Tidal Disruption Events (TDEs) as Probes of Single and Binary SMBHs

- Intro, TDEs in X-rays
- Emission-line „light echoes“
- TDEs in SMBBHs: lighcurves
  emission lines
- Finding TDEs in large numbers: *Einstein Probe*

S. Komossa
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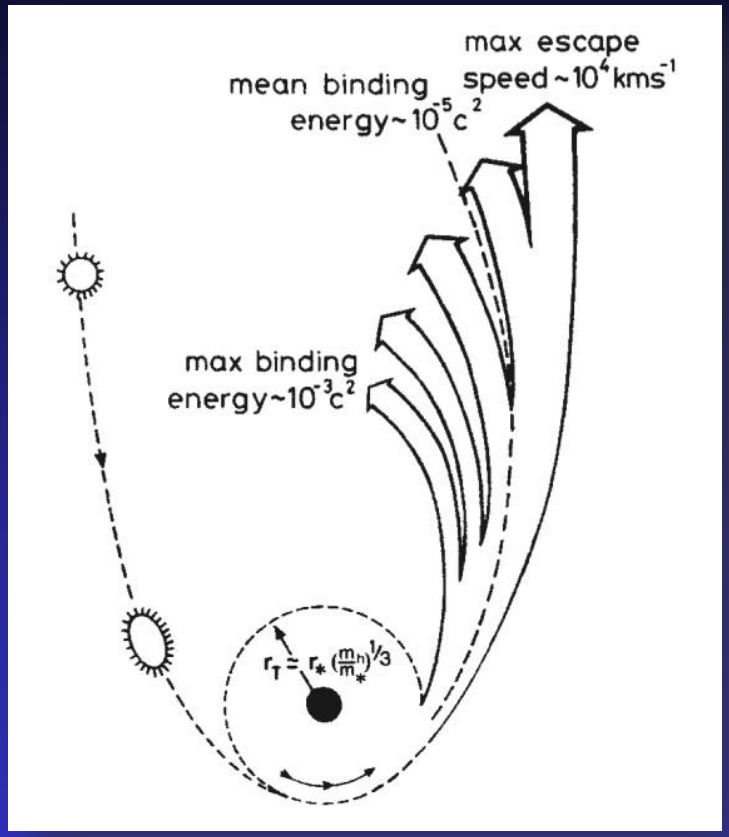
intro: tidal capture & disruption of stars by SMBHs

