X-Calibur Spectroscopy Workshop
Winchester, UK
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Tidal Disruption Events with high-resolution X-ray spectroscopy

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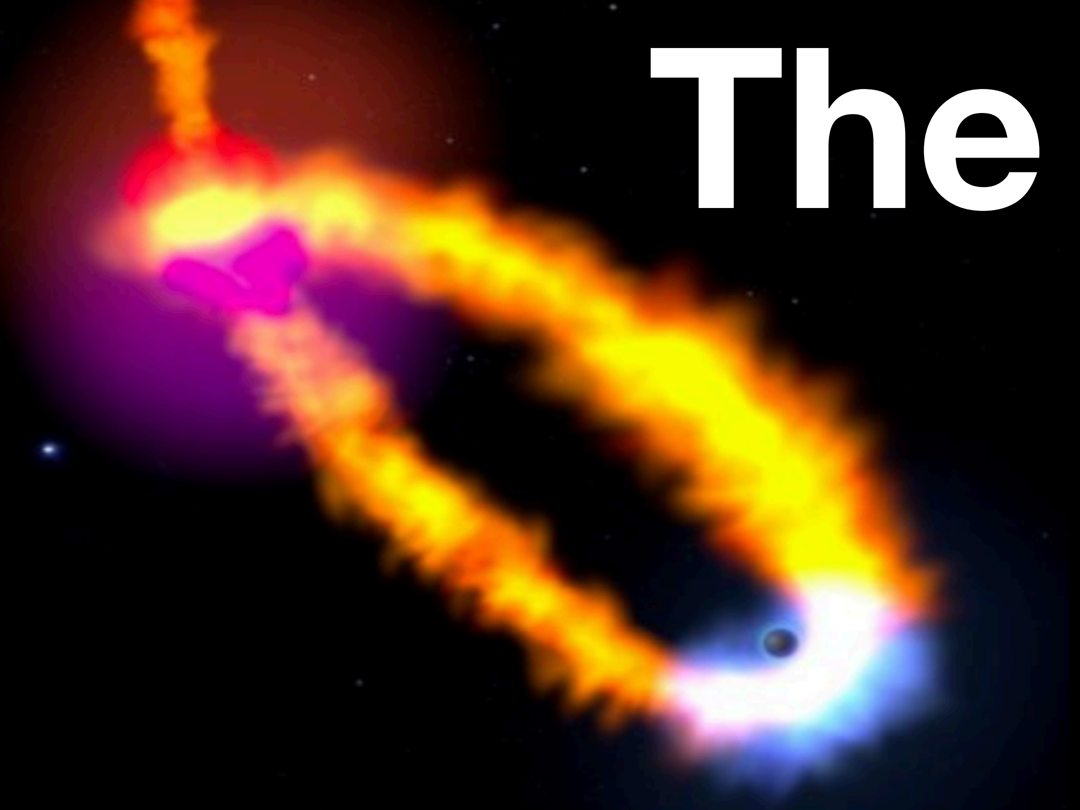
Outline

1. A brief history of TDEs
2. The archetype TDE ASASSN-14li
3. A new X-ray TDE candidate
4. The future



The promise of TDEs

1. **Unique Impulse of accretion**
   - Real time formation of discs, jets
2. **Super-Eddington accretion**
   - Fast outflows, transition between accretion states
3. **Probe population quiescent black holes**
   - Detect intermediate mass black holes?
   - Spins in quiescent black holes?

This is just the beginning.

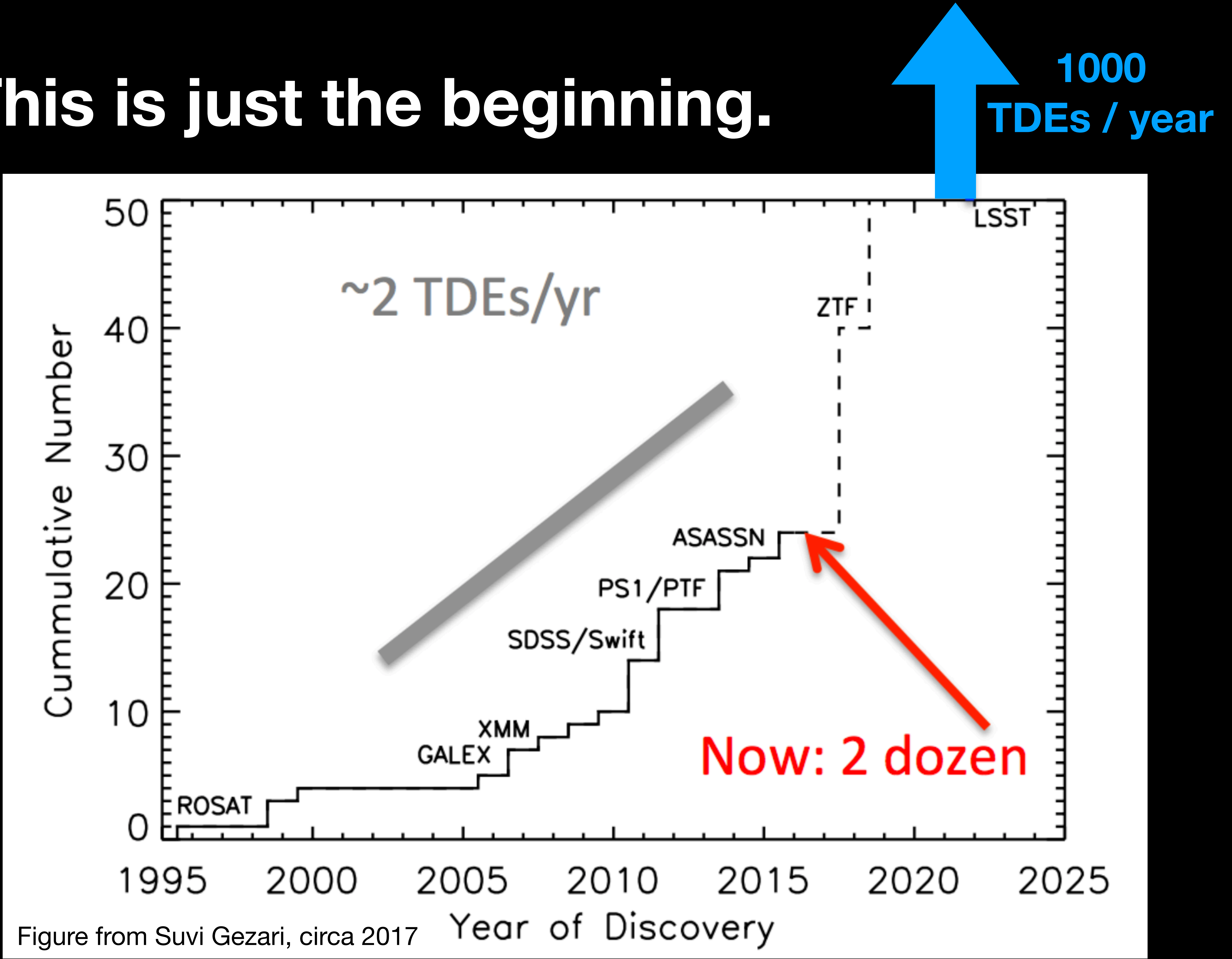


Figure from Suvi Gezari, circa 2017

Are we ready for this?

Are these TDEs at all?

- What is a tell-tale marker of a TDE?

Do they accrete at super-Eddington rates?

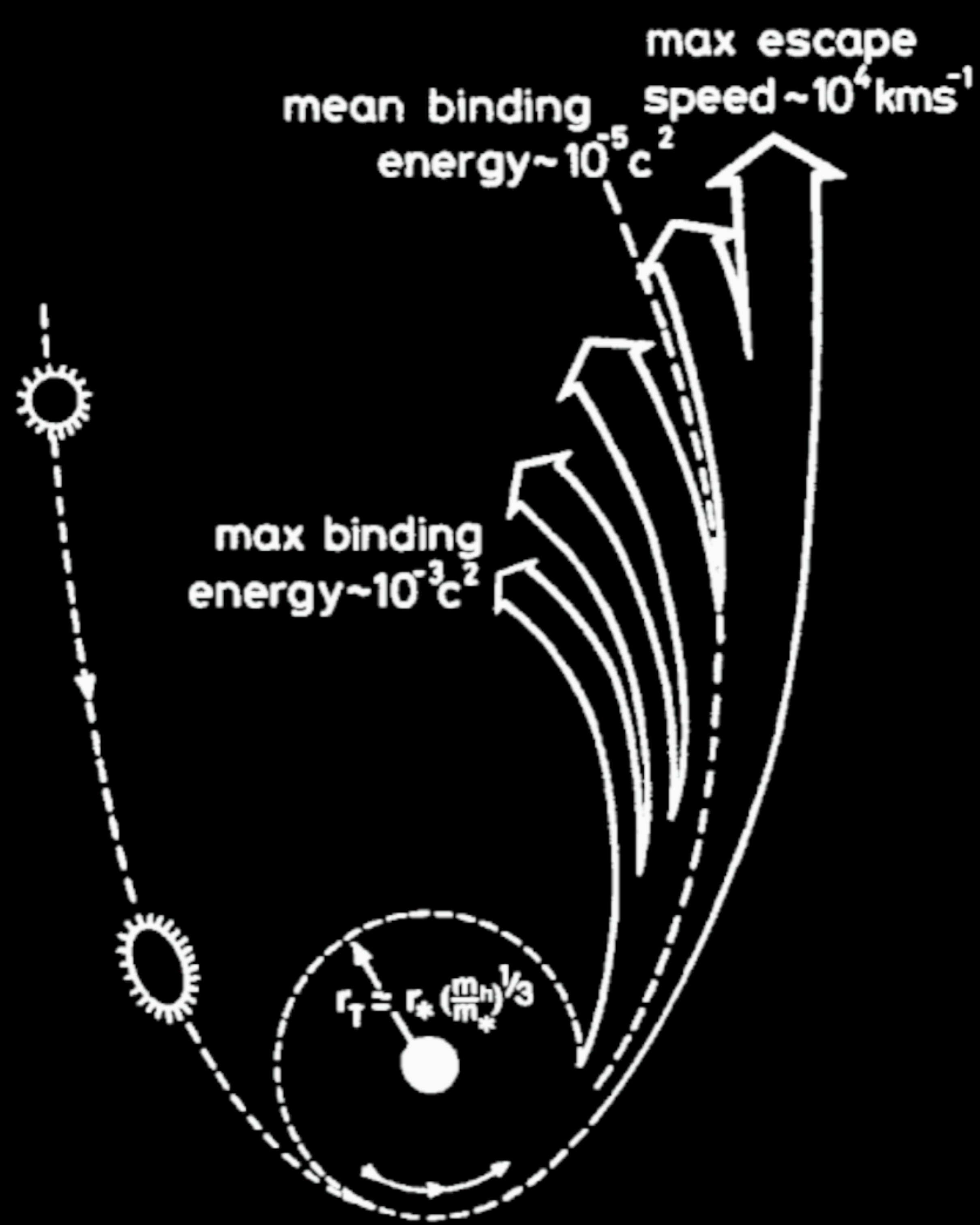
- How much actually makes it into the black hole?

Do TDEs probe mass/spin of quiescent black holes?

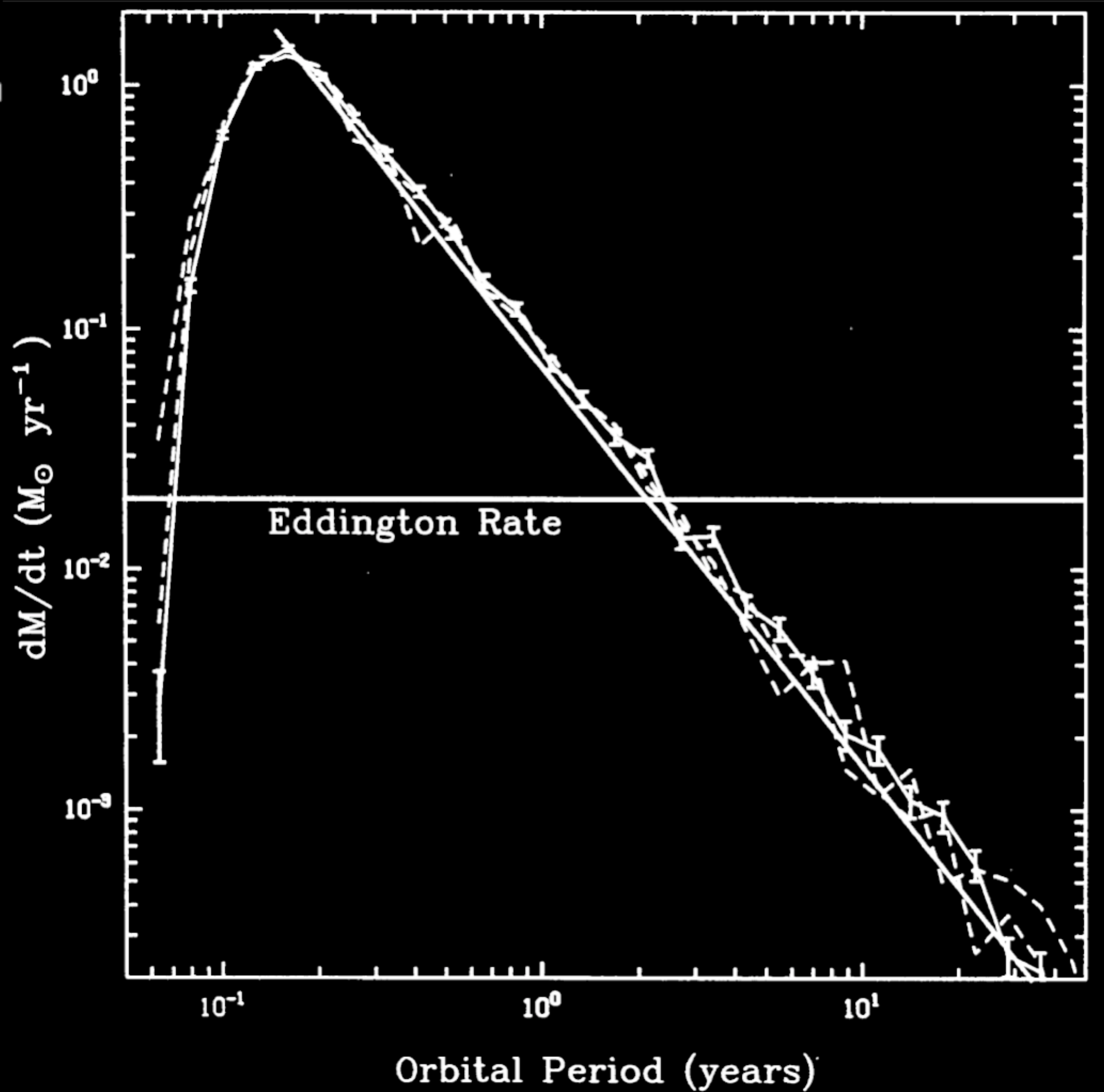
- Fundamentally, where is the emission coming from?

High Resolution X-ray Spectroscopy!

What happens after the TDE?



