Tidal Disruption Events In X-rays

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Outline

Very quick reminders about TDEs.

Some key questions.

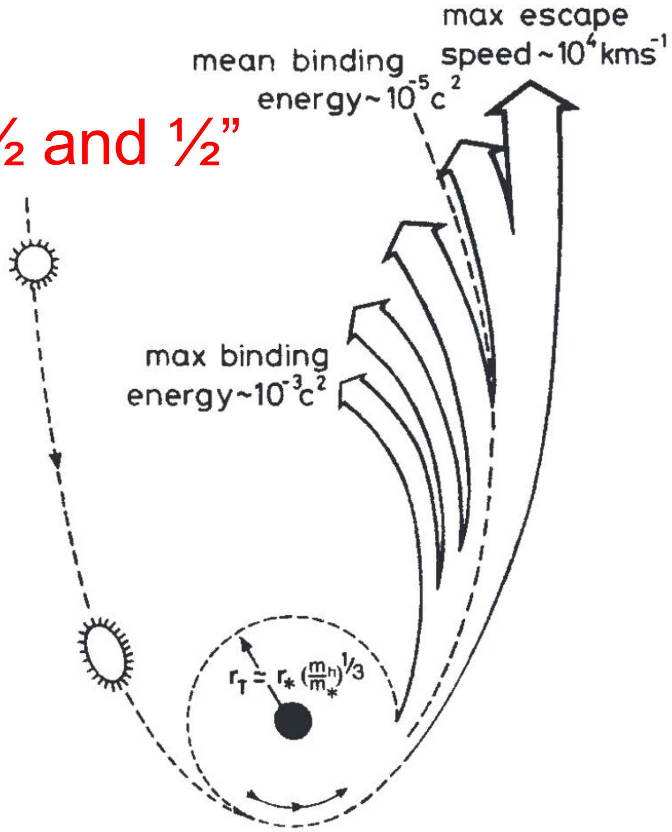
Two case studies through the lens of these questions:

Swift J1644, ASASSN-14li.

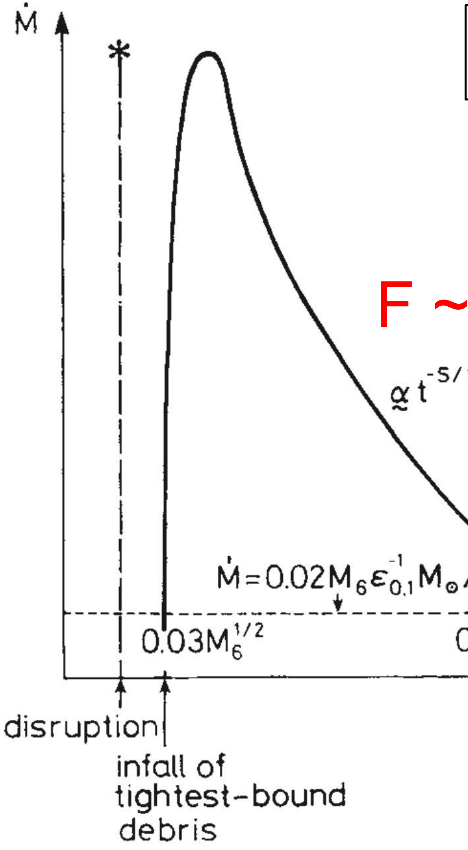
The near, medium, and long-term future.

Unique light curves

“½ and ½”

