Observational insights into flare development

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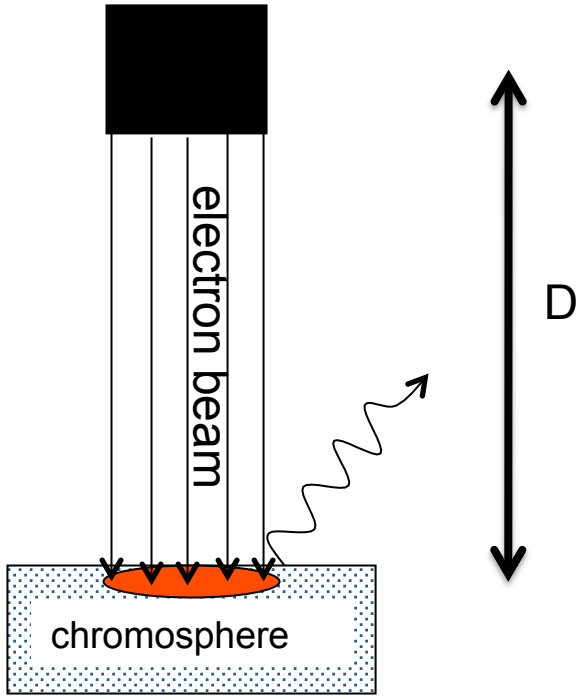
Topics

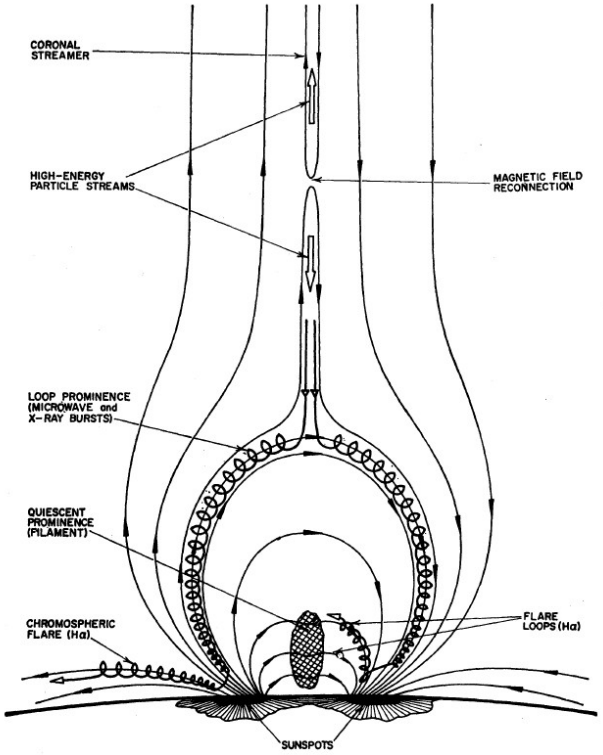
Thesis: The standard models are having serious problems, and ASO-S will be well situated to participate in major new discoveries. I discuss two particular observational issues.

1) The electron beam / “thick target” model
   - Lack of bremsstrahlung directivity
   - Source heights
2) The plasmoid ejection “CSHKP” model
   - Implosions
   - CMEless flares

How does flare energy flow?



Kane & Donnelly, ApJ 164, 171 (1971) – basically, the “thick-target model”



Strauss & Papagiannis, ApJ 164, 369 (1971) – basically, “CSHKP”

Global Energy and Momentum

- We generally accept that “free energy” accumulates slowly, via Poynting transport, in the corona
- Neither of our standard cartoons, CSHKP or thick-target, deals with global conservation laws well
- “Free energy” is not localized and depends upon global considerations (e.g., helicity)
- See my review of these issues in SSR 158, 5 (2010)

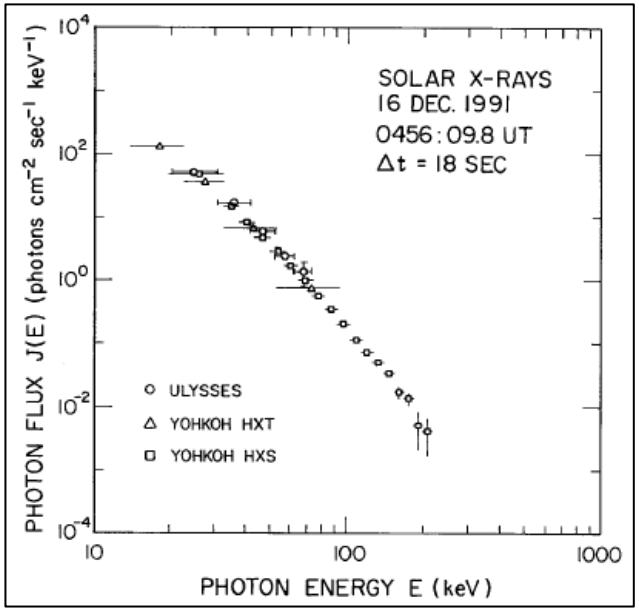
Observational critique of the thick-target model

