Flare energy supply and magnetic field variations

Trying to predict vector field changes during flares

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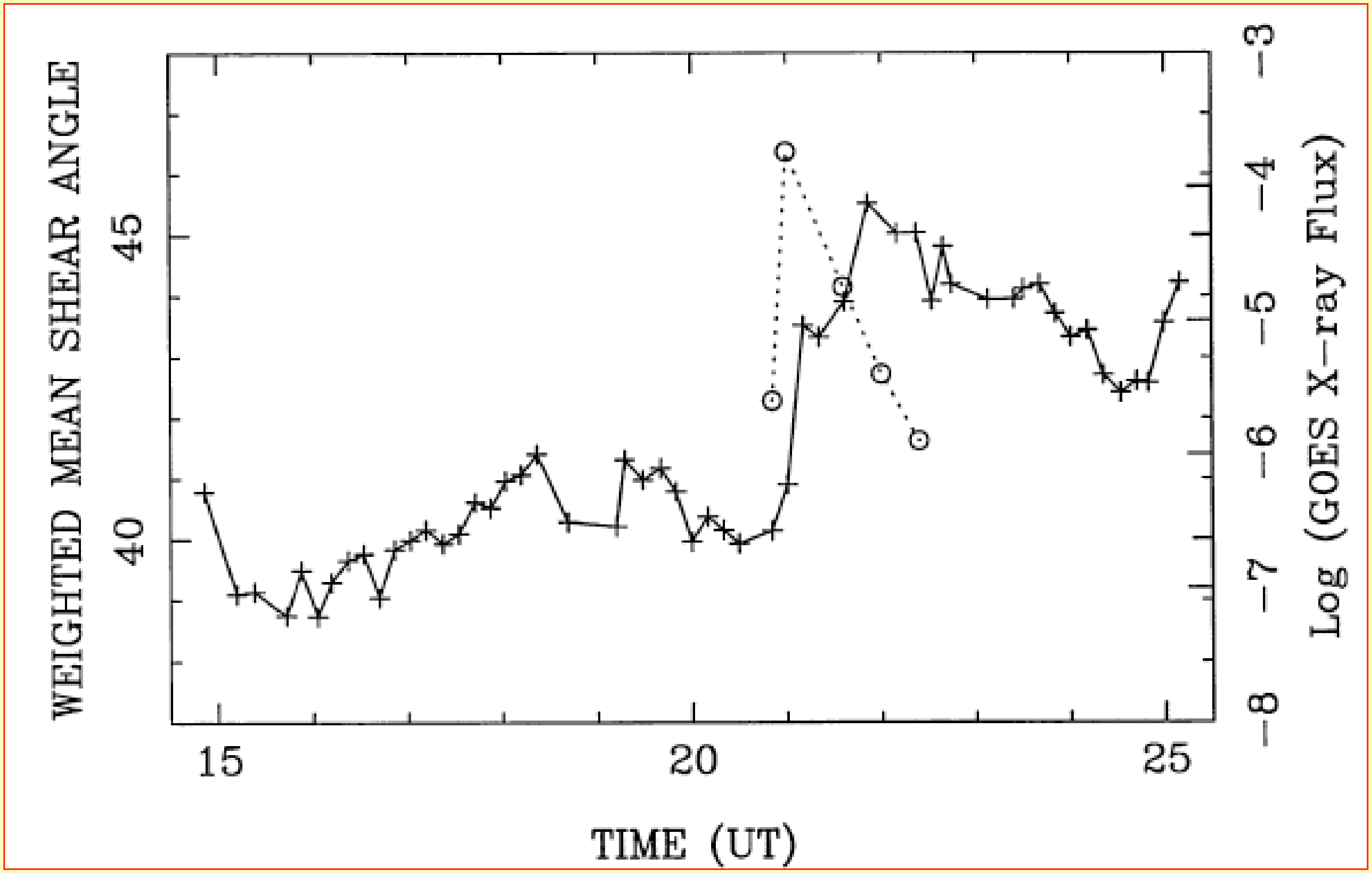
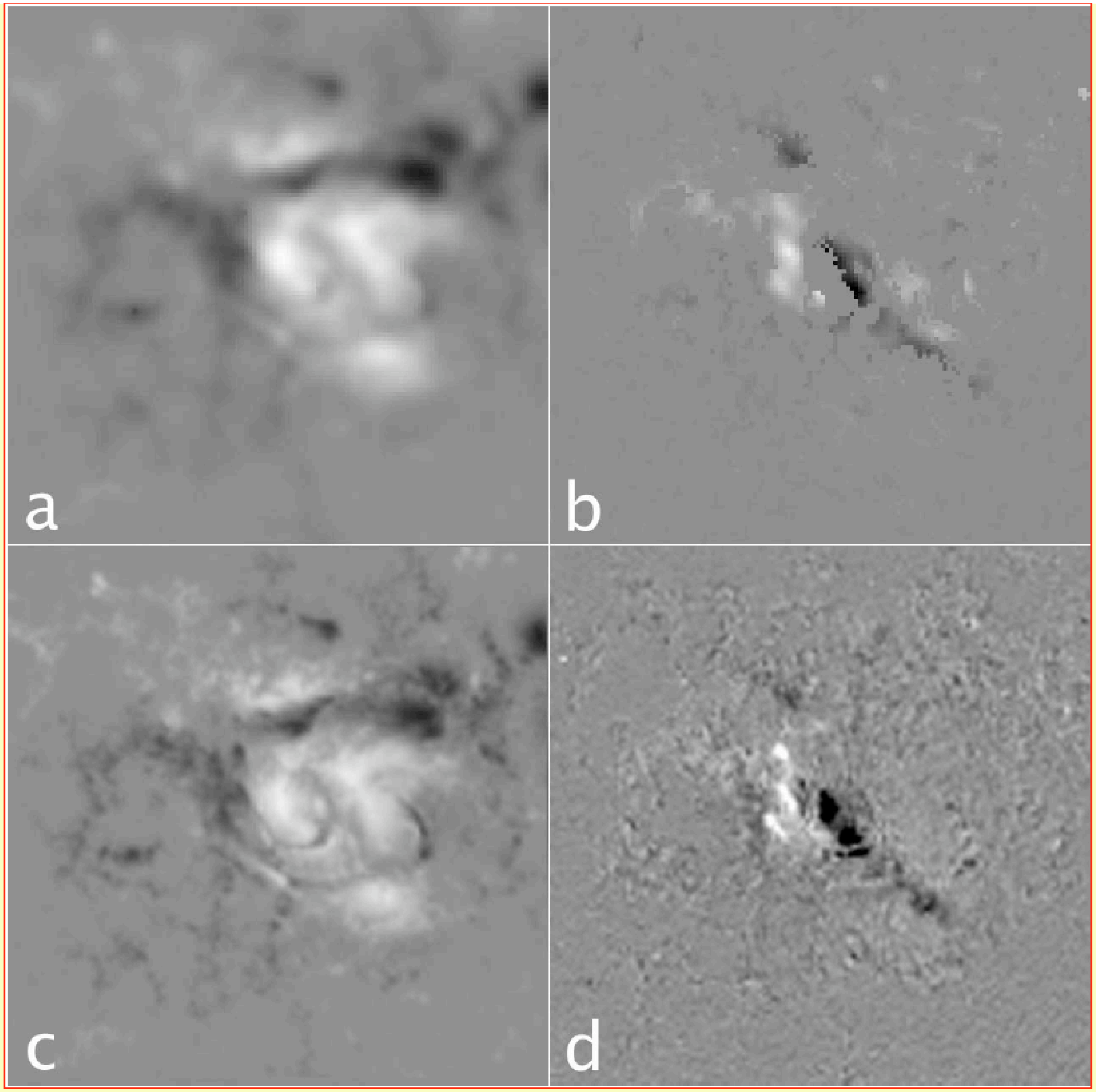
A breakthrough: reliable observations of before/after fields (Sudol & Harvey 2005) confirm that permanent changes of the photospheric magnetic field can be detected systematically for essentially all X-class solar flares (cf H.Wang, Kosovichev & Zharkova, Cameron & Sammis).

