Chapter 8

Simulating Data: XSPEC, PIMMS, Recommd, and the FTOOLS Tasks

At the minimum, proposers are required to estimate the PCA count rate for their source as well as the resulting telemetry rate. All estimated rates will be thoroughly reviewed by the XTE GOF staff during the technical assessment prior to the proposal review.

In this chapter, the reader will be given a tour of XSPEC, PIMMS, recommd (the EDS configuration selector), and one of the FTOOLS tasks, in that order. Having read through this chapter, the reader should be able to simulate a spectrum with the proper flux, estimate a count rate, obtain the optimal EDS mode and configuration, and simulate an observation.

8.1 Using XSPEC

XSPEC is a fairly large and sophisticated program. It has extensive on-line help. XSPEC allows the user to fit spectral data or produce a fake spectrum. It can be used before or after PIMMS to obtain an estimate of a source's count rate. The basic steps to simulate a spectrum are:

- define a model
- read in the response matrix and effective area file
- generate the fake spectrum
- fit the spectrum (if desired)

The on-line help can be consulted at any point, or you may obtain a copy of the `XSPEC` manual by e-mail request to `humphrey@heasrc.gsfc.nasa.gov`. In the sections that follow, the text that is on the user's screen during an `XSPEC` session appears in `typewriter` font.

8.1.1 Defining a model

Models are constructed from basic components. A list of the components available may be obtained by typing

```
XSPEC> model ?
```

Information about the model command may be obtained by typing

```
XSPEC> help model
```

Basic help can be obtained by working through the walk-through presented at the front of the `XSPEC` manual. The example that will be presented below is that of NGC 4151, a relatively low-luminosity source from XTE's point of view. The example below should probably be followed for any weak sources, as the example uses response matrices for all three layers of the PCA. As one might predict, we shall find that this source generates a low count rate in the PCA, so the EDS configuration should be an event mode. Additional comments will be forthcoming later in this section.

The parameters of the NGC 4151 model have been taken from the paper of Weaver et al. 1992, ApJ, 402, L11. This paper describes the observation of NGC 4151 with *BBXRT*. NGC 4151 was chosen for this simulation for several reasons. First, it is an IOC target to measure the HEXTE sensitivity to flux variations. Second, it illustrates the nature of the simulations necessary for weak sources (i.e., consider each layer of the PCA). Third, the spectrum has an Fe line, so this source can demonstrate the spectral resolution available with the XTE instruments (i.e., proportional counter resolution). Finally, given the weakness of the source, a particular EDS configuration can be suggested that will likely have wide applicability.

The model chosen for this source is an absorbed power law with a gaussian to represent the Fe line (the model is illustrative and is not meant to be definitive of AGN in general, nor NGC 4151 in particular). The model is specified by:

```
XSPEC> mo wabs pcfabs power
```

Once the model is specified, `XSPEC` will prompt the user for parameter values. The default values are as listed in the prompt header. A "return" will accept these default values. The column density adopted from the *BBXRT* data is 7.0×10^{22} cm^2, the adopted power law index is 1.68; the partial covering absorption was assumed to be 3.0×10^{22}cm^2 with a covering fraction of 0.9. The power law normalization will be determined shortly. An Fe line at 6.35 keV with a sigma of about 0.3 keV will be added to the model later.

8.1.2 Generating a Fake Data File

The following will step through the entire prescription for generating a fake spectrum for a weak source using all three layers of the PCA. Generating a spectrum for the first layer will be done in detail; appropriate changes can be made for the other layers. The reader should be aware that there are several "contortions" that must be followed so that XSPEC will respond in a statistically correct manner. First, we must generate a model. Properly, the model should use the red-shift versions of each component (i.e., zwabs, zpower, etc.); that detail will be ignored for this simulation.

```
XSPEC> mo wabs pcfabs power
 Input parameter value, delta, min, bot, top, and max values for ...
 Mod parameter 1 of component 1 wabs nH 10^22
 1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
7.0                                         (change default to 7.0)
Mod parameter 2 of component 2 pcfabs nH 10^22
 1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
3.0                                         (change default to 3.0)
 Mod parameter 3 of component 2 pcfabs CvrFract
 0.5000 1.0000E-02 0. 5.0000E-02 0.9500 1.000
0.9                                         (change default to 0.9)
 Mod parameter 4 of component 3 powerlaw PhoIndex
 1.000 1.0000E-02 -3.000 -2.000 9.000 10.00
1.68                                        (change default to 1.68)
 Mod parameter 5 of component 3 powerlaw norm
 1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
 ---------------------------------------------------------------
 mo = wabs[1] pcfabs[2] (powerlaw[3])
 Model Fit Model Component Parameter Value
 par par comp
   1  1   1   wabs       nH 10^22   7.00000       +/- 0.
   2  2   2   pcfabs     nH 10^22   3.00000       +/- 0.
   3  3   2   pcfabs     CvrFract   0.900000      +/- 0.
   4  4   3   powerlaw   PhoIndex   1.68000       +/- 0.
   5  5   3   powerlaw   norm       1.00000       +/- 0.
 -----------------------------------------------------------------
 5 variable fit parameters
```

