Science With the Extreme-ultraviolet Spectrometer (EIS) on Solar-B

by

G. A. Doschek (with contributions from Harry Warren)

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Solar-B Extreme-Ultraviolet Imaging Spectrometer (EIS)

- **EIS reveals the dynamics, temperature, density, and composition of the emitting plasma, information crucial for understanding the physics of the solar atmosphere.**
- **Spectra are obtained with high spatial resolution (~ 730 km), i.e., spectra at many locations within an entire solar structure can be recorded.**
- **Spectra are obtained with sufficient time resolution (seconds) to determine physical parameters as a function of position within magnetic loops without significant ambiguity due to temporal changes within the structures.**
- **Spectra can be accurately related to images obtained from the Solar-B White Light and X-Ray Telescopes, for context purposes.**
- ***EIS is the first EUV solar spectrometer capable of obtaining high spectral resolution data with both high spatial and temporal resolution.***

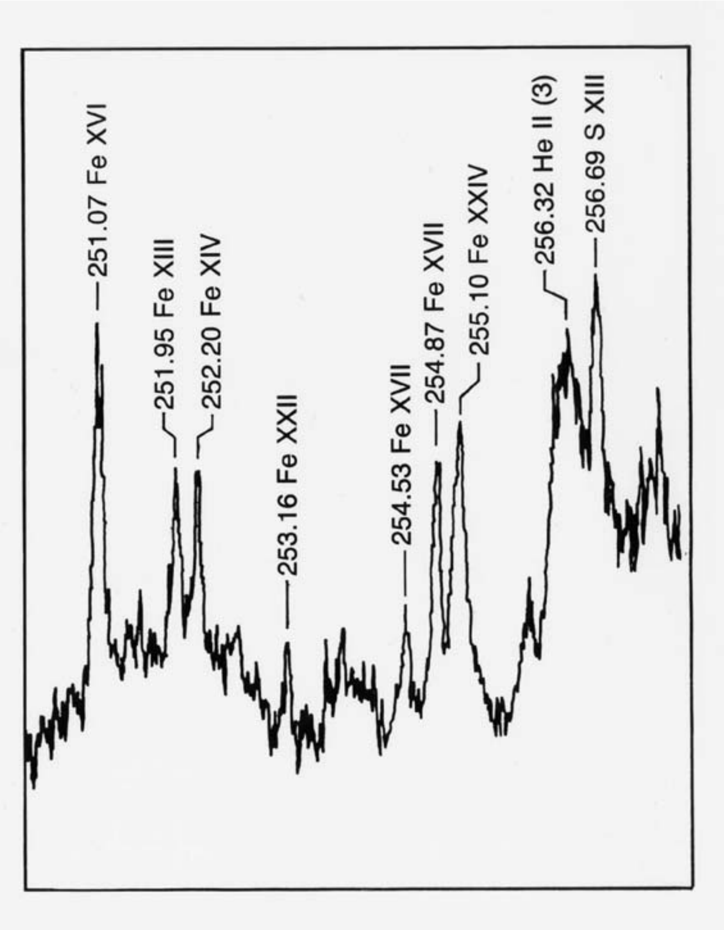
EIS Spatial and Spectral resolution

- **EIS**
  - **Spatial resolution = 2”, 1” pixels**
  - **Spectral resolution = 0.0223 Å/pixel**

- **SERTS**
  - **Spatial resolution = 5”**
  - **Spectral resolution = 0.055 Å in first order, 0.030 Å in second order**

