Astronomical Data Analysis Software and Systems IX
ASP Conference Series, Vol. 216, 2000
N. Manset, C. Veillet, and D. Crabtree, eds.

Chandra Ground Calibration Raytrace Database and Simulator

M. Tibbetts, R. Edgar, T. Gaetz, D. Jerius, K. Michaud, D. Nguyen

Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138

Abstract. The Chandra Ground Calibration Raytrace Database and Simulator provides simulations of tests performed on the Chandra X-Ray Observatory's High Resolution Mirror Assembly (HRMA). Following ground calibrations at Marshall Space Flight Center, we compiled a database of parameters for each subsystem involved in the calibration effort. Using this database and SAOsac raytrace code, developed from the OSAC suite of programs, we are able to reproduce the environment in which each test was conducted; this enables us to simulate the as-run measurements with the ultimate goal of verifying the fidelity of the HRMA models. Here we describe the structure of the parameter database, ancillary data generated from the database, and comparisons of the simulations to the calibration data.

1. Introduction

Prior to its July 23, 1999 launch, the Chandra X-Ray Observatory's High Resolution Mirror Assembly (HRMA) underwent extensive ground calibration (Weisskopf & O'Dell 1997) at Marshall Space Flight Center's X-Ray Calibration Facility (XRCF). The calibrations were designed to determine HRMA's spatial and spectral characteristics.

Data from the various calibration subsystems have been gathered into a RDBMS. With these data and the SAOsac raytrace code, developed from the OSAC suite of programs, we are able to faithfully reproduce the environment in which each test was conducted. This allows us to compare the performance of the raytrace mirror models to the HRMA X-ray data and predict HRMA performance under various conditions.

2. The XRCF Experiment

The physical layout of the XRCF consists of an evacuated chamber containing the various calibration subsystems as shown in Figure 1. At one end of the chamber is the X-Ray Source System (XSS). The XSS offered an Electron Impact Source (EIPS), a Penning source, and two monochrometers, the Double Crystal Monochrometer (DCM) and the High Resolution Erect Field Spectrometer (HIREFS). Further down the chamber is the HRMA which is mounted on a set of stages. The stages pitch and yaw the HRMA relative to the facility optical axis. Downstream of the HRMA is the Shutter Assembly (HSA) containing 16

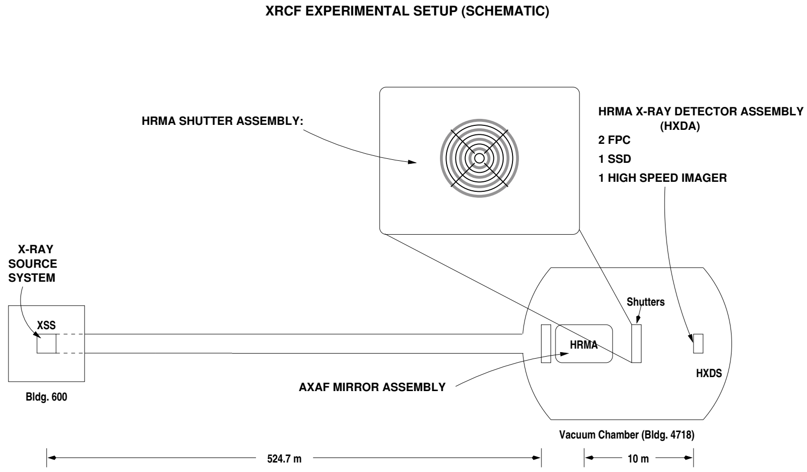

Figure 1. The X-Ray Calibration Facility.

shutters, one for each quadrant of the HRMA's four mirror pairs. Finally, there are the focal plane detectors and apertures. These are mounted on stages that allow them to be moved about the focal plane and allow for various apertures to be placed in front of the detectors.

2.1. Data Collection

The fundamental measurement identifier at the XRCF was the 6 digit runid. During a given runid the XSS source and energy, HRMA pointing, and focal plane aperture and detector were constant. Each runid could contain multiple iterations. From iteration to iteration, the HSA shutter configuration and placement of the focal plane aperture and detector could vary.

