Loss Cone Shielding

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Abstract

- Observed TDE rates: **Γobs ~ 10^{-5} - 10^{-4} /gal / yr** , (Holoien 16, van Velzen 18)
- Theoretically predicted rates**: Γtheory ~ 10^{-3} - 10^{-4} / gal / yr ,** (Merrit & Wang 04)
- E+A galaxies : are overrepresented by a factor of 22 (Hammerstein 21)
- **Observed rates for non E+A galaxies in higher tension with theoretical rate**

Introduction

- Radius of influence, total mass of the stars is equal to the massive black hole mass MBH, for a 10^6 $M_\odot$ radius of influence ~ 1 pc
- Density cusp : $\rho \propto r^{-\gamma}$ will develop with
- Weak segragation: $\gamma_\star \approx 1.3 - 1.5$, $\gamma_{bh} = 1.75 - 2$ (e.g Bahcall & Wolf 77, Preto 10)
- Strong segregation: heavier objects settle to γ_{bh} = 2-11/4 (Alexander & Hopman)

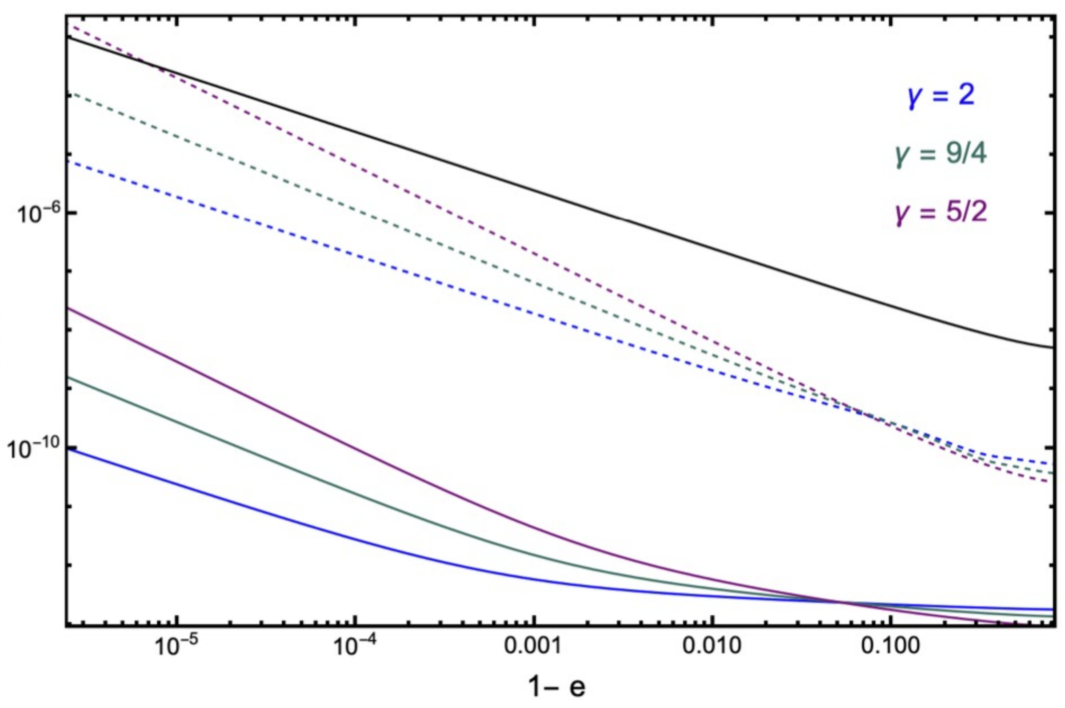
Classical loss cone theory

Classical Loss cone theory: two-body relaxation theory with weak deflections, slow evolution

Orbit-averaged Fokker-Planck $$\frac{\partial f}{\partial \tau} = \frac{1}{4j}\frac{\partial}{\partial j}\left(j\frac{\partial f}{\partial j}\right)$$

where $j \equiv J/J_c(\varepsilon)$ is a dimensionless angular momentum variable and $\tau \equiv \mu(\varepsilon)t \approx t/t_r$ is a dimensionless time, with $\mu(\varepsilon)$ the orbit-averaged diffusion coefficients

