Studying Tidal Disruption Events with UVEX

Yuhan Yao (Caltech)
with Wenbin Lu (UCB), Suvi Gezari (STScI)

UVEX Community Workshop
March 15 2023

Where does the TDE UV/optical emission come from?

Reprocessing of disk emission

Energy dissipation in a shock/envelope

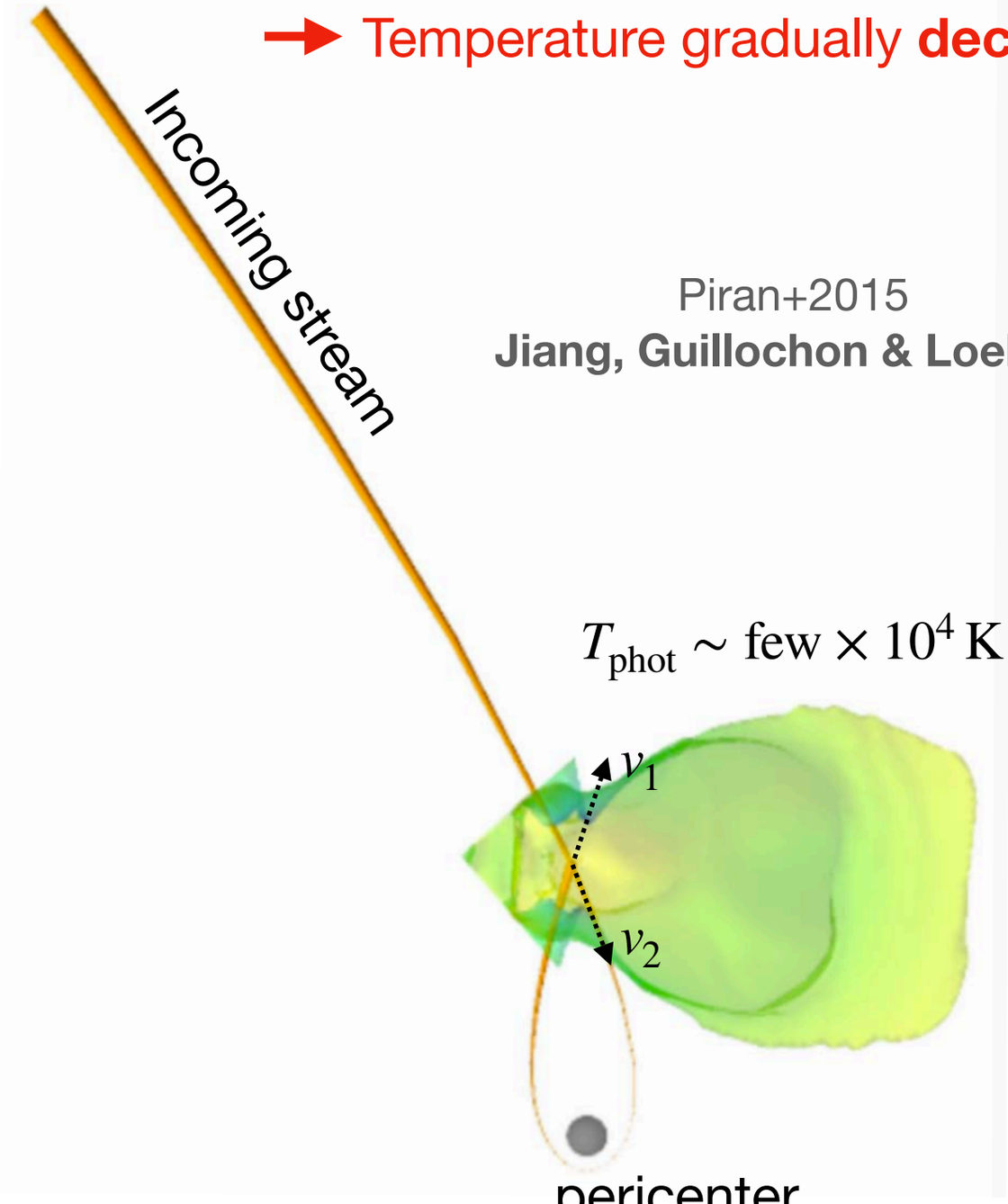
Where does the TDE UV/optical emission come from?

Reprocessing of disk emission

Energy dissipation in a shock/envelope

Self-collision shock:

→ Temperature gradually **decreases**



Piran+2015

Jiang, Guillochon & Loeb 2016

Where does the TDE UV/optical emission come from?

Reprocessing of disk emission

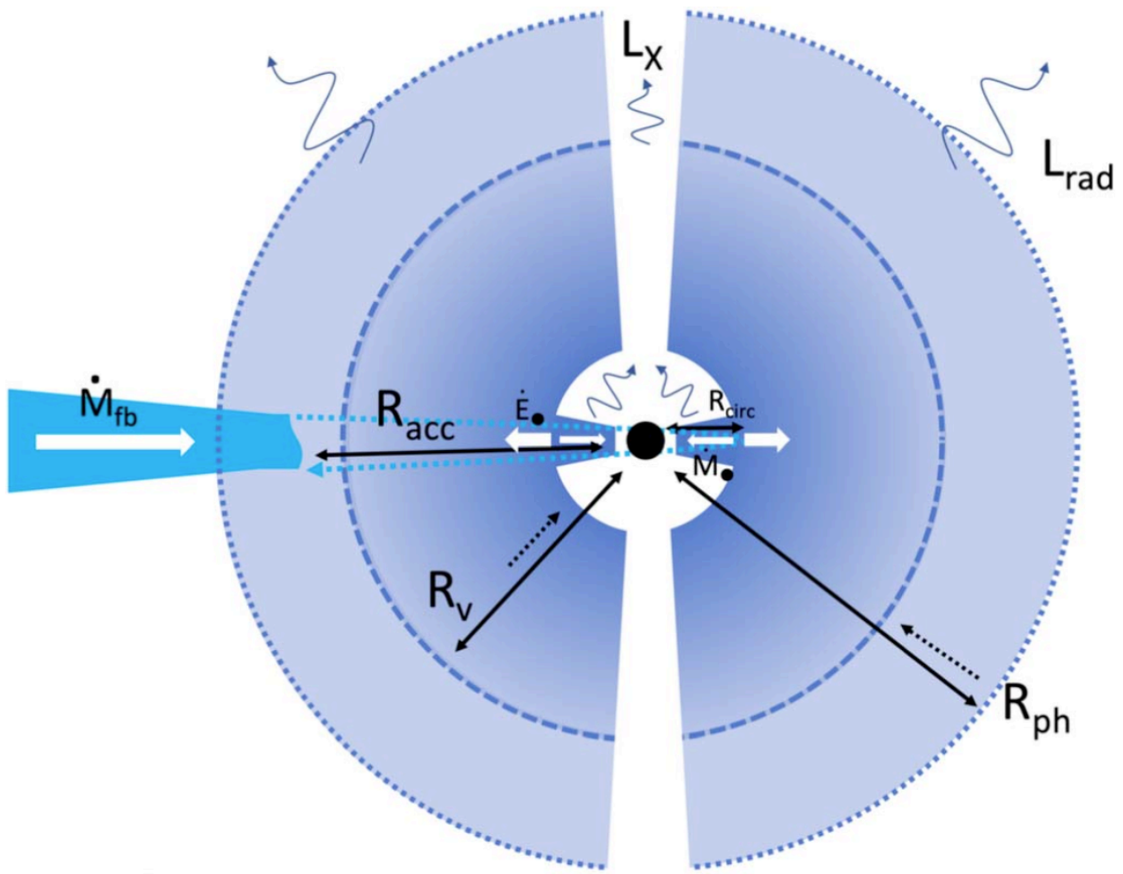
Energy dissipation in a shock/envelope

Self-collision shock:

→ Temperature gradually **decreases**

Quasi-static weakly-bound envelope:

→ Temperature gradually **increases**



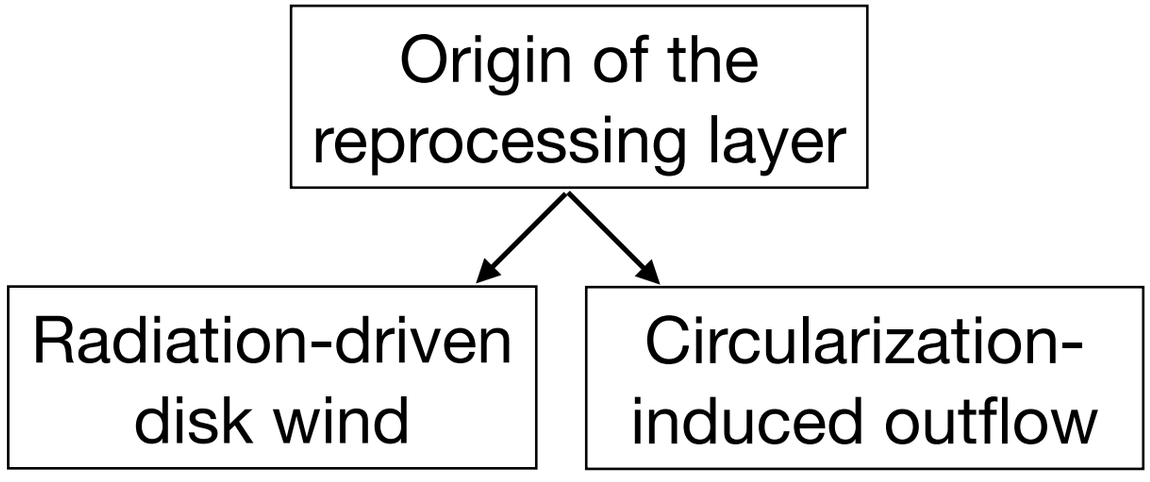
Loeb & Ulmer 1997

Coughlin & Begelman 2014

Metzger 2022

Where does the TDE UV/optical emission come from?

