Transients in RHESSI and Chromospheric flares

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**And TRACE and Hinode*

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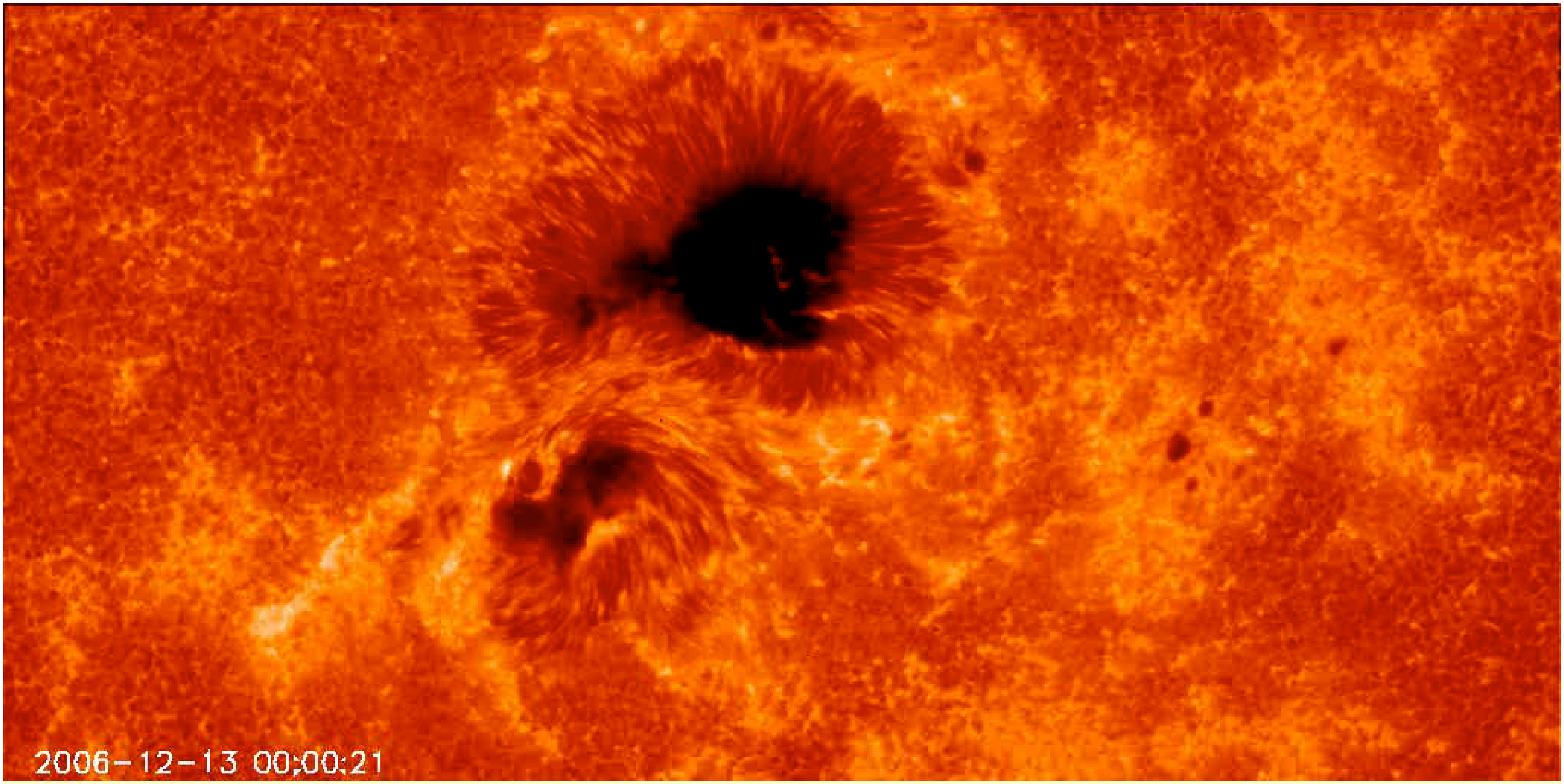
Chronology of flare physics

