Estimating the Background for the PCA

November 27, 1996

Abstract

This document presents the philosophy behind the PCA background estimation tools, an assesment of the current status of the tools, and our expectations about the schedule for improvements to the utility of the tools. As this is an ongoing effort, this document will be updated periodically. Reports on removing the background for an observation of Capella (9-24-96), NGC 4507 (10-16-96), and Algol (11-15-96) are available at as companion documents.

A postscript version of this document is available.

1 Philosophy behind `pcabackest`

Previous proportional counter experiments in earth orbit have successfully modelled the instrument background as a function of one parameter (e.g. HEAO-1 A2) or several parameters (e.g. *Ginga*). Some experiments (EXOSAT) have also employed offset detectors. While some early concepts for the PCA included offset or movable detectors, the flight detectors are all fixed on the RXTE spacecraft and are all pointed along the science axis.

The background consists of two components, the diffuse sky background which enters through the collimator as X-rays, and the internal background which arises from interactions between radiation or particles in orbital environment with the detector or spacecraft. While the sky background is assumed constant at any one pointing position, the internal background may vary as the detectors move through different ambient conditions. The primary function of the tool **`pcabackest`** is to estimate the variable, internal, component to the background. Pcabackest is also be capable of adding a constant term to approximate the sky background.

It is assumed that the internal backgruond varies on a time scale long comapred to 16 seconds, the natural timescale of the PCA Standard 2 data. The design is that the model can be evaluated once every 16 seconds, and that the equivalent of a standard 2 data file can be created with separate information for each detector and each anode chain.

The intended usage is that each observer will run `pcabackest` for each data interval of interest. At this point, the user can extract (with the ftools or any other method) both the data and an estimate of the internal background. In the context of the ftools, all of the good time intervals may be applied to the output files from `pcabackest` exactly as if to the Standard 2 data itself. This allows the observer to exclude certain time intervals from the data collection, and the same intervals are trivially excluded from the background estimate.

2 Running pcabackest

`pcabackest` is written as a standard ftool. Here we list the parameters required for use with version 1.4f by presenting the part of the help page for `pcabackest`. Additional comments of modelfile and filterfile follow.

```
infile [filename]
    The   name   of   the   Standard Mode  2 file  for  which  the
    corresponding background model will be created.   This  file  is
    also  the  source of the values of the parameters upon which the
    model is based.

outfile [filename]
    The name to use for the file containing the background  estimate
    created by pcabackest.

modelfile [filename]
    The  name of the file(s) containing the model created by the PCA
    instrument team.  This may be a list of model  files  containing
    different  model components or "caldb" to select the appropriate
    model files  from  the  calibration  database.   Normally,  only
    models  which  are  valid at the time of the observation will be
    used.  This restriction can be overridden  by  specifying  model
    files and extensions explicitly.

modeltype=both [INTERNAL, EXTERNAL, BOTH]
    Selects  the  type  of  background  models to be included in the
    estimate.  The user may elect to  include  only  internal,  only
    external  (Diffuse  X-ray) or all background.  If this parameter
    is set to "internal" or  "external"  then  the  background  will
    only  include  contributions  from  models  containing a "BGSRC"
    keyword which is set to "INTERNAL" or "EXTERNAL" respectively.
```

(interval=16) [integer]

The interval between successive background estimates in the output file. The Standard mode 2 file contains data for every 16 seconds but the interval in the output can be made either shorter (by interpolating) or longer (by integrating).

(propane=no) [boolean]

Setting propane=yes will cause pcabackest to generate background estimates for the propane layer of each PCU. (Note: there are no model files to support this feature.)

(layers=no) [boolean]

Normally, pcabackest computes the overall background spectrum for each PCU. Setting layers=yes will cause pcabackest to produce a separate background estimate for each anode of each layer of each PCU.

(gaincorr=no) [boolean]

Setting gaincorr=yes will cause pcabackest to perform the gain and offset correction to the background which the EDS applies to data in modes where the data from multiple PCUs are combined. Setting this flag forces the output spectrum to contain 256 channels

gcorrfile [filename]

The name of the file containing the EDS gain and offset corrections. The default value of "caldb" causes pcabackest to search the calibration database for the correct file to apply.

