Using the Latest Pcabackest

Recipes from the RXTE Cook Book

NOTE: There is a new background model for faint sources in the XTE FTOOLS patch 4.1.1. This patch includes new model files as well as a new version of the pcabackest code itself (v2.0). This new model is only applicable, however, to faint sources (< 40 ct/sec/PCU) and to data taken in epoch 3 (after April 15, 1996). For brighter sources, either version of the code will work, but you should still use the released Q6 or VLE models. New models for epochs 1 and 2 as well as for brighter sources are under development.

- Introduction
- Using Pcabackest
- Problems and Remedies
- Notes

Introduction

Pcabackest is an ftool that produces synthetic background data by matching the background conditions of your observation with those in various model files. These model files contain actual background observations sorted by quantities such as the position of the spacecraft with respect to the South Atlantic Anomaly.

The output of pcabackest is in the form of data files very similar in structure to Standard2 data files. They can be put through saextrct to produce background light curves and spectra. Though the background data are in Standard2 format, the count rates apply to the observation, not to that mode. This recipes uses an example where the background will be subtracted from event mode data.

Pcabackest is very much a work in progress: both the program and its models are being continually revised. The current version (v2.0) was released with the XTE patch to FTOOLS version 4.1 along with the new model files for faint sources. This new model significantly reduces the systematic errors on the background for faint sources; see the accompanying release notes for details. A new model for brighter sources is under development, and in the mean time, we still recommend using either the Q6 or VLE models found in CALDB and the Pcabackest page, respectively.

Using Pcabackest

1. **Create a new filter file**

   (following the directions under fhelp xtefilt or in the recipe for creating XTE filter files). This will calculate two new coordinates `BKGD_THETA` and `BKGD_PHI` used to create and evaluate the activation term in the model. (For recently processed data, these columns *may* already be in the

filter files that come with the data. You can easily check using flcol to see if the columns are there. If so, there is no reason to make new filter files.)

2. **Using pcabackest -- an example to apply to event mode data:**

   This recipe will run through an example of using pcabackest to estimate a background to be applied to E_62us_64M_0_1s_L1R1 mode data. Assuming a light curve and spectrum have already been extracted from these data files (following the recipe for event mode spectra), we now go back to XDF and find the Standard2 data files which are always present, whatever other modes you may have requested. For each Standard2 data file, you can run pcabackest to produce a corresponding background data file from which you can then extract lightcurves and spectra. This can be done one file at a time with pcabackest or all at once using the script **runpcabackest**; the inputs are almost all the same, with the exception of a few output options in the latter:

   - `% runpcabackest`
     ```
     This perl script will take a series of input files via @filename
     and run pcabackest multiple times, creating multiple files with the same
     name as the input file with _$outsuffix appended to the input name ready
     to be input into saextrct for farther analysis.

     Running RUNPCABACKEST  version 4.0
     ==========================================
     List of Standard mode 2 Science array FITS files (@filename):[]@std2.xdf
     Output file which will contain the LIST of output files?:[]bkg.xdf
     Suffix appended to the output background files (after underscore _):[]bkg
     ```

     Here, simply input the *list* of Standard2 files rather than each individual file. The script then asks for the name of the *list* of output files, each of which will have the same name as the corresponding Standard2 file followed by a suffix you specify.

   - `XTE Filter file:[]`**`obs1.xfl`**

     The filter file must cover the time range in the input Standard2 data files, so if using the script runpcabackest and giving a list of files which spans more than one Obs. Id., you must us a merged filter file which covers all of the time. (Remember to use "fmerge lastkey=TSTOP" to combine filter files.)

   - `PCA Background model file:[]` **`@models.txt`**

     To get the Q6 versions of the model files, simply enter CALDB at the prompt, and it will find them if you have the current CALDB installed. If not, or if you wish to use beta test models, you can get the Q6 or VLE model files via anonymous FTP at **lheaftp.gsfc.nasa.gov** in the directory `pub/stark`.

