Rates of Tidal Disruption Flares in Post-Starburst Galaxies

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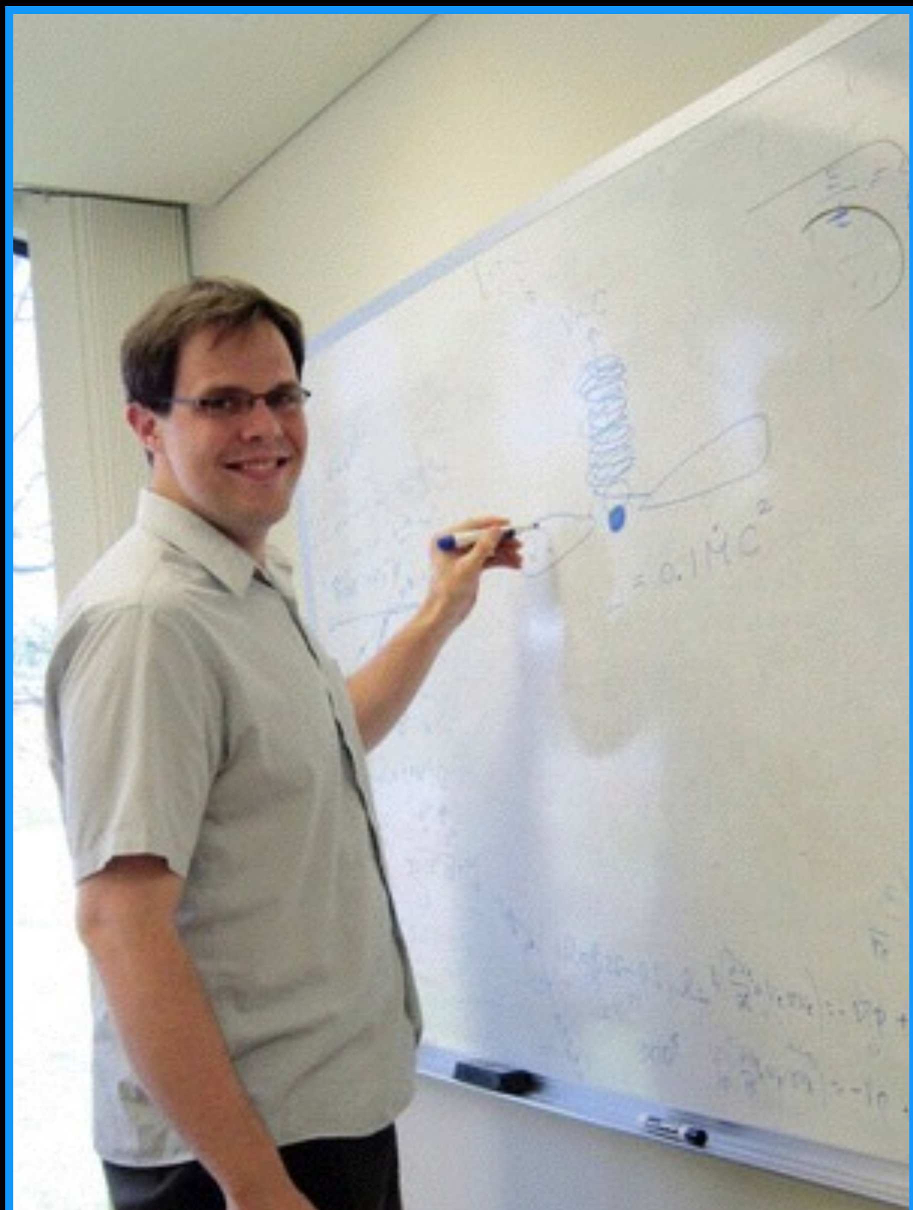
St. Thomas, July 13th 2017



Brian Metzger
(Columbia)

Sjoert van Velzen
(Johns Hopkins)

