Tidal Disruption Events
and Their Surprising Host Galaxy Preference

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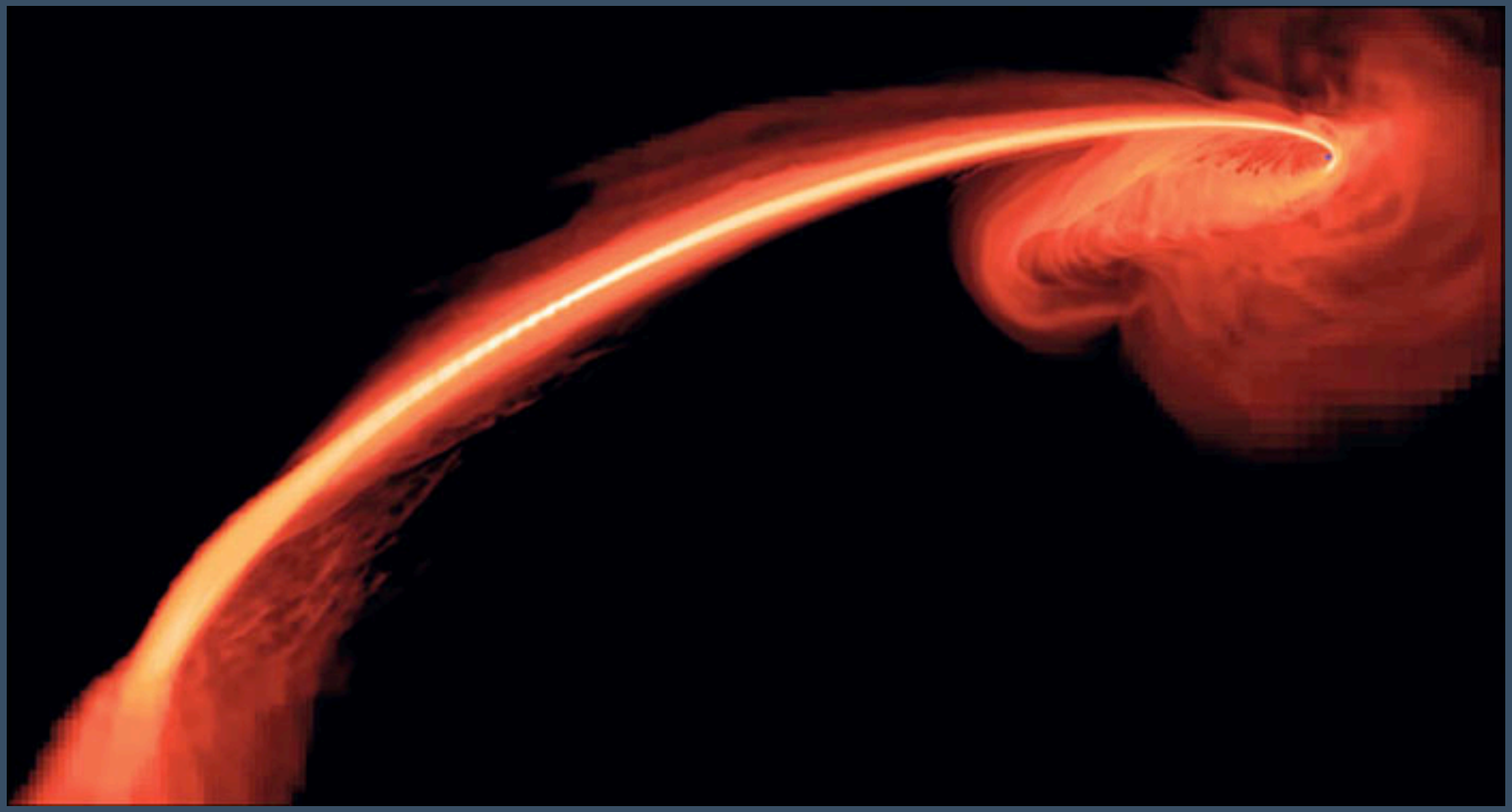
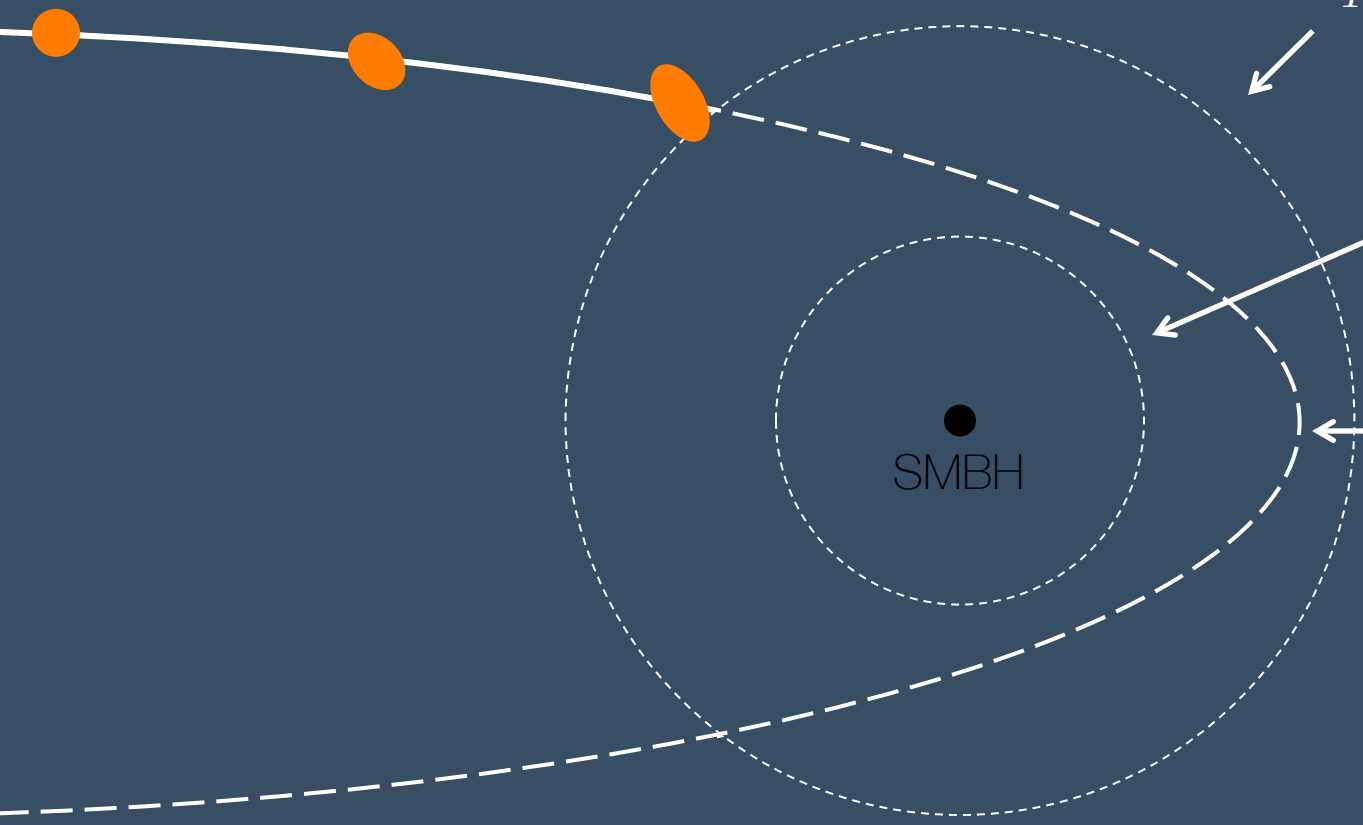
A Tidal Disruption Event (TDE) is Complicated