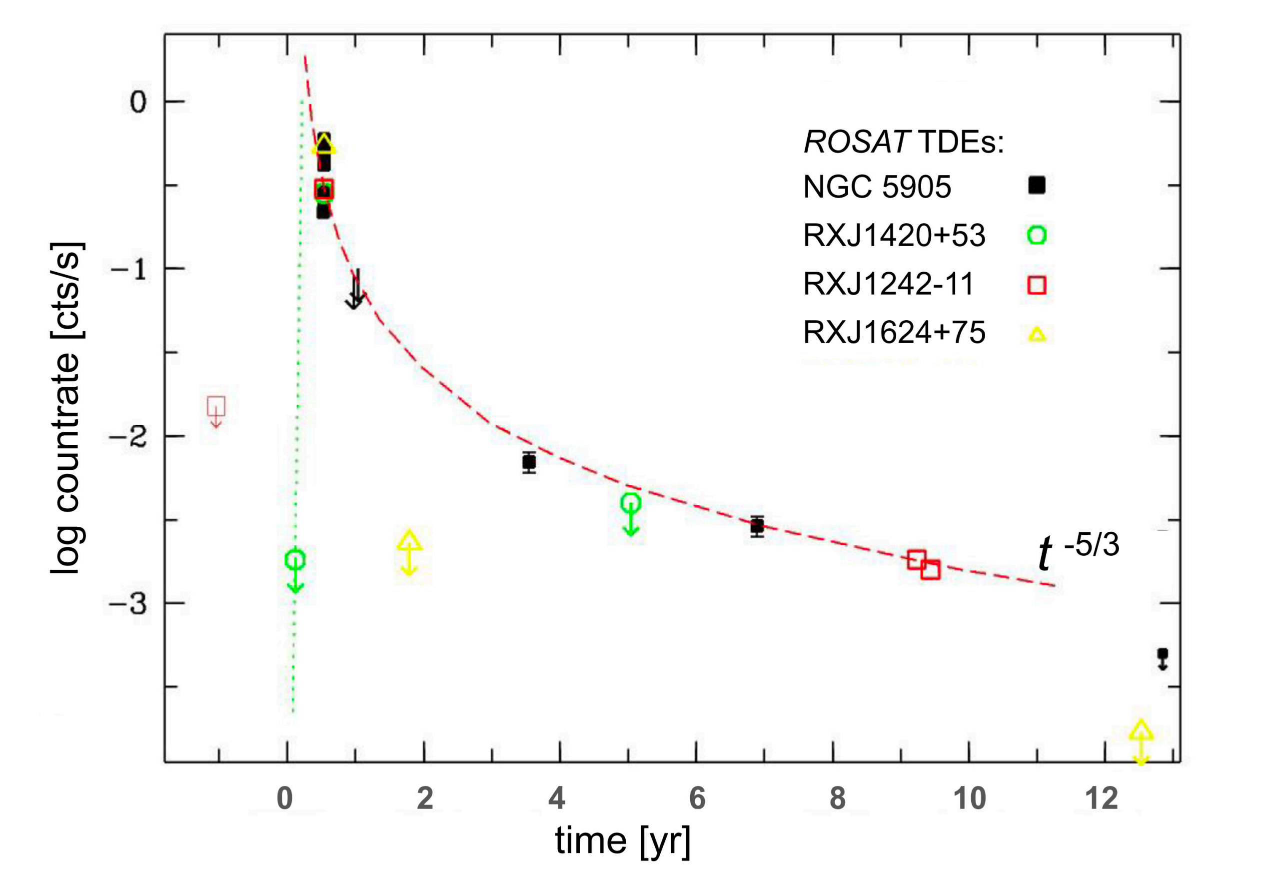
Rees et al., 1988



Evans & Kochanek 1989

X-ray legacy in TDE studies

TDEs were discovered in the ROSAT All-Sky Survey



X-ray

Review by Komossa 2015

$T_{bb}=10^{5-6}$ K
~1 r_g for 10^6 M_{sun}

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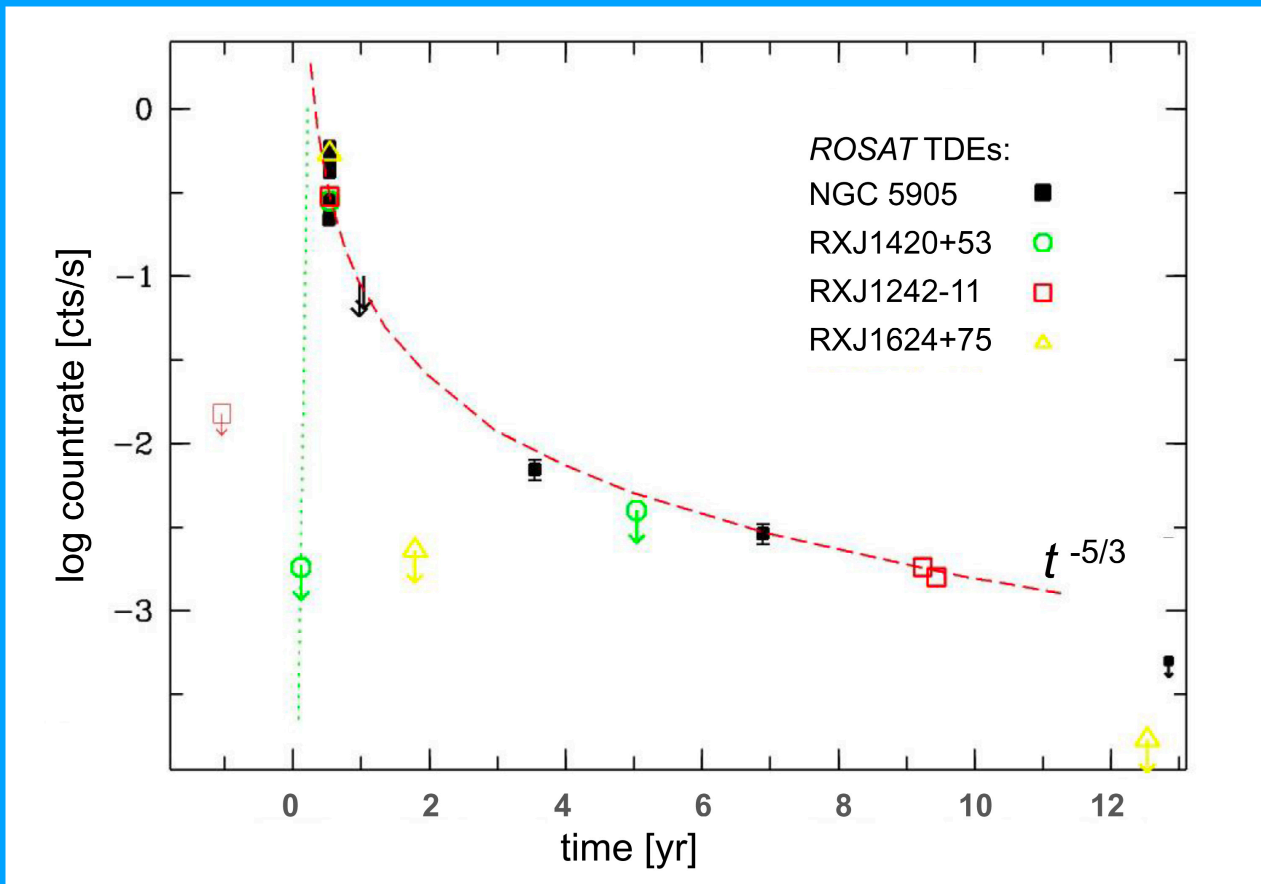

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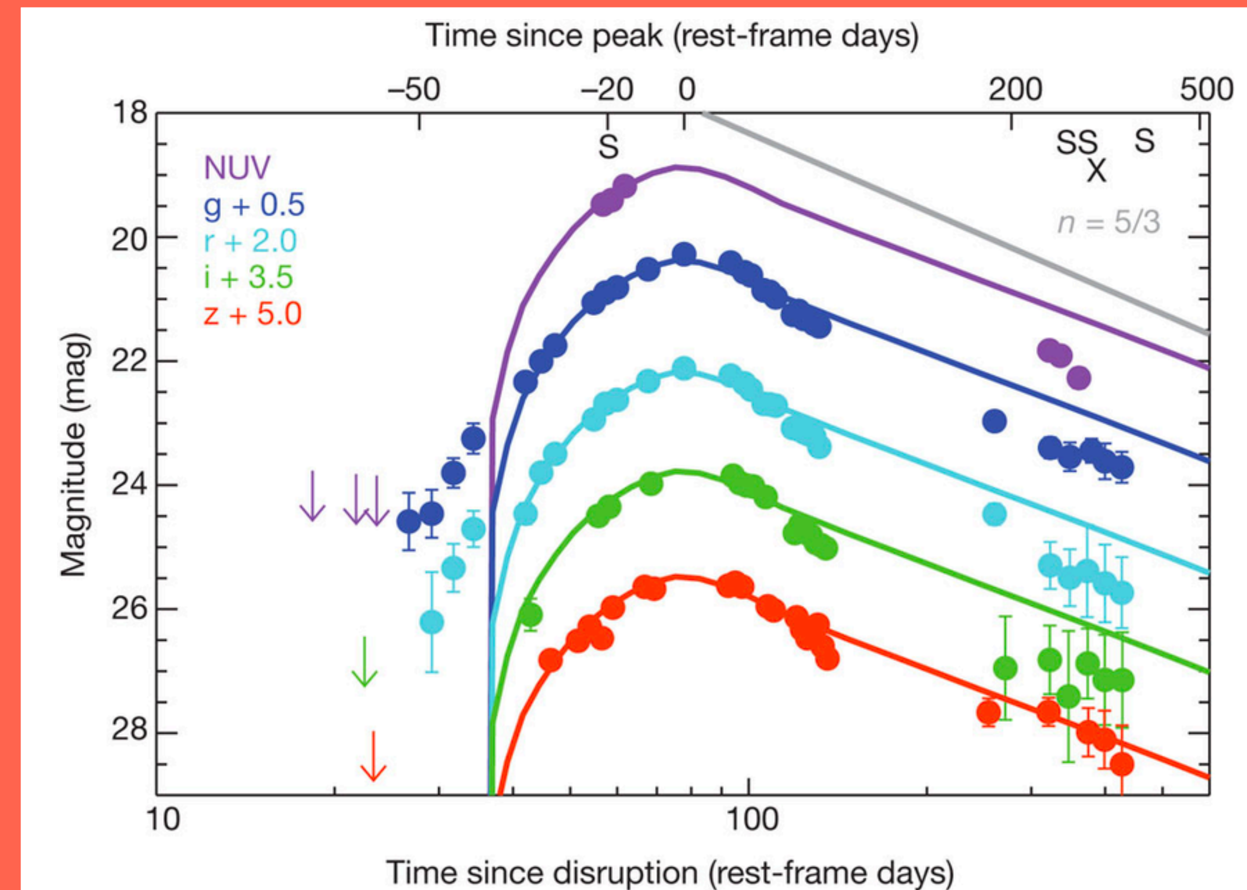


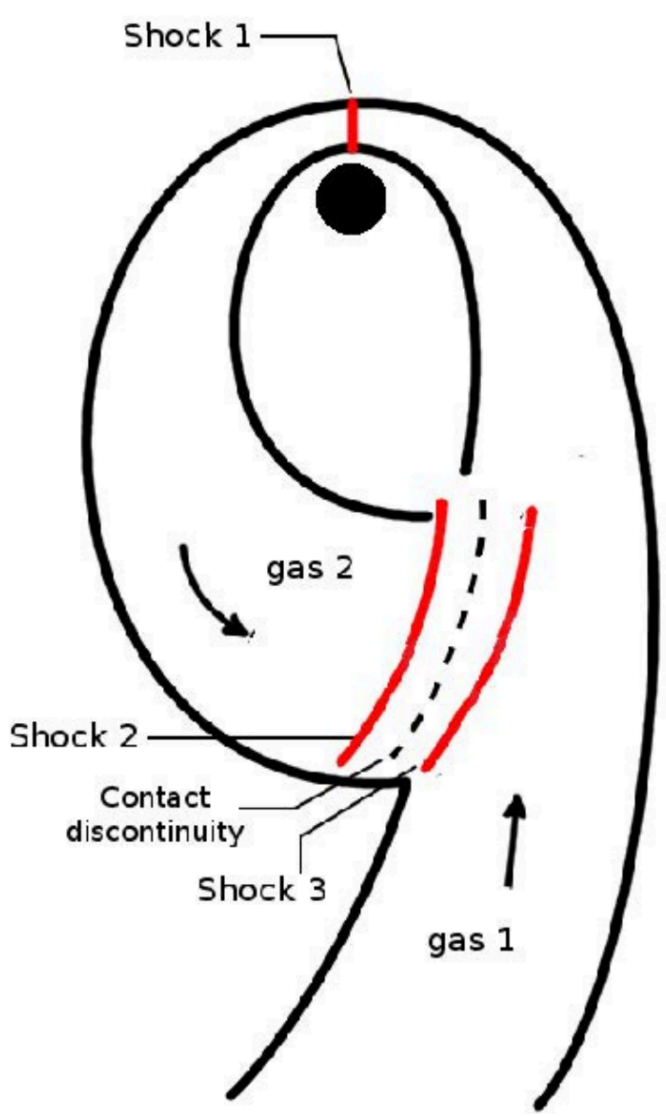
Optical/UV

Gezari et al., *Nature*, 2012

T_{bb} ~ 10^4 K
~1000 r_g for 10^6 M_{sun}

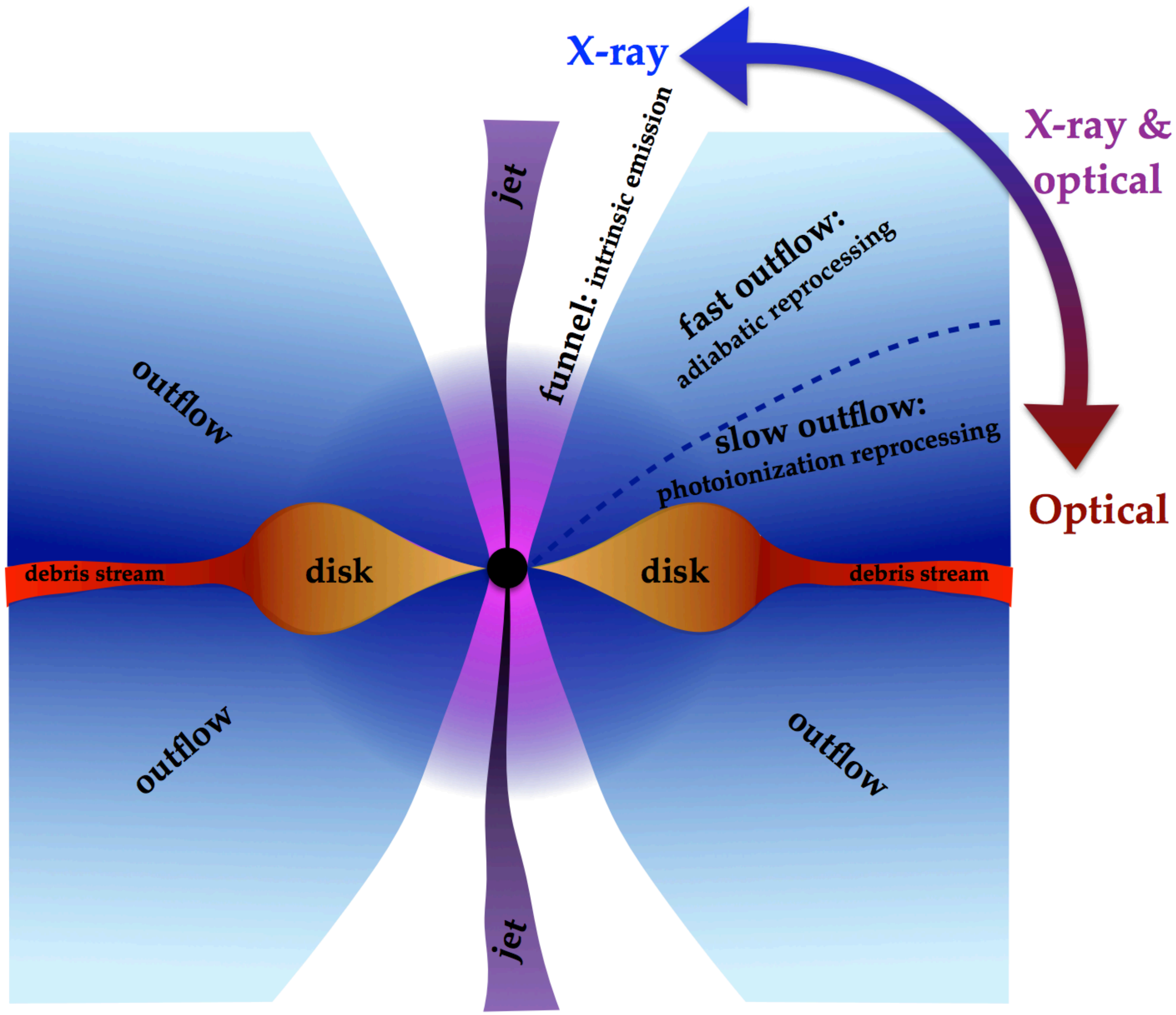
Where does optical continuum originate?

Stream-stream shocks



Piran et al., 2015
Shiokawa+ 2015
Jiang, Guillochon & Loeb 16
Svirski, Piran, & Krolik 17
Bonnerot, Rossi, & Lodato 17

