IXO in the Digital Lab - Instrument Performance Simulations

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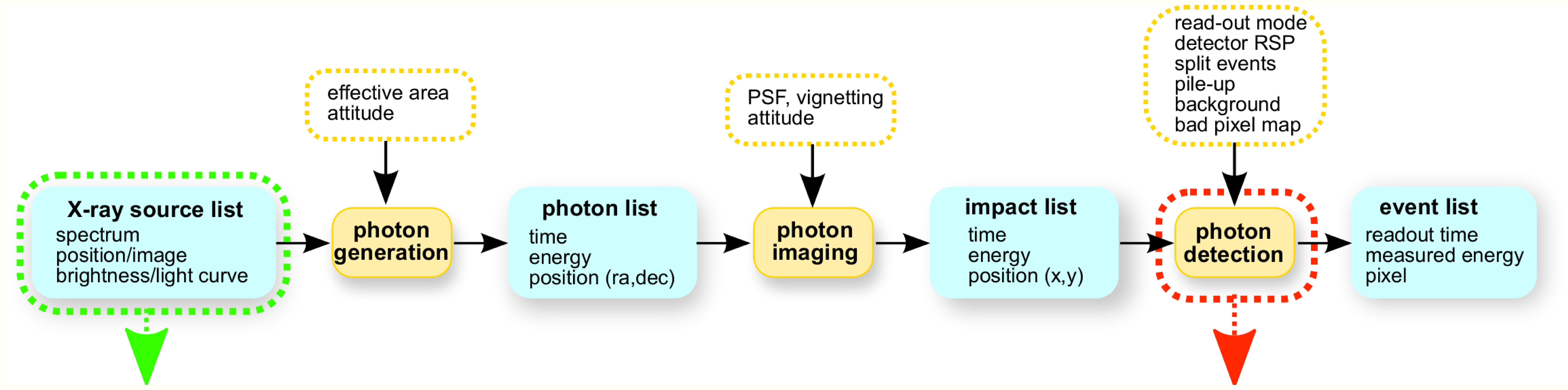
Abstract

We present a simulation software package suitable to study the performance of the X-ray detectors aboard IXO. The package contains individual models for the different instruments taking into account, e.g., their particular geometry and operating modes. The software uses standard calibration files like a PSF resembling the mirror properties and response matrices including detector-specific features concerning the absorption of X-ray photons. As an example for the capabilities of this simulation we present an analysis of the bright source performance of the WFI, the HTRS, and the XMS.

Simulation Software

We have developed a generic simulation software for X-ray telescopes with pixelized detectors. The software package is written in C and implements a common interface by using the APE/PIL library for parameter input and standard FITS files for data access. It contains models for different instruments like the WFI, the HTRS, and the XMS, and it can be easily extended for other detectors. For instance we can also simulate eROSITA, GRAVITAS or the EPIC-pn camera on XMM-Newton.

The simulation is set up as a pipeline of the relevant tasks such as the generation of a sample of X-ray photons, the imaging process in a Wolter telescope, and the photon detection by the respective detector. Individual tools in this pipeline can be replaced easily to adjust the simulation to different missions. The instrument characteristics like the mirror and detector properties are defined by standard calibration files, such as the PSF or RSP.



The software can simulate observations of different kinds of astronomical X-ray sources which are defined according to the SIMulation inPUT (SIMPUT) data format presented in the green box below.

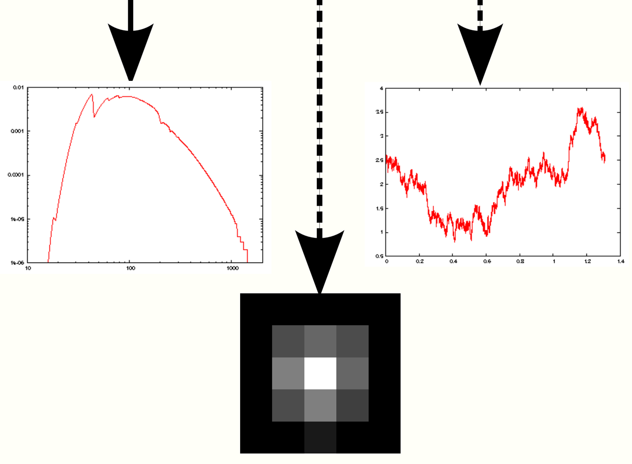
The red boxes below introduce the implemented models of the WFI, the HTRS, and the XMS and display simulation results for the performance of these instruments with respect to pile-up.

SIMPUT Format

The input X-ray sources for the simulation have to be stored in a FITS file according to the SIMPUT format. This format is described in a document, which is currently available as a draft (please contact christian.schmid@sternwarte.uni-erlangen.de to purchase a copy). It provides flexible models to describe catalogs of different kinds of astronomical sources, such as point sources or extended sources with their spatial extent defined by observation images. The sources have characteristic spectra and may exhibit a time-variable brightness as well as polarized emission. The SIMPUT file format can be used to describe any kind of X-ray sources relevant to simulations and it provides a flexible interface for scientists delivering input data for simulations.

