Tidal Disruption Events (TDEs)

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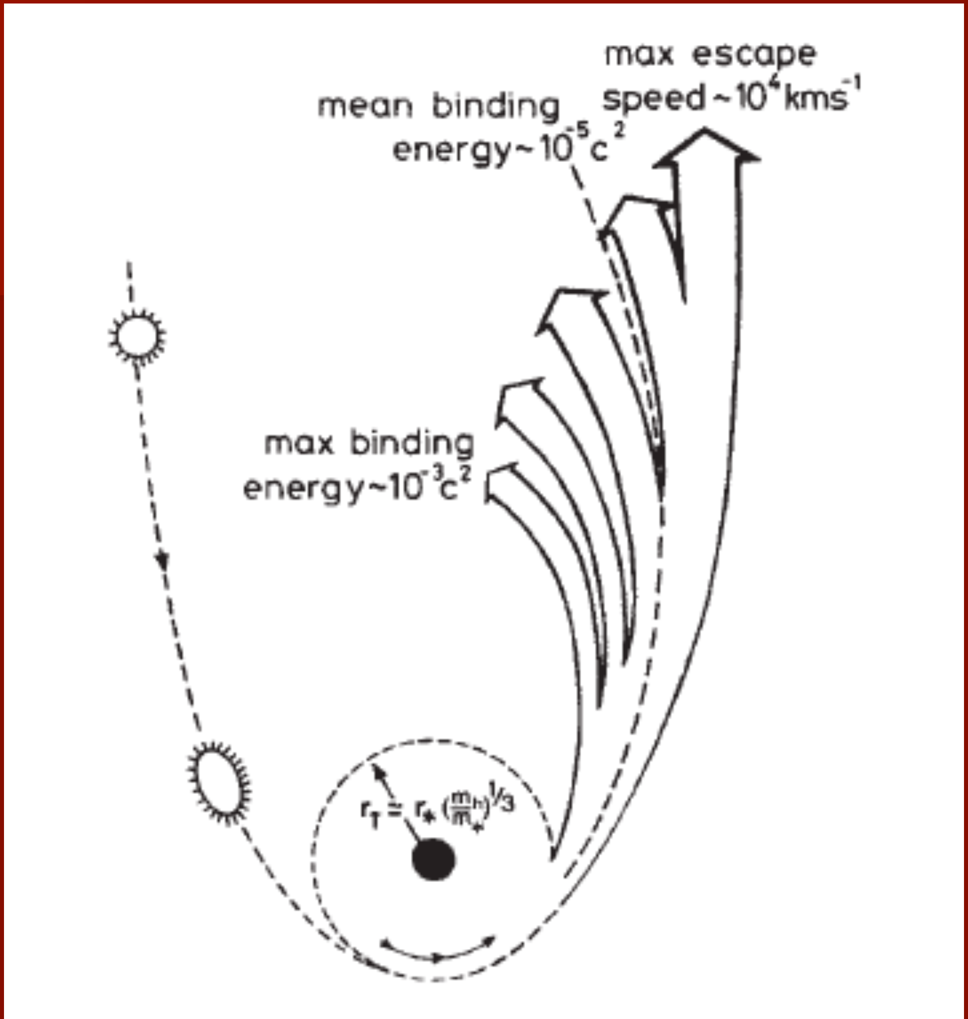
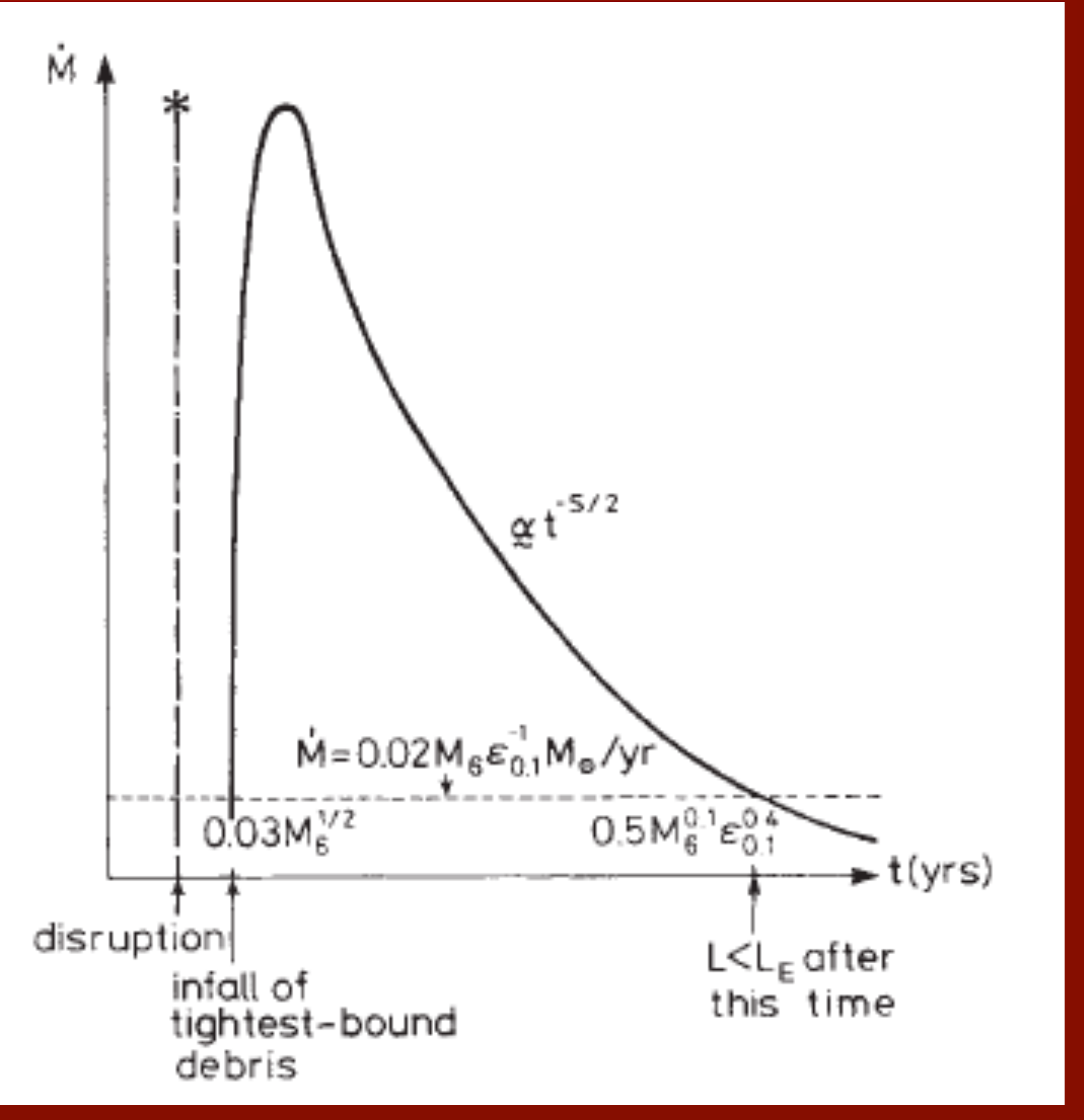
Fundamental Plane of AGN Activity and Radio-loud Narrow Line Seyfert 1 Galaxies

Rees 1988



R (tidal) = R (Schwartzschild) for BH Mass= 10^8 solar masses.



Ṁ
*
∝ t^-5/2
Ṁ=0.02M6ε0.1^-1 M⊙/yr
0.03M6^1/2
0.5M6^0.1 ε0.1^0.4
t(yrs)
disruption
infall of
tightest-bound
debris
L<LE after
this time

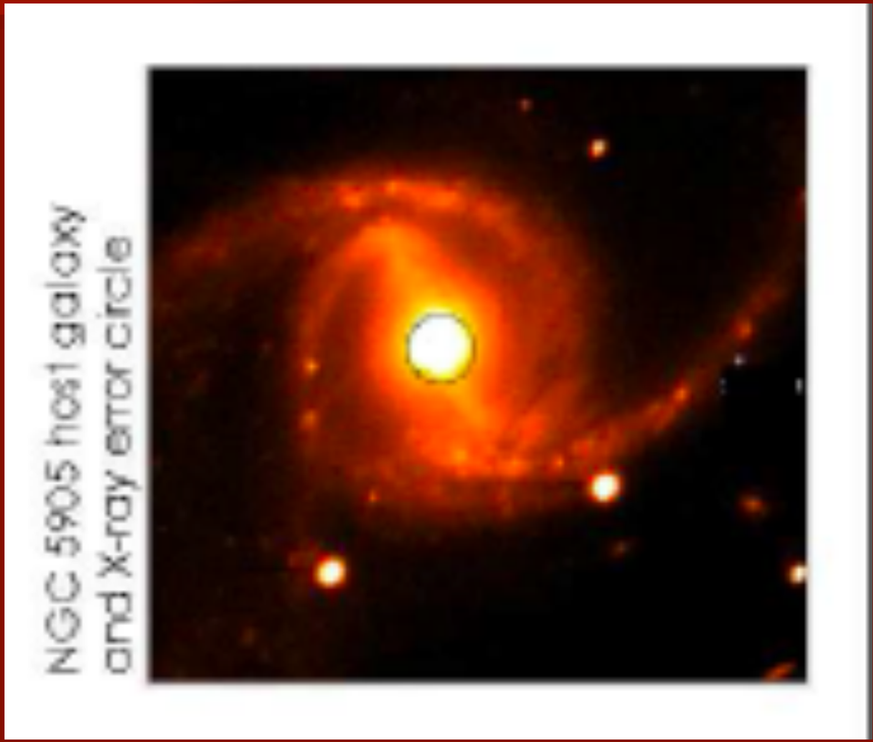
ROSAT discovery of TDE

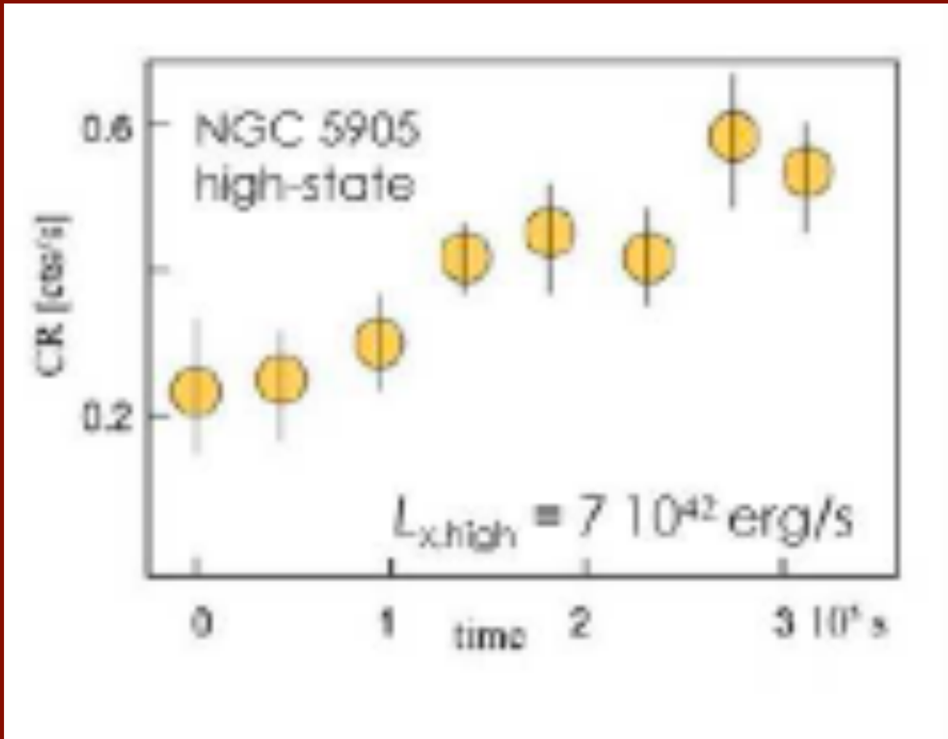
- Peak luminosity several x 10^{44} erg/s
- Very soft X-ray spectra near peak (kT < 0.1 keV), then hardening
- Decline rate consistent with $t^{-5/3}$
- Amplitude of decline factors of 1000 to 6000
- Optically inactive host galaxies
- BH masses 10^{6-8} solar masses