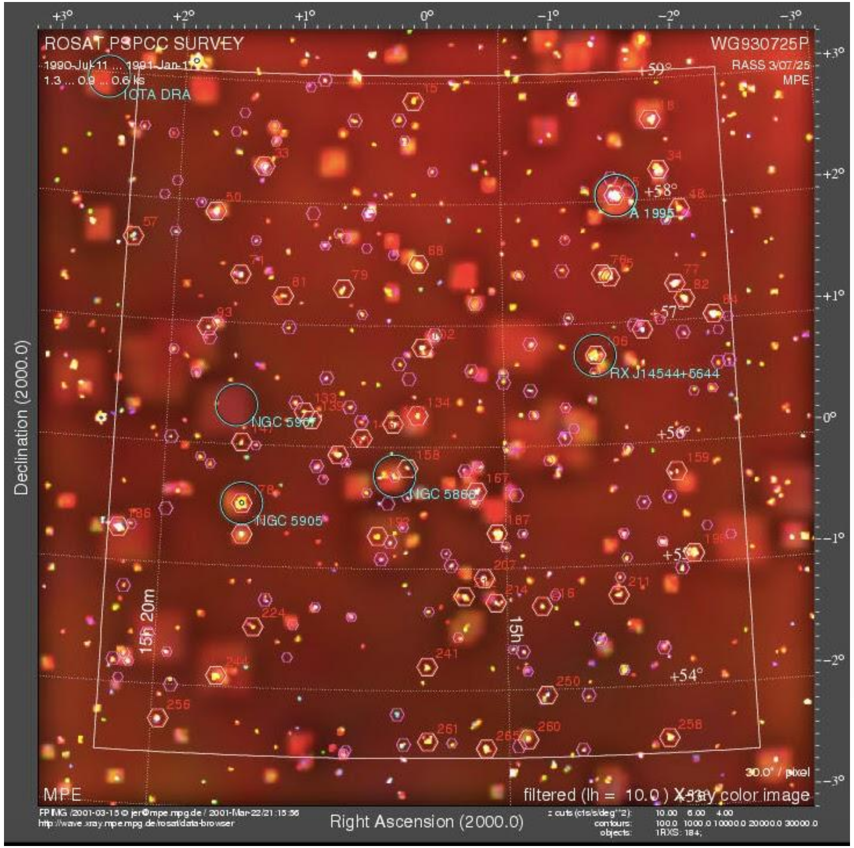


Rees 1988

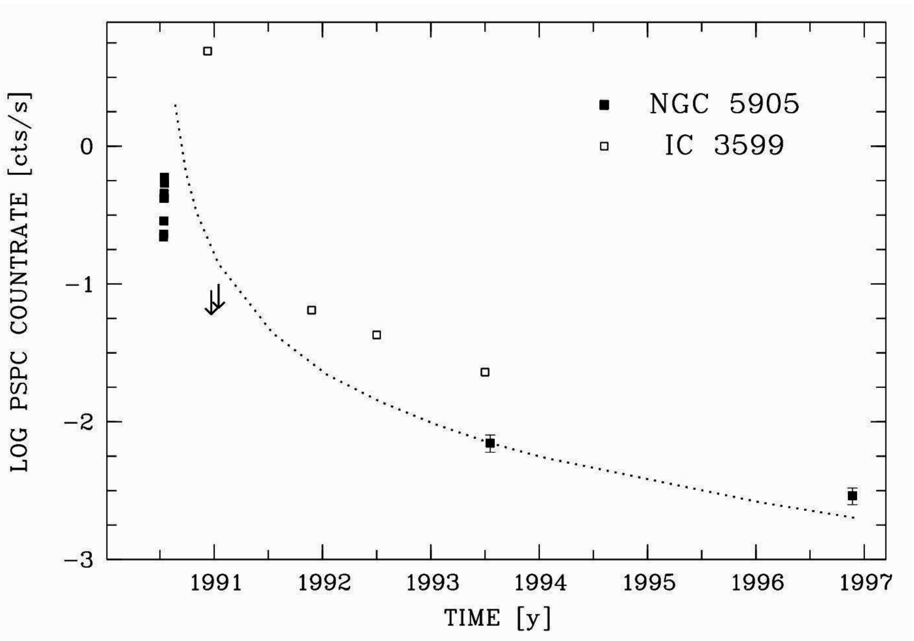


$F \sim t^{-5/3}$

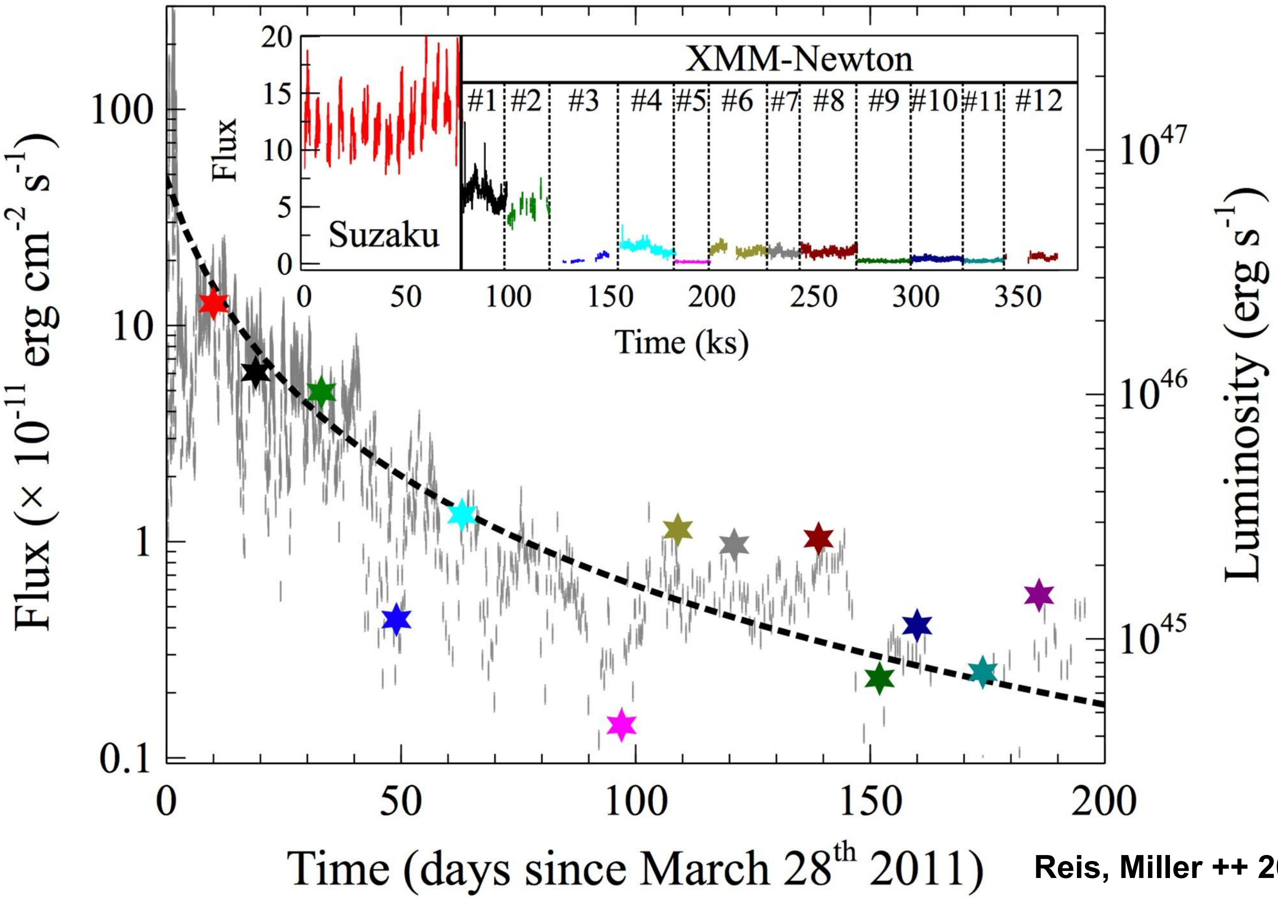
Discovery: Surveys (ROSAT)



Komossa & Bade 1999



Swift J164449.3+573451 (z=0.35)



Reis, Miller ++ 2012

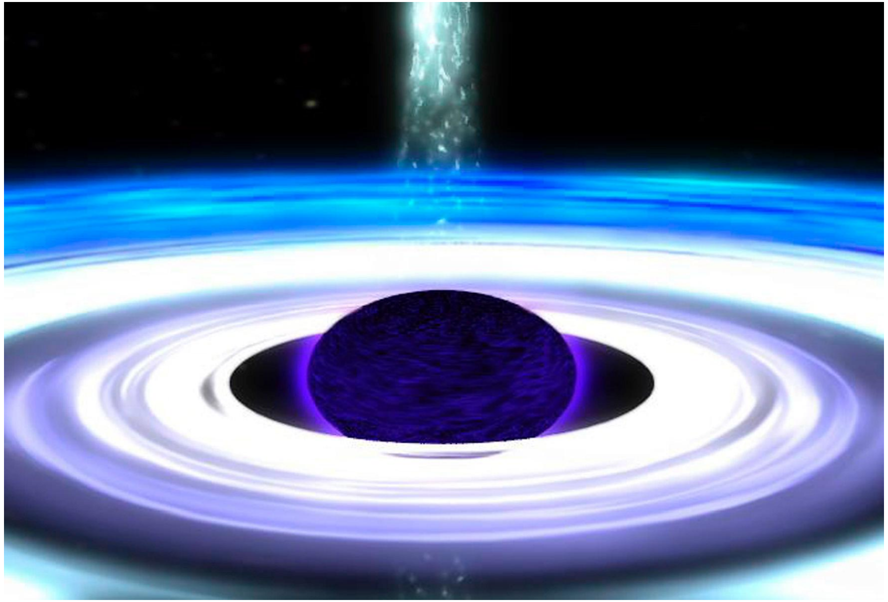
TDEs: Unique Windows on Black Hole Accretion

How do natal disks form and evolve?

When do winds and jets turn on?

What is the nature of the (super-Eddington?) inner flow?

Can we measure masses and spins (in low-mass black holes)?



Swift J164449.3+573451 (z = 0.35)

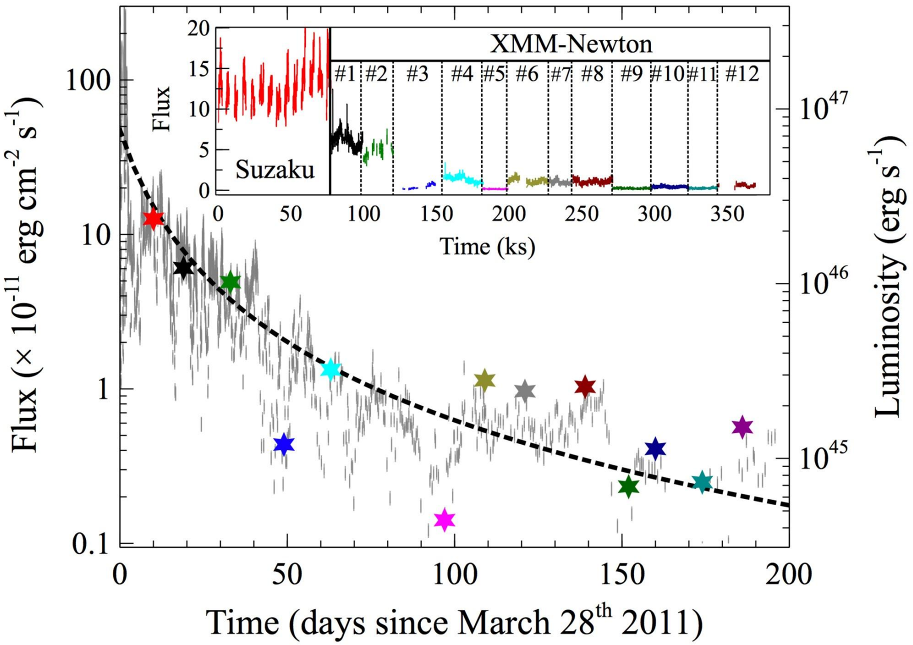
Originally identified as a GRB.

