Error Analysis of Rotational Parameter Estimation in High-Energy Pulsars

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Over the past few decades, significant progress has been made in the estimation of rotational parameters for high-energy pulsars. However, existing approaches still lack standardized, rigorous mathematical frameworks for quantifying uncertainties in rotational parameters, particularly for high-energy periodic sources with Poisson-dominated noise. In this work, we revisit earlier methods and, for the first time, present three computationally efficient approaches based on the Zn2 statistic. Within a narrow-band search, these methods enable reliable estimation of rotational parameters along with their associated uncertainties and consistent confidence intervals. The framework is especially robust when the observation time extends over at least a few thousand seconds, given that typical pulsar periods range from a few milliseconds to a few seconds. Through extensive Monte Carlo simulations, we assess the reliability of these methods under a wide range of conditions, including variations in signal-to-noise ratio, photon counts, observation duration, time gaps, and initial parameter choices. Finally, we demonstrate their application to astrophysical data using AstroSat's LAXPC instrument for the Crab pulsar and the ultraluminous X-ray pulsar Swift J0243.6+6124.