Now, the fake spectrum must be generated. The 'none' on the command line below indicates that no response matrix has yet been specified, so `XSPEC` should prompt the user for one. The 'show' command (following the fakeit output) allows the user to check the status of the files. The reader should note that no background file nor auxiliary (effective area) file has yet been specified. Furthermore, the model normalization has not been set. Count rates at this point are pure fiction. The reader should also note that the fake spectrum to be generated will be for the first layer only. The background, response, and effective area files are available on the anonymous FTP account (`legacy.gsfc.nasa.gov`).

```
XSPEC> fakeit none
 For fake data, file # 1 needs response file: 5det_l1.rmf
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (5det_l1.fak): 5det_l1_t.fak
 T, A, Bkg, cornorm ( 1.0000 , 1.0000 , 1.0000 , 0. ): 10000.0
 Net count rate (cts/cm^2/s) for file 1 0.4848 +/- 6.9764E-03
 Chi-Squared = 299.8 using 256 PHA bins.
 Reduced chi-squared = 1.194
XSPEC> show
 15:32:33 26-Oct-94
 Fit statistic in use is Chi-Squared
 Minimization technique is Lev-Marq
 Convergence criterion = 1.0000000000000D-02
 Querying enabled
 Prefit-renorming enabled
 Log file : xspec.log
 Information for file 1
 belonging to plot group 1, data group 1, det id = XTE PCA
 Current data file: 5det_l1_t.fak
 No current background
 No current correction
 Response (RMF) file : 5det_l1.rmf
 Auxiliary (ARF) file : none
 Gain correction : 0.000 0.00
 Noticed channels 1 to 256
 File observed count rate 0.4848 +/-6.97639E-03 cts/cm^2/s
 0.4848 +/-6.97639E-03 cts/s
 After correction of 0. ; Model predicted rate: 0.4853
 ---------------------------------------------------------------
 mo = wabs[1] pcfabs[2] (powerlaw[3])
 Model Fit Model Component Parameter Value
 par par comp
   1   1   1   wabs      nH 10^22    7.00000     +/- 0.
   2   2   2   pcfabs    nH 10^22    3.00000     +/- 0.
```

```
   3   3   2   pcfabs    CvrFract    0.900000    +/- 0.
   4   4   3   powerlaw  PhoIndex    1.68000     +/- 0.
   5   5   3   powerlaw  norm        1.00000     +/- 0.
 ---------------------------------------------------------------
 Chi-Squared = 299.8 using 256 PHA bins.
 Reduced chi-squared = 1.194
```

8.1.3 Specify Background and Effective Area

At this point, the background file and effective area file must be specified, again, for layer 1. XSPEC always looks for a background spectrum to use with the model when generating a fake spectrum. To obtain the proper statistical response, the user wants that background spectrum to be free of statistics so that it can be incorporated into the source + background correctly. The background files (cxb_ib_x.fak, where 'x' is the layer ID) in the anonymous FTP account do **not** include statistics and should be considered as 'seed' files only.

Return now to the example, where we specify the effective area (.arf) and the background.

```
XSPEC> backgr cxb_ib_l1.fak
 Net count rate (cts/cm^2/s) for file 1 -42.17 +/- 6.5684E-02
 Chi-Squared = 4.2184E+05 using 256 PHA bins.
 Reduced chi-squared = 1681.
XSPEC> arf 5det_l1.arf
 Chi-Squared = 2.4511E+09 using 256 PHA bins.
 Reduced chi-squared = 9.7654E+06
```

A 'show' at this point would reveal that the background and auxiliary file pointers have been set.

8.1.4 Apply Background Statistics

The background file that has been read in does **not** have any statistics on the individual channel bins. To obtain proper χ^2 statistics, the background spectrum must have the proper statistics. To achieve that goal, another 'fakeit' must be used prior to generating a "real" fake spectrum. This time, set the model continuum normalization to zero; the 'fakeit' request will then generate statistics on the background as that will be the only "data" XSPEC sees.

```
XSPEC> newpar 5 0.0
 5 variable fit parameters
 Chi-Squared = 1.6015E+07 using 256 PHA bins.
 Reduced chi-squared = 6.3805E+04
XSPEC> fakeit
```

```
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (cxb_ib_l1.fak):test-bk.fak (Note name change)
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 100000.0
 Net count rate (cts/cm^2/s) for file 1 -4.1750E-02+/- 6.8503E-02
 Chi-Squared = 25.48 using 256 PHA bins.
 Reduced chi-squared = 0.1015
```

(A parenthetical comment: the user should note that, if s/he wishes to re-use this background file for other sources, then it should be renamed so it is saved (the name change), and one of the keywords should be fixed. The keyword in question is the '`backfile`' keyword. When the background file is generated, the keyword points to the seed file (the '`cxb_ib_X.fak`' file). Properly, the background file should point to itself, since XSPEC automatically subtracts the background file if the XSPEC-associated background pointer is set. If the keyword '`backfile`' points to itself, then, if this file is ever read into XSPEC as a data file, the user will be alerted that it is really a background file. To fix the '`backfile`' keyword, use the following FTool:

```
     grppha test-bk.fak
     chkey backfile test-bk.fak)
```

8.1.5 Set Model Normalization

Restore the model normalization to 1.0 and be certain the background file pointer is set to the no-statistics background (the "seed" file '`cxb_ib_l1.fak`'). Fake the spectrum and look at the count rate. It should be rather high. Now set the background file pointer to the proper background file (recall that XSPEC automatically subtracts the background) ('`test-bk.fak`'). Check the flux.

```
XSPEC> flux 2 10
 Model flux 0.2711 photons (2.4537E-09 ergs)cm**-2 s**-1 ( 2.000-
10.000)
```

