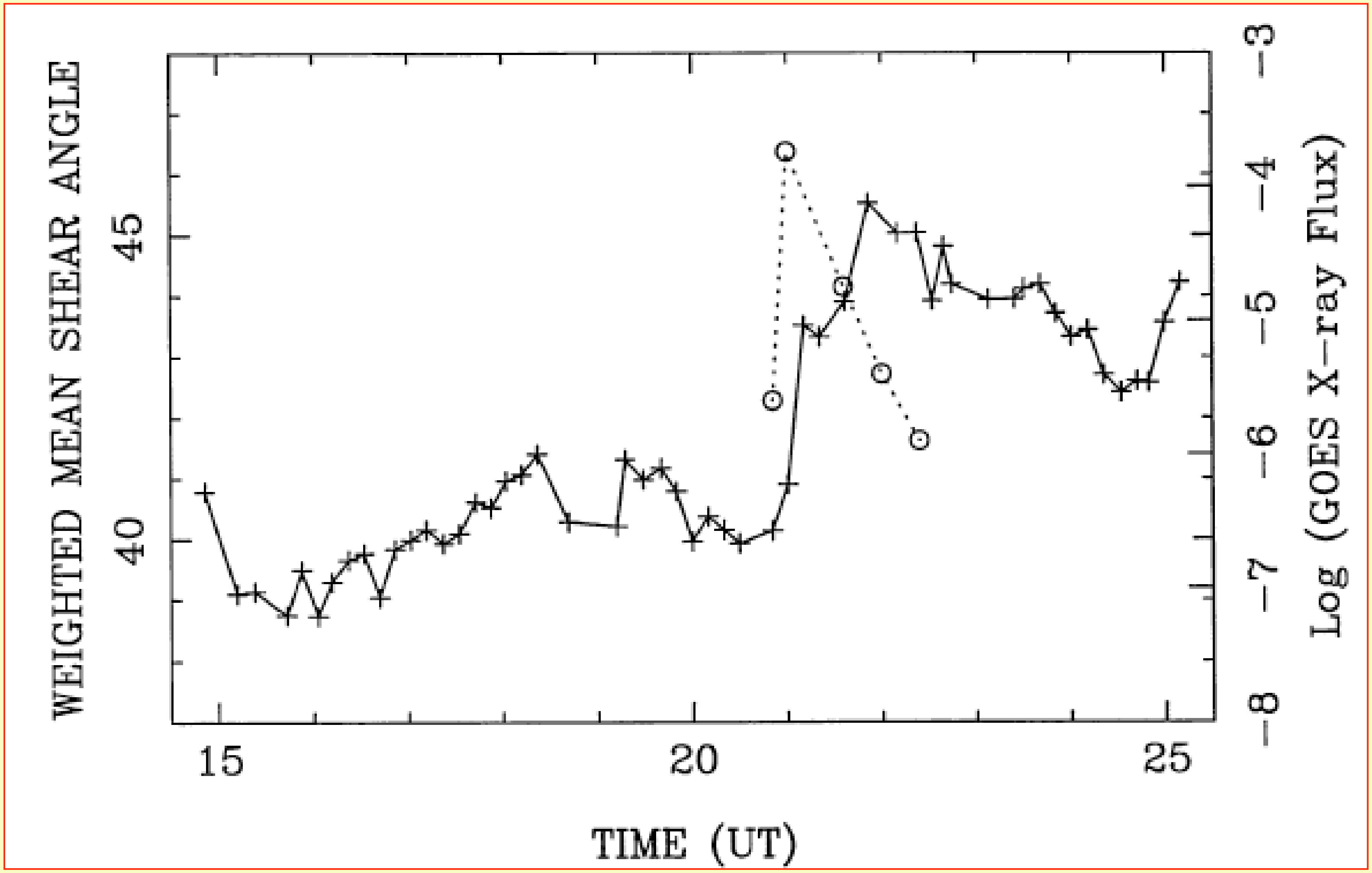
Flare-related current systems

H. S. Hudson & B. T. Welsch
Space Sciences Lab, UC Berkeley

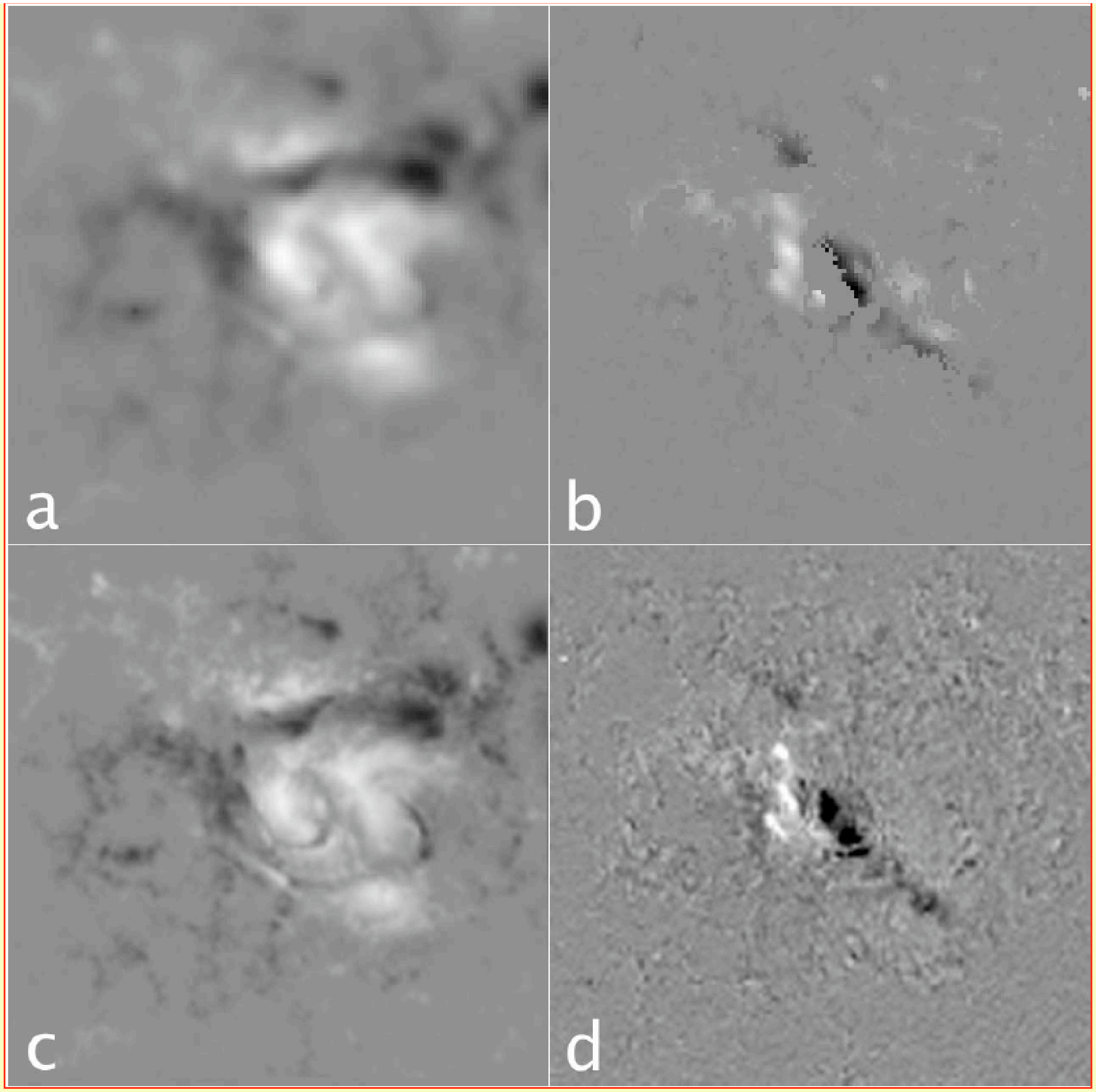
A breakthrough: reliable observations of before/after fields (Sudol & Harvey 2005) confirm that permanent changes of the photospheric magnetic field can be detected systematically for essentially all X-class solar flares (cf H.Wang, Kosovichev & Zharkova, Cameron & Sammis).