First in 1999

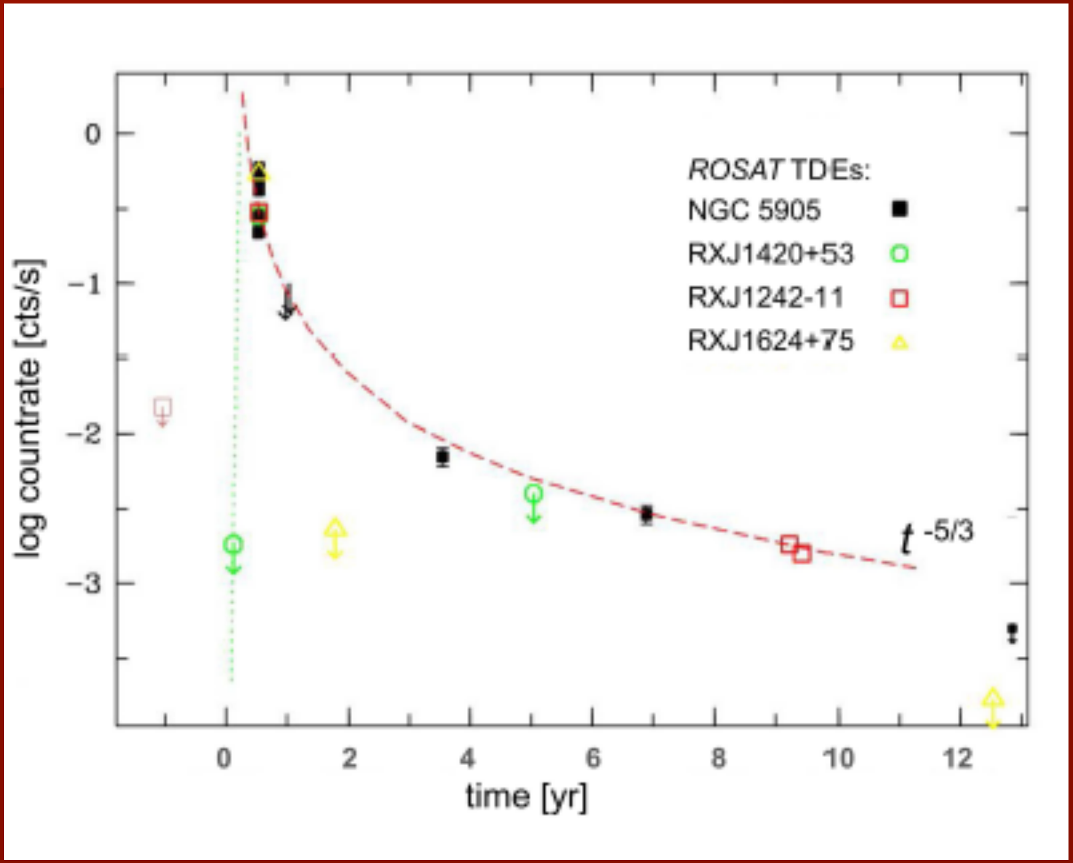
Komossa 2015

NGC5905

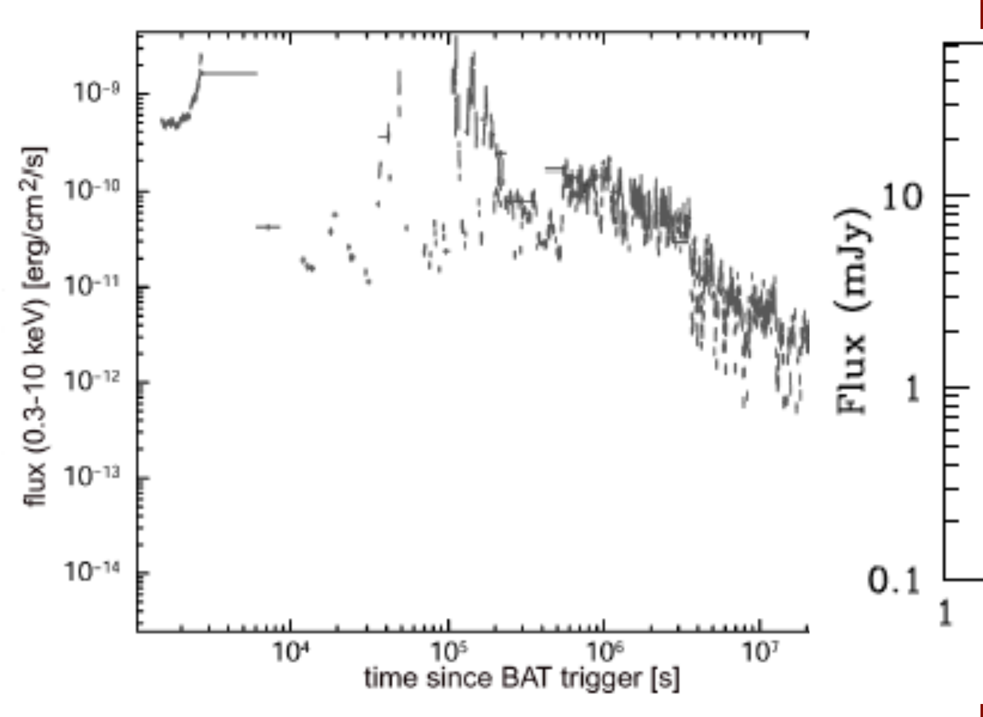

NGC 5905 host galaxy
and X-ray error circle

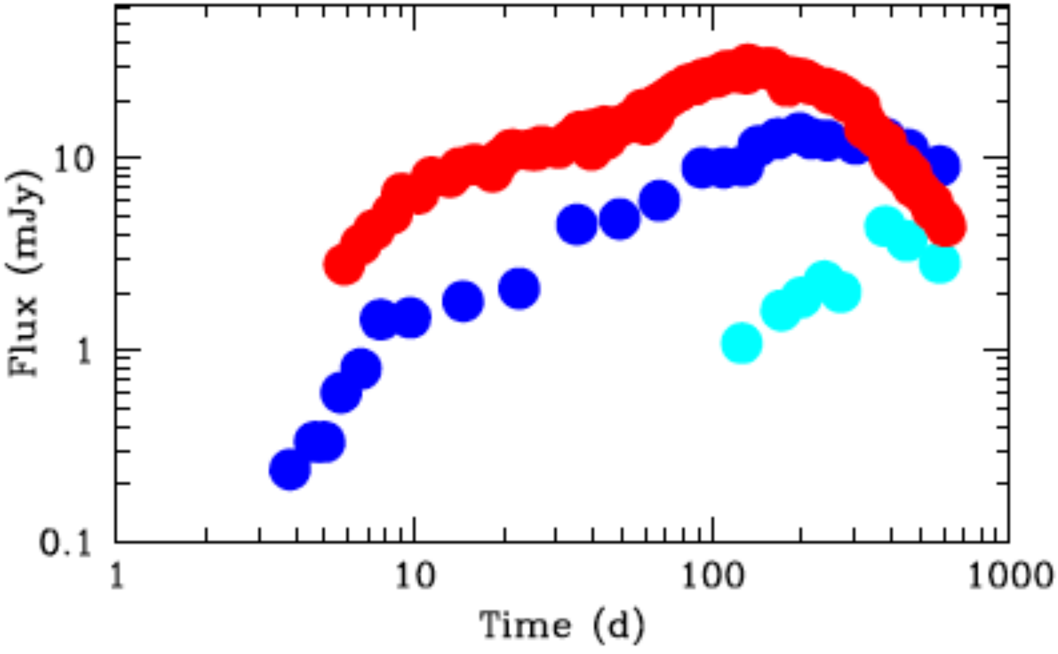

NGC 5905
high-state
0.6
0.2
CR [cts/s]
$L_{x,high}$ = 7 10^{42} erg/s
0
1
time
2
3