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

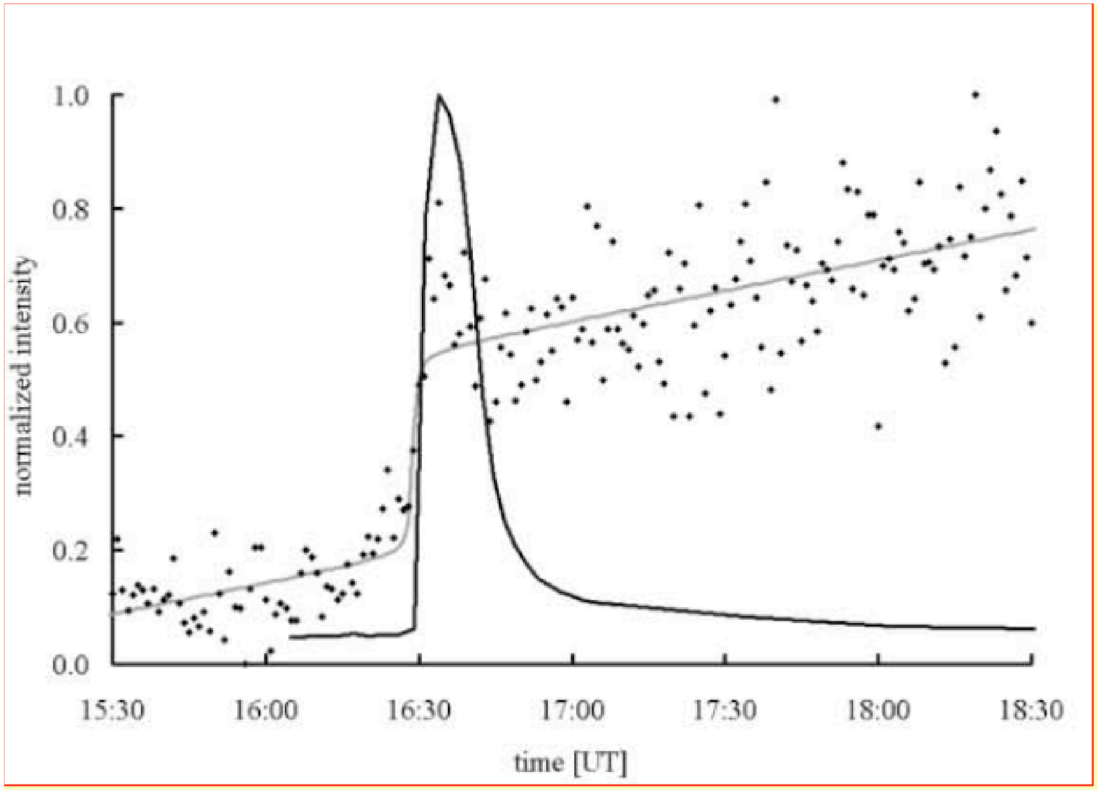
First clear evidence for flare-associated field changes?