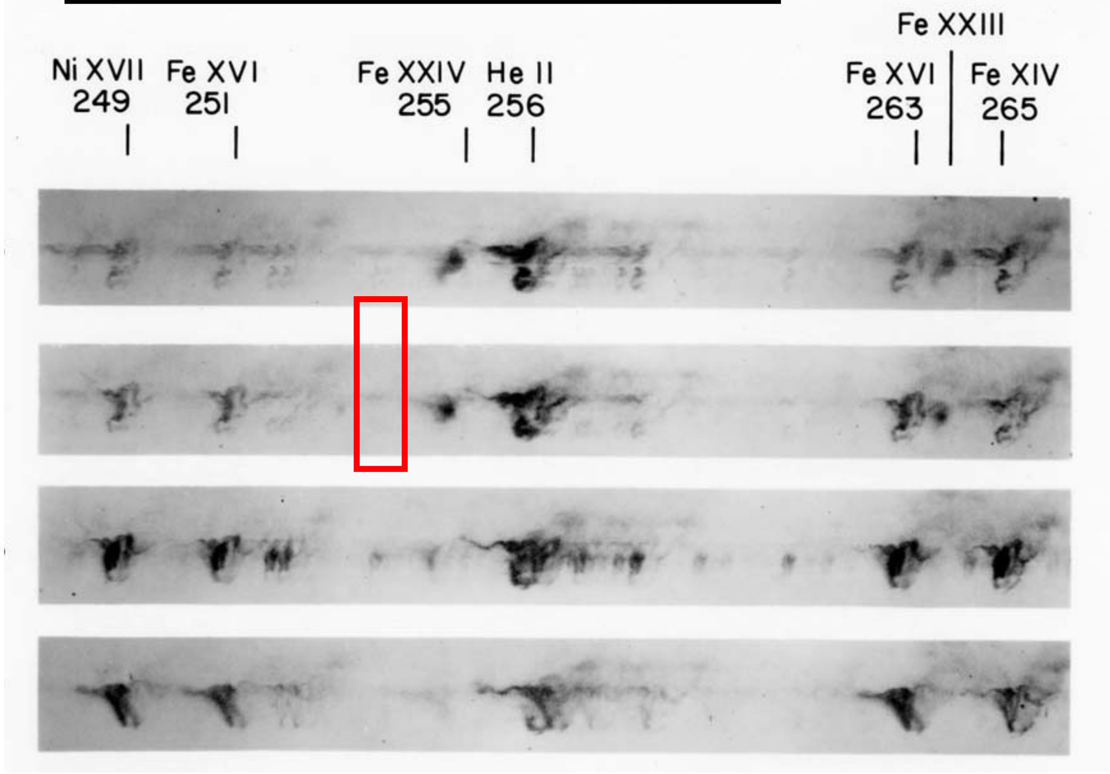
- **Skylab**
  - **Spatial resolution = 2-3”**
  - **Spectral resolution = 0.0223 Å/2” spatial resolution element**

EIS: The Use of Slits and Slots



Slit spectra give line profiles

Solar M3 flare time sequence



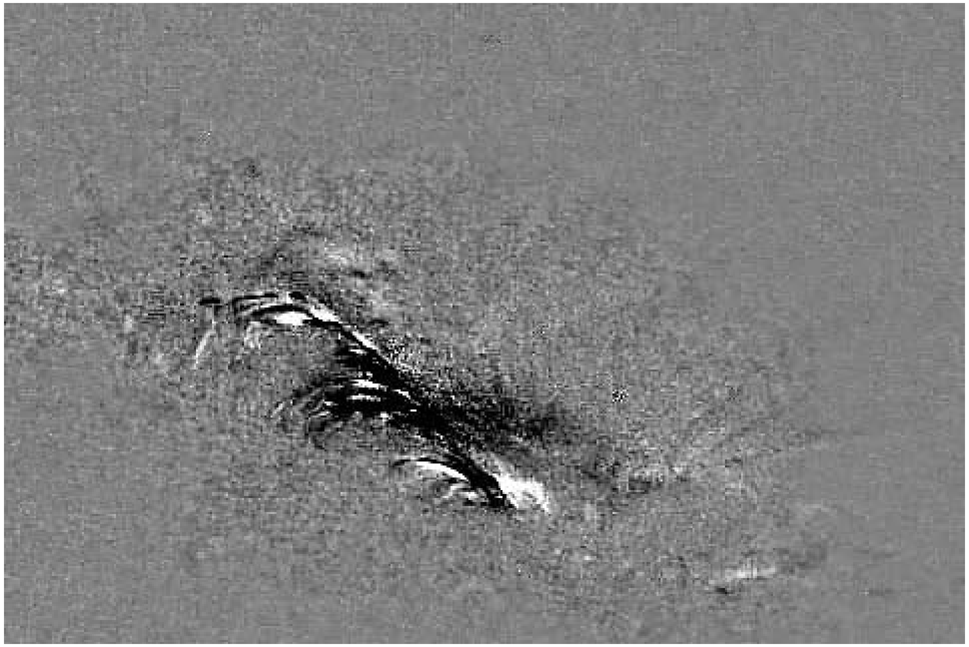
***Skylab* flare spectral images**
and EIS 40” wide slot

