Parameterization of *Chandra*'s PSF

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Chandra Calibration Workshop

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Overview

For many uses a simple parameterization of *Chandra*'s PSF may be all that is required:

- *Subtraction of point sources from an extended object*

  This requires a parameterization of the geometric regions to excise and an estimate of how much flux remains of the excised sources.

- *Distinguishing point sources from extended sources*

  This is a bit more complicated, as the shape parameterization may be not be sensitive enough to distinguish off-axis objects with small extents.

- *Specifying search areas for automated source detection*

  For example, the CIAO `celldetect` tool determines its analysis cell size from a user specified fractional encircled energy and source reference energy as well as the off-axis angle.

Parameterization Approaches

Several approaches are possible:

- Fit the PSF to an analytical function.

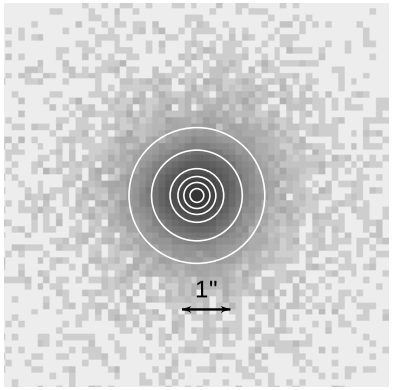
  This would allow for simple modelling of sources, but the complicated PSF structure is a major roadblock:
  - The HRMA focal plane is not matched exactly to detector planes
  - The Wolter type I geometry introduces rapid evolution as sources move off-axis
  - HRMA alignment errors induce assymmetric structures and caustics in the PSF core which are difficult to model analytically.

- Parameterize characteristics of the PSF (like the encircled energy) using simple geometric regions, such as circles or ellipses.

In both cases, we parameterize the SAOsac model, *not* actual observations, as the data in general do not have enough statistics and breadth in focal plane and energy coverage. We compare the parameterization against real data for consistency.

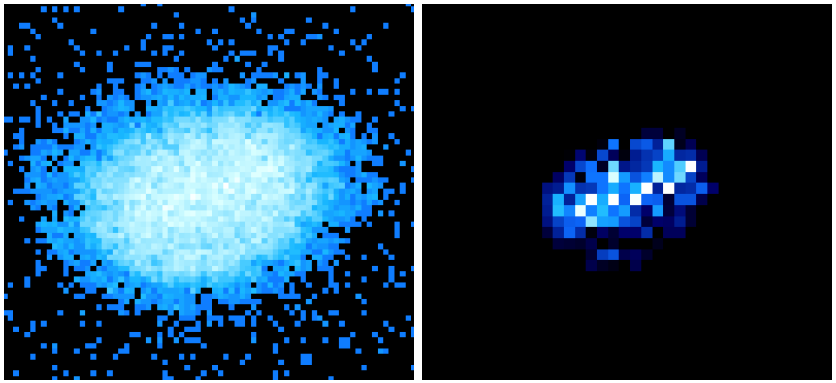
Parameterization of the Encircled Energy Fraction

Historically, the encircled energy fraction is determined in circular apertures centered about the source.



AR Lac, HRC-I, On Axis

This works well for on-axis sources.