(fullspec=no) [boolean]

By default, pcabackest produces 129 channel background spectrum which correspond to the 129 channels of Standard Mode 2. Setting fullspec=yes will cause pcabackest to produce 256 channel background spectrum. This flag is automatically set when gaincorr is set.

(interp=yes) [boolean]

Some models contain a small number of bins in the modelled parameter(s) but contain additional information so that intermediate values can be obtained by interpolation. Setting this parameter to "no" inhibits this interpolation but setting it to "yes" does not cause models without the additional information to be interpolated.

syserr=yes [boolean]
Forces the detailed computation of the estimated systematic error in the background. Setting this parameter to "no" causes pcabackest to execute much faster. It is likely that the systematic error for a particular PCA background spectrum can be determined without performing the detailed calculation. Setting this parameter to "yes" causes pcabackest to create additional spectral columns in its output which contain information related to the systematic error estimate. This information must be extracted using saextrct and manipulated further in a way to be described later to be useful.

(maxmodels=256) [integer]
The limit on the number of background models that can be processed at one time. If a background estimate involves many different model components then this may have to be larger but that is unlikely.

(clobber=yes) [boolean]
If set to "yes" then pcabackest will overwrite any existing file with the same name as the background estimate file being created.

The modelfile is either the name of a model file, the name of a file which itself contains the names of several modelfiles (using the ftools @filename convention), or CALDB which will cause `pcabackest` to search the CALDB for appropriate models. As of 27 November 1996, three models are available although only one is installed in the most recent CALDB (associated with the release of ftools v3.6). Information on obtaining the latest models is available from the http://lheawww.gsfc.nasa.gov/users/stark/pca/pcabackest.html. The three models are discussed below; the three models represent different components of the total background, and are intended to be used together.

The filterfile gives the name of the XTE filter file which is required for processing the activation model. Note that the standard processing (as of November 1996) creates a filter file in the stdprod subdirectory; however, for `pcabackest` to run properly, two additional parameters (BKGD_THETA and BKGD_PHI) are required. These can be obtained by rerunning `xtefilt` using updated tools available from the pcabackest page. These parameters are described below.

3 Particle model

The first model is based on the instantaneous particle flux, assumed to be well measured by the housekeeping parameters `Q6VxVpXeCntPcuN (N=1-5)`, which measures the rate of events which trigger exactly 6 of the lower level discriminators in each PCU. Background components which are created by unvetoed particle tracks or by interaction between particles and the the spacecraft or detector body should be well tracked by this rate. The rate is variable by a factor of 2.5 over the course of a single orbit, and is well correlated with latitude, magnetic rigidity, or McIlwain L.

We examine the success of this model in three bands (channel 0-40, 41-120, and 121-249 which correspond, for IOC data, to roughly 0-11 keV, 11-32 keV, and 32-65 keV). All three of these bands show short term variations ($\sim$ 20 minutes) which are well modelled by the particle model. These are difficult to see in the plots which cover an entire day, although the data-background_model files show less vertical spread. 4 shows 2 orbits. The 3 panels represent the data, the modle background, and the data-model. The smooth variation is largely removed.

We also present the pulse height spectra integrated over the entire set of data shown in 1 through 3.

As currently implemented the particle based model is evaluated during orbits where the activation terms are deemed inconsequential (about half of the total).

4 Activation model

Beyond the suggestion in the q6 model results, we have additional evidence for activation. This representation leads to the suggestion that we can parameterize the background as a function of coordinates. In the world map shown, any satellite track through a given earth latitude and longitude can