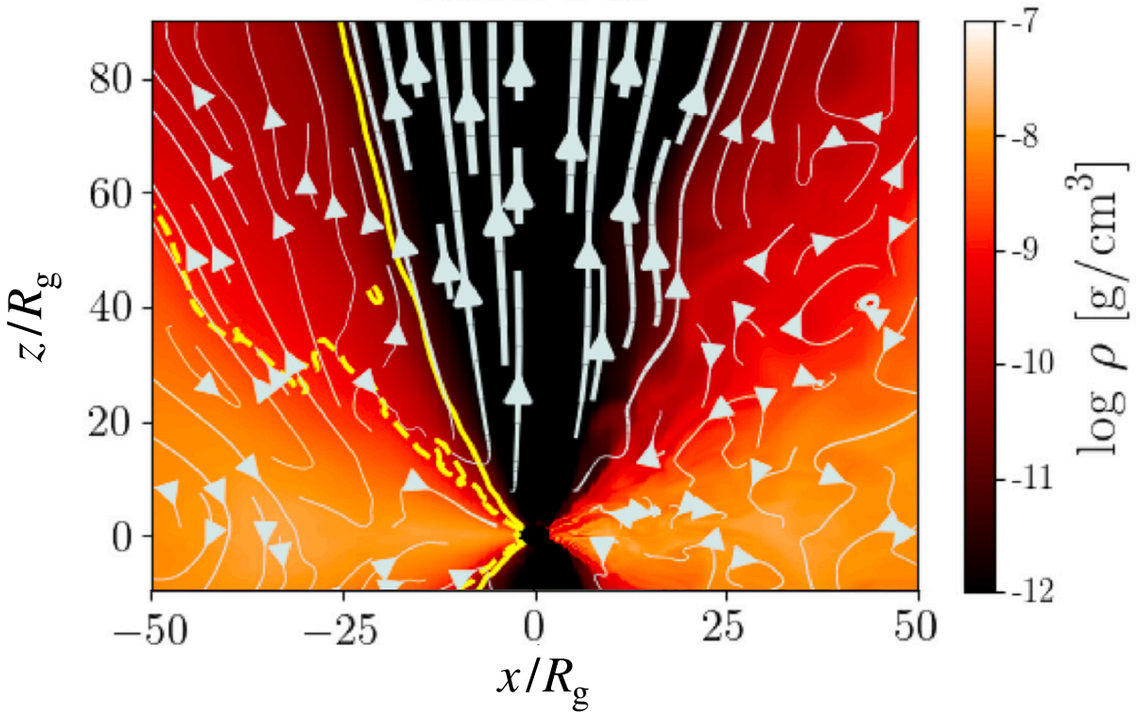
Reprocessing of disk emission



→ Constant temperature + **sudden** changes

Miller 2015, Dai+2018

Curd & Narayan 2019



Energy dissipation in a shock/envelope

Self-collision shock:

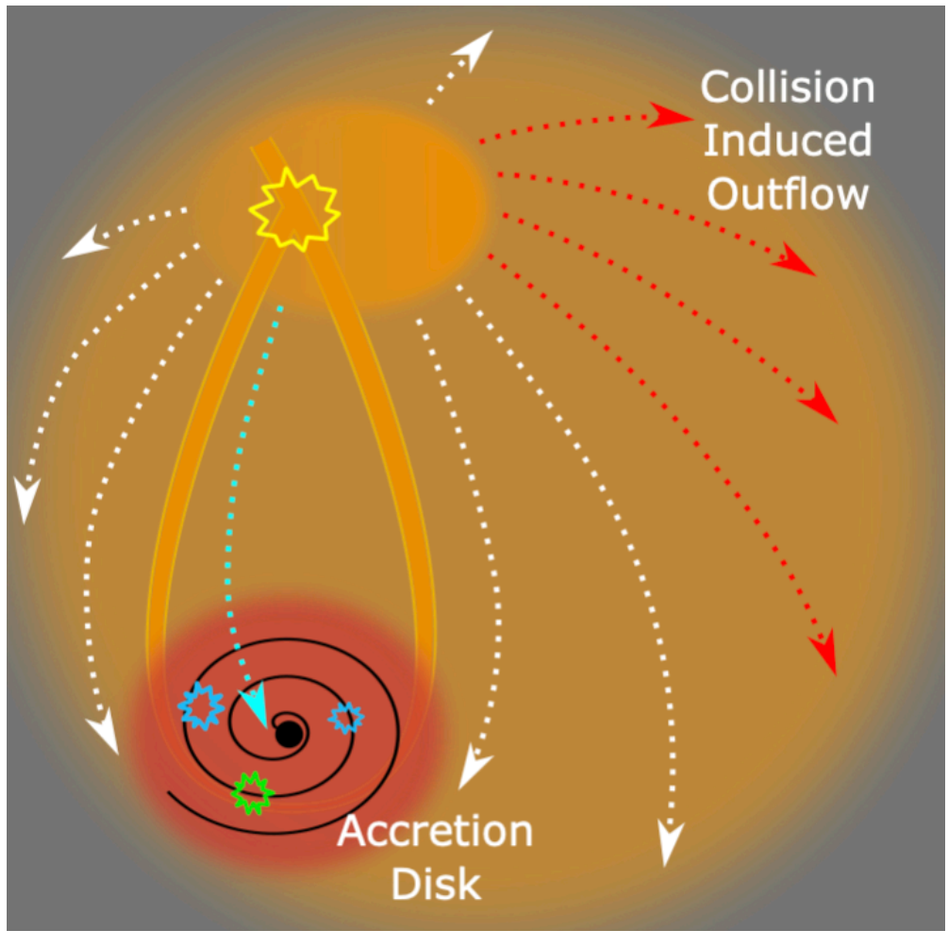
→ Temperature gradually **decreases**

Quasi-static weakly-bound envelope:

→ Temperature gradually **increases**

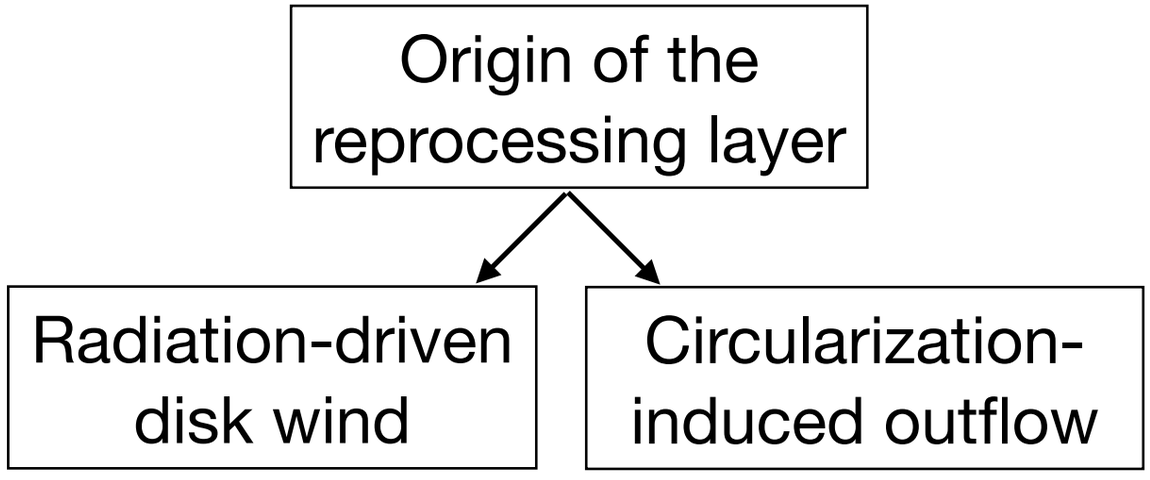
Metzger & Stone 2016

Lu & Bonnerot 2020



Where does the TDE UV/optical emission come from?

