



华中科技大学 天文学系

HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY Department of Astronomy

# An Explanation for the TDE Rate Overenhancement in Post-Starburst Galaxies

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arXiv: 2311.07040v2

# Outline

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**1. Background and motivation**

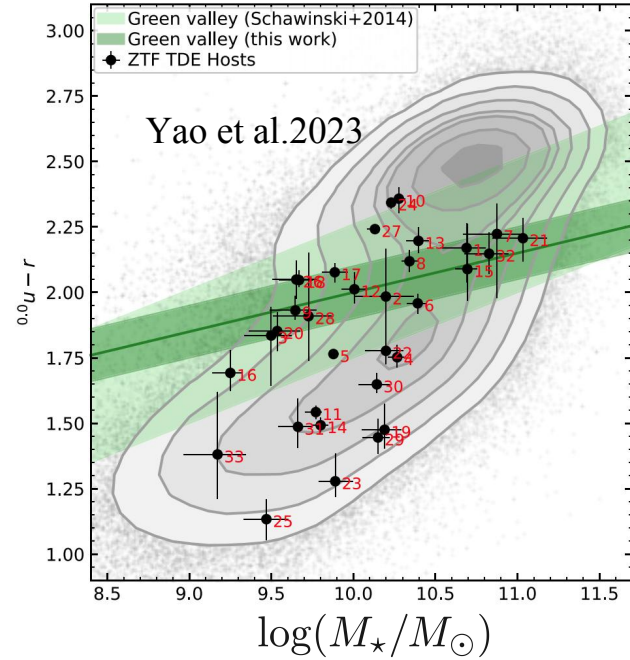
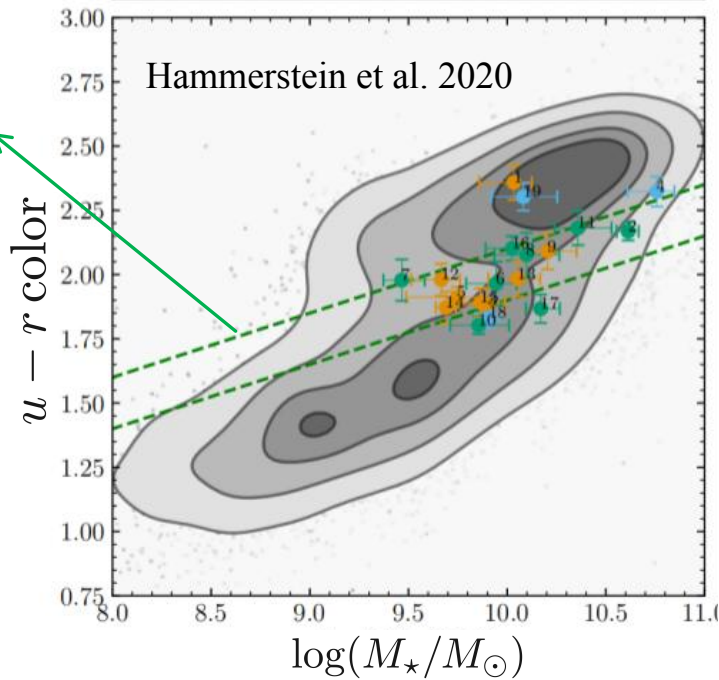
**2. Model: evolution after galaxies merger**

**3. Method and Results: Evolution of TDE rate over time**

**4. Summary**

# TDE hosts: Green valley galaxies

Green valley



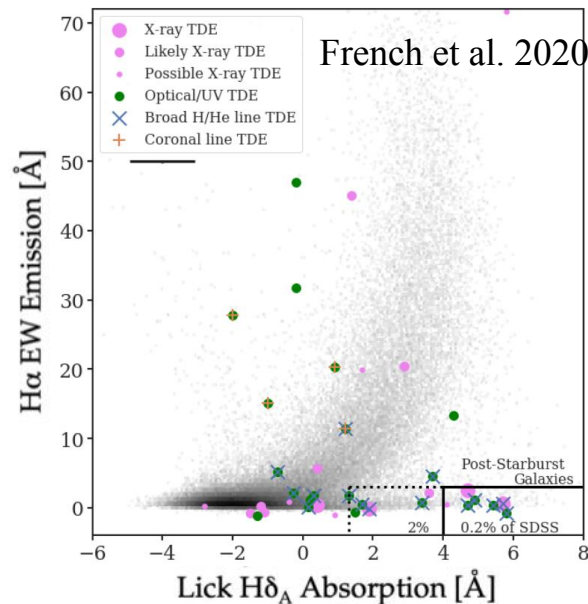
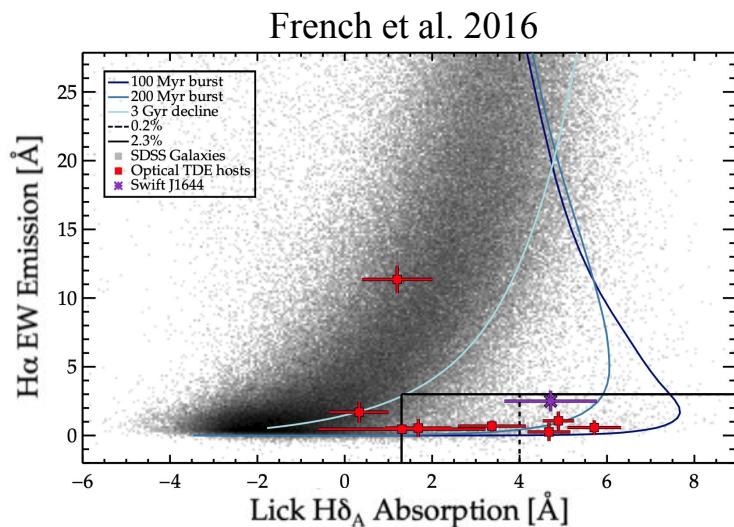
TDE rate enhance: >10 times

