MIT Kavli Institute **Chandra X-Ray Center**

MEMORANDUM
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To:	Jonathan McDowell, SDS Group Leader
From:	Glenn Allen (SDS) for the ACIS Background Working Group
Subject:	acis_make_bkgd
Revision:	1.4
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1 acis_make_bkgd

1.1 Description

When users analyze the spectral data of a source on some region of an ACIS detector, they should try to estimate the background spectrum using data from a nearby, on-chip, source-free region. The advantages of such a background spectrum are that the background region has experienced essentially the same charged-particle radiation as the source region and that the data from both regions have been processed in the same manner (i.e. using the same CTI, tgain and gain files and the same set of filter criteria). However, it is not always possible or convenient to use an on-chip background. For example, some extended sources fill the entire field of view of the ACIS instrument. For such sources, there are no source-free regions on the detectors.

The calibration team has prepared some event-data files that can be used to estimate the charged-particle background. This spec describes the algorithm for the tool acis_make_bkgd, which can be used to process the background calibration files and create an observation-specific background event-data file. The output is unique to a given observation because it is created using the same WCS and aspect information as the observation. Once a background file has been created, dmextract can be used with some region specification (e.g. the same region specification used to extract the spectral data of the source) to extract a sample background spectrum. Note that the background spectrum will generally have a different EXPOSURE than the source spectrum, but this difference is handled by the spectral-fitting packages Sherpa, ISIS and XSPEC in a manner which is transparent to the user (see sec. 1.6).

1.2 Parameters

1. infile,f,a,“”,,,“Input source event file with WCS and GTI information”
2. outfile,f,a,“”,,,“Output background event file”
3. bkgfile,f,a,“CALDB”,,,“Input background event file or stack (CALDB | ⟨filename⟩)”
4. asolfile,f,a,“”,,,“Input source aspect-solution file or stack”
5. geompar,f,h,“geom”,,,“Parameter file for pixlib geometry files”

6. energy_min,r,h,7,0.3,12,"Minimum energy of range used for renormalization in keV"
7. energy_max,r,h,10,0.3,12,"Maximum energy of range used for renormalization in keV"
8. clobber,b,h,"no",,,"Overwrite output event file if it already exists?"
9. verbose,i,h,0,0,5,"Amount of messages produced (0=none, 5=most)"
10. mode,s,h,"ql",,,"q=query, h=do not query and l=save values used"

1.3 Input

1. The source event-data file (including the WCS and GTI information) for which a background file is being created (e.g. acis*evt2.fits)
2. A calibration background event-data file
3. The aspect-solution file(s) corresponding to the input source event-data file (e.g. pcad*asol1.fits)
4. A geometry parameter file for pixlib corresponding to the geometry files used for the source event-data file (e.g. geom.par)

1.4 Output

1. A background event-data file where the sky coordinates are on the same WCS as the coordinates of the source events

1.5 Processing

1. Verify that the specified input files exist. If the parameter clobber = "no," then verify that the output file does not exist.
2. If the keyword DATAMODE in infile is not FAINT, FAINT_BIAS, VFAINT or GRADED, then exit with an error message.
3. Read the WCS information from the infile.
4. Read the values of the keywords SIM_X, SIM_Y, SIM_Z, RA_NOM and DEC_NOM from the asolfile.
5. Read the input geometry files.
6. Determine which CCDs were active from the keyword DETNAM in the header of the infile. If the keyword is missing, then use the column CCD_ID in the EVENTS extension of the infile to determine the CCDs for which events were reported.
7. Begin a loop over each active CCD.
8. Read the set of GTIs used for CCD_ID = i from the infile (not the bkgfile).
9. Read the bkgfile for CCD_ID = i. If there is no file for CCD_ID = i, then exit with an error message.
10. For each background event j,

    i Randomly select a TIME t for event j from the set GTIs for CCD_ID = i. The random deviates should be uniformly distributed within the set of GTIs. (The times must be randomly chosen since the input CHIPX and CHIPY coordinates may be sorted.)

    ii Determine which values of RA, DEC, ROLL, dy and dz from the asolfile are appropriate for TIME = t. If there is no aspect information for TIME = t, then exit with an error message.

