Mass-Gap Extreme mass ratio inspirals

Zhen Pan, Perimeter Institute
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EMRI introduction

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$:= 1$ massive BH (MBH) $+$ 1 inspiralling stellar-mass BH (sBH)

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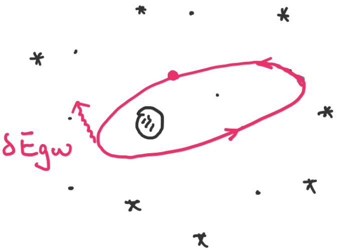
1 mass-gap EMRI
:= 1 MBH + 1 inspiralling MGO

Dry EMRIs (loss cone)



$t_{\rm gw}$: GW emission timescale

$t_{\rm rlx}$: 2-body scatterings

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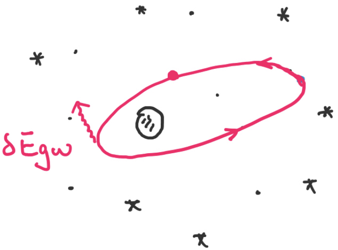

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$t_{\rm gw} < t_{\rm rlx}$: EMRI formation

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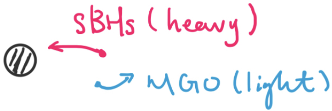

Figure: Mass segragation

$t_{\rm gw}$: GW emission timescale

$t_{\rm rlx}$: 2-body scatterings

heavier closer, easier EMRI formation

$t_{\rm gw} < t_{\rm rlx}$: EMRI formation

Fiducial model: Galactic MBH $M_\bullet = 4 \times 10^6 M_\odot$

Initial condition: Tremaine's cluster model of a nuclear stellar cluster

$m_{\rm mgo,sbh} = (3, 10) M_\odot$, $N_{\rm mgo} : N_{\rm sbh} = 1 : 1$

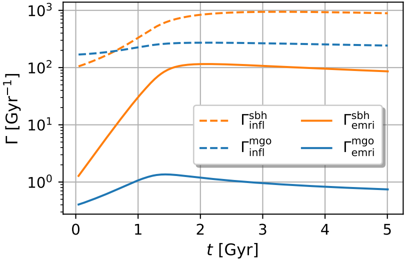

Figure: $\Gamma^{\rm sbh}_{\rm emri} \approx 10^2\ {\rm Gyr}^{-1}$, $\Gamma^{\rm mgo}_{\rm emri} \approx 10^0\ {\rm Gyr}^{-1}$ $\leftarrow$ Mass segragation

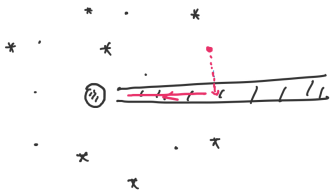

Figure: Disk cartoon

3 timescales:

$t_{\rm cap}$: inclination damping

$t_{\rm mig}$: migration inward

$T_{\rm dsk}$: disk lifetime

Wet EMRIs

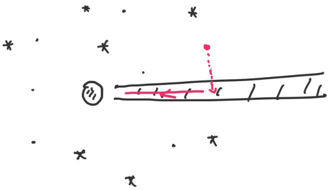

Figure: Disk cartoon

3 timescales:

$t_{\rm cap}$: inclination damping

$t_{\rm mig}$: migration inward

$T_{\rm dsk}$: disk lifetime

$t_{\rm mig} < T_{\rm dsk} \Rightarrow$ EMRI formation

e.g., $M_\bullet = 4 \times 10^6 M_\odot, 0.1 \dot{M}_{\rm Edd}$

$$t_{\rm cap} \sim 10^{1-2} yr, \; t_{\rm mig} \sim 10^{5-6} yr, \; T_{\rm dsk} \sim 10^{7-8} yr$$

Initial condition: final state of the no-disk MBH-nuclear cluster.

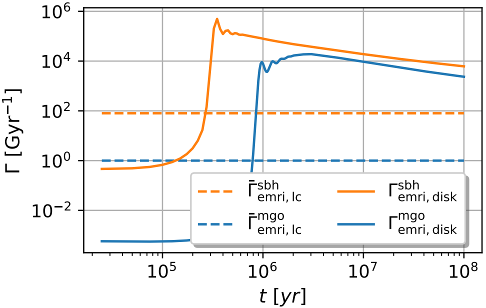

Figure: $\Gamma^{\rm sbh}_{\rm emri}/\Gamma^{\rm mgo}_{\rm emri} \approx m_{\rm sbh}/m_{\rm mgo}$

Summary

$$M_\bullet = 4 \times 10^6 M_\odot,\ \frac{\langle \Gamma^{\rm sbh}_{\rm wet} \rangle}{\langle \Gamma^{\rm sbh}_{\rm dry} \rangle} = \mathcal{O}(10^2 - 10^3),\ \frac{\langle \Gamma^{\rm mgo}_{\rm wet} \rangle}{\langle \Gamma^{\rm mgo}_{\rm dry} \rangle} = \mathcal{O}(10^3 - 10^4)$$

$$M_\bullet = 1 \times 10^5 M_\odot,\ \frac{\langle \Gamma^{\rm sbh}_{\rm wet} \rangle}{\langle \Gamma^{\rm sbh}_{\rm dry} \rangle} = \mathcal{O}(10^1 - 10^2),\ \frac{\langle \Gamma^{\rm mgo}_{\rm wet} \rangle}{\langle \Gamma^{\rm mgo}_{\rm dry} \rangle} = \mathcal{O}(10^2 - 10^3)$$

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AGN fraction:

$$f_{\rm AGN}(z \lesssim 1) \sim 1\%$$

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Wet channel should contribute an important fraction of sBH EMRIs and a dominant fraction of mass-gap EMRIs.

Discussion

Expected number of EMRI detections $D_{\rm sbh}, D_{\rm mgo}$ are sensitive to unknown MBH mass function, but their ratio $D_{\rm sbh}/D_{\rm mgo}$ is not.

$$D_{\rm sbh}/D_{\rm mgo} \approx 120 \times (N_{\rm sbh}/N_{\rm mgo}) \quad ({\rm DRY})$$

$$D_{\rm sbh}/D_{\rm mgo} \approx (5-10) \times (N_{\rm sbh}/N_{\rm mgo}) \quad ({\rm WET})$$

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Observable wet&dry $D_{\rm sbh}/D_{\rm mgo} \rightarrow N_{\rm sbh}/N_{\rm mgo}$