Calibrating *Chandra*'s PSF: Comparison of Models to Data

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Overview

Chandra's PSF is a complicated function of source position, energy, and the focal plane detector. Calibration of the PSF is usually done by parameterizing some characteristic of the PSF, such as its radial profile or encircled energy function.

With *Chandra*, however, we have at our disposal a model, SAOsac, which has successfully predicted the optics' performance during ground calibration, and has proven effective in qualitatively describing the on-orbit performance.

Rather than simply cataloguing the optics' performance by measuring metrics (which we do in any case), we can determine how well the model predicts the on-orbit performance and thus whether we can trust its predictions for areas where calibration data is less available.

In this analysis we utilize the PSF azimuthally averaged profile as well as it's encircled energy fractions to calibrate the model.

AR Lac, the Reprise

Chandra observed the star AR Lacertae with HRC-I early on in the mission. The observation has been used as the primary measurement of the optics' on-axis performance for several prior analyses.

Here we present its farewell analysis:

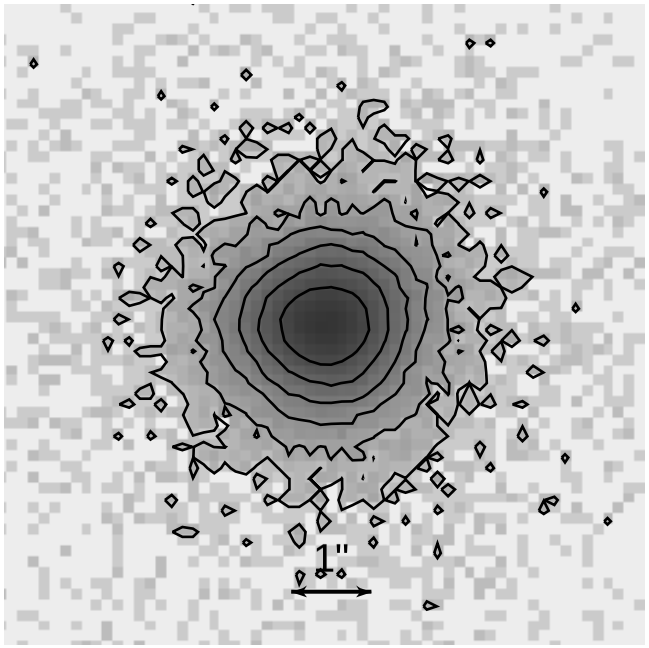
- Improved correction for HRC-I position reconstruction artifacts
- Improved background subtraction; results out to $10''$.

AR Lac Trivia:

- AR Lac appears to have no extended X-Ray emission
- AR Lac is a relatively soft source
- The observation, OBSID 1385, was made with the HRC-I for 18.8 ksec, resulting in ~ 124000 source events.
- AR Lac was observed $0.29'$ off-axis

The Observation

The observation, after standard CXC pipeline processing shows a striking asymmetry in the core:



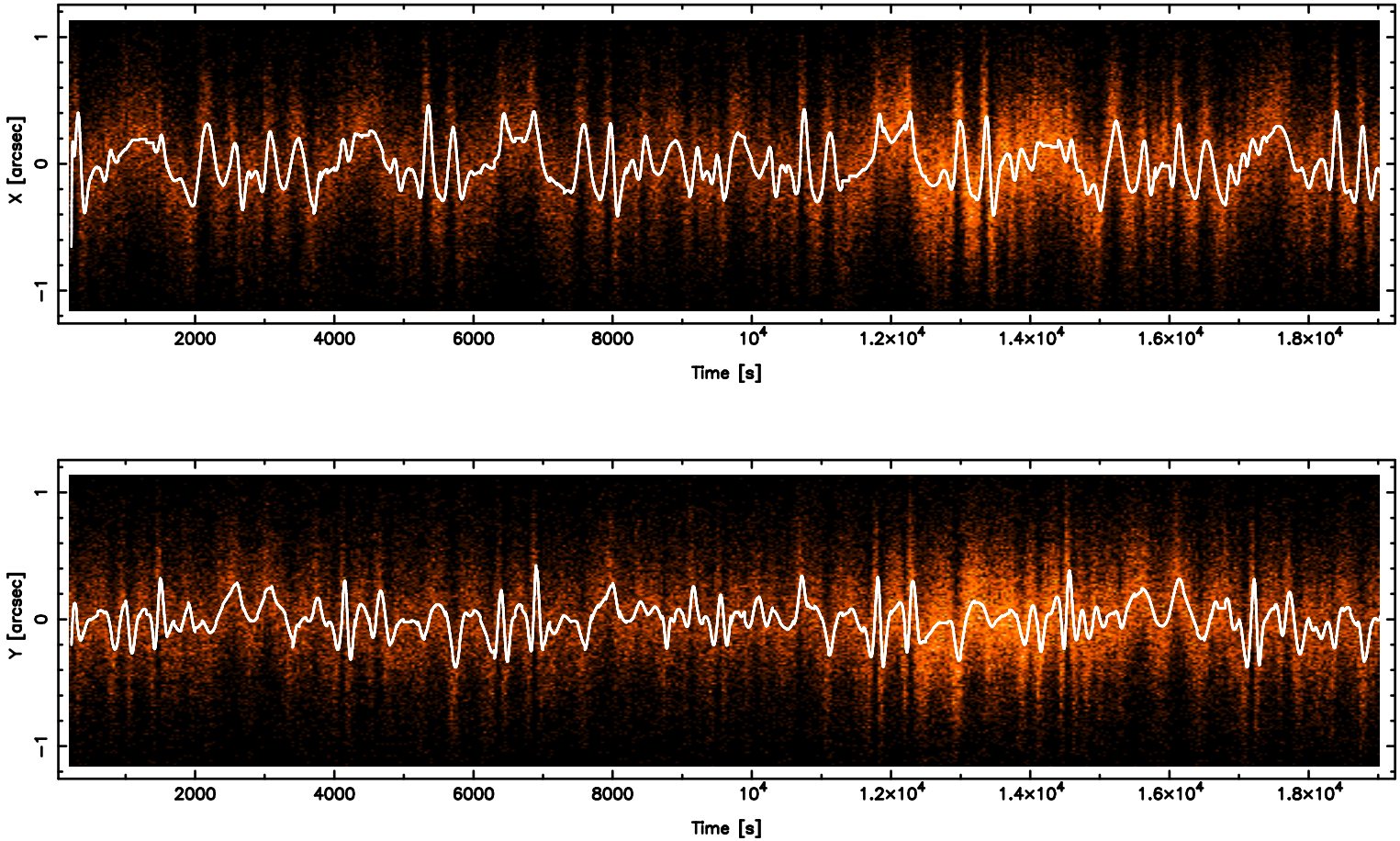
"Raw" AR Lac (log stretch)

This is neither predicted nor expected. It could be

- Aspect
- The Detector
- The Optics

Diagnosing the Asymmetry (or, Time Will Tell)

The time history of the image centroid.



Note the ~ 5.3 ksec periodicity.