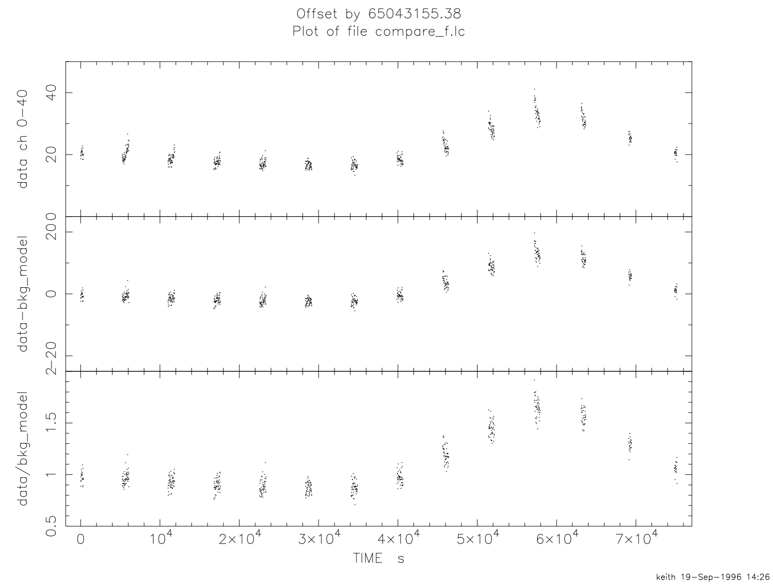

Figure 1: Channel 0-40, total count rate during occults, q6 model

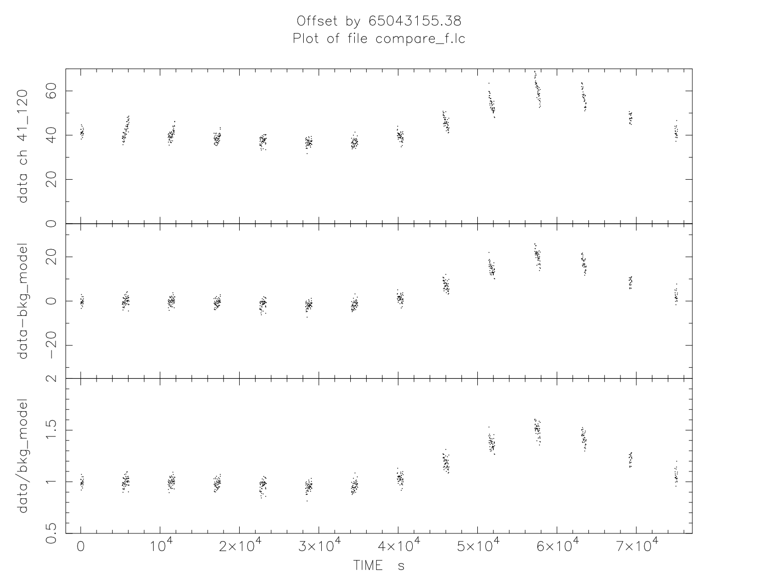

Figure 2: Channel 41-120, total count rate during occults, q6 model

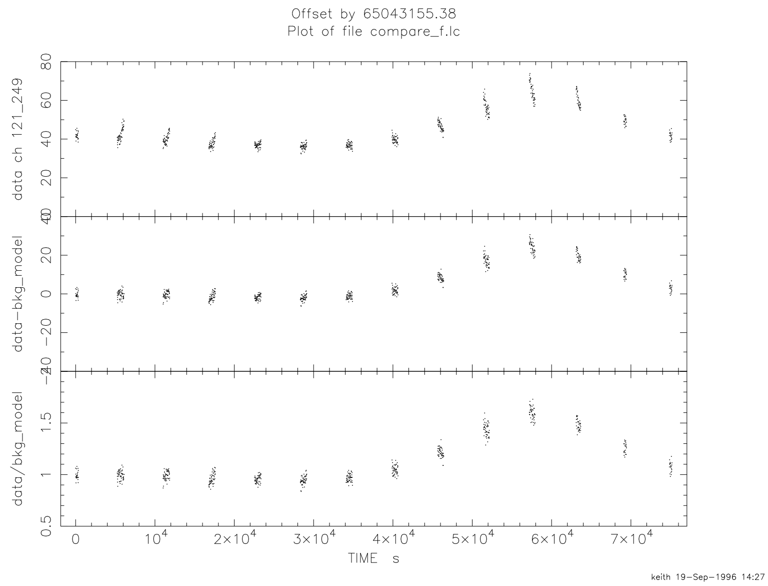

Figure 3: Channel 121-249, total count rate during occults, q6 model

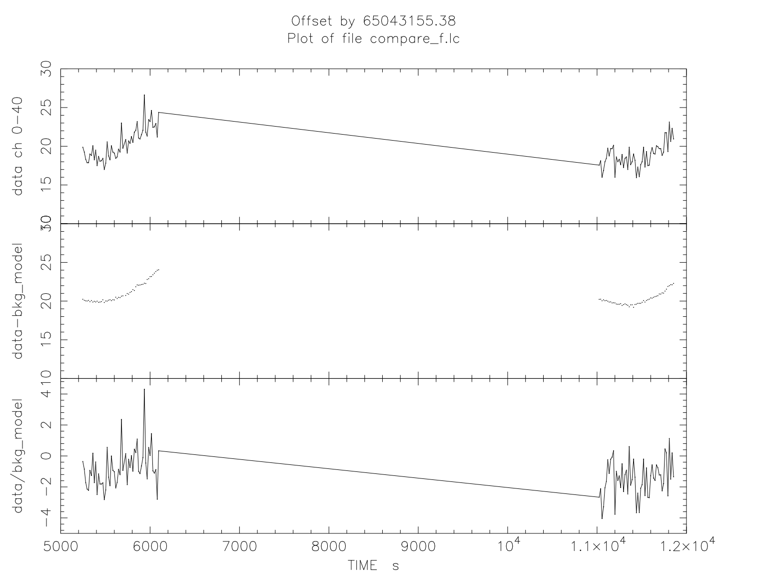

Figure 4: Channel 0-40, total count rate during two occults, q6 model

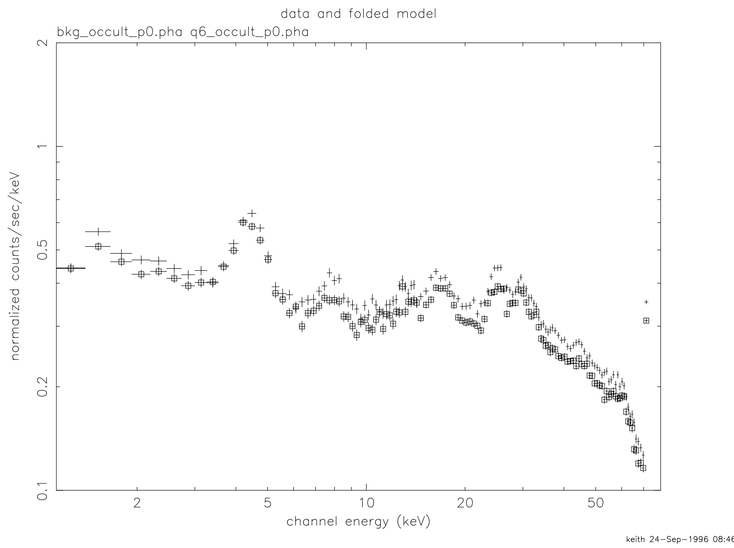

Figure 5: Data and model, PCU 0, integrated over occults, q6 model