Super-Eddington outflow



Loeb & Ulmer 1997
Lodato & Rossi 2011
Strubbe & Quataert 09

Roth et al., 2016
Metzger & Stone 16
Dai et al., 2018

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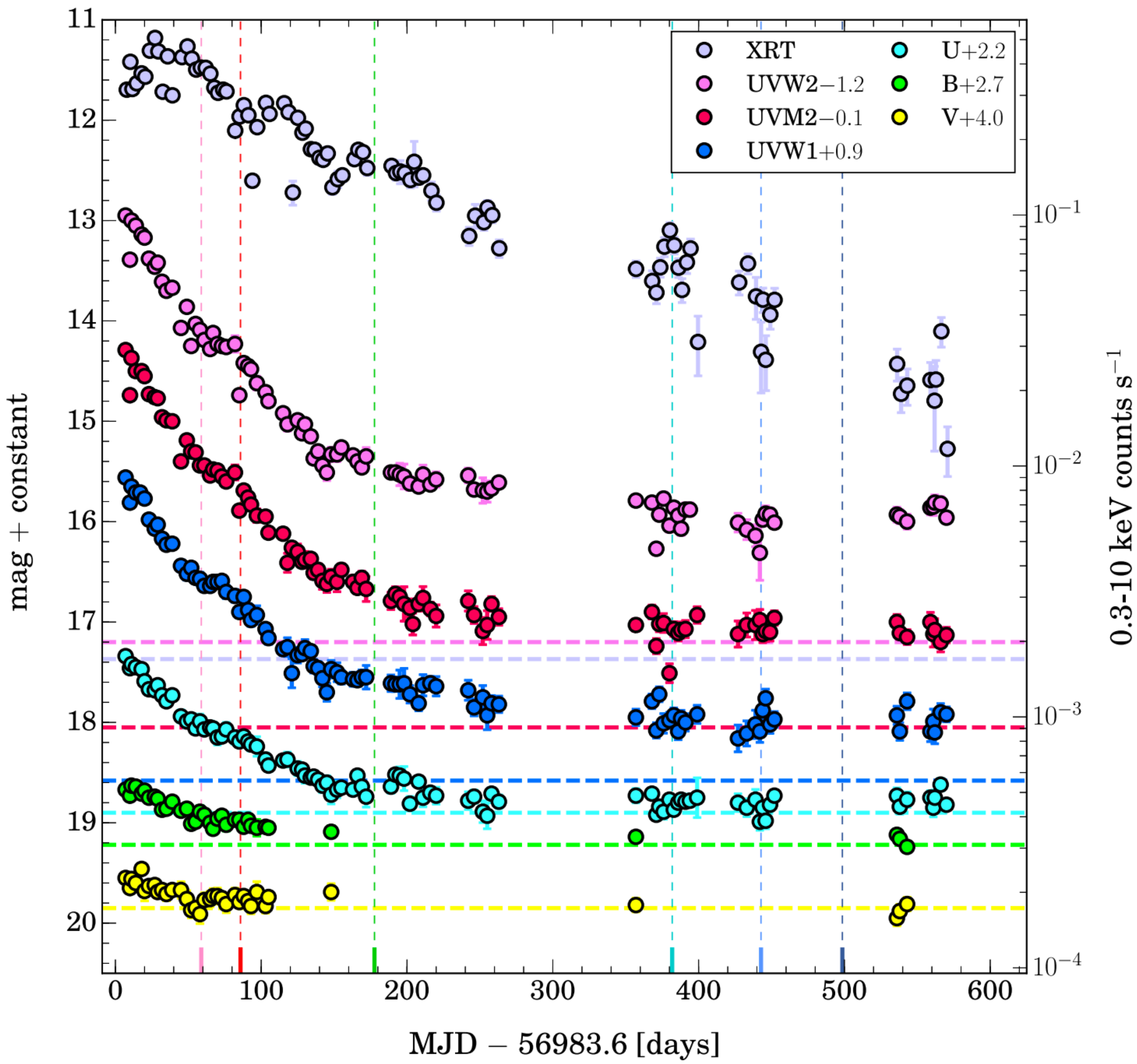
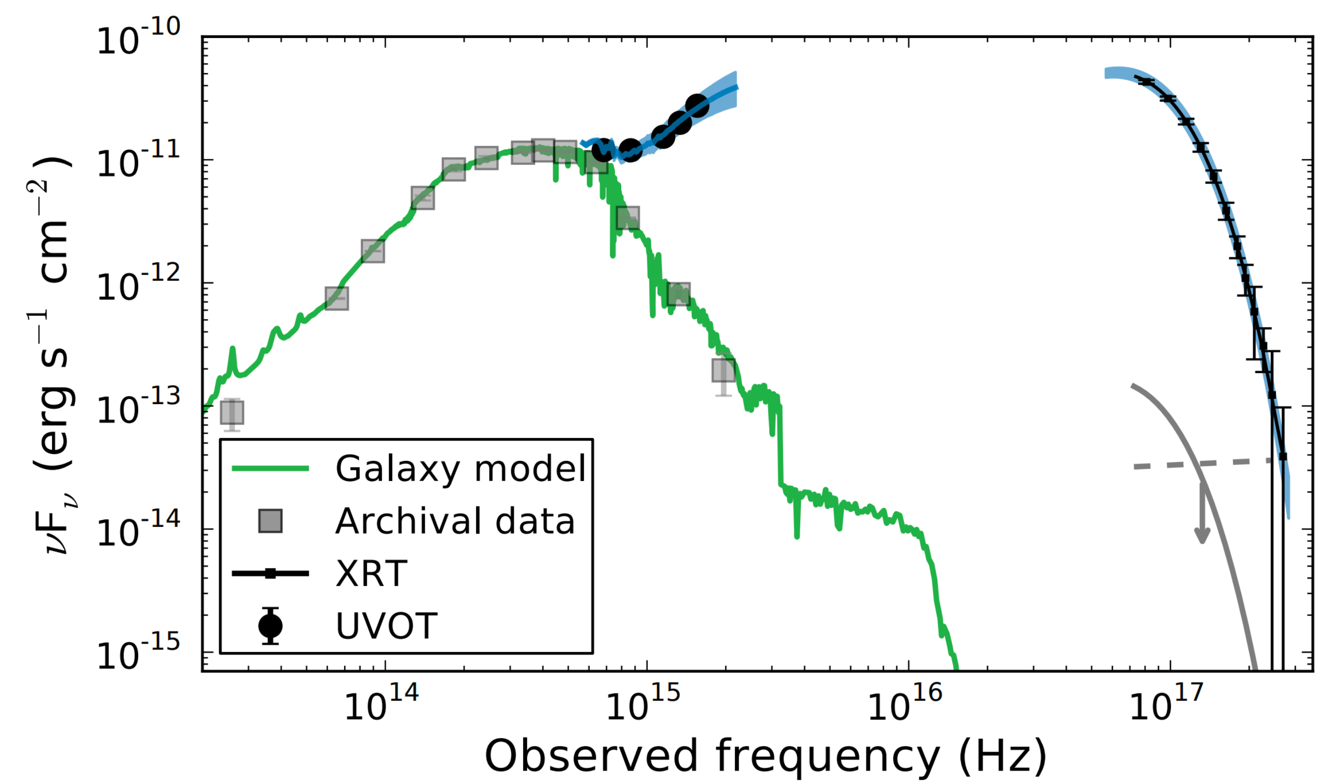
Our hallmark TDE ASASSN-14li

Nearby at 90 Mpc



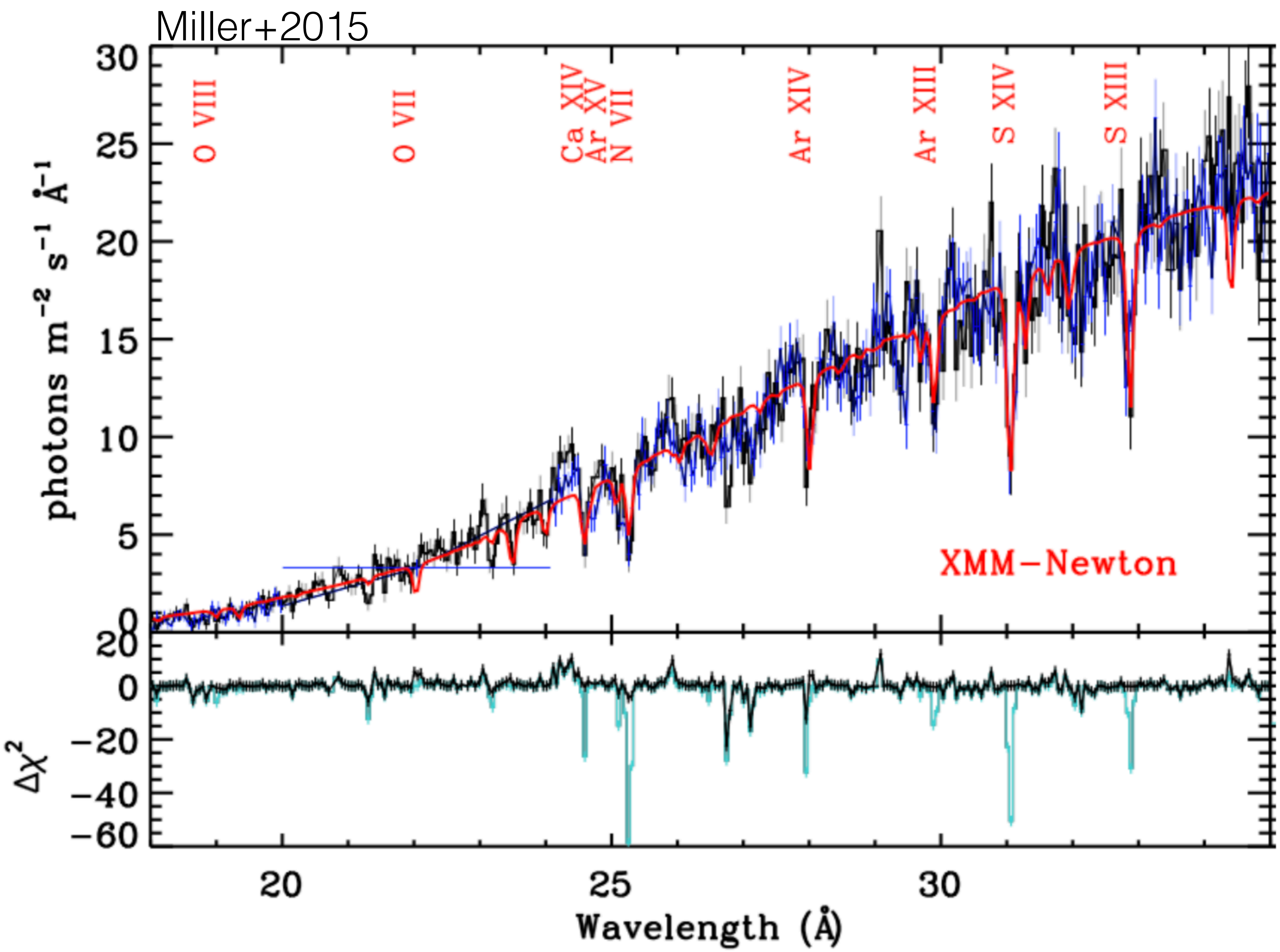
Brown et al., 2017
Holoien et al., 2016



Van Velzen et al., *Science*, 2016

Soft X-ray emission
~10^5 K blackbody
(no emission above ~1 keV)

ASASSN-14li with XMM/RGS



Highly ionised plasma log(Xi)~3

Narrow line widths (50-100 km/s)

Gas spans a narrow range of radii

Change in velocity on timescales of tens of ks

Gas within 10^4 GM/c²

Low outflow velocity (150-350 km/s)

$v < v_{escape}$ @ 10^4 GM/c²

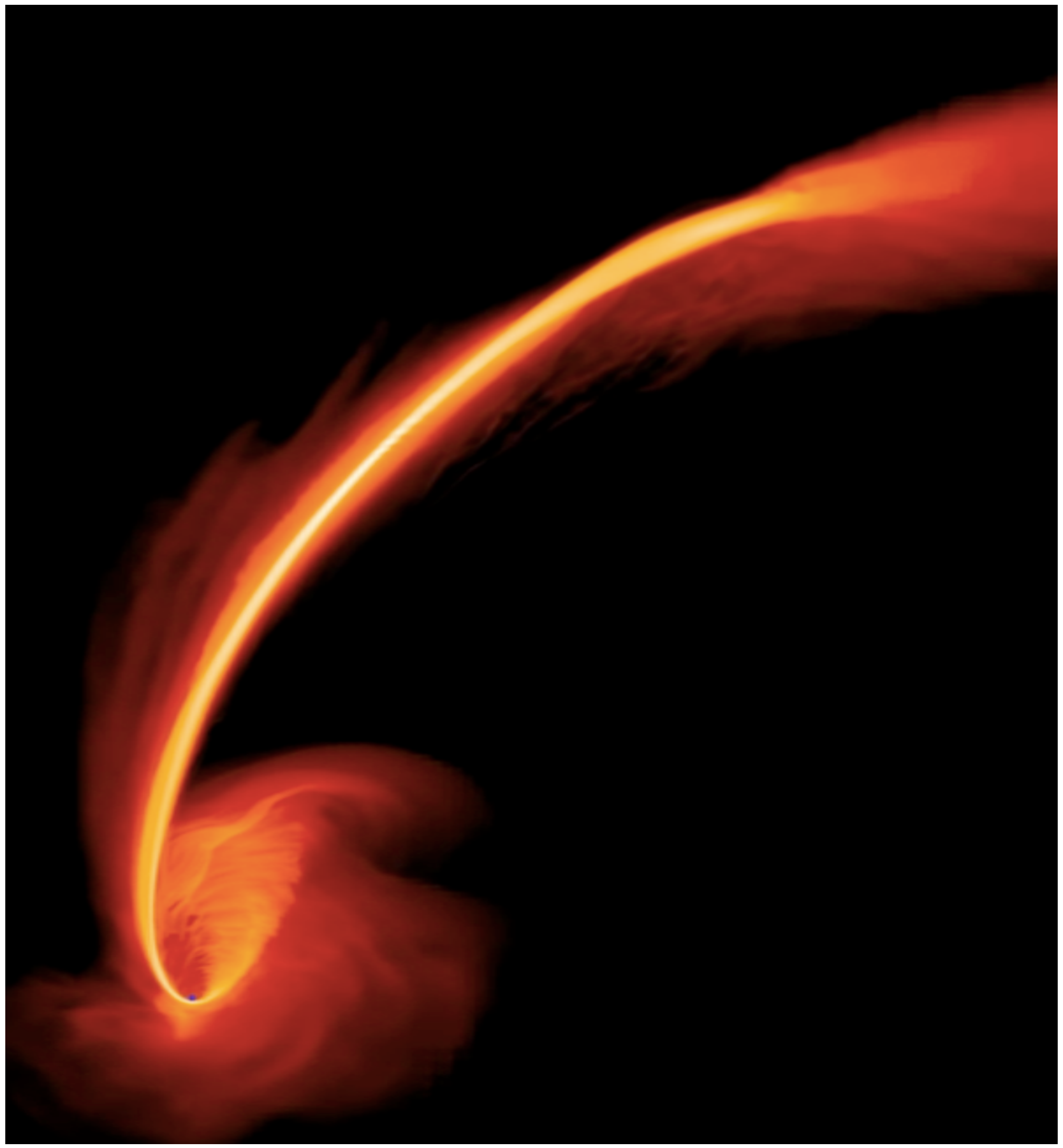
Super-Eddington disc wind

or

absorption through stellar debris filament

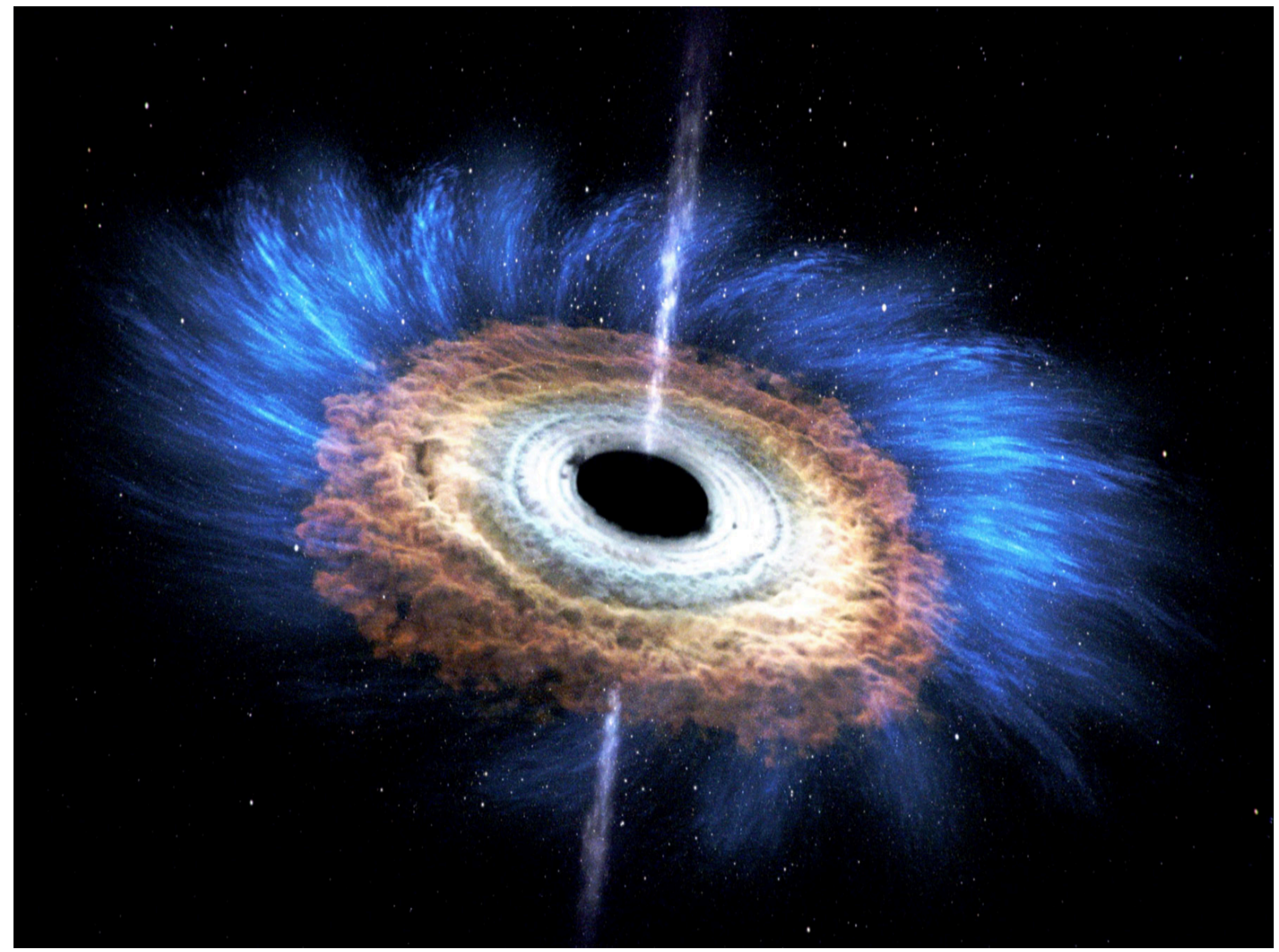
Origin of the narrow X-ray lines

Debris filaments at apocenter



Requires special geometry

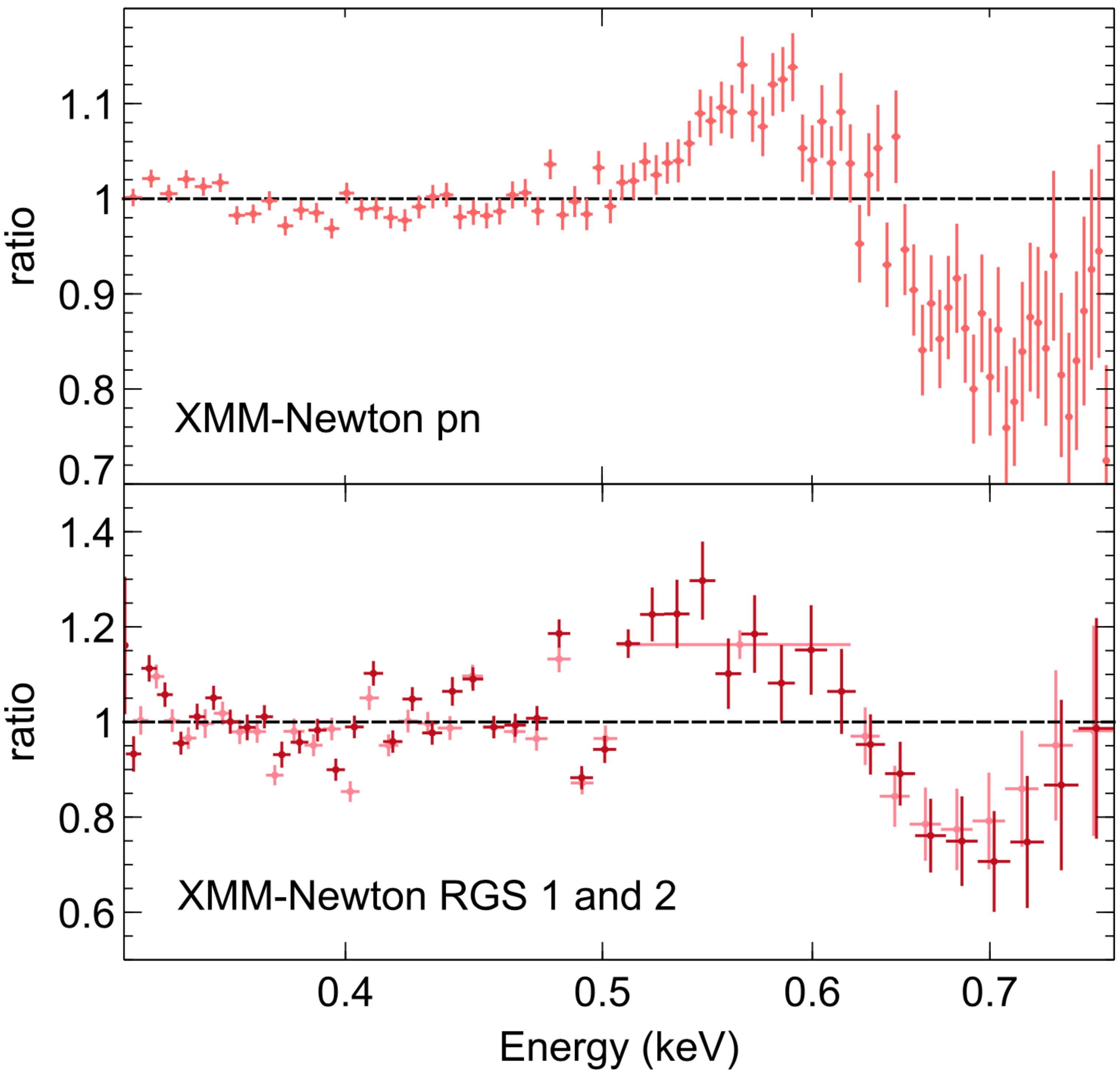
Super-Eddington disc wind



Doesn't explain low velocity or low column density

Potenital Ultrafast Outflow in ASASSN-14li

Kara et al., 2018



Caution—this is just one line

Highly ionised plasma log(Xi)~3

Broad line widths (~20,000 km/s)