ROSAT and Swift TDEs



Jetted TDEs



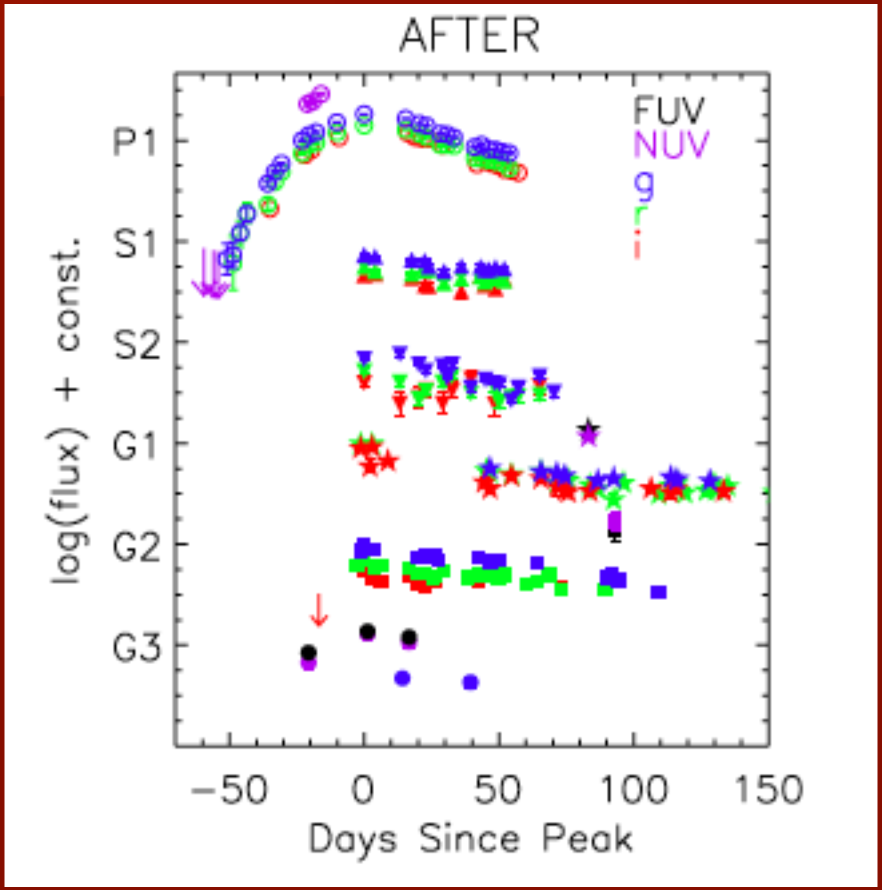


X-ray

Radio

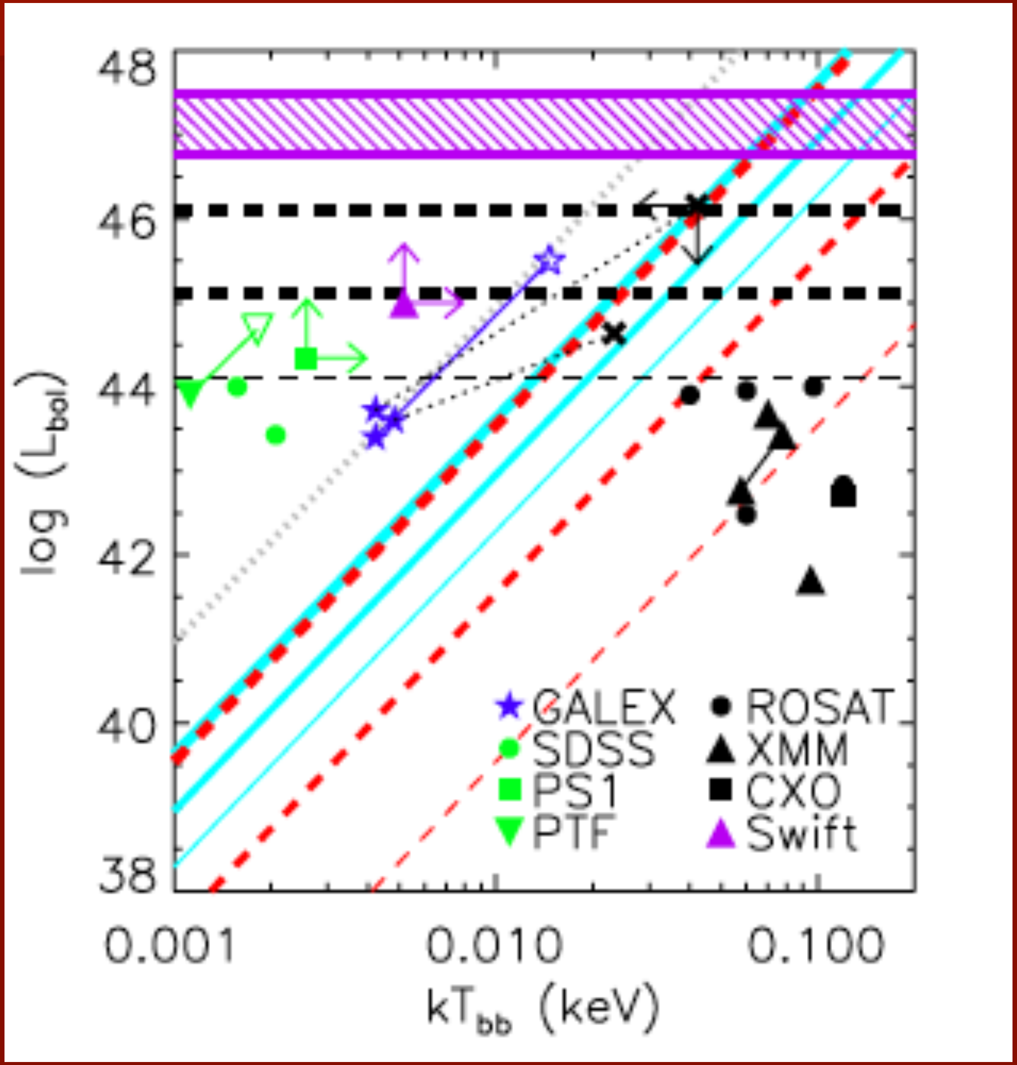
SDSS J1644+75

Optical and UV TDEs



Gezari 2012

Demographics of TDE candidates

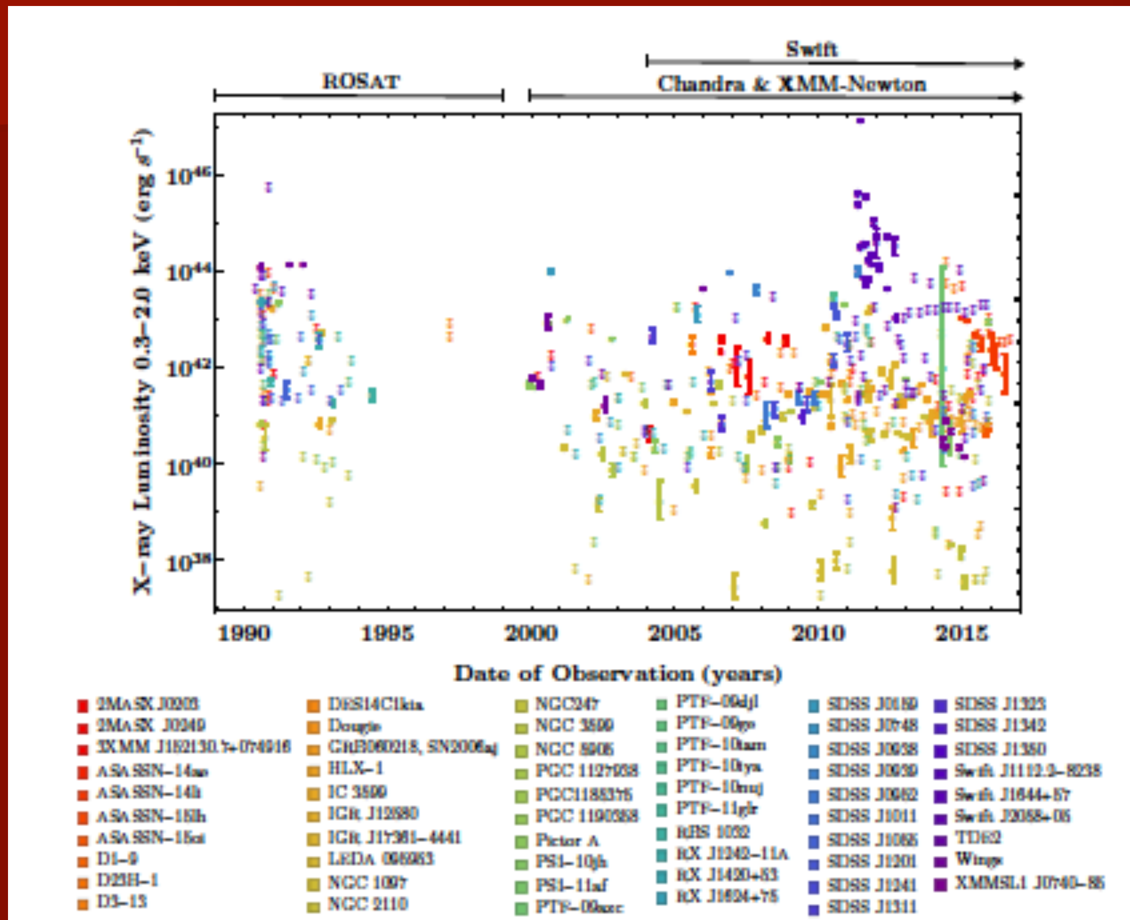


TDE characteristics

$T_{eff} \approx 2.5 \times 10^5 M_6^{1/12} (r_*/r_\odot)^{-1/2}$
$(m_*/m_\odot)^{-1/6} (r/r_T)^{-1/2}$

Mass accretion rate depends on:

BH Mass, Stellar Mass, Stellar Radius, polytropic index γ, and $\beta = r_T/r_P$



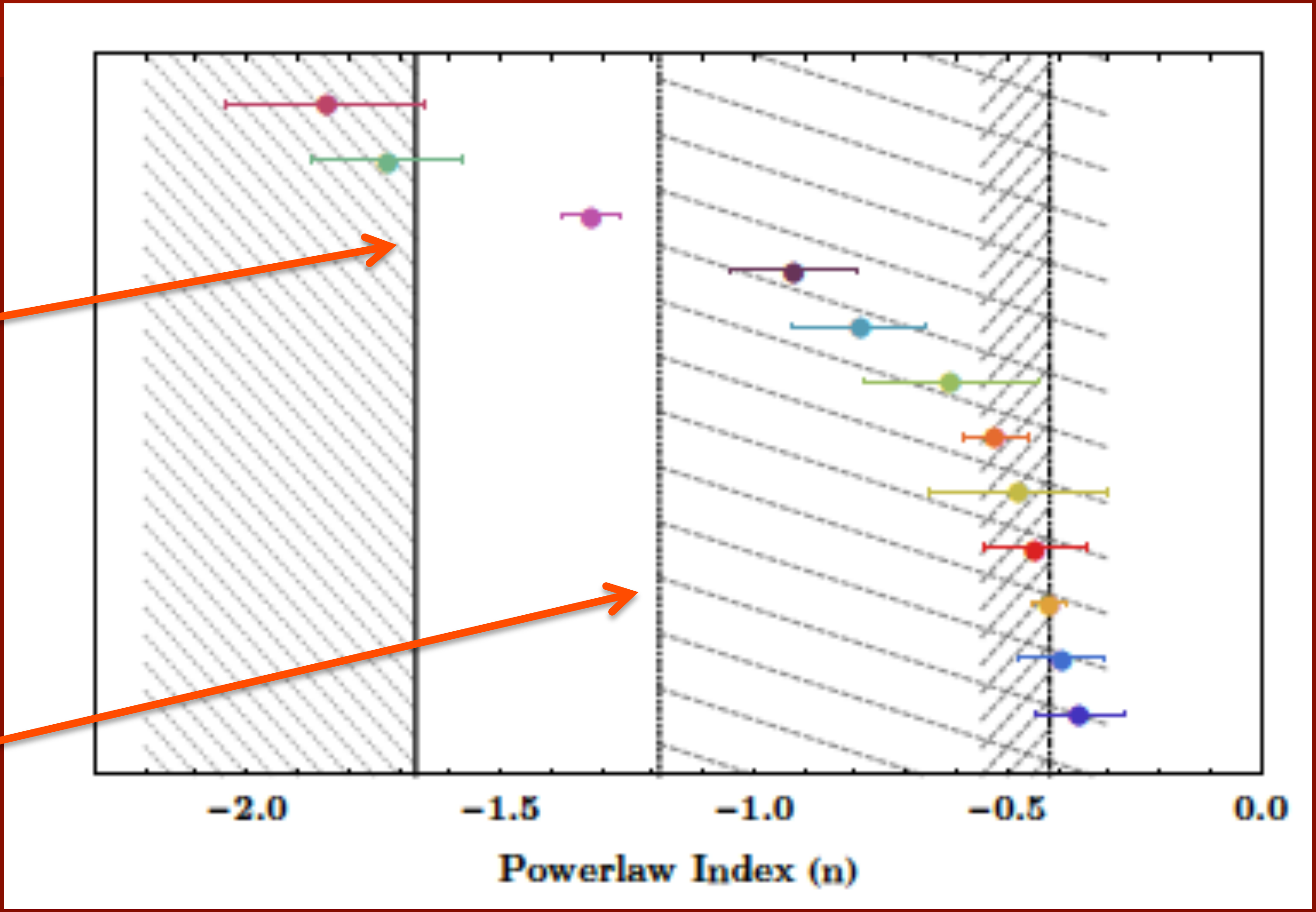
Auchettle + 2016

TDEs with a range of decay rates. Depends on super- or sub-Eddington accretion and on waveband