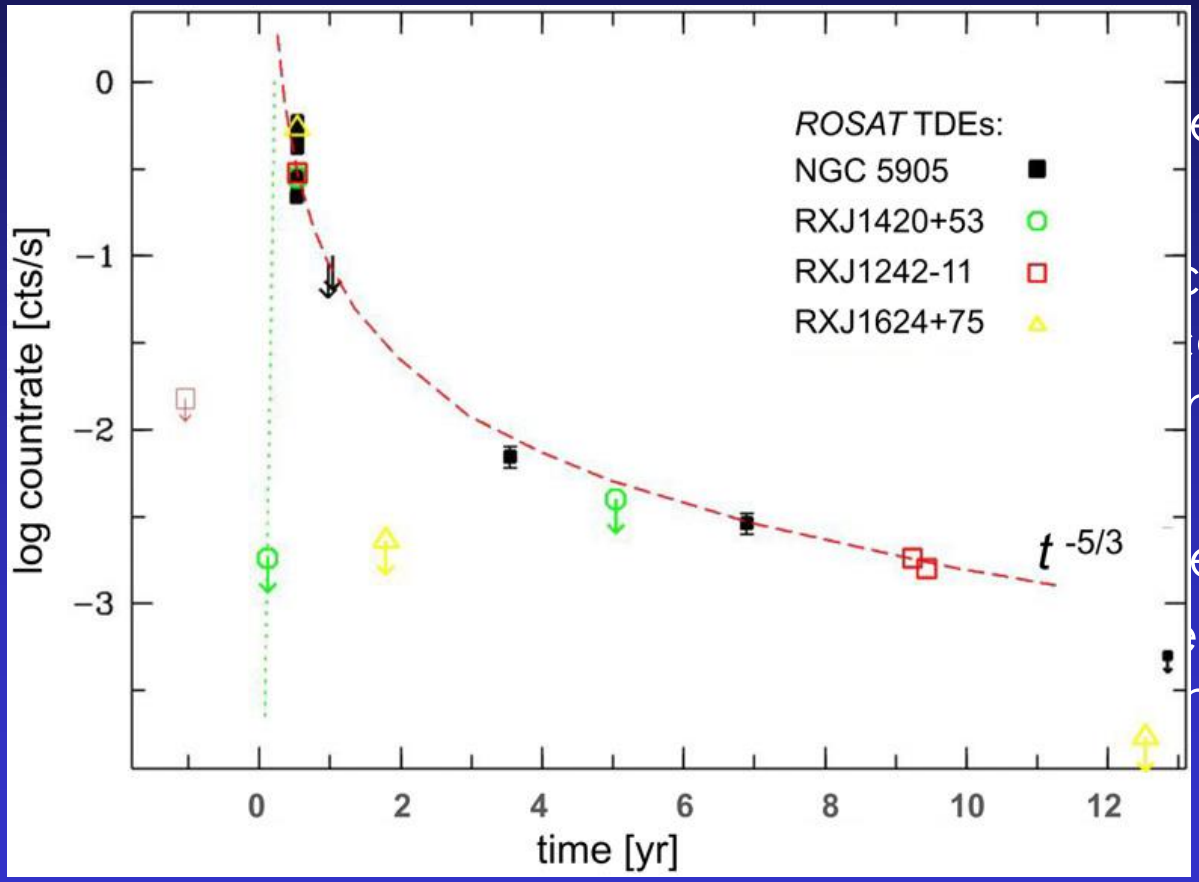


- probe of SMBH demographics in *inactive* galaxies
- signposts of SMBBHs (rates, characteristic features in TDE lightcurves)
- signposts of recoiling SMBHs (off-center BHs)
- new probes of radio jet formation (SwiftJ1644)
- e.m. ctrparts to GW signals of EMRIs (partially disrupted WDs and NSs)

„*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]

intro: tidal disruption of stars by SMBHs

- **high L_{peak} , up to L_{Edd},** rapid rise**, slow decline, lasting for months - yrs**



[NGC 5905: Komossa & Bade 99,
RXJ1242-11: Komossa & Greiner 00, Komossa+ 04]

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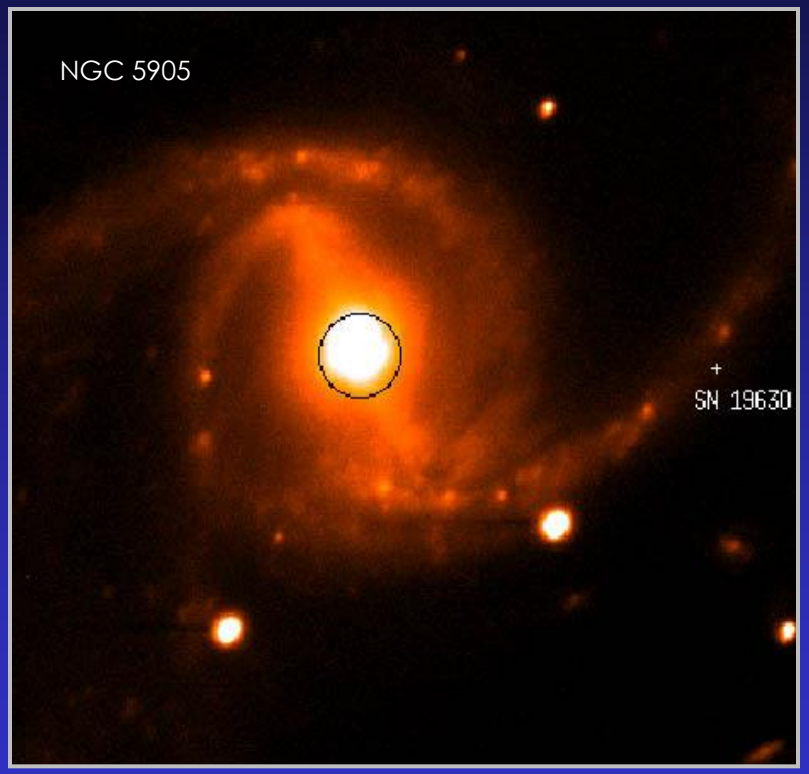

- high L_{peak} , up to L_{Edd}, rapid rise, slow decline, lasting for months - yrs
- **from very cores of galaxies…**
- …which are otherwise quiescent (= inactive, i.e. non-AGN) !!
- soft spectra, $T_{BB} \sim 10^{5-6}$ K
- $t^{-5/3}$ decline, late-phase drop, ….

