Unveiling the faintest X-ray AGN populations in the NewATHENA Era: Insights from Cosmological Simulations

Background

Recent observations have improved our understanding of galaxy formation and evolution, yet significant challenges remain, especially in the high-energy X-ray regime critical for studying AGN. To address these limitations, next-generation observatories such as ESA's NewATHENA (see Figure 1) are being developed. As NewATHENA progresses through phase B (preliminary design), a comprehensive testing campaign is essential to ensure it meets its scientific objectives, especially given the incomplete understanding of the AGN population at high redshift.

In this context, Cosmological Simulations of Galaxy Formation play a crucial role in informing our understanding of high redshift AGN, in a complementary way to a purely observational approach, by providing a virtual laboratory to explore AGN characteristics and detectability.

The aim of this work is to support the NewATHENA mission with quantitative predictions regarding the performance of the Wide Filed Imager (WFI) survey.

Methodology

- The state-of-the-art Hydrodynamical Cosmological Simulation IllustrisTNG is employed to model the SMBH. 100 snapshots from the TNG300-1 box are converted to a 10 deg^2 light cone that covers the redshift range 0-12.
- Detailed post-processing assumptions, including a bolometric luminosity model, X-ray bolometric corrections, an obscuration model and realistic spectral templates, are applied to transform the SMBH light cone into an X-ray AGN mock catalogue.
- Subsequently, this catalogue is used as input for the SIXTE simulation software to conduct comprehensive end-to-end Monte Carlo simulations (see Figure 2), generating mock observations (see the central figure).
- A source detection pipeline, which incorporates wavelet filtering and detection with SExtractor, is utilized to extract the AGN.

Main Findings

- The mock catalogue predicts a greater number of high redshift AGN compared to current (pre-JWST) observational constraints (see Figure 3).
- A high redshift and luminosity dependent Compton Thick (CTK) fraction, as well as intrinsic X-ray weakness, are necessary to align the predictions of the mock with the Cosmic X-ray Background (CXB).
- NewATHENA will significantly improve the detection of high redshift AGN, compared to current X-ray surveys, providing the first statistically significant X-ray selected sample of AGN in the EoR (see Table 1.1).
- These results also suggest a higher number of CTK AGN detections than previously predicted, even beyond z>4.

Cosmological simulations reveal that **NewATHENA** will improve the detection of AGN in the **EoR**, shedding light on SMBH growth.

