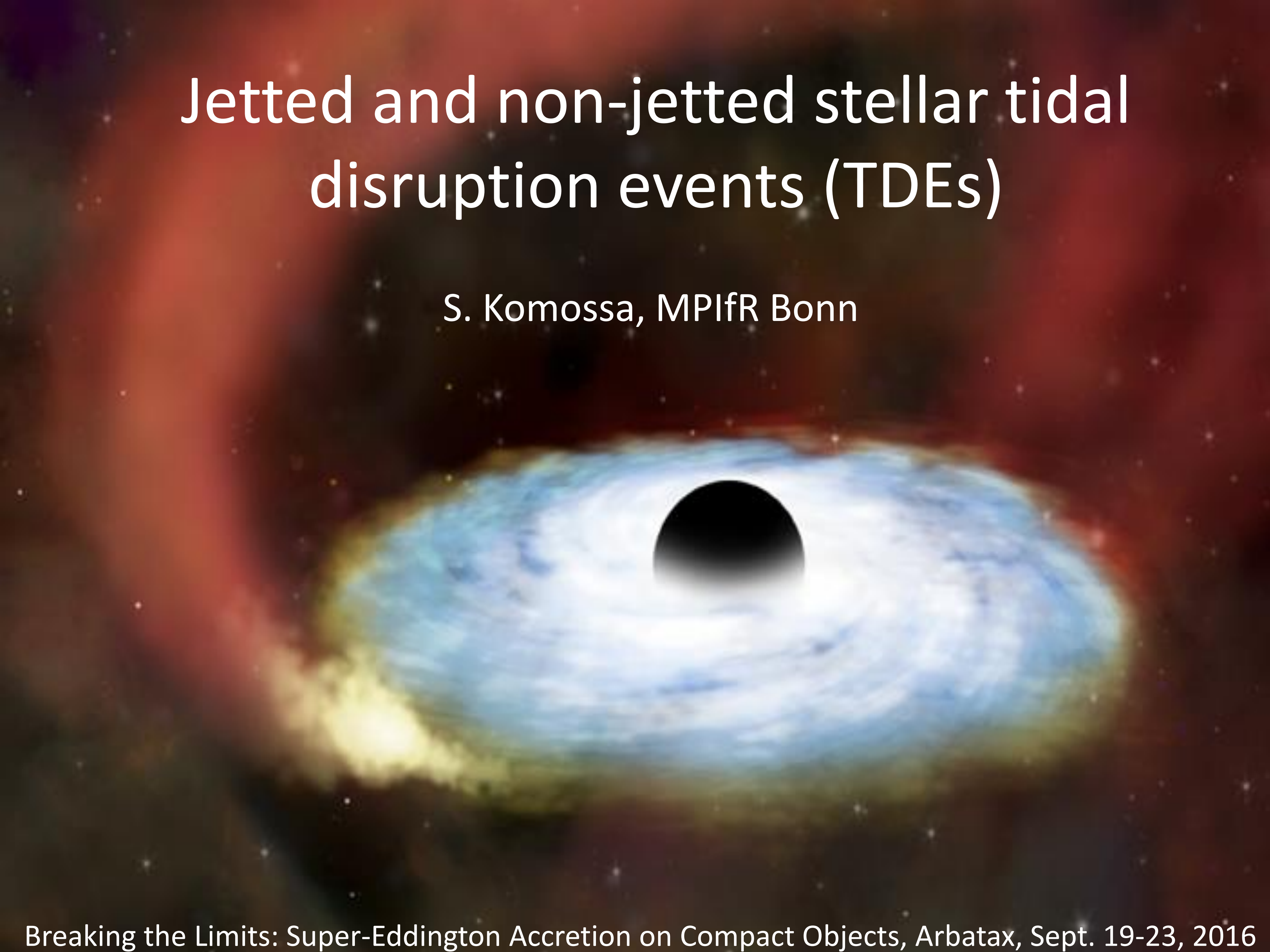


Jetted and non-jetted stellar tidal disruption events (TDEs)

S. Komossa, MPIfR Bonn

Breaking the Limits: Super-Eddington Accretion on Compact Objects, Arbatax, Sept. 19-23, 2016

tidal capture & disruption of stars by SMBHs

Possible power source of Seyfert galaxies and QSOs

J. G. Hills *Nature Vol. 254 March 27 1975*

Department of Astronomy, University of Michigan, Ann Arbor, Michigan 48

The possible presence of massive black holes in the nuclei of galaxies has been suggested many times. In addition, there is considerable observational evidence for high stellar densities in these nuclei. I show that the tidal breakup of stars passing within the Roche limit of a black hole initiates a chain of events that may explain many of the observed principal characteristics of QSOs and the nuclei of Seyfert galaxies.

letters

Nature Vol. 280 19 July 1979

Accretion on massive black holes in galactic nuclei

V. G. Gurzadyan
L. M. Ozernoy

STELLAR collisions and/or tidal break-up of stars by a massiv black hole[1-3] accompanied by subsequent accretion of th released gas onto the hole play a crucial part in most black hol models of quasars and active galactic nuclei. It is usuall assumed that an accretion disk forms around the hole due to th large orbital momentum of a disrupting star. However, we shov here that the accretion mostly has disk characteristics only whe $M < M_{cr}$ and becomes quasi-spherical when $M \gg M_{cr}$.

ARTICLES

Pancake detonation of stars by black holes in galactic nuclei

B. Carter & J. P. Luminet

Groupe d'Astrophysique Relativiste, Observatoire de Paris, 92190 Meudon, France

Recent efforts to understand exotic phenomena in galactic nuclei commonly postulate the presence of a massive black hole accreting gas produced by tidal or collisional disruption of stars. For black holes in the mass range 10^4–$10^7 M_\odot$, individual stars penetrating well inside the Roche radius will undergo compression to a short-lived pancake configuration very similar to that produced by a high velocity symmetric collision of the kind likely to occur in the neighbourhood of black holes in the higher mass range $\geq 10^9 M_\odot$. Thermonuclear energy release ensuing in the more extreme events may be sufficient to modify substantially the working of the entire accretion process.

NATURE VOL. 333 9 JUNE 1988

Tidal disruption of stars by black holes of 10^6–10^8 solar masses in nearby galaxies

Martin J. Rees

Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK

Stars in galactic nuclei can be captured or tidally disrupted by a central black hole. Some debris would be ejected at high speed; the remainder would be swallowed by the hole, causing a bright flare lasting at most a few years. Such phenomena are compatible with the presence of 10^6–$10^8 M_\odot$ holes in the nuclei of many nearby galaxies. Stellar disruption may have interesting consequences in our own Galactic Centre if a $\sim 10^6 M_\odot$ hole lurks there.

"Dead Quasars" in Nearby Galaxies?

Martin J. Rees

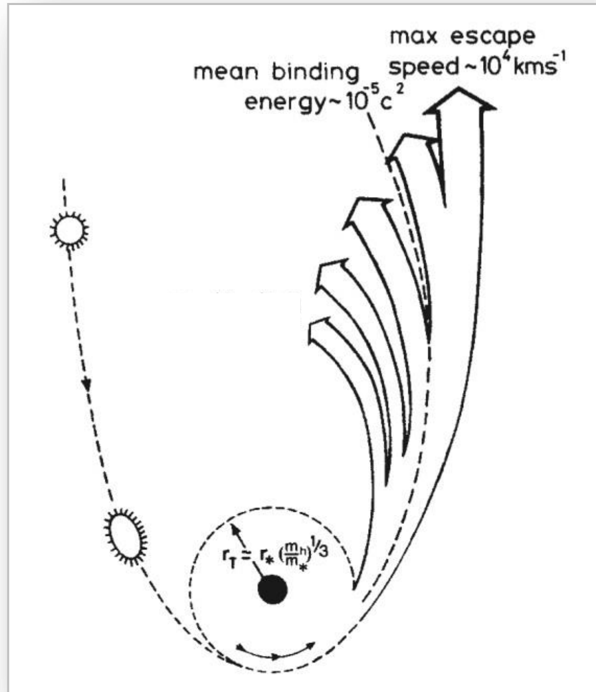
SCIENCE, VOL. 247 16 FEBRUARY 1990

The nuclei of some galaxies undergo violent activity, quasars being the most extreme instances of this phenomenon. Such activity is probably short-lived compared to galactic lifetimes, and was most prevalent when the universe was only about one-fifth of its present age. A evolved to the stage where runaway activity gets triggered in their nuclei (2).

Quasar activity is apparently a distinctive feature of *rather young* galaxies. The quasar density peaked soon after galaxies formed. The population then seems to have dwindled as the universe (with its constituent galaxies) got older. A current estimate (3) of the relative

„The best diagnostic for a BH's presence would be some inevitable concomitant that cannot be explained in any other way."

[M. Rees, *Nature*, 1988]



tidal disruption of stars by SMBHs

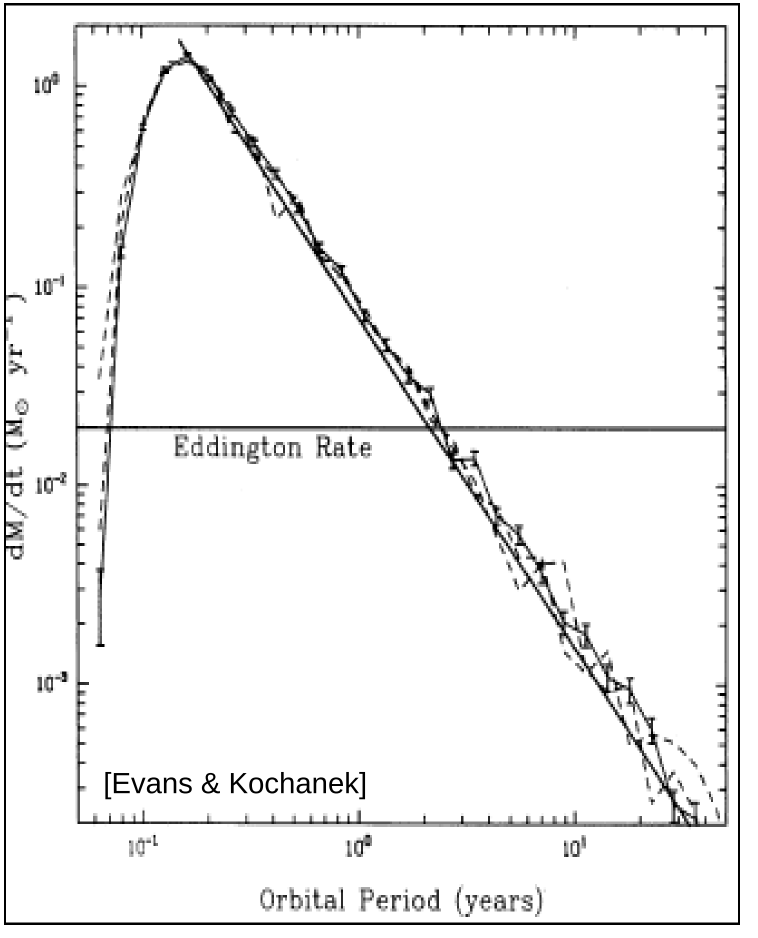
- disruption at $r = r_{\rm tidal}$, with tidal radius $r_{\rm tidal} = R_*(M_{\rm BH}/m_*)^{1/3} = 7\ 10^{12}\ M_{\rm BH,6}^{1/3}\ (R_*/R_{\rm sun})\ (m_*/m_{\rm sun})^{-1/3}$ cm

  → solar-type stars swallowed whole above $M_{\rm BH} \sim 10^8\ M_{\rm sun}$

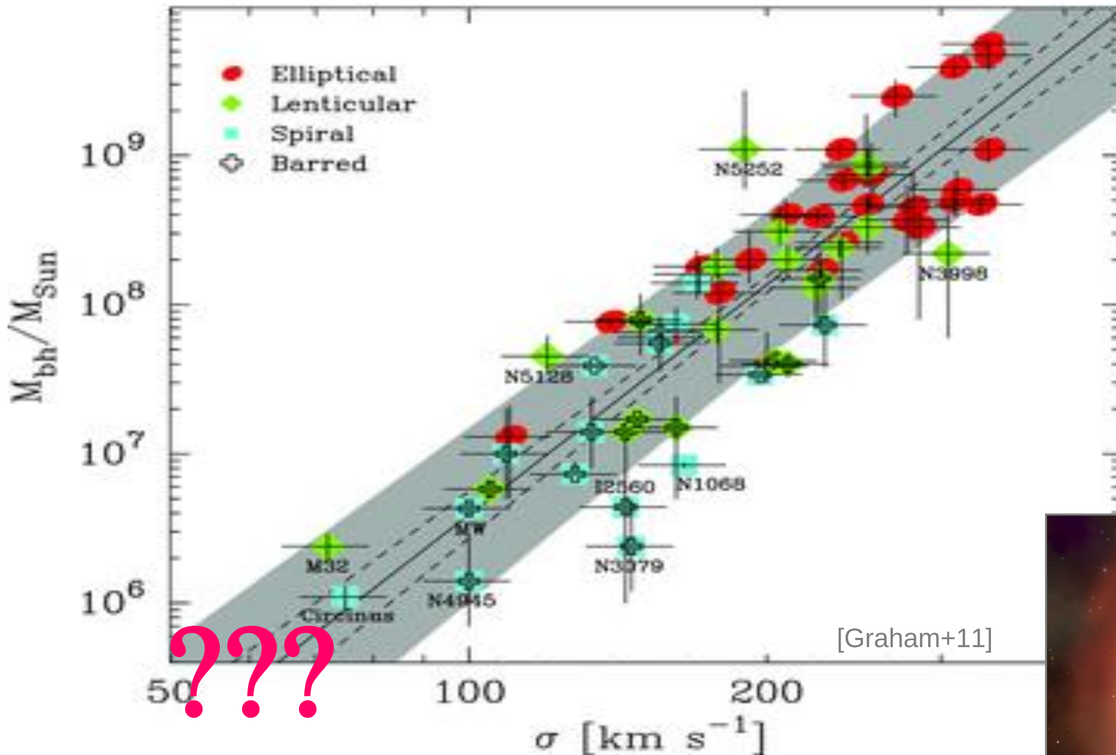
  → disruption of WDs requires $M_{\rm BH} < 10^5 M_{\rm sun}$