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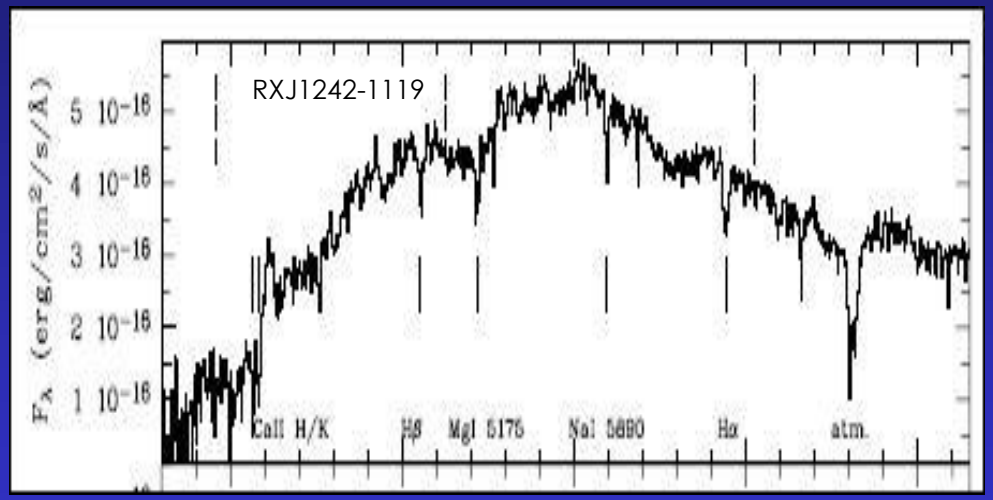

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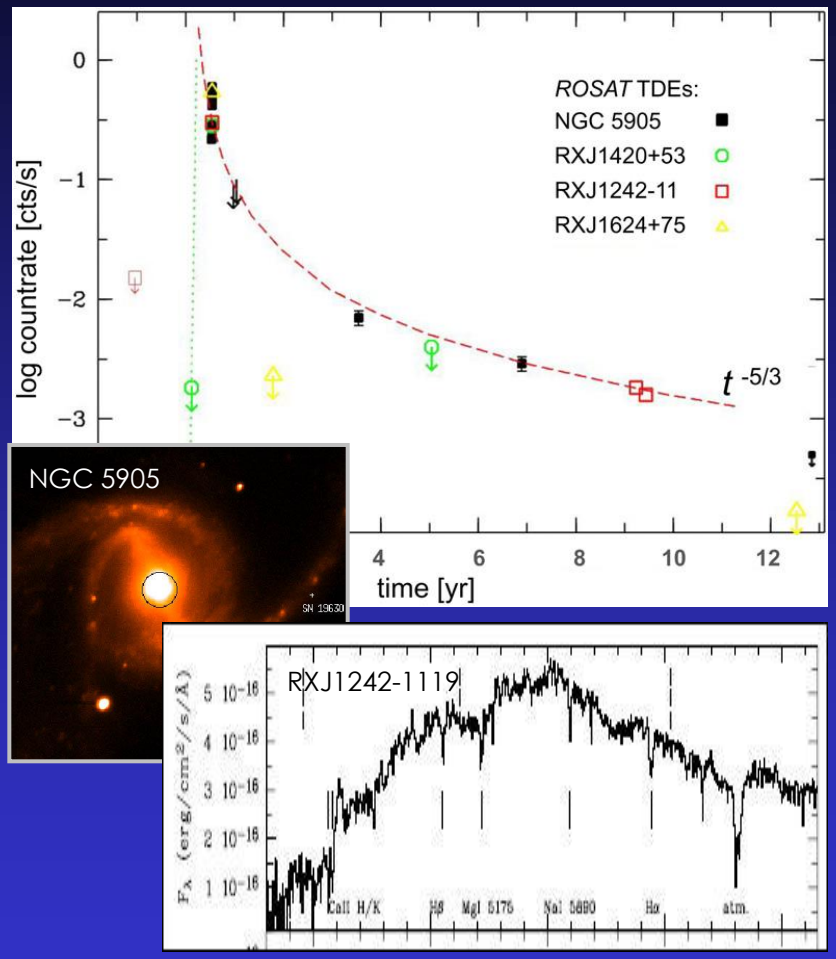

