Tidal disruption events in the presence of pre-existing accretion disks

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Basic Theory of TDEs

- Stars that orbit too close to a supermassive blackhole (SMBH) can get torn apart by the tidal forces of the SMBH. The distance at which the disruption occurs is called the tidal radius (r_t).

- Within the tidal radius, the tidal force from the SMBH exceeds the self-gravity of the star,

$$r_t = R_* \left(\frac{M_{bh}}{M_*} \right)^{\frac{1}{3}}$$

Adapted from
Guillochon et al. (2014)

Unbound

Bound

orbit of pre-disrupted star

pre-existing accretion
disk

8
7
6
5
4
3
2
1

Idea and Motivation

- Many observed TDE candidates originating from galactic centers.

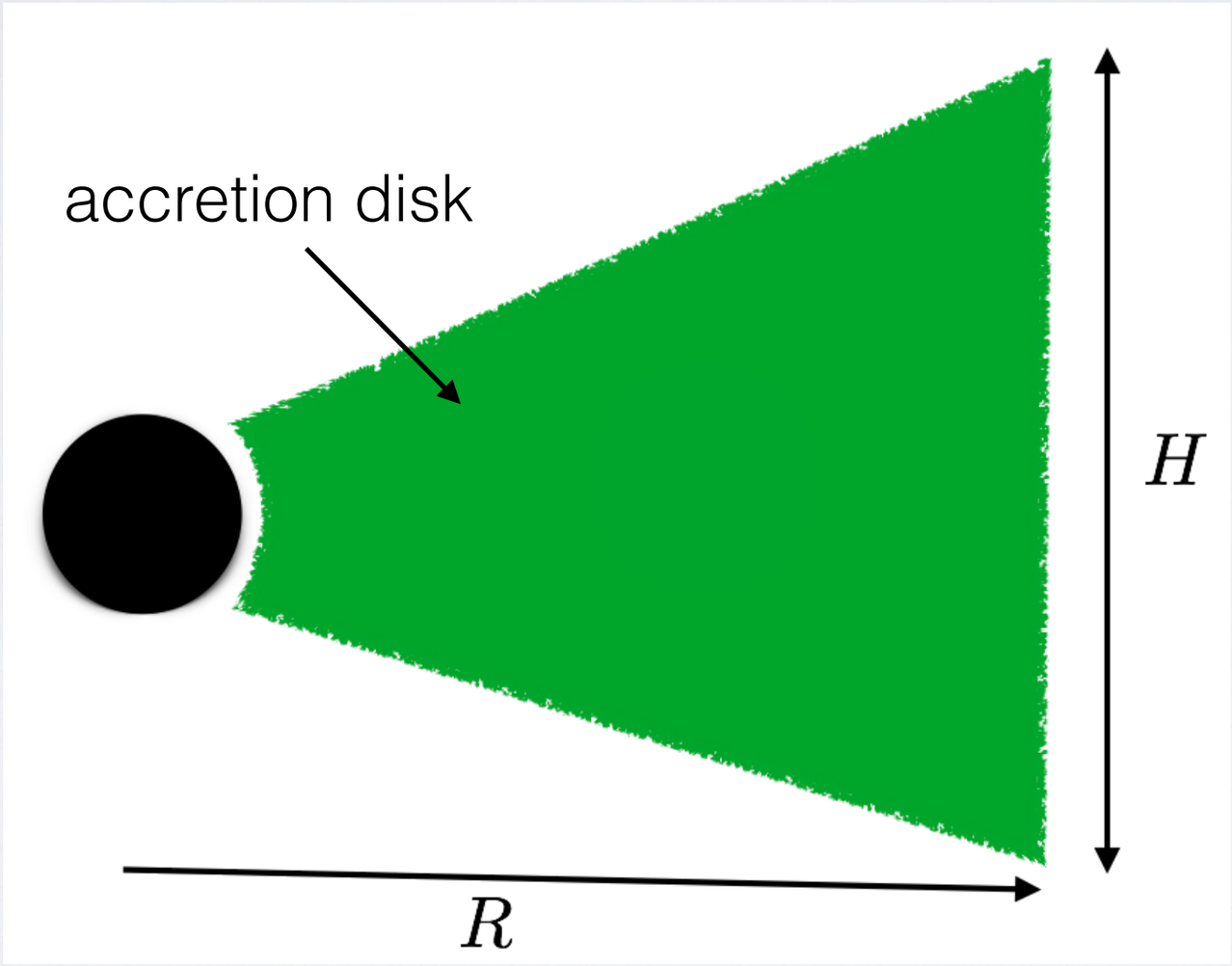
- Some of these host galaxies show properties of a weak AGN (e.g. ASASSN-14li, SJ1644, SJ2058).