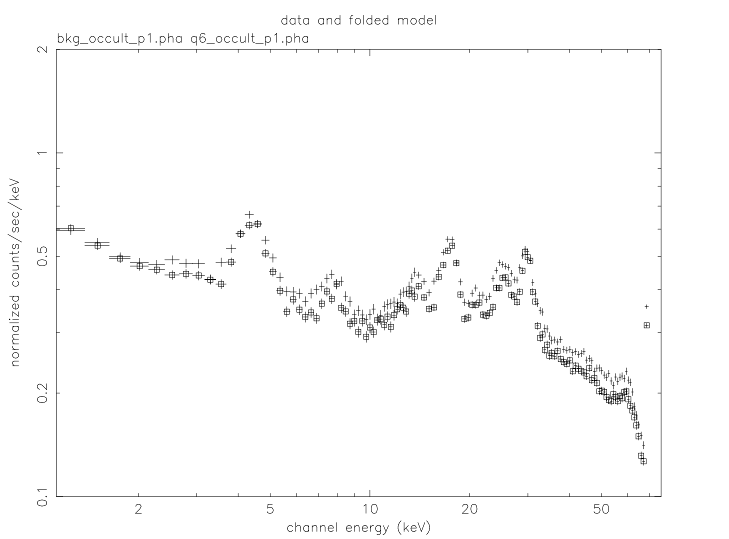

Figure 6: Data and model, PCU 1, integrated over occults, q6 model

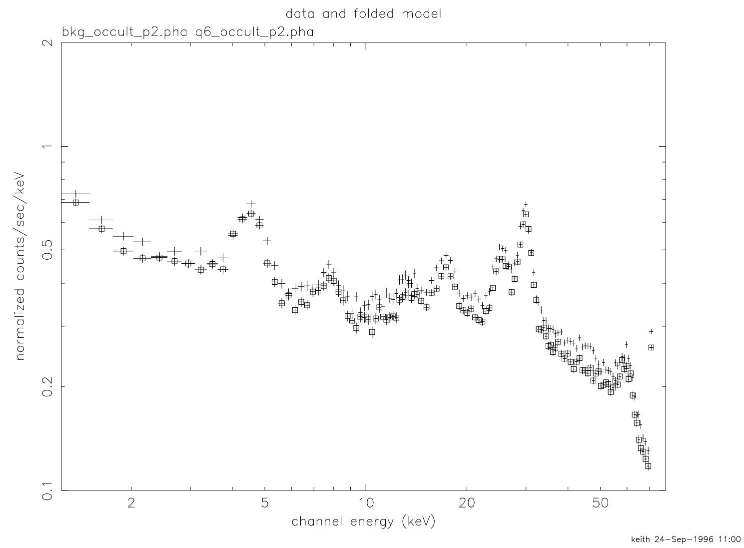

Figure 7: Data and model, PCU 2, integrated over occults, q6 model

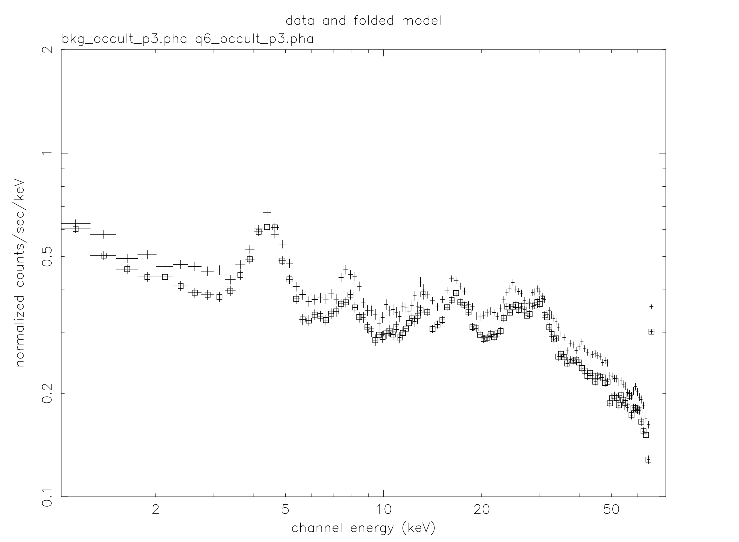

Figure 8: Data and model, PCU 3, integrated over occults, q6 model

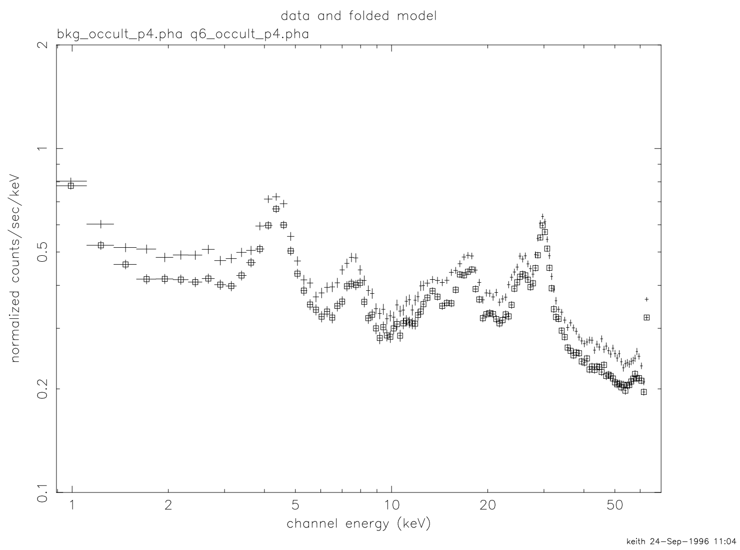

Figure 9: Data and model, PCU 4, integrated over occults, q6 model

have only two histories, and the two histories are separated by whether the z-velocity is positive or negative. A simpler representation is to recast the coordinates into earth longitude at which the satellite crosses the equator going north and orbit phase relative to equator crossings. The activation model attempts to parameterize the extra background component as a function of these two parameters. This is equivalent to assuming that the effect of the SAA is aproximately constant for each passs; the validity of this assumption will be addressed later as more experience is gained with applying the model over a wide range of mission times.

