Raytracing the *Chandra* PSF
Try this at Home!

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Outline

Introduction

The ability to simulate a *Chandra* observation is useful in a variety of circumstances to . . .

- . . . examine the feasibility of making an observation
- . . . understand the sensitivity of an observation to variations in an astrophysical model
- . . . explore the implications of analysis techniques on the robustness of results
- . . . examine the statistical properties of a sample of objects
- . . . understand the systematics of surveys

Tools for Raytracing *Chandra*

MARX

Complete end-to-end simulation of the telescope

- Pro: Easy to install, Documented, One-stop-shop, Fast
- Con: Simplified Optics model, single source

SAOTrace

Simulates the HRMA only

- Pro: Refined Optics model, multiple sources
- Con: More difficult to install, uneven documentation, No telescope dither, Not so Fast

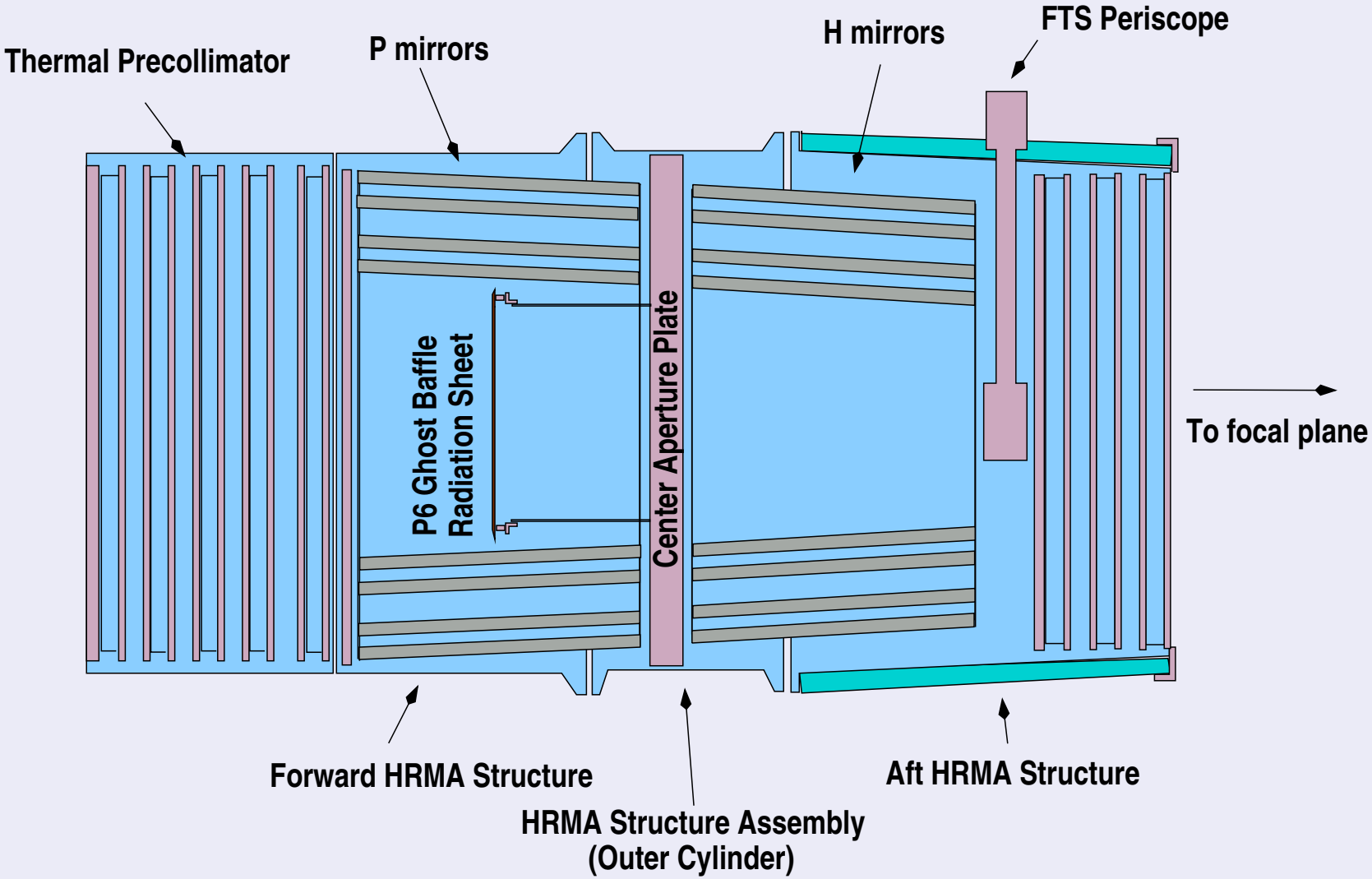
SAOTrace Overview

SAOTrace is now publically available as a technology release.

1. Developed by the CXC Optics and Telescope Scientist groups, SAO Engineering
2. Engineering tool: designed to evaluate designs, perform sensitivity studies, simulate tests, predict performance
3. Semi-empirical model based upon measured characteristics of the mirrors, support structures and baffles:
   - Precision metrology of the optics' surfaces
   - Accurate measurements of optical constants of the Ir coating
   - As-built support and baffle dimensions
   - As-built optic positions and alignment, augmented by XRCF measurements
   - Empirical correction of A_{eff} to match XRCF measurements
