Analysis of Extended Sources

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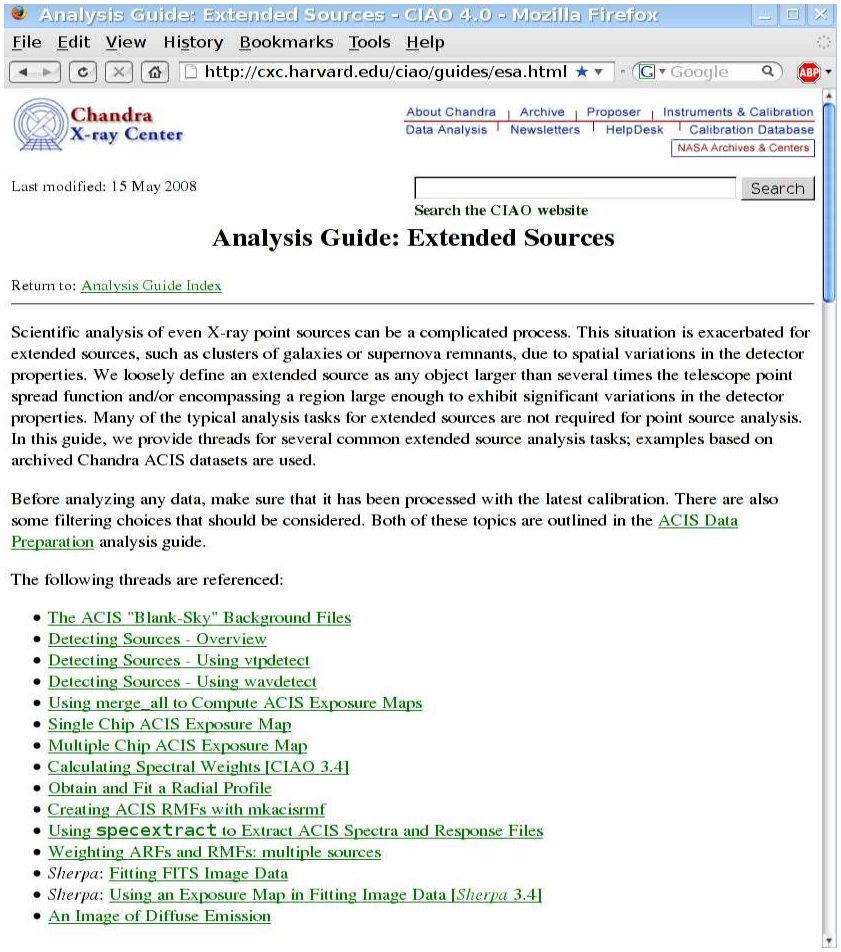


