An accretion disk with magnetic outflows triggered by a TDE in changing-look AGN 1ES 1927+654

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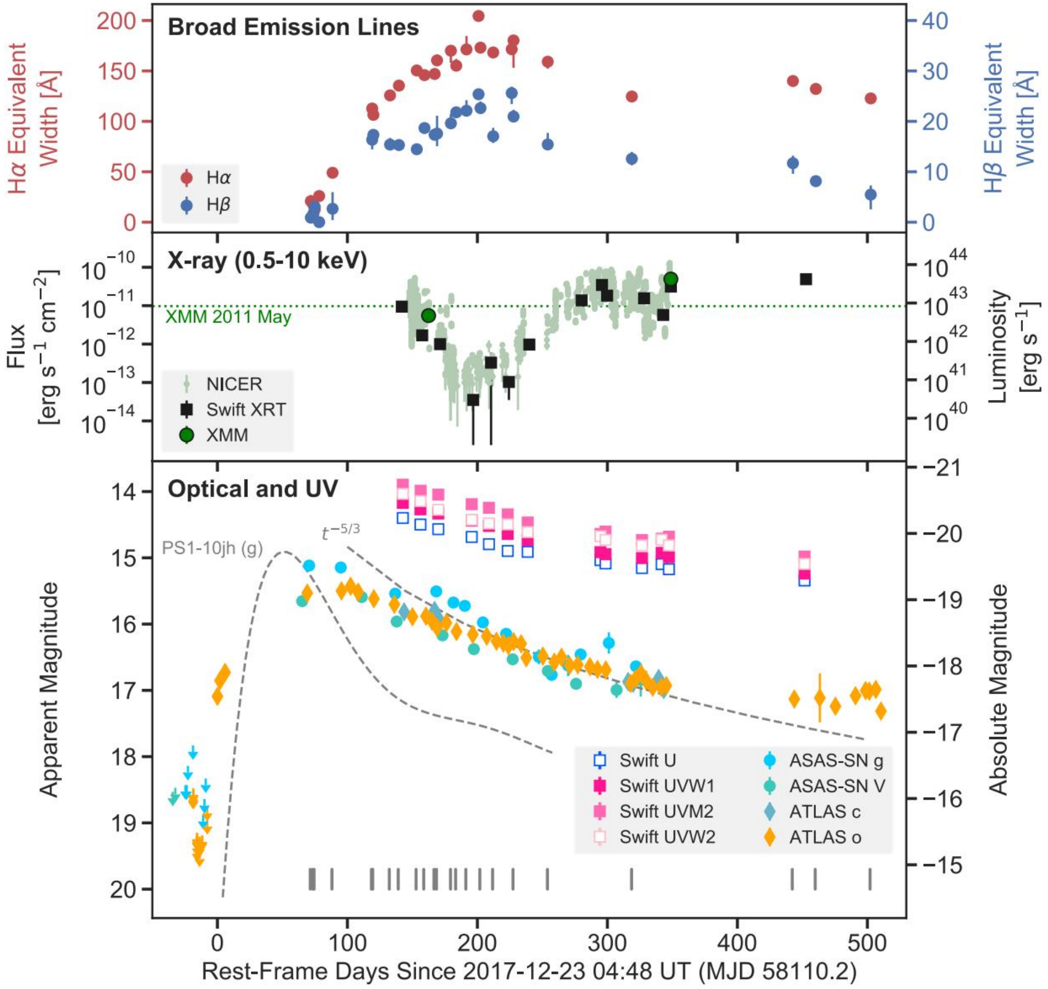
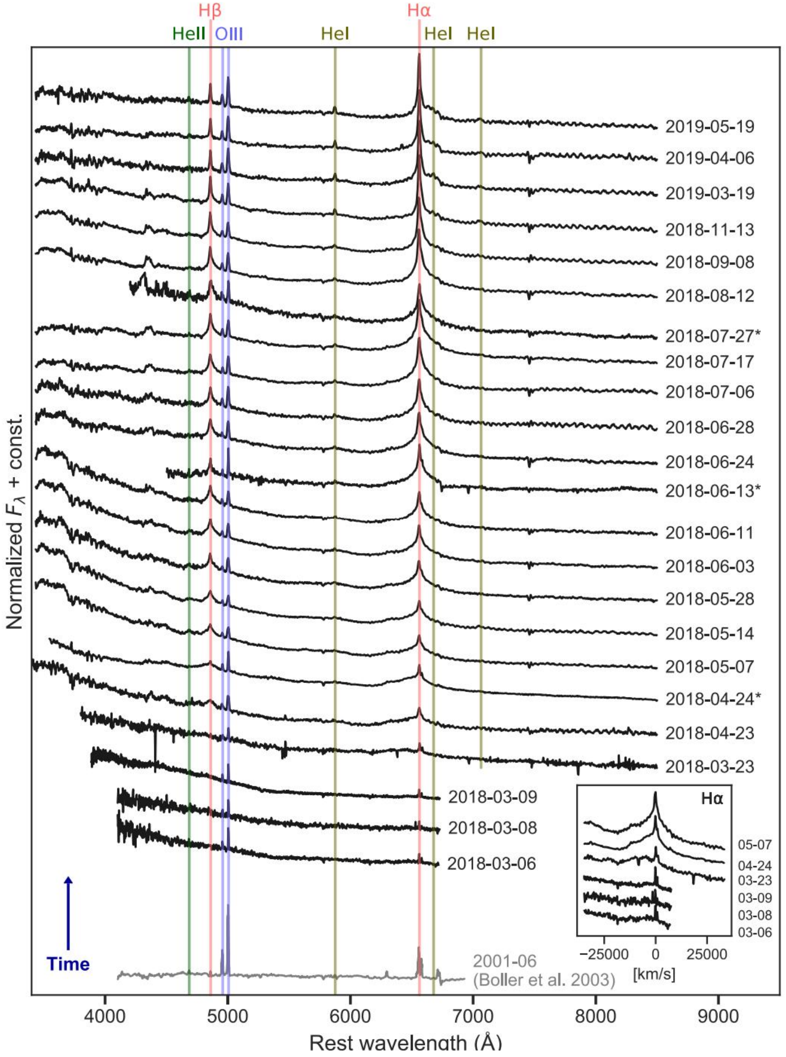
1ES 1927+654 was a narrow-line Seyfert galaxy before the UV/optical outburst in 2017
z = 0.019422





Trakhtenbrot+ 2019, ApJ, 883, 94

Observational features:

1. L(0.3-10keV)=6.81e42 erg/s (observed in 2011 as a Seyfert 2 galaxy);

2. A UV/optical outburst was observed in the end of 2017:

   a. peak emission is about four magnitudes brighter than that in the pre-outburst state
   b. UV/optical emission declined slowly, similar to a typical light-curve of a TDE

3. X-ray dip (~150 days after UV/optical outburst):

   a. flux declines rapidly with the power-law component completely disappearing a couple of days before the X-ray emission reached its lowest level ~150 days after the UV/optical peak;
   b. With the soft X-ray emission increasing from the lowest flux, the power law X-ray emission reappeared and backed to (or even brighter than) the flux before the X-ray dip within the next ~100 days.