Gas spans a wide range of radii, large filling factor

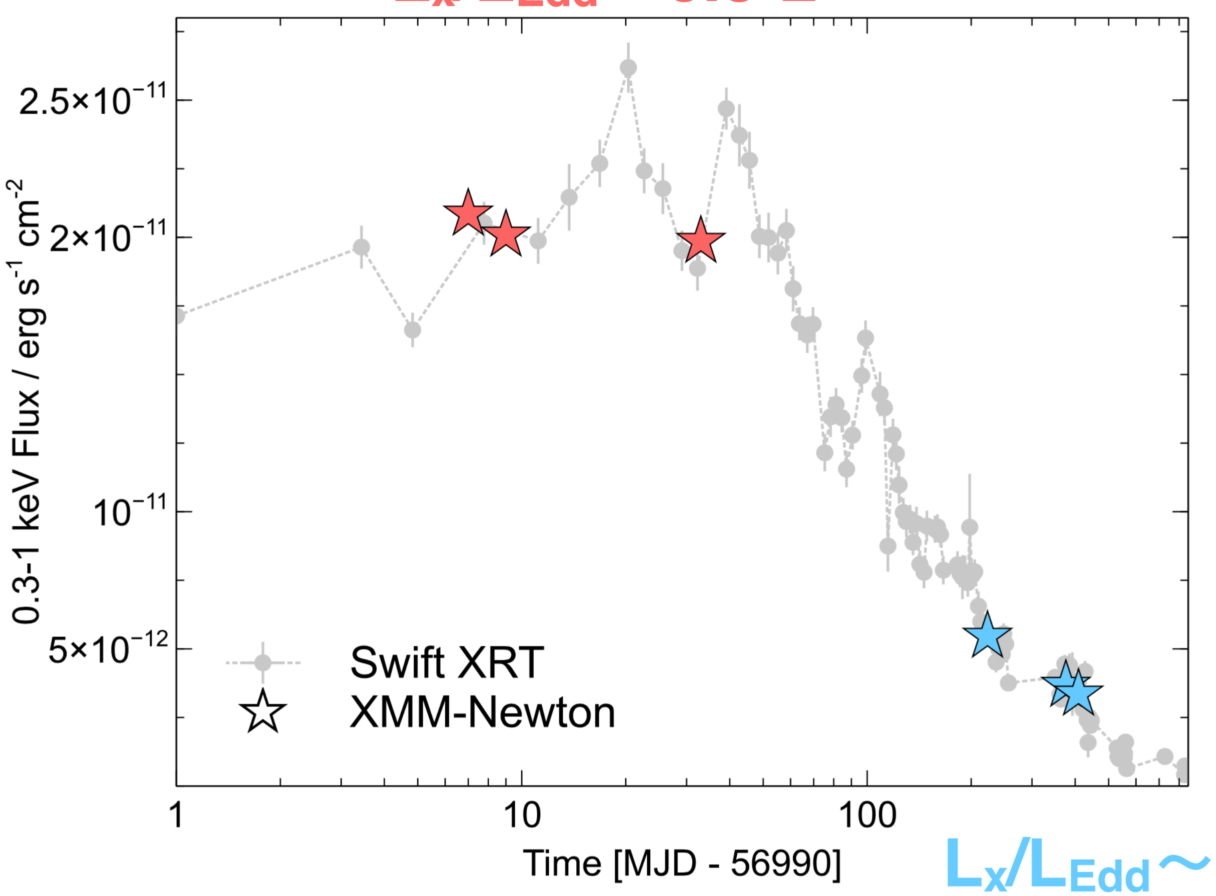
OVII blueshifted by 0.2c

v_{escape} @ 20 GM/c²

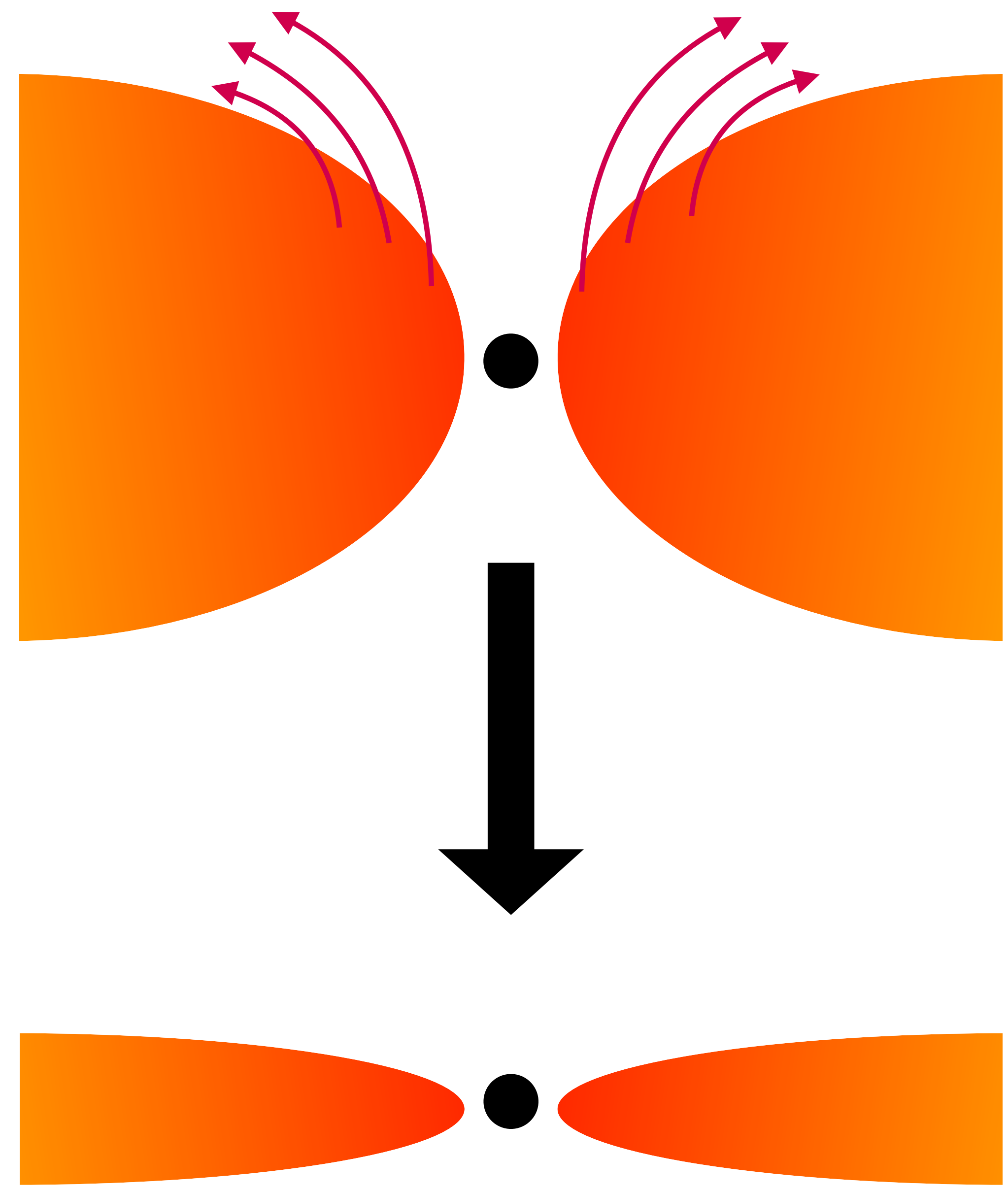
Evidence for change in accretion flow structure?

Outflows not present at late times

$L_X/L_{Edd} \sim 0.5\text{-}2$



$L_X/L_{Edd} \sim$ 0.05-0.2



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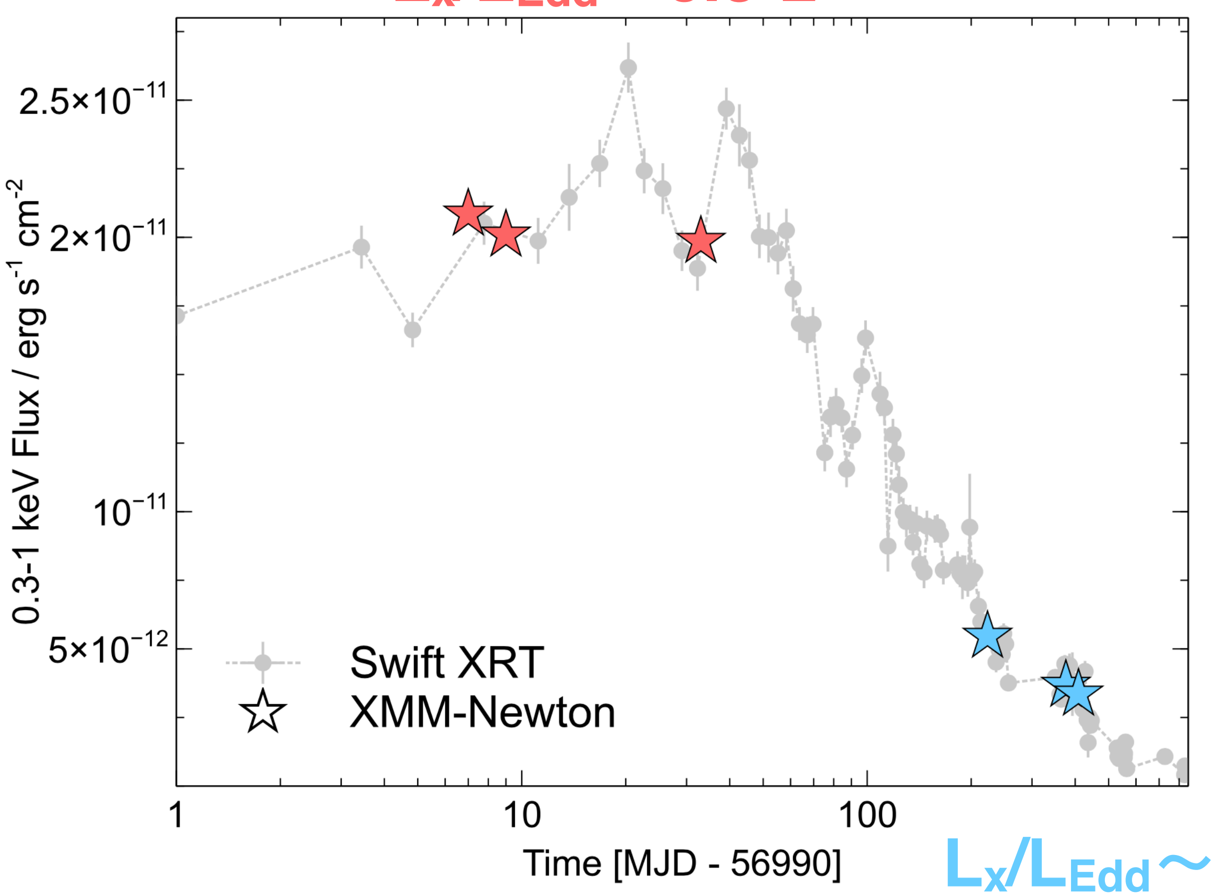

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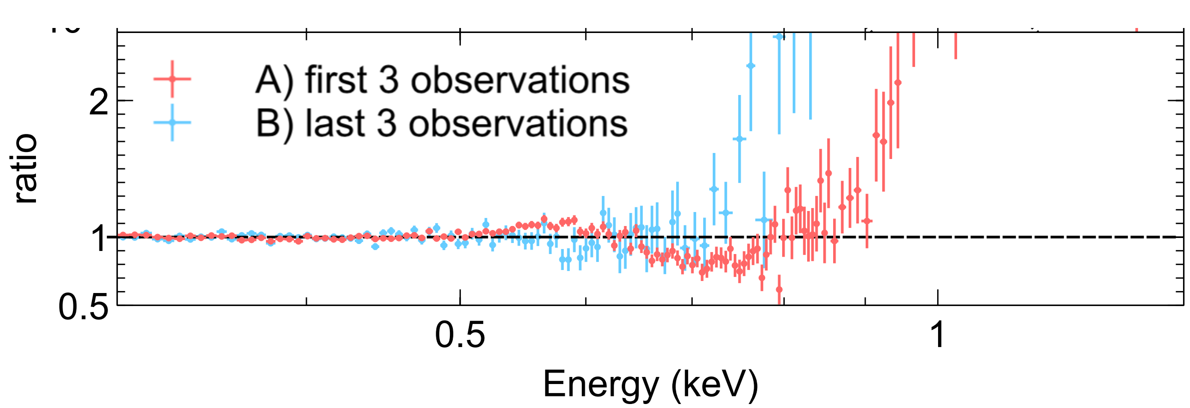

