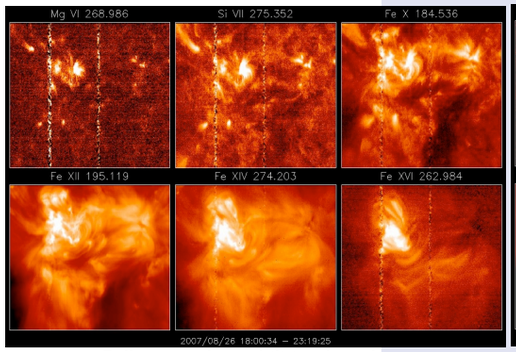
Exploiting EIS/Hinode Imaging Diagnostic Capabilities

Ignacio Ugarte-Urra[1,2] & Harry P. Warren[1]
[1]Naval Research Laboratory, [2]George Mason University

Using a wide slit, also called slot, the Extreme-ultraviolet Imaging Spectrometer, on-board Hinode, is capable of obtaining relatively fast (1-3 min) simultaneous monochromatic images of various spectral lines with different formation temperatures ranging 0.4-3 MK. This mode allows us to study morphology and dynamics of solar coronal and transition region structures across the temperature spectrum in a similar way to an EUV imager. This is achieved at the expense of spectral resolution. In this paper we investigate the plasma diagnostic capabilities of these spectrally pure images. Wide slit images can be interpreted as a superposition of simultaneous narrow slit spectra from adjacent solar positions. From the comparison of consecutive narrow slit rasters and wide slit images, we demonstrate that by making simple assumptions it is possible to extract the narrow slit spectra out of the slot images. This encouraging result opens up the door for plasma diagnostics, like electron density from spectral line ratios and differential emission measure analysis, for solar dynamic events.

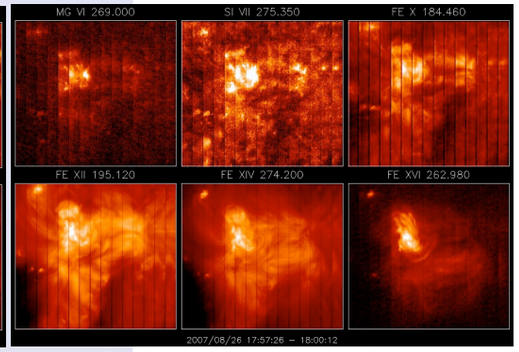
EIS/Hinode.
Two modes of observation*
Same target.

1" slit
FOV: 460x384
Total time: 5h20m



Full spectral capabilities, but slow

40" slit
FOV: 600x512
Total time: 3m

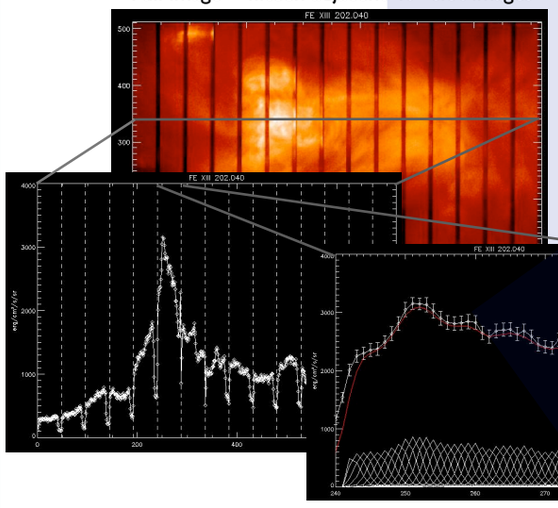


Fast, but loss of spectral resolution

Is there an intermediate performance?
Can we deconvolve the 1" spectra hidden under the 40" slot images?
Yes, we can..
... given reasonable assumptions

Deconvolution

Full image = fifteen adjacent 40" slot images



Model = 40 Gaussians displaced 1 spectral pixel

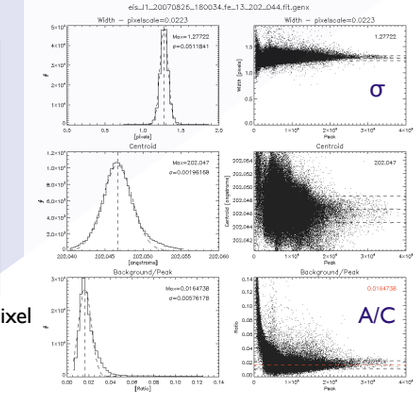
Assumptions

- Slot images intensity cross-section can be modeled with 40 overlapping Gaussians (one per spectral pixel).

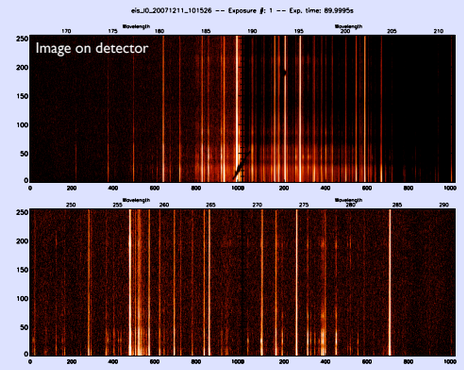
$$I = A\,e^{\frac{-(\lambda-\lambda_0)^2}{2\sigma^2}} + C$$ where C is a constant continuum

- Same spectral width for all Gaussians (implicit: same thermal, non-thermal and instrumental width). Fixed σ.