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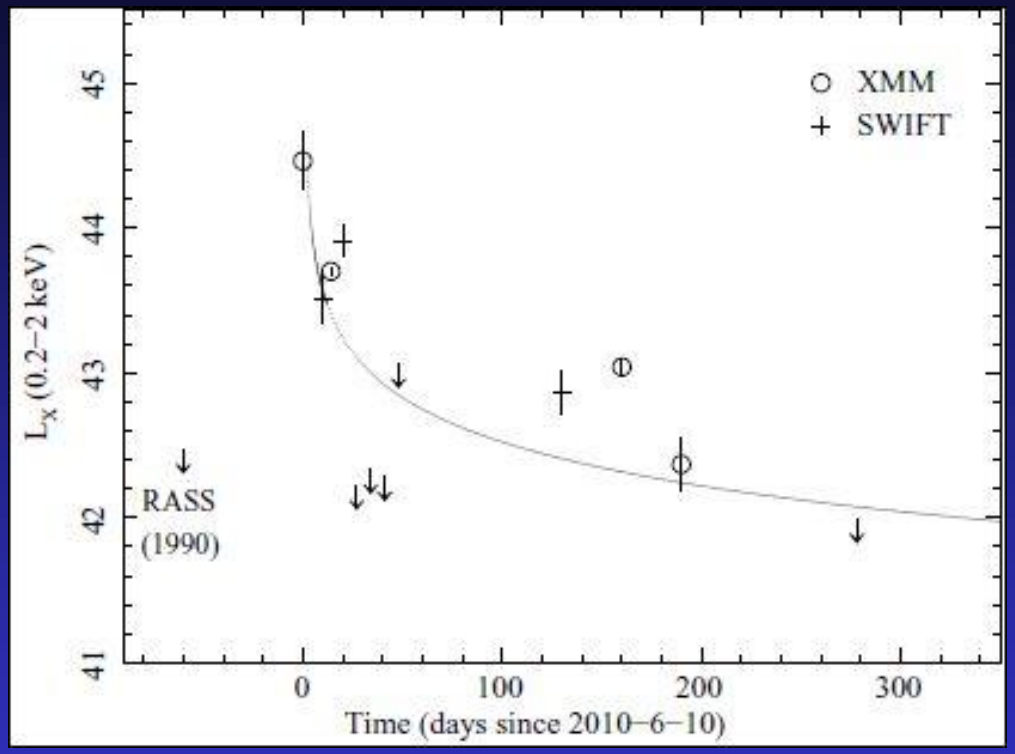
The peculiar lightcurve of SDSSJ1201+30



- $L_{x,hi}$ = 3 10^{44} erg/s
- z = 0.14
- $\Gamma_{x,hi}$ ~ 3
- M_{BH} ~ $10^{6\text{-}7}$ M_{sun}
- puzzling: deep (fct 50), sharp dip, at t~30 d, within 7d, lasting 20 – 115d
- no radio detection

[Saxton+ 12]

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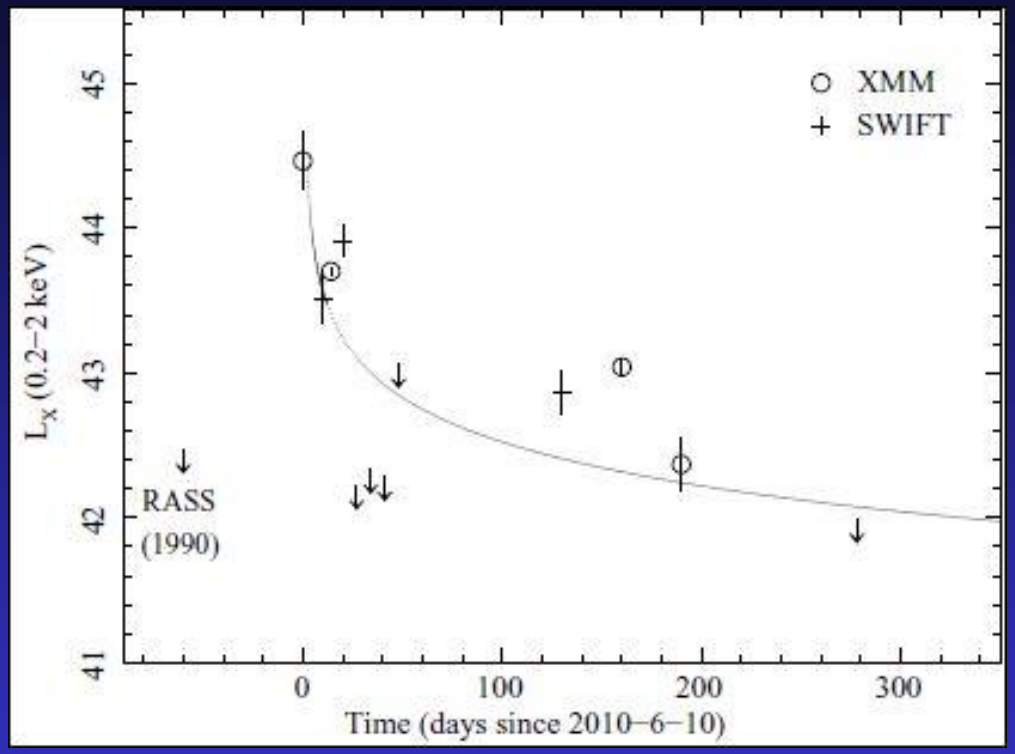
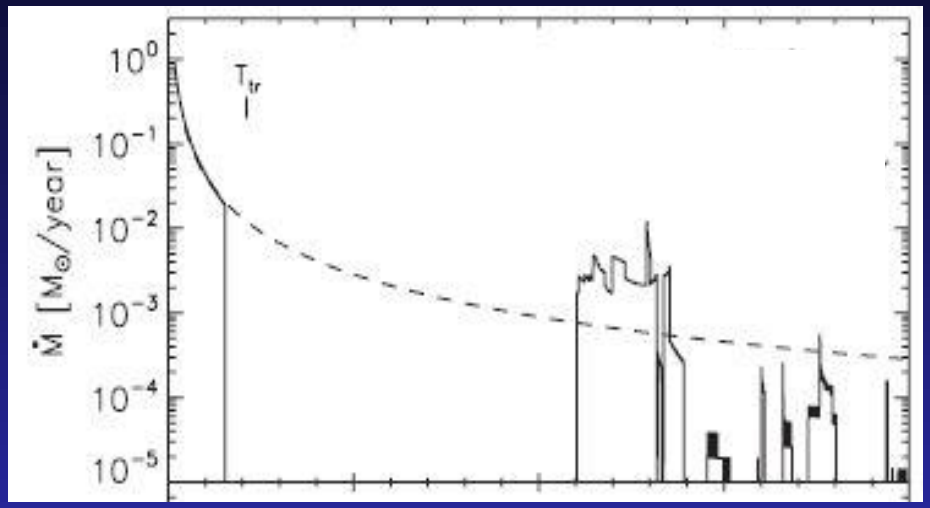