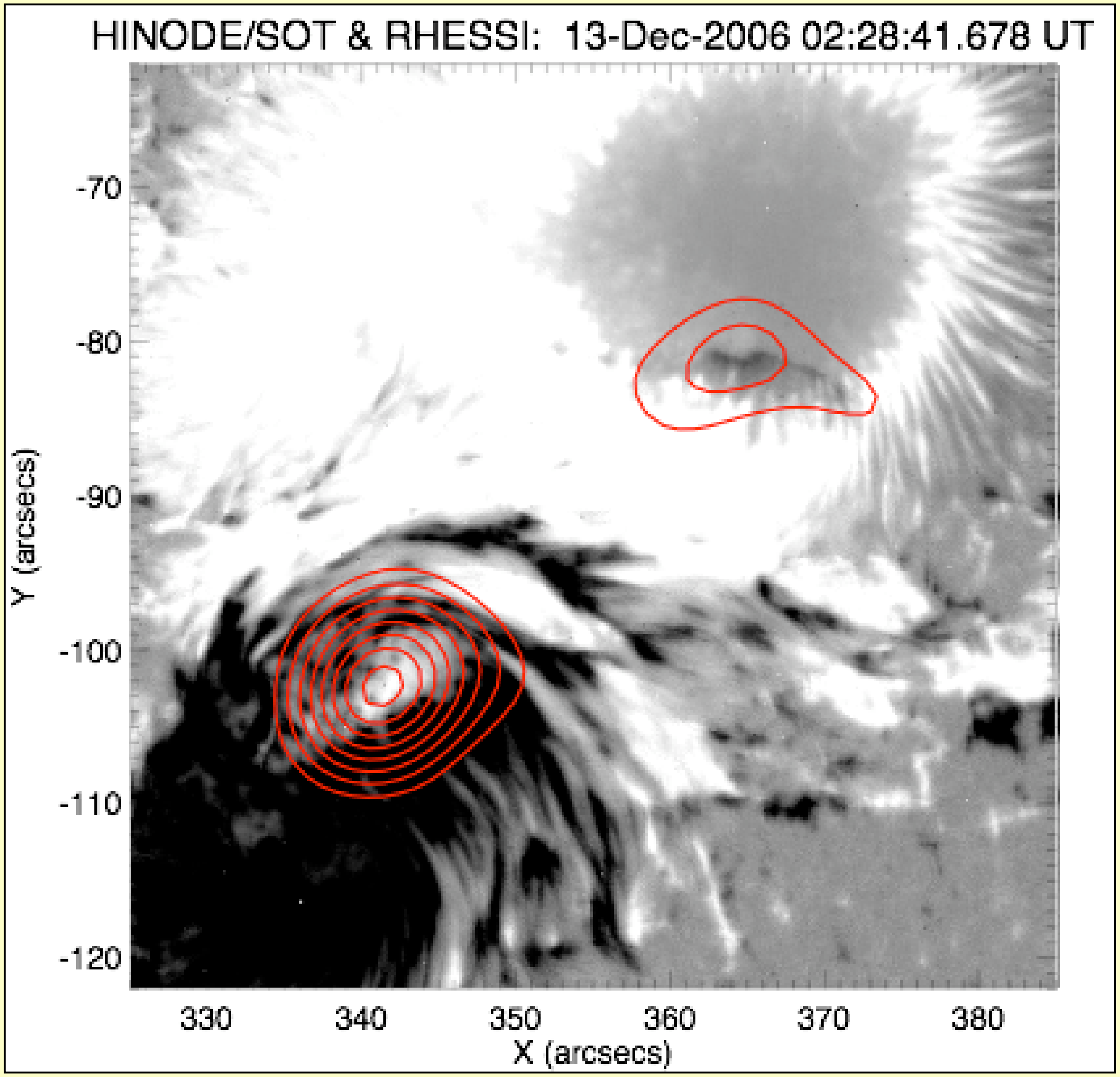
- 19th century. The photosphere (Carrington; Trouvelot)
- Early 20th century. The chromosphere (spectroscopic observations, Ha)
- Late 20th century. The corona (X-rays, CMEs). Major theoretical ideas formulated
- Current. Let us think further about the chromosphere!

Recent review material on the chromosphere:
P. Heinzel, R. Rutten, I. Dorotovich (eds.), "The Physics of the Chromospheric Plasmas," ASP-308
(see ADS; some articles are on Astro-PH)



