Optimizing UV Observing Strategies for Detecting Quasi-Periodic Eruptions in Active Galactic Nuclei

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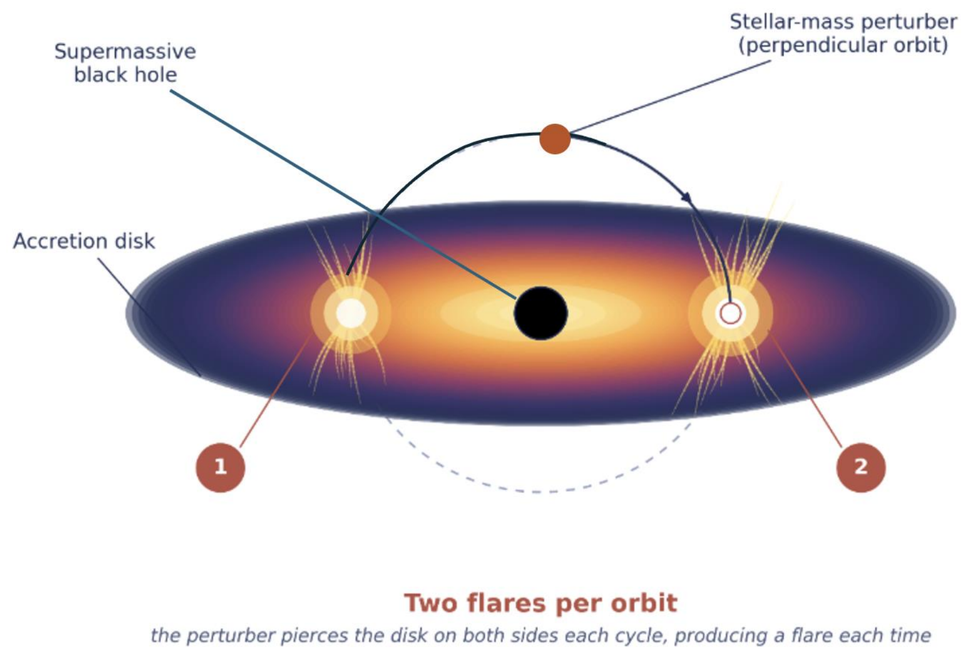
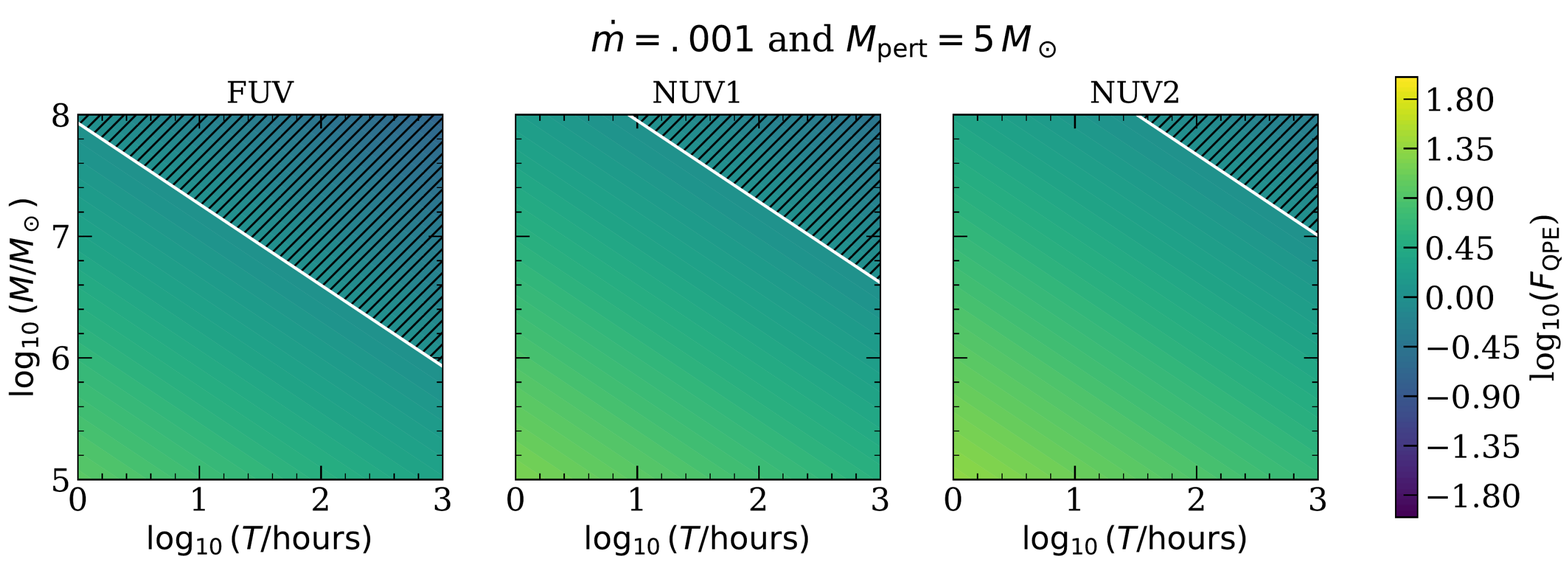
Quasi-periodic eruptions (QPEs) are repeating soft X-ray flares, likely with UV/optical counterparts, seen in low-mass galactic nuclei hosting supermassive black holes. Their origin remains uncertain, but leading models suggest a stellar-mass object interacting with the inner accretion disk through repeated crossings or EMRI-like behavior. Since active galactic nuclei are already intrinsically variable, these signals can be difficult to distinguish from normal stochastic disk variability, especially in the UV where thermal reprocessing dominates. We explore whether QPE-like signatures could still be detected in low-mass, low-Eddington AGN, bridging known QPE hosts and the broader AGN population.

