1995ASPC...77..418V

Astronomical Data Analysis Software and Systems IV
ASP Conference Series, Vol. 77, 1995
R. A. Shaw, H. E. Payne, and J. J. E. Hayes, eds.

Recreating Einstein Level One Processing Exposure Masks and Background Maps in IRAF

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Abstract. This paper describes the main algorithms used by the Einstein Level One processing to create the exposure masks and the background maps for *Einstein* IPC images, and how these algorithms were recreated in the IRAF environment.

1. Introduction

Our goal was to recreate the algorithms used by the Level One Processing to create exposure masks and background maps for *Einstein* Image Proportional Counter (IPC) data (cf. sections 2.5 and 2.7 of Harnden et al. 1984). Although these images have not been archived on CD-ROMs, the aspect and original background image information have been. From this information, one can either recreate the original background images, or recalculate and create exposure masks and background maps from within IRAF. Special consideration is given to extend the background map algorithm to work on the *Einstein* unscreened IPC images[1].

2. Exposure Masks

The aspect information for an image contains a timeline of the aspect solution for the duration of the observation. The exposure mask is simply the sum of multiple images, where each image is the result of applying an aspect solution to the IPC geometry, weighted by that aspect's duration. This algorithm does not attempt to correct for vignetting.

2.1. Exposure Mask Algorithm

For each set of aspect data and duration, an exposure mask is created by looking at each pixel in the final exposure mask, and finding the pixel in detector coordinates by de-applying aspect, and seeing that if the detector coordinates lie within the IPC geometry[2], add duration of aspect data to the image pixel.

[1] The unscreened images were published on CD-ROMs in March 1994 (McDowell et al. 1994).

[2] The IPC geometry is defined as all pixels $287 \leq x \leq 737$ and $288 \leq y \leq 738$ which are at least 15 pixels away from the rib centers of $x = 359.6$, $x = 656.8$, $y = 376.6$ and $y = 673.8$. All values are in PROS coordinates, the system used on the CD-ROM archive.

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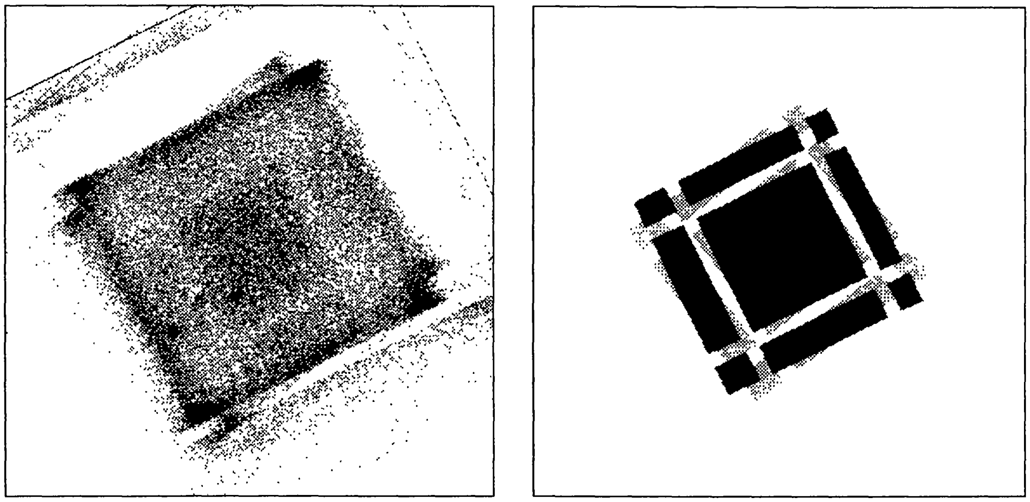

Figure 1. The *Einstein* unscreened IPC image for sequence I5803, along with its exposure mask created by the EINTOOLS task exp_make.

3. Background Maps

The main idea behind the background map algorithm is that the background for an individual image can be modeled as some combination of blank field ("deep survey") images and flat field ("bright Earth") images. The reason that the blank field image by itself is not a sufficient model is that each image (including the blank field) has a variable amount of particle induced and/or stray light background. Our algorithm accounts for this by including some (possibly negative!) amount of flat field data in the model background.

We assume that the blank field rate is constant over time, and thus the normalization we use for the deep survey image is based solely on the duration of the exposure. The normalization for the bright Earth image is set so that the total number of background counts (excluding sources) in the model is the same as those in the image, as determined by the following relation:

$$\text{image counts} = \text{source counts} + (\text{deep survey counts} + \text{bright Earth counts})$$

Note that the background map algorithm does not explicitly take into account internal or particle induced background.

3.1. Background Map Algorithm

The algorithm used to create a background map is as follows: (1) calculate counts in the image due to sources[3] (SRC_CNTS); (2) calculate counts in deep survey and bright Earth maps[4] (DS_CNTS & BE_CNTS); then (3) for each set of aspect data and duration:

[3] See section 3.2.