   - Addition of contamination layer to match on-orbit measurements.

Chandra's Optics

The High Resolution Mirror Assembly (HRMA)



SAOTrace *Chandra* Model Components

What's Included...

Baffles	Thermal-precollimator, P6 Ghost Baffle, CAP, Post-collimator
Surface	Non-ideal optic figures, surface micro-roughness, multilayer coating, inter-layer roughness
Source	Multiple sources Source geometry: images, point, disk, rectangle Arbitrary spectra

...And What's Not

- FTS Periscope
- Scatter off of baffles or support structure
- Gratings
- Telescope dither

Limitations of the Model

The model is not reality – it is best used to increase the understanding of how telescope and optics systematics can affect your analyses and conclusions, but don't expect it to exactly predict an observation.

What we trust (from on-orbit calibration)

- $<$ 3 keV On-axis PSF within $\sim 5''$ (but see caveats)
- $<$ 3 keV Off-axis PSF, $\theta < 5'$ (qualitatively out further)
- $<$ 3 keV vignetting
- $<$ 3 keV A_{eff}(but see other CCW talks about cross-calibration)

Caveats

- On-axis PSF not good enough to use in deconvolution
- On-axis PSF $E > 3keV$ not calibrated; may have issues
- Far Wings ($> 10''$) not well simulated
- Model of off-axis PSF ($\theta > 5'$) gets worse as θ increases
- Detector systematics affect the PSF:
  HRC-I image artifacts, ACIS Pileup, Dither + ACIS pixelization.

Words to the Wise

Don't push the model. If working in an area where it is known to be weak (e.g. PSF wings) use other observations and CXC Calibration analyses to determine the telescope response.

