EUV IMAGING SPECTROMETER
Hinode

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Instrumental line widths for the narrow slits of EIS

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1 Overview

The EIS emission lines have widths that are dominated by an instrumental component, and this instrumental width is found to vary with CCD Y-pixel position. An IDL routine called `eis_slit_width.pro` is provided to EIS users that yields the instrumental width for the 1″ and 2″ slits as a function of CCD Y-pixel number. The present EIS software note describes how the instrumental width was obtained and gives background information related to the instrumental width.

2 Previous work

Korendyke et al. (2006) and Lang et al. (2006) report a pre-launch line width of 0.056 Å for the He II λ256.32 line which we take to be a measure of the instrumental broadening only. Doschek et al. (2007) compared the width of the Fe XII λ193.51 line above the limb in quiet Sun with the width of the Fe XII λ1242 forbidden line observed with *Skylab* and SUMER and came up with the same value for the instrumental width (56 mÅ). Note that this implies the instrumental width is independent of wavelength.

Brown et al. (2008) gave more details on the pre-launch laboratory measurements and cited widths of 47 mÅ for Mg III λ187 in the SW band, and widths of 56 and 58 mÅ for He II λ256 and Ne III λ267, respectively. Correcting for the thermal broadening from the 10^4 K plasma within the calibration lamp yields instrumental widths of 47, 55 and 57 mÅ for the three lines. Based on the solar spectra obtained with EIS, Brown et al. (2008) estimate an instrumental width of 54 mÅ for the SW band based on the Fe X λ190.04 width, and widths of around 55 mÅ for the LW band based on several lines. The conclusion is that the instrumental width for the SW band has become a little worse since launch, and the instrumental widths should be taken as 54 mÅ and 55 mÅ for the SW and LW bands, respectively.

None of these works considered the variation of the line width with Y-position on the EIS CCD.

3 EIS field of view

The EIS CCDs are 1024 pixels high (solar-Y direction) and the EIS slit, projected onto the CCD, extends for almost the complete height of the CCD. On board software restrictions prevent the entire CCD height from being obtained in a single exposure – the maximum size is 512 pixels. In addition, up to April 2008 software restrictions allowed only the central 512 pixels to be downloaded, i.e., pixels from 256 to 767. When this restriction was relaxed, the full CCD height could be observed by using two exposures, one covering the bottom of the CCD, the other covering the top of the CCD.

The position of an EIS exposure on the CCD is usually determined by the pointing selected by the EIS Chief Observer (CO). That is, the EIS planning software takes a requested solar-Y pointing and converts it to a pixel position on the CCD. The CO can manually choose where the exposure appears on the CCD by specifying a YIP (Y Initial Position) value, which is the pixel corresponding to the bottom of the EIS raster. YIP takes a value between 1 and 1023. The very bottom pixel, YIP=0, can not be selected.

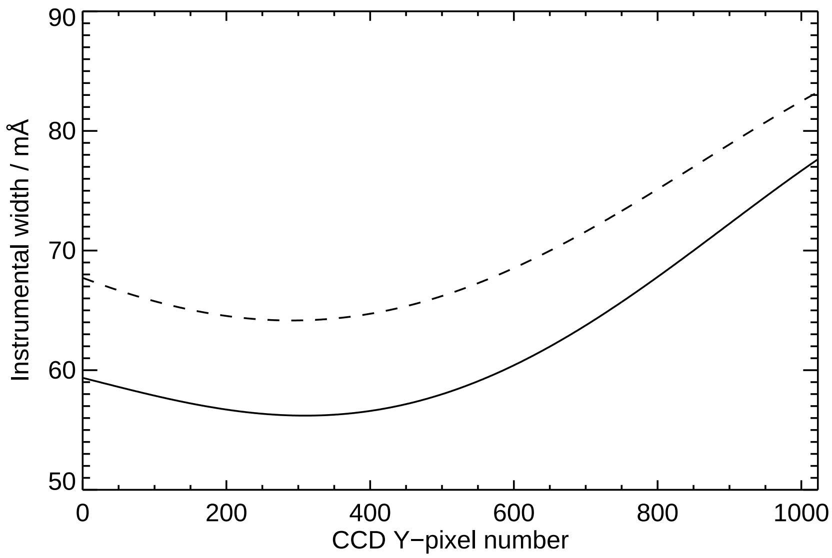

Figure 1: Output from the routine eis_slit_width showing the variation of the instrumental widths with CCD Y-pixel position for the 1″ (solid line) and 2″ (dashed line) slits.

Normally EIS observes the same region observed by SOT. The center of the SOT field of view is approximately YIP=560. Therefore an EIS raster 200 pixels high centered on the SOT field of view will extend from YIP=460 to YIP=659 (approximately).

As shown in the following sections, the EIS instrumental line width has its minimum around YIP=200–300, and so this is where the instrumental width is smallest.