- This supports the presence of a pre-existing accretion disk.

- We want to investigate if this disk can have any observable effects on a TDE. If so, can we use these observations to infer any properties of the disk?

Modeling the accretion disk and debris stream

- We assume a thick disk ($H \sim R/2$) and take the density $\rho \propto R^{-\lambda}$ with $\lambda = 0.5 - 1.5$ (e.g., Narayan & Yi 1994; Quateart & Gruzinov 2000).



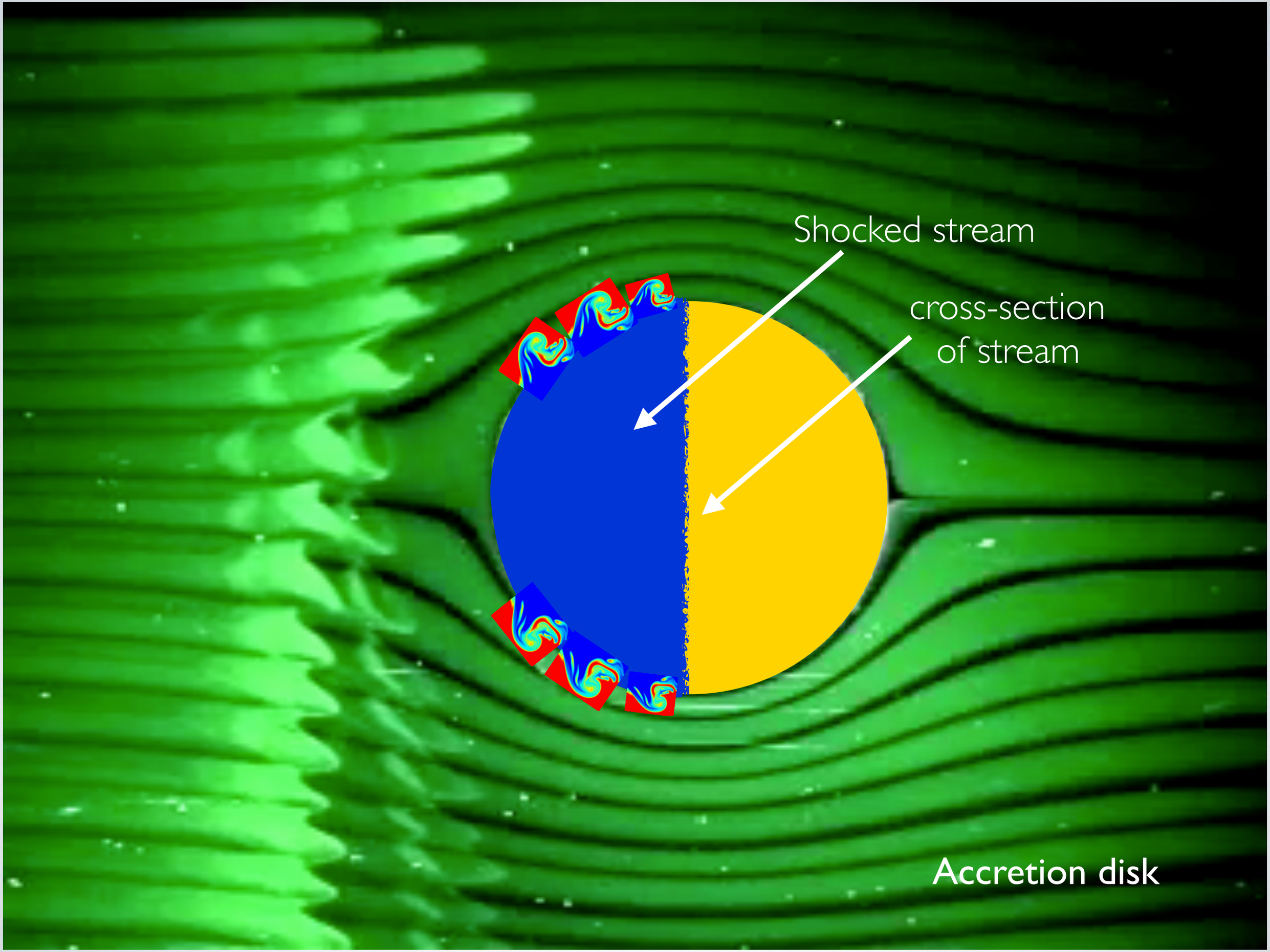
- For the bound stream, we follow the evolution given in Kochanek (1994) & Guillochon et al. (2016).

