# Dynamics of Transients in galactic nuclei


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**Technion, Israel**

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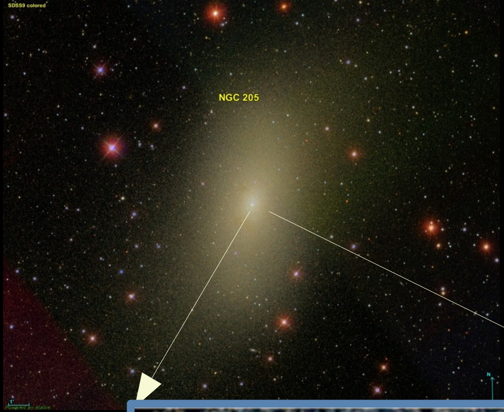
With: Nicholas Stone, Re’em Sari, Hagai Perets, Barak Rom

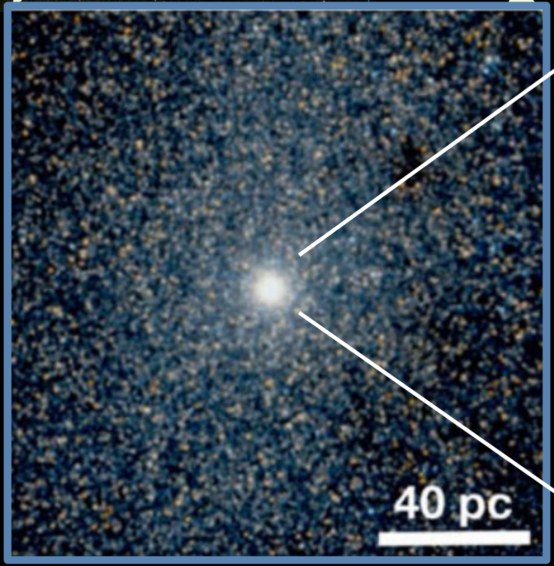
# Nuclear Star Cluster


Extreme Stellar Densities $n_* \approx 10^6\ pc^{-3}$




# Nuclear Star Cluster

*Massive Black hole*





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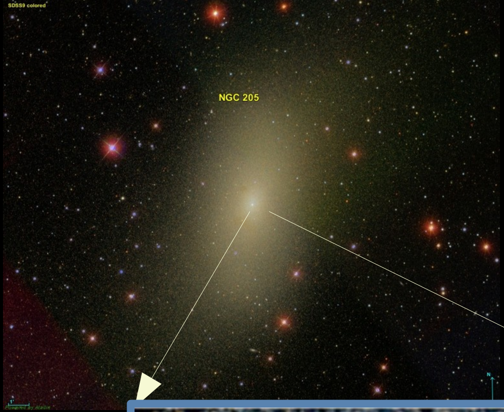


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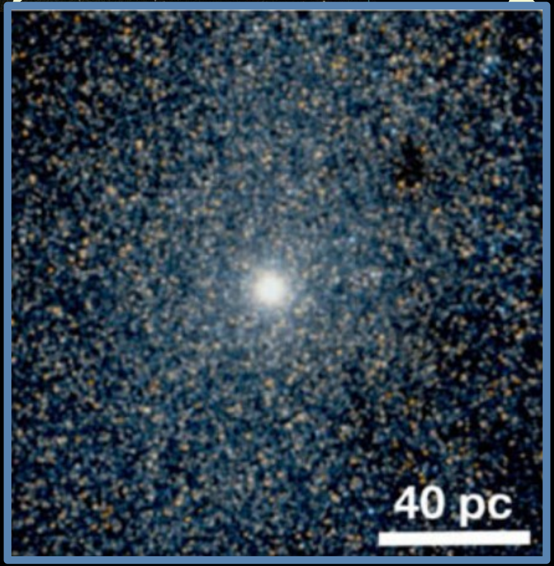
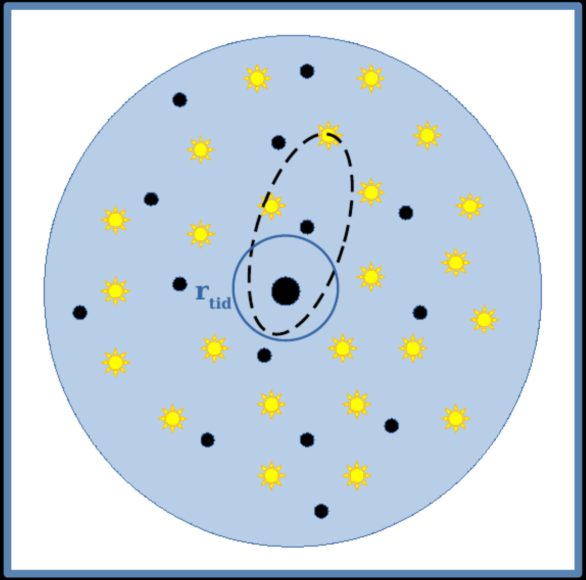


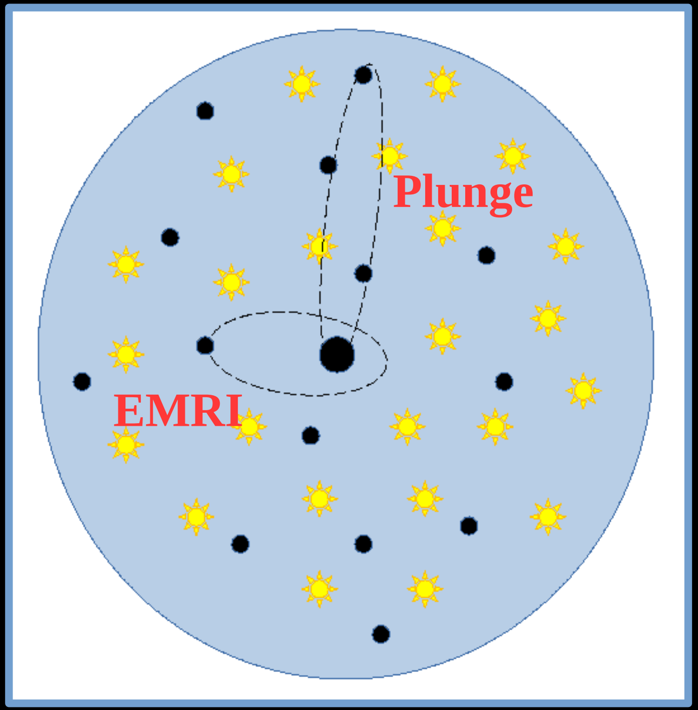


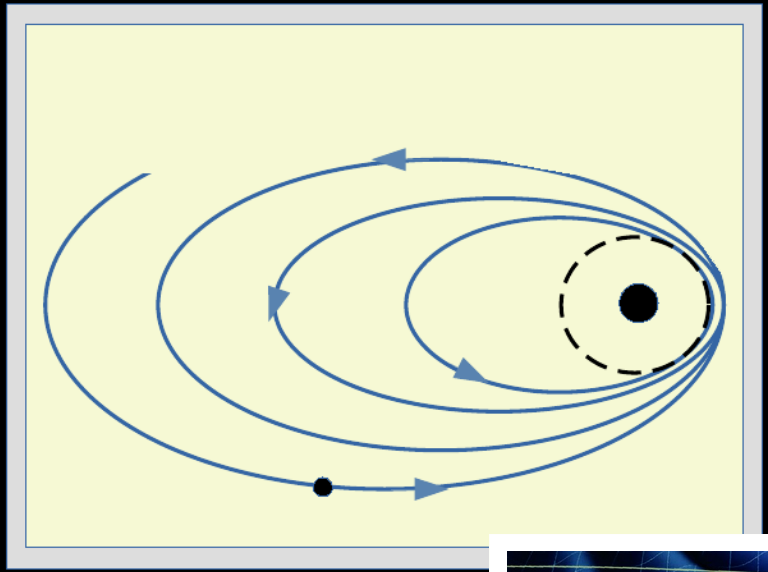



Extreme Stellar Densities $n_* \approx 10^6 \ pc^{-3}$

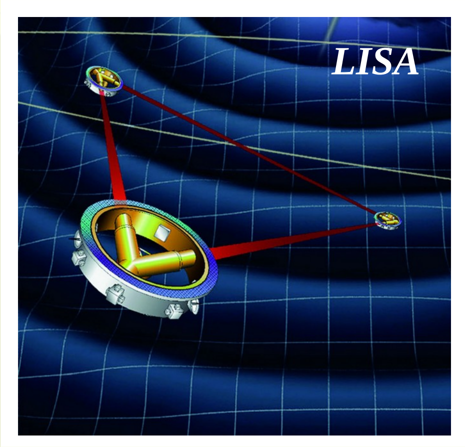
Breeding Ground of Transients!

# Extreme-Mass Ratio Inspirals (EMRIs)



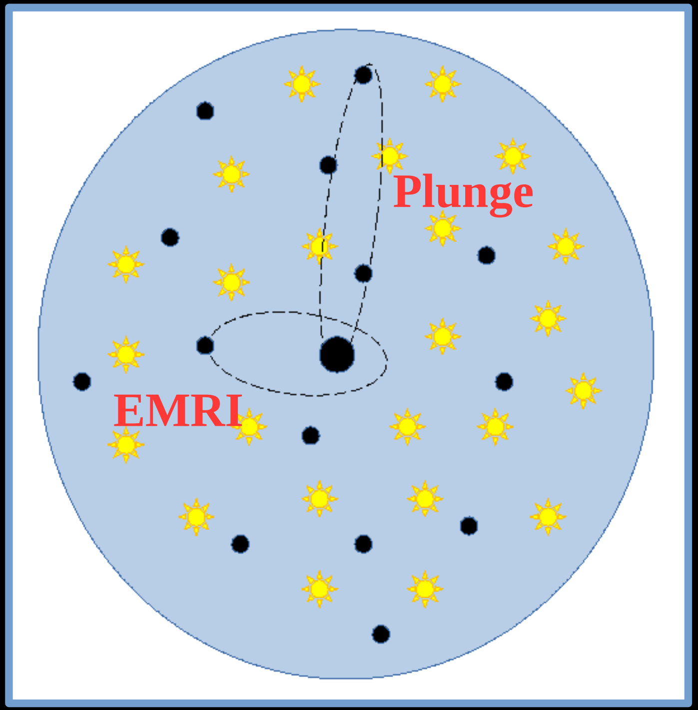



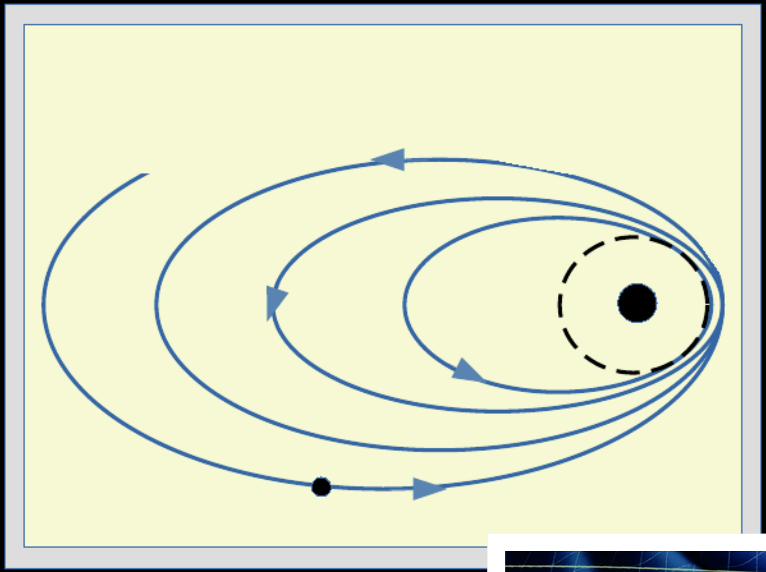
*Low-frequency (mHz)*
*Gravitational waves*




*Plunging radius* $r_{plunge} = 4\,R_s \approx 0.1\,AU\,M_6$

# Extreme-Mass Ratio Inspirals (EMRIs)



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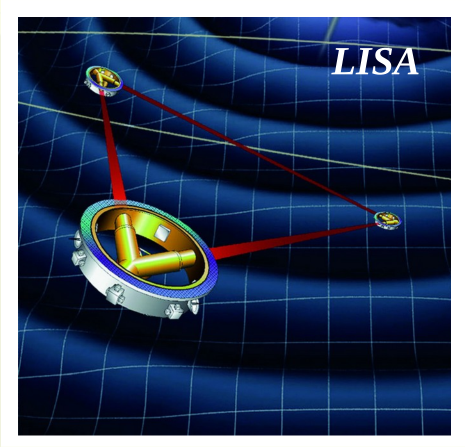
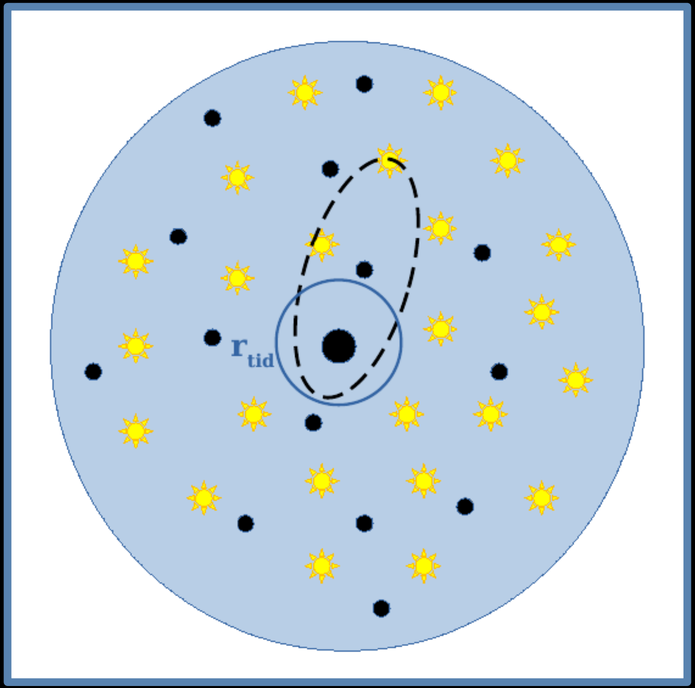


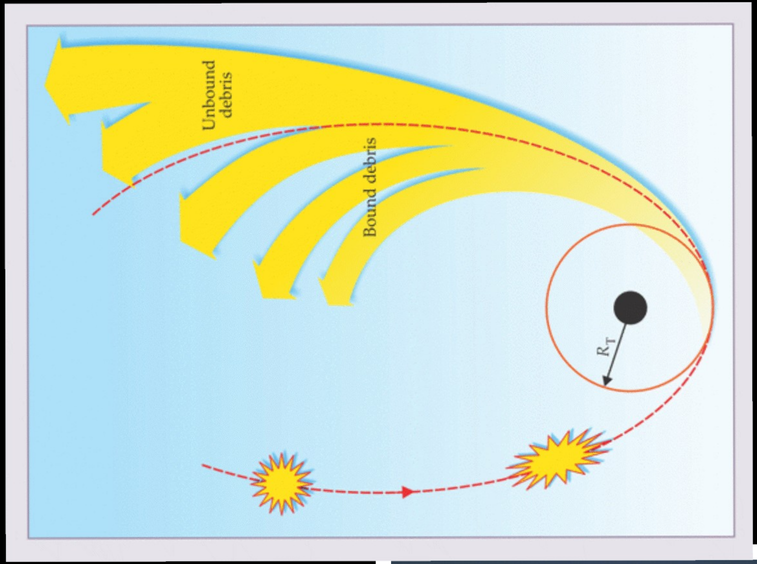

*Plunging radius* $r_{plunge} = 4\,R_s \approx 0.1\,AU\,M_6$

$$M_6 = M/10^6\,M_{\odot}$$

# Tidal Disruption Events (TDEs)

Hills 1975, Rees 1988



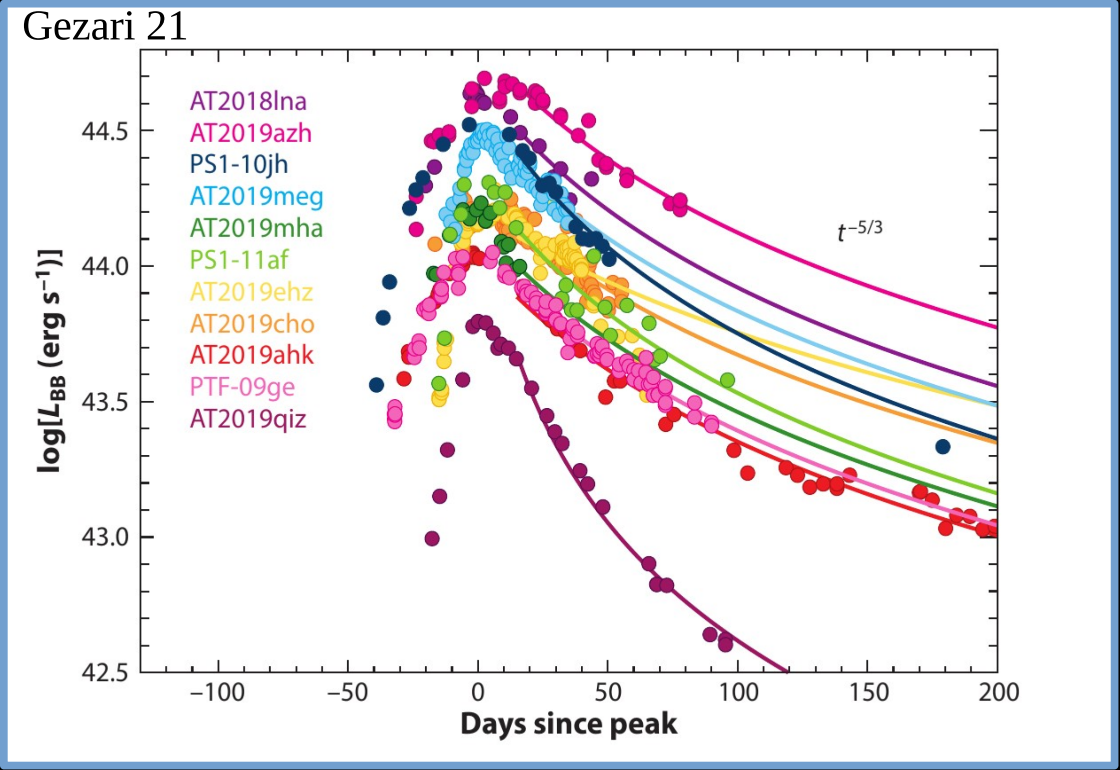


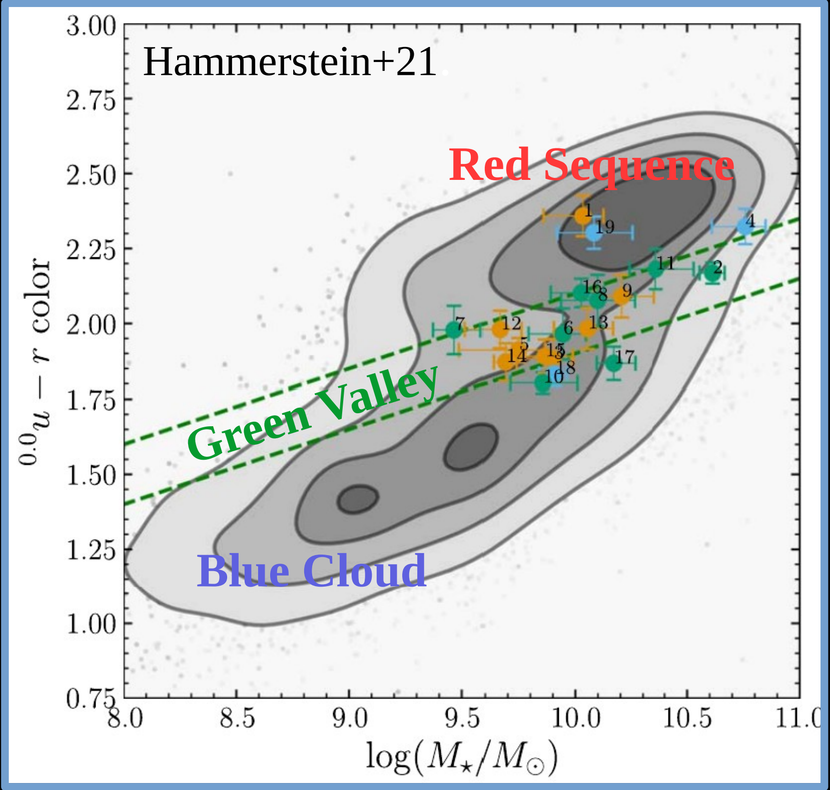
*Electromagnetic flare in radio, optical, X-rays*

*Tidal disruption radius*

$$r_{tid} = R_* \left( \frac{M}{m_*} \right)^{1/3} \approx 0.5\, AU\, M_6^{1/3}$$

# TDEs and their Hosts

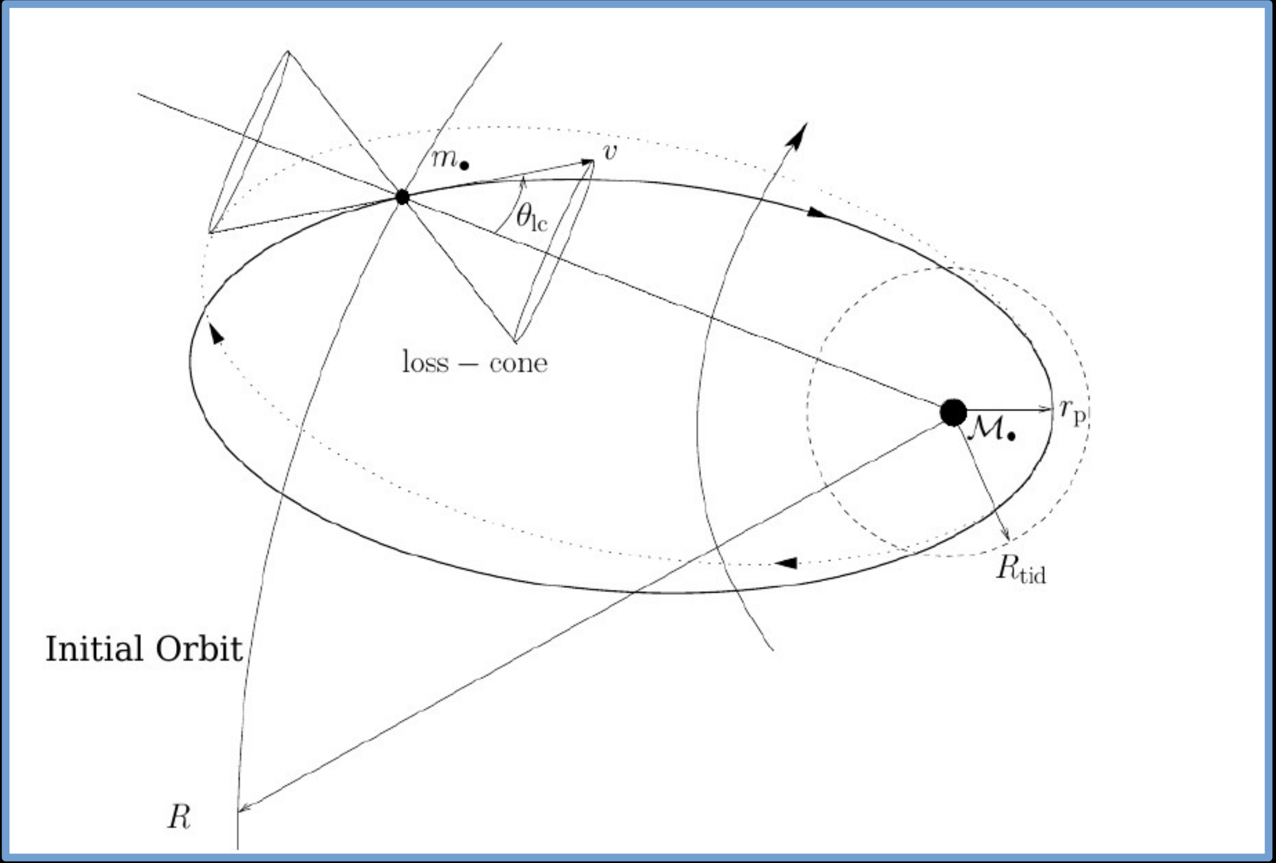



*~ 100 TDE candidates*

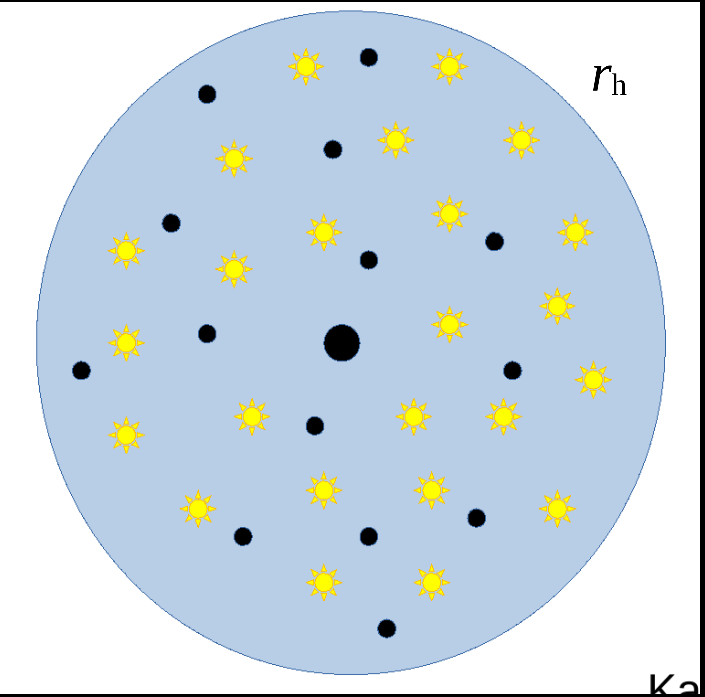
- Preferred hosts are Post-starburst (E+A) galaxies
- Association with recently faded Active Galactic Nuclei AGNs (Wevers & French 2024)

# Loss Cone Dynamics




Frank & Rees 76,
Lightman & Shapiro 77,
Cohn & Kulsrud 78,
Amaro-Seoane 18

# Loss cones in Spherical NSC

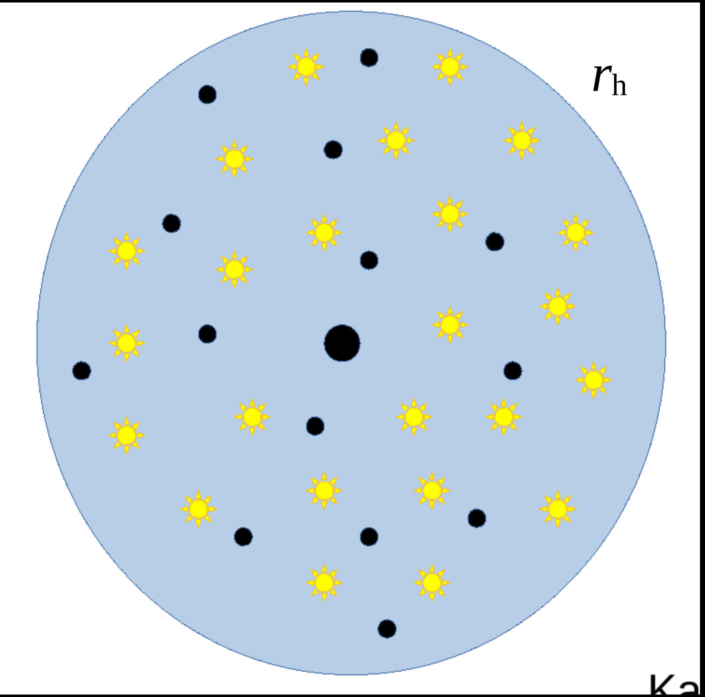


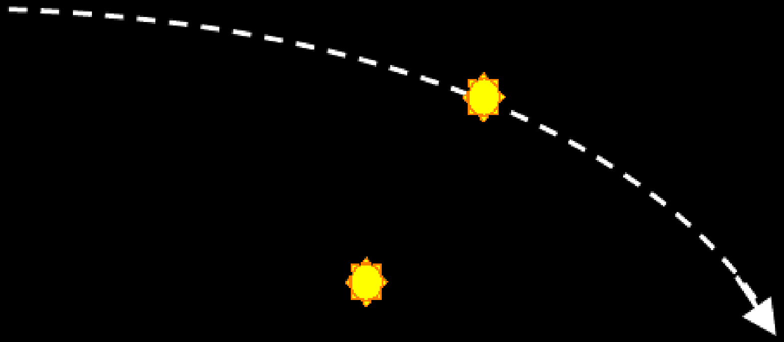

Radius of influence

$$r_h \approx \frac{G\,M}{\sigma^2} \approx 1\,pc\,\sqrt{M_6}$$

From $M \propto \sigma^4$ relation

# Loss cones in Spherical NSC



$\Delta v \Rightarrow \Delta E, \Delta L$

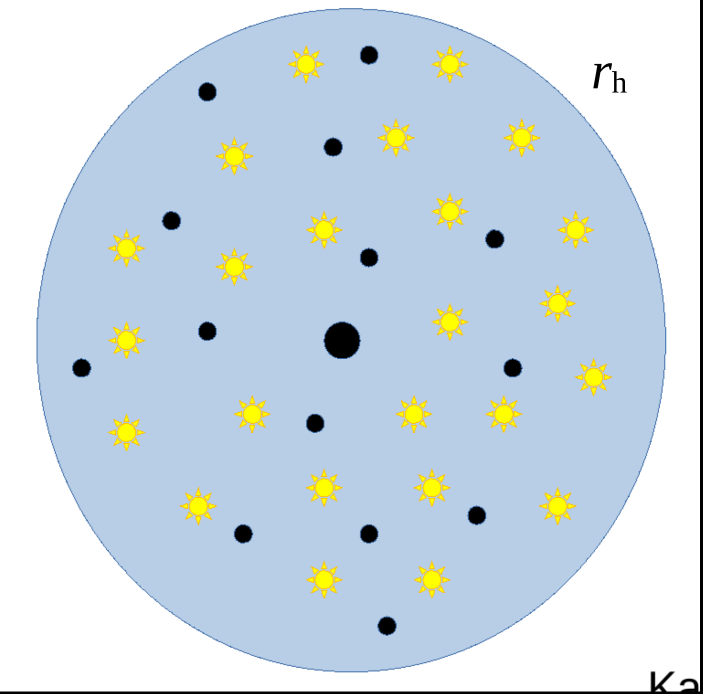
*Two-body scatterings*

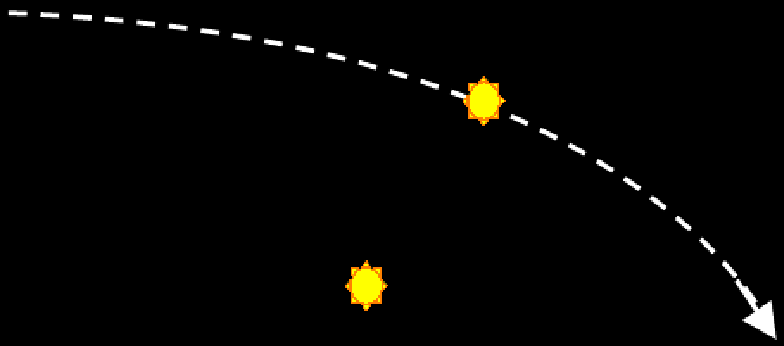
Hyperbolic gravitational interactions

$\Delta E = v \Delta v$

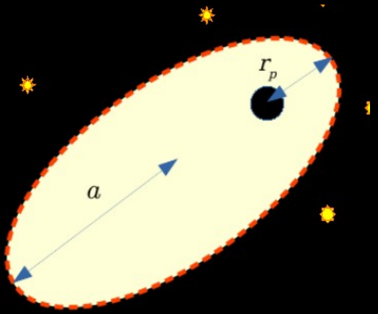
$\Delta L = r \Delta v$

# Loss cones in Spherical NSC



$$\Delta v \Rightarrow \Delta E, \Delta L$$



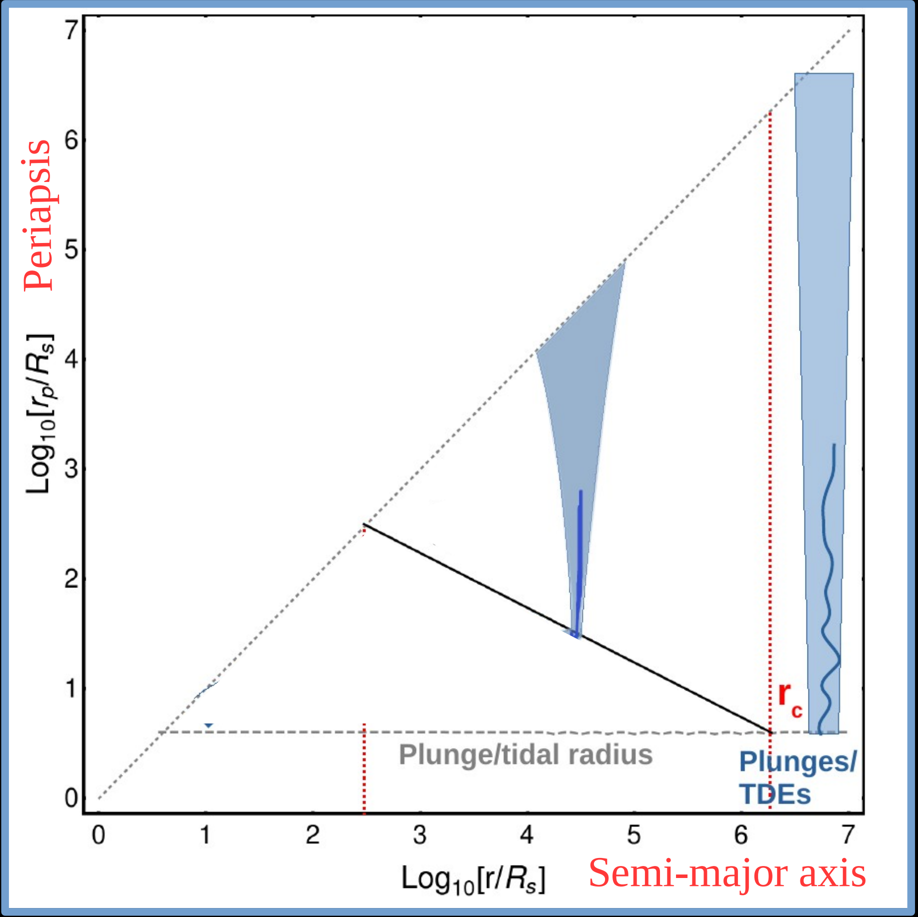

$\Delta E = v \Delta v$ *Pericentre*

$\Delta L = r \Delta v$ *Apocentre*

*Diffusion in L much faster than E for high ecc orbits.*

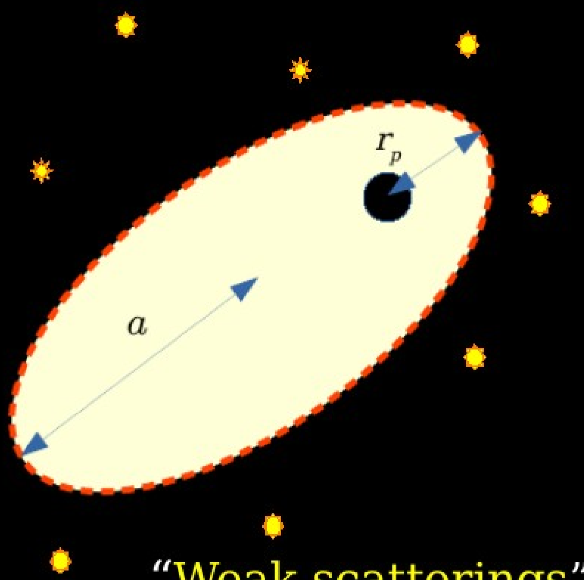
# Loss cones in Spherical NSC

Kaur, Rom & Sari (2025)