Spectral Parameters Obtained for the 14 Swift/XRT Observations (See Section B.2 and Figure B1)

(1) Obs. ID	(2) kT (eV)	(3) Γ	(4) C-stat/DOF	(5) $L_{0.3-2}$ (erg s^{-1})
00010682001	149 ± 10	$4.52^{+0.56}_{-0.41}$	161/129	$1.26^{+0.03}_{-0.06} \times 10^{43}$
00010682002	101^{+7}_{-6}	⋯	54/68	$2.60^{+0.15}_{-0.19} \times 10^{42}$
00010682003	105^{+10}_{-9}	⋯	47/58	$1.47^{+0.12}_{-0.15} \times 10^{42}$
00010682004	56^{+41}_{-23}	⋯	8/5	$1.40^{+0.12}_{-1.40} \times 10^{41}$
00010682005	$\geqslant 71$	⋯	13/3	$3.10^{+2.68}_{-3.10} \times 10^{41}$
00010682006	85^{+19}_{-16}	⋯	10/18	$3.31^{+0.49}_{-0.90} \times 10^{41}$
00010682007	94 ± 8	⋯	52/59	$1.62^{+0.12}_{-0.15} \times 10^{42}$
00010682008	141^{+13}_{-10}	$2.95^{+0.51}_{-0.70}$	146/128	$1.42^{+0.12}_{-0.05} \times 10^{43}$
00010682009	205^{+26}_{-23}	$3.48^{+0.37}_{-0.32}$	151/165	$3.60^{+0.13}_{-0.15} \times 10^{43}$
00010682010	159^{+13}_{-12}	$3.96^{+0.80}_{-0.70}$	126/124	$2.09^{+0.08}_{-0.09} \times 10^{43}$
00010682011	148^{+12}_{-8}	$3.11^{+0.77}_{-1.63}$	127/123	$1.68^{+0.13}_{-0.05} \times 10^{43}$
00010682012	132^{+11}_{-10}	$4.36^{+2.60}_{-4.36}$	101/104	$7.33^{+0.92}_{-0.65} \times 10^{42}$
00010682013	153^{+11}_{-7}	$3.16^{+0.46}_{-0.78}$	122/149	$2.68^{+0.18}_{-0.14} \times 10^{43}$
00010682014	182^{+10}_{-8}	$2.84^{+0.22}_{-0.27}$	214/218	$4.54 \pm 0.10 \times 10^{43}$

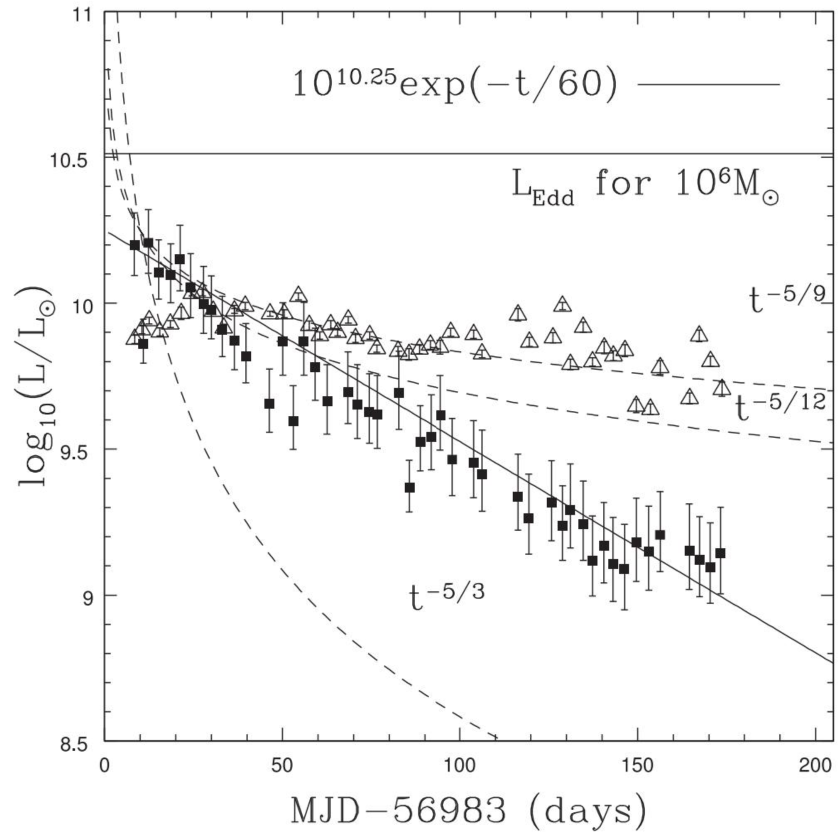
TDE

1. For a normal solar-like star captured by a massive BH, its tidal disruption radius is very close to the ISCO;

2. For 1ES 1927+654, its inner accretion disk with corona would be destructed instantly when a normal star is tidally disrupted by the BH;

3. The radiation from the newly formed disk after the TDE should dominate in the soft X-ray energy band, whereas no similar slowly declining light-curve in X-ray energy bands has been observed as those observed in normal TDEs;