Example of EIS Science: Solar Flares

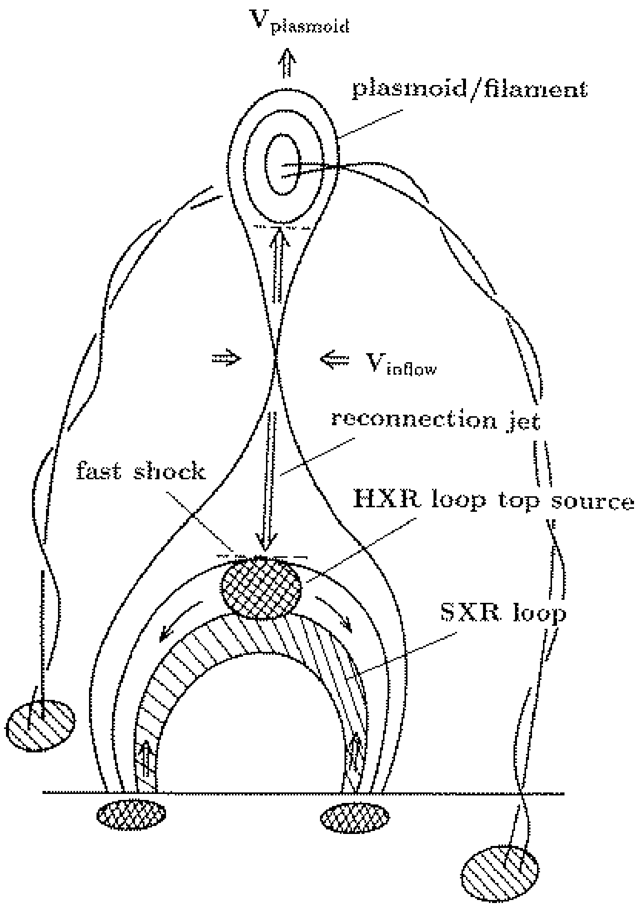
- Test the magnetic reconnection model of solar flares
- Understand the structure of multi-million degree flare loops. Why are there confined bright regions at the tops of loops? Specifically, what is the extent of their boundary regions?
- Resolve the apparent discrepancies between numerical simulations of flare loops and observations of multimillion degree upflows due to chromospheric evaporation.

The Elusive Reconnection Region

- **Observe motions of ejecta and inflows above arcade**
  - **Requires cooler lines and longer exposures – summing of images**