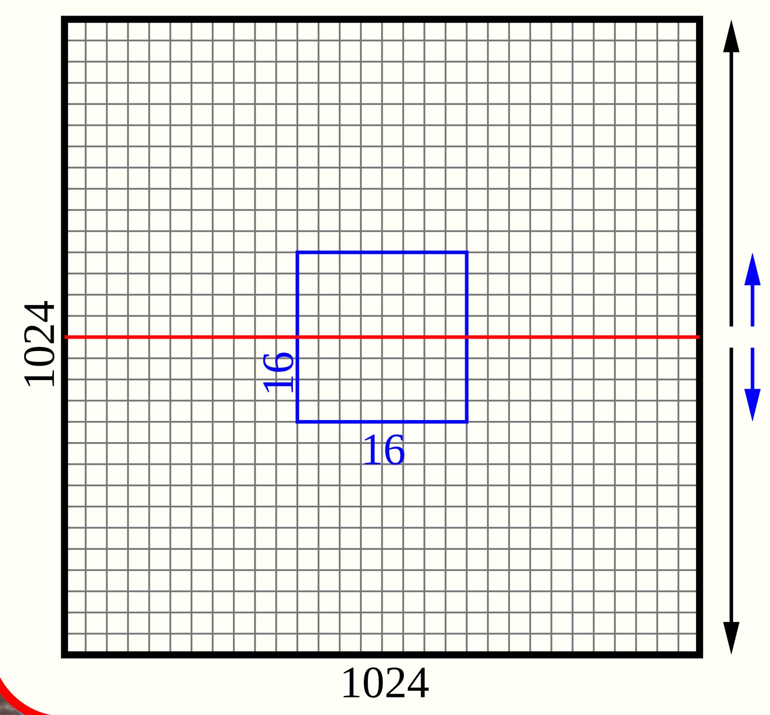
Source Catalog Extension

	SRC_ID	SRC_NAME	RA	DEC	FLUX	E_MIN	E_MAX	SPECTRUM	IMAGE	LIGHTCUR
1.										
2.										
⋮										



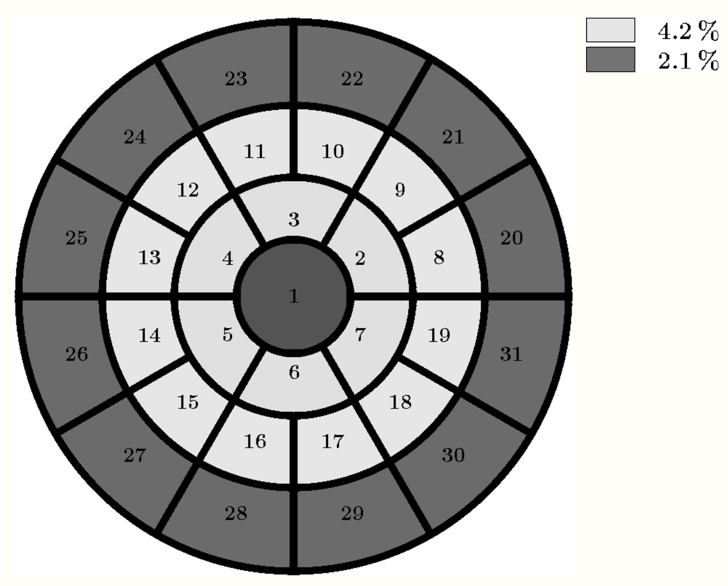
The upper sketch describes the layout of a SIMPUT source catalog. Each X-ray source is defined by an entry in the catalog table with its basic properties like right ascension, declination, or energy flux density. More complex data like spectra, images of extended sources, or light curves are stored in additional FITS file HDU's and are assigned to the particular catalog entries. By combination of several spectra, light curves, and images even complicated models for time-variable sources with different emission characteristic for different phases can be described.

Wide Field Imager (WFI)