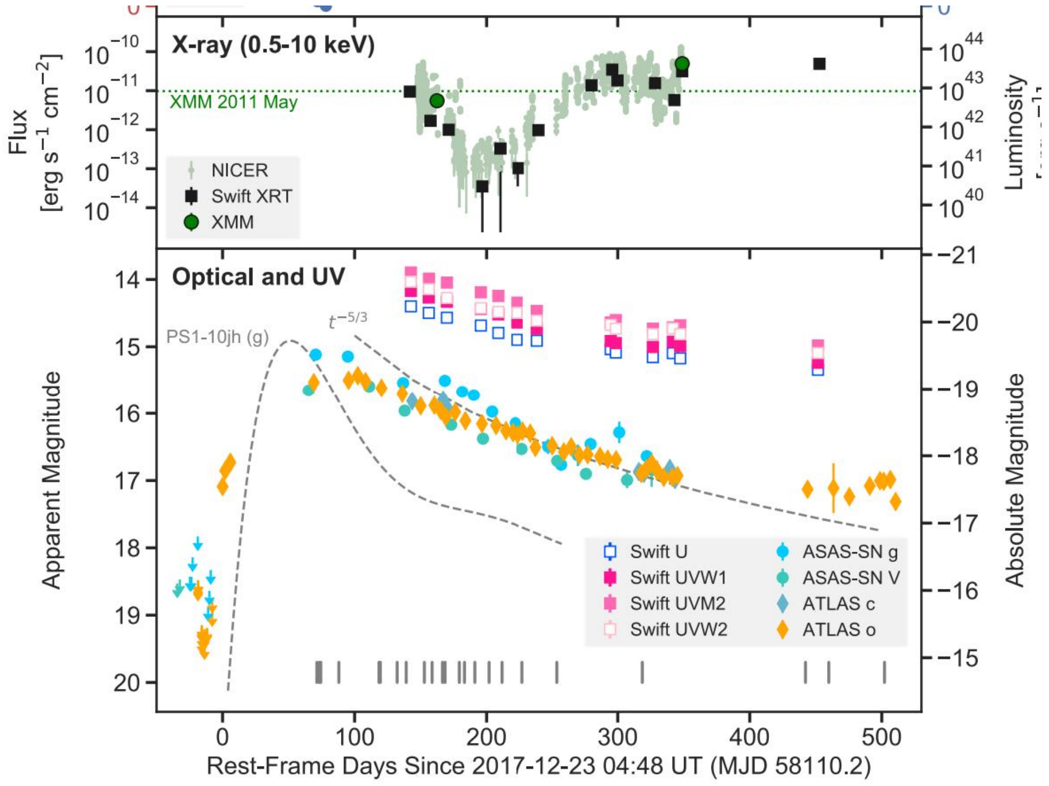
Evolution of TDE ASASSN-14li's light curves

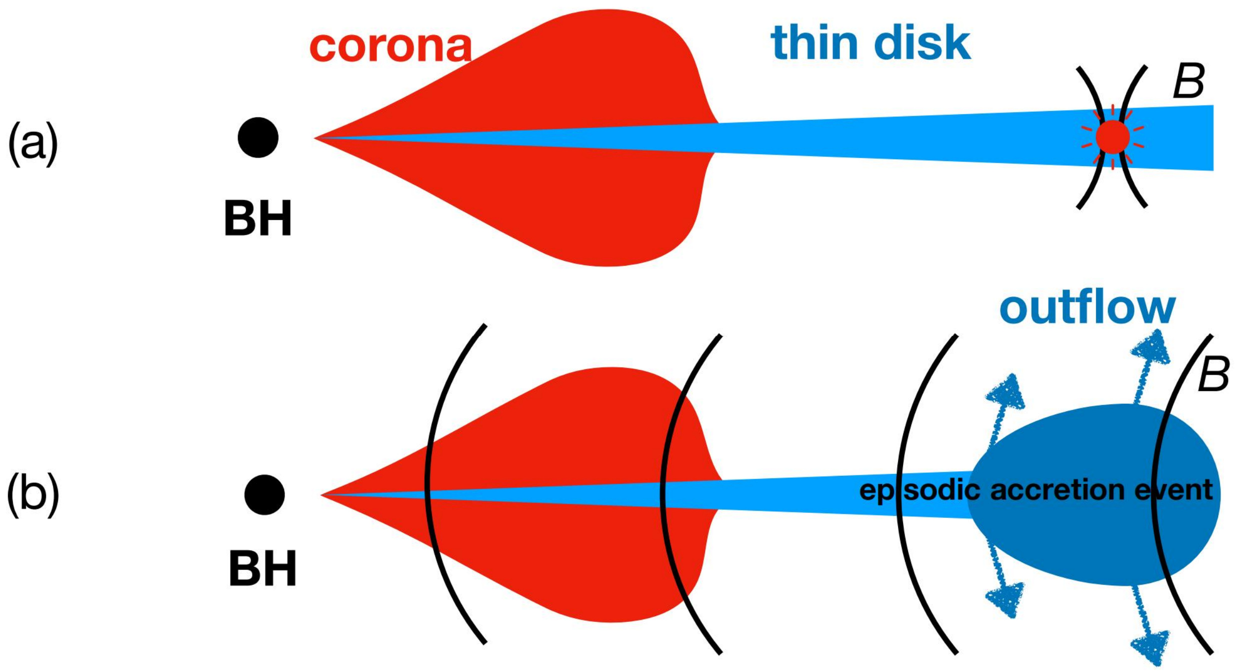


Holoien+ 2016, MNRAS 455, 2918

Model

We assume that a TDE takes place in the outer region of the disk that emits UV/optical photons





The disk-corona surrounding the BH is destructed by the TED disk within ~150 days.

Impact of an episodic accretion event on the inner accretion disk

Assuming that the inner disk corona is swept up by the TDE disk in a timescale of $\delta\tau$, the momentum change of the inner disk during the period $\delta\tau$ is

$$\delta p \sim M_{\rm d}(R < R_{\rm epi}) v_{\rm d}, \qquad v_{\rm d} \sim R_{\rm epi}/\delta\tau$$