Ca H line movie from *Hinode:* the X-class flare of December 13, 2006

Hard X-ray and magnetic counterparts



S. Krucker

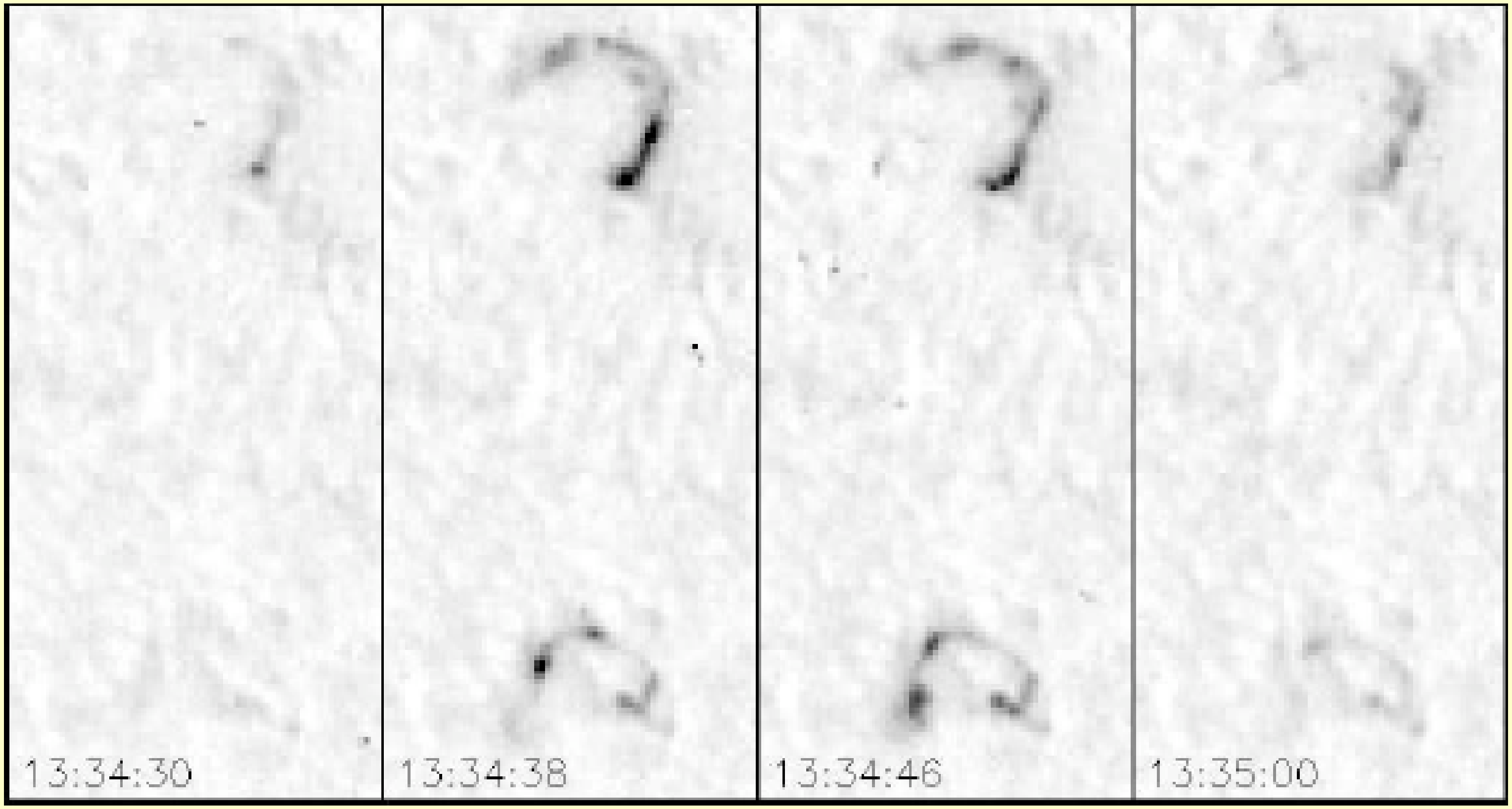
Outline of presentation

- Introduction √
- Specific topics
  - White-light flares
  - Microflares
  - Active-region structure
- Conclusions

White-light flares

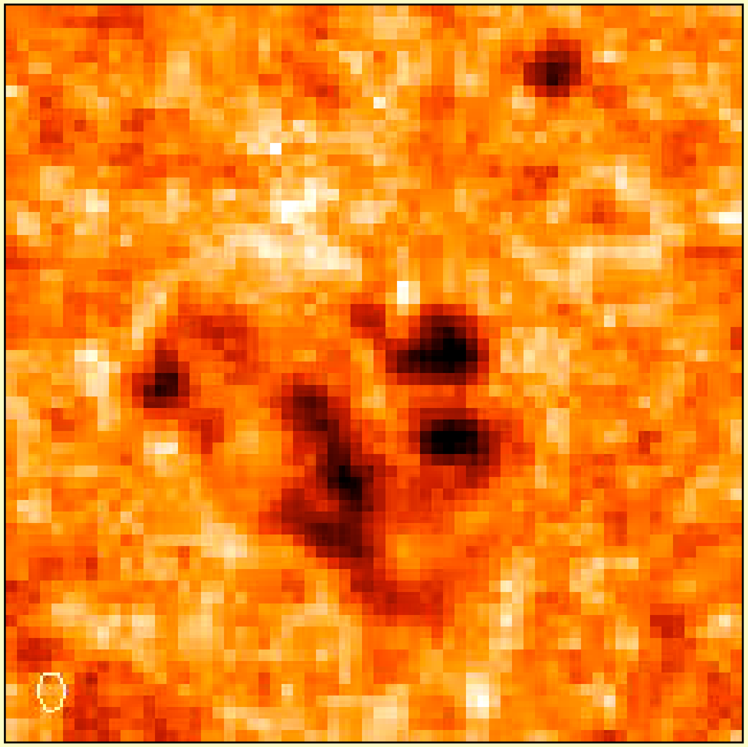
- The visible and UV continuum contains most of the flare radiant energy
- It forms in the chromosphere or upper photosphere and is closely related to hard X-ray emission
- Its appearance reveals rapid variability both in space and time