The count rate (1652 cts/s) and the 2-10 keV flux obtained are not correct because the model normalizations appropriate to NGC 4151 have not been set. The Weaver et al. paper includes the flux in the 2-10 keV energy band. The continuum normalization follows from the ratio of the published flux to the calculated flux. In this case, the published continuum flux is approximately 1.37×10^{-10} ergs s^{-1} cm^{-2} in the 2-10 keV band. As the calculated flux is about 2.45×10^{-9} ergs s^{-1} cm^{-2}, the power law normalization should be about 0.056.

```
XSPEC> newpar 5 0.056
 6 variable fit parameters
 Chi-Squared = 86.86 using 256 PHA bins.
 Reduced chi-squared = 0.3475
```

With the model normalization now set, re-set the background to the seed file (‘cxb_ib_l1.fak’) and fake the spectrum again. The result should be the simulated spectrum of NGC 4151 using the *first* layer of the PCA.

```
XSPEC> fakeit
Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (test-bk.fak):cxb_ib_l1.fak
 T, A, Bkg, cornorm ( 1.00000E+05, 1.0000 , 1.0000 , 0. ): 10000.0
 Net count rate (cts/cm^2/s) for file 1 92.46 +/- 0.1295
 Chi-Squared = 145.3 using 256 PHA bins.
 Reduced chi-squared = 0.5788
```

The above contortions have produced a fake data file, with proper pointers and statistics, for the *first* PCA layer. The prescription above should be repeated for layers 2 and 3 (5det_l2.rmf, 5det_l3.rmf, etc.) if the contributions of the other two layers will be significant. If the contributions of layers 2 and 3 are not significant, the reader may skip the next section.

8.1.6 Generate Final Spectrum

First, treat the fake data files created as “observed” data files. (Ignore any warning messages about detector ID mismatches.) Having worked through the tedious process in the sections above, the user will note that once the data files are read in, so, too, are the effective area files, the background files, and the response matrices.

```
XSPEC> data 5det_l1_t.fak 5det_l2_t.fak 5det_l3_t.fak
 Net count rate (cts/cm^2/s) for file 1 92.46 +/- 0.1295
 Net count rate (cts/cm^2/s) for file 2 15.81 +/- 7.9917E-02
 Net count rate (cts/cm^2/s) for file 3 7.631 +/- 7.5193E-02
 Chi-Squared = 405.0 using 768 PHA bins.
 Reduced chi-squared = 0.5309
XSPEC> show
 15:50:56 26-Oct-94
 Fit statistic in use is Chi-Squared
 Minimization technique is Lev-Marq
 Convergence criterion = 1.0000000000000D-02
 Querying enabled
 Prefit-renorming enabled
 Log file : xspec.log
 Information for file 1
 belonging to plot group 1, data group 1, det id = XTE PCA XTE PCA
```

```
 Current data file: 5det_l1_t.fak
 Background file :cxb_ib_l1.fak
 No current correction
 Response (RMF) file : 5det_l1.rmf
 Auxiliary (ARF) file : 5det_l1.arf
 Noticed channels 1 to 256
 File observed count rate 92.46 +/-0.12953 cts/cm^2/s
 92.46 +/-0.12953 cts/s
 After correction of 0. ; Model predicted rate: 82.62

 Information for file 2
 belonging to plot group 2, data group 1, det id = XTE PCA XTE PCA
 Current data file: 5det_l2_t.fak
 Background file :cxb_ib_l2.fak
 No current correction
 Response (RMF) file : 5det_l2.rmf
 Auxiliary (ARF) file : 5det_l2.arf
 Noticed channels 1 to 256
 File observed count rate 15.81 +/-7.99168E-02 cts/cm^2/s
14.15 +/-7.99168E-02 cts/s
 After correction of 0. ; Model predicted rate: 14.07

 Information for file 3
 belonging to plot group 3, data group 1, det id = XTE PCA XTE PCA
 Current data file: 5det_l3_t.fak
 Background file :cxb_ib_l3.fak
 No current correction
 Response (RMF) file : 5det_l3.rmf
 Auxiliary (ARF) file : 5det_l3.arf
 Noticed channels 1 to 256
 File observed count rate 7.631 +/-7.51929E-02 cts/cm^2/s
 6.863 +/-7.51929E-02 cts/s
 After correction of 0. ; Model predicted rate: 6.905

 -------------------------------------------------------------
 mo = wabs[1] pcfabs[2] (powerlaw[3])
 Model Fit Model Component Parameter Value
 par par comp
  1   1   1   wabs            nH 10^22   7.00000   +/- 0.
  2   2   2   pcfabs          nH 10^22   3.00000   +/- 0.
```

```
  3   3   2   pcfabs          CvrFract   0.900000  +/- 0.
  4   4   3   powerlaw        PhoIndex   1.68000   +/- 0.
  5   5   3   powerlaw        norm       5.000E-02 +/- 0.
 -------------------------------------------------------------
 Chi-Squared = 405.0 using 768 PHA bins.
 Reduced chi-squared = 0.5309
```

Now, issue the final ‘fakeit’ request, entering a realistic observation time.