Reprocessing of disk emission



Energy dissipation in a shock/envelope

Self-collision shock:

→ Temperature gradually **decreases**

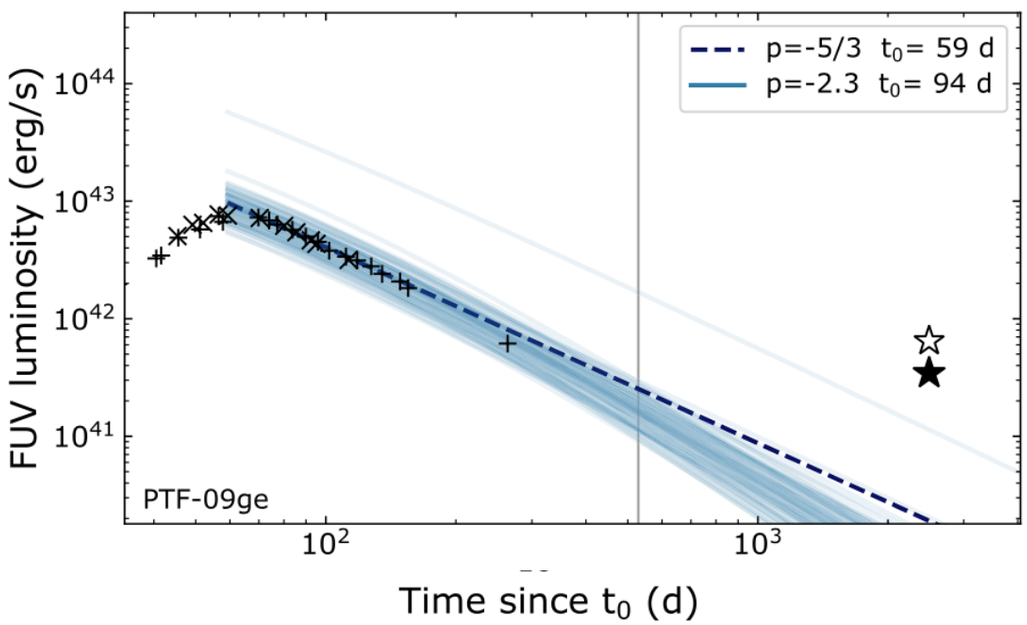
Quasi-static weakly-bound envelope:

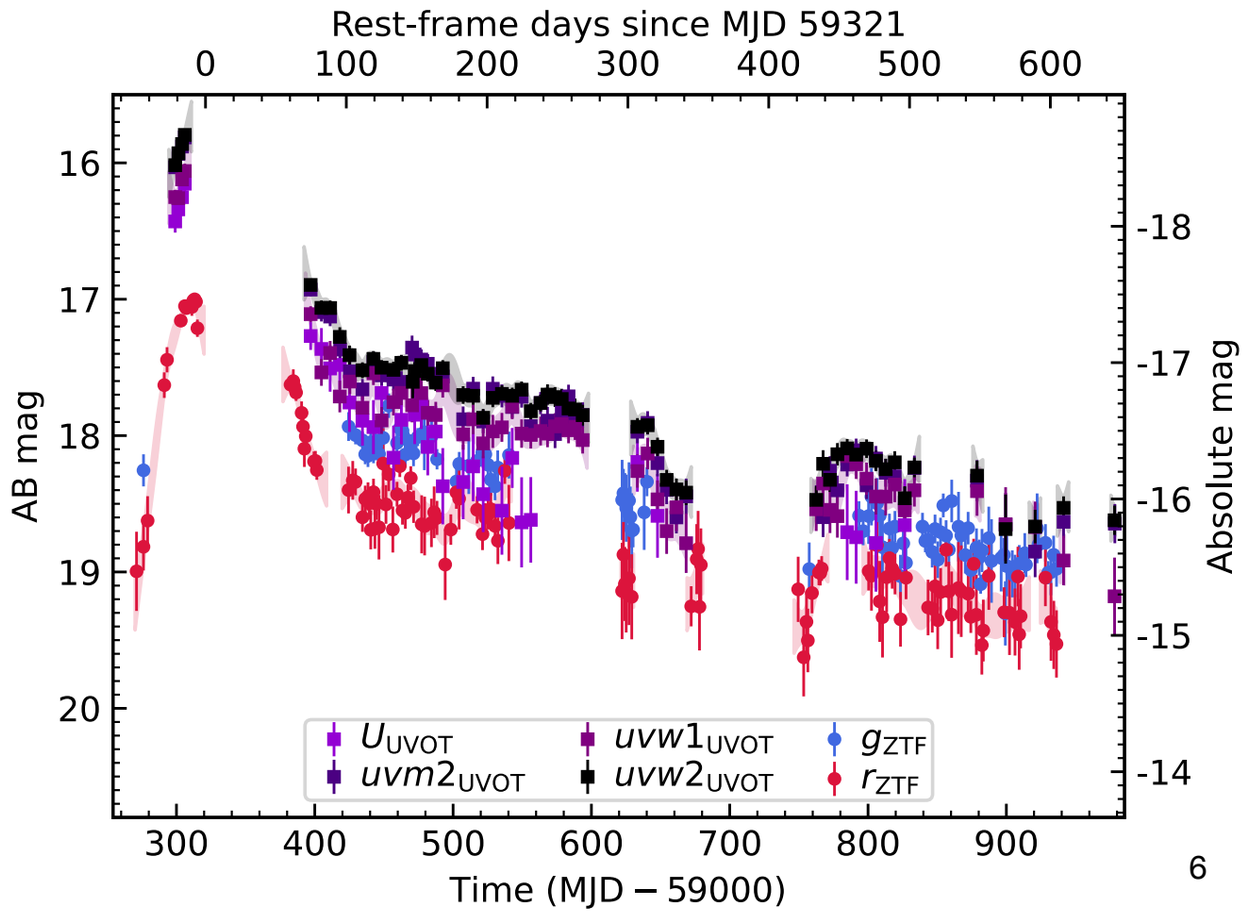
→ Temperature gradually **increases**

→ Constant temperature + **sudden** changes

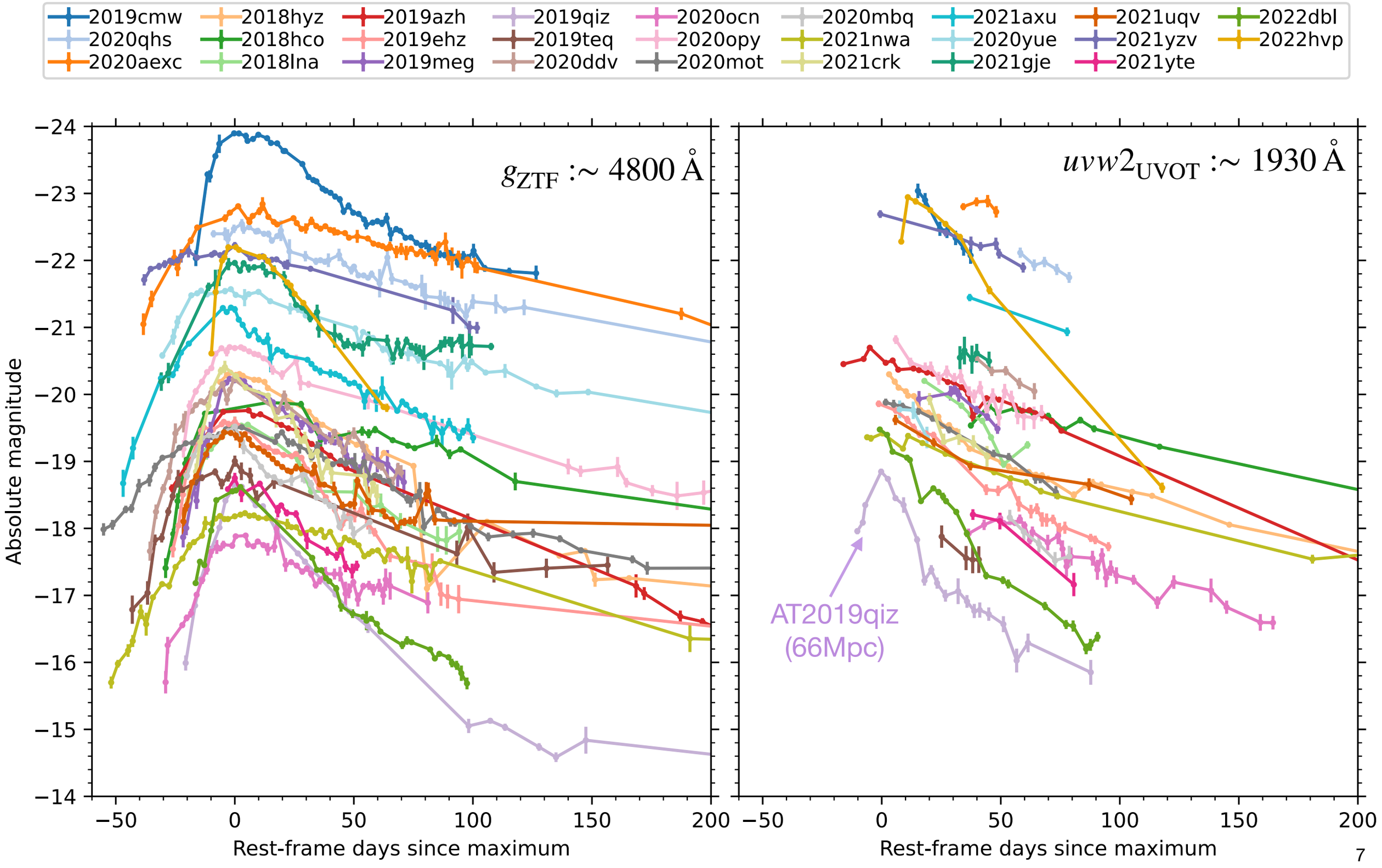
Late time: viscous disk accretion

van Velzen+2019, Yao+2022



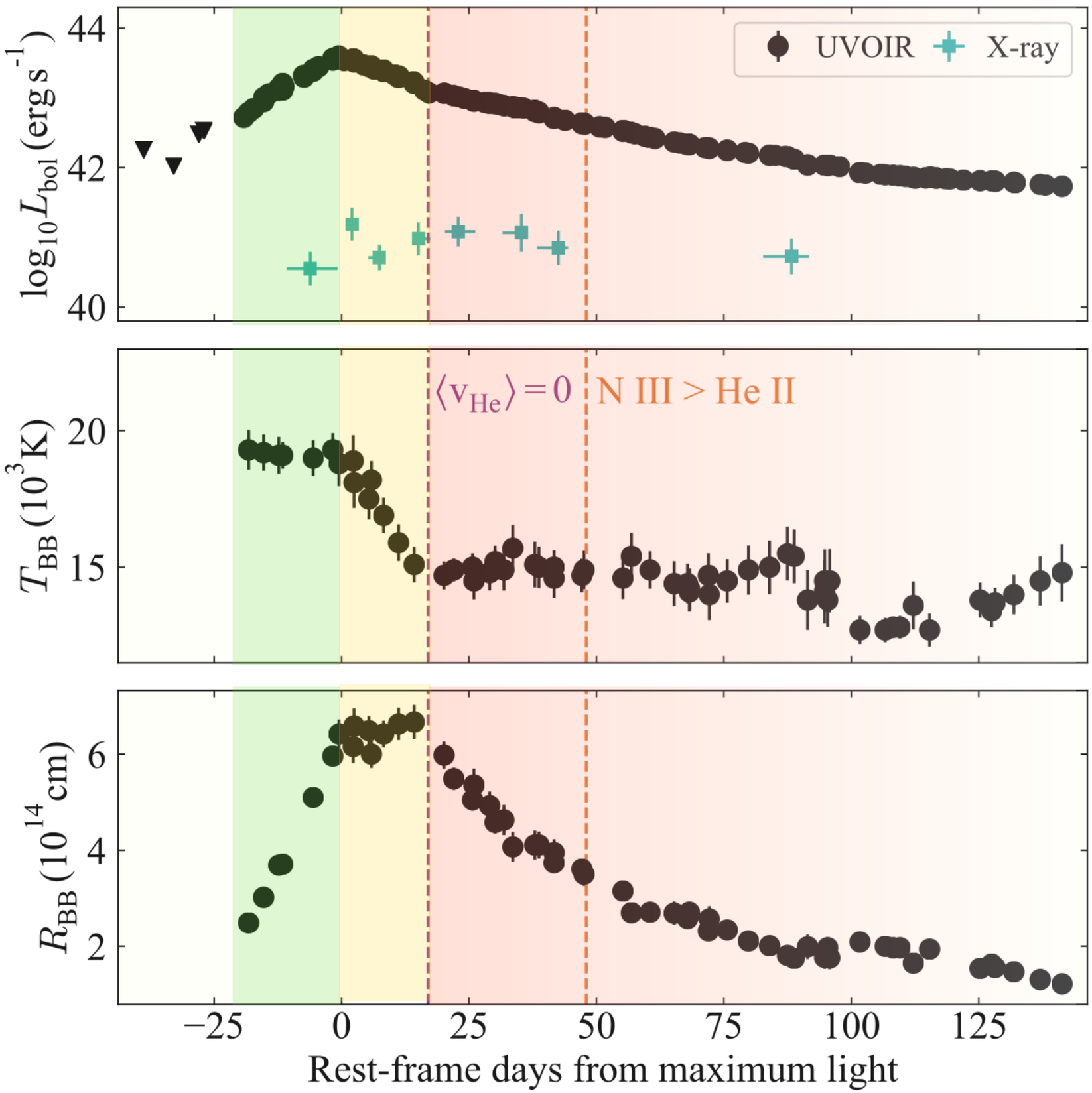


The dearth of pre-peak UV data



Evolution of AT2019qiz

Nicholl+2020



Where does the TDE UV/optical emission come from?

Favored by AT2019qiz

Reprocessing of disk emission

Origin of the reprocessing layer

Radiation-driven disk wind

Circularization-induced outflow

Energy dissipation in a shock/envelope

Self-collision shock:

→ Temperature gradually **decreases**

Quasi-static weakly-bound envelope:

→ Temperature gradually **increases**

→ Constant temperature + **sudden** changes

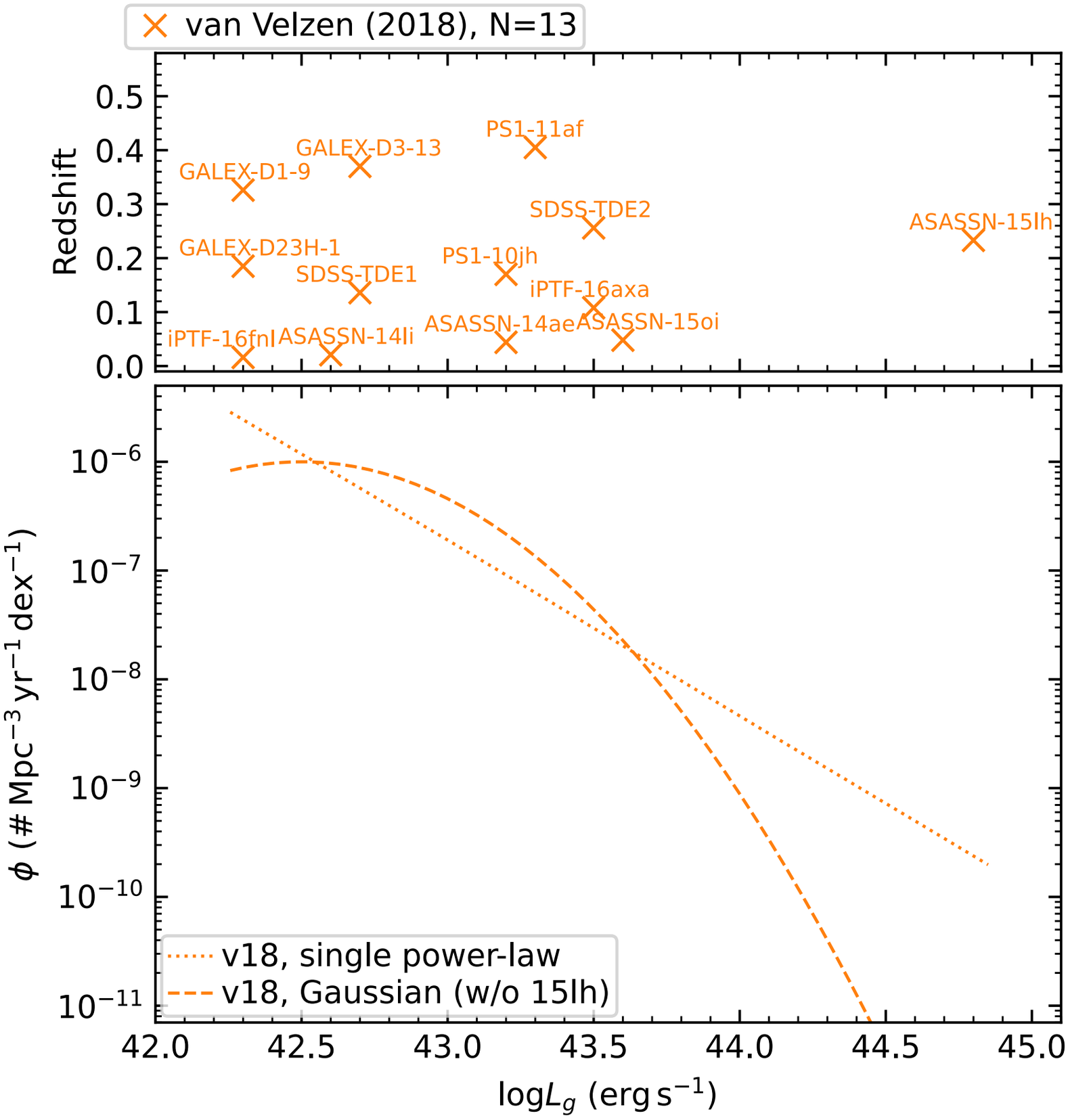
***UVEX* will**

see Cenko's talk

- Enable pre-peak identification of TDEs (trigger early spectroscopy)
- Provide temperature evolution diagnostics in a large sample of TDEs