NASA, S Gezari/JHU and J Guillochon/UCSC

Important Scales



$$R_T = \left(\frac{M_{BH}}{M_*}\right)^{1/3} R_*$$

$$R_S = \frac{2GM_{BH}}{c^2}$$

R_p

$\beta = R_T/R_p$

$$R_T \gtrsim R_S \text{ for } M_{BH} \lesssim 10^8 M_\odot \cdot \left(\frac{R_*}{R_\odot}\right)^{3/2} \left(\frac{M_*}{M_\odot}\right)^{-1/2}$$

Motivation: Study SMBHs

TDEs can be used to study quiescent massive black holes (and the M-Sigma relation) **beyond the nearby Universe**

Not A New Idea, But Events Are Rare

Hills (1975) – A star could be disrupted by a massive BH.

Rees (1988), Phinney (1989), Evans & Kochanek (1989) – Half of the material is bound, half unbound, expect emission when the bound material falls back to the BH as $t^{-5/3}$.

From the accretion onto the SMBH, expect emission in soft x-rays and hard UV.

Donley et al. (2002), Wang & Merritt (2004), Kesden (2012), Stone & Metzger (2014) – Rate is 10^{-4}-10^{-5} events per galaxy per year.

Early Observations Were Archival, Sparse Data

ROSAT (X-Rays) – 5 archival candidates (Donley et al. 2002).

XMM-Newton (X-Rays) – 5 additional archival candidates (Esquej et al. 2007).

SDSS (optical) – 2 archival candidates (van Velzen et al 2011).

GALEX (UV) + CFHT (optical) – one candidate (~year cadence light curve; Gezari et al. 2006).

Two Major Discoveries in 2011 and 2012

Swift J1644 (Bloom et al. 2011, Burrows et al. 2011, Levan et al. 2011, Zauderer et al. 2011)

Gamma and X-rays, radio
No optical

Non-thermal spectrum
Plateau in X-ray light curve
then ~$t^{-5/3}$ decline

PS1-10jh (Gezari et al. 2012)

UV / Optical
No X-rays

Hot blackbody (30,000K)
Smooth rise and fall light curve
~$t^{-5/3}$ decline

Two Major Discoveries in 2011 and 2012

High Energy TDEs

Swift J1644 (Bloom et al. 2011, Burrows et al. 2011, Levan et al. 2011, Zauderer et al. 2011)

Gamma and X-rays, radio
No optical

Non-thermal spectrum
Plateau in X-ray light curve
then ~$t^{-5/3}$ decline

Additional events:
Swift J2058 (Cenko et al. 2012), Swift J1112 (Brown et al. 2015)

Optical+NUV TDEs

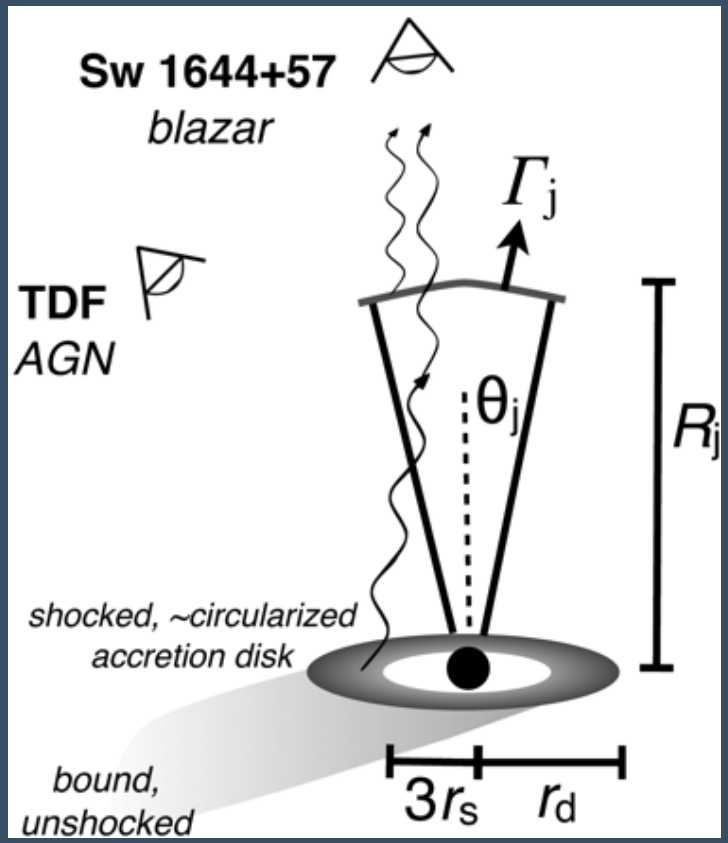
PS1-10jh (Gezari et al. 2012)

UV / Optical
No X-rays

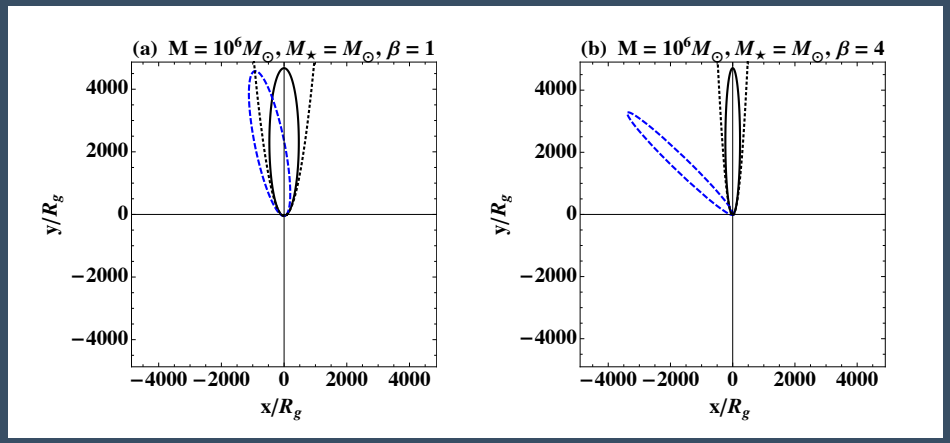
Hot blackbody (30,000K)
Smooth rise and fall light curve
~$t^{-5/3}$ decline

