The ellipticities of merging binaries as seen by ET

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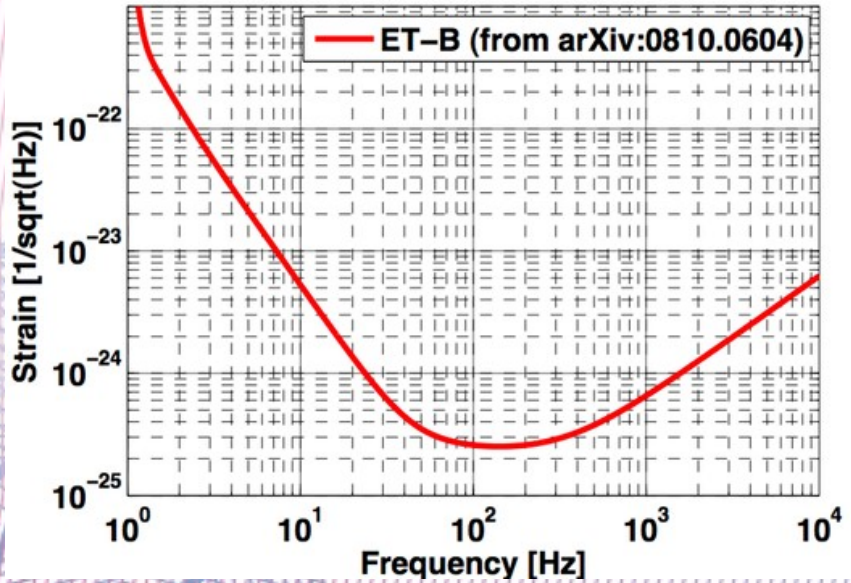
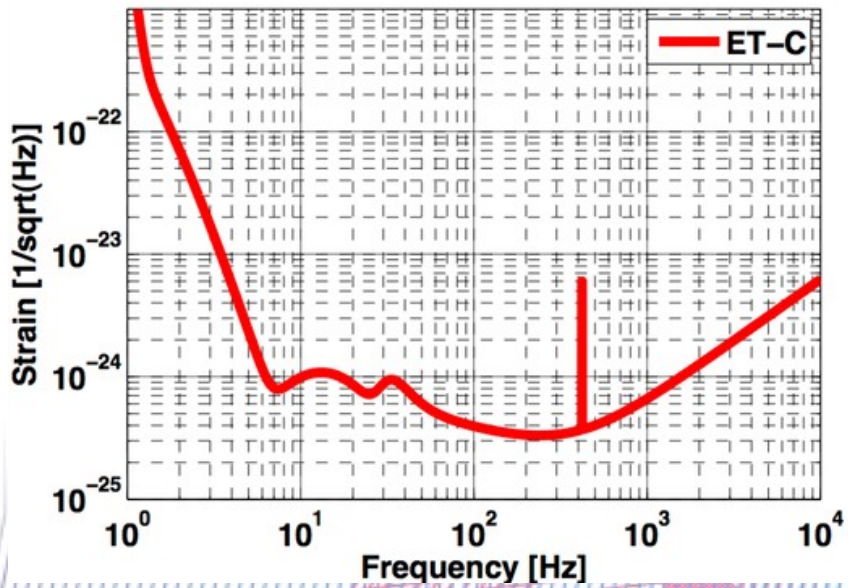
Why worry about ellipticity?

- GW emission circularize orbits
- By how much?
- What are the ellipticities for realistic binaries?
- Do they affect the data analysis?

S. Hild, S. Chelkowski, A. Freise:(http://arxiv.org/abs/0810.0604)



S.Hild, S.Chelkowski, A.Freise, J.Franc, N.Morgado, R.Flaminio and R.DeSalvo: (http://arxiv.org/abs/0906.2655)



Evolution of separation and ellipticity

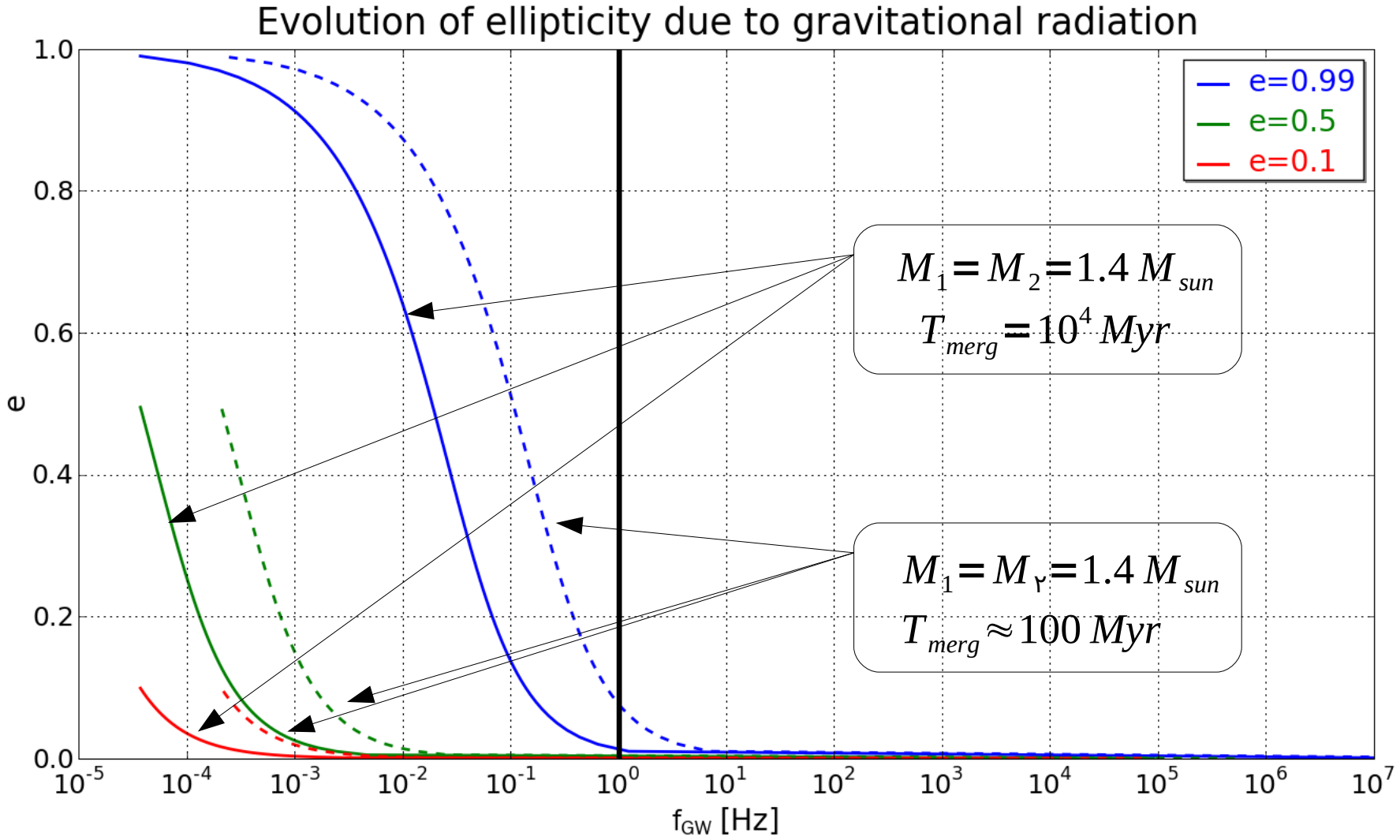
$$a(e) = \frac{c_0 e^{12/19}}{(1-e^2)}\left[1+\frac{121}{304}e^2\right]^{870/2299}$$