Momentum conservation requires

X-ray observation in 2011

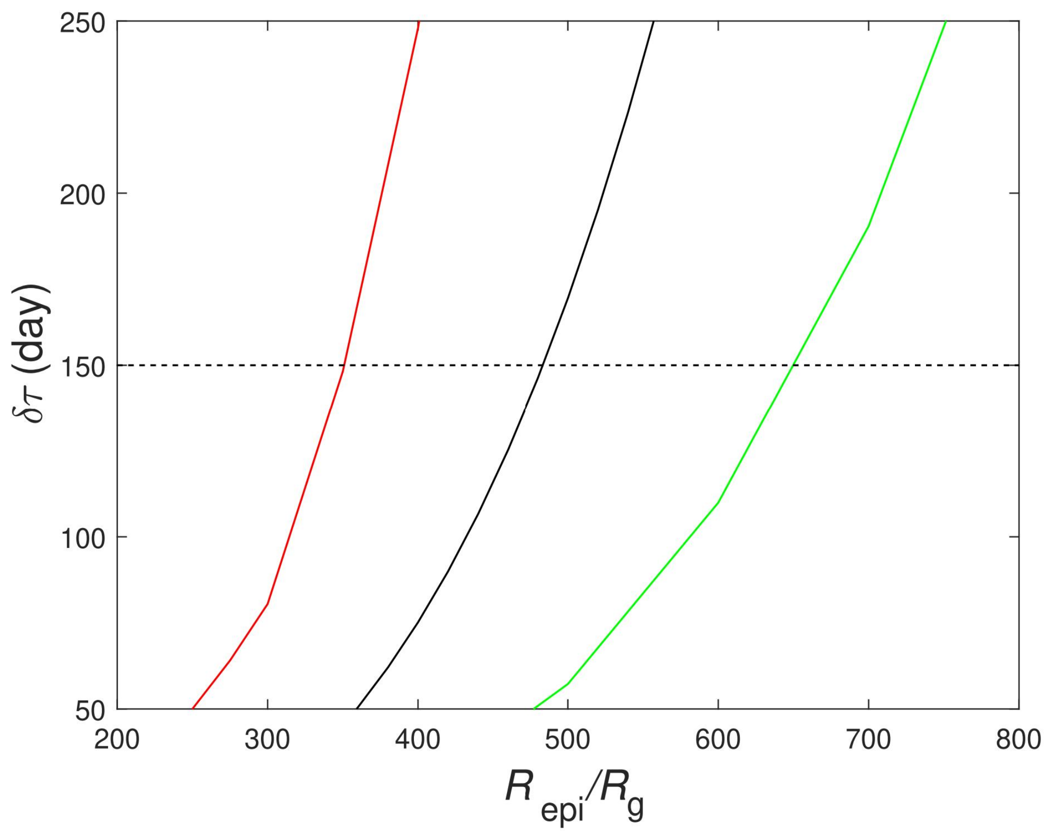
$$\dot{M}_{\rm epi} v_{\rm epi}(R_{\rm epi})\delta\tau \sim M_{\rm d}(R < R_{\rm epi}) v_{\rm d} \sim M_{\rm d}(R < R_{\rm epi}) R_{\rm epi}/\delta\tau$$

UV/optical outburst

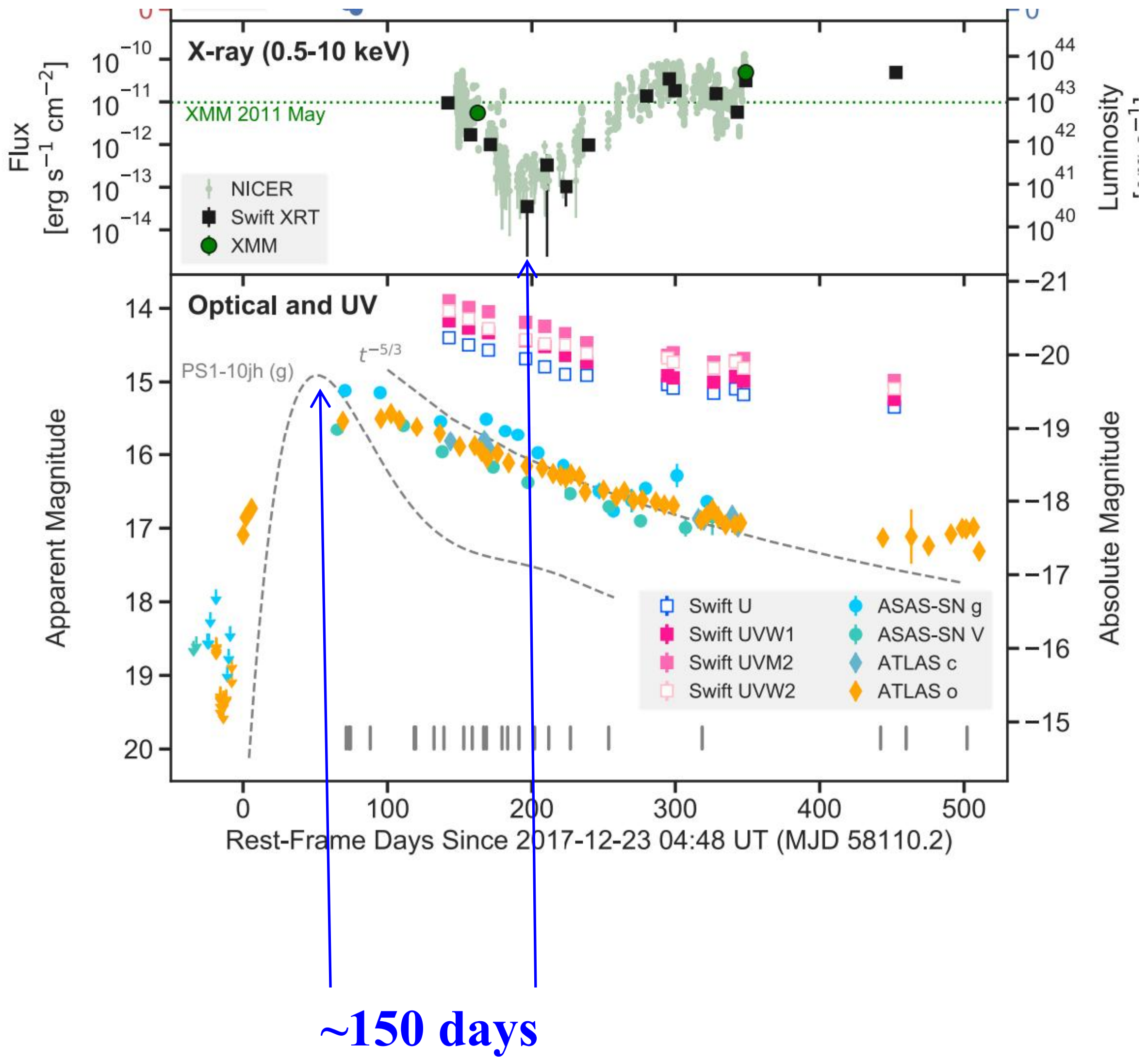
$$\delta\tau \sim \left[\frac{M_{\rm d}(R < R_{\rm epi}) R_{\rm epi}}{\dot{M}_{\rm epi} v_{\rm epi}}\right]^{1/2} \qquad \frac{M_{\rm d}(R < R_{\rm epi})}{\dot{M}_{\rm epi}} = 7.8 \times 10^{-14} \alpha^{-1} m \dot{m}^{-1} \dot{m}_{\rm epi}^{-1} r_{\rm epi}^{7/2}, \quad {\rm day}$$

The front of the TDE disk moves inwards, and pushes the inner disk, which shrinks in size accordingly.