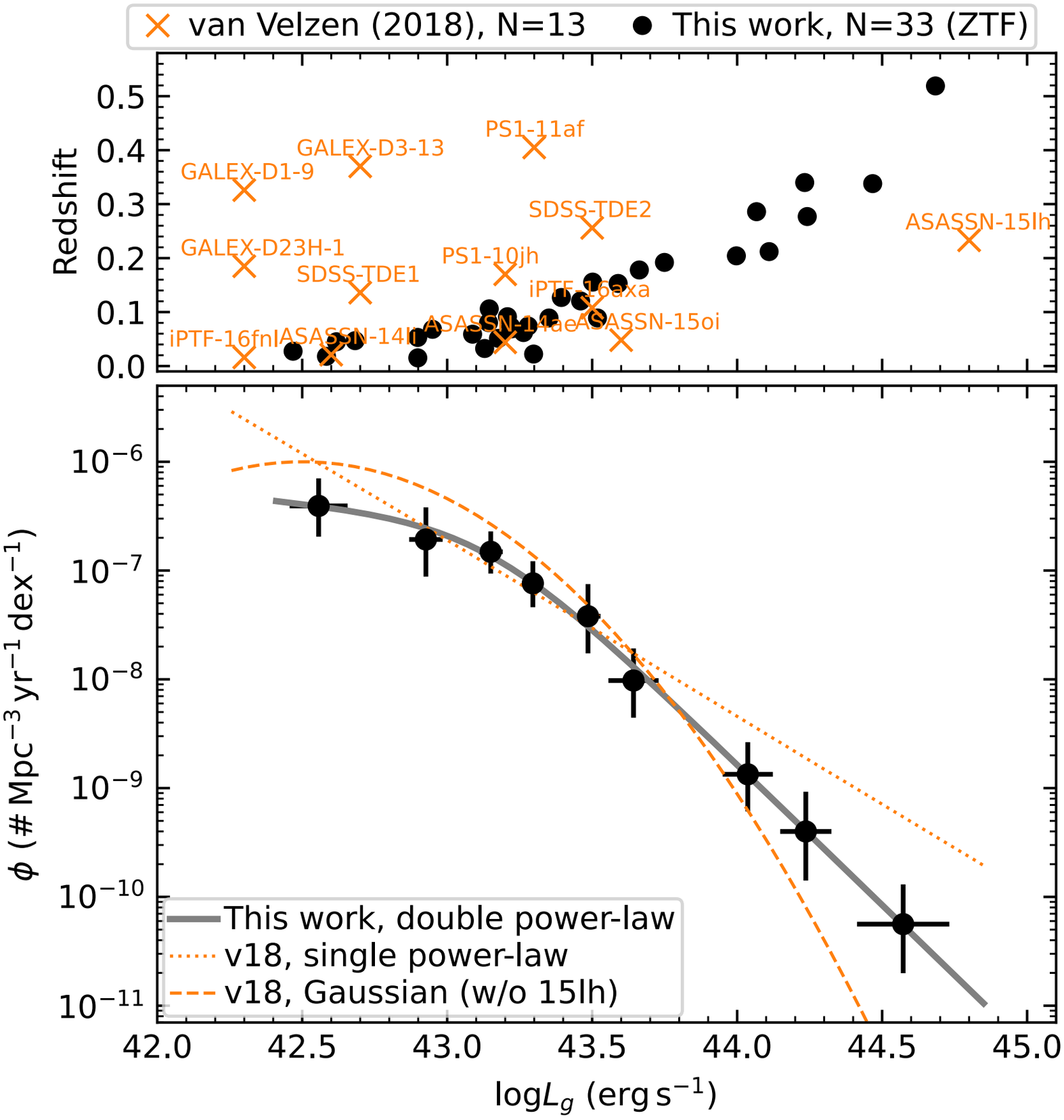
TDE luminosity function

van Velzen 2018



TDE luminosity function

Yao+2023
arxiv: 2303.06523



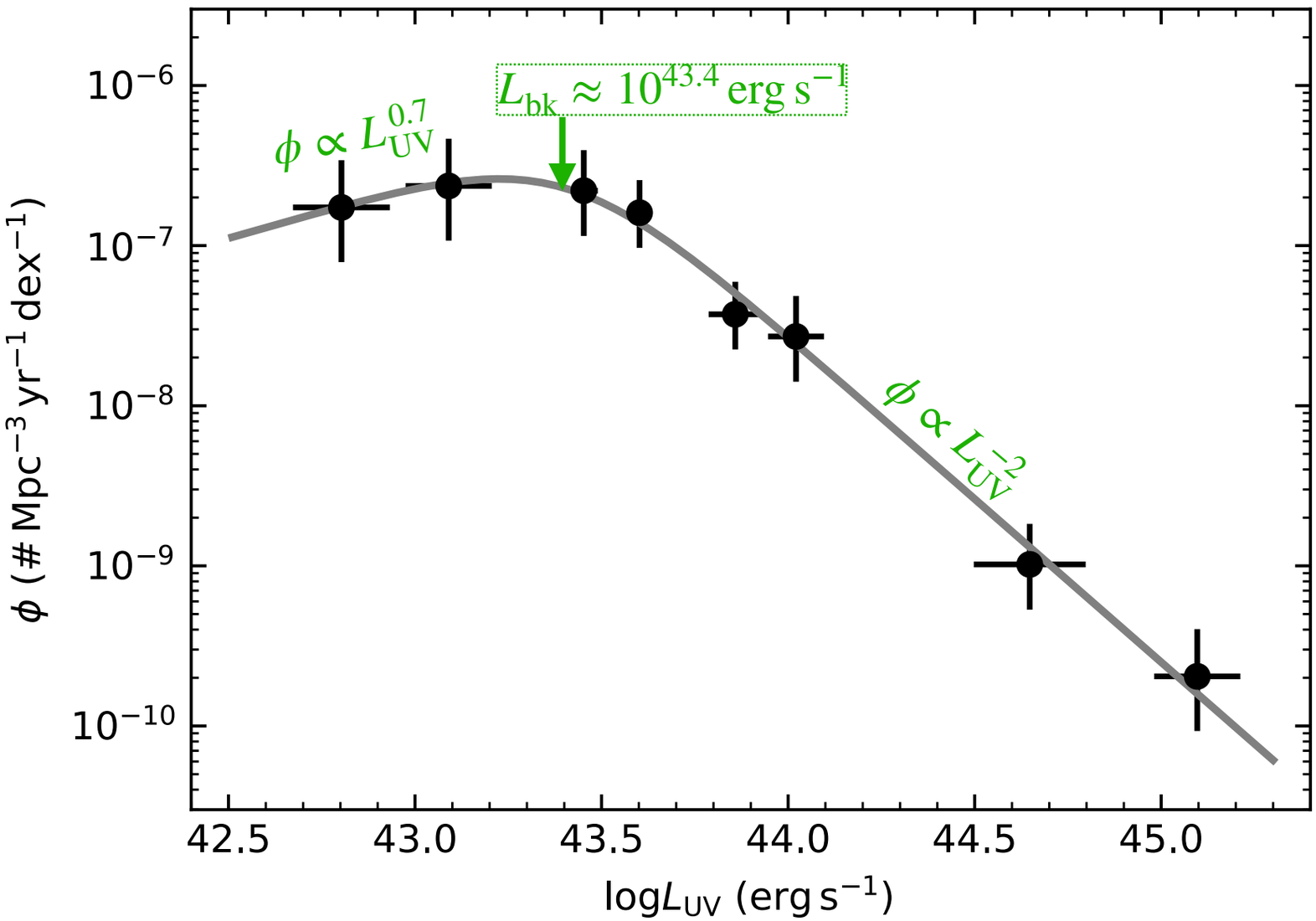
Expected *UVEX* TDE rate

- *UVEX* 900s dwell depth: 24.5 mag
- Count TDEs that peak at < 22.5 mag
- # of TDEs = 1099 Ω *t;* Ω (rad²) is the survey area, t (yr) is the survey duration

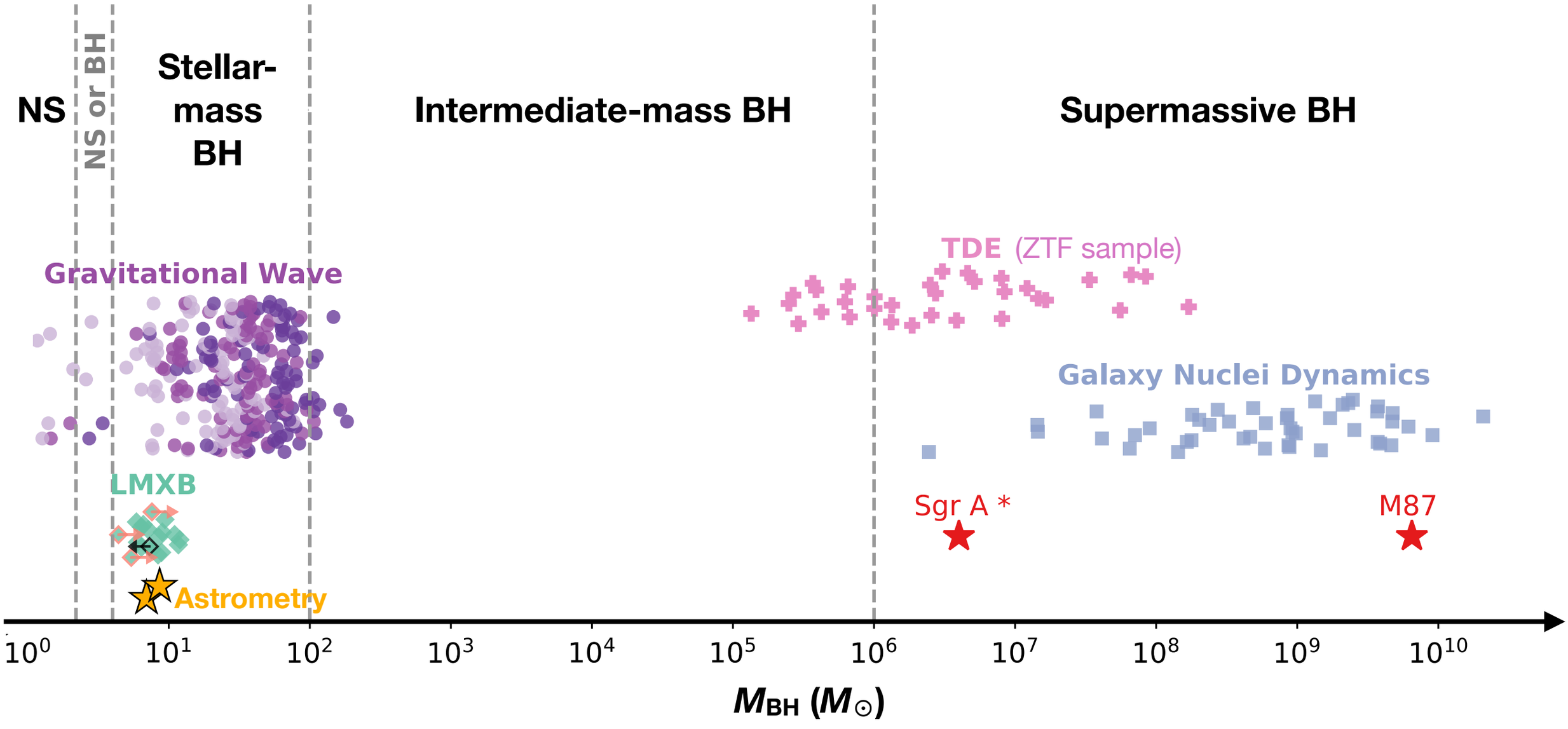
See Appendix A of Kulkarni+2023

$\Omega = 0.6$ rad^2 = 2000 deg^2
t = 7x8/365 = 0.15 yr

→ identify & get T_{bb} evolution for **100** TDEs



TDEs as probes of the BH population



BH mass function & primordial BH formation

BH seeding:

Light seeds: Population III

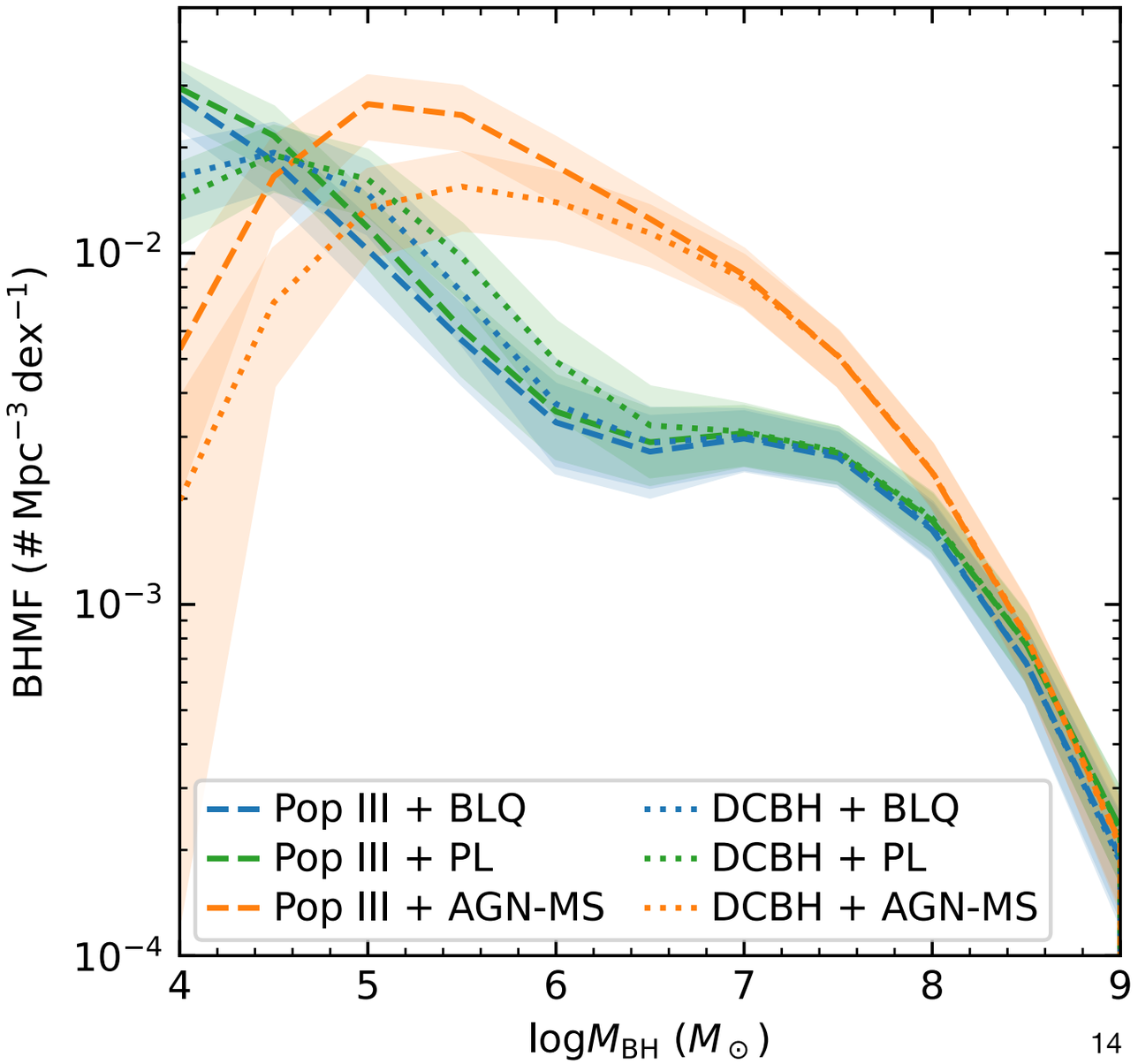
Heavy seeds: direct collapse (DCBH)

BH growth:

PL, AGN-MS, BLQ

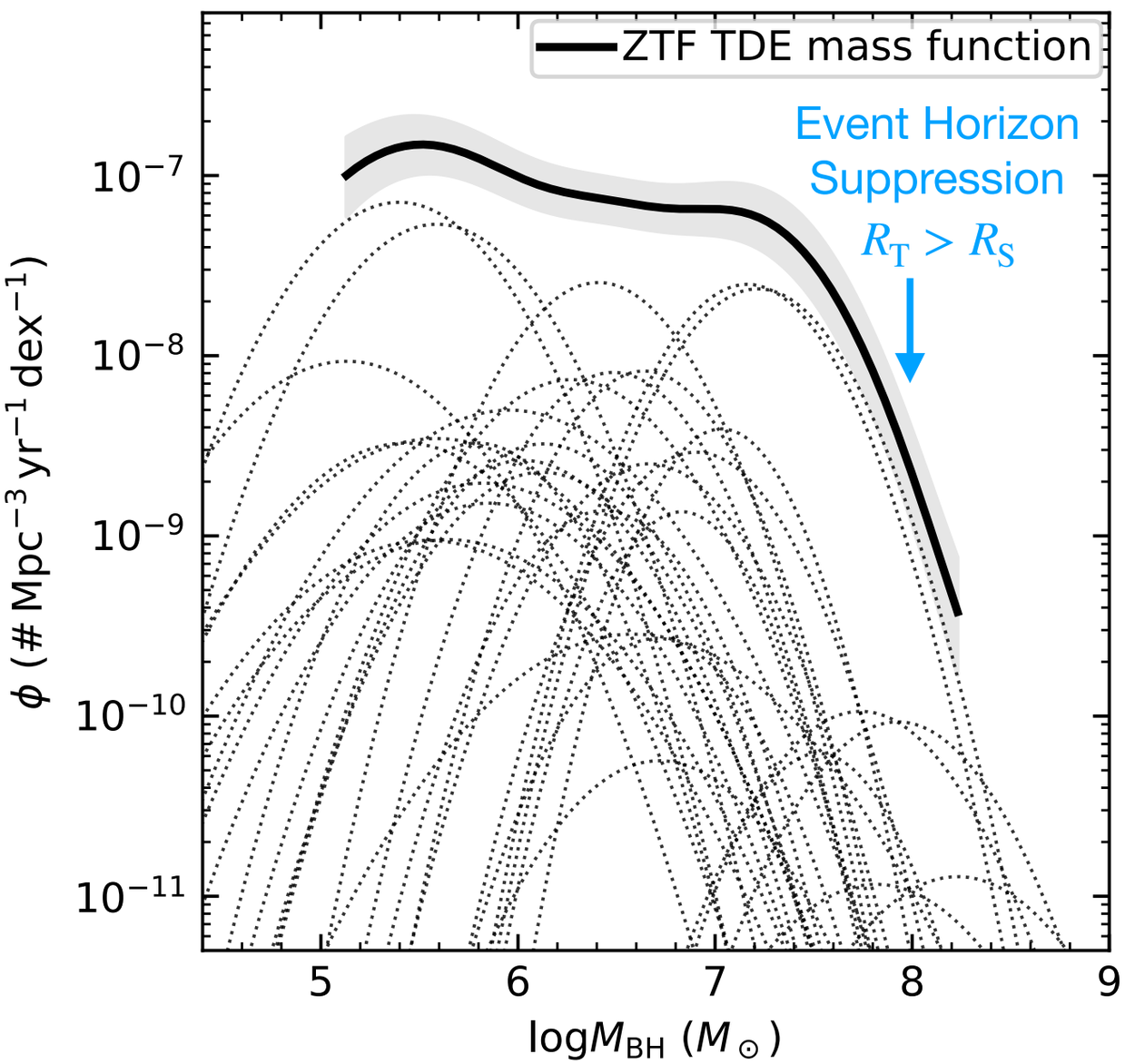
See details in:

Ricarte & Natarajan 2018 a,b;
Ricarte+2019, Chadayammuri+2022



BH mass function from TDE observations

Yao+2023



BH mass function from TDE observations

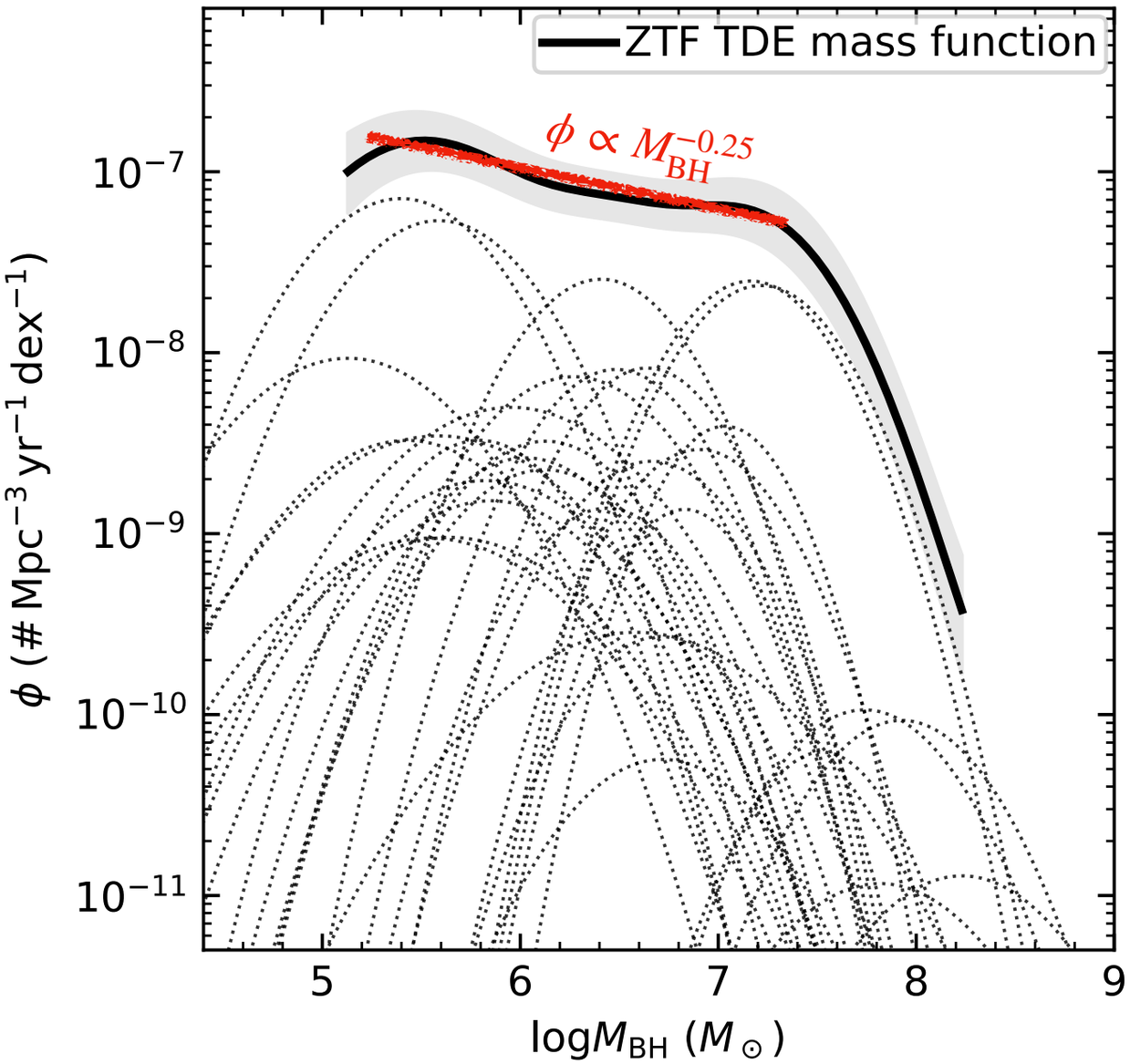
$$\phi_{\rm TDE}(M_{\rm BH}) \equiv \frac{dn_{\rm TDE}}{d\log M_{\rm BH}} = \dot{N}_0 \left(\frac{M_{\rm BH}}{10^6\,M_\odot}\right)^{\beta} \frac{dn_{\rm BH}}{d\log M_{\rm BH}}$$

$\beta \approx -0.25$ see Wang+2004, Stone & Metzger 2016, Stone+2020

Normalization term (10^{-5} – 10^{-4} yr^{-1})

Two-body relaxation time scales with $M_{\rm BH}$

Black hole mass function (BHMF)



BH mass function from TDE observations

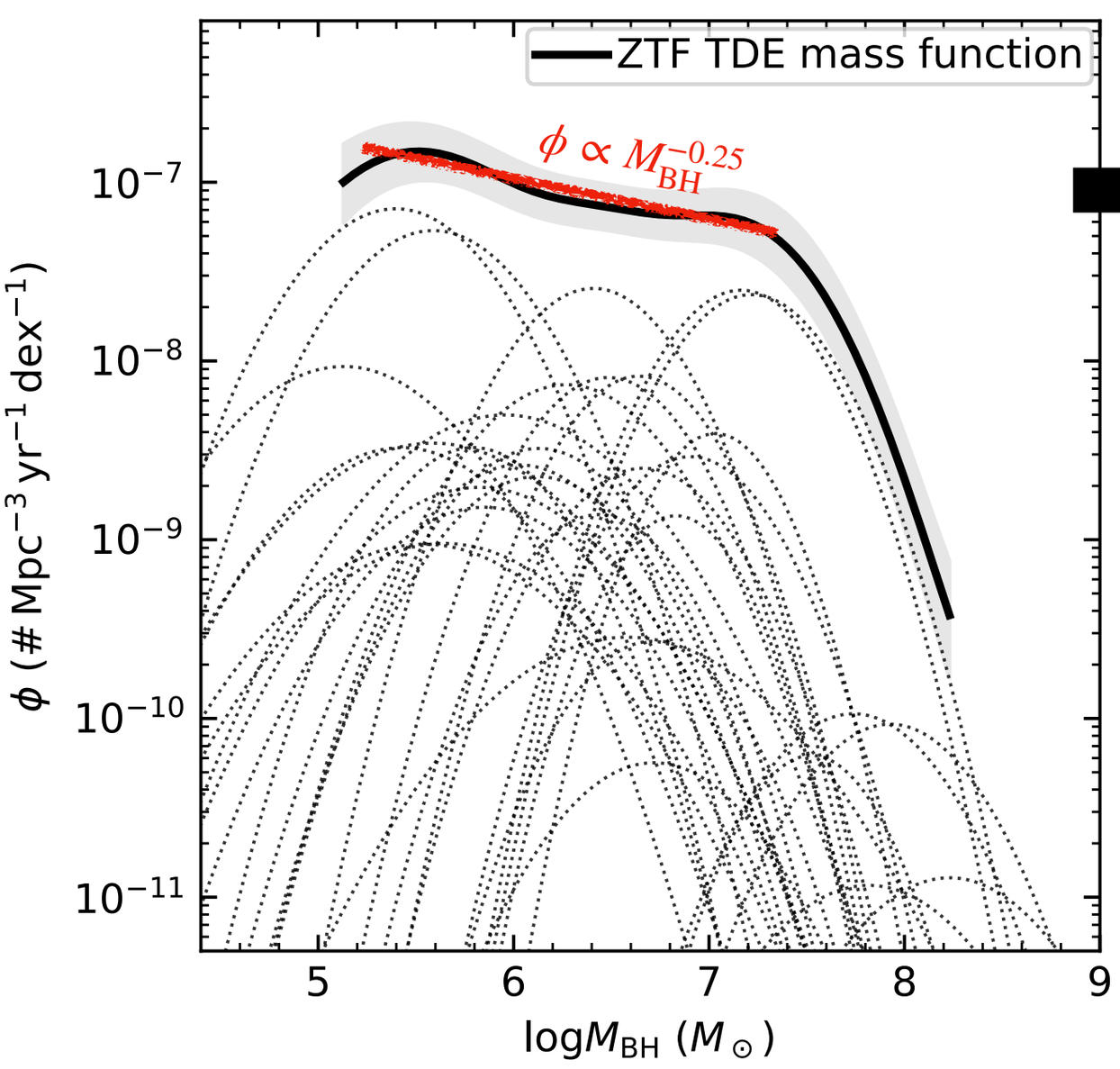
$$\phi_{\rm TDE}(M_{\rm BH}) \equiv \frac{dn_{\rm TDE}}{d\log M_{\rm BH}} = \dot{N}_0 \left(\frac{M_{\rm BH}}{10^6\,M_\odot}\right)^{\beta} \frac{dn_{\rm BH}}{d\log M_{\rm BH}}$$