~ 5 times

TDE rate overenhancement in green valley

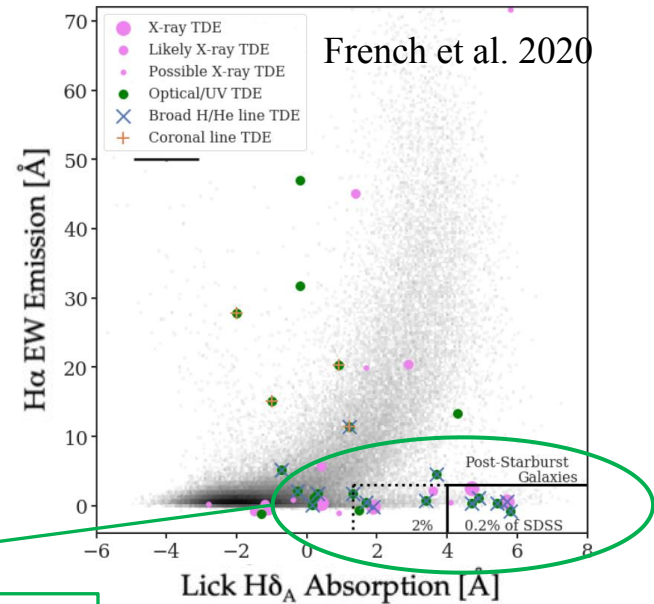
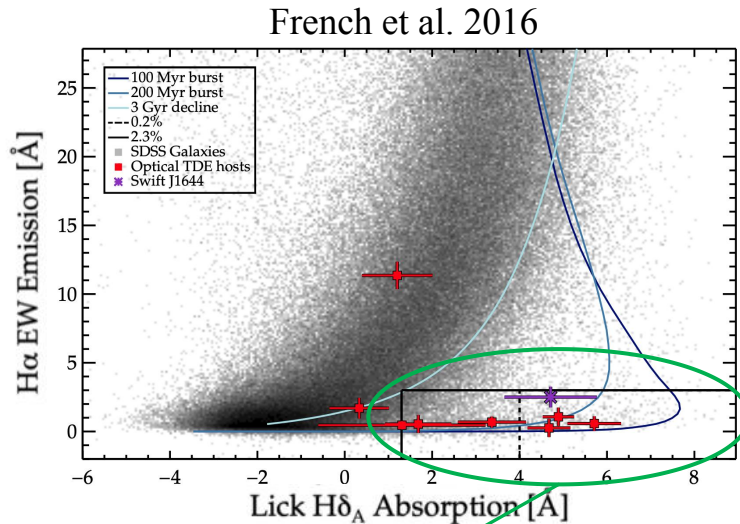
# Star formation history in TDE hosts

- $H\alpha$  emission  $\longrightarrow$  current star formation
- $H\delta_A$  absorption  $\longrightarrow$  star formation over the past Gyr



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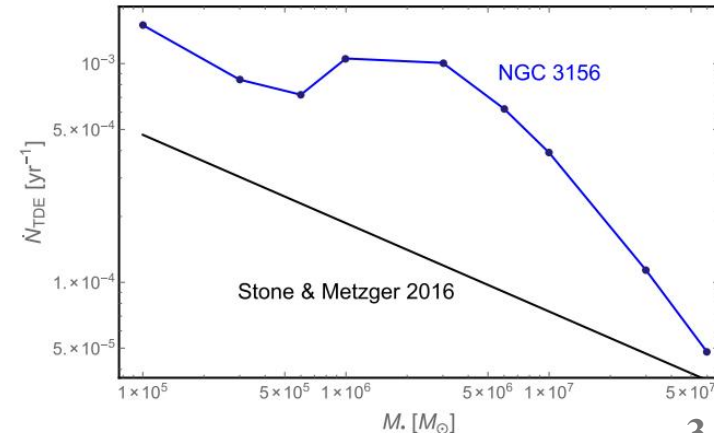
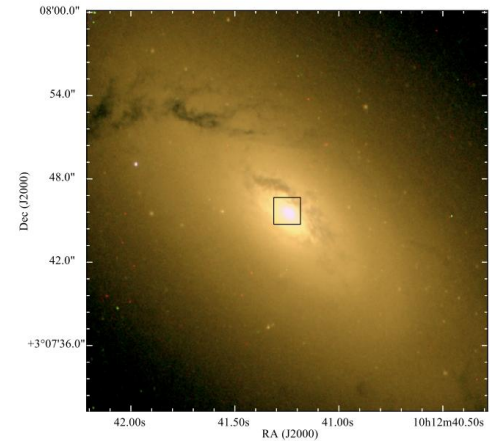
- High star formation rate in the past
- Low star formation rate in the present

$\longrightarrow$  Post-starburst galaxies

# Possible physical mechanisms

- **Overdense central star cluster** (Stone & Metzger 2016; Stone & van Velzen 2016; French et al. 2020a; Chen et al. 2023)
- **SMBH binary system** (Ivanov et al. 2005; Chen et al. 2011; Stone & Loeb 2011; Melchor et al. 2023)
- **The radial anisotropies** (Stone et al. 2018), **nuclear triaxiality** (Merritt & Poon 2004) and **eccentric nuclear stellar disk** (Madigan et al. 2018)

Stone & van Velzen 2016



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# Model: TDE rate evolution after galaxies merger

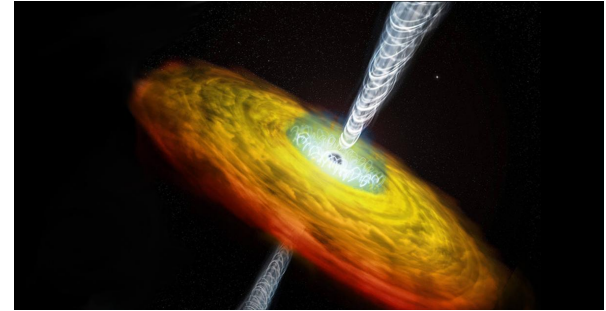
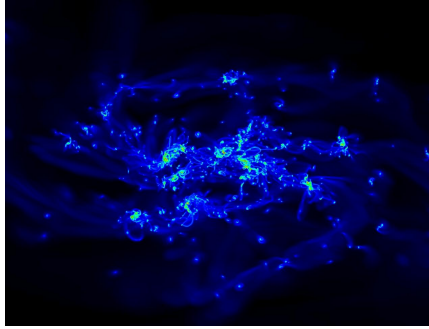
Galaxies merger



Starburst



AGN activity

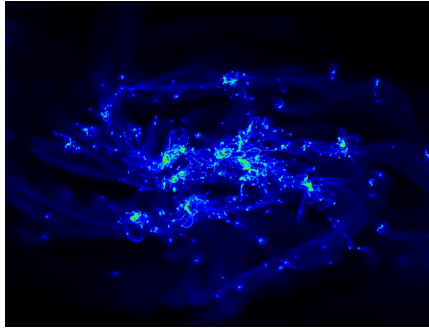


# Model: TDE rate evolution after galaxies merger

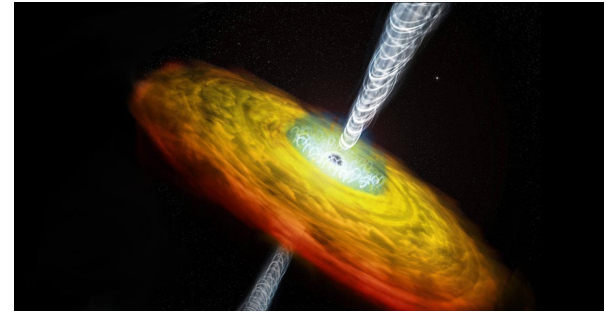
Galaxies merger



Starburst



AGN activity



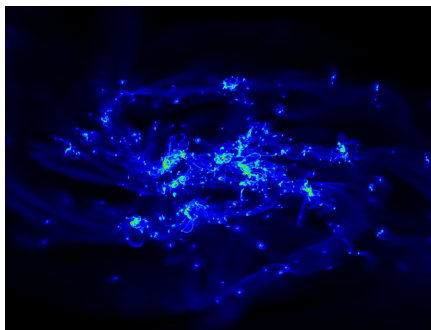
How about the subsequent evolution of the TDE rate?