$t^{-5/3}$

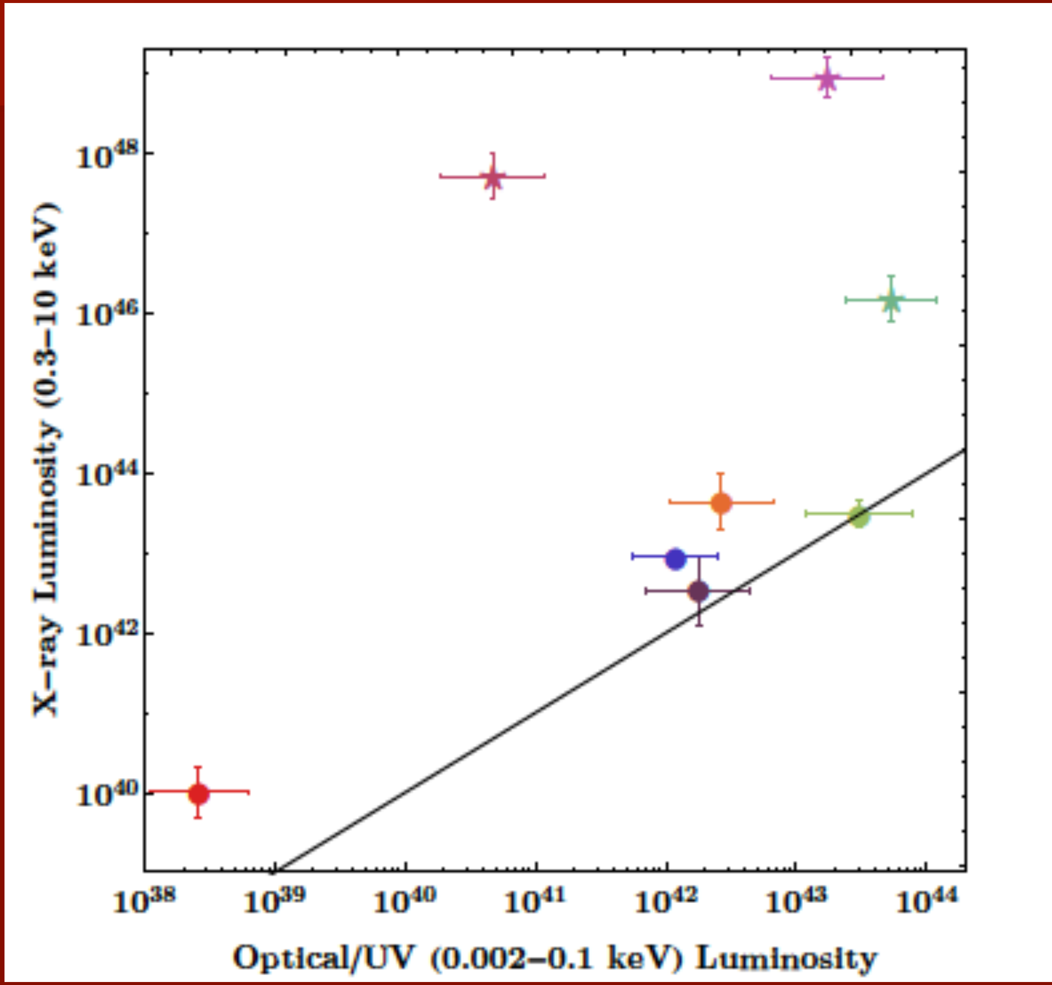
Fallback

$t^{-19/16}$



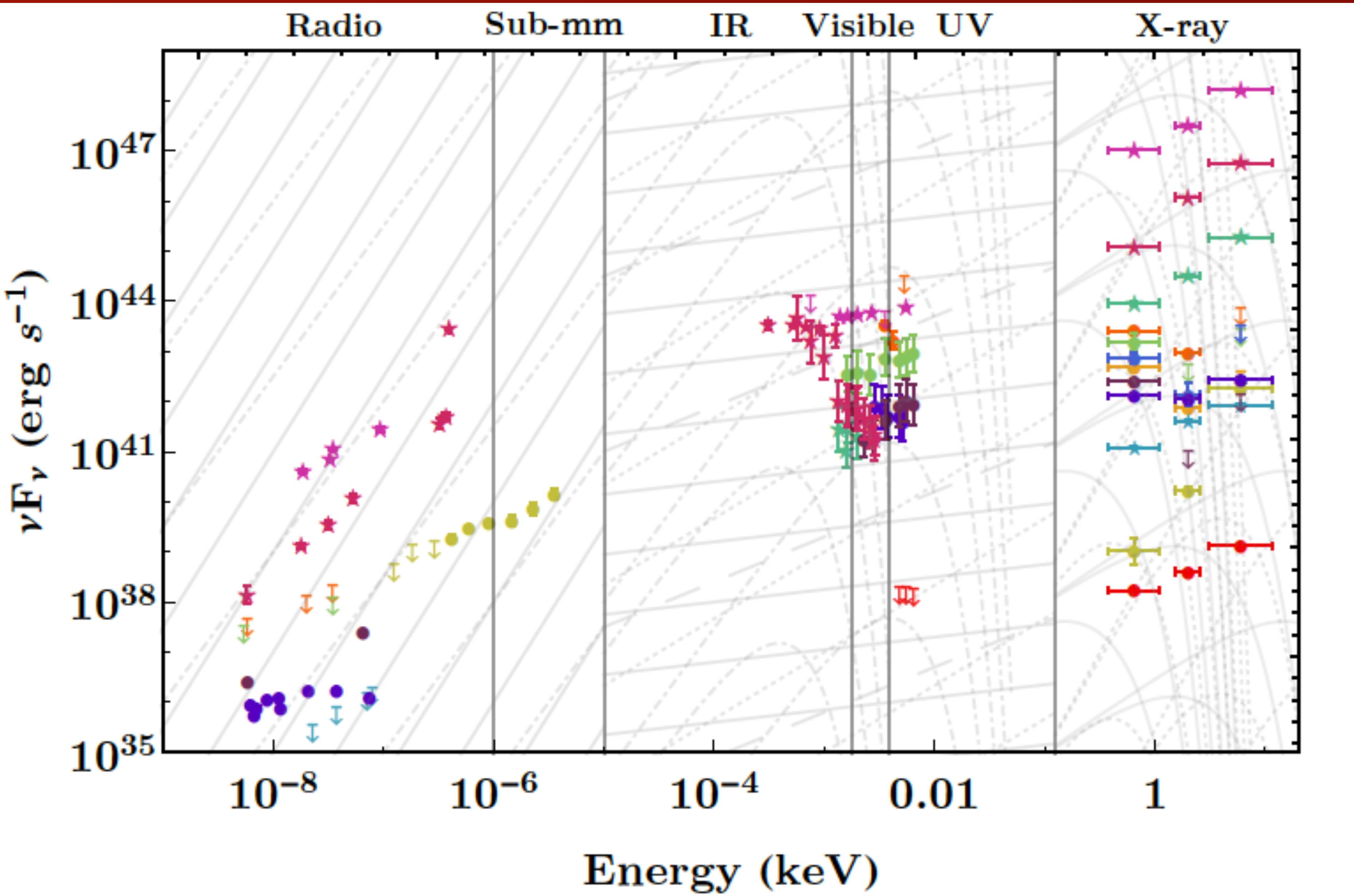
Viscous disk accretion

A range of X-ray to Optical/UV luminosities



Only about 40 to 50% of TDEs are X-ray TDEs

Broad band spectral energy distribution



Different emission mechanisms

- X-ray band:

  -Thermal black-body (no emission above 2keV)

  -Synchrotron

  -Inverse Compton

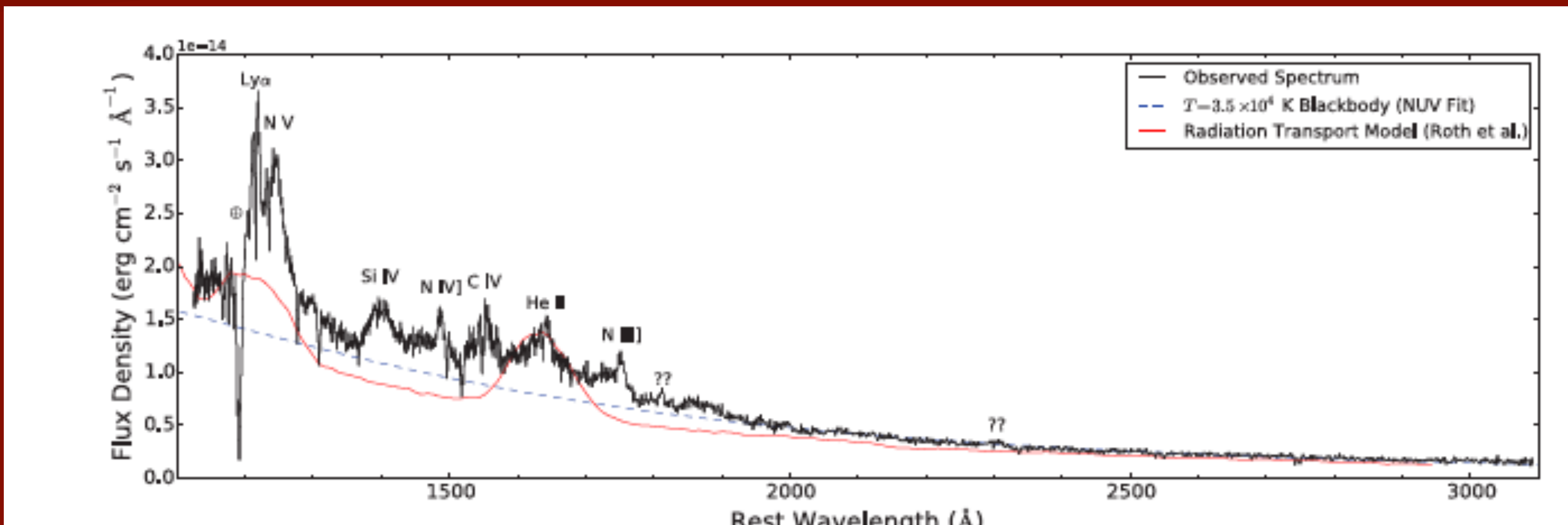
- Optical/UV:

  -Thermal black body

  -Multicolor accretion disk

  -Optically thin synchrotron

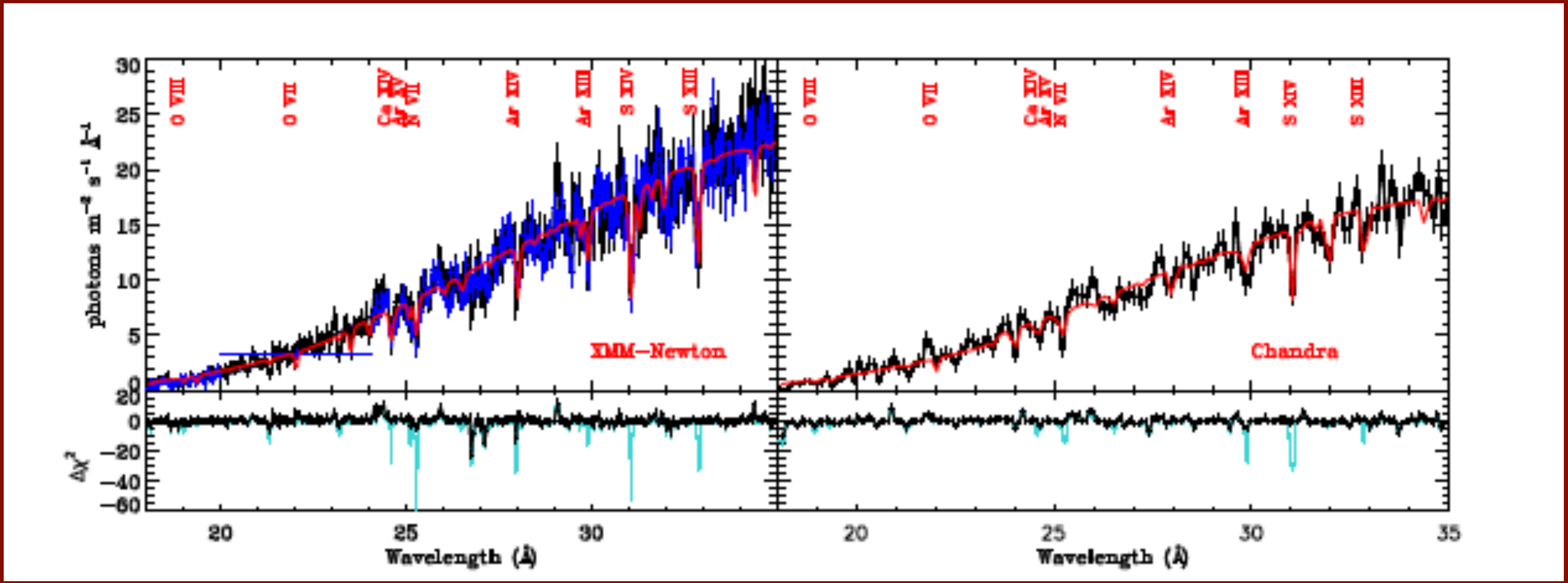
TDEs also produce emission/ absorption lines in UV



HST STIS spectrum of ASASSN-14li. Cenko et al. 2016.