     If you install the XTE FTOOLS 4.1.1 patch, the two new faint source model files will be in the $LHEA_DATA directory:

     pca_bkgd_faint240_e03v02.mdl
     pca_bkgd_faintl7_e03v01.mdl

     Write their names into an ASCII file, one per line (and make sure there's a return after the

last), then enter the name of the list (e.g. "models.txt") at the pcabackest "modelfile" prompt preceded by the '@' character.

- `Seconds between successive estimates:[]`**16**

  The background estimator uses count rates found in the Standard2 data files and therefore has at best 16 second resolution. If you want to subtract a light curve at less than 16 second binning, you can still do so using lcmath. This tool will take a total light curve binned finer than 16 seconds and subtract the corresponding value of the coarser-binned background.

- `Include individual xenon layer spectra? (Yes, No):[]`**yes**

  If you will wish to select by layer in the extractor, you must tell pcabackest to include individual xenon layer spectra. This will produce a column for each anode, just as is found in Standard2, which can then be extracted separately in saextrct. Otherwise, each PCU will have only one column. In this example, we want to apply the background to an event mode which only includes layer 1, so we will have to select the appropriate columns when we saextrct the background files. So we must answer yes to this prompt.

- `Correct for PCU Xenon gain variations? (Yes, No):[no]`**yes**
  `EDS gain correction file (CALDB) :[]`**caldb**

  or

  `Correct for PCU Xenon gain variations? (Yes, No):[]`**no**
  `Expand xenon layer spectra to 256 channels? (Yes, No):[]`**yes**

  If you will use the background to analyze Standard1, Standard2, or Good Xenon modes, you should ***not*** apply the gain correction. For other modes, the gain correction is applied to the data on board the satellite, because data from the various PCU's are combined before being sent down. This function of pcabackest is to adjust the background in the same way *only* if it is to be compared to data from modes where the correction has already been applied, e.g. binned or event modes. For this example applied to an event mode, answer "yes" to apply the gain correction, and enter "CALDB" for the EDS gain correction file.

  If you will be using the background spectra on anything but Standard2 binned data, as in this case with event mode data, you will have to expand the background spectra to the full 256 channels. Then the extracted spectra can be rebinned using rbnpha with the binfile from rddescr. If you apply the EDS Gain Correction, then the spectra will automatically be expanded to 256 channels, so this prompt does not appear.

- `PCA SAA passage history file:[none]` **pca_saa_history_v04**

  This applies only if you are using the new faint source model. It requires the appropriate file pca_saa_history_v*N*; this file will be updated periodically. The pca_saa_history_v04 file released with the FTOOLS 4.1.1 patch covers data up until May 1998 and can be found in the $LHEA_DATA directory after you have installed the patch. For more recent data, obtain the latest file from the XTE ftp site.

- `Compute systematic error estimate? (Yes, No):[]`**no**

For this version, answer "no" to compute the systematic error estimate. This is under development and not currently useful.

- You will then see the script call pcabackest with the first of the data files in the list you gave runpcabackest. It will go to CALDB and find the model files and apply each to every good xenon column in the Standard2 file. When it is done, it will tell you what it output and ask:

```
Update Parameter file for PCABACKEST? (Yes, No):yes
PCABACKEST parameter file updated.

Run SAEXTRCT on the files created? (Yes, No):no

or

Run SAEXTRCT on the files created? (Yes, No):yes
Do you want to process the GOOD columns? (Yes, No)yes
Calling SAEXTRCT with infile=@outlist, columns=GOOD, and outroot=sac_good

Running SAEXTRCT version 4.0a
===============================================
Input GTI files to be OR'd with INFILE (APPLY):[APPLY]

etc.
```

  If you answer yes to run the extractor, the script will then put you into saextrct with one key difference: it will automatically call saextrct with columns=GOOD. This means that you would not be able to enter a list of columns in order to select on detector or layer. In our example, we do need to do this selection, so we simply say "no" to running the extractor, and then run saextrct by itself from the command line.