How do we exploit this phenomenon with the new and better data from *Hinode*, SDO, ATST etc?

First clear evidence for flare-associated field changes?



H. Wang, 1993



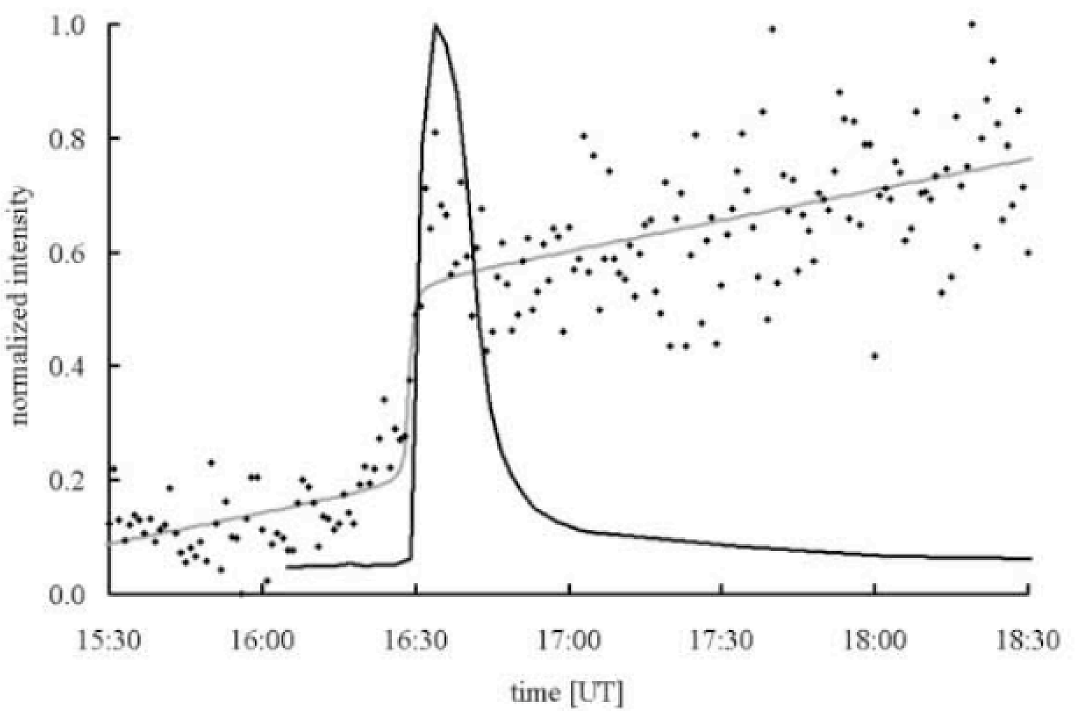
GONG

SOHO/MDI

B

dB

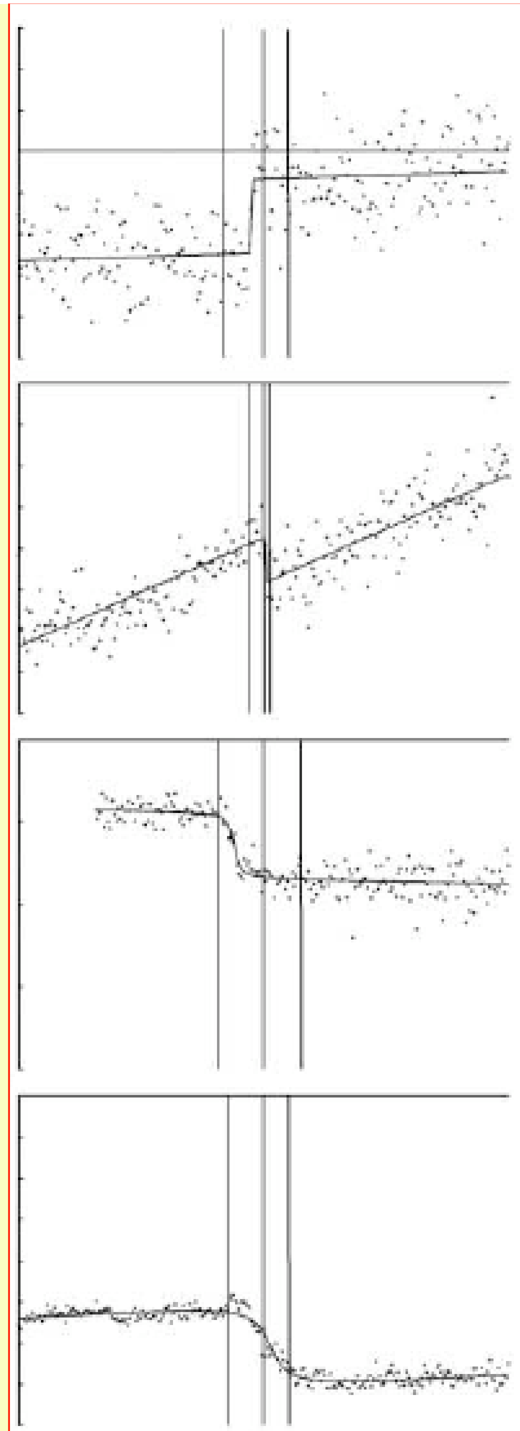
Sudol & Harvey (2005), flare of 2003 Oct. 29,
line-of-sight field differences



Flare of 2001 Aug. 25
GONG + TRACE 1600A

The changes are stepwise, of order 10% of the line-of-sight field, and primarily occur at the impulsive phase of the flare