Web Documentation

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

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

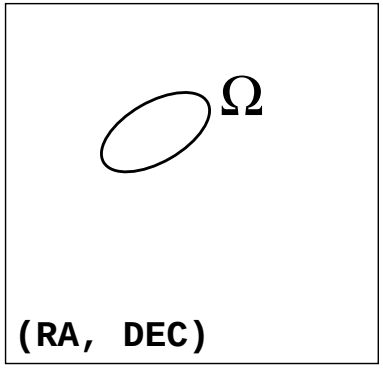
Important Issues

1. Position-dependent response
   - work in *PI* space
   - weighted responses

2. Background
   - remove flares, point-sources
   - local measurement *vs.* *ACIS* blank-sky background

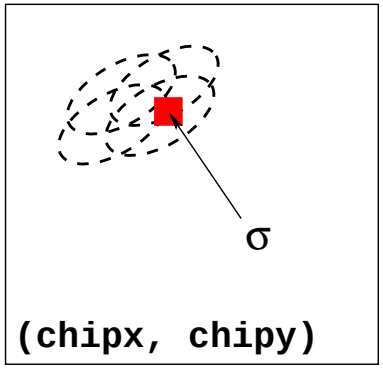
Response Spatial Variation

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



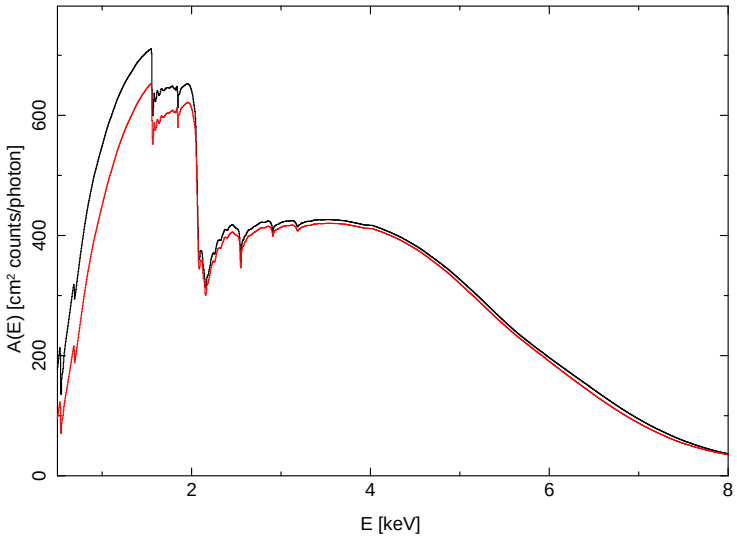
Problem: *Define* $R_\Omega(h,E)$ *and* $A_\Omega(E)$ *so that*

$$C_\Omega(h) = B(h) + \tau_{\rm eff} \int {\rm d}E \; R_\Omega(h,E) \; A_\Omega(E) \; S_\Omega(E)$$

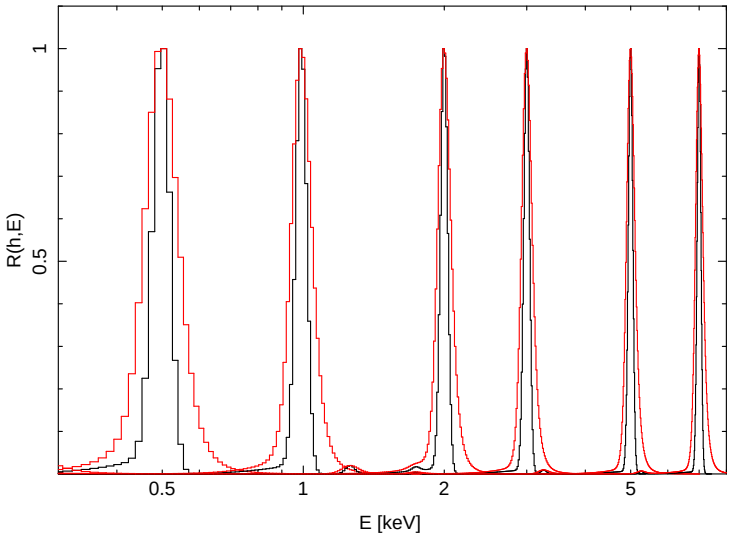


Response Spatial Variation

Contamination (*ACIS-7 ARF*)



CTI (*ACIS-3 FI-RMF*)