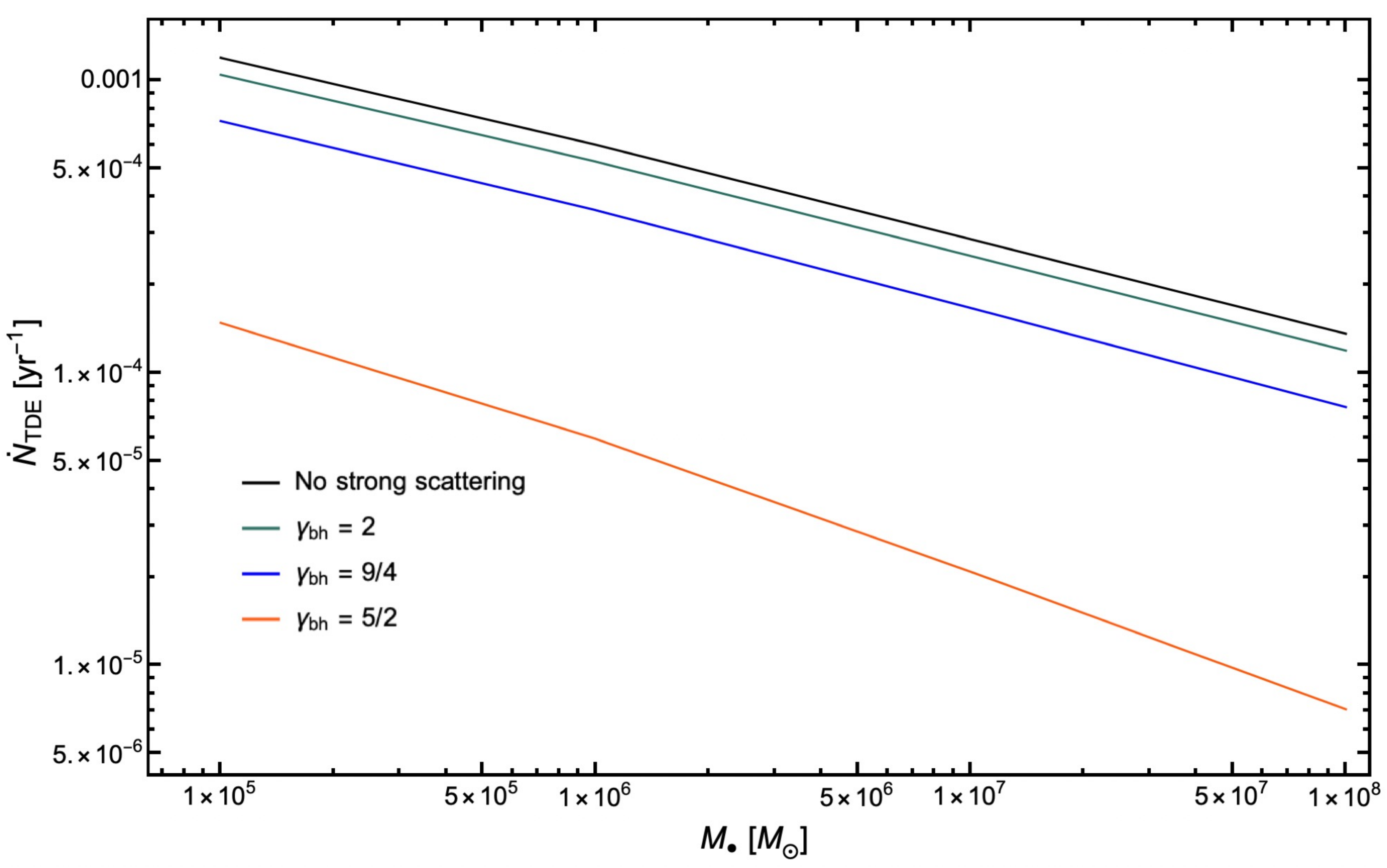
Rate of close encounters



Average rates of close encounters between stars and sBH, as a function of the dimensionless test star pericenter $1 - e$. The test star has semimajor axis $a = r_{infl}$ and results are shown for different black hole slopes (color-coded). Dashed lines: strong scattering ejection rates; full lines: tidal capture and micro-TDE rates.