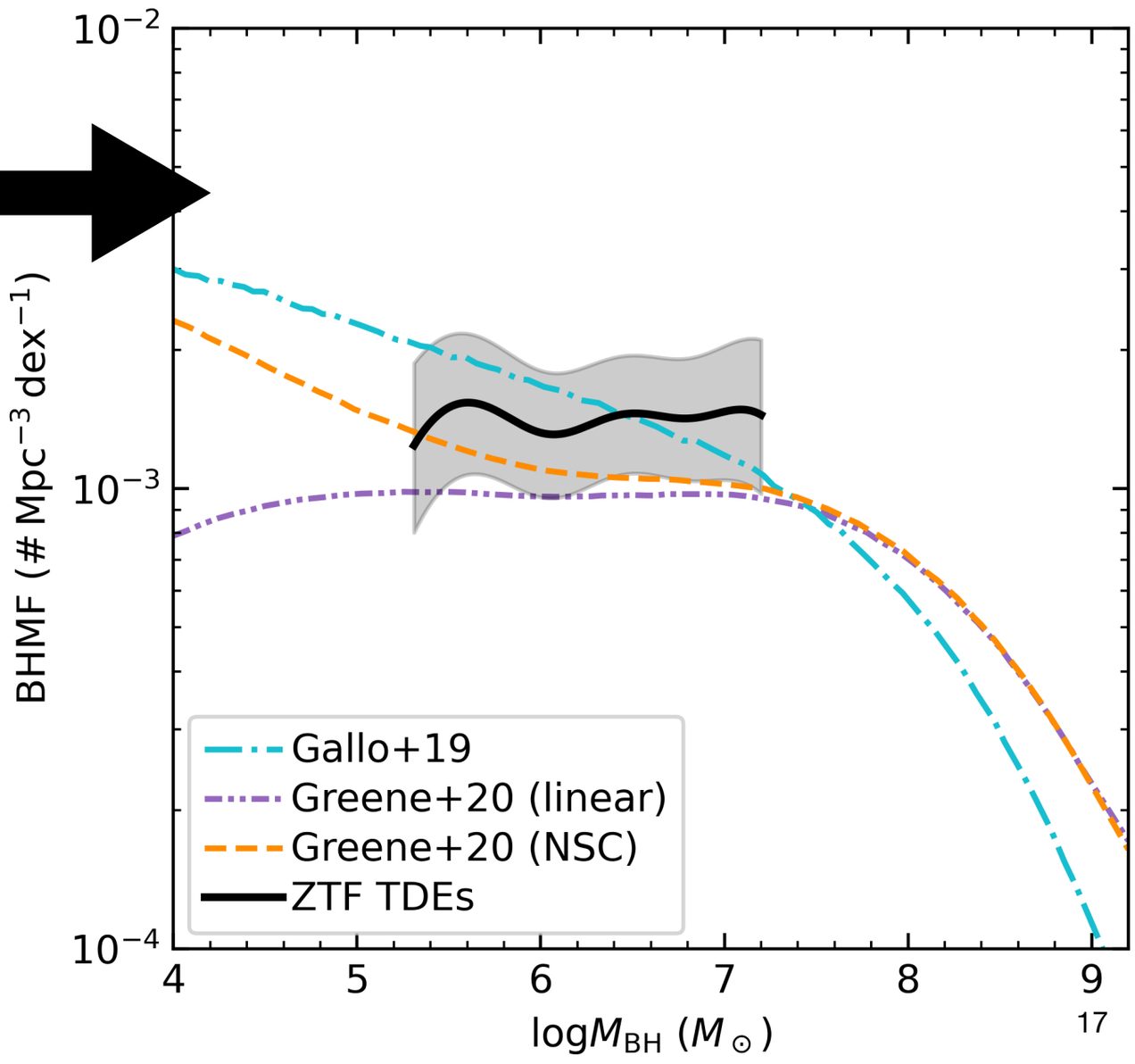
$\beta \approx -0.25$ see Wang+2004, Stone & Metzger 2016, Stone+2020

Normalization term (10^{-5} – 10^{-4} yr^{-1})

Two-body relaxation time scales with $M_{\rm BH}$

Black hole mass function (BHMF)

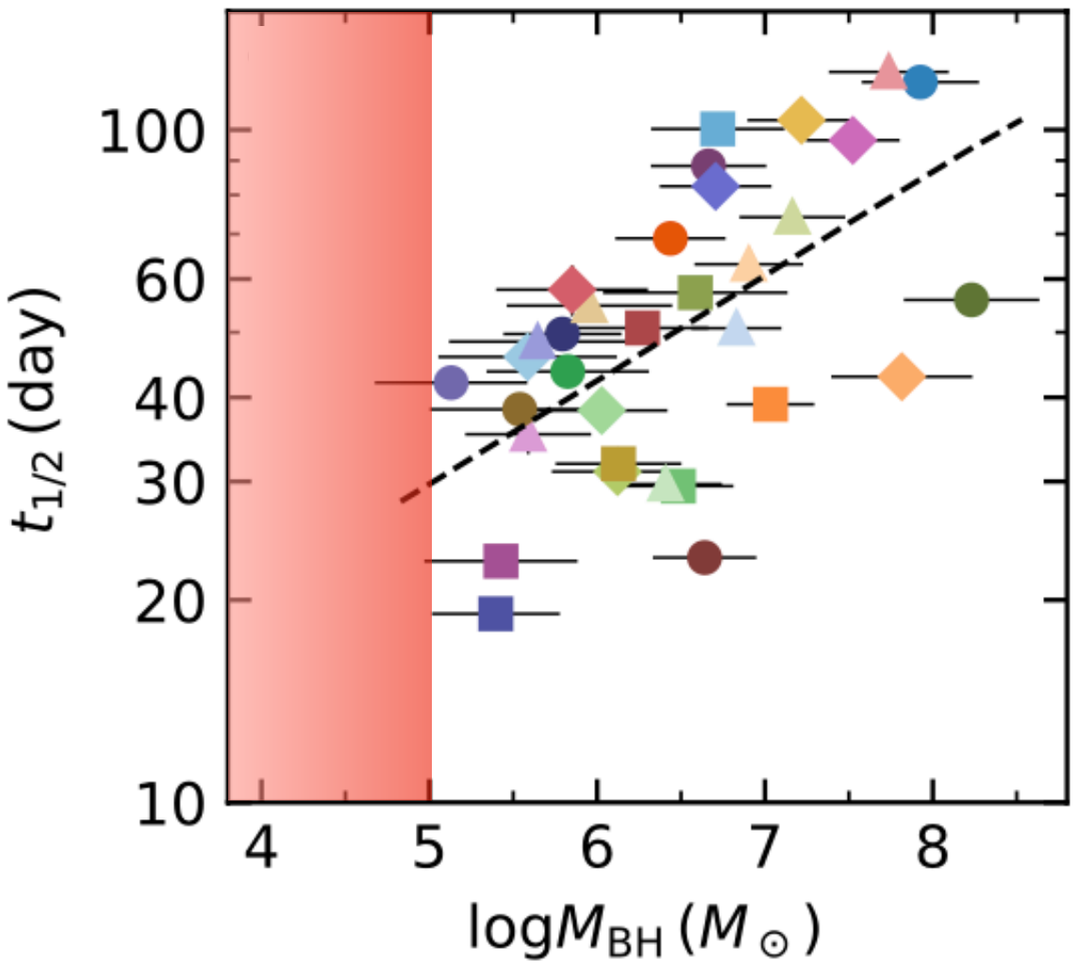




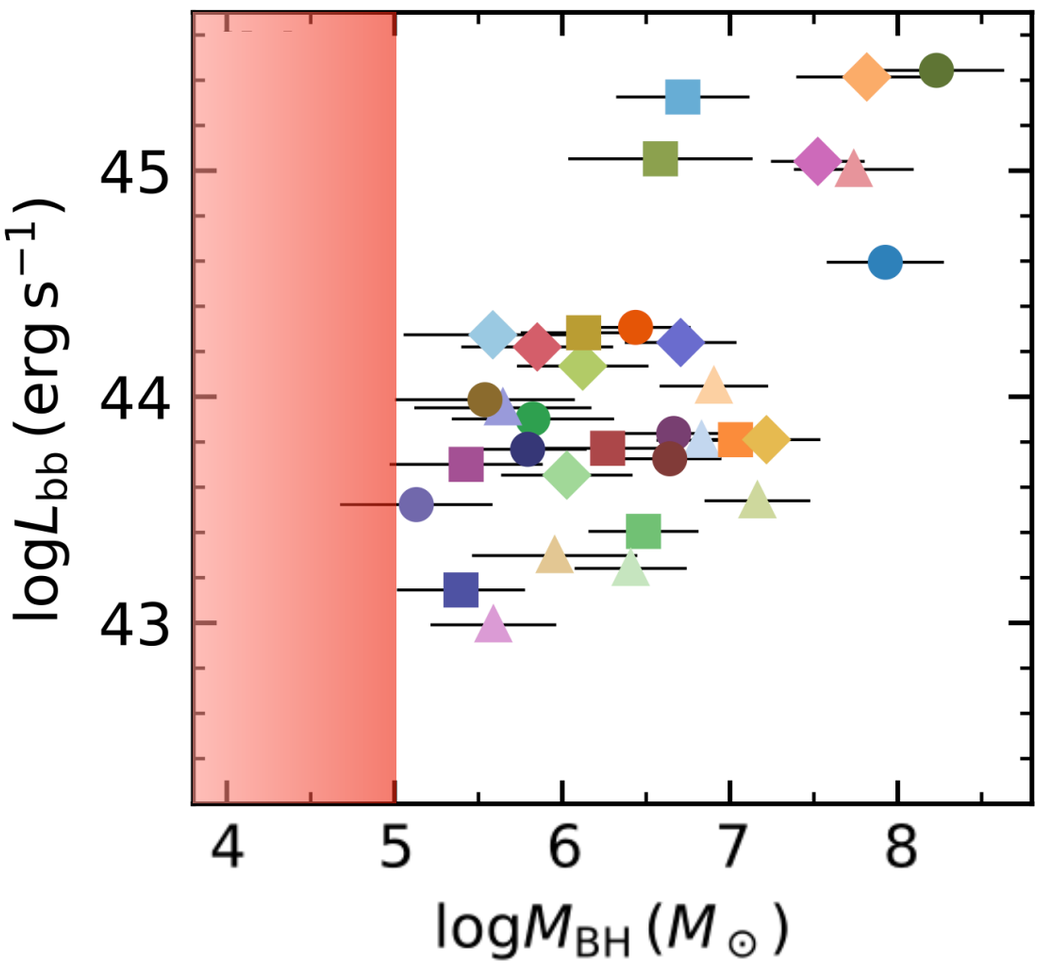
IMBHs: the fast and faint (?) TDEs

Yao+2023

Rest-frame duration above half-max



Peak blackbody luminosity



***UVEX* will**

- Provide UV transient alerts (synergies with *ULTRASAT*, Rubin, etc)
- Provide the TDE host reference catalog (local dwarfs $M_* < 10^9\ M_\odot$)