Additional events:
Arcavi et al. 2014, Holoien et al. 2014, 2016a,b, Wyrzykowski et al. 2016

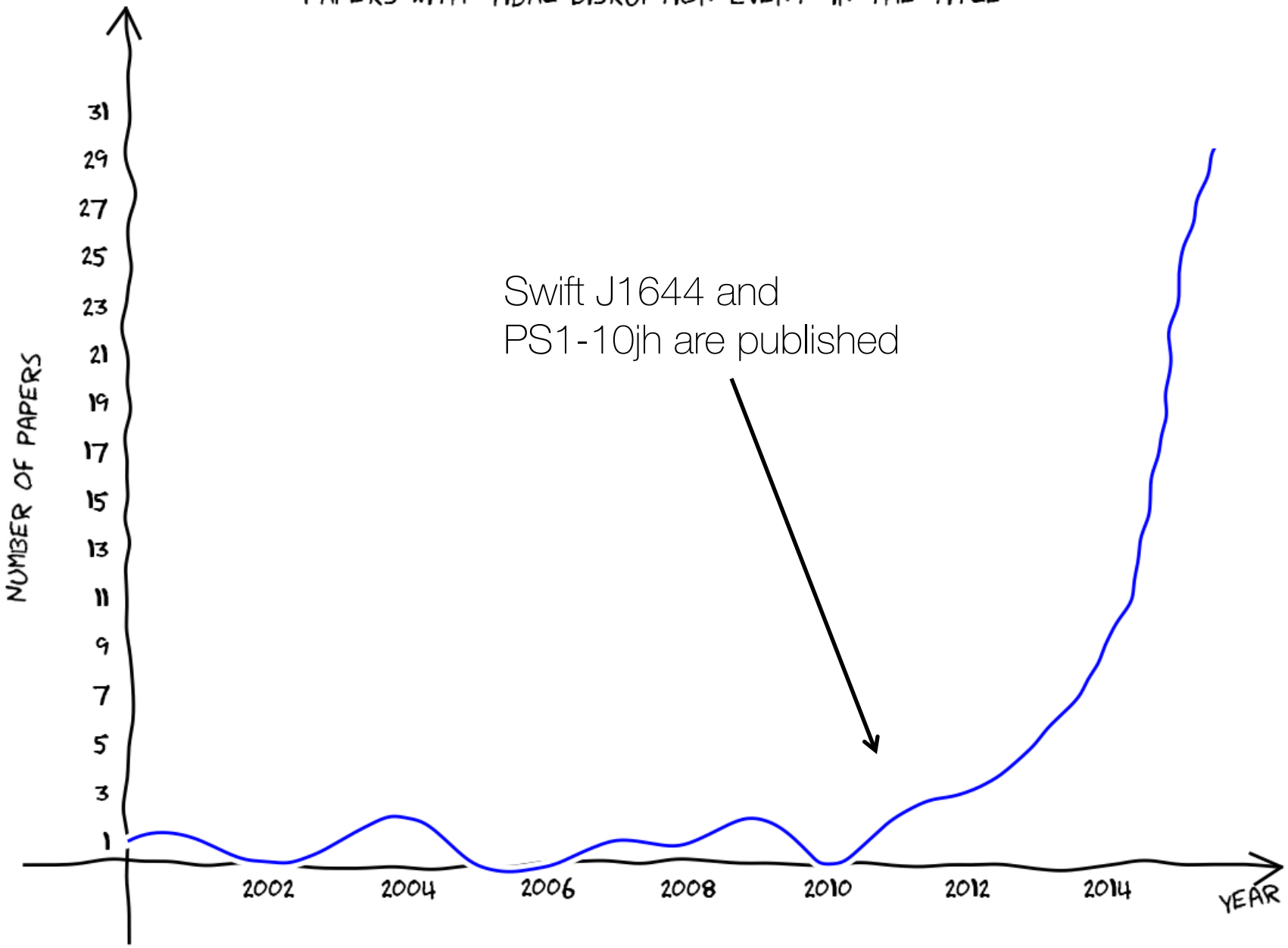
Why Two So Different Types of TDEs?



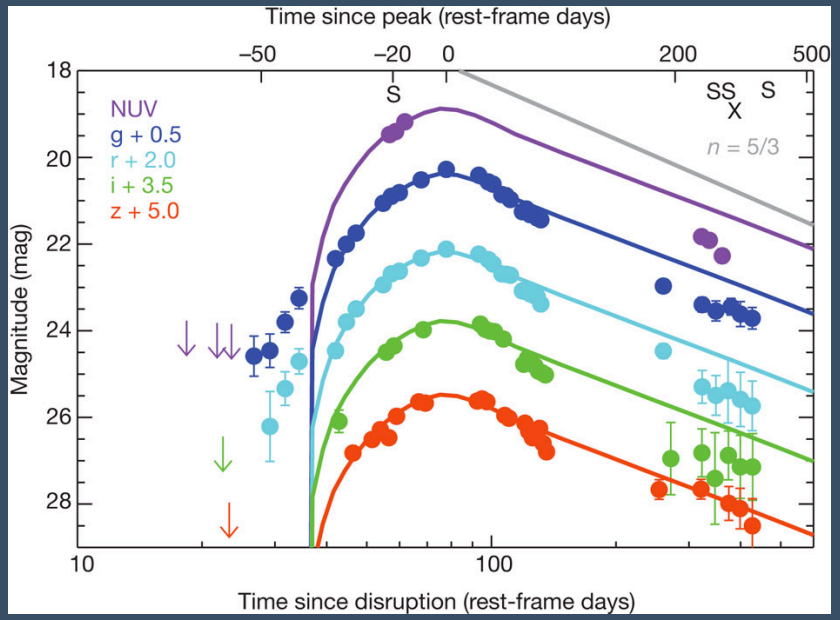
Bloom et al. (2011): Viewing angle effect

