

Chandra PSFs and PSF Library

M. Karovska

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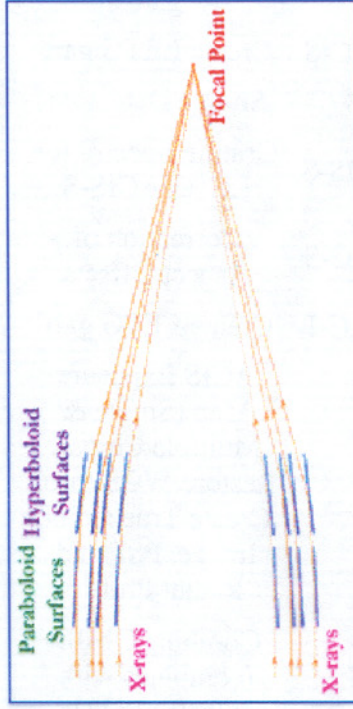


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About the Chandra

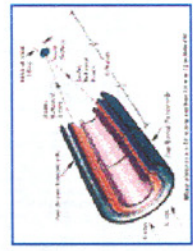
Telescope System

The Chandra telescope system consists of four pairs of mirrors and their support structure.



X-ray telescopes must be very different from optical telescopes. Because of their high energy, X-ray photons penetrate into a mirror in much the same way that bullets slam into a wall. Likewise, just as bullets ricochet when they hit a wall at a grazing angle, so too will X-rays ricochet off mirrors.

The mirrors have to be exquisitely shaped and aligned nearly parallel to incoming X-rays. Thus they look more like glass barrels than the familiar dish shape of optical telescopes.



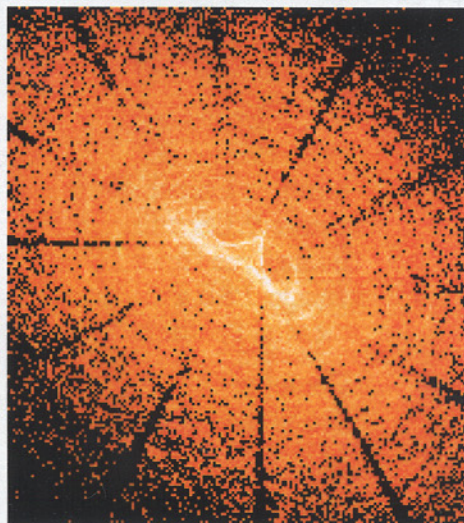
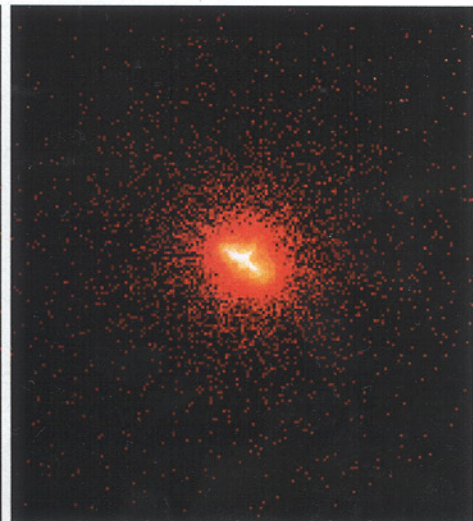
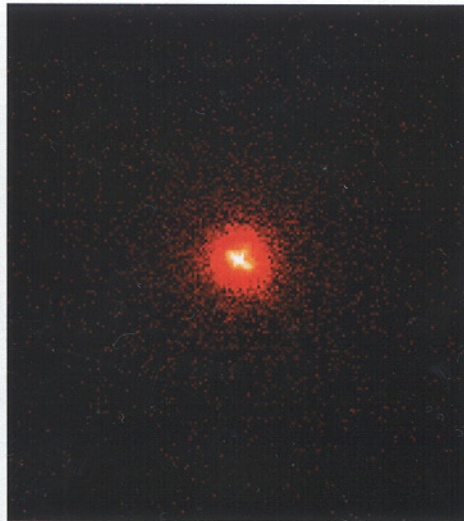
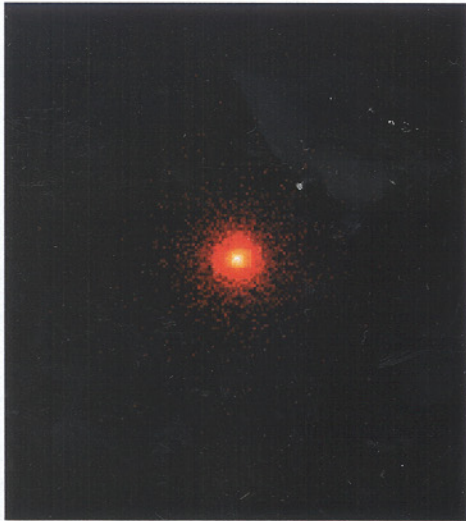
2. Chandra PSFs (Simulations and Examples)