# Model: TDE rate evolution after galaxies merger

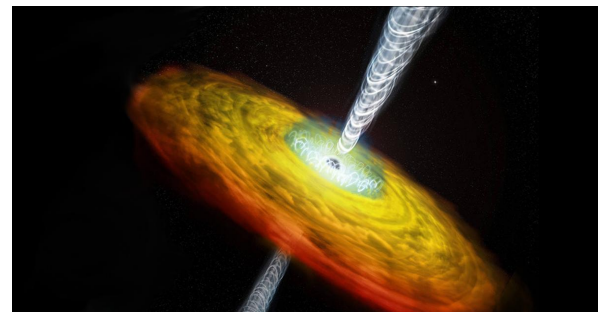
Galaxies merger



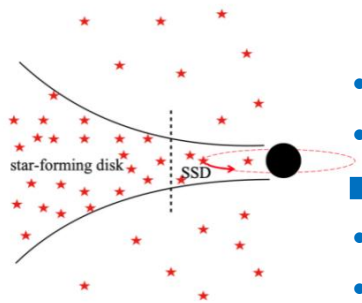
Starburst



AGN activity



How about the subsequent evolution of the TDE rate?



- orbital migration
- orbital circularization
- disk capture
- in-situ star formation

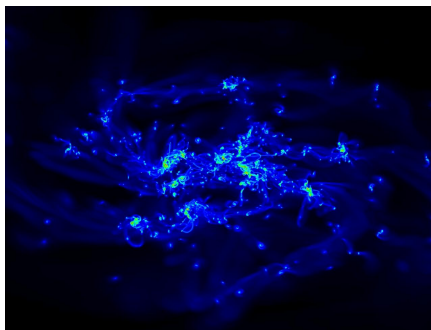
**Active stage:  
accumulate stars**

# Model: TDE rate evolution after galaxies merger

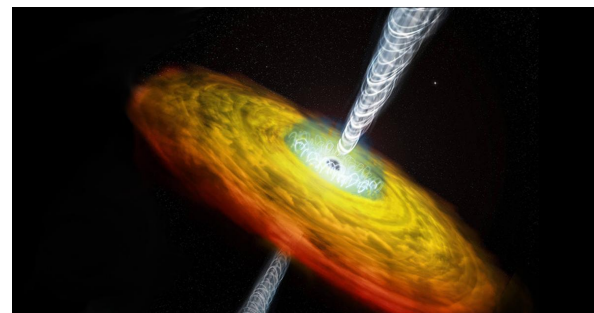
Galaxies merger



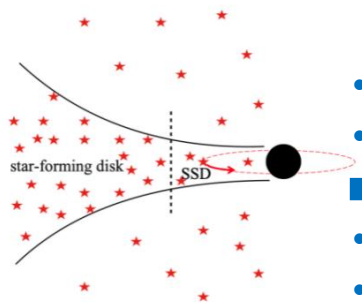
Starburst



AGN activity

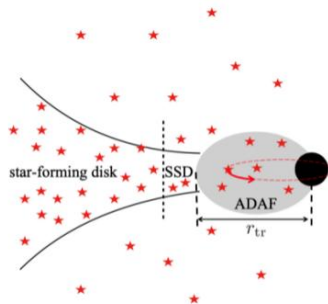


How about the subsequent evolution of the TDE rate?



**Active stage:**  
accumulate stars

- orbital migration
- orbital circularization
- disk capture
- in-situ star formation



**Transitional stage:**  
TDE rate increases

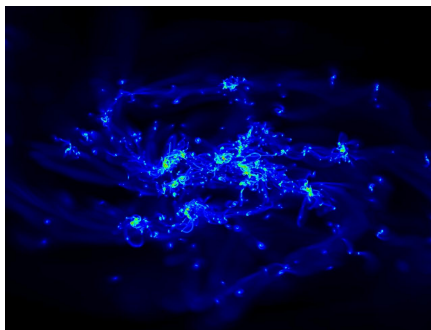
Two-body relaxation

# Model: TDE rate evolution after galaxies merger

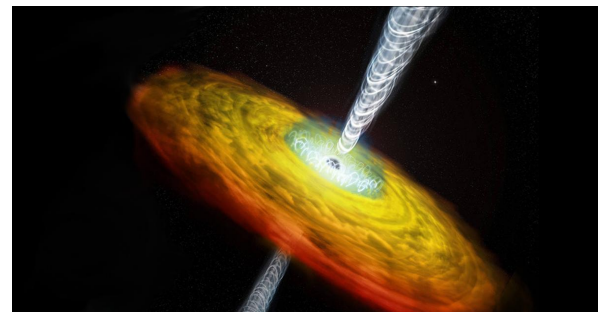
Galaxies merger



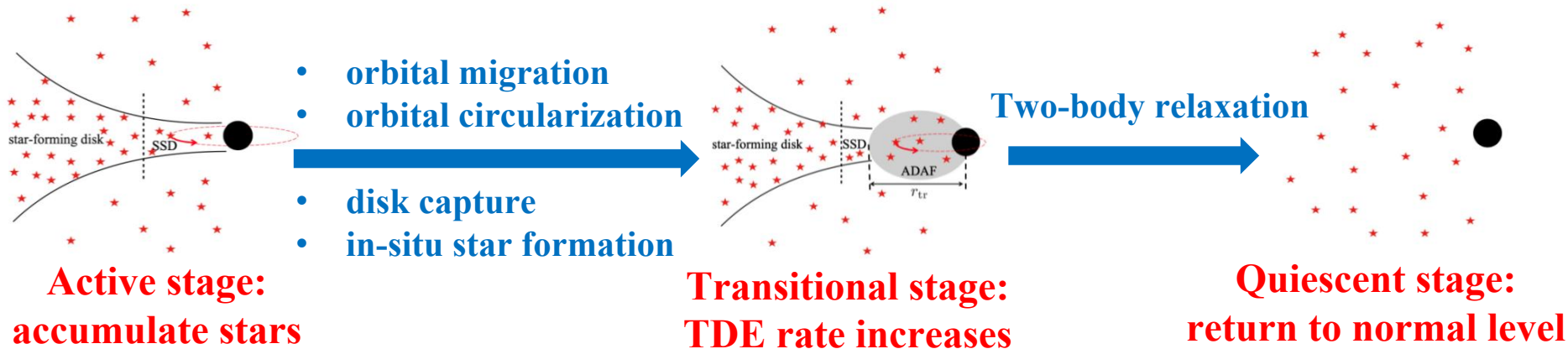
Starburst



AGN activity



How about the subsequent evolution of the TDE rate?

