Compact objects binaries population up to high redshifts

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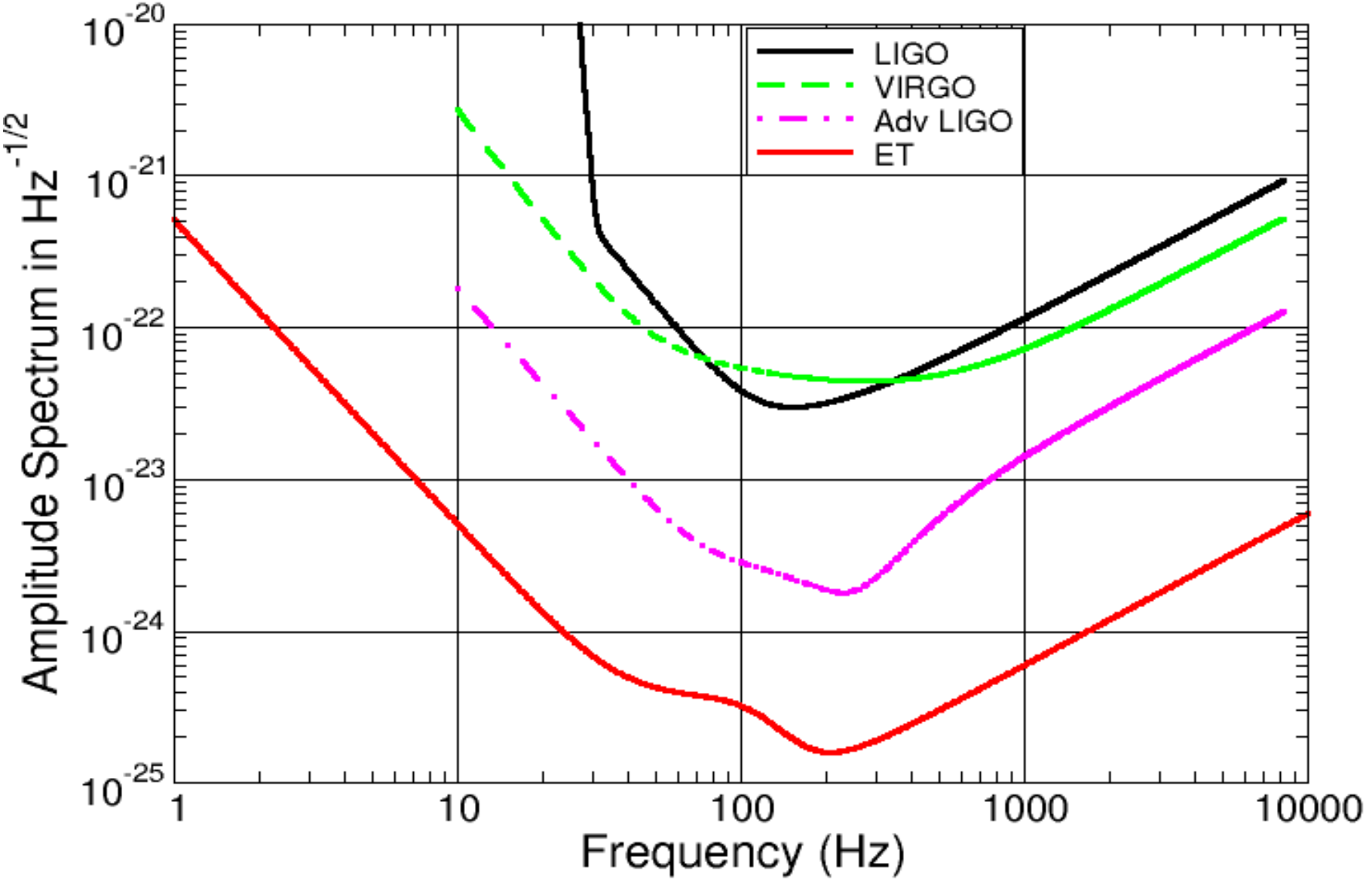
Sensitivity



Rates for NSNS inspiral

- The uncertainties are there
- Range – volume – number of galaxies

$$D \approx 3\mathrm{Gpc}$$

$$V \approx 1.2 \times 10^{11}\mathrm{Mpc}^3$$

$$N_{Gal} \approx 10^{10}$$

$$Rate \approx 10^4 - 10^5 \mathrm{yr}^{-1}$$

An inspiral to detect every few hours! Source confusion?