HRMA PSFs @ 1.5 keV

0'

1.5'

3'



6'

12'

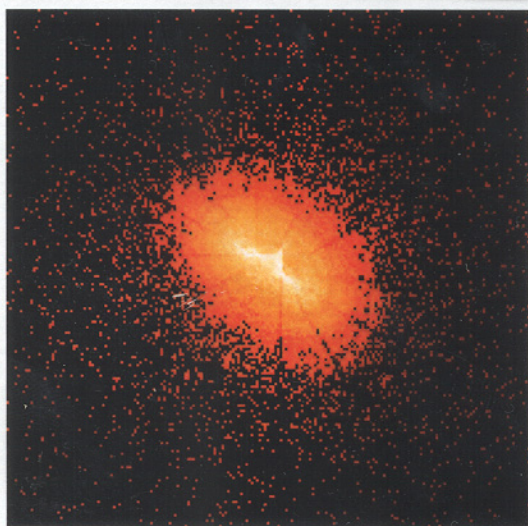
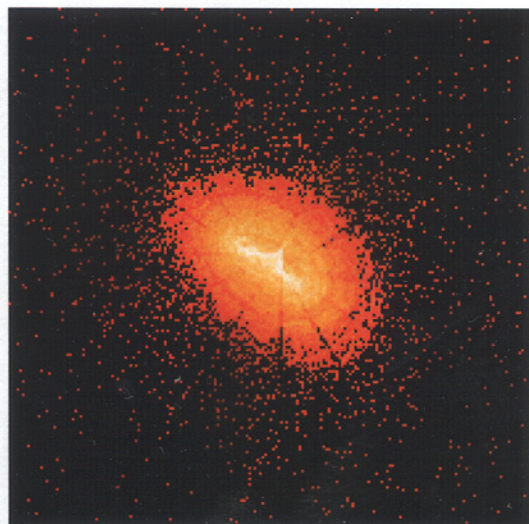
FOV 0.5'

HRMA PSFs @ 6'