Advection in $E$

Fast diffusion in $L$

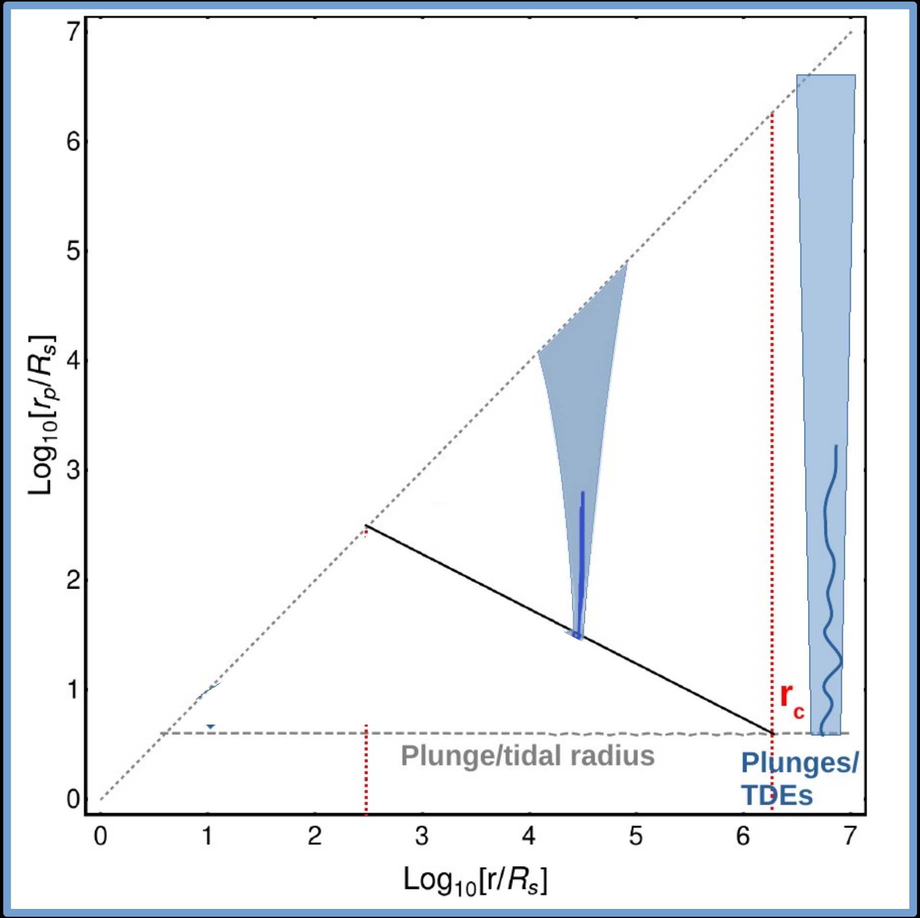



"Weak scatterings"

$$E = -\frac{GM}{2a}$$

$$L \simeq \sqrt{2GMr_p}$$

# Loss cones in Spherical NSC




Advection in *E*

Fast diffusion in *L*

## 2-Body Relaxation Time

$$T_L \sim T_{2b} r_p / a$$

$$T_{2b} \sim \frac{T_{kep}}{\ln \Lambda} \left( \frac{M}{m_f} \right)^2 \frac{1}{N_f(a)} \simeq 1\,Gyr\, M_6^{5/4} a_1^{\gamma - 3/2}$$

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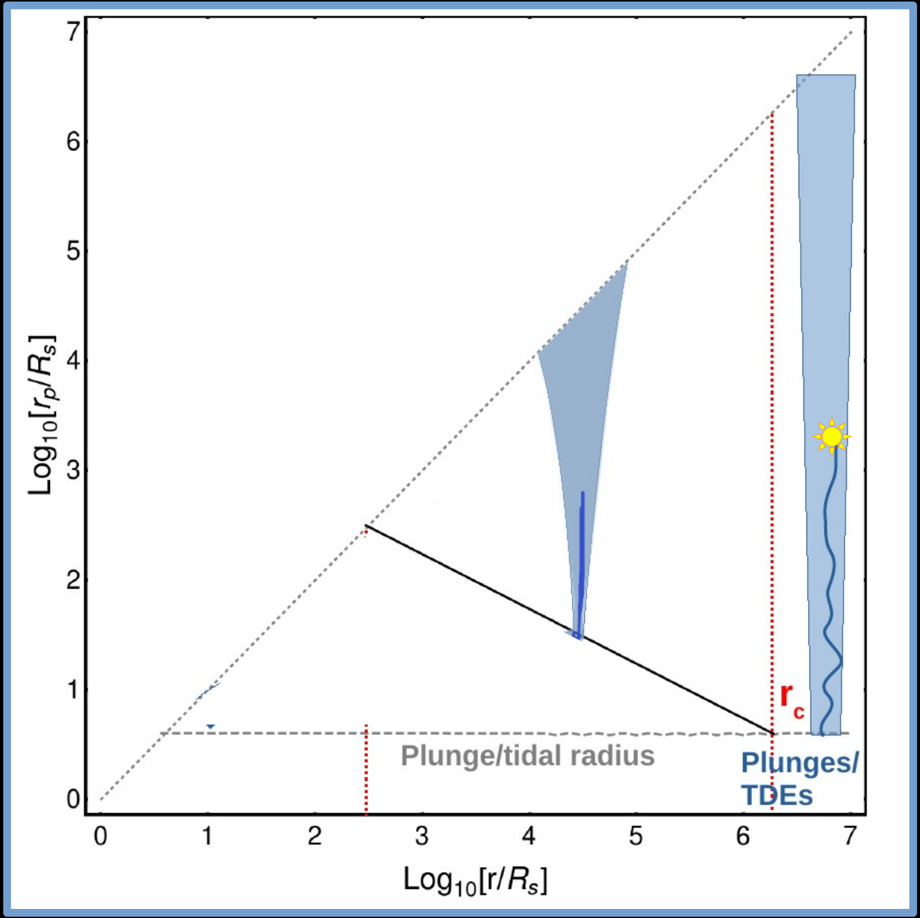
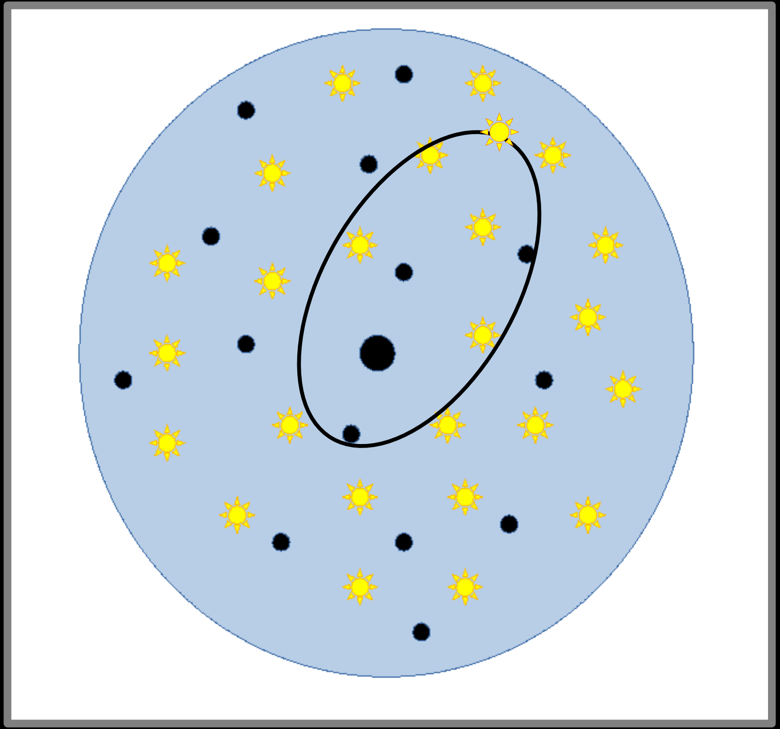



Advection in *E*

2-Body Relaxation

Fast diffusion in *L*



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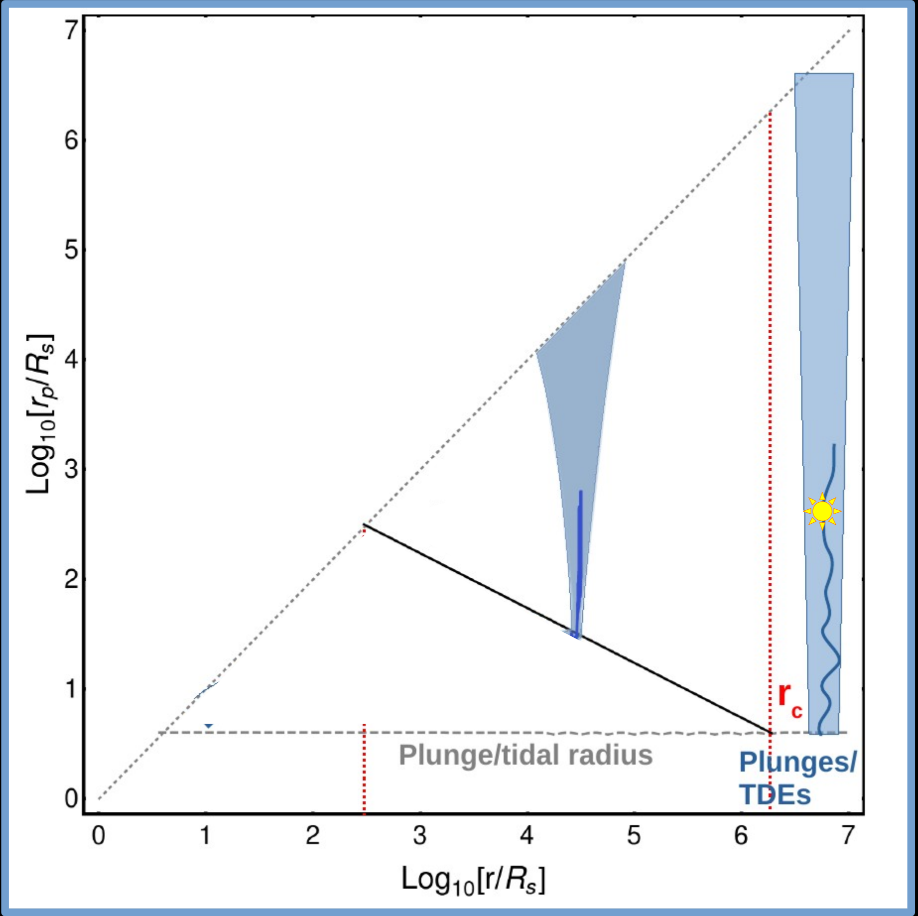


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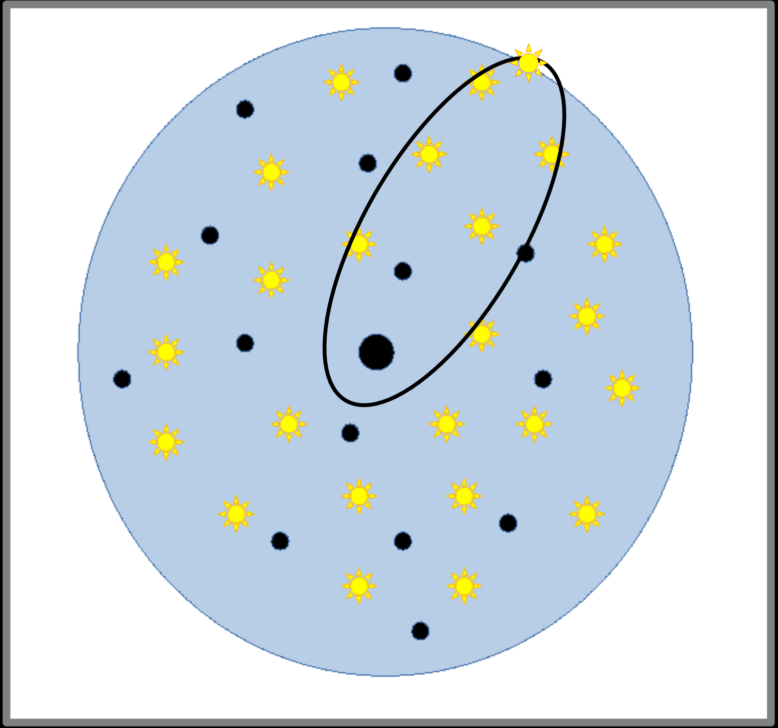

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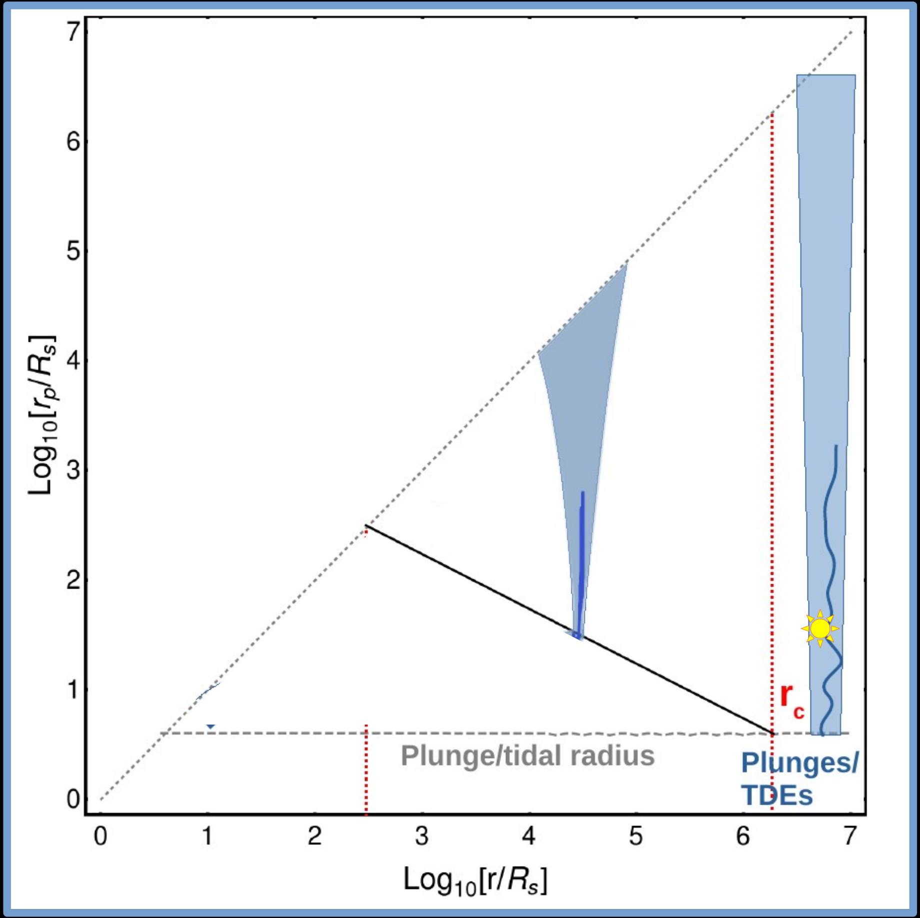


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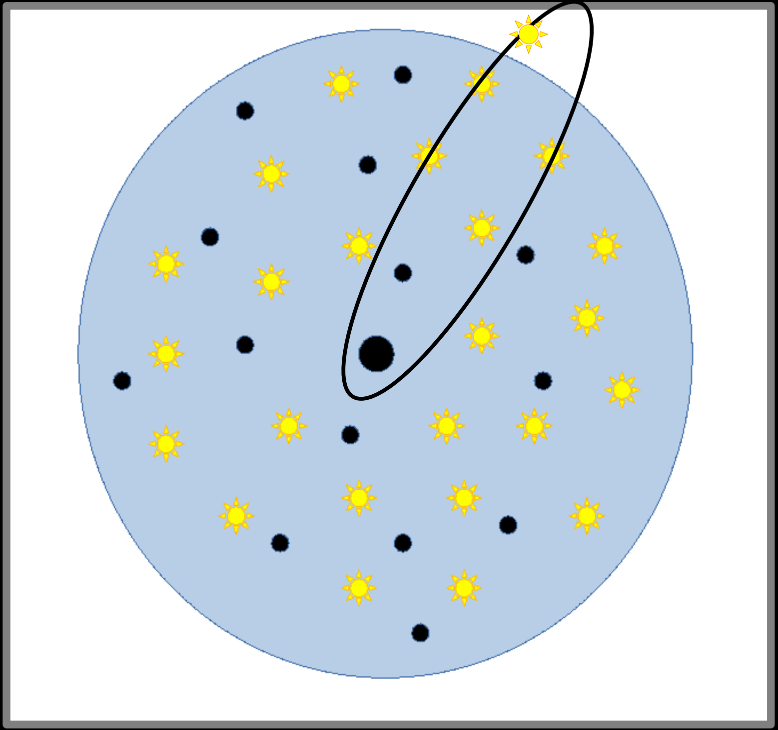

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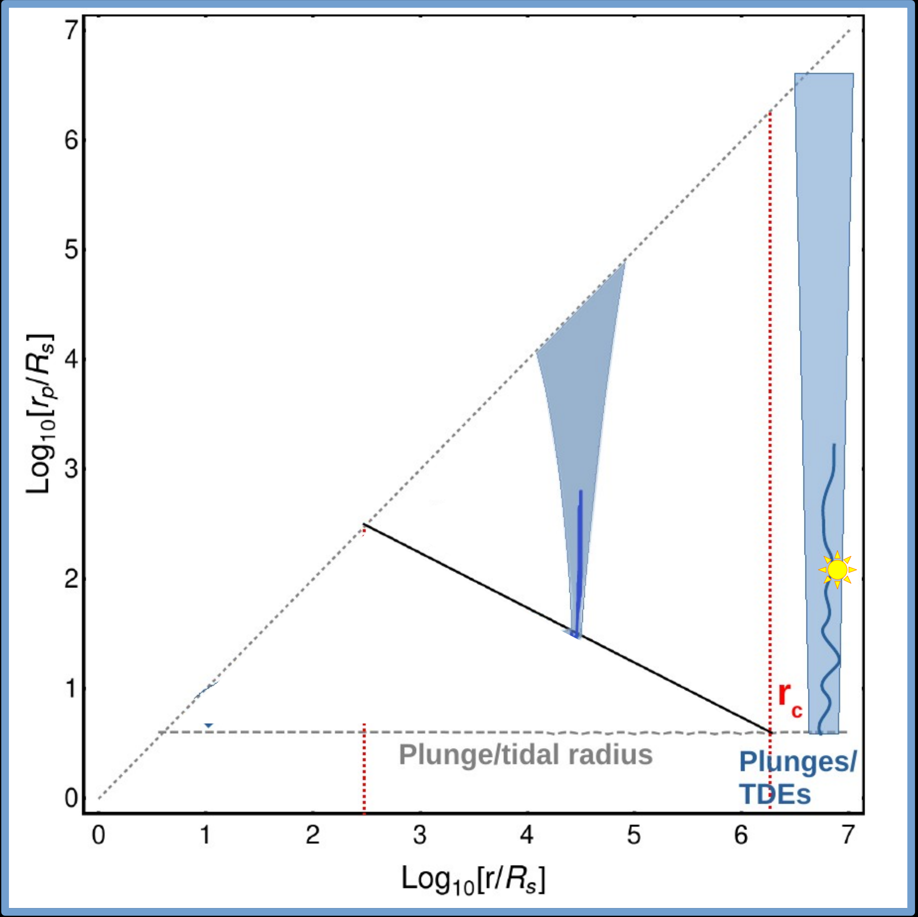


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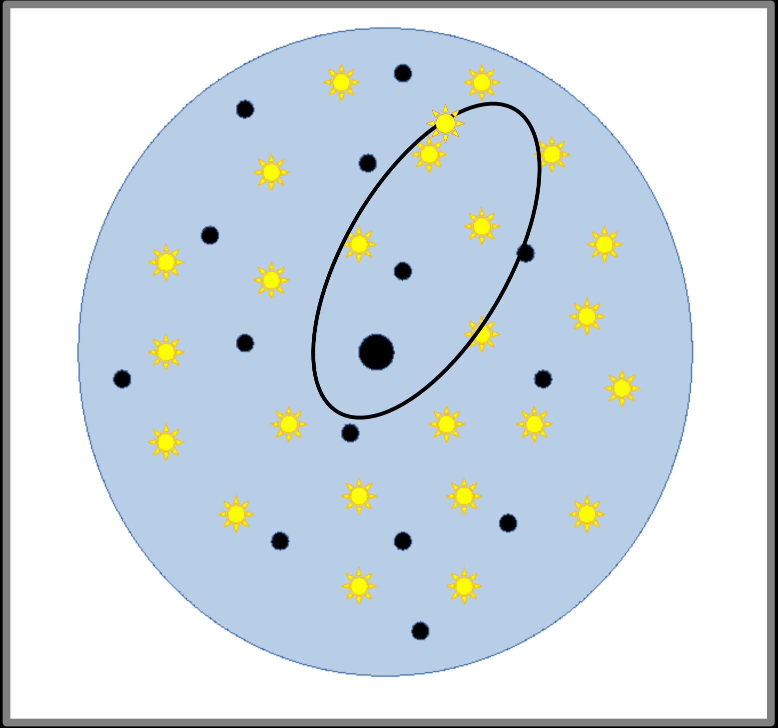

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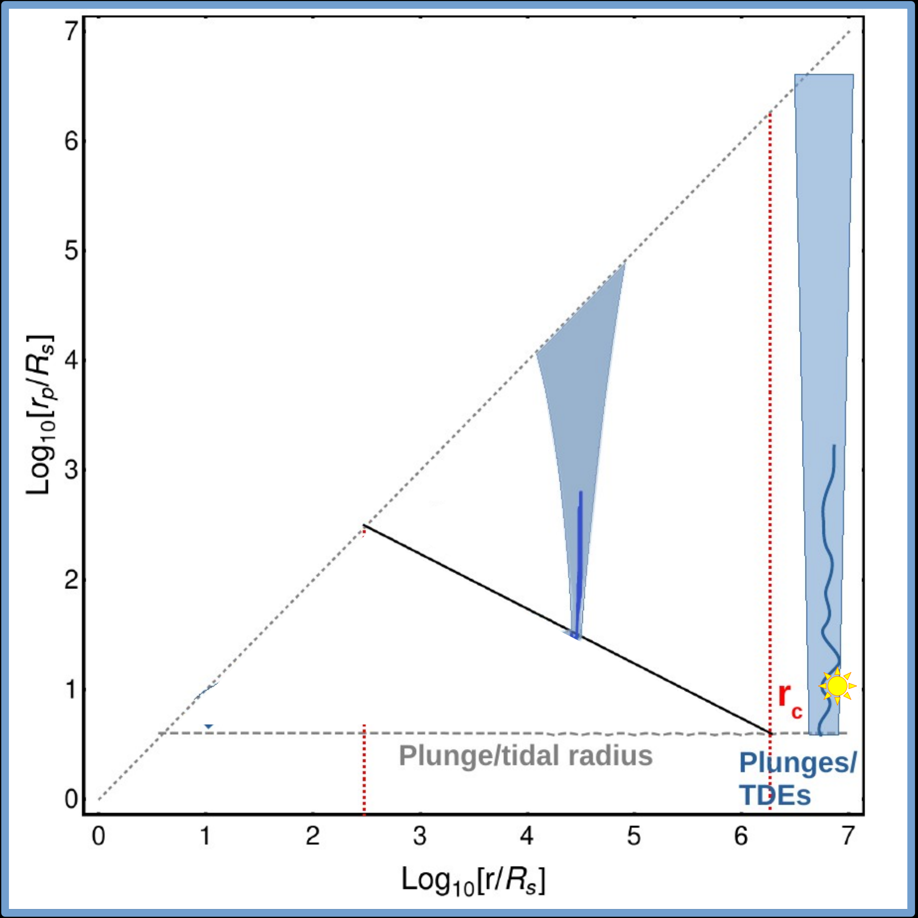


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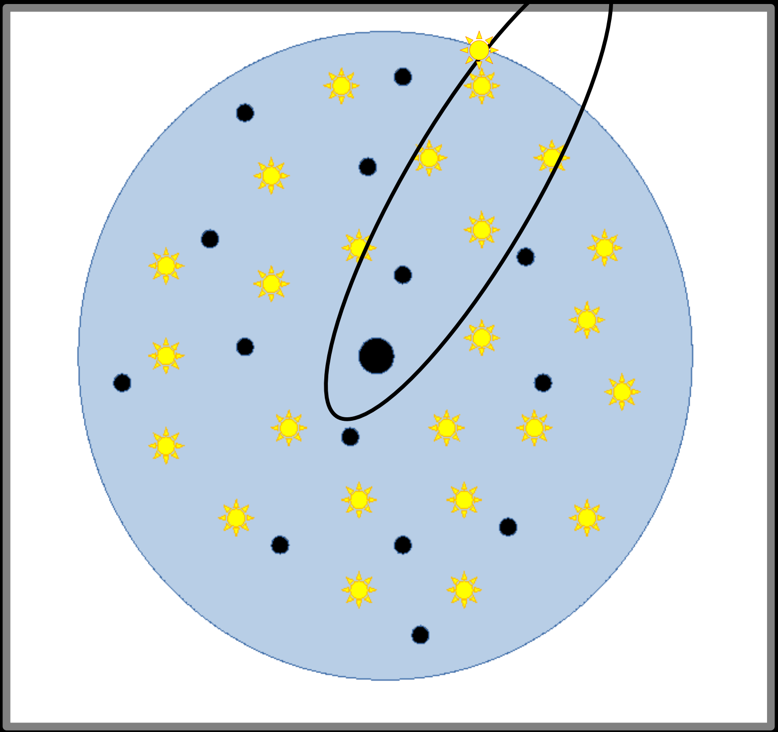

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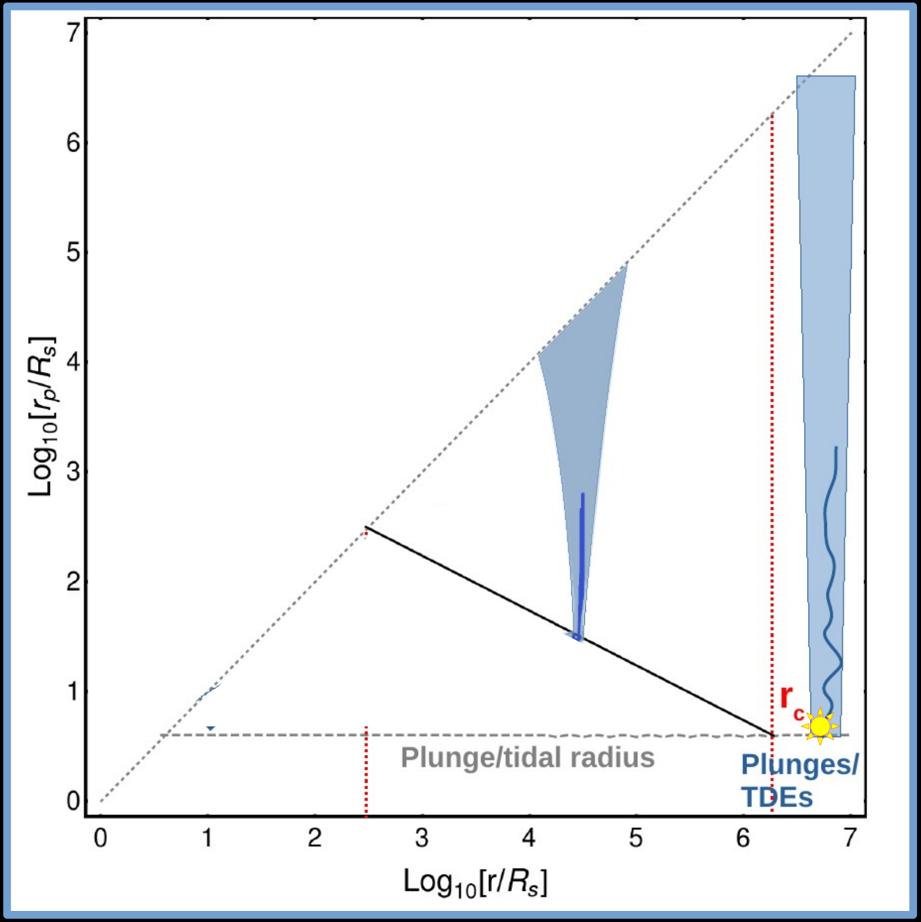


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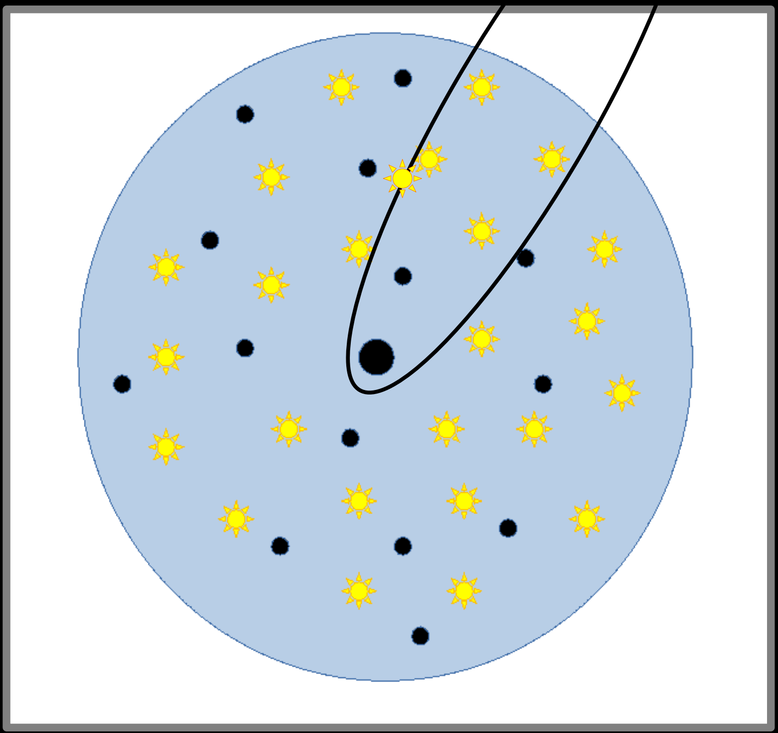

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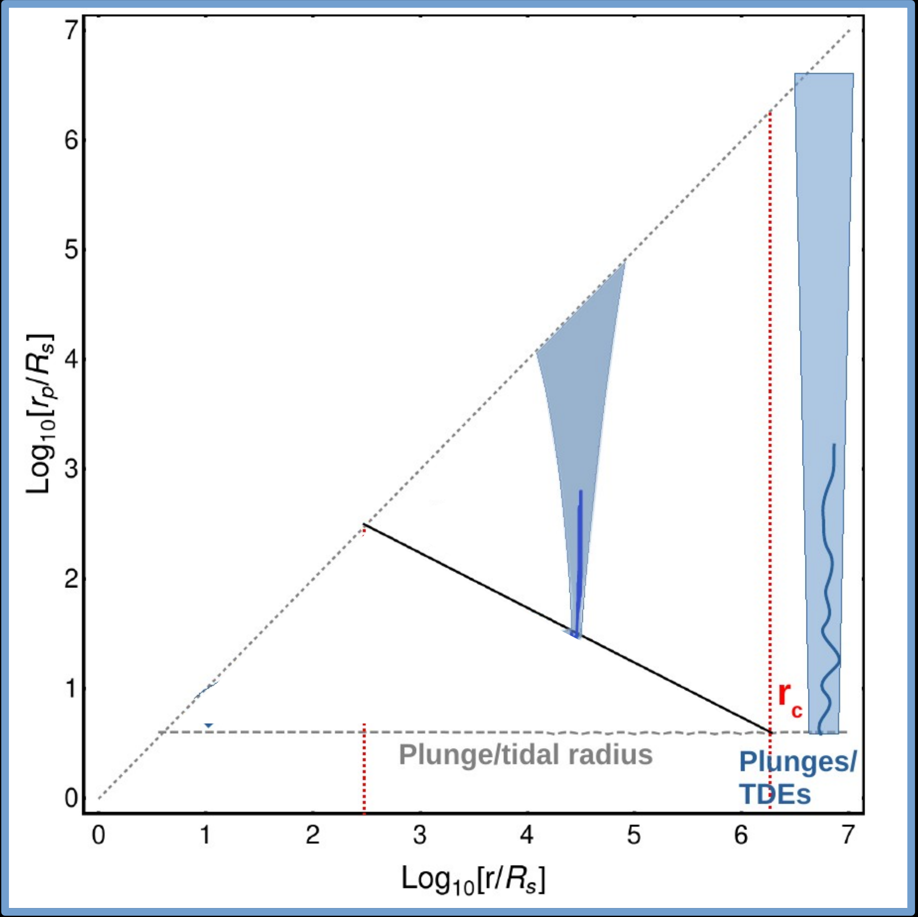