Flaring on time scale of 78s is commensurate with AGN inner disks.
M < 8 * 10^6 Msun.

Bloom et al. 2011 suggested that it might be a TDE.

Closest analogy: GRBs & blazars.
Jetted event viewed close to the axis.

Reis, Miller, ++2012



Swift J164449.3+573451

Why think *that*?

$L_{ISO} \sim 10^{47}$ erg/s, or L_{Edd} for 10^9 Msun.

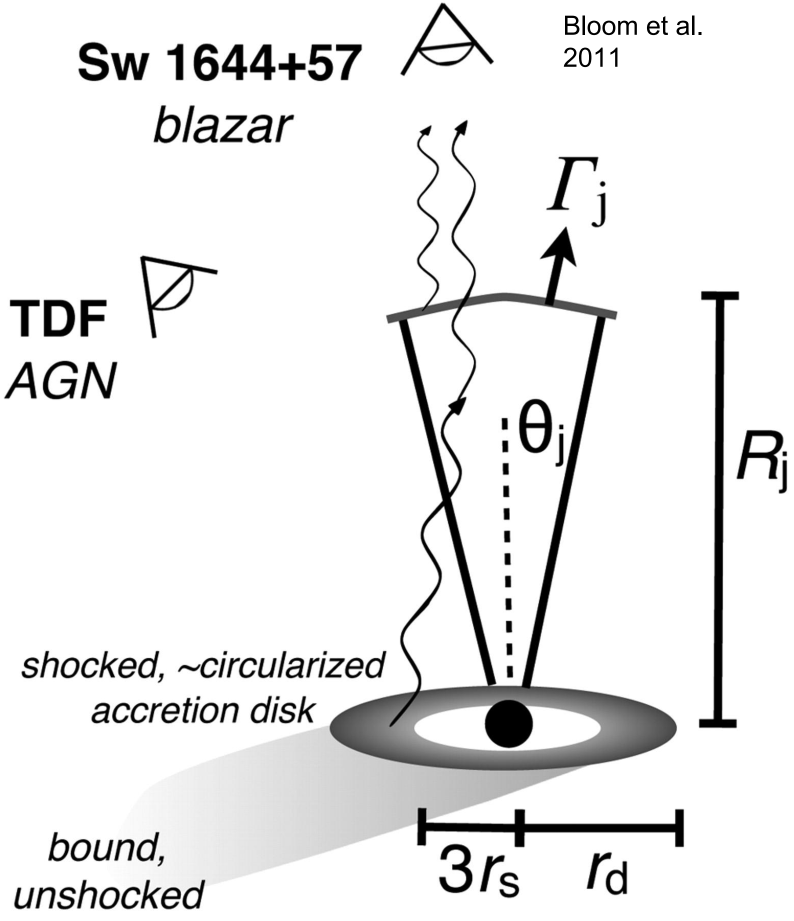
So it <u>must</u> be beamed.

$f_b = (1-\cos\theta_j) < 1$

$f_b * L = 10^{45}$ erg/s e.g. L_{Edd} for 10^7 Msun

iff $\theta_j = 1 / \Gamma_j \sim 0.1$

$\Gamma_j \sim 10$ as per blazars.



Swift J164449.3+573451

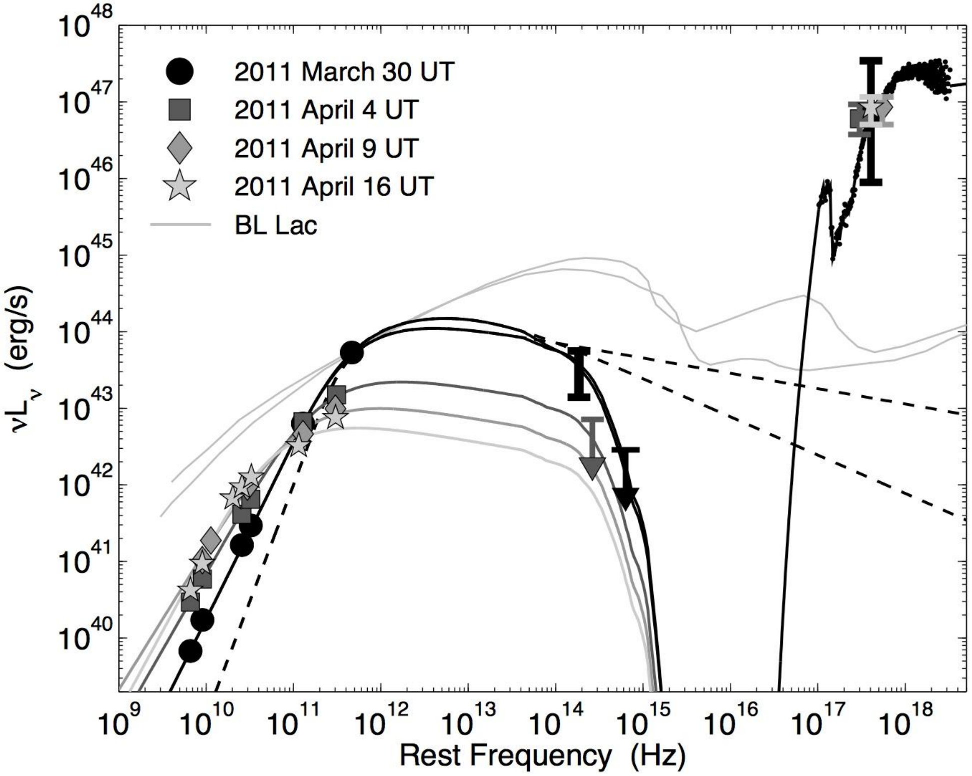
Zauderer et al. 2011

SED shows Synchr, SSC, EC.
Very similar to blazars.

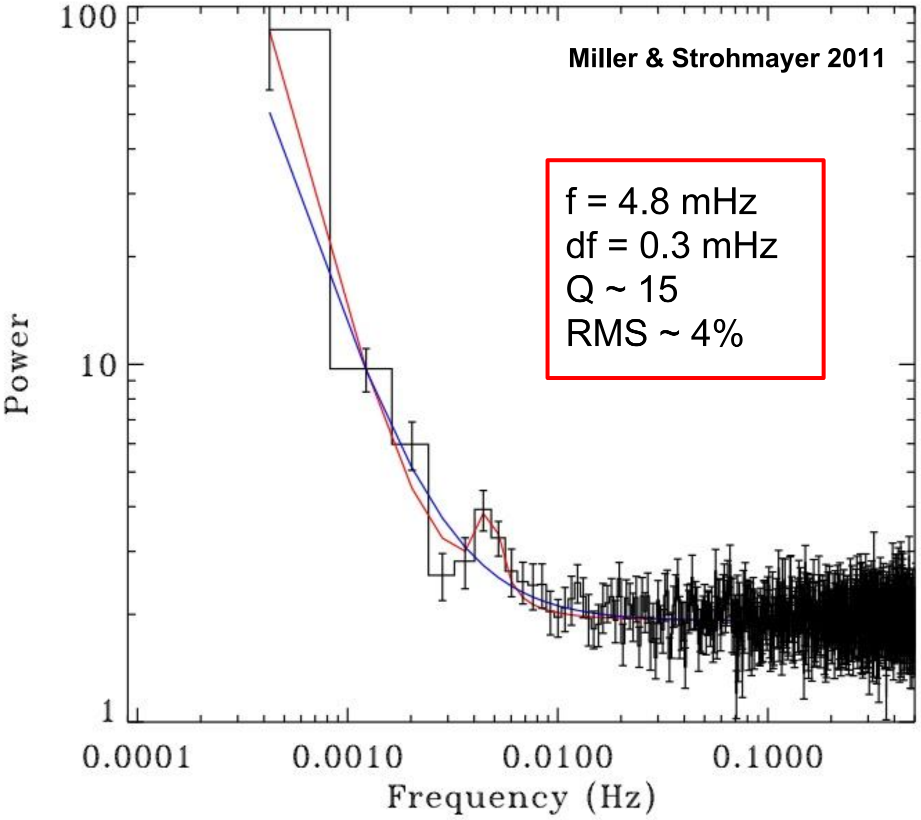
Equipartition between electrons and B fields implies minimum size, relativistic expansion.