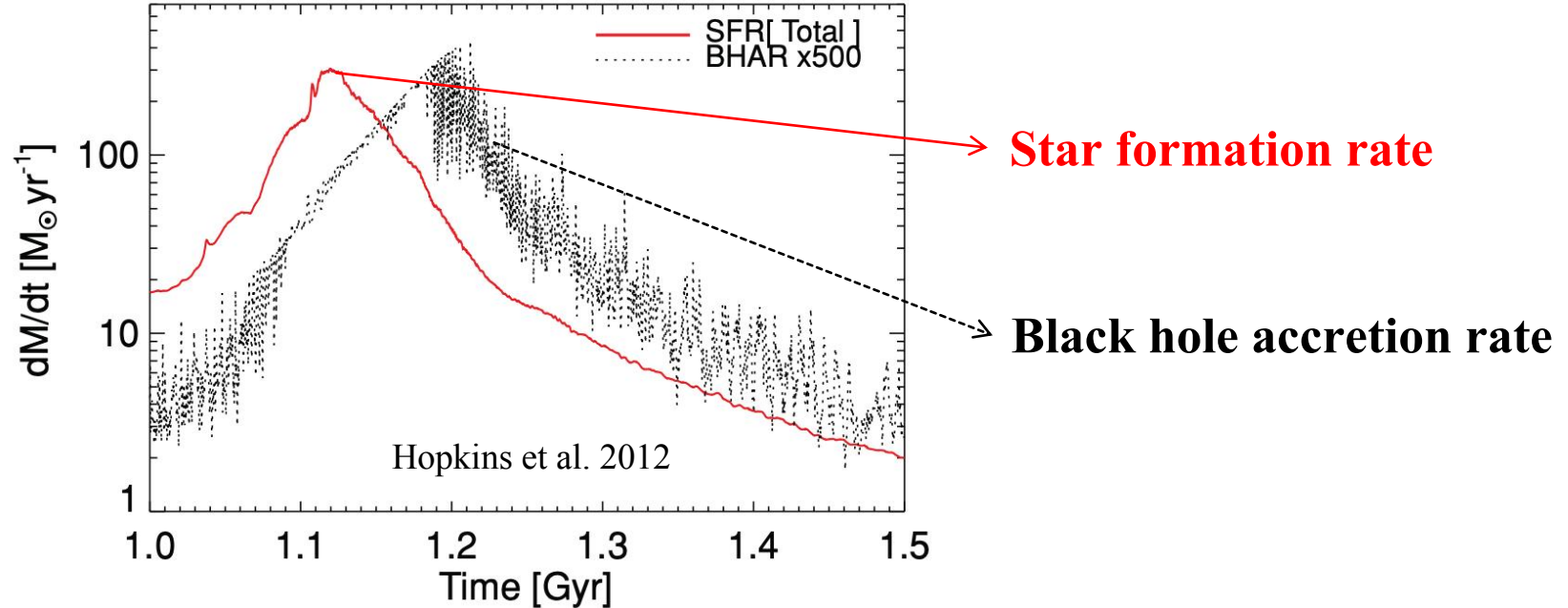


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**What is the motivation of our model?**

# Motivation I: connection between SFR and BHAR

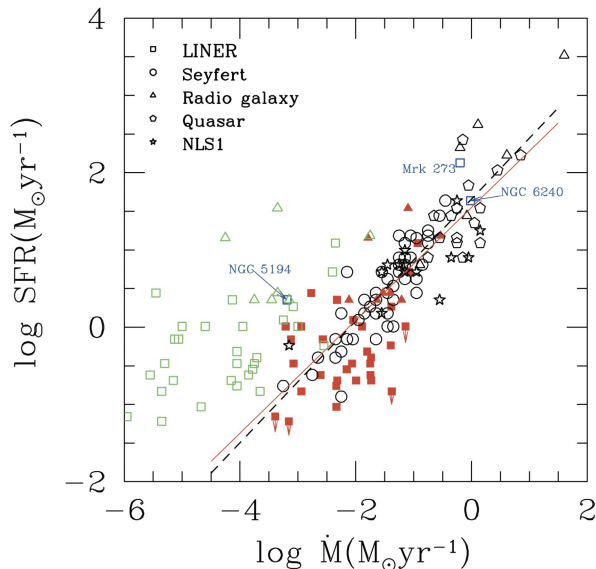
## Simulation of galaxies merger



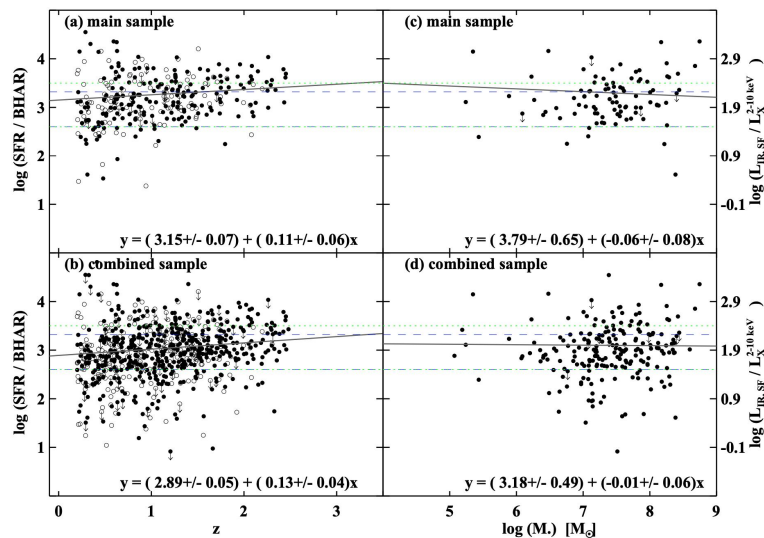
$\sim 10^8$  years delay between starburst and AGN activity