Fast diffusion in $L$

Advection in $E$

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$$T_L \sim T_{2b} r_p / a$$

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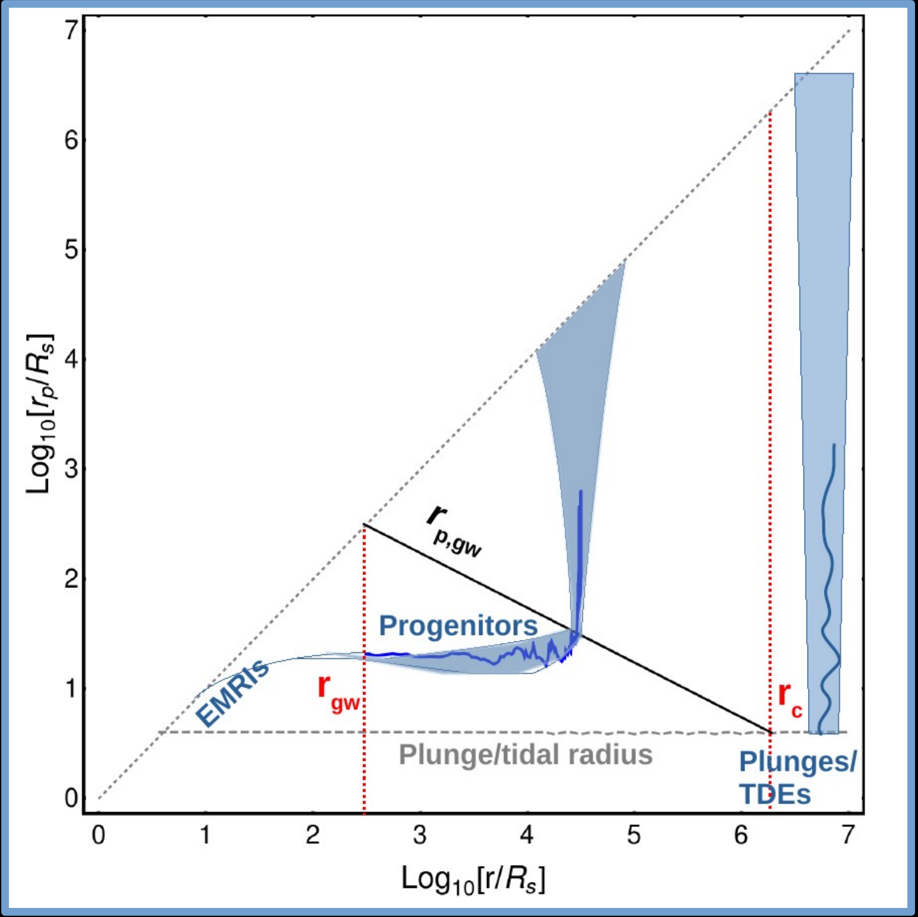


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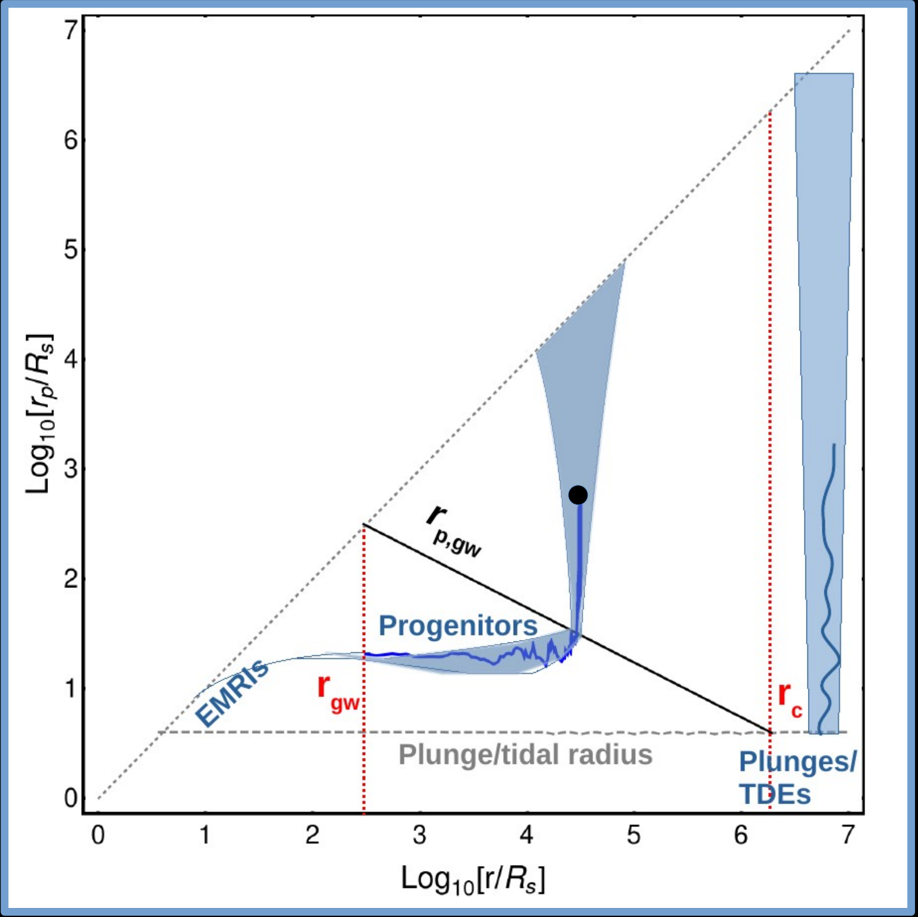
GW Inspiral Time

$$T_{gw} \sim \frac{R_s}{c} \frac{M}{m} \left( \frac{r_p}{R_s} \right)^{7/2} \left( \frac{a}{R_s} \right)^{1/2} \simeq 10^3\, yr\, a_{-2}^{1/2} r_{p,-7}^{7/2} M_6^{7/4}$$

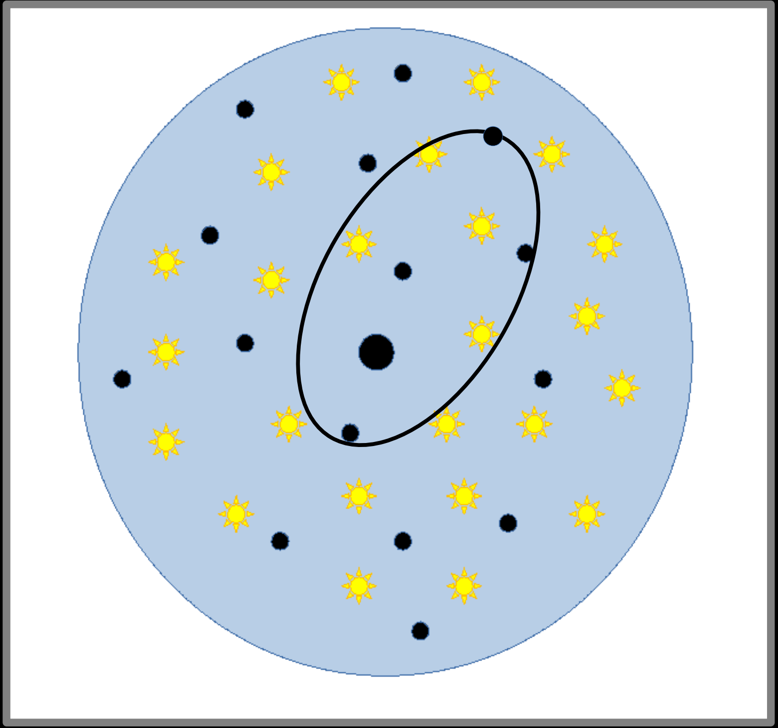
# Loss cones in Spherical NSC




Advection in *E*

Fast diffusion in *L*

2-Body Relaxation & GW inspiral



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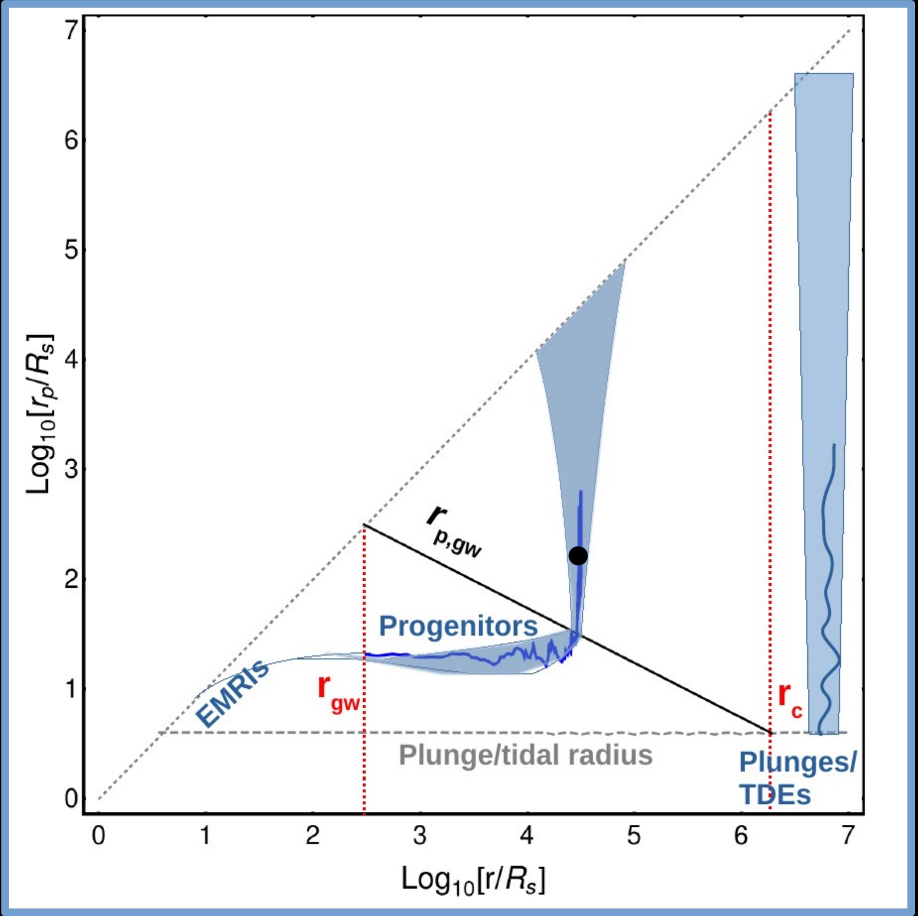


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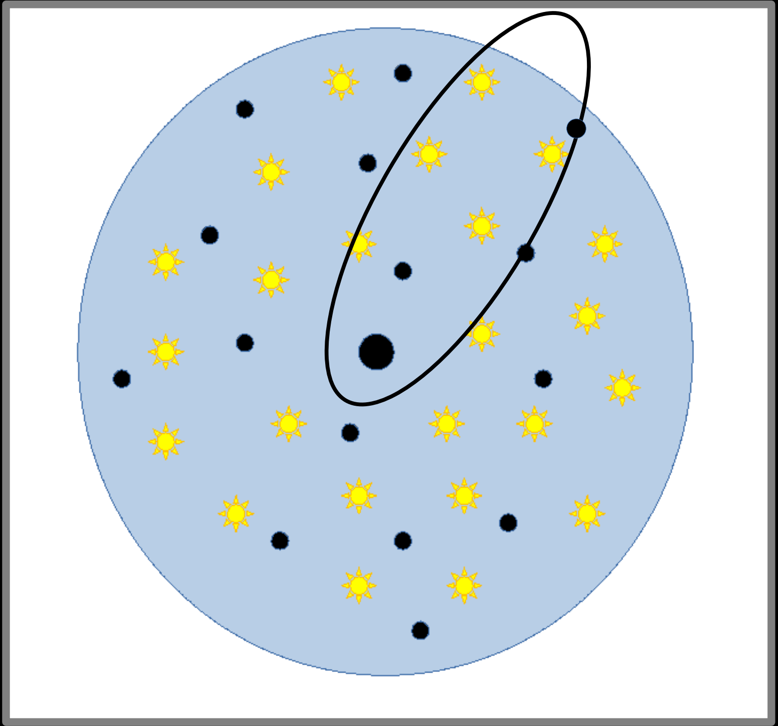

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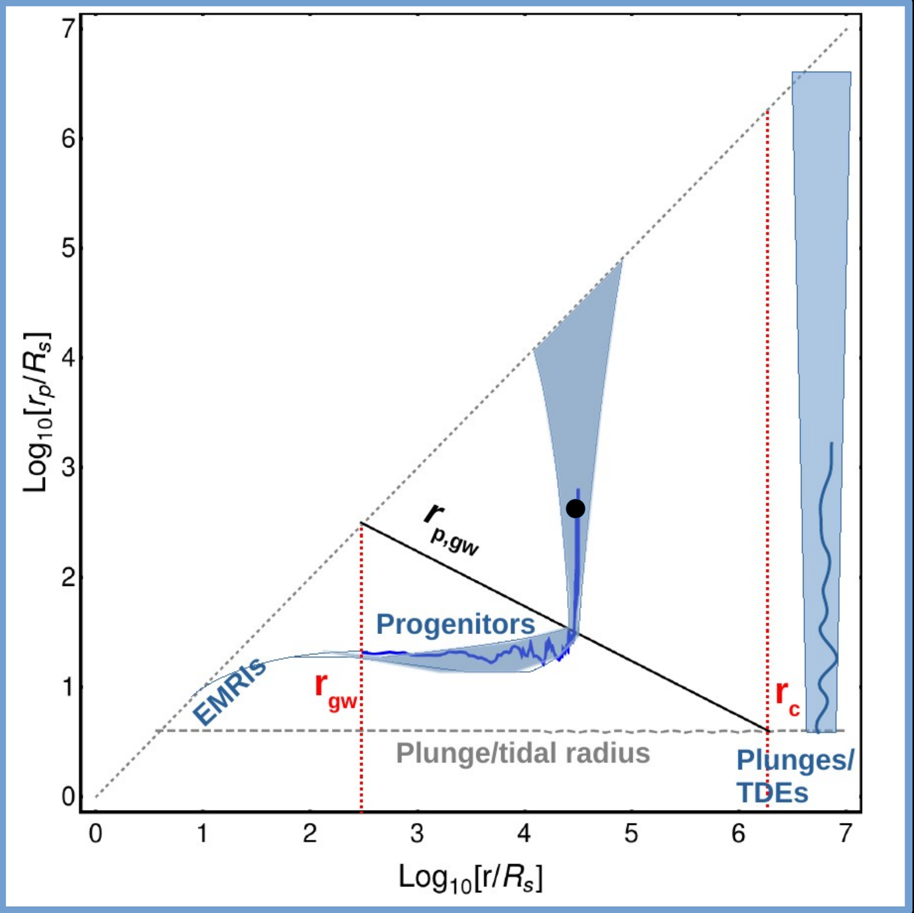


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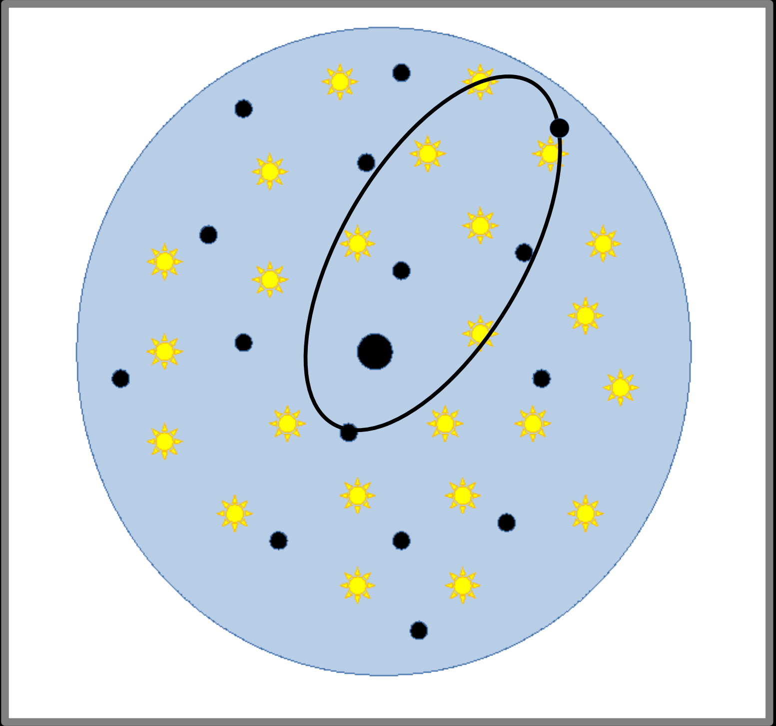

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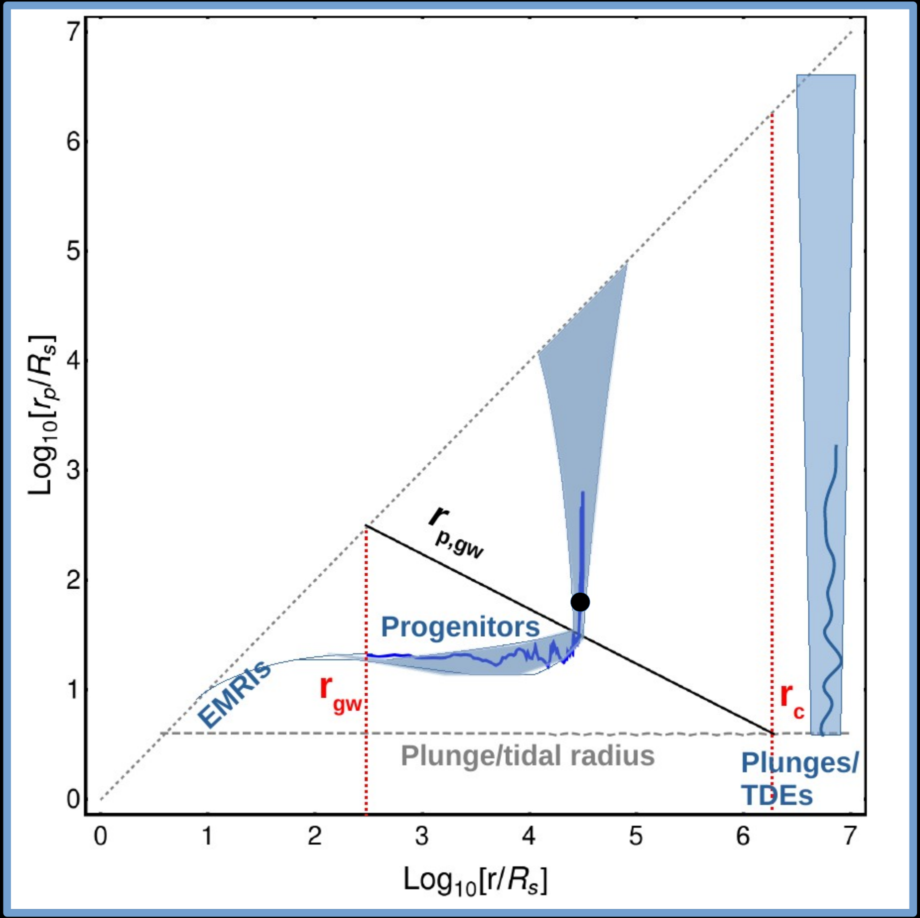


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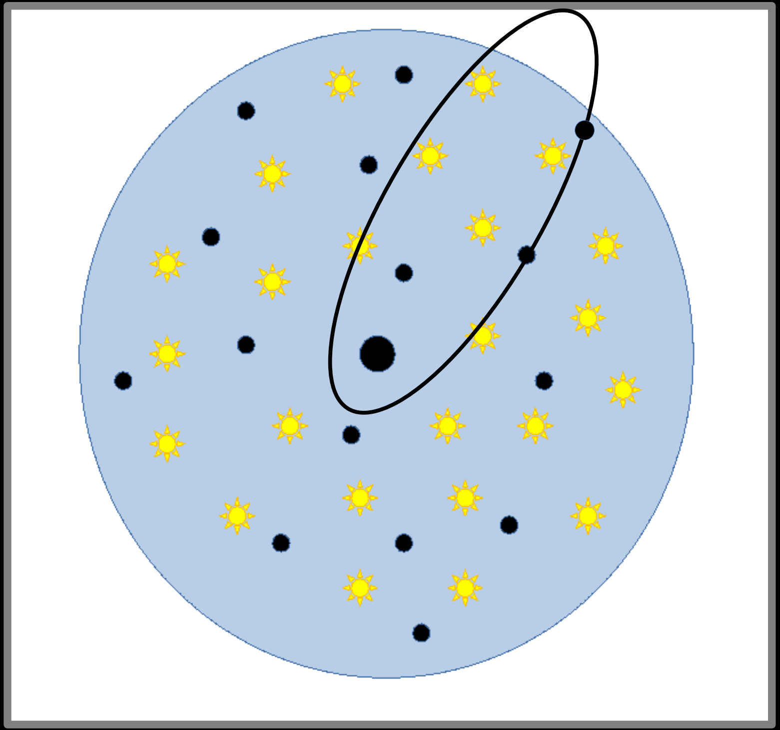

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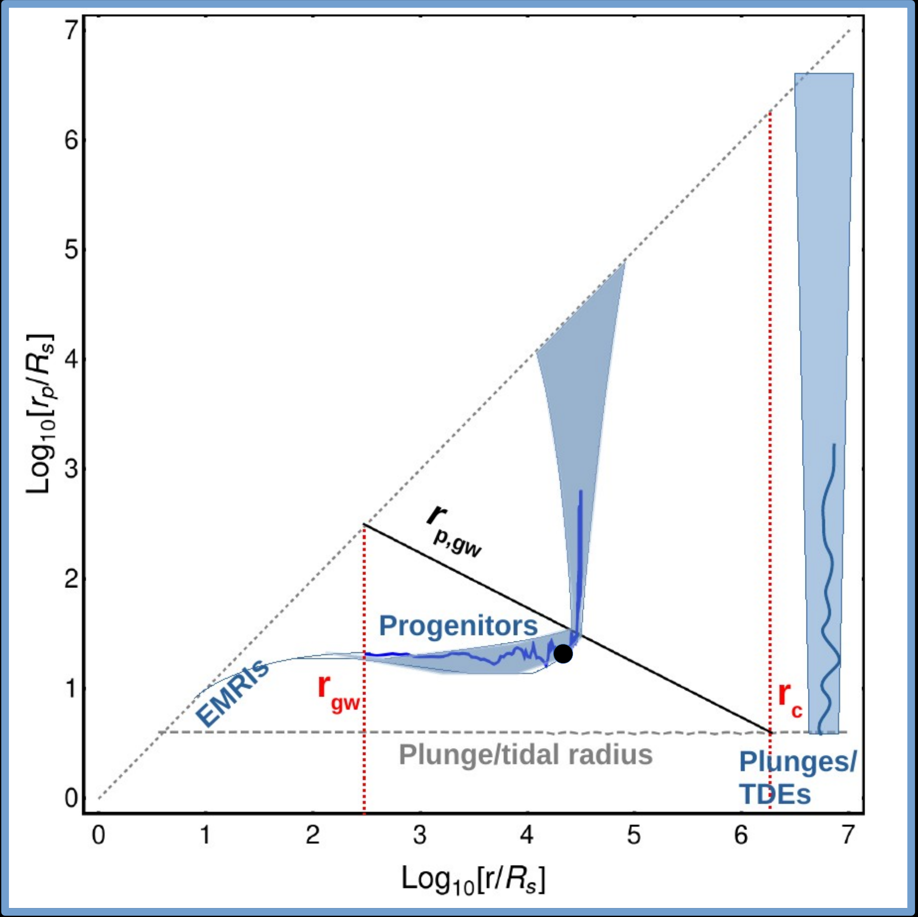


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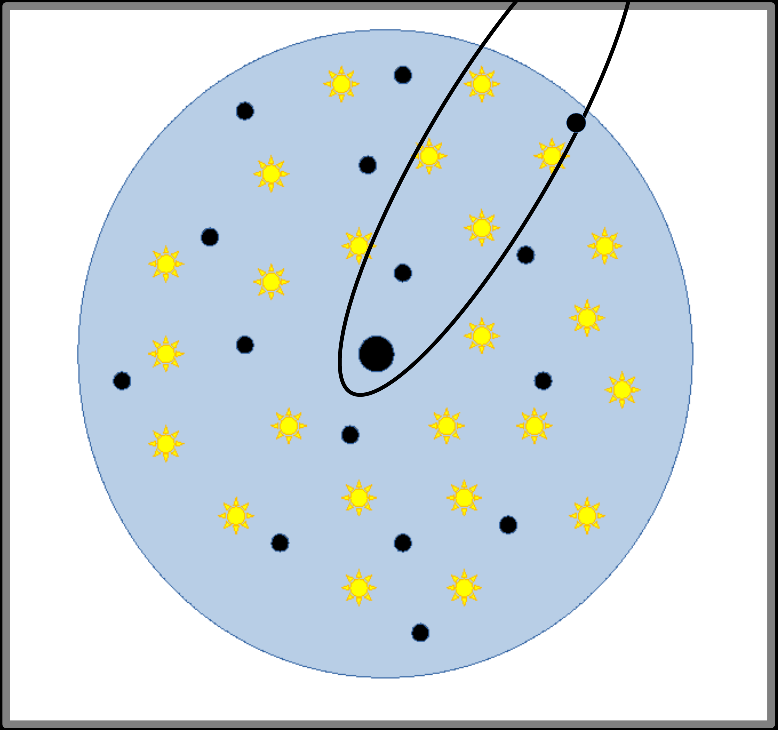

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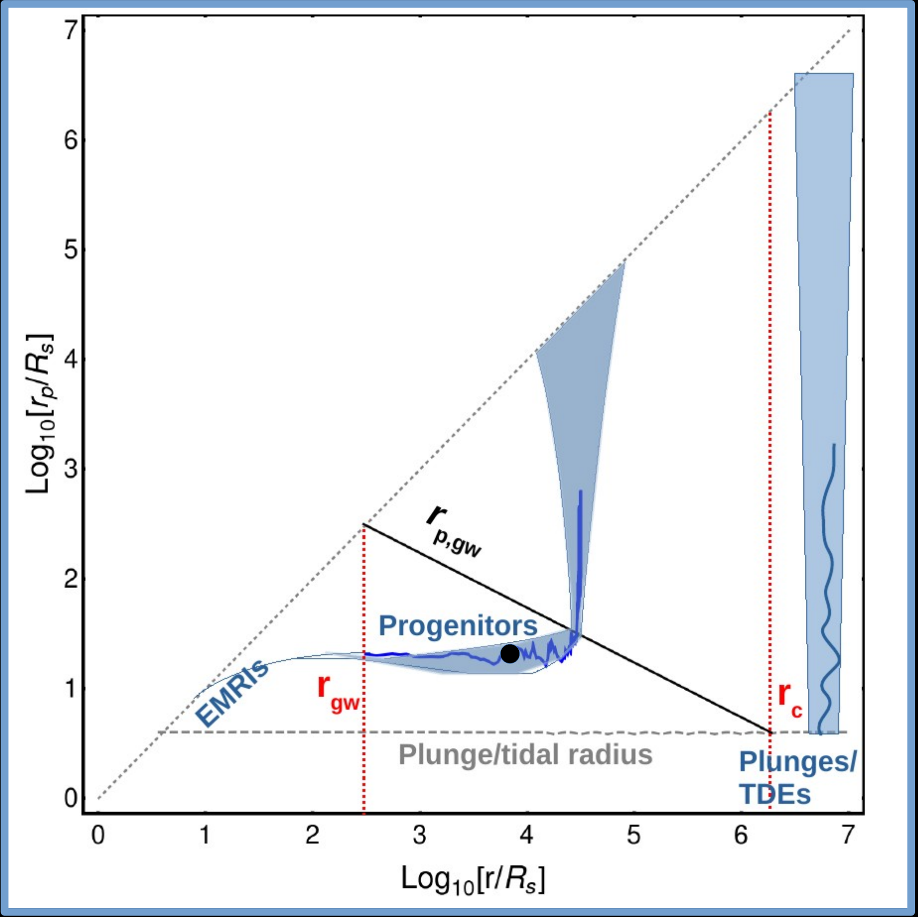


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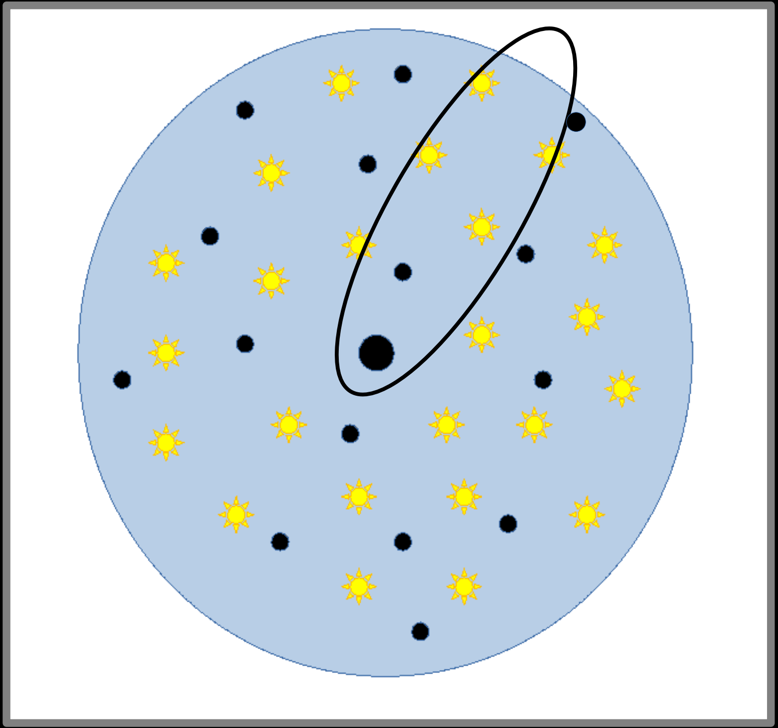

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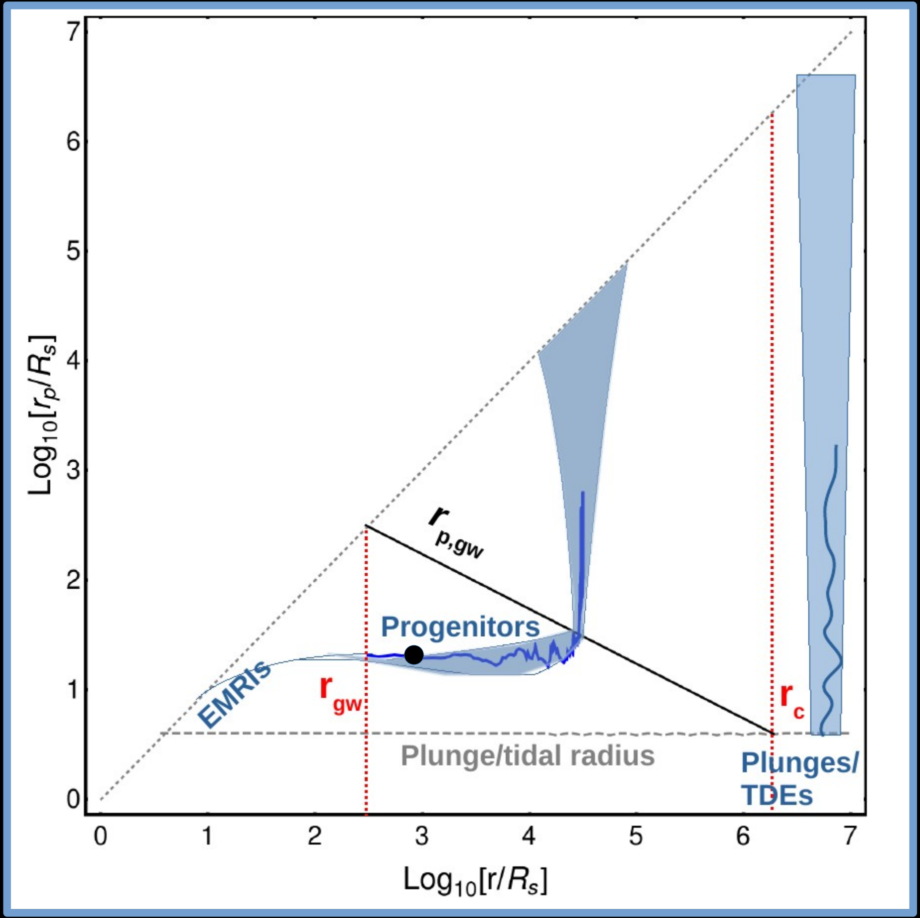