4 The routine EIS_SLIT_WIDTH

The routine `eis_slit_width.pro` is available within the EIS branch of *Solarsoft* and yields the instrumental width, in Å, as follows:

```
IDL> wid=eis_slit_width(ypix,slit_ind=slit_ind)
```

The input YPIX is the CCD Y-pixel number, which varies from 0 to 1023 (bottom to top of the CCD). The optional input SLIT_IND allows the EIS slit to be specified: 0 for the 1″ slit (the default), and 2 for the 2″ slit.

The widths returned by `eis_slit_width.pro` (as of 2011 October) are shown in Fig. 1.

For a particular data-set, the CCD Y-pixel values can be obtained from an EIS data object as follows:

```
IDL> yws=obj->getinfo('YWS')
IDL> ny=obj->getinfo('YW')
IDL> ypix=indgen(ny)+yws
```

From an EIS windata structure they are obtained with

```
IDL> yws=windata.hdr.yws
IDL> ny=windata.hdr.yw
IDL> ypix=indgen(ny)+yws
```

If the eis_auto_fit suite of routines is used, then the Gaussian fits to the data are automatically corrected for the instrumental widths with the command:

```
IDL> wid=eis_get_fitdata(fit,/wid)
```

see EIS Software Note No. 16 for more details.

The method for deriving the instrumental widths is described below.

5 Deriving the instrumental widths

The method described here requires measurements of the Fe XII λ193.51 line above the quiet Sun limb at the equator. The observations were obtained with the study CALIB_SLIT_SLOT.

5.1 The CALIB_SLIT_SLOT study

A study, CALIB_SLIT_SLOT (ID 352), was designed to obtain narrow rasters using the 40″, 1″ and 2″ slits and taking the full 512 pixel height in Y. It was intended to be run twice, the first covering the top half of the CCD (Y-pixels 512 to 1023) and the second covering the bottom half (Y-pixels 1 to 512). Each run of CALIB_SLIT_SLOT yields three different rasters. The first is a raster with the 40″ slit which has three scan positions separated by 32″ and an exposure time of 20 s. The second raster is obtained with the 1″ slit, has 15 scan positions and a 40 s exposure time. The third raster uses the 2″ slit, has 15 scan positions and a 20 s exposure time. The two narrow slit rasters use the same line list, consisting of the three core lines, Fe VIII λ185.21, Fe XII λ193.51, Fe XIII $\lambda\lambda$202.04, 203.82, Si VII λ275.35 and Fe XV λ284.16.

The dates on which CALIB_SLIT_SLOT observed both the top and bottom of the CCD are given in Table 1. For the period Nov.–Dec. 2009 the study was run in quiet off-limb regions above the equator.

Table 1: CALIB_SLIT_SLOT runs.

Date	Location	Comment
5-Nov-2009	East limb	
13-Nov-2009	East limb	AR loops in north of raster?
19-Nov-2009	West limb	
26-Nov-2009	East limb	
11-Dec-2009	West limb	

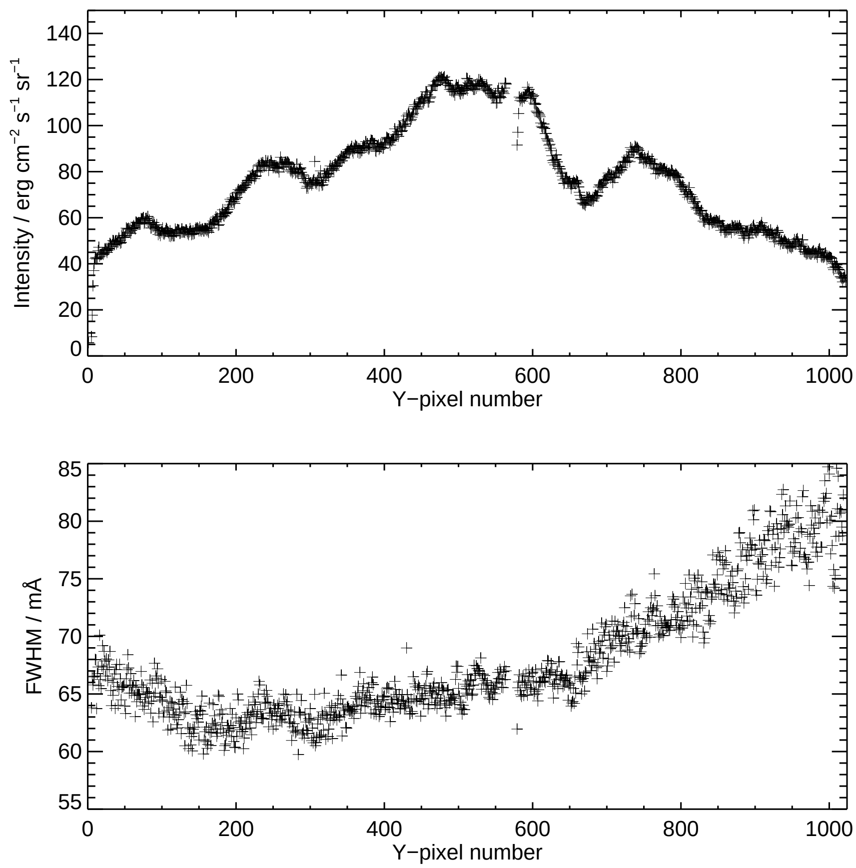

Figure 2: Variation of intensity (upper panel) and full width at half maximum (FWHM; lower panel) over the CCD height for Fe XII $\lambda193.51$, as obtained from the 2009 November 19 CALIB_SLIT_SLOT data-set. Both the intensity and FWHM have been averaged over 15 pixels in the X-direction. The $\lambda193.51$ line is affected by a dust particle on the CCD at Y-pixels 560–580.

