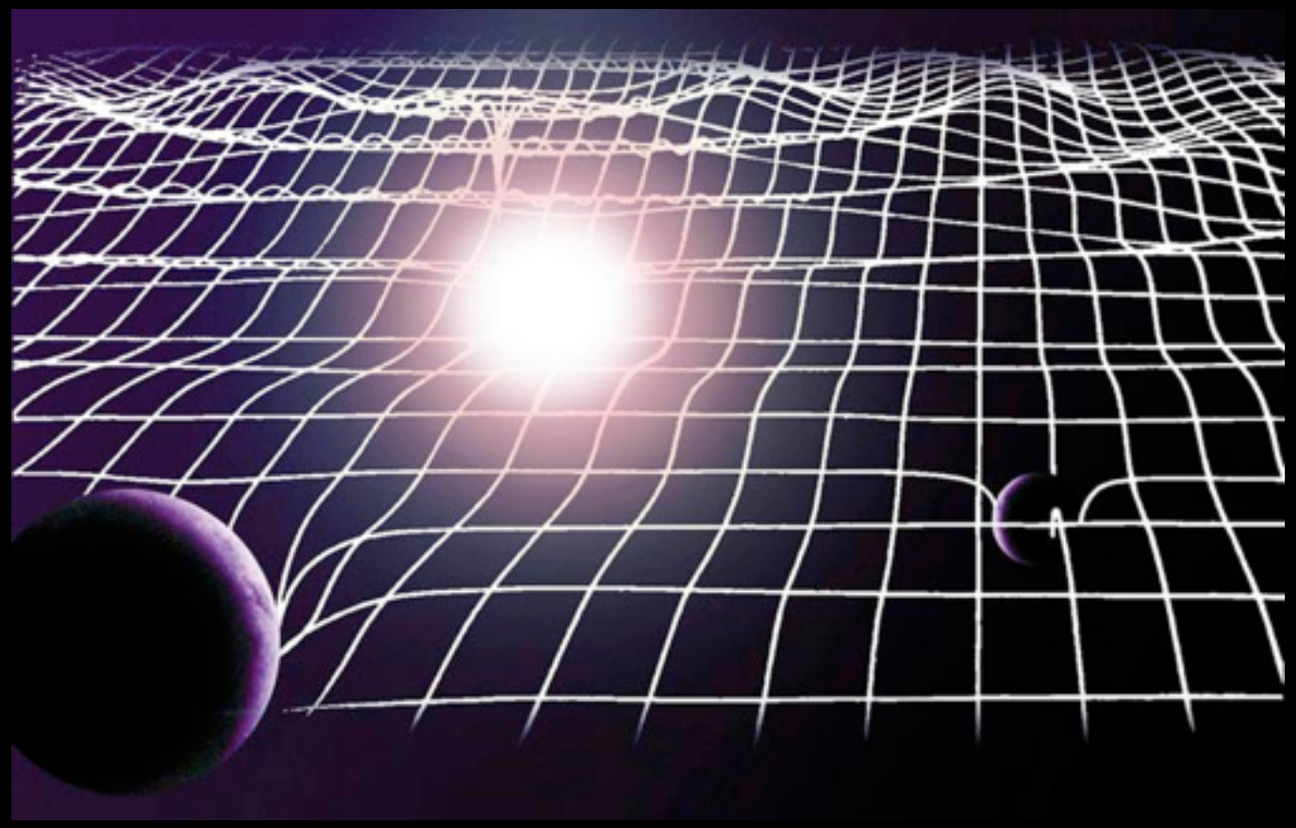
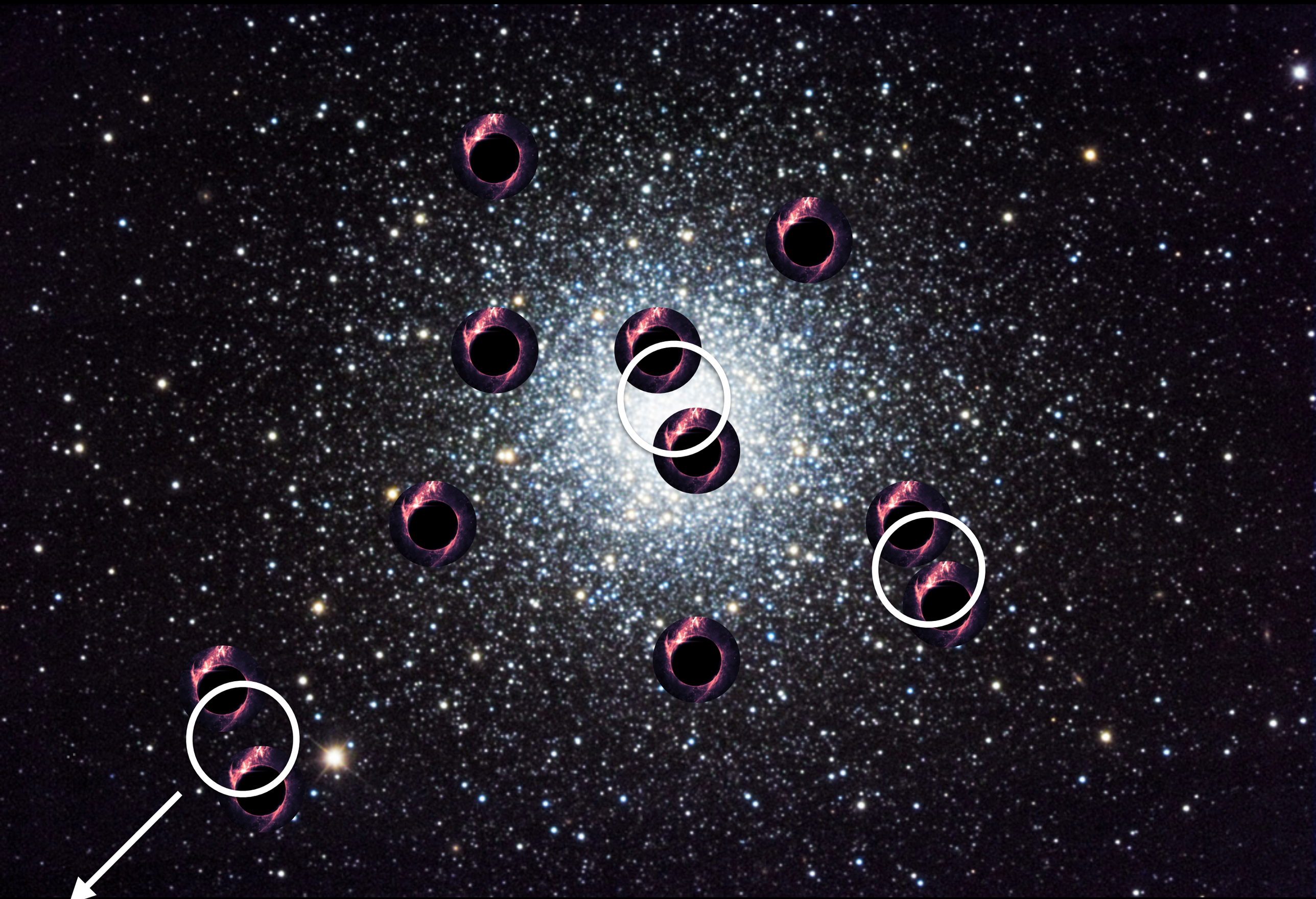
Formation of High Eccentricity GW Mergers