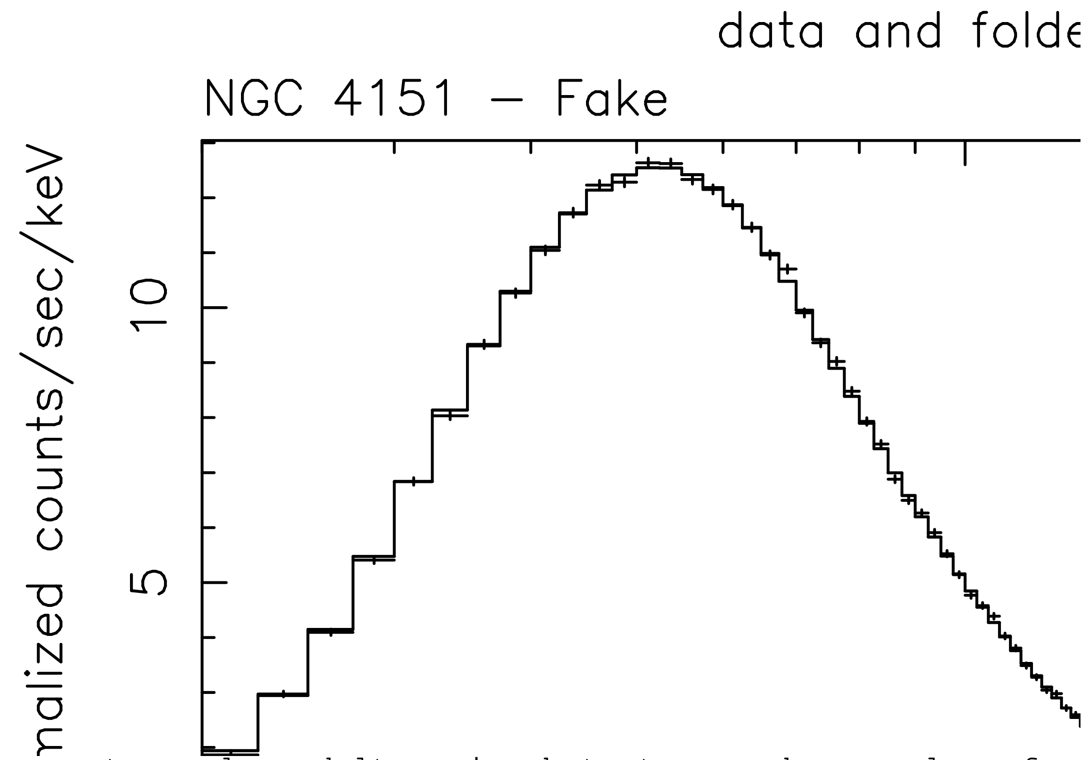
```
XSPEC> fakeit
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (5det_l1_t.fak): 5det_test.fak
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 1000.0
 Override default values for file # 2
 Fake data filename (5det_l2_t.fak): 5det_test2.fak
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 1000.0
 Override default values for file # 3
 Fake data filename (5det_l3_t.fak): 5det_test3.fak
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 1000.0
 Net count rate (cts/cm^2/s) for file 1 92.61 +/- 0.3735
 Net count rate (cts/cm^2/s) for file 2 15.78 +/- 0.2077
 Net count rate (cts/cm^2/s) for file 3 7.534 +/- 0.1867
 Chi-Squared = 776.5 using 768 PHA bins.
 Reduced chi-squared = 1.018
XSPEC> backgr 1:1 test-bk1.fak 2:2 test-bk2.fak 3:3 test-bk3.fak
XSPEC> flux 2.0 10.0
Model flux 1.5179E-02 photons (1.3741E-10 ergs) cm**-2 s**-1 ( 2.00-
10.00)
```

Figure 1 (next page) shows the result of the above simulation. Note the peak at about 5 keV. The PCA effective area is largest at this energy. Also note that χ^2 is approximately the number of degrees of freedom, as required. The flux is within a few percent of the published value.

8.1.7 Add Fe Line

Now, add the gaussian component representing the iron line, and fake the spectrum again. The same procedure should be followed to obtain the gaussian normalization as was done for the continuum normalization. Here, the correct normalization is already “known”.

```
XSPEC> addcomp 4 gauss
```




```
Input parameter value, delta, min, bot, top, and max values for ...
Mod parameter 6 of component 4 gaussian LineE
6.500 5.0000E-02 0. 0. 100.0 100.0
6.4
Mod parameter 7 of component 4 gaussian Sigma
0.1000 5.0000E-02 0. 0. 10.00 20.00
0.3
Mod parameter 8 of component 4 gaussian norm
1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
5.0e-4
---------------------------------------------------------------
mo = wabs[1] pcfabs[2] (powerlaw[3] + gaussian[4])
Model Fit Model Component Parameter Value
par par comp
  1   1   1    wabs       nH 10^22     7.00000    +/- 0.
  2   2   2    pcfabs     nH 10^22     3.00000    +/- 0.
```