Other examples with GOES times



Where does the flare energy come from? McClymont & Fisher 1989

Mechanical sources of flare energy: how to drive the coronal current system?

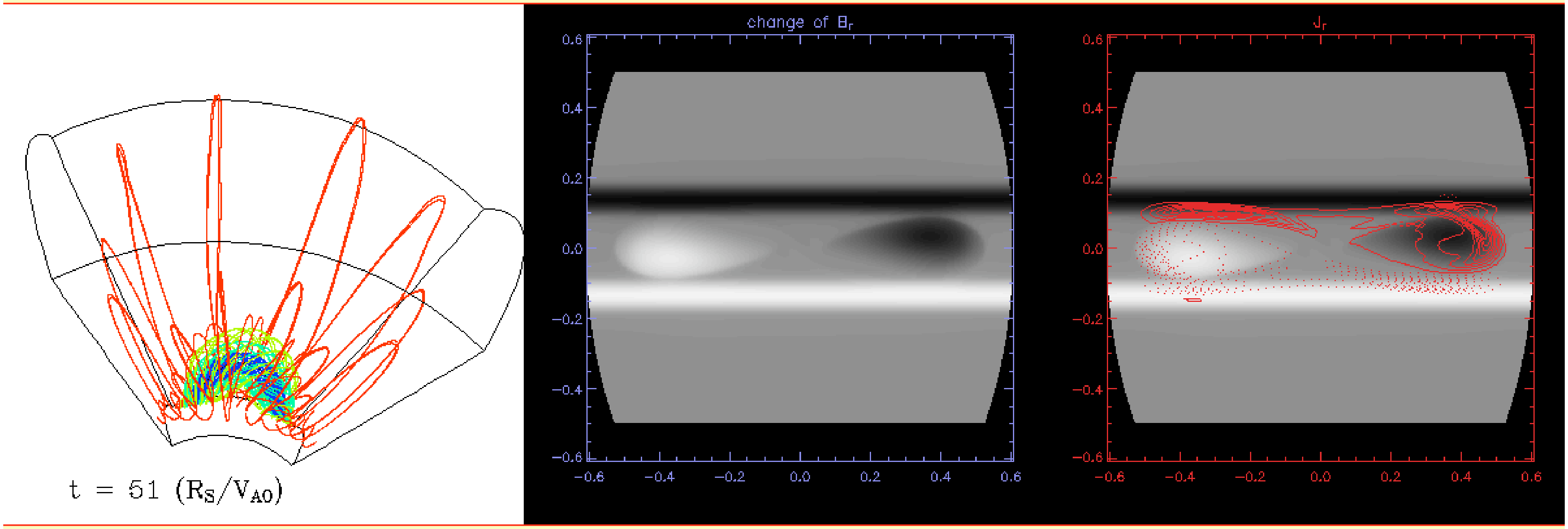
- Surface dynamo action on photospheric field
- Energy supply from deep-seated field
- Energy supply via flux emergence
- Unknown physics in upper convection zone

What theoretical tools are available?