explanations that fail:

- jet precession/ wobbling
- absorption from stellar stream or clouds
- transient eclipses due to orbiting star
- disk precession

[Liu, Li, Komossa 2014]

a SMBBH explanation for SDSSJ1201+30 ?



- characteristic dips in lightcurve predicted by SMBBH model of Liu,Li&Chen 2009, where 2nd BH perturbs stream of stellar debris, temporarily interrupting accretion process

[Liu, Li, Komossa 2014]

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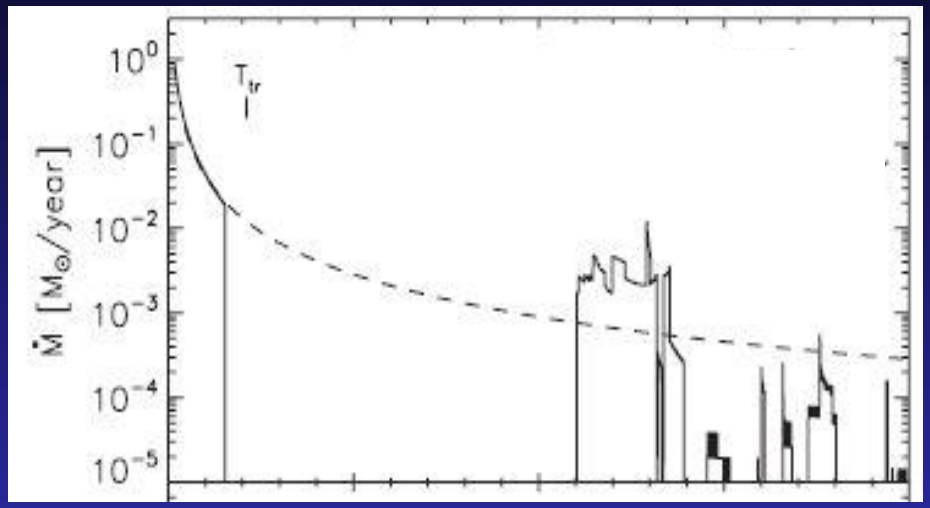
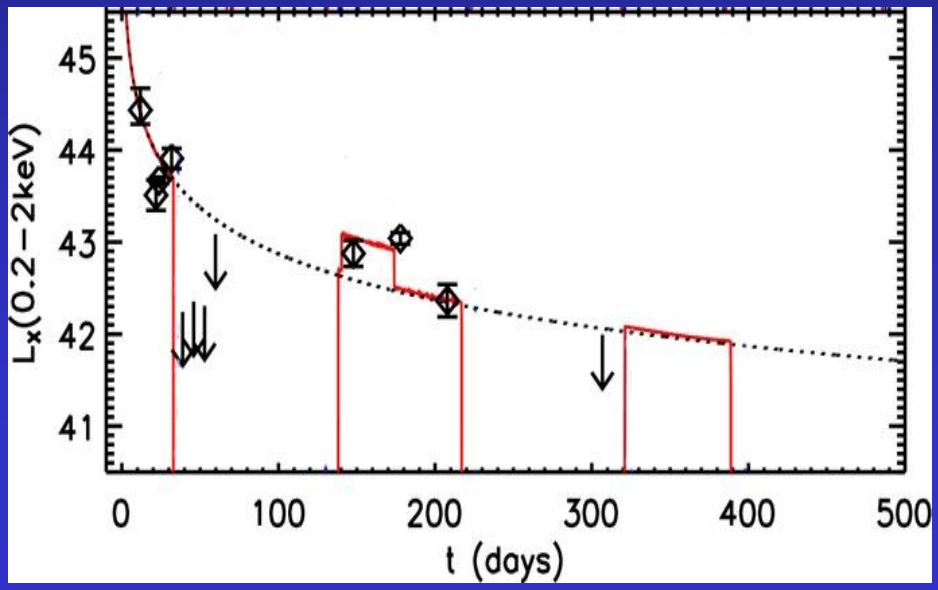