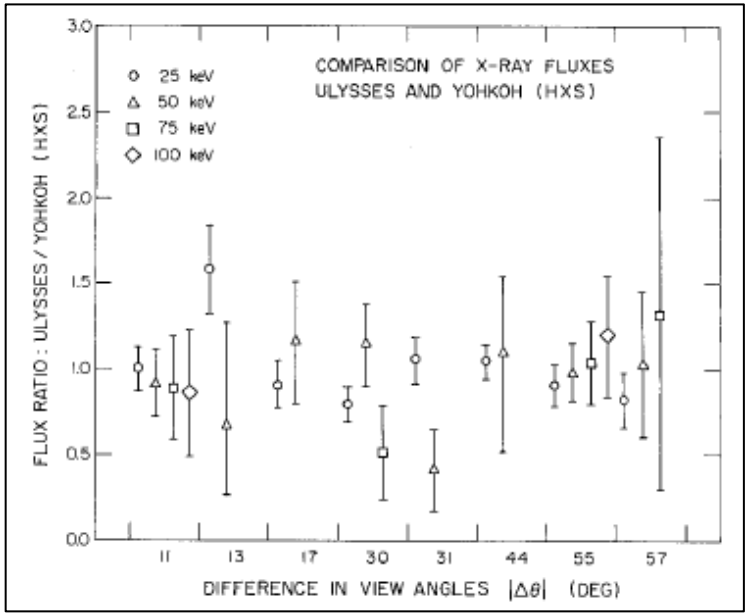
- It predicts strong directivity for hard X-rays

  - Neither direct anisotropy observations, nor Kontar's ingenious "dentist's mirror," reveals directivity

- We now have the capability to observe hard X-ray source heights directly, and they do not match the predictions of the thick-target model

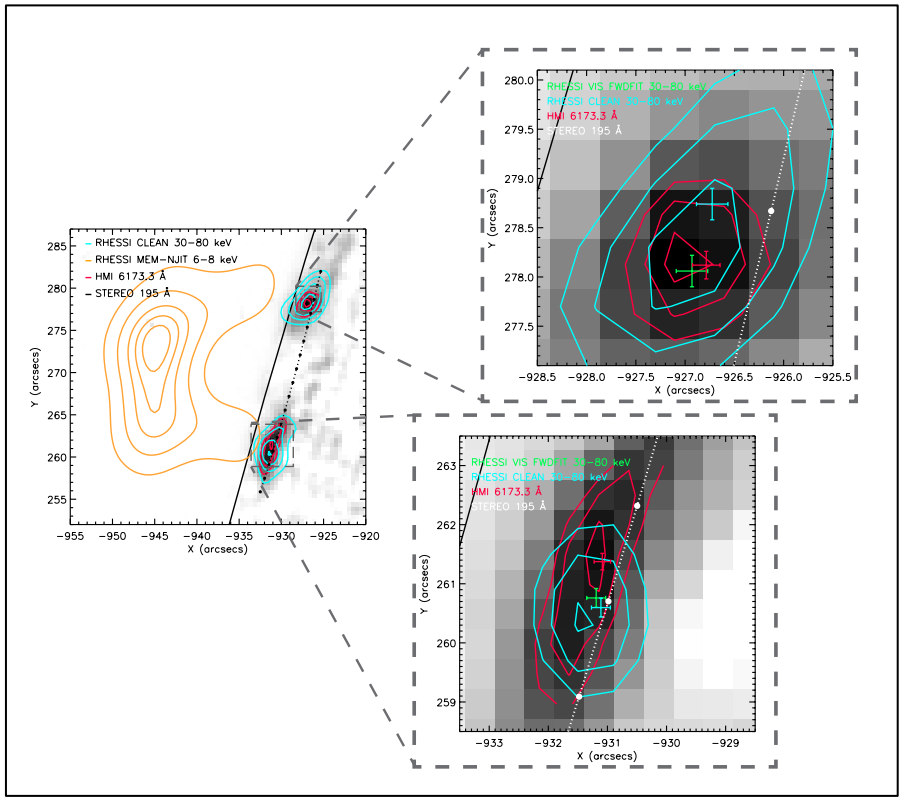
The Ulysses and Yohkoh Stereo Pair (Kane et al., 1998)