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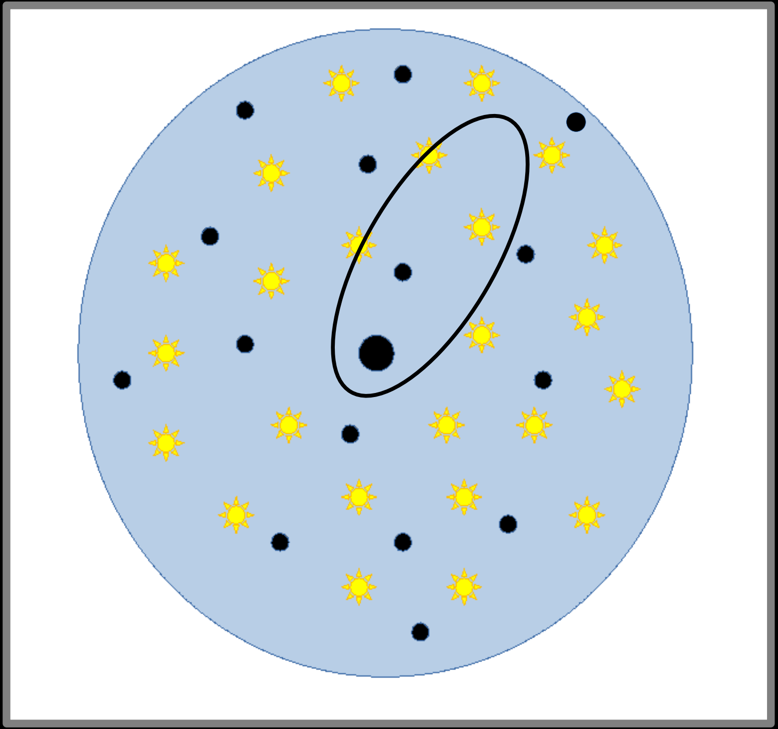

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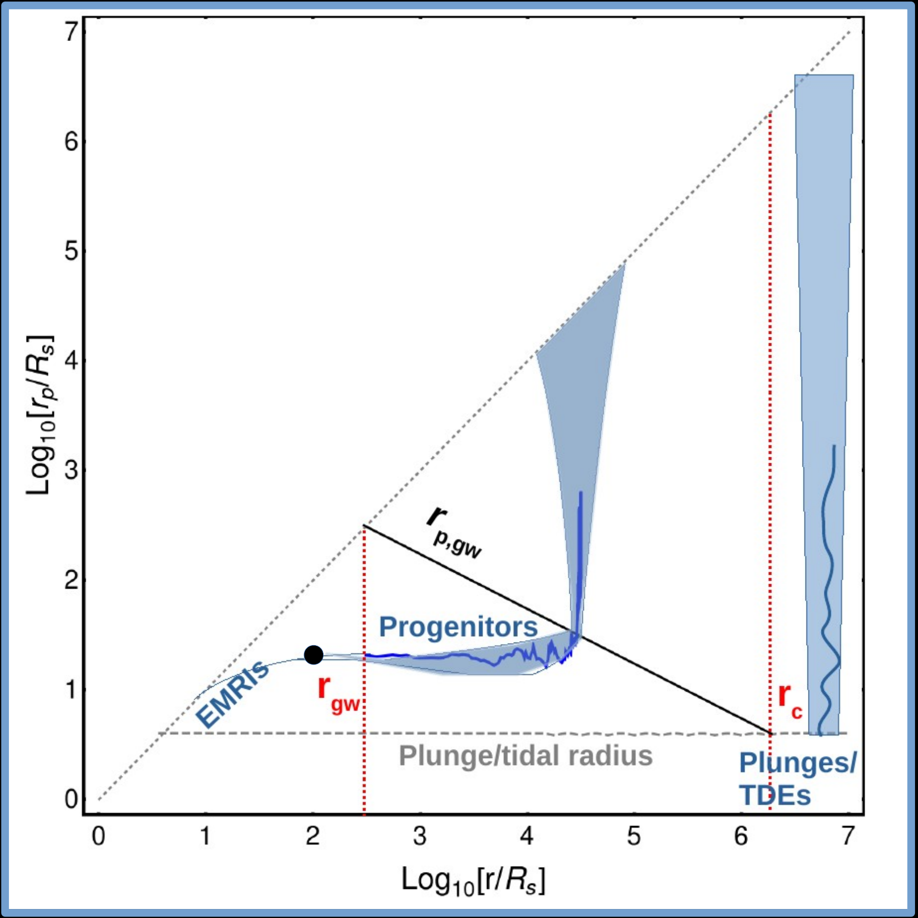


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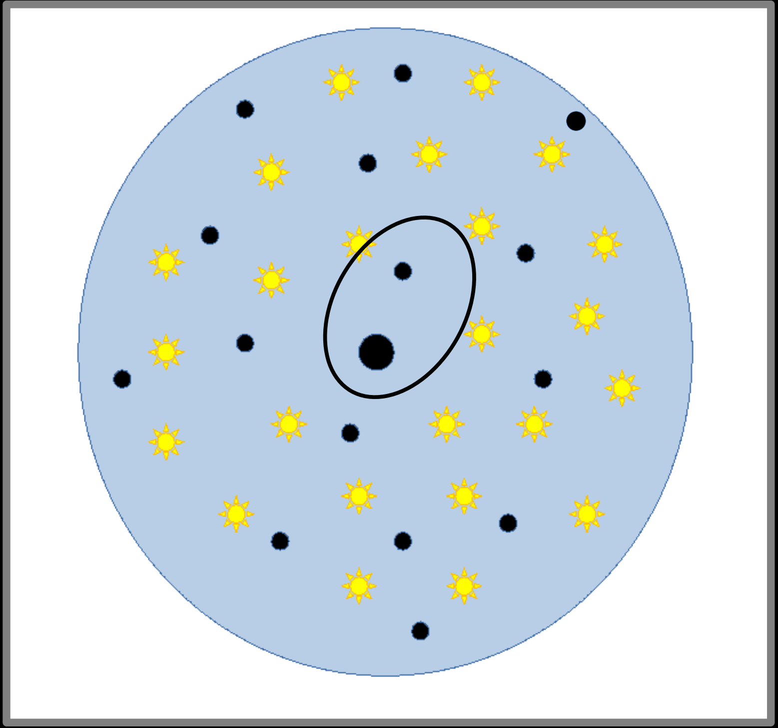

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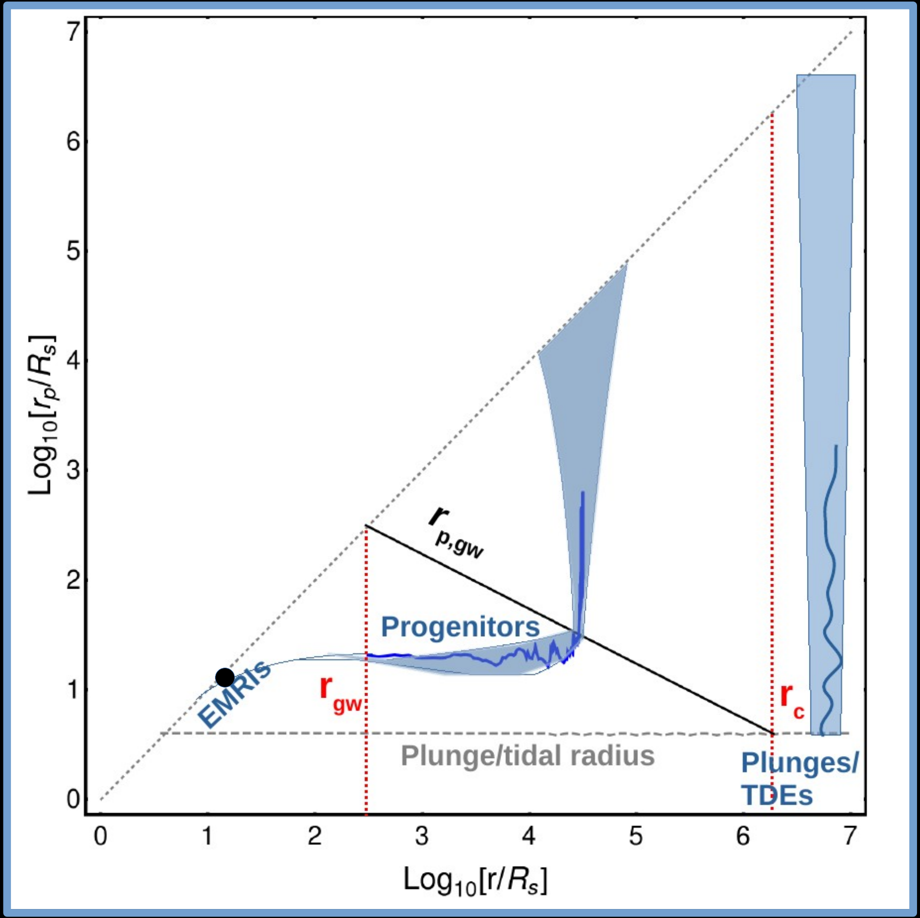


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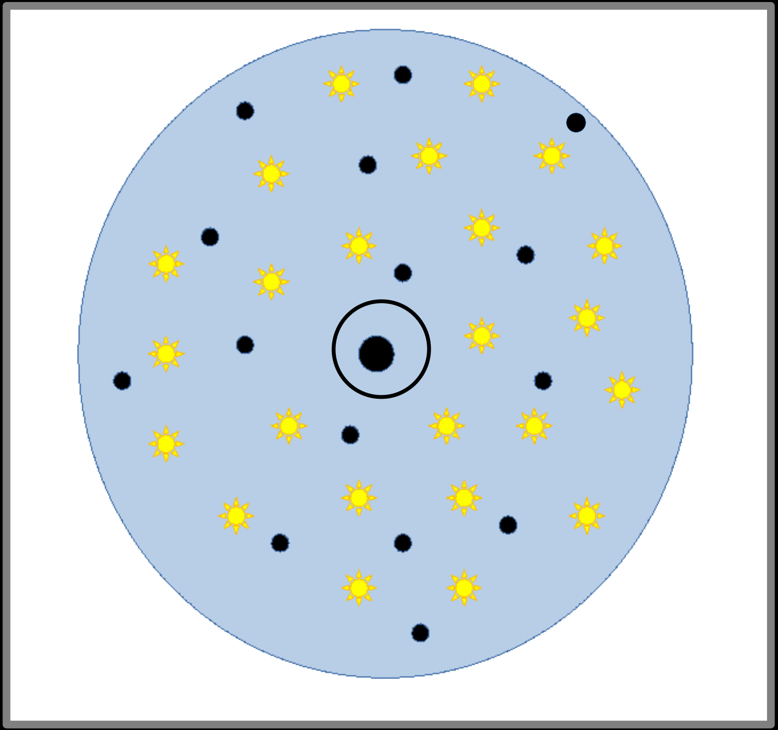

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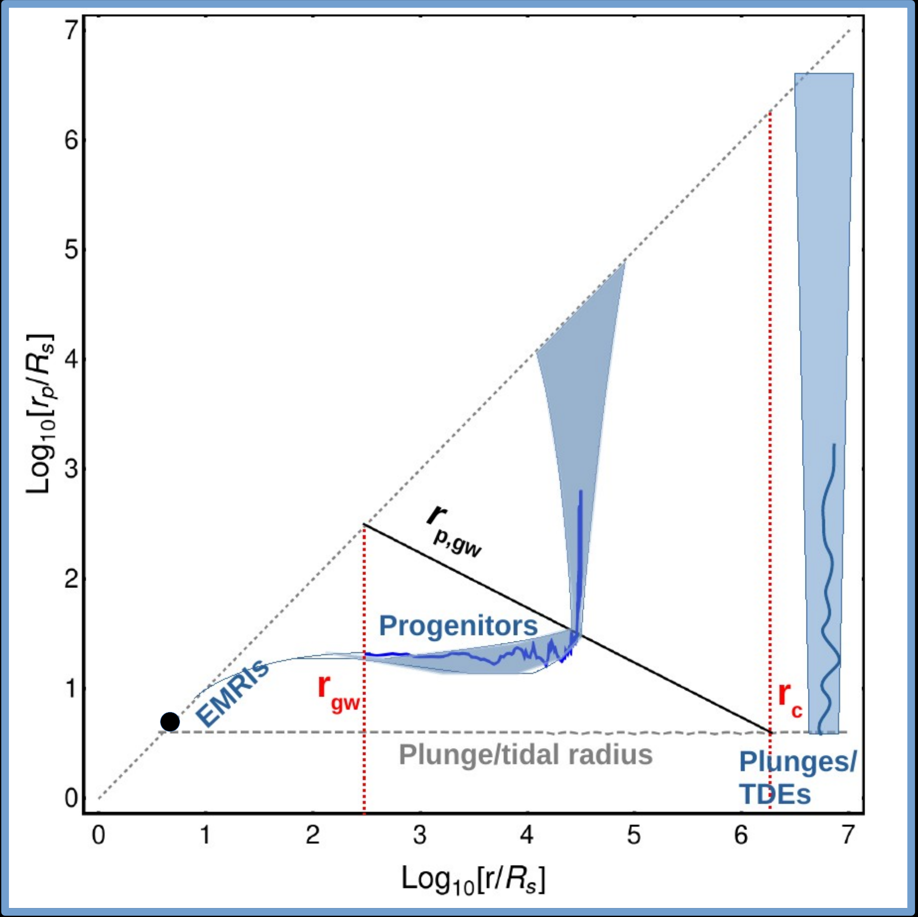


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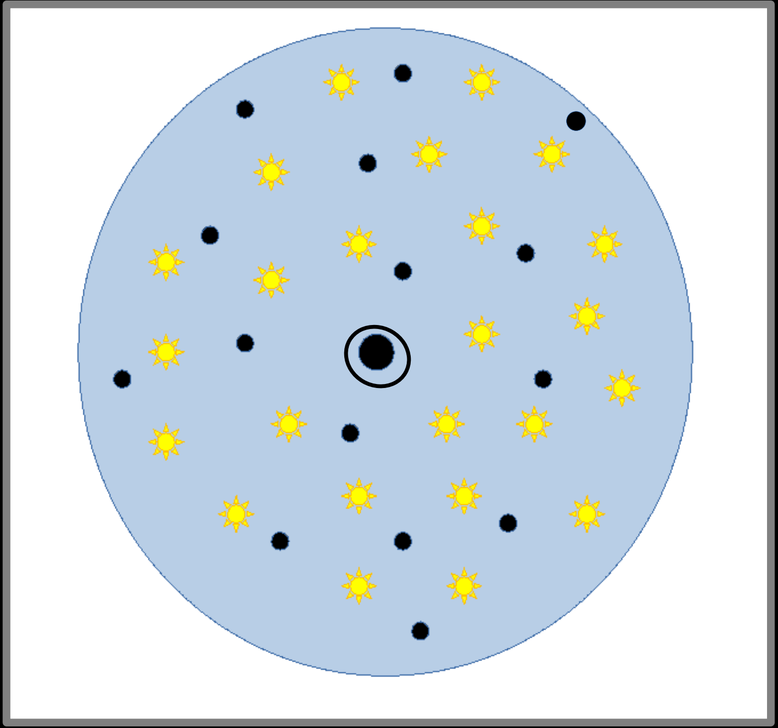

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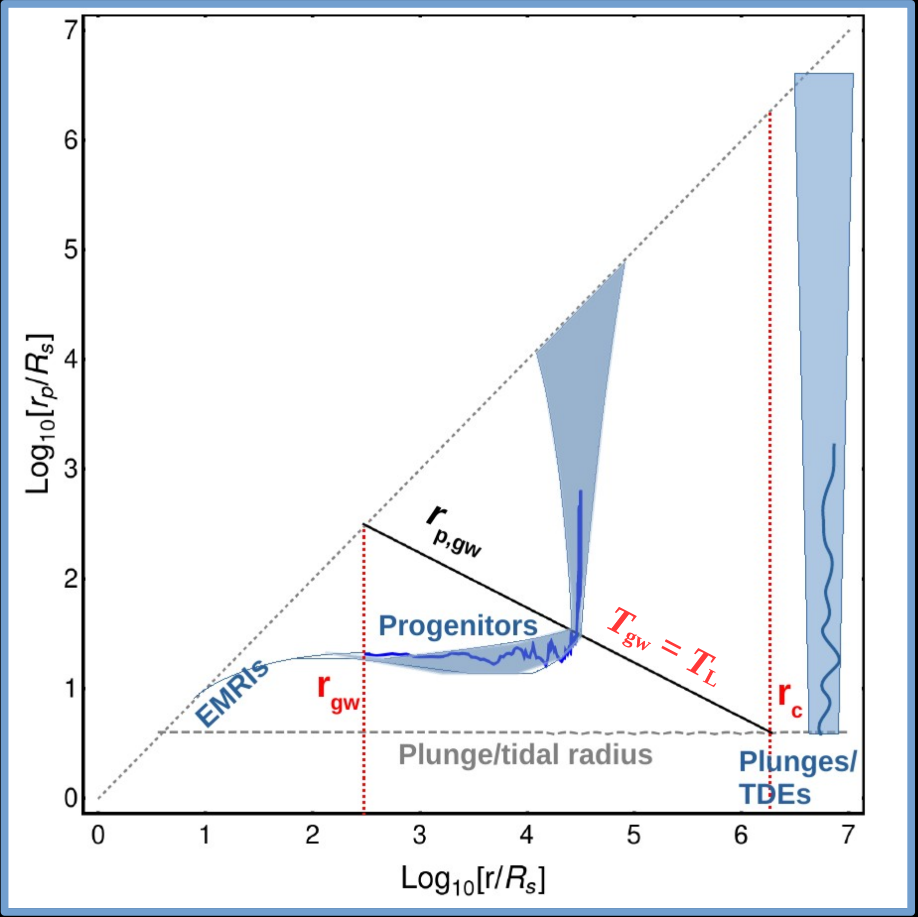



## 2-Body Relaxation Time

$$T_L \sim T_{2b} r_p / a$$

$$T_{2b} \sim \frac{T_{kep}}{\ln \Lambda} \left( \frac{M}{m_f} \right)^2 \frac{1}{N_f(a)} \simeq 1\, Gyr\, M_6^{5/4} a_1^{\gamma - 3/2}$$

## GW Inspiral Time

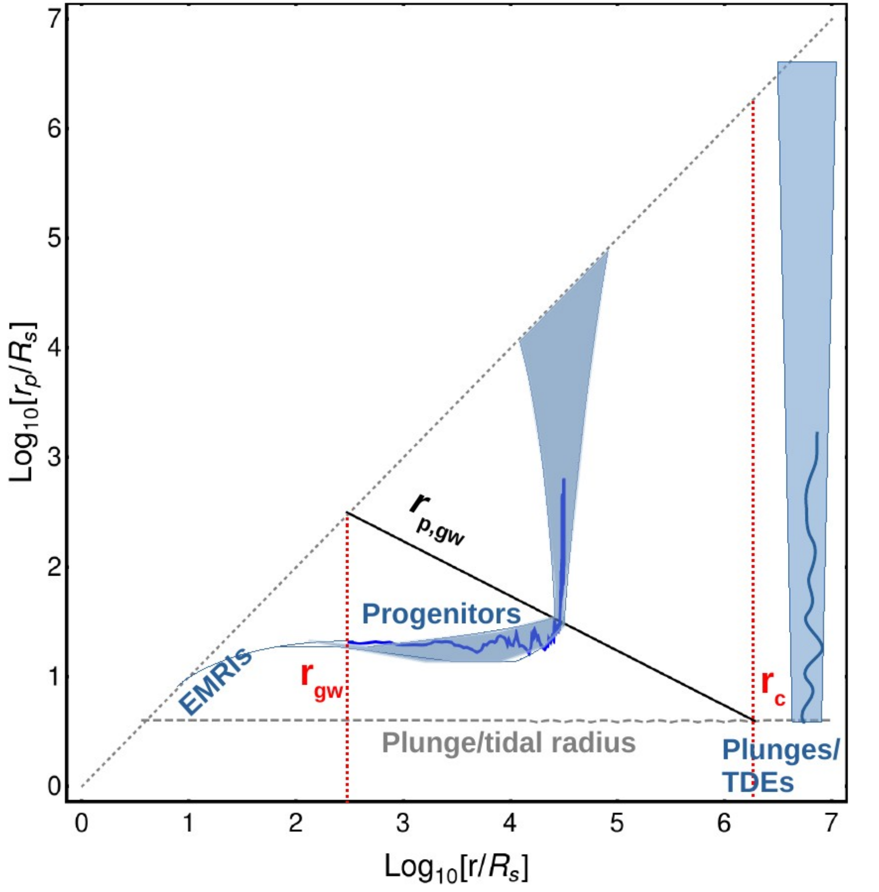
$$T_{gw} \sim \frac{R_s}{c} \frac{M}{m} \left( \frac{r_p}{R_s} \right)^{7/2} \left( \frac{a}{R_s} \right)^{1/2} \simeq 10^3\, yr\, a_{-2}^{1/2} r_{p,-7}^{3/2} M_6^{7/4}$$

## GW Loss Cone $r_{p,gw}$

$r_c \sim 0.05\, r_h$ $\qquad$ $r_{gw} \sim 100\, R_s$

# Loss cones in Spherical NSC

Kaur, Rom & Sari (2025)




Fast diffusion in $L$

Advection in $E$

**Fokker-Planck Equation**

$$\frac{\partial \mathcal{N}}{\partial t} = \frac{\partial \mathcal{F}_p}{\partial r_p} + \frac{\partial \mathcal{F}_r}{\partial r}$$

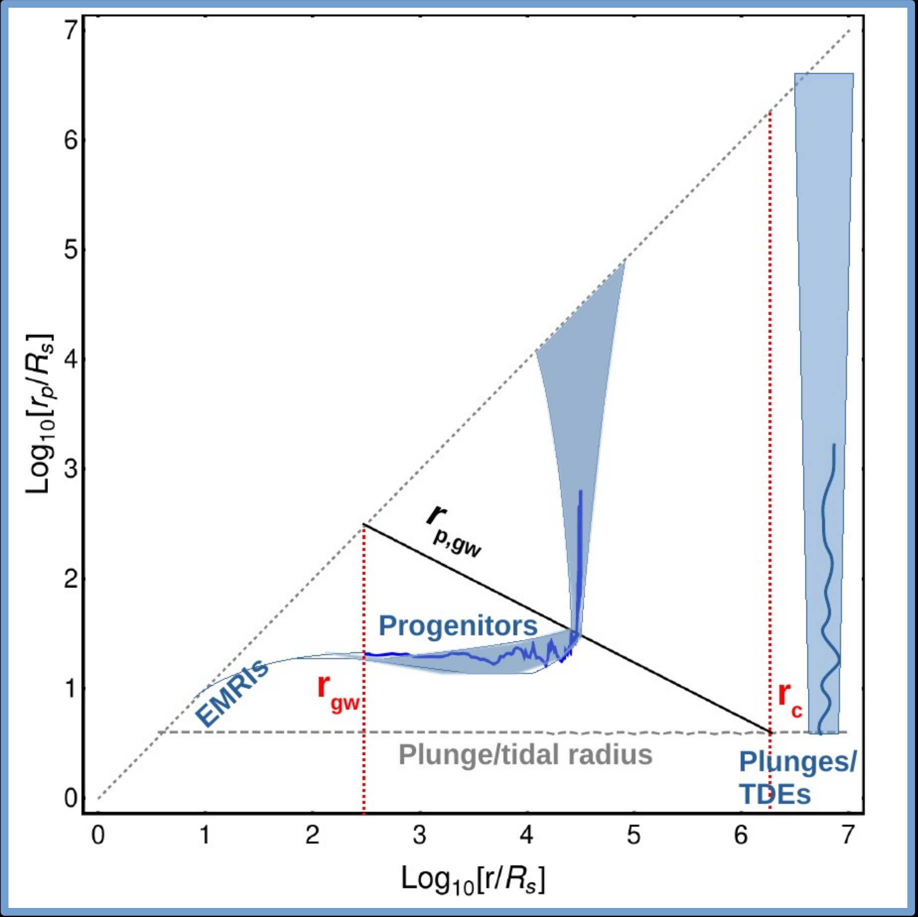
$$\mathcal{F}_p = \frac{r}{2\,T_{2\mathrm{b}}(r)}\, r_p \frac{\partial \mathcal{N}}{\partial r_p}$$

Diffusive flux in $r_p$

$$\mathcal{F}_r = \frac{r\mathcal{N}}{T_{\mathrm{gw}}(r, r_p)}$$

Advective flux in $r$

# Loss cones in Spherical NSC




Advection in $E$

Fast diffusion in $L$

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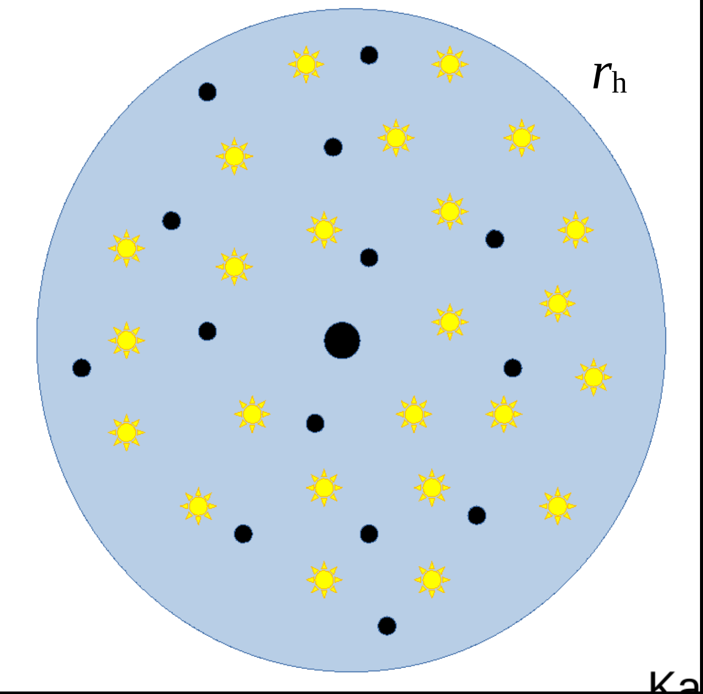
Diffusive flux in $r_p$

$$\mathcal{F}_r = \frac{r\mathcal{N}}{T_{gw}(r, r_p)}$$

Advective flux in $r$

*Initial conditions need results from E relaxation!*

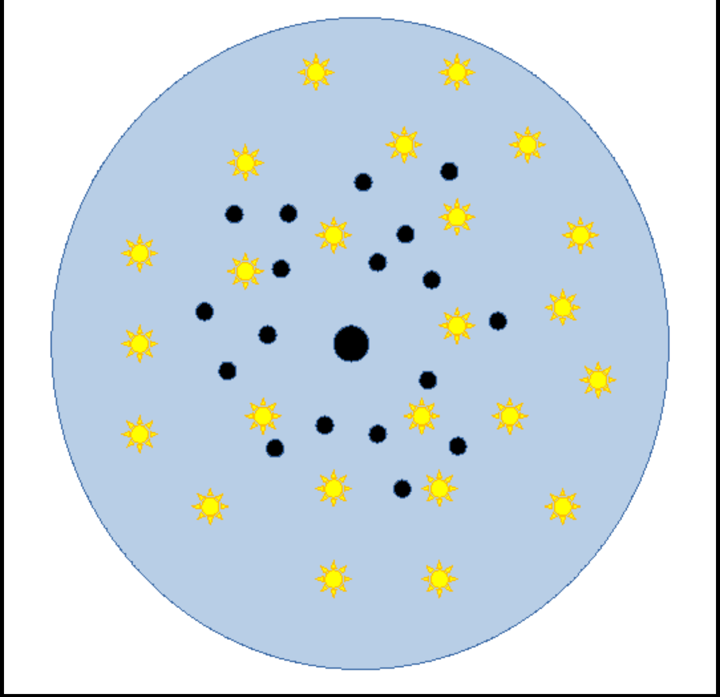
# Loss cones in Spherical NSC




Bahcall-Wolf (1976) profile from only diffusion in E

$\rho(a) \propto a^{-\gamma}$ $\gamma = \frac{7}{4}$ *Single species*

# Loss cones in Spherical NSC



Bahcall-Wolf (1976,77) profile from only diffusion in E

$$\rho(a) \propto a^{-\gamma} \qquad \gamma = \frac{7}{4}$$

*Single species*

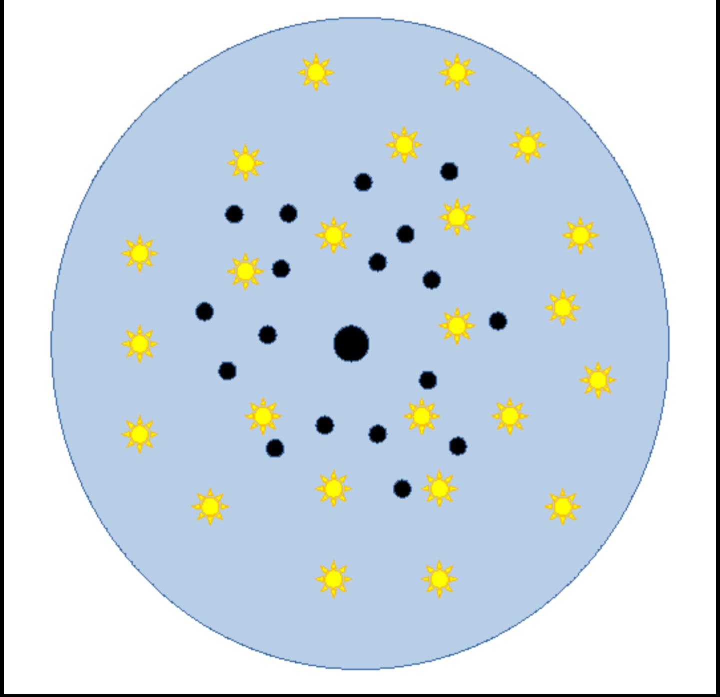
Multiple Stellar populations:

Heavier BHs sink inwards and form steep profiles.
Stars form shallower profiles.

$$\gamma_{bh} = \frac{7}{4} \qquad \gamma_{*} = \frac{3}{2}$$

*Mass segregation*

# Loss cones in Spherical NSC



Bahcall-Wolf (1976) profile from only diffusion in $E$

$\rho(a) \propto a^{-\gamma}$ $\gamma = \frac{7}{4}$ *Single species*

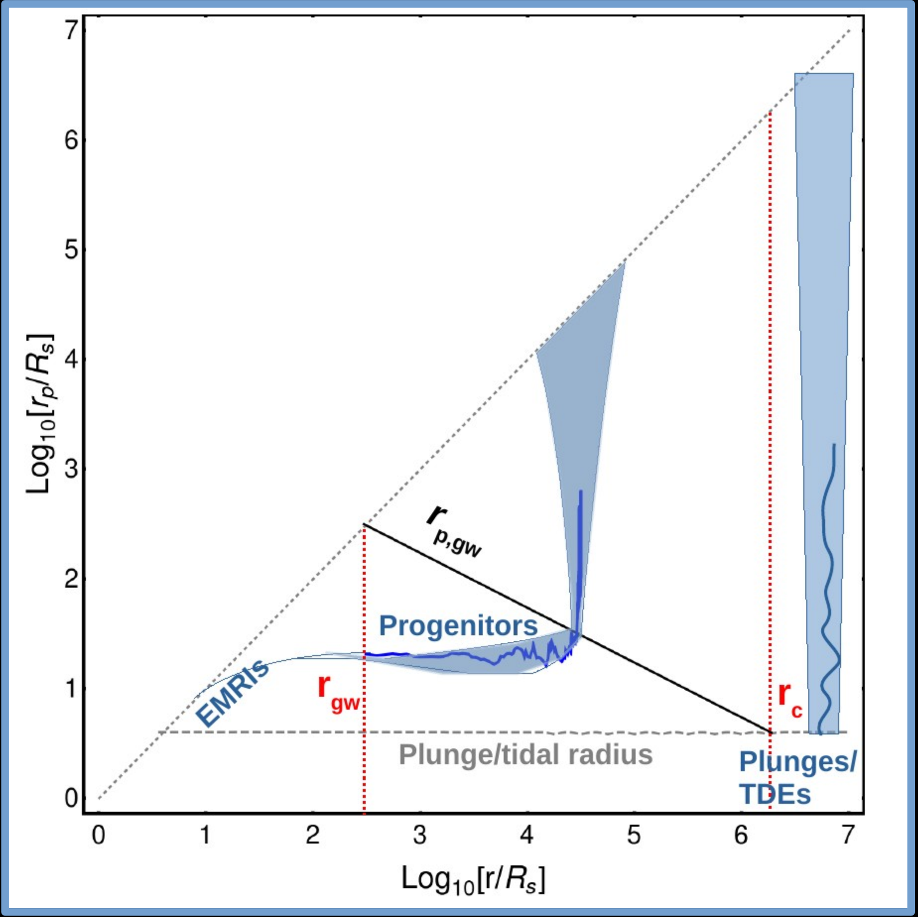
Multiple Stellar populations:

Heavier BHs sink inwards and form steep profiles.
Stars form shallower profiles.