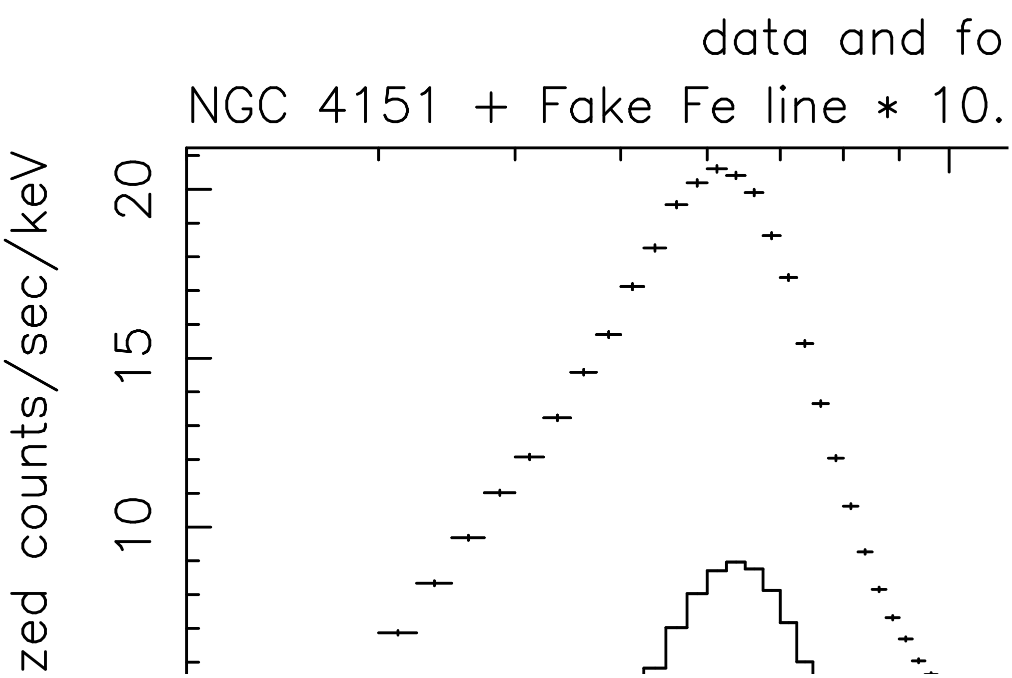
```
   3   3   2    pcfabs    CvrFract    0.900000   +/- 0.
   4   4   3    powerlaw  PhoIndex    1.68000    +/- 0.
   5   5   3    powerlaw  norm        5.0000E-02 +/- 0.
   6   6   4    gaussian  LineE       6.40000    +/- 0.
   7   7   4    gaussian  Sigma       0.300000   +/- 0.
   8   8   4    gaussian  norm        5.0000E-04 +/- 0.
 ---------------------------------------------------------------
 8 variable fit parameters
 Chi-Squared = 883.9 using 768 PHA bins.
 Reduced chi-squared = 1.163
XSPEC> backgr 1:1 cxb_ib_l1.fak 2:2 cxb_ib_l2.fak 3:3 cxb_ib_l3.fak
XSPEC> fakeit
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (5det_test.fak): 5det_t1_G.fak
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Override default values for file # 2
 Fake data filename (5det_test2.fak): 5det_t2_G.fak
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ): 1000.0
 Override default values for file # 3
 Fake data filename (5det_test3.fak): 5det_t3_G.fak
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ): 1000.0
 Net count rate (cts/cm^2/s) for file 1 94.90 +/- 0.3766
 Net count rate (cts/cm^2/s) for file 2 15.75 +/- 0.2076
 Net count rate (cts/cm^2/s) for file 3 7.915 +/- 0.1877
 Chi-Squared = 649.4 using 768 PHA bins.
 Reduced chi-squared = 0.8545
XSPEC> eqw 4
Additive group equiv width for model 4 (gaussian): 214. eV
```

The result does not show a particularly strong iron line. Increase the normalization of the iron line by a factor of 10 (science fiction, but useful for illustration).

```
XSPEC> newpar 8 5.0e-3
 8 variable fit parameters
 Chi-Squared = 1.1760E+04 using 768 PHA bins.
 Reduced chi-squared = 15.47
XSPEC> fakeit
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
```

```
 Override default values for file # 1
 Fake data filename (5det_test1_G.fak):
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Override default values for file # 2
 Fake data filename (5det_test2_G.fak):
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Override default values for file # 3
 Fake data filename (5det_test3_G.fak):
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Net count rate (cts/cm^2/s) for file 1 117.2 +/- 0.4054
 Net count rate (cts/cm^2/s) for file 2 16.30 +/- 0.2089
 Net count rate (cts/cm^2/s) for file 3 7.959 +/- 0.1878
 Chi-Squared = 663.5 using 768 PHA bins.
 Reduced chi-squared = 0.8730
XSPEC> eqw 4
Additive group equiv width for model 4 (gaussian): 2.14 keV
```

The figure shows the spectrum with continuum model normalization set to zero so the line component is visible.



8.1.8 Fitting the Fake Spectrum

At this point, the desired data have been completely simulated. The user may wish to fit the simulated data (using the `fit` command) to see the extent of the errors. Once the spectrum has been fit, the χ^2 contours may be generated (by using the `steppar` command) to evaluate the scientific return that may be expected. Remember to switch between the background file without statistics (for generating a fake spectrum) and the background file with statistics (for fitting, or checking the flux).