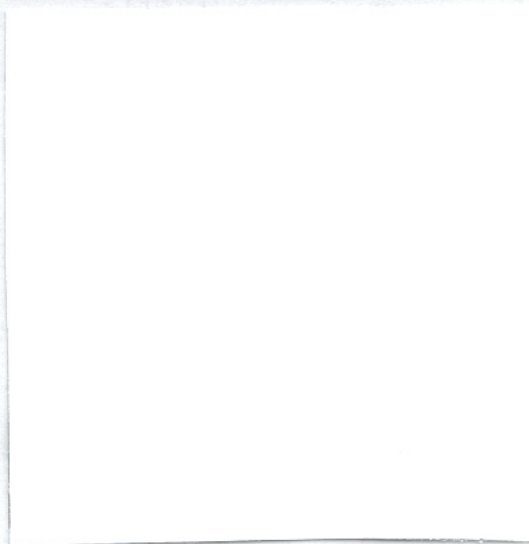
0.277 keV



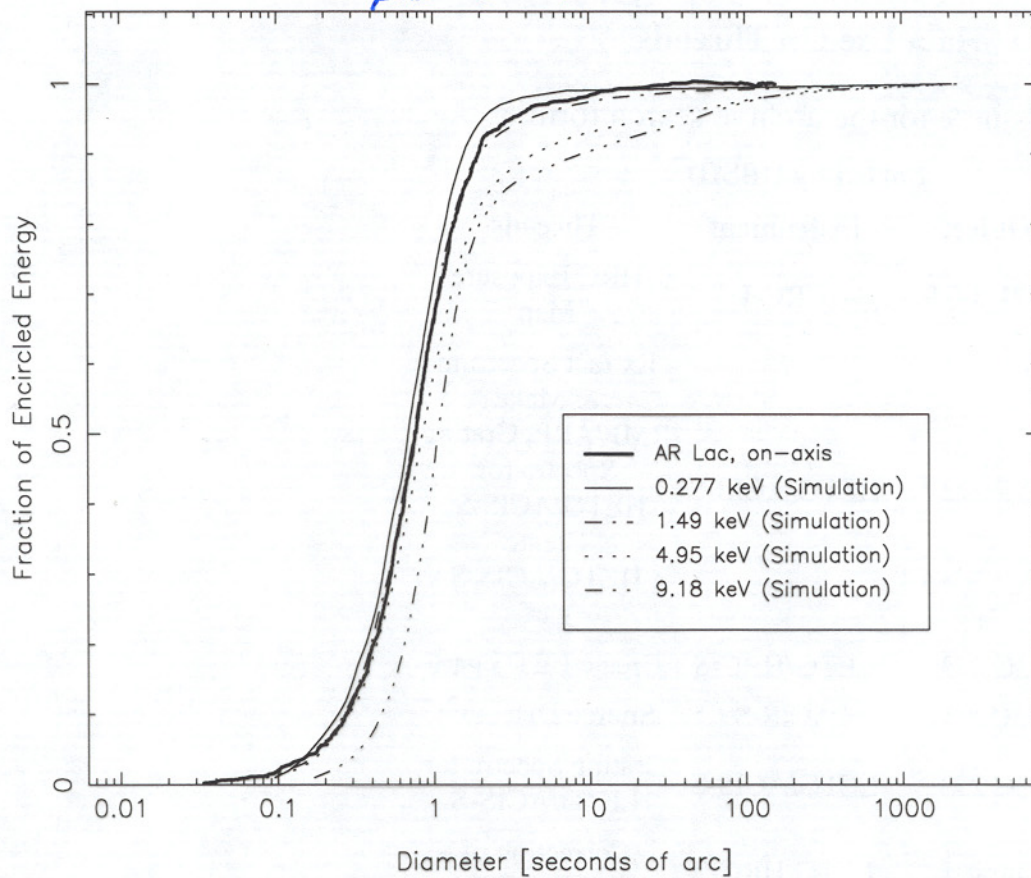
1.5 keV



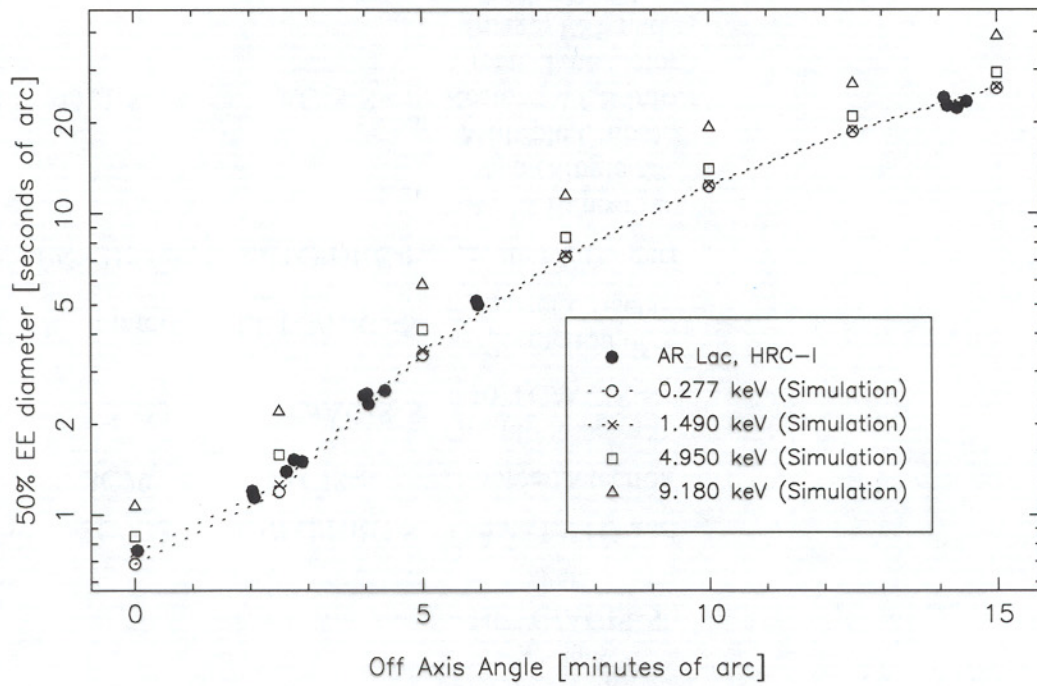
4.5 keV



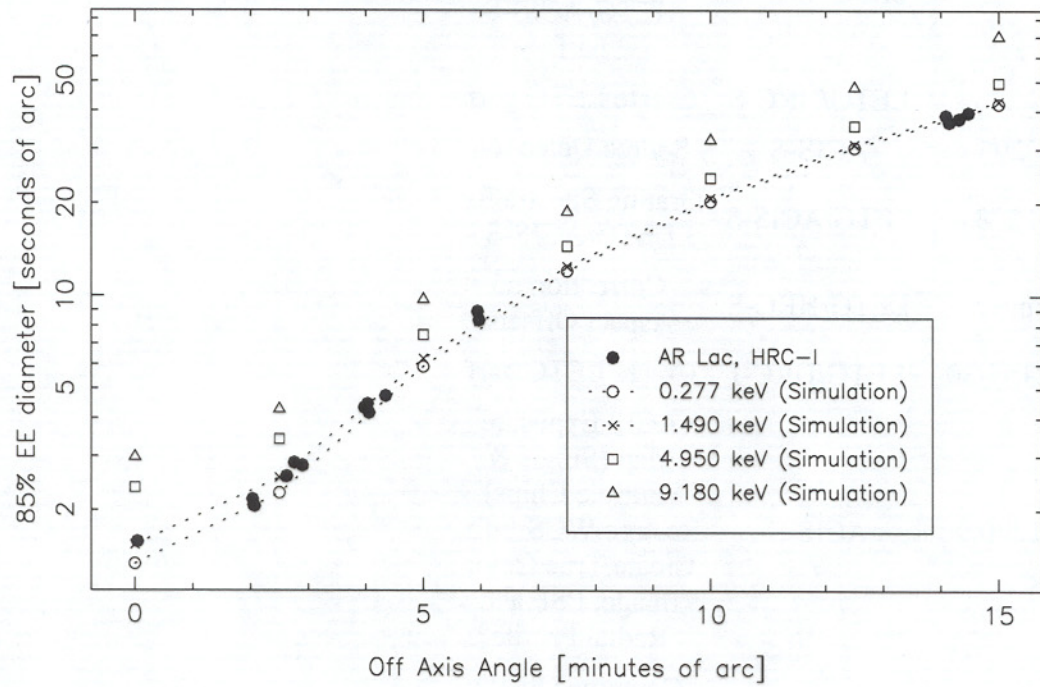
EE ON-AXIS



50% EE off-AXIS



85%. EE off-AXIS



3. CIAO PSF Library

- general structure
- standard set of library files

3. CIAO PSF LIBRARY

3.1. General PSF Library Definition and Format

The PSF library general format is summarized in Table 1:

The HDUs in PSF data FITS files		
HDU	Type	Description
Primary array	1	hypercube
IMAGE extension	2	SUMRCTS image (optional)
BINARY table	3	Irregular coordinate definitions (as many as needed; optional)

Table 1: Single hypercube self-contained PS F

HDU type 1 – the PSF image: - These are n-dimensional images, hypercubes (primary array) that extend along a minimum of five coordinates. The known coordinate axes are:

l - spatial x-direction of the PSF image (PSFX)

m - spatial y-direction of the PSF image (PSFY)

X - spatial x-direction offset coordinate (DETX)

Y - spatial y-direction offset coordinate (DETY)

E - energy (ENERG)

f - defocus (DEFOCUS)

Every image is required to have the following axes: (l, m, E, X, Y, f)

Each coordinate may be regularly sampled, in which case the sample points are defined by the usual CTYPEi, etc., keywords; or irregularly, in which case the sample points are defined in a table extension (in the same file).

Each coordinate has to have one or more pixels, but one is expressly allowed. If there is only one point along any of the required axes, the axis still needs to be present and its coordinate value are defined in the usual way (CTYPEi, etc.). The coordinate axes (most notably the spatial ones) have several aliases defined in the header. The headers of these images contain the required Caldb keywords. These images have SUMRCTS=1.0.

HDU type 2 – the irregularly sampled coordinate definition table s: - These are binary tables which allow an unambiguous translation of "bins" or "pixels" to physical coordinates (e.g., energy, defocus).

HDU type 3 – SUMRCTS image: - The SUMRCTS images contain the information on how many photons (weights) are there per individual PSF data in the PSF hypercubes. These images match the PSF hypercubes exactly, except that the l and m axes are missing. The image pixels indicate the number of counts used for each 2-D PSF image. The SUMRCTS images are kept in IMAGE extensions.

Simulated PSFs

The simulated Chandra PSFs used in the PSF library files are generated in two steps:

1. ray files are generated using SAOsac , a ray-trace code which models the interaction of photons (rays) passing through HRMA (Jerius et al 2000, Proc. SPIE 4012)
2. PSF model images are made by projecting these rays to the detector planes and then creating images with pixel smaller than the pixel sizes of the detectors (HRC: 0.13175"; ACIS: 0.492")

3.2. STANDARD PSF LIBRARY FILES

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Bookmarks Location: http://asc.harvard.edu/ciao/documents_dictionary.html#psf What's Related

PSF: Point Spread Function

Describes the shape of the image produced by a delta function (point) source on the detector. Also known as 'Point Response Function' or PRF.

[\(Standard OGIP file format\)](#)

PSF Libraries

The Chandra [PSFs](#) vary strongly with source location in the telescope field of view, as well as somewhat with the energy, and so with the spectrum of the source. Standard sets of simulated Chandra PSFs covering the field of view of the [ACIS-I](#), [ACIS-S](#), [HRC-I](#) and [HRC-S](#) detectors are available via the standard PSF library files. The CIAO tool [mkpsf](#) reads one of these libraries (at the users choice) and interpolates. Naturally this interpolation is more accurate for the finer grids.

There are 4 standard PSF libraries provided per instrument:

Medium res library (file No. 1) 1 arcmin step size between images. 6 micron pixel images.

Grid about the optical axis covering:

ACIS-I and HRC-I: a -10 to +10 arcmin square grid (21x21);

ACIS-S and HRC-S: a -10 to +10 arcmin in azimuth and -5 to +5 arcmin in elevation grid (21x11).

Low res library (file No. 2) 5 arcmin step size between images. 12 micron pixel images.

