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End-to-End Simulation Frameworks and Machine Learning Techniques for Astronomical Spectrographs and X-ray Data Exploration

The growing complexity of astronomical instruments and the need for efficient, data-driven analysis require software frameworks that can fully exploit modern computing infrastructures. Within the context of the ICSC Spoke 2 - Fundamental Research & Space Economy, this work combines physics-based simulations and machine-learning techniques to support both instrument development and data-driven analysis.
A flexible End-to-End simulation framework has been developed to reproduce the full optical and detector response of spectrographs. The tool can be adapted to different optical layouts and has been used within the SOXS and CUBES instrument teams to generate synthetic data for performance analysis, calibration planning, and verification activities.
On top of these simulations, a deep-learning model (A3I) has been designed to assist optical alignment. By analysing simulated detector images, A3I identifies which optical elements are degrading the image quality and suggests the corresponding alignment adjustments, providing a fast and robust decision-support tool during integration and testing.
In parallel, Self-Organizing Maps have been applied to the Chandra Source Catalog to produce a two-dimensional, topology-preserving representation of X-ray sources. This mapping enables efficient visualization, clustering, and classification, and is accessible through a public web interface.

INFN OpenAccess Repository link

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