3. **Use SAEXTRCT to extract estimated background spectra that correspond to your sources.**

We now run saextrct on the background data files to extract the spectra and lightcurves corresponding to those extracted from the data. Whether the data are Standard2, event, or another mode, you should extract the background using the same selection and binning criteria, i.e. the same GTIAND file, the same number of detectors and layers, the same time or channel filters, etc.

In this case, we want to apply a background to the event mode E_62us_64M_0_1s_L1R1; this has 62 us timing, 64M_0 channel binning, and layer one only. It is the last which forces us to run saextrct from the command line. We need a column list corresponding to only the layer 1 anodes of the PCU that were on during the observation. Suppose we have checked the filter file and plotted the columns PCU0_ON, PCU1_ON, etc., and determined that PCU3 had been off for the entire observation; then our column list looks like:

```
X1LSpecPcu0
X1RSpecPcu0
X1LSpecPcu1
X1RSpecPcu1
X1LSpecPcu2
X1RSpecPcu2
X1LSpecPcu4
X1RSpecPcu4
```

We then input this list (preceded by '@') for the columns to be accumulated.

You will also want to only extract those channels which are included in your event mode. If you "fkeyprint TDDES2", you'll see that this 64M_0 binning has only channels 0-249, so this is the channel range you want to give the extractor.

4. **Applying and checking the background:**

   In our example, the resulting spectrum will have the full 256 channel binning (though in this case, the last five will be empty), so you will have to rebin it according to the binning in your data file. Take the spectrum extracted from the event data, use **pcarsp** to create the appropriate response matrix (in the process, this script will set the gain in the header of the pha), and then use **rddescr** to read the PHA header and create a file containing the binning information, "chan.txt" for instance. Then you can use this channel information file with the hidden parameter "binfile" in the tool **rbnpha**:

```
% rbnpha binfile=chan.txt
Please enter PHA filename:[]bkg.pha
Please enter output filename:[] bkg_rbn.pha
 ** rbnpha 2.1.0
 ** rbnpha 2.1.0 completed successfully
```

   Now you have the correct background PHA file and light curve to apply to your data.

   A quick and qualitative way to check your background is to compare the spectrum to that of the data at the higher PCA energies. Above 20-30 keV, the spectrum is dominated by the background. Enter the two spectra into XSPEC as two data series, with the same response entered for both, and plot them together. You should see that above 30 keV, they lie right on top of one another. If there is an offset, then there is something mismatched in the way the two spectra were extracted, and you should check that you selected the appropriate detectors and anodes, channels, time intervals, etc.

   Note: while pcabackest does not currently compute systematic errors, you may want to apply a value yourself using fparkey to change the SYS_ERR keyword in the PHA file. You can use one percent as a simple estimate or make your own determination. If your source is weak and not especially hard, for instance, you do not expect any counts below 10 keV in the third layer. Extracting only this layer and comparing the background to the data will give you an idea of how large the errors are.

Problems and Remedies

If your background spectrum appears to be slightly overestimating or underestimating (apparent in the highest energy band where there are no source counts), it is most likely due to uncertainties in the activation model. (A large offset is probably just due to extracting the wrong number of anodes or detectors.) Immediately after SAA passage, the activation in the PCA is falling rapidly, but the rate of this fall is not modeled with great precision. You may see variations in the net light curve which are due solely to the activation component of the background estimation, and this may correspond to a total

over- or under-estimation of background counts which is apparent when you plot the two spectra (data and background estimation) on top of one another. Until the activation model improves, there are two work-arounds for this problem.

- The simplest is to exclude the data immediately following SAA. You can do this by hand, looking at the raw light curve and judging the times past the steepest activation fall-off. For a more consistent method, you could produce background files using only the activation component, extract a light curve, and use maketime to make a GTI simply by thresholding the resulting rate due to activation.