Intermittency: consecutive TRACE images

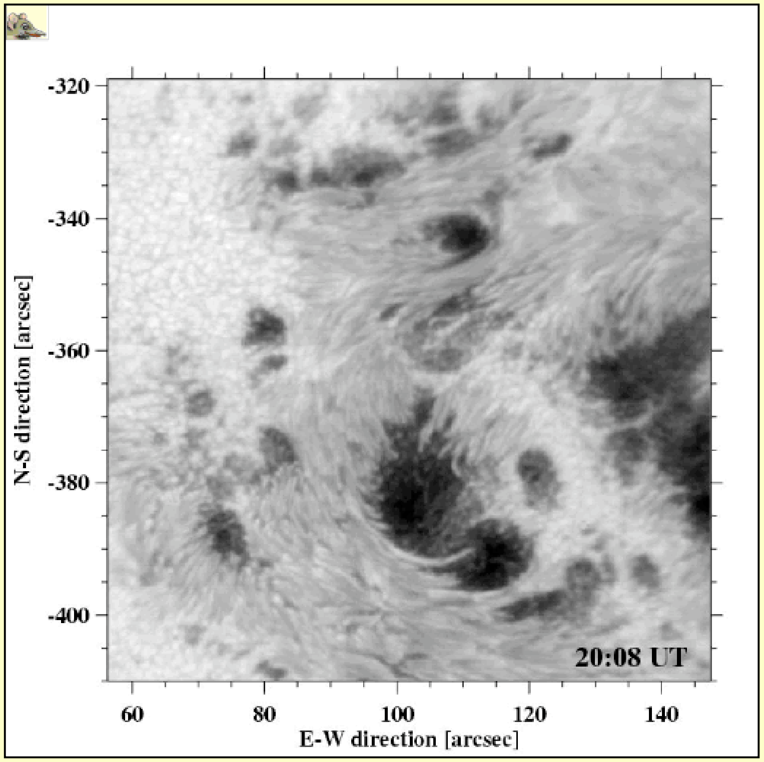


24 July 2004, C4.8
32 x 68 arc s frames

- Flare radiant energy appears in the form of compact, intense patches
- The high-energy footpoint excitation moves rapidly, with a crossing time of order <30 sec (Schrijver et al. 2006)
- The emission appears as low as the "opacity maximum", 1.56μ