    iii Read the values of CHIPX and CHIPY from the bkgfile for event j.

iv Use CCD_ID $= i$, the coordinates CHIPX and CHIPY, the values of RA, DEC, ROLL, dy and dz for TIME $= t$ and the values of RA_NOM, DEC_NOM, SIM_X, SIM_Y and SIM_Z to compute the values of NODE_ID, TDETX, TDETY, DETX, DETY, X, and Y for event j.

v Randomly select a TIME t' for event j from the GTIs in the bkgfile (not the infile). Set the value of TIME for event j equal to t' less the value of TSTART from the bkgfile.

vi Write the data to the outfile (see Tables 1–6).

11. Set the value of TSTOP for $CCD\_ID = i$ in HDUn ($n\epsilon[2, 7]$) of the outfile equal to the difference between TSTOP and TSTART in the bkgfile.

12. Set the value of TSTART for $CCD\_ID = i$ in HDUn of the outfile equal to zero.

13. Since the charged-particle flux during the source observation may not have been the same as the charged-particle flux during the observations used for the input background file, the EXPOSURE for the output background file is determined by using the relative numbers of counts in the source and background files at the high-energy (i.e. source-free) end of the spectrum. For this reason, set the value of DTCOR for $CCD\_ID = i$ in HDUn of the outfile to be

$$\mathrm{DTCOR_{out}} = \frac{N_{\mathrm{bkg}}}{N_{\mathrm{in}}}\mathrm{DTCOR_{bkg}}, \tag{1}$$

where N_{bkg} is the total number of counts in the bkgfile such that CCD_ID $= i$ and energy_min $\leq$ ENERGY/1000 $<$ energy_max, N_{in} is the total number of counts in the input source file such that CCD_ID $= i$ and energy_min $\leq$ ENERGY/1000 $<$ energy_max and $\mathrm{DTCOR_{bkg}}$ is the value of DTCOR in the bkgfile.

14. End the loop over each active CCD.

15. Compute the value of ONTIMEn, ONTIME, EXPOSURn, EXPOSURE, LIVTIMEn and LIVETIME as usual.

16. Set the value of TSTART in HDU0 and HDU1 of the outfile equal to zero.

17. Set the value of TSTOP in HDU0 and HDU1 of the outfile equal to the largest of the values of TSTOP in the remaining HDUs of the outfile.

18. If the keywords BPIXFILE, CTI_CORR, CTIFILE, GAINFILE, TGAINCOR and TGAINFIL exist in the bkgfile, then copy the values of these keywords to the output file. Otherwise, exclude the keywords from the output file. If more than one input background file is used and the values of these keywords are not the same, then write a warning message and exclude the keywords that differ from the output file.

19. If the values of any of the keywords CTI_CORR, CTIFILE, GAINFILE and TGAINCOR in the infile differ from the values of the same keywords in the bkgfile(s), then write a warning message that there may be a mismatch between the pulse height processing of the input event file and the input background file.

20. TIME sort the output file.

1.6 Usage

Once a background event file has been created, an estimate of the background spectrum for a source can be obtained using, for example, the tool dmextract with the same region specification as the source. The only difference is that the background spectrum is created from the background event data file instead of the source event data file. The Sherpa and XSPEC spectral-fitting packages perform a background subtraction to obtain the number of source counts S in spectral bin i

$$S(i) = D(i) - \frac{\mathrm{AREASCAL_D}}{\mathrm{AREASCAL_B}}\frac{\mathrm{BACKSCAL_D}}{\mathrm{BACKSCAL_B}}\frac{\mathrm{EXPOSURE_D}}{\mathrm{EXPOSURE_B}}B(i), \tag{2}$$

Table 1. Structure of the outfile

HDU	Format
0	Null
1	Table of event data
2–7[a]	Table of GTI data

[a] As required

Table 2. Selected keywords in the HDU0 header of the outfile

Keyword	Instructions
DATE-OBS	Copied from infile
DATE-END	Copied from infile
MJD_OBS	Copied from infile
TSTART	Calculated[a]
TSTOP	Calculated[a]
OBS_ID	Copied from infile
OBI_NUM	Copied from infile
SEQ_NUM	Copied from infile
COMMENT	***
COMMENT	> This is an artificial ACIS event-data file. It should be used <
COMMENT	> only for the purpose of estimating the background. Do not <
COMMENT	> reprocess this file. <
COMMENT	***

