Calibration of the Chandra PSF: On-Axis PSF

CXO Calibration Review
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An accurate measurement of the Chandra on-axis PSF is challenging:

- There are few bright on-axis sources
- Mostly soft sources
- ACIS observations are plagued by pile-up
- No spectral sensitivity in HRC
- Systematics in HRC event position reconstruction
  - correlated with position on detector
  - complex time variation due to dither

Our best bet is to use a bright HRC-I observation and attempt to correct for the event position artifacts. In this analysis we have chosen an observation of AR Lac:

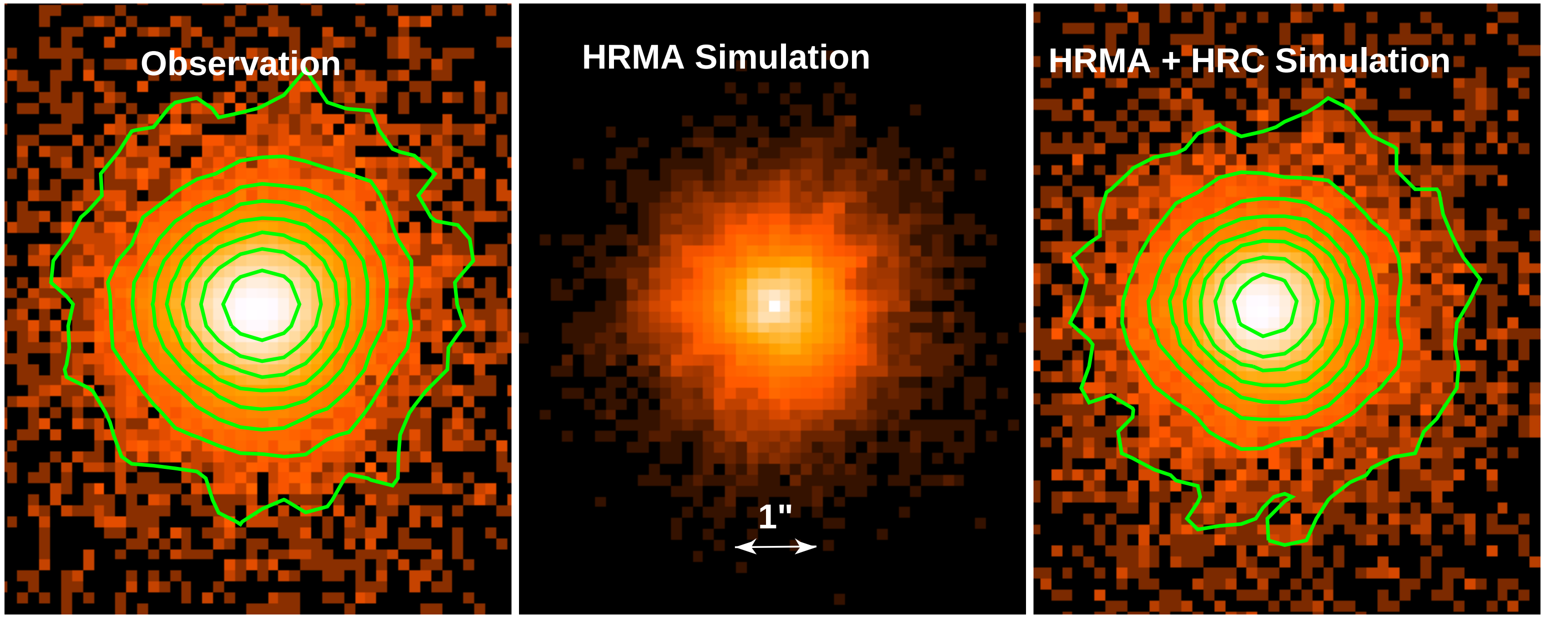
Observation:

Target:	AR Lac
OBSID:	1385
Instrument:	HRC-I
Exposure:	18832 s
Angular distance:	$17.3''$
Azimuth:	203.8°
AP Reprocess date:	2001-04-16T22:51:41
Events:	hrcf01385N004_evt2.fits

Simulations:

Mirror:	SAOsac
Spectrum:	AR Lac
HRC Resolution:	20 $\mu\mathrm{m}$ FWHM
HRC QE:	hrciD1999-07-22qeN0003
Aspect:	$\sigma = 0.11''$

Qualitative comparison of the AR Lac image:



HRC Event Position Reconstruction: Issues

There are systematic offsets in the reconstructed HRC event positions which are dependent upon where on the tile the event landed. The offsets seem due to the HRC electronics. An overview of *some* of the issues is available:

`http://hea-www/~juda/memos/spie2000_tap_correction.html`

The offsets add a several-pixel blur to the image.

