Comparison of Frequentist and Bayesian Approaches in X-ray Spectral Fitting

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Abstract

Spectral fitting of X-ray data is traditionally performed using the frequentist approach due to its computational efficiency. However, this method does not fully explore parameter degeneracies and may become trapped in local minima, making the fitted model dependent on initial parameters and minimization techniques. To draw more robust conclusions, a Bayesian approach can be applied, allowing for a broader exploration of the parameter space and providing posterior distributions to assess degeneracies among parameters.

The main goal of this project is to employ both frequentist and Bayesian approaches to fit X-ray spectral data and compare their results and computational times. Specifically, for the Bayesian approach, I will utilize Markov Chain Monte Carlo (MCMC) methods via XSPEC (Arnaud, 1996) and the Nested Sampling method using BXA (Buchner, 2021), evaluating their convergence.

I will fit spectral data of the active galactic nucleus (AGN) NGC 4051 from NICER (0.2–15 keV) and compare different models based on criteria such as reduced chi-squared, Bayesian Information Criterion (BIC), and Akaike Information Criterion (AIC). For simpler models, both frequentist and Bayesian methods are expected to yield similar results. However, for complex models such as RELXILL (Dauser *et al.*, 2016), the two methods may differ: the frequentist approach is prone to becoming trapped in local minima, while the Bayesian approach may be computationally intensive or may not converge.

In conclusion, this project aims to compare the results and challenges associated with frequentist and Bayesian approaches, evaluate their computational times, and discuss how posterior distributions can contribute to robust scientific conclusions.

References

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