22 HST orbits approved for an ASASSN TDE in Cycle 24

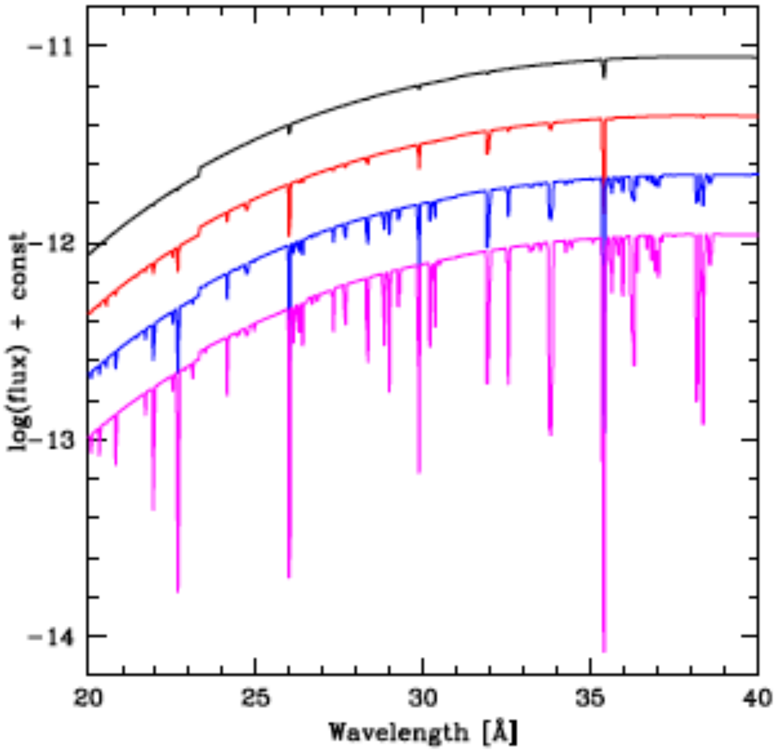
and in X-ray

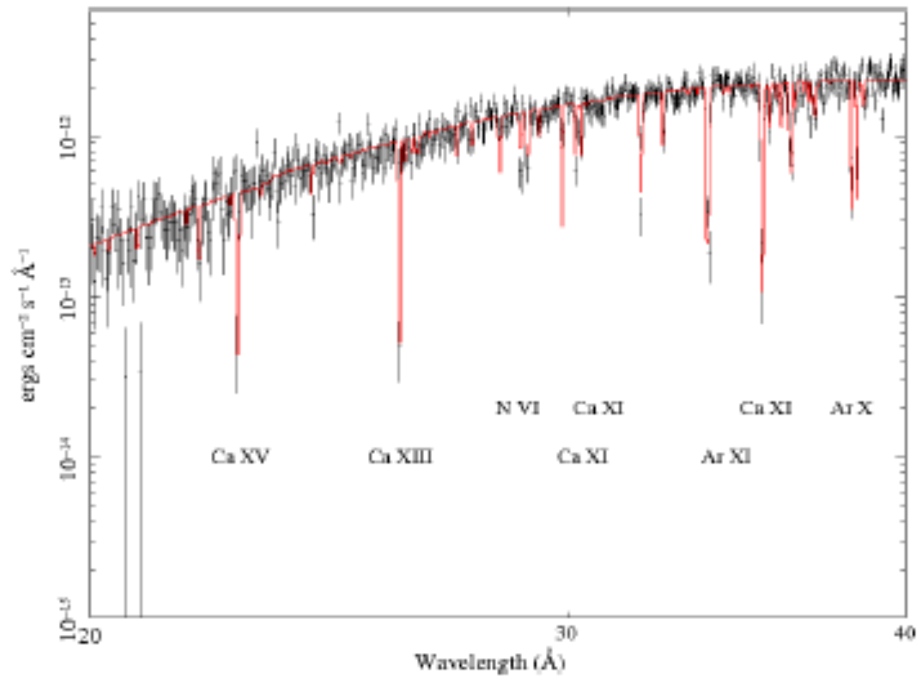


XMM

Chandra

Miller + 2015

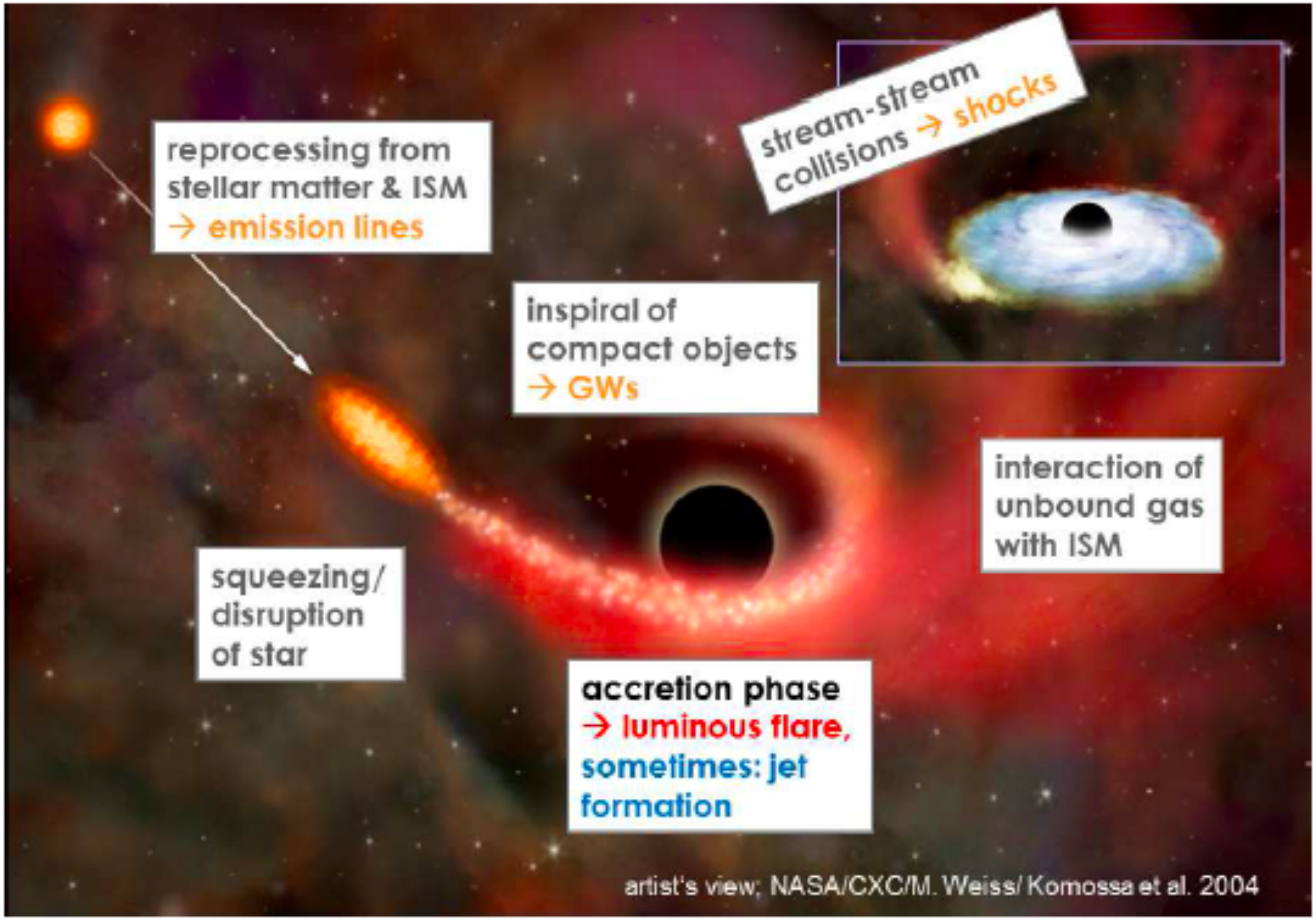




400 ks approved Chandra TOO time for an ASASSN TDE in Cycle 18

A unique view into stellar interior

- Photoionized debris produces lines
- [N/C] ratio can be 2 to 10 times higher
- Strong He lines, but no H: lost H envelop?


reprocessing from
stellar matter & ISM
→ emission lines
stream-stream
collisions → shocks
inspiral of
compact objects
→ GWs
interaction of
unbound gas
with ISM
squeezing/
disruption
of star
accretion phase
→ luminous flare,
sometimes: jet
formation
artist's view; NASA/CXC/M. Weiss/ Komossa et al. 2004

ASAS-SN TDEs

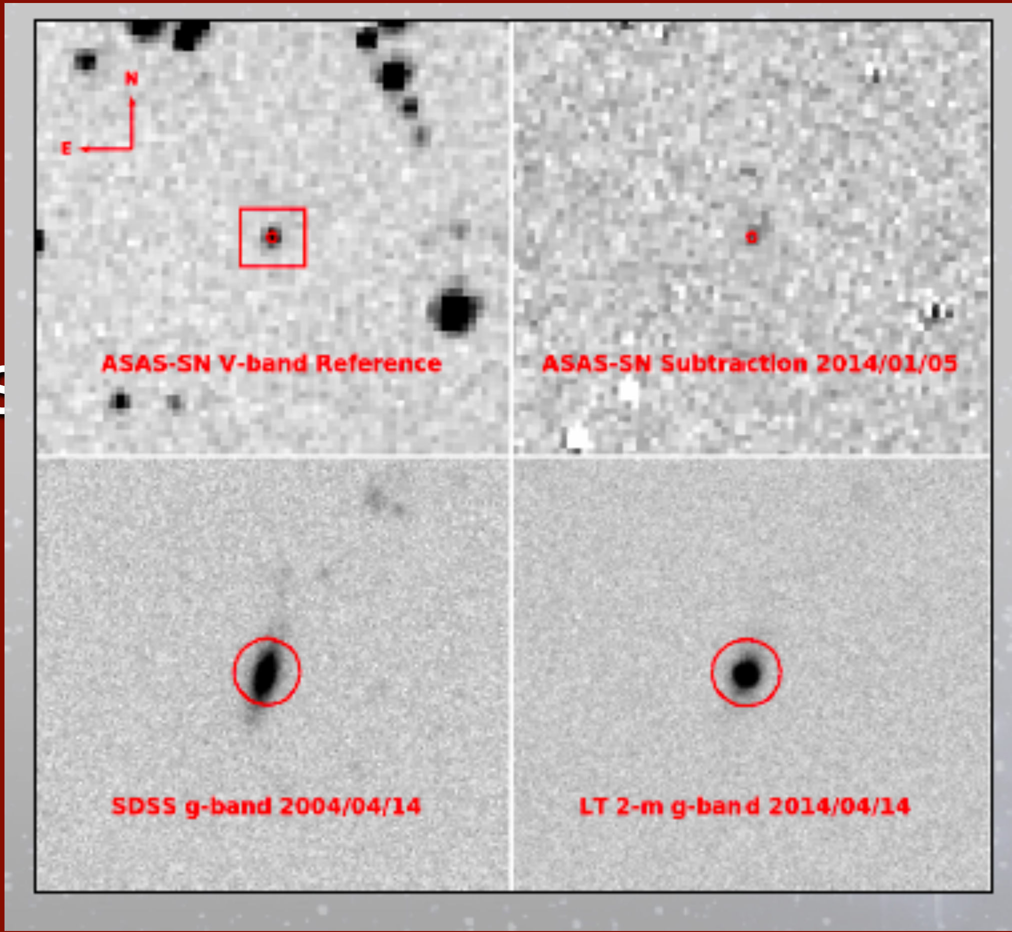
- The **A**ll-**S**ky **A**utomated **S**urvey for **S**uper**N**ovae
- Goal: survey the entire sky to ~17th magnitude with a rapid cadence
- 14-cm lenses, 4.5 X 4.5 degrees, V-band.
- Current: 2 units, 20,000 sq. degrees per night.
- 237 supernovae, 3 TDEs.