# Motivation I: connection between SFR and BHAR

## Observational relation



Wu & Cao 2006

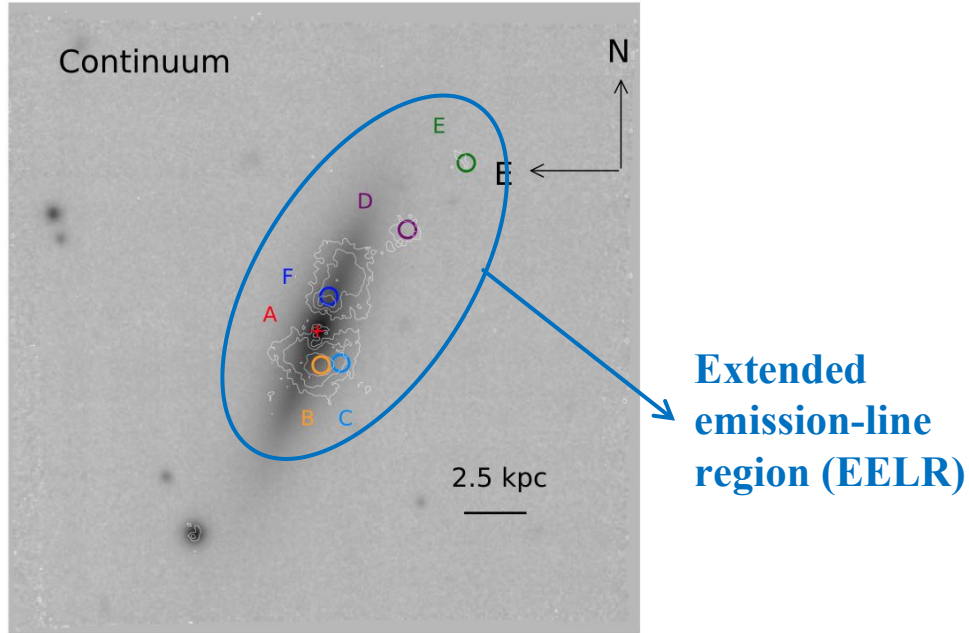


Dai et al. 2018

**BHAR is positively correlated with the galaxy's SFR.**

# Motivation II: connection between TDE hosts and EELRs

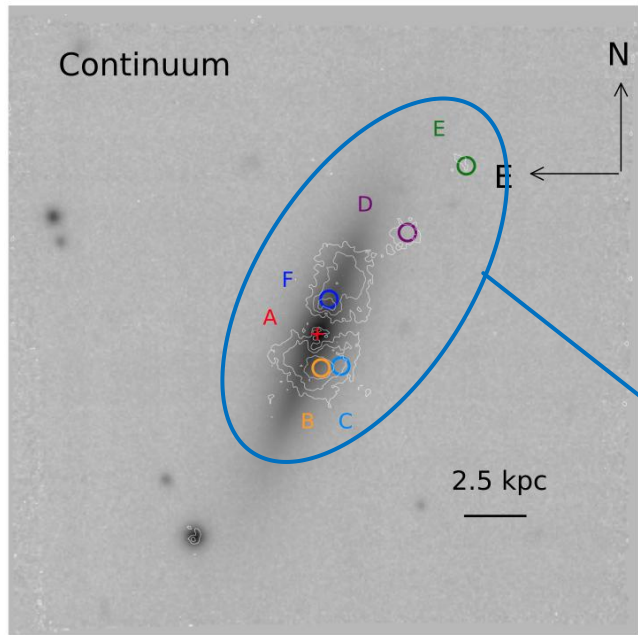
Mrk 950 (TDE iPTF16)



emission-line contour maps of [O III] overlaid on a continuum image

# Motivation II: connection between TDE hosts and EELRs

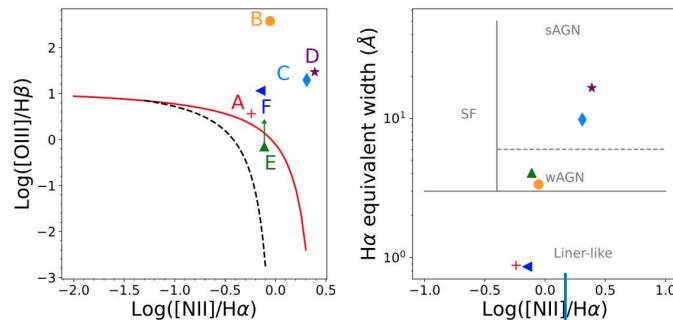
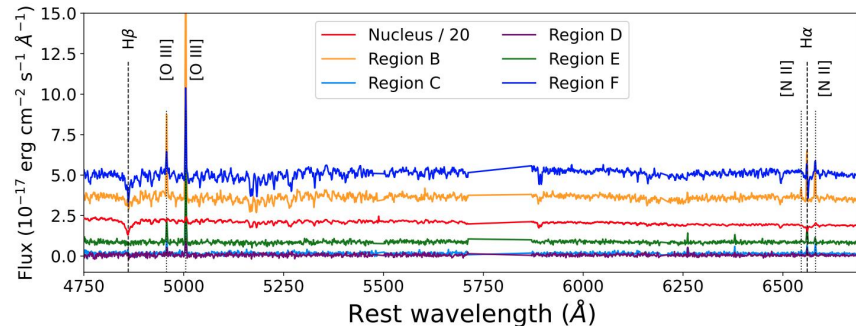
Mrk 950 (TDE iPTF16)



Extended emission-line region (EELR)