H. Wang, 1993



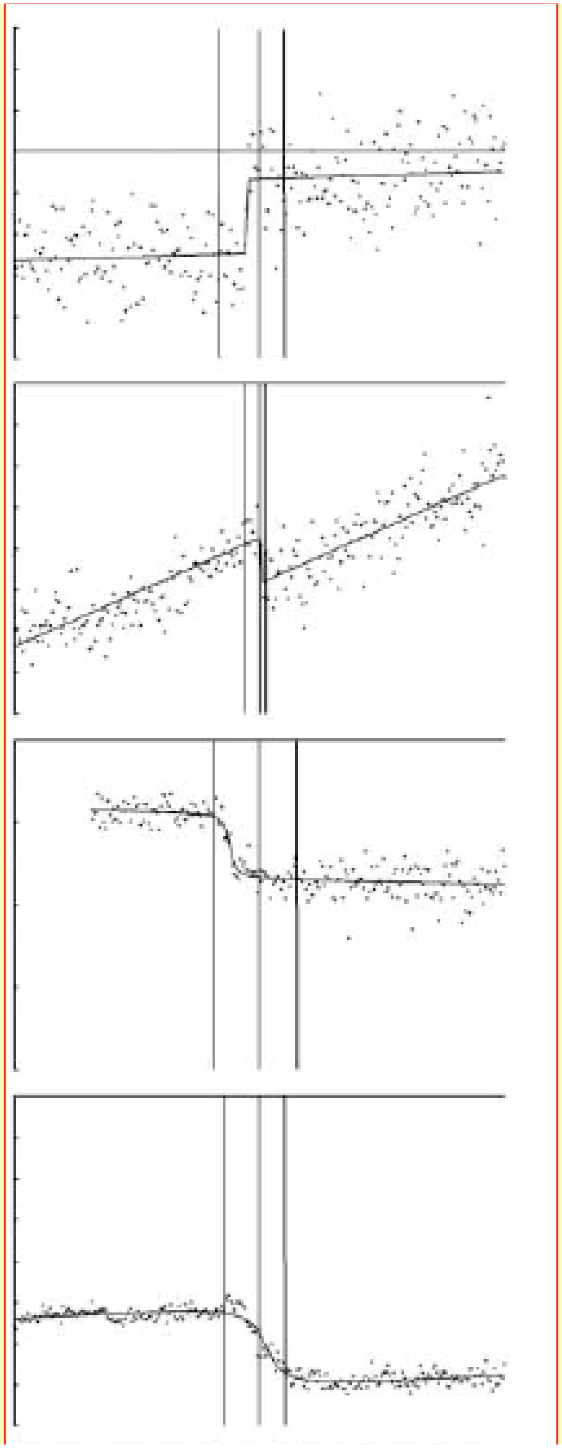
Sudol & Harvey (2005), flare of 2003 Oct. 29,
line-of-sight field differences



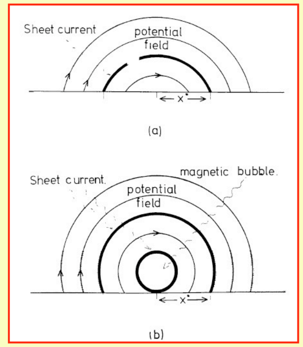
Flare of 2001 Aug. 25
GONG + TRACE 1600A

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

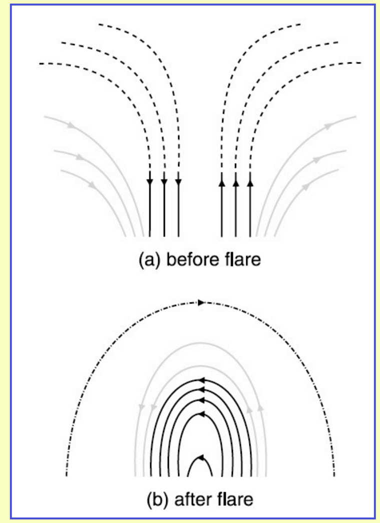
Other examples with GOES times



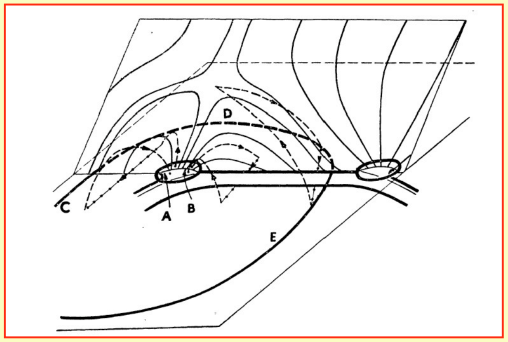
A Cartoon Sampler



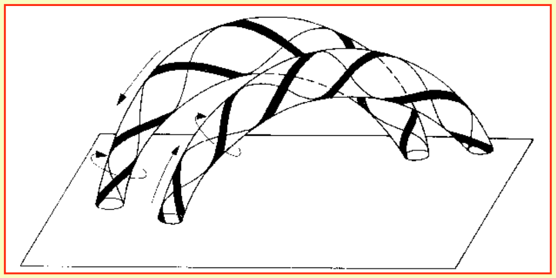
Priest & Milne (1980)