8.1.9 Summary of Fake Spectrum Generation

To provide more 'forest' after the 'trees' of the past 8 sections, an outline is listed below of the steps to produce a fake spectrum.

a. Create a model

b. Use 'fakeit none' (will prompt user for redistribution matrix and effective area file). Note that the fake spectrum generated at this point will not have the proper statistics, nor any information from the background.

c. Set the background file pointer to the no-statistics seed file. Set the model normalization to zero.

d. Use 'fakeit' to generate a fake background file with the proper statistics. Rename this file so it is not over-written.

e. Re-set the model normalization. Check that the background file pointer is still set to the no-statistics seed file. Use 'fakeit' to generate a model file with the proper statistics on source + background.

f. Set the background file pointer to the background file with the proper statistics that you saved in (d) above. Use the 'flux' command to generate the model flux.

g. Adjust the model normalization so that the flux will be the correct flux for the source. Re-set the background file pointer so that it points to the background file without statistics.

h. Use 'fakeit' to generate the final fake spectrum for the first layer. Repeat steps b-h for layers 2 and 3 if necessary.

8.2 Using `PIMMS`

Now that we've simulated a spectrum, we want to check that the count rate is reasonable. `PIMMS` (Portable, Interactive, Multi-Mission Simulator) allows the user to produce a count rate. Whether the user uses `PIMMS` before or after XSPEC is by choice. The use of one can serve as a check on the use of the other. See Appendix 2 to obtain a copy of `PIMMS`.

The models available in `PIMMS` are a power law, thermal bremsstrahlung, and blackbody. Other models may be imported (see the `PIMMS` manual for help on this feature). The general approach to estimating a count rate is to specify the instrument (the default is the *ASCA* SIS), select a model, and specify the product (the default is a count rate). The user then activates `PIMMS` by using the 'GO' command.

The initial header for `PIMMS` is:

```
*** PIMMS Version 1.2 (1993 May 26 release) ***
 Reading mission directory, please wait
 * PIMMS simulation product is COUNT
 count rates for various instruments or intrinsic fluxes can be
estimated
 <--- Use 'PRODUCT' to simulate images
 * Current model is BREMSSTRAHLUNG, kT= 10.0000 keV; NH = 1.000E+21
 <--- Use 'MODEL' command to change
 * By default, input rate is taken to be
 Flux ( 2.000- 10.000 keV) in ergs/cm/cm/s
 <--- Use 'FROM' command to change the default
 * Simulation product will be
 Count rate in ASCA SIS
 <--- Use 'INSTRUMENT' command to switch to another instrument
```

We are interested in estimating a count rate for the PCA on XTE, so the command is:

```
 PIMMS > instrument xte pca
```

The model choice is the power law absorbed by a hydrogen column of 7×10^{22} cm^{-2}. As `PIMMS` does not have a rich suite of models, we will only consider the continuum contribution. The next command tells `PIMMS` to calculate the count rate based upon the 2-10 keV flux of NGC 4151 (with units of ergs cm^{-2} s^{-1}, indicated by the key word "ergs"). The resulting count rate, 174.7 counts/sec, is somewhat close to the estimated count rate from `XSPEC` (118 counts/sec).

```
 PIMMS > mo pl 1.68 7.0e+22
 PIMMS > go 1.8e-10 flux ergs 2-10
 * For power law model with photon index = 1.6800; NH = 7.000E+22
 and a flux ( 2.000- 10.000keV) of 1.800E-10 ergs/cm/cm/s
 (Model normalization = 6.577E-02)
 * PIMMS predicts 1.747E+02 cps with XTE PCA
 PIMMS >
```

8.3 Using `recommd`

`recommd` is the EDS configuration recommendation tool. It was written by Dr. A. Rots of the XTE GOF. `recommd` generates a table of recommended configurations for the EDS for given count and telemetry rates. It assumes that the user has used `PIMMS` or `XSPEC` to generate a count rate for each of the following 6 energy bands: 0-3.2 keV, 3.2-4.3 keV, 4.3-5.7 keV, 5.7-8.6 keV, 8.6-12.1 keV, and 12.1-60.0 keV for the PCA. `PIMMS` will generate count rates for each of these bands as a default option whenever the chosen instrument is the XTE PCA. `recommd` is available from the anonymous FTP account.

The input to `recommd` consists of:

- the number of Event Analyzers to be used;
- the allowed telemetry rate (a guest observer must argue increasingly effectively for telemetry rates above 20 kbps);
- an estimate of the observing efficiency (for now, assume 50%);
- the desired time resolution (or "optimize" or "don't care");
- the spectral resolution desired (or "optimize" or "don't care");
- the count rates in the above-mentioned energy bands
- the quantity of output desired from `recommd`.

