Astronomical Data Analysis Software and Systems VIII
ASP Conference Series, Vol. 172, 1999
D. M. Mehringer, R. L. Plante, and D. A. Roberts, eds.

Novel Use of a Simulator for the Calibrations of Scientific Instruments

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Abstract. The XMM Science Operations Team developed a detailed simulator to describe the performance of the scientific payload on-board European Space Agency's X-Ray Mission XMM. This simulator was written in modern programming languages (C++ and F90). Its application is not limited to simulations of instrumental data, but the simulator also plays a key role in calibrating the instruments, and as such it will become an integral part of the XMM analysis system.

1. Introduction

The European Space Agency's X-ray observatory mission XMM[1] (Lumb et al. 1996 and references therein) consists of three telescopes, each containing 58 highly polished mirror shells. About 50% of the light of two of these mirror modules is intercepted by two reflection grating arrays, which disperse the X-rays to a secondary focus. The dispersed rays are detected by a strip of nine CCDs per instrument. This comprises the Reflection Grating Spectrometer (RGS), which has a bandwidth from 0.3–2.4 keV (5–35 Å) and a resolving power ($\lambda/\Delta\lambda$) from 300 to 800.

Each of the three primary foci is equipped with a European Photon Imaging Camera (EPIC), with each containing assemblies of CCDs. The EPIC detectors provide imaging and medium spectroscopic information over a band from 0.1–12 keV (1–123 Å).

In order to complement X-ray observations, an Optical Monitor (OM) is included in the payload of XMM to monitor sources simultaneously in the visible/UV band from 70–600 nm.

All instruments are co-aligned, operate in parallel, and cover the same field of the sky. Photon counting of all instruments provides spectral and imaging information at the same time.

[1] http://astro.estec.esa.nl/XMM

2. Instrumental Calibration and the Role of Simulations

The scientific calibration of the instruments depends in a complex way on many variables, such as operating parameters of the instruments, and also on the characteristics of the celestial target and possible background. This large variety prohibits full calibration of all aspects of the instruments during the pre-launch phase. Therefore, detailed models of each instrument were developed in the form of simulation programs, which were subsequently calibrated with a selected set of critical test cases. Simulations are then carried out to generate further data such that the remainder of the calibration parameter space is filled and the transfer of the ground calibrations to in-orbit conditions can be performed. A major effort was spent in building the XMM simulator SciSim[2].

SciSim will also be used to establish the dependencies of the calibrations on the exact circumstances of each observation (e.g., precise position of the source in the field of view, background, stray-light, etc.). With the help of SciSim, calibration data can be generated every observation for each specific set of modified parameters, and the optimum calibration accuracy can be obtained.

3. Summary of Additional Applications of the XMM Simulator

Due to the detailed instrument specific properties included in SciSim, it is is also used for the generation of test data to aid the development of instrument health and monitoring software, which is part of the XMM ground station.

During the development of the scientific analysis software (as discussed at this conference by F. Jansen), SciSim provides input not only in the form of test data, but also as an aid to investigate analysis strategies and to optimize the pipeline data production for the continuous build up of the XMM archive.

General observers are making use of SciSim during the preparations of observation proposals to optimize exposure times and instrument configuration details. Simulations will be performed during data analysis for the definition of data selection and filtering strategies, allowing for feed-back on observed features. Instrumental and calibration effects will be separable from true source characteristics enabling ultimate verification of observed data.

In summary, SciSim represents a novel use of a simulator, because of its key position to conduct X-ray observations with XMM and to analyze data from XMM. It represents an integral part of XMM data.

4. Software Implementation

The simulations of the instruments of XMM are implemented in the form of several free standing modules, each module simulating only one part of the instrumentation. Communication between modules is performed via rays of a uniform structure by using pipes. Each ray represents the probability of one incident photon. Therefore, the simulation process is very flexible and different groupings of the individual simulation modules are possible for the purpose

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[2] `http://astro.estec.esa.nl/XMM/scisim`

of addition of analysis and filtering tasks, or for efficiently bypassing unused instruments.

Modern programming languages such as FORTRAN 90 and C++ were used in a combined way. Great care was taken to only select libraries from the public domain so that distribution of SciSim is not subject to limitations due to software licensing issues.

Detailed documentation is also made available, which allows efficient use of SciSim. Furthermore, documentation of the source code is also publicly available and should be at a level that is adequate for future projects to re-use SciSim. Adaptation not only of configuration files, but also of code, can be performed in a controlled manner where necessary.

Because several separate processes are used for one simulation, the tasks can be split among several processors and executed in parallel. The performance of SciSim easily allows simulations of exposures faster than real time.

5. User Interface and Setup of Simulations

The user interface is provided by a set of GUIs which control the simulation. Separate widgets are started for access to the most commonly used parameters (additional flexibility is provided via ASCII configuration files). Figure 1 shows the main GUI which summarizes and controls the status of the simulation. The large window shows a celestial display. Source positions are indicated by small dots, and the field of views of the three basic instruments (EPIC, RGS, OM) are represented by colored lines. Positions of sources may either be provided by the user via a dedicated widget, where the spectral parameters are also accessible, or may be obtained from a catalogue. Several sources can be defined for the same simulation with different emission spectra.