Interactions between disk and bound stream

- We assume the stream is within the plane of the disk.
- We consider interactions from three different mechanisms.

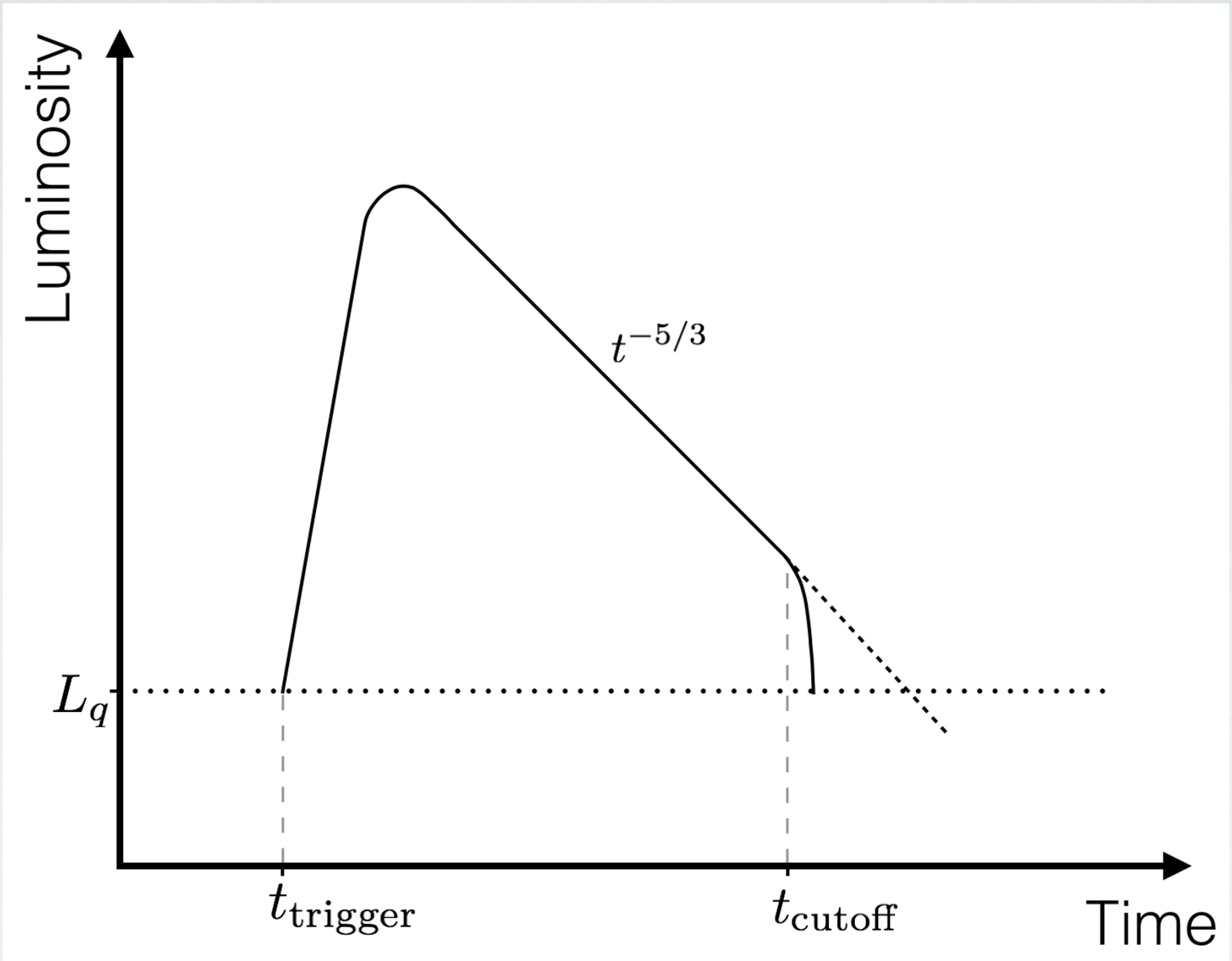
1. shocks from impact of disk on to stream
2. Kelvin-Helmholtz instabilities at disk-stream interface