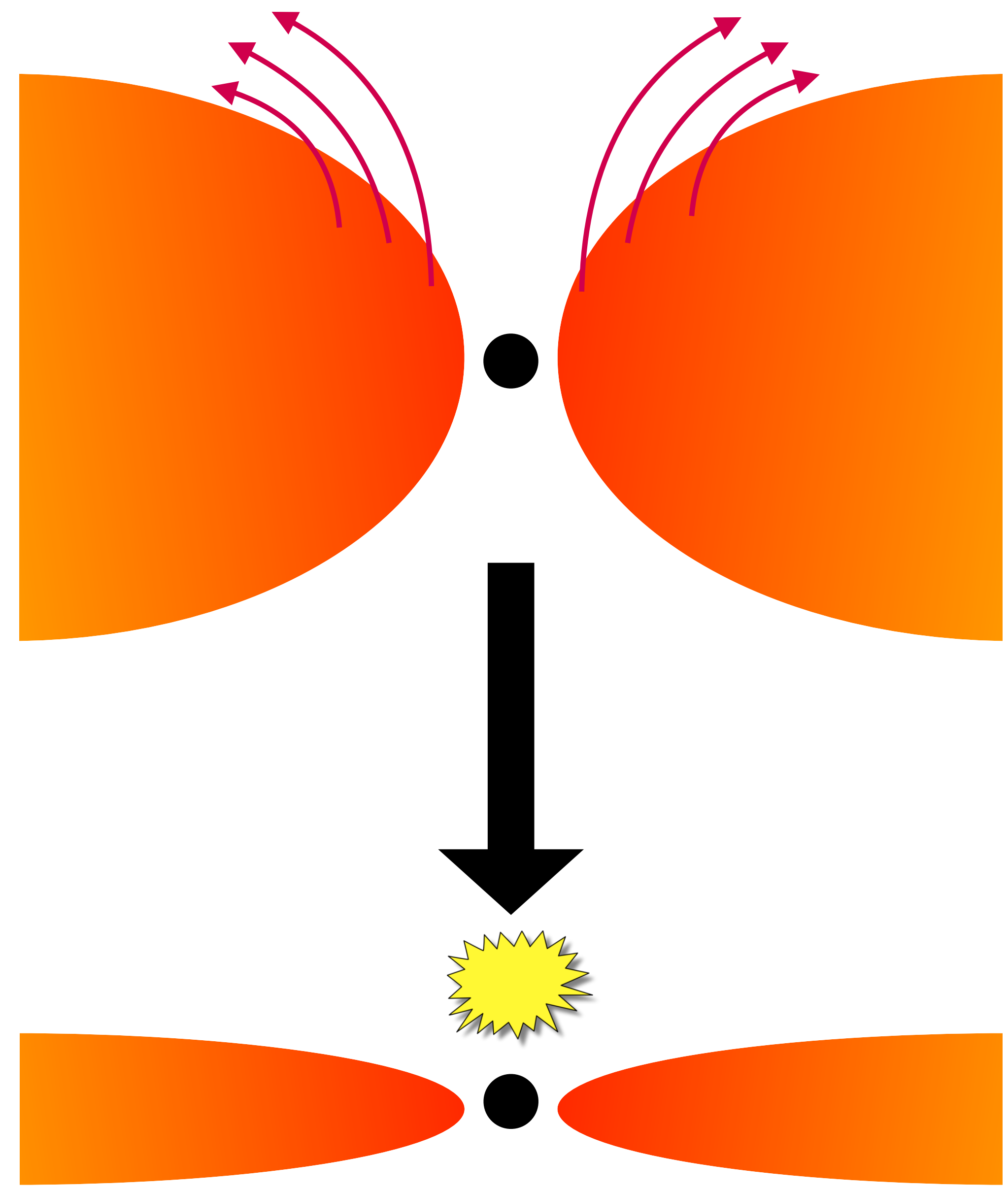

Consistent with the emergence of a hard X-ray component

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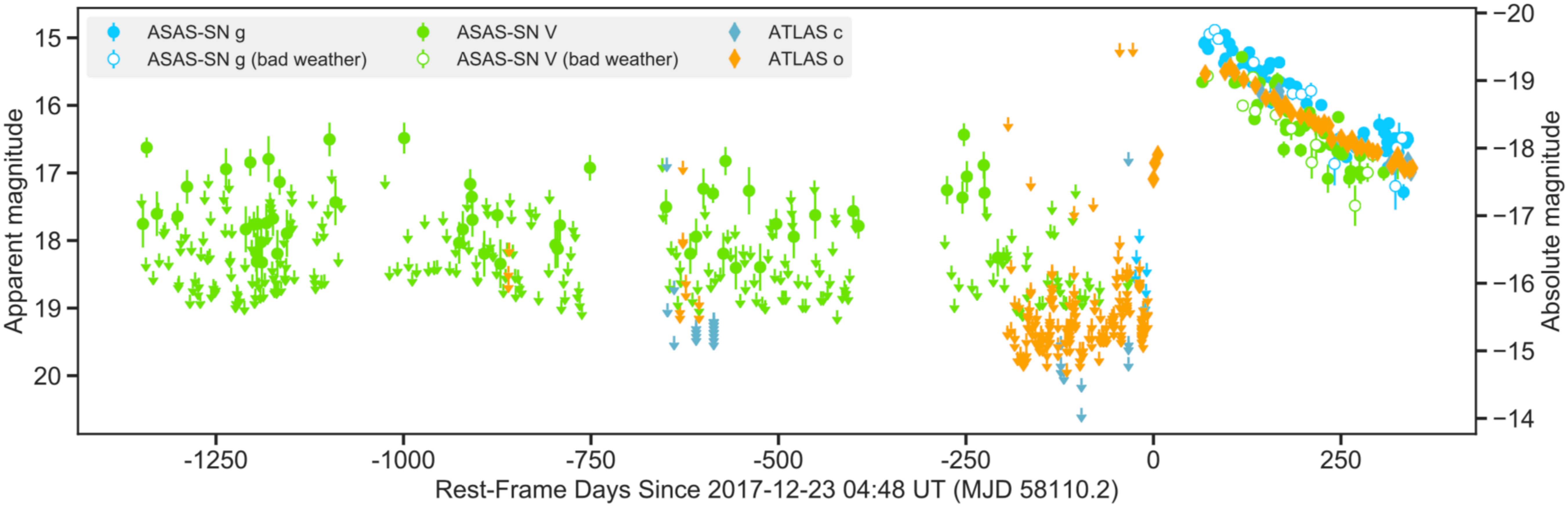
The ongoing story of 1ES 1927+654

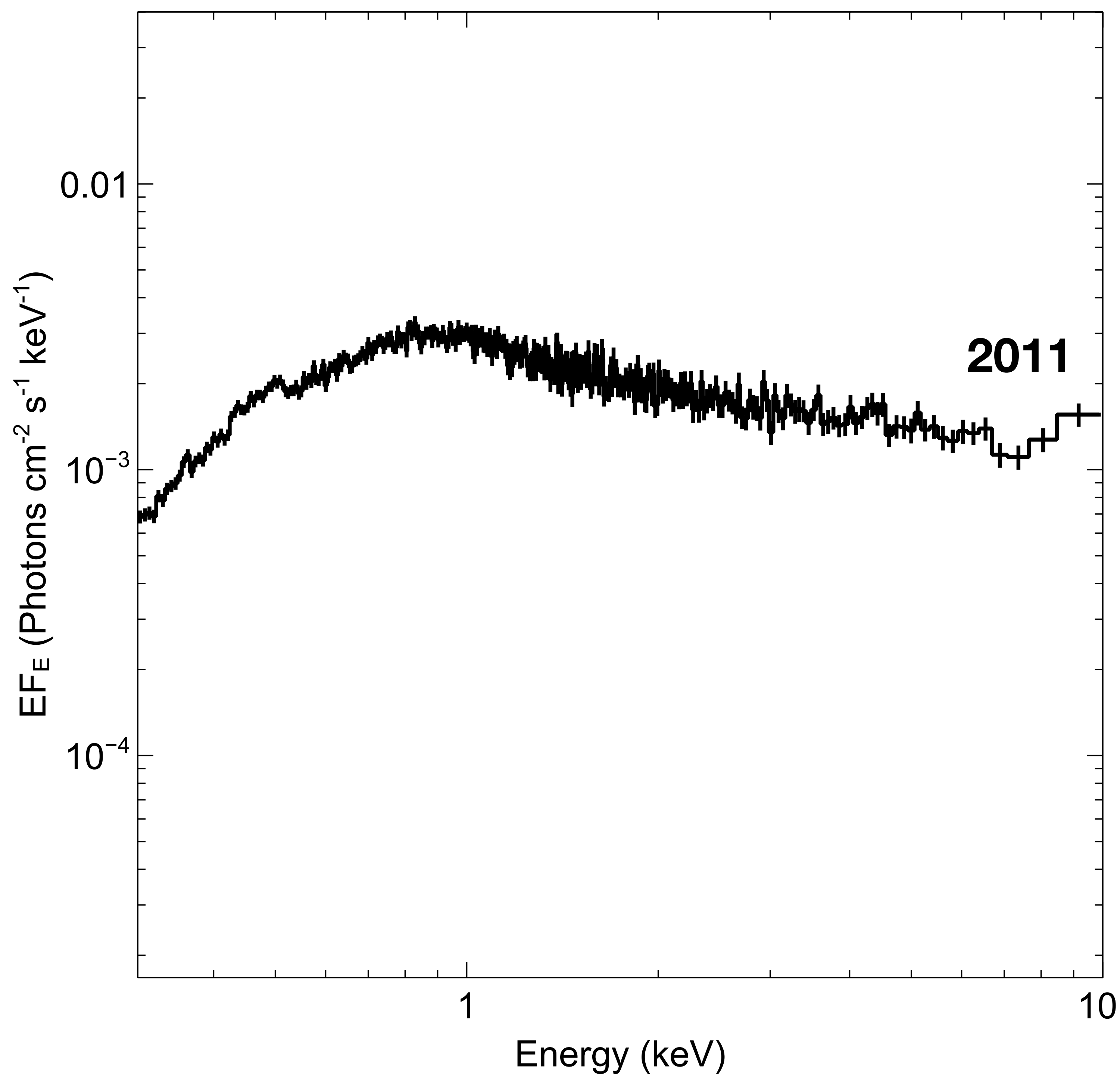
March 3, 2018:
ASAS-SN detects nuclear transient ASASSN18el



What do we know about this galaxy?

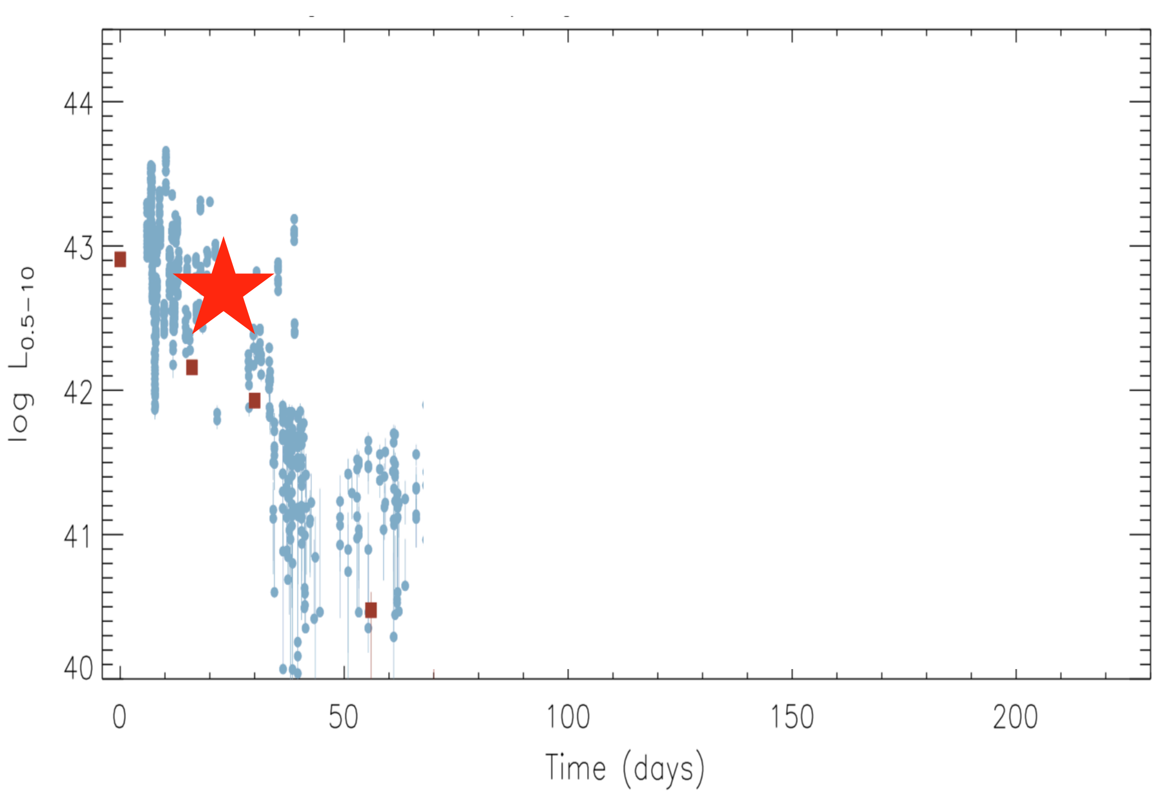
See optical/UV spectral evolution in Trakhtenbrot et al., 2019b

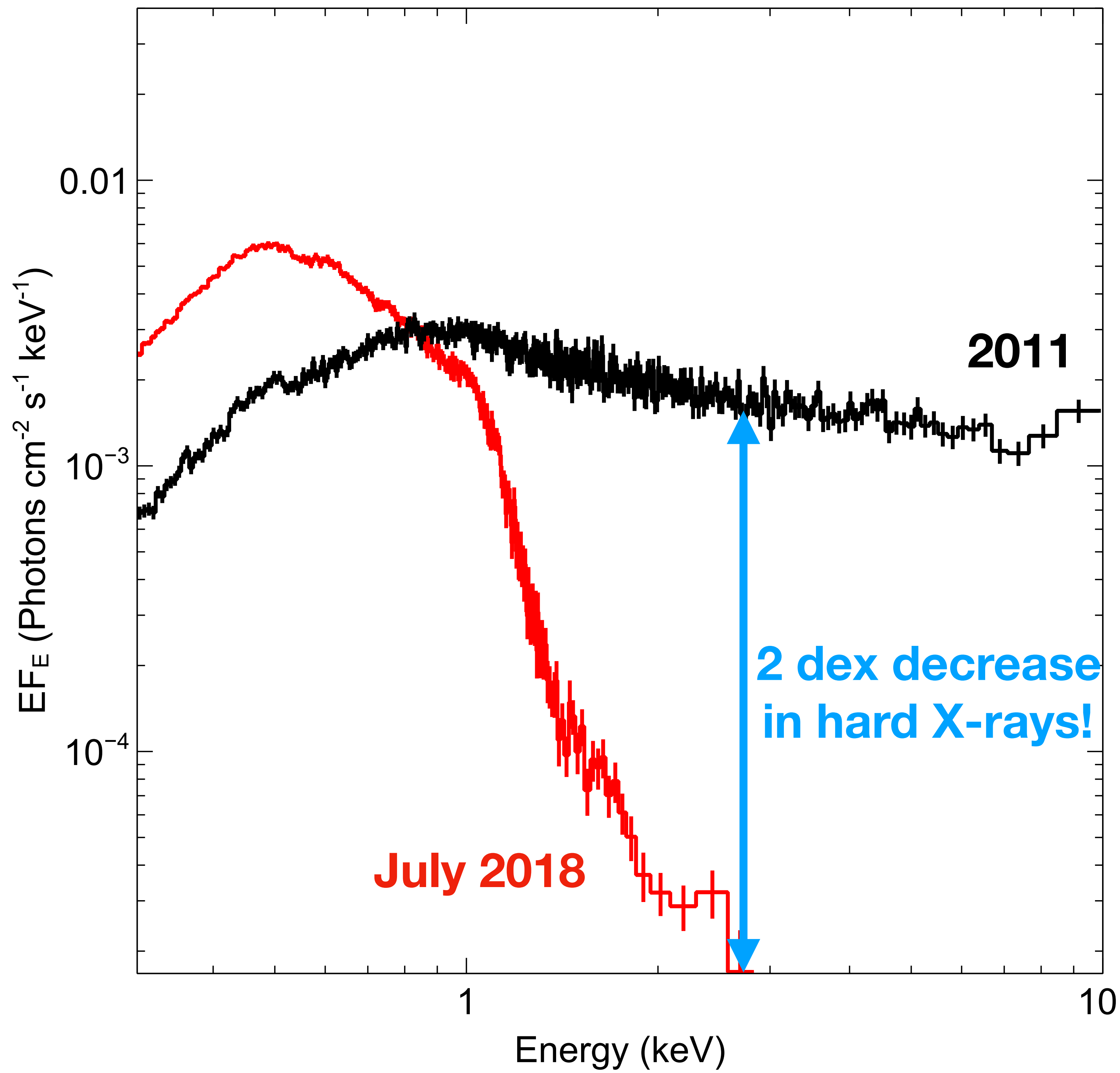
a dramatic change in X-rays



Ricci, Kara, Loewenstein + NICER Observatory Science Working Group, in prep.

a dramatic change in X-rays





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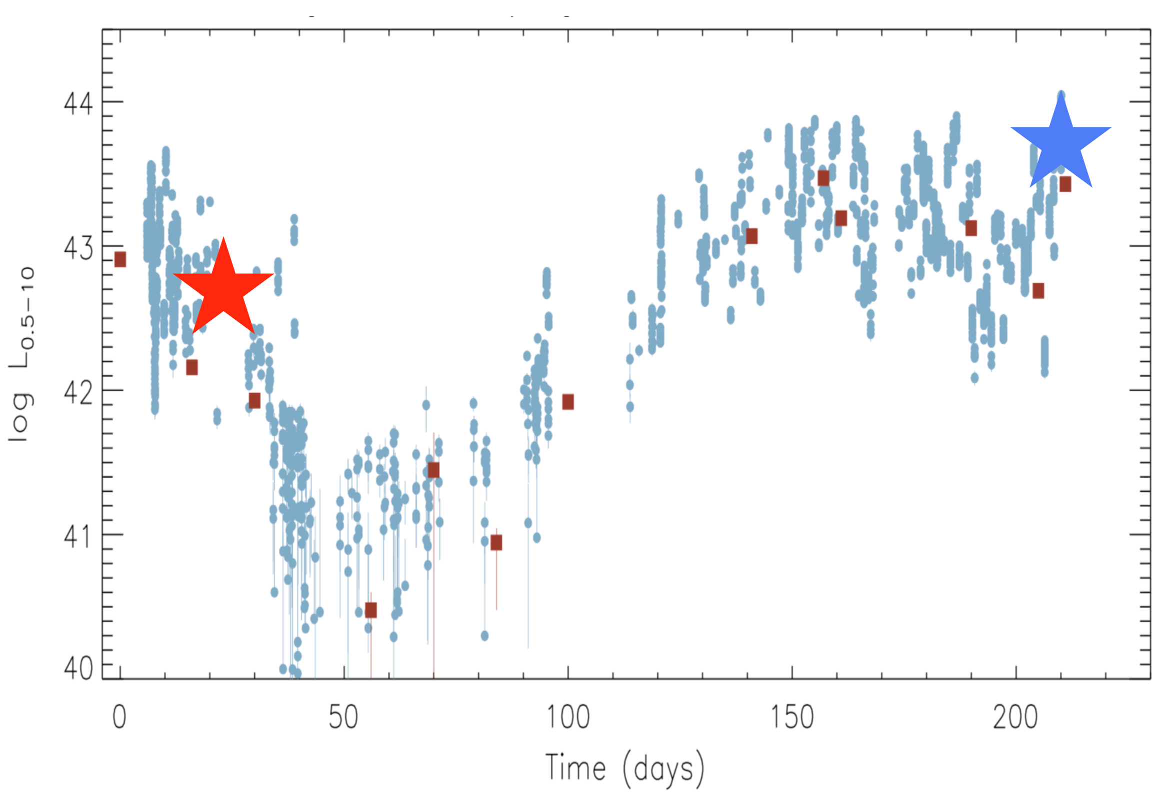