[a] See sec. 1.5.

where $D(i)$ is the total number of counts in the source region, $B(i)$ is the estimated number of background events in the source region, $\mathrm{AREASCAL_D}$ is the value of the keyword AREASCAL in the source spectral-data file (typically one for *Chandra* data), $\mathrm{AREASCAL_B}$ is the value of the keyword AREASCAL in the background spectral-data file (typically one for *Chandra* data), $\mathrm{BACKSCAL_D}$ is the value of the keyword BACKSCAL in the source spectral-data file (which is proportional to the size of the source extraction area), $\mathrm{BACKSCAL_B}$ is the value of the keyword BACKSCAL in the background spectral-data file (which is proportional to the size of the background extraction area), $\mathrm{EXPOSURE_D}$ is the value of the keyword EXPOSURE in the source spectral-data file and $\mathrm{EXPOSURE_B}$ is the value of the keyword EXPOSURE in the background spectral-data file.

Table 3. Selected keywords in the HDU1 header of the outfile

Keyword	Instructions
DATE-OBS	Copied from infile
DATE-END	Copied from infile
MJD_OBS	Copied from infile
TSTART	Calculated[a]
TSTOP	Calculated[a]
TIMEDEL	Copied from infile
OBSERVER	Copied from infile
TITLE	Copied from infile
OBS_ID	Copied from infile
OBI_NUM	Copied from infile
SEQ_NUM	Copied from infile
DETNAM	Copied from infile
GRATING	Copied from infile
READMODE	Copied from infile
DATAMODE	Copied from infile
SIM_X	Copied from infile
SIM_Y	Copied from infile
SIM_Z	Copied from infile
ONTIME	Calculated[a]
LIVETIME	Calculated[a]
EXPOSURE	Calculated[a]
DTCOR	Set equal to one
OBJECT	Copied from infile and appended with ' BACKGROUND'
RA_NOM	Copied from infile
DEC_NOM	Copied from infile
ROLL_NOM	Copied from infile
COMMENT	**
COMMENT	$>$ This is an artificial ACIS event-data file. It should be used $<$
COMMENT	$>$ only for the purpose of estimating the background. Do not $<$
COMMENT	$>$ reprocess this file. $<$
COMMENT	**

[a] See sec. 1.5.

Table 4. Contents of HDU1 of the outfile

Column[a]	Instructions
TIME	Calculated[b]
CCD_ID	Determined from bkgfile
NODE_ID	Calculated[b]
CHIPX	Copied from bkgfile
CHIPY	Copied from bkgfile
TDETX	Calculated[b]
TDETY	Calculated[b]
DETX	Calculated[b]
DETY	Calculated[b]
X	Calculated[b]
Y	Calculated[b]
PHA	Copied from bkgfile
ENERGY	Copied from bkgfile
PI	Copied from bkgfile
FLTGRADE	Copied from bkgfile
GRADE	Copied from bkgfile
STATUS	Copied from bkgfile

[a] Exclude EXPNO, PHAS and PHA_RO from the output file.
[b] See sec. 1.5.

Table 5. Selected keywords in the HDU2 header of the outfile[a]

Keyword	Instructions
DATE-OBS	Copied from bkgfile
DATE-END	Copied from bkgfile
MJD_OBS	Copied from bkgfile
TSTART	Copied from bkgfile
TSTOP	Copied from bkgfile
CCD_ID	Copied from bkgfile
DTCOR	Calculated[b]
COMMENT	***
COMMENT	> This is an artificial ACIS event-data file. It should be used <
COMMENT	> only for the purpose of estimating the background. Do not <
COMMENT	> reprocess this file. <
COMMENT	***

[a] And subsequent HDUs if necessary
[b] See sec. 1.5

Table 6. Contents of HDU2 of the outfile[a]

Column	Instructions
START	Calculated[b]
STOP	Calculated[b]

[a] And subsequent HDUs if necessary
[b] See sec. 1.5