- characteristic dips in lightcurve predicted by SMBBH model of Liu,Li&Chen 2009, where 2nd BH perturbs stream of stellar debris, temporarily interrupting accretion process
- a 0.6 milli-pc SMBBH with $M_{BH} = 10^{6-7}\ M_{sun}$, and mass-ratio q=0.1 reproduces the lightcurve well
- tests: long-term lc, more cases

[Liu, Li, Komossa 2014]

a SMBBH explanation for SDSSJ1201+30 ?
Implications

- at sub-milli-parsec, closest known candidate BBH
- has overcome „last parsec problem“

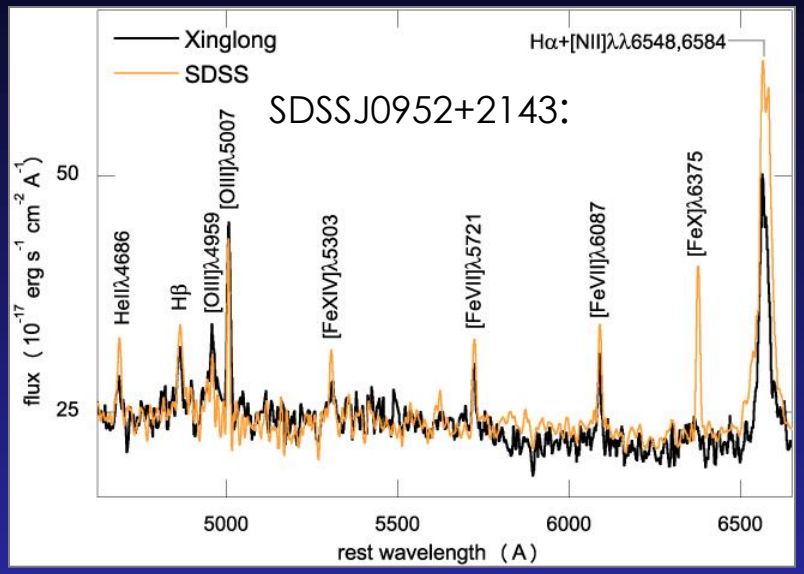
- will shrink due to GW emission and coalesce in ~10^6 years
- then a prime source of GWs in e*LISA* band

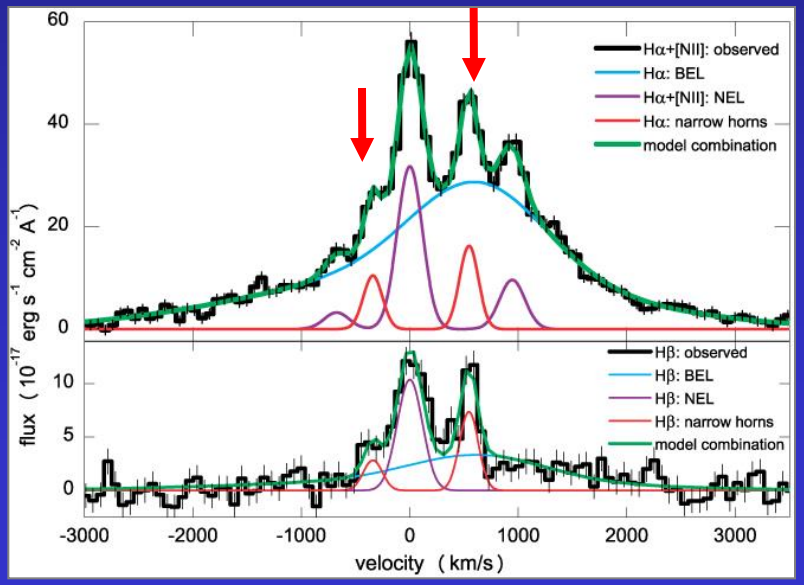
- currently, this method is the only way (except GC) to detect SMBBHs in *quiescent* galaxies

- how many of them are out there ?
  → based on known TDE X-ray lightcurves, SDSSJ1201+30 is the only good candidate
  → need dedicated mission, well-covered lightcurves (→ EP)

[Liu, Li, Komossa 2014]

flares in gas-rich environments: emission lines





[Komossa+ 08, 09]