Perturber–Disk Model

- Low-Eddington Shakura–Sunyaev thin disk
- Stellar-mass perturber on a perpendicular orbit
- Hill radius sets the size of the disrupted disk region
- Two disk crossings corresponds to two flares per orbit
- Flare strength depends on SMBH mass, orbital period, and wavelength



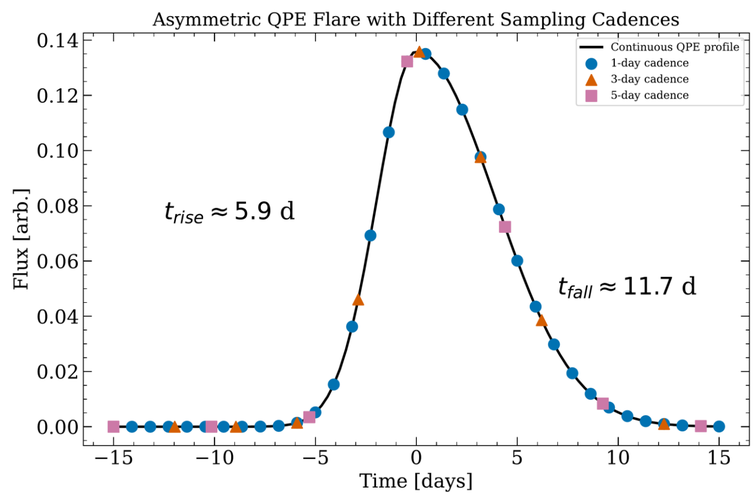
Detectability Across Parameter Space



- Compare flare strength to steady disk emission across UV bands
- White contour shows the detectability threshold $f_{QPE} = 1$, where flare emission matches the steady disk background
- QPE signals are easiest to recover when flare emission exceeds the disk background
- Detectability is strongest for low-mass SMBHs and Shorter period QPEs

