RAPID ACCRETION DISC STATE TRANSITIONS in Repeating Partial Tidal Disruption Events

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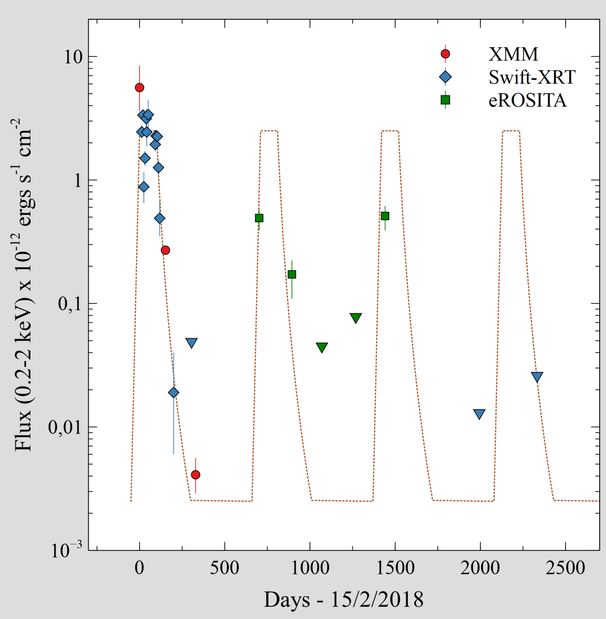
Abstract: The dynamic environment which exists in black hole accretion discs has traditionally been probed in stellar-mass Galactic black holes where the timescale for changes is short. In principle, if the quantity of material in a disc around a super-massive black hole is small and is not replenished, then the disc will drain on a timescale of a few hundred days and the system can pass through several states during a short monitoring campaign. Partial tidal disruption events, where the atmosphere of a star is stripped and consumed by a nuclear black hole, gives us the perfect opportunity to test whether disc states and state changes are mass-invariant? We present some recent results.

Tidal Disruption Events (TDEs) can show fast transitions (months to years) between accretion disc states. Partial TDEs (pTDE), where a limited amount of material is stripped from an orbiting stellar companion, can be even faster (days to months).

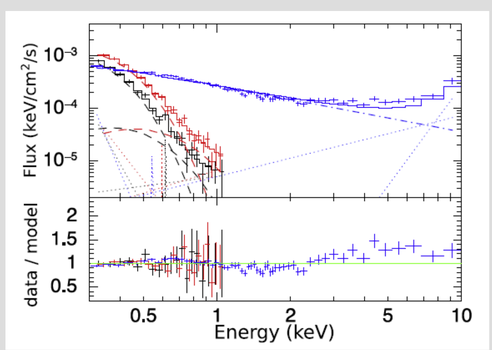
A handful of pTDEs have been well monitored, with Swift playing an important role: AT2018fyk (Wevers+21), AT2021ehb (Yao+22), eRASStJ0456 (Liu+23), HLX-1 (Lin+19) all show repeating flares and a hardening and softening of the X-ray spectrum.

Spectral transitions in pTDEs



XMMSL2 J1404-2511 long-term light curve. Evidence is seen for three peaks. Another flare may be coming in late 2025 – early 2026. (Saxton+ submitted)

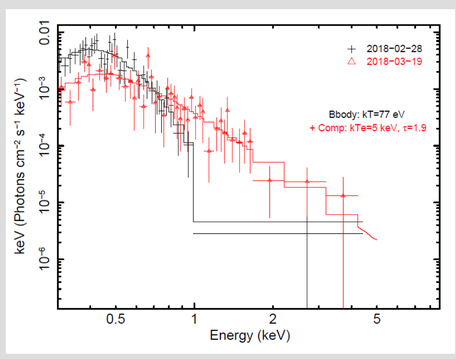
AT2020ocn

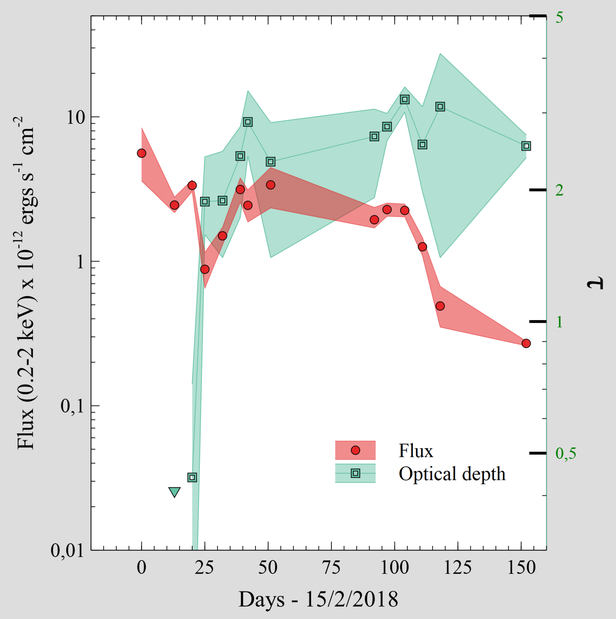


Cao+24: black+red are early observations, blue is from 10 months later

Swift-XRT spectra of XMMSL2 J1404-2511 from 2018-02-28 fitted with a black-body (black) and 2018-03-19 fitted with a COMPBB model (red).