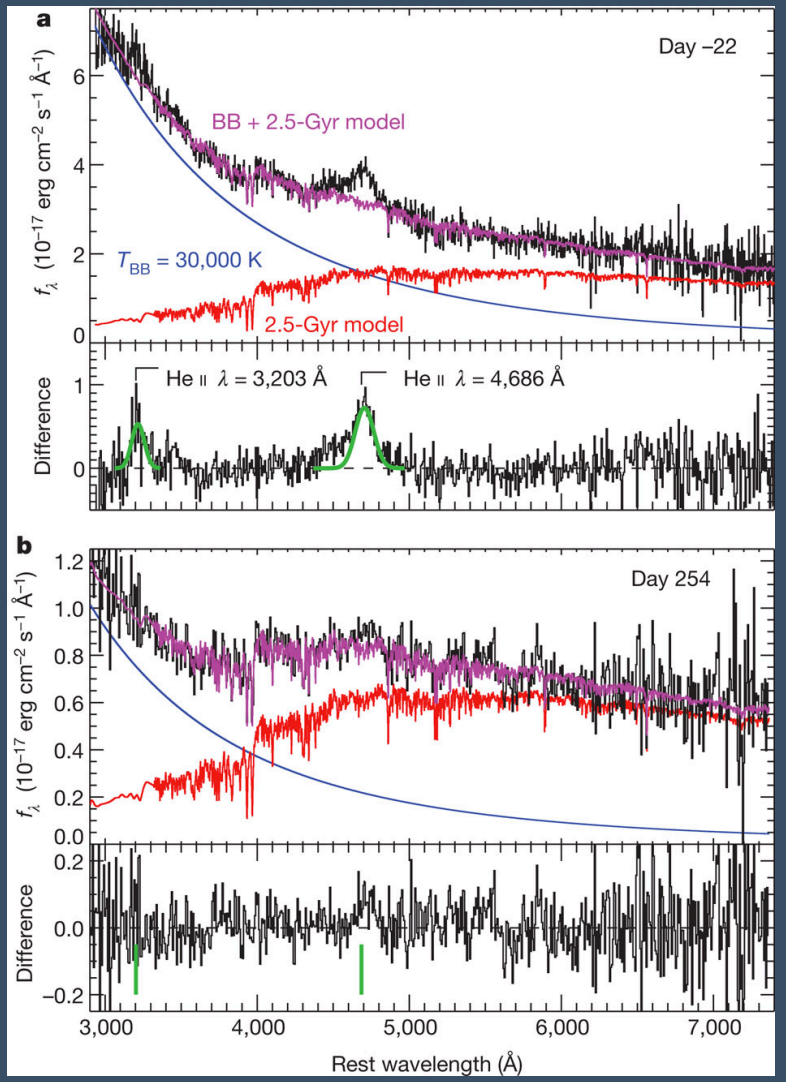


Dai et al. (2015): β effect


PAPERS WITH "TIDAL DISRUPTION EVENT" IN THE TITLE
NUMBER OF PAPERS
31
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1
2002
2004
2006
2008
2010
2012
2014
YEAR
Swift J1644 and
PS1-10jh are published

