

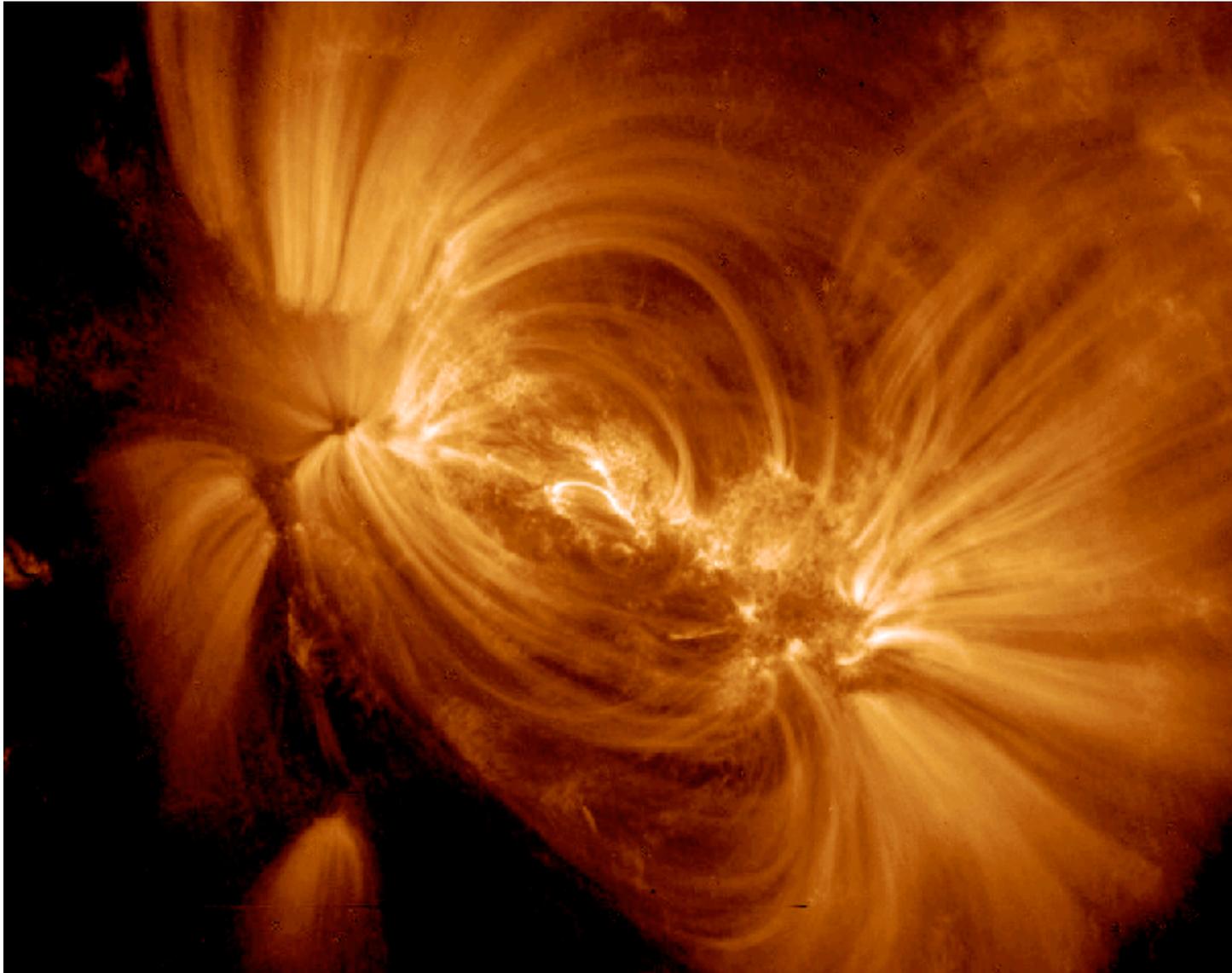
CME/Flare energetics and RHESSEI observations

H.S. Hudson

SSL/UCB

Outline

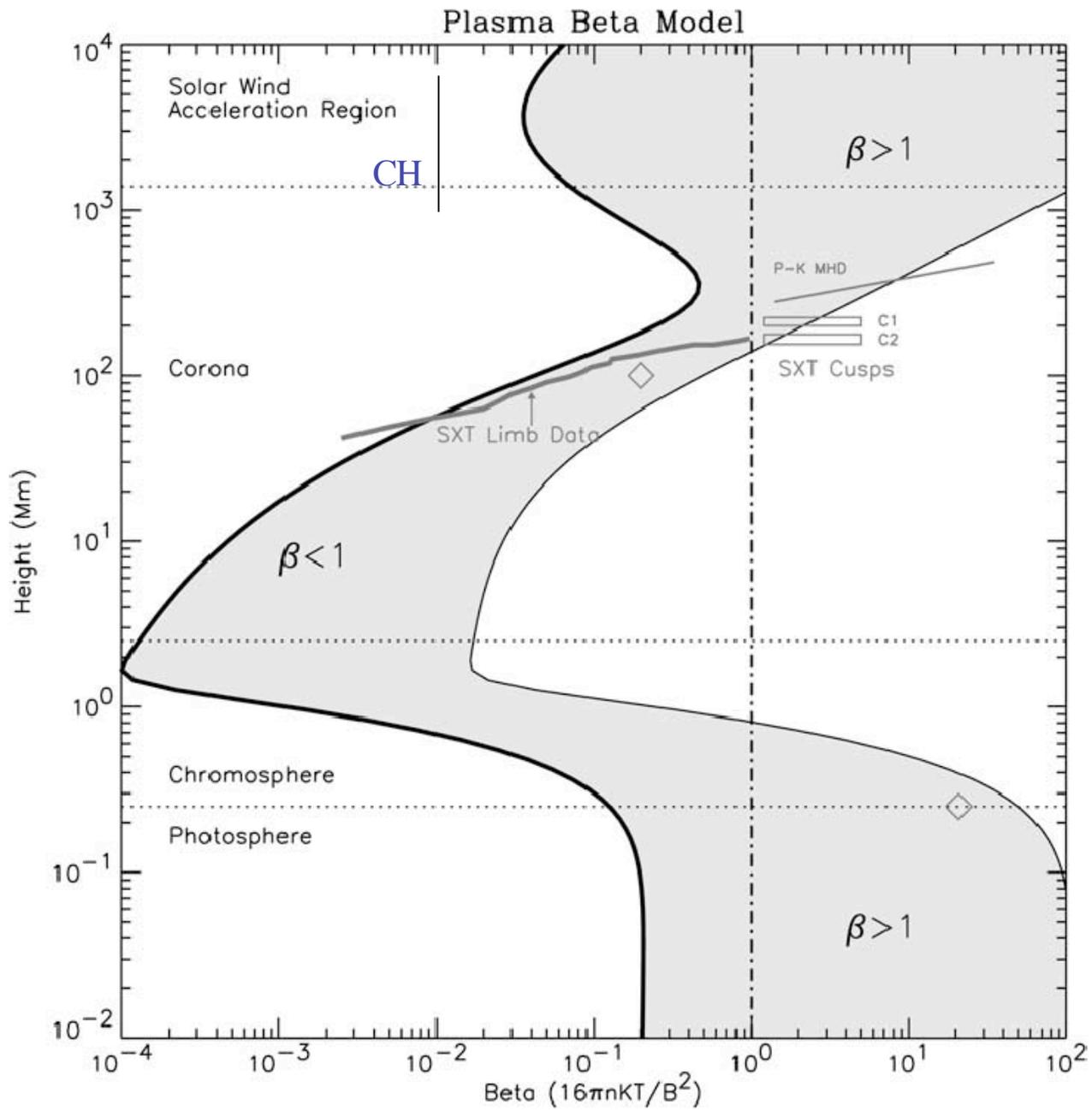
- Description of a solar active region
- Waves, oscillations, and restructuring
- RHESSI observations of eruptive flares
- CME/Flare Energetics
- Flares and CMEs: reconciling two viewpoints



TRACE 171A view of an active region,
courtesy LMSAL “cool stars” Web material

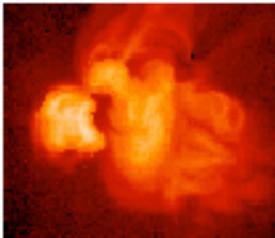
Mechanical properties of an active region in the corona

- Flares and CMEs are magnetically driven, according to consensus, from energy stored in the corona
- In such conditions, ie low plasma beta, the mechanical stresses can be represented as a pressure and a tension

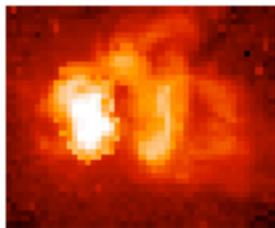


Observation

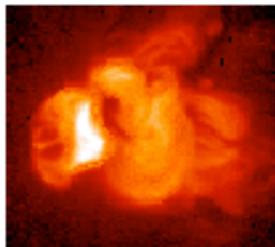
14:01 UT



17:57 UT

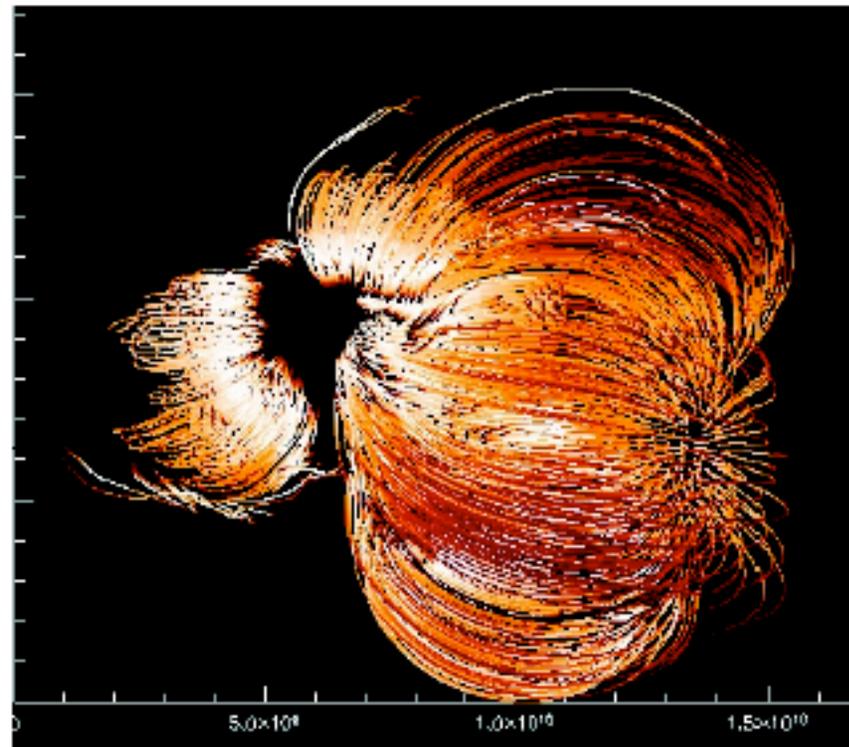


21:12 UT



Yohkoh SXT
AR 8210 May 1, 1998

Reconstruction from m-gram data at 19:40



Emissivity
along
fieldlines
convolved
with SXT
response
function.

