Correcting for PCA Deadtime

Recipes from the RXTE Cook Book

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Introduction & Preliminary Definitions

The PCUs cannot process events instantaneously, nor can they process more than one event at a time. This limitation results in deadtime - time during which the detector, when occupied processing an event, cannot process another.

Deadtime obviously depends on count rate. If the countrate is low enough, detector deadtime occurs mostly during the gaps between events. At high count rates, when the time between events approaches the deadtime, an appreciable fraction of events arrive before the detector can detect them. The observed result is a lower-than-expected countrate, the signature of deadtime.

Before explaining how to correct for deadtime, here are some definitions: by DTF (deadtime fraction) we mean the fraction of time spent not collecting data due to deadtime. With this definition, the corrected count rate C' is related to the detected count rate C by:

```
C′ = C/(1 − DTF)
```

And if DT is actual deadtime per event in seconds, then in general:

```
DTF = C * DT
```

Calculating PCA Deadtime

Since all events in the PCA cause deadtime, we have to make sure that all events are accounted for when we calculate the dead time. These fall into four main categories (in order of decreasing count rate for a bright observation):

1. **Good Xenon Events:** These are events which pass all the discriminators and anti-coincidence vetoes (all configurations include good xenon data - not just the "Good Xenon" configuration).

2. **Coincident Events:** These events are detected in more than one anode simultaneously. They are not included with the good xenon events since they are most likely due to particles. [At very high count rates, however, it becomes increasingly likely that two coincident anode firings are due to two real photon events rather than one particle event.]

3. **Very Large Events (VLE):** These are events above the upper discriminator. Like the coincident events, they are mostly due to particles.

4. **Propane Events:** Each PCU has a layer of propane in front of the xenon layers. Events detected in this layer are not included with the good xenon events.

By design, the two Standard PCA configurations contain all these events (all other configurations contain only good xenon events). Moreover, each event is counted only once, i.e. a good xenon event is not counted as a propane event nor as a coincident or VLE event. For the purpose of working out dead time, Standard-1 is better than Standard-2 because it has 0.125-second resolution as opposed to 16-second.

In the Standard-1 files themselves, the columns containing the count rates can be listed with the ftool flcol:

```
> flcol standard1.fits
___Column_Names_________Formats______Dims______Units___
Time                      D                     s
XeCntPcu0                 1024I     (1024)      count
XeCntPcu1                 1024I     (1024)      count
XeCntPcu2                 1024I     (1024)      count
XeCntPcu3                 1024I     (1024)      count
XeCntPcu4                 1024I     (1024)      count
RemainingCnt              1024I     (1024)      count
VpCnt                     1024I     (1024)      count
VLECnt                    1024I     (1024)      count
CalX1LSpecPcu0            256I      (256)       count
CalX1RSpecPcu0            256I      (256)       count
.                         .         .           .
.                         .         .           .
.                         .         .           .
```

These are:

```
XeCntPcu0-4       (Good xenon count rate in PCU0-4)
VpCnt             (Propane layer count rate, all five PCU combined)
VLECnt            (Very Large Event count rate, all five PCU combined)
RemainingCnt      (Coincident events, all PCU combined)
CalX1LSpec..      (Spectrum of the internal calibration source in the
                   various PCU/anodes - does not contribute to dead
                   time)
```

Note that the Good Xenon count rate is split over the five PCU, while the other count rates are for the whole array. Here you have to be somewhat careful: deadtime arises in the processors of each PCU, but this does not mean that the total deadtime for the PCA is the sum of the individual PCU deadtimes. Rather, deadtime is like TV advertising: if you watch several TV sets tuned the same channel, you'll see the same fraction of time devoted to ads regardless of how many TV sets are on. **Deadtime should be calculated per PCU: always divide the count rates by the number of PCUs actually on.**

Now the dead time per event is approximately 10 microseconds for good xenon, propane and coincident events. For VLE, the dead time per event depends on the setting, the default being "2" which corresponds to 150 microseconds. This means that the dead time fraction at time t for each PCU is the sum of the following terms:

```
C(t)_XeCnt * 1.0E-05 / N_on        DTF good xenon events

C(t)_VpCnt * 1.0E-05 / N_on        DTF for coincident events

C(t)_RemainingCnt * 1.0E-05 / N_on DTF for of propane events

C(t)_VLECnt * 1.5E-04 / N_on       DTF for  VLE in
```

where C(t)_XeCnt is the sum of the count rates in columns XeCntPcu0 - XeCntPcu4 and N_on is the number of PCU on.

How to Correct for PCA Deadtime in Spectra

1. Extract the spectrum you wish to analyze, noting how many PCU, N_on, were on during the accumulation.

2. With the same time selection settings (GTI, timeint etc.), extract a second spectrum from the corresponding Standard-1 data. This time, however, use the following list of columns:

   ```
   XeCntPcu0
   XeCntPcu1
   XeCntPcu2
   XeCntPcu3
   XeCntPcu4
   RemainingCnt
   VpCnt
   ```

3. When the extraction is over, look at the screen output from the extractor and make a note of the count rate in the spectrum (which you can discard - it only had one bin anyway).

4. Repeat steps 2 & 3 but with the column VLECnt.

5. Calculate DTF, the dead time fraction:

   ```
   DTF = (NonVLE_Countrate x 1.0E-5 + VLE_Countrate x 1.5E-4)/N_on
   ```

   from which you get the deadtime correction factor, DCOR:

   ```
   DCOR = 1/(1-DTF)
   ```

6. To apply the deadtime correction, you should adjust the exposure of the spectrum:

   1. Use the ftool fkeyprint to display the current, uncorrected exposure, e.g.:

      ```
      fkeyprint burst2.pha exposure
      # EXTENSION:    1
      EXPOSURE=  3.79839999999917E+04 / Exposure time
      ```

   2. Divide the exposure by DCOR.

   3. Create an ASCII file called, e.g. `new_exposure` containing the new exposure (36,175.24 s in

this example):

```
EXPOSURE 36175.24 / Uncorrected exposure was 37984.0
```

The comment following the / is for information only and is not obligatory.

4. Insert the new exposure into the PHA file with the ftool fmodhead:

```
fmodhead burst2.pha new_exposure
```

7. Repeat for background spectrum. This is necessary because even when the good xenon countrates are low, the contributions to the deadtime of the other countrates are not negligible. Furthermore, these other count rates fluctuate considerably during a typical observation. For example, in a blank sky observation taken in November 1996, the deadtime varied between 1.5 and 4.9 percent, which corresponds to a countrate fluctuation of 3 counts per second (all PCUs and all anodes).

In practice, the deadtime for the background is calculated with the same formula but with the good xenon background countrate (from pcabackest) used instead of the good xenon source countrate (but use the same `RemainingCnt`, `VpCnt` and `VLECnt` as for the source).

8. Proceed with spectral analysis with xspec in the usual way.

Footnote on VLE settings: The VLE setting is "2" by default which corresponds to a dead time per event of 150 microseconds. It is only changed on the explicit instruction of the PI before or during the observation. If you want verify the VLE setting for yourself, you should look in the PCA housekeeping (AppIds 90-94 for PCUs 0-4, respectively) for a column called `dsVle`. It can have four values of which the shortest is not allowed:

dsVle	deadtime per event (microseconds)
0	12
1	60
2	150
3	500

The values vary from one detector to the next: the figures above are accurate to 10 percent.

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