PS1-10jh: The First Optical + NUV TDE

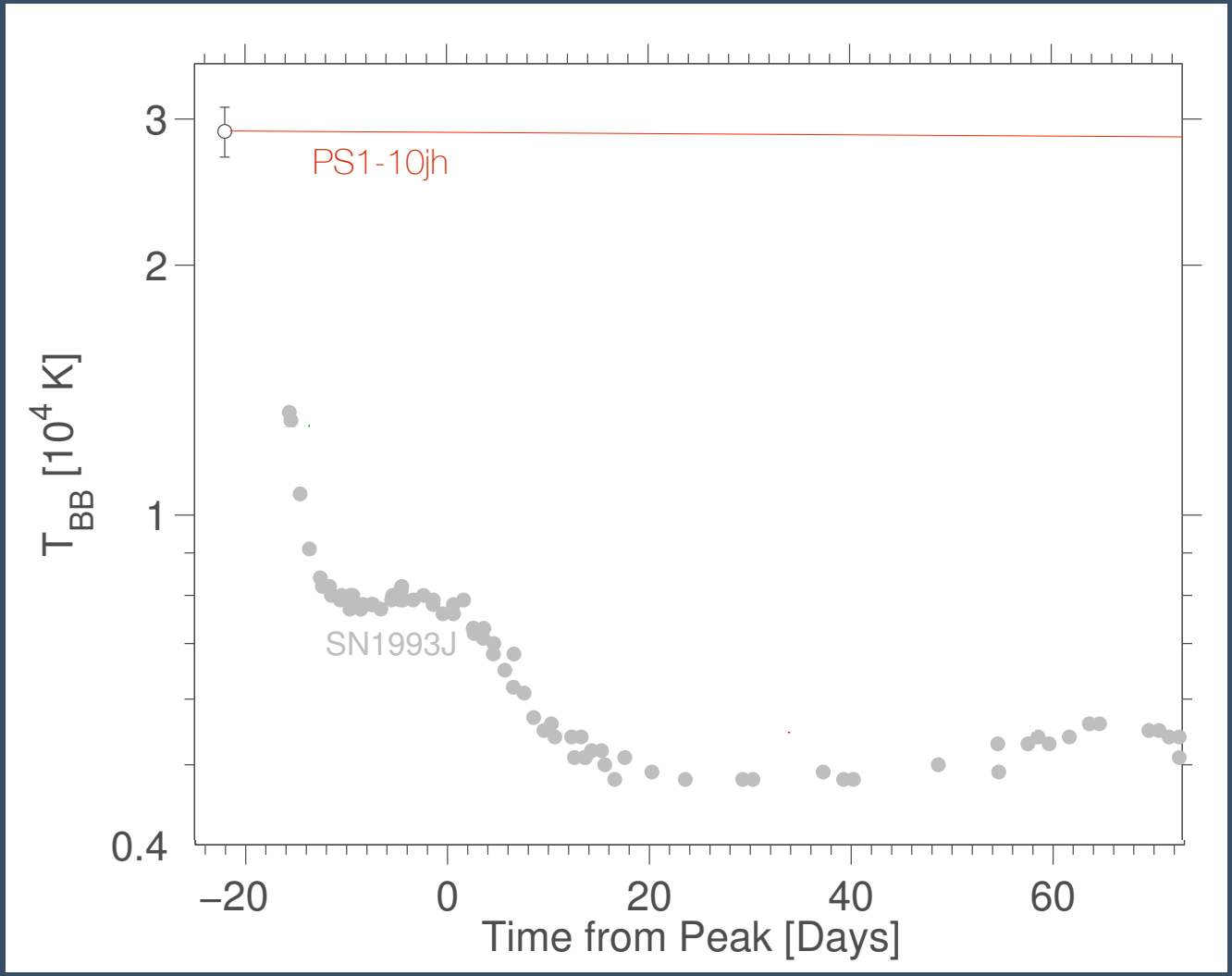




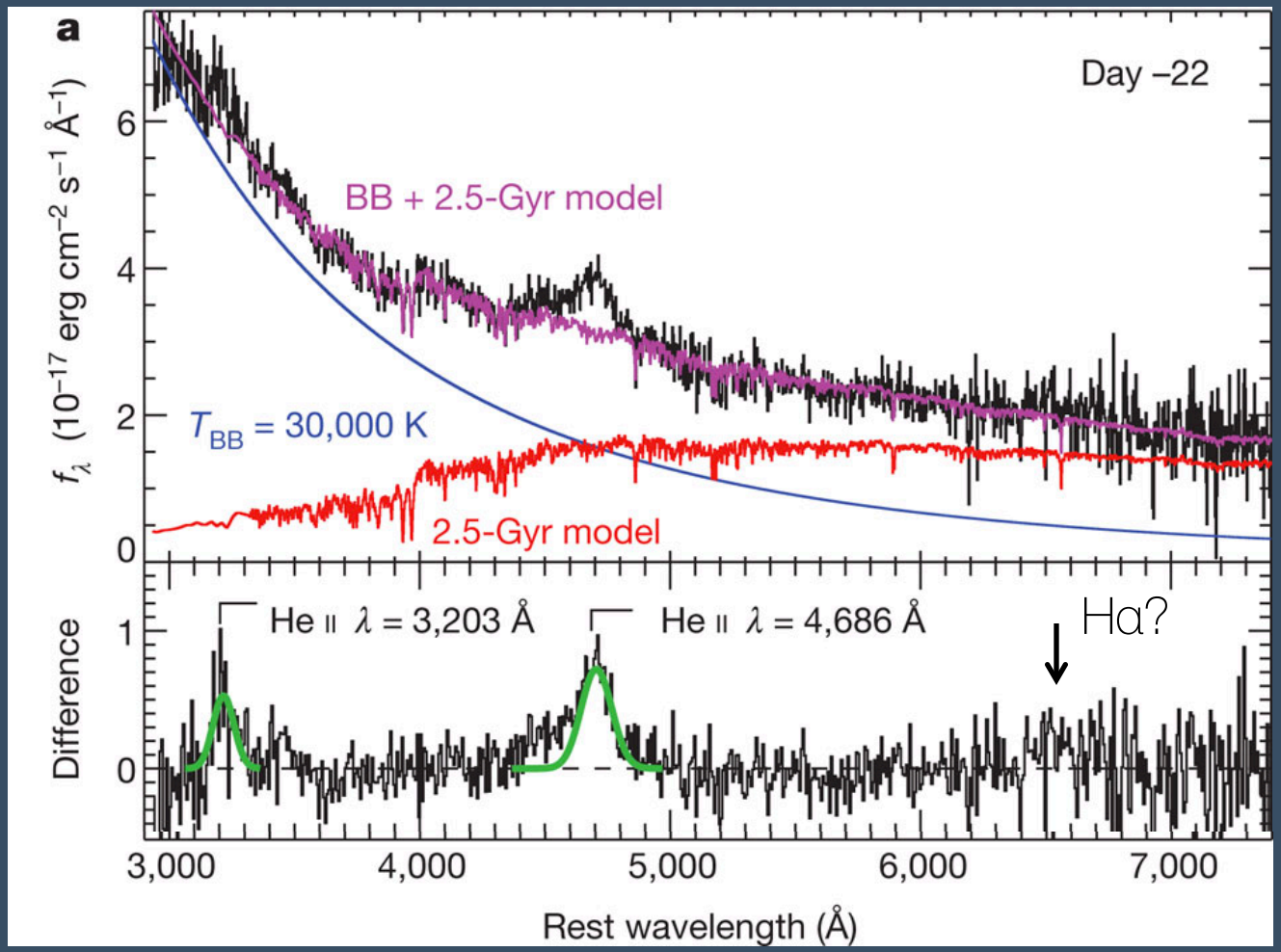
- Coincident with the center of a non-starforming galaxy.
- Peak magnitude -20
- Constant blue colors
- Only broad He II in spectrum

Gezari et al. (2012)

