Analysis of Extended Sources

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Web Documentation

http://cxc.harvard.edu/ciao/guides/esa.html

- ACIS blank-sky background
- Point-source detection
- Exposure maps
- Weighted responses
- Radial profiles
- Image fitting

CXC

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Important Issues

1. Background
   - remove background flares, point-sources
   - consider local background measurement \textit{vs.} ACIS blank-sky

2. Position-dependent response
   - usually extract \textit{PI} spectra, not PHA
   - consider weighted responses
Exclude high background intervals:

- extract light-curve \texttt{[dmextract]}
- determine GTIs \texttt{[lc\_sigma\_clip()]} \\
- filter \texttt{[dmcopy]}

\begin{verbatim}
dmcopy "evt2.fits[@lc_dmgti.gti]"
  evt2_clean.fits
\end{verbatim}
Filtered Counts Image

Counts

- reprocess [acis_process_events]
- apply custom filters (flares, bad pixels, ...)
  [dmcopy]
- remove point sources [wavdetect]

Remember...

Counts and photons are not the same!
(QE < 1)
Flux Images
(For details, see Davis, 2001, ApJ, 548, 1010)

When mirror area & PSF vary slowly with position,

\[ C(h, \hat{p}) = \tau_{\text{eff}} \int dE \ A(h, E, \hat{p}) \ S_{\text{PSF}}(E, \hat{p}). \]

*If \( A \approx \text{constant within } \Delta E \) then, summing over \( \Delta h, \Delta E \):

\[ \text{"Flux" } \equiv \int_{\Delta E} dE \ S_{\text{PSF}}(E, \hat{p}) \approx \frac{1}{\tau_{\text{eff}} \ A(\Delta h, \Delta E, \hat{p})} \frac{C(\Delta h, \hat{p})}{A(\Delta h, \Delta E, \hat{p})}. \]

\( \mathcal{A}(\Delta h, \Delta E, \hat{p}) \) is the exposure map.
Instrument Map

ACIS-7

ACIS-6

CHIPY

CHIPX
Spectrum-Weighted Instrument Map

Approximating the effective area, \( A(E) \), as piecewise constant,

\[
C(h) = \tau \sum_k \int_{\Delta E_k} A(E) s(E) dE \approx \left( \tau \sum_k A_k w_k \right) \int_{E_{\text{min}}}^{E_{\text{max}}} s(E) dE
\]

using weights defined by: \( w_k \equiv \frac{1}{s_{\text{tot}}} \int_{\Delta E_k} s(E) dE \) where 1 = \( \sum_k w_k \).
Exposure Map $\mathcal{A}(\Delta h, \Delta E, \hat{p})$:

- $\texttt{mkexpmap}$ projects the instrument maps onto the sky and includes dither.
"Flux"

- extract counts image for $\Delta E$ of interest
  \[ \text{[dmcopy]} \]
- Divide counts by exposure map:
  \[
  F(\Delta E, \hat{p}) = \frac{C(\Delta h, \hat{p})}{\tau_{\text{eff}} A(\Delta h, \Delta E, \hat{p})}
  \]
  \[ \text{[photons s}^{-1} \text{ cm}^{-2}] \]
  \[ \text{[dmimgthresh, dmimgcalc]} \]
Surface Brightness Profiles

In $i^{th}$ elliptical annulus, compute the surface brightness,

$$S_i = \frac{\sum_{k \in i} C_k}{\tau_{\text{eff}} \sum_{k \in i} A_k}.$$
"Flux"  
SB Profile Image  
Flux residual
Overlay Radio Contours

[ds9]

- generate & save radio contours (RA, DEC)
- load contours & overlay on X-ray image
- Alternatively, use images as RGB components.
Spectral Analysis

- choose sky region, $\Omega$
- extract source PI spectrum, $C_\Omega(h)$ [dmeextract]
- compute ARF, $A_\Omega(E)$ [mkarf/mkwarf]
- compute RMF, $R_\Omega(h, E)$ [mkacisrmf]
- extract background PI spectrum, $B(h)$ (local vs. ACIS blank-sky background)
- Fit model $S_\Omega(E) \rightarrow \min(\chi^2)$
Response Spatial Variation

Extract spectrum, $C_\Omega(h)$, from sky region, $\Omega$, that spans several calibrated detector regions, $\{\sigma\}$.

**Problem:** Define $R_\Omega(h, E)$ and $A_\Omega(E)$ so that

$$C_\Omega(h) = B(h) + \tau_{\text{eff}} \int dE \ R_\Omega(h, E) \ A_\Omega(E) \ S_\Omega(E)$$
Response Spatial Variation

**Contamination** (*ACIS-7 ARF*)

**CTI** (*ACIS-3 FI-RMF*)
Weighted Responses

$R_\Omega(h, E)$ and $A_\Omega(E)$ can be defined in terms of a *weight map* ($WMAP$).

1. obtain $WMAP$ e.g. from dmextract
2. weighted $RMF$ from mkacisrmf
3. weighted $ARF$ from mkwarf
Default WMAP does not account for bad pixels:

obsid 5827, ACIS-3, box(3514,4214,2,2,128), fracexpo=0.892