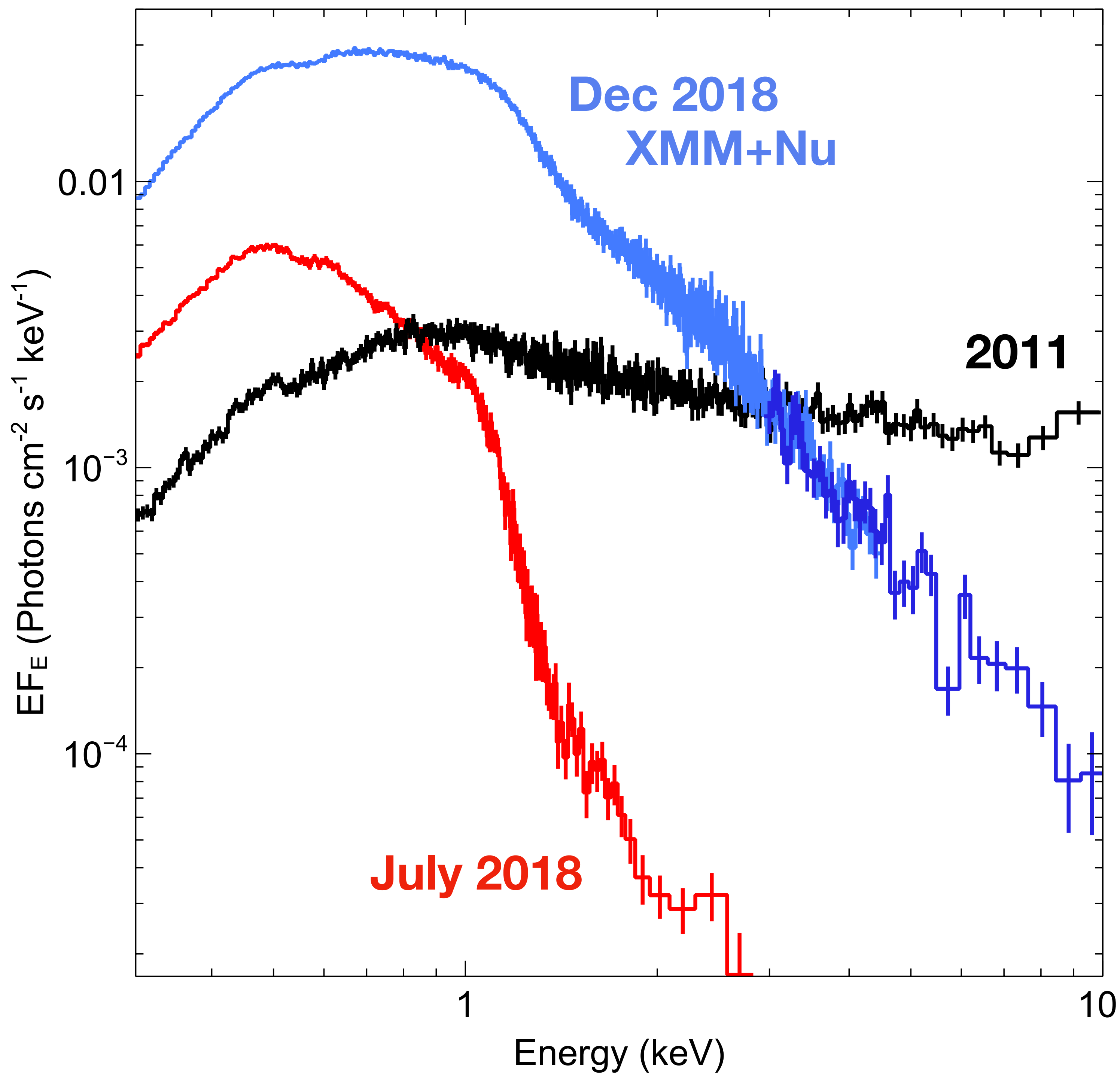

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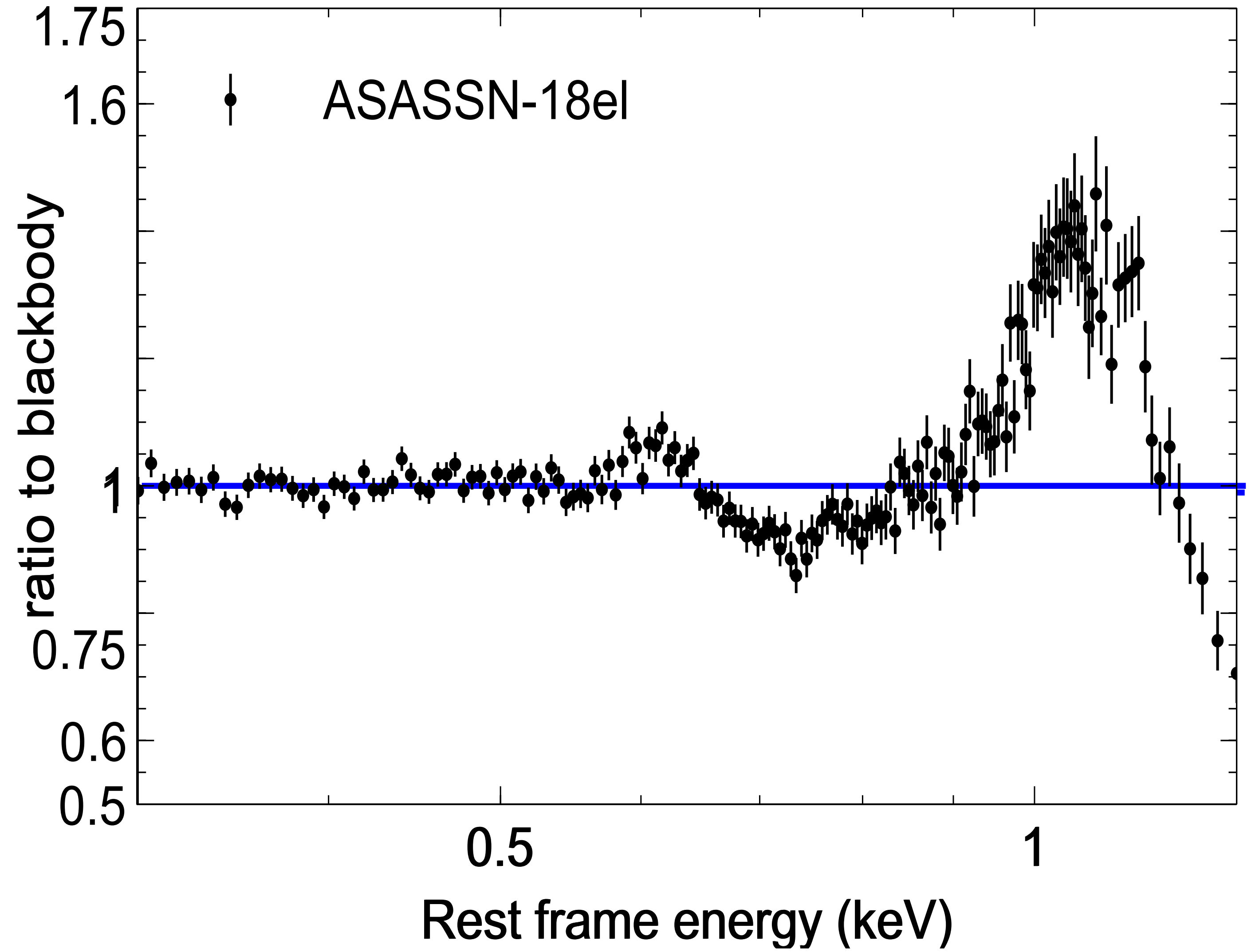
The tantalizing feature at 1 keV

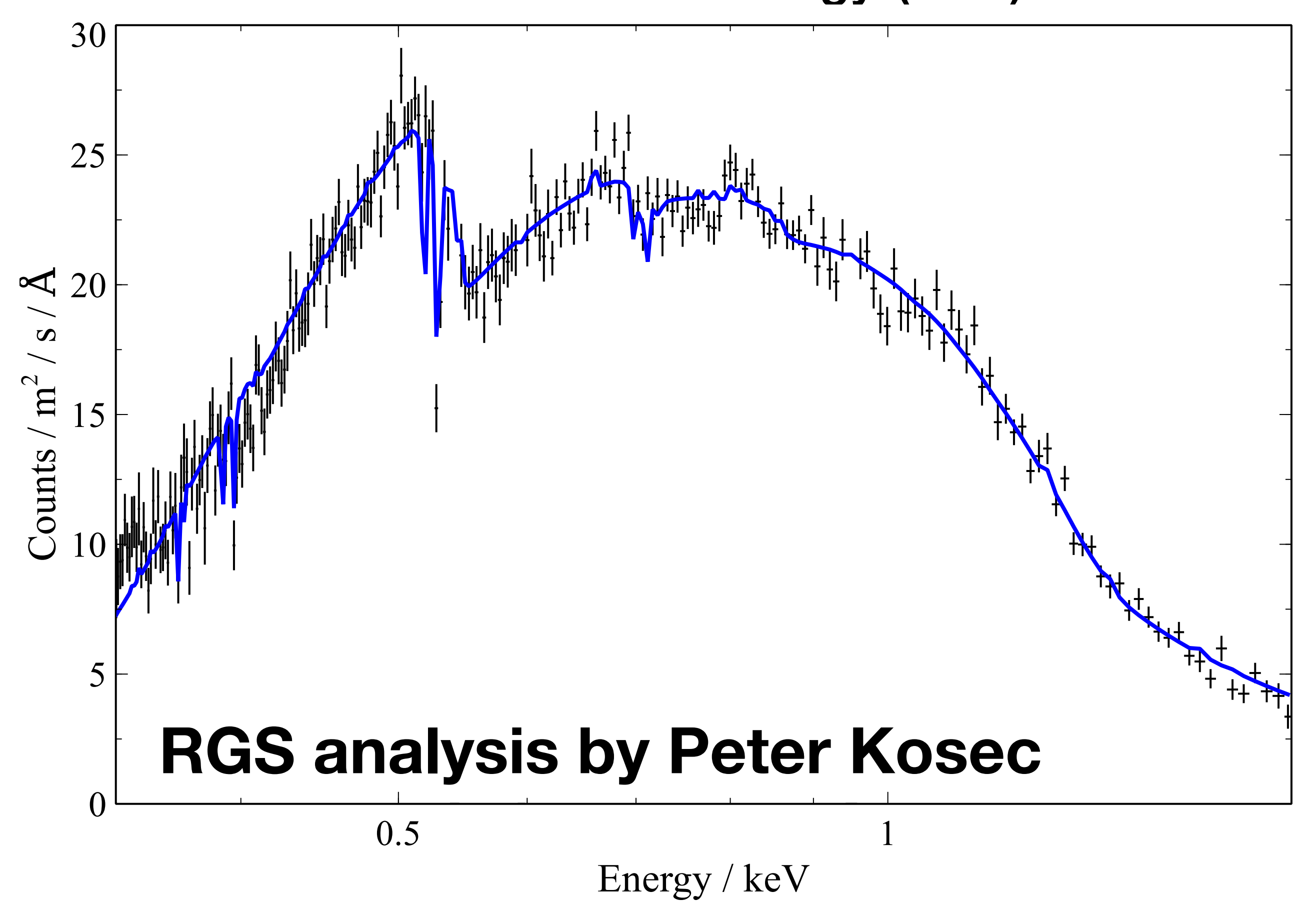
Well fit by gaussian

Not well fit by iron L from relativistic reflection



It is indeed broad

No narrow lines in RGS



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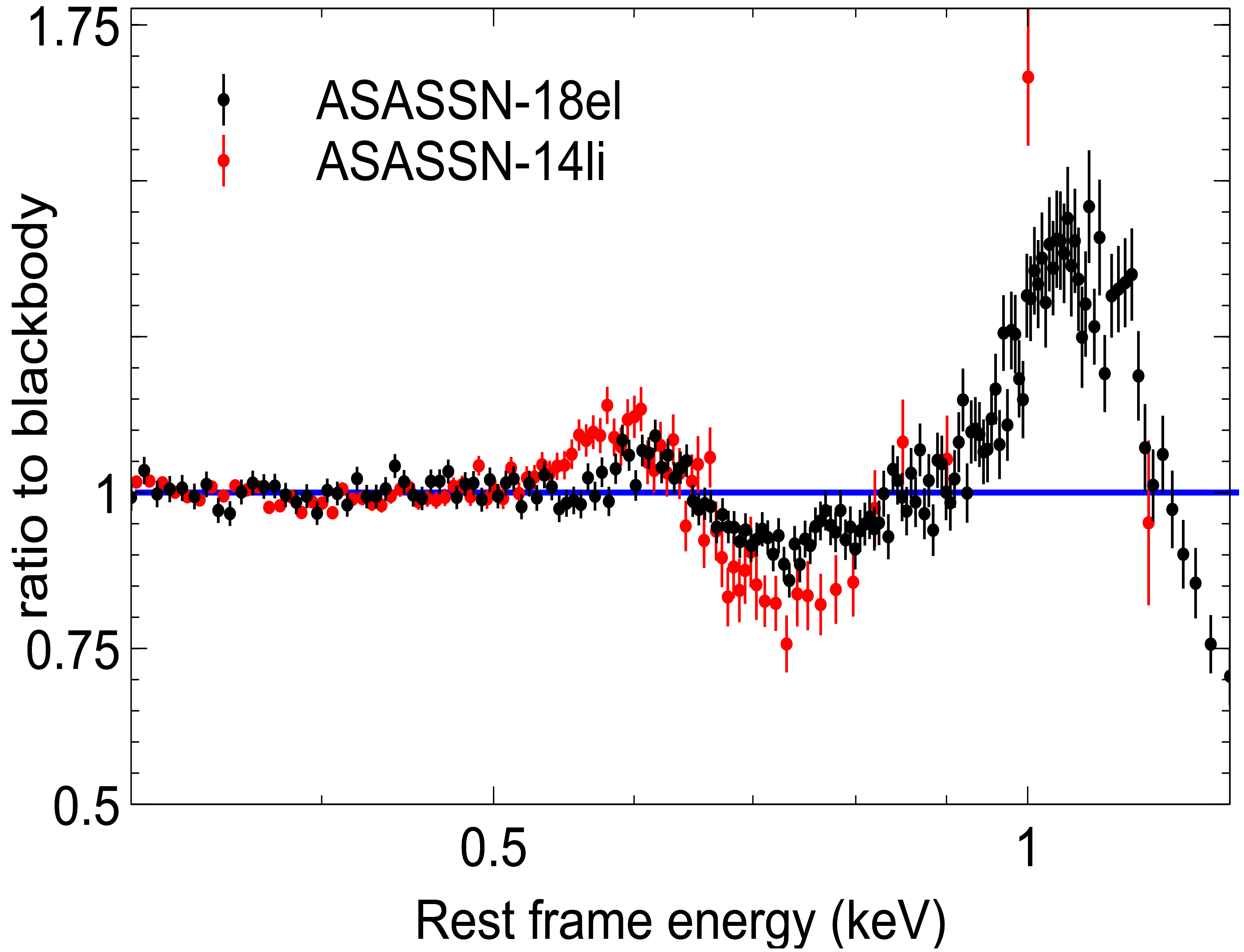
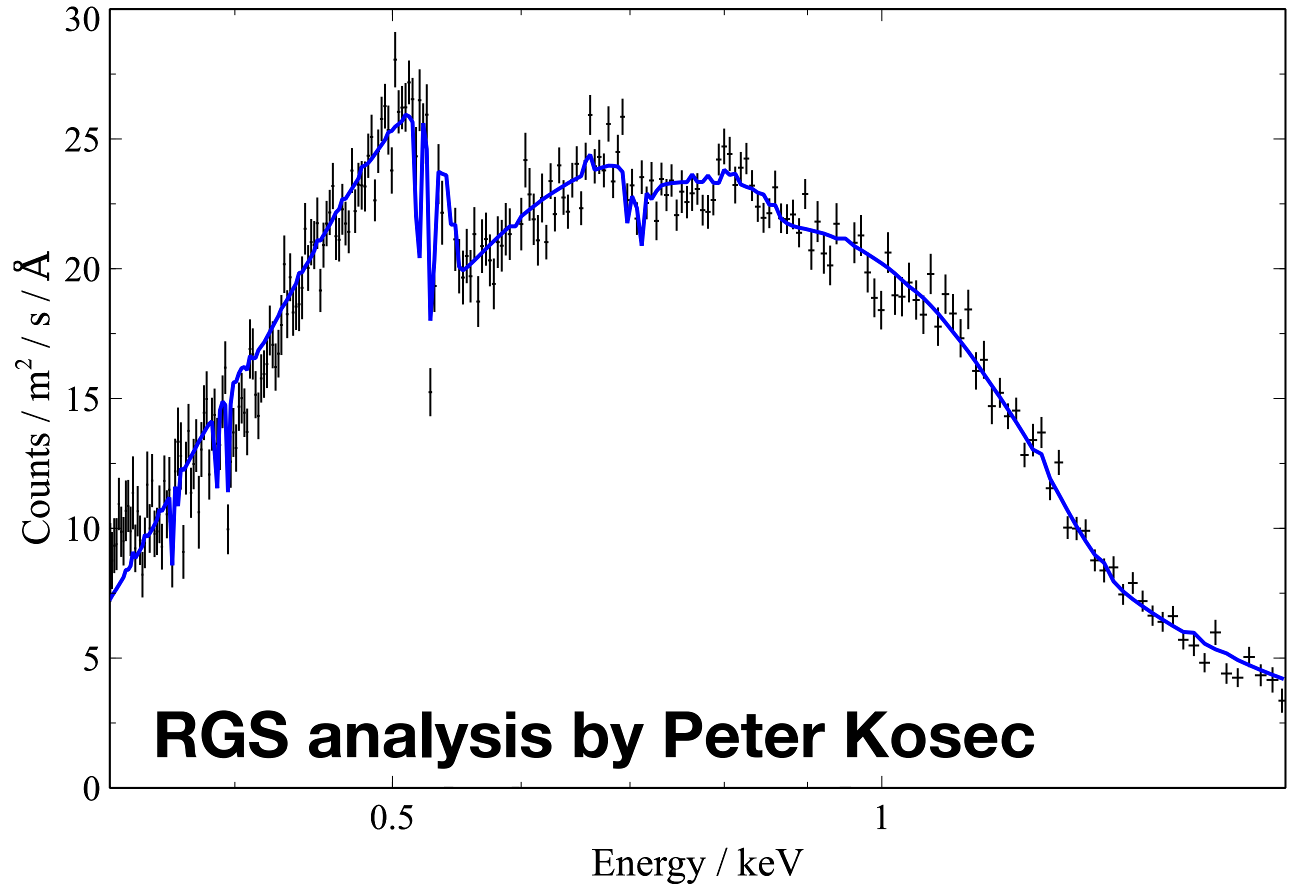
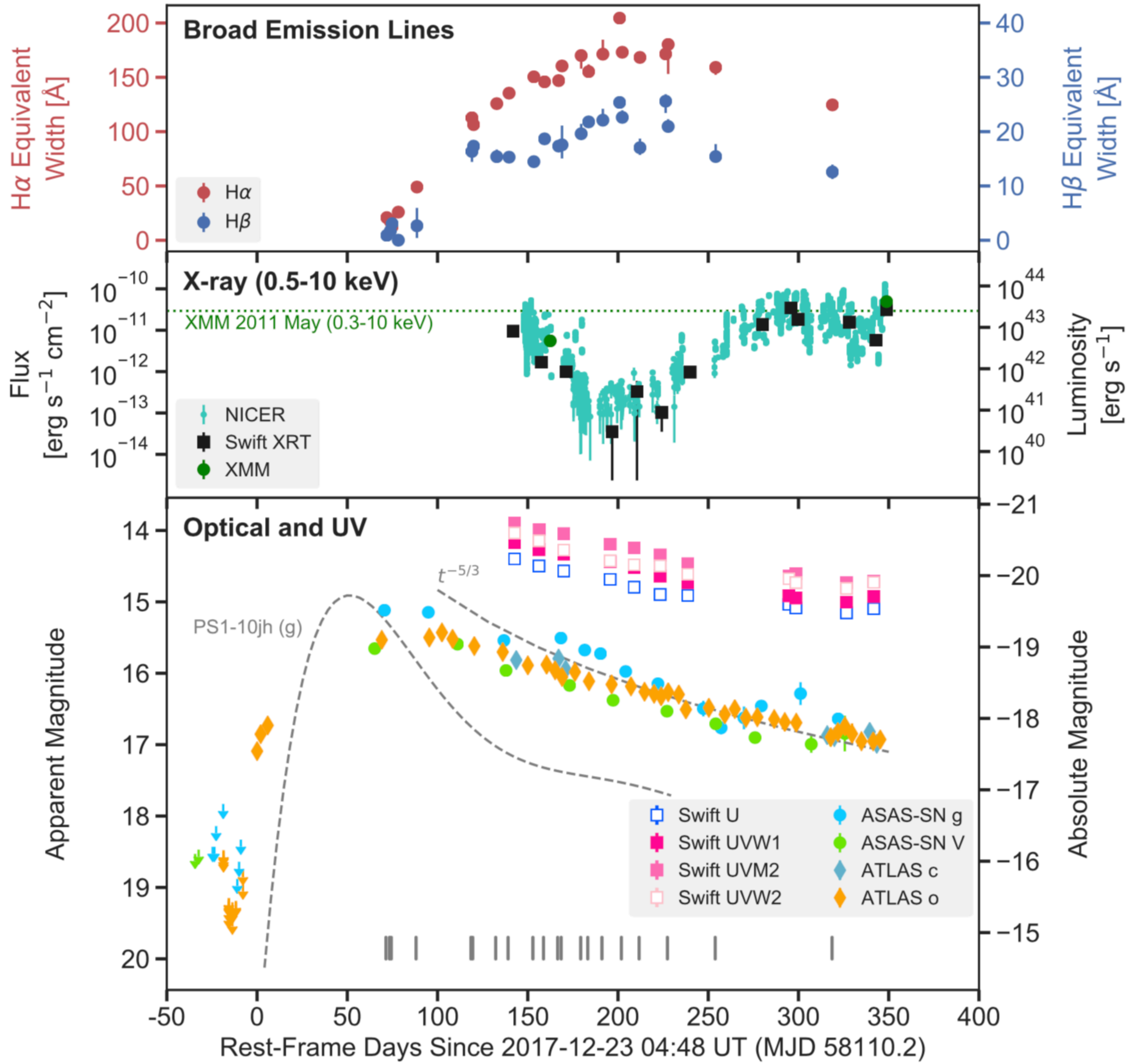