And, scintillation can be used to Imply Γ ~ 5.

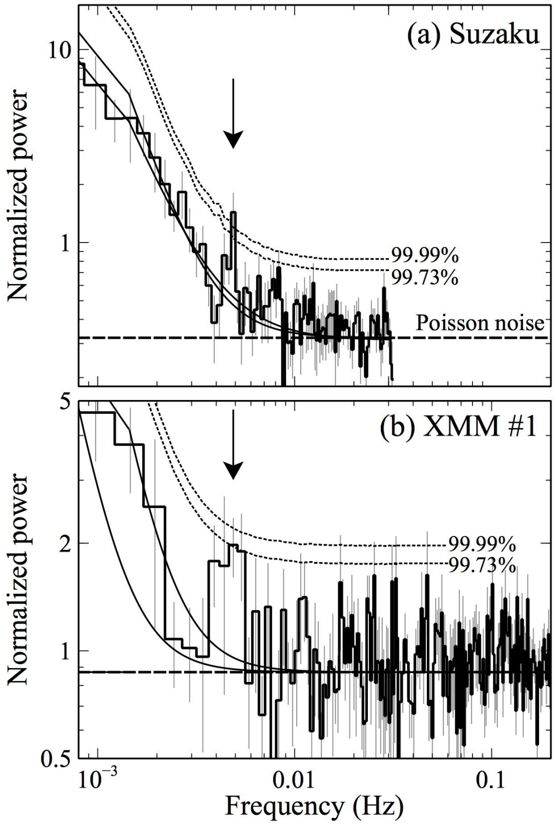
Second case of jetted TDE:
Swift J2015.4+0516
(Cenko et al. 2012).



Swift J1644: P = 200s (5 mHz QPO)



Reis, Miller, ++ 2012



Reis, Miller, ++ 2012

Swift J1644: P = 200s

IFF QPOs are likely disk phenomena:

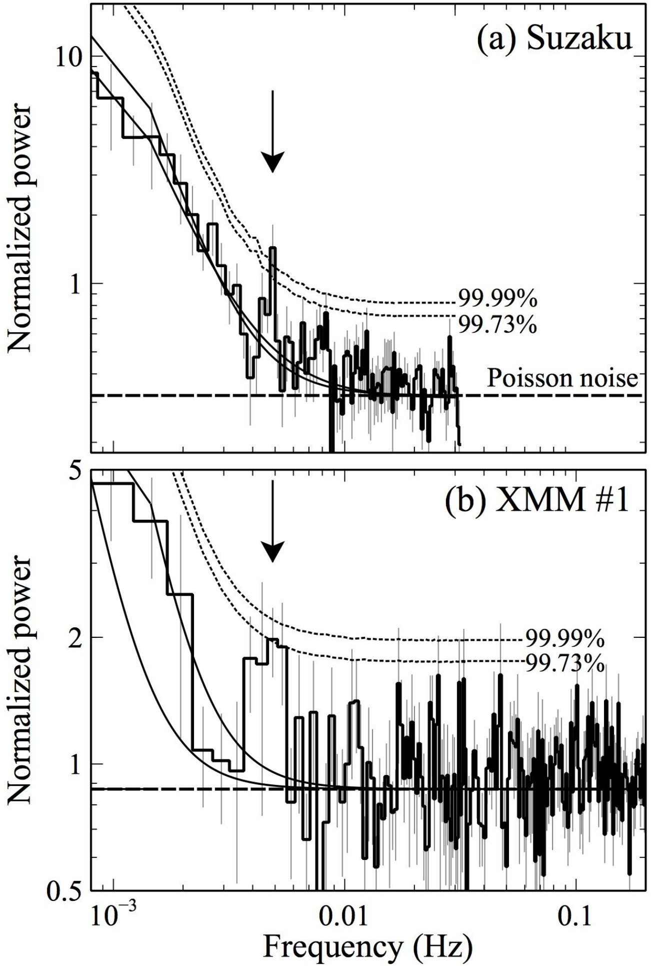
Independent angle on disk existence.

t_{fall} ~ 1 day, QPOs @ 10 days.

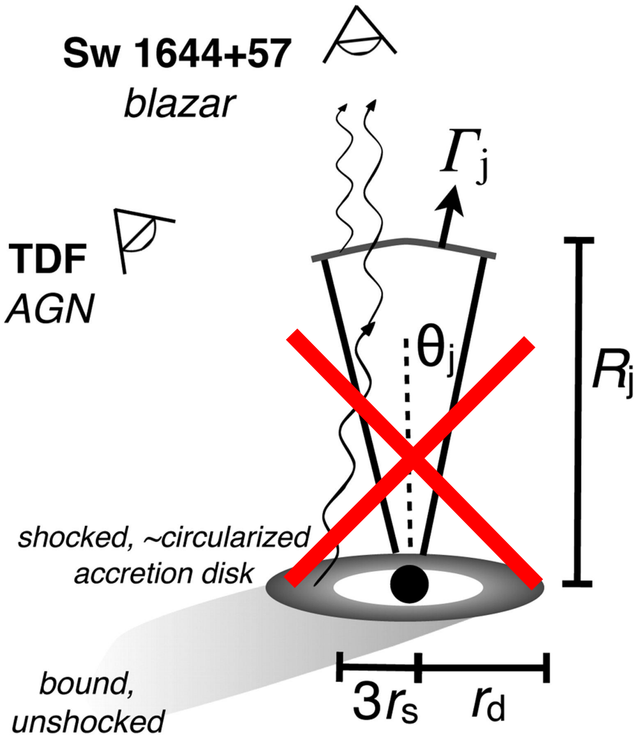
Independent mass constraint:

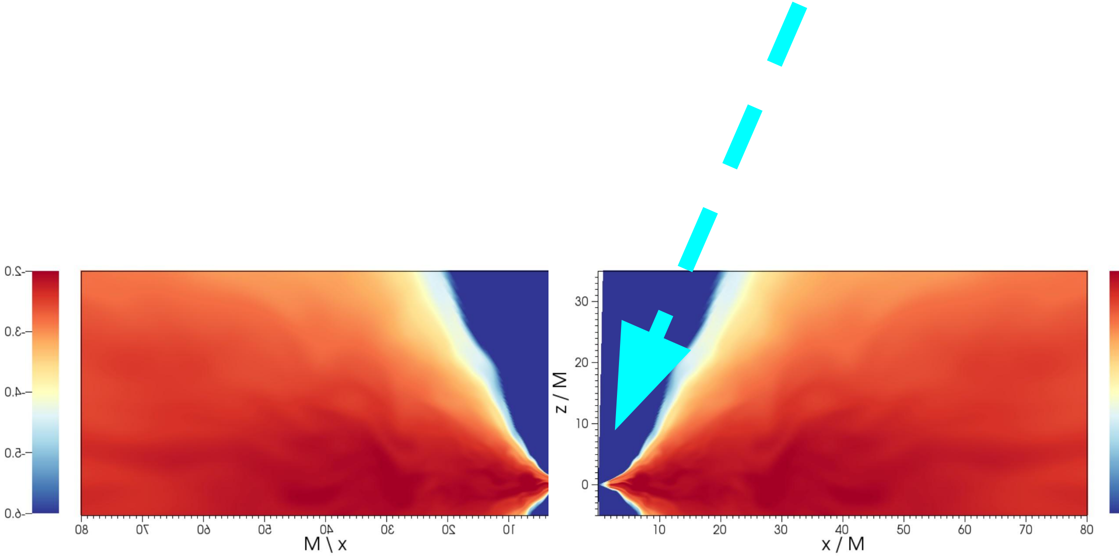
Associate 5 mHz with ISCO frequency,
→ 5 * 10^{5-6} Msun, depending on a/M.