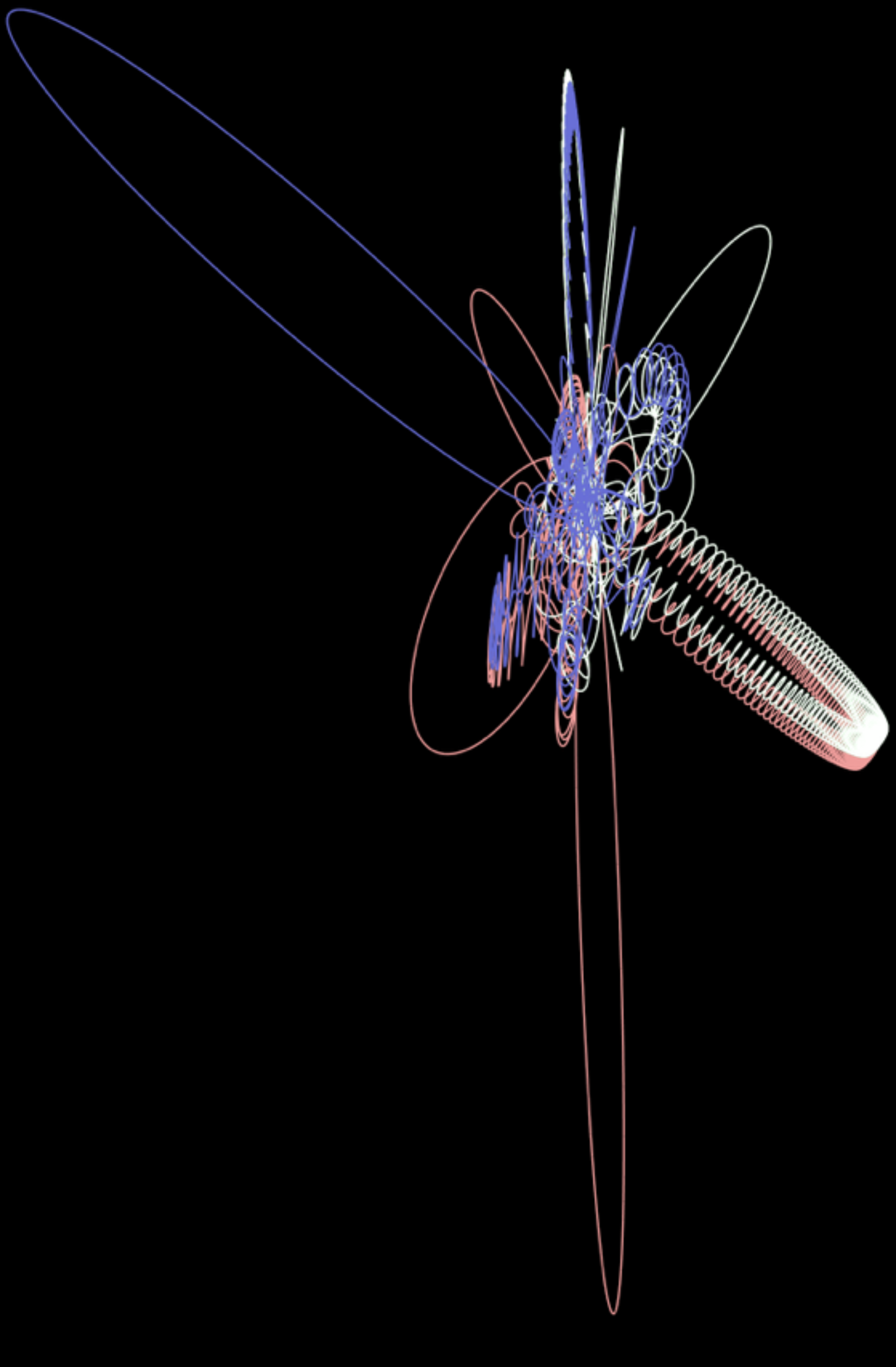
Johan Samsing
Princeton

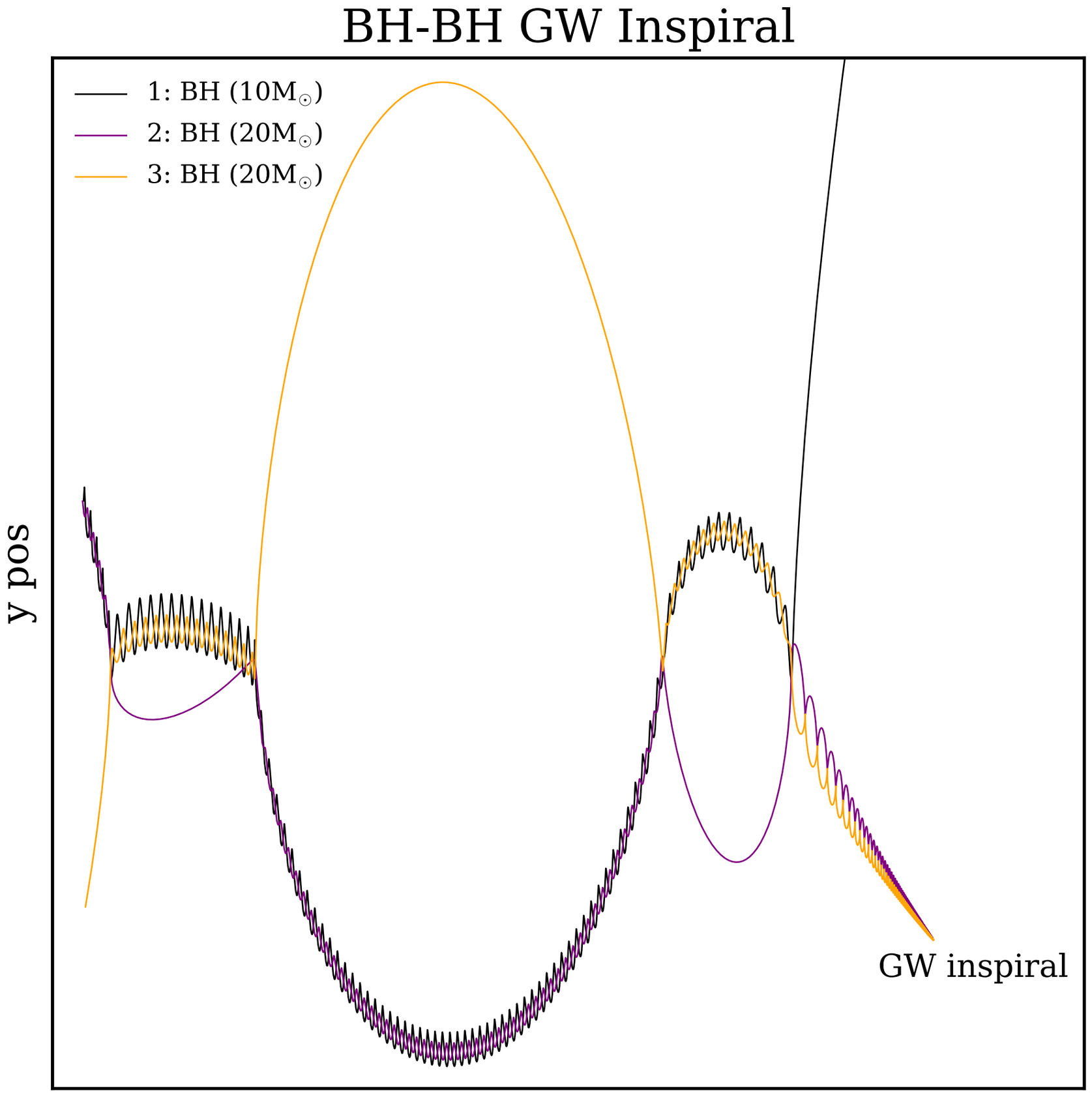


What is the origin of BBH mergers?