- Flux transport in convection zone via thin fluxtube approximation
- Mixing-length theory
- Numerical simulation

Large-scale numerical simulations?

- Problem areas
  - Reconnection vs. ideal MHD instability
  - Problem of modeling the chromosphere
  - Lack of correct treatment of reconnection
- Current status
  - Steady progress
  - Nothing yet that has predictive capability



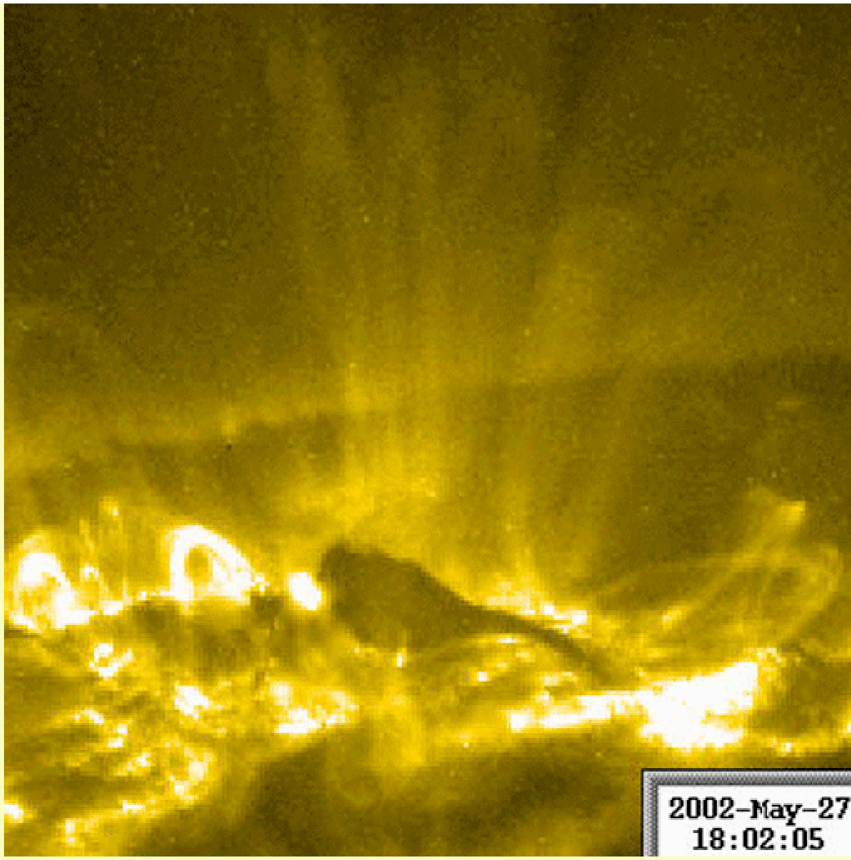
Courtesy Yuhong Fan, Dec. 2006

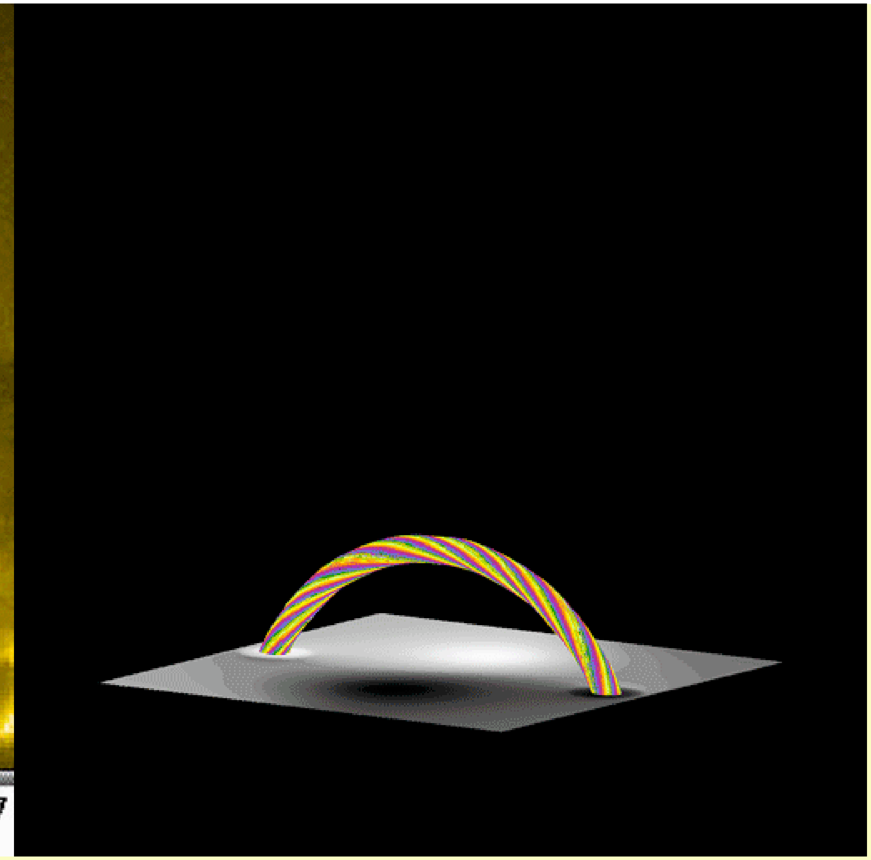
Notes:

(1) This simulation has strong magnetic reconnection.
A kink-driven eruption would have a different current pattern.