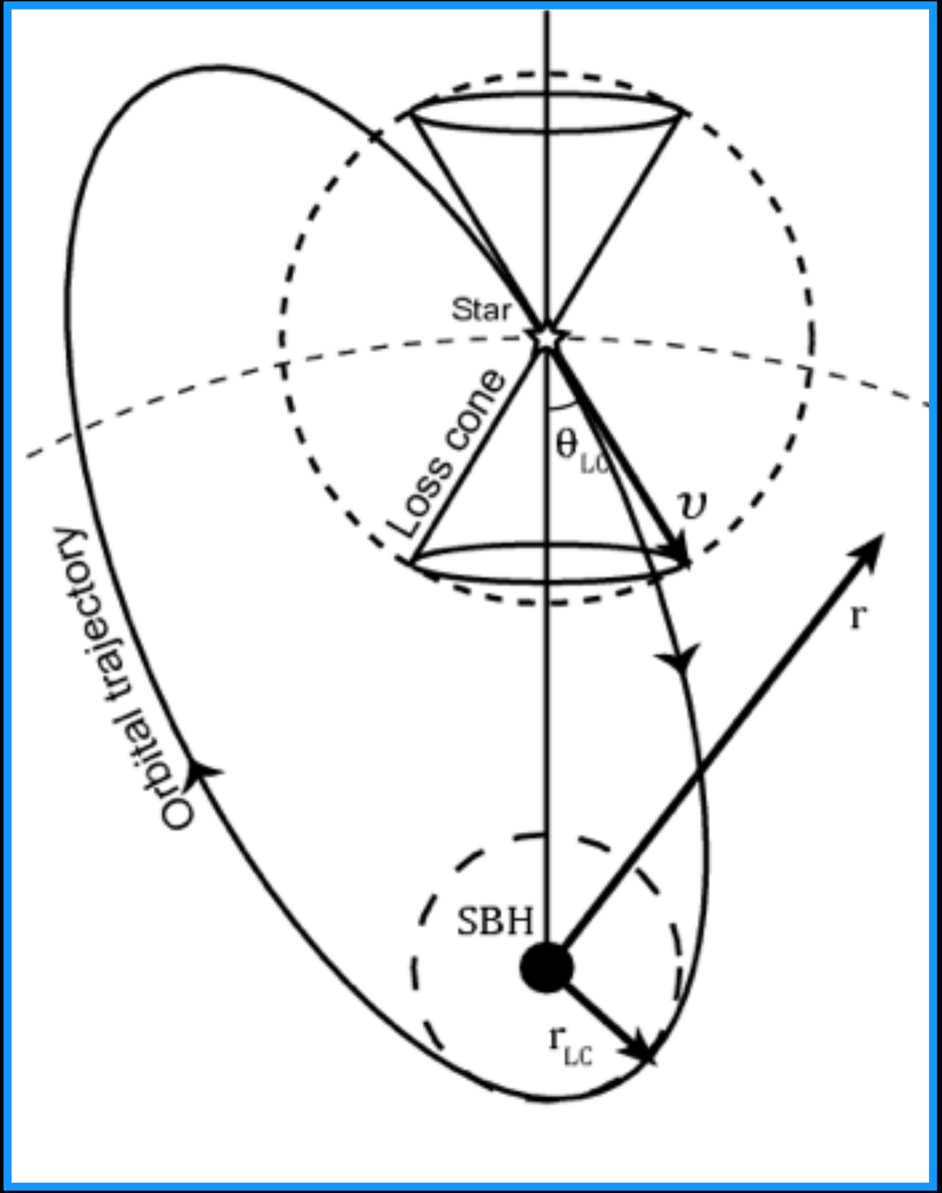
Aleksey Generozov
(Columbia grad)

Tidal Disruption Overview

- Many applications:
  - Tools to measure **SMBH mass** (see Guillochon talk)
  - Possibly **SMBH spin** (Stone & Loeb 12)
  - **Accretion/jet launching physics** laboratories (discussion)
  - Rates encode **stellar dynamical processes**
- A few strong candidate flares per year, soon to be tens (ZTF) hundreds (eROSITA), and thousands (LSST)