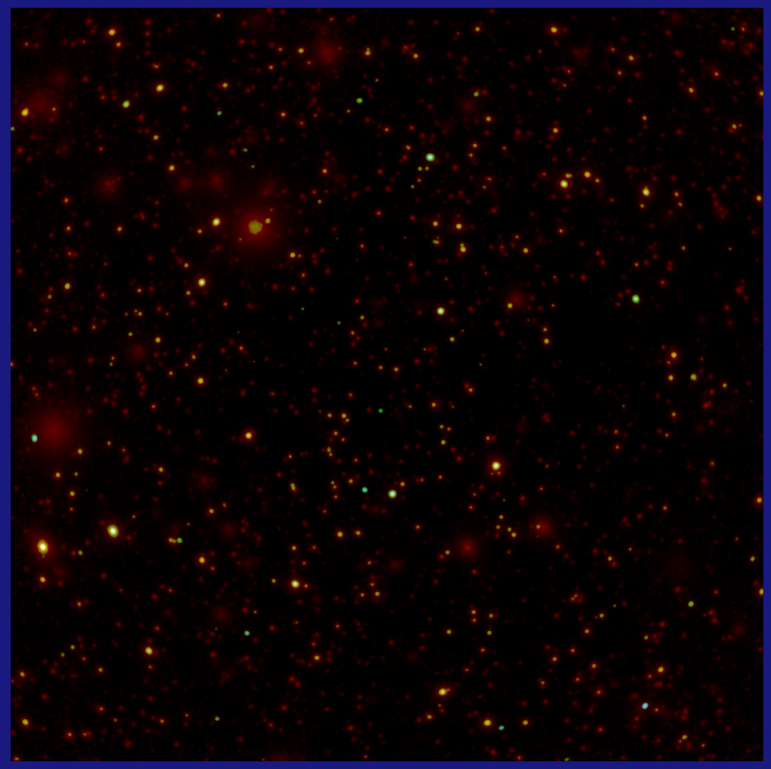

Table 1.1: Predictions for the Survey of the NewATHENA mission. These results are extrapolated from 9 pointings taken from a grid in the Mock Catalogue. The different columns show a breakdown of the number of detected AGN above a given redshift threshold, as well as the logarithm of the 0.5-2 keV Luminosity, assuming a flux of 5×10^{-17} $ergs^{-1}cm^{-2}$. The second row presents the results for all sources, while the third row only considers Compton Thick AGN.

	z>1		z>2		z>3		z>4		z>5		z>6		z>7	
	N_{src}	L_{lim}	N_{src}	L_{lim}	N_{src}	L_{lim}	N_{src}	L_{lim}	N_{src}	L_{lim}	N_{src}	L_{lim}	N_{src}	L_{lim}
All AGN	187755	41.4	86367	42.2	21089	42.6	3189	42.8	433	43.0	33	43.2	11	43.4
CTK AGN	7489	43.3	5367	43.7	1611	44.0	189	44.2	11	44.3	0	-	0	-

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Supplementary Images

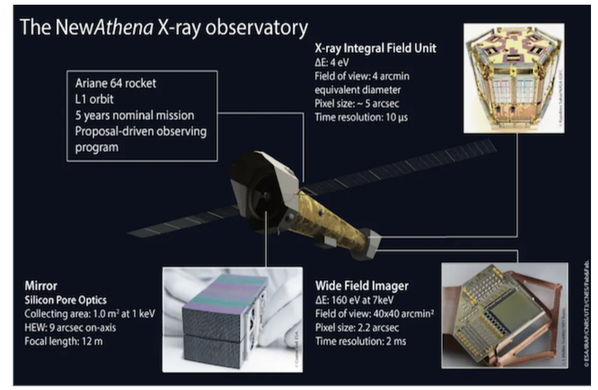

Figure 1: Illustration of the NewATHENA telescope.

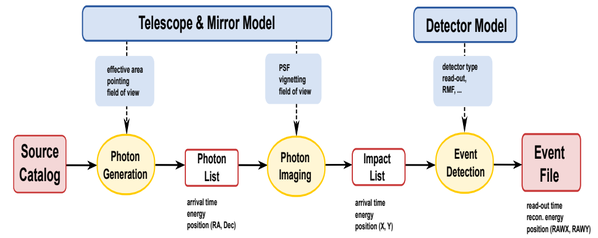

Figure 2: SIXTE flowchart illustrating the simulation process.

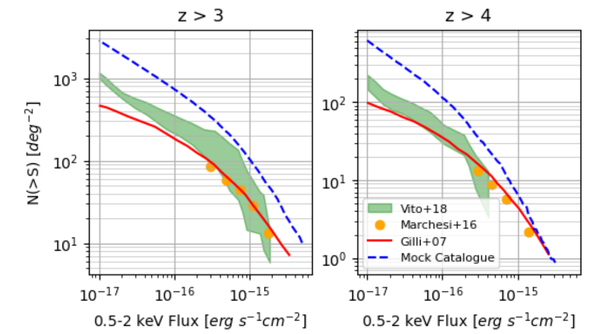

Figure 3: High redshift cumulative number counts of X-ray AGN, comparing the mock catalogue (blue line) with observations.

Links

- NewATHENA: `https://www.the-athena-x-ray-observatory.eu/en`
- IllustrisTNG: `https://www.tng-project.org/`
- SIXTE: `https://www.sternwarte.uni-erlangen.de/sixte/`