An example of the quality of data from CALIB_SLIT_SLOT is shown in Fig. 2, obtained from the 2009 November 19 data-set.

5.2 Method

A single CALIB_SLIT_SLOT data-set is processed with the following steps:

- The $\lambda193.51$ line is fit with a Gaussian at every spatial pixel in both the top and bottom rasters using the routine EIS_AUTO_FIT.
- The line widths are extracted from the fits, and averaged over blocks of 15×16 pixels, leaving a 1D array with 32 elements of line widths as a function of Y-position.
- The top and bottom data-sets are combined to yield a 64 element array of average widths covering the complete CCD height.

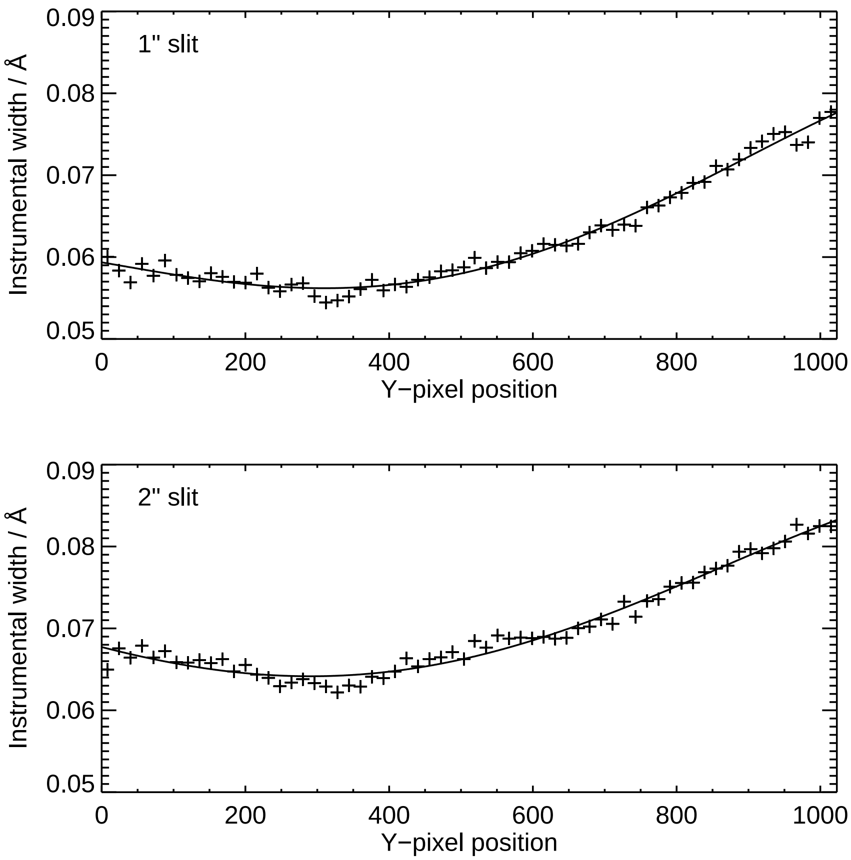

Figure 3: Instrumental widths (crosses) derived from the CALIB_SLIT_SLOT data-sets for the 1″ (top) and 2″ (bottom) slits. The solid curves represent fourth order polynomial fits to the data.

The results from multiple data-sets are then combined by constructing a single 64 element array of widths that contains the minimum width from the data-sets. For example, if the widths at Y-position 10 from three data-sets are 63, 60 and 65 mÅ, then the final array will contain the value 60 mÅ. The idea being that the minimum width will always be closest to the true instrumental width.

The final step is to subtract a thermal width from the widths, and a value of 0.0232 Å is used. This was computed for the Fe XII λ193.51 line by assuming a temperature of $\log T = 6.2$.

With the final 64 element array constructed, a fourth order polynomial is fit to the data-points. The coefficients of this polynomial are then coded into the routine EIS_SLIT_WIDTH.

5.3 Results

The runs of CALIB_SLIT_SLOT from 2009 November 19 and 16, and December 11 were considered the best. The method described above yields the results shown in Fig. 3. The crosses represent the final 64 element arrays obtained from finding the minimum widths across the three data-sets. The solid lines are the polynomial fits to these arrays.

The instrumental widths are estimated to be accurate to about 3 mÅ. Further measurements are required to give improved statistics for determining the widths.

References

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Doschek, G. A., Mariska, J. T., Warren, H. P., et al. 2007, ApJ, 667, L109

Korendyke, C. M., Brown, C. M., Thomas, R. J., et al. 2006, Appl. Optics, 45, 8674

Lang, J., Kent, B. J., Paustian, W., et al., 2006, Appl. Optics, 45, 8689