From Sheeley, Warren, and Wang, ApJ, 2004



From Shibata et al., ApJ, 1995

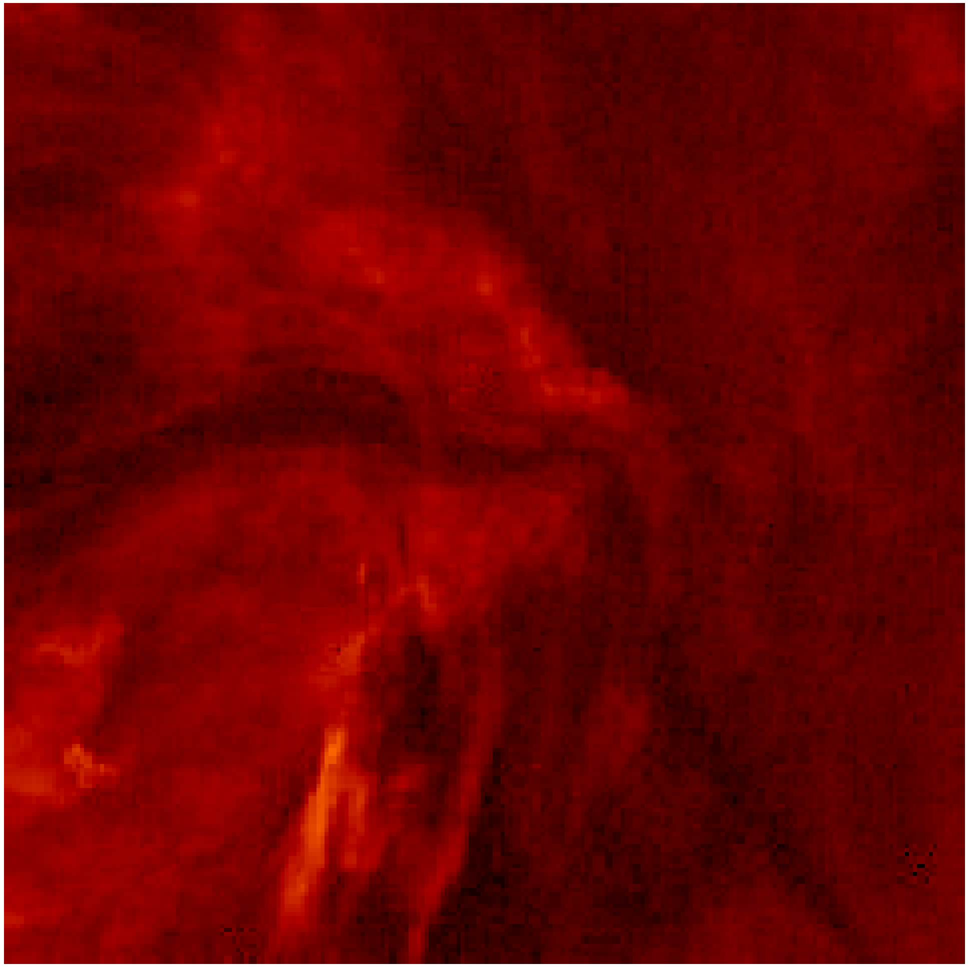
Images of Multi-million Degree Flare Loops

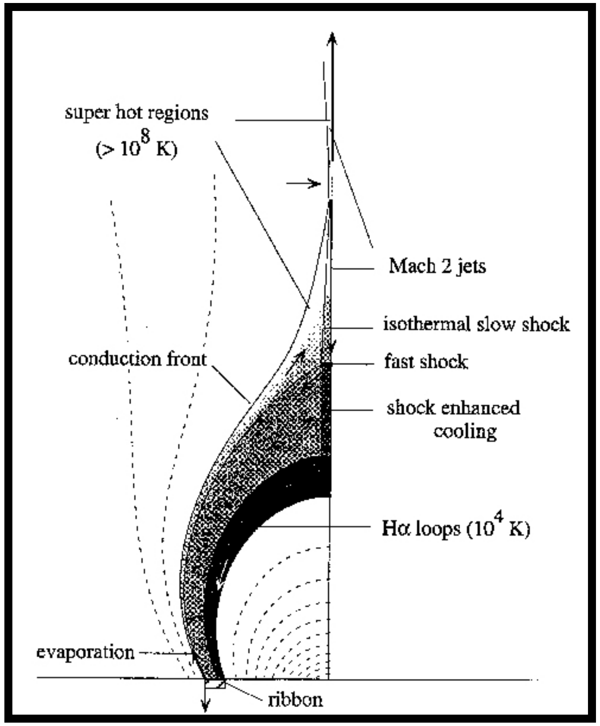
- **Do flare loops at temperatures of 12-25 MK look like what we expect???**
  - **No, they don’t, but as they cool to 1-3 MK they look more and more like respectable 1D loops should.**

  TRACE observations confirm the gross flare loop morphology seen by *Yohkoh*; EIS will enable the detailed temperature structure of flare loops to be determined.