emission-line contour maps of [O III] overlaid on a continuum image

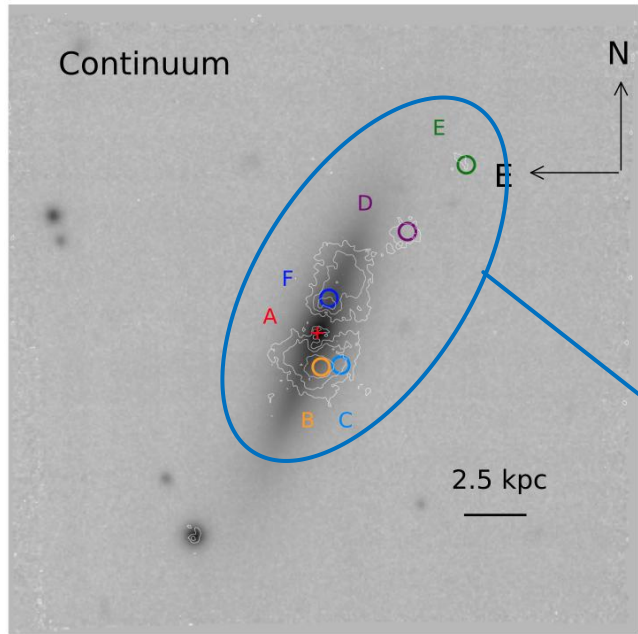
Wevers et al. 2024



Low-luminosity AGN

# Motivation II: connection between TDE hosts and EELRs

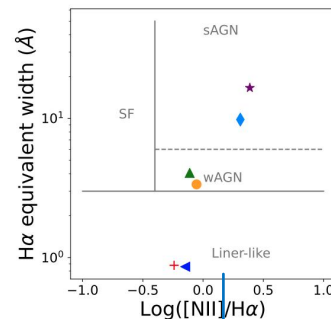
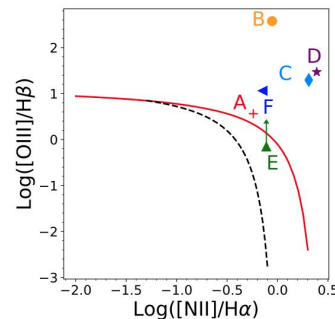
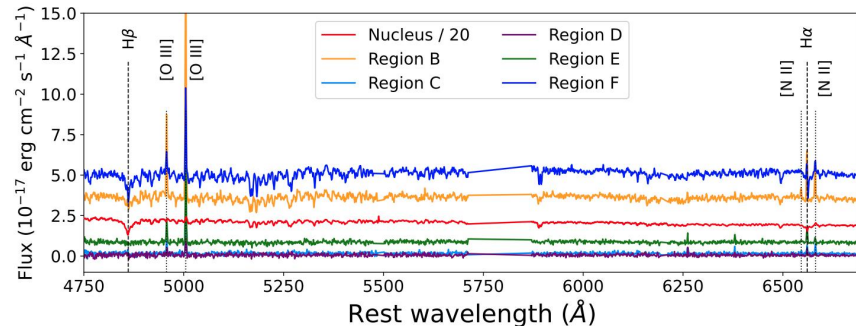
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Wevers et al. 2024

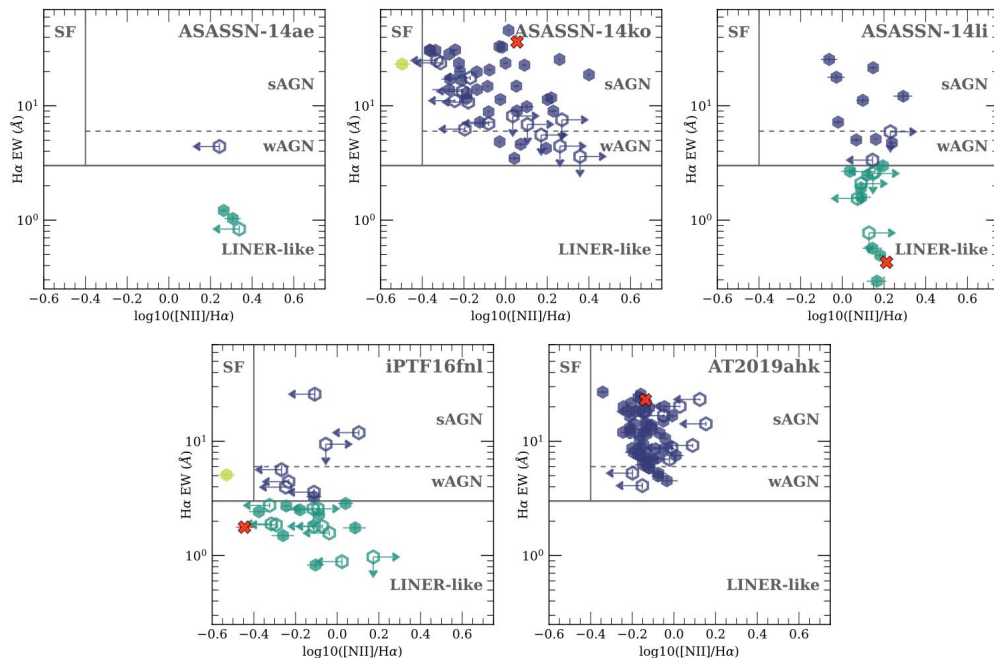


Low-luminosity AGN

TDE host galaxy  $\longleftrightarrow$  Low-luminosity AGN

# Motivation II: connection between TDE hosts and EELRs

Pursiainen et al. 2025



**5/20 PSB galaxies host TDE and EELRs**

- Strong relation between TDEs and galaxy mergers
- Half of post-merger systems have EELRs

TDE	$n$	$R$ (kpc)	$L$ ( $10^{38}$ ) (erg/s)	$\text{Log}(L_{\text{ion}})$ (erg/s)	$\text{Log}(L_{\text{nucl}})$ (erg/s)
14ae	7	0.6–2.4	0.98–9.90	> 41.8	< 41.3
14li	32	0.6–6.9	0.11–6.63	> 42.4	41.3
14ko	66	2.4–22.9	0.53–22.10	> 44.2	43.4
16fml	53	0.7–7.5	0.09–4.60	> 42.8	40.8
19ahk	65	1.9–6.2	0.17–9.27	> 43.1	42.9

**Table 2.** Details of the identified EELR bins.  $n$  states the number of bins identified per galaxy,  $R$  the range of projected offset of the bins from the nucleus of the galaxy and  $L$  the range of the [O III]  $\lambda 5007$  emission line luminosities. We also show the minimum required luminosity to ionise the EELRs ( $L_{\text{ion}}$ ), and the estimated integrated nuclear luminosity ( $L_{\text{nucl}}$ ).

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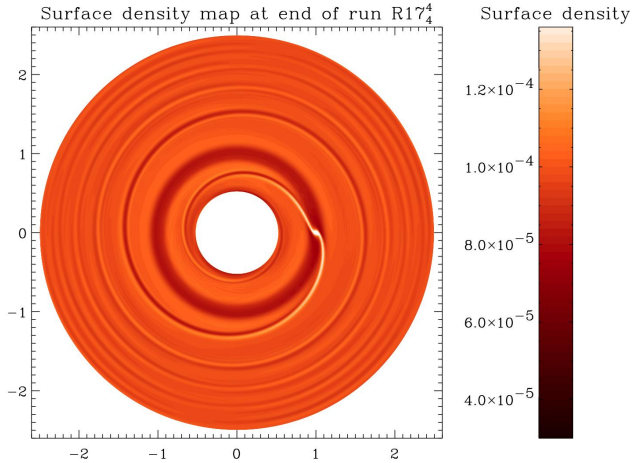
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# Disk effect: Star-Disk Interactions