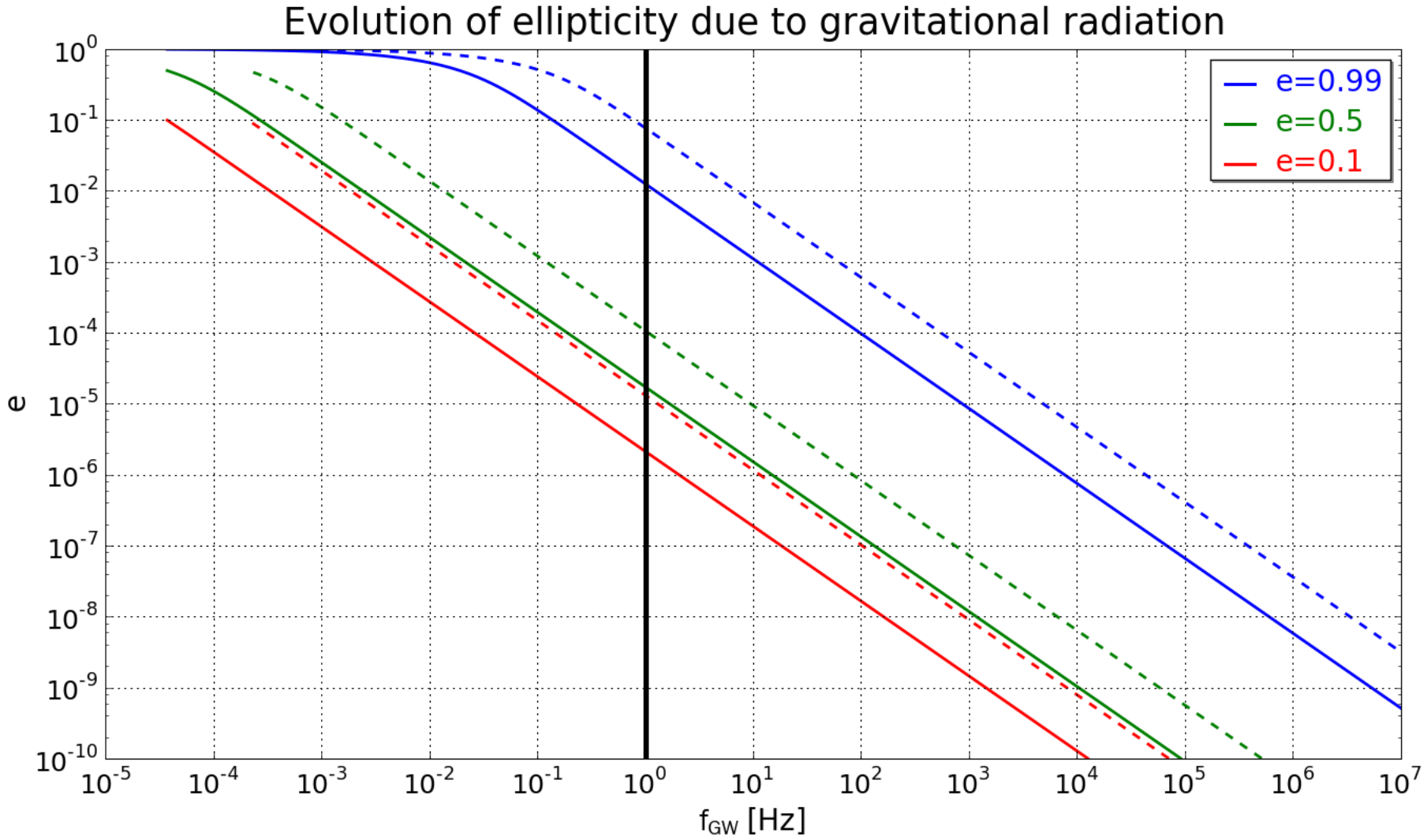
P.C. Peters, 1964, Phys. Rev. 136, 4B, 1224-1232

$$c_0 = \frac{a_0(1-e_0^2)}{e_0^{12/19}}\left[1+\frac{121}{304}e_0^2\right]^{-870/2299}$$

Frequency of gravitational waves (first non-zero harmonic):

$$f_{GW}(e) = \frac{G^{1/2}(M_1+M_2)^{1/2}}{\pi}\frac{(1-e^2)^{3/2}}{c_0^{3/2}e^{18/19}}\left[1+\frac{121}{304}e^2\right]^{-1305/2299}$$


Evolution of ellipticity due to gravitational radiation
e
f_{GW} [Hz]
e=0.99
e=0.5
e=0.1
$M_1 = M_2 = 1.4\,M_{sun}$
$T_{merg} = 10^4\,Myr$
$M_1 = M_\gamma = 1.4\,M_{sun}$
$T_{merg} \approx 100\,Myr$


Evolution of ellipticity due to gravitational radiation
e=0.99
e=0.5
e=0.1
e
f_{GW} [Hz]
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}

How about initial conditions

???