150 Mm

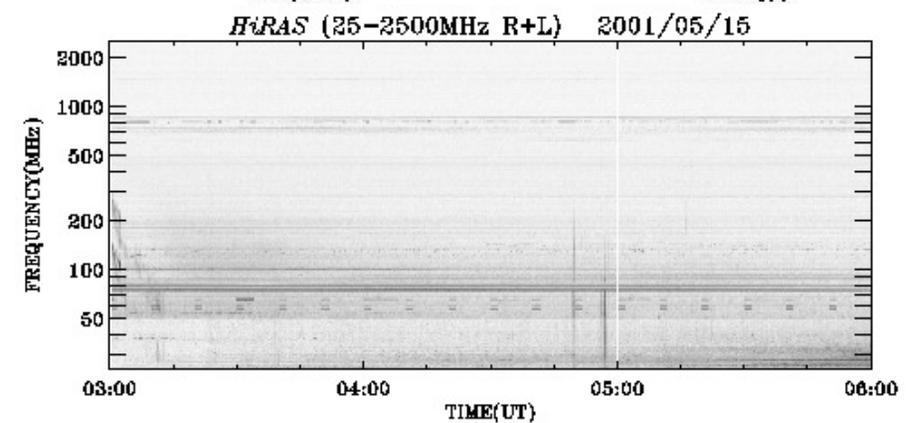
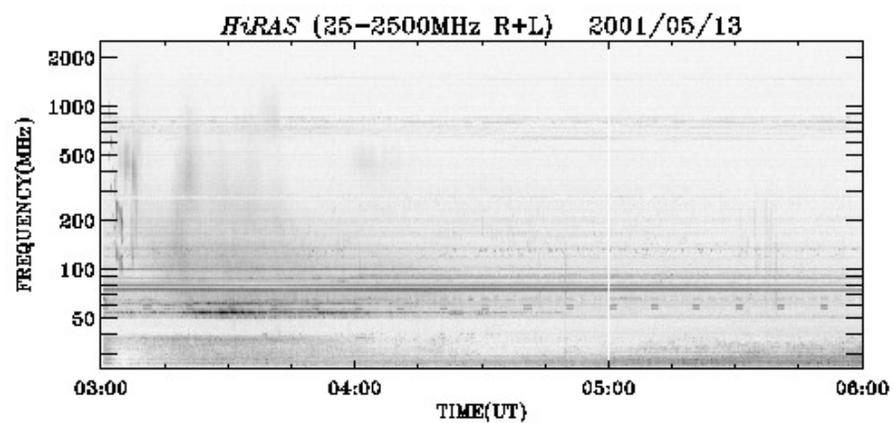
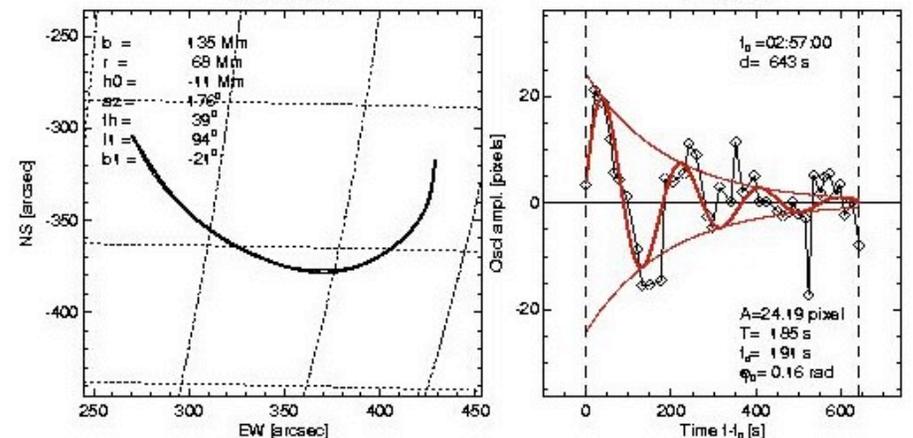
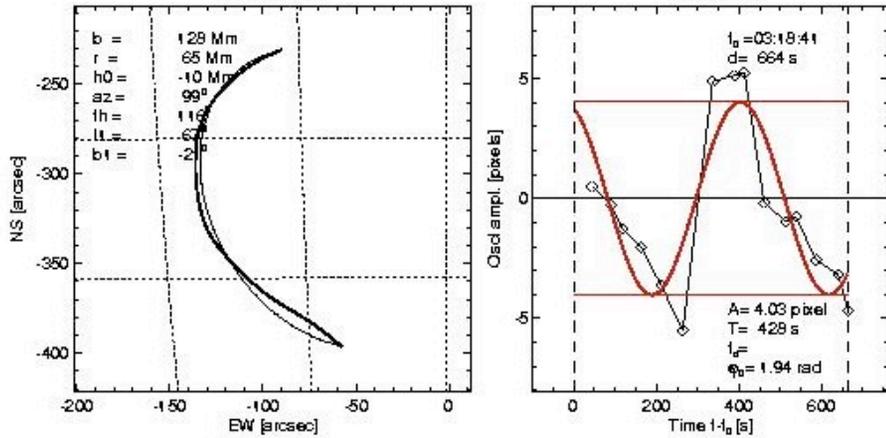
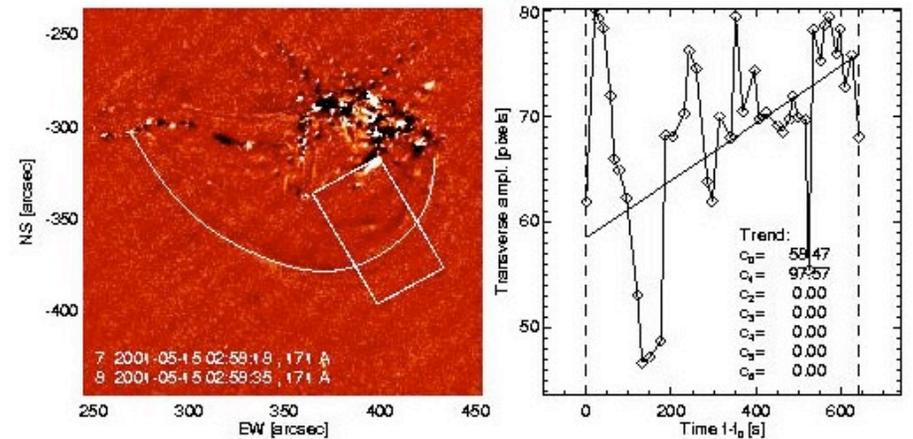
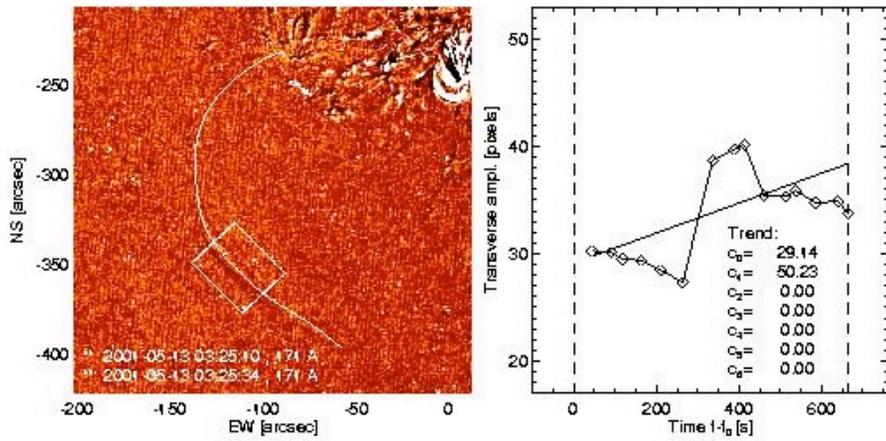
Lundquist et al., SPD 2004

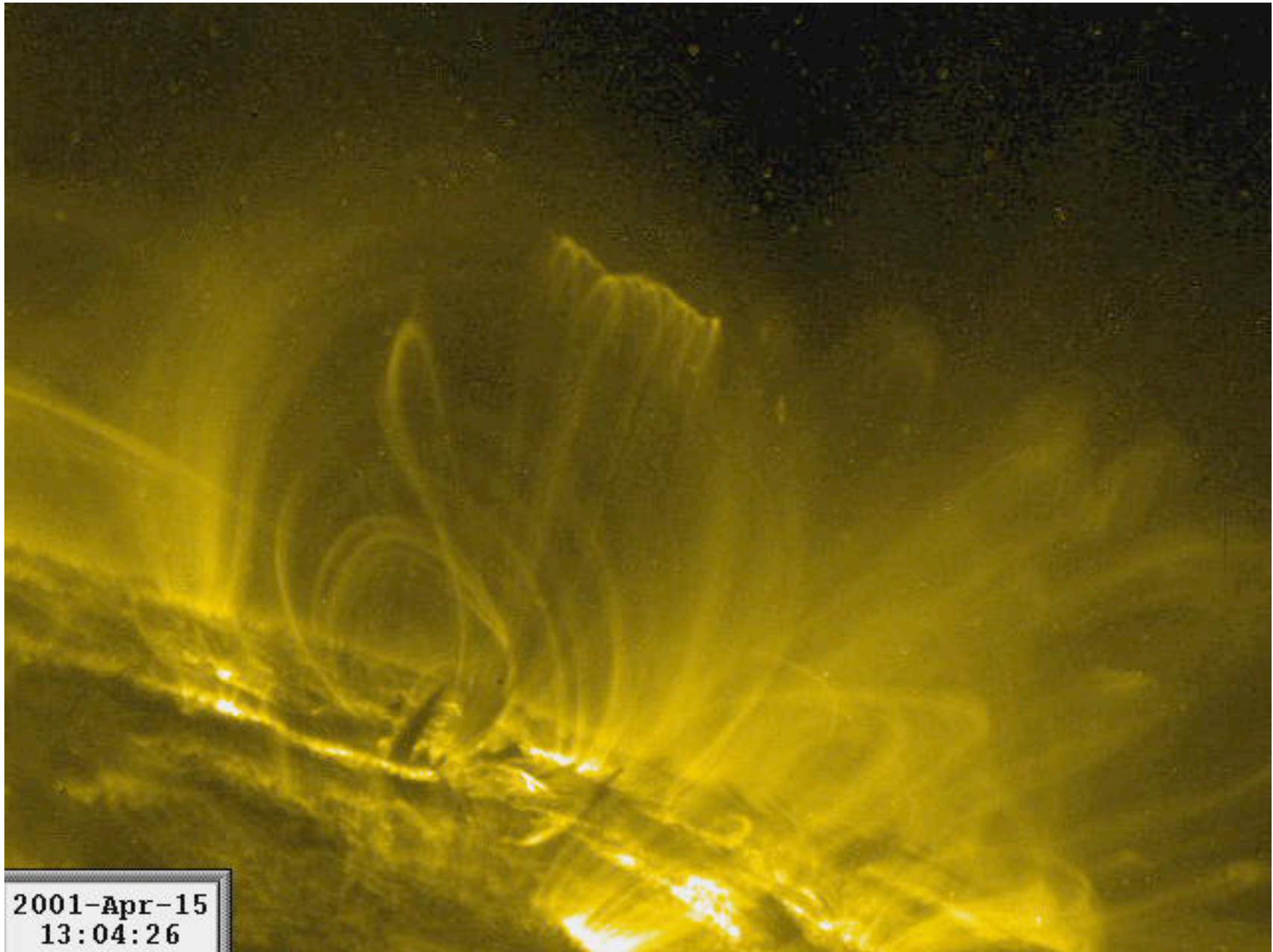
The normal state of the active-region corona is an equilibrium