## Disk stars

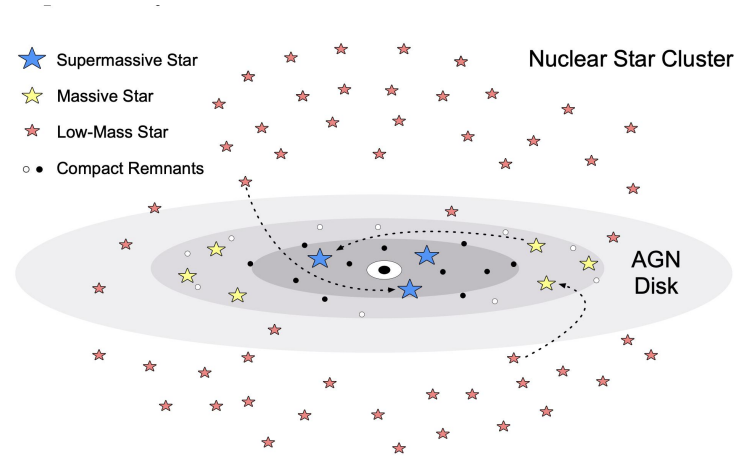


Masset et al.2002

Density wave by Lindblad and corotation resonance

- **Orbital migration**
- **Orbital circularization**

## Cluster stars



Cantiello et al.2021

Stars captured by star-disk interactions

- **Disk capture**

# Disk effect: in-situ star formation

TQM disk model (Toomre's Q parameter  $\sim 1$ )

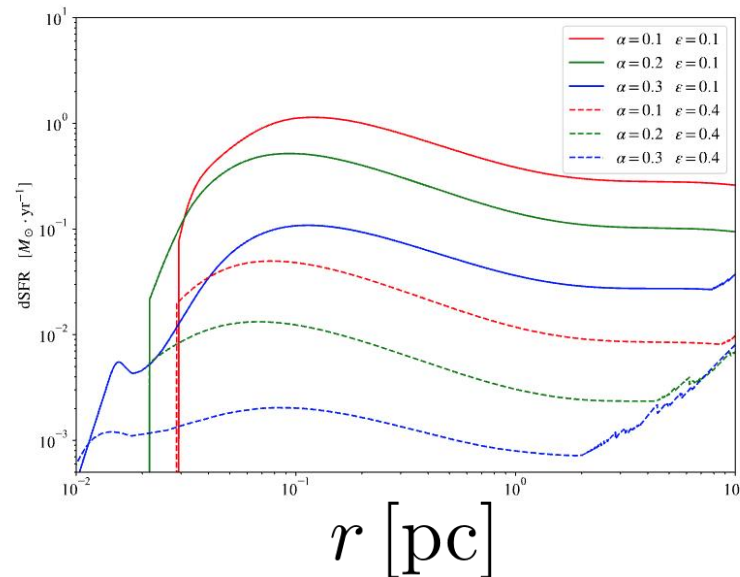
Star formation rate in the disk

$$\dot{M} = \dot{M}_{\text{out}} - \int_{R_{\text{out}}}^r 2\pi r \dot{\Sigma}_{\star} dr.$$

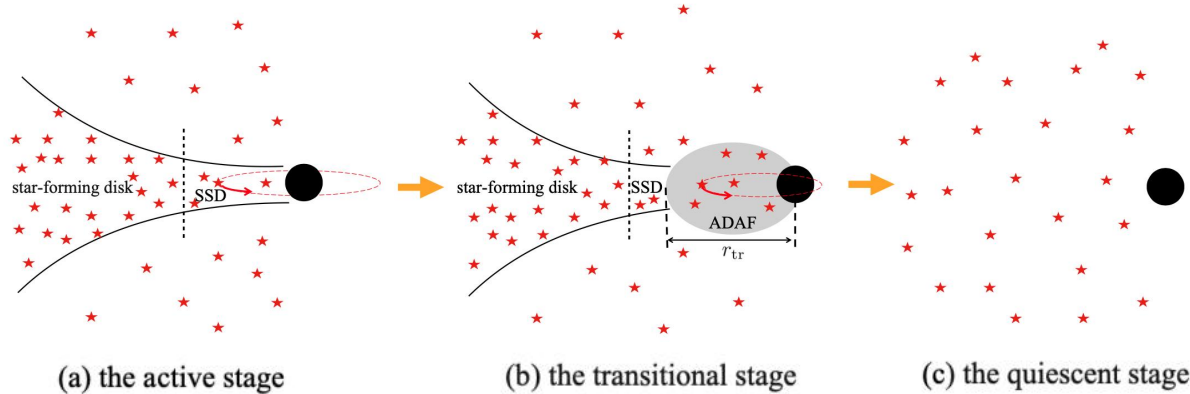
Star formation

$$\sigma_{\text{SB}} T_{\text{eff}}^4 = \frac{1}{2} \epsilon \dot{\Sigma}_{\star} c^2 + \frac{3}{8\pi} \dot{M} \left(1 - \sqrt{R_{\text{in}}/r}\right) \Omega^2.$$

Radiation pressure  
from massive stars  
and stellar-mass BH



# Disk modified Fokker-Planck equations



cluster stars: 
$$C \frac{\partial f}{\partial t} = -\frac{\partial}{\partial E} F_E^f - \frac{\partial}{\partial R} F_R^f - S_{\text{cap}},$$

disk stars: 
$$C \frac{\partial g}{\partial t} = -\frac{\partial}{\partial E} F_E^g - \frac{\partial}{\partial R} F_R^g + S_{\text{cap}} + S_{\text{dSF}}$$

orbital migration 
$$D_E^g = D_E - C \frac{E}{\tau_{\text{mig}}},$$

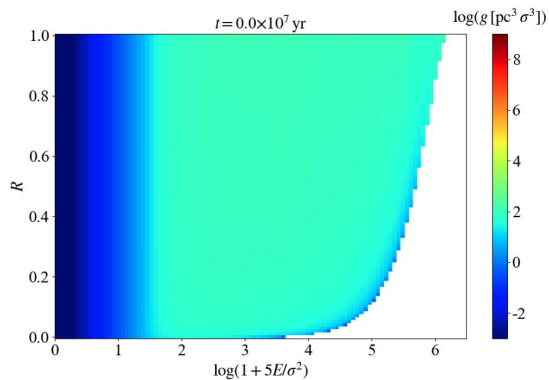
circularization 
$$D_R^g = D_R - C \frac{1-R}{\tau_e},$$

disk capture 
$$S_{\text{cap}}(E, R) = \mu_{\text{cap}} C \frac{J}{\tau_{\text{mig}}},$$