  Alternatively, an approximate (within 2 minutes) formula for the time since the peak of the most recent SAA passage is given by:

  ```
  delta_t = 0.272*BKGD_PHI + 0.214*BKGD_THETA + 15.7  (in minutes)
  ```

  where -70 < BKGD_THETA < 150 (outside this range, the satellite is just grazing the edge of SAA and activation shouldn't be a large effect.) Otherwise, you can use fcalc to add this quantity to your filter file and use it to select out the times after SAA. For instance, if you judge that the background estimator is bad for 30 minutes after the peak of SAA, you could use fcalc again to create an expression like:

  ```
  1 - ( delta_t > 0 && delta_t < 30 ) * ( BKGD_THETA > -70 && BKGD_THETA
  ```

  You can then use this column to form a GTI wherever it is equal to one. The new **xtederive v2.8** (called by xtefilt) released with the XTE FTOOLS 4.1.1 patch calculates a similar quantity to delta_t automatically. With the latest tools, your filter file has a TIME_SINCE_SAA column which may be used directly in maketime. Be advised that this formula is not meant to be taken and applied blindly. It is simply an example which may not work for your particular observation. Try using different bounds for delta_t or TIME_SINCE_SAA and compare the resulting times with your light curve to see how well they reflect what you judge to be good times. It will take some adjusting to get the result you want.

- Another method for correcting the Q6 or VLE background spectrum is to separate the activation component of the model and extract it as a separate spectrum. Simply input the model files by hand at the pcabackest prompt, once giving the Q6 and X-ray models and separately the activation model; then extract three spectra from each, separating the three layers. Likewise, extract three spectra from the data, and form the appropriate response matrix for each. In XSPEC, read in the three data files, the background files (the Q6 and X-ray component), and the activation files as correction files:

  ```
  XSPEC> data 1:1 layer1_src 2:2 layer2_src 3:3 layer3_src
  XSPEC> back layer1_bkg layer2_bkg layer3_bkg
  XSPEC> corfile layer1_act layer2_act layer3_act
  XSPEC> resp pca_LR1_961101.rsp pca_LR2_961101.rsp pca_LR3_961101.rsp
  ```

  The idea is to fit a model to the data (using the band where your source dominates the background) and in the process to find the normalization factor for the correction file which gives the best fit (using the highest energy band to minimize the efficiency for cosmic X-rays.) This involves alternating fitting the model with renormalizing the correction; you can do this by hand or use a command file such as in the following example:

Make one file, "setcor.xcm", with the commands to renormalize the correction file:

```
notice 1-3:60.-90.
ignore 1-3:0.-60. 90.-**
recornrm 1
recornrm 2
recornrm 3
```

and another file, "refit.xcm":

```
notice 1:2.5-50.
notice 2-3:8.-50.
ignore 1:0.-2.5 50.-**
ignore 1-3:0.-8. 50.-**
fit
```

This example fits the model from 2.5-50 keV, and will renormalize using 60-90 keV, but these values will depend on your source. So define your model and make a preliminary fit with the normalization still at the default of zero. Then alternate running "@setcor.xcm" and "@refit.xcm" until they converge.

Notes

- For some data sets the activation model returns error messages that theta and phi are out of range. Ignore these as the model simply has no values here (by construction)
- The xray background model is an average of several high latitude pointings in the IOC phase. Fluctuations from point to point may be as large as 1 ct/sec, so you will be better able to search for variations than determine the absolute flux at the level of 1-3 count/sec.
- If you wish to beta test the latest versions of pcabackest and the newest models, the `pub/stark` directory also includes the experimental VLE models. This recipe may apply equally well to other models and software, but we cannot make guarantees about beta test tools. Please see the pcabackest web page for more information about new versions of the software and of the models and address your questions to the PCA team.

If you have a question about RXTE, please send email to one of our help desks. This page is maintained by the RXTE GOF and was last modified on Monday, 17-Aug-1998 14:58:17 EDT.

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