EW inversely correlated with X-ray

Optical/UV continue to fall

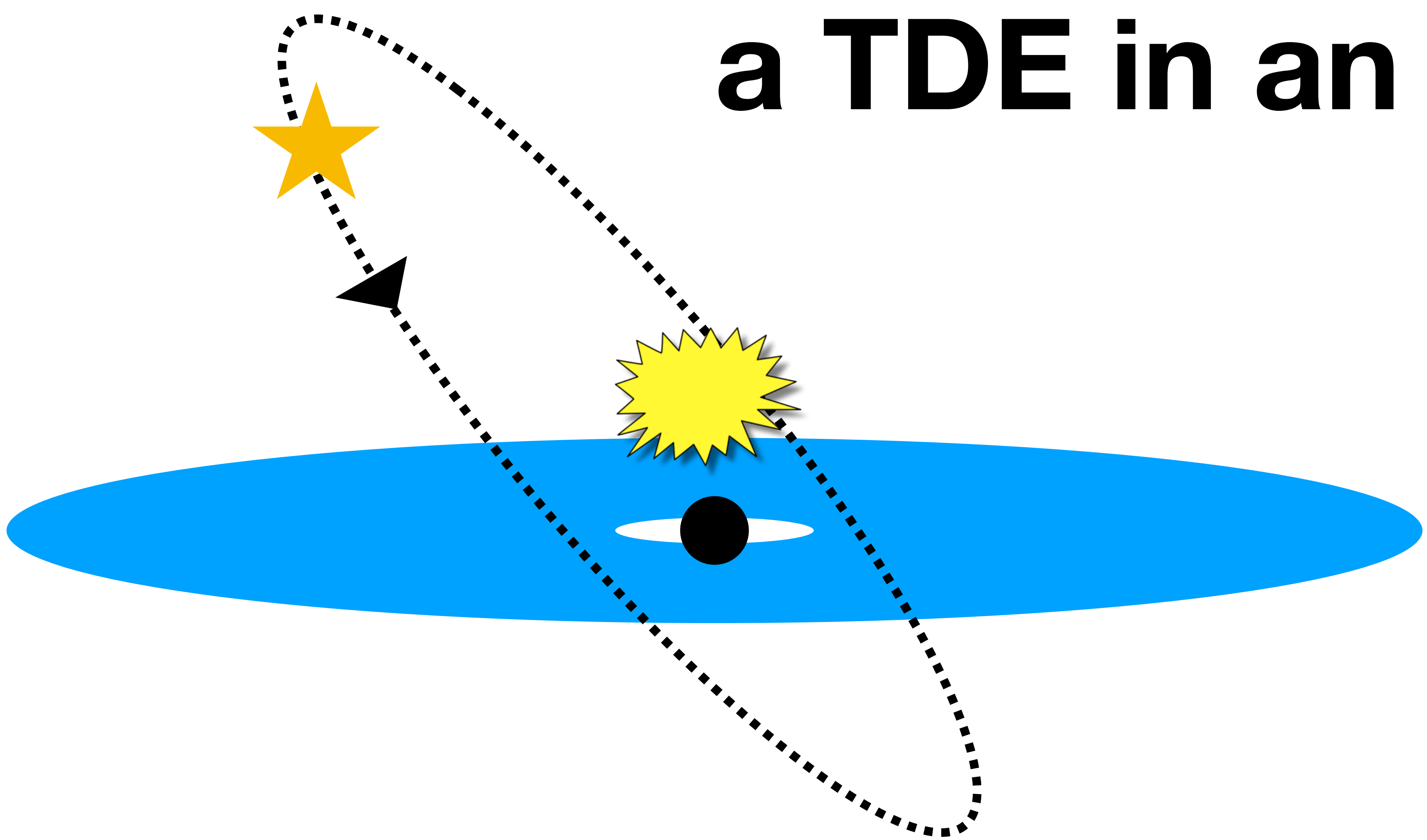
Trakhtenbrot et al., 2019b

1ES 1927+654 is a clear changing-look AGN

What's causing the change?

One possible explanation…
(not unique)

a TDE in an AGN



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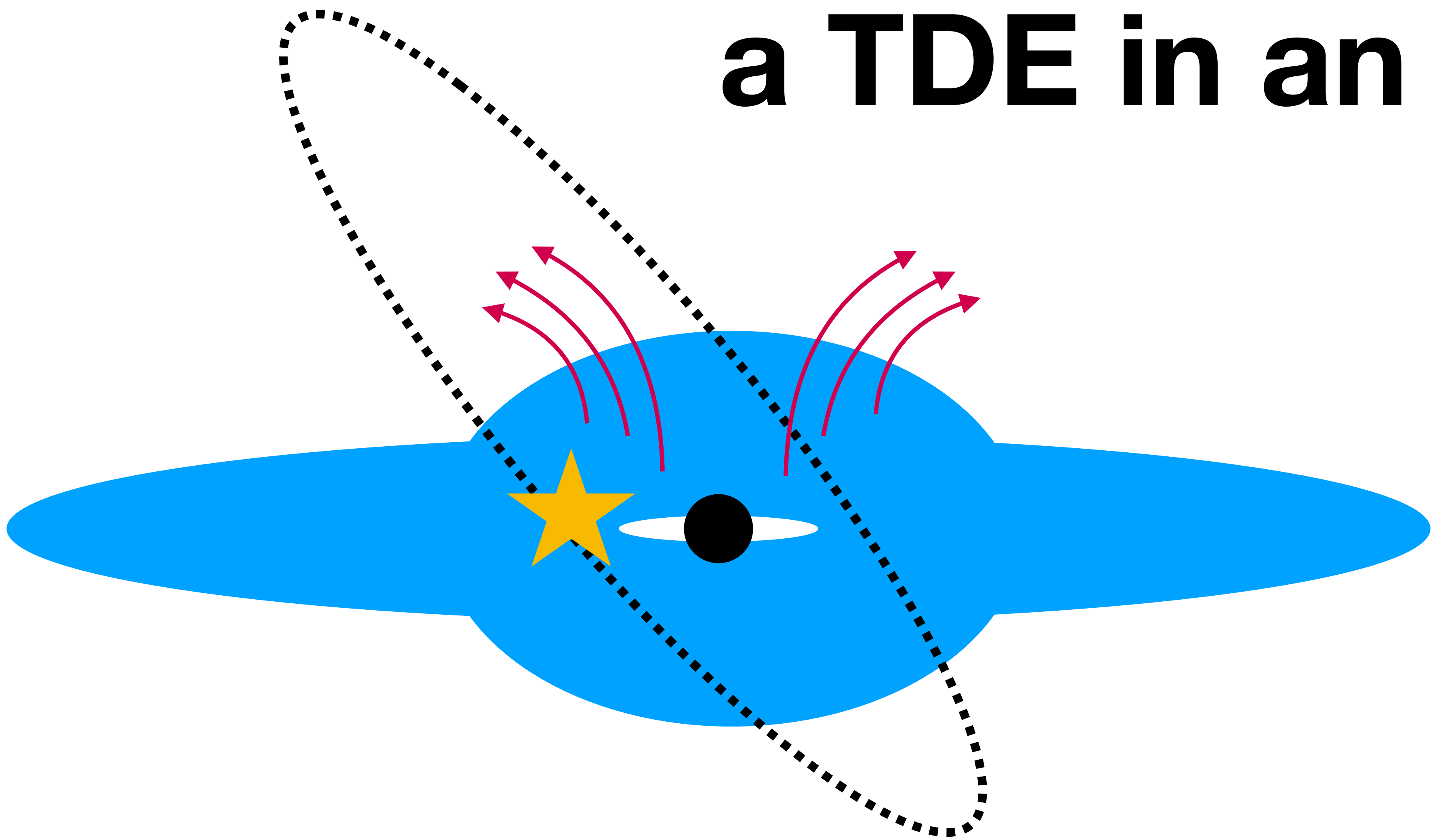

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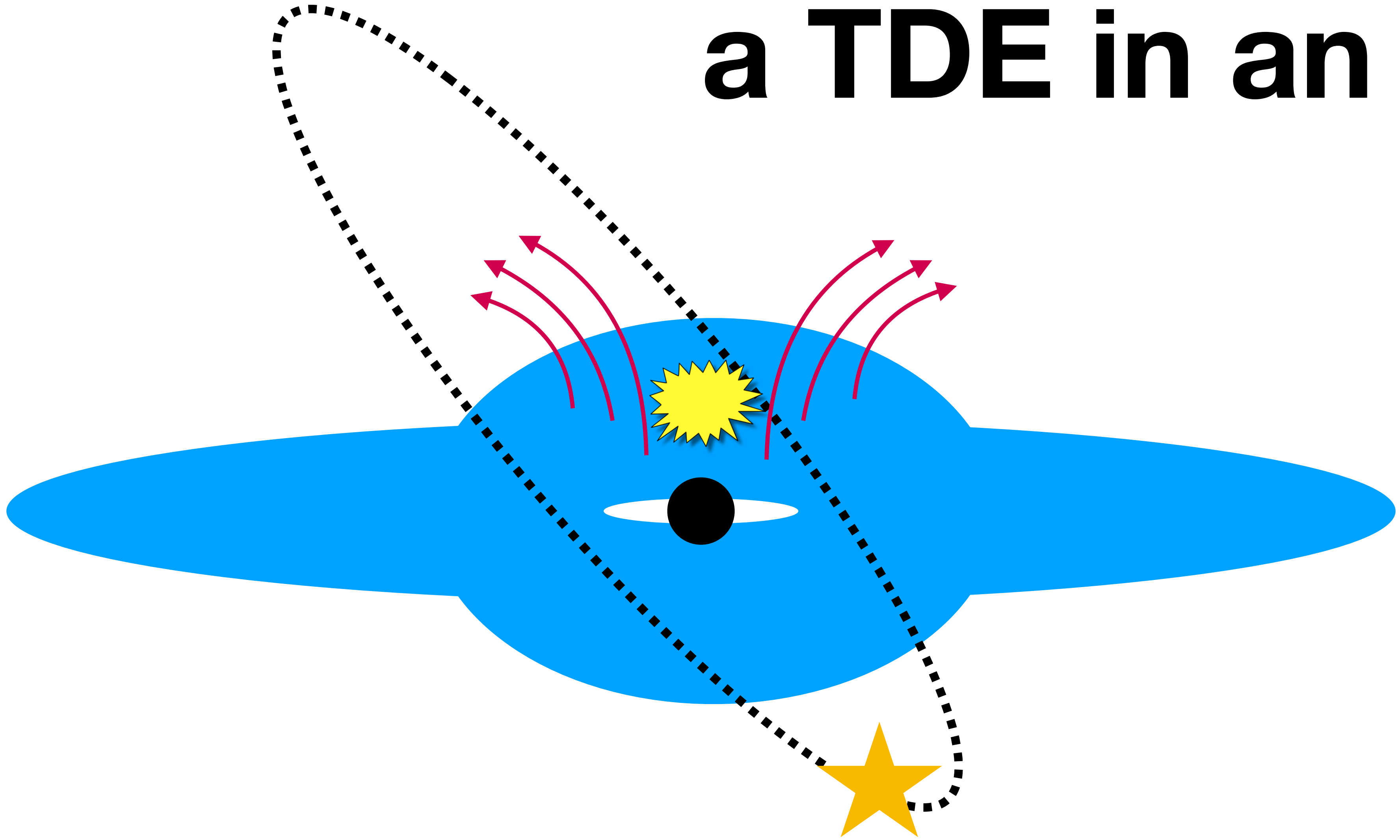

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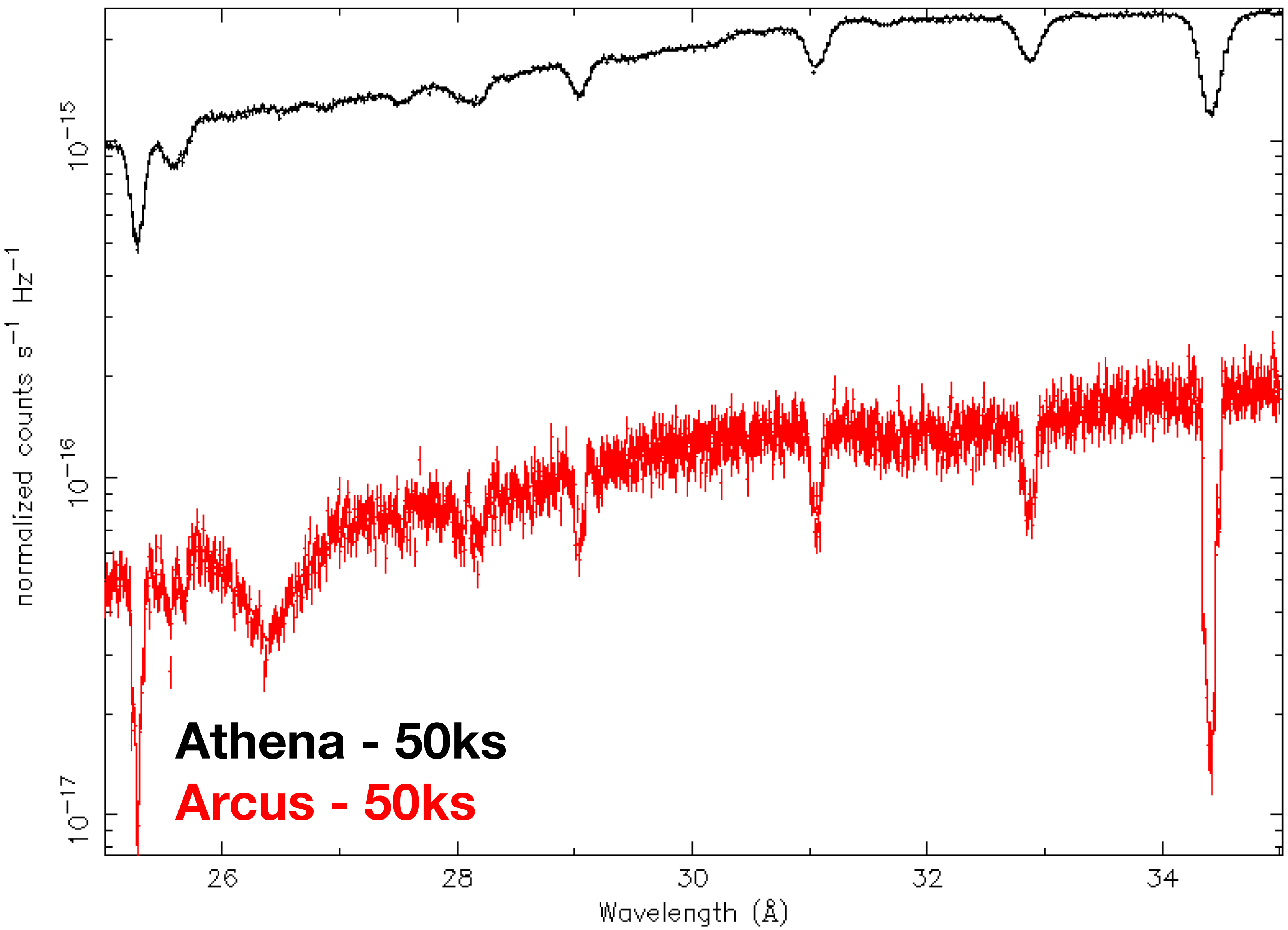
What comes next?



