

# Athena End-to-End Simulations



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What will Athena's scientific data look like? What is the performance of the Wide Field Imager (WFI) and the X-ray Integral Field Unit (XIFU)? In order to be able to answer such questions, detailed mathematical models of the optics and the instruments of Athena are being developed, in which all of their relevant capabilities are taken into account. This model is the Athena end-to-end (e2e) simulation software, which is part of the SIXTE simulation package.

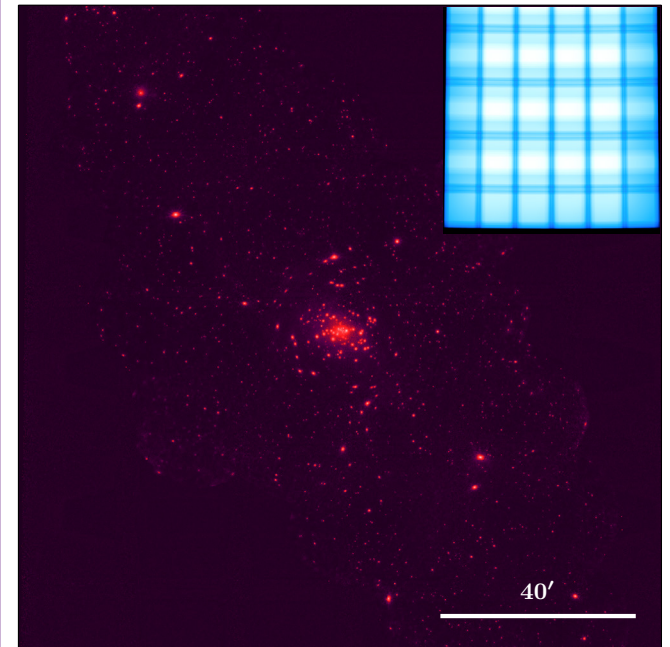
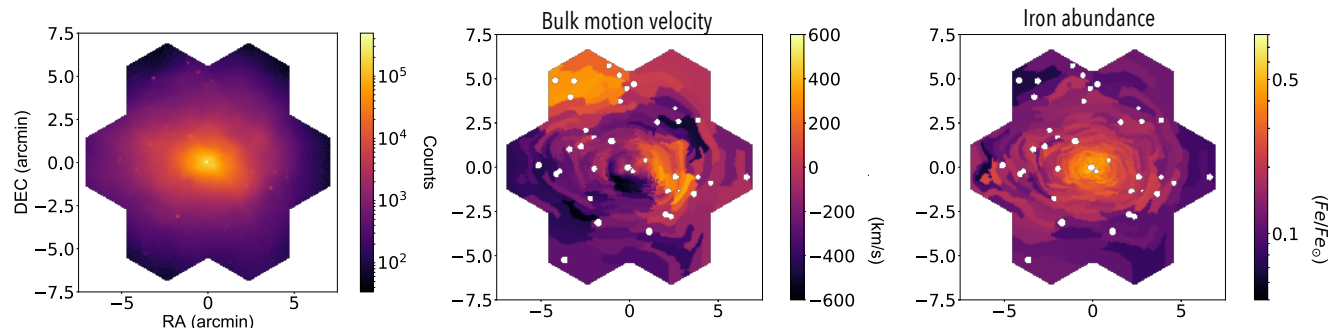
With SIXTE, scientists can model realistic observations of astrophysical sources. Objects can be described as point sources or extended sources, with any spectral shape, time variability, and even 3D distribution. Simulations can be performed for single sources or for deep fields containing thousands of individual objects, and both, staring observations as well as dithering or slew observations can be simulated.

The software accurately describes the major features of the optics and the instruments. For the WFI, the simulation includes a description of the charge cloud behavior in the sensors as well as the details of the electronic detector readout. For the X-IFU, simulations include modeling the physics of the transition edge sensor and its first stage readout, including the cross talk between individual pixels, and the characteristics of the on-board event energy reconstruction. In addition, a simplified, but faster, version of the X-IFU simulator is also available which still yields a faithful representation of X-IFU measurements for deep observations involving the full instrument.

The output of the simulations are event files in the FITS-format that can be processed with standard X-ray astronomical analysis software. In addition, the end-to-end team also provides data reduction pipelines for these data, as well as other tools needed for the analysis such as, e.g., the calculation of exposure maps.

The Athena e2e-software is still under active development, and will continue to be developed. We strive to always have the software in a state that represents the current design of the instruments. Our team offers documentation and example input for the simulations, and we also offer annual SIXTE simulation workshops for those who want to start using this tool.

Galaxy clusters allow astronomers to probe the early enrichment of the Universe. The figure shows a mosaic of 7 X-IFU pointings of 100ks each that are based on a numerically simulated massive ( $10^{14}$  solar masses), local ( $z \sim 0.1$ ) galaxy cluster. Left: 0.2-10 keV surface brightness map. Middle: bulk motion determined from line shifts. Right: Iron abundance profile. X-IFU simulations by E. Cucchetti, E. Pointecouteau, P. Peille, and N. Clerc; numerical cluster simulations by E. Rasia, V. Biffi, S. Borgani, and K. Dolag.



M31 simulation using a grid of 5x5 WFI pointing during which the satellite was dithering in order to remove the gap between the CCDs. The inset shows the resulting exposure map. This simulation by T. Dauser is based on existing XMM-Newton EPIC-pn pointings. Areas without sources were not covered by XMM.