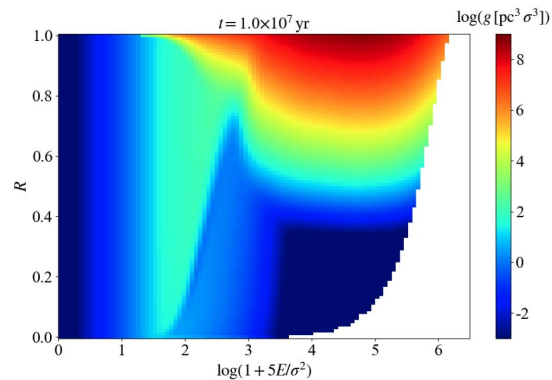
star formation 
$$S_{\text{dSF}}(E, R) = \frac{1}{m_{\text{star}}} \frac{\partial \text{dSFR}}{\partial E \partial R}$$

The TDE rates are determined by the flux in the R-direction: 
$$\Gamma_{\text{TDE}}(M_{\text{BH}}, t) = \int -(F_R^g + F_R^f) dE. \quad 12$$

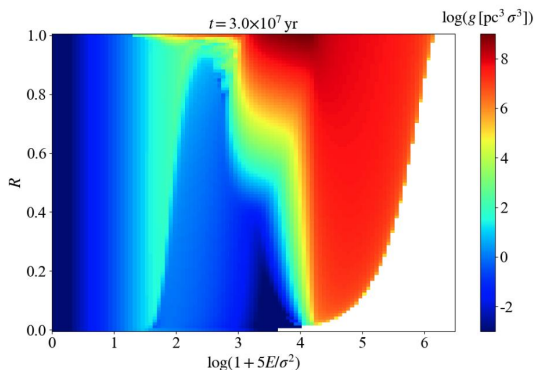
# Evolution of distribution function (DF)



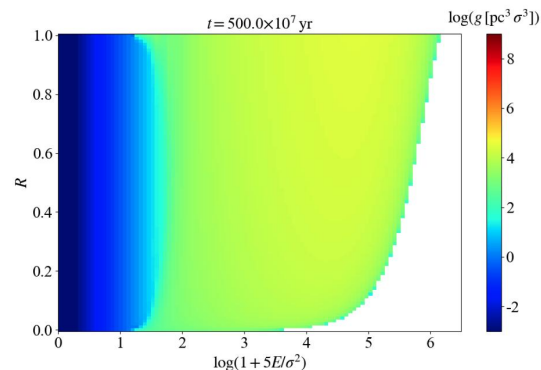
**The initial DF**



**The active stage**

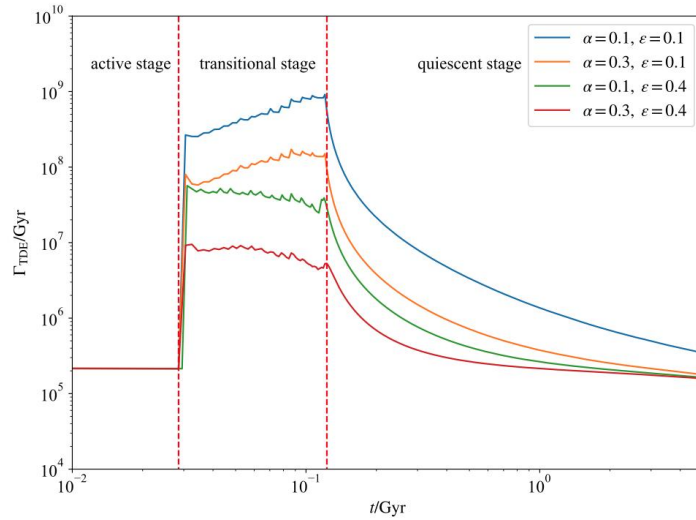


**The transitional stage**



**The quiescent stage**

# Evolution of TDE rate

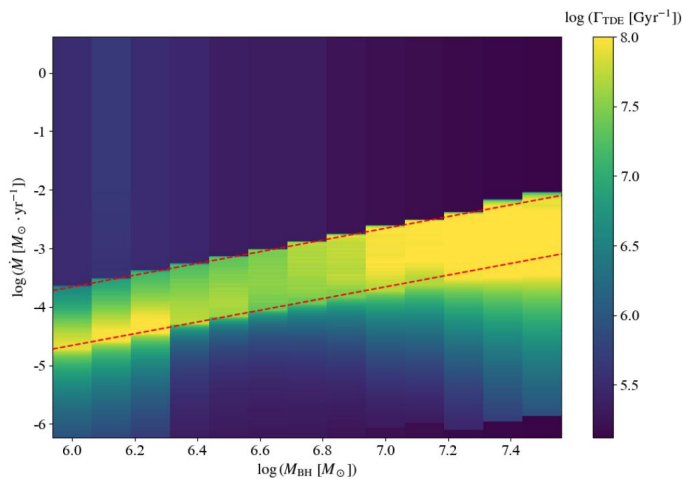


Evolution of TDE rate over time

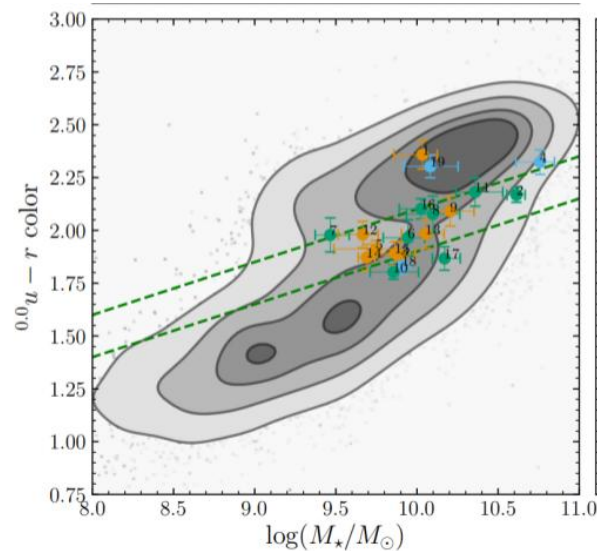
The average TDE rates over 1Gyr:  
320x, 65x, 22x and 5x for different  
disk parameters

- The active stage: the TDE rate is consistent with quiescent galaxies
- The transitional stage: the TDE rate rapidly increases due to the disk disappearing.
- The quiescent stage: the TDE rate returns to the level of normal galaxies.

# TDE rate distribution in transitional stage



The TDE rate distribution in  $(M_{BH}, \dot{M}_{BH})$



Hammerstein et al. 2020

The peak of TDE rate locates at low-luminosity AGN stage

# Summary

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