XRISM - 2022

>> Particularly great for hard X-ray TDEs, where iron lines have been seen (Kara+16)

Arcus - 2028

>> low-energy bandpass well suited for most TDEs

Athena - 2031

>> Broadband coverage

>> Large area allows for short observations

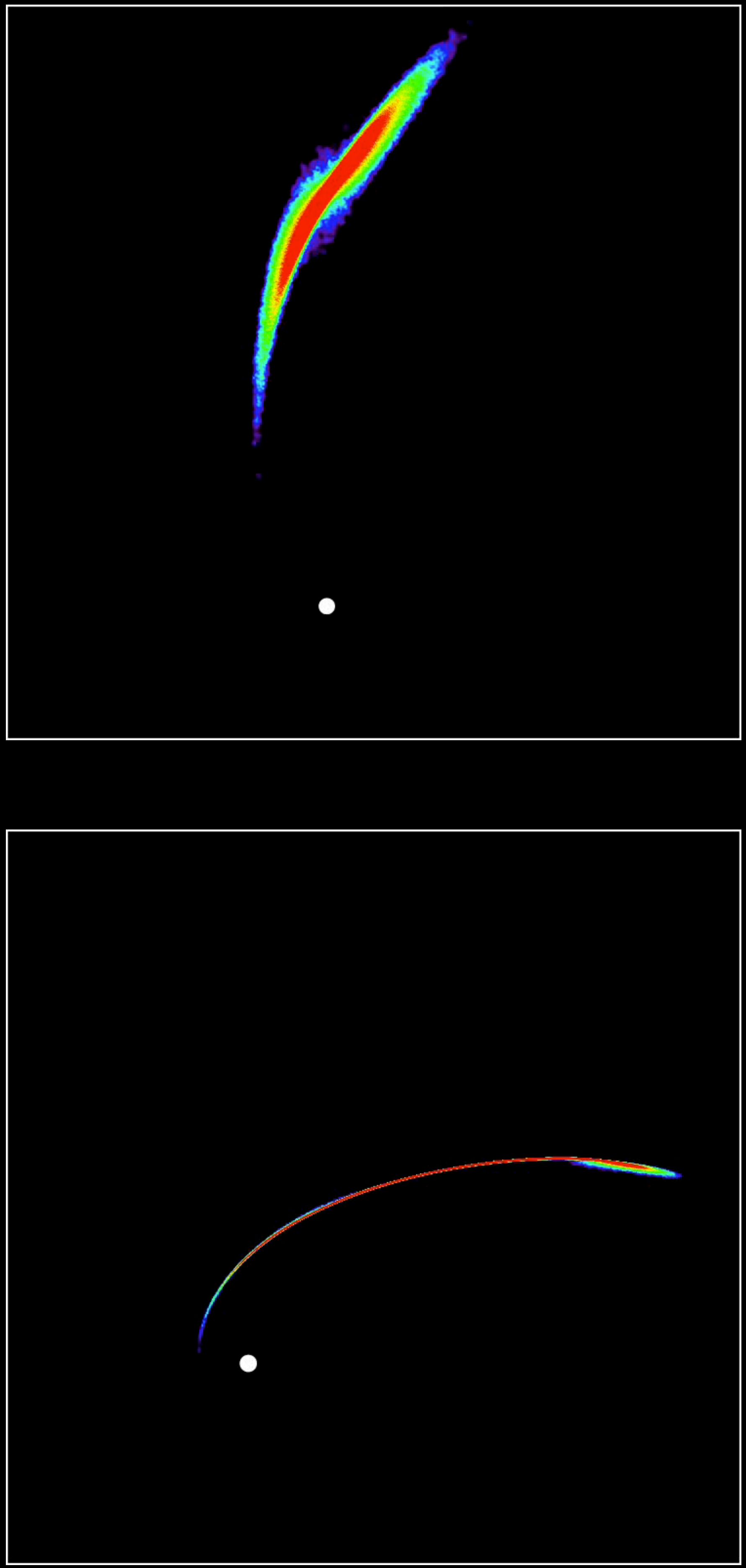
Perhaps more importantly: Athena will easily measure lines in much **fainter** TDEs

Spectroscopy can map out debris stream

Debris stream smaller for:

- more compact star
- larger penetration parameter
- larger black hole mass
- smaller black hole spin

Test models for super-Eddington accretion



Bonnerot et al., 2017

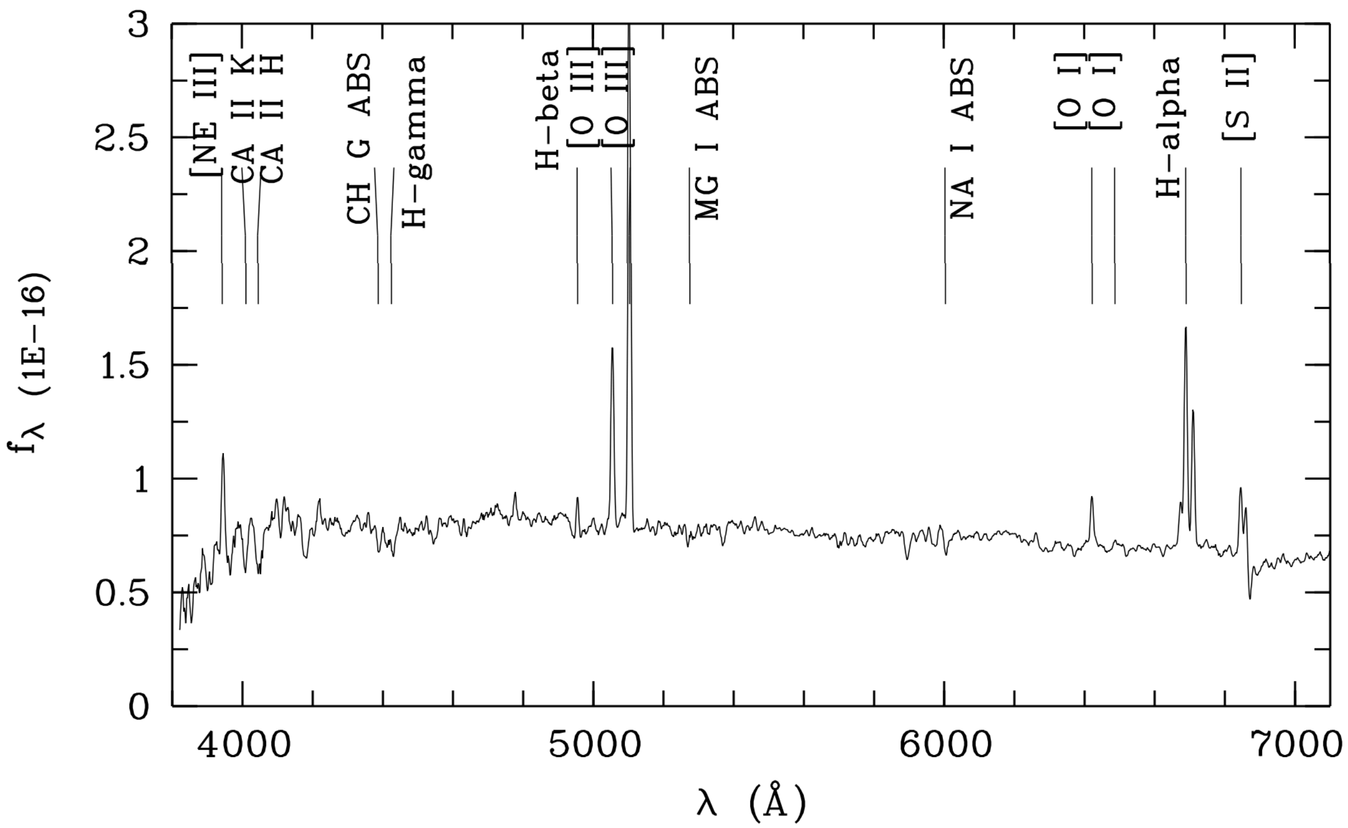
Conclusions

1. TDE discoveries occur more and more in the optical, but X-rays are extremely important

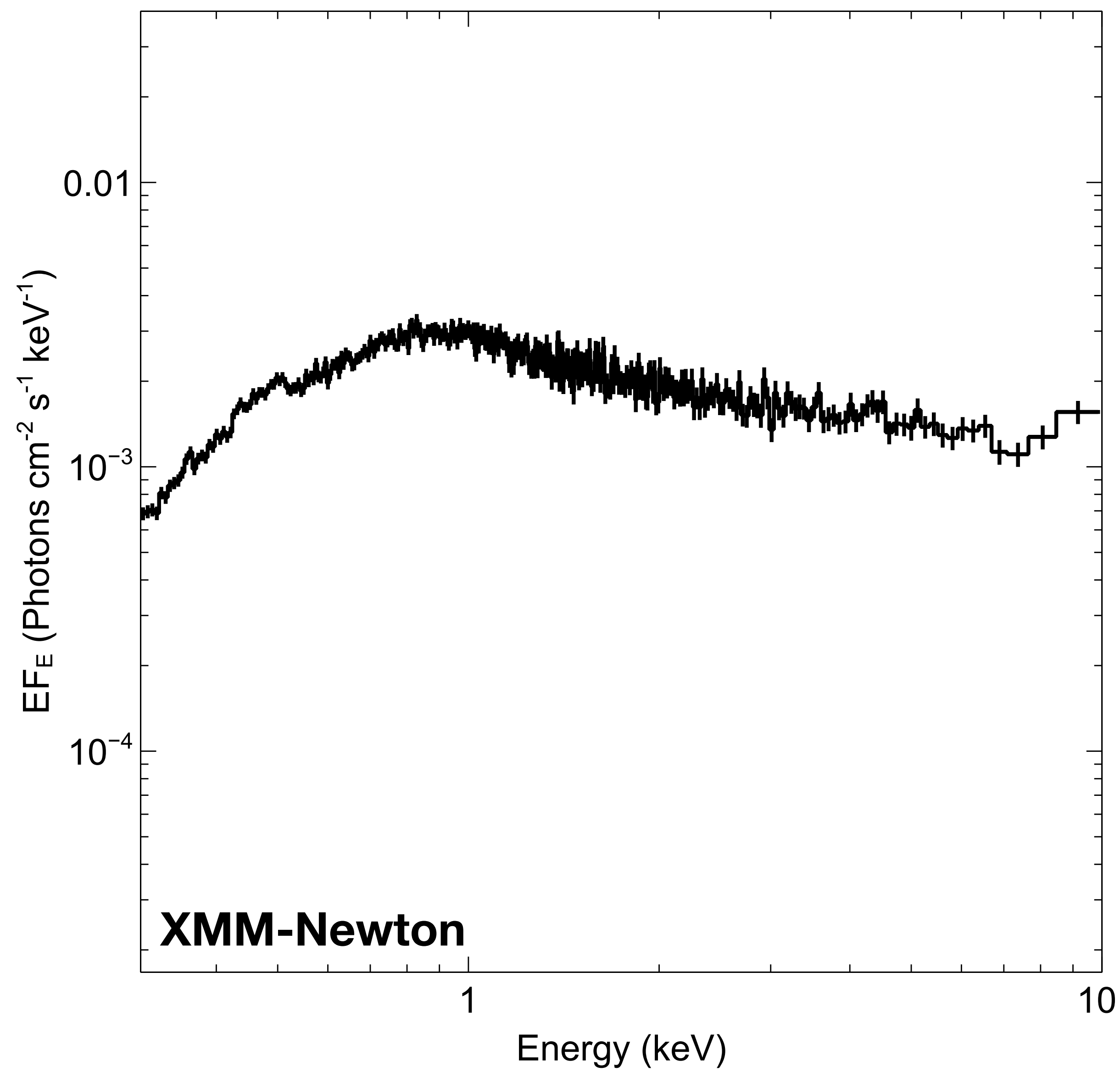
2. Environments around a TDE are different than an AGN. Spectroscopy can help solve debates on that environment

3. XRISM, Athena and hopefully Arcus and Lynx will be major players

archival observations: a ‘true’ type 2

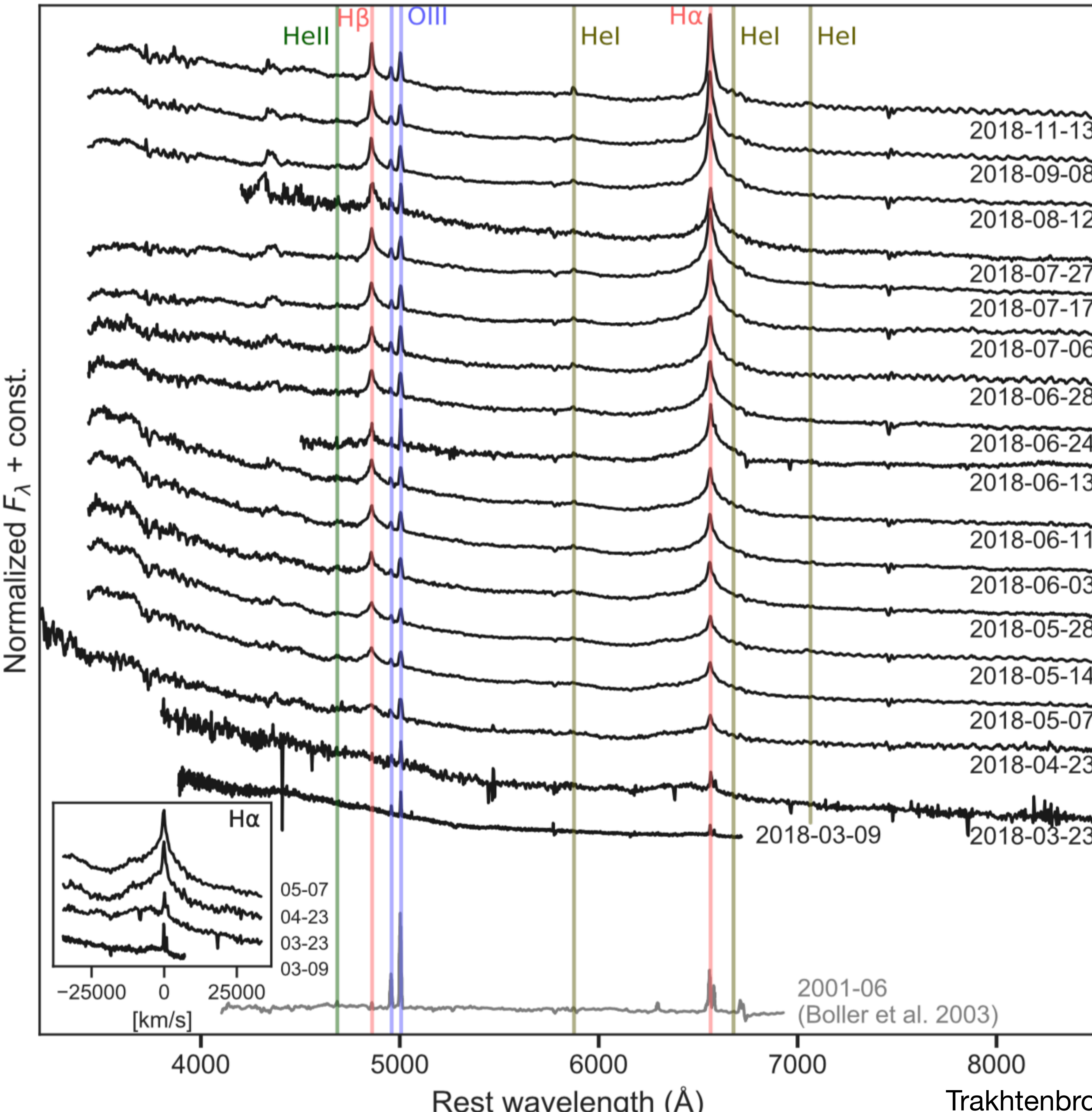


Boller et al., 2003



Gallo et al., 2013

real time CLAGN



- Blue continuum appears first, followed 1-3 months later by broad emission lines
- The lag is ~consistent with what is expected from the R(BLR)-L(opt.) relation!

Trakhtenbrot et al., to be submitted

But…the HST spectra