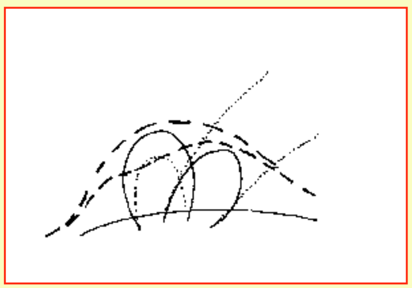
Liu et al. (2005)



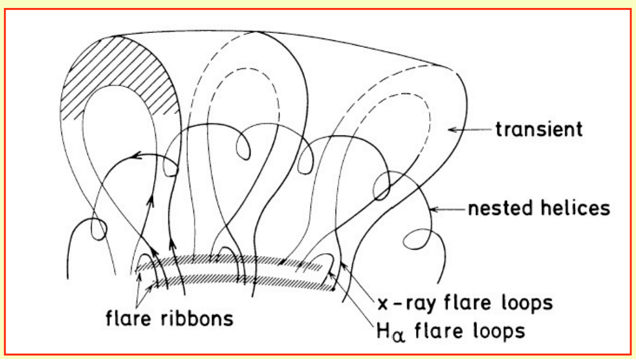
Giovanelli (1948)



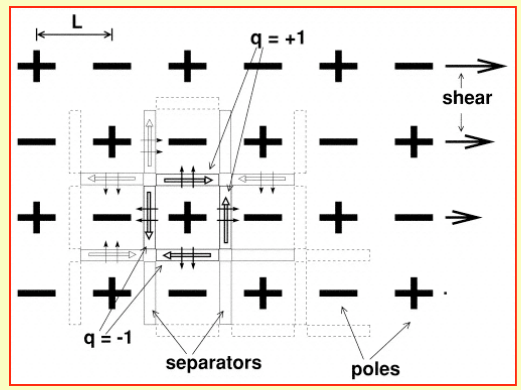
Gold & Hoyle (1961)



Hudson (2000)



Anzer & Pneuman (1982)



Longcope & Noonan (2000)

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

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

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

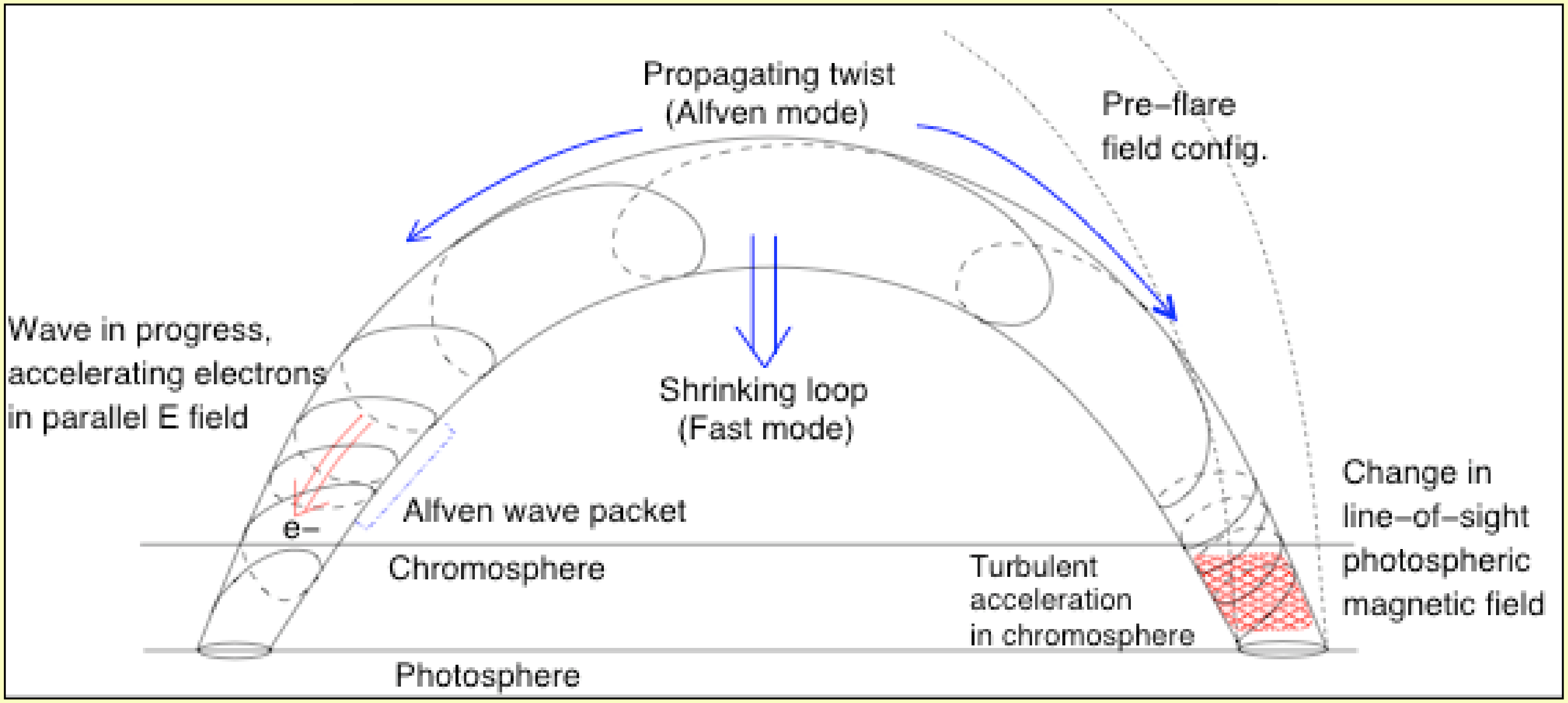
- Surface dynamo action on photospheric field
- Energy supply from deep-seated field
- Energy supply via flux emergence
- Unknown physics in upper convection zone