- An equilibrium system will oscillate around its rest configuration if perturbed slightly
- We observe coronal oscillations via spectroscopy, photometry, and in movies
- The oscillations have small amplitudes and can be studied via MHD theory

Kink-mode oscillations

- Flare waves associated with metric type II bursts often (12/30 cases) appear with TRACE loop oscillations
- These oscillations allow us to study the equilibrium state of the non-erupting part of the corona
- See the Hudson-Warmuth poster on this subject

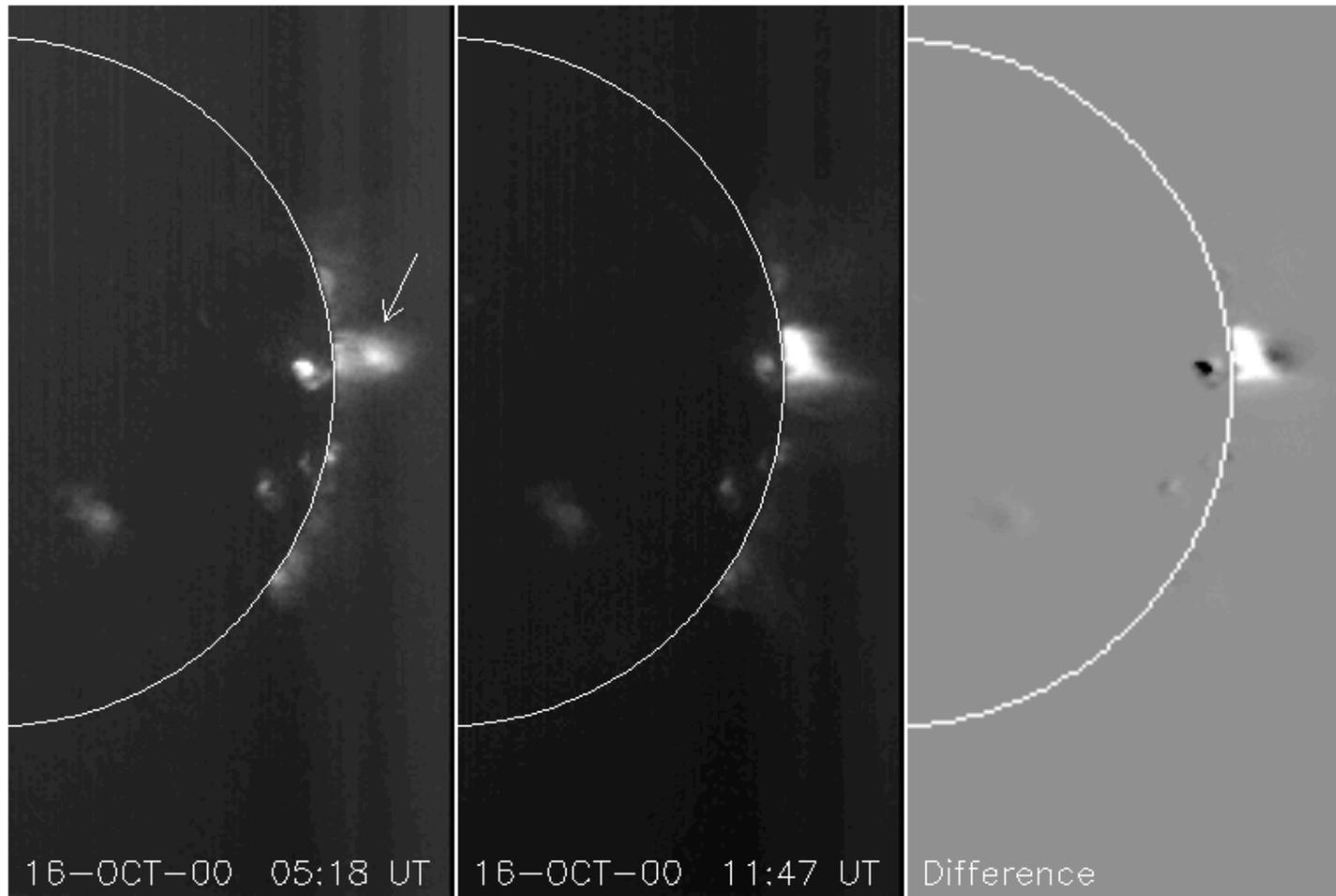




Schrijver et al., Solar Phys. 206, 69, 2002

Studying coronal equilibria

- One often hears about the dynamic nature of the corona, but on large scales it tends to stability
- We can study the equilibrium states via the oscillations; there are several modalities
- We can also study before/after equilibrium states (cf. FASR)

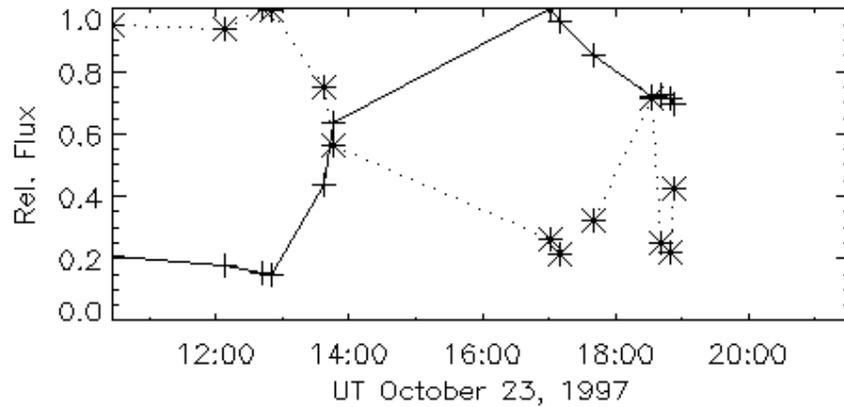


SXT observations of the blow-out of a loop prominence system

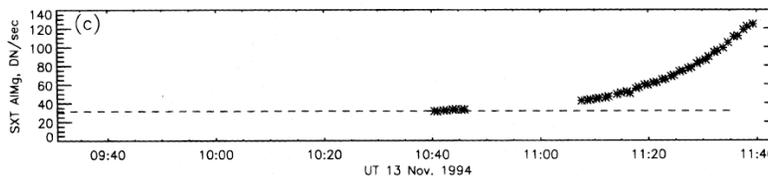
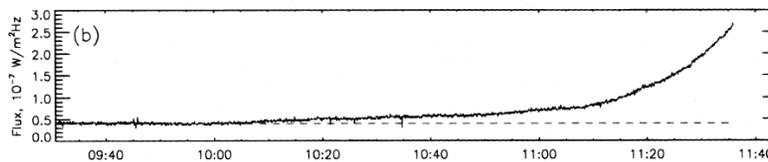
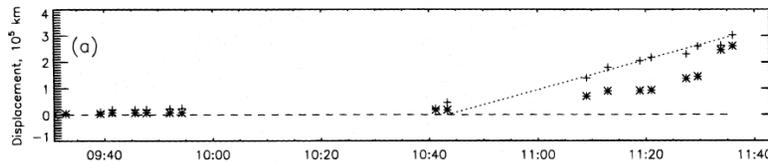
(Low)-coronal dimming

- CME depletions can be observed via dimming in the low corona
- Broad-band observations (soft X-rays) are the easiest to interpret in terms of mass flow
- The timing of soft X-ray dimming matches the flare brightening

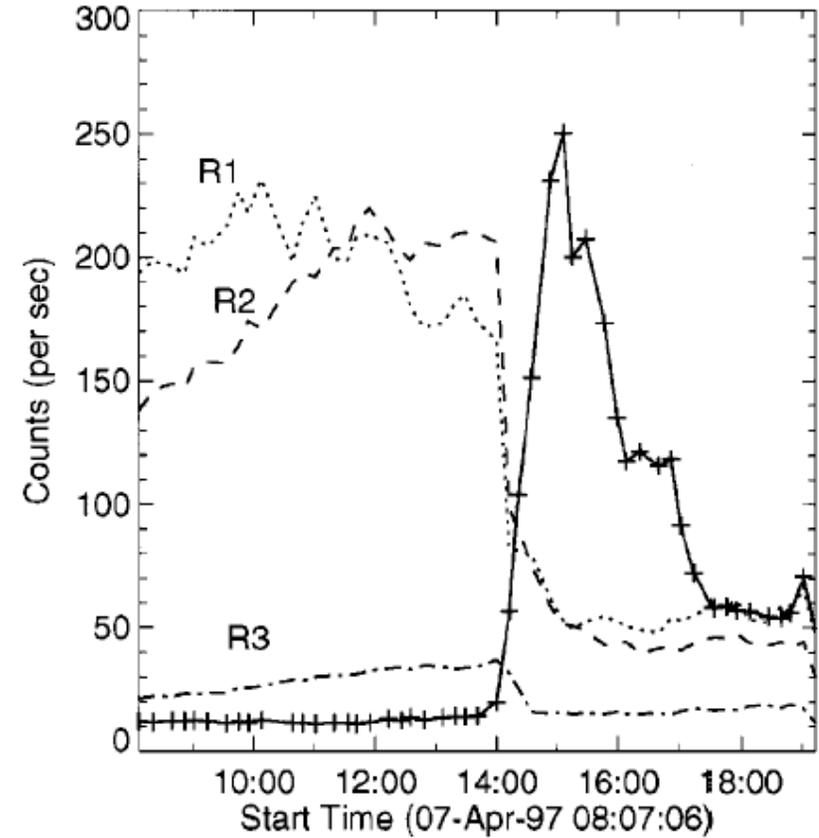
Simultaneity of CME dimming and flare brightening