Would give a/M for very accurate M.



Swift J1644: P = 200s (5 mHz QPO)

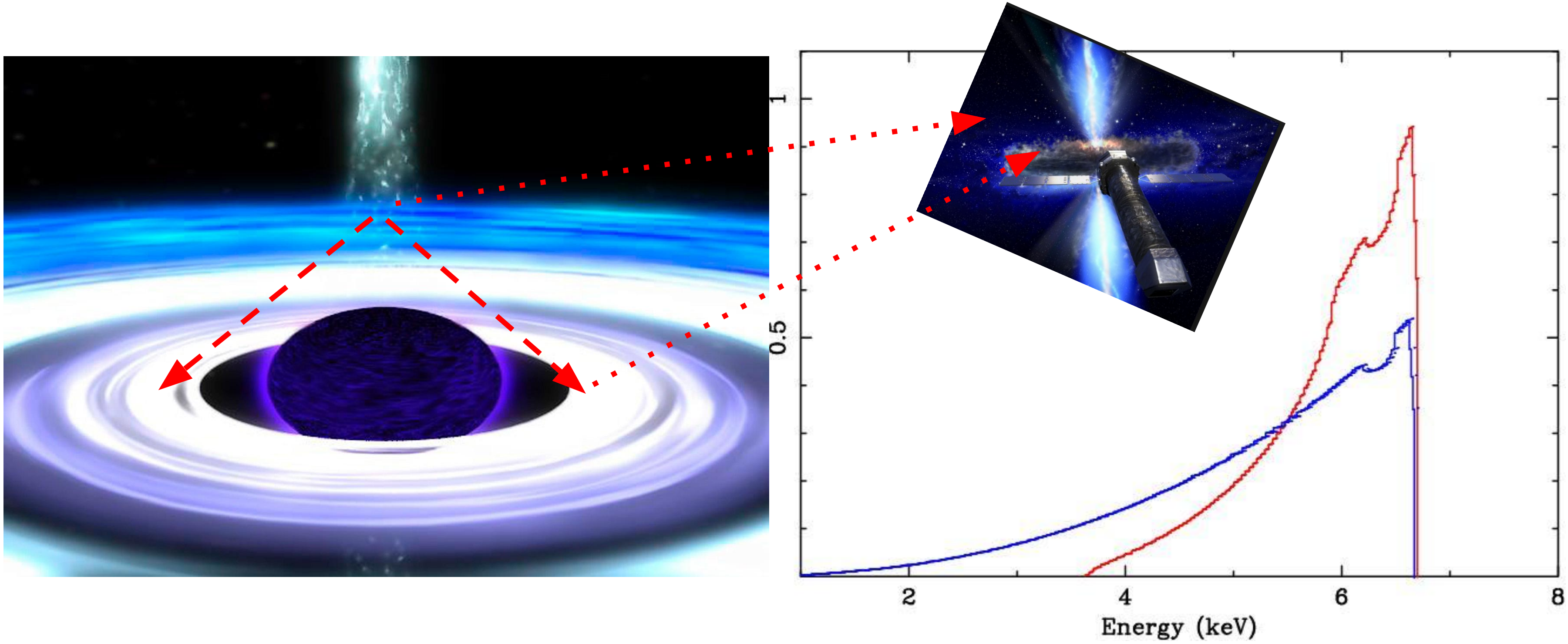




Lasota et al. 2016

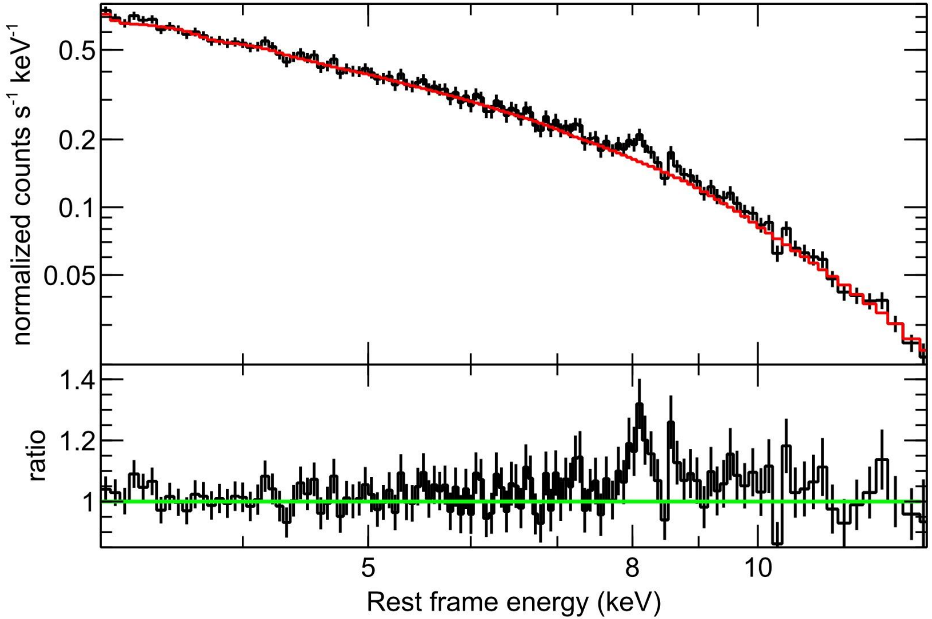
We must be seeing close to the black hole.

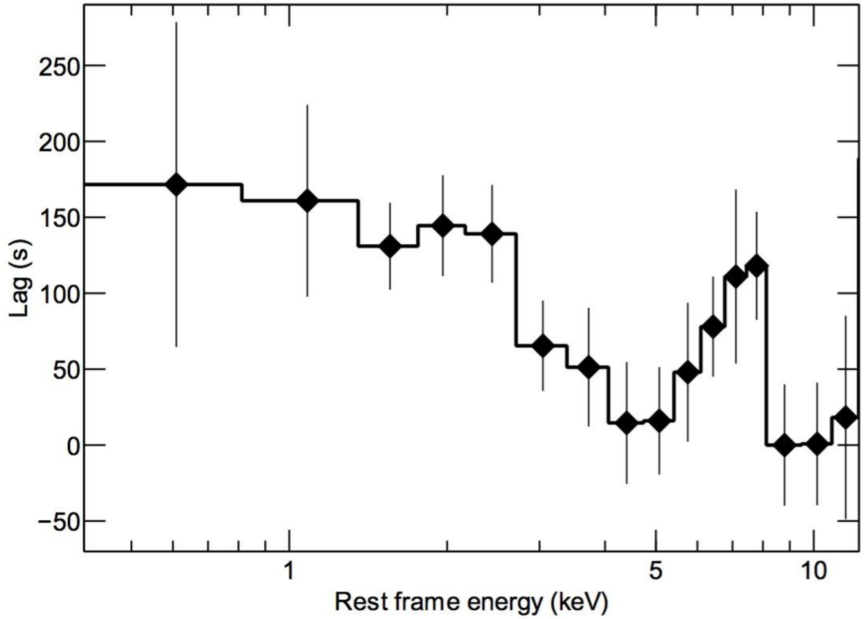
Reflection, Reverberation



Swift J1644: Reflection and Reverberation

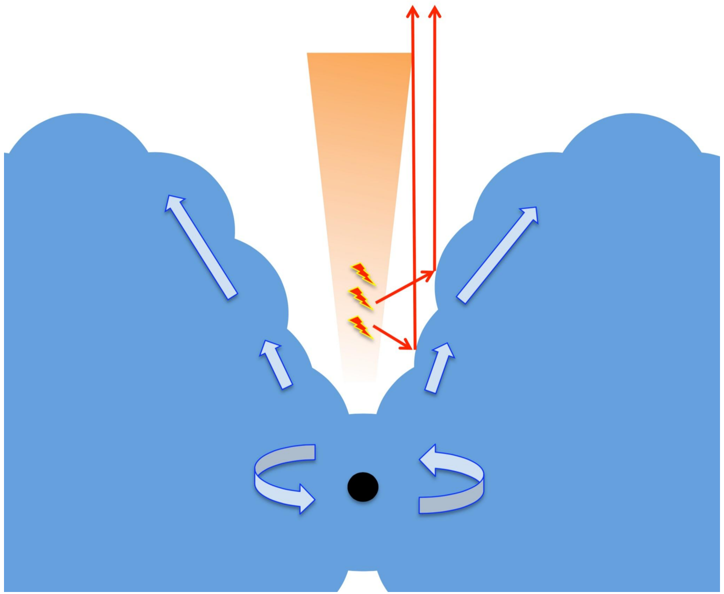
Kara, Miller, ++ 2016





- **The central engine must be visible.**
- **Mass, spin, and geometry (distances, inclinations, etc.)**