Star Track code

- Detailed population synthesis code
- Evolution of single stars
- Binary interactions: mass transfers, common envelope evolution
- Supernovae explosions: kick velocities, masses of compact objects
- Possibility of parameter studies

StarTrack initial conditions

- Initial mass function – Scalo
- Orbital separation – uniform in log(a)
- Mass ratio distribution– uniform
- Ellipticity distribution– proportional to e, but practically irrelevant

Standard model – important parameters

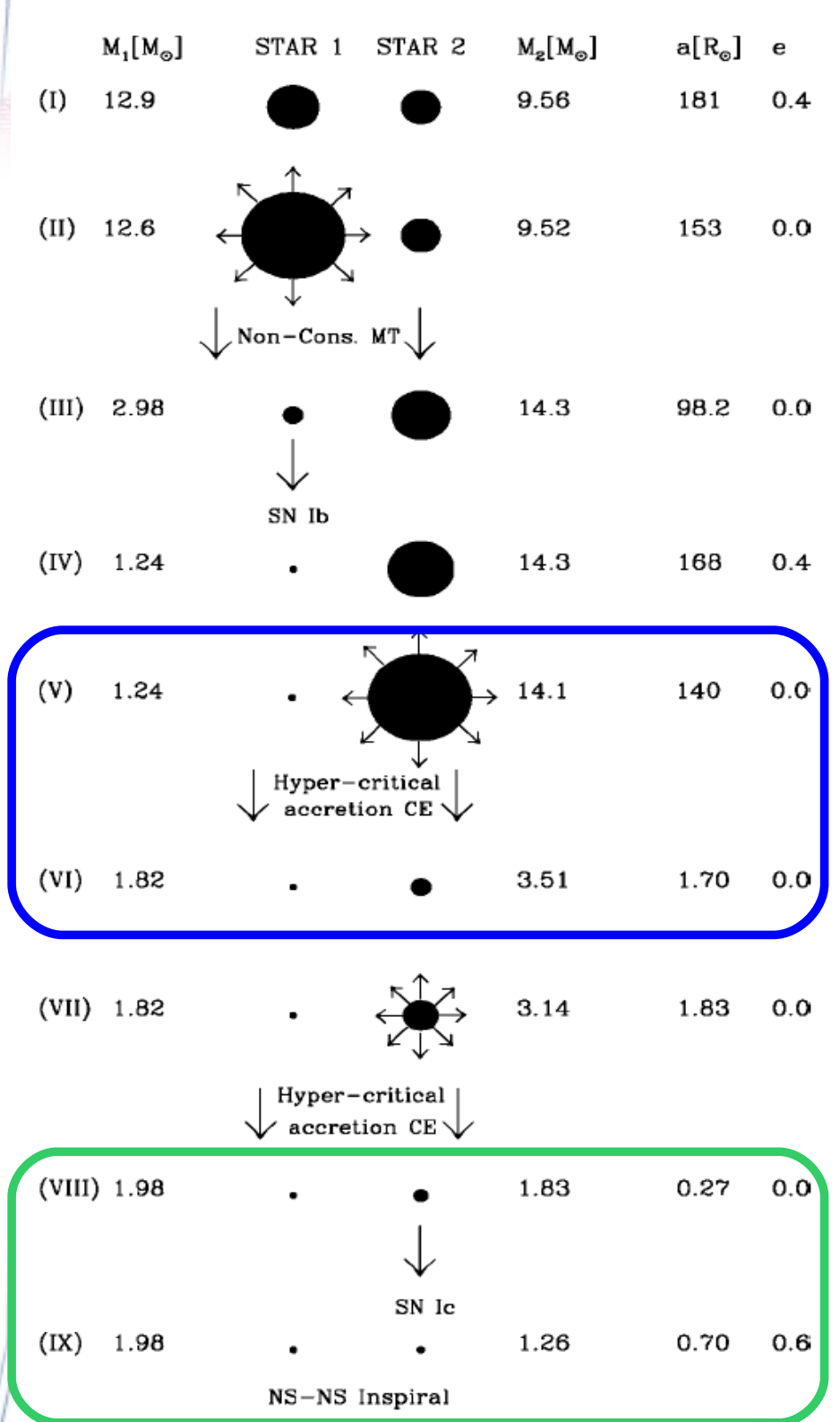
- Kick distribution
- Mass transfer efficiency
- Common envelope treatment
- Maximum NS mass (BH/NS divider)

