Chandra Extended Source Analysis

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Elementary X-ray Spectral Analysis

The fundamental equation linking a PHA spectrum N(p) with a true incident spectrum f(E) is

$$N(p) = \int ARF(E) RMF(E, p) f(E) dE$$

Here the response is broken up into an overall detection efficiency ARF and a redistribution RMF (such that $\int RMF(E, p) dp = 1$). Since RMF is not diagonal, we must use forward folding instead of trying to invert it.

What are the ARF and RMF? In fact, they depend on the location of the source on the chip, C. The ARF also depends on the mirror off-axis angle θ via the vignetting.

$$N(p, C, \theta) = \int ARF(E, C, \theta) RMF(E, p, C) f(E) dE$$

We extract a PHA spectrum over some region of C,θ space versus time, corresponding to a given celestial source. We wish to determine f(E) (averaging over any spatial variation it may have). How do we address the variation of ARF and RMF over the source region? There are three basic approaches:
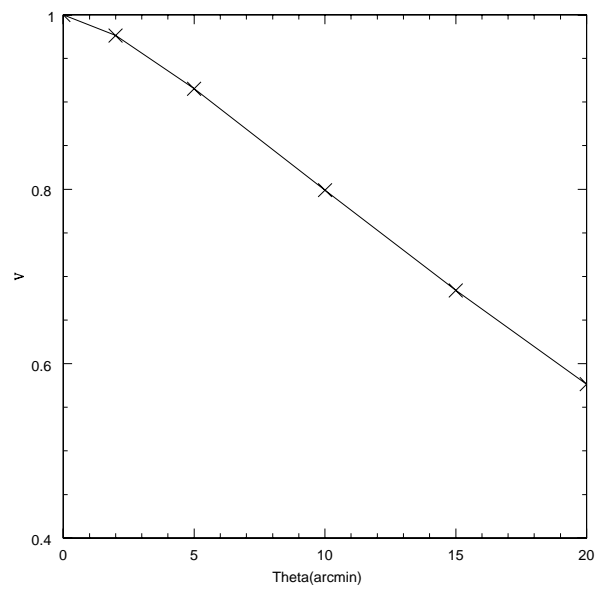
- Ignore the variations and use the ARF and RMF evaluated at a single point. This is often fine, particularly on the BI chips.

- Evaluate an average ARF and RMF over the region, weighted appropriately. Because of the linearity of the integral, this can be a reasonable approach.

- Reextract the spectrum into multiple PHA files each covering a smaller region, and fit the regions simultaneously. This is the most accurate approach if the signal-to-noise is sufficient.

Calibration considerations

- S3 is pretty uniform (mostly RMF FWHM const to 10%)

- QE variations not significant?

- I0-I3 vary hugely;

- E scale change taken out with PI

- FWHM increases linearly with CHIPY

- Also changes on node boundaries

- QE variations mostly CTI

- For CHIPY ¿ 512 CTI is not too bad.

- Calibrated on 32x32 pixel (16") squares

- Key parameters: S/N and extent

- Depends also on science question (more critical for line detections than overall temperature)

- Vignetting changes by 10% on 5 arcmin scales

Possible approaches

```
                        Low         Med         High
                        S/N                     S/N


Point source            1 RMF     Average    Multiple
extended source <1'     Average?   Average    Multiple
extended source >1'       ?       Multiple?  Multiple
```

Creating response for extended regions using calcrmf/calcarf

What we need:

- A screened events file

- The distribution of Alexey Vikhlinin's programs, available from
  http://hea-www.harvard.edu/j̃cm/asc/dist/av/av105.tar

The thread step by step

1. Define the region to extract the spectrum.

2. Extract a PI spectrum

   ```
   dmextract "evt.fits[sky=region(src.reg)][bin pi]" pi.fits
   ```

3. Create the weighting map used to weight the different RMFs and ARFs.
   This is a binned image in detector coordinates. We use the soft band.

   ```
   \item dmcopy "evt.fits[sky=region(src.reg),energy=500:2000]
       [bin det=8]"     wmap.fits
   ```

4. Find the temperature of the CCD during the observation.

   ```
   dmlist evt.fits header | grep FP_TEMP
   dmlist evt.fits header | grep DATE-OBS
   ```

   If FP_TEMP isn't there, use the observation date to figure it out (see the
   CIAO threads)

5. Update the parameter file (see below).

6. Generate the RMF

   ```
   calcrmf -phafile pi.fits -wmap wmap.fits -o rmf.fits @par.file
   ```

7. Generate the ARF

   ```
   calcarf -phafile pi.fits -wmap wmap.fits -o arf.fits @par.file
   ```

8. Now you can fit a spectrum using Sherpa or XSPEC.

The tricky bit is to make the Zhtools parameter file which you can do by editing the one provided in the distribution. You have to figure out where the various calibration files are, since the program doesn't use the CALDB to find them itself.

```
evtfile = acis_s_evt.fits
fptemp=-110
CALDIR = /data9/ciao/CALDB/data/chandra/
hrma_onaxis_area = $CALDIR/tel/hrma/bcf/effarea/hrmaD1996-12-20axeffaN0004.f:
hrma_vignetting  = $CALDIR/tel/hrma/bcf/vignet/hrmaD1996-12-20vignetN0003.fit
ccd_qe =          $CALDIR/acis/bcf/qe/acisD1997-04-17qeN0003.fits
ccd_qeu =         $CALDIR/acis/bcf/qe/acisD1999-09-16qeuN0002.fits
fef=$CALDIR/acis/cpf/fefs/acisD1999-09-16fef_piN0001.fits
ref_pi_rmf=ref.rmf
xcol    = X
ycol    = Y
xdetcol = DETX
ydetcol = DETY
timename = TIME
eventsname = EVENTS
```