EUV IMAGING SPECTROMETER
Hinode

EIS SOFTWARE NOTE No. 3

Version 1.0 21 July 2011

Spatial Y-offsets between different wavelengths (spectrum tilt and CCD offset)

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1 Overview

Images obtained in different EIS emission lines occur at different Y-positions on the EIS detectors. There are two instrumental effects that contribute to this:

1. a tilt of the grating dispersion axis relative to the CCD axes; and
2. a spatial offset in Y between the two CCDs of EIS.

The offsets are measured using the EIS spectra themselves, but the measurements are made difficult by the fact that solar features appear different in the various emission lines observed by EIS. This document summarizes measurements that have been made of the offsets and presents an IDL routine called `eis_ccd_offset.pro` that is used to give the offset for any wavelength.

2 Basic information and notation

EIS has a single grating that disperses light onto two CCDs, one for the short wavelength channel (SW; 166–212 Å) and one for the long wavelength channel (LW; 246–291 Å).

Although the grating tilt is the same for both CCDs, the two CCDs could be tilted relative to each other, meaning that the spectra observed on the two CCDs could have a different tilt. We therefore refer to the observed effect (as seen on the CCDs) as "spectrum tilt", with the two CCDs potentially having different spectrum tilts. Alternative names for this effect are "spectrum rotation", "grating tilt" and "slit slant". Note that the effect is completely different to the "slit tilt" which is described in EIS Software Note No. 4 and is due to a slight mis-alignment between the EIS slits and the CCDs.

3 Definitions

The spectrum tilt, T, is defined as:

$$T = \frac{Y_2 - Y_1}{\lambda_2 - \lambda_1} \tag{1}$$

where Y is the Y-pixel position of an observed feature on the detector, and λ is the wavelength in which the feature is observed.

He II λ256.32 is taken as the reference line and defined to have a zero Y-offset, and Fe VIII λ185.21 and Si VII λ275.37 are used to define the offset, Δ, between the two CCDs.

Therefore the Y-offset for a general wavelength, λ, is

$$Y = \begin{cases} T_{\rm SW}(\lambda - 185.21) + \Delta & \text{(SW channel)} \\ \\ T_{\rm LW}(\lambda - 256.32) & \text{(LW channel)} \end{cases} \tag{2}$$

In reality, the spectrum tilts found for the two CCDs are very similar and a single tilt value is used for both in the software implementation (Sect. 5).

4 Measurements of Y-offsets

Young et al. (2009) used solar features observed in Fe VIII and Fe XII emission lines to determine the spectrum tilt in the EIS SW channel. The gradient was found to be −0.0792 pixel/Å.

Del Zanna & Ishikawa (2009) found that the Y-offsets between the endpoints of both the SW and LW channels were 3.66 ± 0.20 pixel, after cross-correlating intensities from lines at different wavelengths. These offsets convert to gradients of −0.0802 and −0.0804 pixel/Å for the SW and LW channels, respectively.

Unpublished work of P.R. Young used images formed from Si VII λ275.37 and Fe VIII λ185.21 to determine the spatial offset between the SW and LW channels. An offset of 18.5 Y-pixels between the two lines was found. An example is shown in Fig. 1 where some loop footpoints from an observation from 2009 November 21 23:44 UT are shown. The intensity images from λ275.37 and λ185.21 are usually very similar in appearance, and the contour plot on the right panel shows that excellent spatial alignment between the two images is found after a 18.5 pixel adjustment is made in the Y-direction.