What theoretical tools are available?

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

The coronal action of a flare

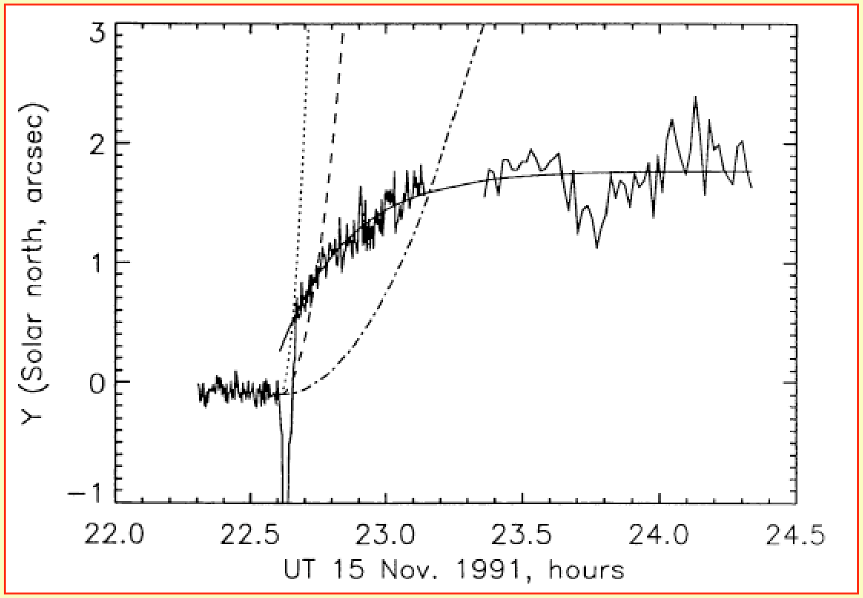
- Large-scale restructuring
- Large-scale Alfven and fast-mode waves
- The "jerk" as an alternative source of seismic waves



Fletcher & Hudson 2007

The McClymont jerk

- *Yohkoh* and Mees observations of rapid sunspot motion during the flare of 15 Nov. 1991
- Estimate of jerk penetration depth of 1.2 Mm in 4 min
- Energy coupling estimated at 3×10^{29} to 2×10^{30} ergs



Anwar et al., Solar Phys. 147, 287 (1993)

Large-scale numerical simulations

- Problem areas
  - Usually no chromosphere
  - Incorrect treatment of reconnection
  - Incorrect lower boundary condition
  - Lack of attention to energetics
- Current status
  - Steady progress
  - Nothing yet that has predictive capability