M9.1 flare, time in sec,TRACE WL

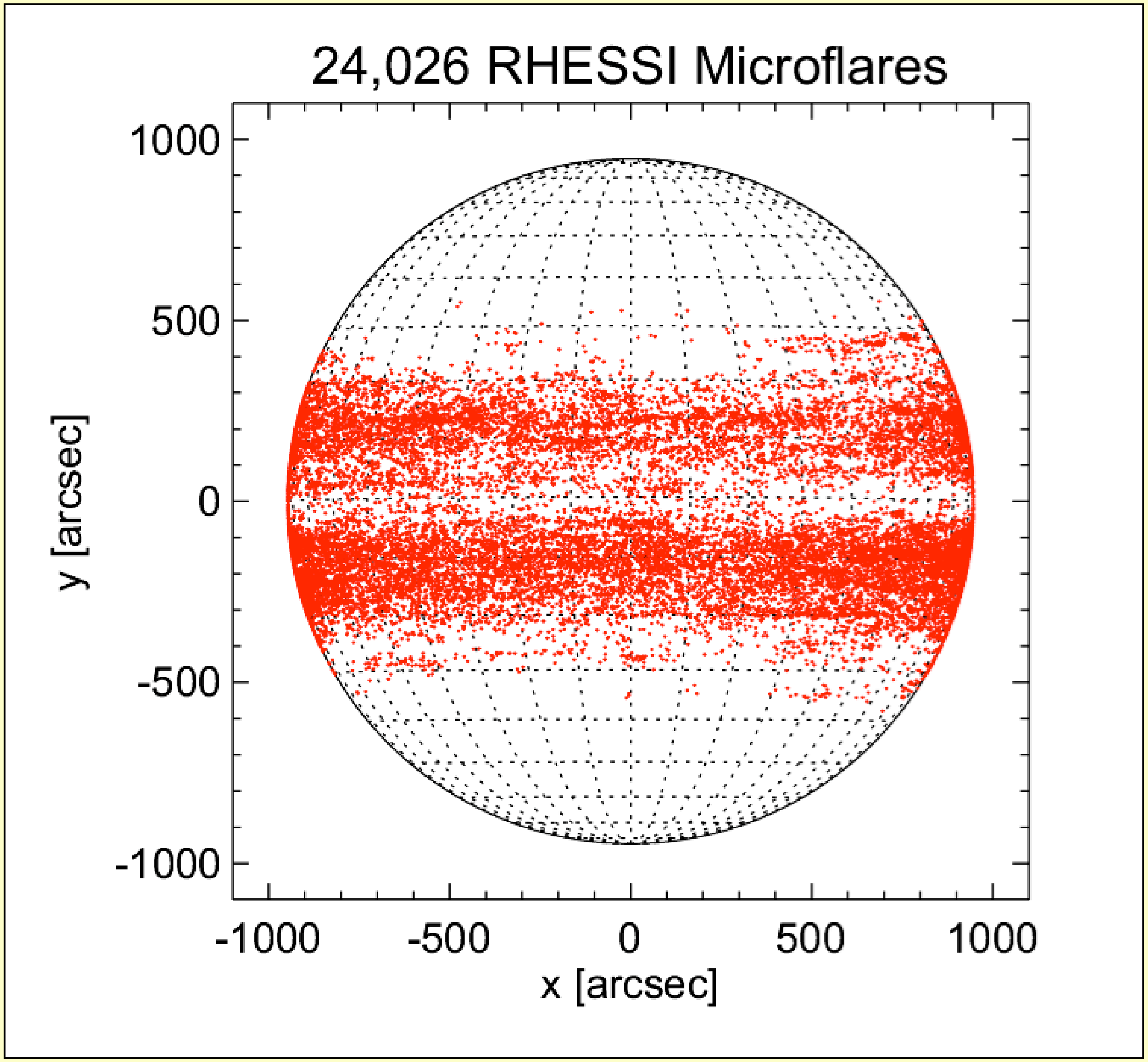


X10 flare, 1.56 μ (Xu et al., 2004)

What is not understood?

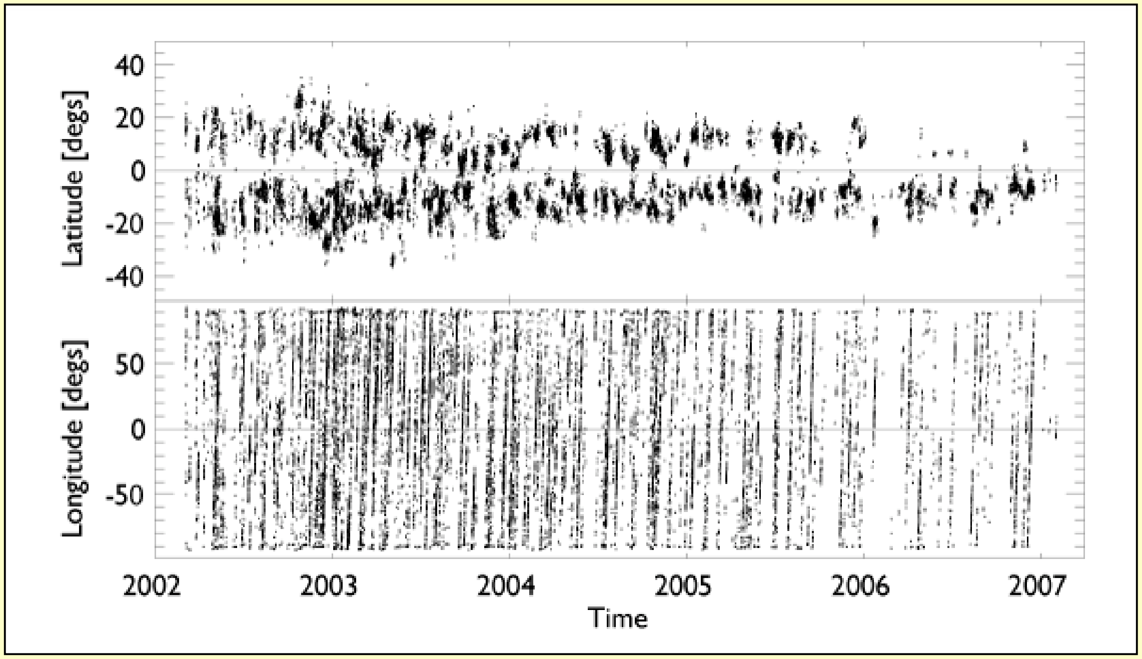
- How the bulk of flare energy can be focused into these tiny chromospheric structures
- How the solar atmosphere reacts to the flare energy
- How important flare effects can appear as deep as the opacity minimum (or below, as seismic disturbances)