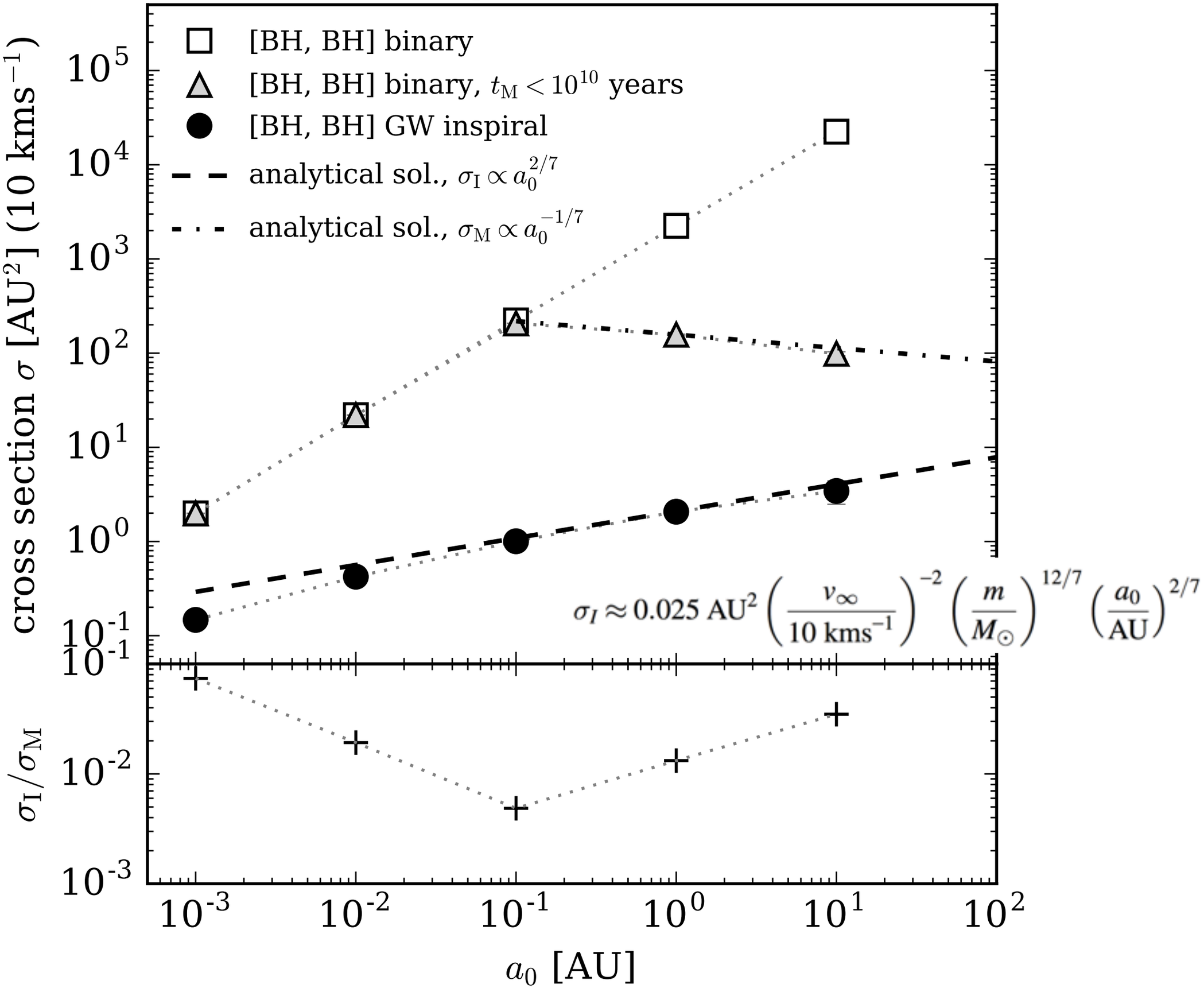
* Spin
* Mass
* Eccentricity






BH-BH GW Inspiral
1: BH (10M⊙)
2: BH (20M⊙)
3: BH (20M⊙)
y pos
x pos
GW inspiral

GW Mergers and Inspirals



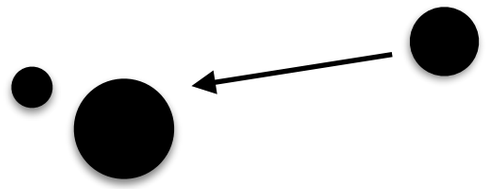
Analytical Solution

$$\frac{\sigma_I}{\sigma_M^{<\tau}} \gtrsim 0.01 \left(\frac{m}{10M_\odot}\right)^{5/28} \left(\frac{\tau}{t_{\rm H}}\right)^{-5/28}$$