TDE Rates

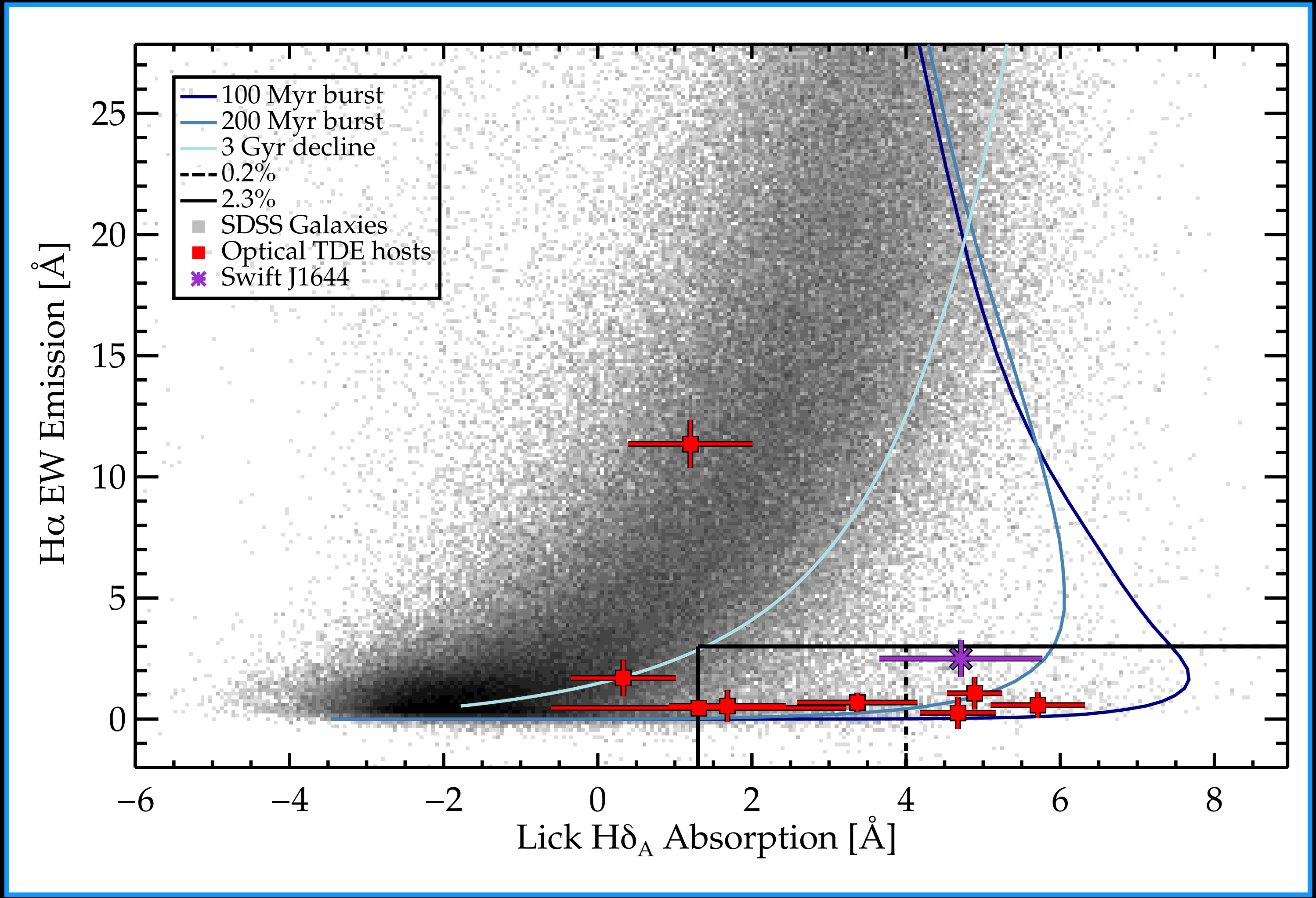
- Optical/X-ray/UV rate estimates find $\mathscr{R}_{obs}$~1-10 x 10^{-5}/gal/yr
- Theoretical rate estimates set by diffusion of stars into **loss cone**
  - ✦ Two-body relaxation ubiquitous
- Theoretical rates calculated semi-empirically (**NCS** & Metzger 16):
  - ✦ Take sample of 140 nearby galaxies
  - ✦ Deproject I(R) -> ρ(r) *[assumes sphericity]*
  - ✦ Invert ρ(r) -> f(ε) *[assumes isotropy]*
  - ✦ Compute diffusion coefficients μ(ε), loss cone flux $\mathscr{F}$(ε) *[assumes Kroupa IMF]*
- $\mathscr{R}_{obs} < \mathscr{R}_{theory}$ ~ few x 10^{-4}/gal/yr ?
  - ✦ **But see van Velzen 2017!**



(Freitag & Benz 02)

Unusual Host Galaxy Preferences

- Most optical TDE hosts are **rare post-starburst/E+A galaxies** (Arcavi+14, French+16, 17, Law-Smith+17)
- Possible explanations:
  - ✦ **Binary SMBHs**; chaotic 3-body scatterings (Arcavi+14)
  - ✦ **Central overdensities**; short relaxation times (**NCS** & Metzger 16)
  - ✦ **Radial anisotropies**: low angular momentum systems (**NCS+** in prep)
  - ✦ **Eccentric nuclear disks:** secular instabilities (Madigan+17)
  - ✦ **Nuclear triaxiality:** collisionless effects
- How to discriminate between these? **Delay time distributions**



(French+ 16)