Yohkoh science nugget #1, Oct. 24, 1997

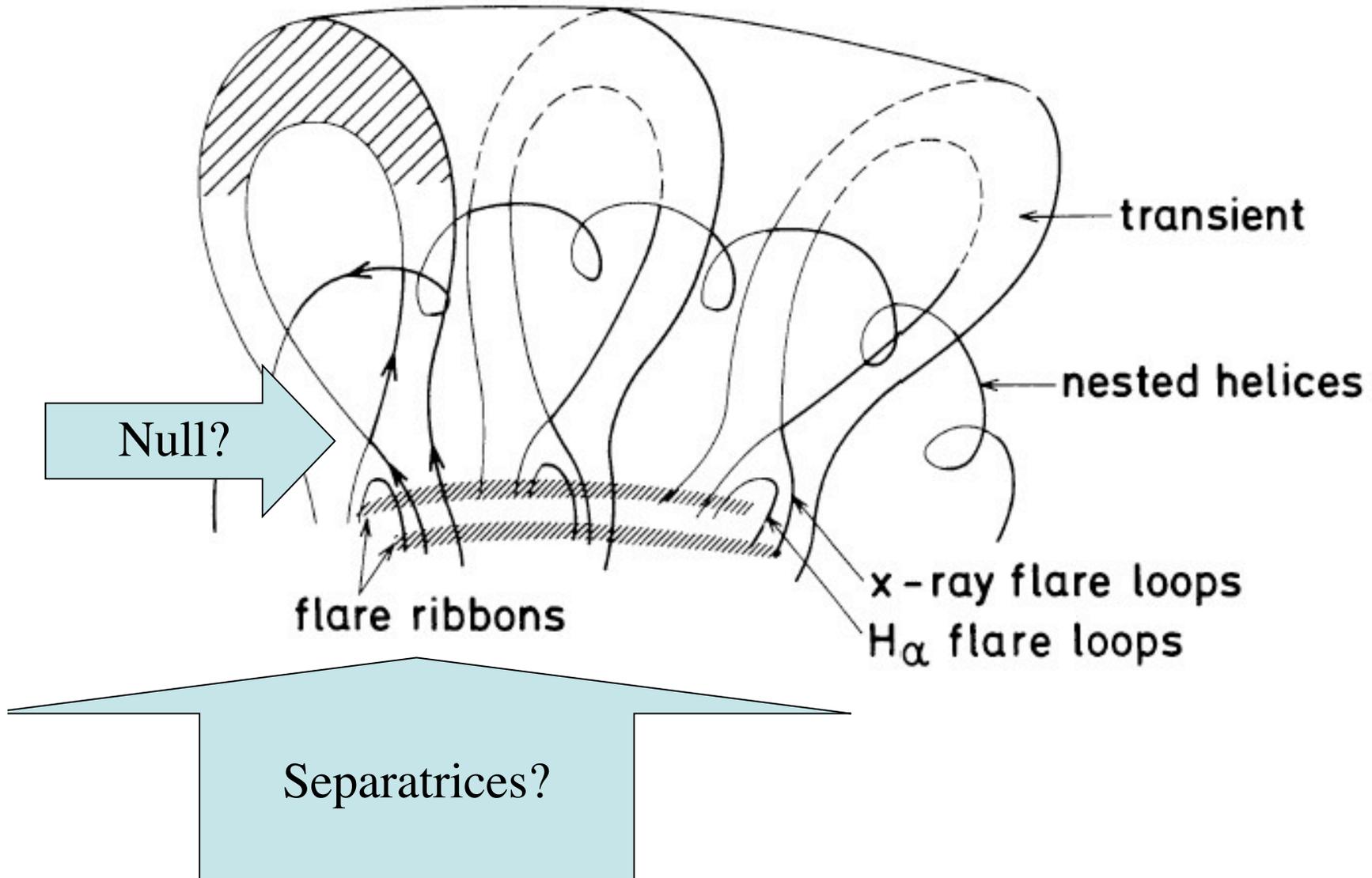


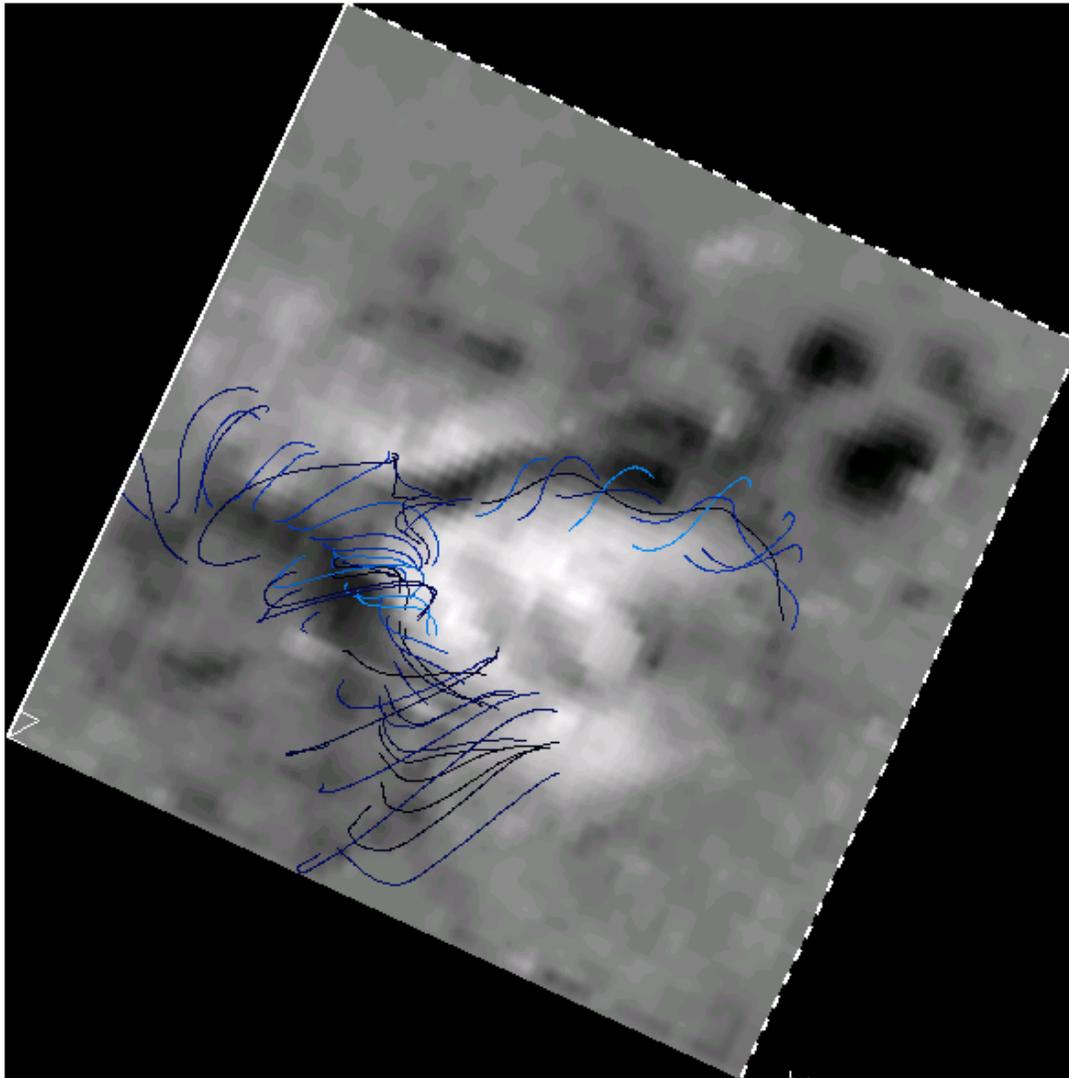
Hudson, Acton & Freeland, ApJ 470, 629, 1996



