Title: BAT Point Spread Function

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Version:	2
Document:	SWIFT-BAT-CALDB-PSF-v2

1. Summary

This document describes the BAT point spread function (PSF) is approximately a two dimensional gaussian with a width of 22.5 arcmin (FWHM).

2. Component Files

None. (the batcelldetect task contains built-in point spread function models)

3. Scope of Document

This document relates to the determination of the BAT point spread function. This function is used by the BAT task batcelldetect to determine fluxes and significances of sources in BAT sky images.

4. Reason for Update

The original release of this document (version 1), erroneously stated that the BAT point spread function was a truncated pyramidal frustum. Further analysis has shown that the correct PSF is very close to a gaussian.

5. Discussion

The BAT is not a focussing optics imager. All images must be reconstructed using cross correlation techniques. Thus, the point spread function itself is dependent on the reconstruction technique and the geometry of the instrument.

BAT images are created by forming a sliding cross correlation between the mask aperture pattern and the detector array. There are several relevant quantities.

Quantity	Value
Focal Length	1 m
Mask tile width	5 mm
Detector pitch	4.2 mm
Detector width	4.0 mm

For convenience, we work in tangent plane units. For example, the mask cells are 5 mm, and 1 m away from the detector plane, so they subtend a tangent(angle) of 5/1000 = 0.005. These units are useful for BAT imaging because in tangent plane units each sky pixel is the same size.

The mask casts a shadow of size 0.005 tangent plane units, and is recorded by detector elements which have a size of 0.004 units. The result is a square box function 0.005 units wide convolved with one 0.004 units wide. This gives a flat-topped pyramid, with FWHM of 0.005 units (and full-width zero response of 0.014 units).

The image reconstruction task, batfftimage, creates an image by correlating the observed data with a theoretical version of itself, so the expected PSF is a flat-topped pyramid convolved with itself. This profile is remarkably close to Gaussian (which is a consequence of the central limit theorem). A gaussian fit to this function produces a good fit, with a width of about 22.5 arcmin (FWHM), with slight differences depending on whether one measures along one of the primary axes or along the diagonal.

The measured PSF is shown below.

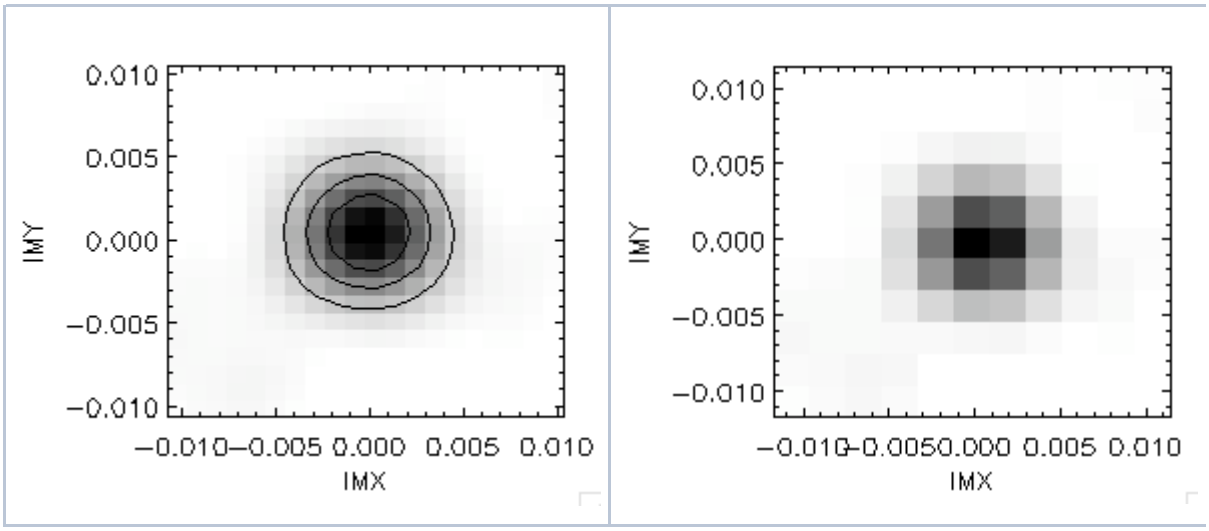

Figure 1. Images of the BAT point spread function for 4-times oversampling (left) and 2-times oversampling (right; the default of batfftimage). The contours indicate 25%, 50% and 75% of unit response.

As shown, BAT point spread function is approximately a gaussian. The measured width of the point spread function is 22.5 arcminutes (FWHM on-axis). In tangent plane coordinates, the PSF shape is very uniform across the BAT field of view; i.e. the FWHM is tan(22.5') = 0.0065 in image coordinates. Figure 1 shows the point spread function for a bright source at two oversampling levels.