Grid about the optical axis covering:

ACIS-I: a -25 to +10 arcmin in elevation and -10 to +10 arcmin in azimuth (8x5) grid;

ACIS-S: a -25 to +25 arcmin in azimuth and -5 to +5 arcmin in elevation (11x3) grid;

HRC-I: a -25 to +25 arcmin in elevation and -25 to +25 arcmin in azimuth (11x11) grid;

HRC-S: a -30 to +30 arcmin in azimuth and -5 to +5 arcmin in elevation (13x3) grid

High res library (file No. 3) 1 arcmin step size between images. 2 micron pixel images.

Grid covering a -6 to +6 arcmin (11x11) in azimuth and elevation about the optical axis.

High res library (file No. 4) 1 arcmin step size between images. 1 micron pixel images.

Grid covering a -1 to +1 arcmin (3x3) about the optical axis.

[NB: ACIS pixel size is 24 microns; HRC pixel size is 6 microns]

See also:

- [PSF Manual](#)
- [Cal's HRMA PSF Page](#)

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Navigation icons: Home, Back, Forward, Reload, Stop, Print, Security, Shop, What's Related, and system tray icons.

- . . -

HRC-I Standard Library files

The center of the coordinate system is the HRC-I aimpoint at $x=16384.5$, $y=16384.5$ in DETECTOR coordinates (0,0 in azimuth and elevation).

File 1 (F1):

256x256 pixels images for currently only one defocus position (0), 5 energies, and 21x21 off-axis angles defined by the elevations:

elevation (-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10) arcminutes

azimuth (-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10) arcminutes

Pixel size: $6 \mu\text{m}$

File Size 580 Mb

File 2 (F2):

512x512 pixels images for one defocus position, 5 energies, and off-axis angles defined by the following elevations and azimuths:

elevation (-25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25) arcminutes

azimuth (-25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25) arcminutes

Pixel size: $12 \mu\text{m}$

File Size 620 Mb.

File 3 (F3):

512x512 pixels images for one defocus position, 5 energies, and 13x13 off-axis angles defined by the following SAOSAC elevations and azimuths in arcminutes:

elevation (-6,-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6) arcminutes

azimuth (-6,-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6) arcminutes

Pixel size: $2 \mu\text{m}$

File Size 890 Mb

File 4 (F4):