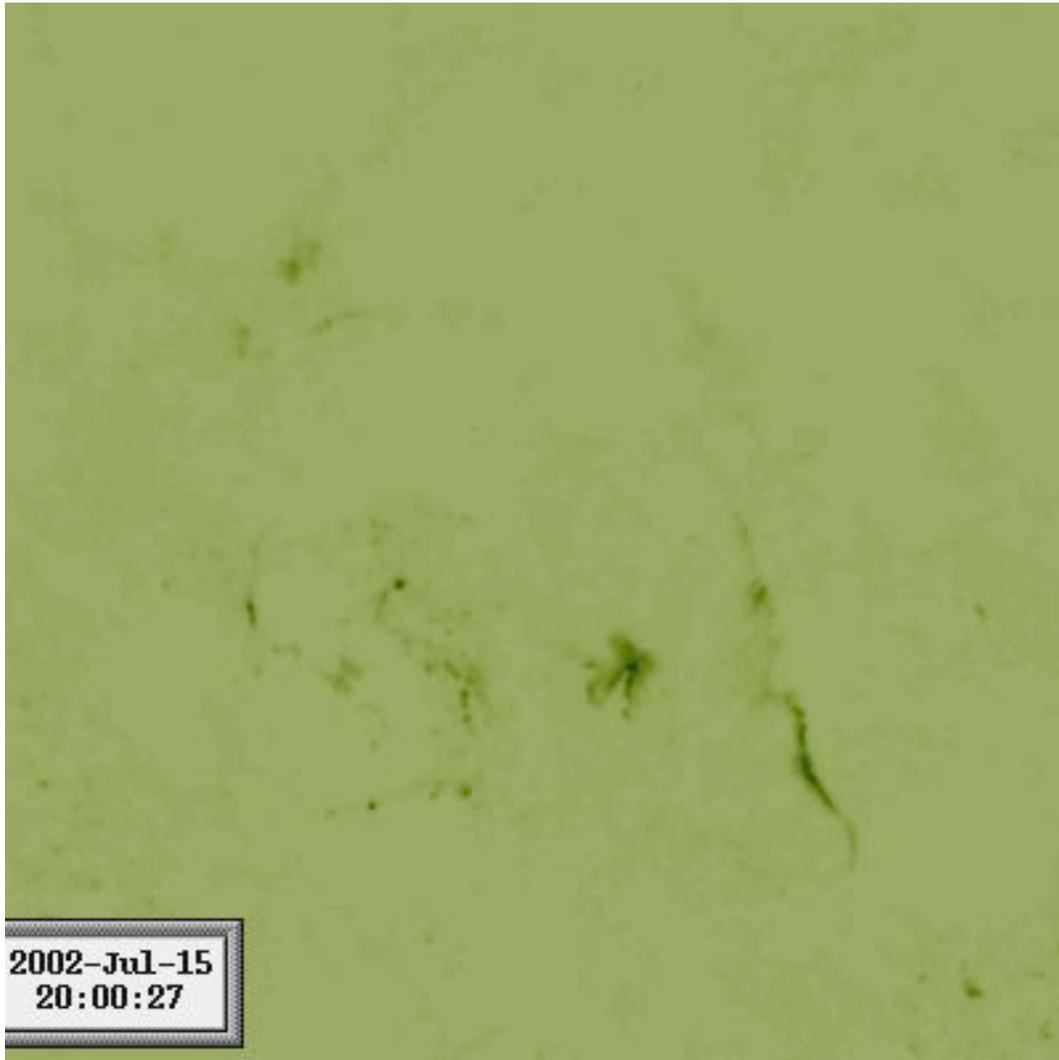
Zarro et al., ApJ 50, L139, 1999

Anzer-Pneuman, 1982





AR8210 courtesy J. McTiernan

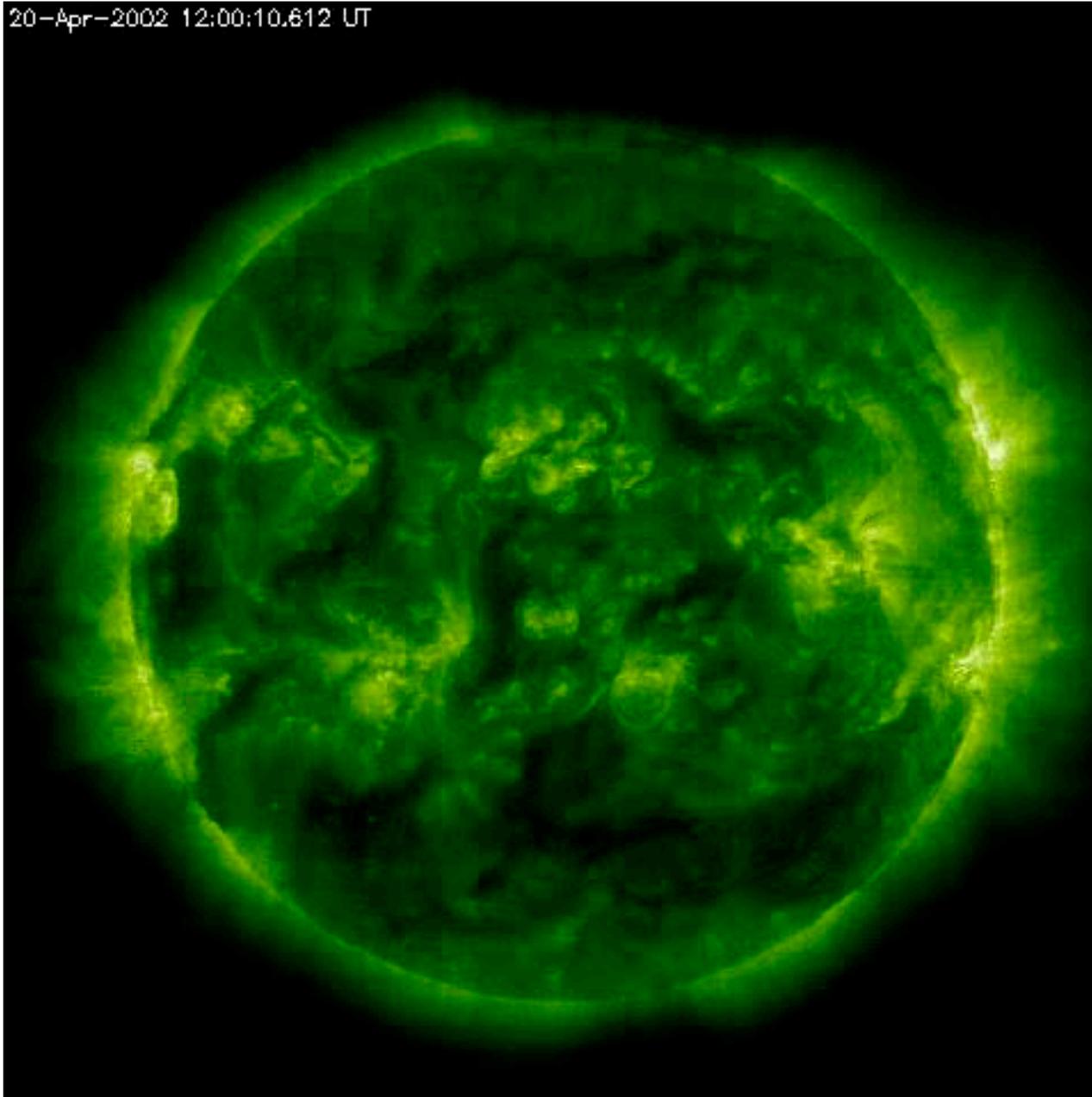


2002-Jul-15
20:00:27

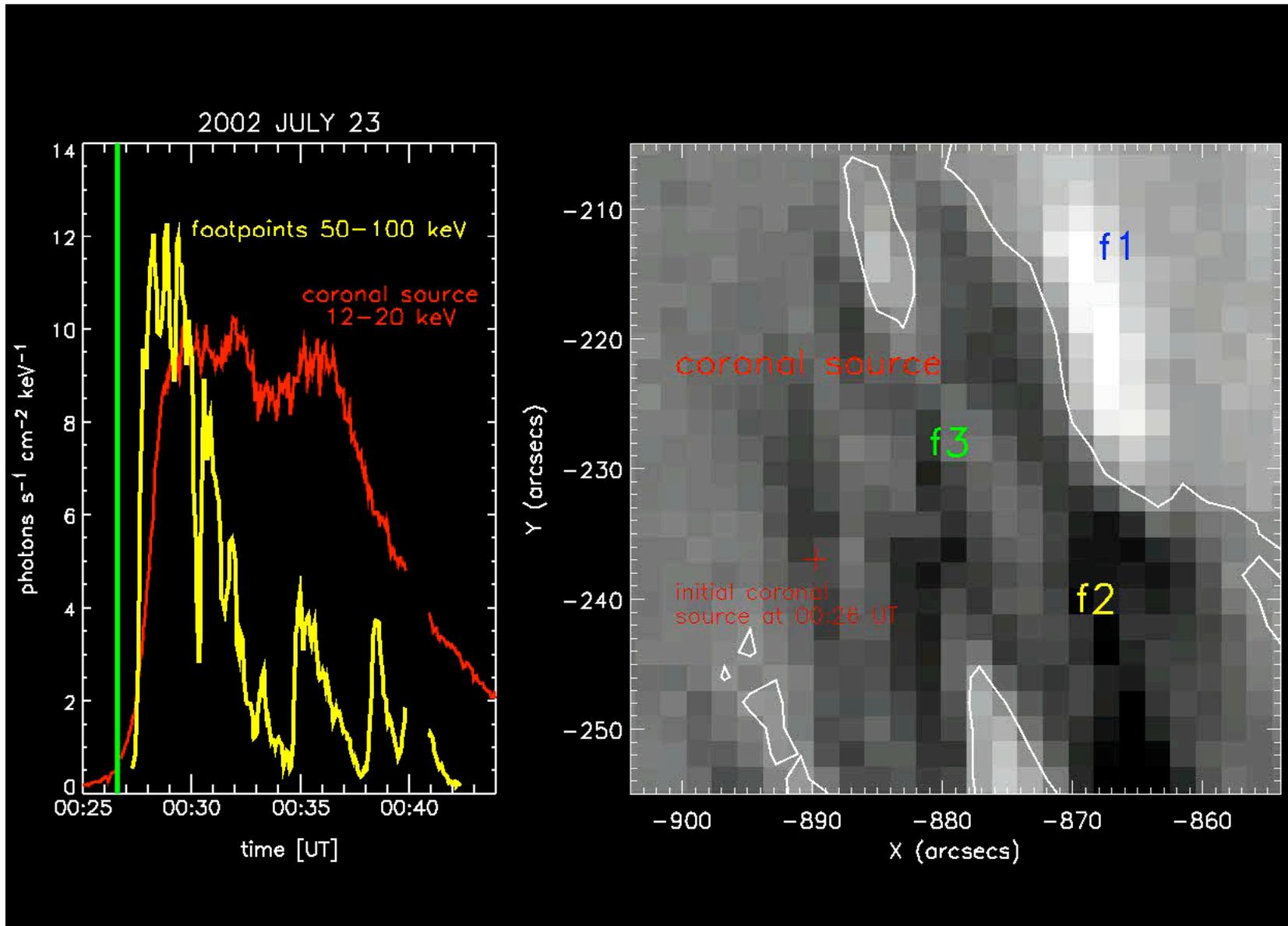
Using RHESSI for CME dynamics/energetics