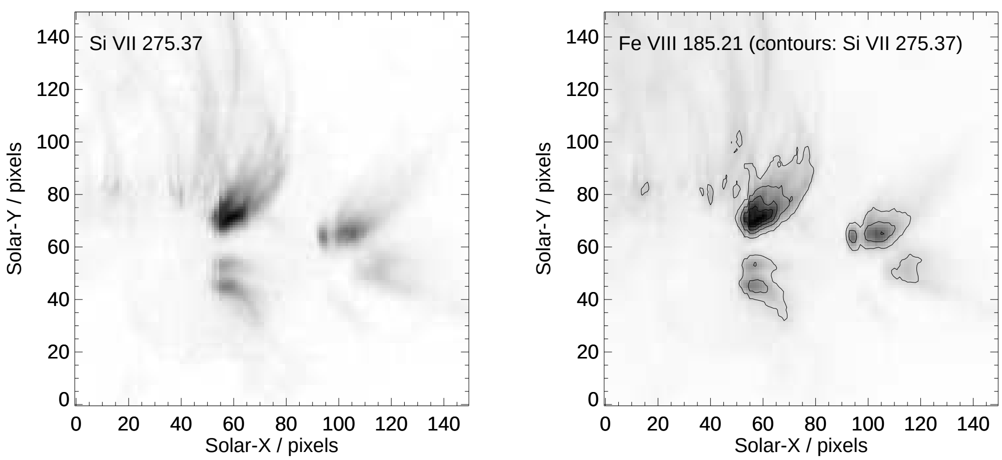

Figure 1: The left panel shows an intensity image formed from Si VII λ275.37, and the right panel an intensity image from Fe VIII λ185.21. A sub-section of the original raster is shown, highlighting a number of loop footpoints. The raster was obtained on 2009 November 21 23:44 UT.

A different approach was applied by Kamio & Hara (2008) who used EIS observations of the Mercury transit of 2006 November 8. Since Mercury is unambiguously the same in all wavelengths (it appears as a small absorption spot against the solar corona), then it can be used to determine the Y-offsets between different wavelengths. Kamio & Hara (2008) used slot observations in a number of lines to determine gradients of −0.0872 and −0.0768 pixel/Å for the SW and LW channels, respectively. The work also yielded the offset between the two CCDs and, expressed as the offset between λ185.21 and λ275.37, a value of 18.5 pixels was found, in excellent agreement with the value of P.R. Young.

5 The IDL routine eis_ccd_offset

This routine is called as

```
IDL> offset=eis_ccd_offset(wavelength)
```

where `wavelength` is specified in angstroms. The offset is given in terms of CCD Y pixels, and the reference wavelength is 256.32 Å, the position of the He II line.

Giving a wavelength of 195.12 Å yields an offset of 16.2 pixels (as of 2011 July 21). This means that a solar feature that emits in both Fe XII and He II will be positioned 16.2 pixels higher, in terms of CCD Y-coordinates, in λ195.12 that it is in He II.

The first version of `eis_ccd_offset` (circa 2008 August) used the spectrum tilt gradient of Young et al. (2009) and assumed that the same gradient applied to the LW channel. The offset between the two CCDs was taken from the 18.5 pixel offset between Si VII λ275.37 and Fe VIII λ185.21. Although Del Zanna & Ishikawa (2009) and Kamio & Hara (2008) found slightly different gradients, as described above, the differences amount to a small fraction of a Y-pixel and so the original formulation of the Y-offset is retained.

Correctly accounting for the Y-offset between different wavelengths can be very important for certain EIS analyzes. In particular, the derivation of densities from lines separated in wavelength, and the creation of full CCD spectra of compact solar features. Some EIS software routines automatically correct for the Y-offset. For example, the routine `eis_mask_spectrum.pro` (see EIS Software Note No. 16) creates full CCD spectra of user-selected features within a raster. Also, the routine `eis_density.pro` automatically corrects intensity maps in different lines when creating a line ratio map that is then converted to density (see EIS Software Note No. 15). Both of these routines make use of `eis_ccd_offset.pro`.

6 Physical offset between the two CCDs

A spectrum tilt gradient of -0.0792 pixel/Å means that, of the 18.5 pixel offset between Si VII λ275.37 and Fe VIII λ185.21, 7.1 pixels are due to the grating tilt. The remaining 11.4 pixels are due to a physical offset in the Y direction between the SW and LW CCDs. The CCD pixel size is 13.5 μm, therefore the physical offset is 0.15 mm.

References

Del Zanna, G., & Ishikawa, Y. 2009, A&A, 508, 1517

Kamio, S. & Hara, H. 2008, Note published on EIS wiki and available at http://msslxr.mssl.ucl.ac.uk:8080/eiswiki/attach/CCDOffset/yoffset.pdf

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