High-Cadence Adaptive Reverberation Mapping of Variable Quasars to Resolve Light-Hour Accretion Disk Structures in Supermassive Black Holes

Wang, Thomas Jichen (School: Shady Side Academy)

Supermassive black hole accretion disks, predicted to emit optical continuum from regions spanning light-hours, remain challenging to resolve via traditional reverberation mapping (RM) techniques limited by: 1) Long, daily to monthly observational cadence and 2) Oversmoothing in damped random walk (DRW) time-series models. I present a 6-month, high-cadence (3–5 hr/night), cost-effective photometric RM campaign using the 24-inch Keeler Telescope at the Allegheny Observatory, monitoring quasar PG0804+761 in g' and r' bands. Preprocessing incorporated differential photometry and 10-min binned spline interpolation, yielding <0.01 mag precision. By developing an adaptive Bayesian time-series RM model, I achieved hourly-scale lag sensitivity through a truncated DRW kernel, a mixture density network, and GPU-accelerated Markov chain Monte Carlo sampling. On 15,000 simulated optical light curves with known, short time lags, the model correctly predicted 92.17% of lags within 0.2 days, and outperformed the state-of-the-art RM model by 35.89% while computing 13.27x faster. For PG0804+761, cross-correlation analysis revealed inter-band time lags of 0.61 ± 0.24 days, corresponding to disk radii scaling within the thin disk theory. On 20 publicly available daily-cadence quasar light curves, the model yielded lags of 0.18-2.10 days, consistent with literature with improved uncertainty. My results, the first to resolve light-hour accretion disk radii, favor models with vertical reprocessing regions or inhomogeneous disk temperatures. This work rivals large-scale, space-based accretion disk research with a sub-meter telescope, and enables robust hour-scale RM critical for next-generation active galactic nuclei research across cosmic time.

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