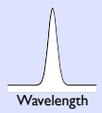
- No Doppler shift displacements allowed. Fixed λ_0.



* EIS/Hinode: Two modes of observation

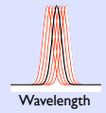


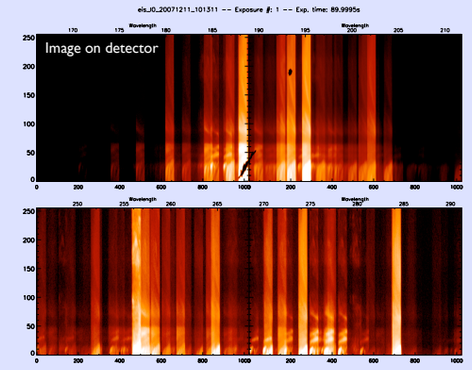
1" slit



vs

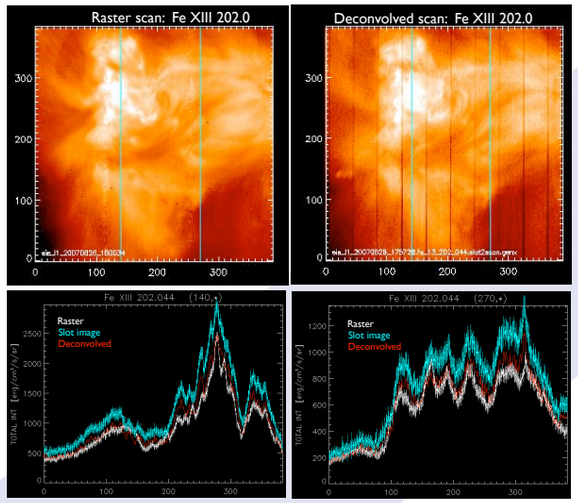
40" slit





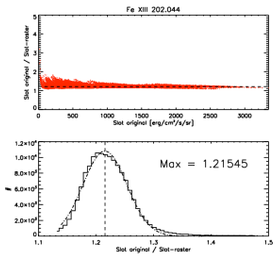
Spectra from neighboring solar areas overlap in spectral direction

Intensities: raster vs deconvolution



Allowing for time dependent intensity variations, the deconvolution returns intensities consistent with those of a 1" slit raster taken immediately after the slot scan.

The ratio of the original slot image intensities to the deconvolved intensities is weakly dependent on intensity and can be approximated by a constant. This constant can be used to infer the expected intensities from a raster scan without the time consuming deconvolution process.



Summary

EIS slot data is useful in several ways.
Take advantage of it!

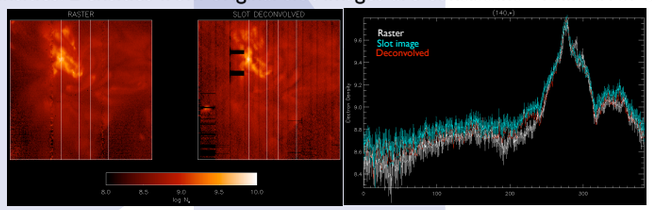
- Imaging: monochromatic and fast. Several spectral lines at a wide range of T (0.4-1.3 MK): Mg VI, Si VII, Fe XII - XVI...
- Diagnostics: slot intensities can be used for density and DEM estimates. No corrections needed on first order.

More info at the EIS Wiki (http://msslxr.mssl.ucl.ac.uk:8080/eiswiki/)
or contacting us: iugarte@ssd5.nrl.navy.mil

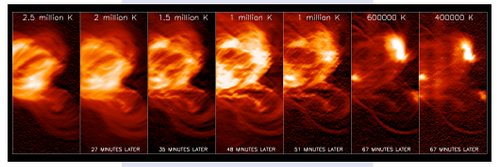
Diagnostics

Electron density

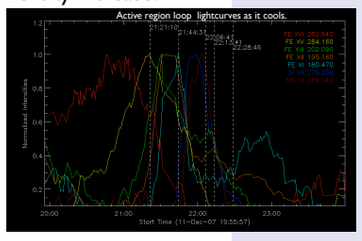
For the same target region, electron density values obtained from the ion ratio (Fe XIII 203.8/202.0) of deconvolved intensities are in agreement with raster intensities. Densities from original slot images are consistent within error bars.

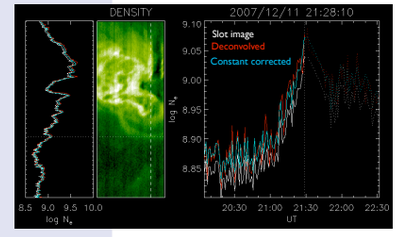


Time evolution:



An observed active region cooling loop (Ugarte-Urra et al. 2009) serves as a test to demonstrate the time dependent diagnostic capabilities of the slot. The loop, observed as a local enhancement of EUV intensities, is a result of an electron density increase.





Differential Emission Measure

Slot intensities can be used to study the temporal variation of the DEM. Original and constant corrected intensities result in consistent DEMs. Cooling is evident.