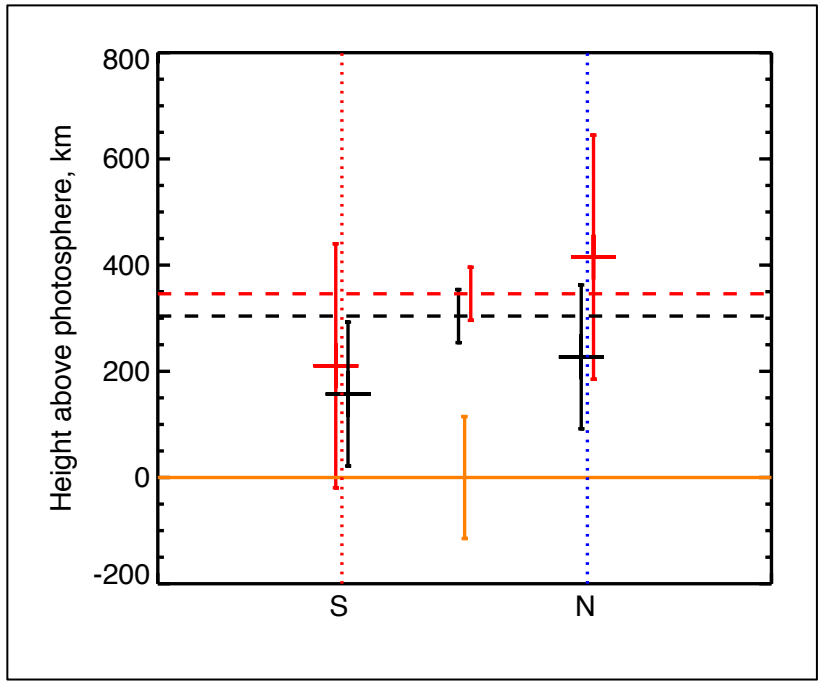




"These and other observations of directivity at higher energies are consistent with a nearly isotropic distribution of energetic electrons in most solar flares."

Where does flare energy appear?





Martínez Oliveros et al., ApJ 753, 26, 2012

The first absolute height determination of hard X-ray and white-light emission shows them *both* to be near or at their respective $\tau = 1$ heights. The 30-80 keV centroid is at 350 +- 170 km.

Summary of discrepancies

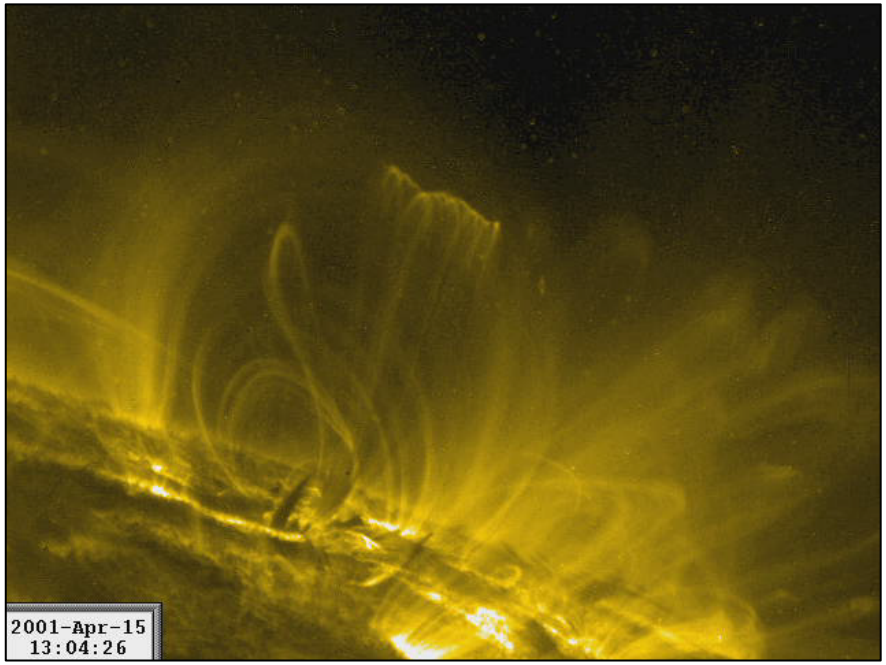
- Flare energy usually appears in the chromosphere and upper photosphere (e.g., Kretzschmar, A&A 530, 284), beyond the range of electrons injected from the corona
- Bremsstrahlung directivity is not detectable