Predictions of *Hinode* **B** variation*

(**B** => **B**+$\mathbf{B_1}$ during flare)

- J_z = constant (Melrose)
- Curl($\mathbf{B}$)$_z$ = Curl($\mathbf{B} + \mathbf{B}_1$)$_z$ = constant
- Difference $\mathbf{B}_1$ is a potential-like field
- Ampere's law integral is an easy test

- Conjugate McClymont jerks

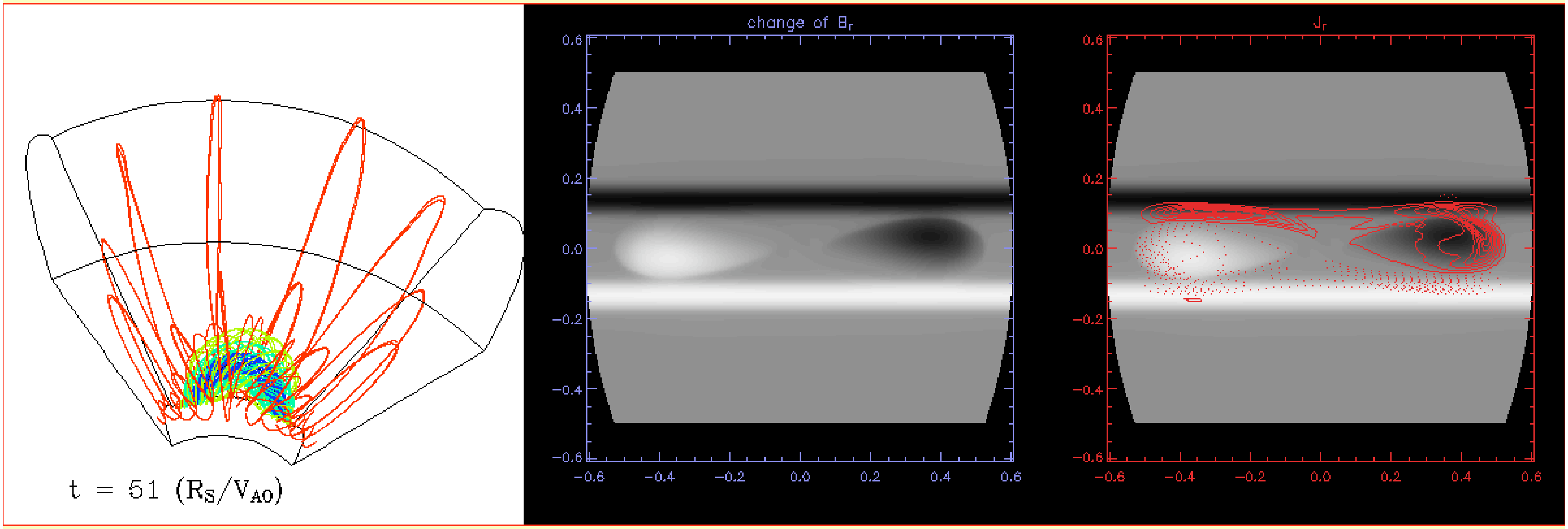
*HSH only, not necessarily agreed upon by BTW

Conclusions

- The pattern of field changes may make it possible to identify the physics of flare causation and energy supply
- The "McClymont Jerk" could play a role in launching flare seismic waves
- We should encourage research related to the imminent *Hinode* observations of vector field displacements