PS1-10jh: Hotter Than Supernovae



PS1-10jh: Spectra Not Like Any Known Supernova

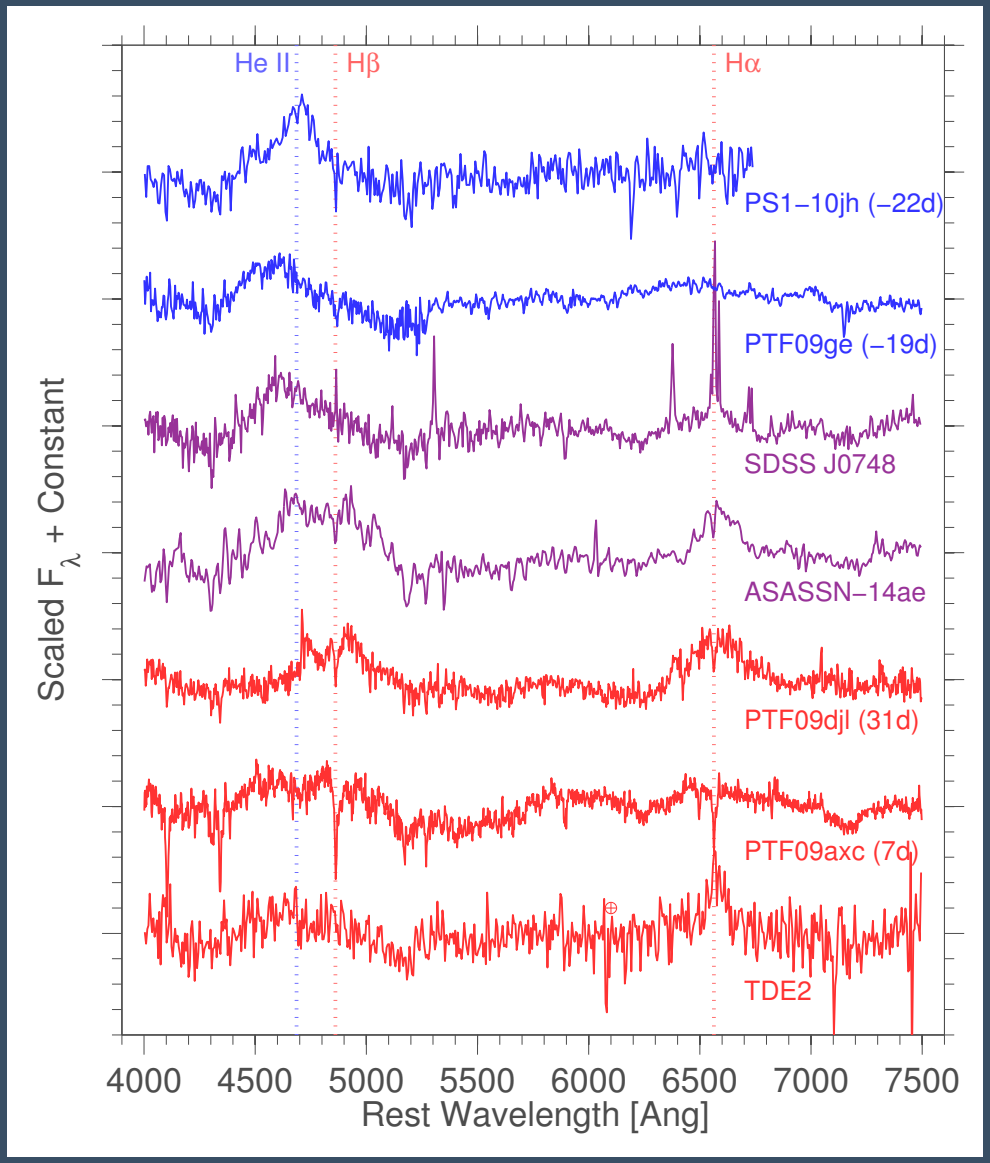


Gezari et al. (2012)

PS1-10jh Does Not Look as Expected for a TDE

Expected	Observed	
Center of galaxy	Center of galaxy	✓
$L \propto t^{-5/3}$	$L \propto t^{-5/3}$	✓
$T \sim 10^5 - 10^6\,\mathrm{K}$	$T = 3 \cdot 10^4\,\mathrm{K}$	✗
$R \sim R_T \sim 10^{13}\,\mathrm{cm}$	$R \sim 10^{15}\,\mathrm{cm}$	✗
$E \sim 0.1 M_\odot c^2 \sim 10^{53}\,\mathrm{erg}$	$E \sim 10^{51}\,\mathrm{erg}$	✗
Evolving Temperature	Constant Temperature	✗
Hydrogen from the star	No hydrogen, only helium	✗

Forming a Class, All in Galaxy Centers



Gezari+ 12

Arcavi+ 14

Wang+ 11

Arcavi+ 14

Holoien+ 14

Arcavi+ 14

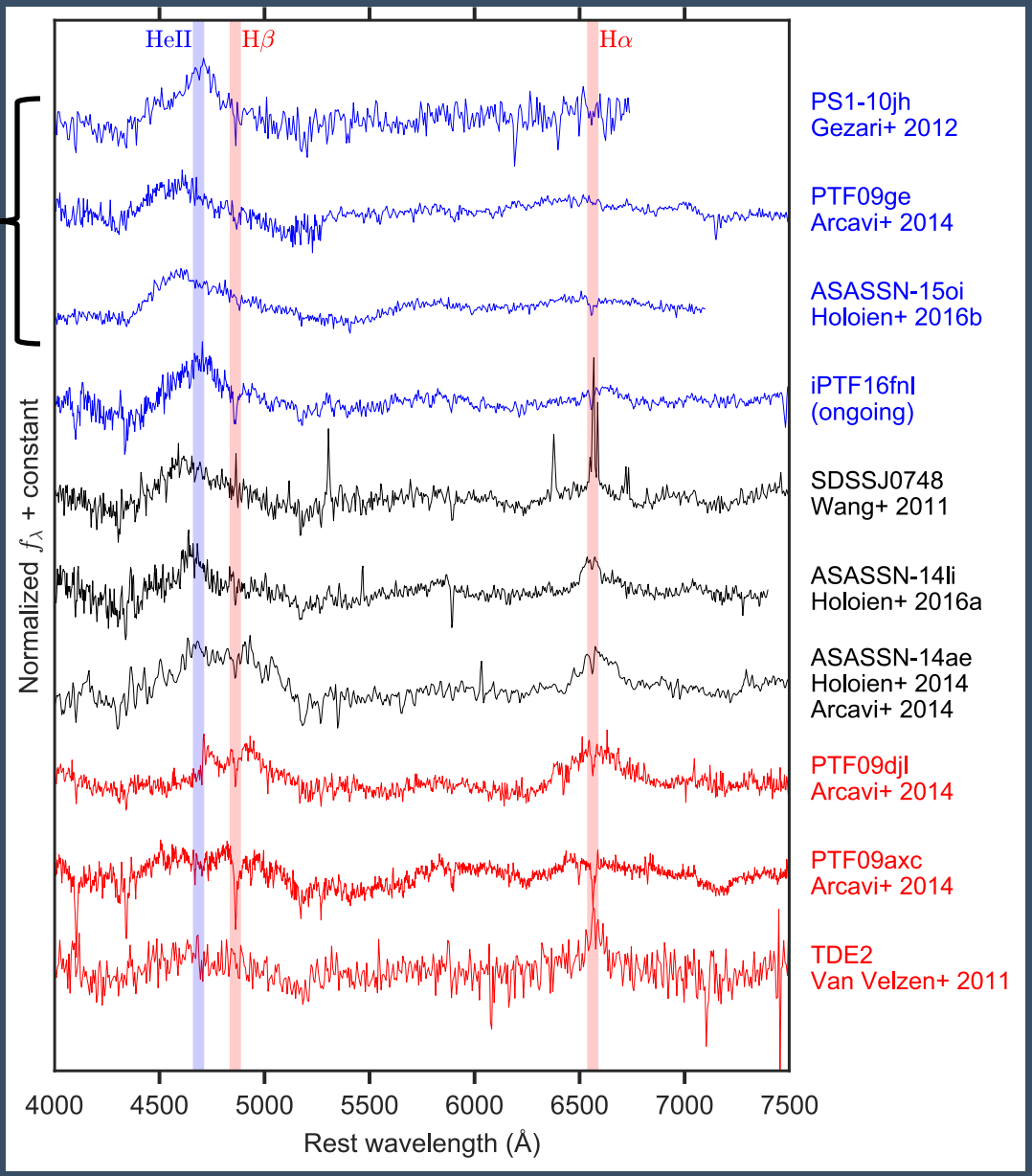
Arcavi+ 14

van Velzen+ 11

Arcavi et al. 2014

A Class of Events Now, All in Galaxy Centers

1/3 of disrupted stars are helium stars? Not likely.