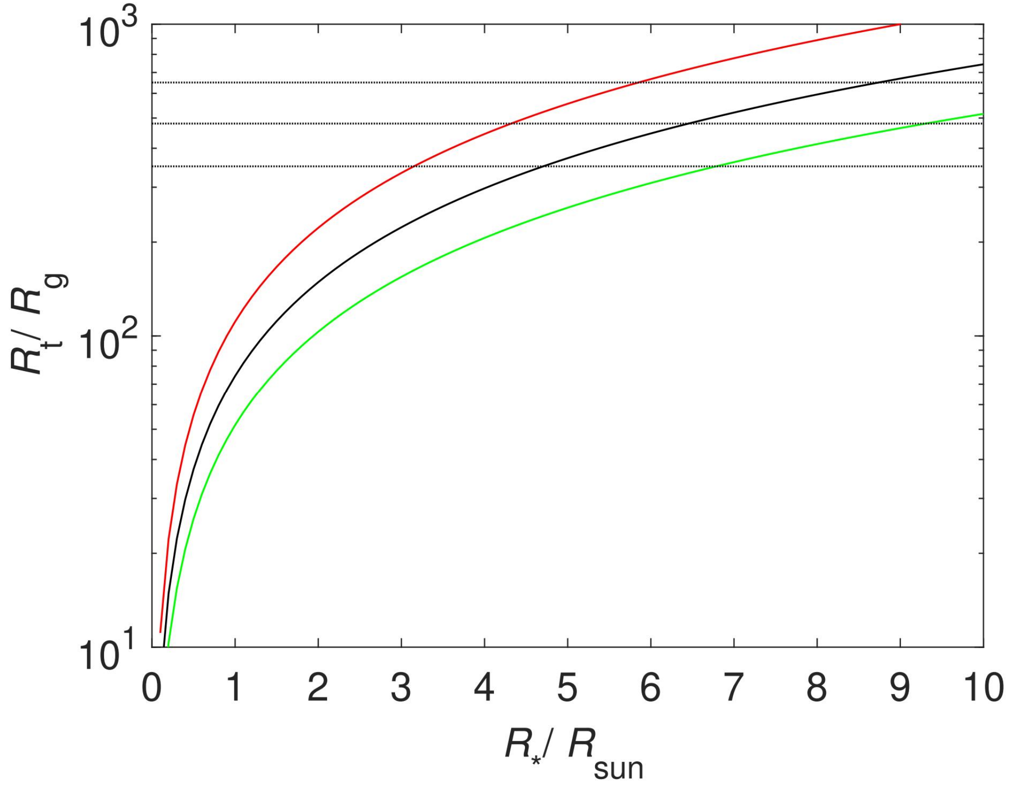
It finally disappeared within ~150 days



α = 0.03 (red), 0.1 (black), and 0.3 (green)



$$r_t \equiv \frac{R_t}{R_g} = 33.3 \left(\frac{M_{bh}}{10^6 M_\odot}\right)^{-2/3} \left(\frac{R_*}{R_\odot}\right) \left(\frac{M_*}{M_\odot}\right)^{-1/3}$$



The tidal disruption radius R_t versus the star radius with different star masses (red: $0.3M_\odot$, black: $1M_\odot$, and green: $3M_\odot$). The horizontal dotted lines denote $R_t = 350R_g$, $480R_g$, and $650R_g$, respectively.

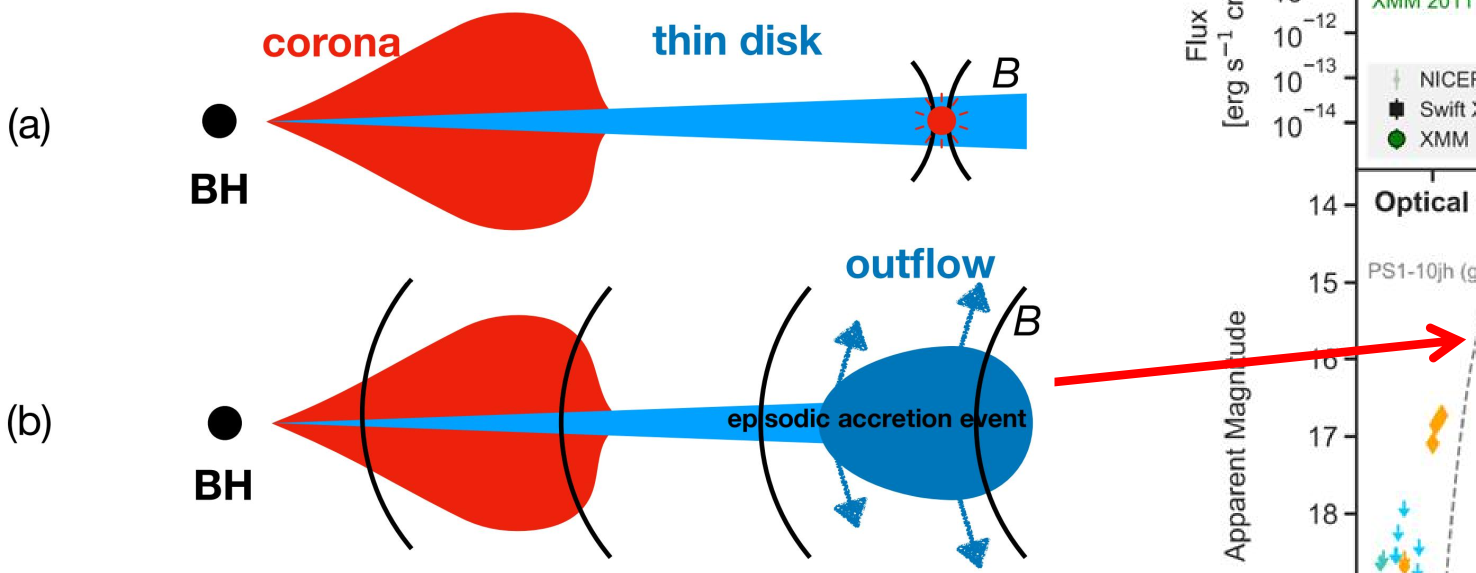
Possible candidates:

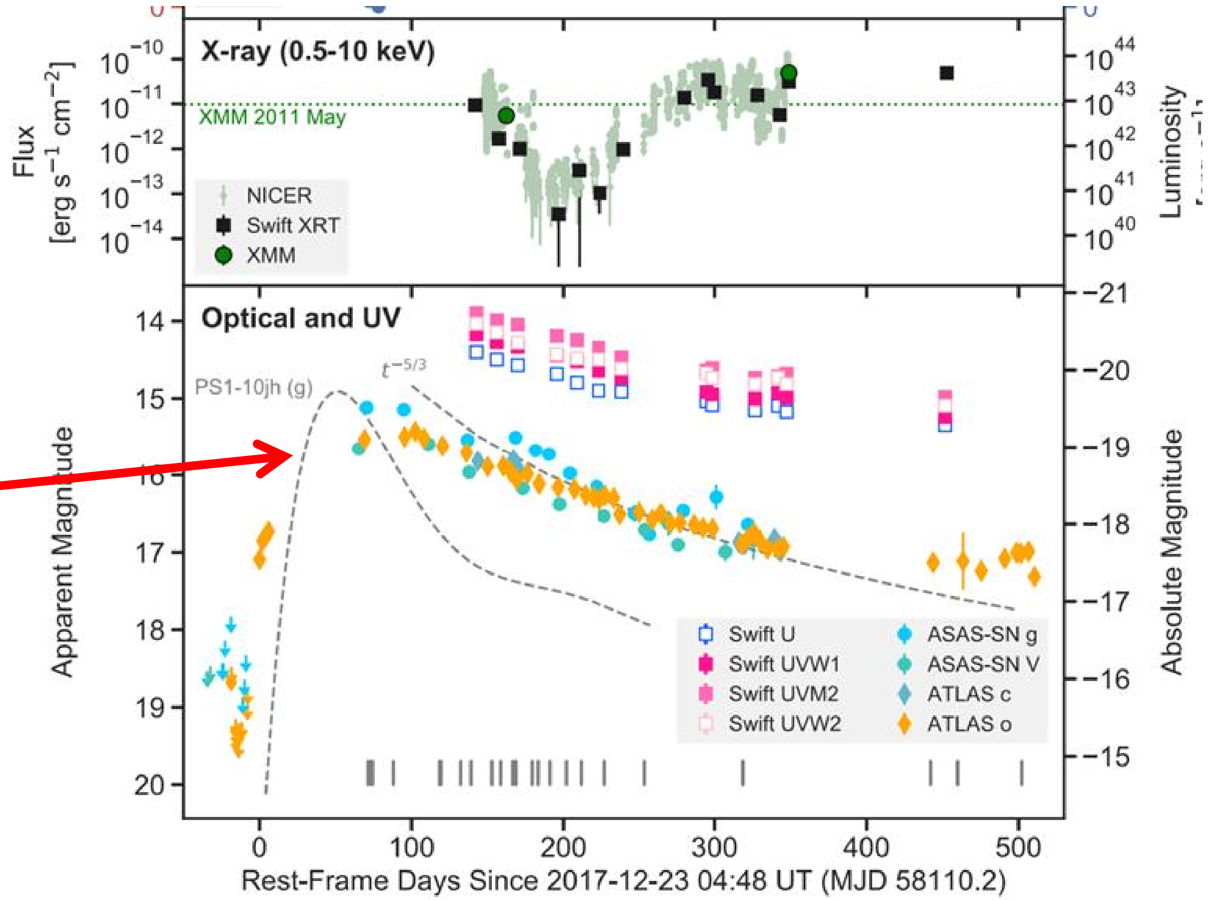
1. red giant
2. protostar in Hayashi track

We suggest a solar-mass red giant star with ~5 solar radii is disrupted in the outer region of the accretion disk!

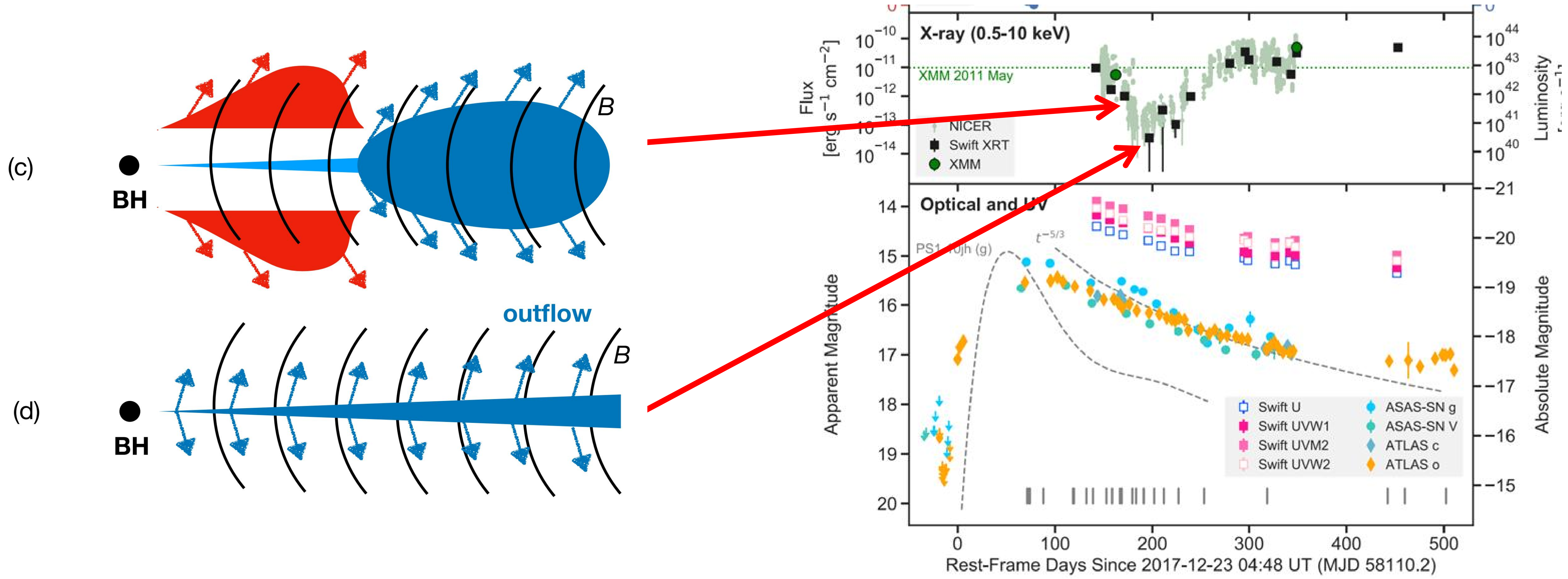
$$t_{\rm fb} = 0.36 \left(\frac{R_{\rm t}}{R_{\rm p}}\right)^{-3n/2} \left(\frac{M_{\rm bh}}{10^7 M_\odot}\right)^{1/2} \left(\frac{M_*}{M_\odot}\right)^{-1} \left(\frac{R_*}{R_\odot}\right)^{3/2} \text{yr},$$

Fallback time of TDE debris is ~50 days, consistent with the rising timescale of the optical burst!