Data from each of the subsystems was logged during our time at the XRCF. Both continuous logging and state change logging techniques were used. Some subsystems, such as the stages controlling the aperture placement, were keyed by runid. In most cases though, subsystems were keyed by time. To reconstruct the conditions during a given measurement, we needed to create relationships between the continuously logged data, state change data keyed by time, and runid-iteration pairs. This task was complicated by the fact that the clocks used to generate the time keys for the various subsystems occasionally got out of synch with one another. We were able to reconstruct some of the corrupted logs, especially the state change logs, with the help of valid logs from the same period. However, some data were lost during the corrupted times.

2.2. Reconstructing Measurements

When determining subsystem parameters the XRCF raytrace simulator, `xrcf_rt`[1], attempts to find "as run" values from the logs where available. However, there are a number of cases where "as run" values are unavailable. In these

[1] `http://hea-www.harvard.edu/MST/simul/software/docs/html/xrcf_rt.html`

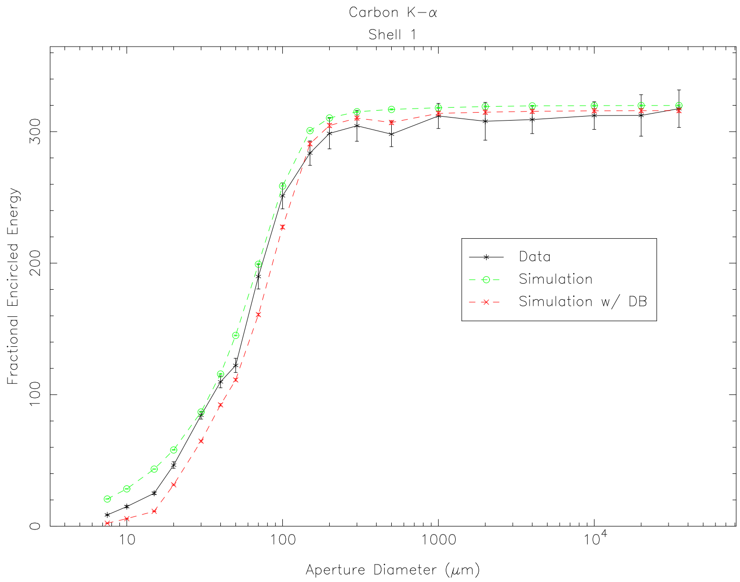

Figure 2. Fractional encircled energy.

cases, "as requested" values are substituted. These requested values often differ from the "as run" values since changes on the floor were common.

Additional complications are due in part to stage motor failures. During the XRCF testing, one of the actuators that controlled the HRMA tilts failed. This complicates the process of determining the angle of the HRMA relative to the optical axis and thus placement of focal plane apertures and detectors. The motors on the HSA also had occasional troubles. This led to uncertainty about whether a given shutter was out of the beam or still occulting part of the beam.

Other complications arise from the XSS sources. We do not have a complete set of source maps for the XSS sources used during the tests at the XRCF. Instead, we have matched measurements to existing source maps. This correspondence defaults to an ideal point source for measurements where there is not an XSS source map available.

2.3. Simulations vs. Data

Figure 2 shows the results of effective area measurements on a representative shell. The XRCF data are plotted along with simulations using the requested configuration and simulations using the as-run configuration generated by `xrcf_rt`. Note the improvement around the $500\mu m$ aperture where the requested configuration differed from the as-run configuration due a misalignment of the aperture.

3. Conclusion

A comparison of the data and `xrcf_rt` generated simulations indicates that there are still discrepancies between the configuration as derived by the simulator and the actual configuration. The discrepancies are most prevalent in the smaller apertures. Since the width of the point spread function (PSF) is smaller than the larger, $\geq 1000\mu m$, apertures the measurements are insensitive to aperture placement. For apertures on the order of the width of the PSF, small displacements in the focal plane can lead to large changes in the flux measured.

By running simulations using the same equipment configurations used in the XRCF experiments, we have gained confidence in the mirror models. To improve agreement between data and the simulator, we must continue working on corrections to the stage positions when there were motor failures and improve the default XSS source maps used for measurements where no image maps are available.

Acknowledgments. We acknowledge support through NASA contracts NAS8-40224 and NAS8-39073.

References

Weisskopf, M. C. & O'Dell, S. L. 1997, Proc. SPIE, Vol. 3113, p. 2-17