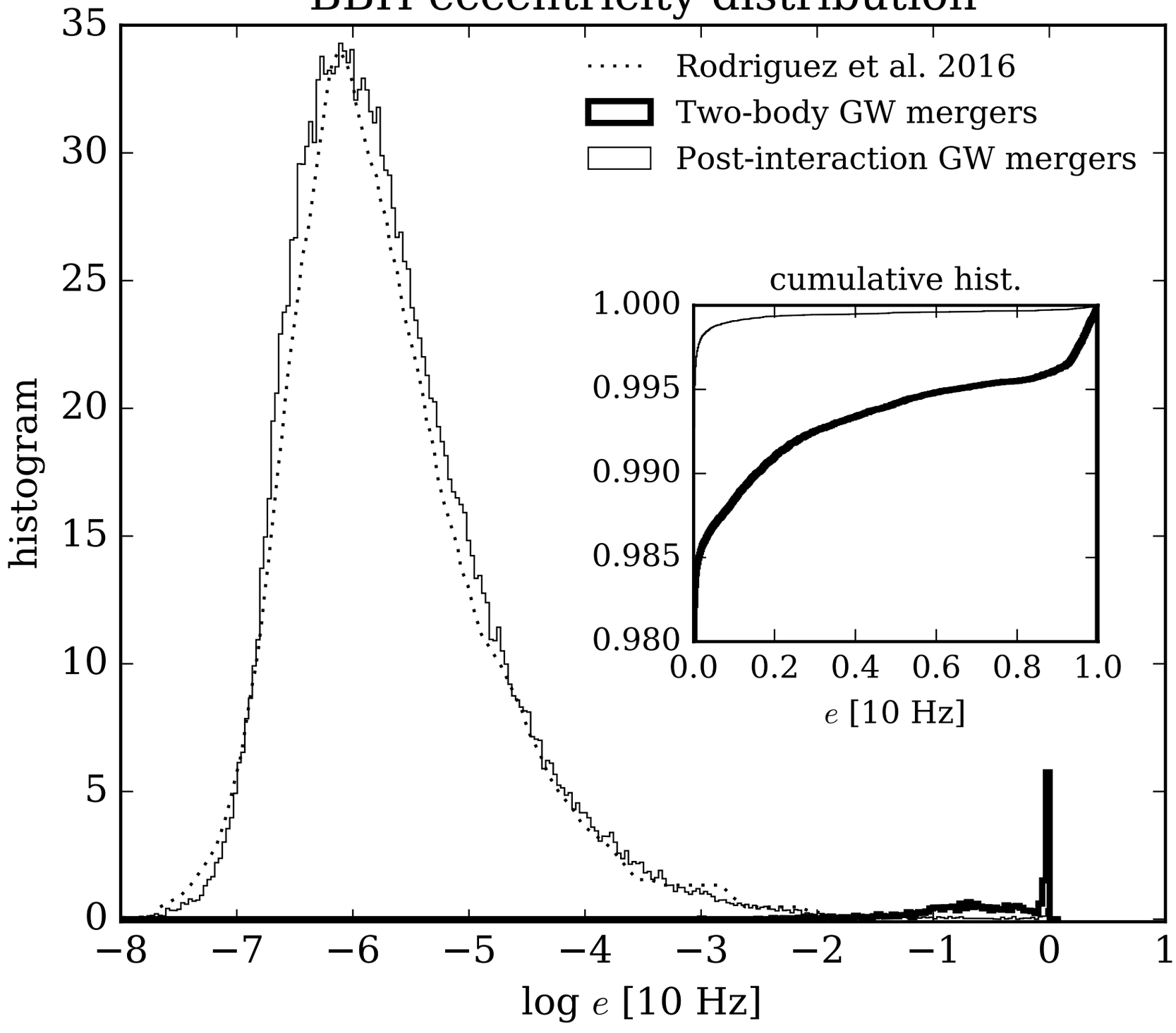
$$\frac{\Gamma_I}{\Gamma_M} \gtrsim 0.01 \left(\frac{m}{10M_\odot}\right)^{5/28}$$

$$\frac{\Gamma_{f_{\rm GW}}}{\Gamma_I} \approx 0.2 \left(\frac{m}{20M_\odot}\right)^{-8/21} \left(\frac{f_{\rm GW}}{10{\rm Hz}}\right)^{-2/3} \left(\frac{a_0}{0.1{\rm AU}}\right)^{-2/7}$$

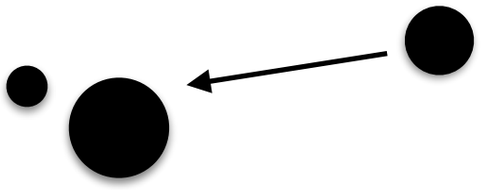
No `N-body groups' incl. these corrections yet.



BBH eccentricity distribution



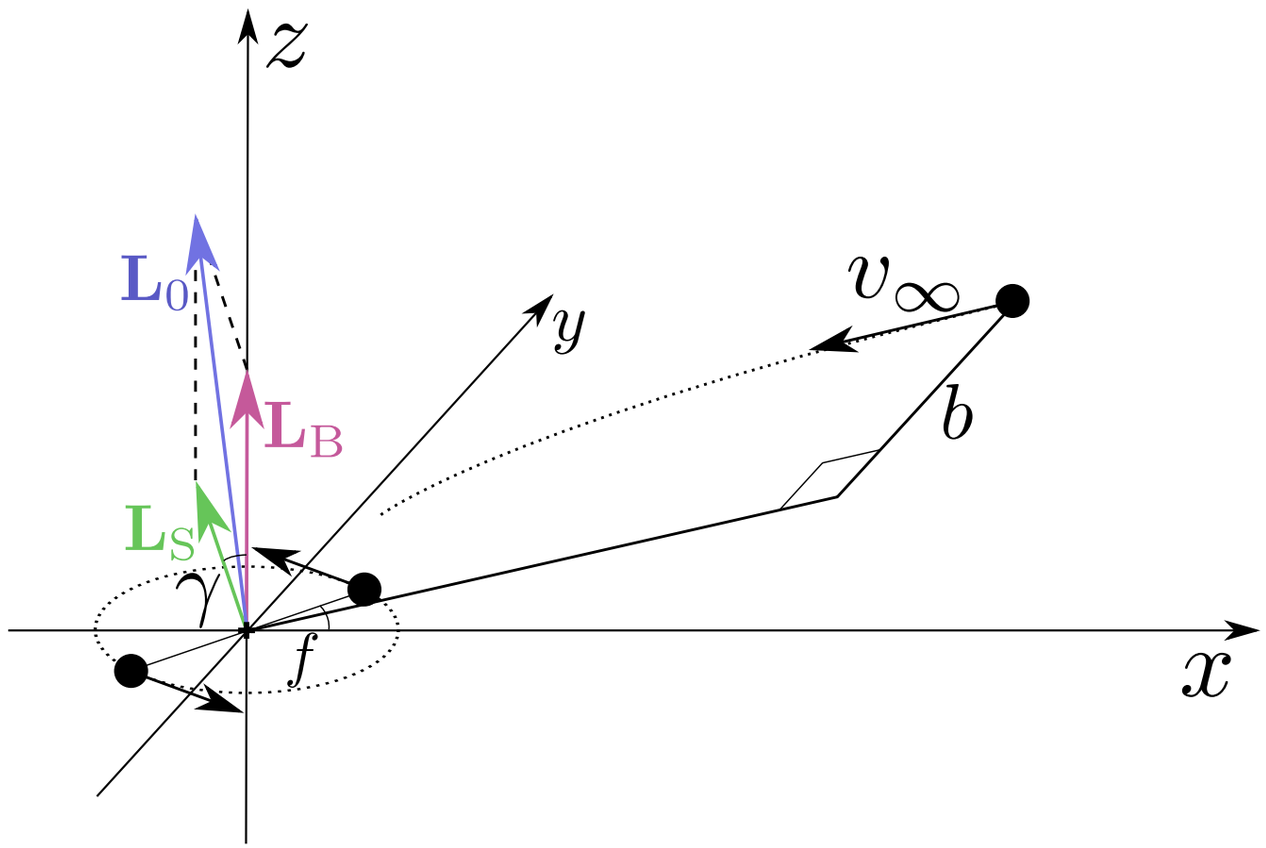
Current work.