Solar Flare Reconnection Model

Solar flare
45,000 km

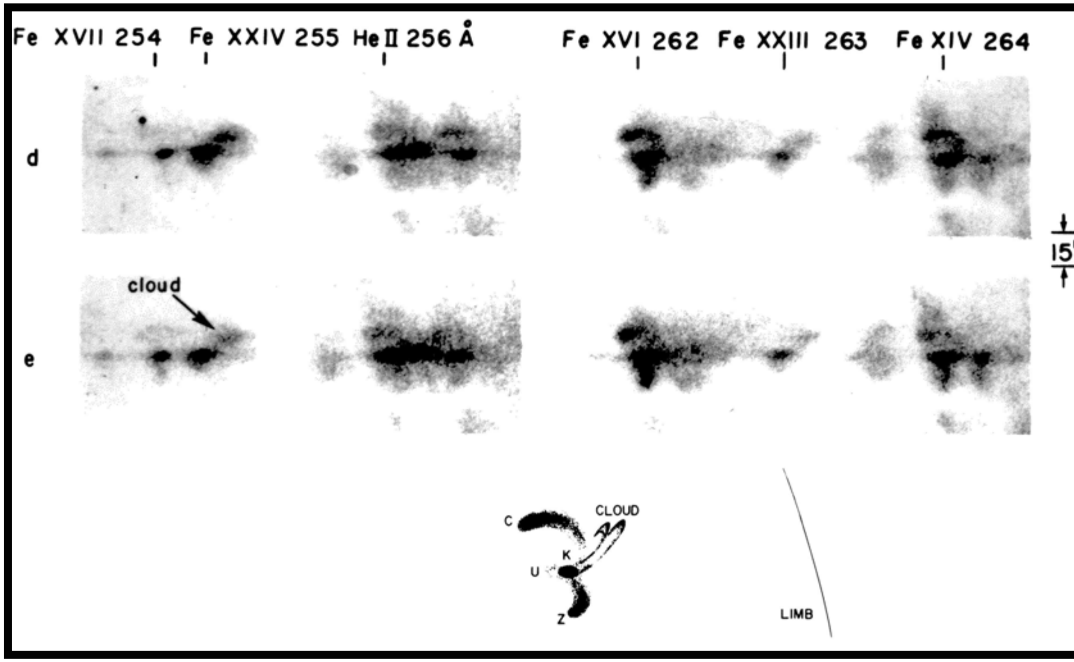


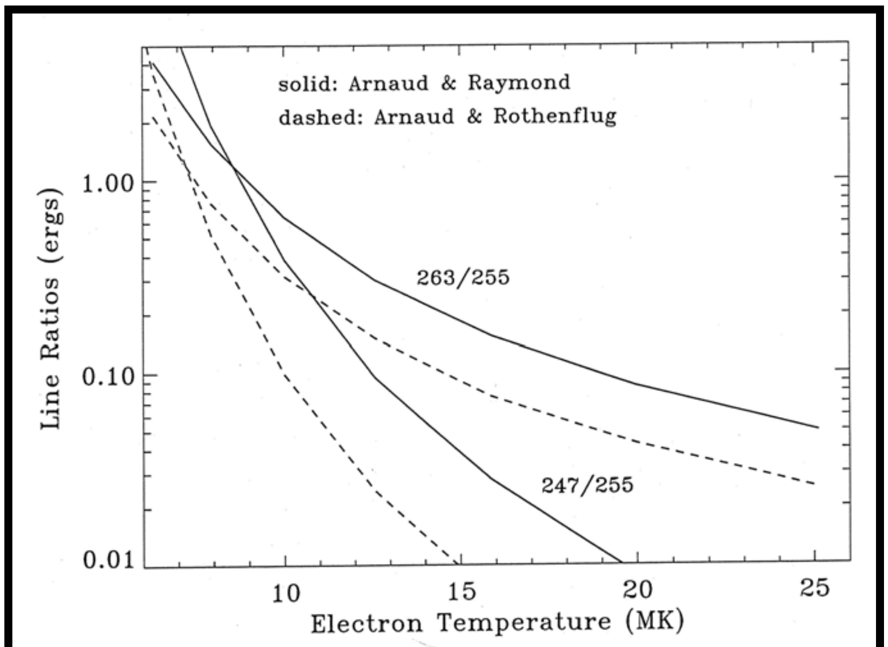


This schematic flare model provides theoretical guidance for analyzing solar flare data.