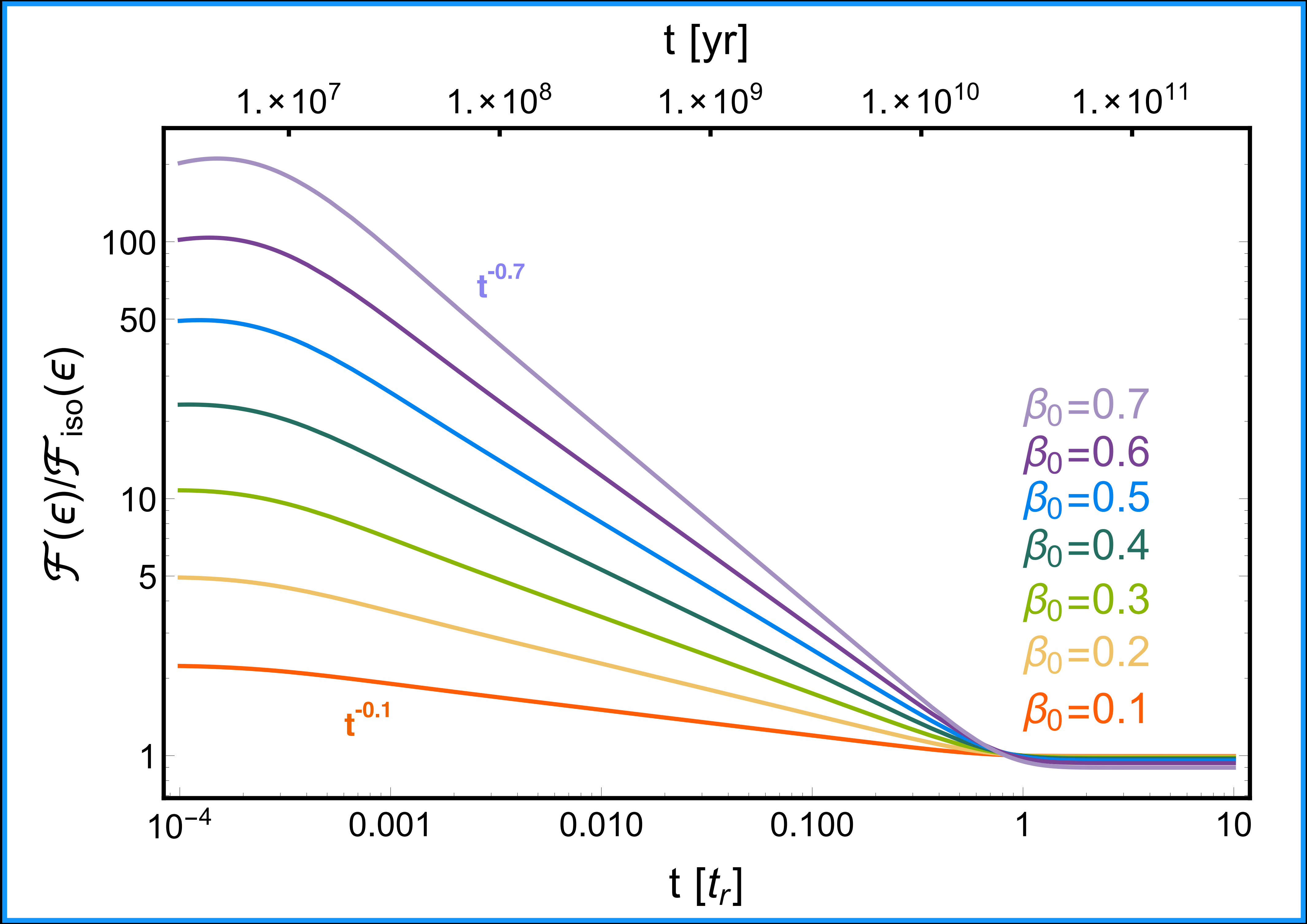
Radial Orbit Anisotropies

- One possibility: anisotropic velocities with radial bias
- Consider constant anisotropy $\beta=1-T_{\perp}/2T_r$
  - $\beta<\beta_{ROI}\sim0.6$ to avoid radial orbit instability
- Solve 1D Fokker-Planck equation in angular momentum space:

$$\frac{\partial f}{\partial \tau} = \frac{1}{4j}\frac{\partial}{\partial j}\left(j\frac{\partial f}{\partial j}\right)$$

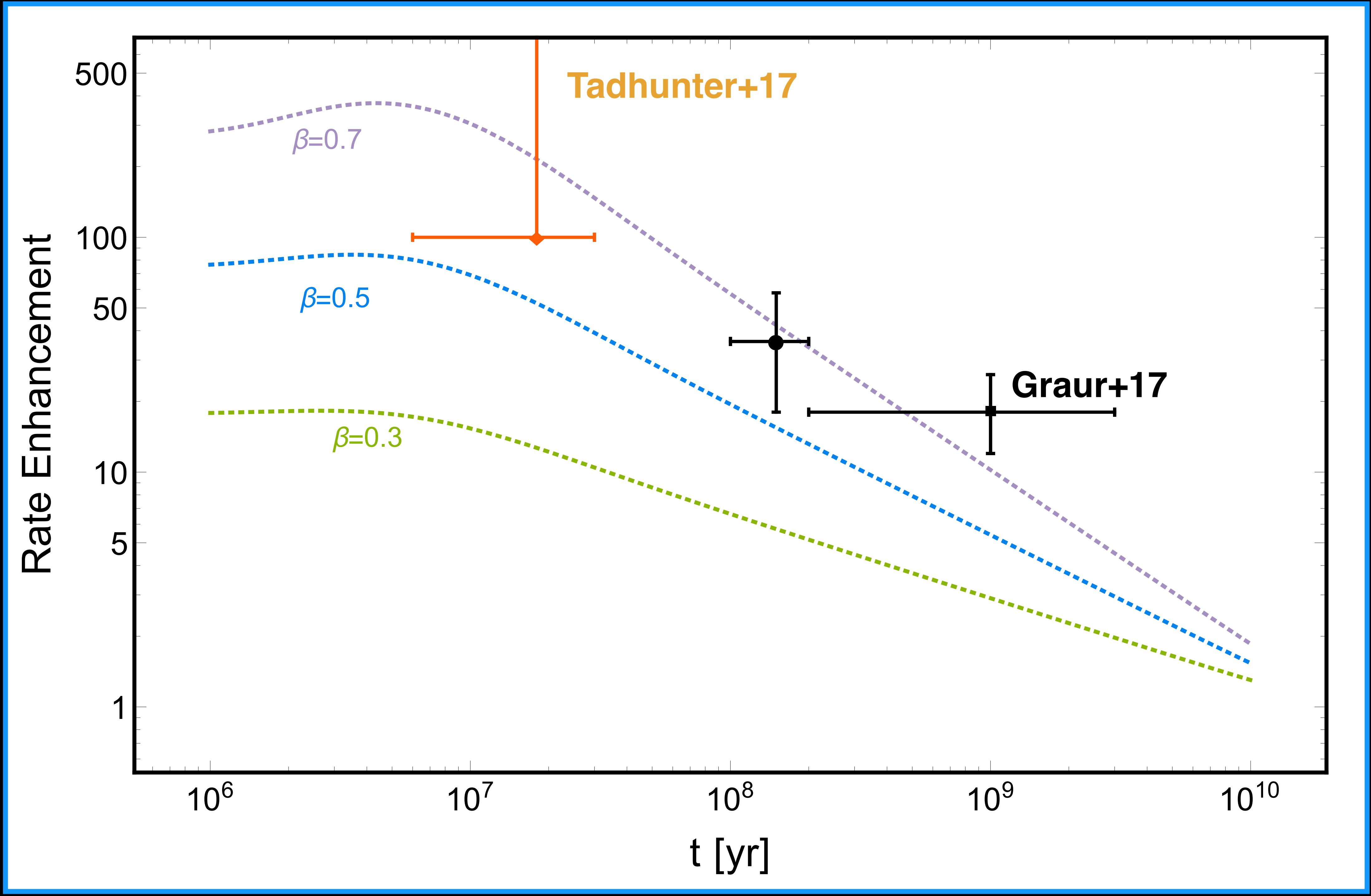
- TDE rate $dN/dt \sim t^{-\beta}$ in an isotropizing cusp