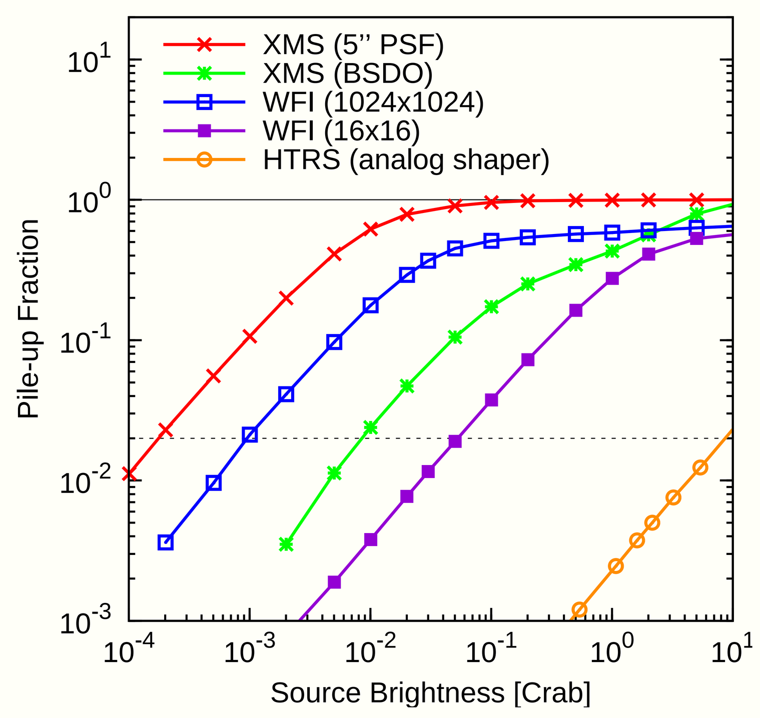
The WFI consists of an array of 1024×1024 Depleted P-channel Field Effect Transistor (DePFET) pixels. The array is divided in 2 halfs, which are read out simultaneously with 1 active line each (see left-hand image). The time required to read-out the whole 1024×1024 array is approximately 1 ms. For observations of bright sources a 16×16 window mode with a fast read-out cycle of $16\,\mu s$ is provided. The capabilities of the detector to observe bright sources are limited by energy pile-up (multiple photons hitting the same pixel during one read-out cycle) and pattern pile-up (photon impacts in adjacent pixels).

High Time Resolution Spectrometer (HTRS)



The HTRS consists of 31 Silicon Drift Detectors (SDD) arranged in a circular pattern and is in particular designed for observations of bright galactic sources. In order to cope with the corresponding high photon rates due to the large effective area of IXO (the Crab spectrum corresponds to 170 000 photons per second) the detector is mounted at a distance of 12.6 cm behind the focal plane, such that the photon beam is spread over all 31 pixels (indicated by the brightness scale of the left-hand image). This reduces energy pile-up, which occurs if the time between subsequent photons is too short for accurate shaping of the voltage pulse. Pattern pile-up and charge splitting are prevented by an absorbing mask on top of the pixel edges.

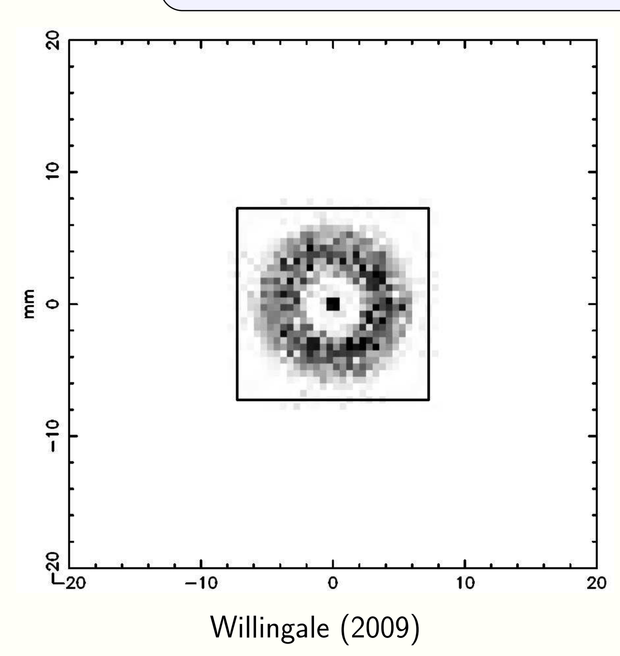
Bright Source Performance



We have simulated observations of differently bright X-ray sources for the presented detector models in order to investigate the performance of these instruments. The plot on the left-hand side displays the fraction of events affected by pile-up among the detected valid events as a function of the source brightness. Depending on the instrument the Crab spectrum corresponds to roughly 150 000 photons per second.

Spectral parameters are significantly distorted for pile-up fractions above 2 % (dashed line). As you can see from the plot, the XMS with its high energy resolution is mainly suitable for low up to intermediate count rates (with the BSDO). The WFI with its fast window mode can observe sources up to about 50 mCrab and the HTRS is suitable even for observations of very bright galactic sources.

X-ray Microcalorimeter Spectrometer (XMS)



The XMS consists of an array of Transition Edge Sensor (TES) pixels. The energy of incident photons is determined with high accuracy by measuring the shape of the produced current pulse. Therefore a minimum time interval between subsequent photon impacts is required (6 ms for high resolution and 1.5 ms for intermediate resolution, the presented simulations consider only high resolution events). The Bright Source Defocussing Optics (BSDO) proposed by Willingale (2009) distribute a fraction of the incident photon beam among a torus with a bigger number of pixels (see left-hand image) in order to enable observations of up to moderately bright sources.

References & Acknowledgments

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