- April 21, 2002
- July 23, 2003

20-Apr-2002 12:00:10.612 UT

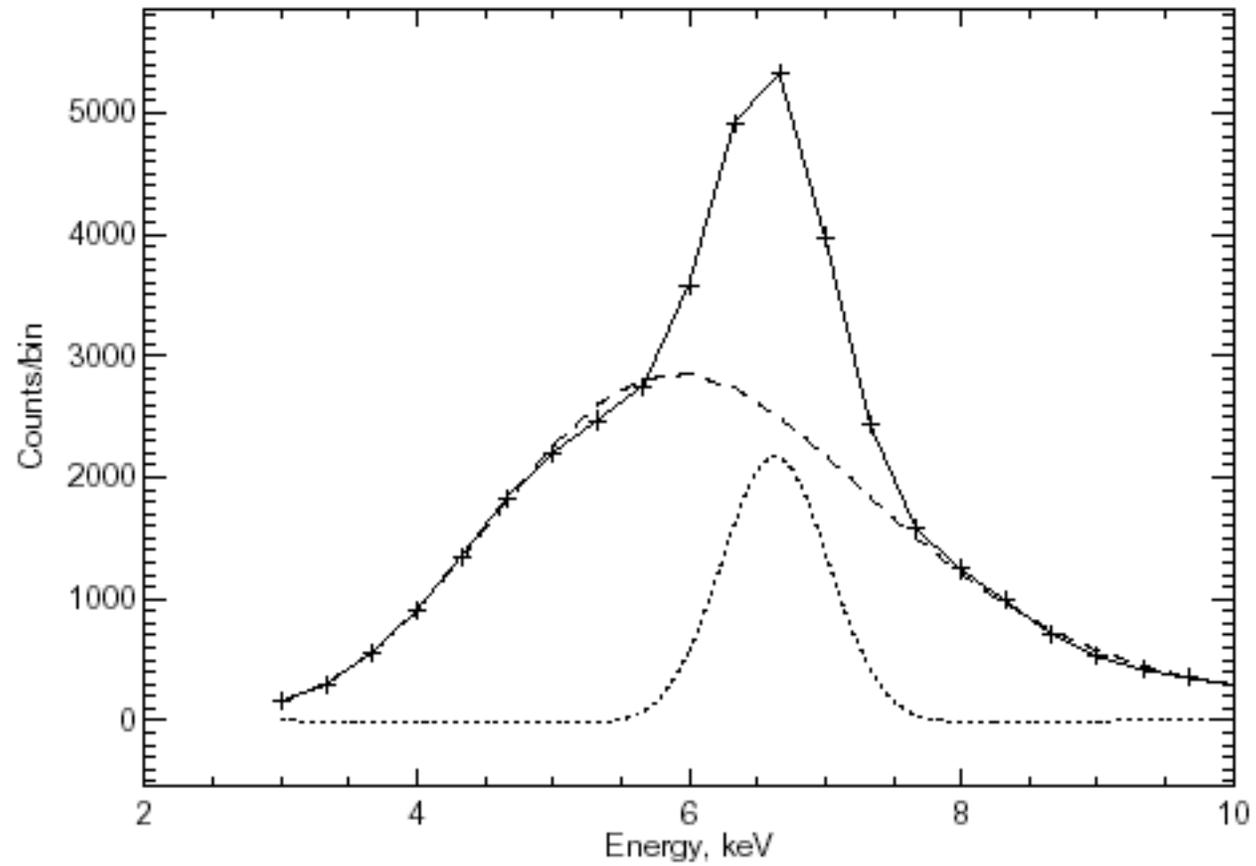


B. Dennis & P. Gallagher



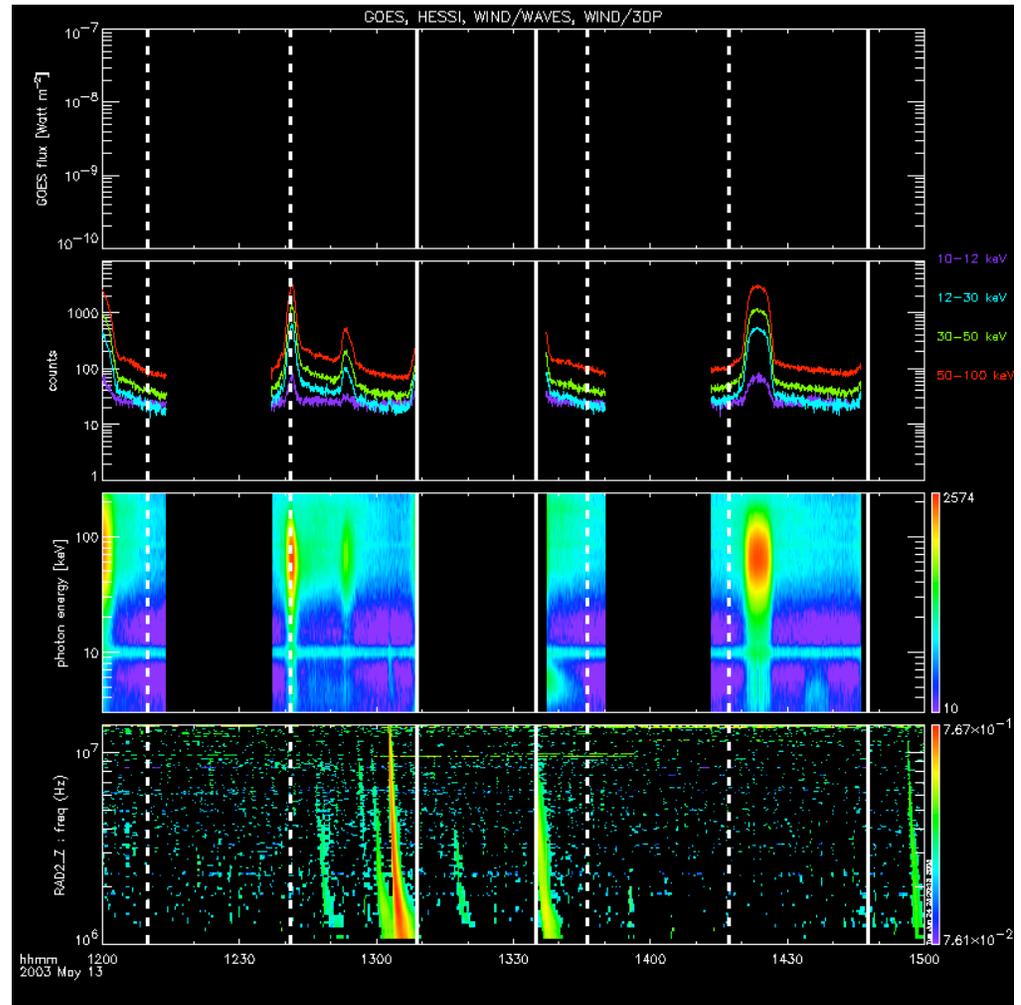
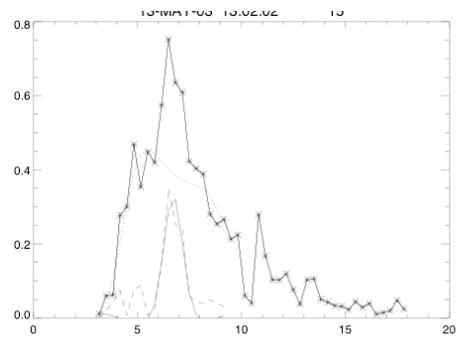
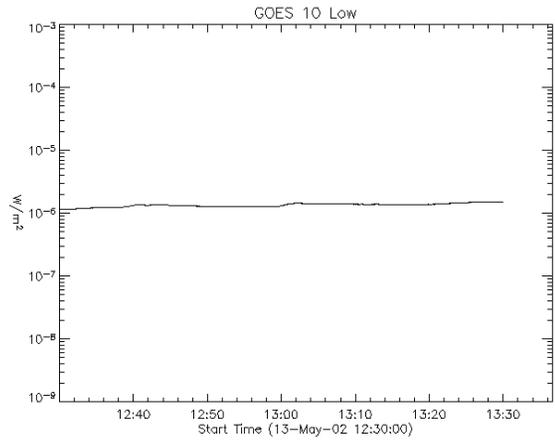
23 July 2002 courtesy Sa'm Krucker

RHESSI observes the Fe line complex!