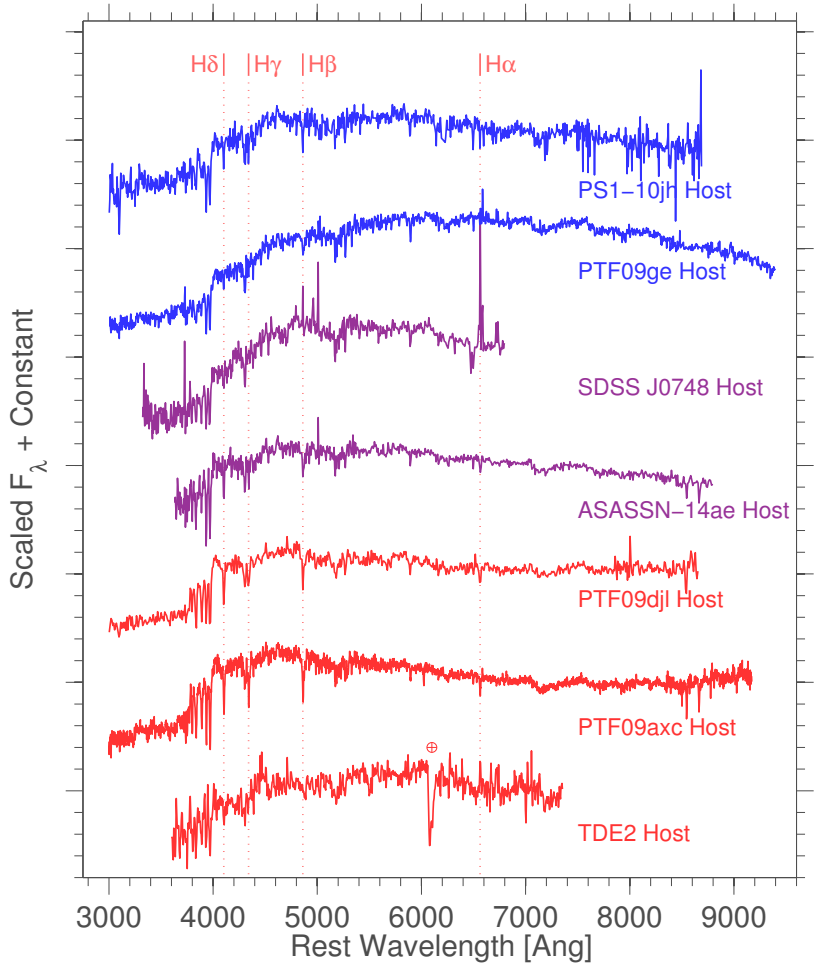


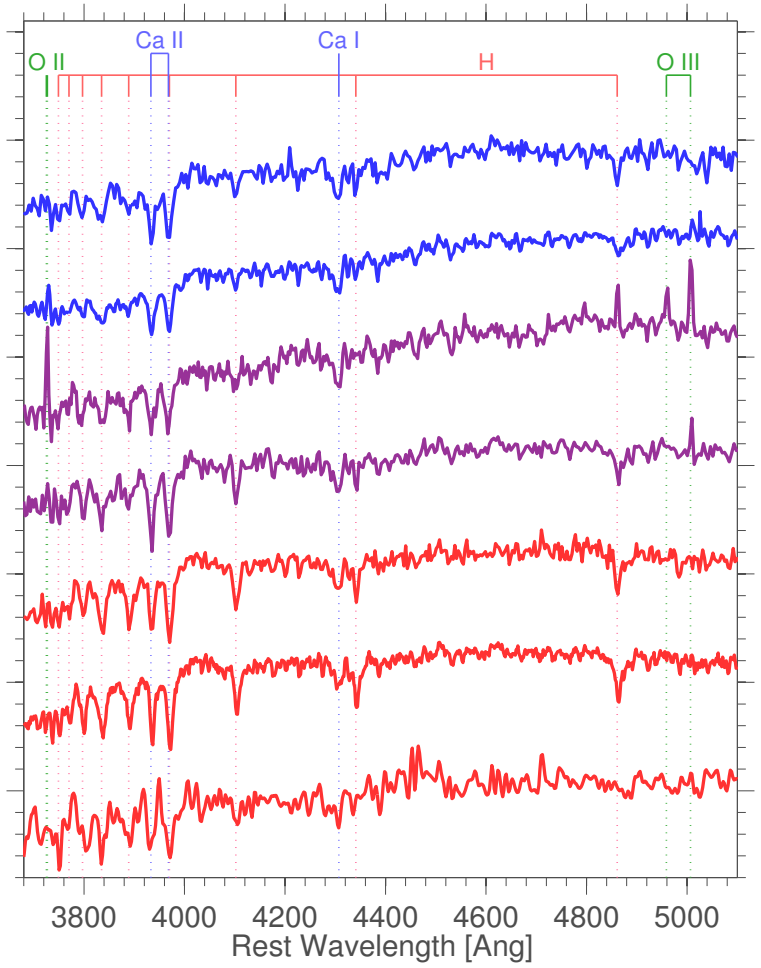
Motivation: Study SMBHs and Accretion Physics

TDEs can be used to study quiescent massive black holes (and the M-Sigma relation) **beyond the nearby Universe**

But first, we need to understand the events: what they look like and why, how are the TDE observables related to the SMBH properties

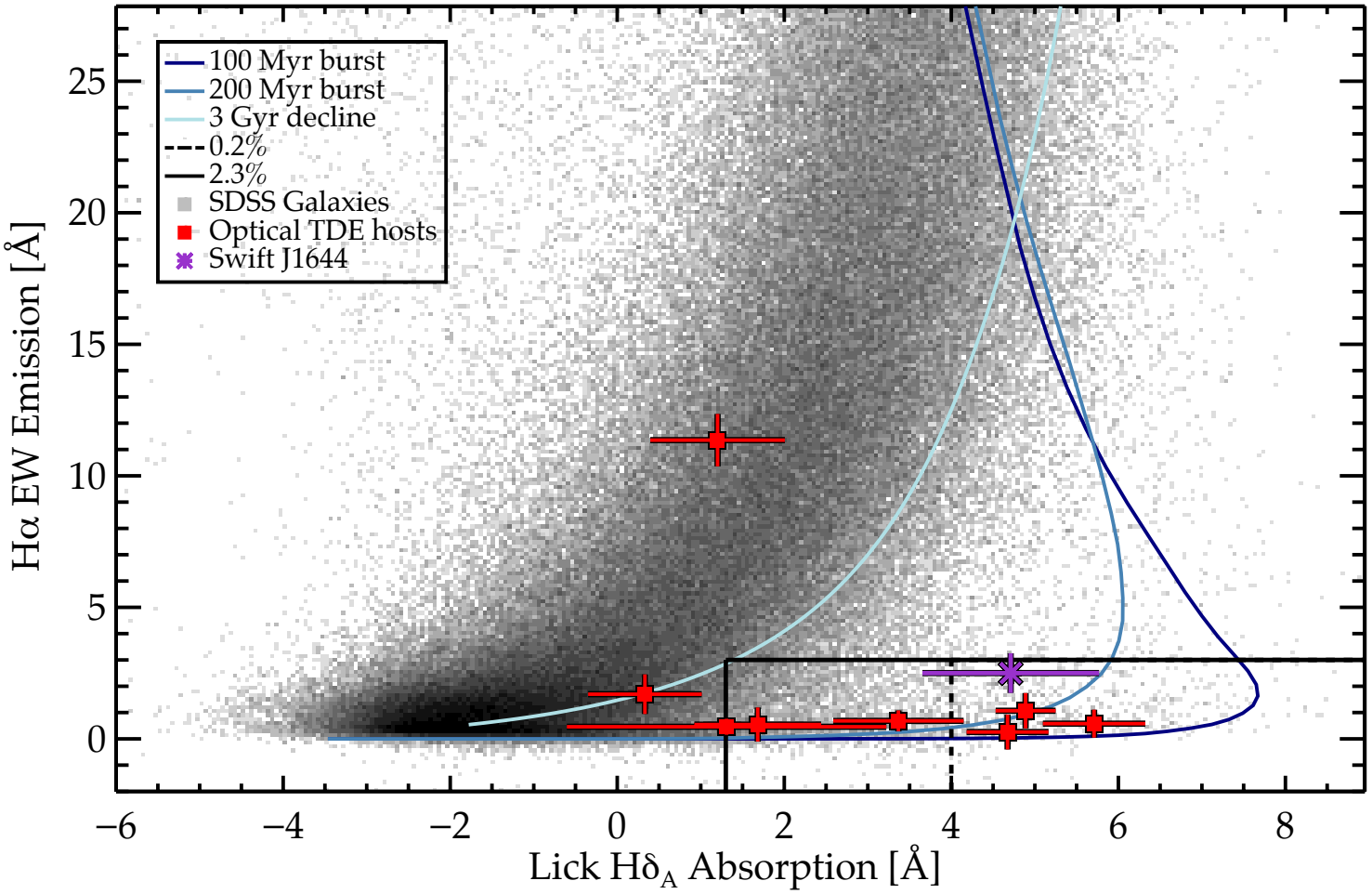
Optical+UV TDEs Prefer Post-Starburst Galaxies