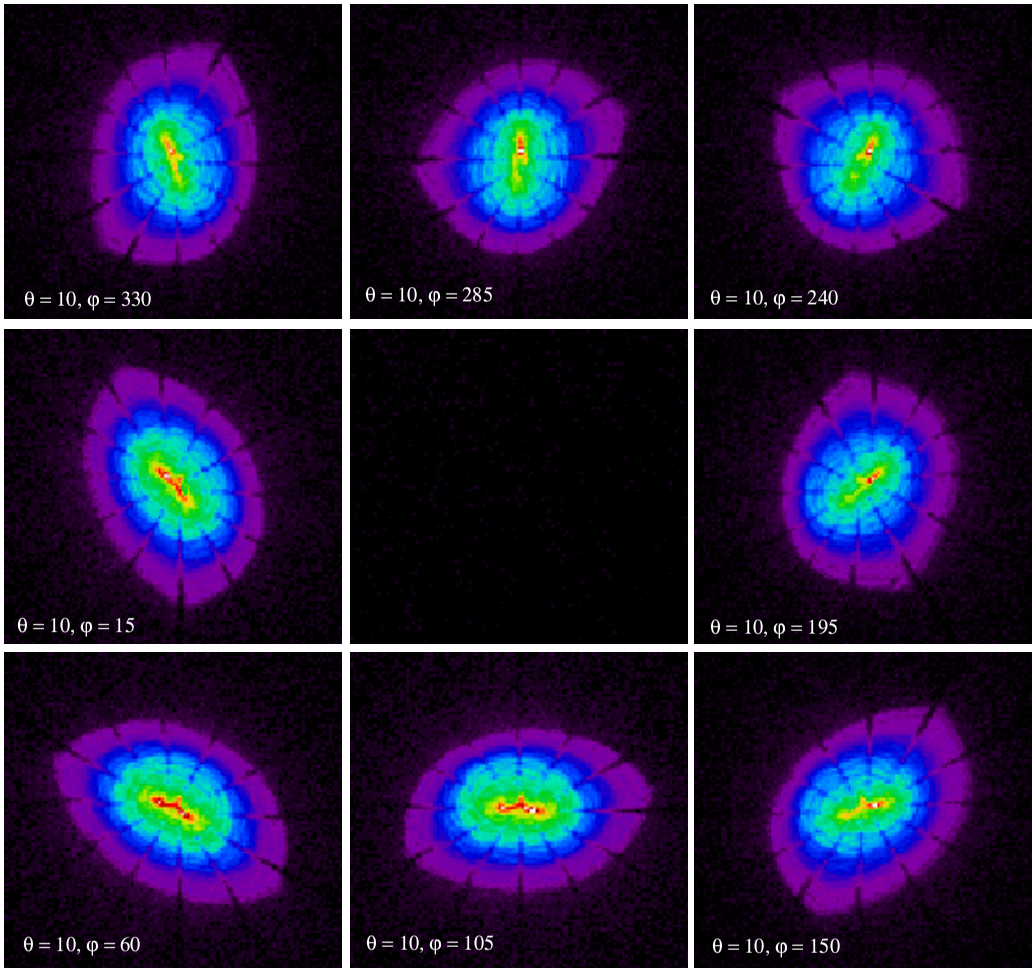


LMC X1, ACIS-S (log, left ; linear right)

But not so well for off-axis sources with asymmetric structures.

Parameterization of the Encircled Energy Fraction

In particular, we'd like the regions to track the "general" structure of the PSF.