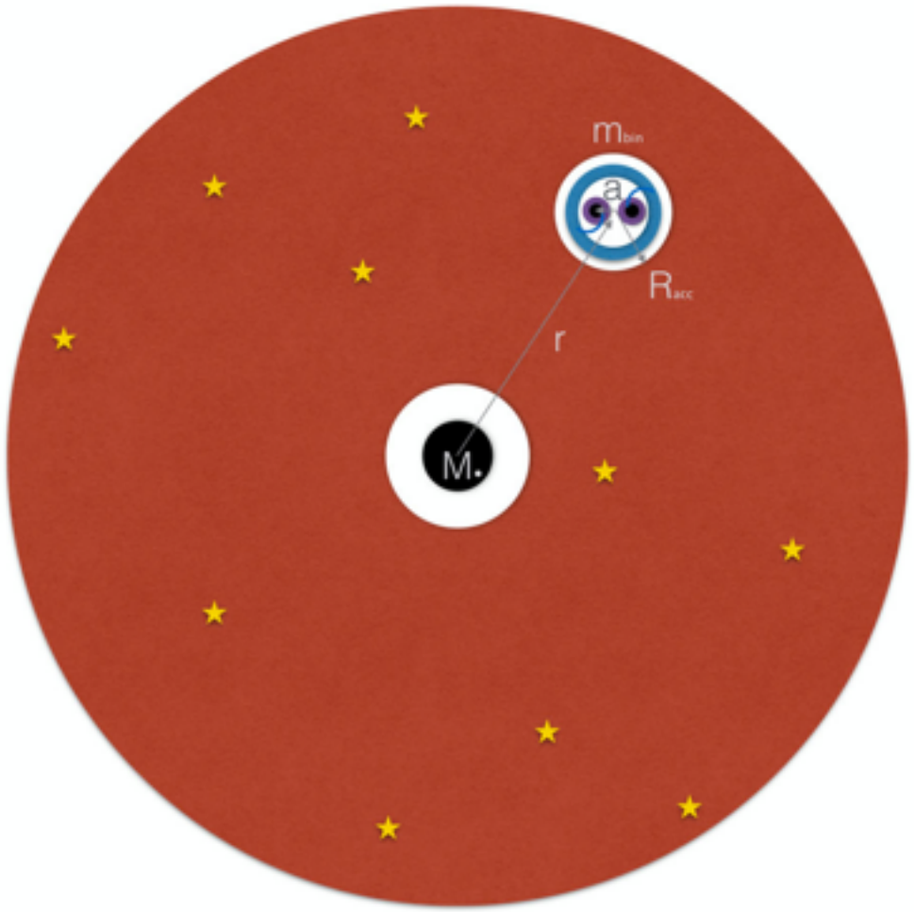
* Improve analytical models (higher fractions?)
* Analyze full globular cluster simulations.
* Eccentricity distribution: compare different models.

Not all interactions are equally likely

Initial conditions



AGN example



Endstates

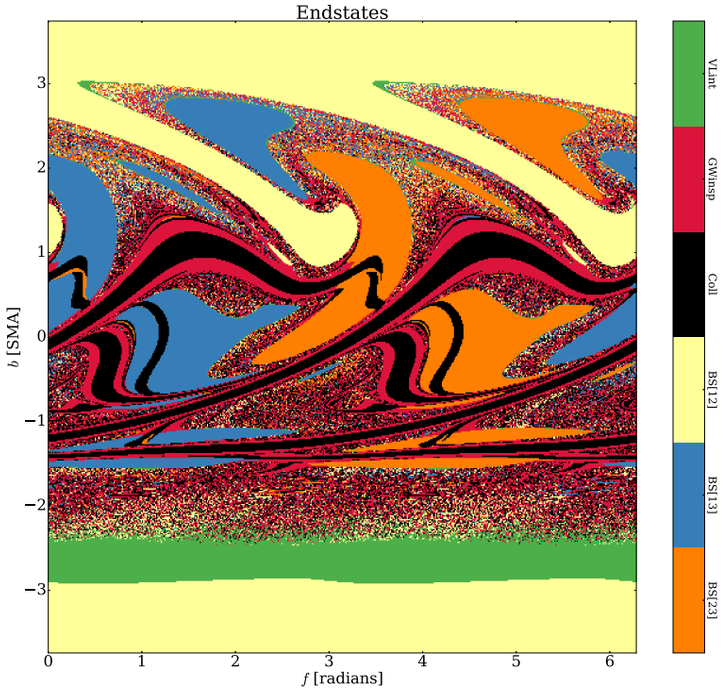
b [SMA]