We perform an *ad hoc* correction to remove this effect, with the following assumptions:

- AR Lac is a point source.
- Residuals in event positions due to the aspect solution are random in direction and uncorrelated with the position of the events on the detector.
- Variations in time of aspect corrected positions from the overall mean source position are due to this instrumental effect. That is, dithering samples different parts of the detector and we expect to see a slow, time-dependent, deviation from the mean source position.
- The dither period is long enough and the source count rate is high enough that we can sample the aspect corrected positions in a small enough time slice that the systematic offsets are constant over that time period.

HRC Event Position Reconstruction: The Correction

We correct for the systematic event position offsets with the following algorithm:

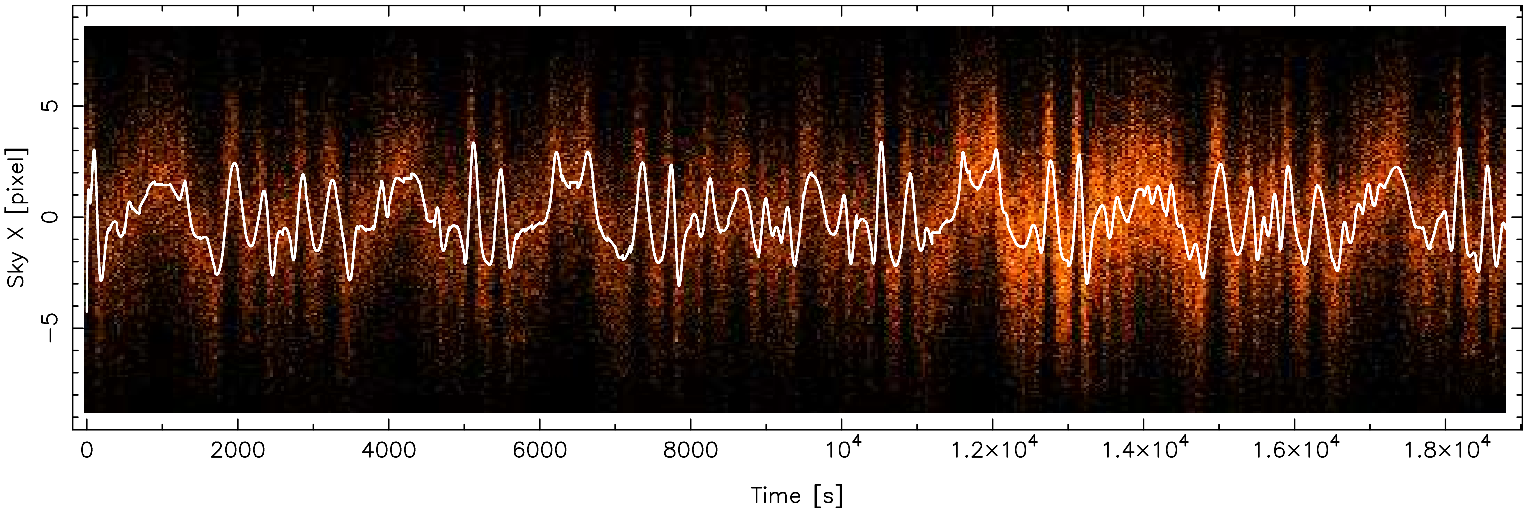
- Events are divided into segments of 100s duration.
- Segments are grouped into sets consisting of three contiguous segments. Each set overlaps the previous set by one segment.
- A 10th order polynomial is fit to each set.
- The polynomial is evaluated for, and subtracted from, the events in the middle segment of each set.