(2) The simulation has no realistic chromosphere, so the current patterns are merely illustrative at this time.

(3) The simulation does not connect one equilibrium state with another.





Courtesy Török & Kliem

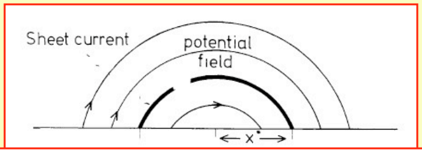
Notes:

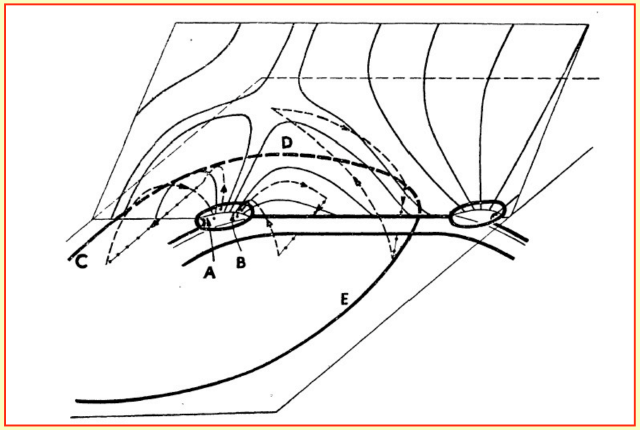
(1) This simulation shows a kink instability.

(2) The simulation has no realistic chromosphere, so the current patterns are merely illustrative at this time.

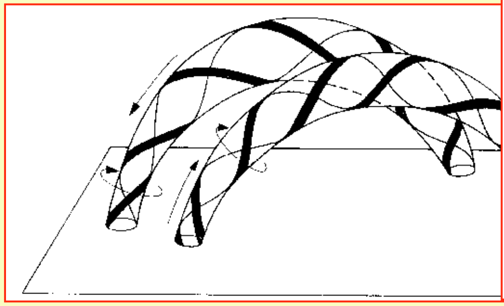
(3) The simulation does not connect one equilibrium state with another.