$\gamma_{bh} = \frac{7}{4}$ $\gamma_{*} = \frac{3}{2}$ *Mass segregation* Bahcall & Wolf (1977)

$\gamma_{bh} = 2 - 2.5$ *Strong mass segregation* Alexander & Hopman (2009)

# Loss cones in Spherical NSC




Fast diffusion in $L$

Advection in $E$

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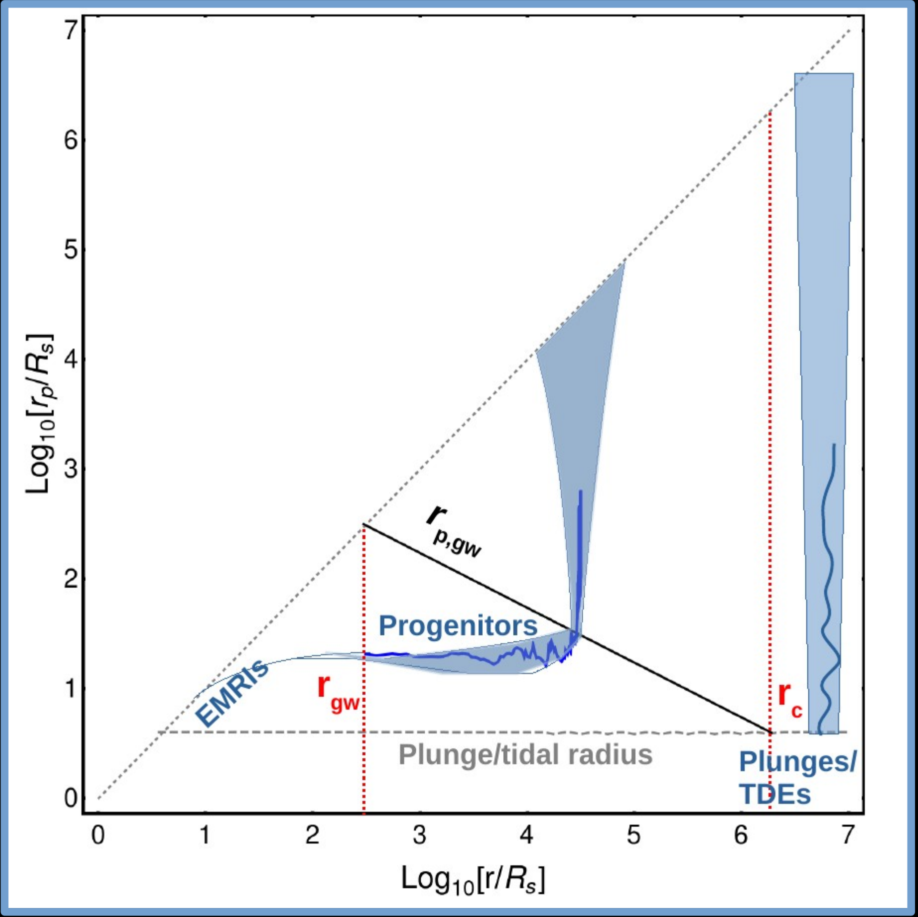
Advective flux in $r$

# Loss cones in Spherical NSC




Fast diffusion in $L$

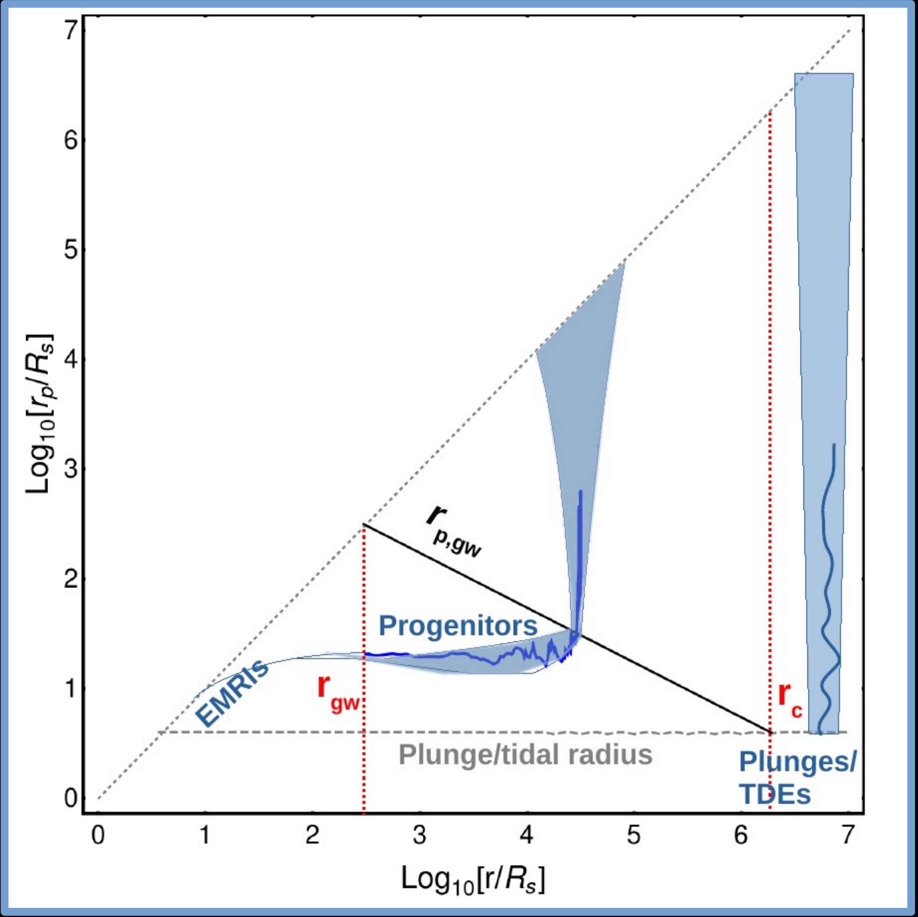
Advection in $E$

Fokker-Planck Equation

Logarithmic Profile in $r_p$ in diffusive regime

$$\mathcal{N}_i(r, r_p) = \frac{2N_0}{r_h^{3-\gamma}}\, r^{1-\gamma}\, \frac{\ln\left(r_p/r_{p,\mathrm{gw}}\right) + c_0}{\ln \Lambda_0 + c_0}$$

# Loss cones in Spherical NSC




Fast diffusion in $L$

Advection in $E$

## Fokker-Planck Equation

Logarithmic Profile in $r_p$ in diffusive regime

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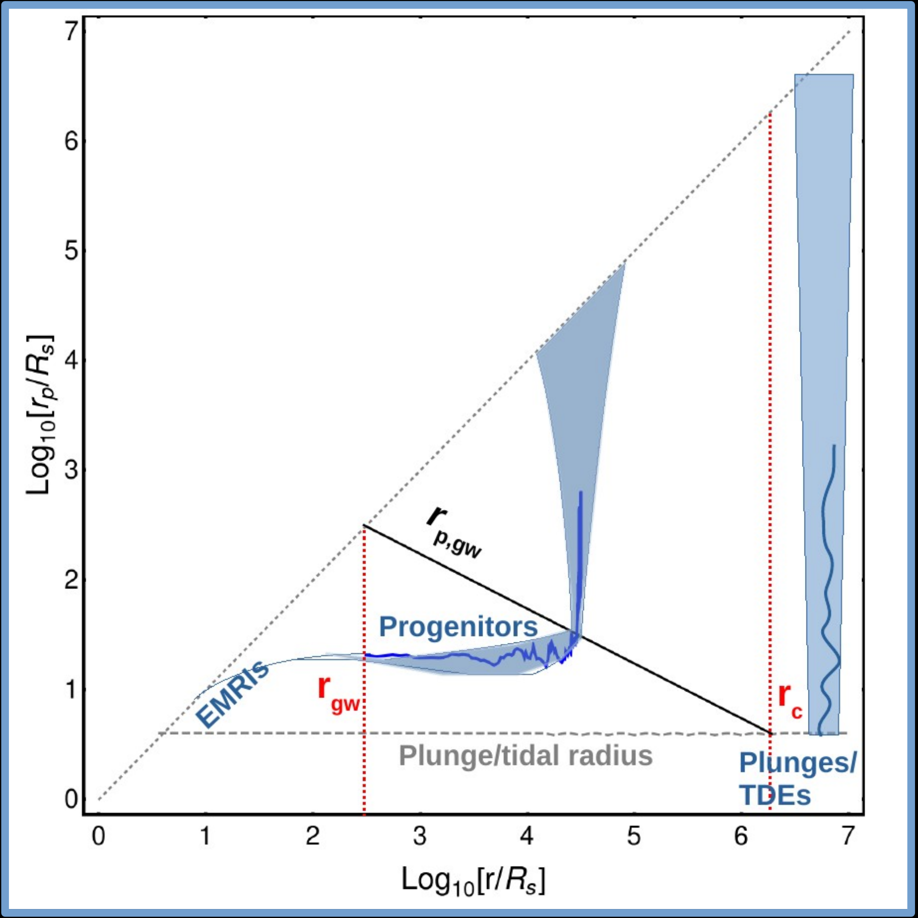
# Loss cones in Spherical NSC




Fast diffusion in *L*

Advection in *E*

**Fokker-Planck Equation**

Logarithmic Profile in $r_p$ in diffusive regime

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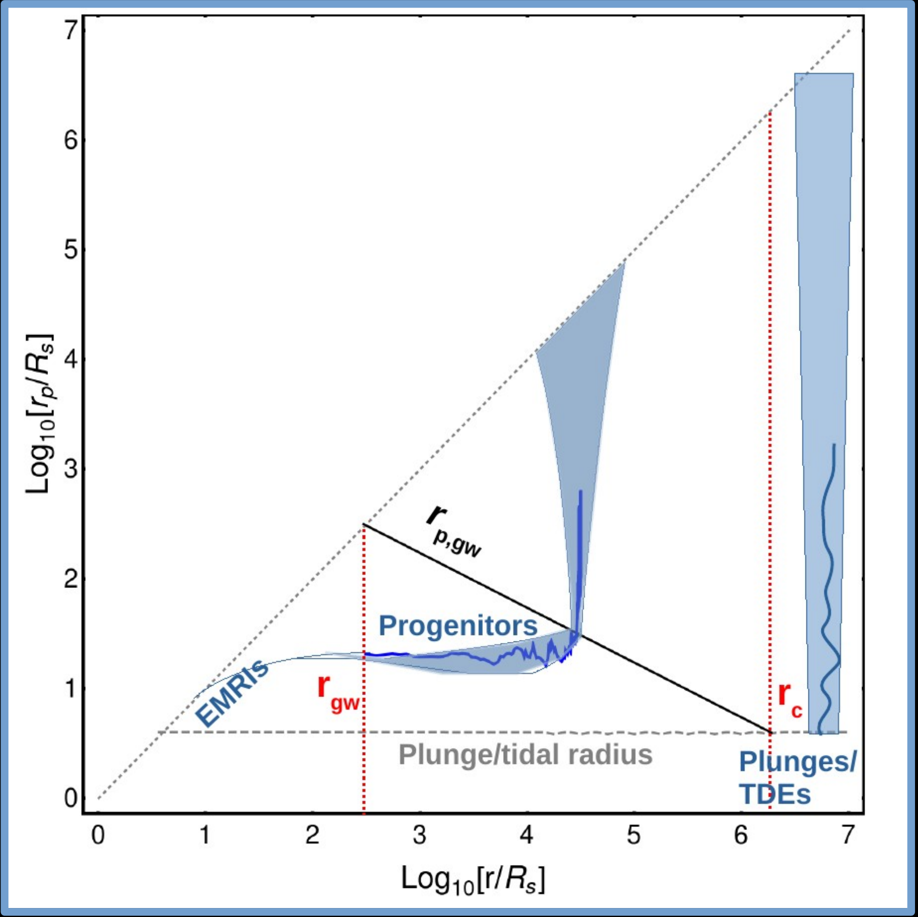
# Loss cones in Spherical NSC




Fast diffusion in *L*

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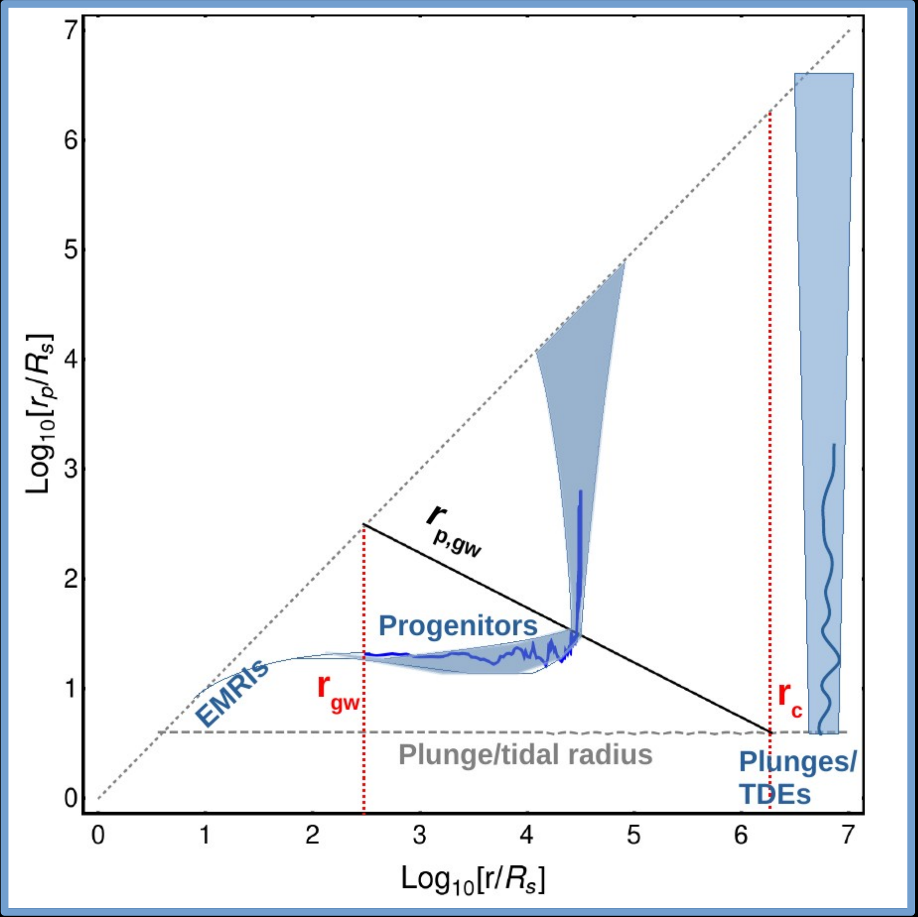
## TDE Rates

$$\dot{N} \sim \frac{N(r_h)}{\ln(1/l_{lc}) T_{2B}(r_h)}$$

Cohn & Kulsrud 78

# Loss cones in Spherical NSC




Advection in $E$

Fast diffusion in $L$

## Fokker-Planck Equation

Logarithmic Profile in $r_p$ in diffusive regime

$$\mathcal{N}_i(r, r_p) = \frac{2N_0}{r_h^{3-\gamma}} r^{1-\gamma} \frac{\ln(r_p/r_{p,\mathrm{gw}}) + c_0}{\ln \Lambda_0 + c_0}$$

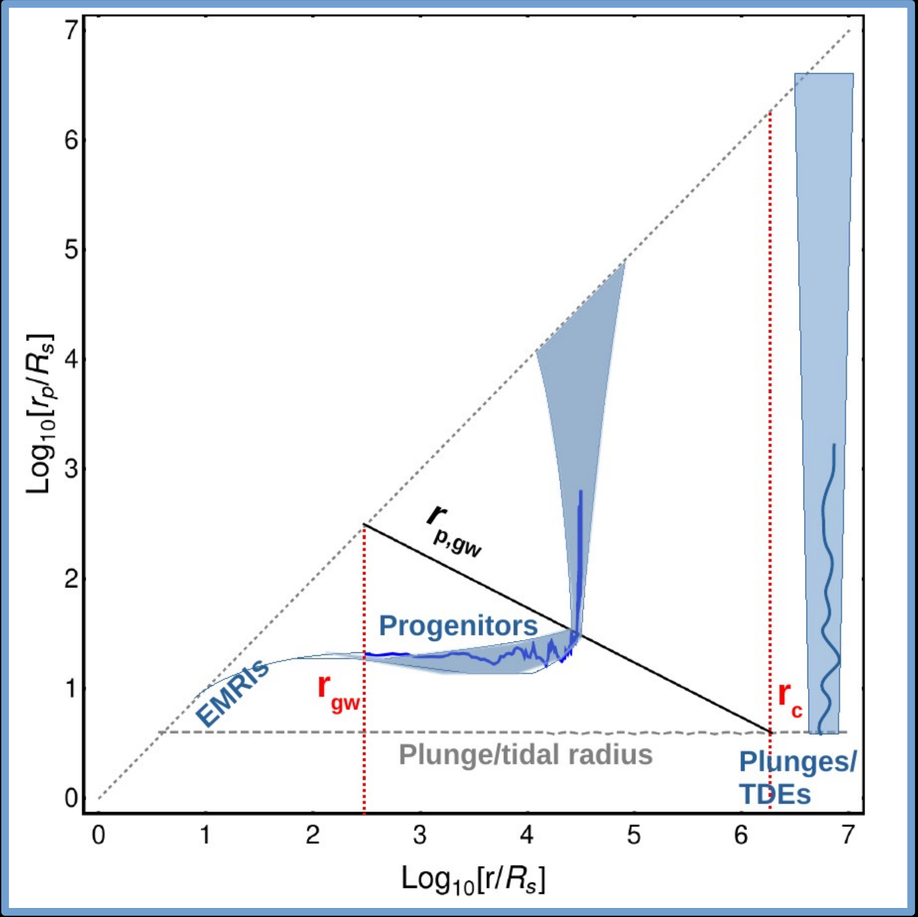
## TDE Rates

$$\dot{N} \sim \frac{N(r_h)}{\ln(1/l_{lc}) T_{2B}(r_h)}$$

$$\dot{N} \sim 10^{-5} - 10^{-4} \ \mathrm{yr}^{-1}$$

Magorrian & Tremaine 99 ,
Stone & Metzger 16,
van Velzen+ 20

# Loss cones in Spherical NSC




Fast diffusion in $L$

Advection in $E$

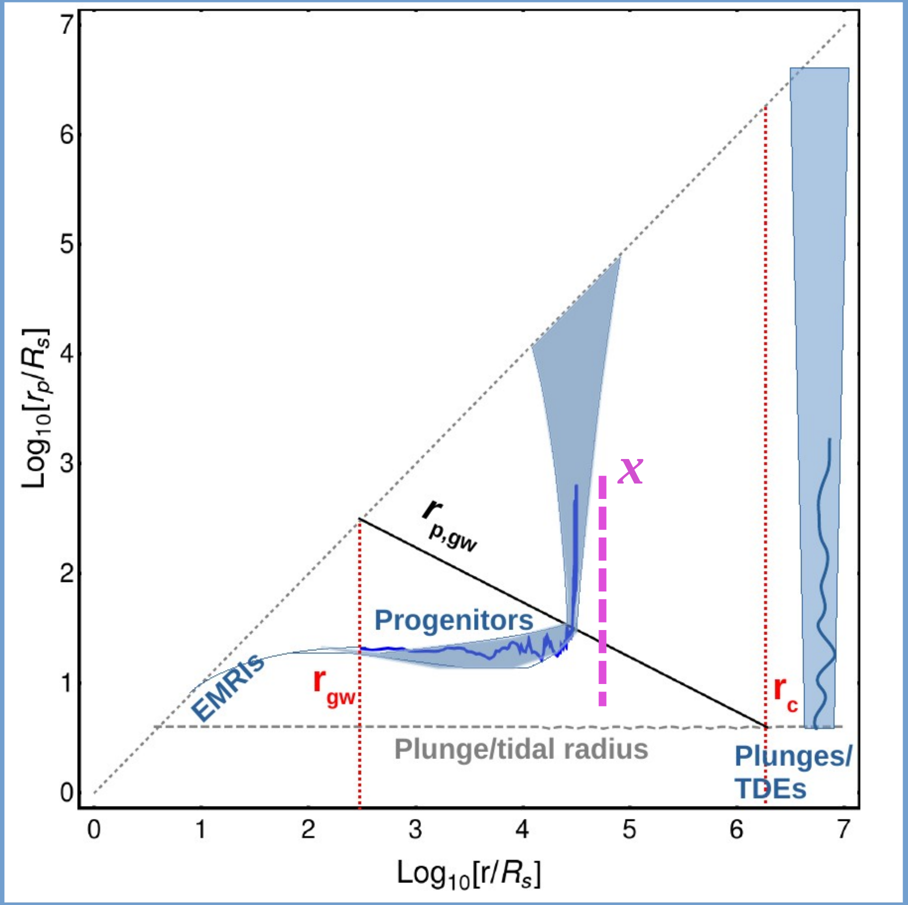
Fokker-Planck Equation

Logarithmic Profile in $r_p$ in diffusive regime

$$\mathcal{N}_i(r, r_p) = \frac{2N_0}{r_h^{3-\gamma}} \, r^{1-\gamma} \, \frac{\ln(r_p/r_{p,\mathrm{gw}}) + c_0}{\ln \Lambda_0 + c_0}$$

# Loss cones in Spherical NSC

Kaur, Rom & Sari (2025)




Fast diffusion in $L$

Advection in $E$

## Fokker-Planck Equation

Logarithmic Profile in $r_p$ in diffusive regime

$$\mathcal{N}_i(r, r_p) = \frac{2N_0}{r_h^{3-\gamma}} r^{1-\gamma} \frac{\ln(r_p/r_{p,\mathrm{gw}}) + c_0}{\ln \Lambda_0 + c_0}$$

"Self-Similar nature"

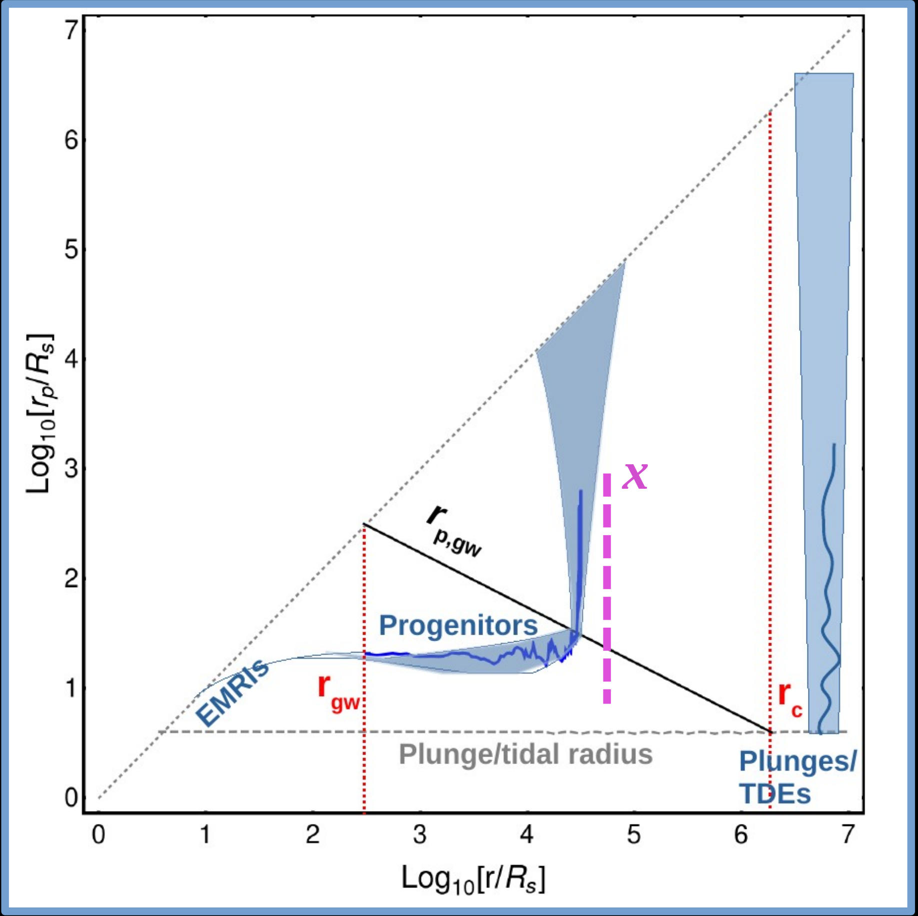
*New Coordinate*

$$x = \frac{r_p}{r_{p,gw}}$$

Proposed form of solution

$$\mathcal{N}(r, r_p) = \frac{2N_0}{r_h^{3-\gamma}} \frac{r^{1-\gamma}}{\ln \Lambda_0 + c_0} g(x)$$

# Loss cones in Spherical NSC



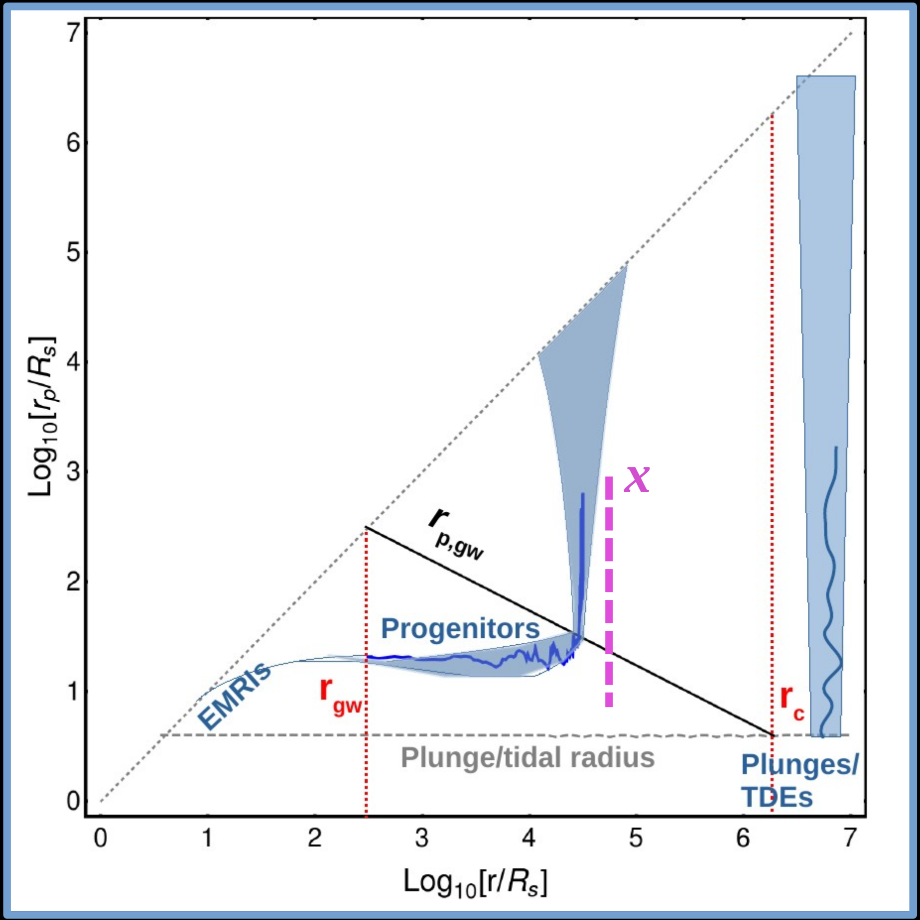

Fast diffusion in *L*

Advection in *E*

Reduced 1D Problem

$$2\,x^{11/2-2\gamma}\,\frac{\mathrm{d}}{\mathrm{d}x}\left(x\,\frac{\mathrm{d}g}{\mathrm{d}x}\right)+\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{g}{x^{2\gamma-3}}\right)=0$$

# Loss cones in Spherical NSC




Advection in $E$

Fast diffusion in $L$

**Reduced 1D Problem**

$$2\,x^{11/2-2\gamma}\,\frac{\mathrm{d}}{\mathrm{d}x}\left(x\,\frac{\mathrm{d}g}{\mathrm{d}x}\right)+\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{g}{x^{2\gamma-3}}\right)=0$$

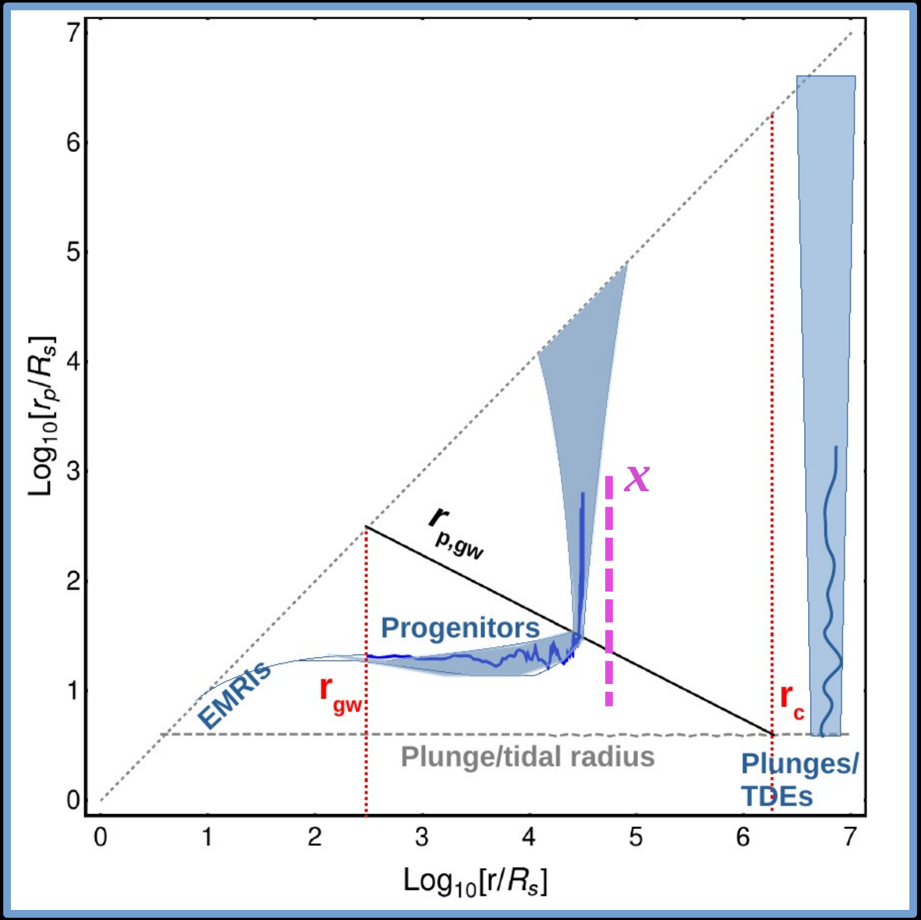
Asymptotic Solution
for x >> 1

$$g_i(x) \;=\; \log x + c_0$$

Asymptotic Solution
for x << 1

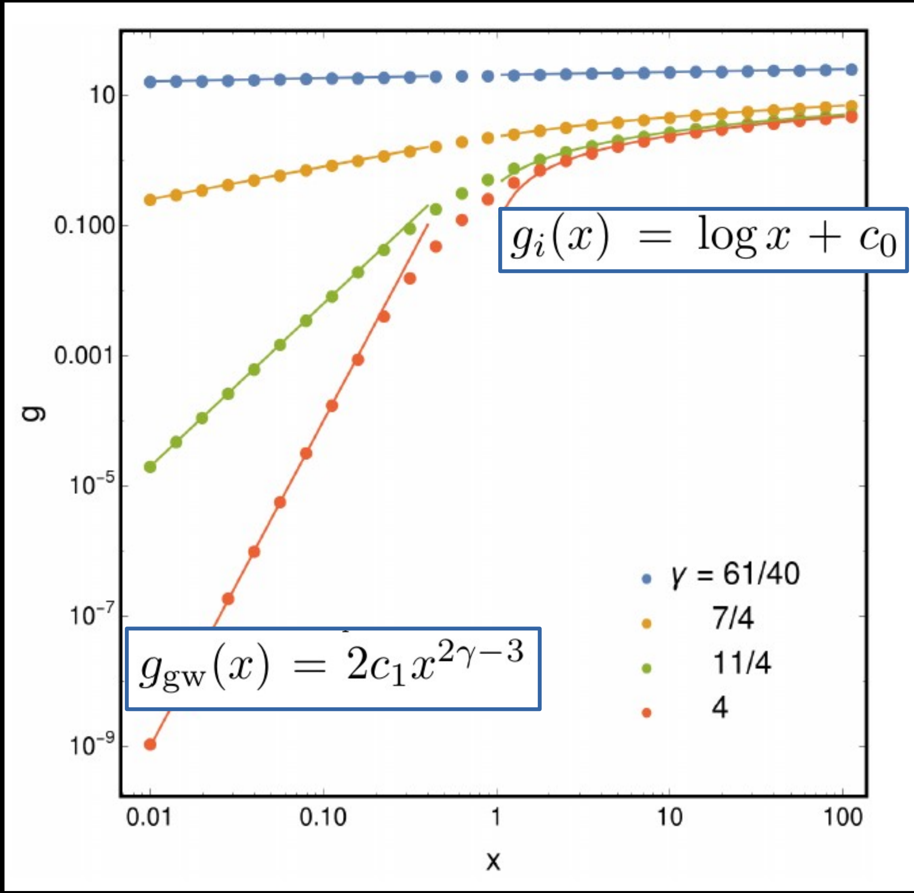
$$g_{\mathrm{gw}}(x) \;=\; 2c_1 x^{2\gamma-3}$$