The output of `recommd` will be the top N (as specified by the user) possible EDS configurations that match the observer's criteria and will be ranked in order of decreasing suitability. Guest observers are free to choose any of the configurations, however, configurations that are less suitable may need additional justification in the proposal.

```
===> RECOMMD, the EDS Configuration Selection Assistant  $Revision: 2.3
===> Results (up to 4 Event Analyzers) for:

     Time resolution:  1.000000 s,     Number of channels  : 128.000000
     alpha =  0.500, beta =  0.500,    alpha =  2.000, beta =  0.125

     Telemetry rate : 18.000000 kb/s, Observing efficiency: 65.000000
     alpha =  4.000, beta =  0.125, gamma =  1.000, breakpoint factor =  1.49
     alpha =  4.000, beta =  0.062 for count capacity
     Bonus factor for detector (PCU) Id:  1.0
     The input source spectrum leads to the following estimates for each of the six canon-
ical bands:
________________________________________________________________________________________
Channel limits          0.0- 13     14- 17     18- 23     24- 35     36- 49   50-249
Energy limits (keV):  0.0- 3.2    3.2- 4.3   4.3- 5.7   5.7- 8.6   8.6-12.1  12.1-60.0
Weights:                0.167      0.167      0.167      0.167      0.167      0.167
Source spectrum:        7.13      12.95      16.03      24.23      15.68      42.88
```

```
Fraction in layer 1:    0.99        0.96       0.95       0.94       0.74       0.48
Background spectrum:    5.84        1.80       2.76       5.28       5.96      69.20
Fraction in layer 1:    0.56        0.55       0.54       0.53       0.51       0.44
S/N (all layers):       1.644       3.183      3.453      4.108      2.985      3.185
S/N (layer 1 only):     1.914       3.275      3.569      4.276      2.759      2.280
S/N (layers 2+3):       0.031       0.354      0.439      0.574      1.295      2.232
```

The above section of the `recommd` output regurgitates the input parameters. Note the appearance of an 'alpha' and a 'beta' parameter for the time resolution and the number of channels. The alpha and beta parameters are weights placed upon the user's choice of the respective parameters. In this particular example, greater spectral resolution receives higher weight than the time resolution, hence the alpha parameter is larger than the beta parameter. The absolute values of alpha and beta are not adjustable by the user, only their relative values. The output above also reproduces the input spectrum and calculates the signal-to-noise in each energy band in the layers.

The material that follows is the output of `recommd`. Only the top 7 recommended configurations are shown here for brevity. (Note that the output may change in detail, but not in spirit. Consult the anonymous FTP account for additional help.)

```
     For this source you may want to consider configurations with spectral distribution
indicator M, if available.

===> Please check whether Standard Mode 2 might satisfy your requirements already
===> You may not need a special configuration

     Recommended Configurations:

Suitability   TLMRate    Configuration     ConfigId   TLM     T_Res   Num    Max    logSuit.
                                                      Rate            Chan   CntRate
         (avg total PCA)
1.30431e+03  11.021  GoodXenon1_16s     0x01000024   5.510  0.000001  256   894.9    3.5405
           ( 10.163  GoodXenon2_16s     0x01000025   5.510  0.000001  256   895.9    3.5405

1.30242e+03  11.149  GoodXenon1_2s      0x01000016   5.574  0.000001  256 8063.0    3.5405
           ( 10.247) GoodXenon2_2s      0x01000017   5.574  0.000001  256 8063.0    3.5405

7.47413e+01   5.517  E_16us_64M_0_8s    0x01000041   5.517  0.000016   64 1919.9    4.1352
             (6.586)

7.45504e+01   5.631  E_16us_64M_0_1s    0x01000040   5.631  0.000016   64 16255.0   4.1352
            ( 6.660)

7.26623e+01   7.602  E_250us_128M_0_8s  0x0100004f   7.602  0.000250  128 1791.0    4.1470
            ( 7.941)

7.25272e+01   7.716  E_250us_128M_0_1s  0x0100004e   7.716  0.000250  128 16127.0   4.1470
```

```
           ( 8.016)

5.14963e+01  10.400  B_16ms_10M_0_13_H  0x02000028   5.094  0.016000   10 15937.5    0.0920
           (  9.760) E_16us_64M_14_8s   0x0100006b   5.306  0.000016   64  1919.9   3.7498
```

The columns are briefly described. The 'suitability' measures each configuration, that are then ranked from high suitability to low, and is the sum of the suitabilities for each mode independently. The 'TLM Rate' column lists the total telemetry rate for both the binned and the event modes. The configuration column lists the exact configuration label that should be entered on the proposal. The 'ConfigID' column is an internal representation of the exact configuration. The second 'TLM Rate' column lists the telemetry rate for each of the configurations independently. The time resolution ('TimeRes') should be optimized, as the input choice was a "don't care" condition. The number of channels ('NumChn') lists the number of spectral channels to be used for that configuration. Finally, the 'MaxCntRate' column indicates the maximum count rate for that configuration within the alloted telemetry. In the example above, the maximum count rate is always above the estimated source count rate.

Note that the top recommended configurations are the GoodXenon configurations. For weak sources, this is perhaps the most appropriate choice, as every event is telemetered to the ground. For brighter sources, binned event modes are necessary to remain within reasonable telemetry limits.

The user is free to choose any of the configurations. The chosen configuration will be checked, however, for its overall suitability. Large differences between the chosen and the most suitable configuration(s) must be justified in the feasibility section of the proposal. The user should note that there are situations where a slight increase in the telemetry rate can yield considerably more information than the `recommd` output may suggest. For example, in the sample above, one of the recommended configurations (near the bottom) is a binned event mode, generating 5.09 kbps. For a slight increase in telemetry (5.09 kbps vs. 5.51 kbps), the user can request a GoodXenon events configuration and download every event. `'recommd'` is an advisor, but should not be a substitute for good knowledge of the capabilities of the EDS nor informed thought.