FLARE STRUCTURE
EIS will enable the flare structure and distribution of physical parameters such as temperature in flare loops to be measured.

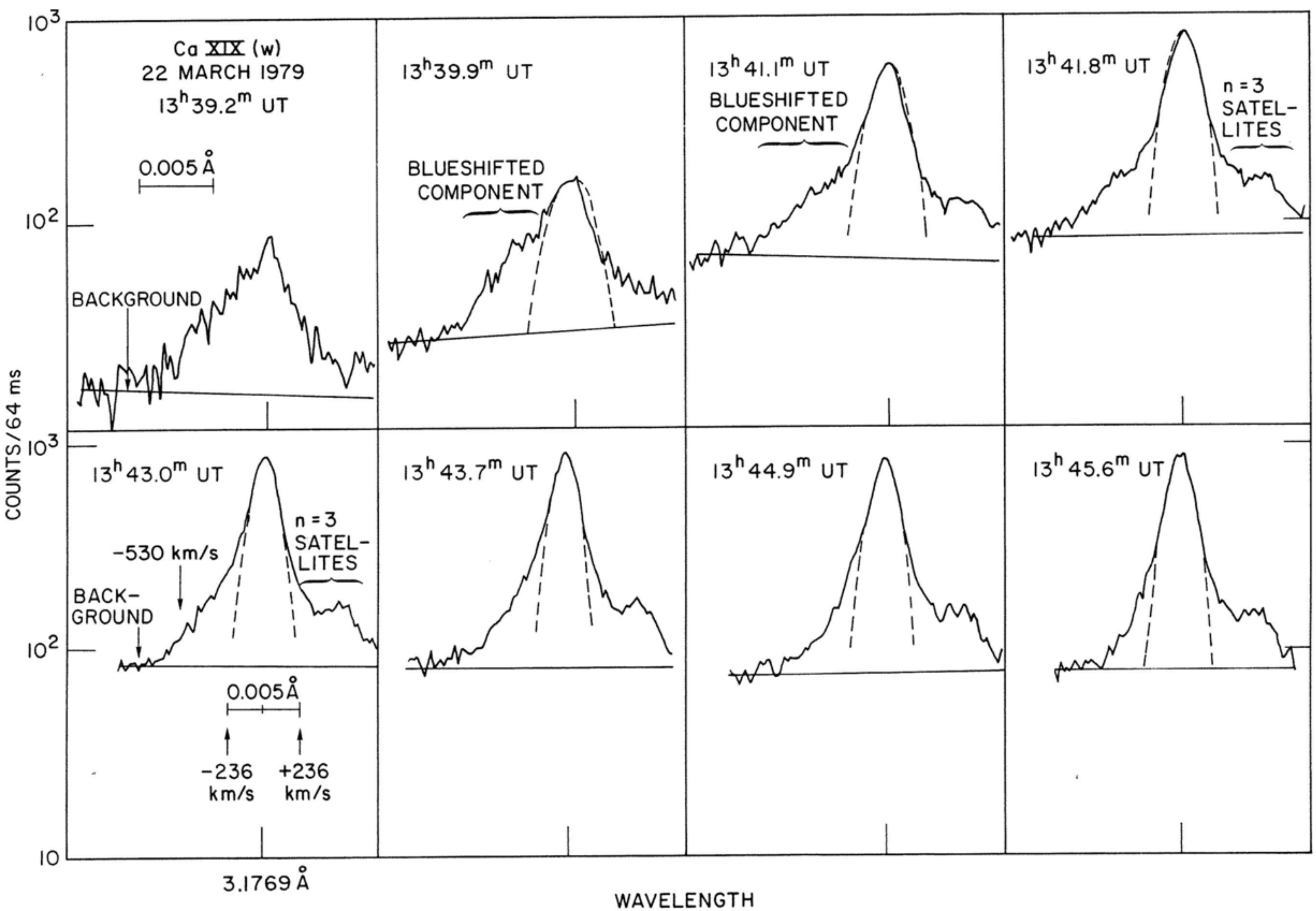
Skylab **imaging spectra**





Spectral line intensity ratios of Fe XXIII/Fe XXIV (263/255) and Fe XXII/Fe XXIV (247/255) will allow the spatial extent of the bright knot boundaries to be determined.