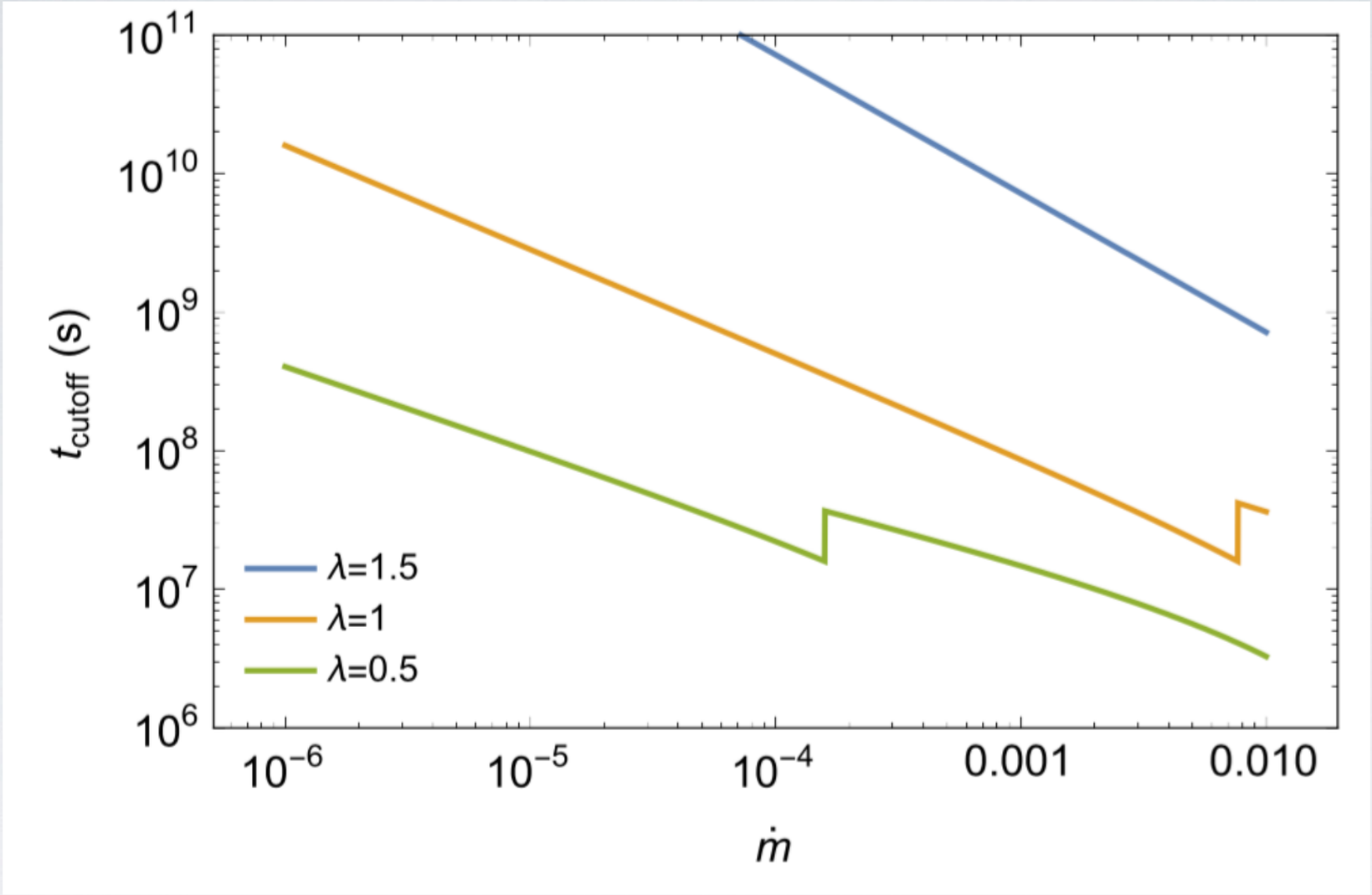
   (Bonnerot et al. 2016)
3. Due to impulse from the disk


