KITE: Kilonova Intelligent Targeting Engine for Time-Resolved Multi-Messenger Forecasting of Neutron Star Merger Transients

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Binary neutron star (BNS) mergers emit gravitational waves and eject neutron-rich matter, powering a short-lived infrared transient known as a kilonova. Immediately after the merger, the hypermassive remnant of the now-merged stellar bodies undergoes quasi-periodic oscillations (QPOs) that define neutron star structure, timescale for collapse to a black hole, and the behavior of supranuclear-density matter (the neutron star equation of state). Gravitational wave detectors remain unable to resolve these frequencies. As such, the Kilonova Intelligent Targeting Engine (KITE) has been developed to predict, prioritize, observe, and analyze kilonova events in near-real time. KITE first infers QPO frequencies from kilonova spectra, integrates with multi-messenger data and first-principles ejecta physics, then uses machine learning. Through Sobolev approximation (local-line radiative transfer for expanding ejecta), synthetic spectra were generated and validated against AT2017gfo, the only available BNS-merger spectra. With a best-fit frequency of 2.16 ± 0.15 kHz (>30s) yielded from ?² minimization over six epochs, KITE provides the first indirect measurement of a QPO in the post-merger remnant. Inferred remnant properties favor moderately stiff equations of state, and are independently congruent with measurements from NASA's NICER mission and GW170817 observations. KITE successfully demonstrates the value of QPO-informed kilonovae tracing for faster and better-parameterized multi-messenger discovery, achieving 99.5% identification accuracy by a physics-informed Random Forest classifier and reducing detection time by 85.6% in 10,000 simulated events. KITE also provides optimized discovery strategies for missions including UVEX, Roman, and future gravitational-wave observatories.

Awards Won:
Third Award of $1,200