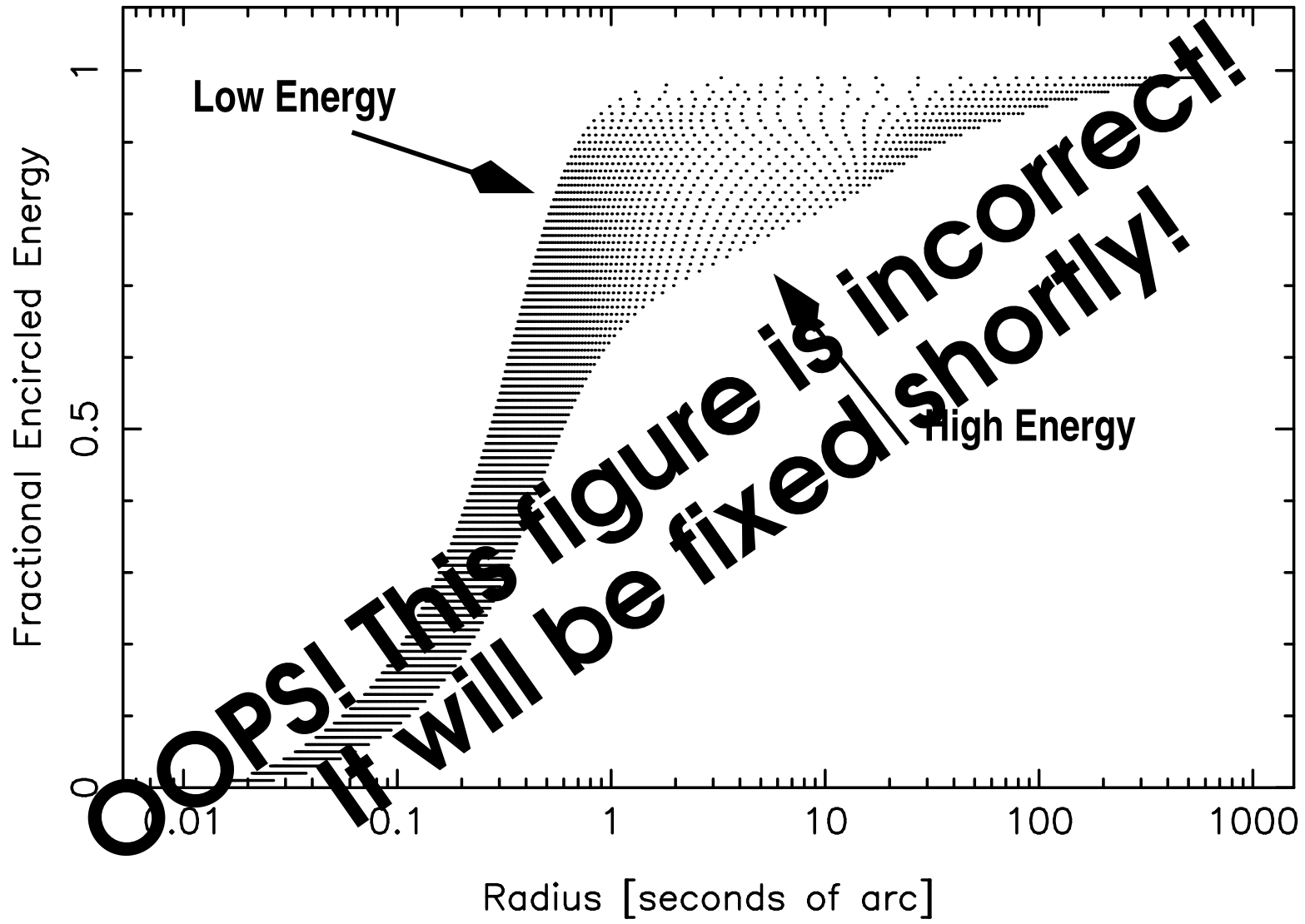
On-Axis Parameterization

The on-axis PSF is reasonably radially symmetric, so parameterization of the encircled energy fraction with circular regions is appropriate.