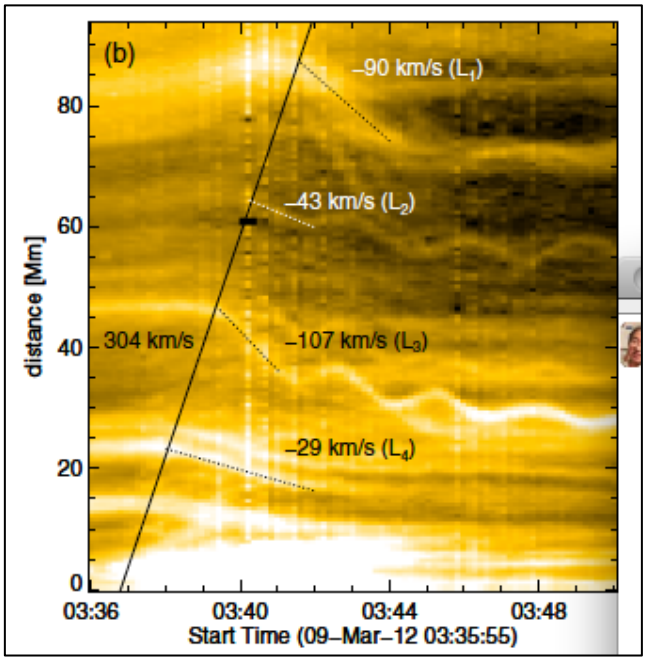
Observational critique of CSHKP

- It does not explain the implosion necessary to release magnetic energy
- Most flares do not have plasmoid ejections; recently AR2192 has produced normal-looking flares up to X3.1 with no eruptive manifestations

- (It does not explain particle acceleration, the locus of flare energy)