Microflares are in ARs



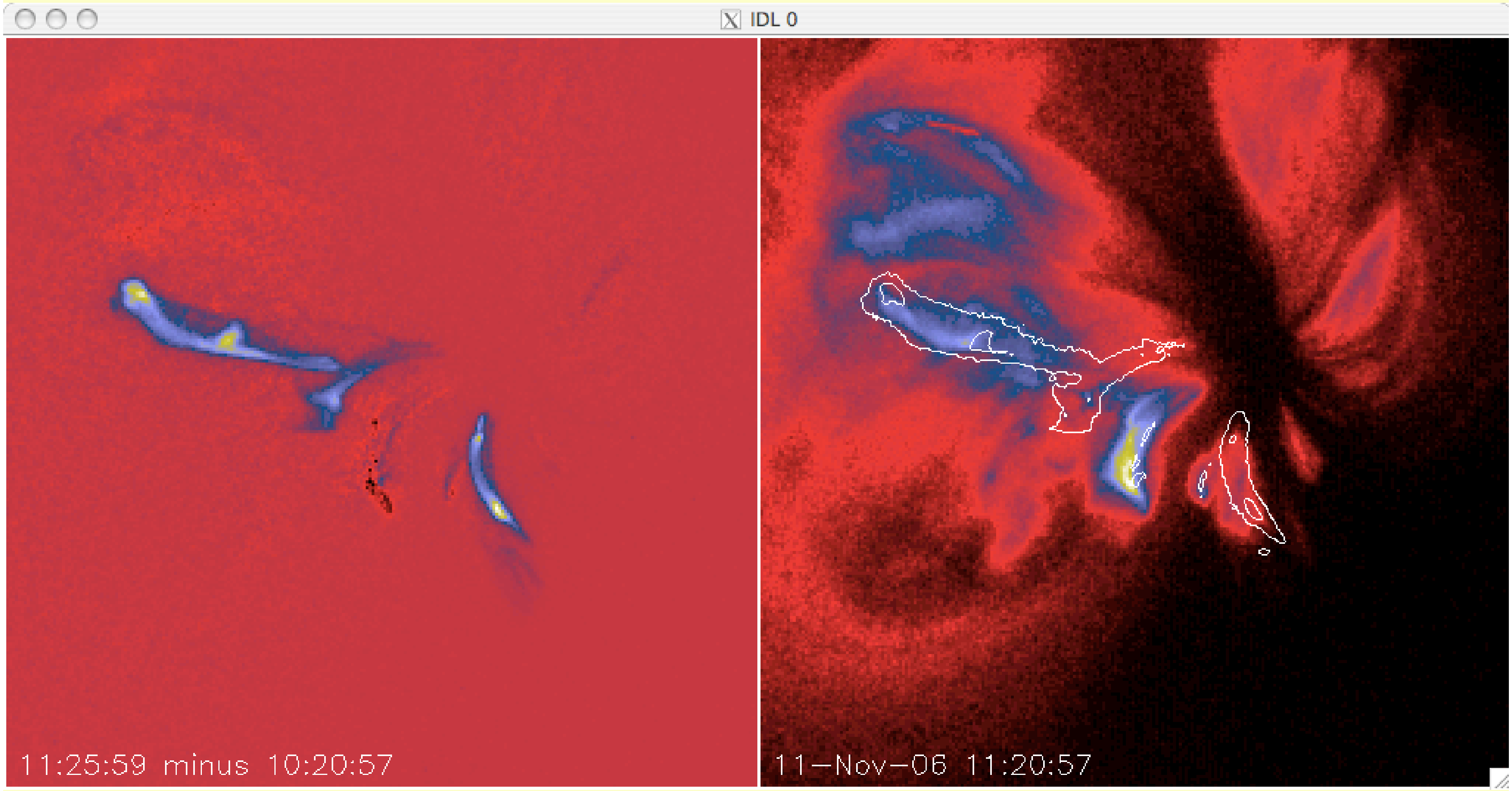
I. Hannah, 2007

A microflare "butterfly diagram"