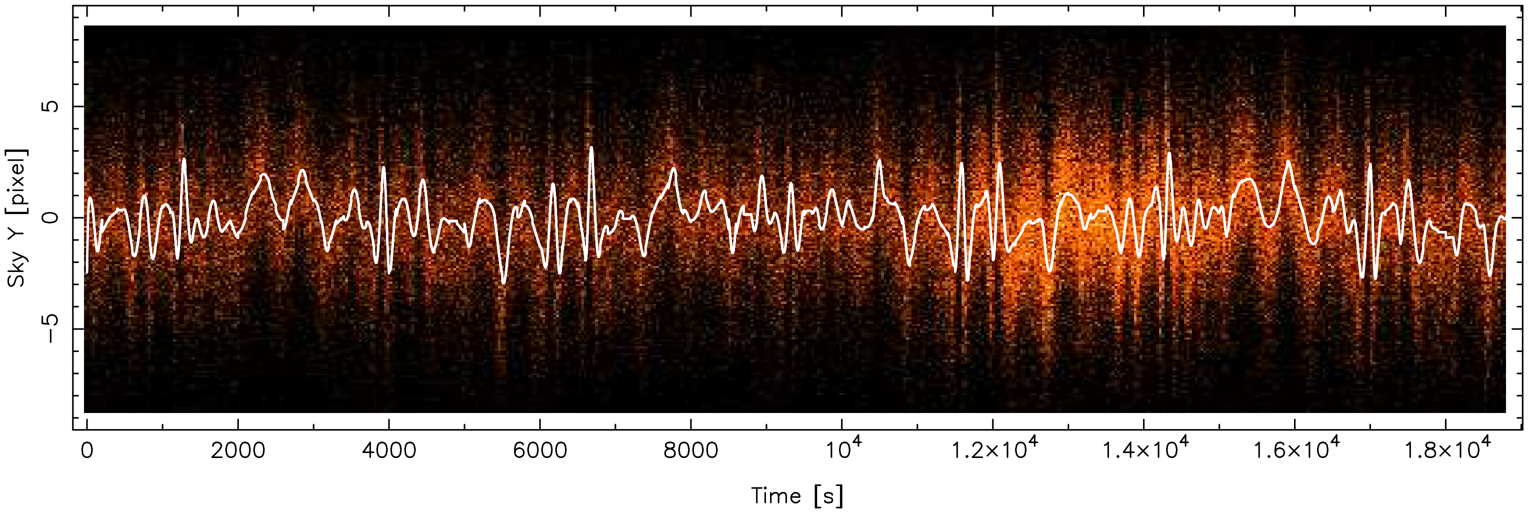
Since the fits are across overlapping sets, this should minimize discontinuities in the correction across neighboring segments.

To gauge how the correction has affected the distribution, we split the events into 100 time bins and calculated the deviation of the mean event positions in each bin from the overall mean source position.