Shocked stream
cross-section
of stream
Accretion disk

The cut-off time

- The duration of accretion of the bound stream on to the SMBH will be denoted as t_{cutoff}.
- We expect the duration of any flare associated with a TDE to be of the order of t_{cutoff}.


Luminosity
$t^{-5/3}$
L_q
t_{trigger}
t_{cutoff}
Time



$$\rho \propto R^{-\lambda}$$

Kathirgamaraju, Barniol Duran & Giannios (2017)

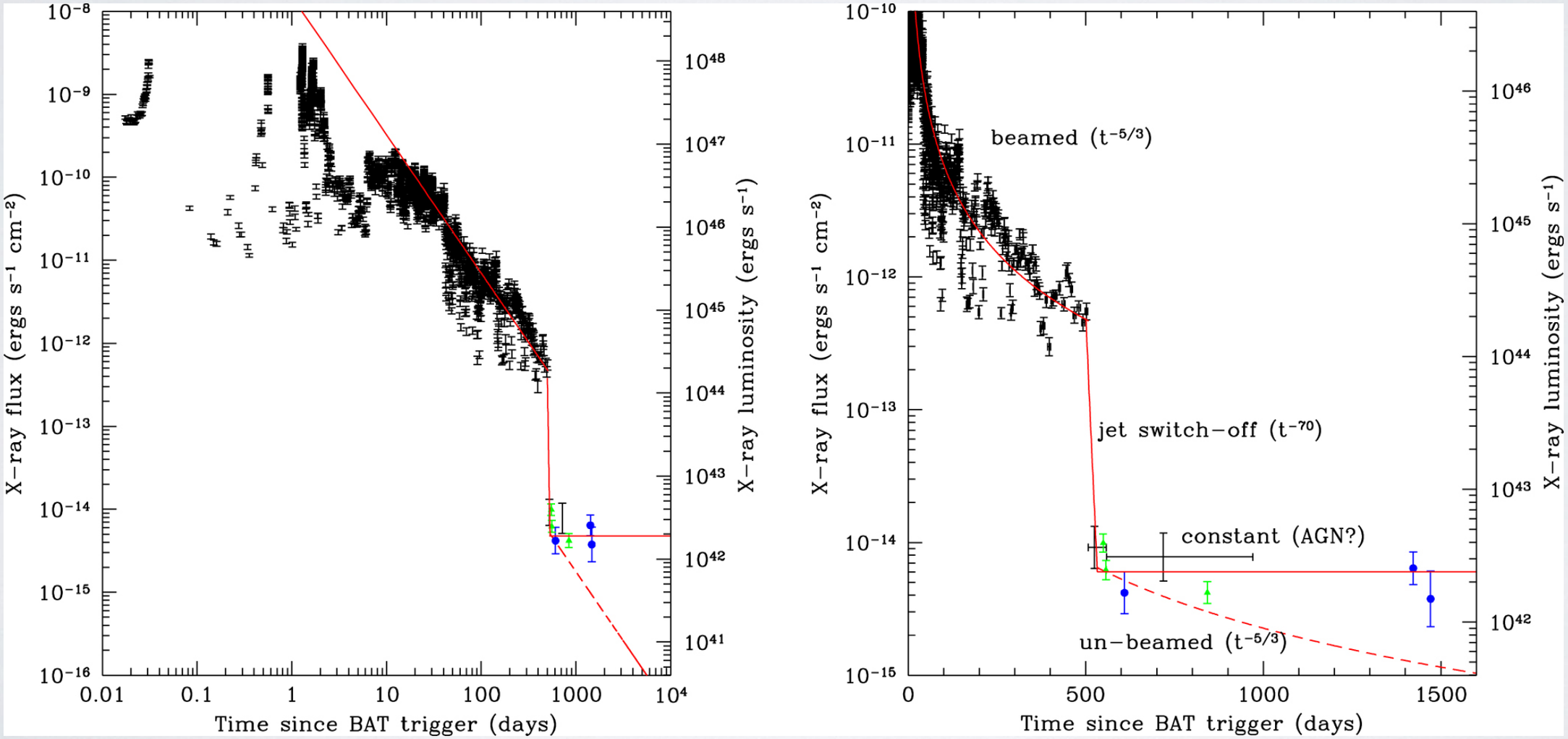
Cut-off time vs quiescent accretion rate (normalized to Eddington) for multiple density profiles (λ).

- The cut-off time is quite sensitive to the density profile, so we can use t_{cutoff} to constrain λ .

Application to TDE candidates

- Using the observed quiescent luminosity and t_{cutoff}, we can place some constraints on λ.

1. SJ 1644 e.g., Bloom et al. (2011), Burrows et al. (2011)



Levan et al. (2016)