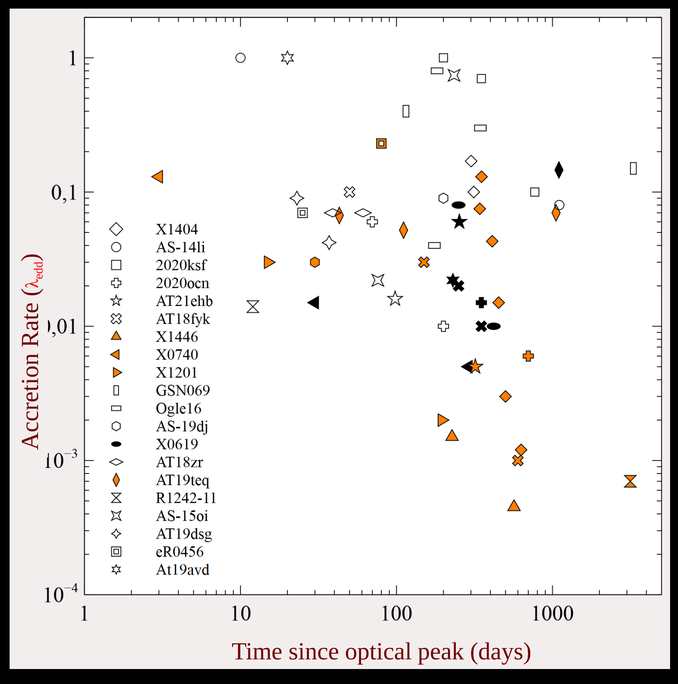
XMMSL2 J1404-25





Optical depth and 0.2–2 keV flux for the first 152 days of observations of XMMSL2 J1404-2511 using a spectral model of COMPBB with kTe = 5keV. A hard component developed in ~7 days.

Disc states v accretion rate

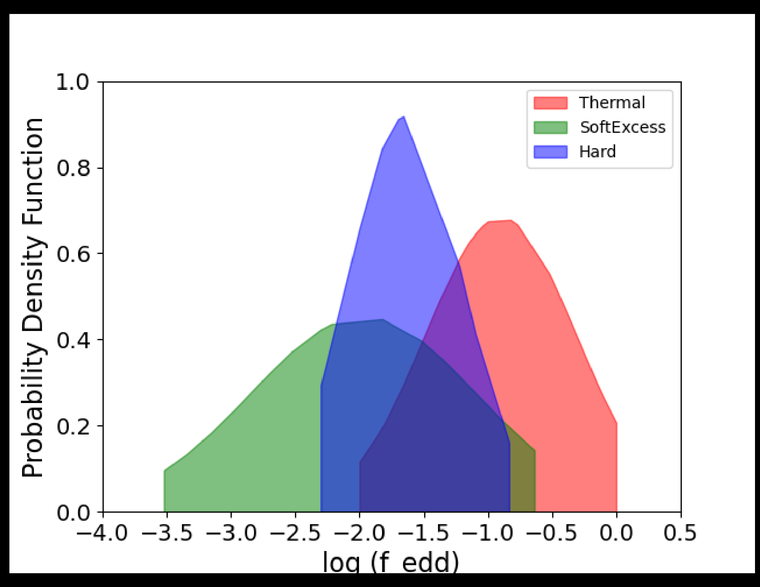


Accretion rate against time since the optical peak for TDEs taken from the literature. Open symbols indicate an X-ray spectrum in the thermal state, orange symbols where it is dominated by a "soft-excess" (Γ>2.5) and filled black symbols where an "AGN-like“ power-law is present (Γ < 2.5).

Thermal state (open syms)
$\mathrm{Log}(\lambda_{edd}) = -0.9+/-0.6$

Hard power-law (black syms)
$\mathrm{Log}(\lambda_{edd}) = -1.6+/-0.4$

Soft excess (orange syms)
$\mathrm{Log}(\lambda_{edd}) = -2.0 +/- 0.9$



In Broad Terms

$$\begin{cases} \dot{m} \gtrsim 0.1 = \text{thermal state} \\ 0.1 \lesssim \dot{m} \lesssim 0.01 = \text{any state} \\ \dot{m} \lesssim 0.01 = \text{soft excess state} \end{cases}$$

Key Result:

* **TDE accretion disc state depends on λ_{edd} but not exclusively.**
* **Transitions between states can occur within a few days**

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