Belczyński et al. 2002, ApJ, 572, 407

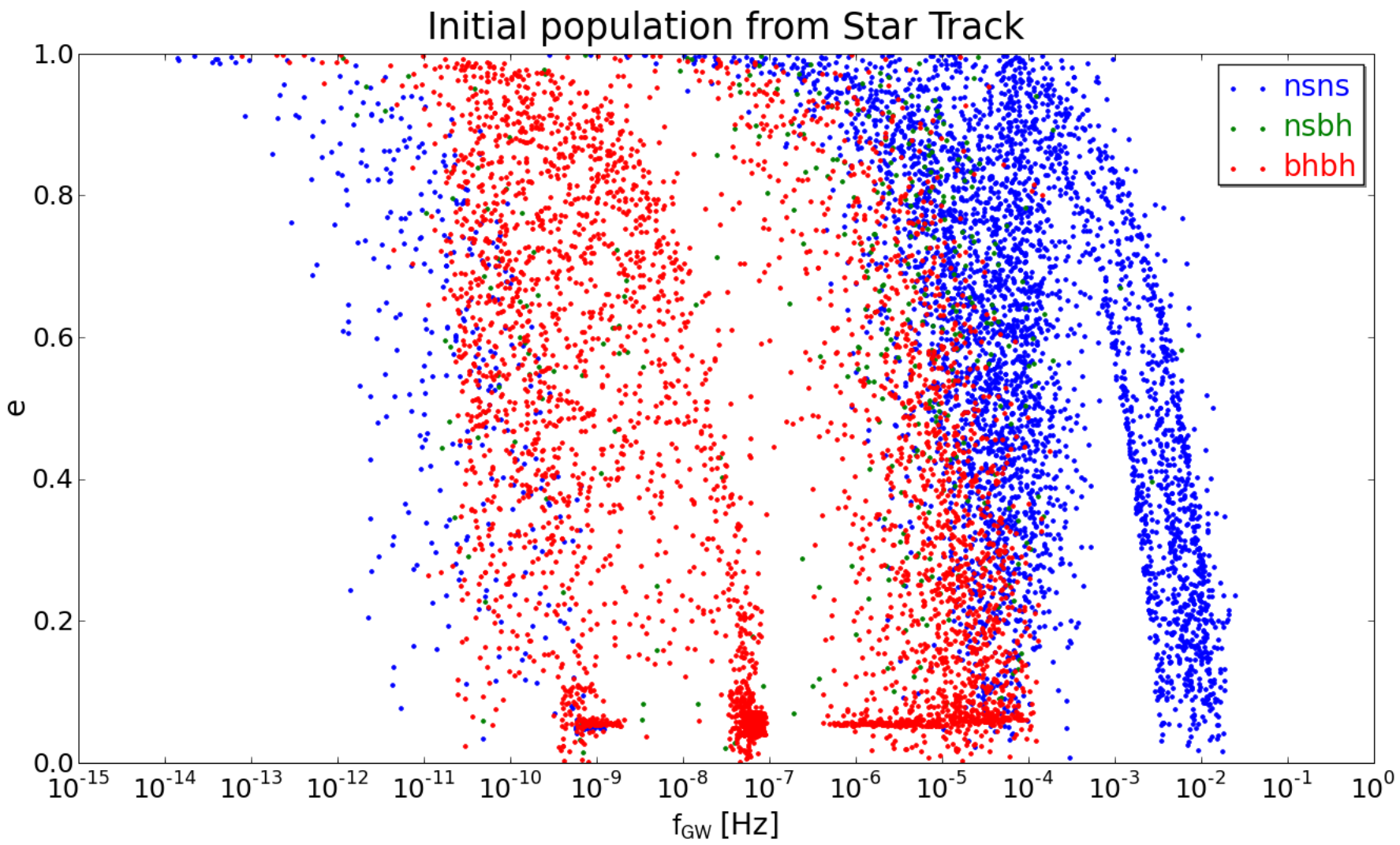
Two most relevant stages for this study:

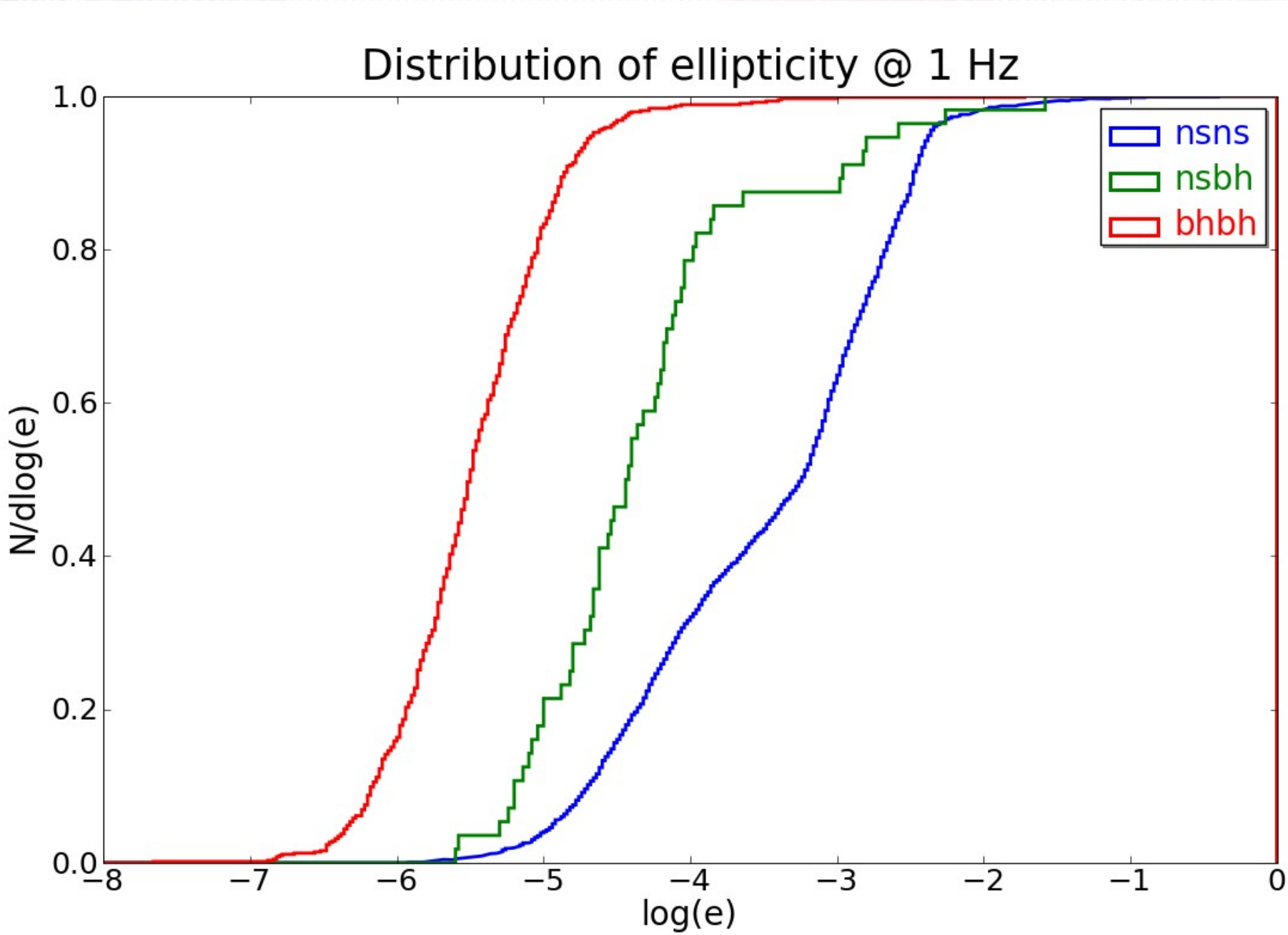
Orbit tightening in CE

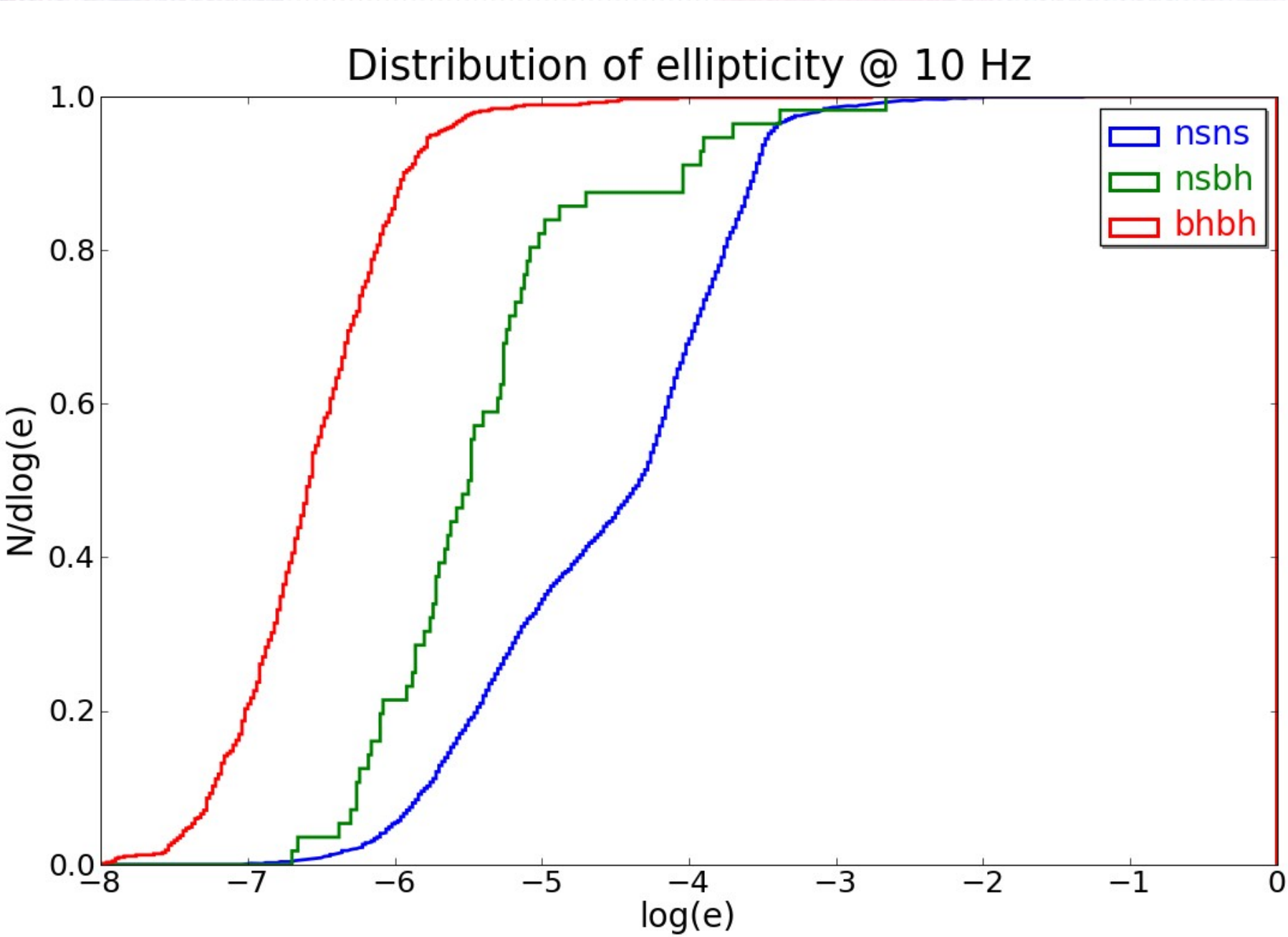
Kicks due to SN explosion – lead to elliptical orbits



Binaries merging in Hubble time




Distribution of ellipticity @ 1 Hz
1.0
0.8
0.6
0.4
0.2
0.0
N/dlog(e)
−8
−7
−6
−5
−4
−3
−2
−1
0
log(e)
nsns
nsbh
bhbh


Distribution of ellipticity @ 10 Hz
1.0
0.8
0.6
0.4
0.2
0.0
N/dlog(e)
−8
−7
−6
−5
−4
−3
−2
−1
0
log(e)
nsns
nsbh
bhbh

Model dependency

In standard model:

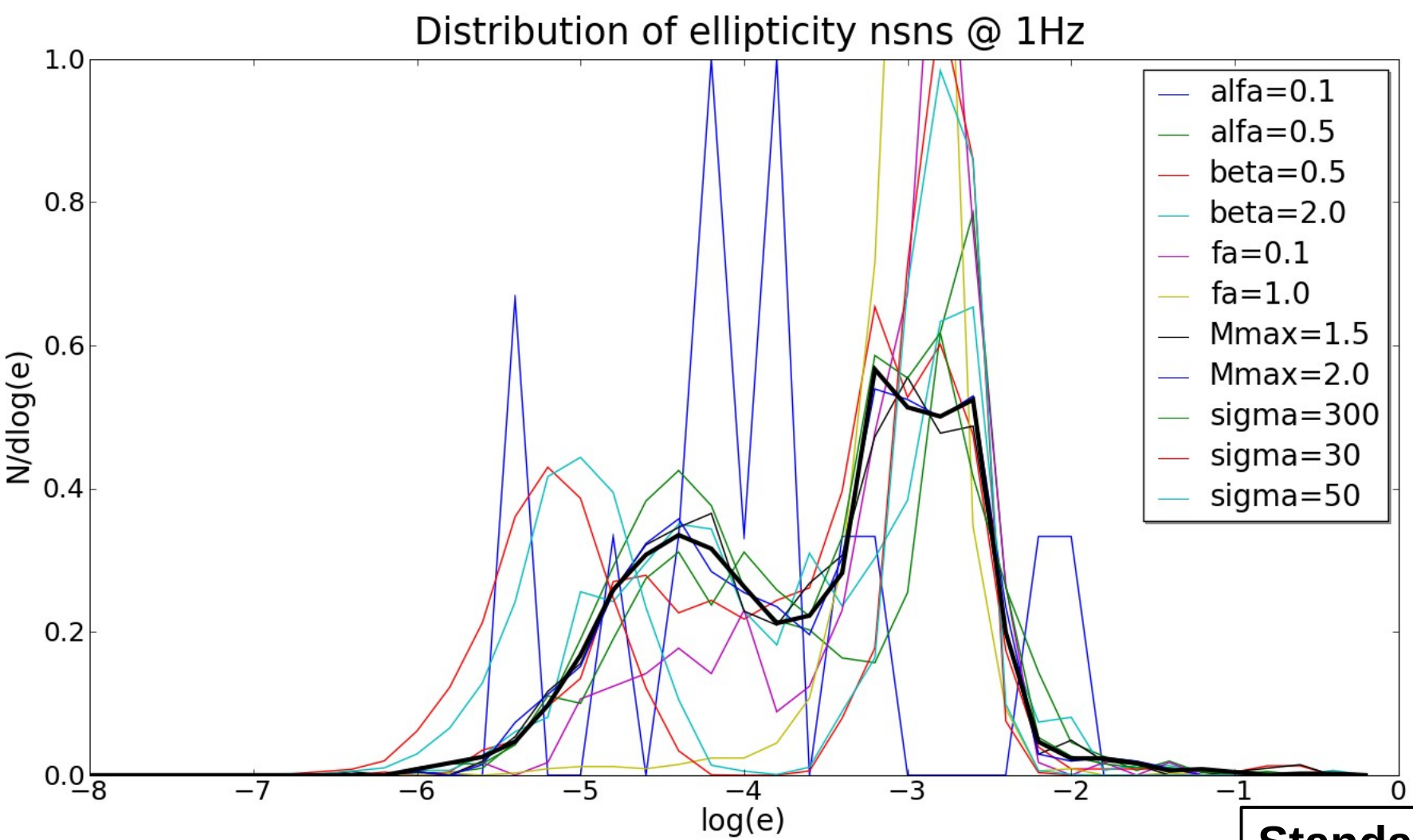
Alfa (efficiency of orbital energy loss for CE ejection) = 1.0

Beta (angular momentum of mater lost in n-c MT) = 1.0

Fa (fraction of mass attached by companion) = 0.5

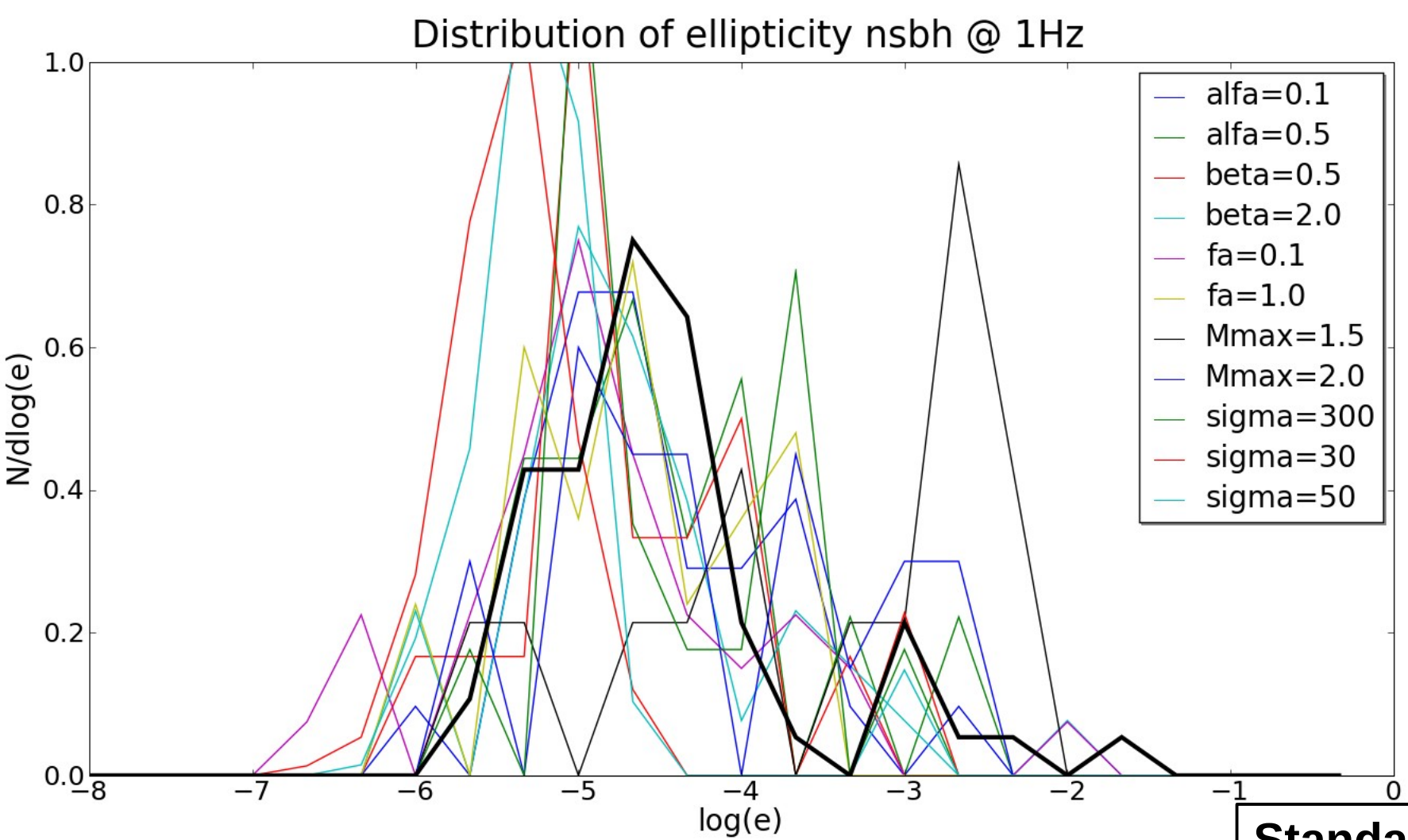
Mmax (maximal mass of Ns) = 2.5 Msun

Sigma (single maxwellian velocity distribution after SN) = 265 km/s



Standard:

Alfa = 1.0
Beta =1.0
Fa = 0.5
Mmax=2.5 Msun
Sigma =265 km/s



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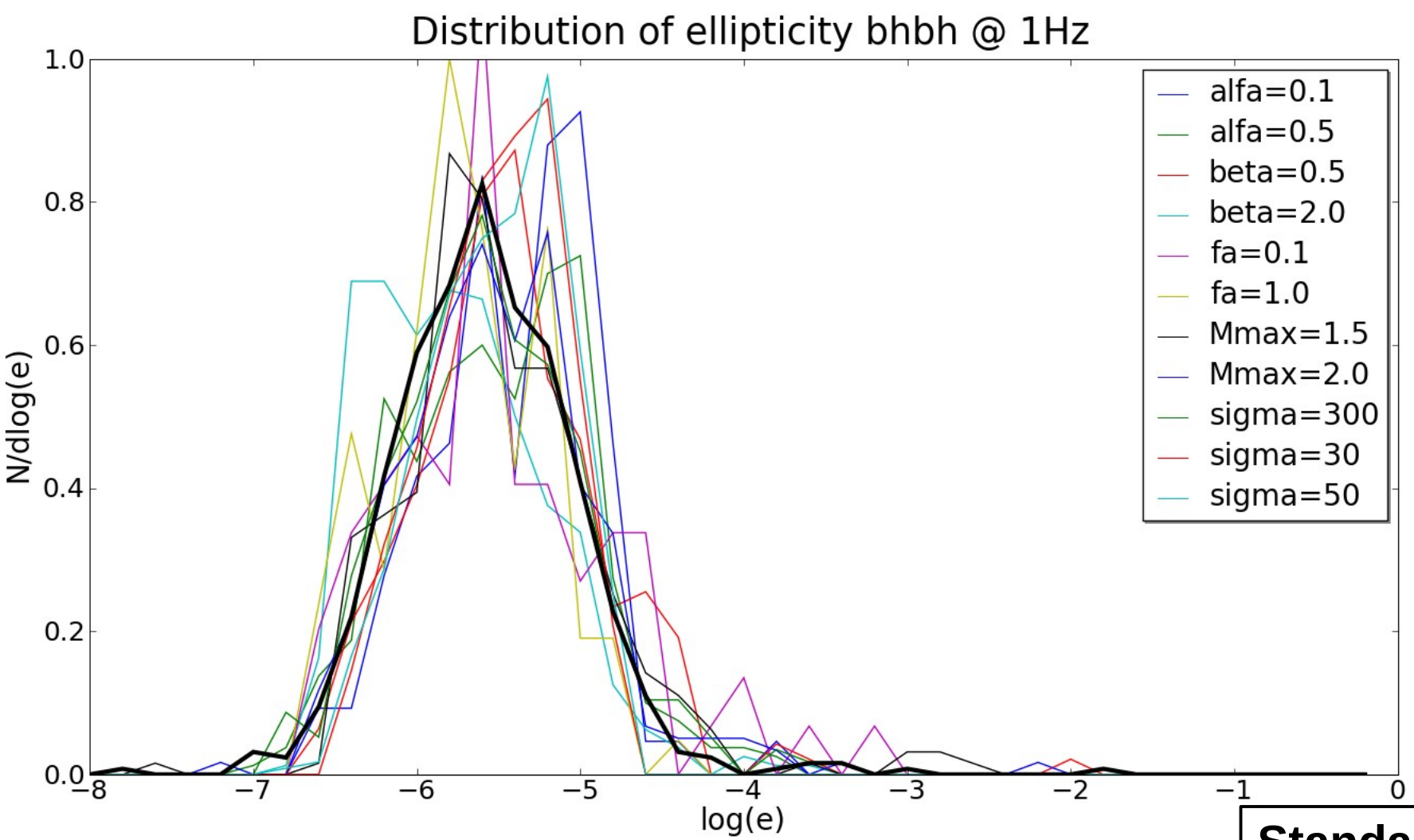