- high initial gas supply rate, up to highly super-Eddington → high $L_{\rm peak}$
- bbdy temperature at r_t $T \sim 10^{5\text{-}6}$ K
- ~ 90% of the stellar material is unbound
- event rate $10^{-4..-5}$ /yr /galaxy

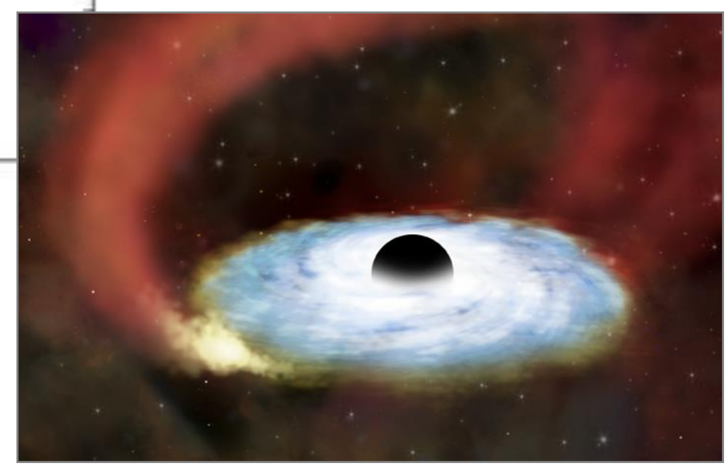
- return rate $dm/dt \sim t^{-5/3}$



tidal disruption of stars by SMBHs



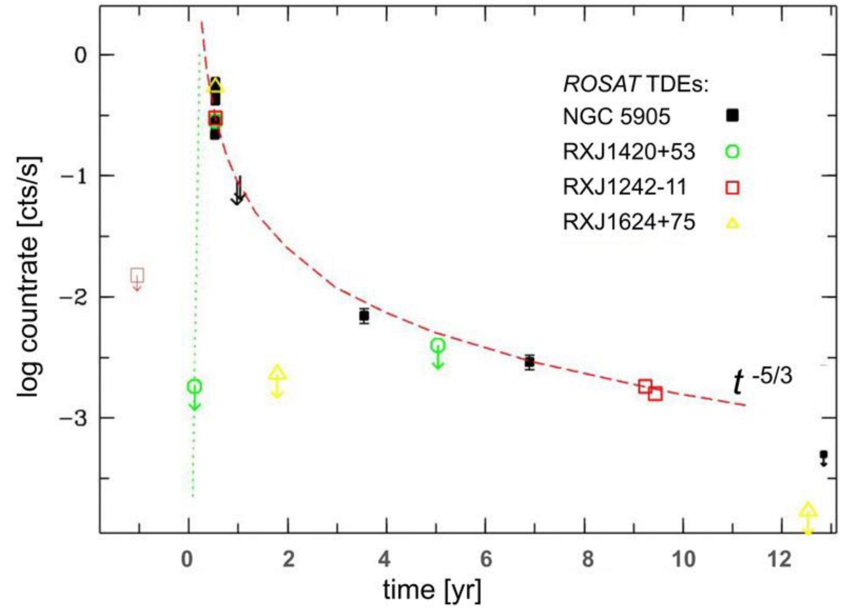
- detection of IMBHs, < 10^6 M_{sun}



- new probe of accretion physics down to last stable orbit, from highly super-Eddington to sub-Eddington within yrs; & of BH spin and jet formation

luminous TDEs in soft X-rays – first detections (ROSAT)

- $L_{x,peak}$ up to sev. 10^{44} erg/s
- very soft X-ray spectra near peak (kT_{BB} ~ 0.04-0.1 keV); then hardening within yrs
- decline consist. with predicted $t^{-5/3}$ law, plus drop at t > sev yrs
- amplitudes of decline up to factor 1000-6000



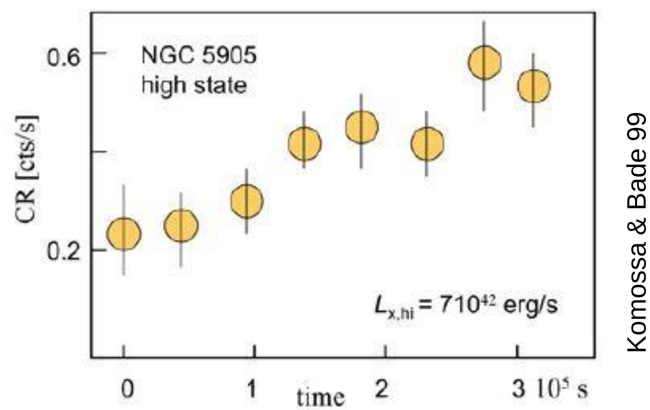


Figure 3. *ROSAT* high-state lightcurve of NGC 5905, observed during the RASS. It shows a rise within several days toward the observed peak of $L_{sx} = 7\,10^{42}$ erg/s.

Komossa & Bade 99

[Bade+96, Komossa & Bade 99, Komossa & Greiner 99, Greiner+ 00, Halpern+ 04, Komossa+ 04]

luminous TDEs in soft X-rays – first detections (ROSAT)

- $L_{x,peak}$ up to sev. 10^{44} erg/s
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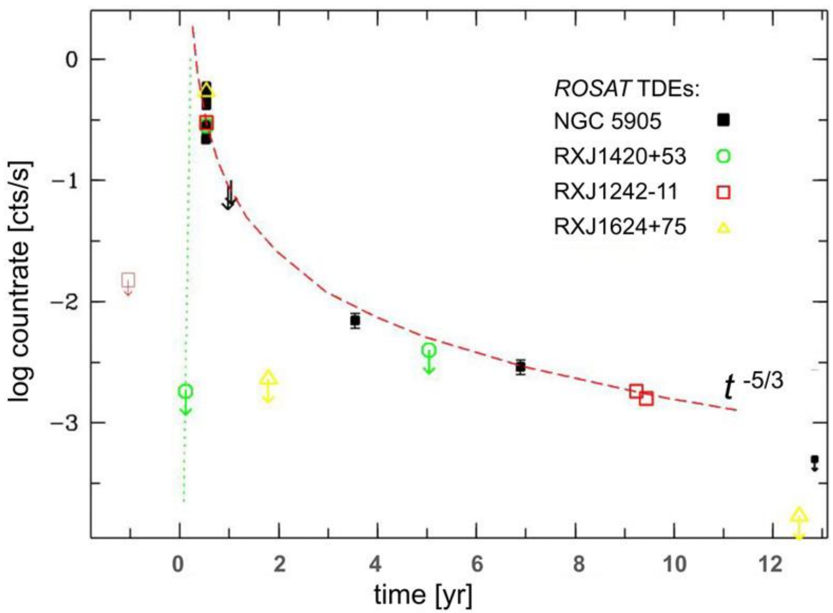
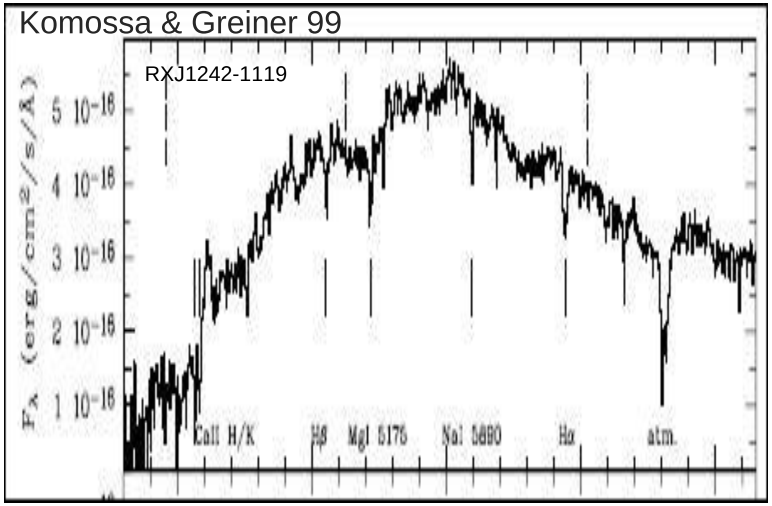
- amplitudes of decline up to factor 1000-6000
- host galaxies are optically *inactive*



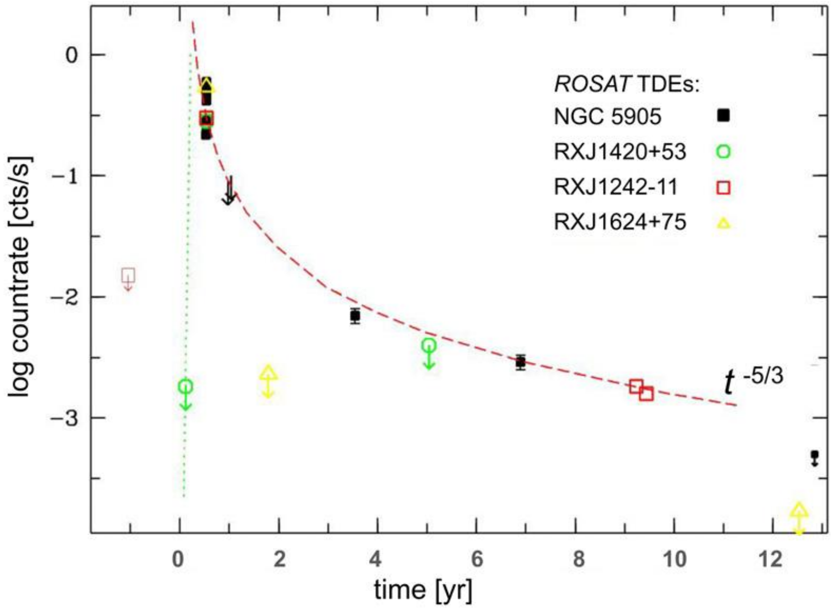


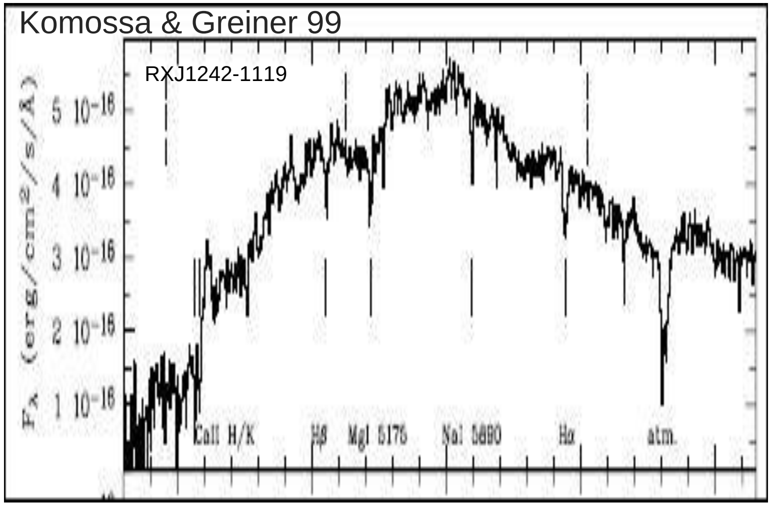
[Bade+96, Komossa & Bade 99, Komossa & Greiner 99, Greiner+ 00, Halpern+ 04, Komossa+ 04]

luminous TDEs in soft X-rays – first detections (ROSAT)

- $L_{x,peak}$ up to sev. 10^{44} erg/s
- very soft X-ray spectra near peak (kT_{BB} ~ 0.04-0.1 keV); then hardening within yrs
- decline consist. with predicted $t^{-5/3}$ law, plus drop at t > sev yrs
- amplitudes of decline up to factor 1000-6000
- host galaxies are optically *inactive*
- M_{BH} ~ 10^{6-8} M_{sun}
- $m_{*,acc}$ < 10% M_{sun}

