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)
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. $M < 8 \times 10^6$ Msun.

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

Closest analogy: GRBs & blazars. *Jetted event viewed close to the axis.*
Swift J164449.3+573451

Why think *that*?

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

So it **must** be beamed.

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

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

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

$\Gamma_j \sim 10$ as per blazars.
Swift J164449.3+573451

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

Equi-partition between electrons and B fields implies minimum size, relativistic expansion.

And, scintillation can be used to imply $\Gamma \sim 5$.

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

$f = 4.8$ mHz  
$df = 0.3$ mHz  
$Q \sim 15$  
$\text{RMS} \sim 4\%$
Swift J1644: $P = 200s$

IFF QPOs are likely disk phenomena:

Independent angle on disk existence.

$t_{\text{fall}} \sim 1 \text{ day}, \text{QPOs} @ 10 \text{ days}$. 

Independent mass constraint:

Associate 5 mHz with ISCO frequency, $\rightarrow 5 \times 10^{5-6} \text{ Msun}$, depending on $a/M$. 

Would give $a/M$ for very accurate $M$. 

Reis, Miller, ++ 2012
Swift J1644: P = 200s (5 mHz QPO)

We must be seeing close to the black hole.
Reflection, Reverberation
• The central engine must be visible.
• Mass, spin, and geometry (distances, inclinations, etc.)
Swift J1644: Reflection and Reverberation

- The central engine must be visible.
- Mass, spin, and geometry (distances, inclinations, etc.)
ASASSN-14li (z=0.0206)

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

Best multi-wavelength coverage yet.

$L \sim 3 \times 10^{44}$ erg/s $\rightarrow M \sim 2.3 \times 10^7$ Msun.

$kT = 55$ eV blackbody. $M = 2 \times 10^6$ Msun. Steady despite flux decline.

Slow “jet”, $v \sim 0.1c$ (Alexander++ 2015).
ASASSN-14li: Similar to Seyferts?

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

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

$N_H = 0.1-2.2 \times 10^{22}$ cm$^{-2}$

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

Density $\xi = L/nr^2$
$n > 2 \times 10^9$ cm$^{-3}$
ASASSN-14li: Flow details

\[ N = n \Delta r \]
\[ \Delta r/r = f \sim 0.002 \]
→ Flow is likely filamentary, or clumpy.

\[ M \text{-dot} \sim 8 \times 10^{23} \Omega \text{ f g/s} \]
\[ M \text{-dot} \sim 2 \times 10^{21} \Omega \text{ g/s} \]

\[ M(<r) \sim 0.2 \Omega \text{ f Msun} \]
\[ M(<r) \sim 4 \times 10^{-4} \Omega \text{ Msun} \]

\[ L_{\text{kin}} \sim 3 \times 10^{35} \text{ erg/s} \]

Radiation >> Mechanical output.
ASASSN-14li: Filament close to apocenter?

+ Explains low velocities.
+ Explains low filling factor.
+ May explain very low M-dot, $L_{\text{kin}}$.
- 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
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.*