Chromospheric Evaporation: Ca XIX X-ray Spectra

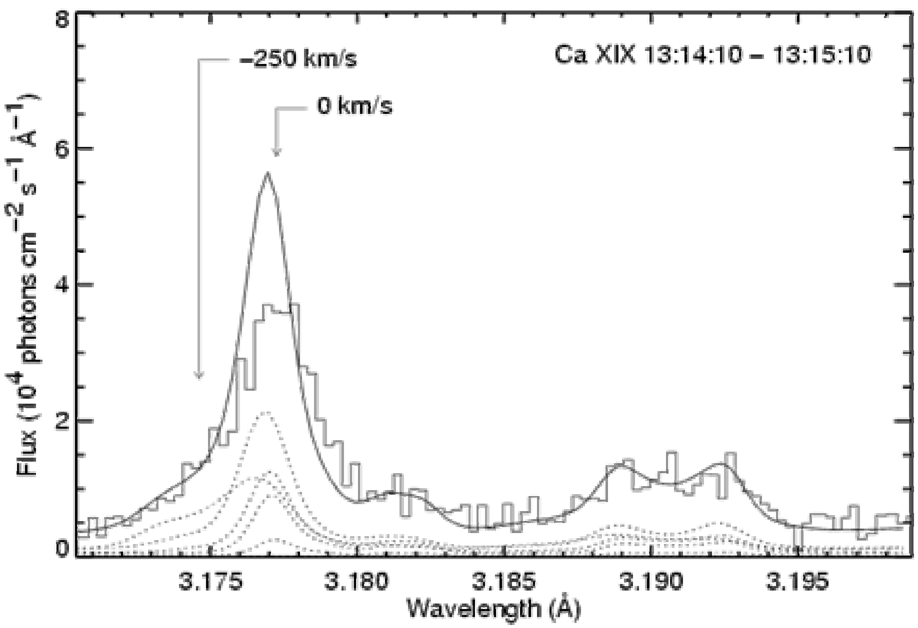


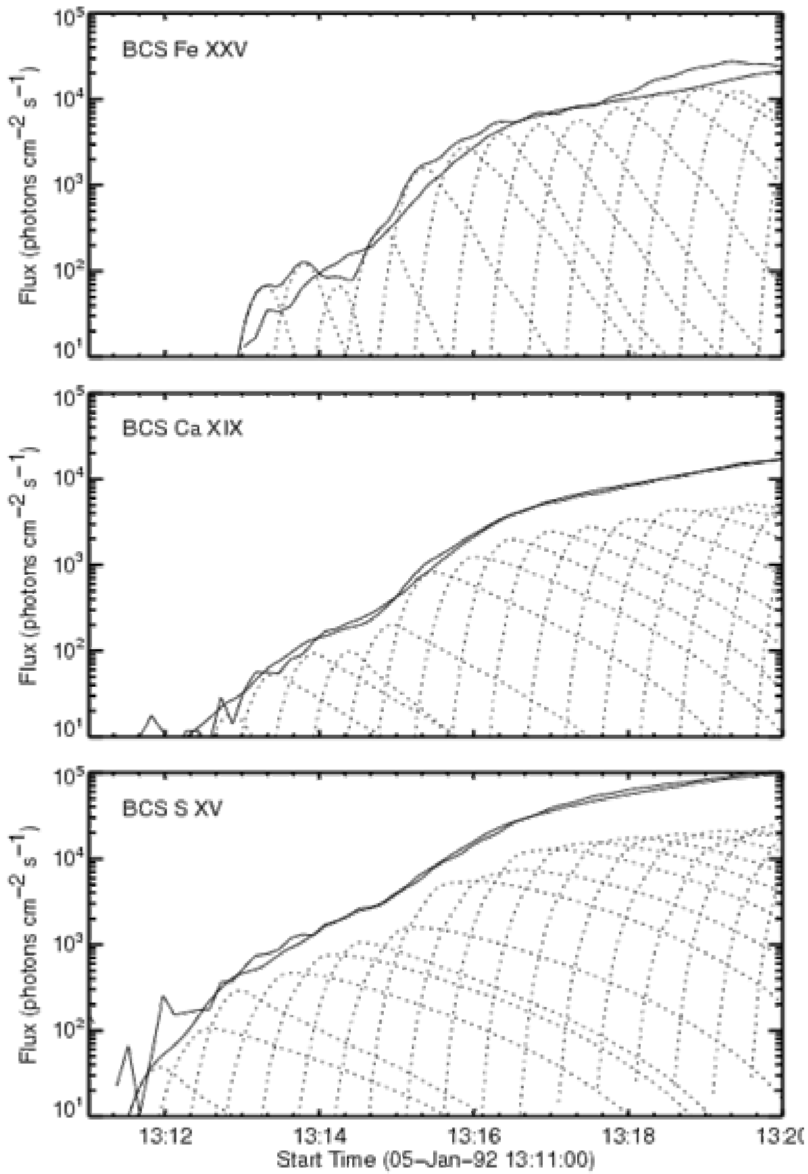
A Multi-Thread Flare Loop Model

- **The overall soft X-ray magnetic flare envelop is assumed to be composed of sub-resolution magnetic "threads". Idea due to Hori, Takaaki, Kosugi, & Shibata (ApJ, 500, 492 (1998)).**
- **The threads are modeled as individual flare loops using the NRL 1D solar flux tube model.**
- **The flare onset is modeled as a succession of independently heated threads.**
- **The length of the flare loop is determined by observations of the overall magnetic envelop.**
- **The energy deposited in each thread and its cross-sectional area are related to the *GOES* fluxes (Warren & Antiochos 1994). The energy in each successively heated thread is determined such that the X-ray flux matches the *GOES* light curves.**
- **The BCS spectrometers on *Yohkoh* serve as a completely independent test of the model.**
- ***The BCS data support the multi-thread model (Warren & Doschek 2005, ApJ, 618, L157).***

A Multi-Thread Flare Loop Simulation

- **Observe evolution and distribution of multi-temperature plasma**
  - **Requires images that span 10^4 – 10^7 K.**





From Warren & Doschek, ApJ, 2005

One Flare Observing Procedure