TDEs in Radially Biased Galaxies



(**NCS**+ in prep)

The Anisotropic DTD

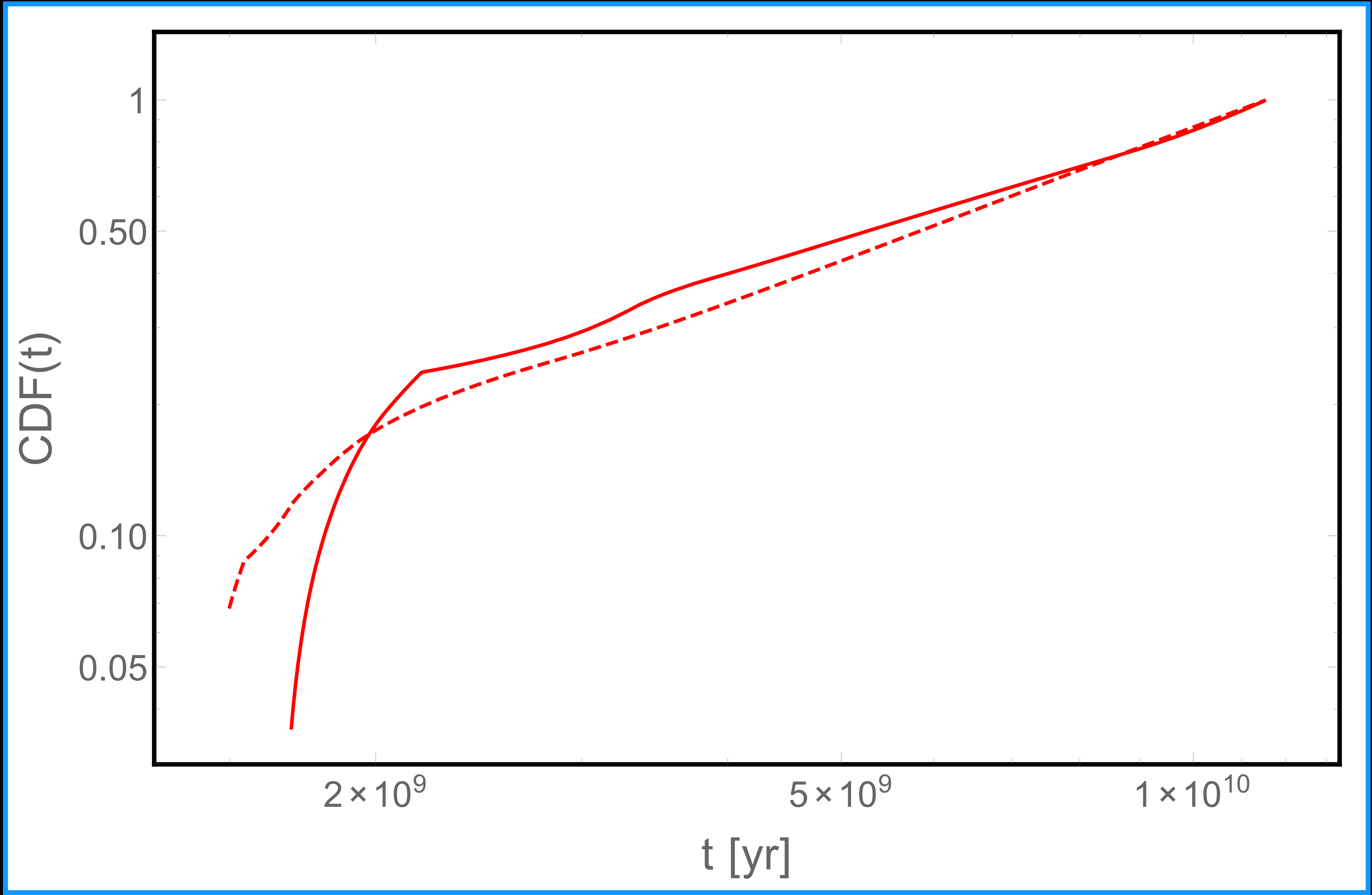


(**NCS**+ in prep)

SMBH Binaries

- Nascent SMBH binaries see increase in TDE rate:
  - Kozai effect (Ivanov+05)
  - Chaotic 3-body scatterings (Chen+11)