# Loss cones in Spherical NSC

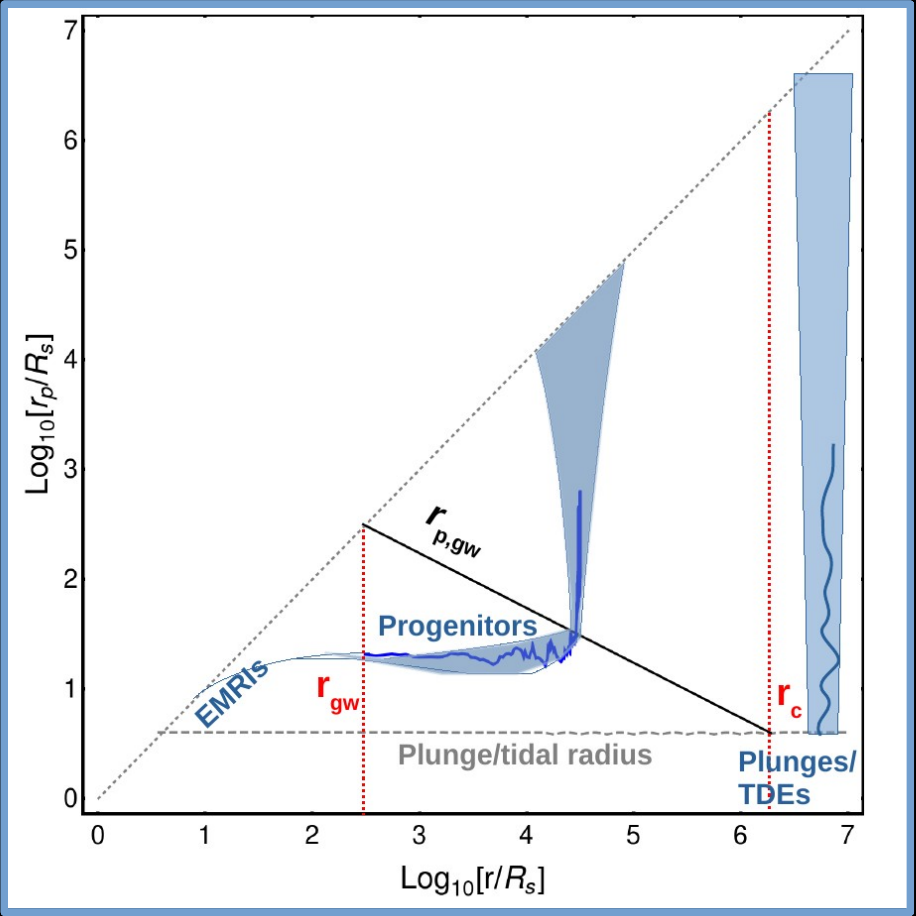



Advection in $E$

Fast diffusion in $L$

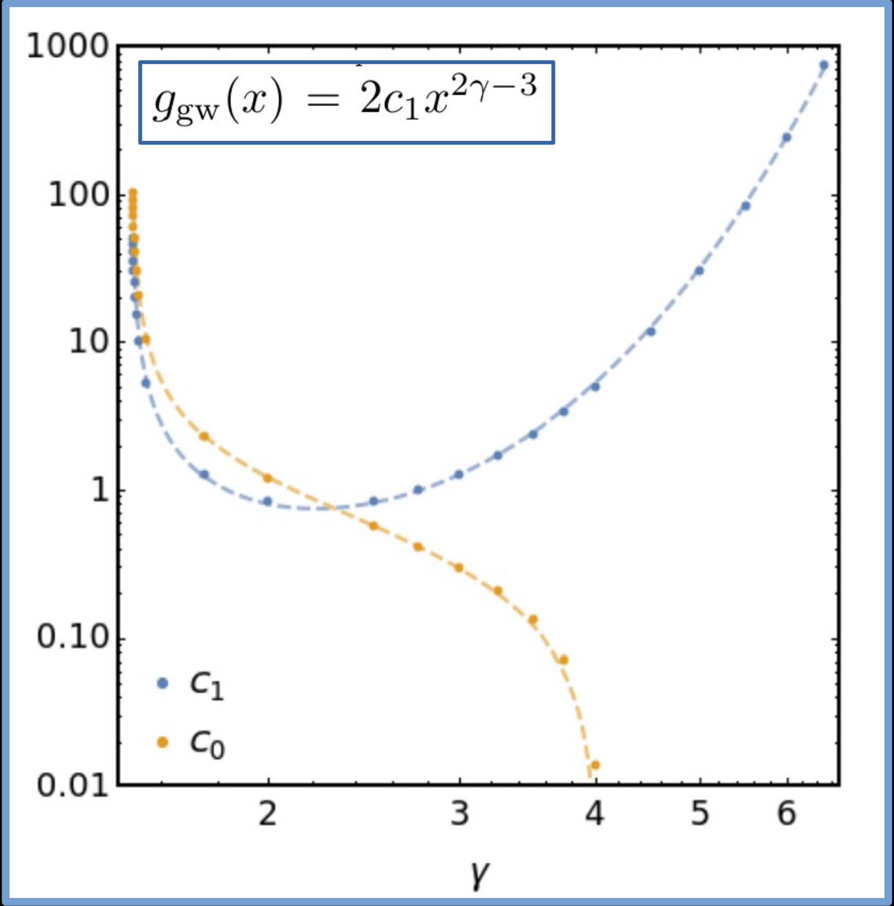


# Loss cones in Spherical NSC

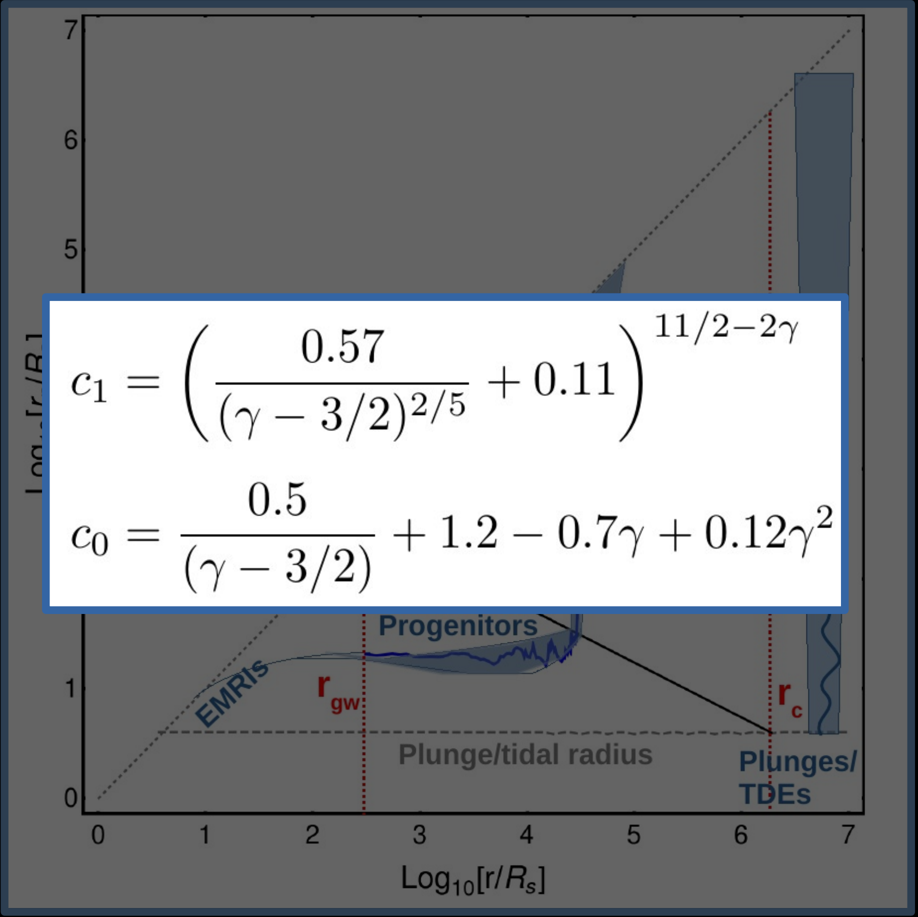



Advection in $E$

Fast diffusion in $L$



# Loss cones in Spherical NSC

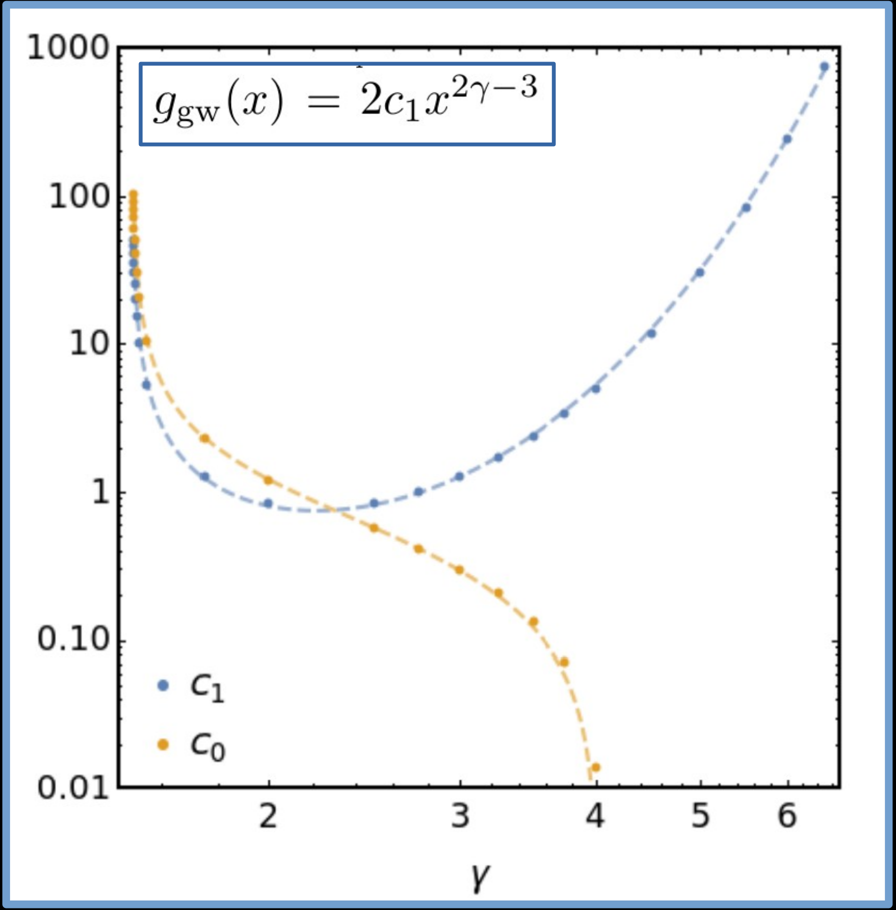



$$c_1 = \left( \frac{0.57}{(\gamma - 3/2)^{2/5}} + 0.11 \right)^{11/2 - 2\gamma}$$

$$c_0 = \frac{0.5}{(\gamma - 3/2)} + 1.2 - 0.7\gamma + 0.12\gamma^2$$

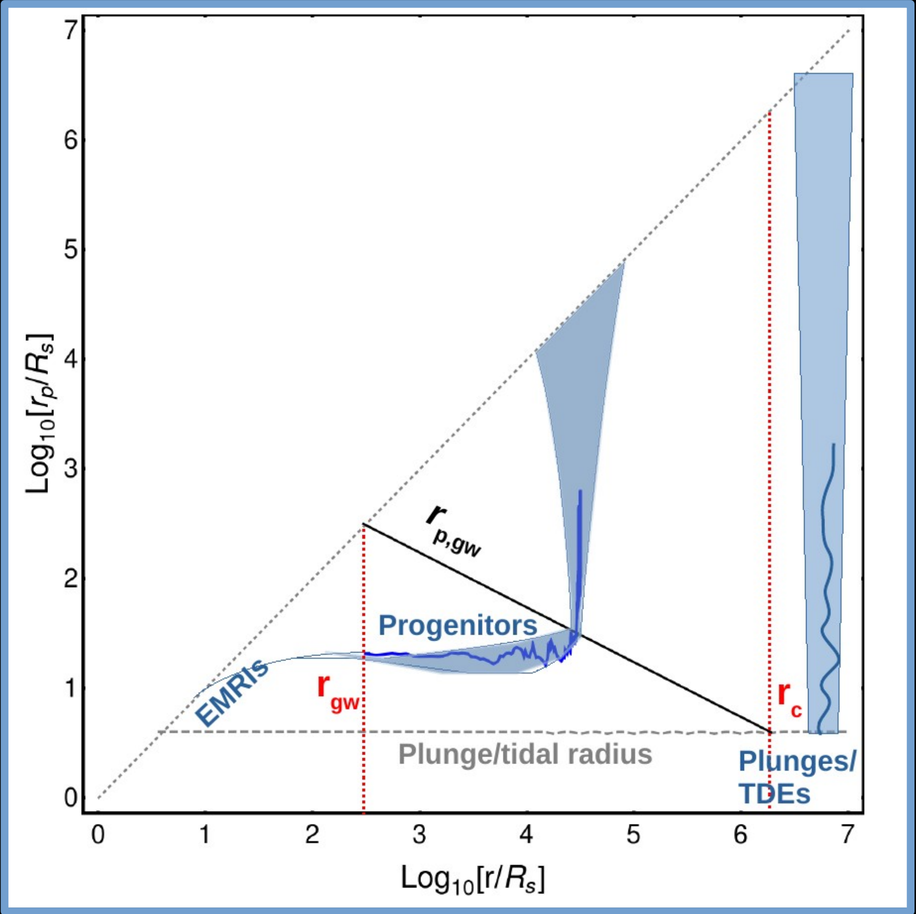
Advection in $E$

Fast diffusion in $L$

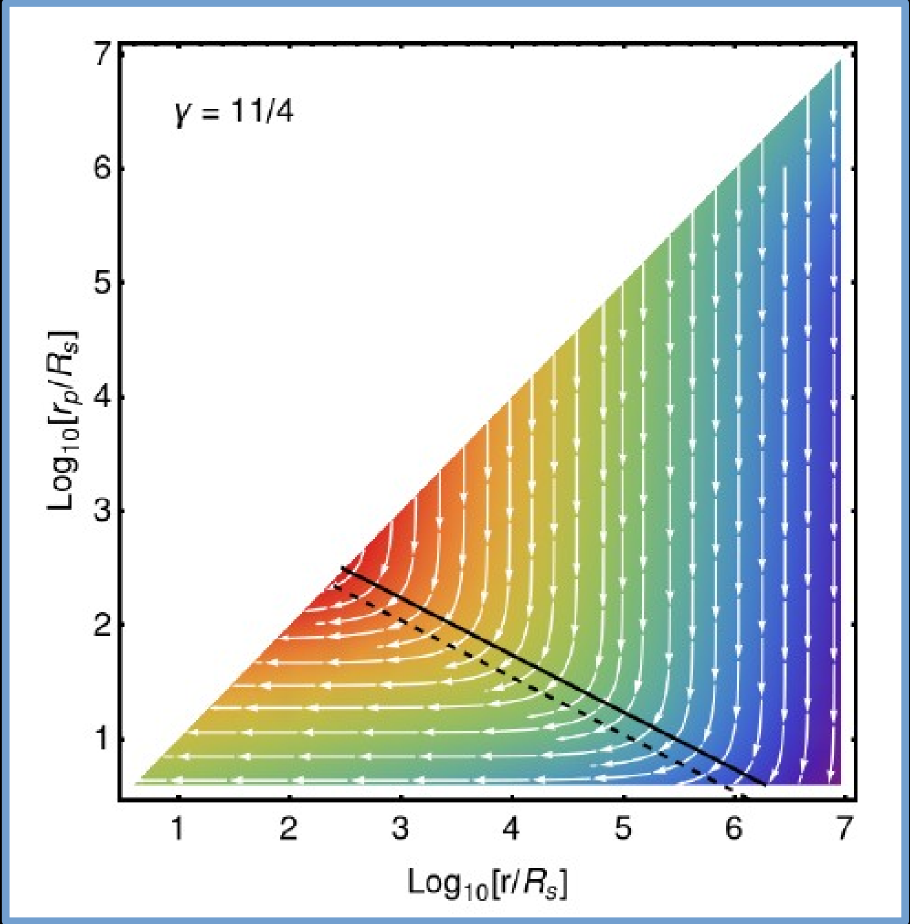



$$g_{\mathrm{gw}}(x) = 2c_1 x^{2\gamma - 3}$$

# Loss cones in Spherical NSC

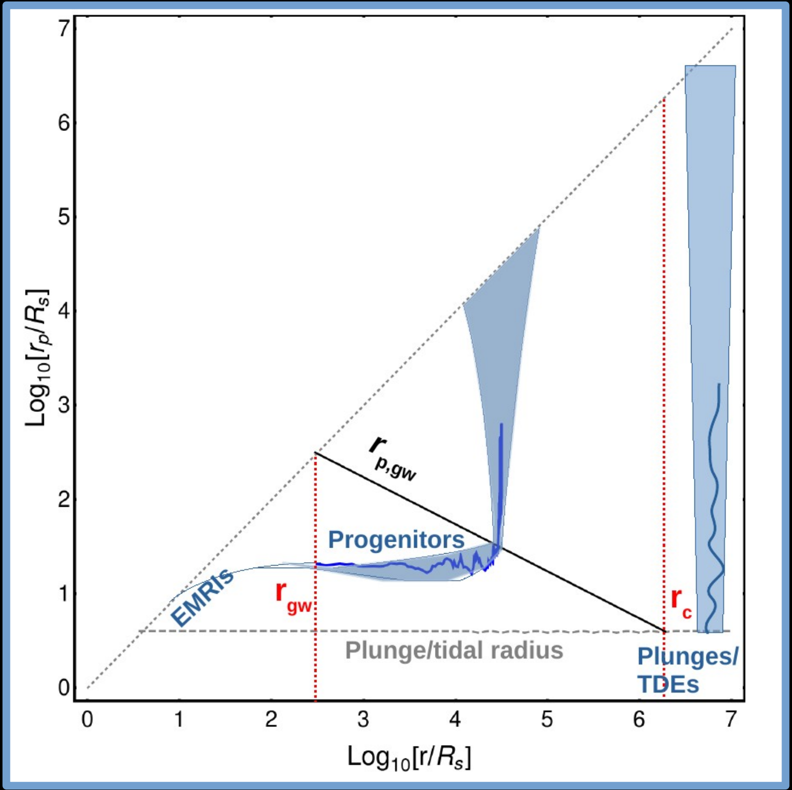



Fast diffusion in $L$




Advection in $E$

# Loss cones in Spherical NSC




**Almost Analytical EMRI rates**

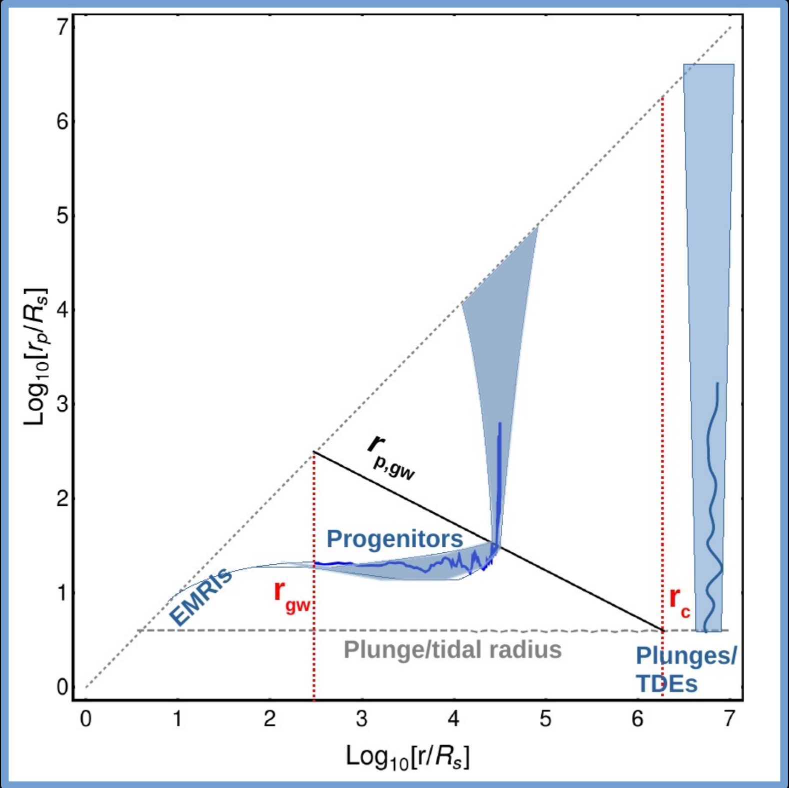
$$\Gamma = 290\ \mathrm{Gyr}^{-1}\ \frac{A\, 1.9^{\frac{\gamma-3/2}{3-\gamma}}\,(f_{-3}\, m_1)^{\frac{3}{2(3-\gamma)}}}{(3-\gamma)\, M_6^{1/4}\, s_{-1}^{3/2}}$$

$$\Gamma = 200 - 2100\ \mathrm{Gyr}^{-1}$$

Amplification factor
compared to analytics

$$A = \frac{c_1 \ln \Lambda_0}{\ln \Lambda_0 + c_0}$$

# Loss cones in Spherical NSC




Almost Analytical EMRI rates

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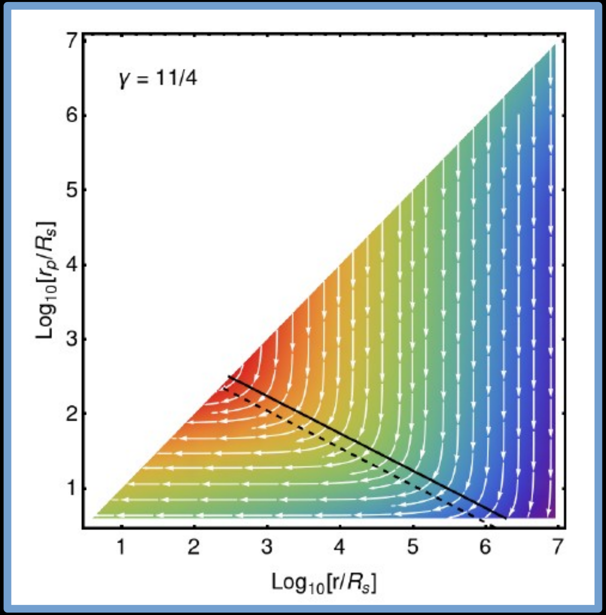
$$\Gamma = 200 - 2100\ \mathrm{Gyr}^{-1}$$

- Thorough analytical recipe to be employed in an evolutionary set-up for detection rate estimates.
- To account for unrelaxed distribution, replenishing and depletion of BHs with time in NSCs.

# Significance

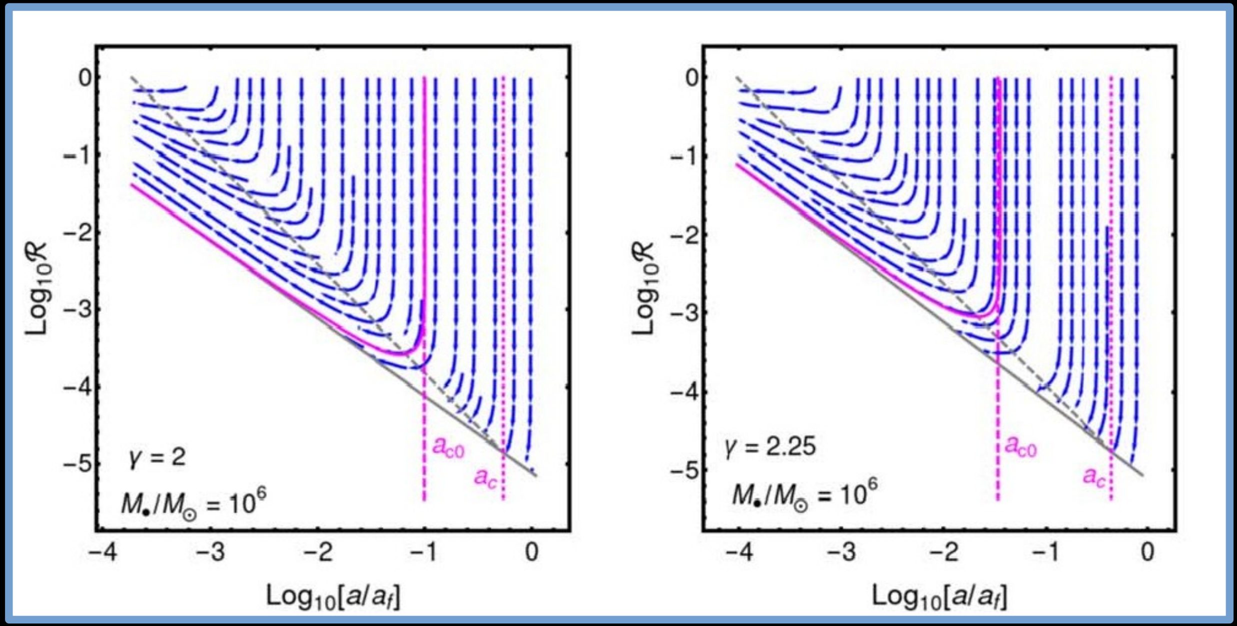
- Our approach captures the effect of variable critical radius $r_c$, missing in earlier analytical approaches. Earlier time-depedent numerical Fokker-Planck methods also account for only fixed critical $r_c$ (Broggi+2023).

Kaur, Rom & Sari 2025



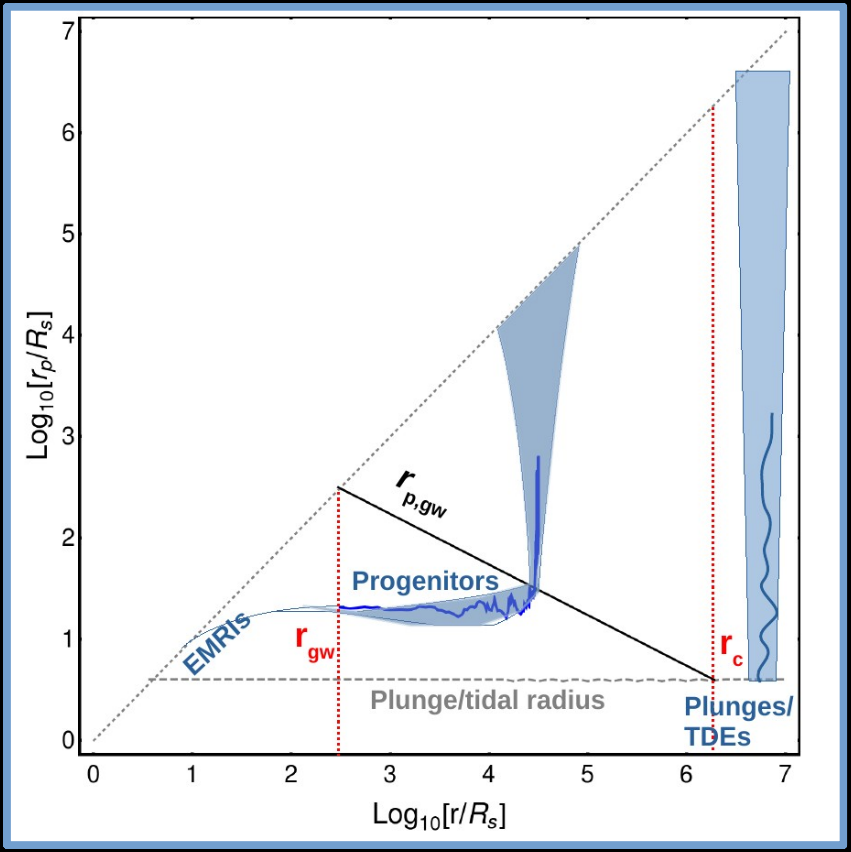

*Numerical Checks*

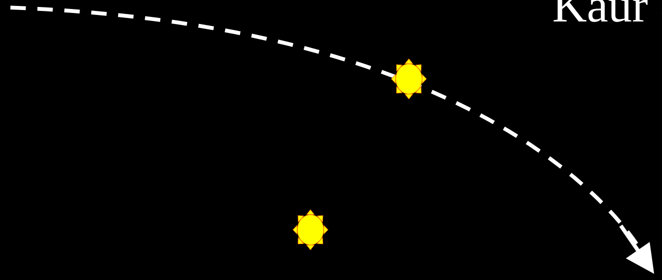
Kaur & Perets 2024



# Close Encounters

Henon 1960 ,
Goodman 1983,
Kaur & Perets 2024



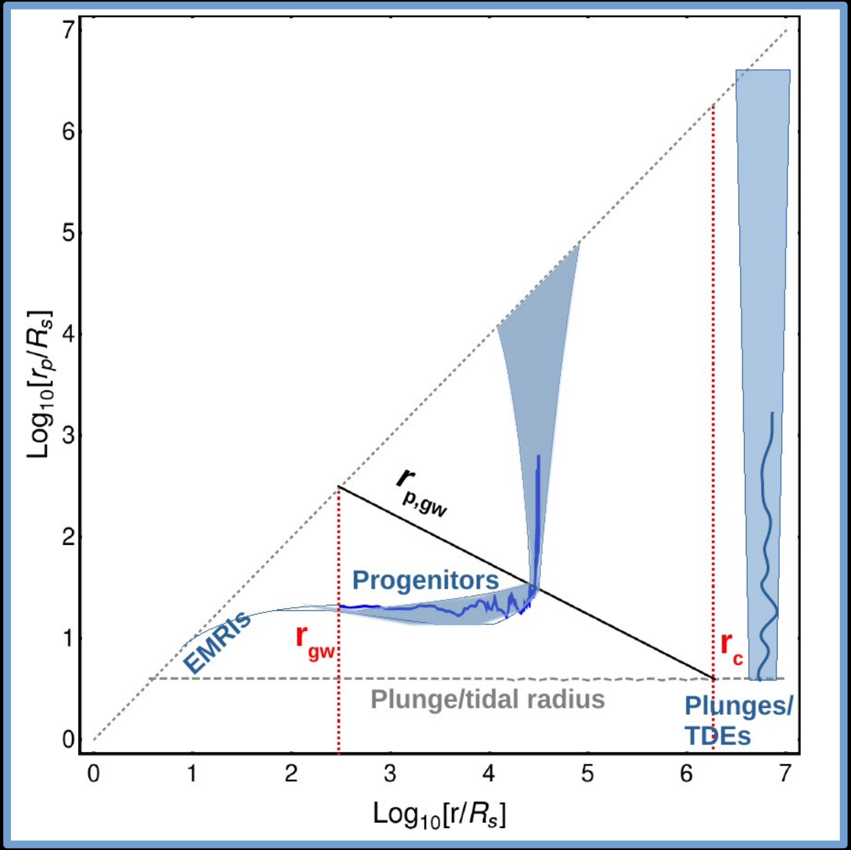
$$\Delta v \sim v$$

$$b_{90} \sim \frac{G m}{v^2} \sim \frac{m}{M} r$$

$$e_{tde} \simeq 1 - \frac{r_{tid}}{r_h} \simeq 0.99999$$

$$e_{emri} \simeq 1 - \frac{4 R_s}{r_c} \simeq 0.9999$$

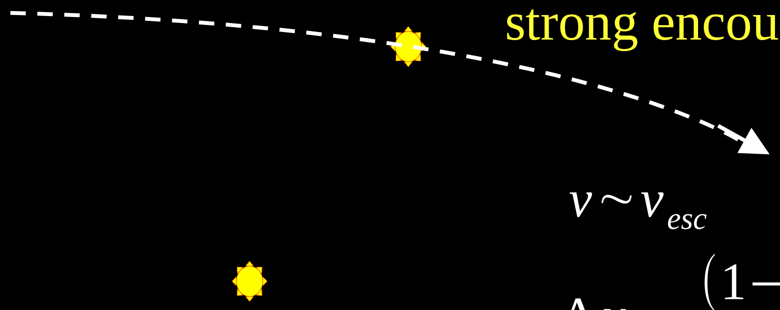
# Close Encounters




$$e_{tde} \simeq 1 - \frac{r_{tid}}{r_h} \simeq 0.99999$$

$$e_{emri} \simeq 1 - \frac{4R_s}{r_c} \simeq 0.9999$$

Ejections of high *e* orbits do not require a strong encounter !