[Bade+96, Komossa & Bade 99, Komossa & Greiner 99, Greiner+ 00, Li+ 02, Halpern+ 04, Komossa+ 04]





TDEs identified in X-rays .... in non-AGN

TDE	z	mission	publication
NGC 5905	0.011	ROSAT	Bade+ 96, Komossa+ 99
RXJ1242-1119	0.050	ROSAT	Komossa & Greiner 99 Komossa+ 04
RXJ1624+7554	0.064	ROSAT	Grupe+ 99
RXJ1420+5334	0.147	ROSAT	Greiner+ 00
NGC 3599	0.003	XMM	Esquej+ 07, 08
SDSS1323+4827	0.087	XMM	Esquej+ 07, 08
TDXF1347-3254	0.037	ROSAT	Cappelluti+ 09
SDSS 1311-0123	0.195	Chandra	Maksym+ 10
2XMMi1847-6317	0.035	XMM	Lin+ 11
SwiftJ1644+57	0.354	Swift	Bloom+ 11, Burrows+ 11
SDSS1201+3003	0.146	XMM	Saxton+ 12
SwiftJ2058+0516	1.185	Swift	Cenko+12
WINGS J1348	0.062	Chandra	Maksym+ 13 Donato+ 14
RBS1032 (?)	0.026	ROSAT	Maksym+14, Khabibullin+14
3XMMJ1521+0749	0.179	XMM	Lin+ 15

[review: Komossa 15]

plus 1-- few in classical AGN [e.g., Nikolajuk & Walter+ 13]

X-ray TDEs: dedicated searches for new events (XMM & Chandra)

~ 10 events identified; overall properties very similar to previous (ROSAT) *soft* X-ray TDEs:

- extreme X-ray softness near max
- high peak luminosities, up to few 10^{44} erg/s
- decline by typ. factors ~ > 100 (ROSAT: > 1000-6000)
- (optically) quiescent galaxies

→ important probes of accretion physics in early stages of TDE evolution; **including the super-Eddington phase**

[Esquej+ 07,08, Cappelluti+ 09, Maksym+ 10,13, Lin+ 11,15, 16—prep., Saxton+ 12, 14,16—prep., Donato+ 14, review: Komossa 15]

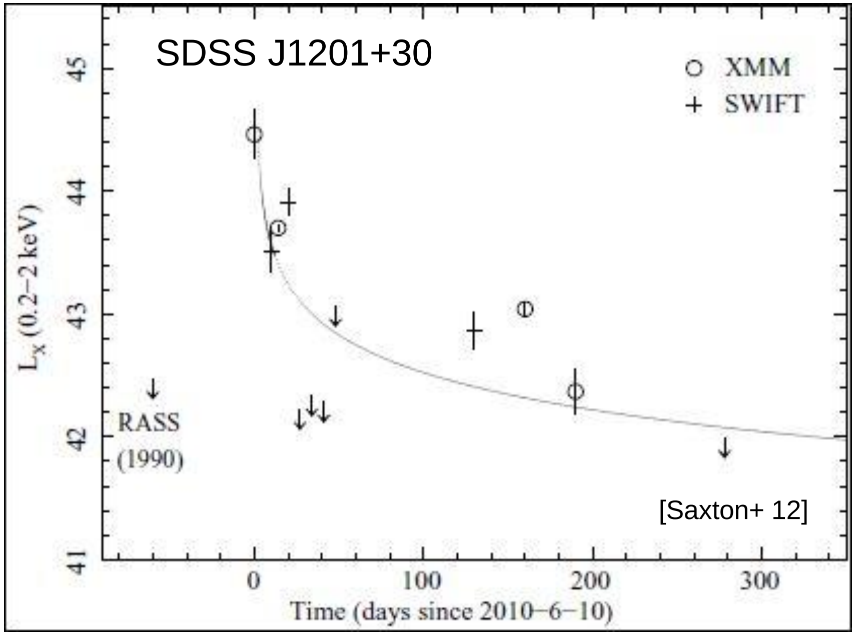
- rate estimates: $10^{-4...-5}$ /yr/gal (based on: RASS, XMM-slew, Chandra DF, gal. clusters)

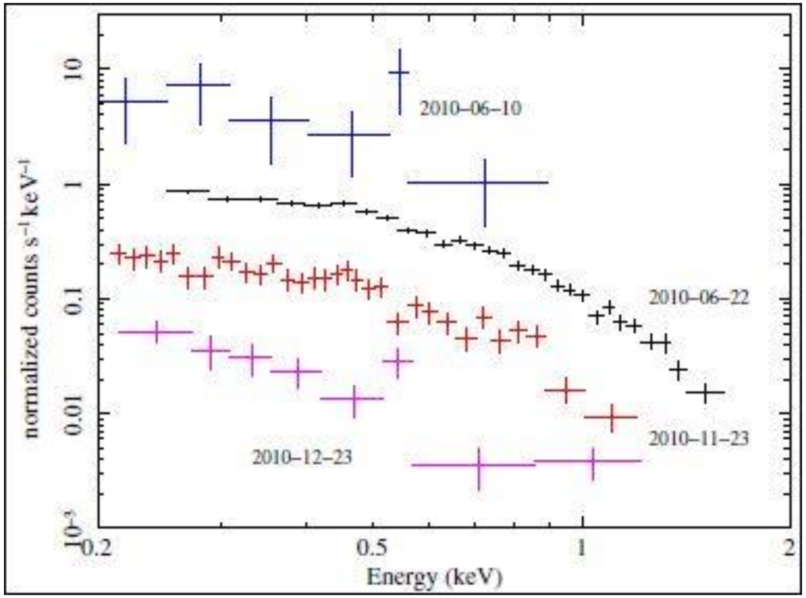
[Donley+ 02, Esquej+ 08, Luo+ 08, Maksym+ 10, Khabibullin+14]

TDEs with XMM & Chandra

SDSSJ1201+30 (z=0.146)

$L_{x,hi}$ = 3 10^{44} erg/s
overall decline, + high-ampl. var
complex X-ray spectrum



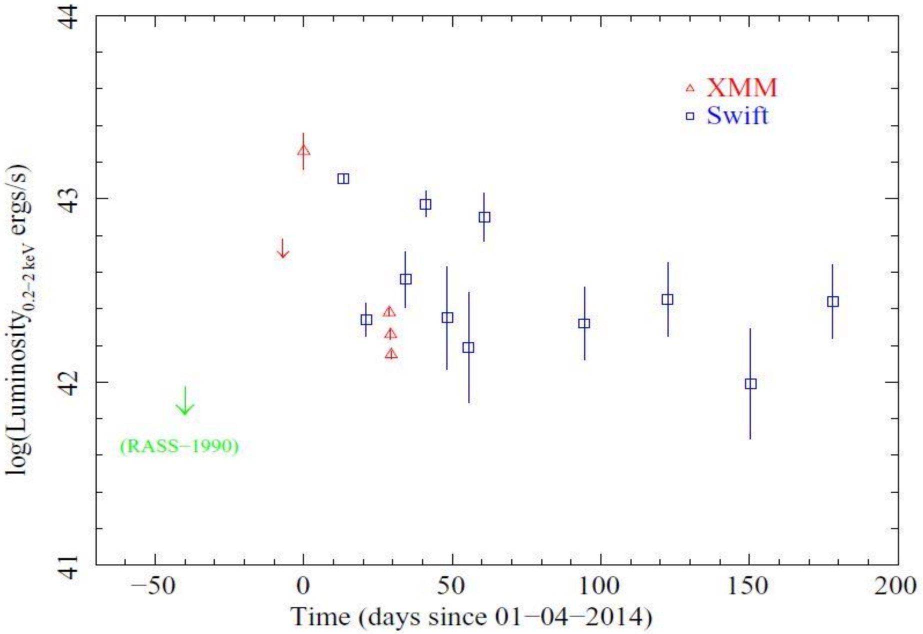


- no emission lines; neither host nor TDE
- no VLA radio detection:
  f < 0.1 mJy (at 8 GHz) after ~1yr
- M_{BH} ~ 10^{6-7} M_{sun}

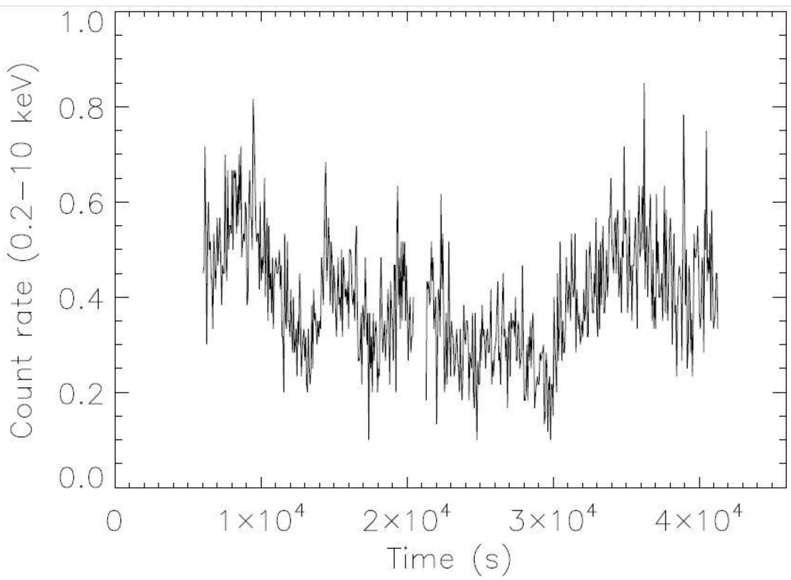
[Saxton+ 12, Liu, Li, Komossa 14]

TDEs with XMM & Chandra

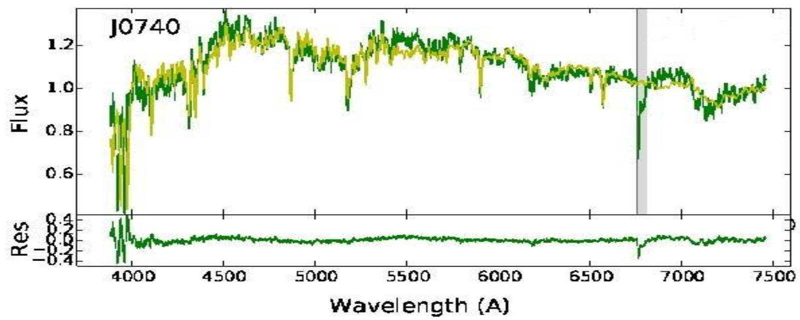
2MASSJ07-85 (z=0.017)



$L_{x,hi}$ = few 10^{43} erg/s
fast variability (XMM): .
doubling timescale 400s
soft spectrum with hard tail



no optical emission lines → inactive galaxy



[16--in prep]

TDEs with XMM & Chandra

3XMMJ1521+0749

$L_x = 5\ 10^{43}$ erg/s

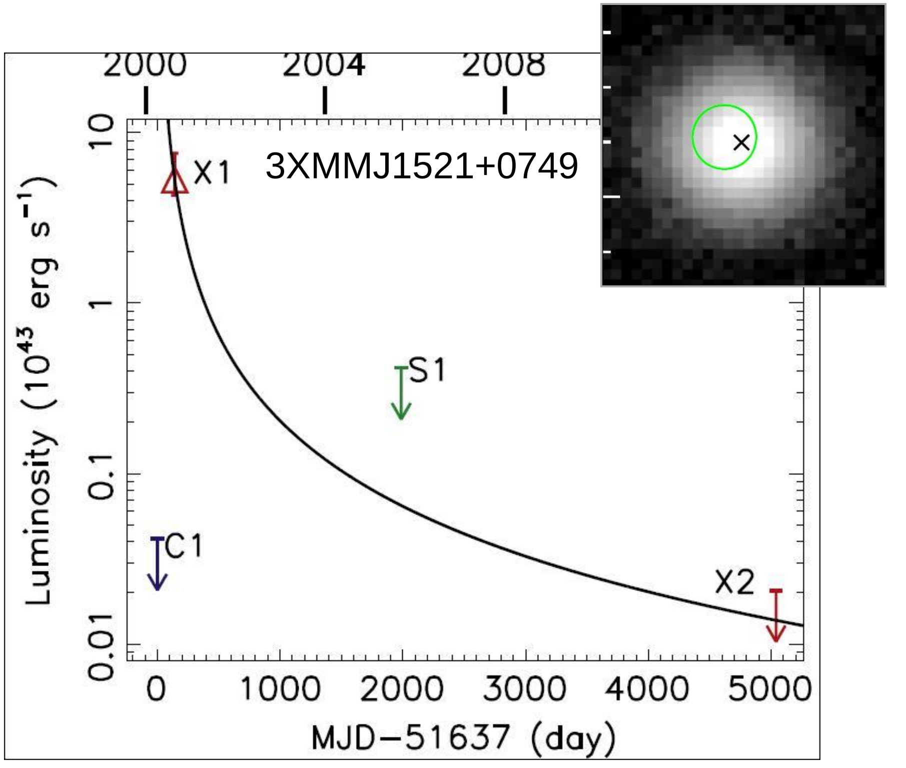
ultra-soft spectrum, kT ~0.1 keV, subject to fast-moving warm absorber (v ~ 0.1 c)