See Phillips, 2004

RHESSI signatures in miniscule events

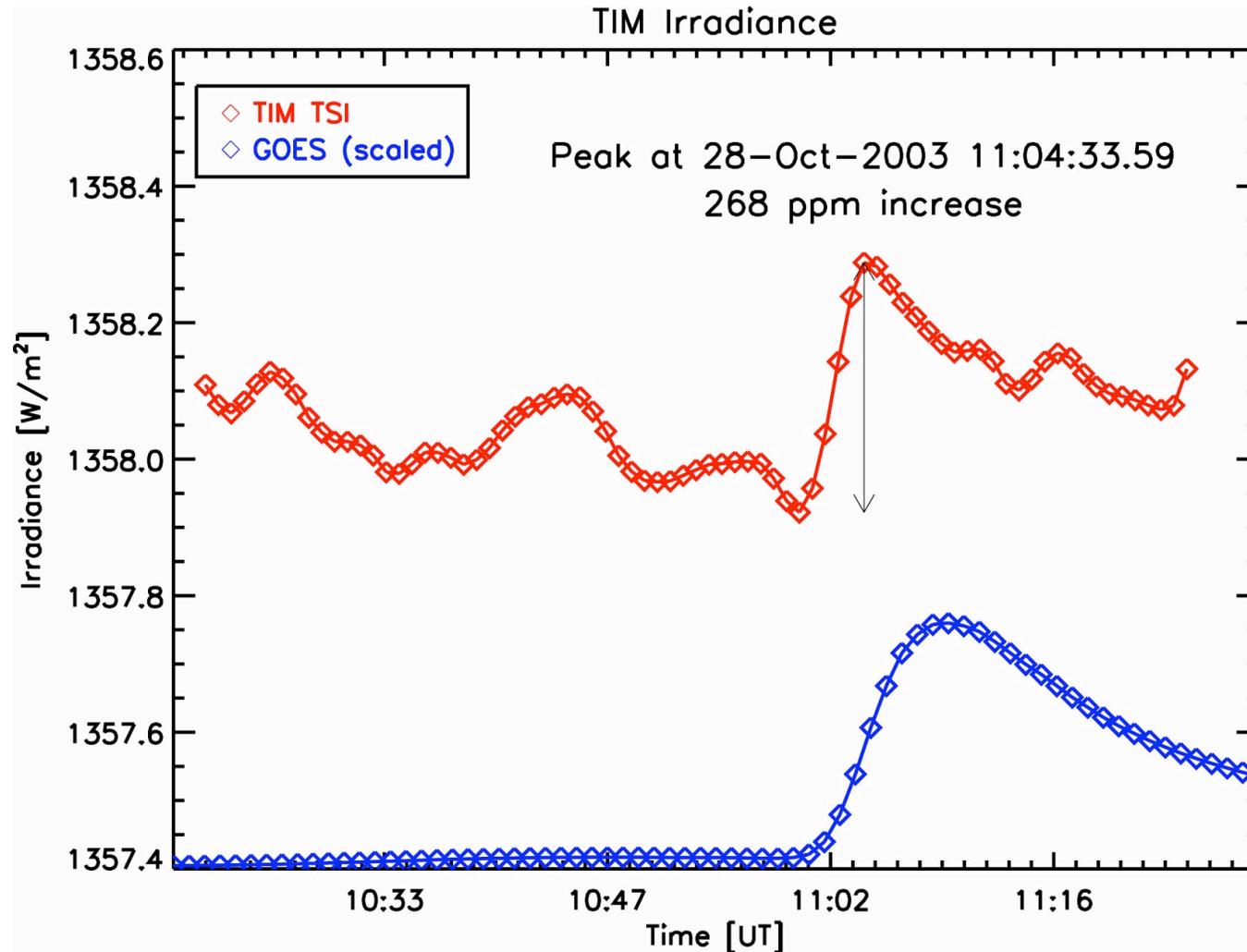


Courtesy A. Shih, E. Rauscher

Significance of “firm” X-rays

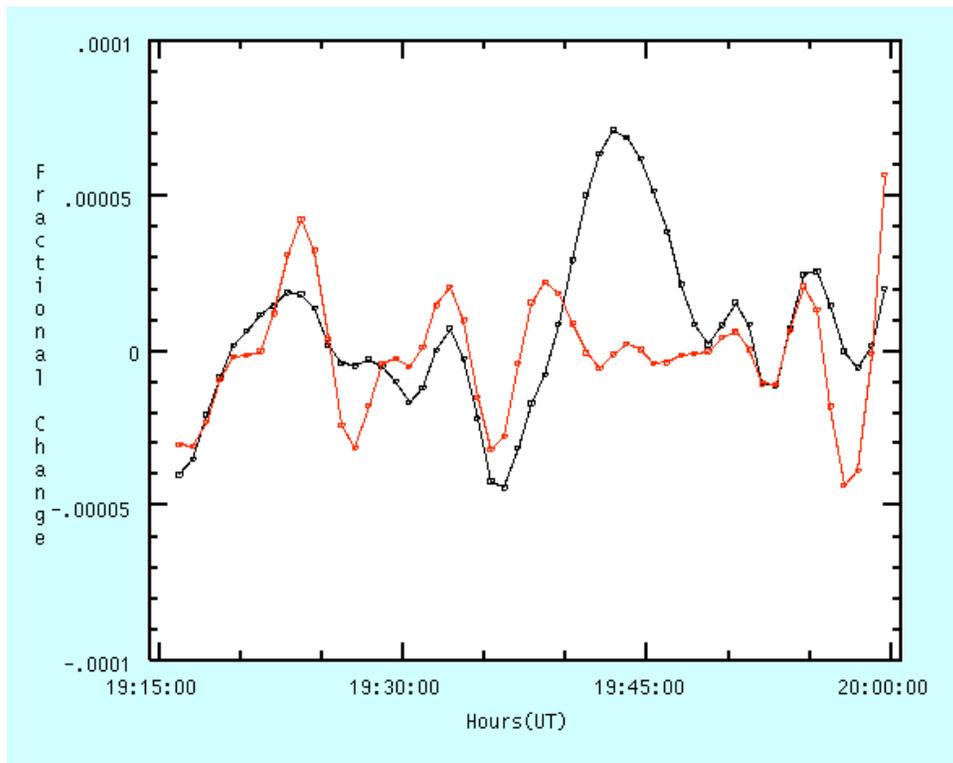
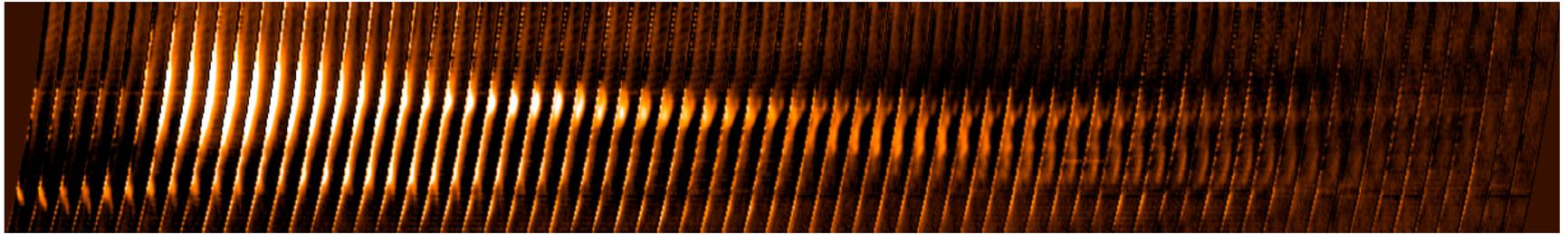
- It is necessary to understand non-Maxwellian distributions and their relaxation
- RHESSI observes the Fe feature and the 3-20 keV continuum well for the first time

SORCE gives first bolometric observations of flares!



G. Kopp, AGU 2003

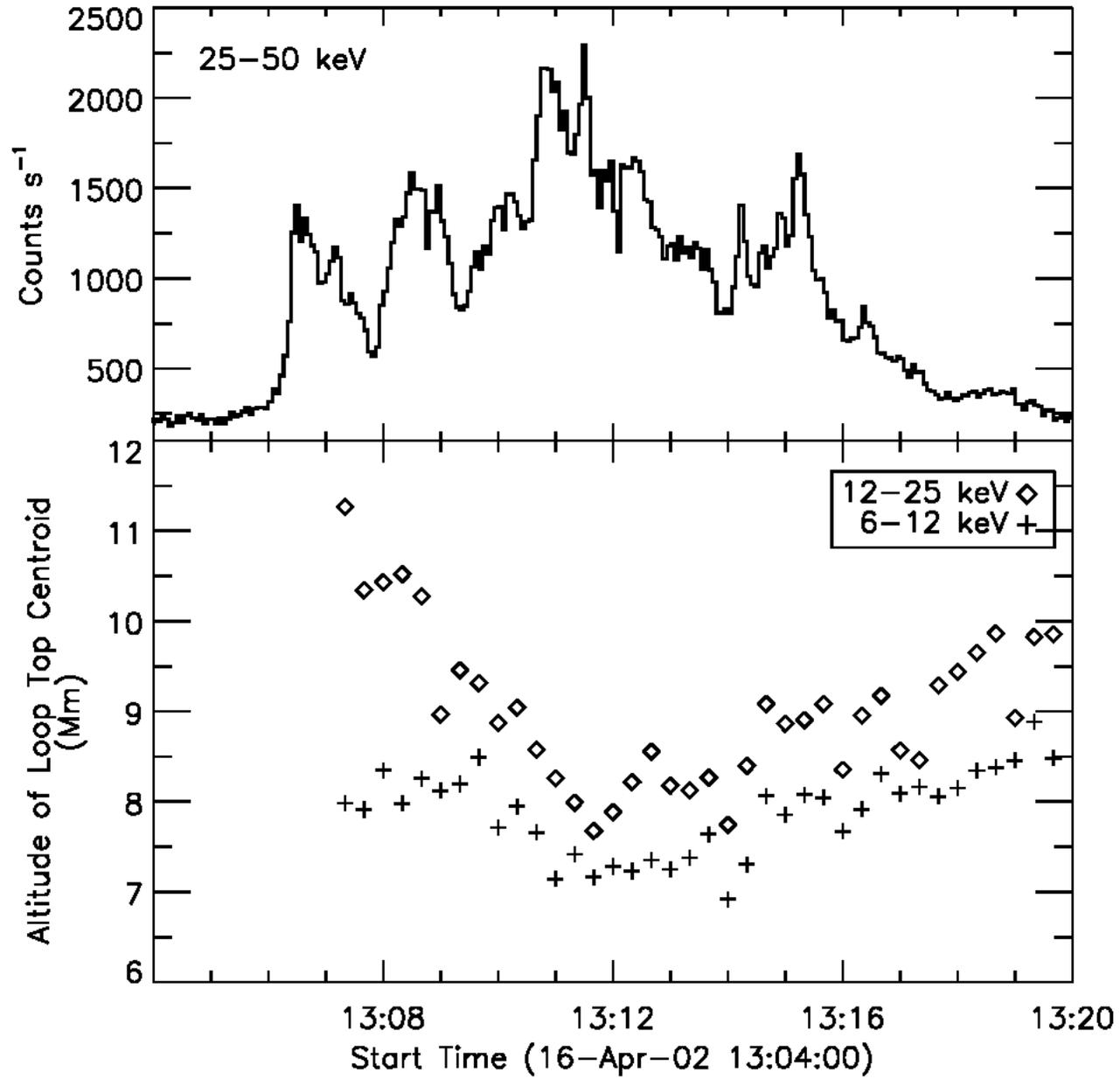
GONG and SORCE observations of Nov. 4, 2003 event