As currently implemented, the activation model is evaluated during the orbits where activation is considered important by first applying the particle based model to the data, and then parameterizing the activation model in terms of the two coordinates BKGD_THETA and BKGD_PHI. This approach results in no predicted activation component for about half of the orbits. The adequacy of this approach is being studied.

We will try to demonstrate the estimated activation component for the occulted observations of NGC 4151 during IOC soon.

5 Cosmic X-ray Background

Spectra of the Cosmic X-ray background are available, and are intended to provide an average high latitude ($|b| \geq 20$ deg) estimate. The currently available spectra are produced from a fraction of the IOC data where the particle model alone was estimated to "work well" (as judged from behaviour during the interspersed occults). More data will be included in this model both from IOC data and from a recently started calibration program where day long observations of blank sky are undertaken about once per month. The first such day was on days 306-307 of 1996; the second has been scheduled for day 336-337 of 1996. These data will be made publicly available in the archive as soon as they are processed.

6 Results

We demonstrate several attempts to estimate and remove the PCA background; each of these sections is identified by the date on which the analysis was done, and therefore give an idea of the advancing sophistication of the background estimation.

6.1 Capella 9-24-96

Capella results may be examined as an html or postscript document. We thank Tom Ayres for use of this data and helping reduce it.

6.2 NGC 4507 10-15-96

NGC 4507 results may be examined as an html or postscript document. We thank Giorgio Matt for allowing us to examine this data.

6.3 Algol 11-17-96

Algol results may be examined as an html or postscript document. We thank Robert Stern and Arnold Rots for providing results of analysis performed at the XTE GOF on this object.

7 Data selection

7.1 Elevation angle: October 10,1996

The mission planning software uses an earth limb angle of 3 deg as the boundary between occulted and non-occulted data. This condition (evaluated on 1 minute intervals) controls whether the guest observer selected Event Analyzers are processing data or suspended. The Standard data modes both collect data through (non SAA) occulted periods. Observations of Cen X3 on October 2 provide illustration as the occults were grazing. The short term timeline shows occulted periods from mission time 86985301-86986201 and 86991061-86991061.

```
1996:277:18:15:00 000086984101 OBSERVATION 10144-03-01-04 START
      PI: THOMAS A. PRINCE
  SOURCE: CEN_X-3
  TARGET: RA=170.313293, DEC=-60.623299, ROLL_BIAS=-9.4, SLEW_RATE=6.0
     EDS: B_250MS_128M_0_254
          Null
          Null
          Standard1b
          Standard2f
          Null
   HEXTE: E_2MS_256_DX1D (LLDA=DEF, DWELLA=DEF, ROCKA=DEF)
          E_2MS_256_DX1D (LLDB=DEF, DWELLB=DEF, ROCKB=DEF)
  EVENTS: start_slew    18:15:00 (000086984101)
          end_slew      18:25:00 (000086984701)
          out_saa       18:25:00 (000086984701)
          in_occult     18:35:00 (000086985301)
          out_occult    18:50:00 (000086986201)
          in_saa        19:27:00 (000086988421)
          out_saa       20:04:00 (000086990641)
          in_occult     20:11:00 (000086991061)
          out_occult    20:26:00 (000086991961)
          in_saa        21:10:00 (000086994601)
GOODTIME: 18:25:00 (000086984701) to 18:35:00 (000086985301)
          18:50:00 (000086986201) to 19:27:00 (000086988421)
          20:04:00 (000086990641) to 20:11:00 (000086991061)
          20:26:00 (000086991961) to 21:10:00 (000086994601)
1996:277:21:30:00 000086995801 OBSERVATION 10144-03-01-04 END
```

