Self-similarity of Pulsar Timing Residuals: A robust pipeline to detect Stochastic Gravitational Wave

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Complexity is ubiquitous behavior in the nature. In cosmology and astronomy, due to initial conditions and internal degree of freedom of underlying processes mainly and mostly because of other relevant phenomena such as foreground effects, stochasticity can be clarified. Mentioned property is widely experienced in cosmological and astrophysical fields in 1,2 and 3 dimensions. Among various astrophysical processes, Millisecond pulsars is highly stable and the predictability of their rotational behavior leading to be an almost proper tool to elucidate various physical phenomena ranging from early universe to late time.

In this talk, inspired by self-similarity of a typical stochastic field, we propose a robust pipeline in order to examine the footprint of stochastic gravitational waves superimposed on the pulsar timing residuals (PTRs). We introduce a new algorithm, the so-called Irregular-Multi-Fractal-Detrended-Cross Correlation-Analysis (Irregular MF-DXA), to deal with irregular data sampling. According to the quadrupolar nature of the spatial cross-correlation function of a gravitational wave background, a new cross-correlation function, derived from Irregular-MF-DXA will be introduced. We propose four strategies based on results derived by MF-DXA to determine the dimensionless amplitude and power-law exponent of the characteristic strain spectrum for stochastic GWB. Using the value of Hurst exponent, one can clarify the type of GWs. The flexibility in the algorithm enables us to manipulate the contribution of noises and trends in PTRs. We apply our pipeline to explore 20 millisecond pulsars observed by Parkes Pulsar Timing Array (PPTA) project. Some upper bounds on the dimensionless amplitude of GWs background, will be reported. Finally, utilizing supervised Machine Learning method, we show that which features are more sensitive to search the footprint of GWB in PTRs.