End

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



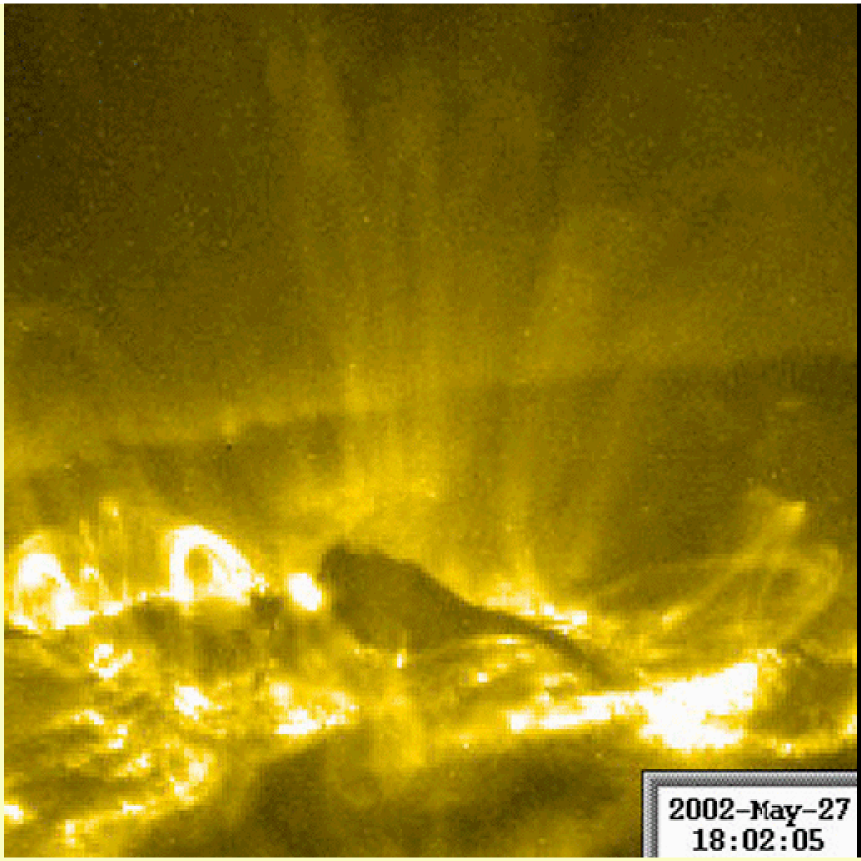
Courtesy Yuhong Fan, Dec. 2006

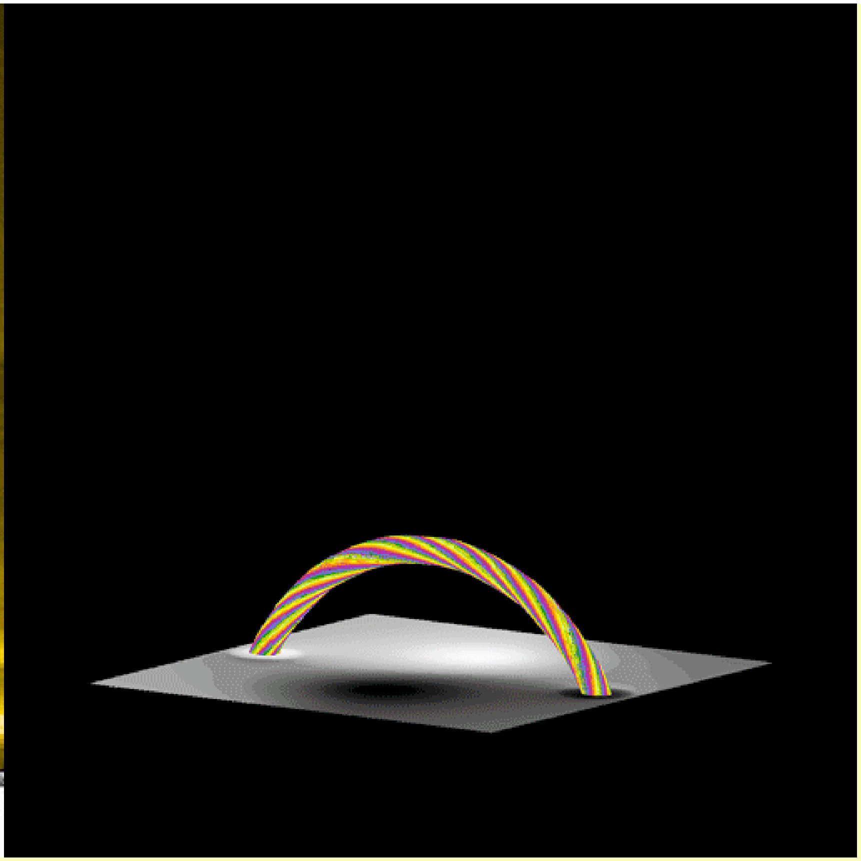
Notes:

(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.