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Nonlinear nature of black hole IGR J17091−3624

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Extracting nonlinear nature of astrophysical systems, particularly from observed data, has long been considering for various kinds of sources. Accretion disks around compact objects are one of them. Our group has been working on it for more than two decades: for GRS 1915+105, Sco X-1, Cyg X-1,2,3, IGR J17091−3624, etc. Sources exhibit sometimes chaotic/deterministic and sometimes stochastic nature. Interestingly, GRS 1915+105, depending on its temporal class, exhibits both. IGR J17091−3624, on the other hand, has been argued to be twin of GRS 1915+105 due to their similar "heartbeat" pattern in lightcurves and high-frequency QPOs, for quite sometime. However, the former is a very faint noise-dominated source, exhibited stochastic nature in timeseries by earlier studies, which further challenged its twin status of GRS 1915+105. We employ several denoising techniques to mitigate noise effects and employ methods like Autoencoder, Principal Component Analysis (PCA), Singular Value Decomposition (SVD), and Correlation Integral (CI) to isolate the deterministic signatures. We find signs of determinism in IGR J17091−3624 after denoising, thus supporting the hypothesis of it being similar to GRS 1915+105, even as a dynamical system. Our findings not only shed light on the complex nature of IGR J17091-3624, but also pave the way for future research employing noise-reduction techniques to analyze non-linearity in observed dynamical systems.

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