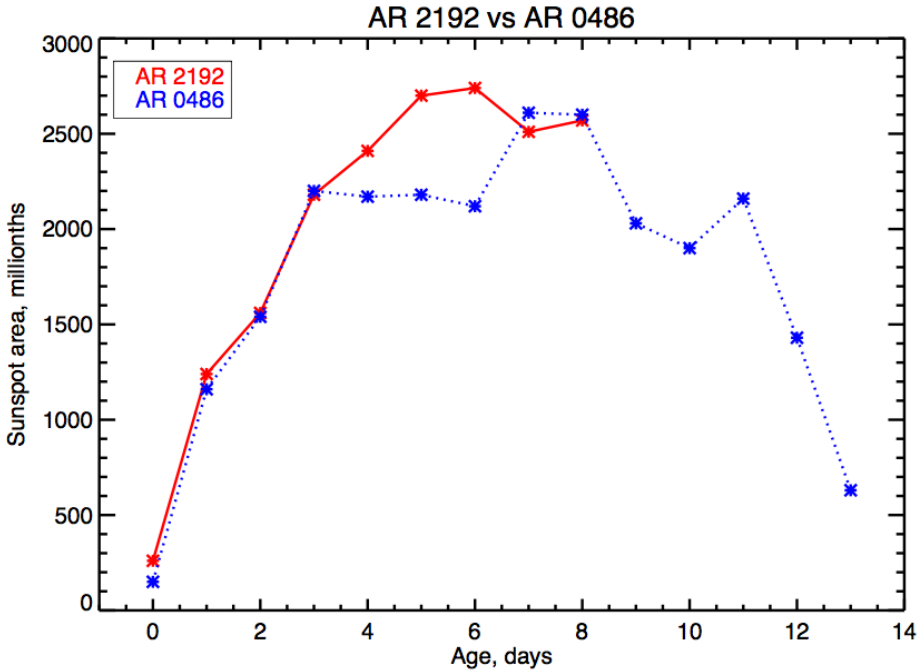
Magnetic implosions

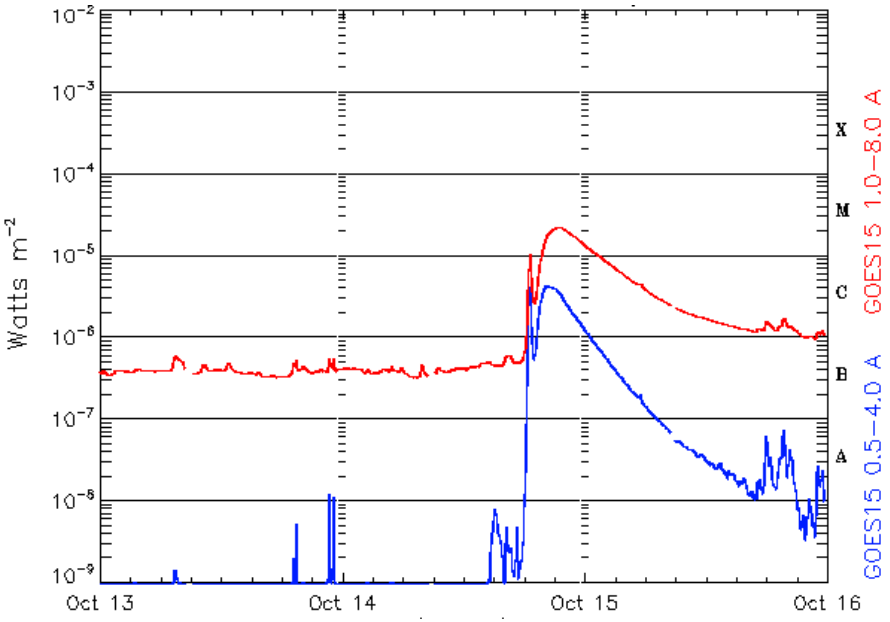




- A magnetic implosion should coincide with energy extraction (Hudson, 2000)
- Considerable literature now exists: see Liu et al. 2012; Simoes et al. 2013 (right panel here)
- Note possibility of implosive action starting at lower altitude