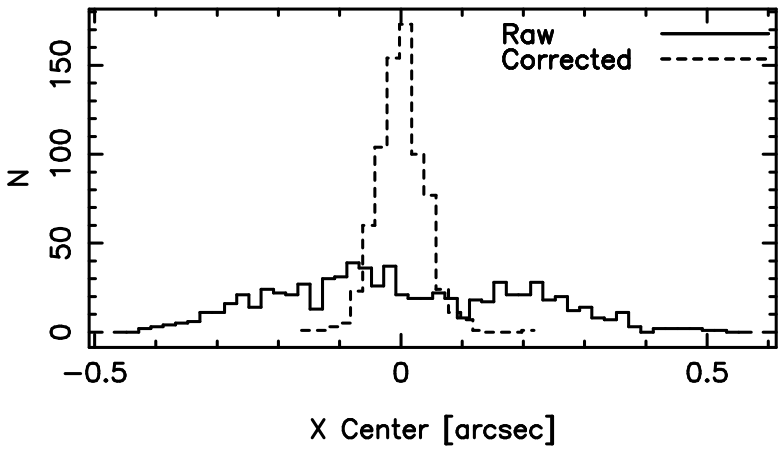
Analysis and Correction

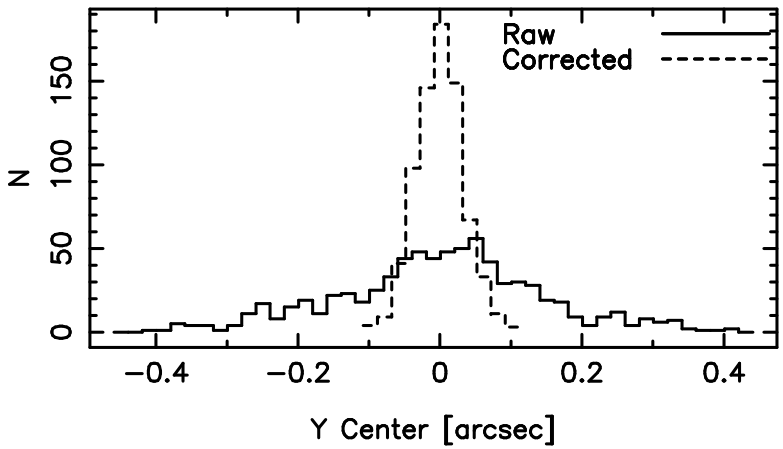
The motion of the image centroid over time indicates a somewhat periodic characteristic which has been shown to be

- *unrelated* to aspect (T. Aldcroft)
- *related* to HRC-I fine position reconstruction (M. Juda)

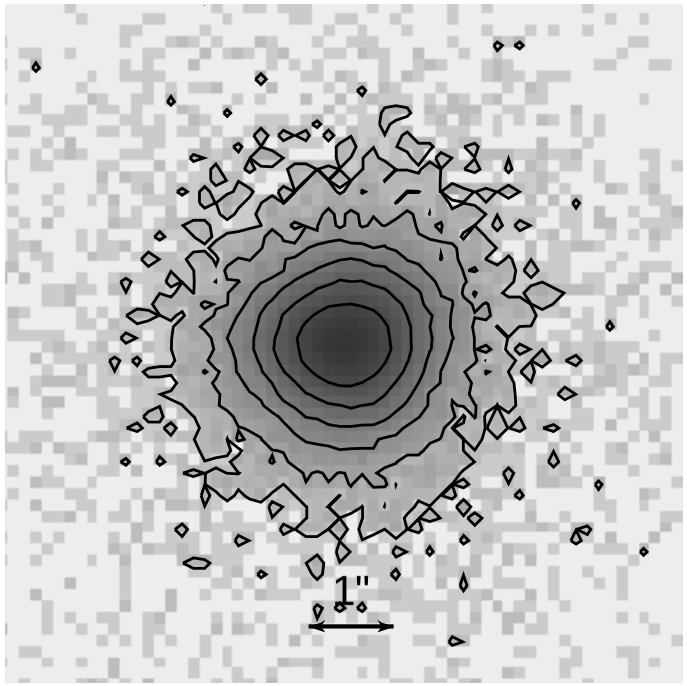
The data were “corrected” by fitting a piecewise “continuous” polynomial to the time motions of the centroid’s coordinates.

The distribution of centroids (determined every 25 seconds) before and after the correction.