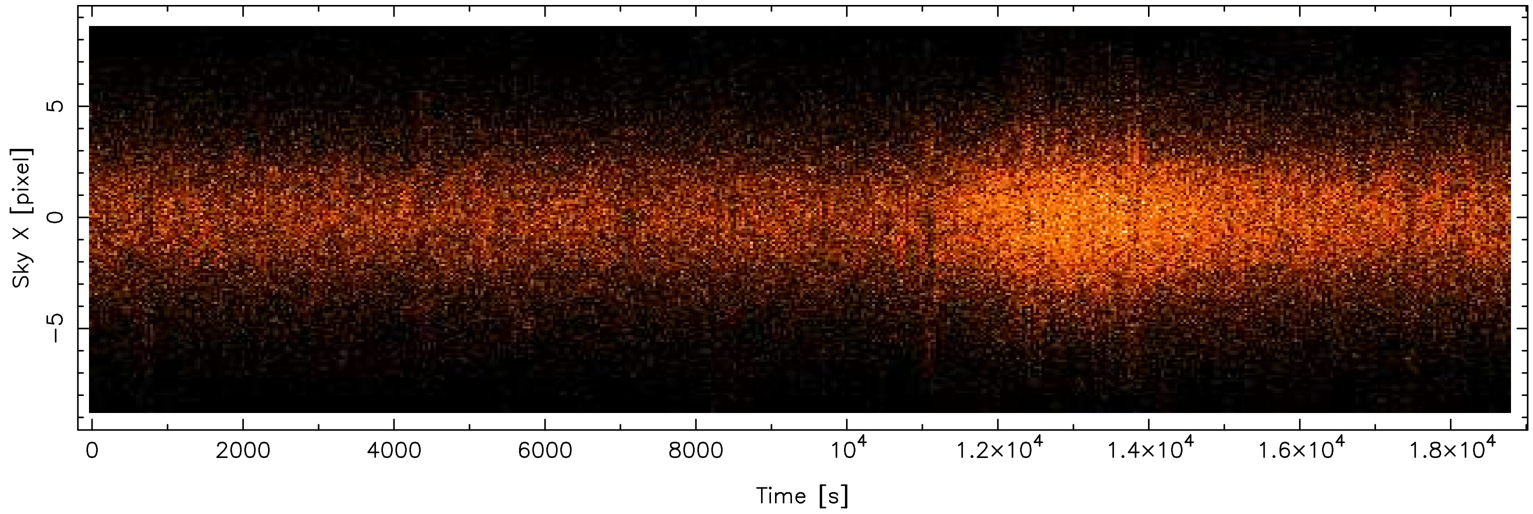
We then calculated the encircled energy fraction as a function of radius, as well as the surface brightness.

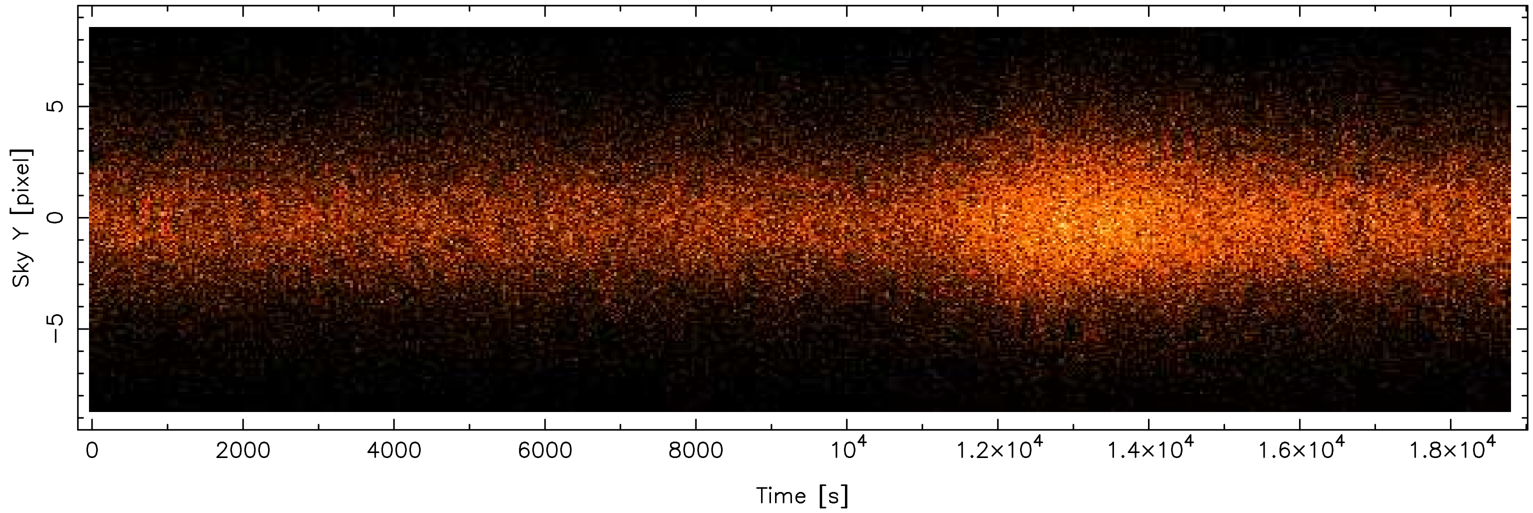
Sky position + polynomial fit to mean sky position:



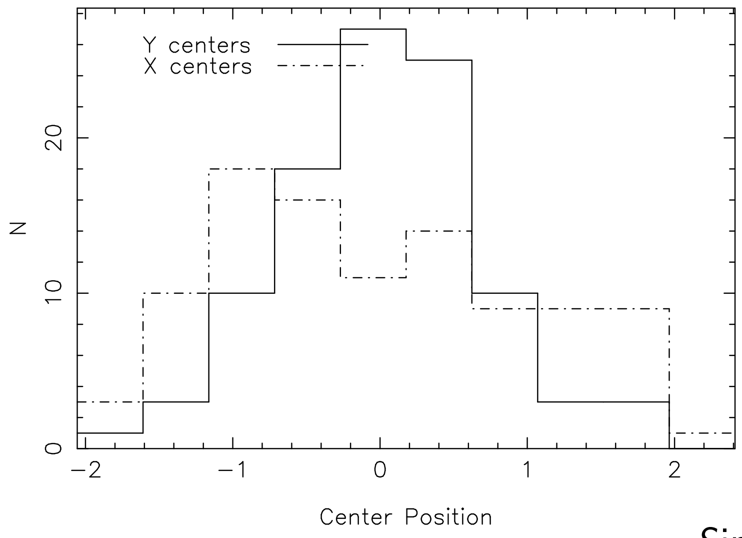


Sky position, after subtraction of polynomial fit

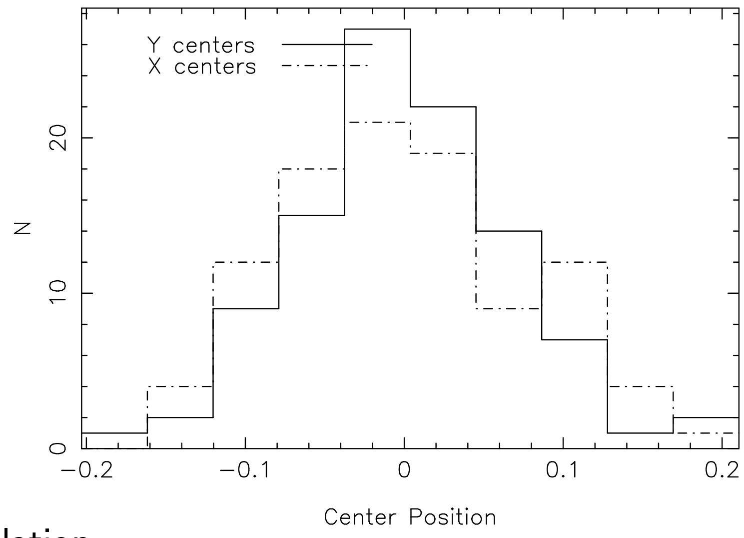




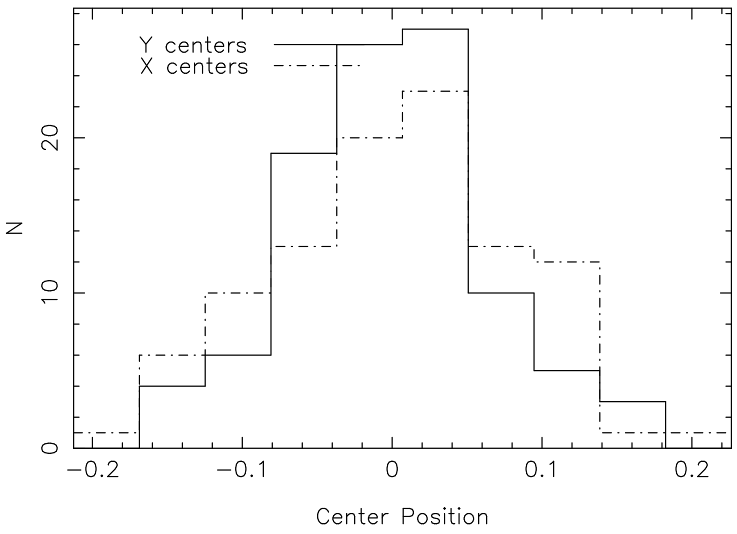
Before subtraction



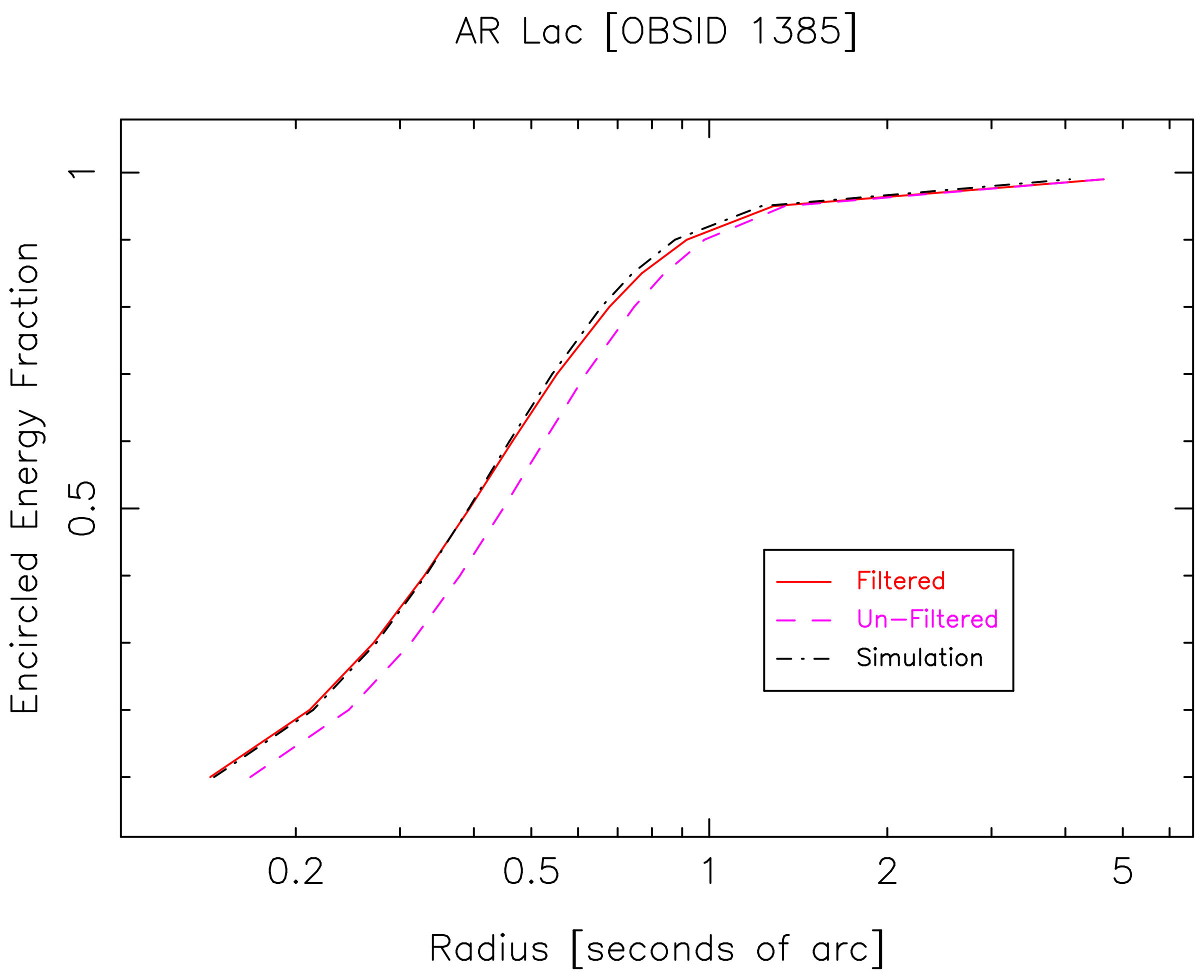
After subtraction



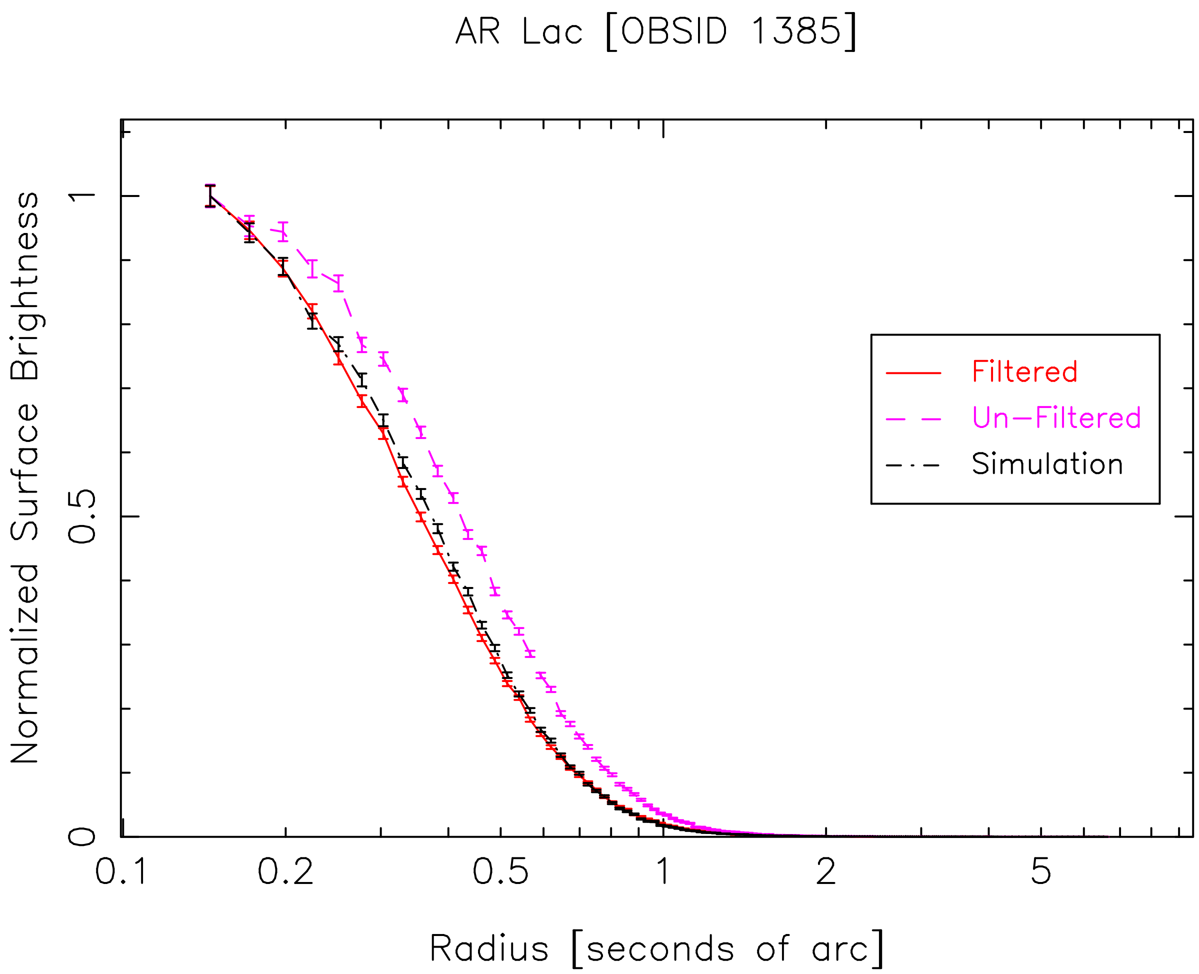
Simulation



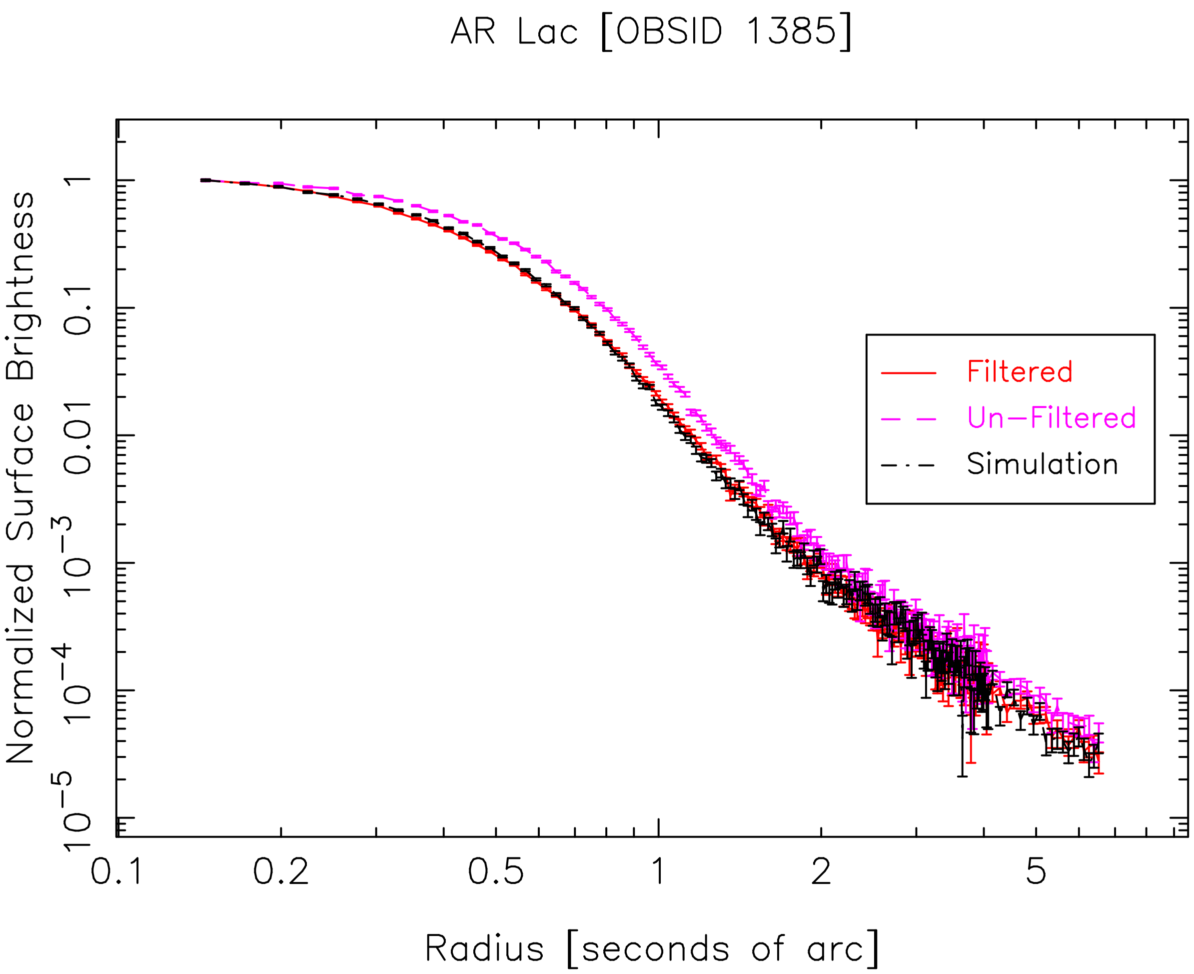
Encircled energy results, relative to flux in a 10″ radius aperture:



Surface brightness within a 10″ radius, log-linear plot:



Surface brightness within a 10″ radius, log-log plot:



Caveats and Conclusions

Caveats:

1. The simulation was a single realization, with a nominal AR Lac spectrum. The errors presented for the simulation are based only the number of simulated events, and do not included any systematic errors.
2. The simulations implement the aspect residuals by applying a Gaussian blur to the final positions.
3. The actual telescope dithering moves the image off-axis in various directions and amounts over time, which results in the measure of an average PSF. We do not simulate this.
4. We do not yet have errors on the encircled energy fractions.
5. AR Lac is a soft source. We cannot extrapolate the high energy PSF.

Conclusions:

1. The corrected data are fit by the simulations remarkably well.
2. The dither-averaging of the PSF, at least $17.3''$ off-axis, does not degrade the PSF appreciably.