- Enhancement huge ($\mathscr{R}$~10^{-1}/yr) but short-lived (~10^5 yr)
  - Occurs before final parsec problem
- Disfavored by:
  - Total rate
  - Mass distribution
  - Fine-tuned timescales

SMBHB Cumulative Distribution

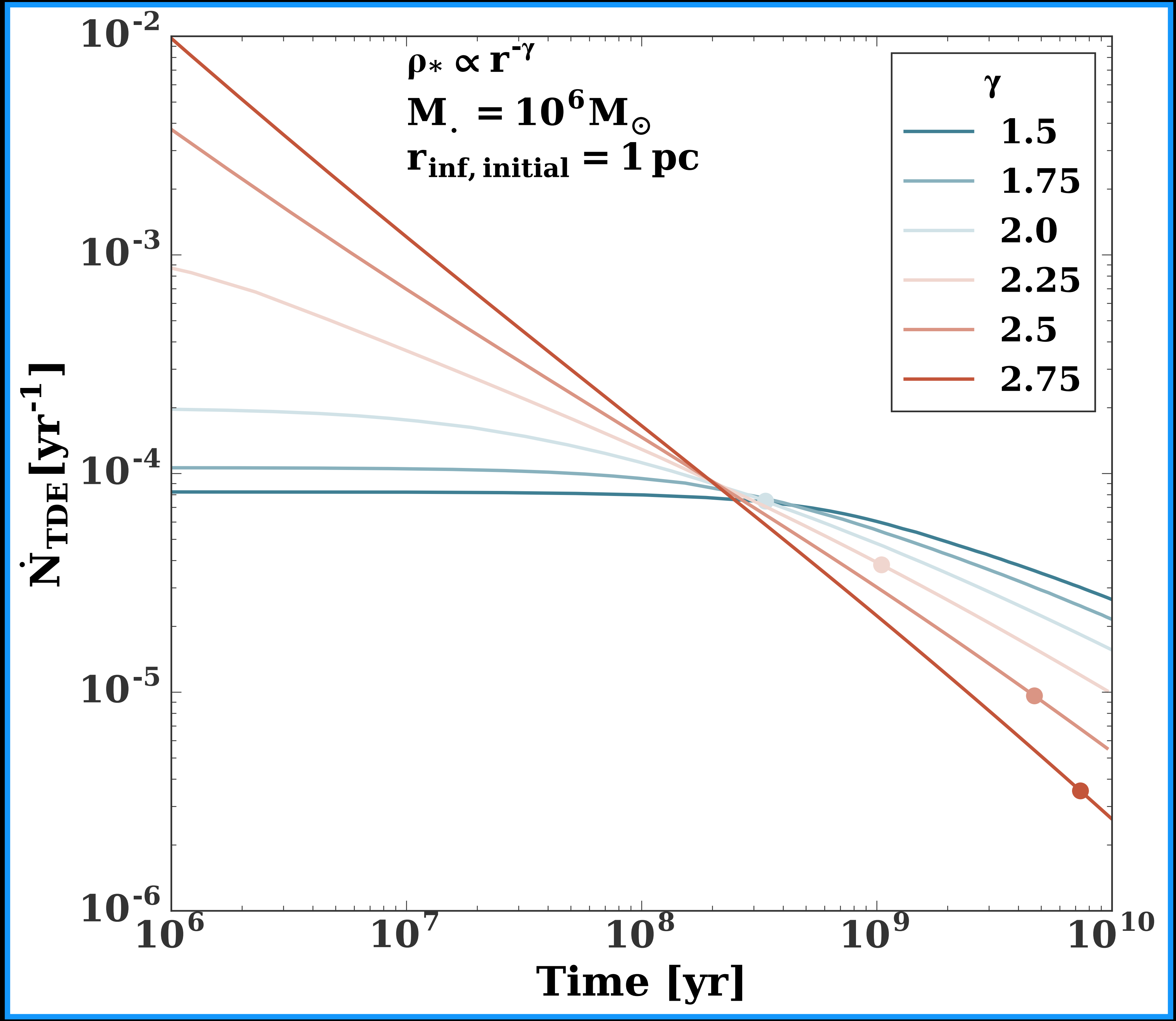


(**NCS**+ in prep)