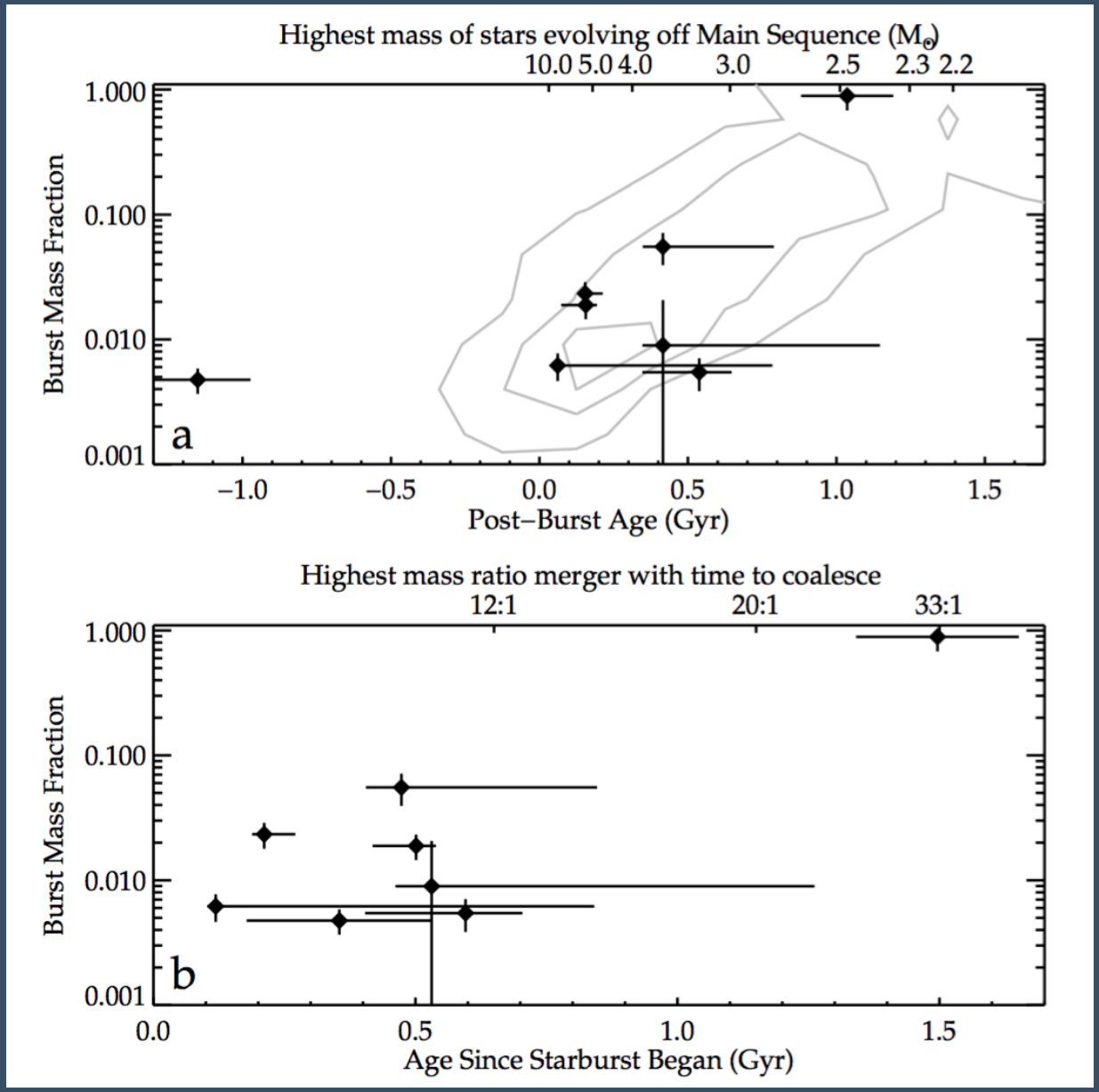
Arcavi et al. 2014

Optical+UV TDEs Prefer Post-Starburst Galaxies



French, Arcavi, Zabludoff, 2016

Why do TDEs Prefer Post-Starburst Galaxies?



French, Arcavi, Zabludoff, submitted (arXiv 1609.04755)

Let's Monitor Post-Starbursts - TDE Goldmine?

SEATiDE (Searching E+A galaxies for Tidal Disruption Events) – Running on the LCOGT network for the last year, 100 galaxies, visited once a month.

aSEATiDE – Running on KAIT, 3000 galaxies, visited once a week. Started last month!

Summary

We see “Optical+NUV TDEs” and “High Energy TDEs”

Emission mechanisms under active debate

Peculiar host-galaxy preference = important clue for something:

- Binary SMBHs?
- Specific stars being disrupted?
- Non-spherical central galaxy potentials?
- Something else?

Using this preference to find more TDEs