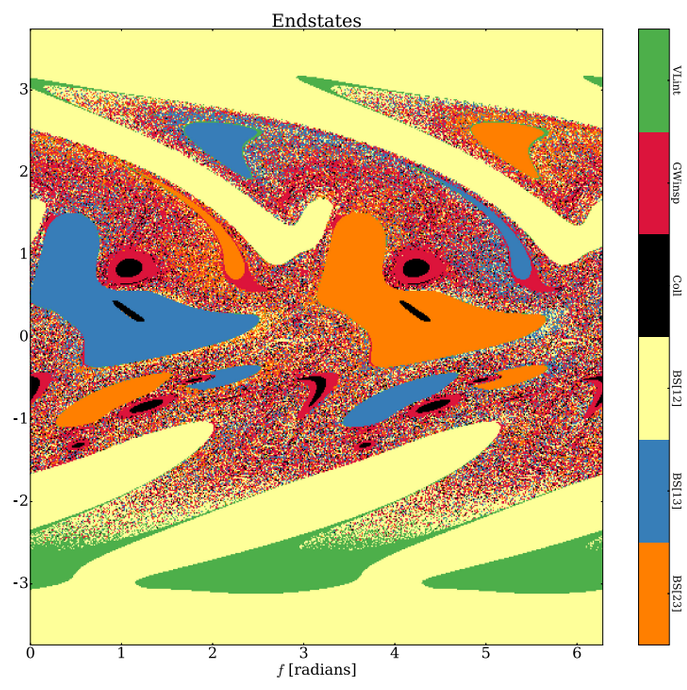
3
2
1
0
−1
−2
−3

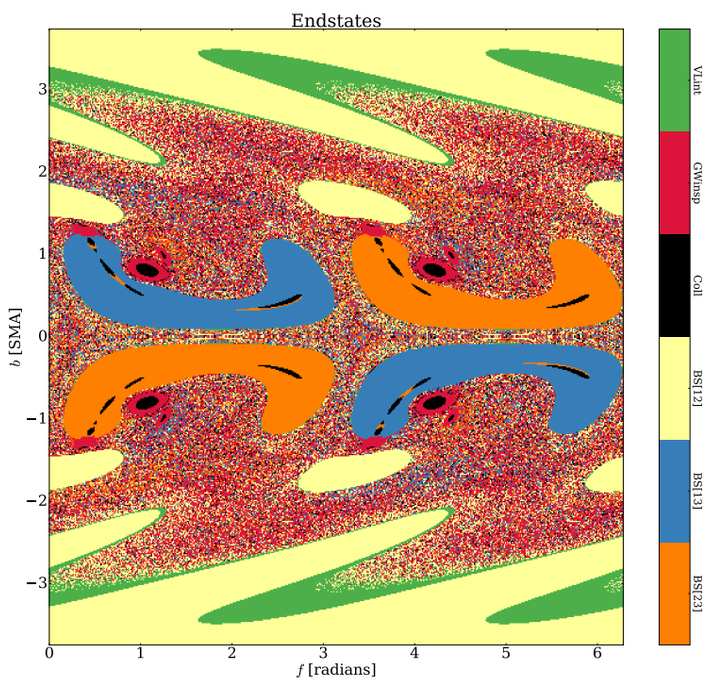
0
1
2
3
4
5
6

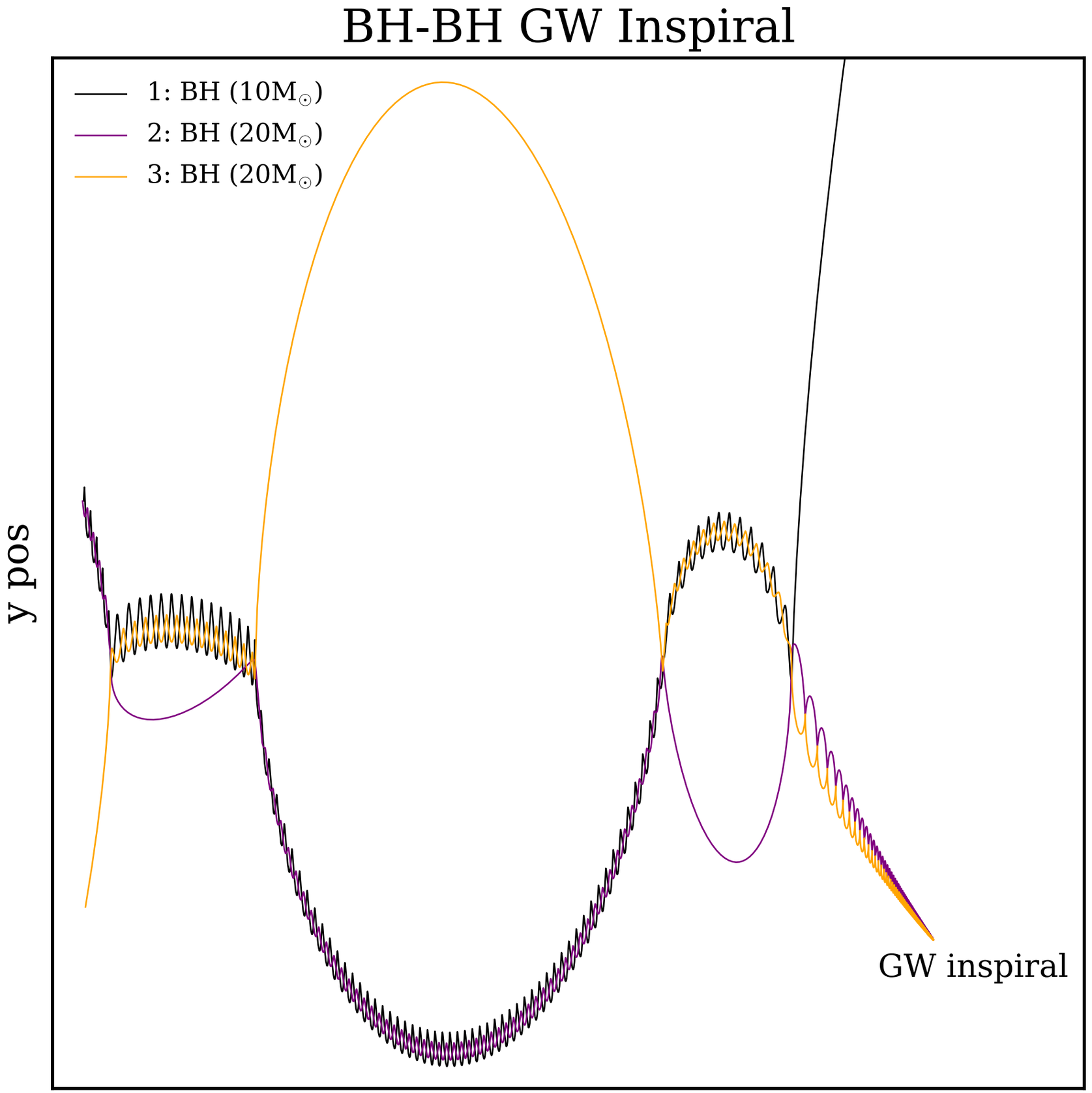
f [radians]

Infty
GWinsp
Coll
BS[12]
BS[13]
BS[23]


Endstates
VLint
GWinsp
Coll
BS[12]
BS[13]
BS[23]
q [SMA]
f [radians]


Endstates
VLint
GWinsp
Coll
BS[12]
BS[13]
BS[23]
f [radians]