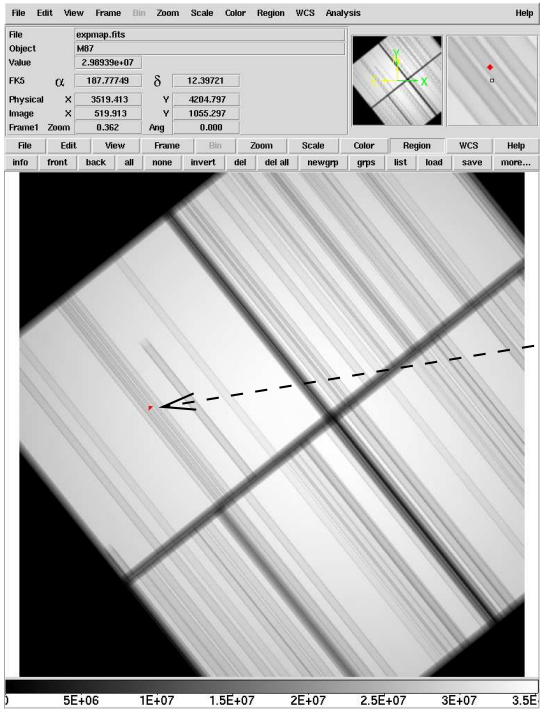
Weighted Responses

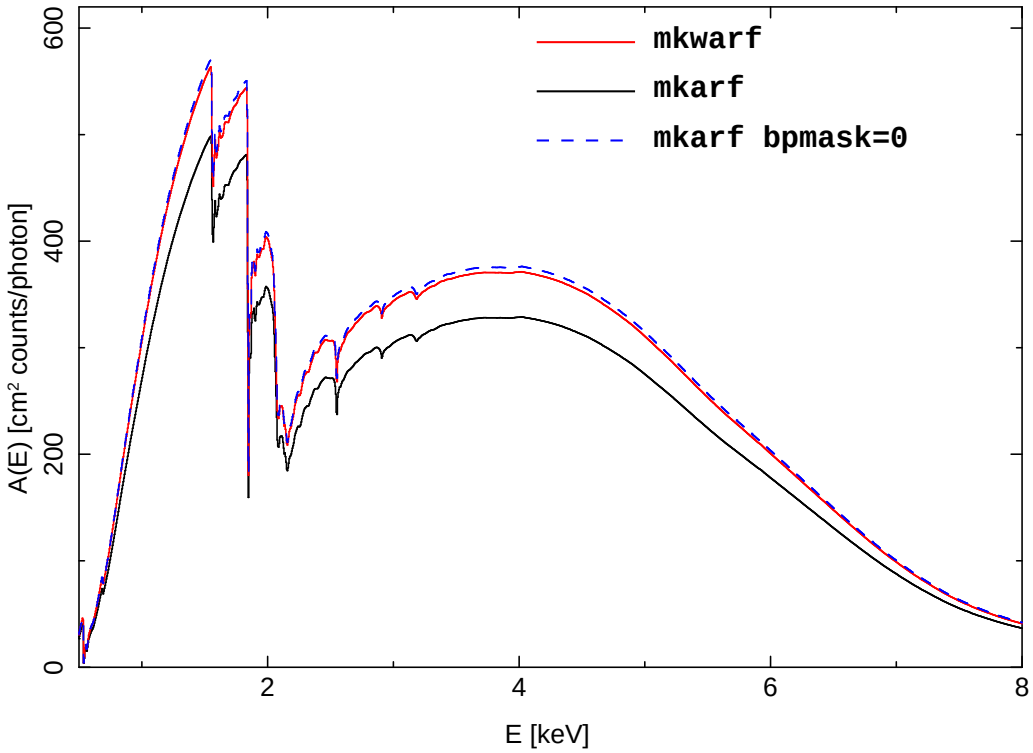
$R_\Omega(h, E)$ and $A_\Omega(E)$ can be defined in terms of a *weight map* ($WMAP$).

1. $WMAP$ from `dmextract`
2. weighted ARF from `mkwarf`
3. weighted RMF from `mkacisrmf`

Limitation: `mkwarf` requires the $WMAP$ in DETX, DETY coordinates; CHIPX, CHIPY would be better (Davis 2001).