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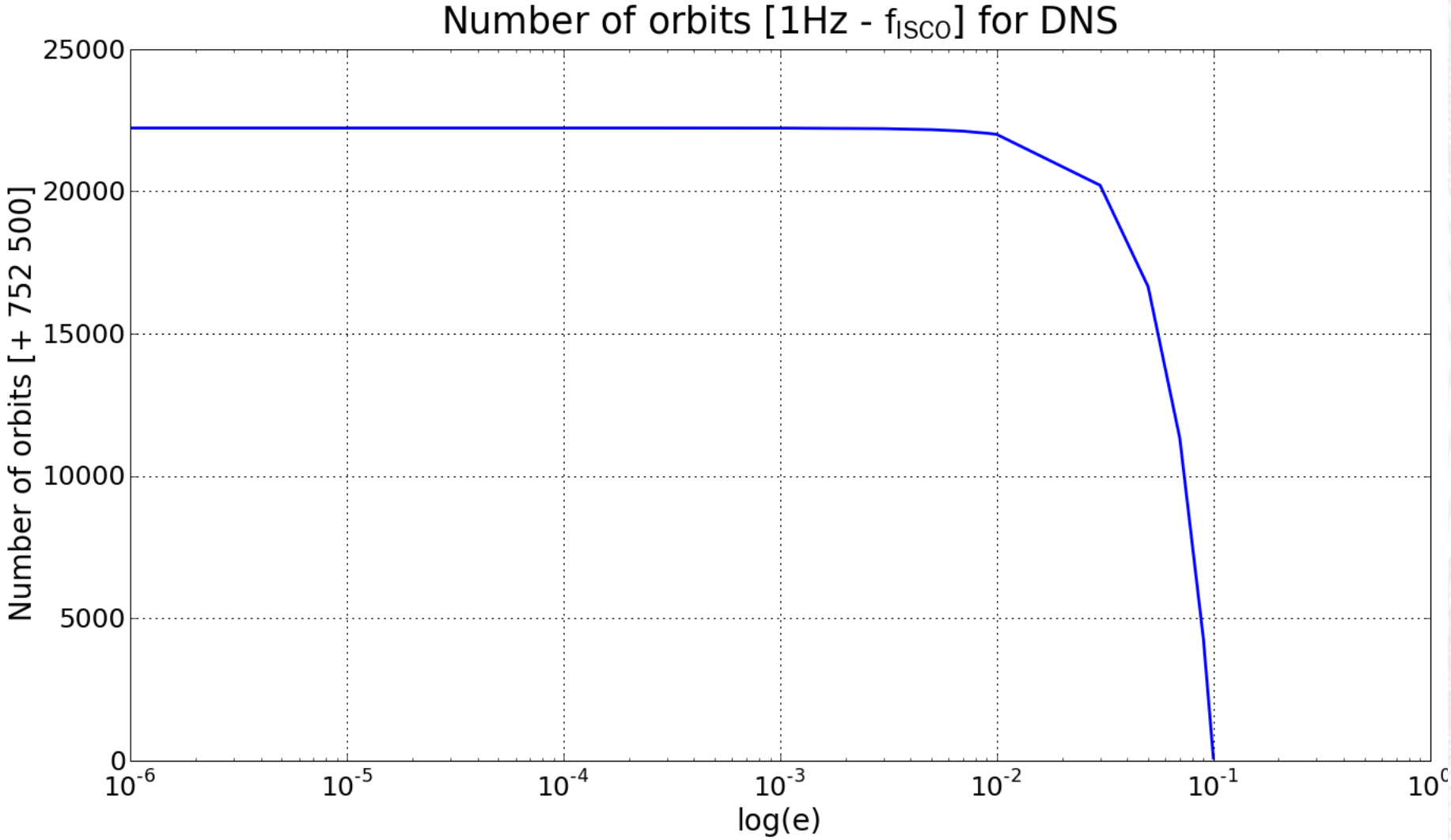
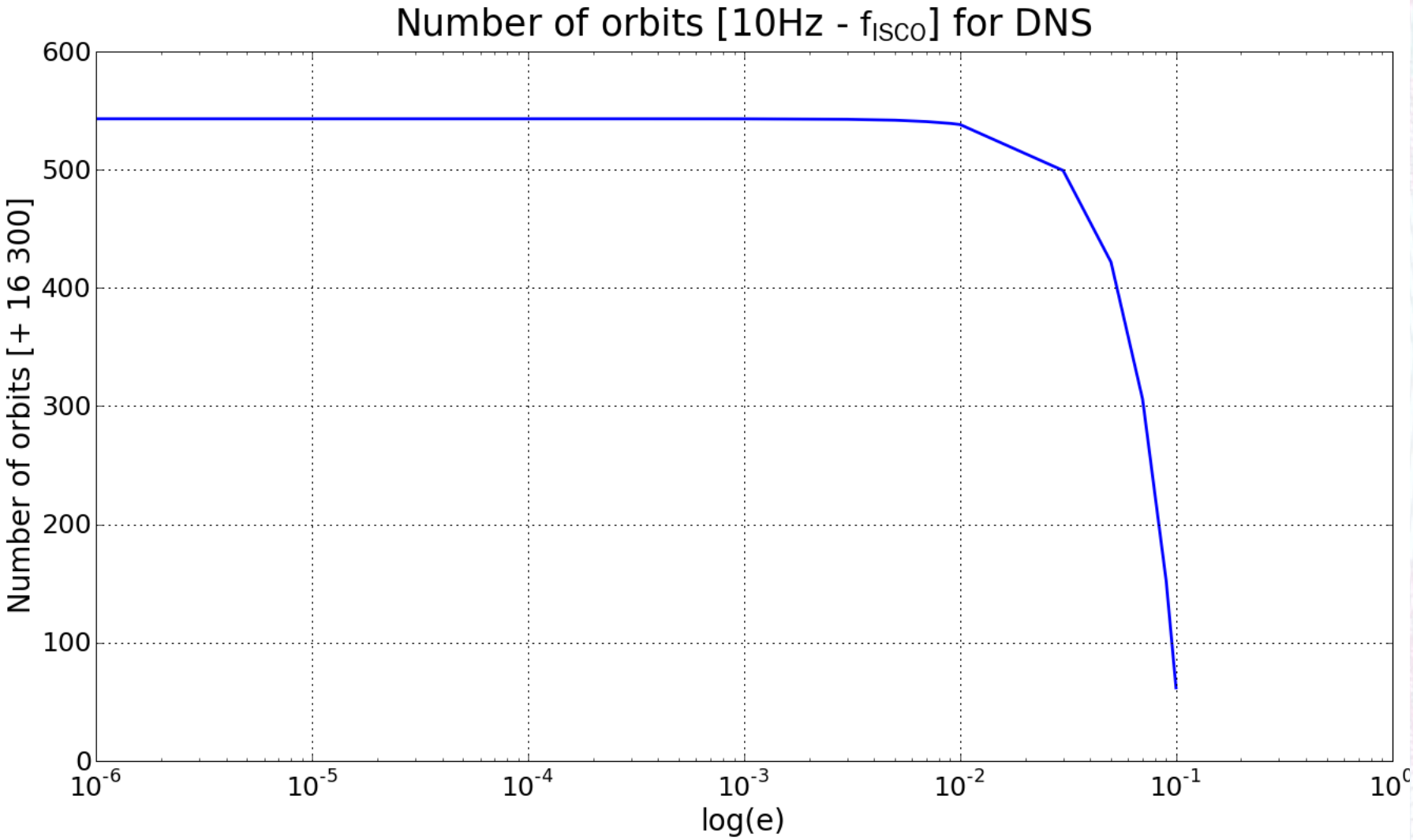
When ellipticity is important?


Number of orbits [1Hz - f_{ISCO}] for DNS
Number of orbits [+ 752 500]
25000
20000
15000
10000
5000
0
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
log(e)


Number of orbits [10Hz - f_{ISCO}] for DNS
Number of orbits [+ 16 300]
log(e)
600
500
400
300
200
100
0
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}

Summary

- Median ellipticity:

	@ 1 Hz	@ 10 Hz
– nsns:	log(e)=-3	log(e)=-4
– nsbh:	log(e)=-4.2	log(e)=-5.5
– bhbh:	log(e)=-5.8	log(e)=-6.9

- DNS: up to 5% have ellipticities above 1e-2

Summary

- Dependence on parameters
- Ellipticites are “large” for $\log(e) > -2$
- Future work: realistic sensitivity curve, space distribution, metallicity dependence
- Globular clusters: ellipticity may be larger due to three body interactions

THANK YOU FOR YOUR ATTENTION