Why use ASAS-SN for TDEs?

- Targets are bright and nearby
- Follow-up is easy
- 100% spectroscopic follow-up
- Discoveries made public upon confirmation.

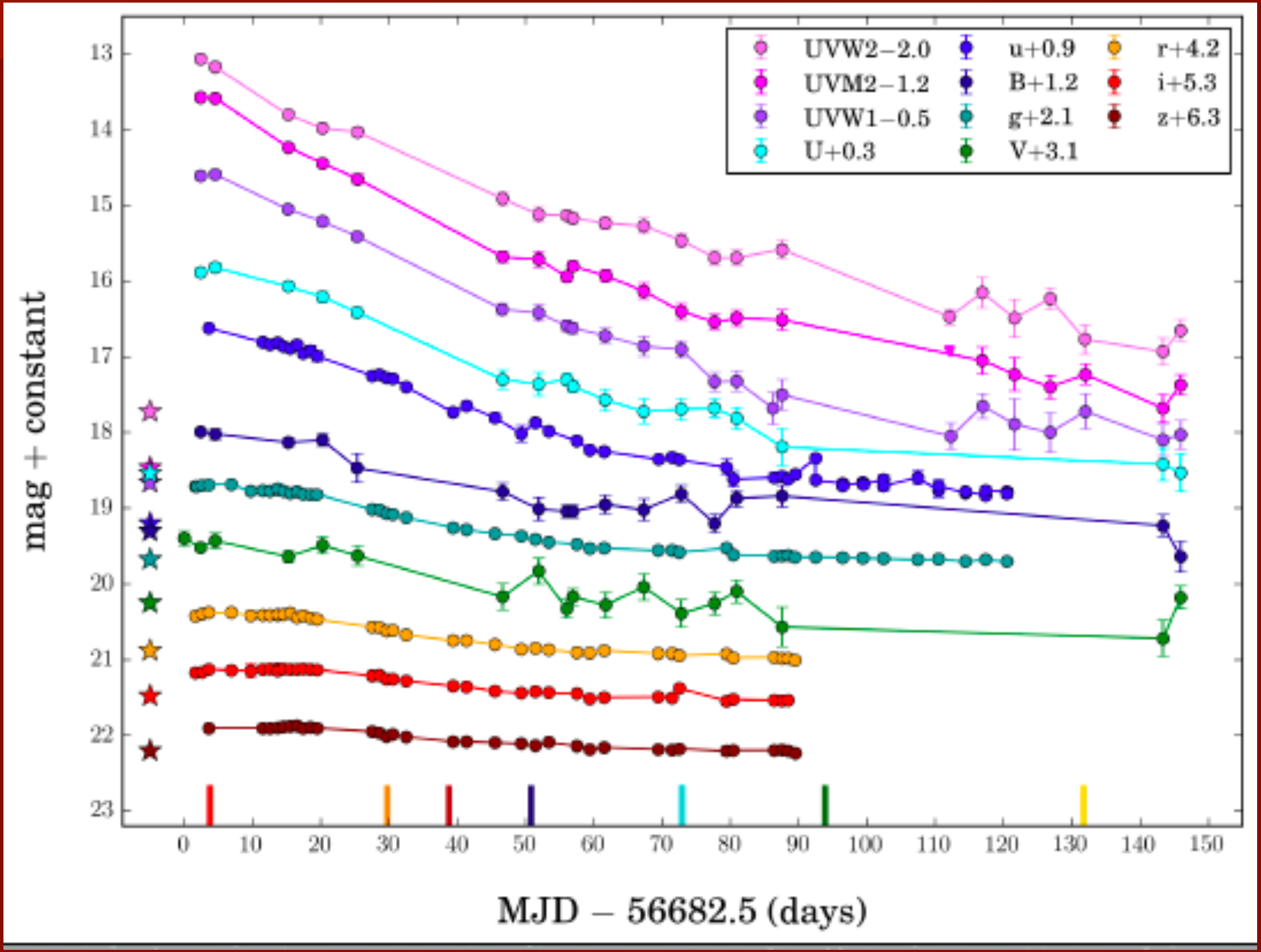
ASASSN-14ae

- Discovered :
  Jan 2014
- d ≈ 200 Mpc
- $L_{peak} \approx 10^{10}\, L_{\odot}$
- $E_{total} \approx 2 \times 10^{50}$ ergs