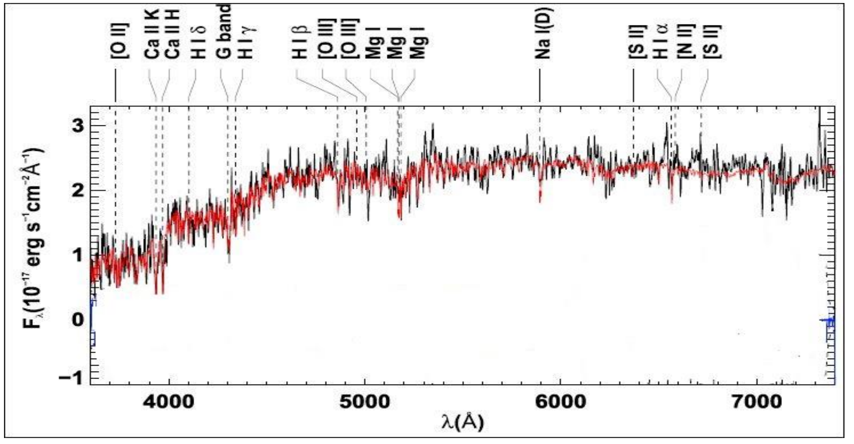
not detected in X in any follow-ups; amplitude of variability: factor 260

X-emi coincident with centre of inactive galaxy at z=0.18

BH mass: M_{BH} = few 10^7 M_{sun}

[Lin+ 15]





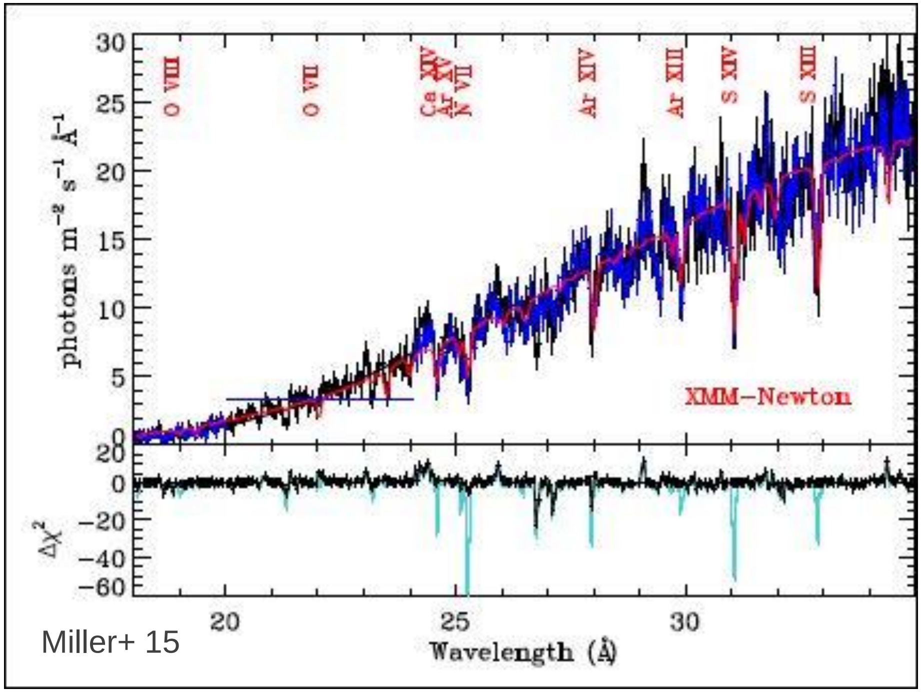
first high-resolution X-ray spectroscopy of a TDE

- optically identified TDE (z=0.02) **ASASSN14li,** with luminous X-rays

- declining radio emission indicates presence of low-power jet/outflow (+ permanent component indicating permanent low-level AGN)

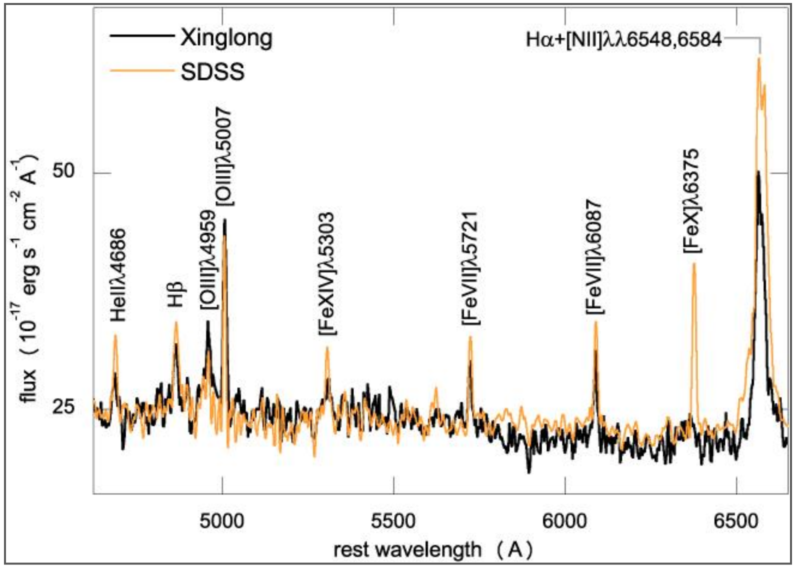
- XMM-RGS: thermal conti (kT ~ 0.05 keV) & highly ionized matter near BH in outflow
  v = few 100 km/s

→ new probe of early formation & evolution of disk wind and/or stellar debris



[Jose+ 14 Atel #6777, Miller+ 15]

TDEs in gas-rich environments: emission lines



SDSSJ0952+2143

- super-strong Fe coronal lines & HeII
- $L_{[FeX],hi}$ = 4 10^{40} erg/s
- fade by factor 10, in ~3yrs

- unusual Balmer profile; incl. redshifted broad comp., fading

- luminous MIR (Spitzer,10-20 m), ~10^{43} erg/s

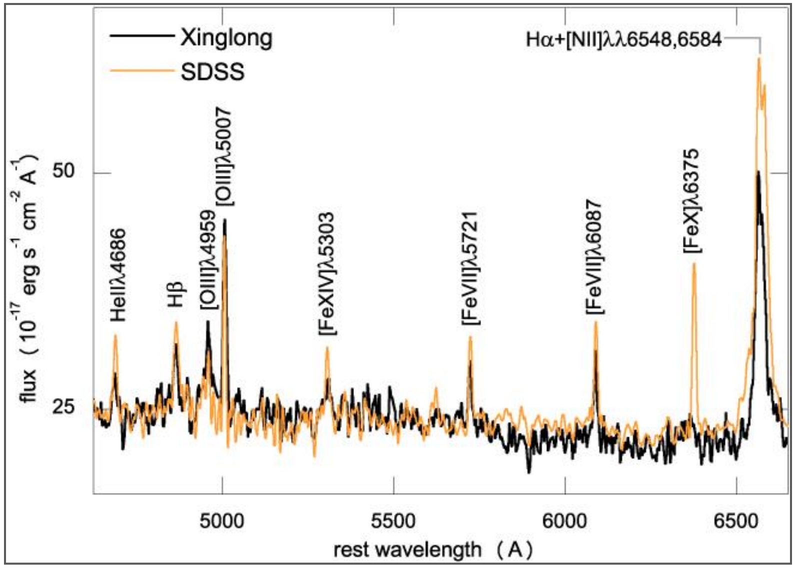
- but faint X-rays, ~10^{41} erg/s, few yrs after ‚SDSS' high-state

- no clear signs of permanent AGN (from line ratios, absence of radio, opt pl, IRAS colours)

- M_{BH} = 7 10^6 M_{sun} (from σ_*)

[Komossa+ 08, 09]

TDEs in gas-rich environments: emission lines



SDSSJ0952+2143

→ luminous EUV-X-ray flare, not observed directly, but in NUV, opt, NIR conti, and in broad and narrow emi lines

- super-strong Fe coronal lines & HeII
- $L_{\mathbf{[FeX],hi}}$ = 4 10^{40} erg/s
- fade by factor 10, in ~3yrs
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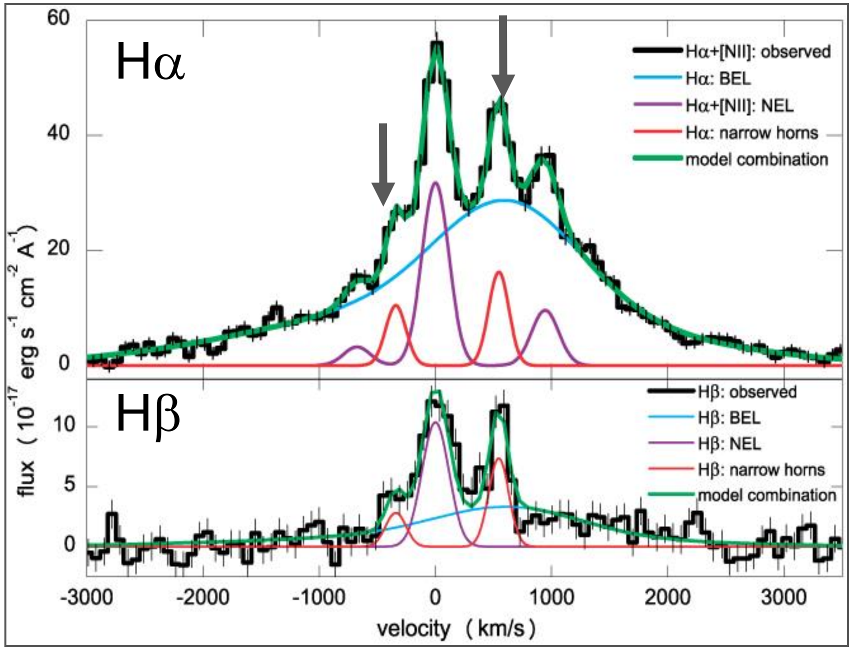
- $M_{BH} = 7\ 10^6\ M_{sun}$ (from σ_*)

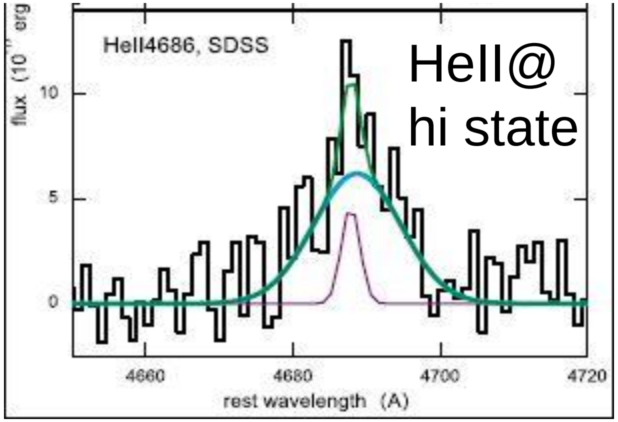
[Komossa+ 08, 09]

TDEs in gas-rich environments: emission lines

very narrow double-peaked "horns" in Balmer lines:



2-component high-ion. Fe and HeII lines:



→ lines excited by TDE, illuminating surrounding ISM (narrow lines), and stellar material (broad lines)? → new method of mapping phys. conditions in galaxy cores

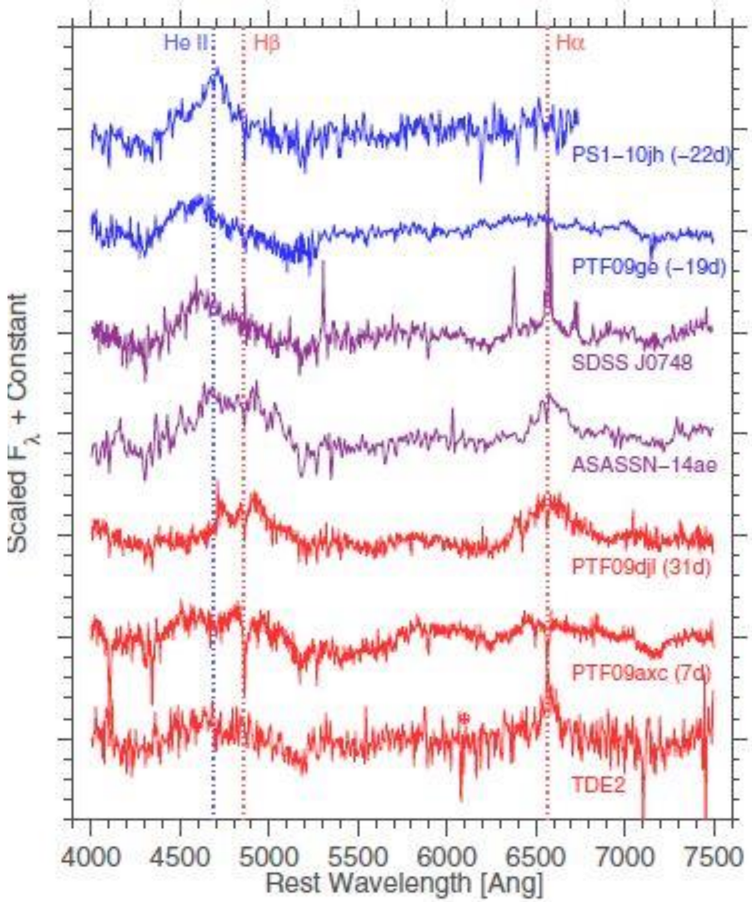
[Komossa+ 08, 09]

TDEs in gas-rich environments: emission lines

several more TDE candidates with transient emission-lines from SDSS, PanSTARS, PTF, ASAS-SN; including in early stages , with strong Balmer lines

→ emission from the tidal debris which formed the temporary accretion disk

→ ongoing discussions:
- do TDE candidates with absent H lines require He-rich stellar core, or photoionization-effects in solar gas ?
- why do their decline lightcurves imply ~constant *T*, $\sim 10^4$ K ?
- why do most opt-UV TDE candidates lack X-ray emission ?