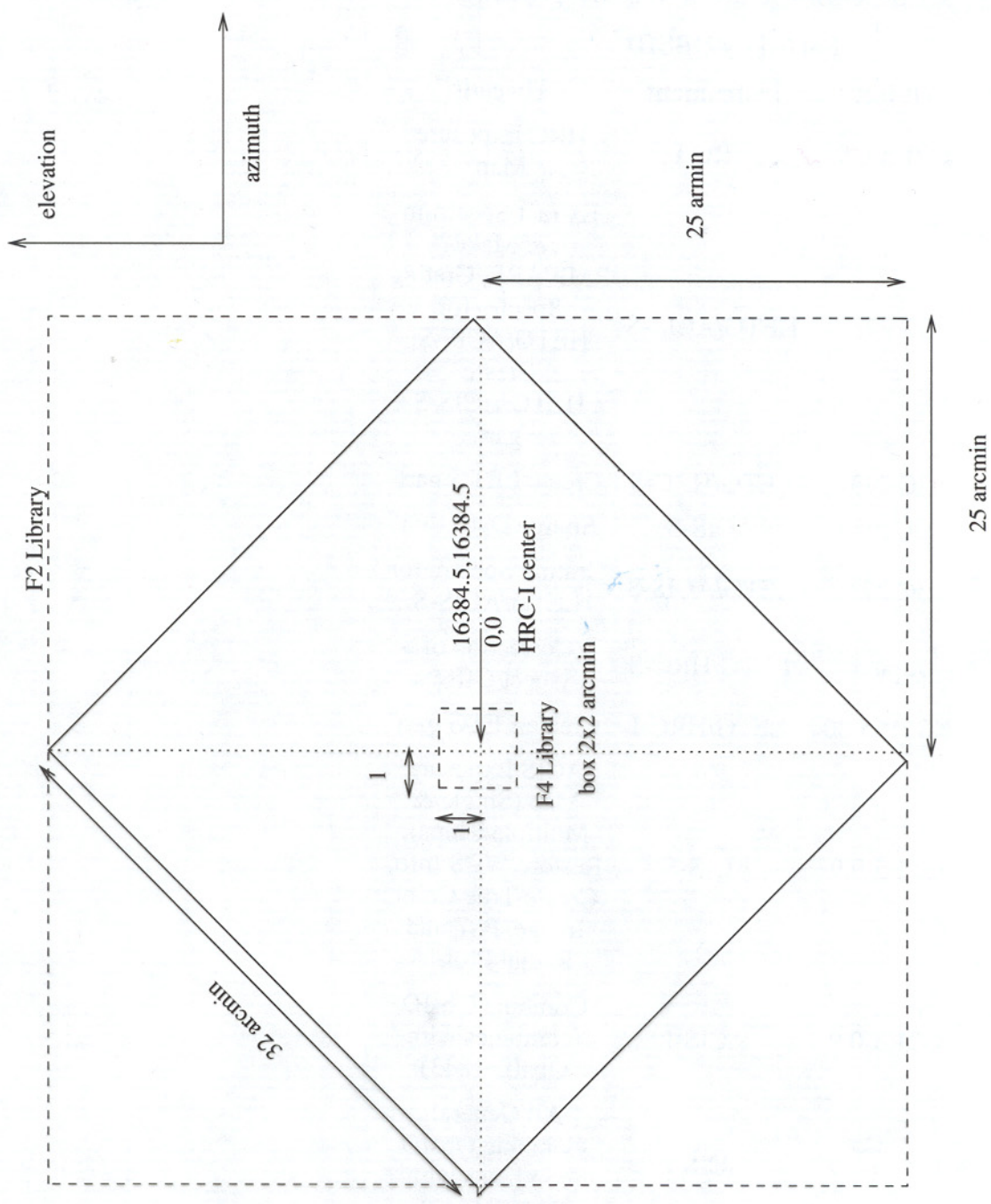
512x512 pixels images for one defocus positions, 5 energies, and 3x3 off-axis angles defined by the following elevations and azimuths:

elevation (-1, 0, 1) arcminutes

azimuth (-1, 0, 1) arcminutes

Pixel size: $1 \mu\text{m}$

File Size 46 Mb.



— A schematic diagram of HRC-I detector. This diagram is NOT TO SCALE!! The aimpoint is marked with a cross. The pixel size is 0.006429 mm, corresponding to 0.13175 arcsec.

4. Make PSFs with mkpsf



CIAO 2.1 Science Threads

Create a PSF (9 April 2001)

[Return to Threads Page.](#)

For illustration, this thread utilizes data from the ObsID 1838 dataset (ACIS-S, G21.5-09), which was downloaded from the Archive.

The aim of this thread is to create an image of the Point Spread Function (PSF) for a source, and normalize it to the source flux. The PSF changes with source position and photon energy, and is created by interpolation of a library of pre-launch, calibration files (the PSF hypercube library) by using the CIAO tool `mkpsf`. The latest information on the status of the PSF libraries can be found in the "Responses" section of the Data Caveats page (especially the `mkpsf` caveats) and the PSF HRMA calibration page. Please review this information before following the thread.

Contents

- A. The PSF Libraries
- B. Characterizing the Source
 1. What is the energy of the source? (`dmextract`, `dmlist`, `chips`)
 2. How far off axis is my source? (`dmcoords`)
 3. Number of photons in the source (`dmstat`)
- C. Create a PSF image file (`mkpsf`)
- D. Normalise PSF to total counts in source (`dmstat`, `dmimgcalc`)
- E. Caveats
 1. Energy
 2. Position

Parameter Files:

- `plist dmextract`
- `plist dmstat`
- `plist mkpsf`