8.4 Using the FTOOLS Routines

In this section, an illustration of the use of the FTOOLS tasks will be given. Only two FTOOLS will be demonstrated (the 'fakelc' and 'addsine' routines), but the other FTOOLS will resemble the demonstration to be presented here. The FTOOLS are available from the anonymous FTP account on `legacy.gsfc.nasa.gov` in the `software/` directory. Considerable information is available, including user guides, developers guides, and installation guides. Instructions on obtaining access to the FTP account are presented in Appendix 2 of this technical manual.

The general approach to using the FTOOLS to simulate timing behavior is the generation of a light curve. The first FTOOL that must be used is 'fakelc', the fake light curve generator. Once the fake light curve exists, it may be modified by adding additional timing behavior to it. For example, the demonstration here will add a sine wave to the fake light curve. All of the FTOOLS tasks are stand-alone FORTRAN programs. Parameter-prompting provides the user interface to the software.

8.4.1 Using 'fakelc'

'fakelc' generates a fake light curve. The user must supply a file name, whether 'fakelc' should generate a binned or event light curve (at the time of writing, only the binned mode will work with other FTOOLS in subsequent use), the observation start time, the bin size and its units, the mean intensity and its units, and a noise option. The file name can be any string; the generated file will be a FITS file that conforms with the OGIP FITS file standards. The time span of the observation time is the total exposure (i.e. 'live') time, exclusive of data gaps. The user may specify that data gaps be inserted, either according to earth occultations and SAA passages in the XTE orbit, or at fixed intervals. See the help file for full details. The input intensity may be either "count/s" or "count" per bin size. In event mode, if count is used, a rate is computed using the bin size. The noise options are (1) Poisson noise and (2) Gaussian noise. The choice of Gaussian noise requires specification of the sigma of the distribution.

The output of 'fakelc' is a FITS file containing the light curve. This light curve may be examined with any software capable of handling the FITS file. The software package XRONOS, the timing leg of the XANADU triad of software (XSPEC and XIMAGE are the other two) will read and plot this light curve. An example of a 'fakelc' run appears below. (Parameters from the previous run appear in paranthesis, and are used as the defaults).

```
unix> fakelc
Name of output FITS file (testg3.lc): testg4.lc
Type of Light Curve: (E) Event or (B) Binned (B): B
Bin Size/Sampling Precision (0.1):
Units for bin size (s=sec, d=days) (s):
Mean intensity (10):
Units for intensity (count/s):
Noise Option (1):
Total Time span of the obsesrvation (1000):
Units for the time span (s=sec, d=days) (s):
```

8.4.2 Using 'addsine'

'addsine' allows the user to add a sine curve to the fake light curve generated with 'fakelc'. The output file from 'fakelc' is the input file to 'addsine' (and to most of the other FTOOLS tasks used for timing simulations). The 'time interval to have sine added to' represents the time intervals (in MJD) in which the sine wave will be added. Those intervals are specified as 'start_time-stop_time'. Either the start or the stop time may be omitted to signify the default for the missing item. Additional parameters are listed in the log file below and include the period of the sine curve, its amplitude, the time of phase zero, and the noise option. The user may also specify a pulse shape to be inserted at the given period.

The output of ‘addsine’ is another FITS file that again can be used in FITS-compatible software such as XRONOS.

```
unix> addsine
Name of FITS file and [ext#] (testg3.lc): testg4.lc
Name of output FITS file (testg3a.lc): testg4a.lc
Time interval(s) to have sine added to (-):
Period of Sine curve (20): 1000.0
Units for period (s or d) (s):
Amplitude of Sine Curve (20):
Time of Zero Phase of Sine Curve (in MJD) (49000):
Noise Option (1):
```

8.4.3 Additional FTOOLS for Timing Simulation

The following FTOOLS tasks exist for timing simulation at the time this section was written (8/94):

- addshots - add shot noise to an input light curve
- perdgrm - perform Fourier analysis on a light curve using J. Scargle’s algorithm (this routine is capable of handling unevenly distributed data)

8.5 Using XRONOS

XRONOS provides the user a tool for timing analysis in a manner similar the use XSPEC provides for spectra. XRONOS is available from the anonymous FTP account on `legacy.gsfc.nasa.gov` in the `software/` directory. XRONOS is a shell wrapped around a series of “stand-alone” FORTRAN programs that each handle a single aspect of timing analysis. For example, once inside XRONOS, the command ‘acf’ calls the autocorrelation function.

Available analysis tools within XRONOS include:

- plot light curve for 1, 2, or 3 time series plus ratio and color-color (if appropriate)
- perform epoch folding for 1 or 2 time series
- perform epoch folding search for periodicities
- power spectrum density analysis
- autocorrelation function analysis

- cross-correlation function analysis

Additional capabilities are likely to be forthcoming.

The user has full control of the binning used in the analysis when using `XRONOS`. As such, of fundamental importance in are the following definitions.

- Bins: these are the time bins of the time series *being analyzed;*
- Newbins: these correspond to the time resolution with which the analysis is done; clearly, newbins cannot be shorter than the longest bin duration of the time series;
- Intervals: this is defined as the number of newbins over which the analysis is done;
- Frames: this consists of the average of the results of the analysis of one or more contiguous intervals; a frame may consist of only one interval.

Full details are contained in the `XRONOS` User's Manual, available from the HEASARC (`humphrey@heasarc.gsfc.nasa.gov)`. An example is not presented here as a walk-through exists in the `XRONOS` manual.