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Cause-mic Universe : Causal Approaches probing Solar and Astrophysical Variability

Astrophysical sources vary across vast timescales, providing insight into extreme dynamical phenomena, from solar outbursts to distant AGNs and GRBs. These time-varying processes are often complex, nonlinear, and non-Gaussian, making it difficult to disentangle underlying causal mechanisms, which may act simultaneously or sequentially. Using solar variability and AGNs as examples, we demonstrate how causal inference and graphical models, supported by synthetic time-series data, help unravel these processes. In solar variability, understanding solar wind and flares is crucial not only for physics but also for space weather forecasting, where supervised and unsupervised machine learning methods have made significant progress. Causal diagnostics enhance interpretability and feature selection. In extragalactic sources like AGNs and GRBs, causal measures enable insights into variability mechanisms and fundamental physics, such as Lorentz Invariance, through precise lag estimates.

AI keywords

causal inference, graphical models, time-series, interpretable forecasting, simulations

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