To help the user with the identification of the necessary modules, a schematic layout of the data flow is provided (see Fig. 2). Through this interface, the control of each simulation component is achieved by separate widgets.

To support the user with the input for each field, two levels of help are available. When moving with the mouse to any field, tool-tips provide additional description. Secondly, a help button is available for all widgets. When pressed, this button displays the locally available HTML formatted on-line documentation using an internet browser.

References

Lumb, D. H., Eggel, H., Lainé, R., & Peacock, A. 1996, in SPIE Proc., Vol. 2808, EUV, X-Ray, and Gamma-Ray Instrumentation for Astronomy VII, ed. O. H. Siegmund & M. A. Gummin, (Bellingham: SPIE), 326

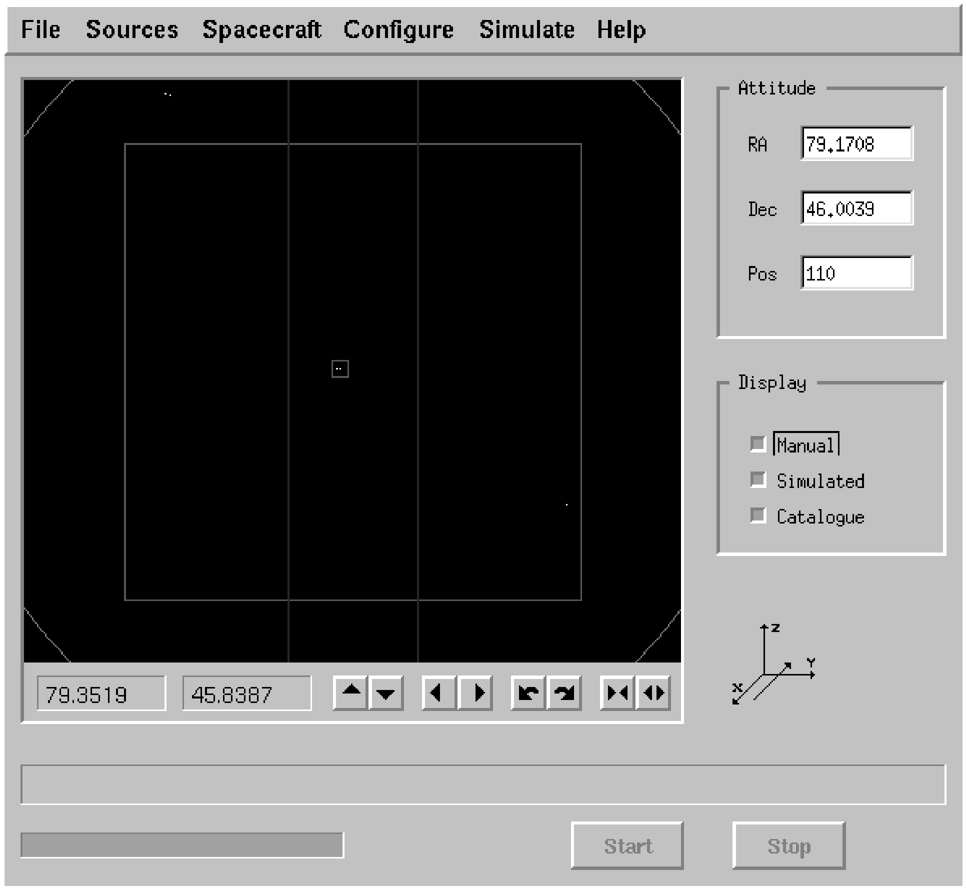

Figure 1. The main SciSim GUI.

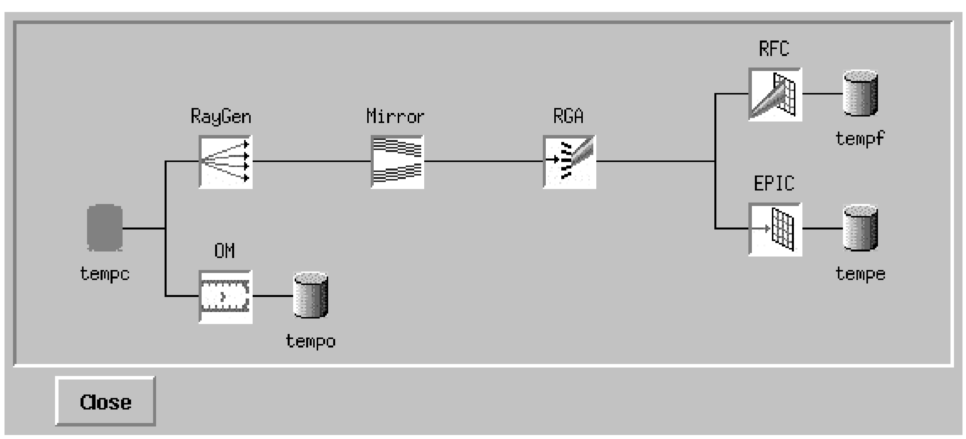

Figure 2. Schematic layout of the data flow that is also used for the control of instrument simulation parameters.