Statistical Analysis and Bayesian Estimation of Distributions of Millisecond Pulsar Parameters for Optimizing Pulsar Searches

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Pulsars are highly magnetized, rotating neutron stars that serve as the most precise clocks in the universe. Millisecond pulsars (MSPs), which have a spin period of less than 10 ms, are especially useful for high-precision timing for gravitational wave (GW) research. The search for sub-millisecond pulsars, a hypothesized class of pulsars with spin period of less than 1 ms, and MSPs would improve efforts to utilize pulsar timing arrays for GW detection. Studying the distributions of the physical parameters of the millisecond pulsar population in comparison to the entire pulsar population may provide key insights into optimizing searches for sub-millisecond pulsars. In this study, frequentist and Bayesian methods are utilized to fit models to the distributions of physical parameters for the entire population of MSPs and compared to the distributions of physical parameters for the entire pulsar population. An ExtraTreesClassifier was applied to data from the ATNF Pulsar Catalogue to determine which parameters would be most closely related to pulsar frequency. The Weibull mixture model was found to be the best-fit distribution for all the parameters that were fitted. A Monte Carlo Markov Chain and Nested Sampling algorithm were also applied to analyze spin down age and pulsar frequency. These methods were selected to account for the possibility that pulsar parameters do not follow a standard distribution and to adjust for selection effects in pulsar searches. The findings in how these parameter distributions vary as pulsar frequency increases may assist in optimizing searches for sub-millisecond pulsars and accelerating the search for pulsars for GW detection.

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