Endstates
VLint
GWinsp
Coll
BS[12]
BS[13]
BS[23]
q [SMA]
f [radians]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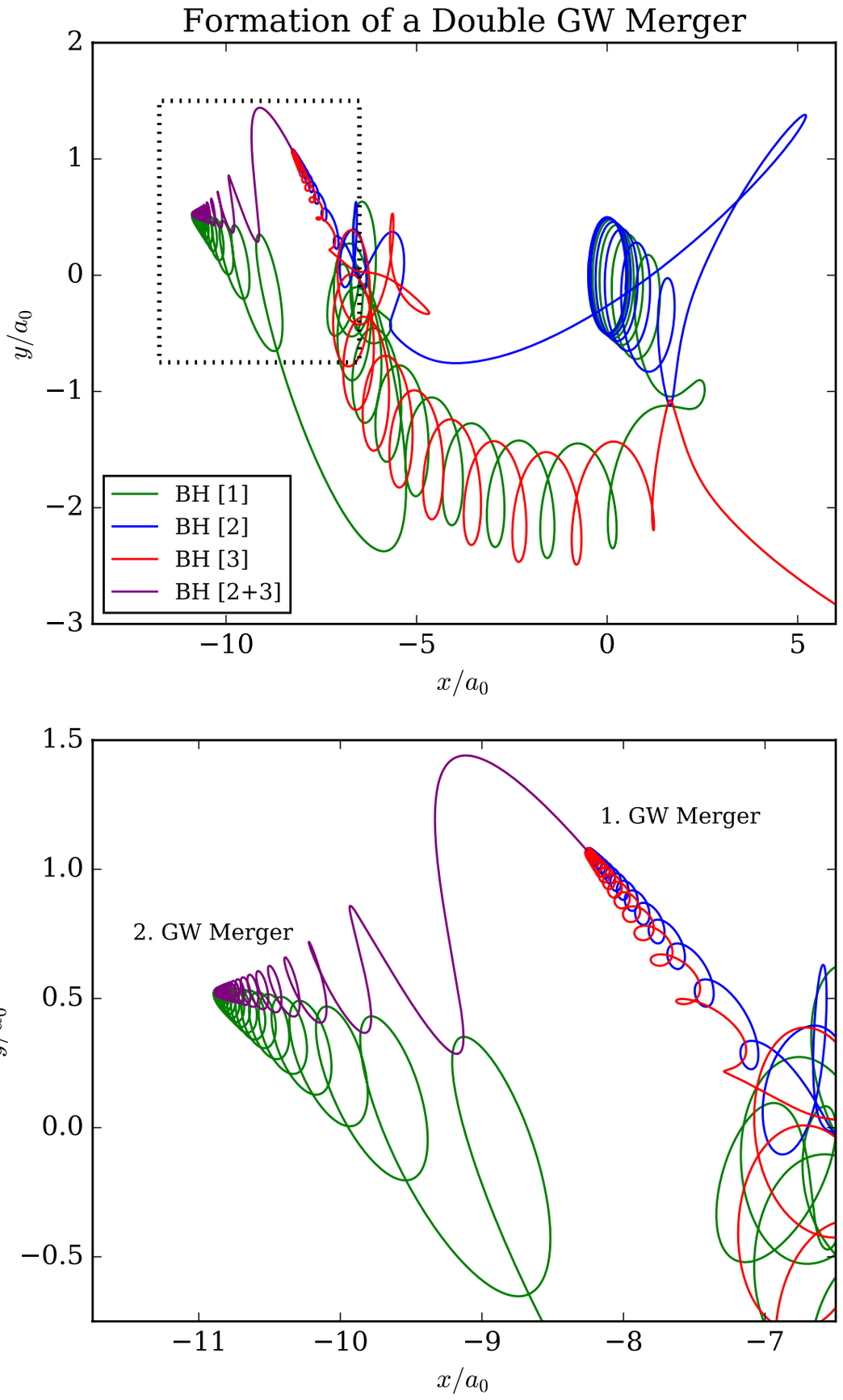
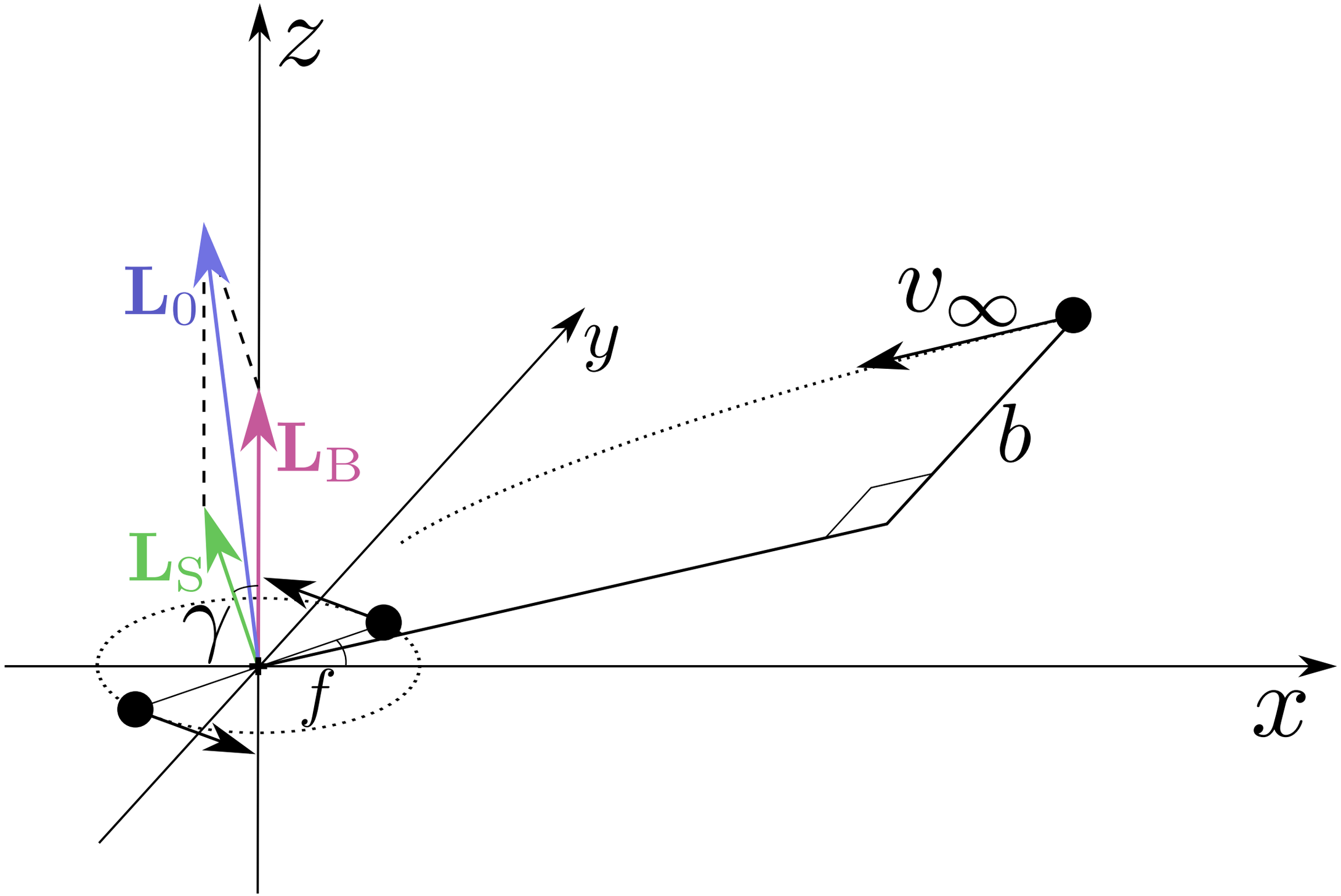
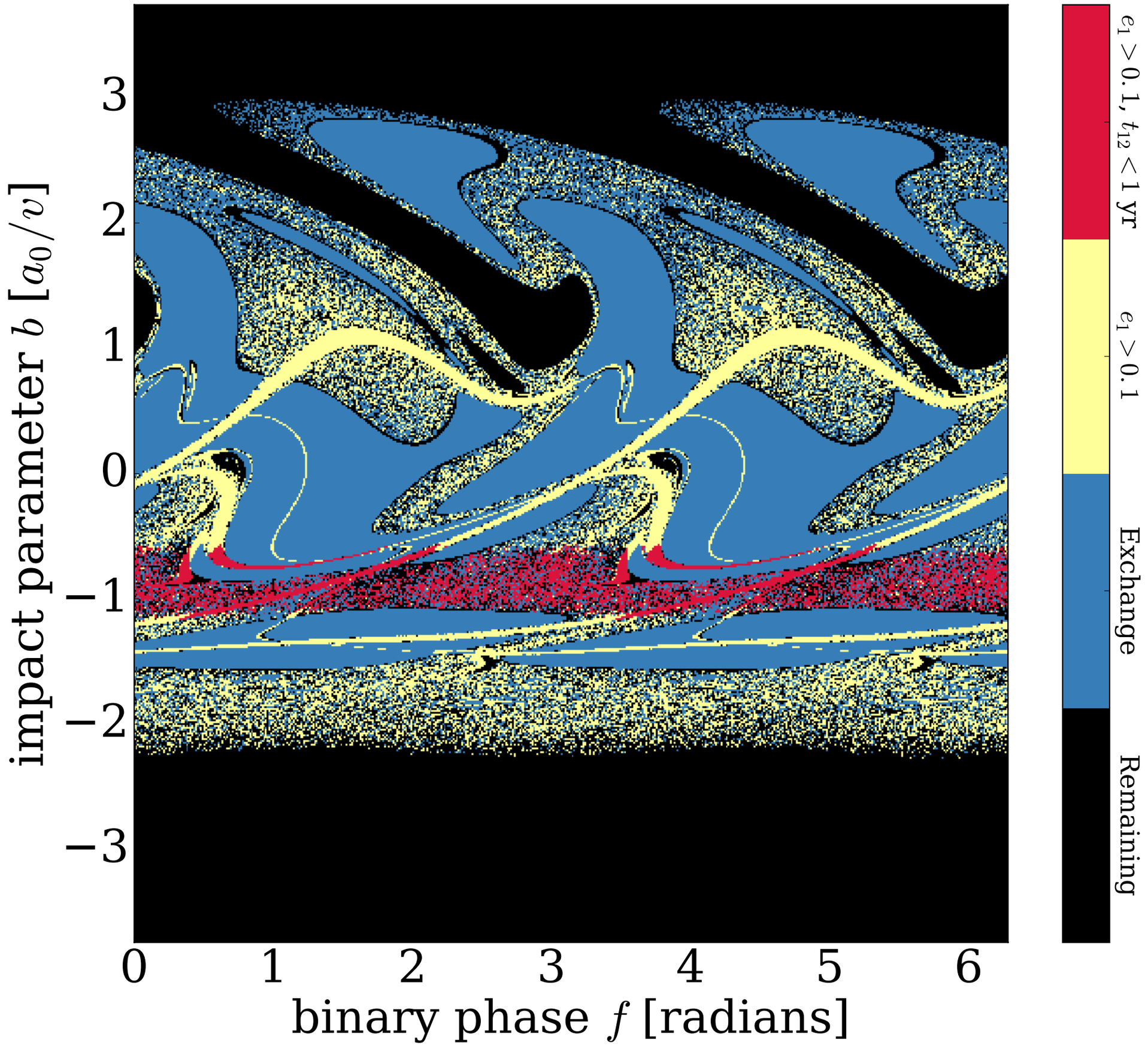