AR2192: big flares, no CMEs





http://sprg.ssl.berkeley.edu/~tohban/wiki/index.php/RHESSI_Science_Nuggets

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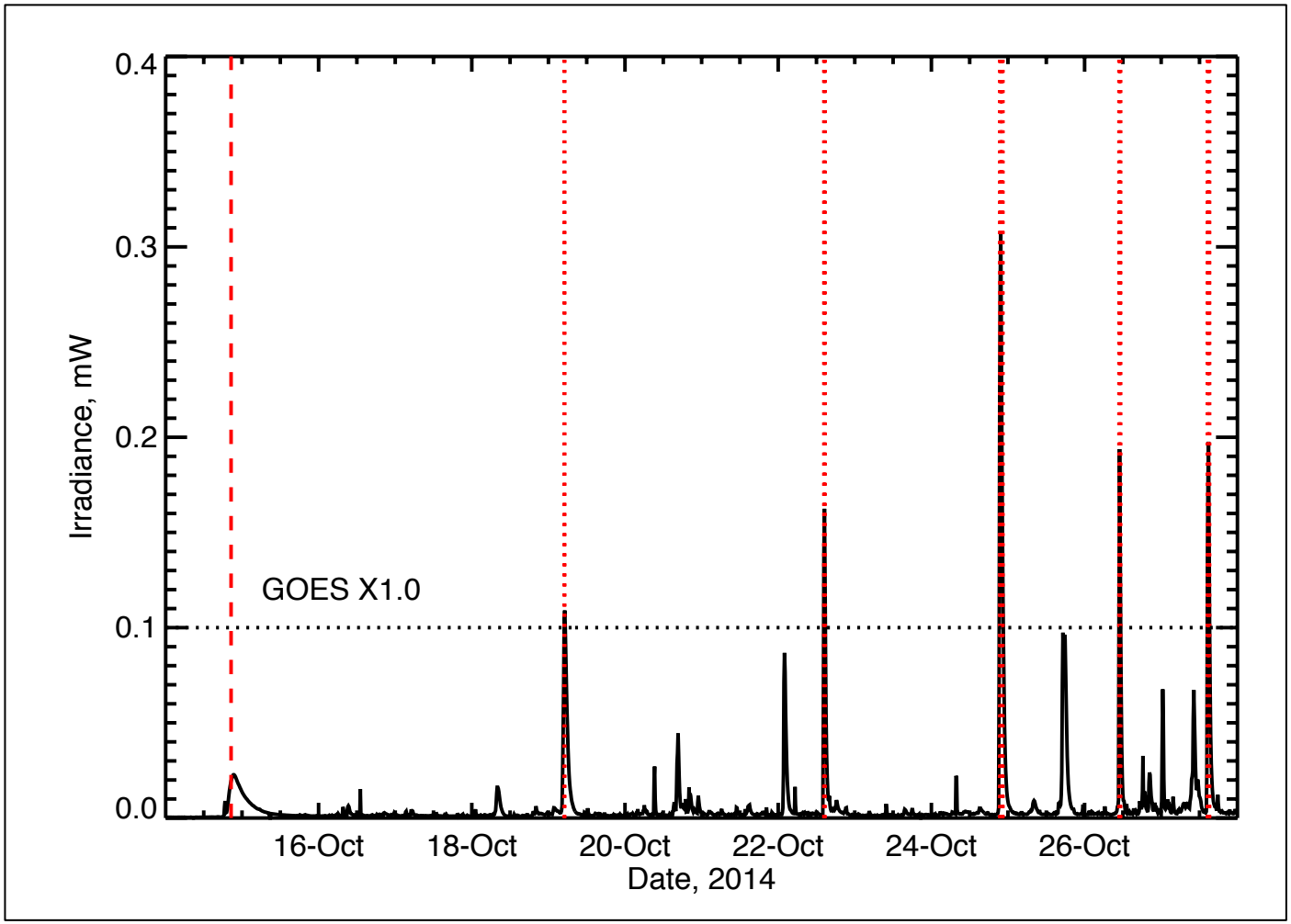
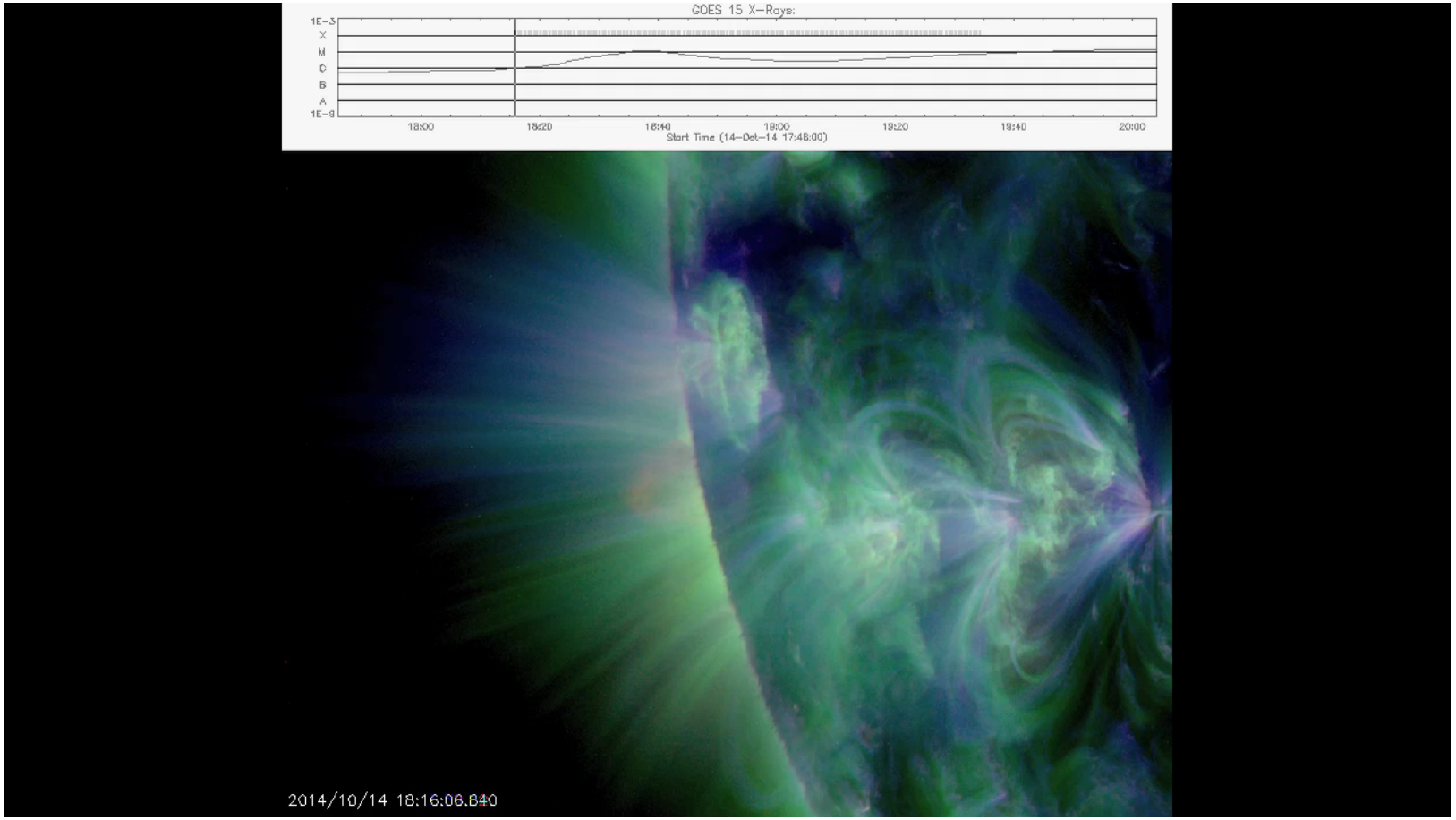
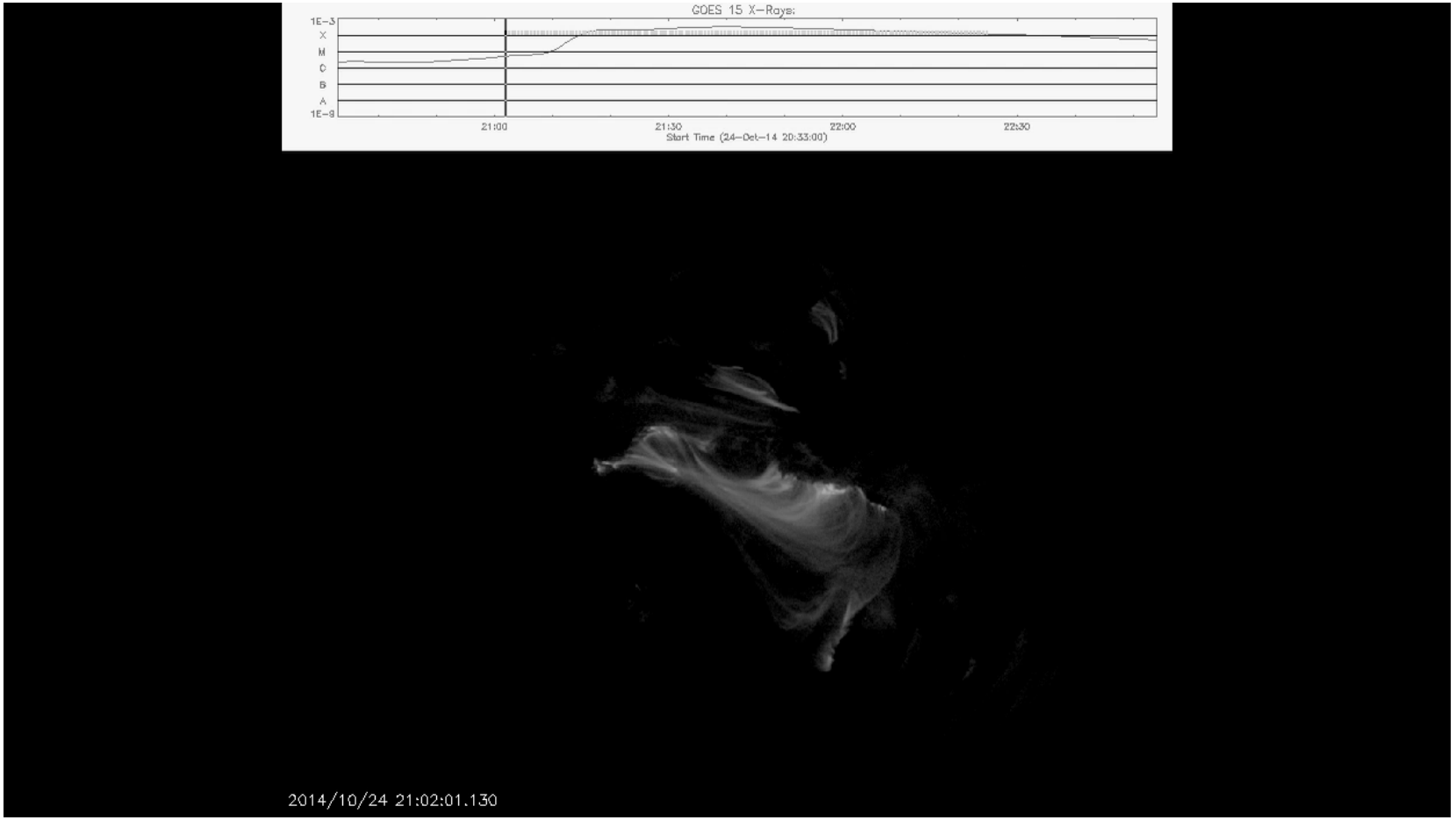