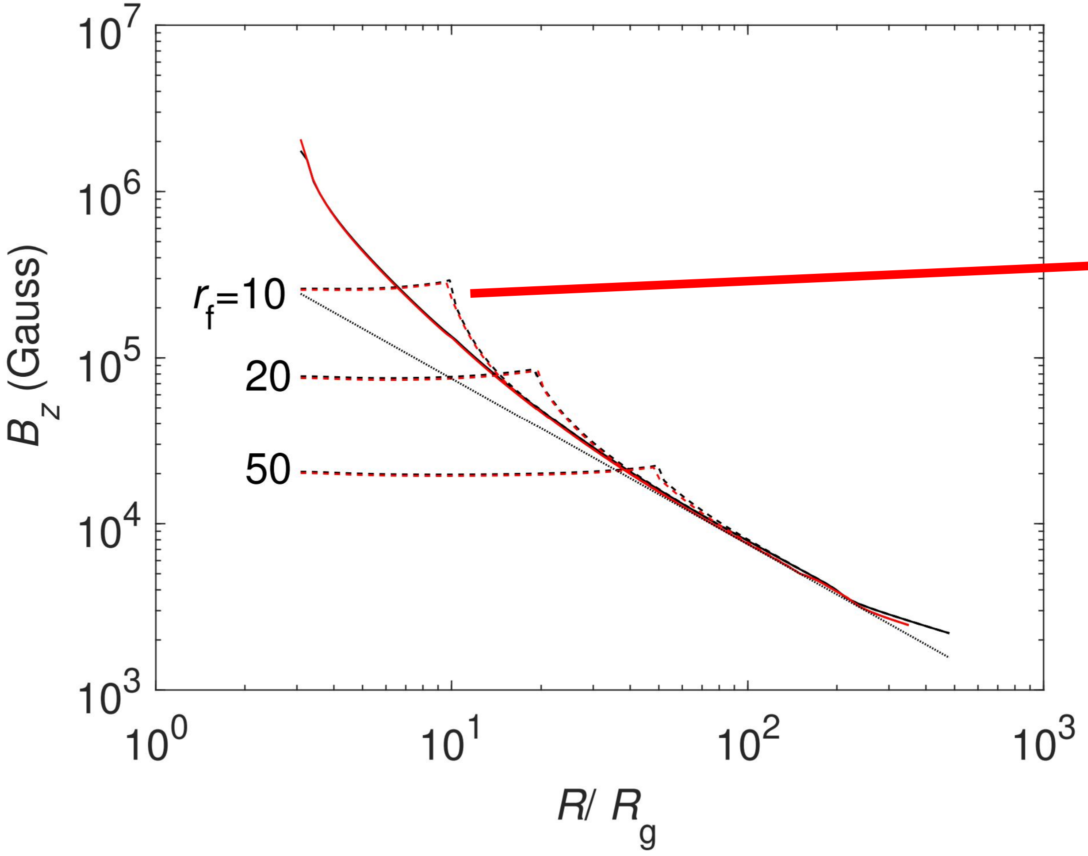


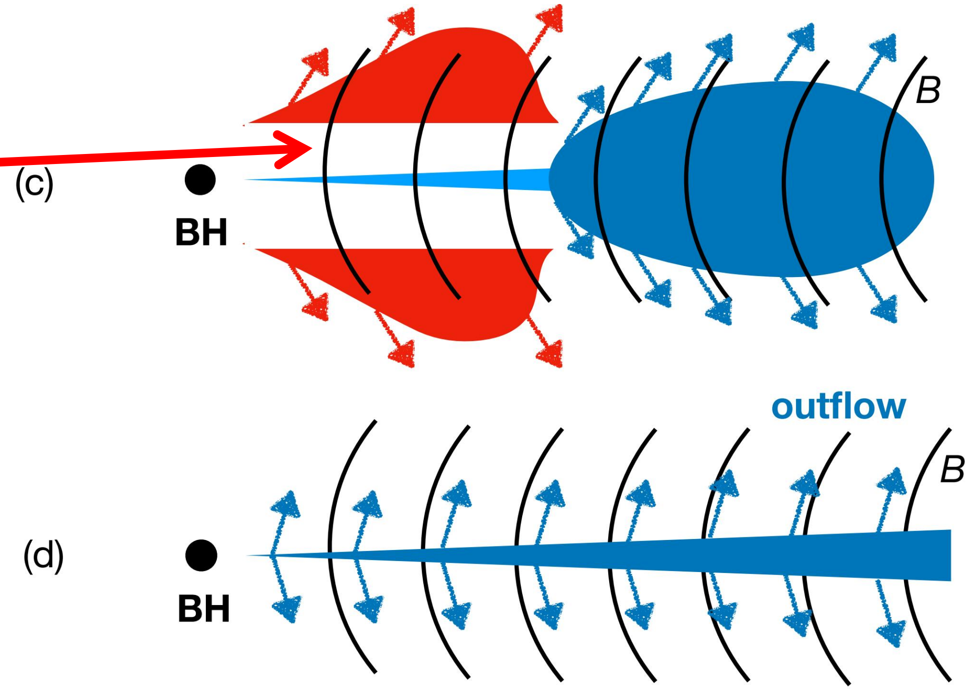
The magnetic field of a giant red star is very strong!



1. The field threading the disrupted star is dragged inwards by the disk formed after the TDE, which accelerates outflows from the disk.