Stellar Overdensities

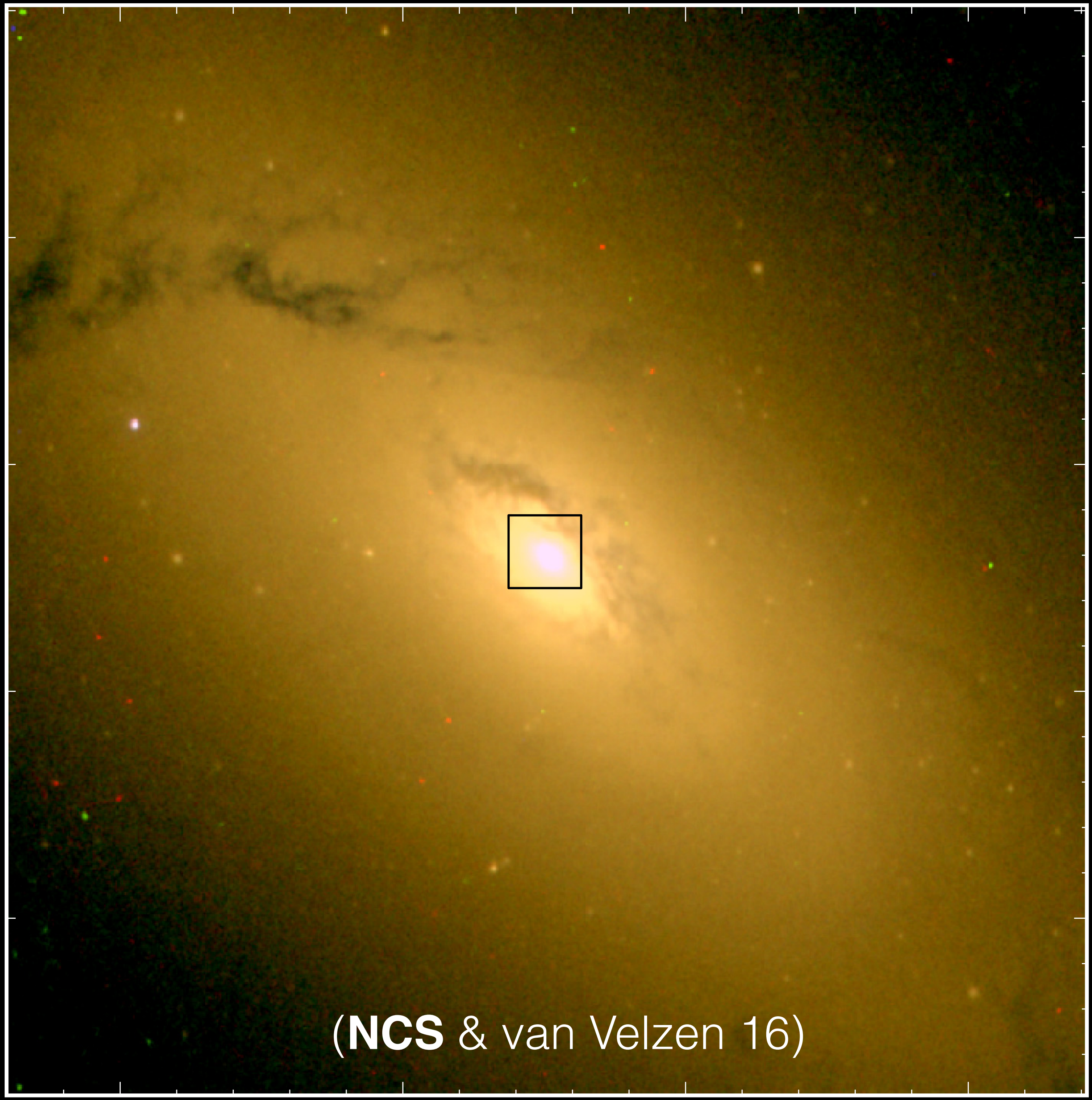
- Overdense nuclei ($\rho=\rho_{infl}(r/r_{infl})^{-\gamma}$) can have short two-body relaxation times if they are overconcentrated or ultrasteep
- Suggestive evidence: color gradients in E+As (Pracy+13)
- Overconcentrated (r_{infl} low):
  - High, slowly evolving TDE rate
- Ultrasteep (γ large):
  - If $\gamma>7/4$, profile flattens with time (Bahcall & Wolf 76)
  - If $\gamma>9/4$, TDE rate diverges inward
  - Transition point $r_{BW} \sim t^{1/(\gamma-3/2)}$
  - $dN/dt \sim t^{-(4\gamma-9)/(2\gamma-3)} / \ln(t)$