Formation of a Double GW Merger
BH [1]
BH [2]
BH [3]
BH [2+3]
y/a_0
x/a_0
1. GW Merger
2. GW Merger


z
$\mathbf{L}_0$
$\mathbf{L}_\mathrm{B}$
$\mathbf{L}_\mathrm{S}$
y
v_∞
b
γ
f
x


impact parameter b [a_0/v]
3
2
1
0
−1
−2
−3
0
1
2
3
4
5
6
binary phase f [radians]
$e_1 > 0.1$, $t_{12} < 1$ yr
$e_1 > 0.1$
Exchange
Remaining

art

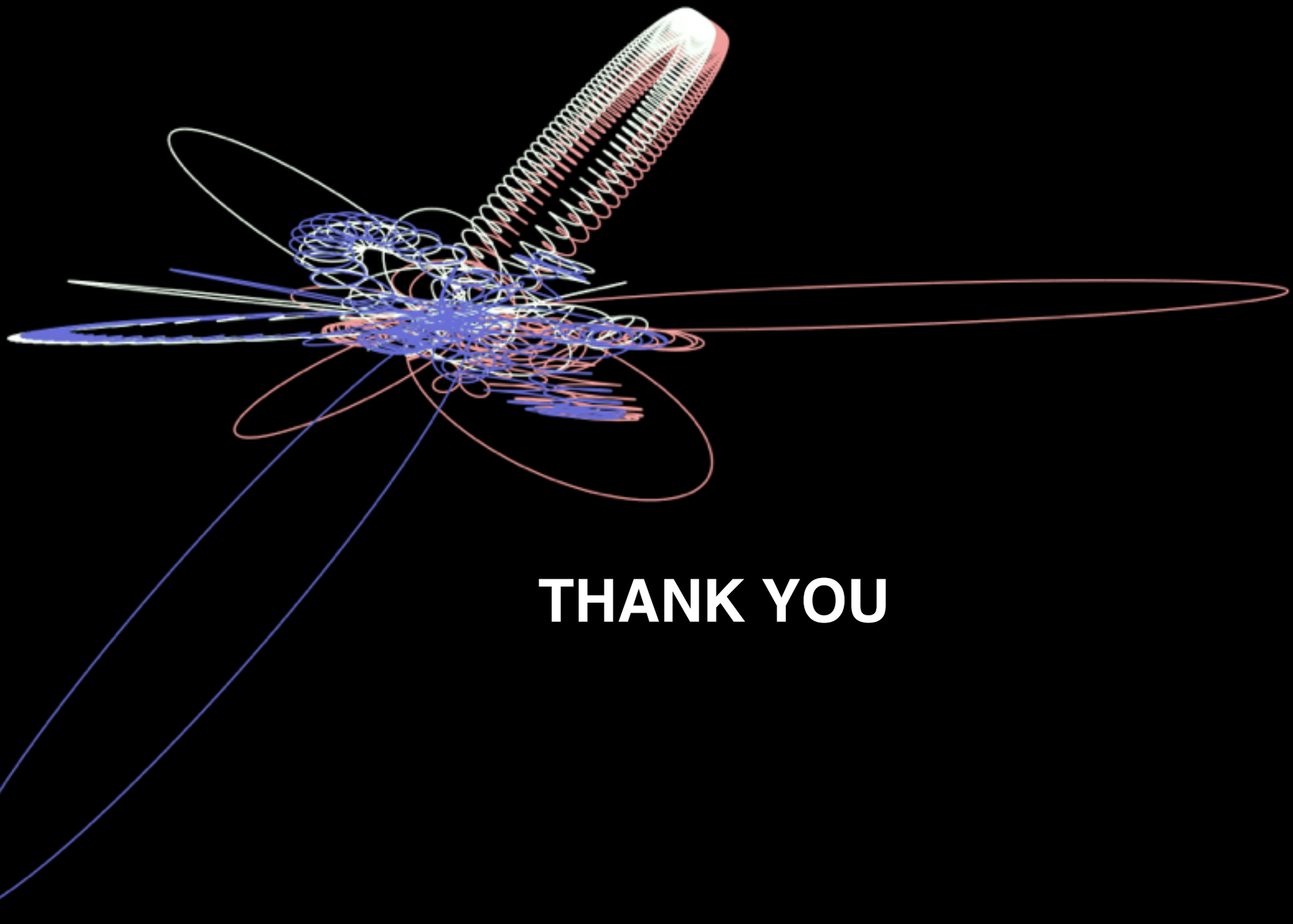
of

science

Colorful Black Holes

Johan Samsing (postdoc)
Department of Astrophysical Sciences

Each pixel in the picture shows the result of a gravitational simulation between a binary and a single black hole, where the x-axis is the initial binary phase and the y-axis is the impact parameter. The three black holes often undergo a chaotic dance before an end-state is reached. Often the dance is vital for at least two of the black holes, as the red and black colors indicate a black hole collision. The remaining colors indicate different ways for the black holes to survive the interaction. By counting the black and red pixels, one can show that more than one percent of all black hole collisions forming in dense stellar systems throughout the universe will have a very open-jet gravitational wave signal that can be observed here on Earth. The picture also shows that the chaotic three body problem is not as chaotic as one might think.



THANK YOU