[e.g., Komossa+ 09, Wang+ 11, 12, van Velzen+ 11, Gezari+ 12, Guillochon+ 14, Gaskell+ 14, Holoien+ 14, 16, Arcavi+ 14, ...]

discovery of jetted TDEs with *Swift*

A Possible Relativistic Jetted Outburst from a Massive Black Hole Fed by a Tidally Disrupted Star

Joshua S. Bloom,[1*] Dimitrios Giannios,[2] Brian D. Metzger,[2] S. Bradley Cenko,[1] Daniel A. Perley,[1] Nathaniel R. Butler,[1] Nial R. Tanvir,[3] Andrew J. Levan,[4] Paul T. O' Brien,[3] Linda E. Strubbe,[1,5] Fabio De Colle,[6] Enrico Ramirez-Ruiz,[6] William H. Lee,[7] Sergei Nayakshin,[3] Eliot Quataert,[1,5] Andrew R. King,[3] Antonino Cucchiara,[1,8] James Guillochon,[6] Geoffrey C. Bower,[9,1] Andrew S. Fruchter,[10] Adam N. Morgan,[1] Alexander J. van der Horst[11]

Gas accretion onto some massive black holes (MBHs) at the centers of galaxies actively powers luminous emission, but most MBHs are considered dormant. Occasionally, a star passing too near an MBH is torn apart by gravitational forces, leading to a bright tidal disruption flare (TDF). Although the high-energy transient Sw 1644+57 initially displayed none of the theoretically an… su… evi… syn… ter…

An Extremely Luminous Panchromatic Outburst from the Nucleus of a Distant Galaxy

A. J. Levan,[1*] N. R. Tanvir,[2] S. B. Cenko,[3] D. A. Perley,[3] K. Wiersema,[2] J. S. Bloom,[3] A. S. Fruchter,[4] A. de Ugarte Postigo,[5] P. T. O'Brien,[2] N. Butler,[3] A. J. van der Horst,[6] G. Leloudas,[5] A. N. Morgan,[3] K. Misra,[4] G. C. Bower,[3] J. Farihi,[2] R. L. Tunnicliffe,[1] M. Modjaz,[7] J. M. Silverman,[3] J. Hjorth,[5] C. Thöne,[8] A. Cucchiara,[3] J. M. Castro Cerón,[9] A. J. Castro-Tirado,[8] J. A. Arnold,[10] M. Bremer,[11] J. P. Brodie,[10] T. Carroll,[12] M. C. Cooper,[13] P. A. Curran,[14] R. M. Cutri,[15] J. Ehle,[12] D. Forbes,[16] J. Fynbo,[5] J. Gorosabel,[8] J. Graham,[4,17] D. I. Hoffman,[15] S. Guziy,[8] P. Jakobsson,[19] A. Kamble,[20] T. Kerr,[12] M. M. Kasliwal,[18] C. Kouveliotou,[21] D. Kocevski,[10] N. M. Law,[22] P. E. Nugent,[3,23] E. O. Ofek,[18] D. Poznanski,[3,23] R. M. Quimby,[18] E. Rol,[24] A. J. Romanowsky,[10] R. Sánchez-Ramírez,[8] S. Schulze,[19] N. Singh,[10,25] L. van Spaandonk,[1,26] R. L. C. Starling,[2] R. G. Strom,[24,27] J. C. Tello,[8] O. Vaduvescu,[28] P. J. Wheatley,[1] R. A. M. J. Wijers,[24] J. M. Winters,[11] D. Xu[29]

Variable x-ray and γ-ray emission is characteristic of the most extreme physical processes in the universe. We present multiwavelength observations of a unique γ-ray–selected transient detected by the Swift satellite, accompanied by bright emission across the electromagnetic spectrum, and whose properties are unlike any previously observed source. We pinpoint the event to the center of a small, star-forming galaxy at redshift $z = 0.3534$. Its high-energy emission has lasted much longer than any γ-ray burst, whereas its peak luminosity was ~100 times higher than bright active galactic nuclei. The association of the outburst with the center of its host galaxy suggests that this phenomenon has its origin in a rare mechanism involving the massive black hole in the nucleus of that galaxy.

LETTER

doi:10.1038/nature10374

Relativistic jet activity from the tidal disruption of a star by a massive black hole

D. N. Burrows[1], J. A. Kennea[1], G. Ghisellini[2], V. Mangano[3], B. Zhang[4], K. L. Page[5], M. Eracleous[1], P. Romano[3], T. Sakamoto[6,7,8], A. D. Falcone[1], J. P. Osborne[5], S. Campana[2], A. P. Beardmore[5], A. A. Breeveld[9], M. M. Chester[1], R. Corbet[6,7,8], S. Covino[2], J. R. Cummings[6,7,8], P. D'Avanzo[2], V. D'Elia[10], P. Esposito[11], P. A. Evans[5], D. Fugazza[2], J. M. Gelbord[1], K. Hiroi[12], S. T. Holland[6,7,13], K. Y. Huang[14], M. Im[15], G. Israel[16], Y. Jeon[15], Y.-B. Jeon[17], H. D. Jun[15], N. Kawai[18,19], J. H. Kim[15], H. A. Krimm[6,7,13], F. E. Marshall[7], P. Mészáros[1], H. Negoro[20], N. Omodei[21,22], W.-K. Park[15], J. S. Perkins[6,7,8], M. Sugizaki[19], H.-I. Sung[17], G. Tagliaferri[2], E. Troja[7], Y. Ueda[12], Y. Urata[23], R. Usui[18], L. A. Antonelli[10,16], S. D. Barthelmy[7], G. Cusumano[3], P. Giommi[10], A. Melandri[2], M. Perri[10], J. L. Racusin[7], B. Sbarufatti[3], M. H. Siegel[1] & N. Gehrels[7]

Supermassive black holes have powerful gravitational fields with strong gradients that can destroy stars that get too close[1,2], producing a bright flare in ultraviolet and X-ray spectral regions from stellar debris that forms an accretion disk around the black hole[3–7]. The aftermath of this process may have been seen several times over the past two decades in the form of sparsely sampled, slowly fading emission from distant galaxies[8–14], but the onset of the stellar disruption event has not hitherto been observed. Here we report observations of a bright X-ray flare from the extragalactic transient Swift J164449.3+573451. This source increased in brightness in the X-ray band by a factor of at least 10,000 since 1990 and by a factor of at least 100 since early 2010. We conclude that we have captured the onset of relativistic jet activity from a supermassive black hole. A companion paper[15] comes to similar conclusions on

is $\sim 2 \times 10^{53}$ erg (1–10 keV). We have found no statistically significant periodic or quasi-periodic signals in the XRT data. Details of our observations and data analysis are given in Supplementary Information section 1.

Swift J164449.3+573451 has not been previously detected at any wavelength and is not present in any sky catalogues. X-ray flux upper limits from observations by ROSAT, XMM-Newton, MAXI and Swift between 1990 and 24 March 2011 are 2–4 orders of magnitude lower than the peak X-ray fluxes measured by Swift (Fig. 2), and the ROSAT upper limits are an order of magnitude below the lowest flux in the first 50 days after the first BAT trigger.

LETTER

doi:10.1038/nature10366

Birth of a relativistic outflow in the unusual γ-ray transient Swift J164449.3+573451

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Active galactic nuclei, which are powered by long-term accretion onto central supermassive black holes, produce[1] relativistic jets with lifetimes of at least one million years, and the observation of the birth of such a jet is therefore unlikely. Transient accretion onto a supermassive black hole, for example through the tidal disruption[2,3] of a stray star, thus offers a rare opportunity to study the birth of a relativistic jet. On 25 March 2011, an unusual transient source (Swift J164449.3+573451) was found[4], potentially representing[5,6] such an accretion event. Here we report observations spanning centimetre to millimetre wavelengths and covering the first month of evolution of a luminous radio transient associated with Swift J164449.3+573451. The radio transient coincides[7] with the nucleus of an inactive galaxy. We conclude that we are seeing a newly formed relativistic outflow, launched by transient accretion onto a million-solar-mass black hole. A relativistic outflow is not predicted in this situation, but we show that the tidal disruption of a star naturally explains the observed high-energy properties and radio luminosity and the inferred rate of such events. The weaker beaming in the radio-frequency spectrum relative to γ-rays or X-rays suggests that radio searches may uncover similar events out to redshifts of $z \approx 6$.

On the discovery[4] of Swift J164449.3+573451 by NASA's Swift satellite, and the identification of a galaxy at a redshift[6] of $z = 0.354$ within Swift's X-ray localization region (radius 1.4″), we initiated radio observations of the transient on 2011 March 29.36 UT with the Expanded Very Large Array (EVLA) at a frequency of 5.8 GHz and discovered an unresolved source with a flux density of 310 ± 7 μJy. Astrometric matching demonstrated that the radio source coincides with the galaxy nucleus (Fig. 1), as was subsequently confirmed[6] with other data. A follow-up EVLA observation 0.9 d later revealed that the

jetted TDEs: SwiftJ1644+57

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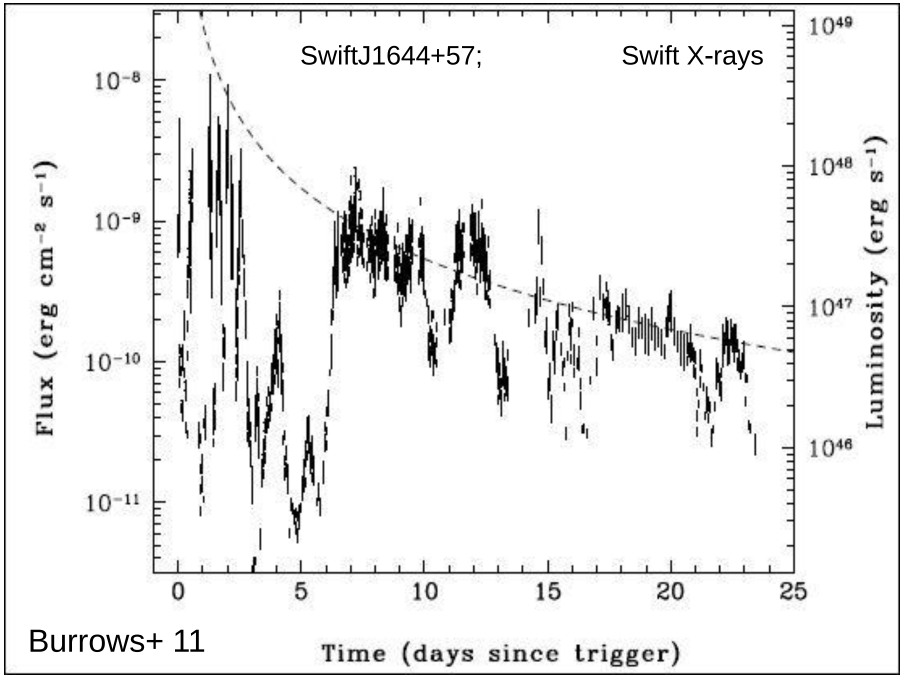
- lightcurve overally declining
- plus rapid variability, Δt ~ 100s



[Bloom+ 11, Burrows+ 11, Levan+ 11, Zauderer+ 11, *multi-λ follow-ups:* Aliu+11, Berger+ 12, Wirsema+ 12, Saxton+ 12, Reis+ 12, Aleksic 13, Zauderer+ 13, Castro-Tirado+ 13 & Gonzales-Rodriguez+ 13, Levan+ 16, Mangano+ 14, 16, Kara+ 16, Yang+ 16]