Swift J1644: Reflection and Reverberation



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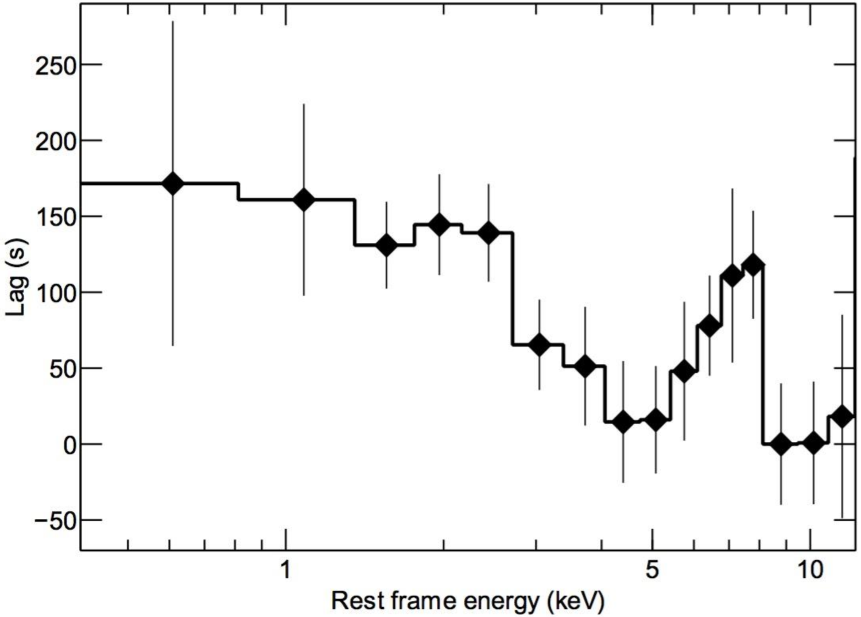

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ASASSN-14li (z=0.0206)

Bright, Sy-like X-ray flux (10^{-11} cgs).

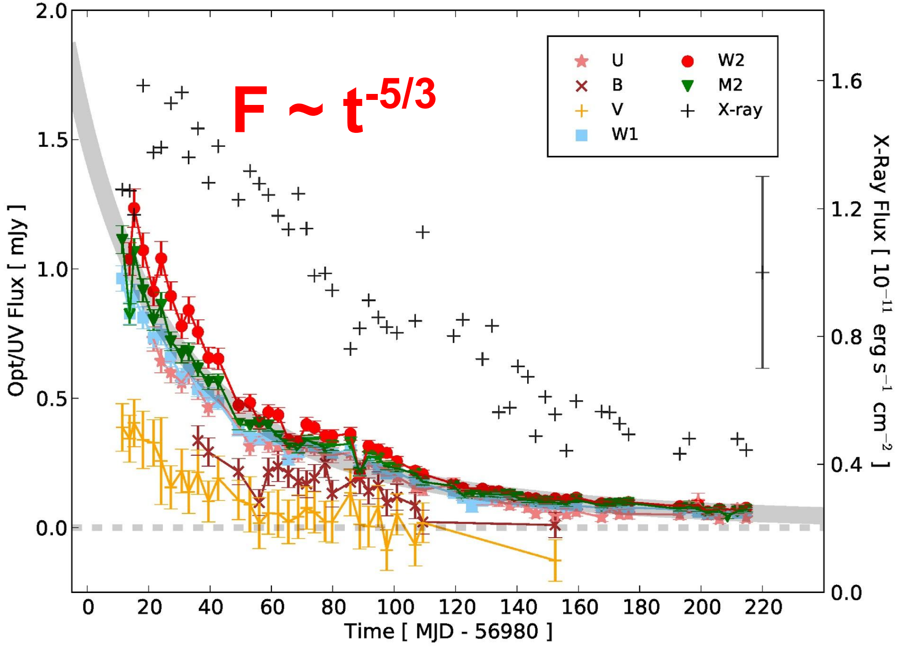
Best multi-wavelength coverage yet.

L ~ $3*10^{44}$ erg/s --> M ~ $2.3*10^{7}$ Msun.

kT = 55 eV blackbody. M = $2*10^{6}$ Msun.
Steady despite flux decline.

Slow “jet”, v~0.1c (Alexander++ 2015).

Miller et al. 2015



ASASSN-14li: Similar to Seyferts?

X-ray wind: 130-360 km/s.

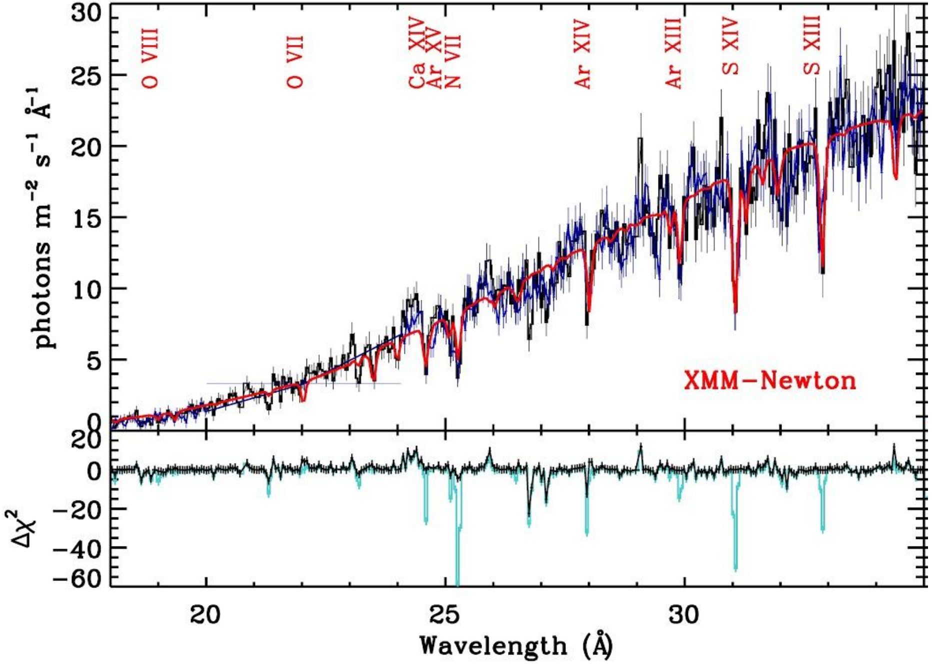
UV wind: v~240-400 km/s (Cenko et al. 2016).