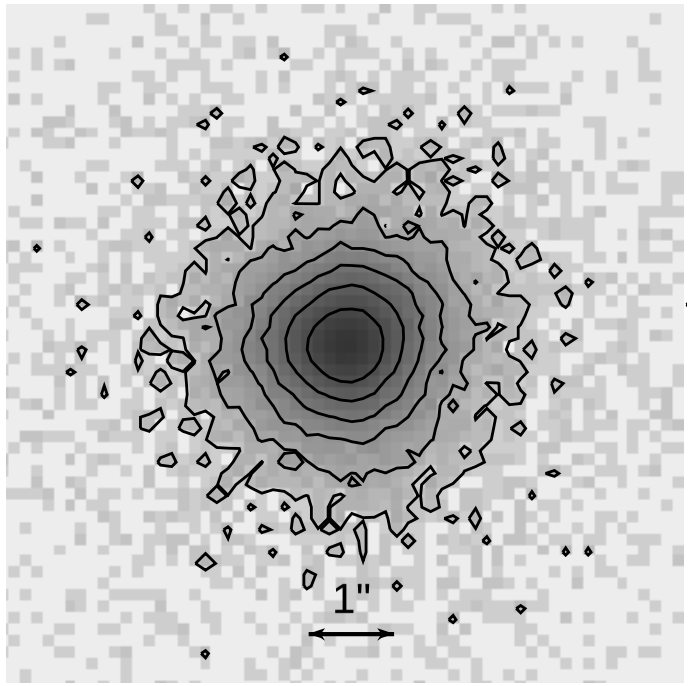




“Corrected” Image



“Before”

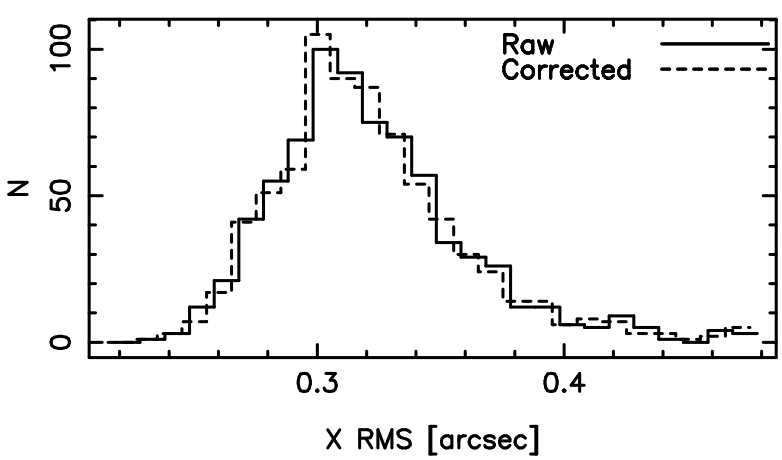


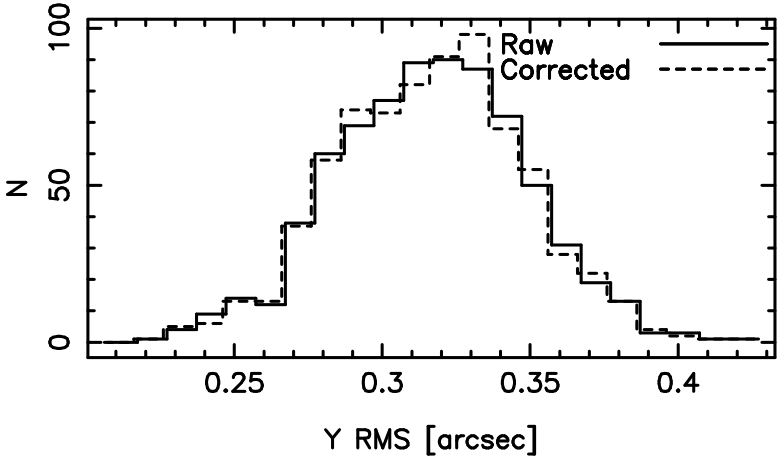
“After”

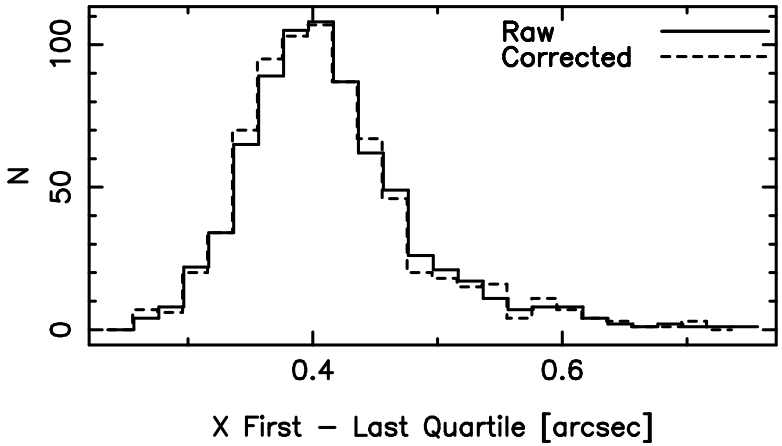
(log stretch)