$$v \sim v_{esc}$$

$$\Delta v_{ej} \sim \frac{(1-e)}{4} v$$

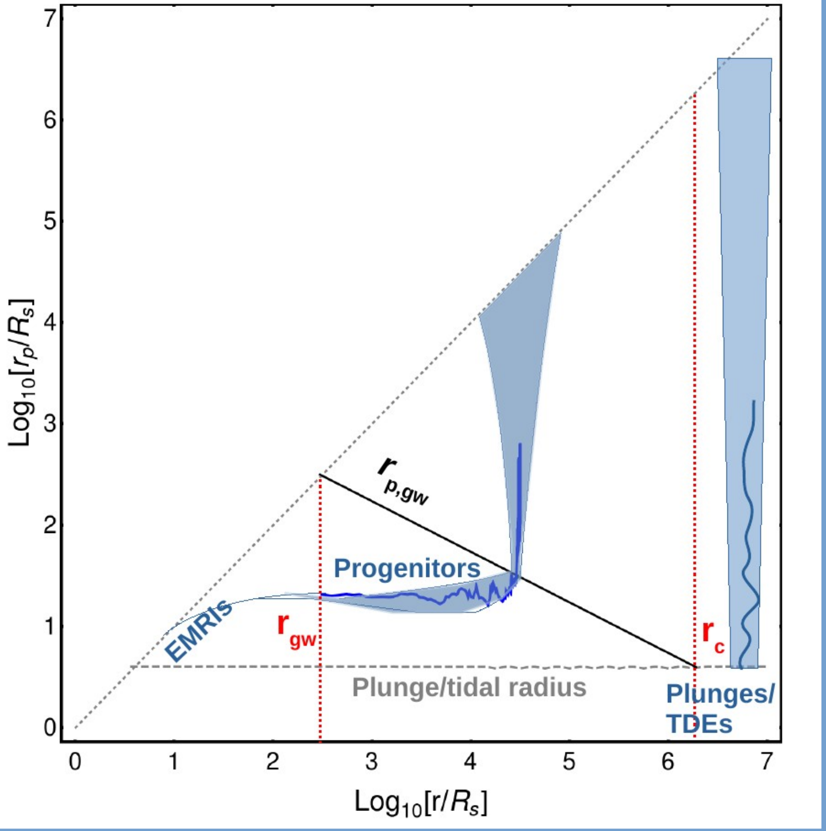
$$b_{ej} \sim \frac{4}{1-e} b_{90}$$

$$\sim \frac{4m}{M} a \gg b_{90}$$

High impact parameter for ejection near periapse

# Impact on EMRI rates

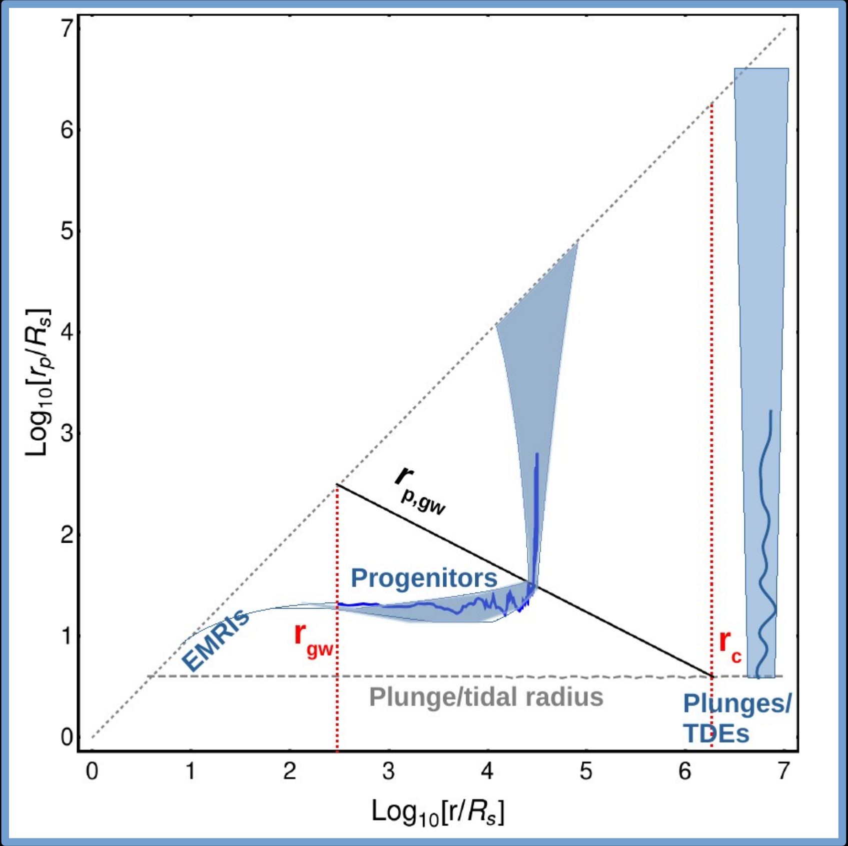
Kaur & Perets 2024

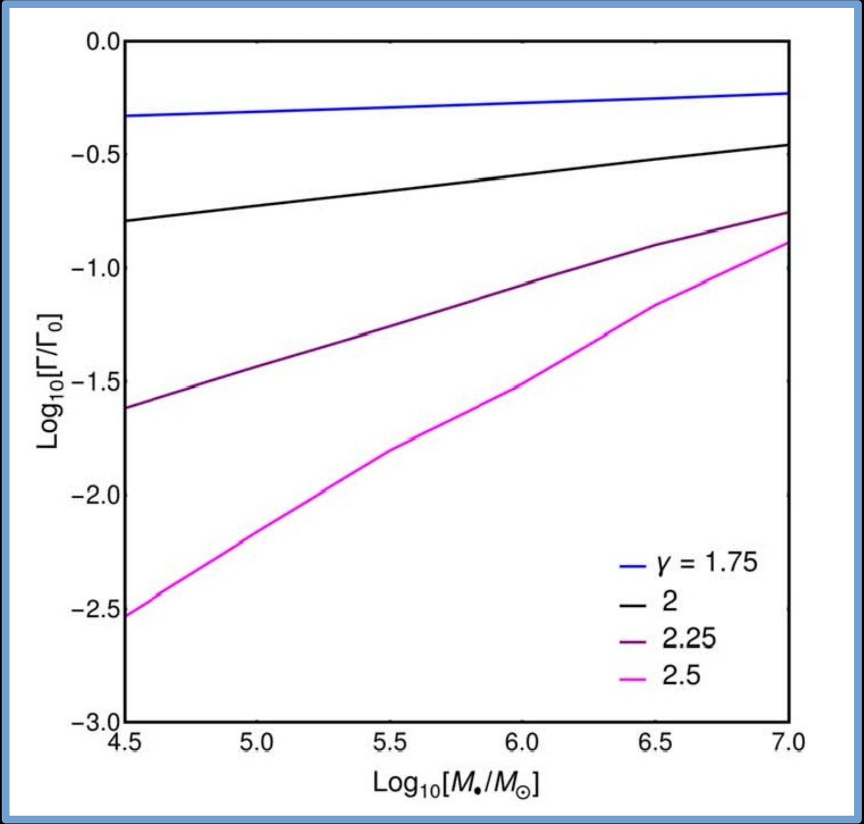



$$\frac{\partial \mathcal{N}}{\partial t} = \left(\frac{a_{\mathrm{f}}}{a}\right)^{\gamma-3/2} \frac{\partial}{\partial \mathcal{R}}\left(\mathcal{R}\frac{\partial \mathcal{N}}{\partial \mathcal{R}}\right) + \frac{\partial}{\partial a}(|\dot{a}|\mathcal{N}) - \frac{\partial}{\partial \mathcal{R}}(|\dot{\mathcal{R}}|\mathcal{N}) - F_{\mathrm{ej}}(a, \mathcal{R})\mathcal{N}.$$

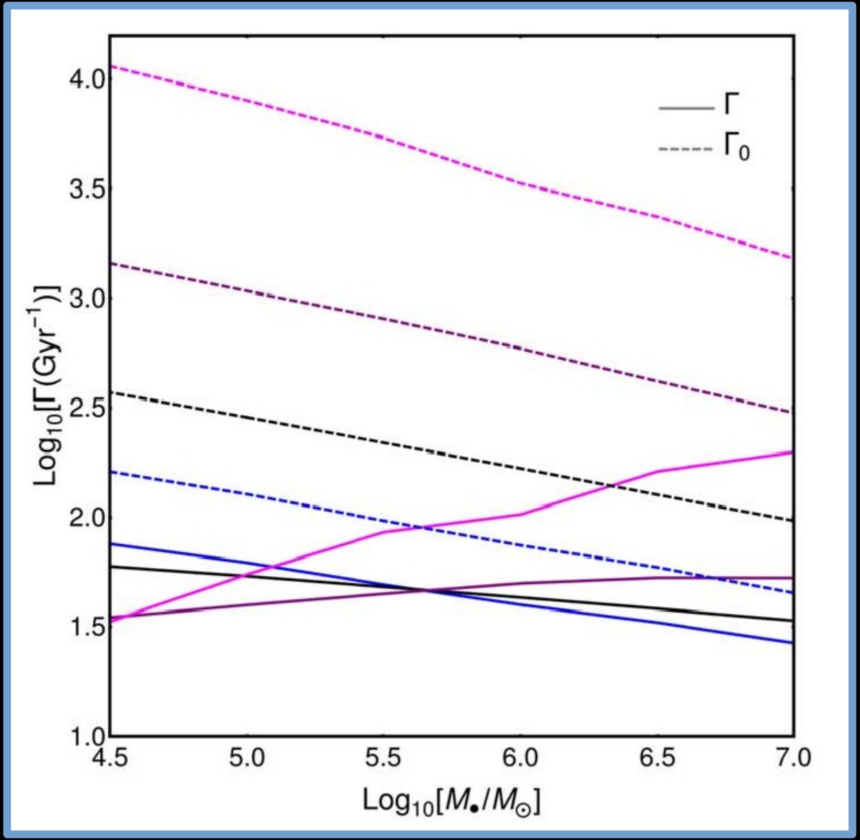
$$\langle \dot{P}_{\mathrm{ej}} \rangle \simeq \frac{1}{\ln\Lambda\, T_{2\mathrm{b}}(a_{\mathrm{f}})} \sqrt{\frac{a}{a_{\mathrm{f}}}} \frac{r_0}{a_{\mathrm{f}}} \left(\frac{a_{\mathrm{f}}}{r_0} - \frac{a_{\mathrm{f}}}{2a}\right)^{\gamma}$$

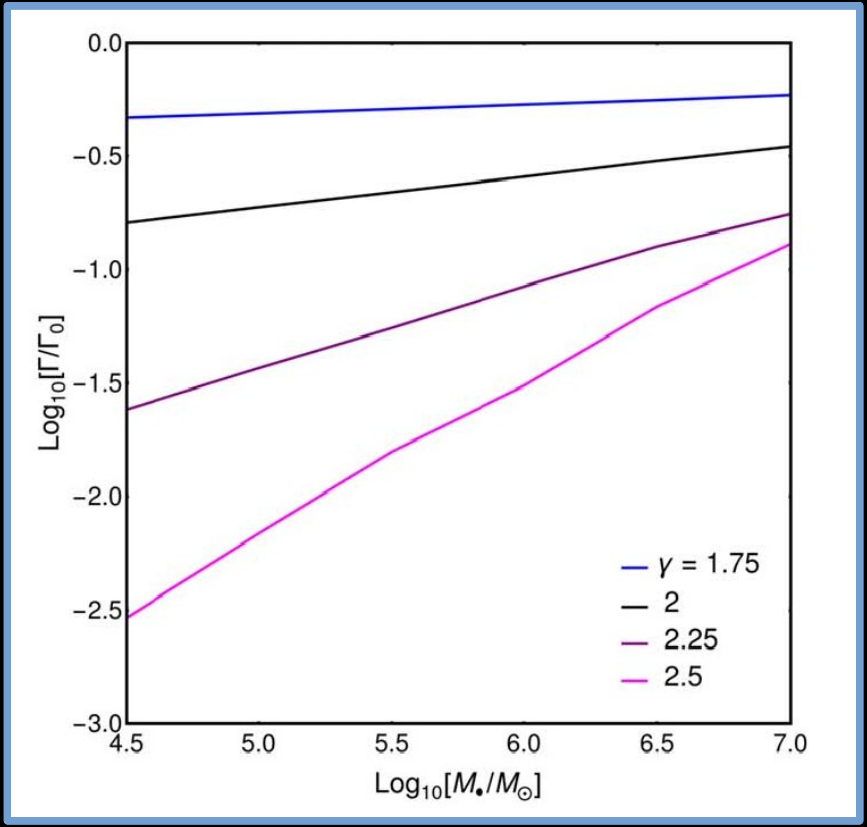
# Impact on EMRI rates



# Impact on EMRI rates

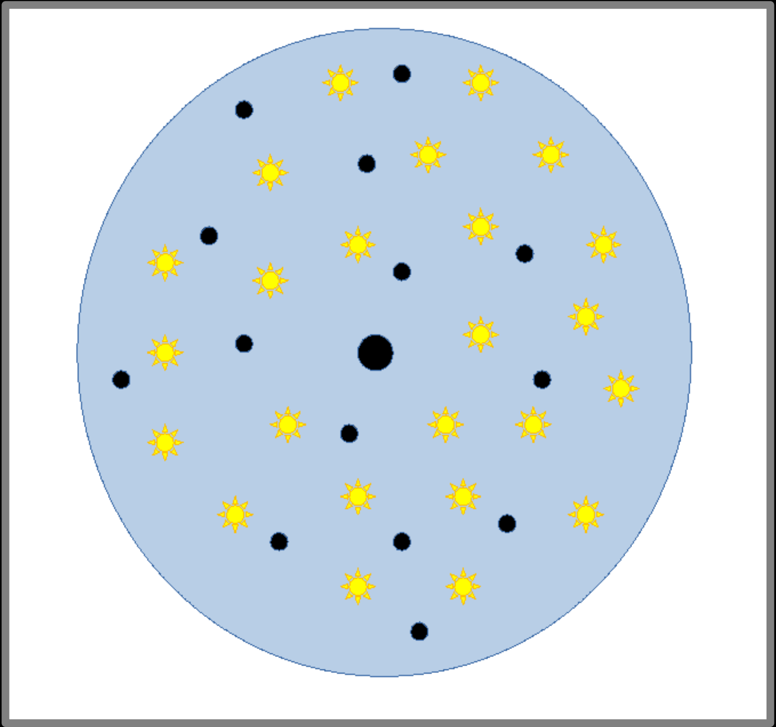


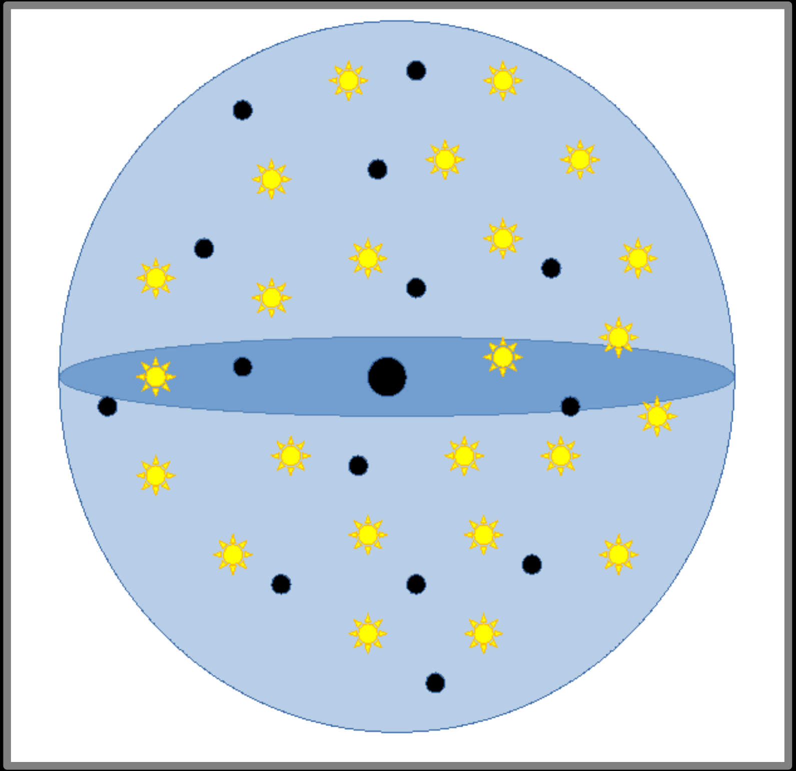




*EMRI rate suppression upto an order of magnitude!*

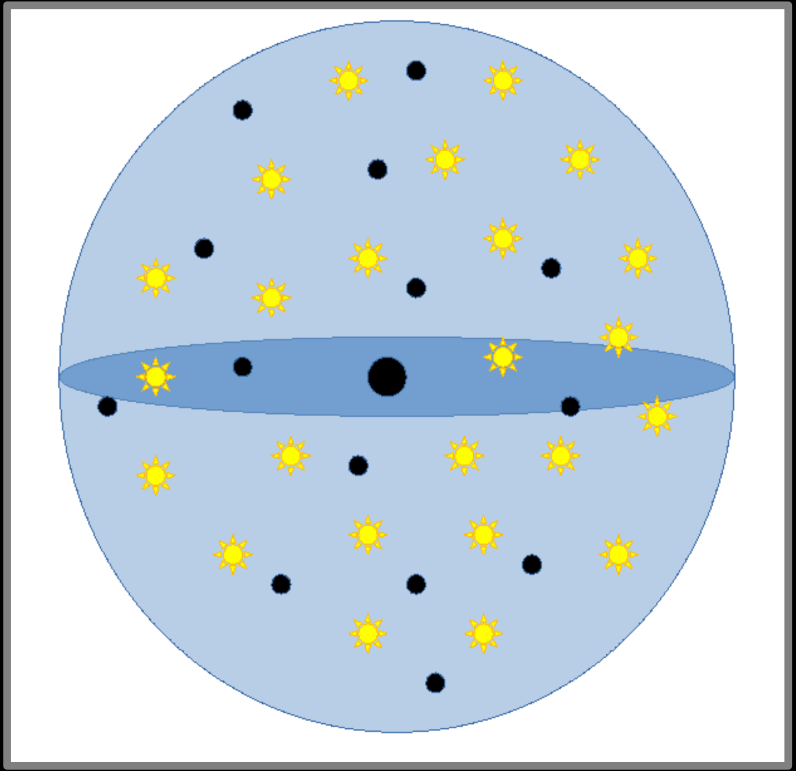
# Conclusions

- Our semi-analytical model provides a thorough recipe for evaluating transition radius $r_c$ and EMRI rates in statistical calculations of EMRI detection rates.
- Strong scatterings can significantly suppress the EMRI rates and should be taken into account in future studies.
- Consistent studies accounting for 2D relaxation are essential for predicting accurate EMRI rates.





*E+A Galaxies – merger scenarios*



MBH binary

Eccentric Stellar Disks

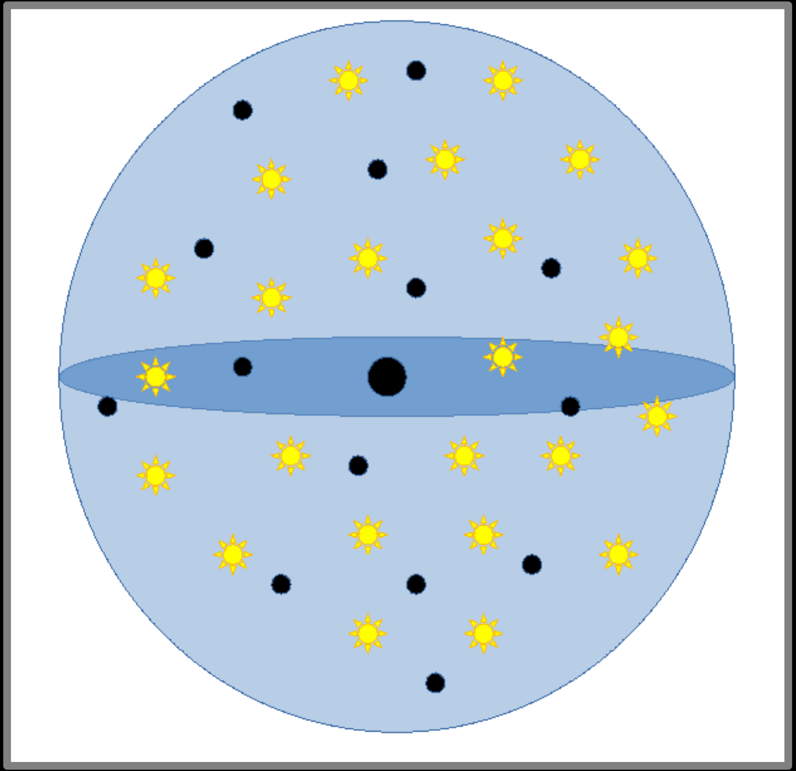
Anisotropic velocity distribution

Steep density distribution

*Karas & Subr 2007; Chen + 2009; Stone & Metzger 2016; Madigan et al. 2018*

*E+A Galaxies – merger scenarios*

*Wet gas-rich mergers can trigger AGN episodes!*



MBH binary

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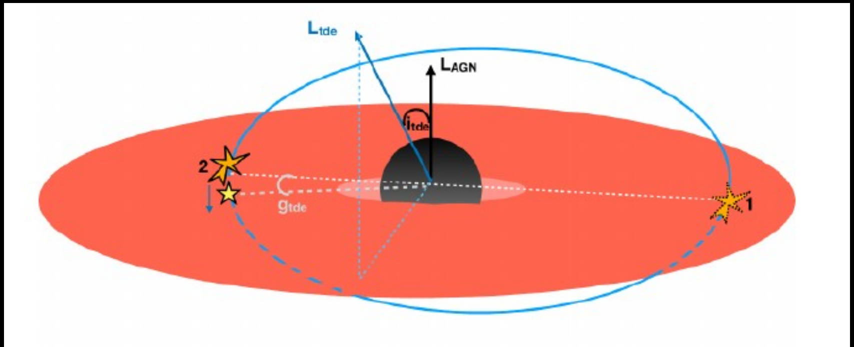
# Loss Cone in Gas-Rich Nuclei

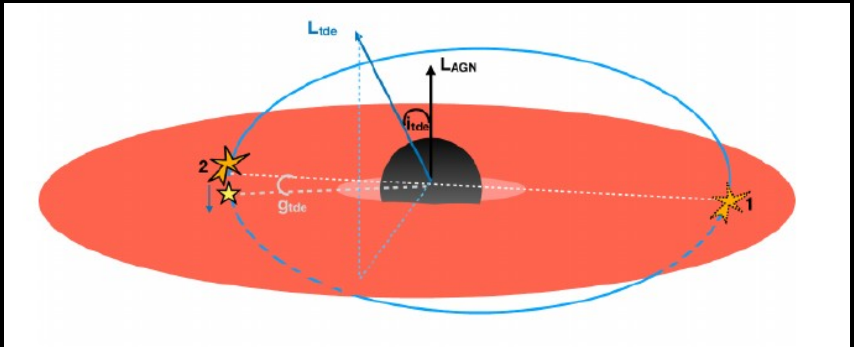
- Non-Spherical systems

Kaur & Stone 2025

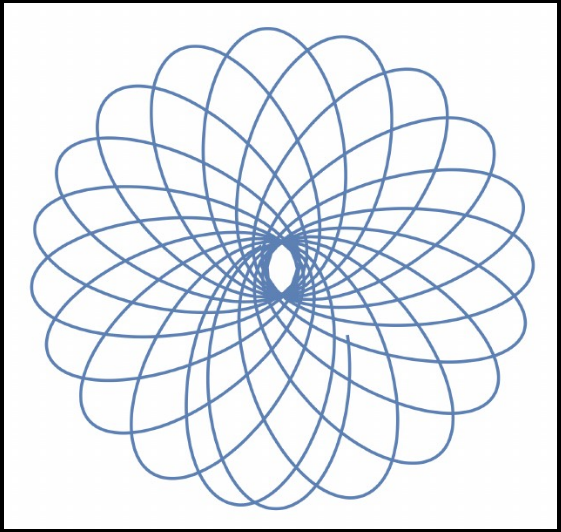


# Loss Cone in Gas-Rich Nuclei

- Non-Spherical systems



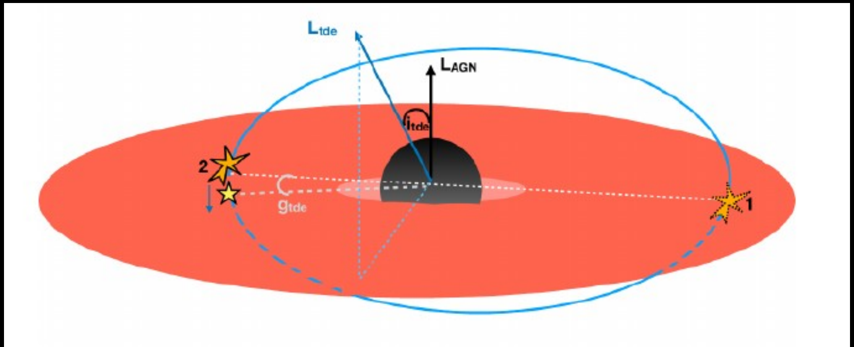

Kaur & Stone 2025



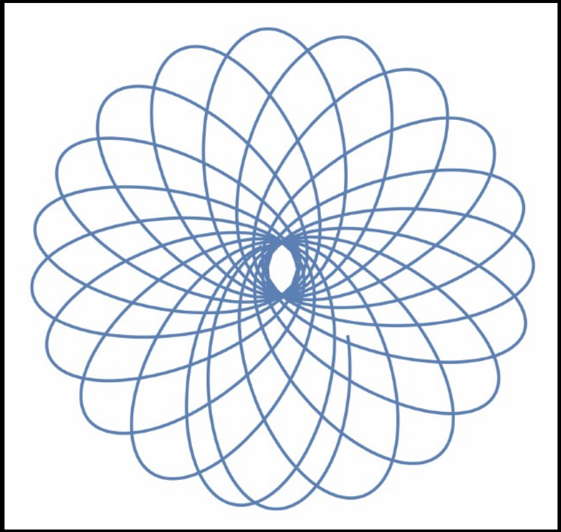
Circulating Orbits

# Loss Cone in Gas-Rich Nuclei

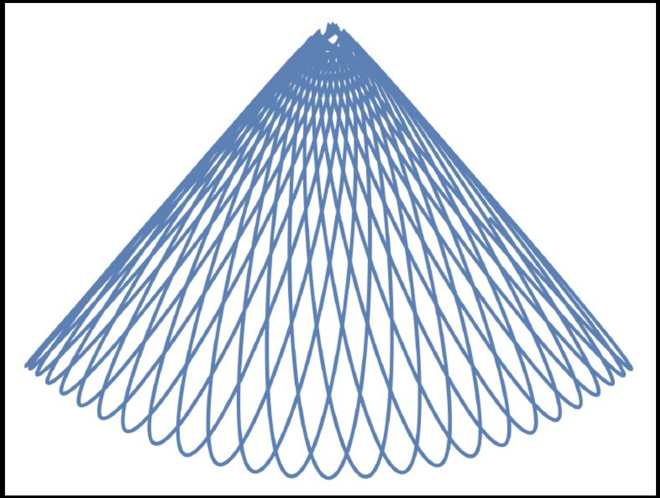
- Non-Spherical systems




Kaur & Stone 2025



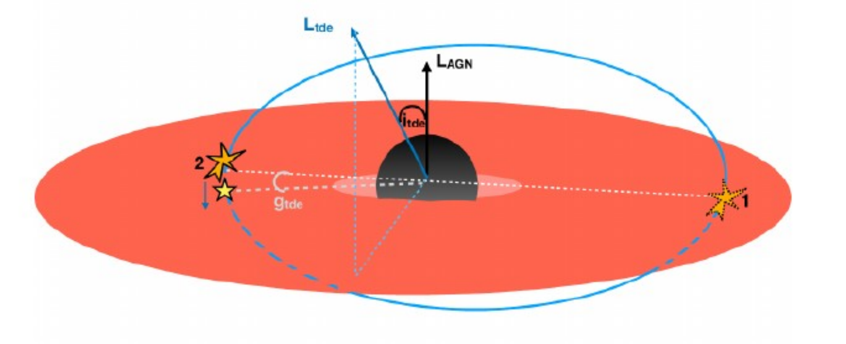
Circulating Orbits



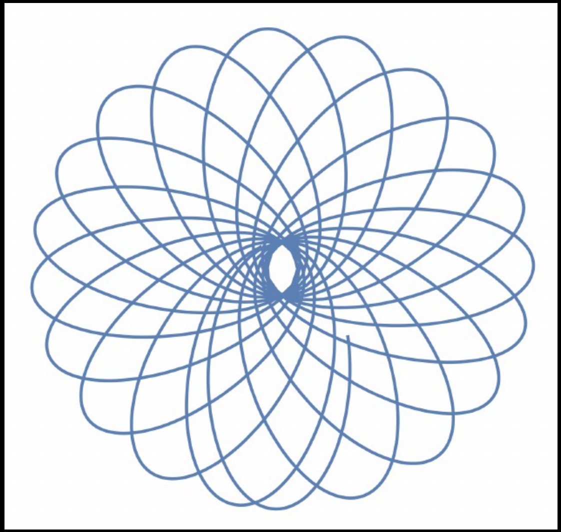
Librating Orbits

# Loss Cone in Gas-Rich Nuclei

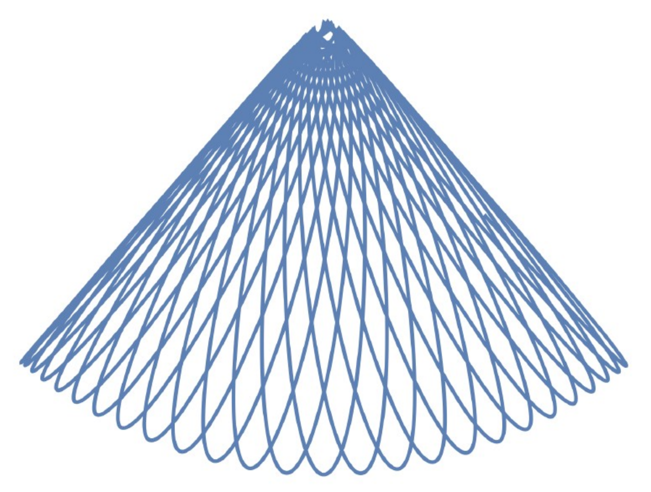
- Non-Spherical systems



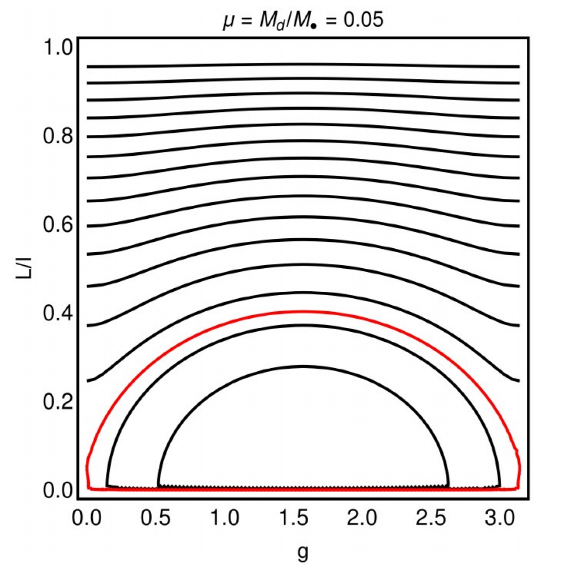

Kaur & Stone 2025



Circulating Orbits



Librating Orbits



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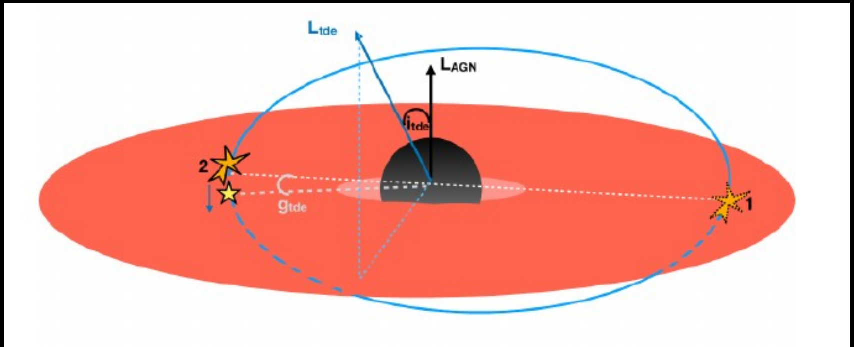
- Non-Spherical systems

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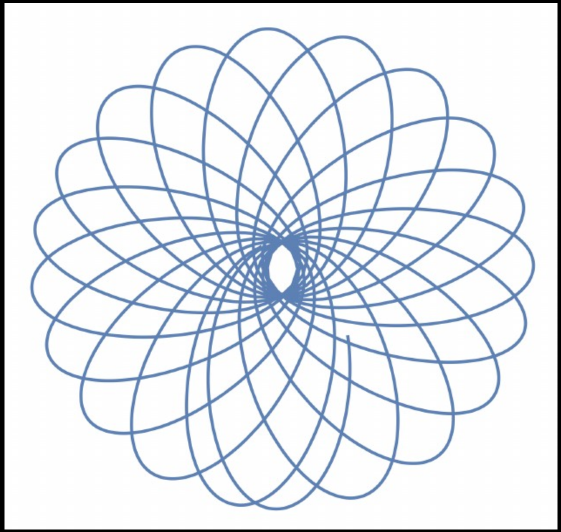

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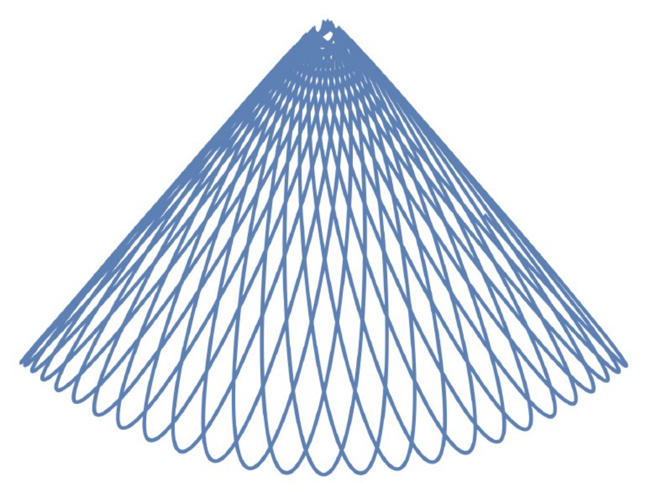

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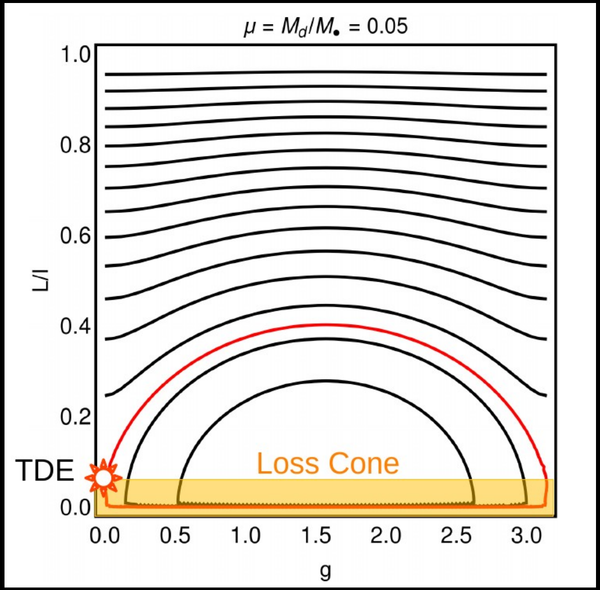