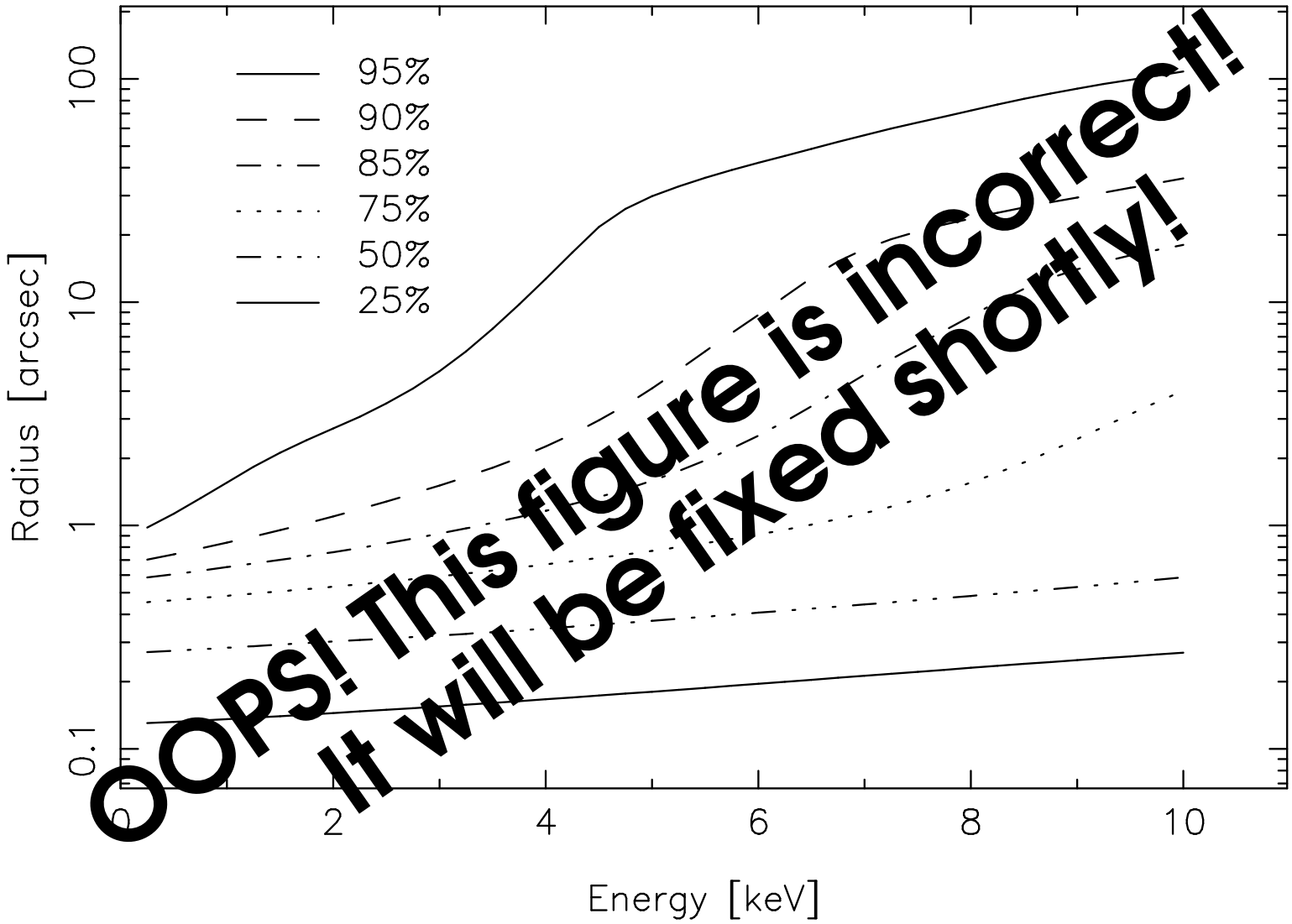
- The PSF is modelled with SAOsac.
- 40 energies: 0-10 keV in steps of 0.25 keV
- 1000 realizations of each simulation are generated to estimate systematic errors.
- Radii of circular regions output in steps of 1% encircled energy
- Detector binning, and detector QE and aspect are *not* applied.

The resultant data set will be available shortly.

On-Axis Parameterization



On-Axis Parameterization



Off-Axis Parameterization

The off-axis PSF can be described better with ellipses with variable position angles. We are currently using the IRAF `ellipse` isophotal photometry package to generate the ellipses.

For more information, see C. Allen's poster in this workshop.

Unfortunately, the narrow "bar" in the center of the PSF at larger off-axis angles confuses the fitting routine; we are evaluating other approaches.

Continuing Work

- *Comparisons to data*
  - AR Lac (this workshop)
  - We have assembled a catalogue of the sources detected by `celldetect` as part of the standard *Chandra* processing pipeline. We will use these data in two ways:
    - for strong sources, we will be able to compare the *shape* of the encircled energy distributions in several energy bands to the simulations.
    - we will combine sources in close "geographic" regions of the focal plane in order to build up statistics and perform shape comparisons.

- Sensitivity Studies
  - Results for sources close to the optical axis may be sensitive to the accuracy of the source center determination
  - As the PSF degrades away from the optical axis, the encircled energy fractions becomes less sensitive to whether the source is unresolved.