$\mathbf{N_H}$ $0.1\text{-}2.2*10^{22}$ cm^{-2}

X-ray radius $r < c\,\Delta t < 3*10^{15}$ cm
$r < 10^4\, GM/c^2$

Density $\xi = L/nr^2$
$n > 2*10^9$ cm^{-3}

Miller et al. 2015



ASASSN-14li: Flow details

N = n Δr
Δr/r = f ~ 0.002
→ *Flow is likely filamentary, or clumpy.*

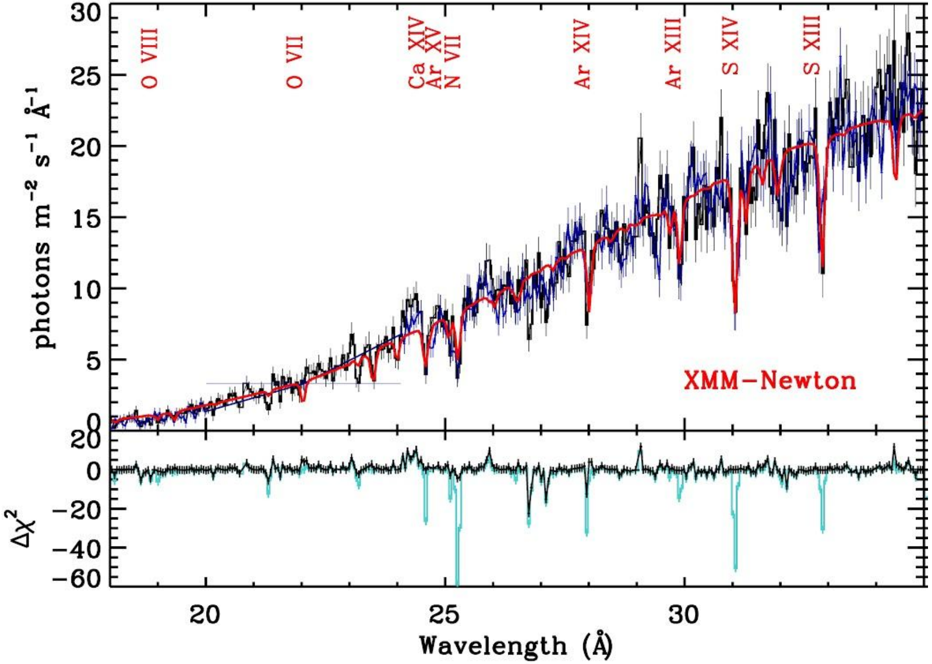
M-dot ~ 8 * 10^{23} Ω f g/s
M-dot ~ 2 * 10^{21} Ω g/s

M (<r) ~ 0.2 Ω f Msun
M (<r) ~ 4 * 10^{-4} Ω Msun

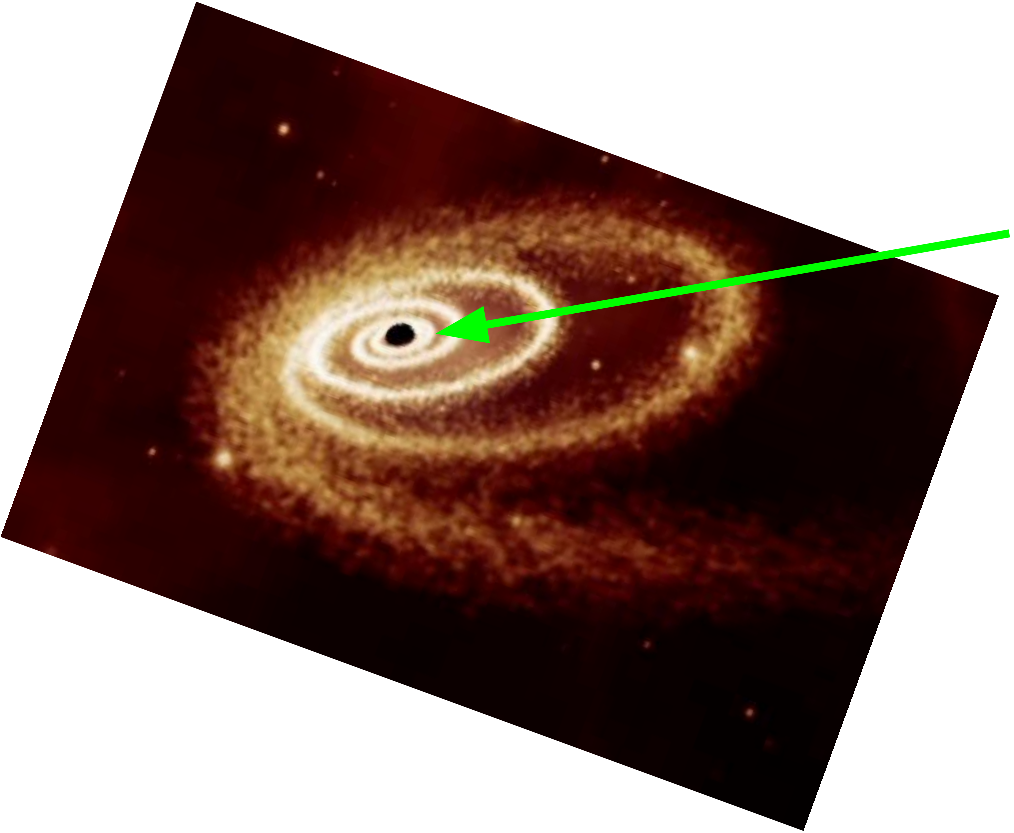
L_{kin} ~ 3 * 10^{35} erg/s

Radiation >> Mechanical output.

Miller et al. 2015



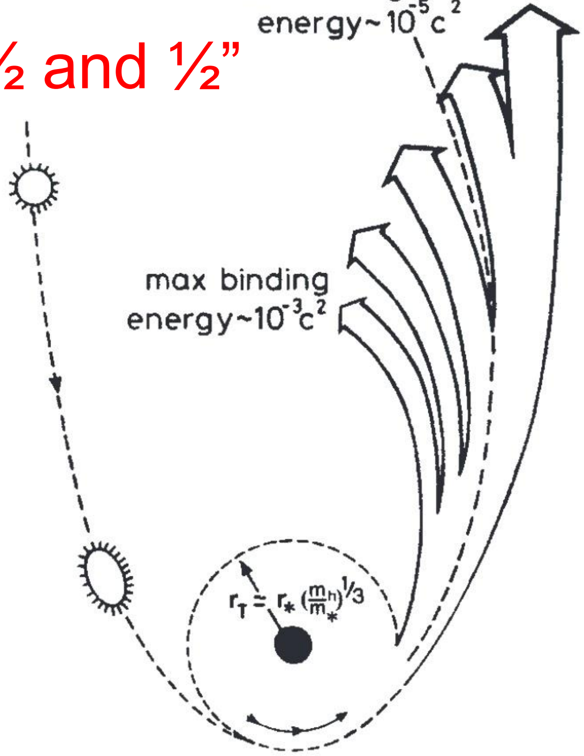
ASASSN-14li: Filament close to apocenter?



- \+ Explains low velocities.
- \+ Explains low filling factor.
- \+ May explain very low M-dot, L_{kin}.
- \- Special geometry?

