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Temporal analysis of light-curves from transient sources

The future of multimessenger astrophysics heavily relies on the number of joint detections of gamma-ray bursts (GRBs) and gravitational waves (GWs) achievable during observing runs conducted by LIGO, Virgo, and KAGRA. Accurate event localization through triangulation methods is increasingly pivotal for this purpose. The innovative HERMES mission is based on the distributed architecture mission concept: a CubeSats constellation enables continuous observation of the entire sky while concurrently providing the position of detected signals. The accuracy of source coordinates is strongly influenced by the type of temporal analysis employed. In particular, techniques based on cross-correlation functions (CCFs) are indispensable for estimating the delays between detectors positioned in different spatial locations. Due to the quantum measurement process of a detector, the single delay evaluated between the light curves of two detectors is a particular Poissonian realization of the true delay. The described techniques allow minimizing the "quantum noise" present in the list of Time of Arrivals (ToAs) observed by the detectors and estimating a "statistical delay" with an associated error. This is the experimental delay closest to the sought theoretical delay. The developed techniques also allow probing quantum gravity theories. Lorentz Invariance Violation can be investigated by verifying delays between high-energy light curves in different energy bands for observed GRBs at different redshifts. Estimates of delays between light curves observed in a selected emission line and those in the continuum emission allow probing both the spatial extent and the internal architecture of the broad-line region (BLR) in active galactic nuclei (AGN). The provided examples justify the broad applicability of the developed techniques in the domain of temporal analysis in the astrophysical realm.

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