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Accelerating Stochastic Gravitational Wave Backgrounds Parameter Estimation in Pulsar Timing Arrays with Flow Matching

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title:Accelerating Stochastic Gravitational Wave Backgrounds
Parameter Estimation in Pulsar Timing Arrays with Flow Matching

abstract:Pulsar timing arrays (PTAs) are essential tools for detecting the stochastic gravitational wave background (SGWB), but their analysis faces significant computational challenges. Traditional methods like Markov-chain Monte Carlo (MCMC) struggle with high-dimensional parameter spaces where noise parameters often dominate, while existing deep learning approaches have so far been validated on synthetic datasets or require training on the full pulsar set, incurring substantial computational and memory costs. We propose a flow-matching-based continuous normalizing flow (CNF) for efficient and accurate PTA parameter estimation. By focusing on the 10 most contributive
pulsars from the NANOGrav 15-year dataset, our method achieves posteriors consistent with MCMC, with a Jensen-Shannon divergence below 10−2 nat, while reducing sampling time from 50 hours to 4 minutes. Powered by a versatile embedding network and a reweighting loss function, our approach prioritizes the SGWB parameters and scales effectively for future datasets. It enables precise reconstruction of SGWB and opens new avenues for exploring vast observational data and
uncovering potential new physics, offering a transformative tool for advancing gravitational wave astronomy.

Collaboration you are representing

Author: LIANG, Bo (中国科学院力学研究所)

Presenter: LIANG, Bo (中国科学院力学研究所)

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