CalibrationStatus/EnergyScale

Title: BAT Energy Scale and Resolution

Revision Date:	2006-05-29
Version:	1
Document:	SWIFT-BAT-CALDB-ESCALE-v1

1. Summary

This document describes the BAT energy scale and resolution.

2. Component Files

File Name	Valid Date	Release Date	Version	Description
swbpulsecal20030101v003.fits	2003-01-01	2005-03-18	3	Best linear DAC-to-energy conversion
swbpulseflt20040101v001.fits	2004-01-01	2004-12-19	1	On-board linear DAC-to-energy conversion
swbquadres20030304v003.fits	2003-03-04	2005-03-18	3	Best non-linear pulser DAC-to-channel conversion

3. Scope of Document

This document relates to the computation of the BAT energy scale (pulse height to absolute energy). BAT events and survey data are typically tagged with a nominal energy based on the amount of charge deposited in the CZT detectors. This document briefly describes the chain of calibrations required to get an absolute energy scale.

4. Reason for Update

Initial document.

5. Discussion

An X-ray absorbed by a BAT detector produces a given amount of charge, that is collected by front end electronics and converted to a raw pulse height channel. Thus, at its basic level, the energy calibration process involves knowing how much charge is deposited by a given energy X-ray photon. The process is complicated by using an intermediate scale (pulser DAC), and that the detector electronics are non-linear.

The BAT performs periodic on-board electronic calibration using a pulser. The pulser injects charge pulses of a known amplitude into the electronics and measures the resulting pulse height channels. The pulser voltage (and hence charge), is controlled by a digital-to-analog converter (DAC). Thus, the raw pulse height scale can be tied to the pulser-DAC scale. During normal operations, the pulser-DAC to pulse height channel calibration is done at two different voltage points, forming a linear relation. This is the "gain-offset" map which is produced frequently by the instrument, and which should be available in each observation. This data is **not** stored in the calibration database, since it can potentially change over short periods of time.

This same process was done on the ground using many pulser voltage points. For almost all detectors, this produces a slight deviation from the linear relation, which is currently best fit by a cubic polynomial. This relation is stored on the ground as the "swbquadres*" CALDB file.

Having determined the pulser-DAC to channel relation, the pulser-DAC to energy relation must be found. This was done primarily by using ground calibration data from many different radioactive sources with known X-ray lines. The conversion may also be done with the on-board calibration sources (two ^{241}Am tagged sources which illuminate the entire array). This linear relation is stored in the swbpulsecal* file in CALDB.

Finally, for survey DPH data, the BAT on-board processing computes a nominal photon energy before binning the data. This nominal energy is based on a crude pre-flight linear relation. To determine a true energy-to-channel conversion for survey data, the flight conversion must first be backed out. This conversion is stored in the swbpulseflt* file in

CALDB.

5.1. Calibration Files

The "swbpulse*" files give the linear conversion coefficients between pulser voltage (in DAC units) and the energy of photons that produce those voltage pulses. These coefficients are different for each detector, so these files give the coefficients for all 32768 detectors. These data are based on ground calibration data taken before launch using various radioactive sources energy references.

The "swbpulsercal" file contains the "correct" best-known coefficients, obtained from calibration data on the ground. The "swbpulseflt" file contains the coefficients that are being used by the flight software. At the present time, the flight software uses a set of pre-programmed coefficients that are not correct. The swbpulseflt file is used by bateconvert to "back out" the improper conversion performed in flight and the swbpulsecal file is used to apply the proper conversion. At some future time, a new table will be uploaded to the flight software with the correct values. When that time comes, a new swbpulseflt calibration file will be added which will be identical to the swbpulsecal file. It is expected that this will somewhat improve the energy assignment made by bateconvert.

The "swbquadres*" file gives the cubic conversion coefficients between pulser voltage (in DAC units) and the channel in which those pulser voltages are centered. The name "quadres" is really a misnomer now, since the coefficients it contains are no longer quadratic (but rather, cubic) nor are they coefficients of the residuals (but rather, of the full conversion equation). The name has been kept the same in hopes that it will lead to less confusion than changing it would.

5.2. Results

Users must use the following tools to obtain the correct energy scale:

1. `bateconvert` for event data (i.e. GRB data).
2. `baterebin` for binned data (i.e. survey DPH data).

Both of these tools apply a detector-dependent energy shift which accounts for the non-linear behavior of the detector electronics, as well as detector-to-detector offset shifts not currently accounted for by the on-board automatic calibration.