[4] The counts are calculated using the bright edge region. See section 3.3.

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1. Find number of photons in image which arrived during this set of aspect data (IM_CNTS)

2. Calculate deep survey factor (DSFAC):

$$\text{DSFAC} = \frac{\text{(aspect duration)}}{\text{(deep survey livetime)}}$$

3. Calculate bright Earth factor (BEFAC):

$$\begin{aligned}\text{(BEFAC)} \times \text{(BE\_CNTS)} &= \text{(IM\_CNTS)} - \text{(DSFAC)} \times \text{(DS\_CNTS)} - \\ &\quad \frac{\text{(aspect duration)}}{\text{(image livetime)}}\text{(SRC\_CNTS)}\end{aligned}$$

4. Apply BEFAC and DSFAC weights to bright Earth map and deep survey maps and sum these two images

5. Apply aspect to the summed image and add to background map

3.2. Source Counts Algorithm

The algorithm used to calculate the number of counts for each source in the image is; (1) calculate total counts in the source circle and in the background annulus [5] (TOT_CNTS & BG_CNTS); (2) calculate the area in the source circle and in the background annulus [6] (SRC_AREA & BG_AREA), and (3) compute the counts attributable to this source by the relation:

$$\text{(SRC\_CNTS)} = \text{CCC} \times \left(\text{(TOT\_CNTS)} - \text{(BG\_CNTS)}\frac{\text{(SRC\_AREA)}}{\text{(BG\_AREA)}}\right)$$

where CCC, the circle composite correction, is defined as the product

$$\text{CCC} = \text{(circle mirror scattering corr.)(circle point response corr.)}.$$

The user can generate a list of sources by using the PROS task LDETECT.

3.3. Masking Detector Hotspots

Our background map algorithm works best if the internal (particle induced) background is small, at a constant rate, and uniform over the field. In order to make this true, we must exclude the regions of very high internal background on the edges of the detector from the calculation of the normalization. This exclusion is performed with the bright edge filter on QPOE files and the bright edge region on the deep survey and bright Earth images[7].

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[5] These counts are calculated using the bright edge filter. See section 3.3.

[6] All areas are calculated using the exposure mask.

[7] The bright edge filter and bright edge region describe identical areas. They differ because one is for filtering detector coordinates within QPOE files whereas the other is a region on an image.

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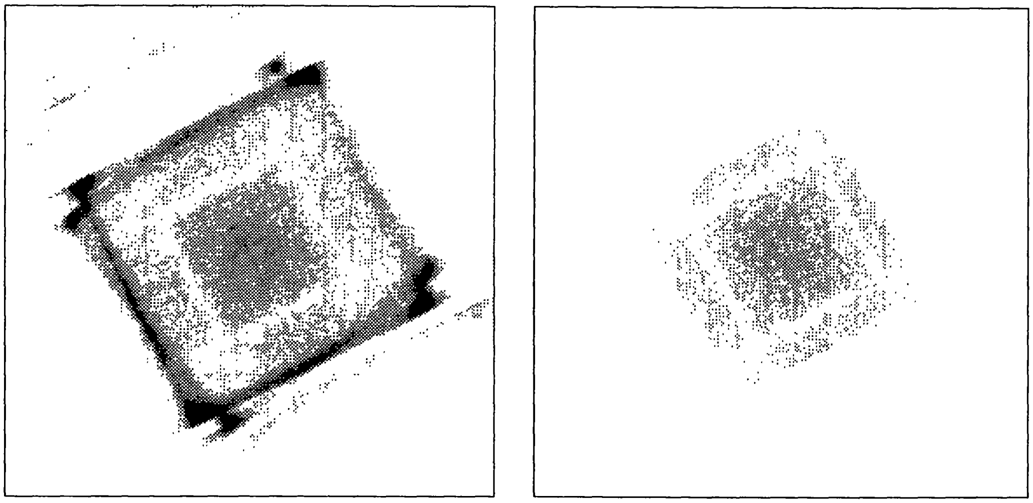

Figure 2. The figure to the left is the broad band background map for the *Einstein* unscreened IPC image I5803, created by the EINTOOLS task bkfac_make. The figure to the right is the original Level One Processing background map created by the EINTOOLS task be_ds_rotate.

4. Eintools

The new PROS package EINTOOLS contains tasks for creating exposure masks and background maps for any *Einstein* IPC QPOE file. One can also create the original Level One Processing background maps using the bright Earth and deep survey factors from the original processing. The tasks allow the user to screen on any time filter, produce background maps for any (possibly nonstandard) PI range, and create exposure masks of any specified resolution.

This package will be available in the next major release of PROS. It is our hope that some of the data structures created for this package (such as a generic time-resolved aspect table) will be used in future programs generating exposure masks or background maps.

Acknowledgments. The PROS project is partially supported by NASA contracts NAS5-30934 (RSDC) and NAS8-30751 (Einstein).

References

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