Overdense TDE Rates

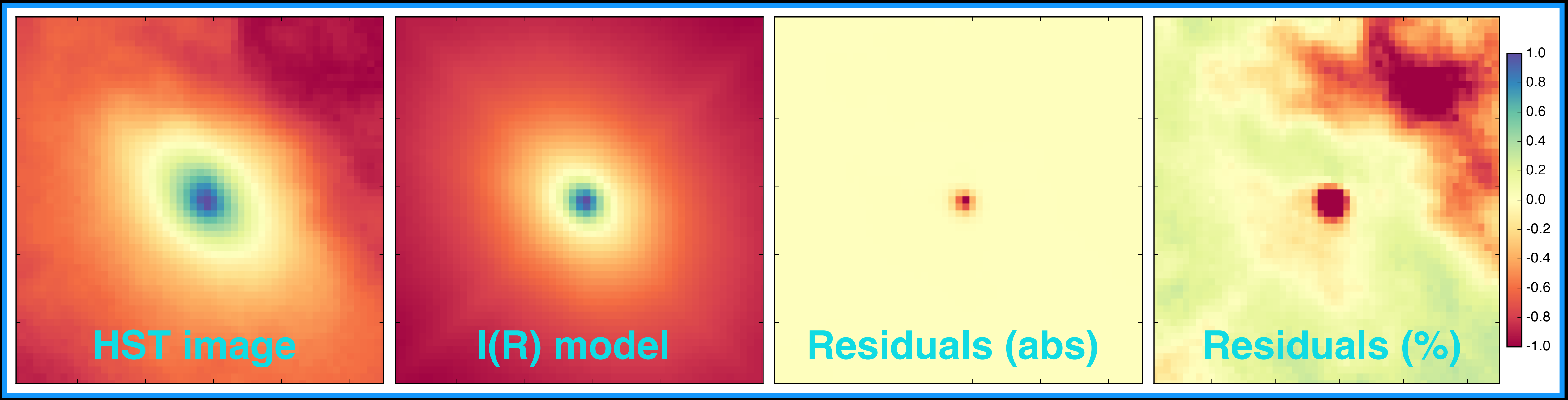


(**NCS**+ in prep)

NGC 3156: A Nearby E+A



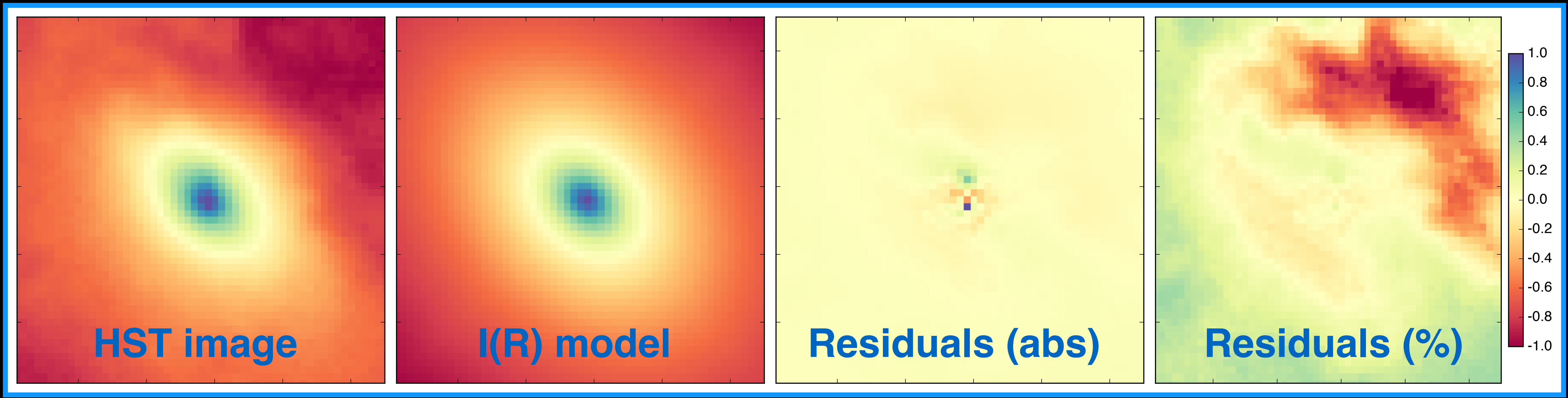
NGC 3156: Modeling



(**NCS** & van Velzen 16)

- Optimal target: 22 Mpc, $M_{BH} = 3x10^6 M_\odot$
- Archival HST observations, I(R) fit (Krajnovic+13)
  - ✦ NGC 3156 extreme outlier in central profile: I(R) α $R^{-1.78}$?

NGC 3156: Modeling



(**NCS** & van Velzen 16)

- Optimal target: 22 Mpc, $M_{BH} = 3 \times 10^6 M_\odot$
- We fit an I(R) model to archival HST observations
    - NGC 3156 **major outlier** in central profile: I(R) α $R^{-1.2}$
- TDE rate $\mathscr{R} \sim 1 \times 10^{-3}$/yr!
    - Will test further with upcoming HST observations