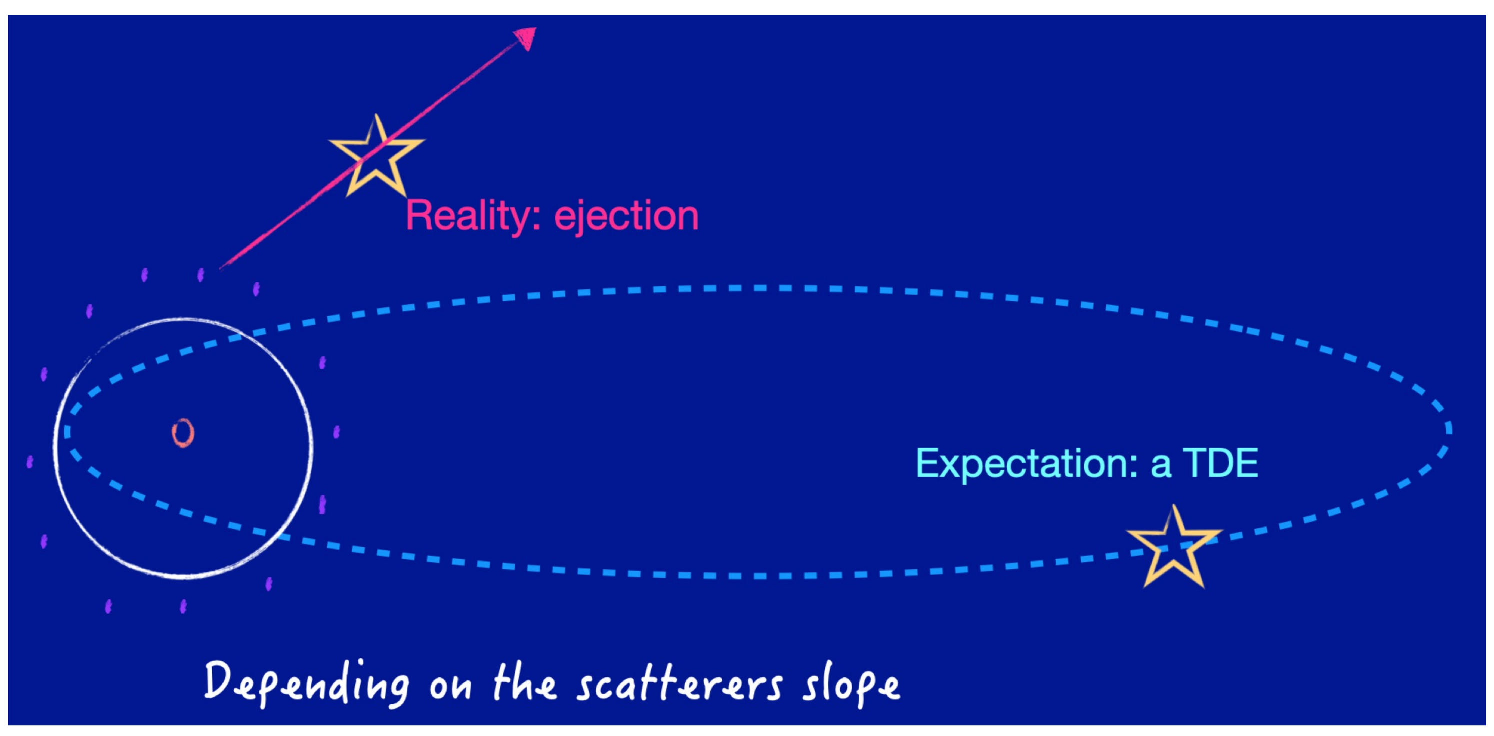
Dominant mechanism at radius of influnece: ***strong scattering***

Impact on TDE rate



Tidal disruption rates N_{TDE} measured in units of stars per year with (colored curves) and without (black curve) strong scattering. Results are plotted against MBH mass $M_\bullet$, with the following parameters: $m_\star = 1M_\odot$, $\gamma_\star = 3/2$, $m_{bh} = 30M_\odot$ and different sBH density profile slopes: in particular, we show $\gamma_{bh} = 2$, $\gamma_{bh} = 9/4$, and $\gamma_{bh} = 5/2$ as green, blue, and orange curves, respectively

Conclusions



Radius of influence: **densest environments of the universe**

- Most TDEs come from within the radius of influence, ***the densest environments of the universe***
- Hence, rare close encounters: collisions, tidal captures and micro-TDEs are more common
- We analytically derive their rates and present some of them in rate of close encounters
- **Strong scattering**: A scattering where the ***velocity of the star after the interaction is larger than the escape velocity at this radius***