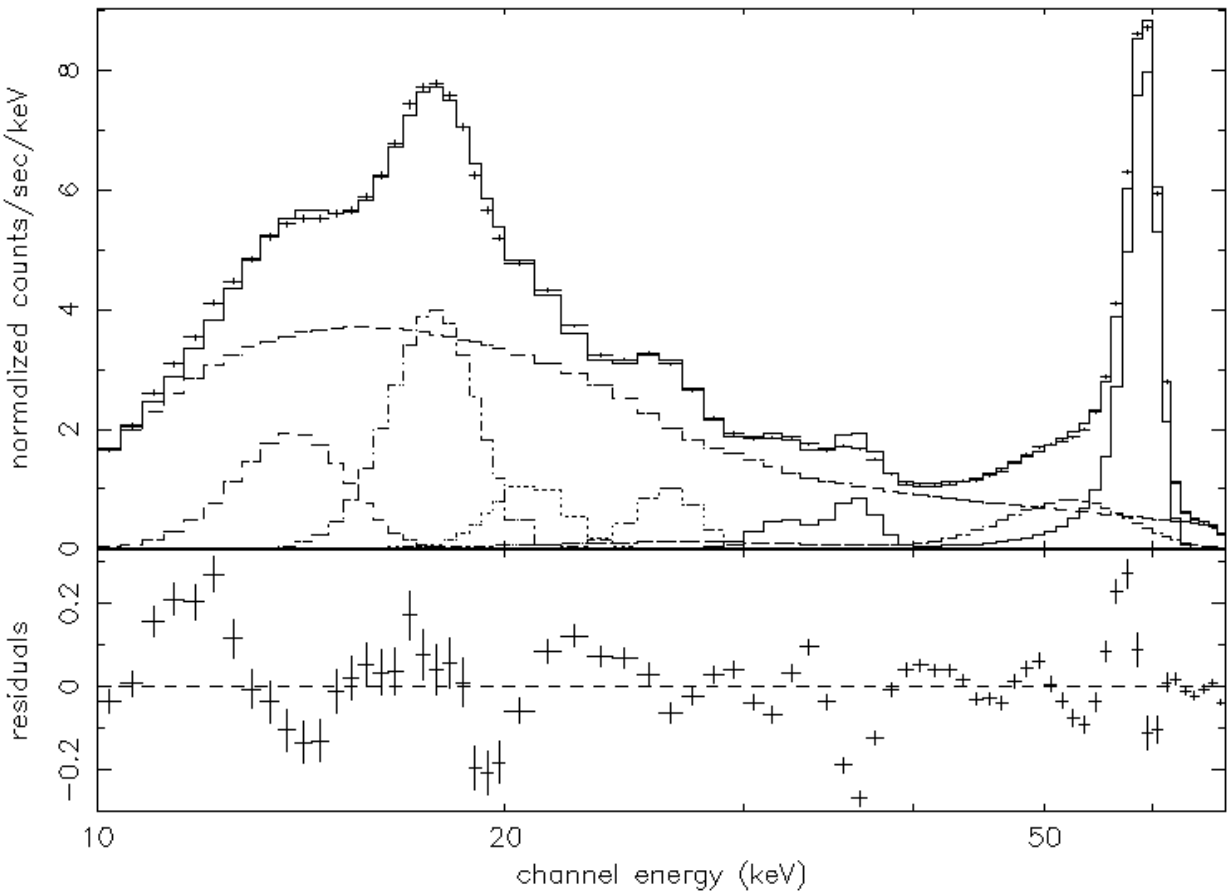

Figure 1. On-board calibration spectrum of the ^{241}Am source. The features include: ^{241}Am lines at 59.5 keV and 26.3 keV (with exponential tail); escape peaks for Cd and Te at 26.7 and 32 keV; L X-ray lines from Np at 14 and 17.75 keV; and a power law representing the sky background.

Figure 1 shows an on-board calibration spectrum with identified lines.

Without the correction, users can expect +/- 2 keV errors (90%, with maximum errors of 10 keV), and increased noise in detector images due to detector-to-detector gain variations.

With correction, users can expect +/- 0.1 keV errors. Figure 11 shows the on-board calibration spectrum after correction. The line centroids are consistent to within 0.1 keV, and the widths are consistent with the broadening derived by ground calibration.

6. Energy Resolution

As described above, and in Figure 1, the resolution is as expected from modeling of the ground calibration data. For example, the FWHM of the ^{241}Am line at 60 keV is <4 keV.

7. Caveat Emptor

WARNING: The SDC currently does not supply all of the gain/offset files required for energy correction of survey DPHs. Only the **first** gain/offset map is provided at the start of the observation, when in fact multiple calibrations can occur between snapshots. This will affect long observations the most. However, the gain behavior of the instrument does not appear to be a strong function of time. Using the first gain/offset map will degrade the energy scale, but only slightly.

Please use the newest software and calibration files, since these contain improvements to the energy scale. For event data, it is worthwhile to re-apply the correction since the SDC may not always be using the most recent software or calibration files.

8. Expected Updates

There are indications of a small energy scale drift with time (< 1 keV per year at 60 keV). As this effect is investigated more thoroughly, it may be required to provide new energy scale calibration files on a ~yearly basis.

9. Version History

9.1. Update 18 Mar 2005

```
 * swbpulsecal20030101v003.fits
 * swbquadres20030304v003.fits

     This pair of files contains new voltage-to-ADU conversion
coefficients,
     including a new FULLCUBIC cubic model, derived from ground
calibration
     data.  These files apply to observations at all times.  They
     DEPEND ON BUILD 14 SOFTWARE.
```

9.2. Updated 19 Dec 2004

```
 Overview
    * One new file, swbpulseflt20040101v001.fits, is introduced
    * This file is *required* for Swift build 11 analysis
```

```
 swbpulseflt20040101v001.fits

     NEW FILE TYPE.  Contains actual on-board pulser DAC to energy
     conversion coefficients.  The current file contains the
default
     per-sandwich average coefficients.

 swbpulsecal20030101v002.fits
 swbquadres20030304v002.fits

     New versions, based on improved knowledge of electronic pulser
     and energy calibration.
```

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