- Use 250” slot, center EIS slot on magnetic neutral line of a magnetically complex active region.
- Use EIS or XRT flare trigger to signify onset of a flare.
- Select eight wavelength windows of 2.5’x2.5’ in size, in spectral lines of Fe XXIV (192, 255), Fe XXIII (263), FeXXII (247), Ca XVII (192), Fe XV (284), Fe XII (195), and He II (256).
- Readout windows in 10s time intervals for 0.5 hours after flare onset.
- Obtain good data sets for both disk and limb events.

Data Reduction and Analysis Program

- **Co-register monochromatic flare images to within 1”**
  - **Optical properties of EIS**
  - **Context images (e.g., Fe XII), and XRT images**
  - **Auto-correlation techniques**
- **Determine structure of flare and physical parameters (e.g., temperature) from the data**
  - **EIS point spread function, filling factors**
- **Comparison of results with theoretical numerical simulations**
  - **NRL 1D Dynamic Flux Tube Model, NRL ARMS Code**
  - **Modifications to numerical simulation codes**

Questions

- How do we optimize exposure time?
  - Avoid saturation of bright lines
  - This may lead to underexposure of weak lines
  - Improve signal-to-noise by summing?

- How do we optimize cadence?
  - We want many windows and high cadence
  - Telemetry is limited
  - Image compression?