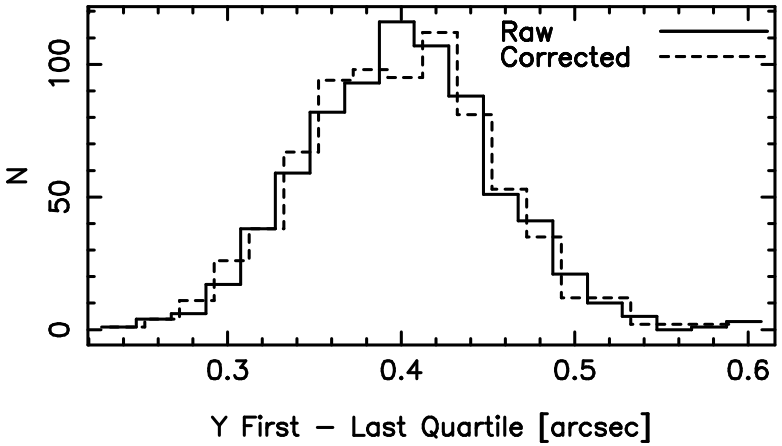
Impact of “Correction” on Image properties

Does the correction distort the intrinsic event distribution and thus bias measurements of the PSF?

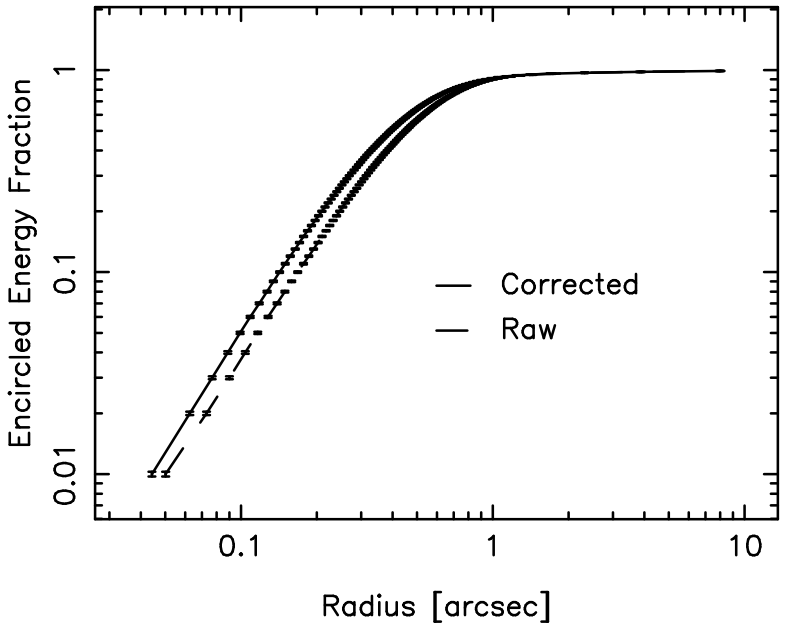


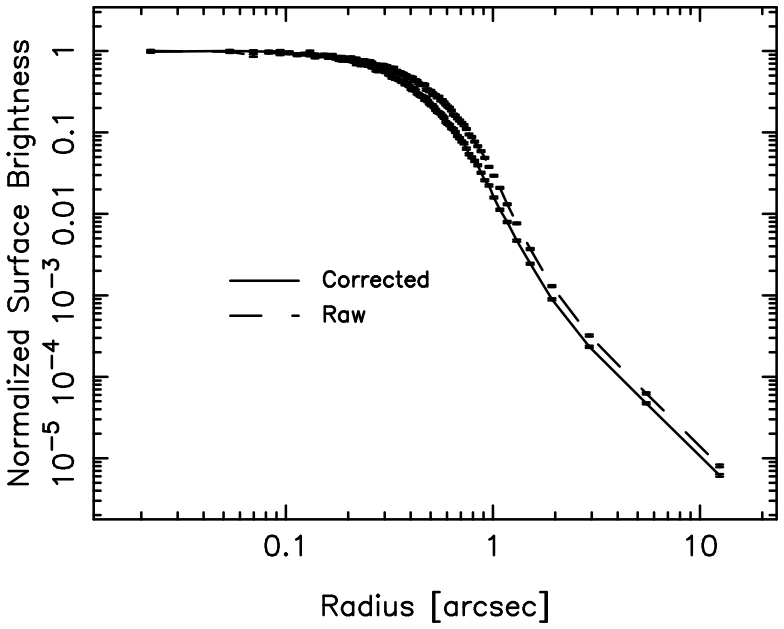






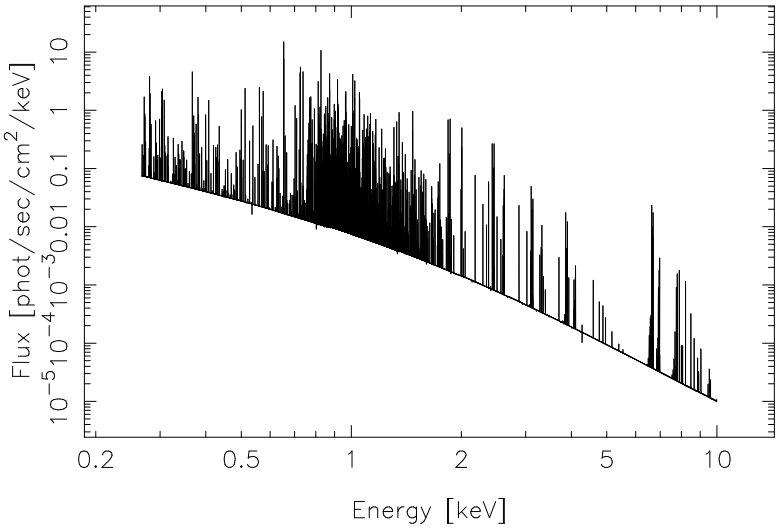
Impact of “Correction” on the parameterized PSF





The Simulations

The observation was simulated with SAOsac, using a spectrum provided by J. Drake.



The detector and aspect contributions to the PSF were modelled by