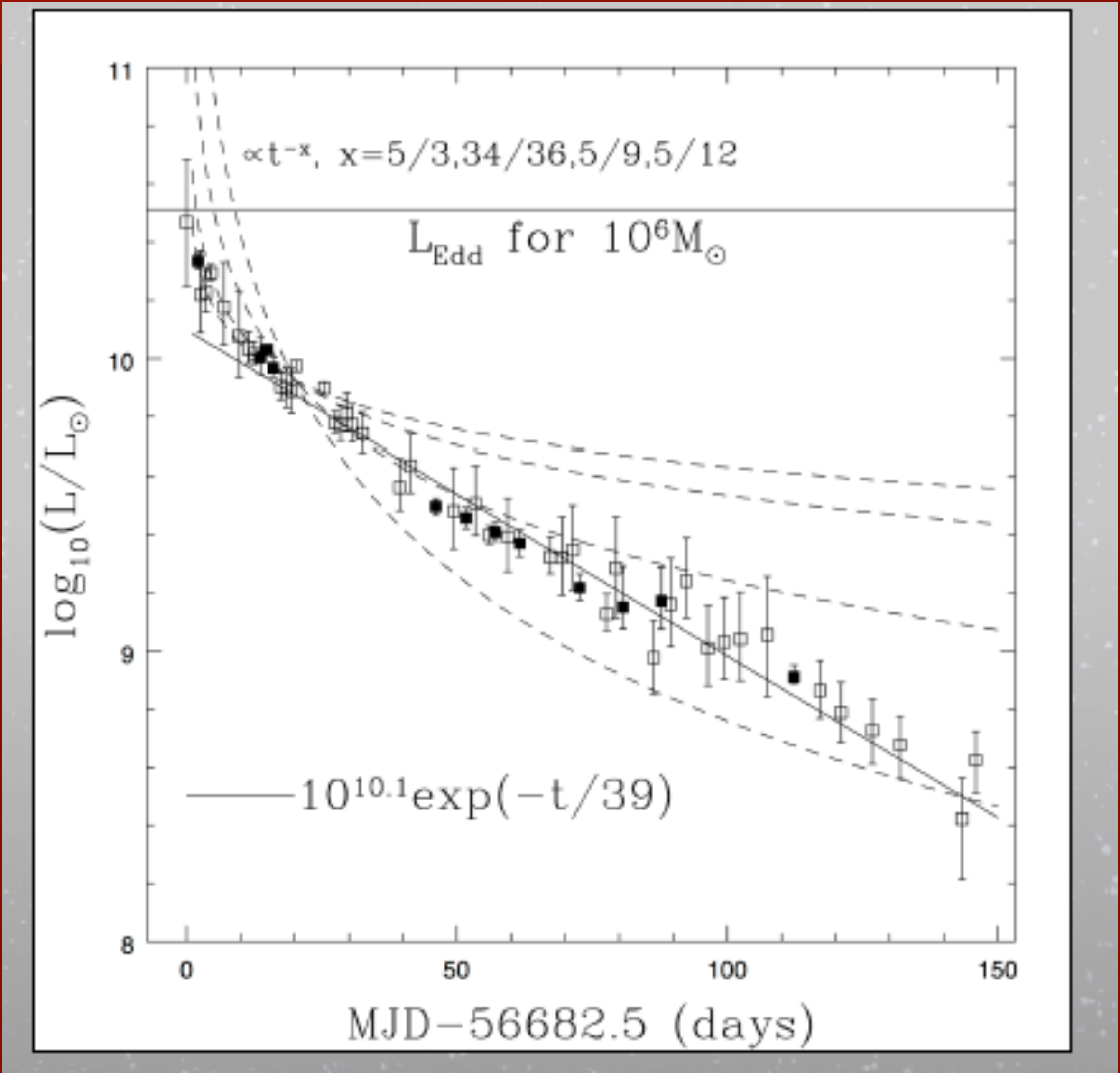


Holoien + 2014

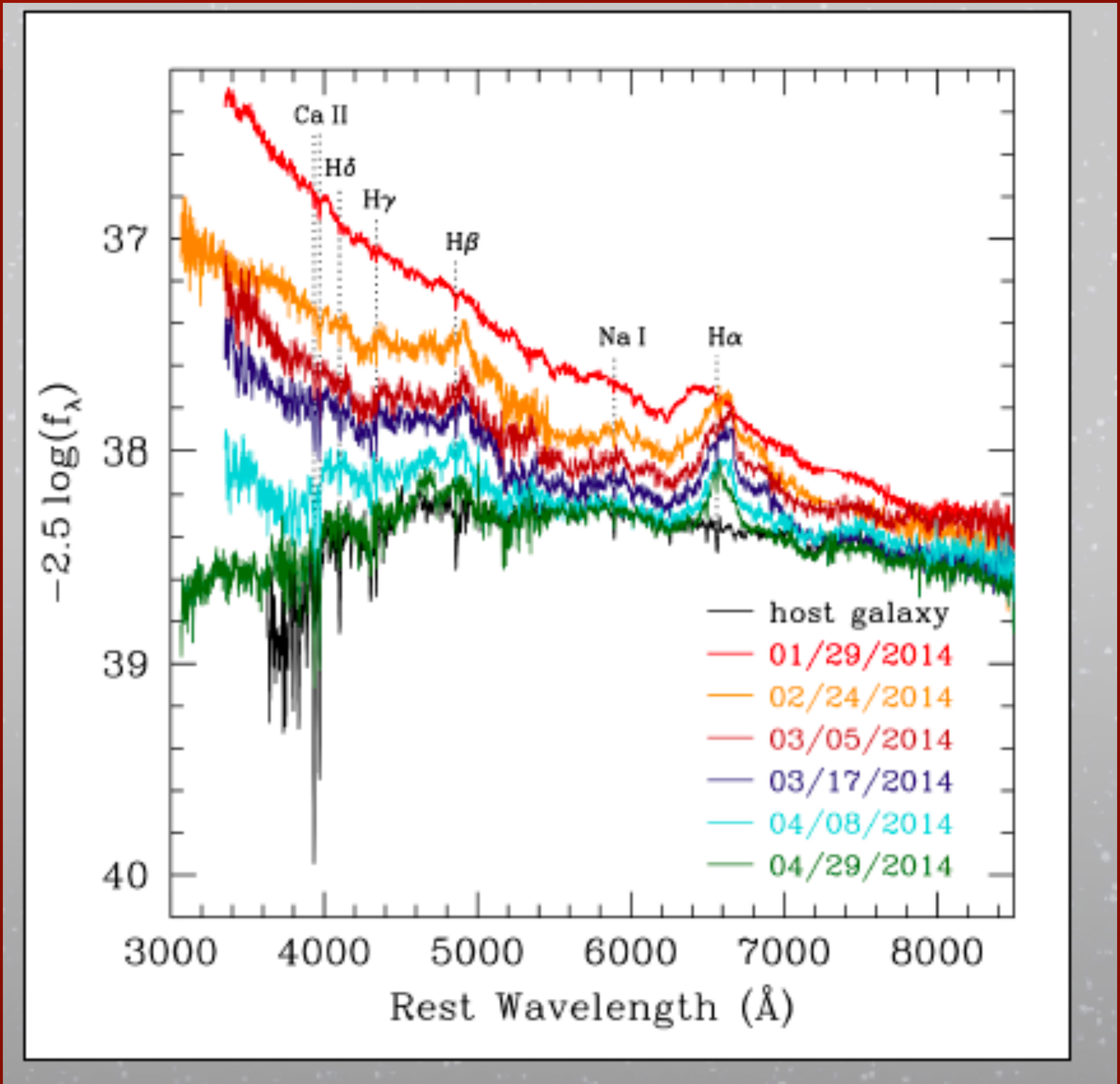
ASASSN-14ae lightcurves



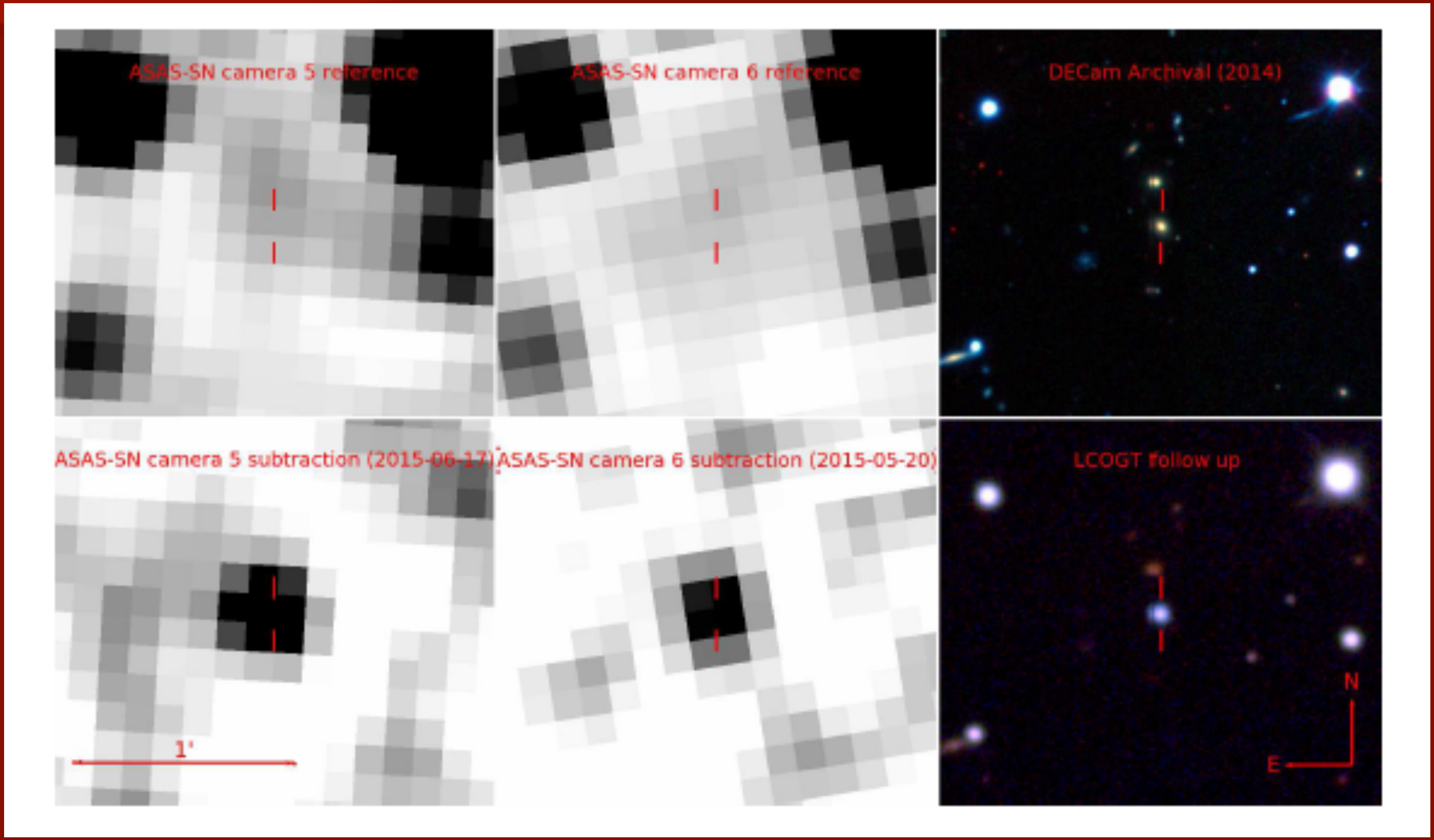
ASASSN-14ae Luminosity

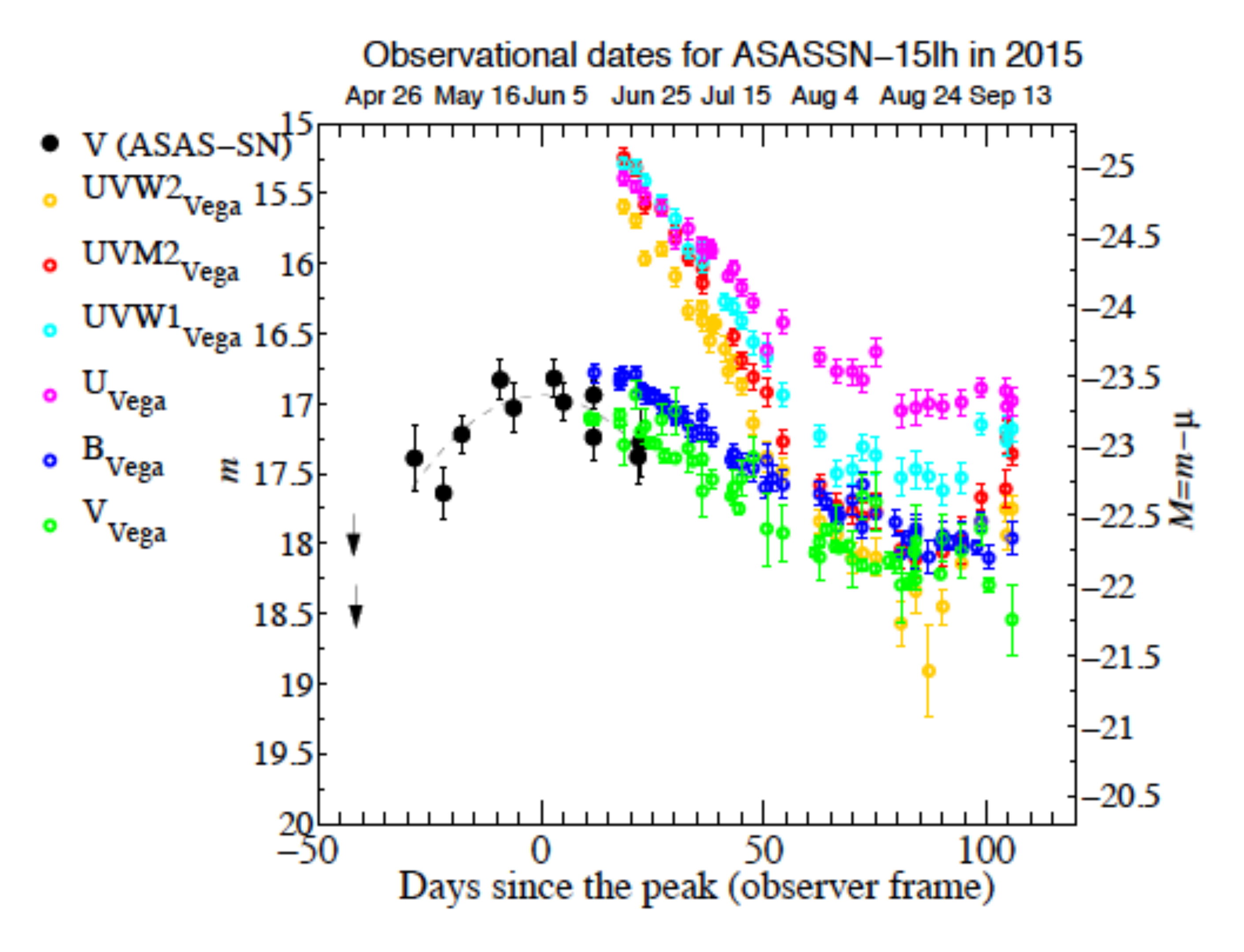


ASASSN-14ae Spectra



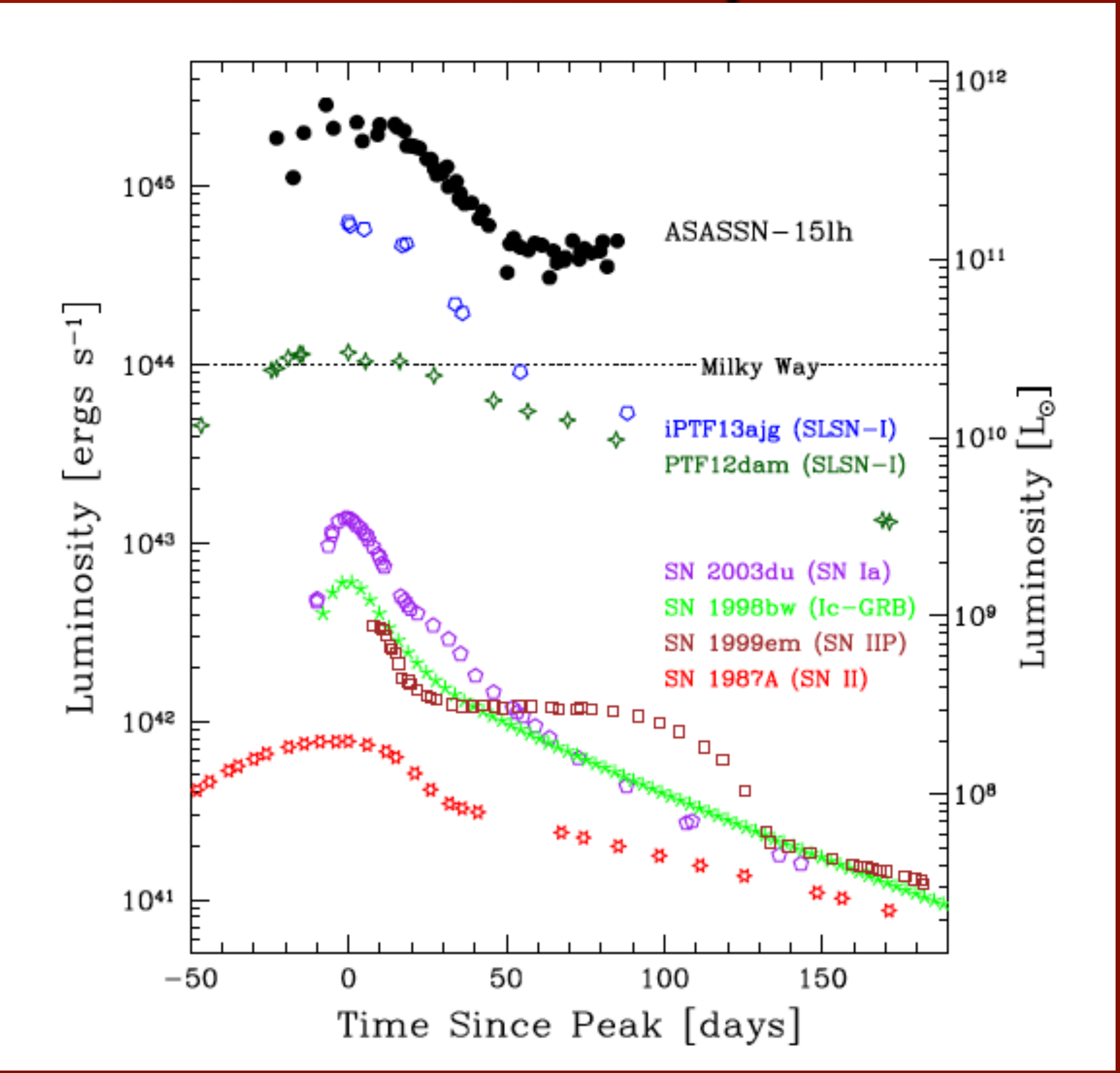
The curious case of ASASSN15lh





Observational dates for ASASSN−15lh in 2015
Apr 26 May 16 Jun 5 Jun 25 Jul 15 Aug 4 Aug 24 Sep 13
V (ASAS−SN)
UVW2Vega
UVM2Vega
UVW1Vega
UVega
BVega
VVega
m
M=m−μ
Days since the peak (observer frame)
15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
−25
−24.5
−24
−23.5
−23
−22.5
−22
−21.5
−21
−20.5
−50
0
50
100

ASASSN15lh: A highly superluminous supernova?



Dong+ 2016
Science

ASASSN15lh: A highly superluminous supernova?

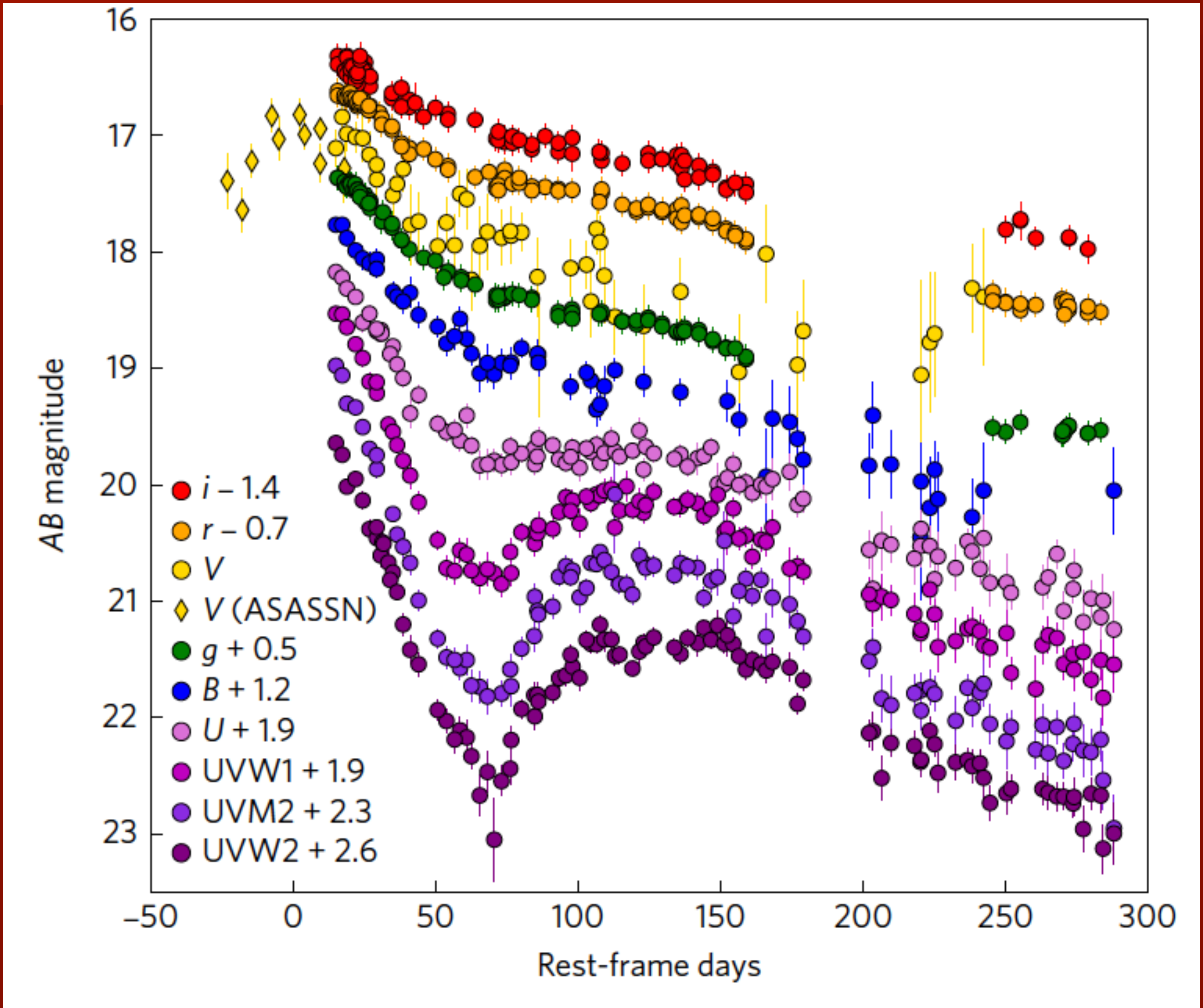