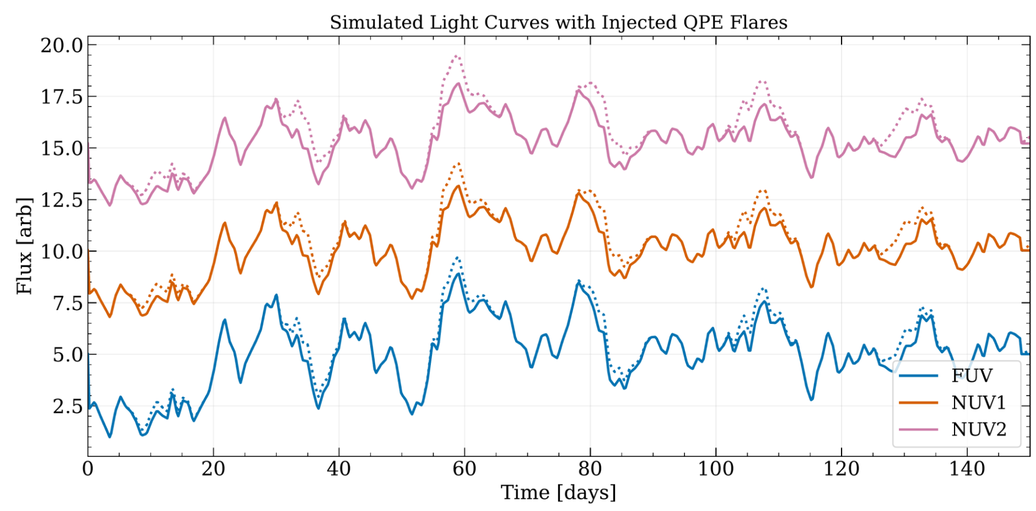
$$f_{\rm QPE} = \frac{L_{\rm flare}}{L_{\rm disk}}$$

QPE Flare Model



- Observed QPEs show a rapid rise followed by a slower decay
- Each flare is modeled as an asymmetric Gaussian pulse
- Peak amplitude is set by the predicted luminosity f_{QPE}
- Flare width is determined by the perturbation timescale t_{QPE}
- t_{QPE} depends on SMBH mass, accretion rate, disk properties, and perturber size
- Lower cadence reduces flare recoverability
- Sparse observations can distort the flare profile or miss the peak entirely

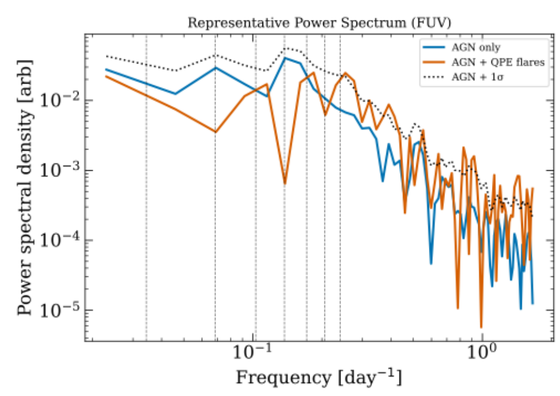
Simulating Light Curves in Variable AGN



- Generate synthetic AGN light curves using the *Amoeba* thin-disk reprocessing framework
- Model intrinsic AGN variability as a damped random walk
- Inject QPE flares predicted by the perturber–disk model
- Test whether periodic QPE signals can be recovered above stochastic AGN noise

Power Spectra

- Compute PSDs using Welch's method
- Compare AGN vs. AGN + QPE variability
- Detectable QPEs appear as distinct periodic peaks
- Signal must stand out above stochastic disk noise



Conclusions

- QPE-like signals are most detectable in low-mass, low-accretion AGN, where flare emission can compete with the steady disk background
- Cadence is critical: sparse sampling can wash out flare structure and weaken periodic signatures in the PSD
- UV observations provide a strong avenue for recovering short-timescale QPE variability
- These results extend QPE searches beyond quiet post-TDE systems to a broader AGN parameter space

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