- super-strong Fe lines & HeII
- fade dramatically, x 10, in yrs

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

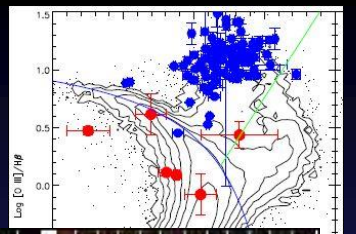
- but faint X-rays, ~10^{41} erg/s, few yrs after SDSS high-state

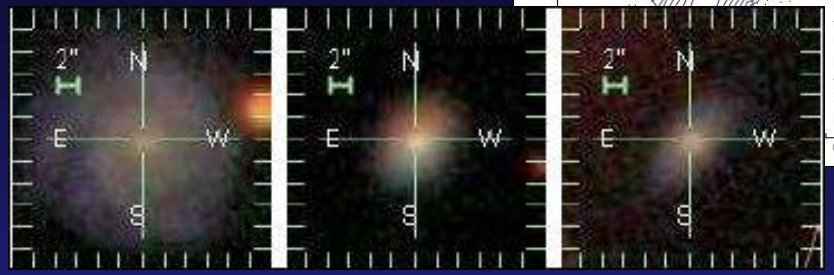
- no clear signs of permanent activity

→ **„light echoes" from TDEs illuminating surrounding ISM** (?)

→ **new method of mapping conditions in galaxy cores**

emission-line „light echoes“





- dedicated SDSS search for further extreme coronal line emitters:

  - sev. more found
  - all with very strong [FeX]-[FeXIV]
  - ~50% without [FeVII]

  - in low-mass galaxies

  - 3 have transient (fading) Fe lines; while [OIII] increases

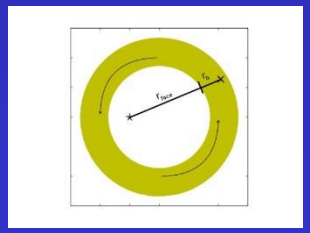
→ same mechanism at work as in J0952

  - rate: ~10^{-5} /yr /galaxy

[Wang+ 11, 12, Komossa+ 14 –inprep,]

- **search for SMBBHs via TDE-excited emission lines:**

dbl-peaked emission lines from circum-binary disk, with charact. tilt in response function

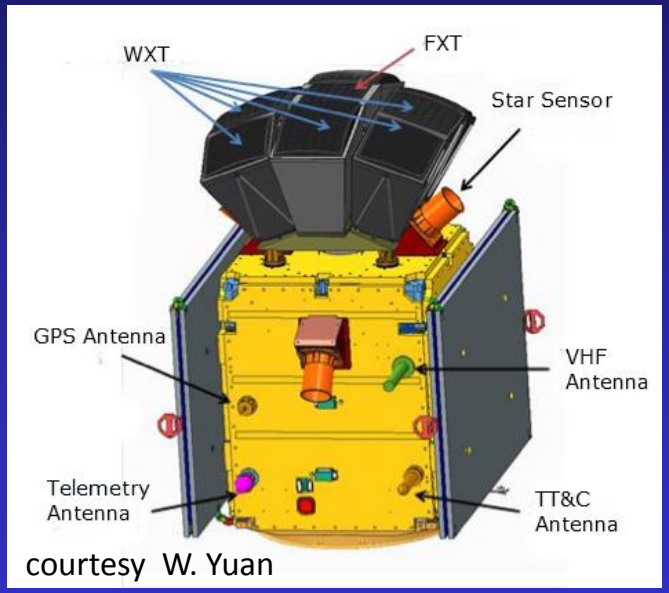


[Brem+ 14—subm.]

TDEs with *Einstein Probe*

- **mission science objective:**
  - time-domain census of soft X-ray transients and variable sources in the universe; esp. TDEs

- **instruments:**
  1. wide-field (60° x 60°) monitor based on lobster-eye micro-pore optics (MPO) technology
  2. narrow-field (1° x 1°) follow-up X-ray telescope

