EUV IMAGING SPECTROMETER
Hinode

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Bright point detection with EIS

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1 Overview

This Software Note gives details on how the bright point trigger works for EIS and gives a prescription for setting the parameter values for a specific study.

In the text we will use the term *hunter study* for the study used to detect the bright point, and *response study* for the study that will be run once a bright point is detected.

2 Basic principles

The bright point trigger is enabled at the planning stage, i.e., when the EIS CO is creating the plan. It is not fixed in the study definition. The bright point trigger should only be enabled for studies with the following properties:

- the study contains a single raster; and
- the raster uses one of the narrow slits ($1''$ or $2''$).

Attempts to use the bright point trigger for other studies may lead to errors!

The threshold parameters for the hunter study need to be carefully calculated based on the exposure time, the emission line selected for the hunting, and the slit being used. The CO should exercise extreme caution in choosing a hunter study "on the fly" at the time of planning.

Suppose a hunter study raster is scheduled to run 10 times, and the 5th raster detects a bright point, then the 5th raster will be *fully completed* before the response study starts, i.e., the response study does not start immediately after the bright point is detected.

If a hunter raster detects multiple bright points that exceed the threshold parameters, then the response study will go to the brightest bright point.

Any study from the EIS database can be chosen as a response study. Note that the response study is not like other studies when it is placed on the timeline. The pointing can not be specified (not surprisingly) but, more importantly, it is not possible to modify the number of repeats of the study's raster(s).

For example, if the study HH_Flare_180x160_v2 was chosen as the response study, it will only be run once with a duration of 6 mins. It is not possible to request that it be run 20 times, for example. This means that it is best to design an ad hoc study with the required number of repeats to be used as the response study.

3 Enabling the bright point trigger within the planning tool

The hunter study should be placed on the EIS timeline in the same way as a normal study, and the CO should select a pointing and choose a number of repeats (if necessary).

The bright point trigger is enabled by first clicking on the raster for which the trigger is to be enabled (it is listed in the part of the planning tool GUI that lists 'ID:', 'Acronym:', 'Compression', etc.). Then the CO should click on the 'Trigger Studies' tab near the bottom of the planning tool GUI, and then click the 'Enable Bright Point Trigger' button.

The bright point trigger parameters then need to be set, by clicking on 'Edit Properties...'. A new widget window will appear.

The set of parameters to be specified by the CO are:

Line Specifies the 'hunter line' to be used for finding BPs.

Ymin The number of threshold pixels in the wavelength direction.

Xmin The number of threshold pixels in the Y direction.

Ythresh The threshold for the wavelength direction.

Xthresh The threshold for the Y direction.

The values for these parameters should have been given to the CO in the weekly planning schedule, otherwise they should be in the study description. If the CO is creating a hunter study on the fly, then a prescription for calculating the parameter values is given below.

4 Prescription for setting parameter values

The following gives a 'quicklook' prescription for setting the BP trigger parameter values. It is intended that scientists use this prescription for quickly generating reasonable trigger parameters without going into the full details of the BP trigger process.

For quiet Sun BP studies the user is recommended to always use the Fe XII λ195.12 line as the hunter line. The data window containing this line has the size $nw \times ny$ and the values of nw and ny can be determined from within eis_mk_plan by looking at the raster properties.

The CCD pedestal value plays an important role in setting the bright point thresholds – see Sect. 6 for more details. A pedestal value of 505 DN for the Fe XII λ195.12 data window is assumed here.

The Ymin and Ythresh parameters will generally not be useful so the user is suggested to set them to Ymin=1 and Ythresh=505 $\times$ ny.