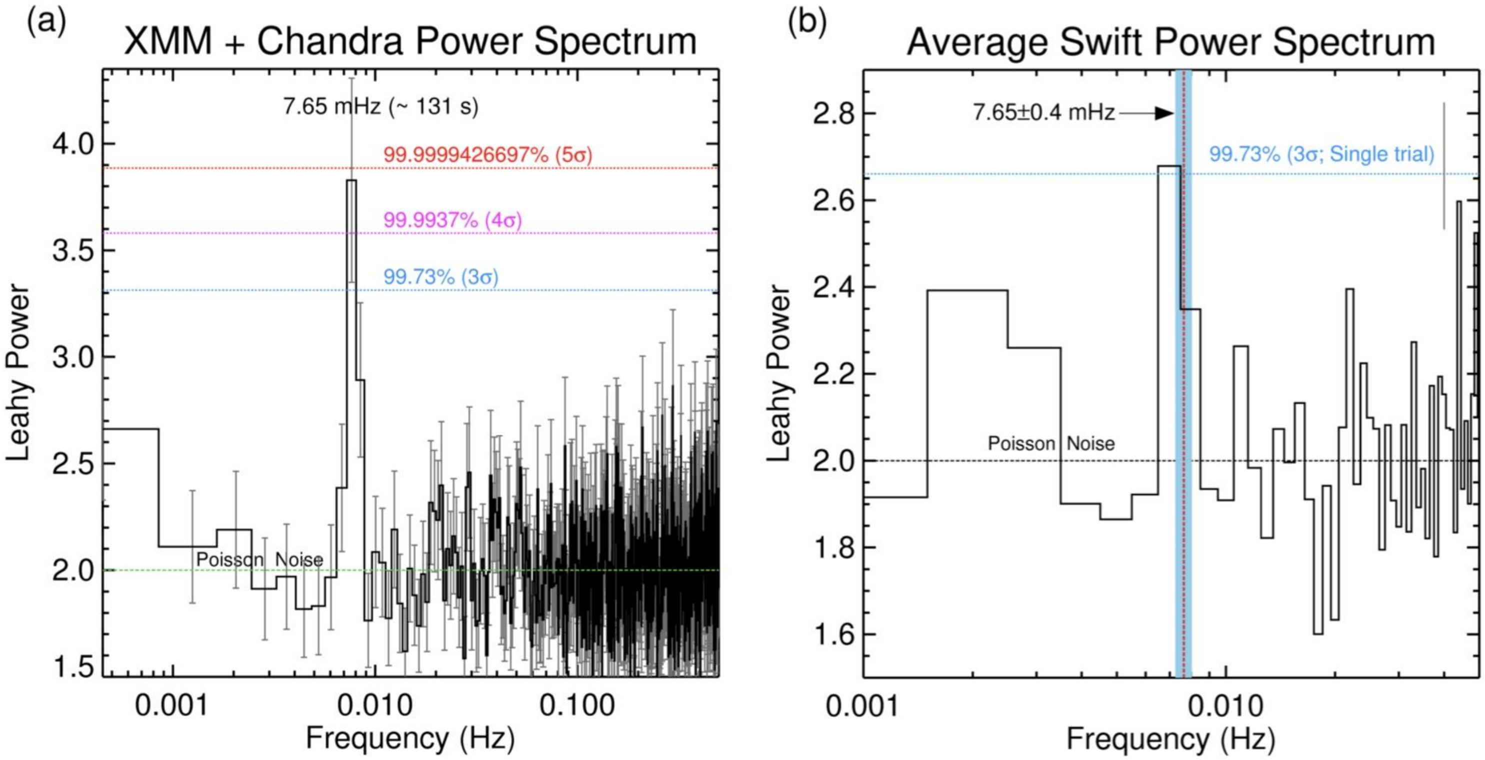
Geometry: angular momentum misalignment

"½ and ½"



Guillochon & Ramirez-Ruiz 2015

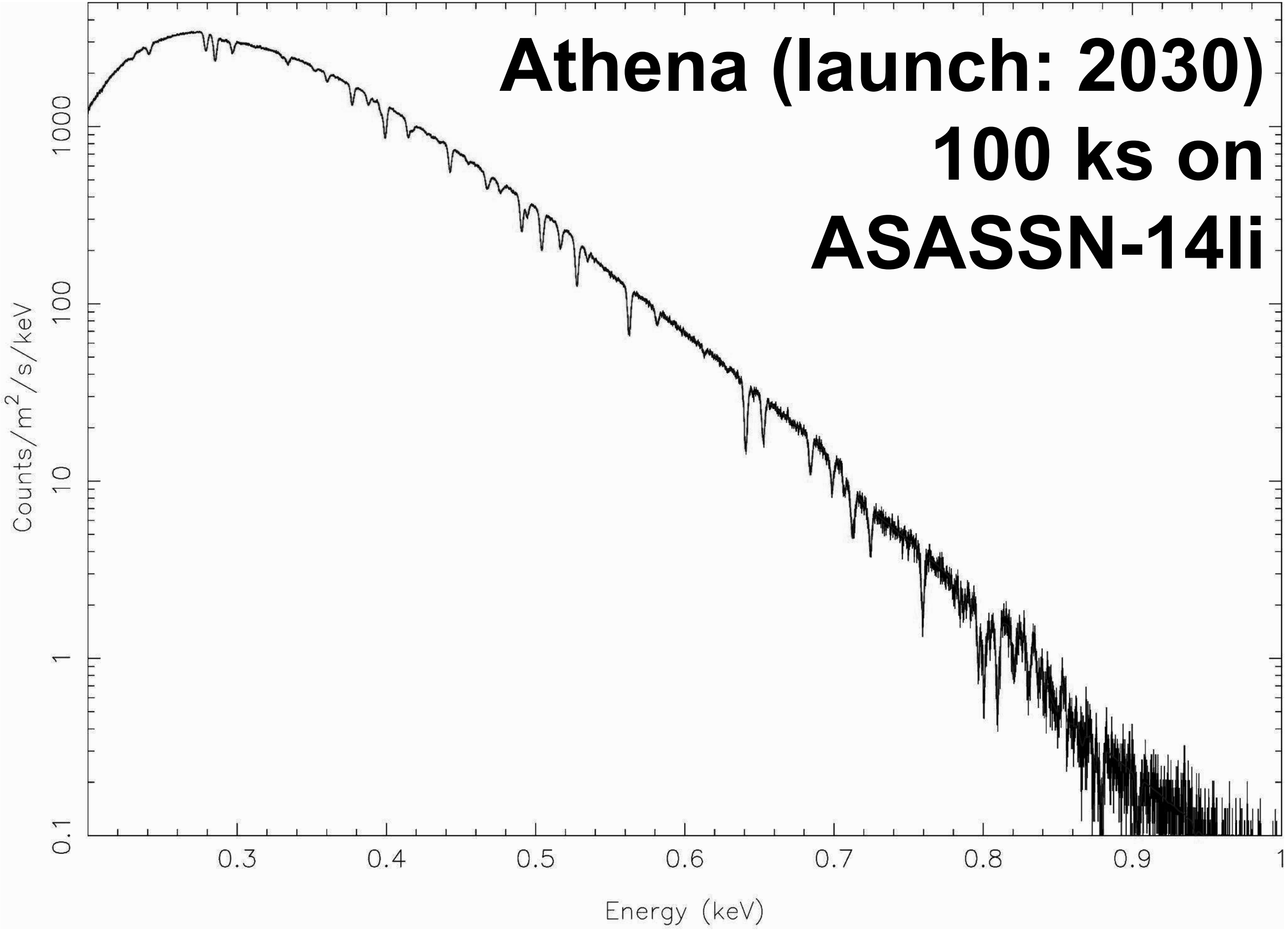
ASASSN-14li: QPOs (Pasham et al. 2019)



When the next X-ray bright TDE is found:

Swift:	200 ks in 100 observations.
Chandra:	Deep spectroscopic observation.
XMM-Newton:	Deep spectroscopic observation.
NuSTAR:	Spectroscopy and timing out to 80 keV.
MDM:	Photometric, spectroscopic monitoring.
Magellan:	Spectroscopy.

We are always interested in new partnerships.


Athena (launch: 2030)
100 ks on
ASASSN-14li
Counts/m2/s/keV
1000
100
10
1
0.1
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Energy (keV)

Summary

Treating TDEs like Seyferts yields results.

- Inner disks form quickly, outer disks circularize slowly.
- Misalignment may be observed.
- Central engines somehow visible despite jet production, unlike blazars.

Jetted vs not: hyper-Eddington vs merely super-Eddington.

We may be stuck with a low rate of X-ray-bright TDEs.

- *It is critical that we make the most of every single instance.*
- *Athena will reveal faint TDEs.*