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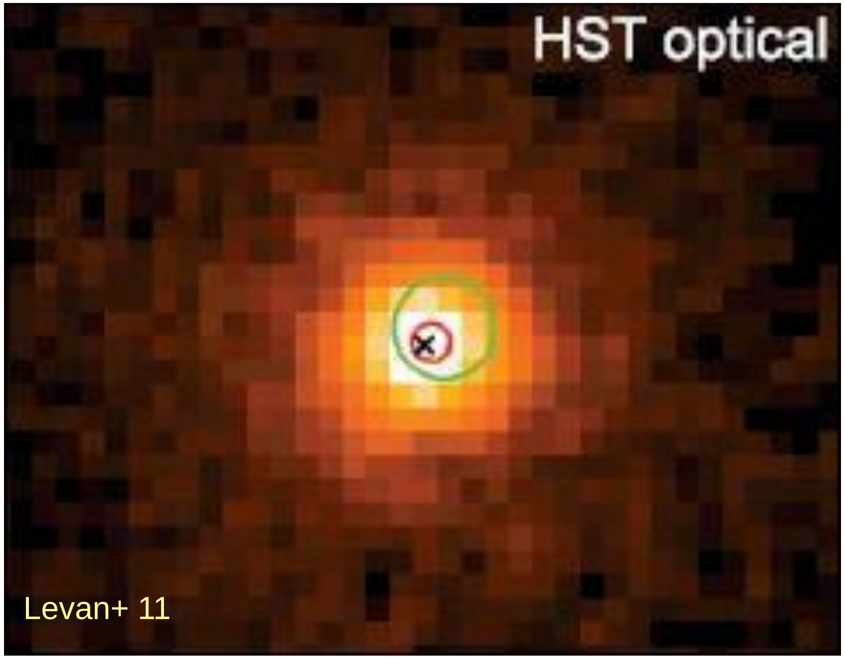
- plus rapid variability, Δt ~ 100s

- $\boldsymbol{z_{\mathrm{host}}}$ **=0.35, optically inactive**

- no UV, opt var (exti), but NIR



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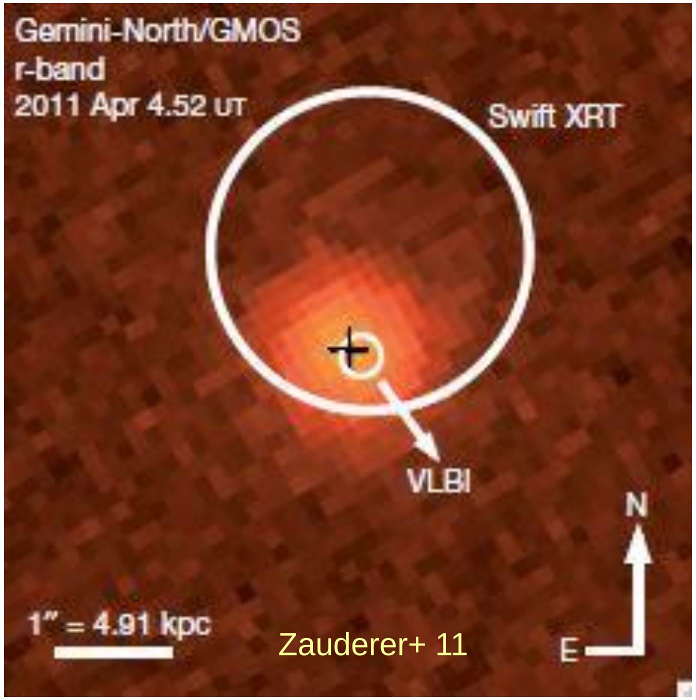
- **unresolved, variable,** beamed **radio emission**



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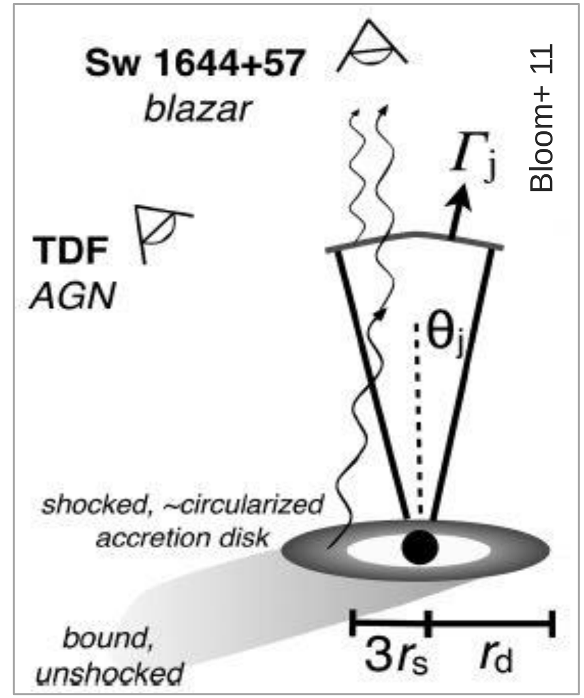
➔ **rapid onset of a powerful jet, following tidal disruption**



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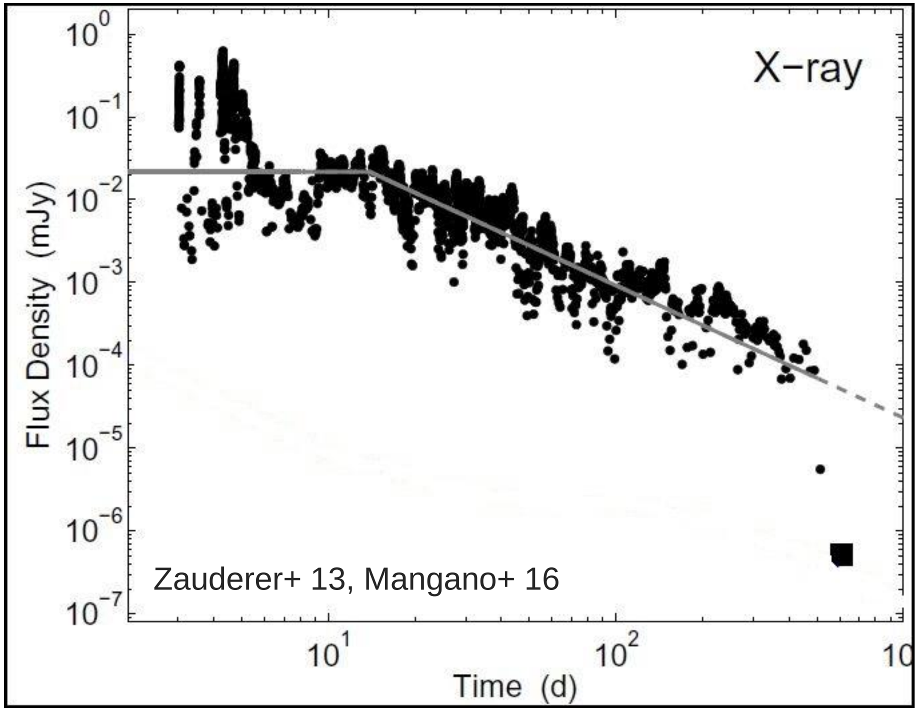

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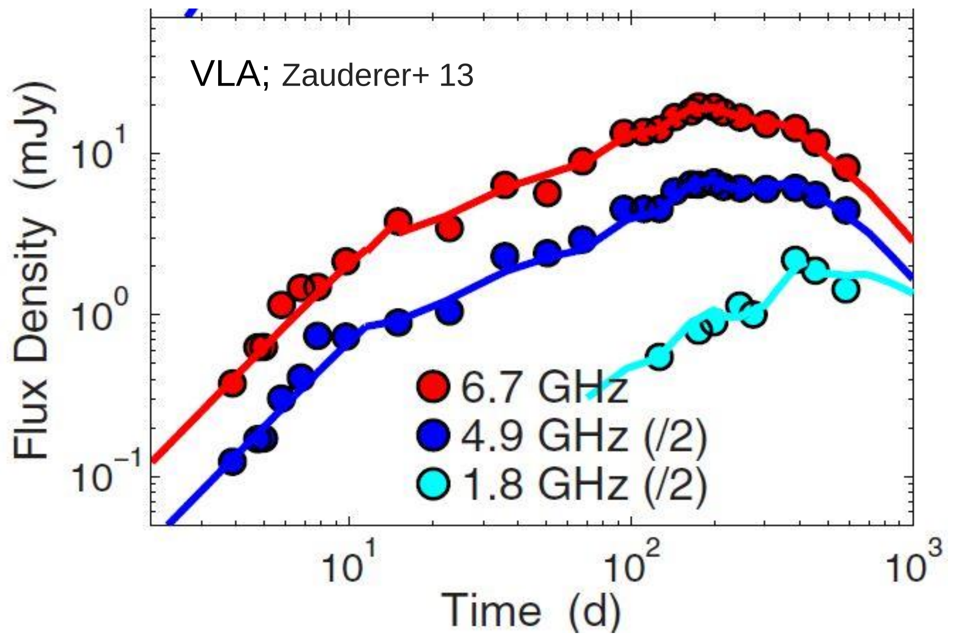
- sudden drop in X-rays after ~1.5 yr
- **not seen in radio**



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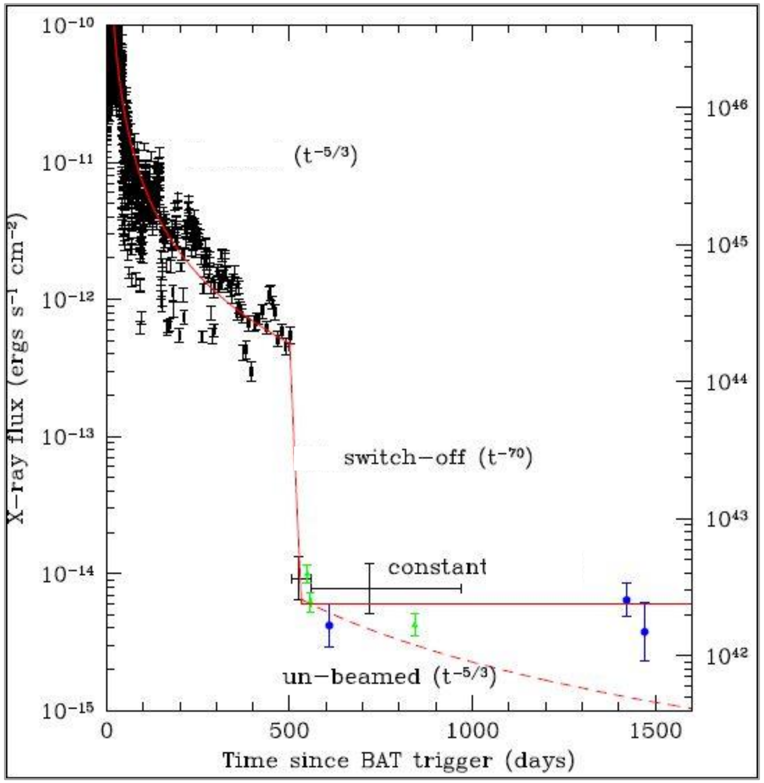
- **late-time X-rays remain faint, ~constant, at $L_{x,low}$ = 5 10^{42} erg/s**



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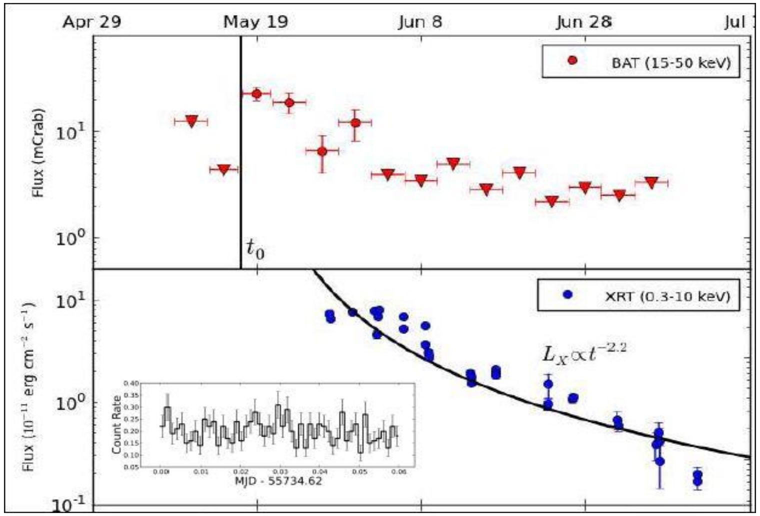
jetted TDEs: two more candidates with Swift:

SwiftJ2058+0516



- $L_{x,iso}$ = 3 10^{47} erg/s
- rapid variability, Δt ~ 1000s
- $z_{likely\text{-}host}$ =1.19, optically inactive
- M_{BH} approx 10^{7-8} M_{sun}
- luminous radio emi, likely beamed

→ many similarities with J1644

SwiftJ1112-8238

- $L_{x,iso} > 10^{47}$ erg/s
- $z_{likely\text{-}host}$ = 0.89 (?)

[Cenko+ 12, Brown+15, Pasham+15]

SwiftJ1644 follow-ups: modelling, theory, implications

- **X-ray & radio emission mechanisms:**
  do X-rays come from disc, inner jet, shocks from jet-ISM interaction, beamed component, ... ?