For Xmin a value of 7 is suggested as this helps prevent SAA events being identified as bright points. The threshold value Xthresh should be set to:

$$\text{Xthresh} = (nx \times 505) + (k \times D_{\text{QS},\lambda}) \tag{1}$$

where k is the brightness of the expected bright point relative to the standard quiet Sun, and $D_{\text{QS},\lambda}$ is the average quiet Sun DN value for the chosen line. The value $D_{\text{QS},\lambda}$ can be obtained from:

$$D_{\text{QS},\lambda} = 0.628\, I_{\text{QS}} A_{\text{eff}}(\lambda)\, S\, t_{\text{exp}} \tag{2}$$

I_{QS} is the average intensity of the line in quiet Sun conditions and values for a number of lines are given in Brooks et al. (2009). A_{eff} is the EIS effective area and can be obtained as follows:

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IDL> print,eis_eff_area(195.12)
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for the case of λ195.12. S is the width of the EIS slit in arcsec (this only applies to the $1''$ and $2''$ slits), and $t_{\rm exp}$ is the exposure time in seconds for the hunter study which can be found in the raster properties.

The crucial parameter for identifying bright points is k. Tests using a sample quiet Sun data-set suggest that $k = 3$ will lead to a fairly quick identification, within 1–2 rasters, say. A value of $k = 4$ may take a number of rasters before identification occurs. More details are given in Sect. 7.

5 The detection algorithm

This section describes in detail how the BP detection algorithm works.

Firstly some definitions. The wavelength window for the hunter line has dimensions $nw \times ny$ where nw is the number of pixels in the wavelength dimension and ny the number of pixels in the Y direction. The DN value of a pixel (i, j) in the array is given by D_{ij}.

To prevent single pixels (e.g., cosmic rays, hot pixels) triggering a false BP response the on board software allows the user to request that more than one adjacent pixels lie above the bright point threshold. This is where the Ymin and Xmin parameters (Sect. 3) come in. Instead of a single pixel acting as a trigger, these parameters allow a region of Ymin×Xmin pixels to be the trigger. How the trigger works in practice is explained below.

Step 1 The software performs the sum

$$P_j = \sum_i D_{ij} \tag{3}$$

where P will have ny elements.

Step 2 The software finds the pixel within P with the maximum intensity (denoted by $j_{\rm max}$). It then checks if Xmin adjacent pixels that include $j_{\rm max}$ all lie above the threshold value Xthresh. If yes, then the software moves on to the next step, otherwise Step 2 is repeated but with the second most intense pixel in P. If no pixel passes the threshold test, then the software discards the exposure, moves on to the next one, and begins with Step 1.

Step 3 If the exposure has passed the threshold test in Step 2, then the following vector is computed:

$$Q_i = \sum_j D_{ij} \tag{4}$$

where Q will have nw elements.

Step 4 The software finds the pixel within Q with the maximum intensity (denoted by $i_{\rm max}$). It then checks if Ymin adjacent pixels that include $i_{\rm max}$ all lie above the threshold value Ythresh. If yes, then the software moves on to the next step, otherwise Step 4 is repeated but with the second most intense pixel in Q. If no pixel passes the threshold test, then the software discards the exposure, moves on to the next one, and begins with Step 1.

Step 5 If $D(i_{\rm max}, j_{\rm max})$ is larger than the $D(i_{\rm max}, j_{\rm max})$ value for any previous exposure in the raster, then the pixel position becomes the new bright point position. Otherwise the old position is retained.

Step 6 After the raster is completed, if a pixel has been identified as a bright point, then the location of that pixel (in solar-X and solar-Y) will be passed on to the response study.

A key point to note is that, upon finding a bright point, the software will not immediately jump to the response study. The hunter study raster must be completely finished before the response study begins.

6 CCD pedestal values

A significant contribution to the threshold values comes from the CCD pedestal. To see this, consider the case where $nw = 16$, $ny = 512$, and Fe XII λ195.12 is used as the trigger line.

The CCD pedestal for the CCD quadrant containing λ195.12 is about 505 DN. Constructing the vector P results in the elements of P having *minimum* values of $16 \times 505 = 8080$ DN. Therefore the threshold Xthresh must be larger than this.

For the vector Q, the elements will have minimum values of $512 \times 505 = 258,650$ DN, so the threshold LX must be larger than this.

7 Testing with real data

The quiet Sun was monitored over a 3 day period during 2008 January 22-25 as part of HOP 59. The study cam_qs_2as_context was run at approximately 50 min intervals over this time, yielding 74 rasters in all. The rasters covered an area of 180$''$ x 360$''$ and were obtained with the 2$''$ slit and 30s exposures.