① Convolution with a Gaussian of $\sigma = 0.11''$ to simulate residual aspect errors.
② Convolution with a Gaussian of FWHM = 20 μm to simulate the HRC-I spatial resolution
③ Binning on a 6.4294 μm grid
④ Multiplication by the HRC-I QE (`hrciD1999-07-22qeN0003`)

The Simulations

Error Estimation is complicated by the following issues

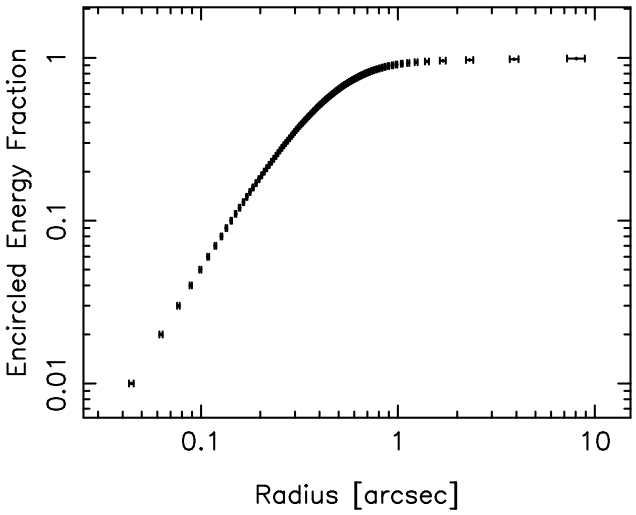
- A single simulation (or observation) samples a very small fraction of the optical system, and may not be indicative of the “median” observation.
- The simulations should have observational errors comparable to the data.