Current WMAP *neglects bad pixels:*

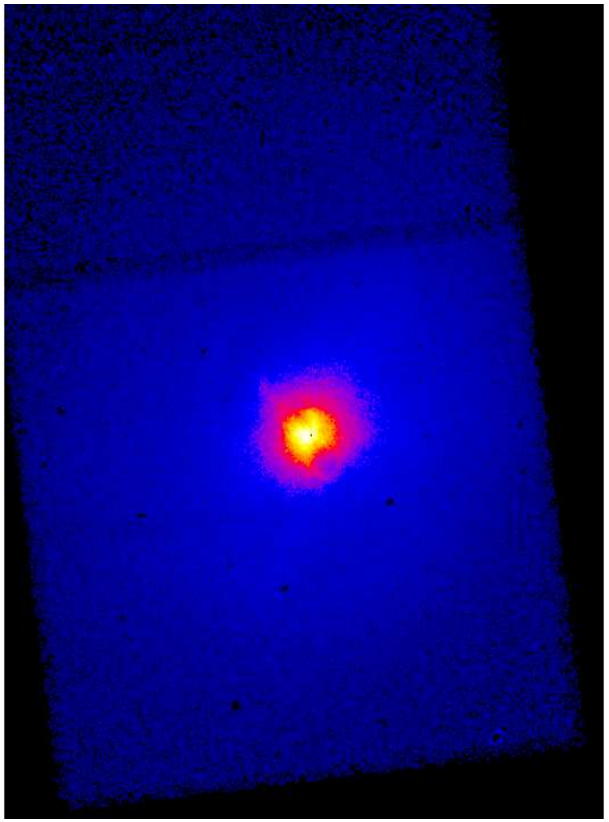




`obsid 5827, ACIS-3, box(3514,4214,2,2,128), fracexpo=0.847`

Event Filtering

Counts



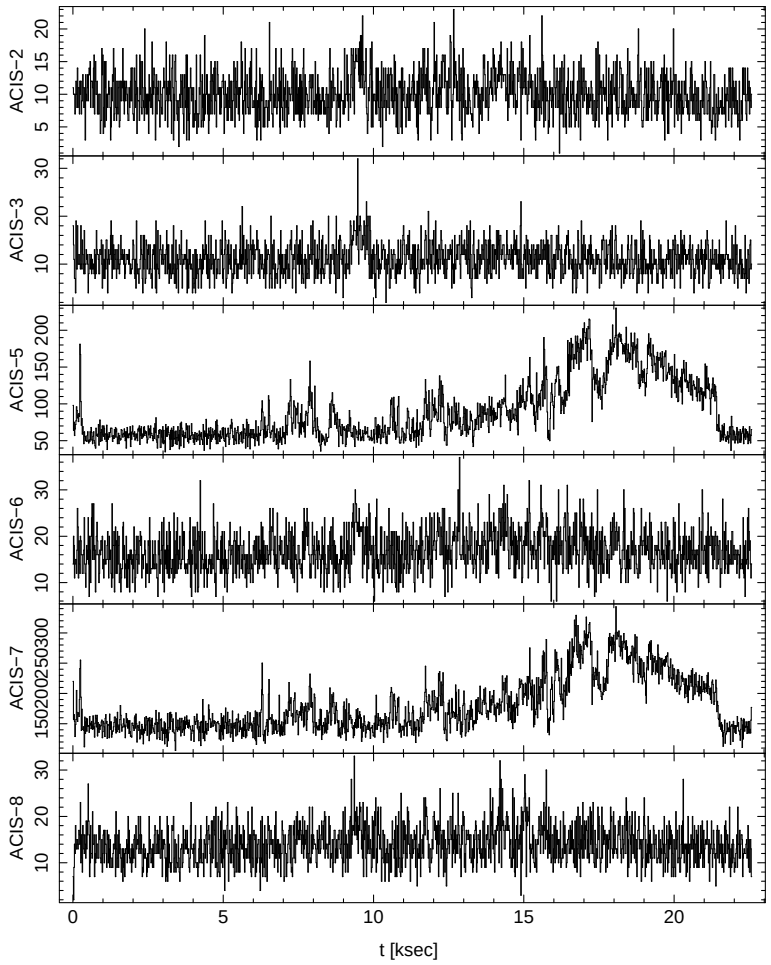
- reprocess [`acis_process_events`]
- apply custom filters (flares, bad pixels, ...) [`dmcopy`]
- remove point sources [`wavdetect`]

Just to be clear...

Counts and photons are NOT the same!

$(QE < 1)$

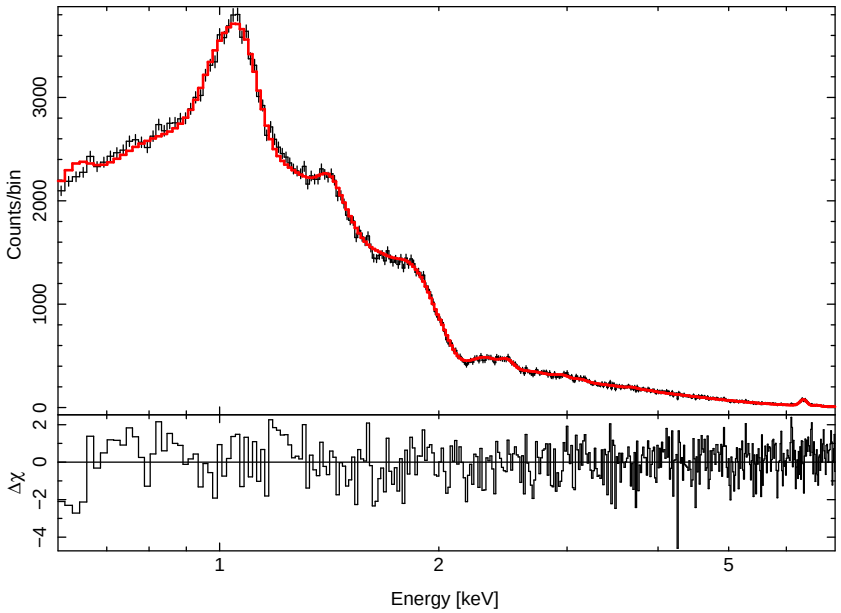
Exclude high background intervals:



- extract light-curve [dmextract]
- determine *GTI*s [analyze_ltcrv.sl]
- filter [dmcopy]

```
dmcopy "evt2.fits[@new_gtis.txt]"
       evt2_clean.fits
```

Spectral Analysis



- choose sky region, Ω
- extract source PI spectrum, $C_\Omega(h)$ [dmextract]
- 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 $S_\Omega(E) \rightarrow \min(\chi^2)$

Flux Images

(For details, see Davis, 2001, ApJ, 548, 1010)

When mirror area & PSF vary slowly with position,

$$C(h, \hat{\mathbf{p}}) = \tau_{\rm eff} \int \mathrm{d}E \, \mathcal{A}(h, E, \hat{\mathbf{p}}) \, \mathcal{S}_{\rm PSF}(E, \hat{\mathbf{p}}).$$

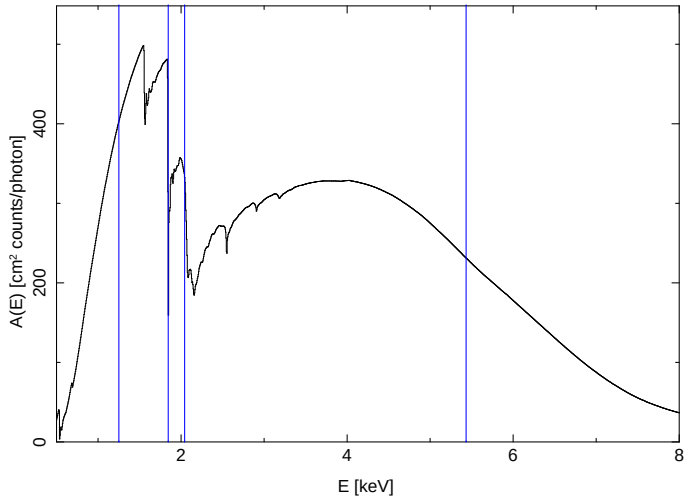
If $\mathcal{A} \approx$ *constant within* ΔE then, summing over Δh, ΔE:

$$\int_{\Delta E} \mathrm{d}E \, \mathcal{S}_{\rm PSF}(E, \hat{\mathbf{p}}) \approx \frac{1}{\tau_{\rm eff}} \frac{C(\Delta h, \hat{\mathbf{p}})}{\mathcal{A}(\Delta h, E, \hat{\mathbf{p}})}.$$

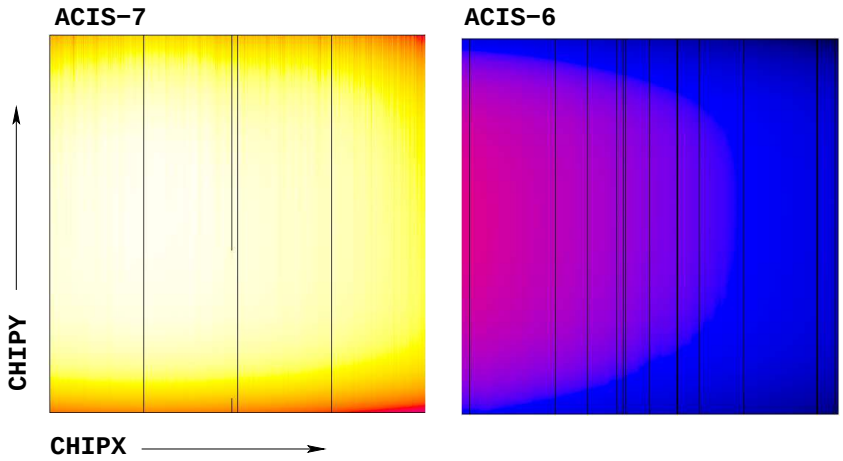
Instrument Map

Use spectrum model, $s(E)$, to weight ΔE_j intervals where the ARF is "slowly" varying:

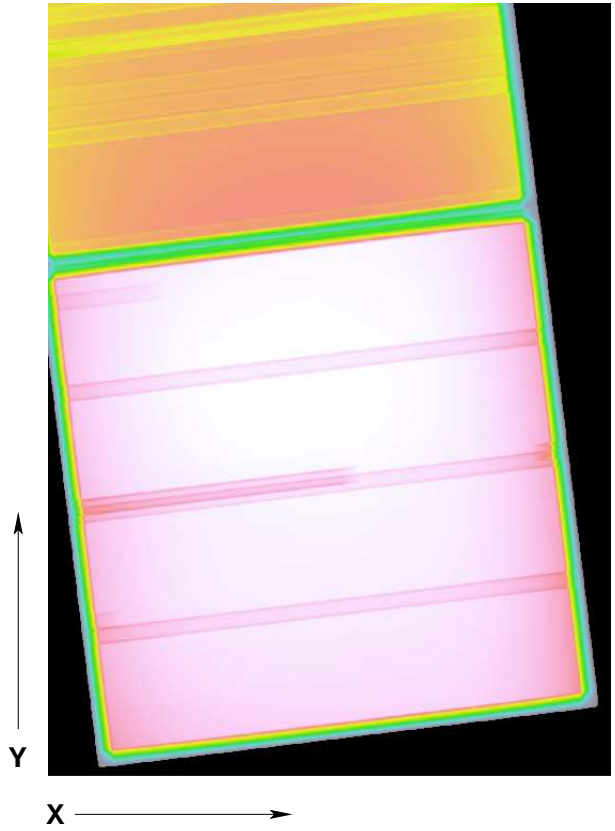
$$f_j \equiv \frac{1}{s_{\rm tot}} \int_{\Delta E_j} s(E) {\rm d}E$$



Instrument Maps

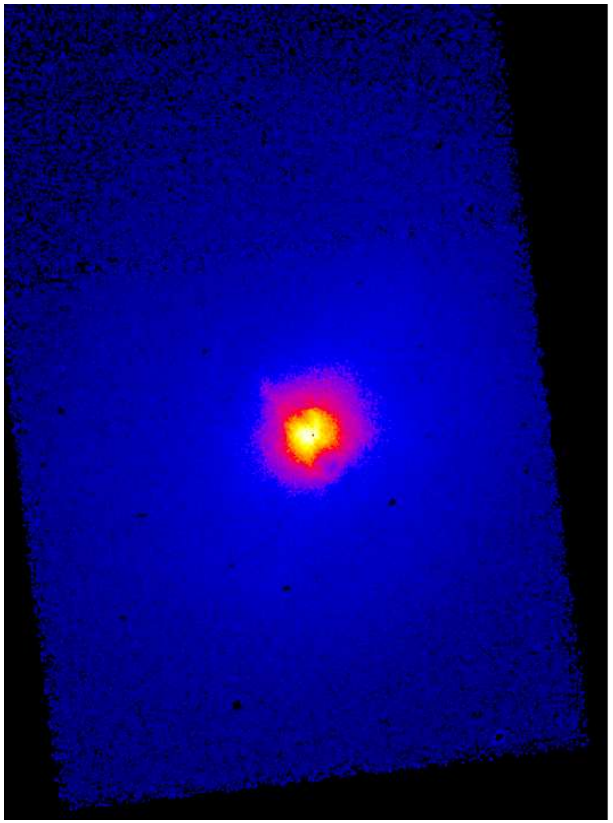


Exposure Map



- `mkexpmap` projects the instrument map onto the sky and includes dither.