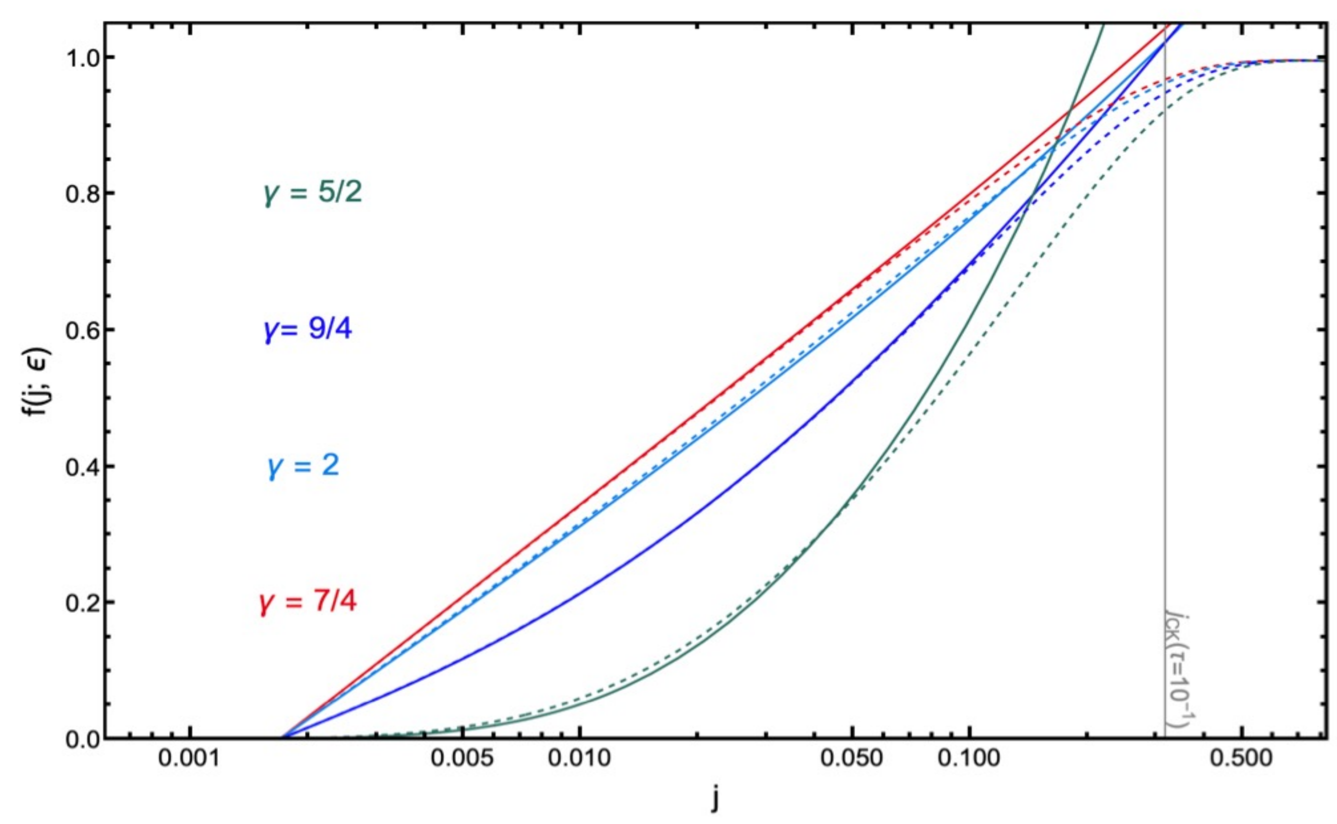
Revised loss cone theory

Revised Loss cone theory: two-body relaxation theory ***and close encounters***: *collisions, tidal captures and micro-TDEs*

Orbit-averaged Fokker-Planck with sink term

$$\frac{\partial f}{\partial \tau} = \frac{1}{4j}\frac{\partial}{\partial j}\left(j\frac{\partial f}{\partial j}\right) - \frac{\langle \dot{N}_{ej}\rangle}{\mu(\epsilon)} f$$ with $\langle N_{ej}\rangle$ the orbit-averaged rate of close encounters