1. SJ 1644

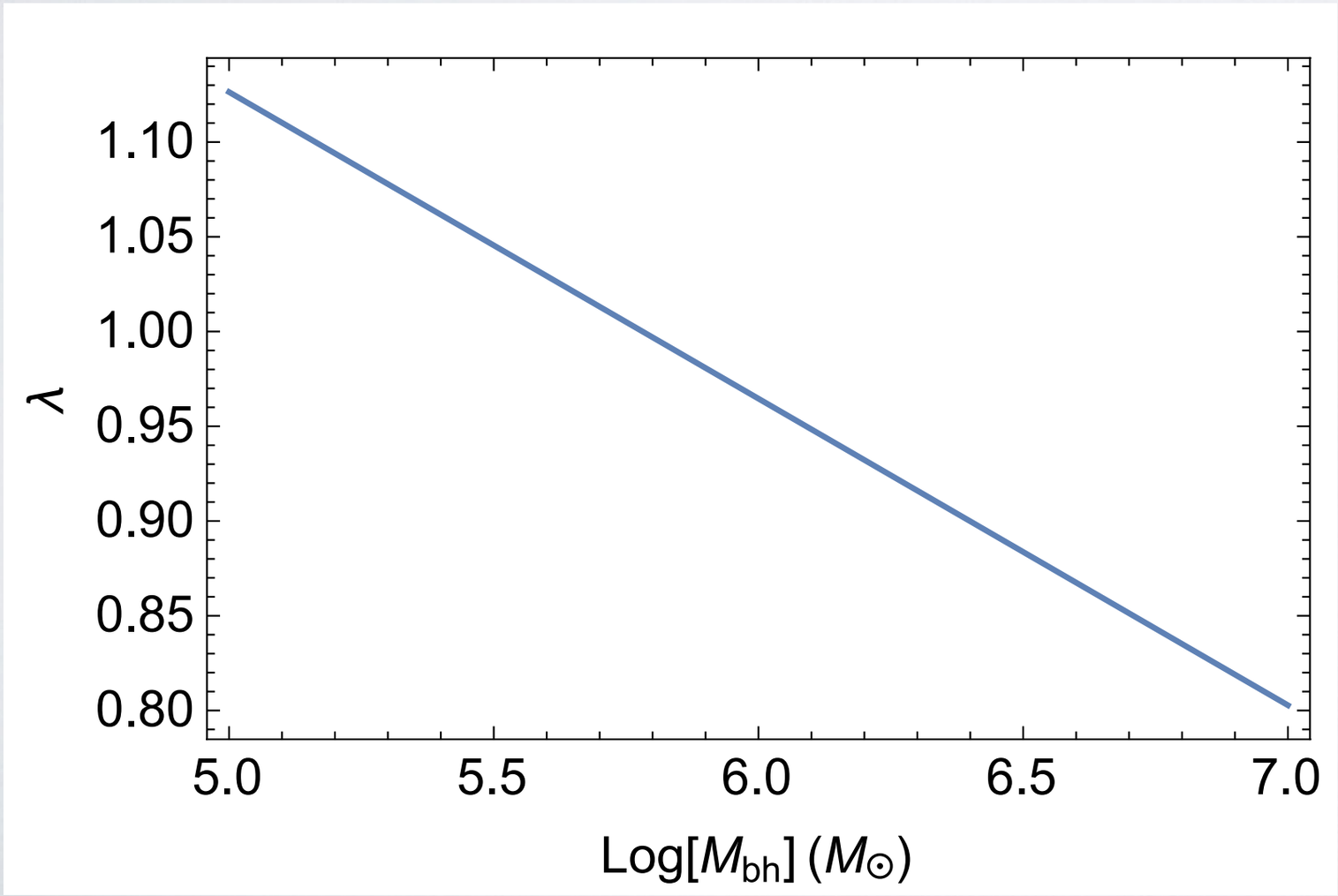
Quantities inferred from observations:

Levan et al. (2016), Tchekhovskoy et al. (2014)