"Flux"



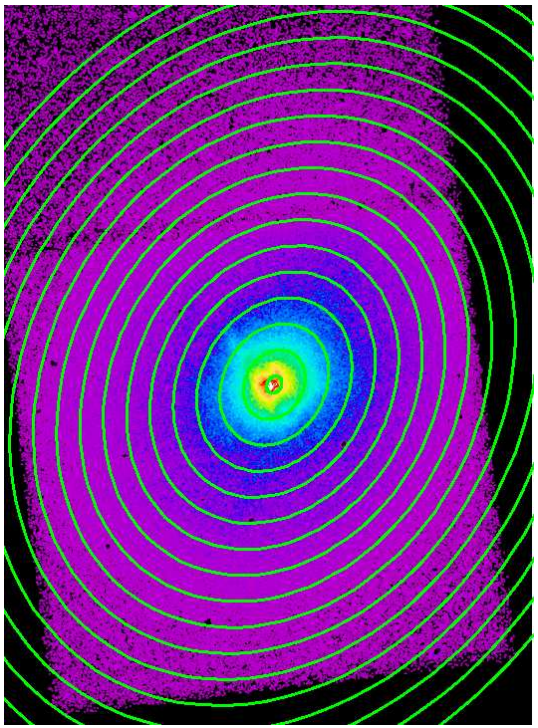
- extract counts image for ΔE of interest
  [dmcopy]
- Divide counts by exposure map:

$$\mathcal{F}(\Delta E, \hat{\mathbf{p}}) = \frac{C(\hat{\mathbf{p}})}{\tau_{\rm eff}\mathcal{A}(\Delta E, \hat{\mathbf{p}})}$$

  [photons $\rm s^{-1}$ $\rm cm^{-2}$]
  [dmimgthresh, dmimgcalc]