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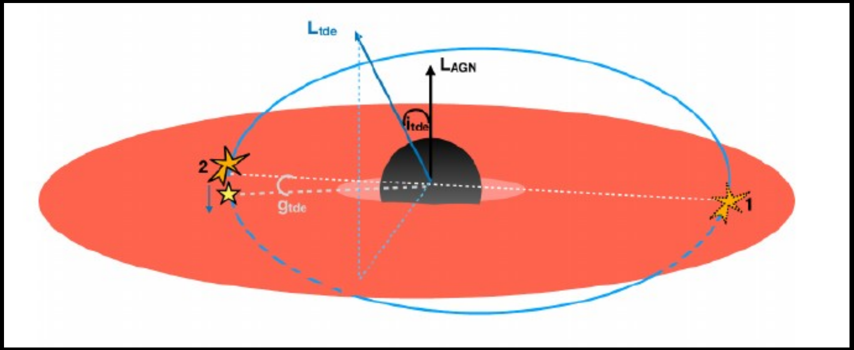
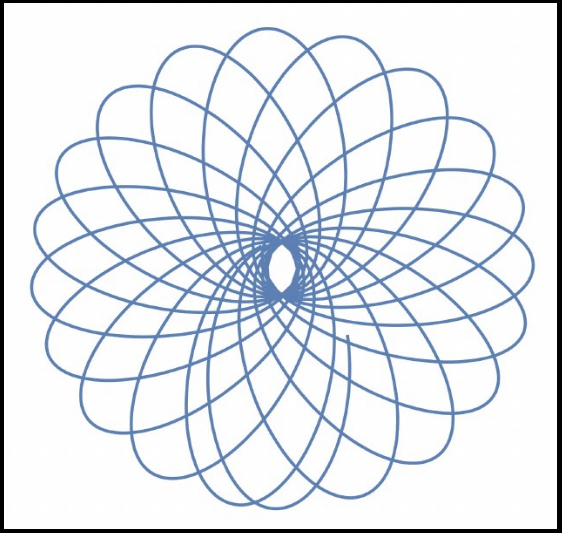
- Non-Spherical systems




Kaur & Stone 2025



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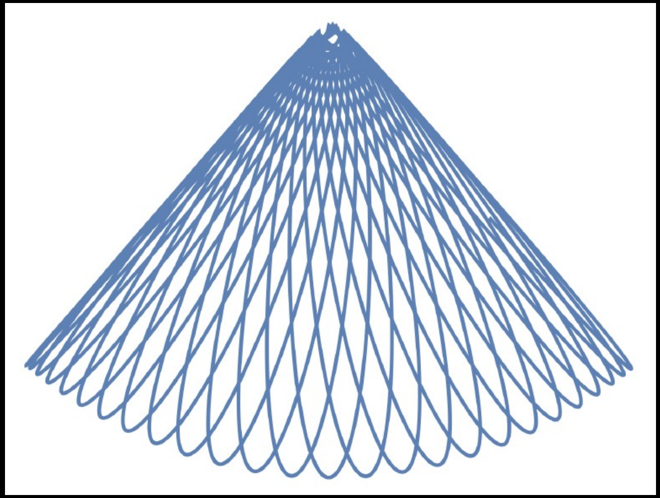

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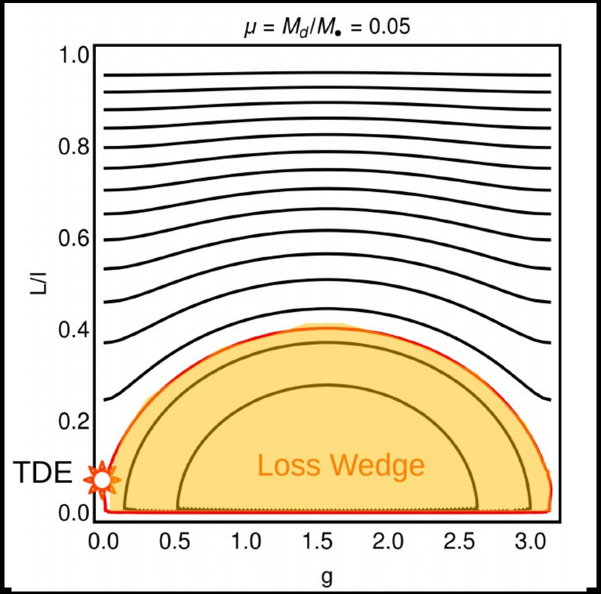
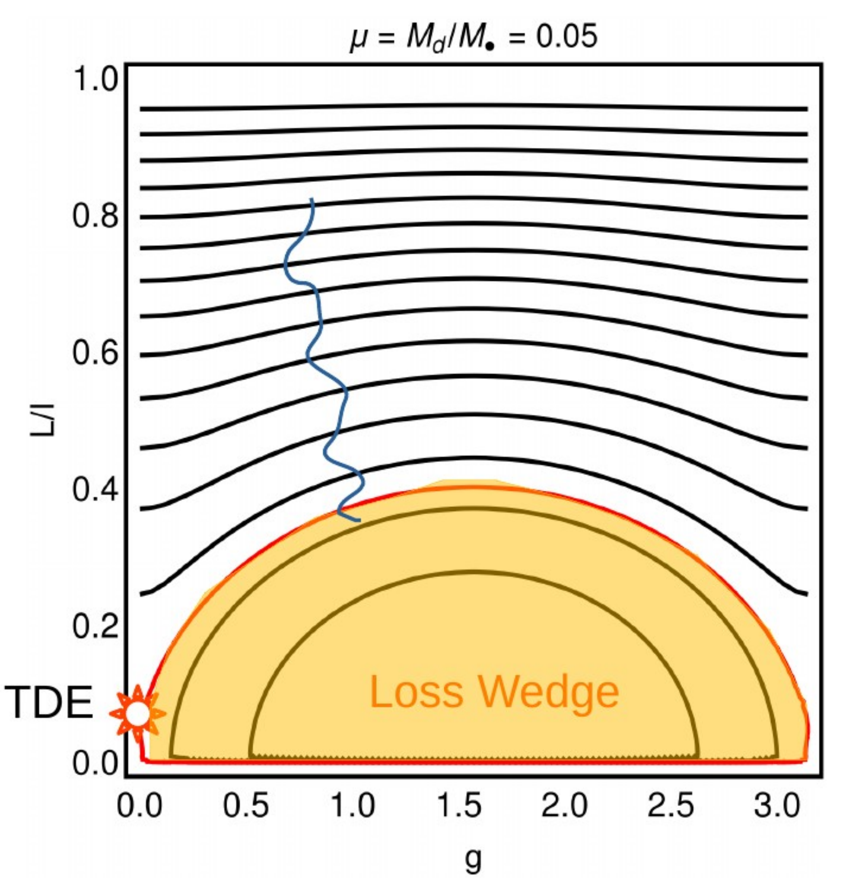


# Filling the Loss Wedge




$$T_{2b} \sim \frac{T_{kep}}{\ln\Lambda}\left(\frac{M}{m_f}\right)^2 \frac{1}{N_f(a)} \simeq 1\,Gyr\,M_6^{5/4}\,a_1^{\gamma-3/2}$$

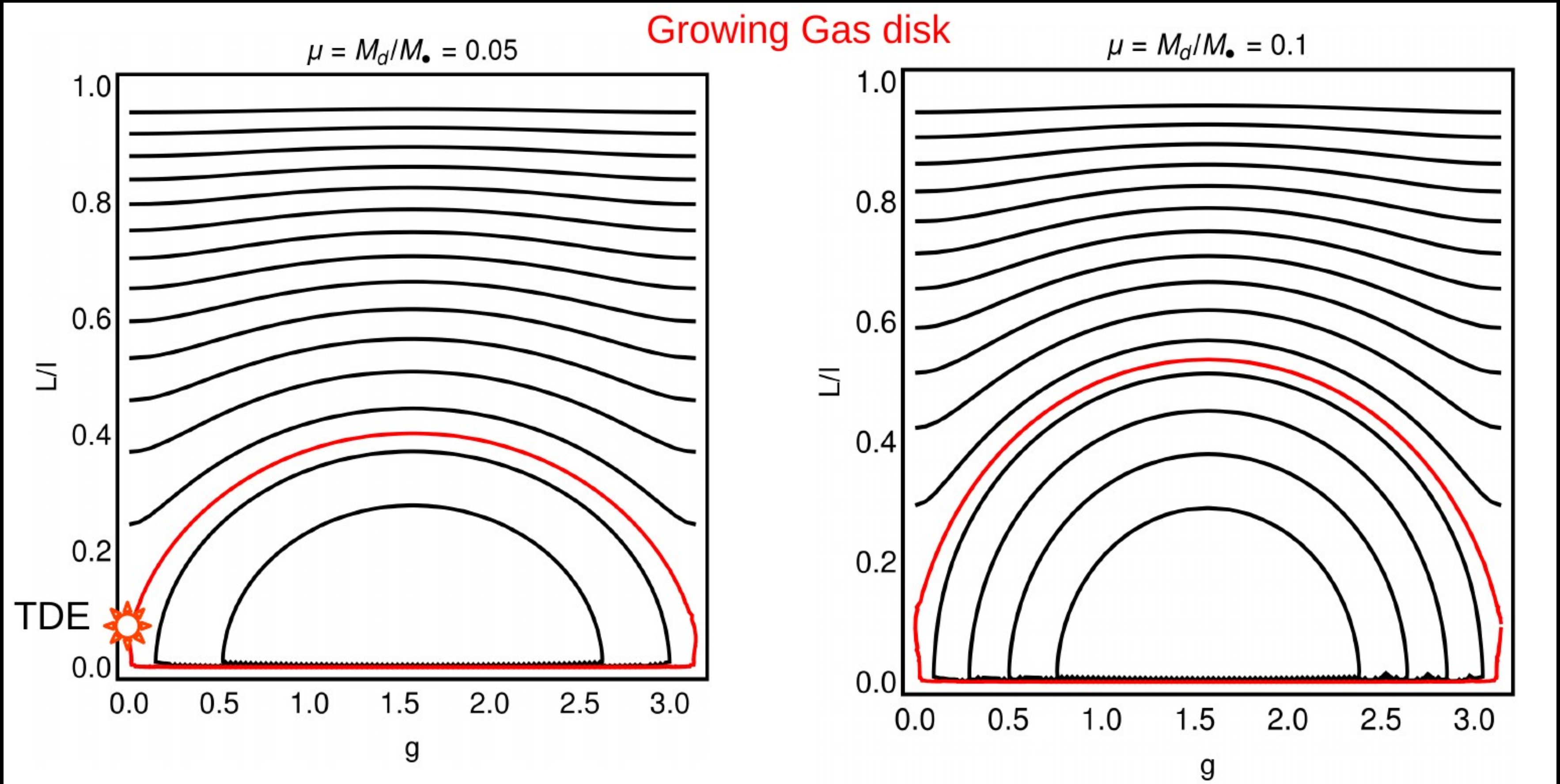
Only logarithmic enhancement in rates due to 2D nature of diffusion in *L* (Magorrian & Tremaine 1999,Vasiliev & Merritt 2013)

$$l_{lc} \sim 10^{-3}$$

$$\dot{N}_{2b} \sim \frac{N(r_h)}{\ln(1/l_{lc})\,T_{2B}(r_h)}$$

$$l_{lw} \sim \sqrt{\mu} \sim 0.1$$

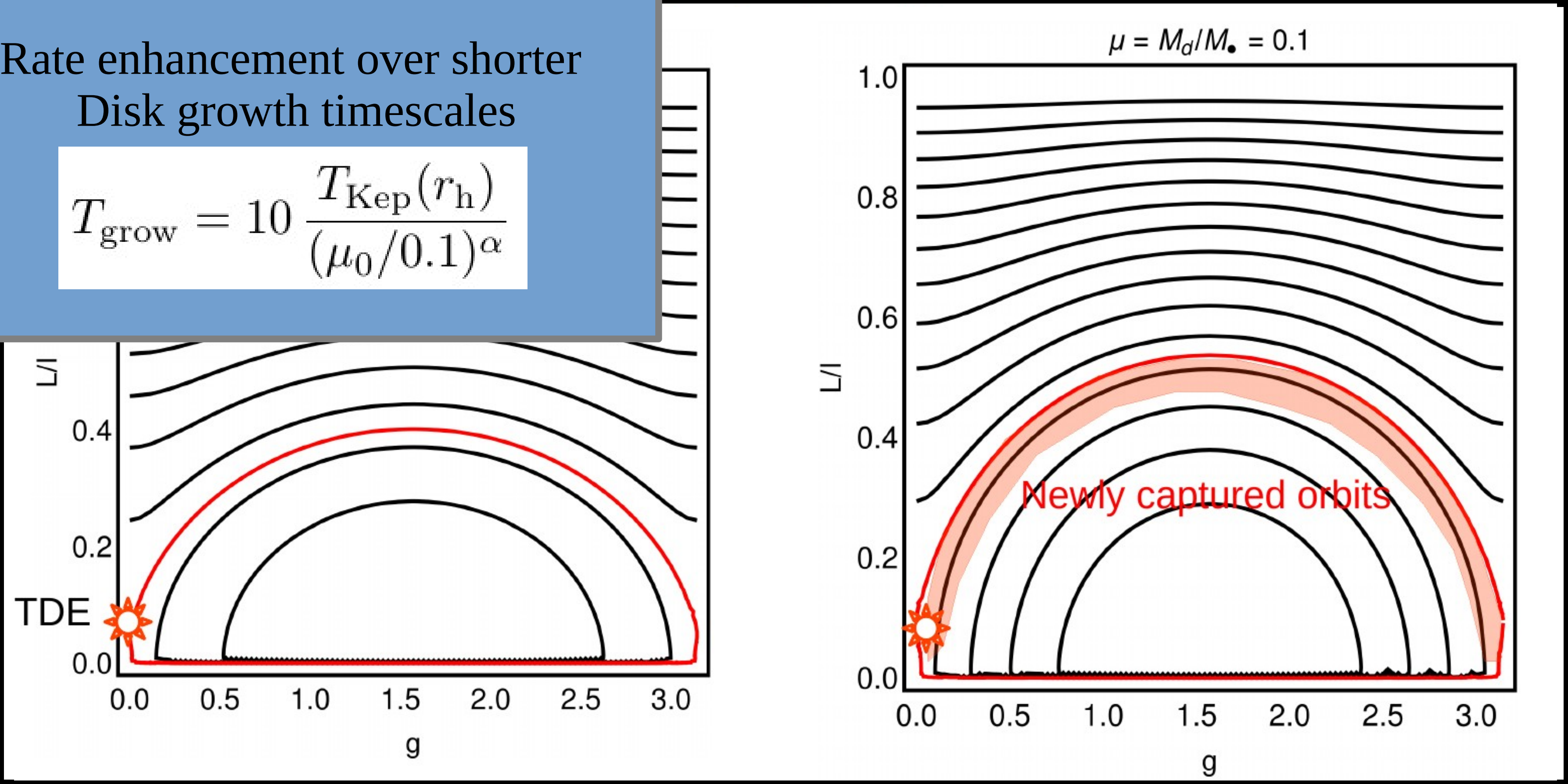
# Filling the Loss Wedge



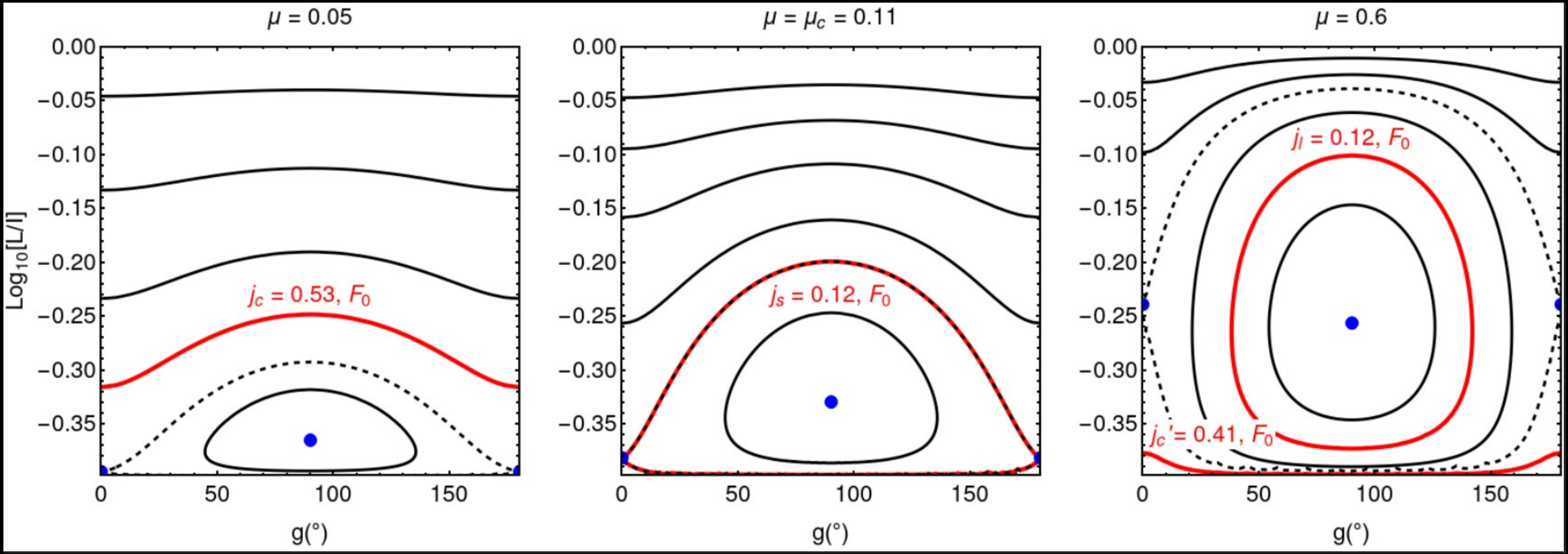
# Filling the Loss Wedge

Rate enhancement over shorter Disk growth timescales

$$T_{\rm grow} = 10\,\frac{T_{\rm Kep}(r_{\rm h})}{(\mu_0/0.1)^{\alpha}}$$



# Growing Libration Island- DF tracking

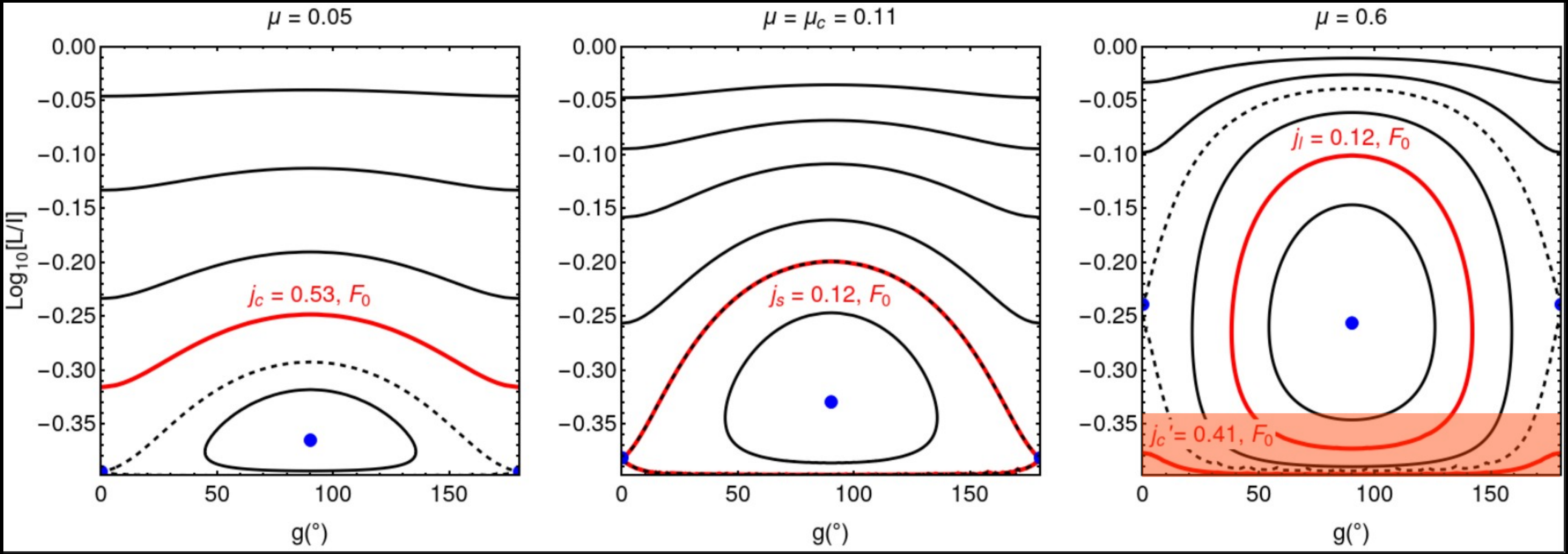



Adiabatic Approach : (1) Actions remain conserved, except at separatrix crossing at $\mu_c$.

Henrard 1982 (2) Distribution function is always conserved, even upon crossing.

Sridhar & Touma 1996

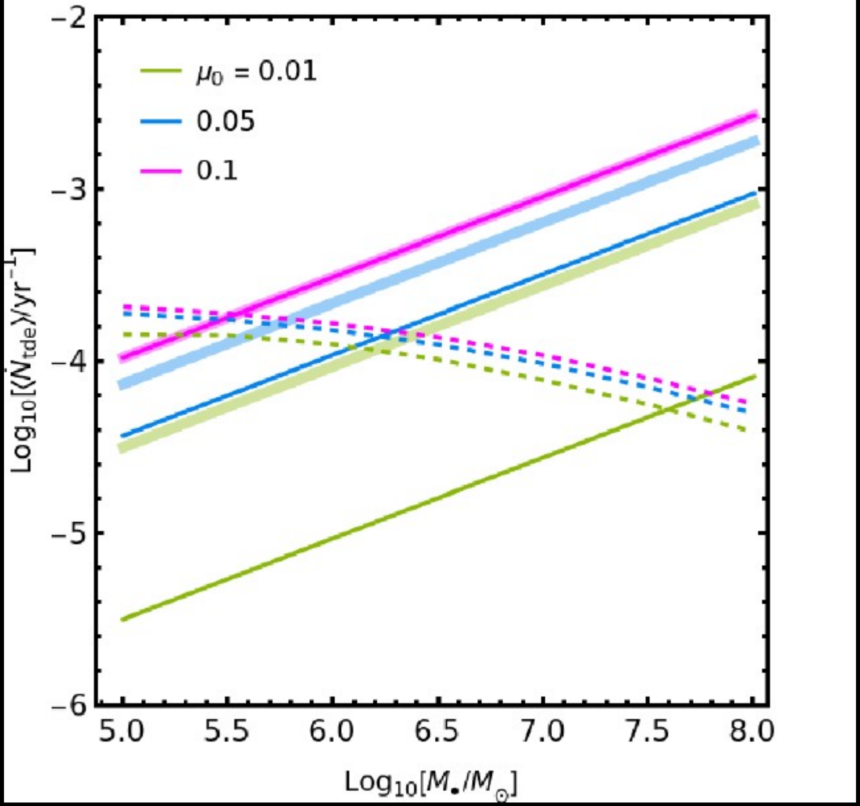
# Growing Libration Island- DF tracking




Adiabatic Approach : (1) DF evaluation at any time t.

(2) Number of TDEs fallen into the loss cone by time t. => TDE rate.

# Enhanced TDE rates




$$\langle \dot{N}_{\mathrm{cl}} \rangle = \frac{N_{\mathrm{h}}}{4T_{\mathrm{Kep}}(r_{\mathrm{h}})} \sqrt{\frac{r_{\mathrm{tid}}}{r_{\mathrm{h}}}} \mu_0^{\alpha-\beta+\frac{1}{2}} \mathfrak{F}(\beta,\gamma)$$

$$= 0.8 \times 10^{-3}\ \mathrm{yr}^{-1}\ M_7^{7/15}\ \mu_{-1}^{\alpha+\frac{1}{2}}$$

Rate enhancement is most important for high $M_\bullet$ and $\mu$

*Tenatative Support from observations:*

* High-amplitude IR flares in AGNs (van Velzen+24)
* Preference of TDE host galaxies towards recently faded AGNs (Wevers & French 24).

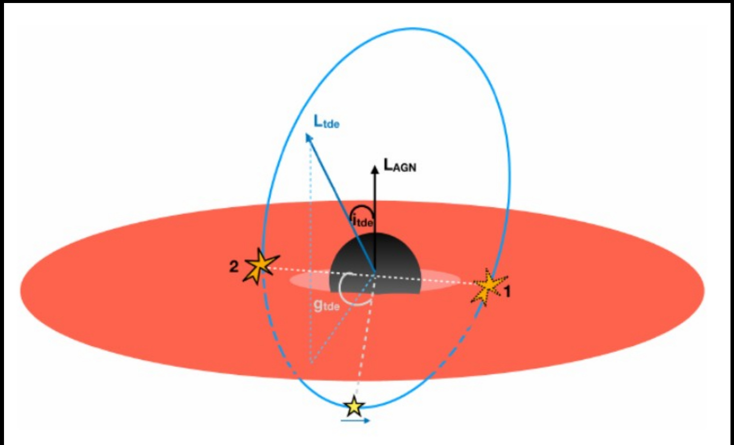
# Conclusions

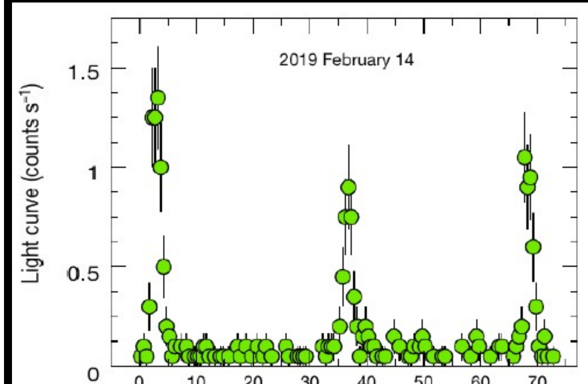
- TDE rates per galaxy from standard channel agree with observed TDE rates on average ~$10^{-4}$ – $10^{-5}$ $yr^{-1}$ . But, it does not present the complete picture!
- TDEs prefer very special galaxy hosts E+A galaxies. The real TDE rates are inhomogeneous among galaxy types.
- Recent evidence of influence of presence of gas on TDE rates. Some of E+A galaxies are associated with recently faded AGNs. Rates as high as ~ $10^{-3}$ $yr^{-1}$ are possible.

# What’s next for loss cones?

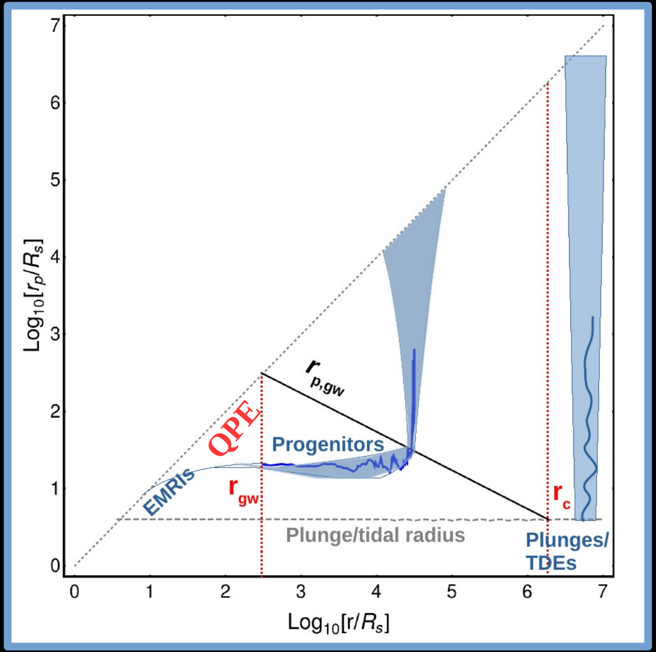
- Transients (TDEs and EMRIs) in gas-rich nuclei – effects of gas dynamical friciton, drag forces, thermal feedback to disk and its dissipation, GR effects and accouting for secular dynamics and 2-body scatterings in asymmetric system and more. What will be the observational signature of such TDEs?
- Deeper surveys like LSST in future; more TDEs and tracking down fertile environments in TDE host galaxies to check these theories. LISA will whisper in mHz in future telling about EMRI formation.
- Quasi-periodic eruptions (QPEs = EMRI + TDE) – these can be early electromagnetic signatures of EMRIs. We need to testify the theory on this ground (Linial & Metzger 23).

# What's next for loss cones?




Minutti+19

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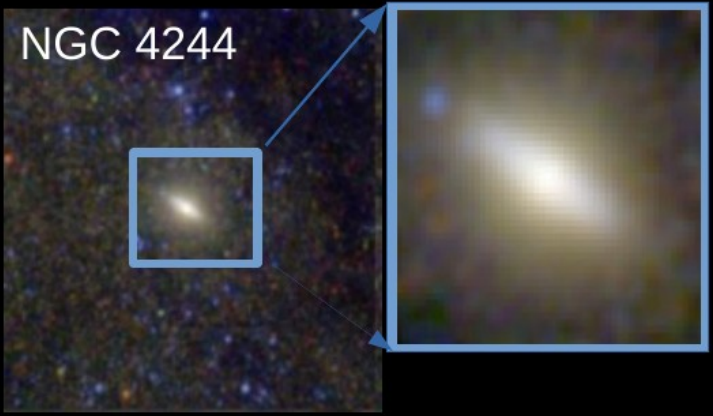
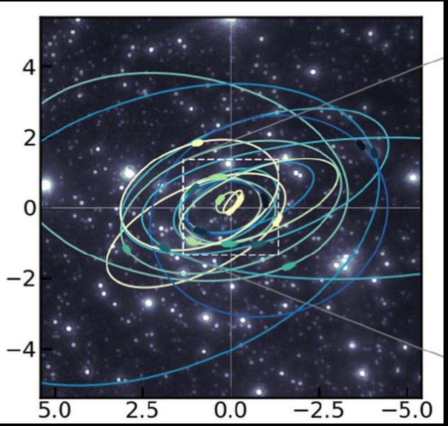
# What's next for loss cones? (cntd)

- Time-dependent evolution of rates important, while accoutning for star formation and depletion of sources for both TDEs and EMRIs. What are abundances and distribution of BHs in galactic nuclei? Important for even TDEs as BHs can be dominant strong scatterers. Currently, this question is not even settled at theoretical level - weak vs strong segregation.
- Transients around intermediate mass black holes (IMBHs) with masses $< 10^5$ $M_{sun}$. The role of full loss cones for EMRI rates and more recent Cliff-hanger EMRIs. How will these EMRIs sound – will they be similar to just plunges? Important source for as LISA sensitivity maximum for these MBH masses.
- Realistic complexities of NSCs. They are significantly flattened as well. We need to evaluate transient (TDE) rates keeping these complexities in view.

# Other directions ...

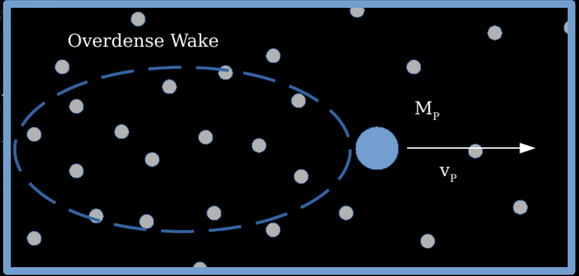
Morphology of NSCs --
Gravitational Instabilities

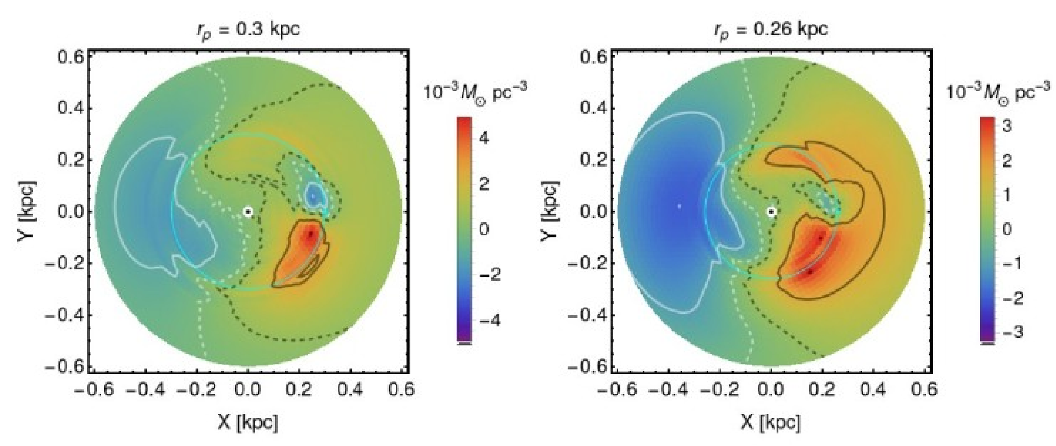


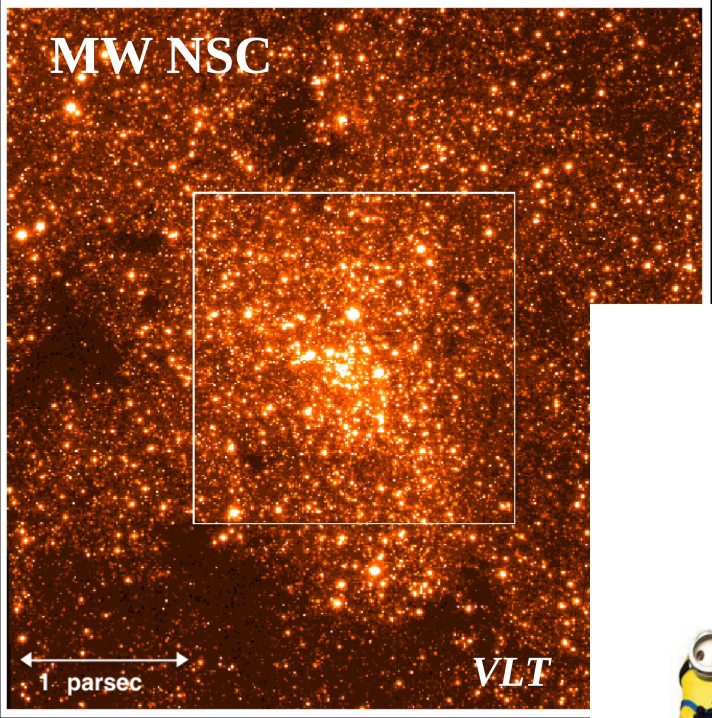




Accretion disc instabilities – impact of magnetic fields


Global Dynamical Friction






# Thanks ..