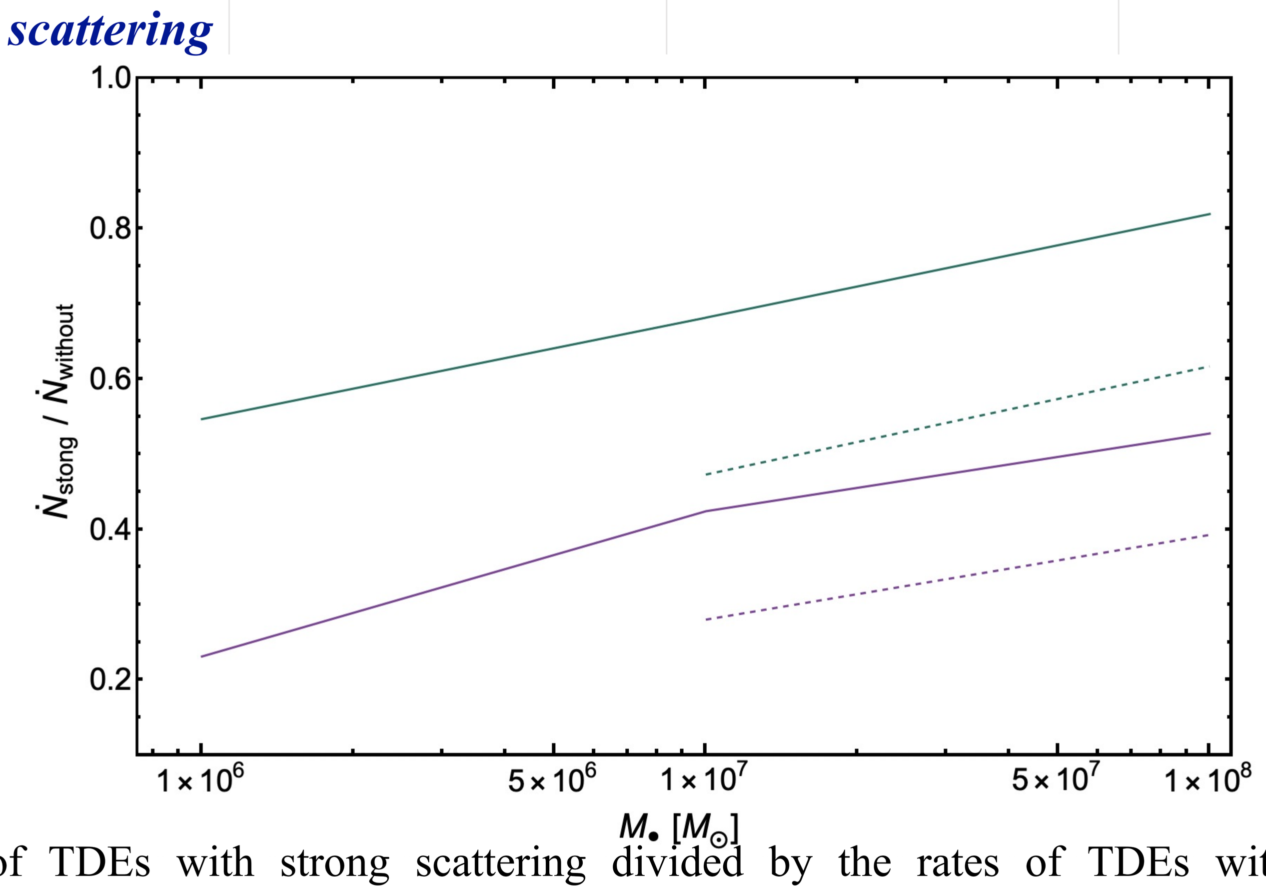
Analytical solution of Fokker-Planck equation with sink term



Evolution of the distribution function $f(j;\varepsilon)$ as a function of the dimensionless angular momentum j at fixed energy ε, at dimensionless time, $\tau = 0.1$ for different slopes of the black holes. Here $\gamma_\star = 3/2$, the stellar mass black holes have a mass $m = 30M_\odot$, and different colors correspond to different sBH slopes γ_{bh} (see labels in figure). The dashed curves show numerical solutions of the 1D Fokker-Planck equation and solid lines show the approximate analytic solution obtained from the method of Frobenius

E+A preference

Why do TDEs prefer E+A galaxies?
One of the favorite explanation: a very steep stellar profile -> ***less likely with strong scattering***



Rates of TDEs with strong scattering divided by the rates of TDEs without strong scattering, shown as a function of the MBH mass. Green lines are for $\gamma_\star = 9/4$, purple lines for $\gamma_\star = 5/2$. Full lines are at t = 10 Myr (15 Myr for $\gamma_\star = 9/4$), dashed lines are at t =100 Myr (150 Myr for $\gamma_\star = 9/4$), at those early times a very steep star power law has not yet relaxed to a broken power law configuration

Future works and Acknowledgements

- Impact on TDE rates of "**less strong**" strong scattering
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