A 200-s Quasi-Periodicity Following the Tidal Disruption of a Star by a Dormant Black Hole

R. C. Reis, J. M. Miller, M. T. Reynolds, K. Gultekin, D. Maitra, A. L. King, T. E. Strohmayer

MNRAS 434, 3078–3088 (2013)
Advance Access publication 2013 August 7

A model for the multiwavelength radiation from tidal disru[...] Swift J1644+57

P. Kumar,[1★] R. Barniol Duran,[2★] Ž. Bošnjak[3★] and T. Piran[2★]

Mon. Not. R. Astron. Soc. 420, 3528–3537 (2012) doi:10.1111/j.1365-2966.2011.20[...]

Afterglow model for the radio emission from the jetted tidal disruption candidate Swift J1644+57

Brian D. Metzger,[1★†] Dimitrios Giannios[1] and Petar Mimica[2]

The Astrophysical Journal > Volume 788 > Number 1

Quasi-periodic Variations in X-Ray Emission and Long-term Radio Observations: Evidence for a Two-component Jet in Sw J1644+57

Jiu-Zhou Wang[1], Wei-Hua Lei[1,2,3], Ding-Xiong Wang[1], Yuan-Chuan Zou[1], Bing Zhang[4,5], He Gao[4], and Chang-Yin Huang[1,6]

MNRAS 437, 2744–2760 (2014)
Advance Access publication 2013 November 30

Swift J1644+57 gone MAD: the case for dynan[...] flux threading the black hole in a jetted tidal disruption event

Alexander Tchekhovskoy,[1,2★†‡§] Brian D. Metzger,[3] Dimitrios Giannios[4] and Luke Z. Kelley[5]

1 10 ... in the U.S.A.

JETS FROM TIDAL DISRUPTIONS OF STARS BY BLACK HOLES

Julian H. Krolik[1] and Tsvi Piran[2]

MNRAS 445, 3919–3938 (2014)

Tidal disruption and magnetic flux capture: powering a jet from a quiescent black hole

Luke Zoltan Kelley,[1★] Alexander Tchekhovskoy[2†] and Ramesh Naraya[...]

The Astrophysical Journal, 760:103 (15pp), 2012 December 1

THE DYNAMICS, APPEARANCE, AND DEMOGRAPHICS OF RELATIVISTI[...] BY TIDAL DISRUPTION OF STARS IN QUIESCENT SUPERMASSIVE BLACK HOLES

Fabio De Colle[1,2], James Guillochon[1], Jill Naiman[1], and Enrico Ramirez-Ruiz[1]

Observing Lense-Thirring Precession in Tidal Disruption Flares

Phys. Rev. Lett. 108, 061302 – Published 6 February 2012

Nicholas Stone and Abraham Loeb

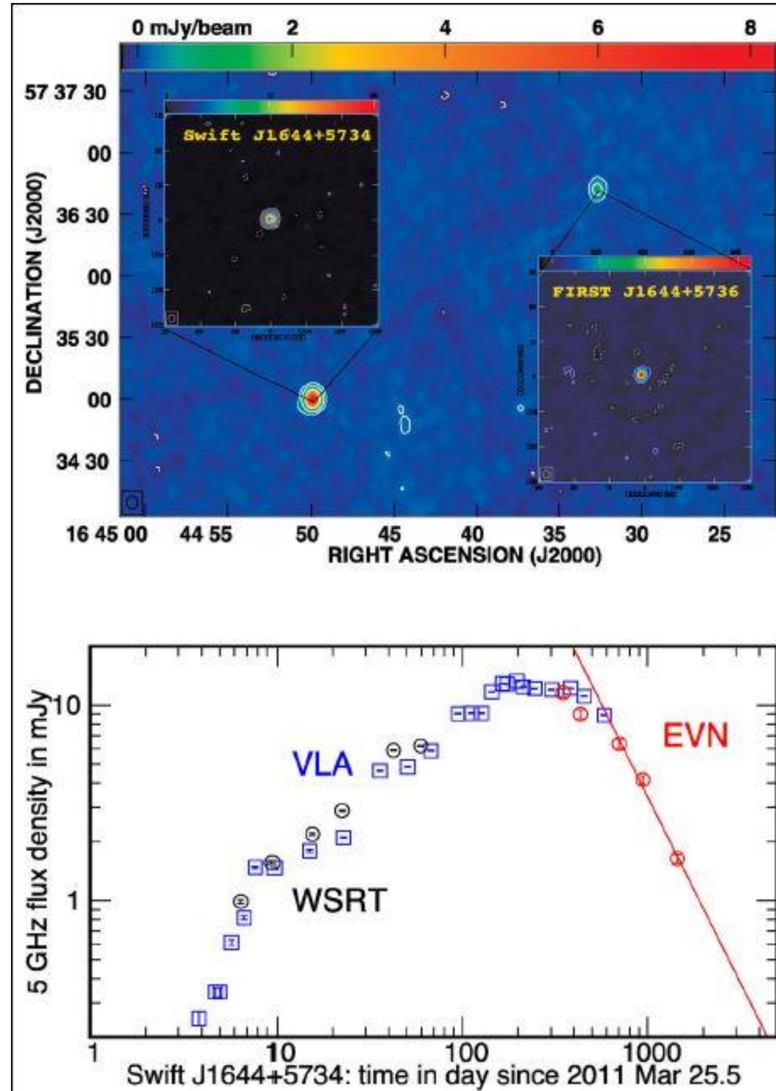
jetted TDE SwiftJ1644+57: how much above Eddington ?

spatially resolving the radio jet

- search for superluminal motion with EVN phase-referencing, at 5 GHz

  spatial resolution: 12 micro-arcsec

  → no superluminal motion detected, βapp < 0.3 c
  → no spatial extent detected



[Yang+ 16]

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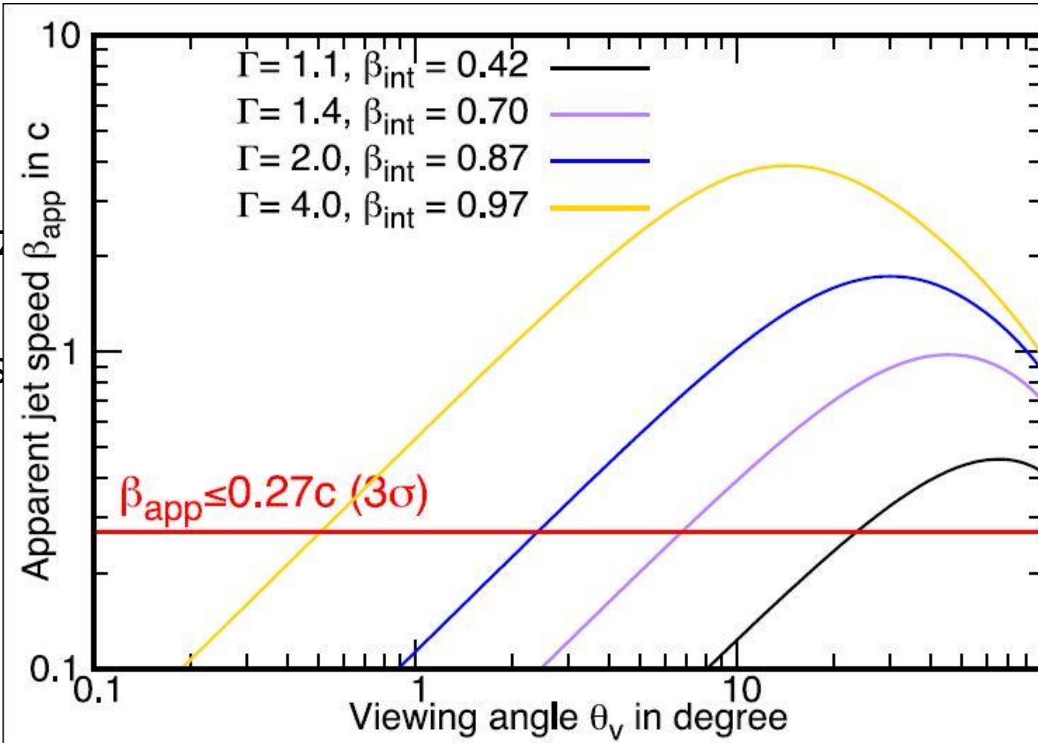

Figure 3. The VLBI constraints on the viewing angle and intrinsic jet speed.

[Yang+ 16]

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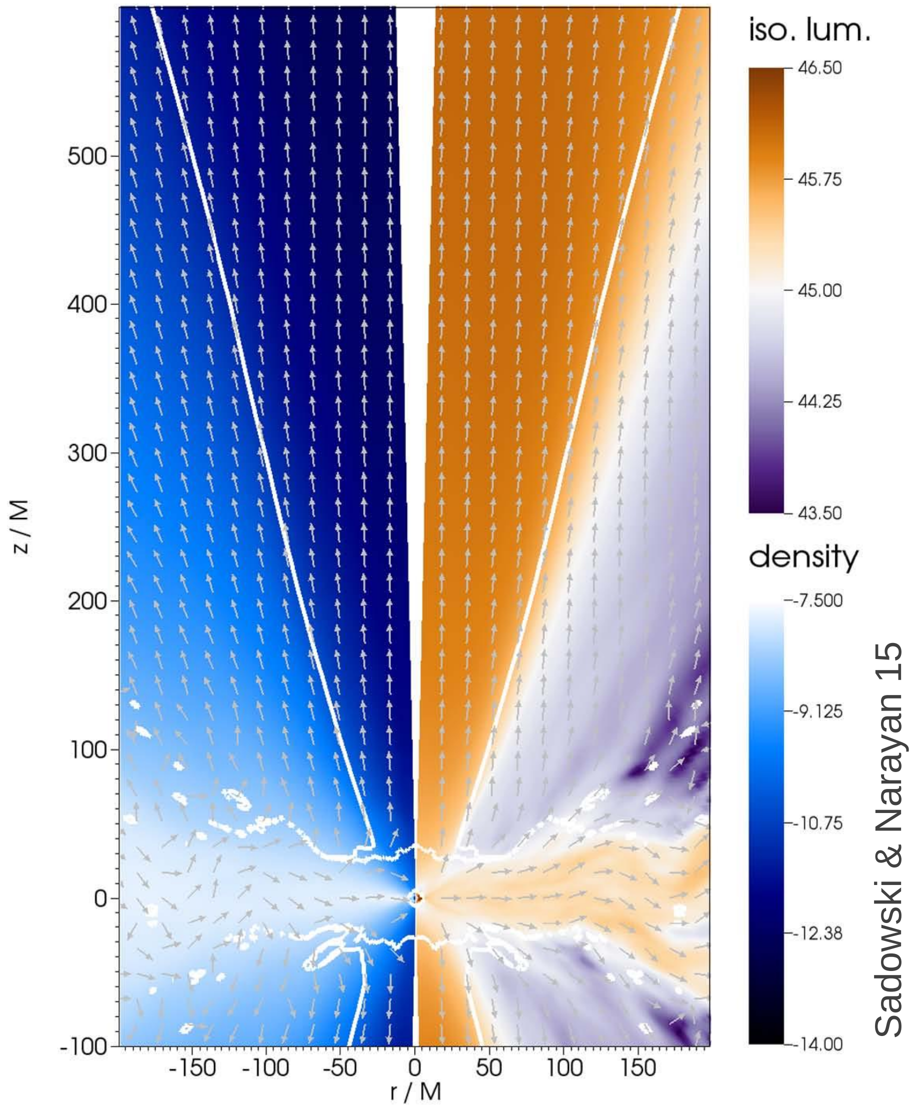
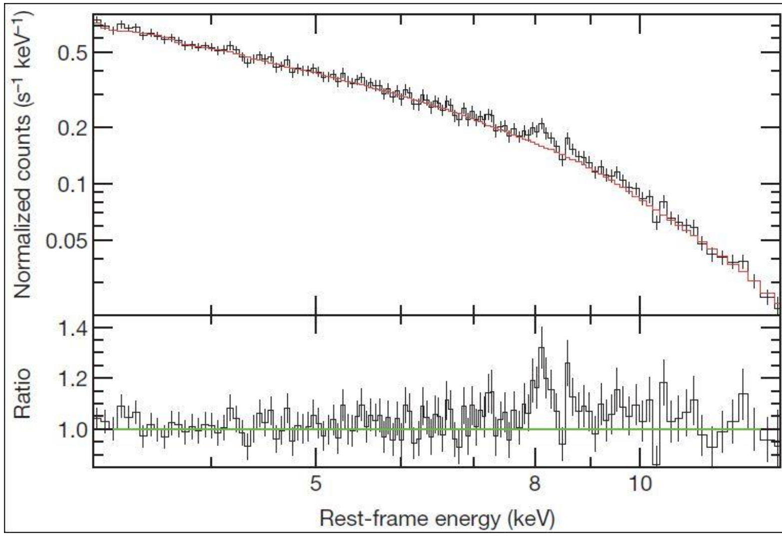


[Yang+ 16]

talks by Alexander Sadowski & Ken Oshuga, this meeting

jetted TDE SwiftJ1644+57: how much above Eddington ?