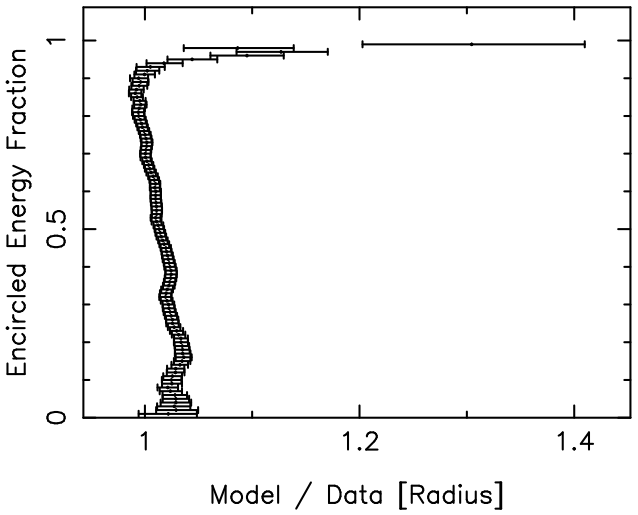
That is, one cannot simply run lots of rays to densely sample the system. We thus ran 1000 simulations of the observation.

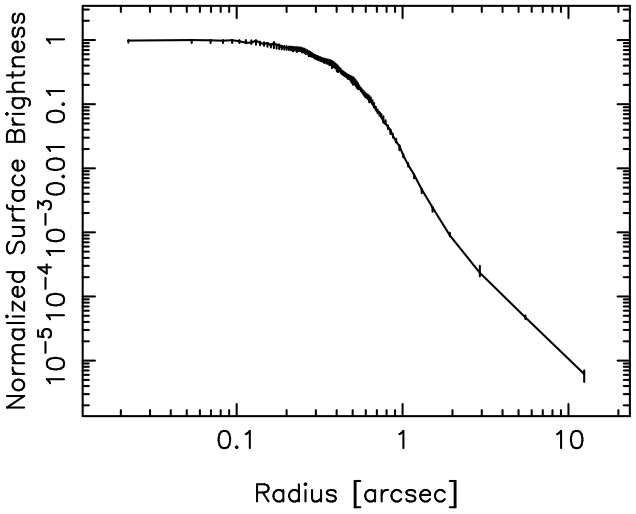
We did *not* simulate the background, as it was not an appreciable factor.

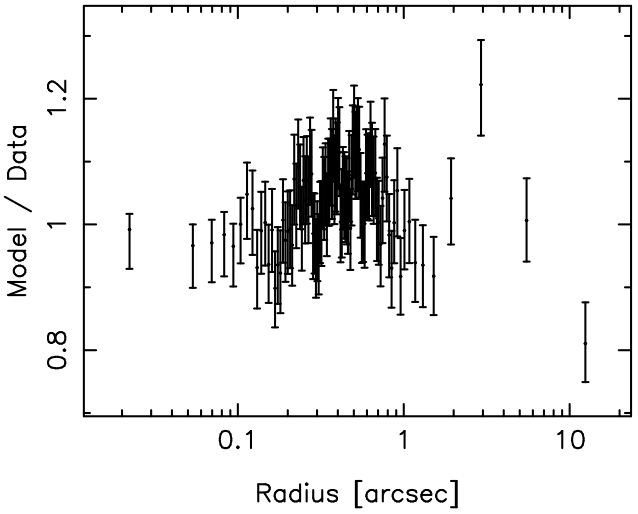
Comparisons of the Simulations to the Data

Error bars indicate the range encompassed by 95% of the simulations.









Conclusions and Future Work

- The simulations agree well with the observations.
- The simulations exhibit a “ringing” in the PSF between 0.5″ and 1″ radius.

Future on-axis work will concentrate on working with ACIS data to provide spectral information.

Off-axis calibration is discussed elsewhere in this workshop.