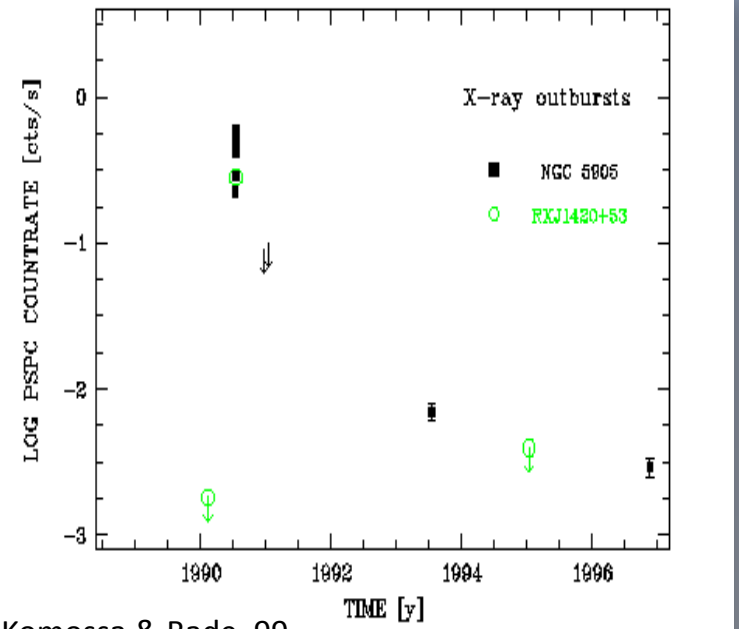


courtesy W. Yuan

  - orbit: 600km mass: 380 kg
  - life time: 3+2 years (expected ~2020)
  - status: selected as one of the "mission candidates for advanced study" under the CAS "Priority Strategy Space Science Program" in 2013. The Advanced Study Phase has started in 2014.

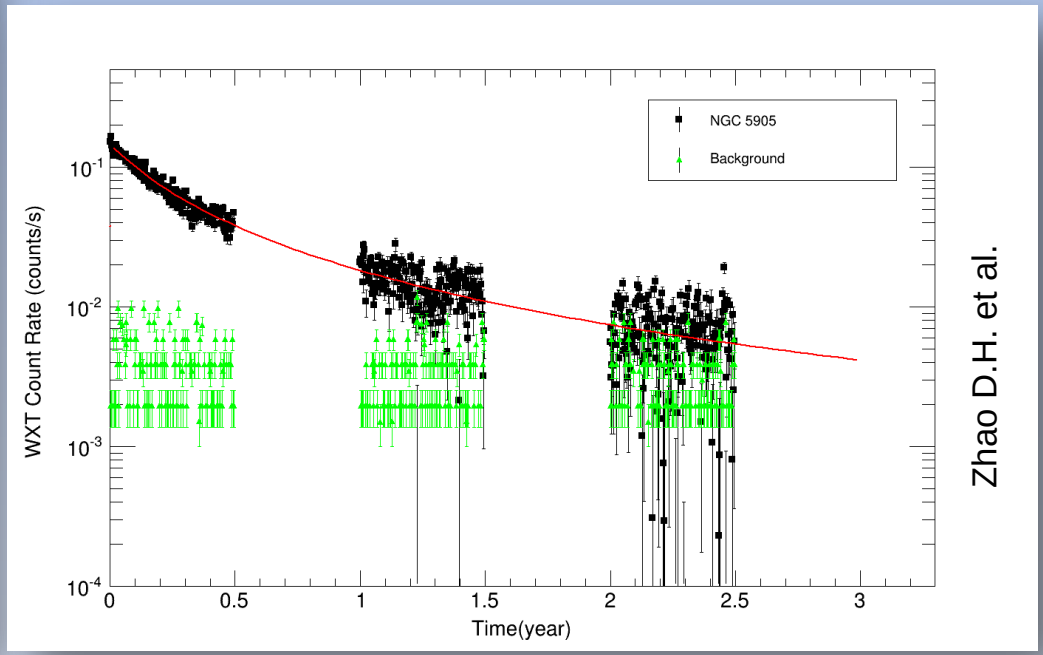
simulated EP light curve of a TDE

NGC5905; ROSAT data



Komossa & Bade 99

simulated EP/WXT light curve of an “NGC 5905 event”



Zhao D.H. et al.

courtesy of D. Zhao/ W. Yuan

TDEs with *Einstein Probe*

- **large f.o.v.:**
  → large number of events: order 100/yr [W. Yuan]
- **energy band: 0.5-4 keV**
  → ideally suited to detect, and follow TDEs
- **rapid follow-ups with NFI** (FXT), **and multiwavelength alerts**
  → excellent *lightcurve* and spectral coverage

enables new science:

>> rates: dependence on hosts
IMBH population

>> lightcurves:
- BH mass & spin [e.g., Lodato+ 09, Kesden 12, Dai & Blandford 13, ...]
- type of disrupted star [e.g., Guillochon+ 13]
- search for SMBBHs [Liu+ 14]
  in *quiescent* galaxies; almost
  completely elusive, otherwise

Summary

- TDEs are probes of presence & environment of SMBHs & SMBBHs in *non-active* galaxies; of accretion (& jet) physics. ~13+ events found in X-rays, first in ROSAT all-sky survey

- the peculiar TDE lightcurve of J1201+30 is well explained by a SMBBH
  → new method, and only one so far, of searching for SMBBHs in quiescent galaxies

- evidence for TDE emission-line reprocessing from optical spectra with broad & narrow, transient, high-ionization lines
  → new way of reverberation-mapping of circum-BH material & ISM

- many interesting future applications, when we find TDEs in large numbers, with the proposed dedicated Chinese *Einstein Probe* soft X-ray mission