detection of X-ray reverberation



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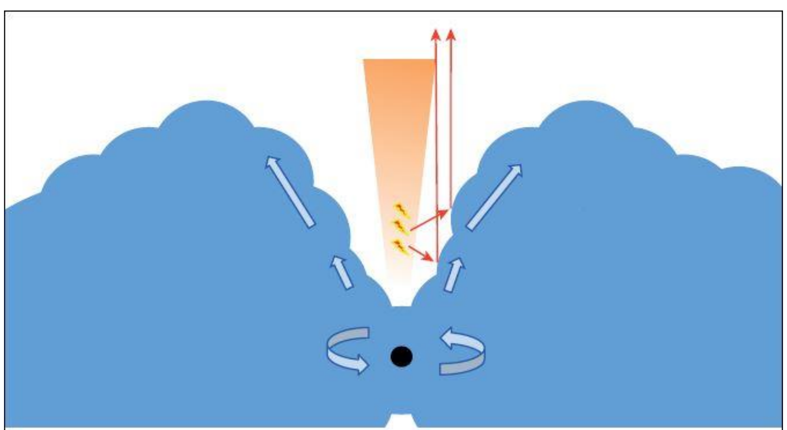
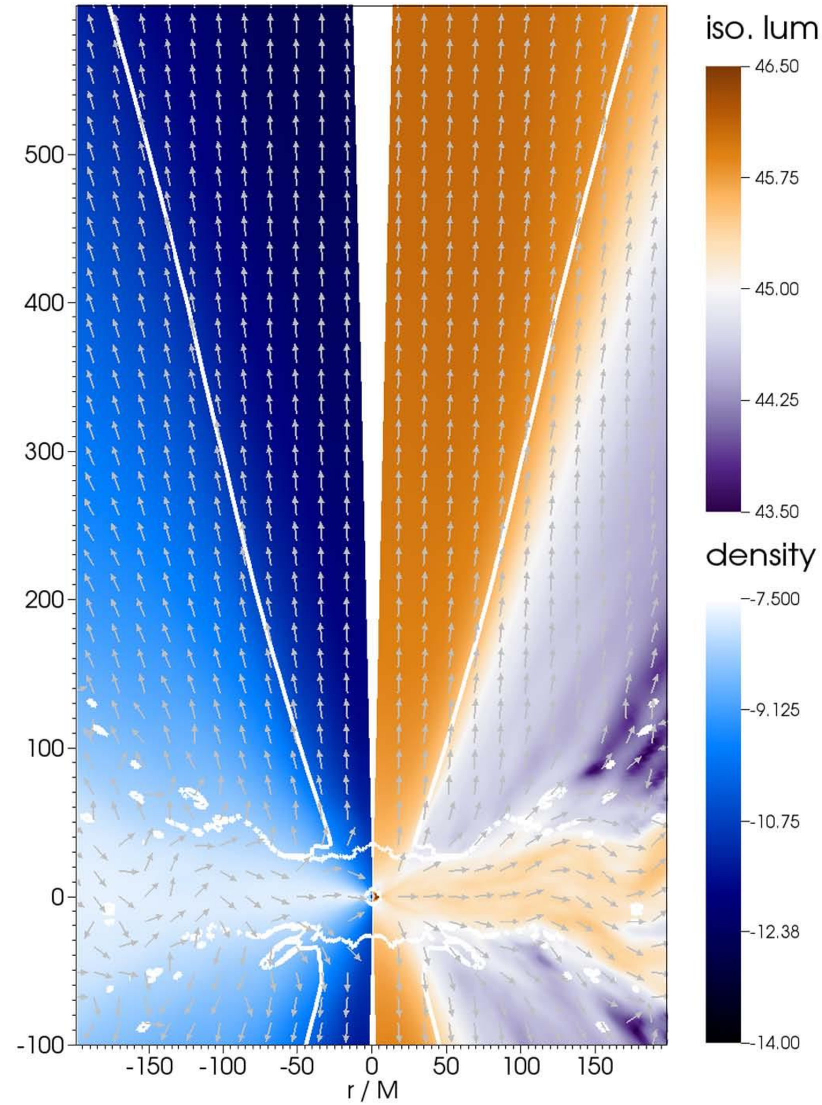
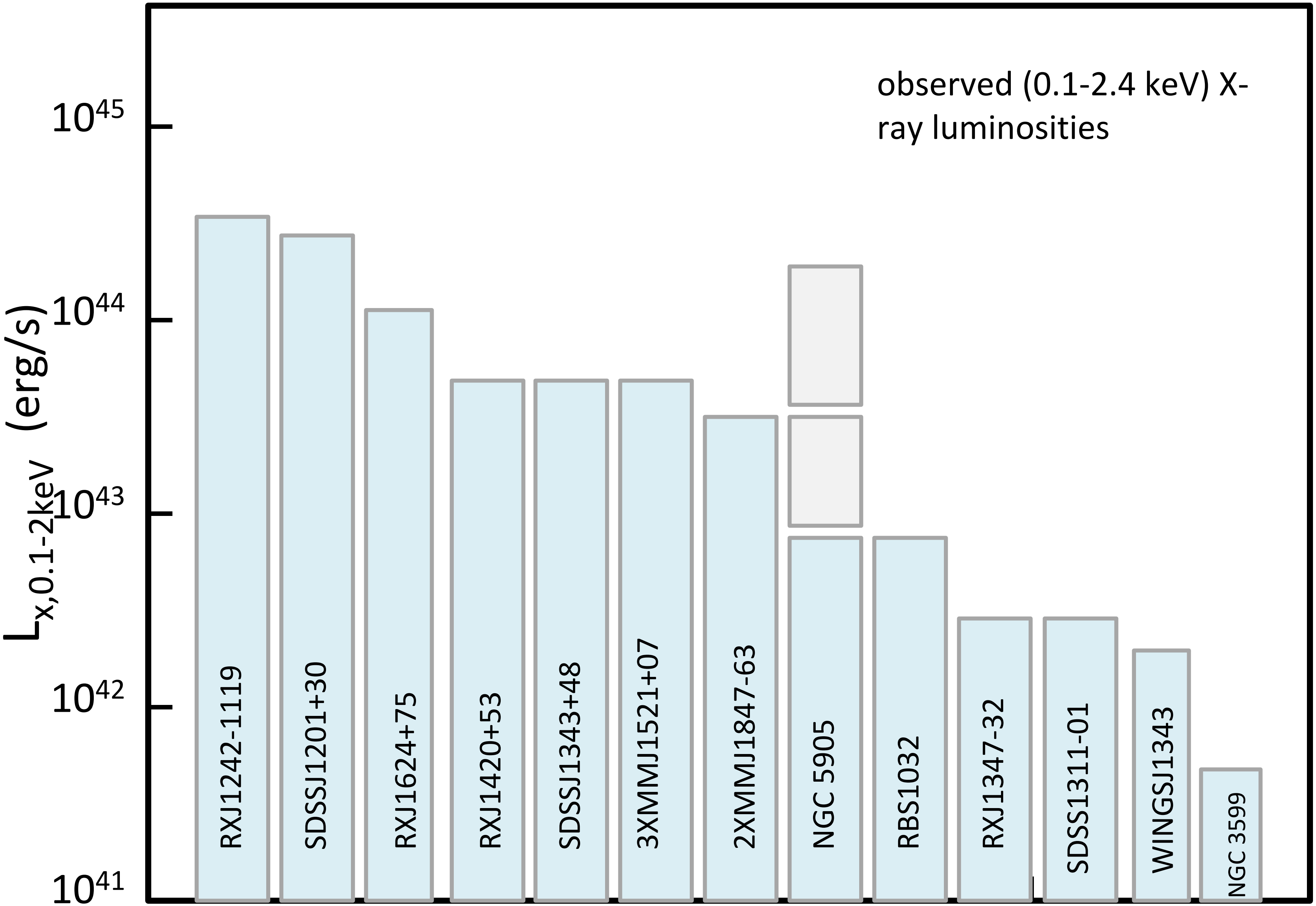


[Kara+ 16]



Sadowski & Narayan 15

soft X-ray (non-jetted) TDEs: how much above Eddington ?



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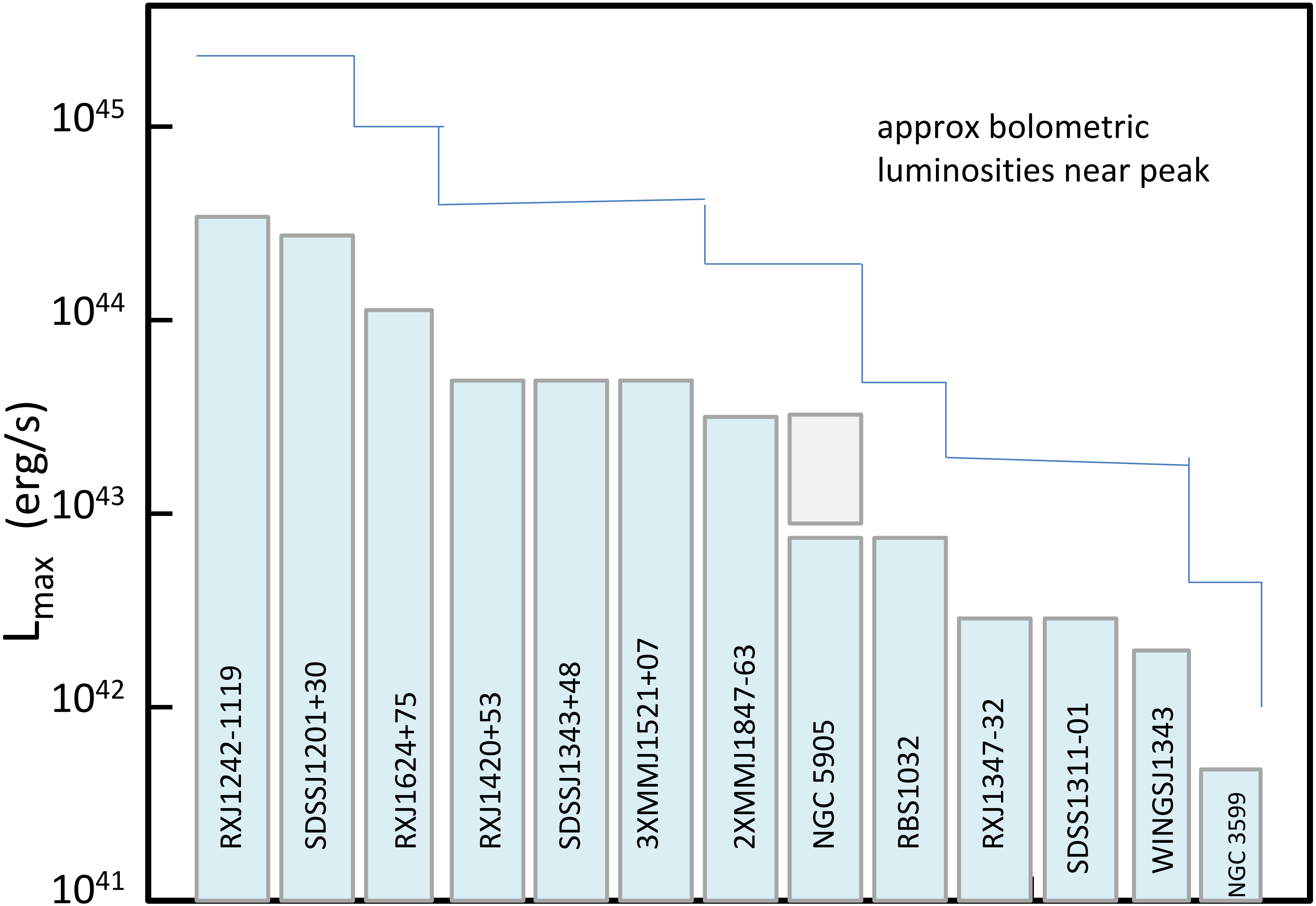

future TDE search & applications

- **statistics: flare rates, frequency of IMBHs**
  when flares detected in 1000s in current & future sky surveys in
  opt – X-ray – radio band (e.g., LSST—opt, *Einstein Probe –X, SKA--radio*)

- **rapid follow-ups:**
  → **in X-rays**: - highest amplitudes (highest contrasts vs hosts, x 10^{4-6}),
  - best chances for observing relativistic effects (broad lines, precession),
  - best probe of accretion physics down to last stable orbit, under extreme conditions, incl. super-Eddington phase

  → **in optical(UV):**
  esp. **emi.-lines**: - reverberation mapping of circum-nuclear gas,
  - of stellar debris, - TDE-EUV conti, - CL atomic parameters

  → **in radio, hard X-rays**: new probe of jet formation & evolution (but not in all events) in *pristine* environment; jet-disk coupling

- **GWs (+em)** from compact cores of partially stripped stars (WDs & NS)
- **new discovery space:** signposts of **SMBBHs**, and **recoiling BHs , ...**
  (→ repeat TDEs, off-center TDEs, no-host TDEs)