6. Off-Axis PSF

As a source moves farther off axis, the transformation between tangent projection and true spherical angles becomes more distorted. The width of the point spread function follows this model:

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FWHM_X = 22.5' / (1 + IMX^2)
FWHM_Y = 22.5' / (1 + IMY^2)
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where IMX and IMY are the tangent plane coordinates. This distortion occurs in celestial coordinates. The PSF shape and width are unchanged in instrument tangent plane coordinates.

7. Comparison to Truncated Pyramidal Frustum

Version 1 of this report stated that the point spread function was a truncated pyramidal frustum, which was incorrect.

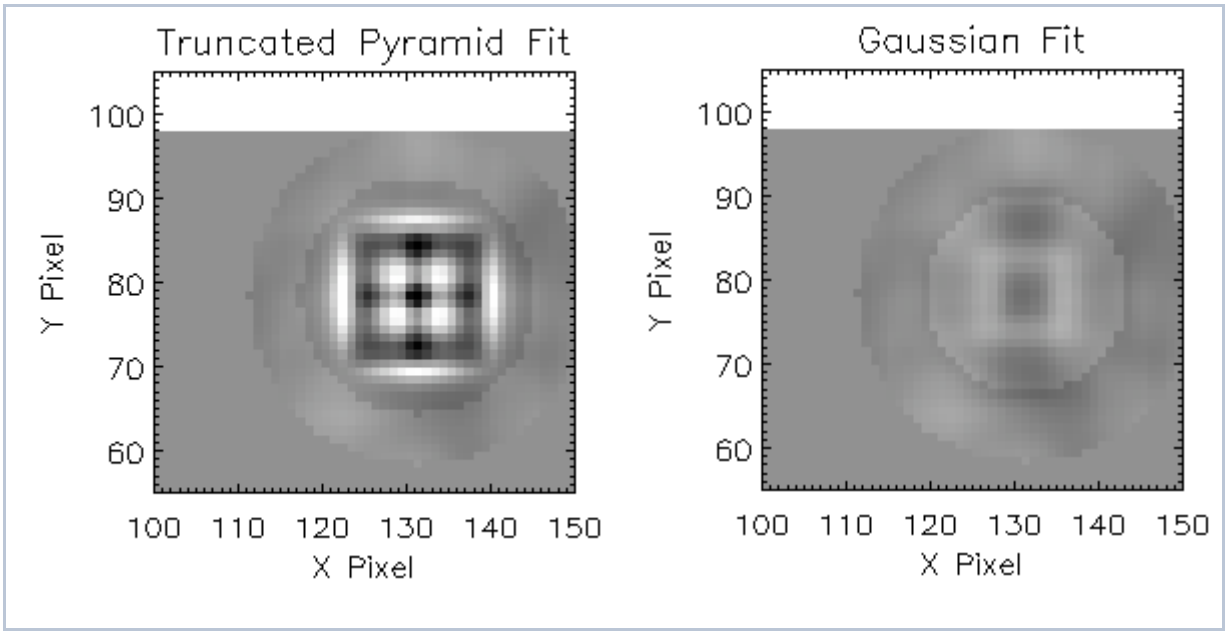

Figure 2. Residuals of the truncated pyramidal frustum fit (left) and the gaussian fit (right). Both images are on the same intensity scale (+/- 5% of the peak height). The faint outer ring corresponds to the region where a source-specific background level is fit.

Figure 2 shows a comparison of the two point spread function types. Clearly the gaussian fits much better than the truncated pyramid (residuals of less than 1% for the gaussian function, compared to ~5% for the pyramid).

The results of the PSF fit normalization and centroid are shown in the table below.

	SNR	COUNTS	COUNTS_ERR	IMX	IMY
GAUSS	178.335	1.0061100	0.0065021	0.00004	-0.00004
PYRAMID	184.400	1.0403239	0.0061580	0.00003	-0.00004

They show that the pyramid function produces fluxes and significances about 3.4% higher than the "correct" gaussian function.

8. Caveat Emptor

NOTE: Some literature quotes the PSF width as 17 arcmin. This value is incorrect, since it does not account for the finite size of the detectors. The correct PSF width is 22.5 arcmin (FWHM).

Also, it should be noted that the focal length of the instrument is slightly dependent on energy. Thus, it is possible for far off-axis sources to be elongated in the radial direction

in an energy-dependent way.

Finally, users should be specific about which PSF they use with the batcelldetect task. The default point spread function has changed in HEASOFT 6.2.1 from 'PYRAMID' to 'GAUSSIAN'. This means that fluxes and significances will change slightly as noted above. Users should pay special attention to mixing and matching fluxes derived from the two different PSFs.

9. Expected Updates

The PSF is not expected to change.

10. Version History

10.1. Update 2007-05-22

Version 2 with correct gaussian function.

10.2. Update 2006-05-29

Initial version 1 (truncated pyramidal function).