$t_{cutoff} \sim 3 \times 10^7$ s

$L_q \sim 10^{42}$ erg/s

$M_{BH} \sim 10^5$ - $10^7 M_\odot$



$$\Longrightarrow 0.8 \lesssim \lambda \lesssim 1.1$$

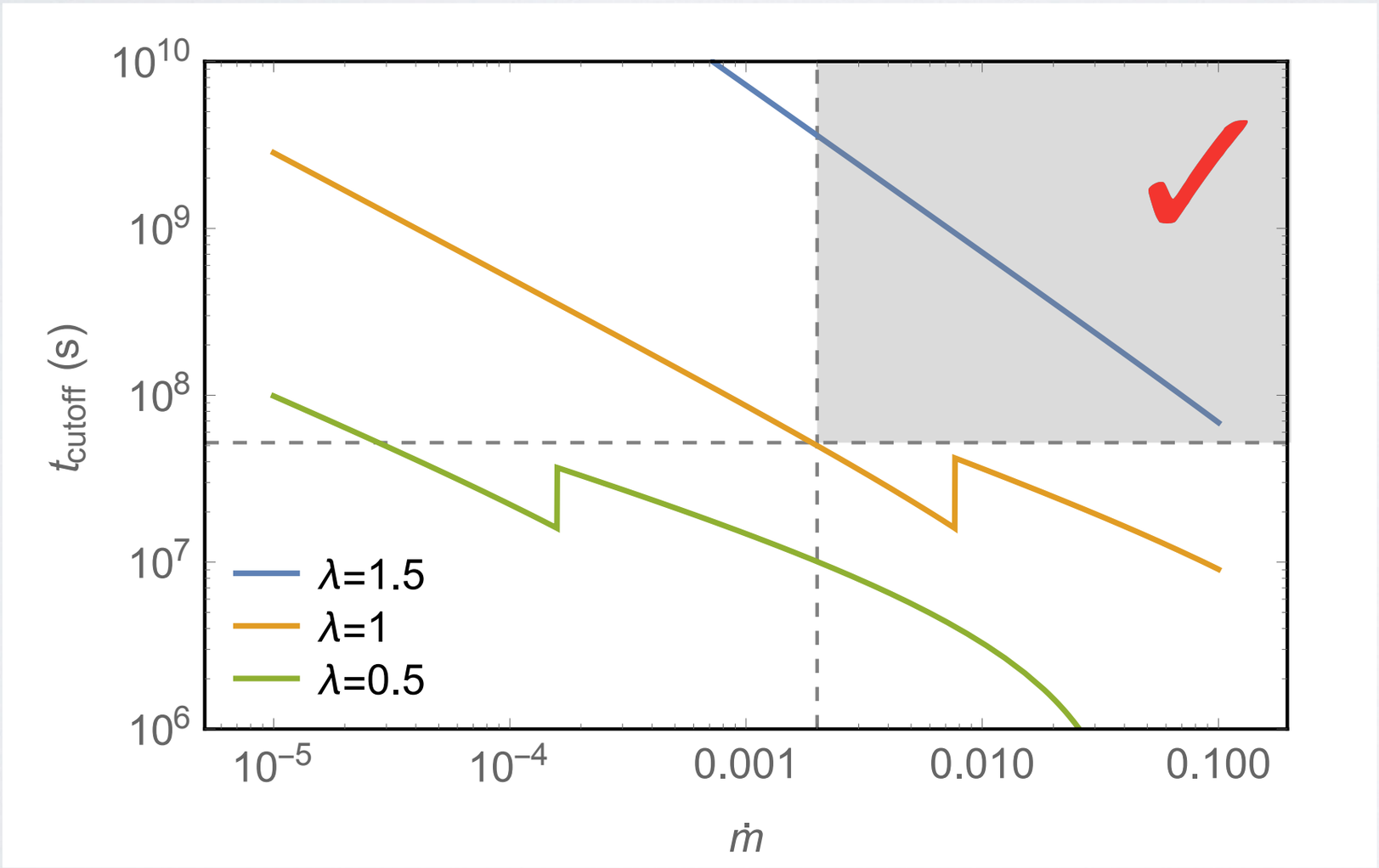
Kathirgamaraju, Barniol Duran & Giannios (2017)

2. ASASSN-14li

Quantities inferred from observations:

Brown et al. (2016), Prieto et al. (2016)

$$t_{\rm cutoff} > 5 \times 10^7 {\rm s}$$
$$L_q \gtrsim 10^{41} {\rm erg/s}$$
$$M_{\rm BH} \sim 10^6 - 10^7 M_\odot$$



$$\Longrightarrow \lambda \gtrsim 1$$

Kathirgamaraju, Barniol Duran & Giannios (2017)

Conclusions

- The effects of a pre-existing accretion disk cannot be ignored when modeling TDEs in weak AGNs.

- Interactions between the pre-existing disk and the tidally disrupted bound stream can halt the accretion of material onto the SMBH, producing a cut-off in the TDE flare.

- This cut-off time can be used to infer the properties of the pre-existing disk e.g., our results are compatible with a disk density profile $\rho \propto R^{-1}$.