MIT
Center for Space Research **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:	1.3
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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 using 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, GTI and aspect information as the observation. Once a background file has been created, dmextract can be used with some region specification (i.e. 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"
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 (e.g. acis7sD2000-12-01bkgrndN0002.fits)
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 (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. Read the WCS information from the input event data file.
3. Read the values of the keywords SIM_X, SIM_Y, SIM_Z, RA_NOM and DEC_NOM from the aspect solution file.
4. Read the input geometry files.
5. Determine which CCDs were active from the keyword DETNAM in the header of the input event-data file. If the keyword is missing, then use the column CCD_ID in the EVENTS extension of the input event data file to determine the CCDs for which events were reported.
6. Begin a loop over each active CCD.
7. Read the set of GTIs used for CCD_ID = i.
8. If the parameter bkgfile = “CALDB,” then identify the appropriate input background event-data file to use for CCD_ID = i. If there is no file for CCD_ID = i, then write a error message and exit.
9. Read the background event data for CCD_ID = i.
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 aspect solution file are appropriate for TIME = t. If there is no aspect information for TIME = t, then write an error message and exit.

iii Read the values of CHIPX, CHIPY, PHA, ENERGY, PI, FLTGRADE, GRADE and STATUS from the input background file 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 Set the value of TIME for event j equal to t less the smallest value of TSTART from the set of GTIs for $\mathrm{CCD_ID} = i$.

vi Write the values of TIME, CCD_ID, NODE_ID, CHIPX, CHIPY, TDETX, TDETY, DETX, DETY, X, Y, PHA, ENERGY, PI, FLTGRADE, GRADE and STATUS to the output file. Do not include the column EXPNO in the output file.

11. End the loop over each active CCD.

12. Set the value of TSTART equal to the smallest time in the set of input GTIs for all active CCDs.

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 EXPOSURi (and LIVTIMEi) in the output file to be

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

where N_{bkg} is the total number of counts in the input background file 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 EXPOSURi_{in} is the value of EXPOSURi in the input source file.

14. Set the value of TSTOP equal to TSTART plus the largest of the values of EXPOSURi.

15. Set the value of EXPOSURE (and LIVETIME) in the output file to be identical to the value of EXPOSURn, where CCD_ID = n is the CCD at the aimpoint.

16. With the following exceptions, the rest of the keywords should be copied from the header of the input source event-data file to the header of the output file.

17. Exclude the keywords ONTIMEi, ONTIME and DTCOR.

18. Set DATAMODE = FAINT and READMODE = TIMED in the output file because this is the mode appropriate for the background data.

19. Set the keyword FILTER = NONE in the output file.

20. Set the keyword OBJECT in the output file:

$$\mathrm{OBJECT}_{\mathrm{out}} = \mathrm{OBJECT}_{\mathrm{in}}\ \mathrm{BACKGRND}. \tag{2}$$

For example, OBJECT='SN 1006-NE' becomes OBJECT='SN 1006-NE BACKGRND'.

21. If the keywords BPIXFILE, CTI_CORR, CTIFILE, GAINFILE, TGAINCOR and TGAINFIL exist in the input background file, 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 differ are not the same, then write a warning message and exclude the keywords that differ from the output file.

22. If the values of any of the keywords CTI_CORR, CTIFILE, GAINFILE and TGAINCOR in the input source event-data file differ from the values of the same keywords in the input background file(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.

23. Exclude the keywords DATE-END, DATE-OBS, OBSERVER, OBS_ID, SEQ_NUM, TIMEPIXR and TITLE from the output file.

24. Add some COMMENTs to the header of the output file, which state that the file is a background file not an event file associated with an observation.

25. TIME sort the output file.

26. Do not append the GTIs used to 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

$$S(i) = D(i) - \frac{\mathrm{AREASCAL_D}}{\mathrm{AREASCAL_B}} \frac{\mathrm{BACKSCAL_D}}{\mathrm{BACKSCAL_B}} \frac{\mathrm{EXPOSURE_D}}{\mathrm{EXPOSURE_B}} B(i), \tag{3}$$

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.