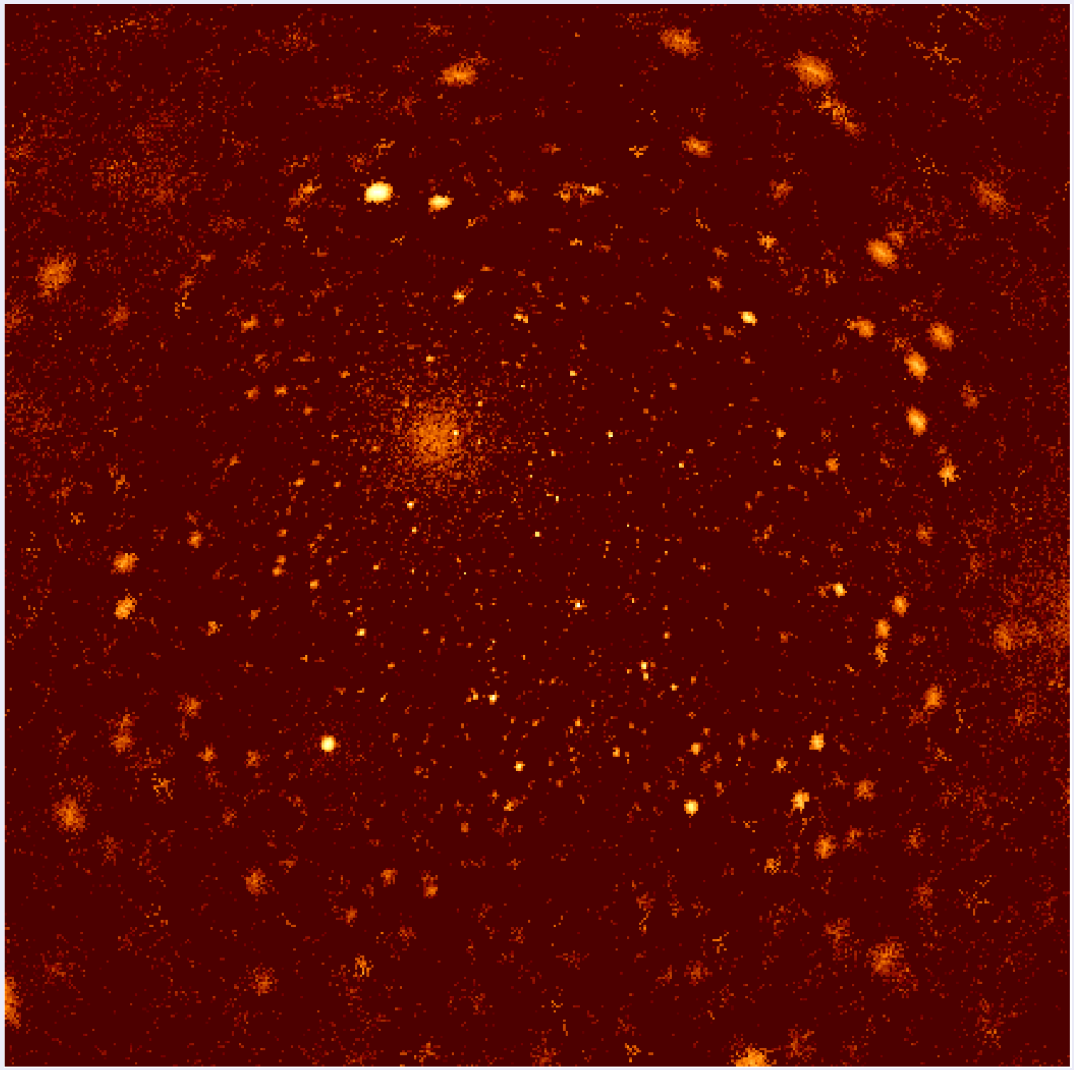
Chandra's optics are not perfect, and exhibit surprisingly complex characteristics, not all of which are understood or calibrated.

When you're working on the edge, recognize that

You may boldly be going where no one has gone before.

Eye Candy

A Simulation of 128 Clusters, 1778 Stars, 18423 AGN's



Future Plans

Internals

- Implement telescope dither, roll
- Implement arbitrary rotation of input images
- Upgrade to work with current versions of external dependencies
- Efficiency improvements in surface roughness scattering program
- Test and integrate new scattering algorithm
- Port to OS X

Externals

- Provide more source examples (deep field, etc)
- Supported version to be released by CXC Data Systems

Calibration

- L3 will provide a large set of sources which will help improve the calibration of the model

Nuts and Bolts

What

- ∼70 C, C++, Fortran and Perl executables and libraries
- ∼15 C, Fortran and Perl external packages

How

Source only – automated configuration and installation is provided.

Platforms

Solaris Sparc: 8|10
GNU/Linux i386/x86_64: Debian$^{3.1|4.0}$ Ubuntu$^{6.06|7.04|7.10}$ Fedora$^{3|4|5|6}$ RHEL^{4}

Support

CXC Data Systems **None**
CXC Optics Group **Minimal** – no resources for general user support

Where

http://cxcoptics.cfa.harvard.edu

Summary

- The ability to simulate *Chandra*'s performance using a realistic model of its optics can greatly increase the fidelity of analyses and conclusions.
- SAOTrace software combined with calibration data provides an effective means of exploring analysis space and illuminating boundary conditions and analysis systematics.
- SAOTrace is available now for the intrepid user. A more user friendly packaging will be made available by the CXC Data Systems group in the future.