2. The disk dimmed since a large fraction of the energy released in the disk is tapped into the outflows.

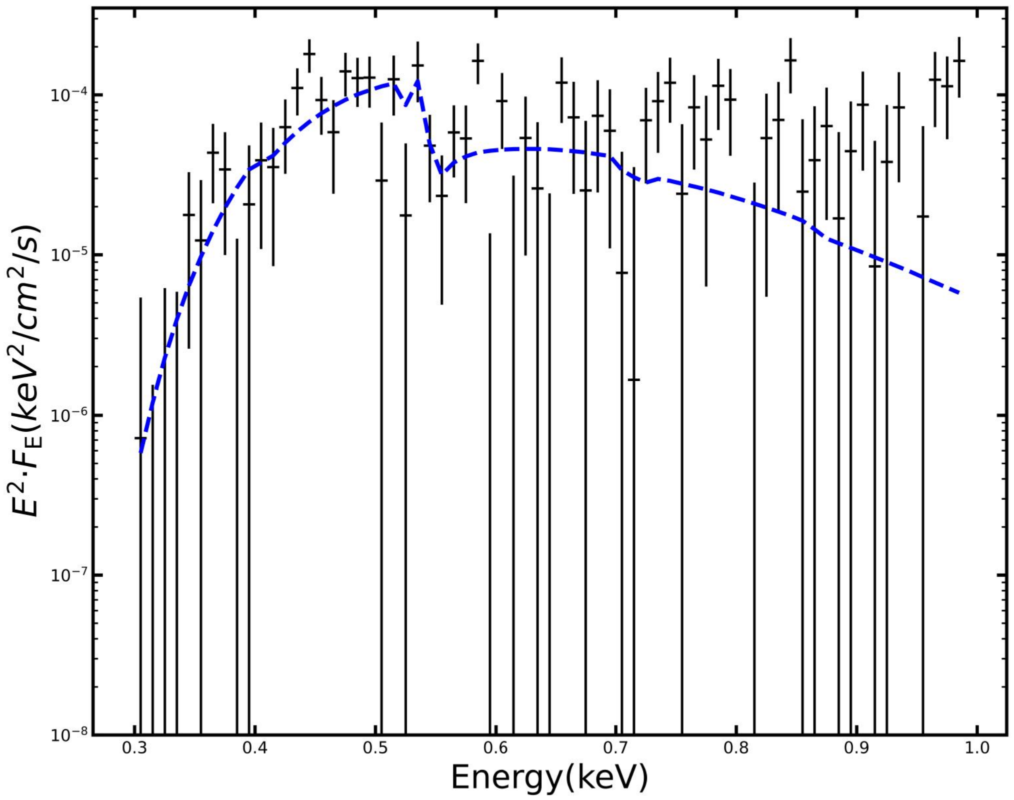




Black line: the minimal magnetic field required to accelerate the corona into outflows
Solid line: the field of the TDE disk extends to the ISCO.

Model fitting of the X-ray spectra

We use our model to fit the X-ray spectra during the X-ray dip.

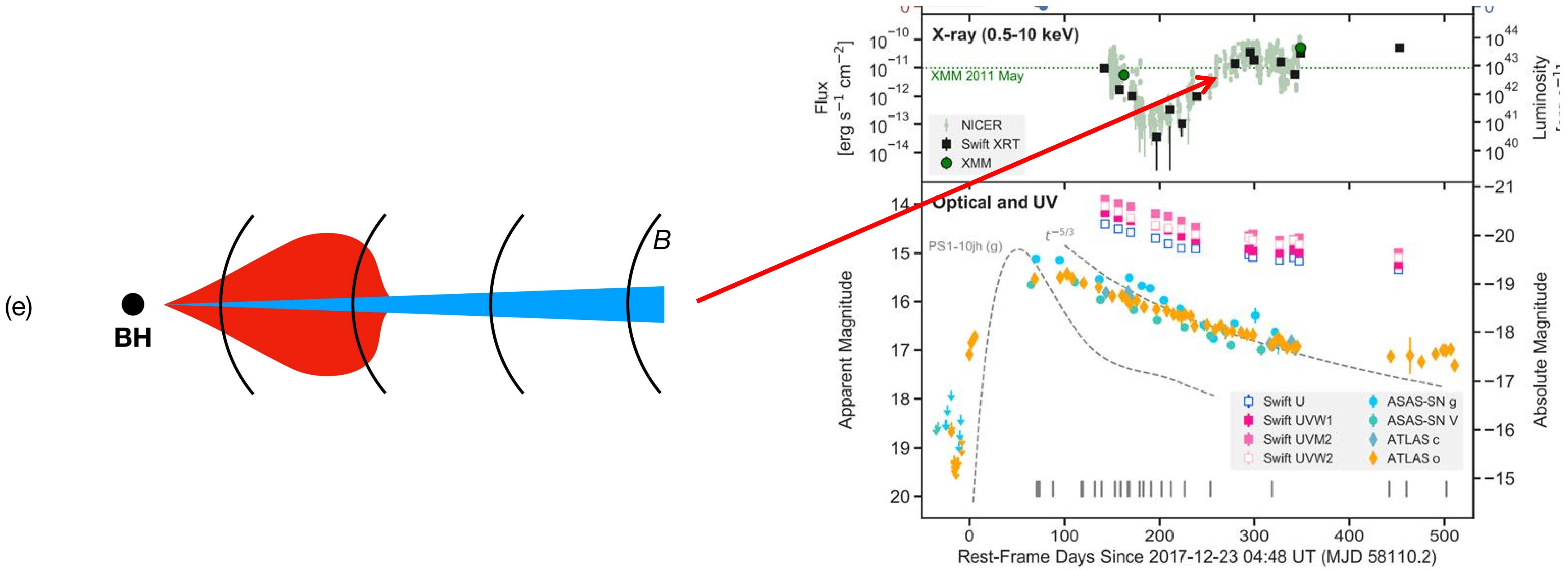


$\alpha = 0.1$

Two epochs: MJD 58323 (Obs ID: 1200190151) and MJD 58325 (ObsID: 1200190153). The spectra of these two epochs are then combined for better statistics using the tool addspec.

We note that, the best-fitting values:
B_{ext} =2.19e3 Gauss (β_{ext} = 85.5)

Typical field strengths of red giant stars are several thousand Gauss in their envelopes, or ~ 10^5 Gauss in the cores of the red giant stars.



1. The accretion rate of the TDE declines, and ultimately it turns out to be a thin disk, which is inefficient for field advection. The field is therefore too weak, and the outflows are switched off.
2. A thin disk with corona reappears later after the outburst.

Summary

1. A red giant star tidally disrupted in the outer region of the disk in 1ES 1927+654 .

2. The inner thin disk with corona is completely swept by the accretion event when the gas reaches the ISCO ~150 days after the UV/optical outburst.

3. The field threading the disrupted star is dragged inwards by the disk formed after the TDE, which accelerates outflows from the disk.

4. The disk dimmed since a large fraction of the energy released in the disk is tapped into the outflows.

5. The accretion rate of the TDE disk declines, and ultimately it turns out to be a thin disk, which is inefficient for field advection, and the outflows are switched off. A thin disk with corona reappears later after the outburst.

Thanks!