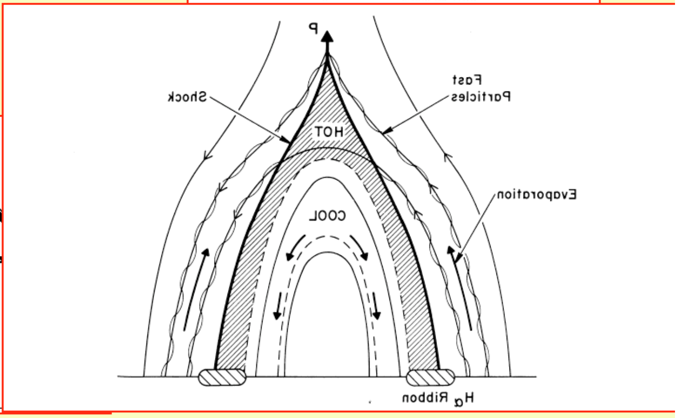
A Cartoon Potpourri



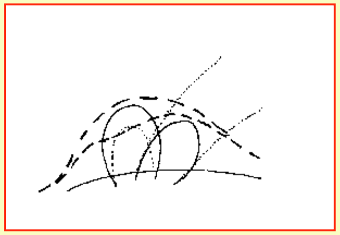


Giovanelli (1948)

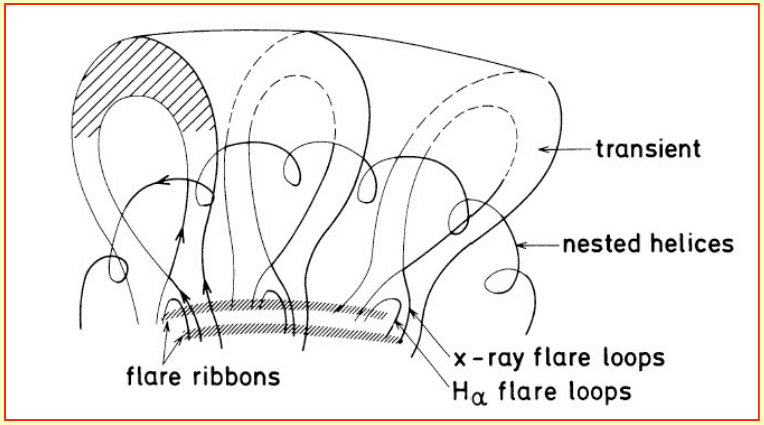




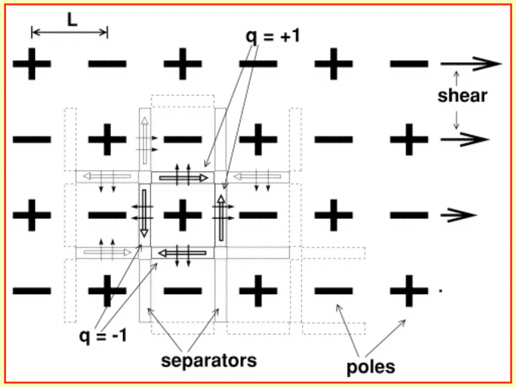
Gold & Hoyle (1961)



Hudson (2000)



Anzer & Pneuman (1982)



Longcope & Noonan (2000)

http://solarmuri.ssl.berkeley.edu/~hhudson/cartoons/

Prediction of *Hinode* **B** variation*

($\mathbf{B} \Rightarrow \mathbf{B}+\mathbf{B_1}$ during flare)

- I_z = constant (Melrose)
- $\mathrm{Curl}(\mathbf{B})_z = \mathrm{Curl}(\mathbf{B} + \mathbf{B}_1)_z$ = constant
- Difference $\mathbf{B}_1$ is a potential-like field
- $dB_x/dy - dB_y/dx = 0$ at photosphere

*HSH only, not necessarily agreed upon by BTW

Conclusions

- The pattern of field changes may make it possible to identify the physics of flare causation and energy supply
- There may be gaps in our knowledge of convection-zone physics
- We should encourage predictions of the imminent *Hinode* observations of vector field displacements

End

Thanks for discussion and input:
Yuhong Fan, Jim Chen, George Fisher, Bernhard Kliem, Dan Spicer