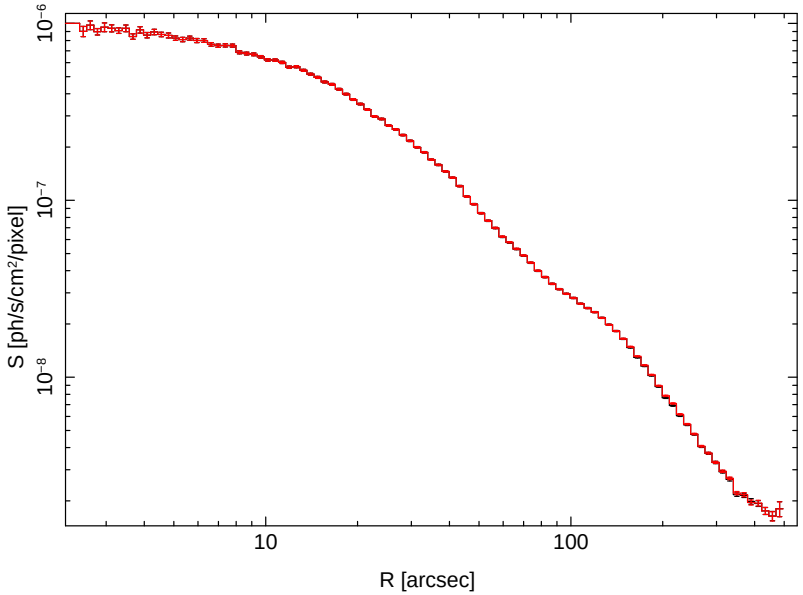
Surface Brightness Profiles

Elliptical Annuli

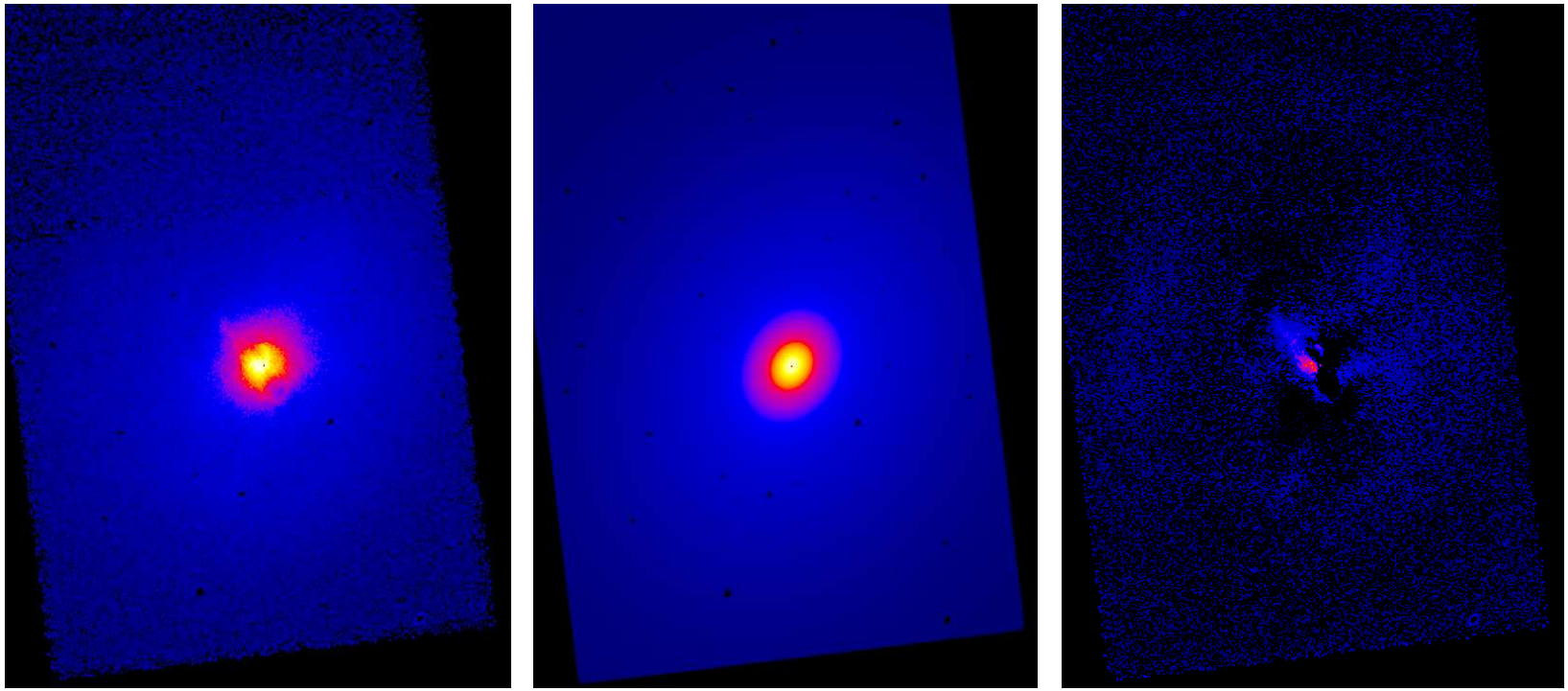


In i^{th} elliptical annulus, compute the surface brightness,

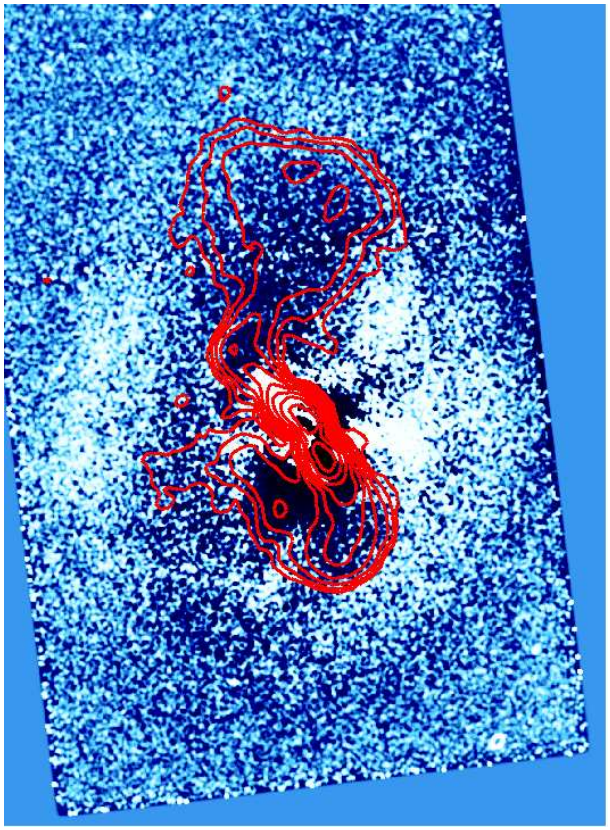
$$S_i = \frac{\sum_{k \in i} C_k}{\tau_{\text{eff}} \sum_{k \in i} \mathcal{A}_k}.$$



"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.