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The impact of uncertainties in current NICER analyses: the case of PSR J0030+0451

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In the last few years, the NICER collaboration has provided mass and radius inferences, via pulse profile modeling, for two pulsars: PSR J0030+0451 and PSR J0740+6620. Given the importance of these results for constraining the equation of state of dense nuclear matter, it is crucial to validate them and test their robustness. We therefore explore the reliability of these results and their sensitivity to analysis settings and random processes, including noise, focusing on the specific case of PSR J0030+0451. In particular our simulations are inspired by the analysis of a revisited version of the NICER data set published in 2019.
We use X-PSI, one of the two main analysis pipelines currently employed by the NICER collaboration for mass and radius inferences.
With synthetic data that mimic the NICER PSR J0030+0451 data set, we evaluate the recovery performances of XP-SI under conditions never tested before, including complex modeling of the thermally emitting neutron star surface. For the test cases explored, our results suggest that X-PSI is capable of recovering the true mass and radius within reasonable credible intervals.
This work also reveals the main vulnerabilities of the analysis: a significant dependence on noise and the presence of multi-modal structure in the likelihood surface.
Noise particularly impacts our sensitivity to the analysis settings and widths of the posterior distributions.
The multi-modal structure in the likelihood suggests that biases could be present if the analysis is unable to exhaustively explore the parameter space.
Convergence testing is one possible solution to these challenges.

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