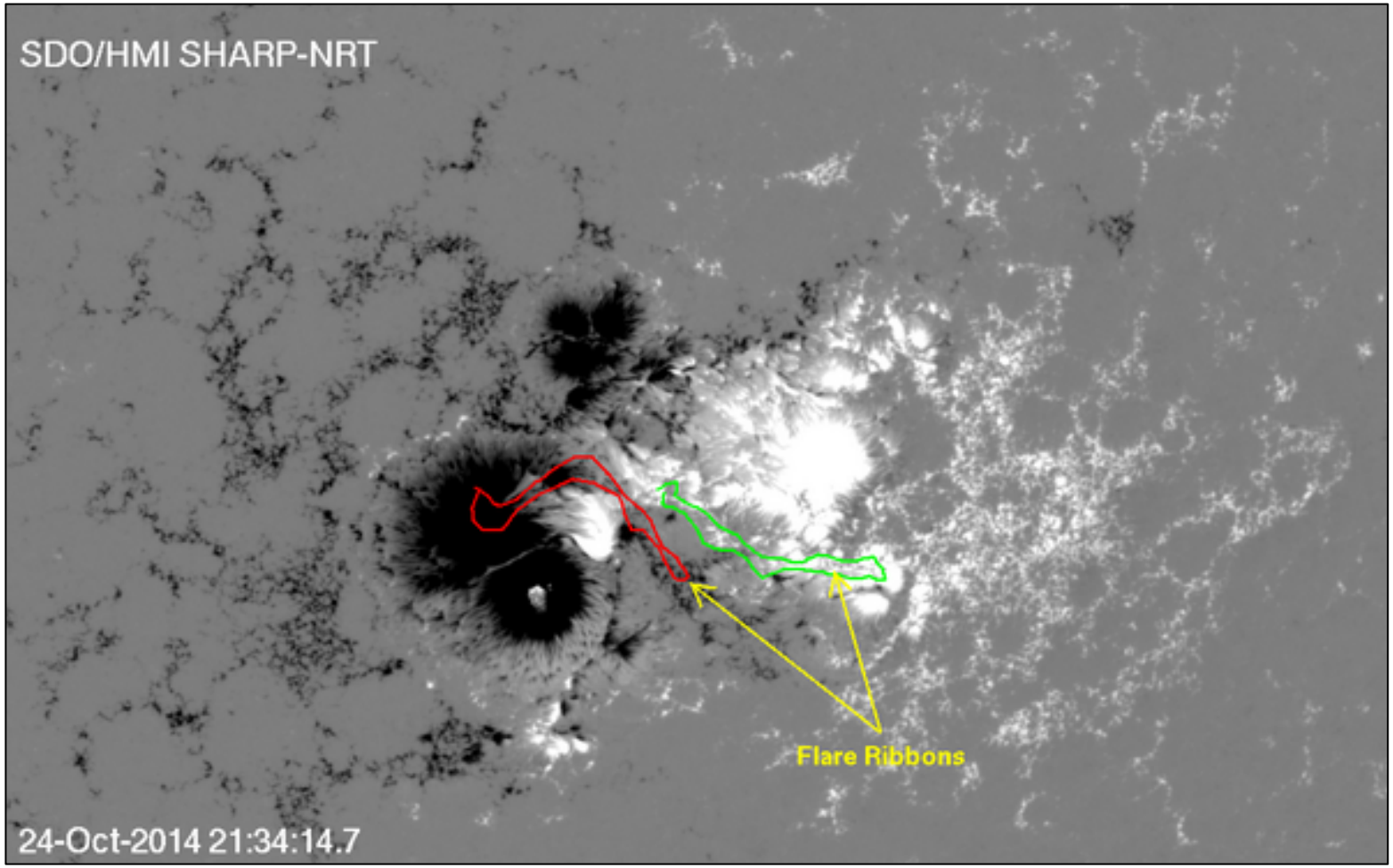
First event in AR2192



X3.1 event in AR2192



AR2192: big flares, no CMEs



Courtesy N. V. Nitta

Summary of discrepancies

- The implosion, the true source of energy, is not hinted at in CSHKP cartoons
- Major CMEless flares (SOL2014-10-24 X3.1) look like normal two-ribbon flares, but do not show many of the expected features:
  - No cusp
  - No large-scale current sheet
  - No CME or other ejection
  - No plasmoid
  - No shock signatures
  - No coronal radio bursts

Conclusions

- Our standard, very old, cartoons are falling short of reality for global flare/CME physics
- We must work as closely as possible with new observations