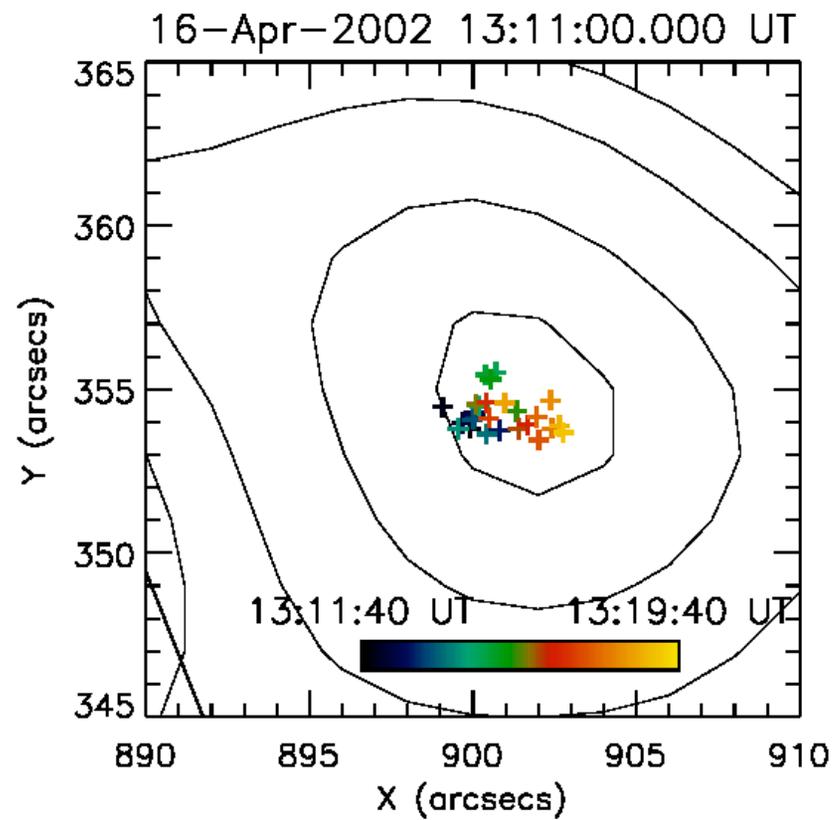
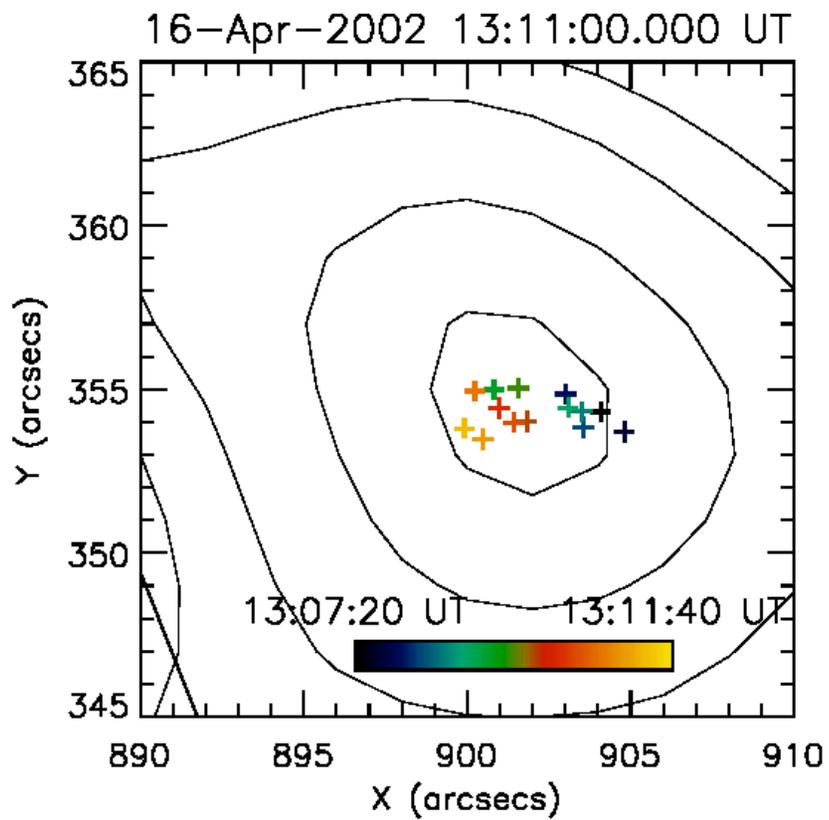
Leibacher et al., SPD 2004

New energetics results

- We now have a means (SORCE) of determining the total radiant energy of a flare bolometrically
- The “white light prominence” observed by GONG means that we can now directly determine the coronal mass of a flare
- RHESSI observes the γ -ray spectrum and can characterize ion as well as electron energy

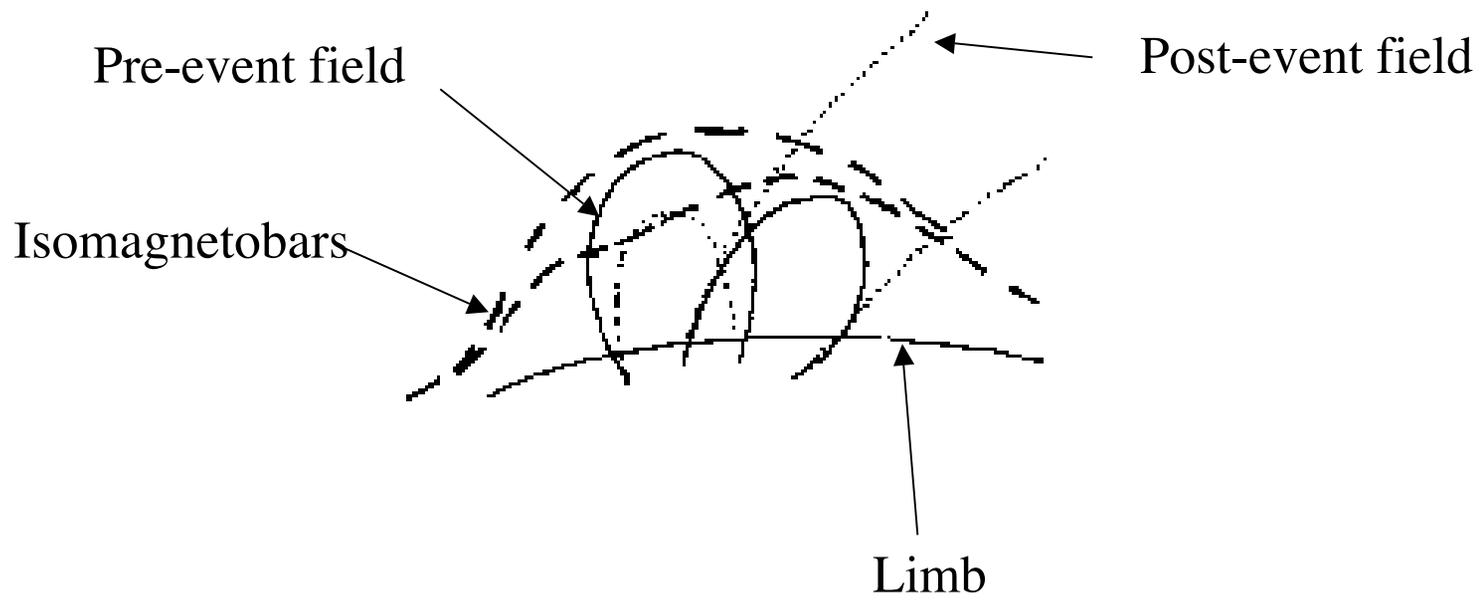


Sui et al., 2004



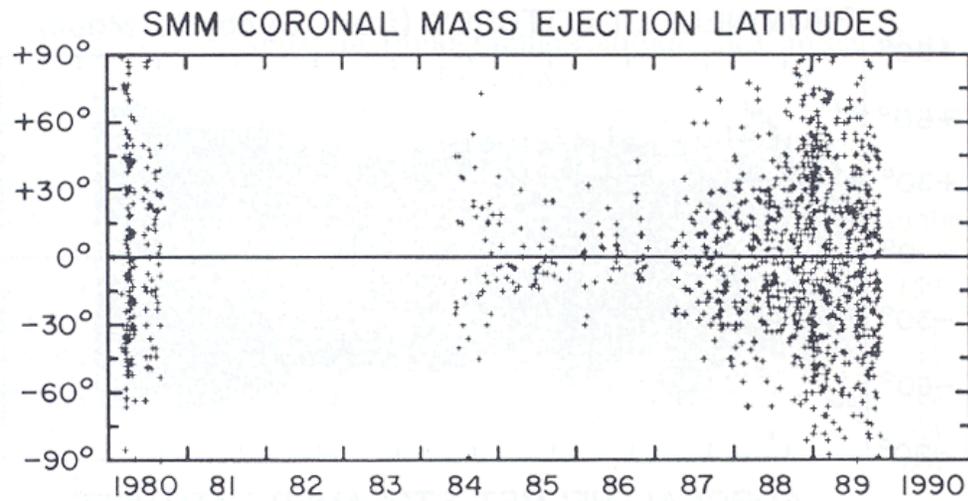
Sui et al., 2004

Cartoon showing implosion

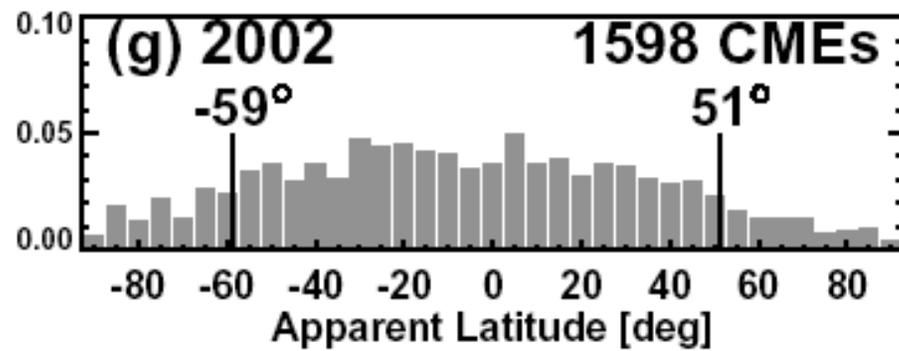


Flares and CMEs

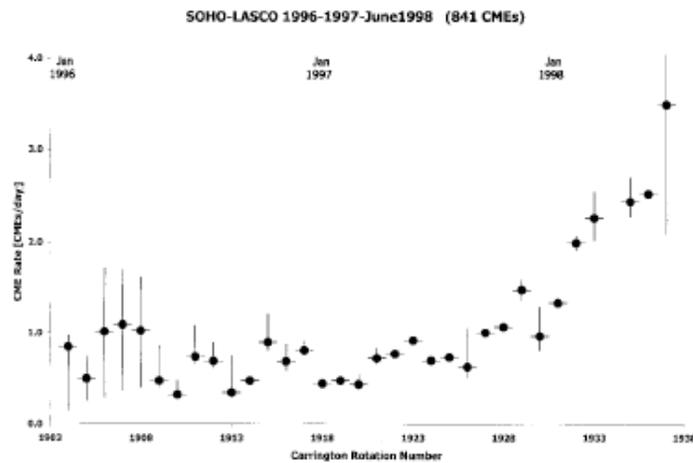
- Traditional view is that CMEs result from large-scale closed magnetic structures, hence not small-scale fields
- New low-coronal data show that most CMEs originate in active regions
- How do we reconcile this apparent contradiction?



Hundhausen, 1993



Yashiro et al., 2004



St. Cyr et al., 2000

A misunderstanding clarified

- The growth of CME apparent latitudes with solar-cycle rise is influenced the sampling
- This conclusion is just based on the event statistics
- There is thus no conflict: CMEs can both come from large-scale structures and have a strong active-region association

Conclusions

- Flare blast waves may help us to understand the basic flare/CME instability
- Energy partition can be understood much better now with RHESSI and other data
- We can now feel comfortable about the strong flare association of CMEs