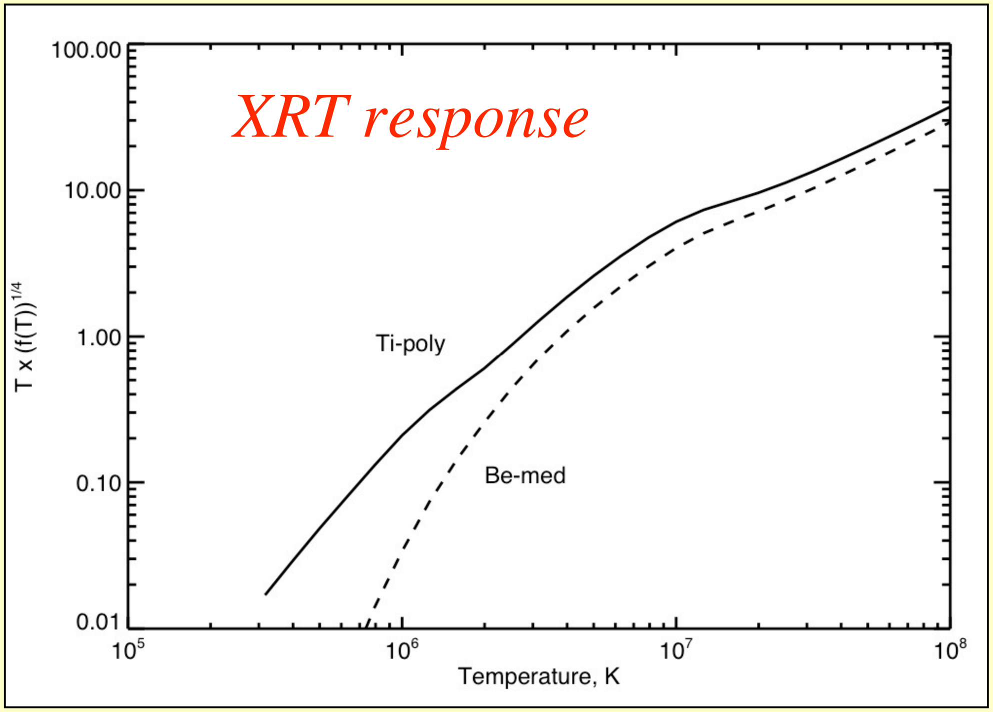


S. Christe (2007)

A *Hinode* X-ray microflare: new loops appear



Analysis for preflare (T, n)



$S = n^2 f(T)\Delta V$ *XRT response*

$T \sim (pL)^{1/3}$ *RTV law*

$\Rightarrow S \sim T^4 f(T)$

$$Tf(T)^{1/4} = T_{ref}\, f(T_{ref})^{1/4} * (S/S_{ref})^{1/4}$$

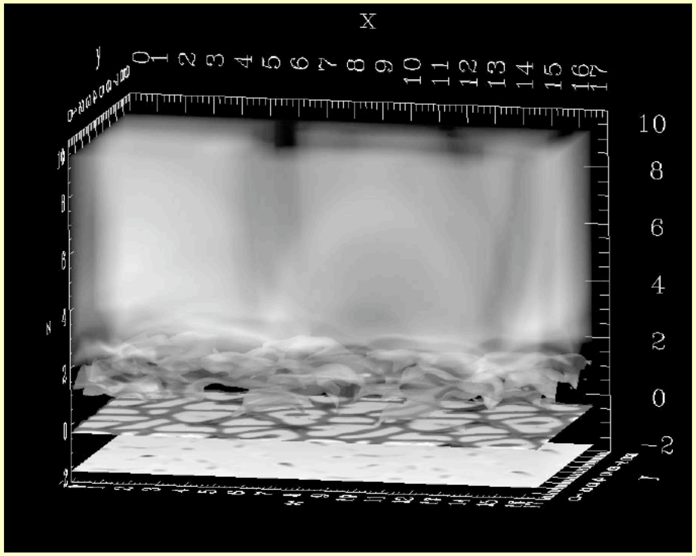
Solve for $T = T(T_{ref}, S)$

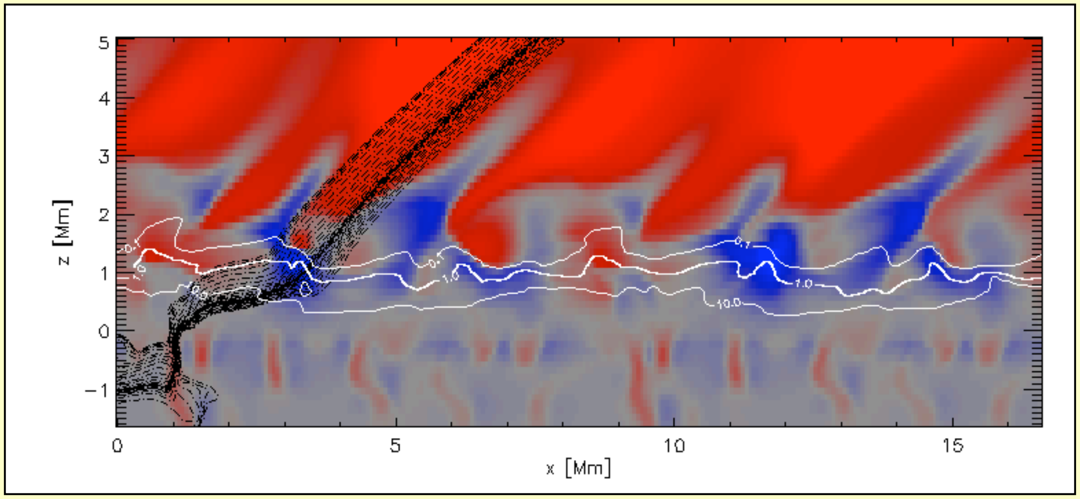
The pre-event density *n* follows from the RTV scaling since $n \sim T^2$ for a fixed reference geometry (nearby loop)