Using the prescription outlined in Sect. 4, the set of rasters from HOP 59 was tested to determine how many of them resulted in a bright point being identified using the Fe XII λ195.12 line. The results are summarized in Table 1 for six different values of k.

Table 1: BP detection results.

	$k = 3$	$k = 3.5$	$k = 4$	$k = 4.5$	$k = 5$	$k = 6$
No. of rasters with BPs	72/74	67/74	62/74	54/74	41/74	23/74
Average no. of BPs in raster	13.9	8.5	5.1	3.2	1.9	0.9
Longest run without a detection	2	5	7	7	7	15

Setting $k = 3$ results in a BP being detected for most of the rasters thus seems to be a good option if you simply want to find the brightest region in the hunter study's field of view. If your science requires study of a particularly bright BP then setting high values of k will be necessary.

8 Study design considerations

The scientist should first determine if the hunter study data will be scientifically useful. If not then a very basic hunter study can be used which will consume very little of the EIS data volume. For example, since BPs typically extend over 5–20 pixels in solar-X and Y then it is not necessary to sample a continuous range in X. E.g., the slit can jump $4''$ between positions. Also since only the hunter line is needed for the trigger, the study can only contain this line. Finally, since only the core of the emission line is going to trigger a BP response, then the wavelength window can be set to 16 or even just 8 pixels.

As an example, consider a raster area of $360''$x $512''$, exposure times of 30s and the $2''$ slit. Choosing just one line with a 16 pixel window, a $4''$ step size, and DPCM compression leads to a data volume of 4.9 Mbits and a raster cadence of 50 mins (data rate 1.6 kbits/s).

When creating a response study, scientists should define the number of rasters they want in the study definition. E.g., if the scientist considers that 20 rasters are required to obtain the time evolution of the bright point then he/she should set the number of repeats in the study definition (at the eis_mk_study stage). *The number of repeats can not be adjusted at the planning stage.*

9 Test of BP trigger (2010 June)

During the EIS planning week of 2010 June 19-26 the EIS BP trigger was tested on board for the first time. The hunter study, BP_HUNTER1 (ID: 422), was defined to cover an area $456'' \times 512''$ using the $2''$ slit, taking only the Fe XII λ195.12 line. The exposure time was 20 s, and the window size for λ195.12 was 16 pixels. The raster duration was 88 mins and the predicted data volume was 12.2 Mbit.

The response study, BP_RESPONSE1_2RASTER (ID: 421), has a raster that covers $100'' \times 128''$ with the $2''$ slit and returns 13 emission lines with an exposure time of 20 s. The study definition requires the raster to run twice and the study duration (to run two rasters) is 39 min, and the data volume is 27 Mbit.

For the first test on June 20 the detection parameters were set according to the prescription set in Sect. 4. For the following two tests on June 24 and 25 the threshold for detection was modified such that the bright point was required to be only a factor 2 bright than average quiet Sun.

All three runs of BP_HUNTER1 resulted in a response with the response study successfully covering a bright point. Some comments on the results:

1. The detection raster crossed South Atlantic Anomaly (SAA) events a couple of times and this did not have an adverse effect on the on-board processing. The detection algorithm guards that were put in place to avoid false triggers in response to cosmic ray hits therefore functioned as desired.

2. Unlike the ground testing, the flight response raster wasnt located (pointed) dead-centre around the BP. Generally speaking and accounting for worse case, the event is off centre by around 6 in the X-direction (west shift) and 8 in the Y-direction (South shift). This is for BPs detected very close to the Sun centre. The closer to the Sun centre, the bigger the drift. The most likely cause of this problem is satellite (or instrument) jitter during the observation,

thus when the EIS scanning mechanism returned to the location of the bright point, the instrument was no longer pointed in exactly the right place.

3. For the first two bright points, the bright point remained very similar in appearance between the hunter study image and response study image. For the third bright point a significant change in shape occurred.

References

Brooks, D. H., Warren, H. P., Williams, D. R., & Watanabe, T. 2009, ApJ, 705, 1522