- $z = 0.2326$
- $L_{peak} \approx 2 \times 10^{45}$ erg/s
- No H or He broad emission lines
- Nuclear BH likely massive in this luminous old galaxy. $M(BH) > 10^8 M_\odot$ making TDE unlikely

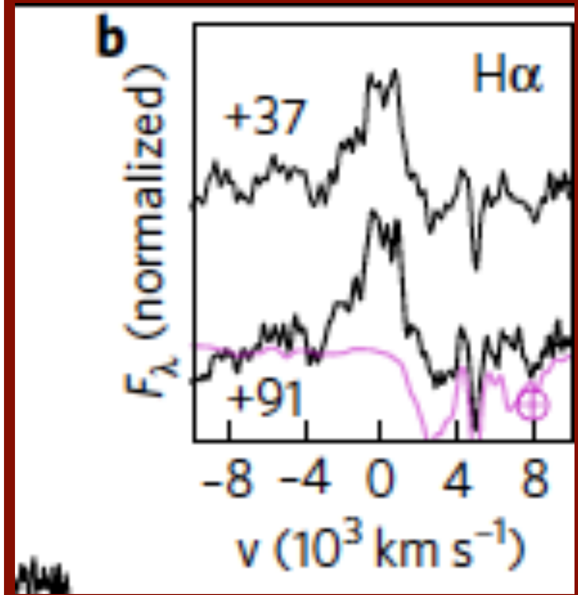
ASASSN15lh: A TDE?

- At galactic center
- In a galaxy with little star-formation
- E (radiated in 4 months) exceeds 10^{52} erg challenging magnetar models for SL-SN

Leloudas + 2016 Science

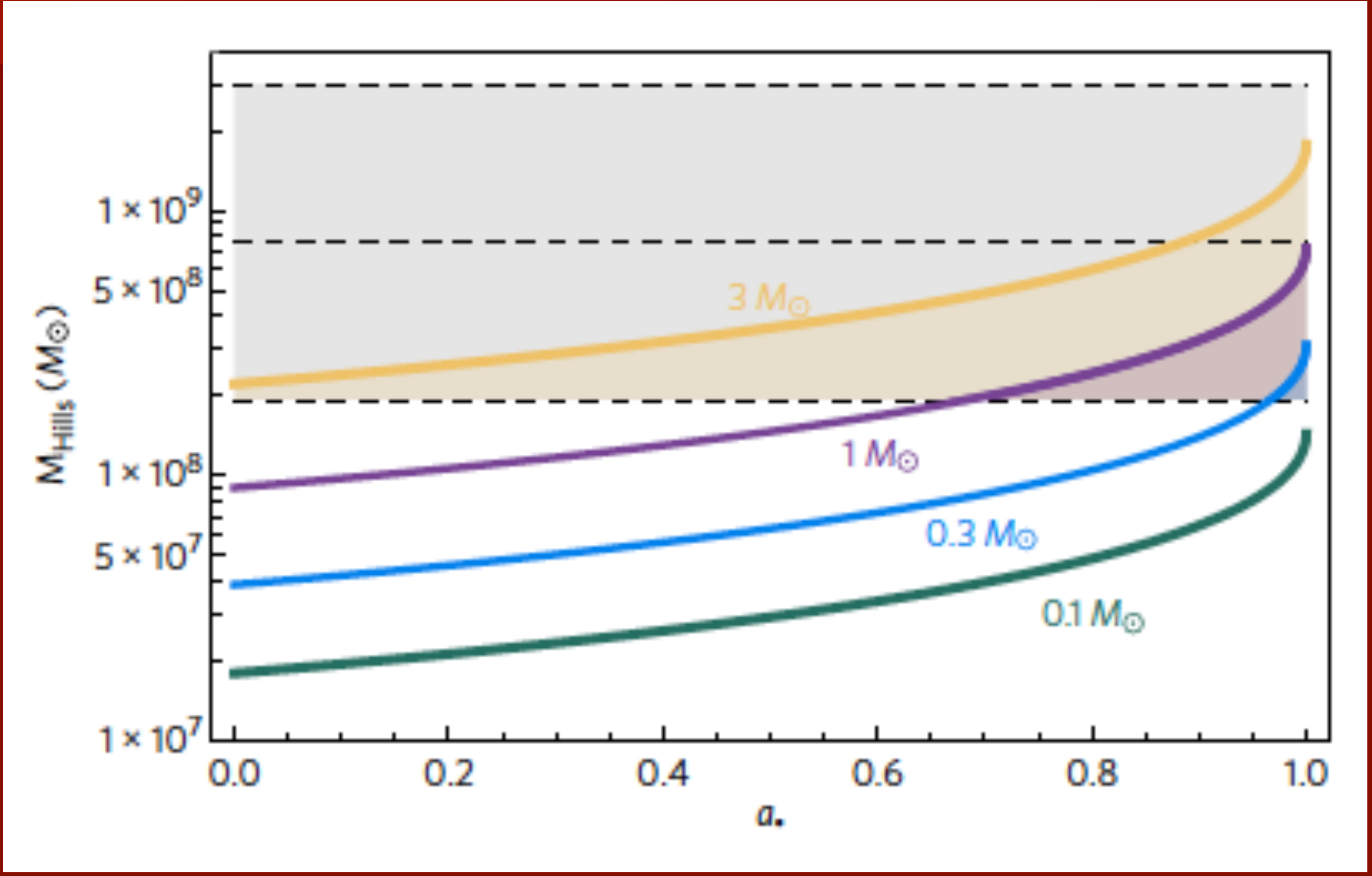
Re-brightening of ASASSN-15lh





Diego + 2015

TDE around a Kerr BH



TDEs with ASTROSAT

- Multi-wavelength coverage essential for TDE science
- ASTROSAT capabilities well suited
- ASTROSAT follow-up of ASAS-SN TDEs
- TDEs provide rich astrophysical laboratories for a range of science from stars to BHs
- Guaranteed to provide important results