Results of RTV-based analysis

Temperature: < 1MK
Density: < 1×10^{8} cgs
Plasma beta: < 1×10^{-4}
Alfvén speed: > 0.1 c (100 G)

These preflare coronal voids imply very low transition-region pressures





M. Carlsson

V. Hansteen

Structures seen in numerical models linking the photosphere with the corona

Such simulations are mainly intended for understanding the quiet solar atmosphere at present, and with limited physics.

The essential problem for solar activity is to understand the role of the chromosphere in modifying the currents injected from the photosphere and penetrating to the corona.

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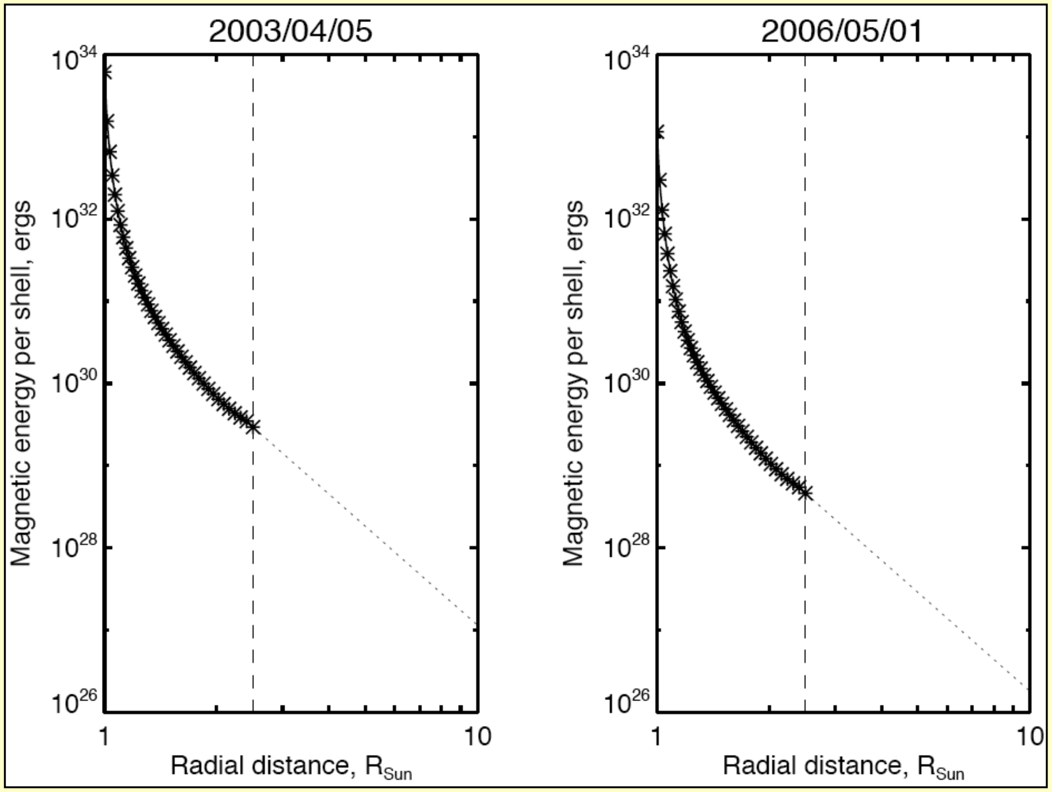
The essential problem for solar activity is to understand the role of the chromosphere in modifying the **currents** injected from the photosphere and penetrating to the corona.

Can the chromospheric provide the energy for a solar flare?

• Mass	10^{16} g	*Enough for a CME…*
• Gravitational energy	10^{31} ergs (to infinity)	
• Gravitational energy	10^{29} ergs (2” altitude)	
• Magnetic energy	10^{30} ergs	
• Ionization energy	10^{29} ergs	
• Thermal energy	10^{29} ergs	
• Energy in flows	10^{26} ergs	

No. There is probably insufficient energy or stress in the chromosphere to power a major flare

The distribution of magnetic energy in the corona (Schrijver-DeRosa PFSS)



The energy for a transient comes from
The lowest layer of the corona

Conclusions

- The radiant energy of a flare appears in the chromosphere and has a strong association with hard X-rays
- Energy release in the chromosphere guides us to coronal dynamics in flares
- The concentration of flare energy into compact flare elements is puzzling
- Microflare observations suggest strong pressure variations across the transition layer
- Model calculations have not yet tackled the essential physics needed to understand the AR chromosphere