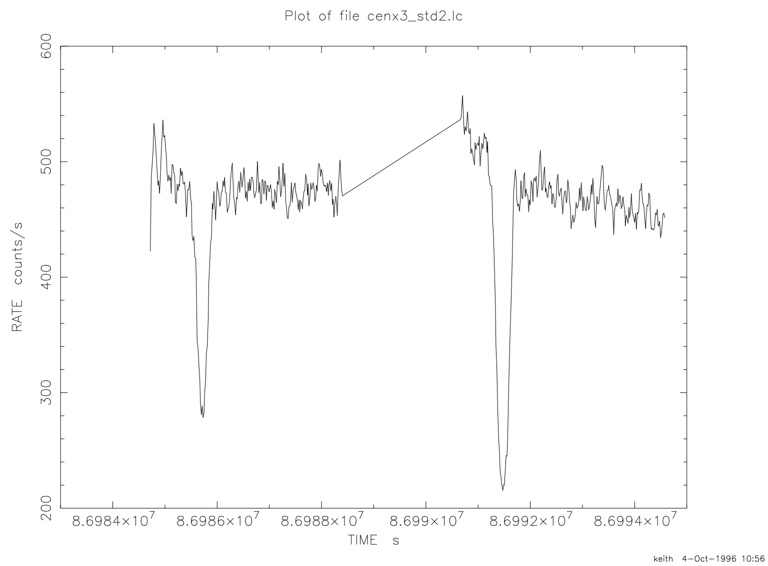

Figure 10: Cen X3 data showing 2 grazing occults. Data from 10144-03-01-04, PI Prince

Figure 10 shows the standard 2 counting rate (sum of all layers and all detectors with 16 second intervals) during this observation, while figure 11 shows the elevation angle plotted on the same horizontal scale. All of this data was captured by the SOF real time system, processed by XFF with the realtime option. The lightcurve was produced with SAEXTRACT 3.6 and the filter file was produced with XTEFILT 1.3.

The GOF recommenation for selecting non-occulted data is usually to select data with elevation greater than 10 degrees. This requires additional selection beyond taking all of the data in the on surce files...

7.2 Electron contamination

The green points in encountered in our search for the activation model are identified as having high values of propane plus first layer coincidences. Such points can be identified by the filtering criteria:

$$\frac{\texttt{VpX1LCntPcu0} + \texttt{VpX1RCntPcu0}}{\texttt{Q6VpVxXeCntPcu0}} \geq 0.1$$

The items in the equation are among the rates available in the Standard2 data.

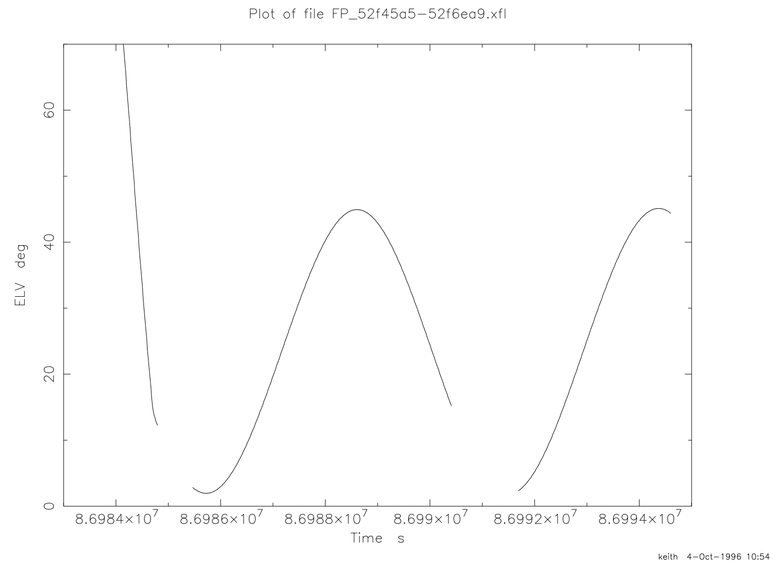

Figure 11: Cen X3 elevation data. Data from 10144-03-01-04, PI Prince

The cleanest data should be available by eliminating intervals which satisfy this criteria, although we hope to be able to model this background as well in the future.