Things to think about:

- Delays between formation and coalescence
- Star formation rate
- Metallicity evolution
- Population III binaries
- Complementary space experiments

Delays from observations

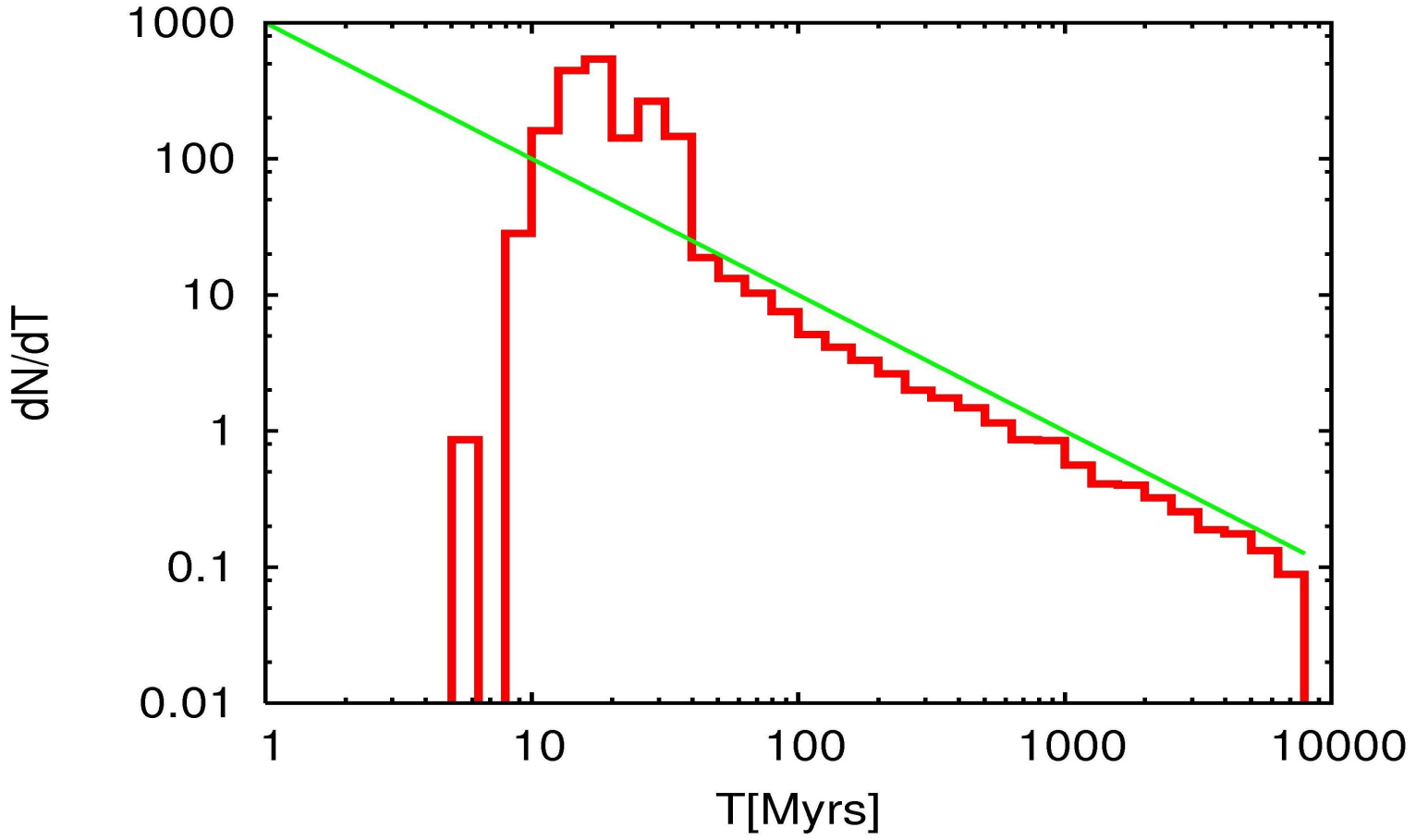
- Observations

Phone No.	P_{orb}/hr	e	t_{mrg}/Gyr	Comment
1) B1913+16	7.75	0.617	0.33	field
2) B1534+12	10.1	0.274	2.7	filed
3) J0737-3039	2.45	0.088	0.09	field
4) J1756-2251	7.67	0.181	1.7	field
5) B2127+11C	8.04	0.681	0.22	cluster
6) (J1906+0746)	3.98	0.085	0.30	??? (field)
7) J1811-1736	451	0.828	1686	field
8) J1518+4904	207	0.25	9829	field
9) J1829+2456	28	0.139	58	field

Roughly equal numbers per decade of merger time.

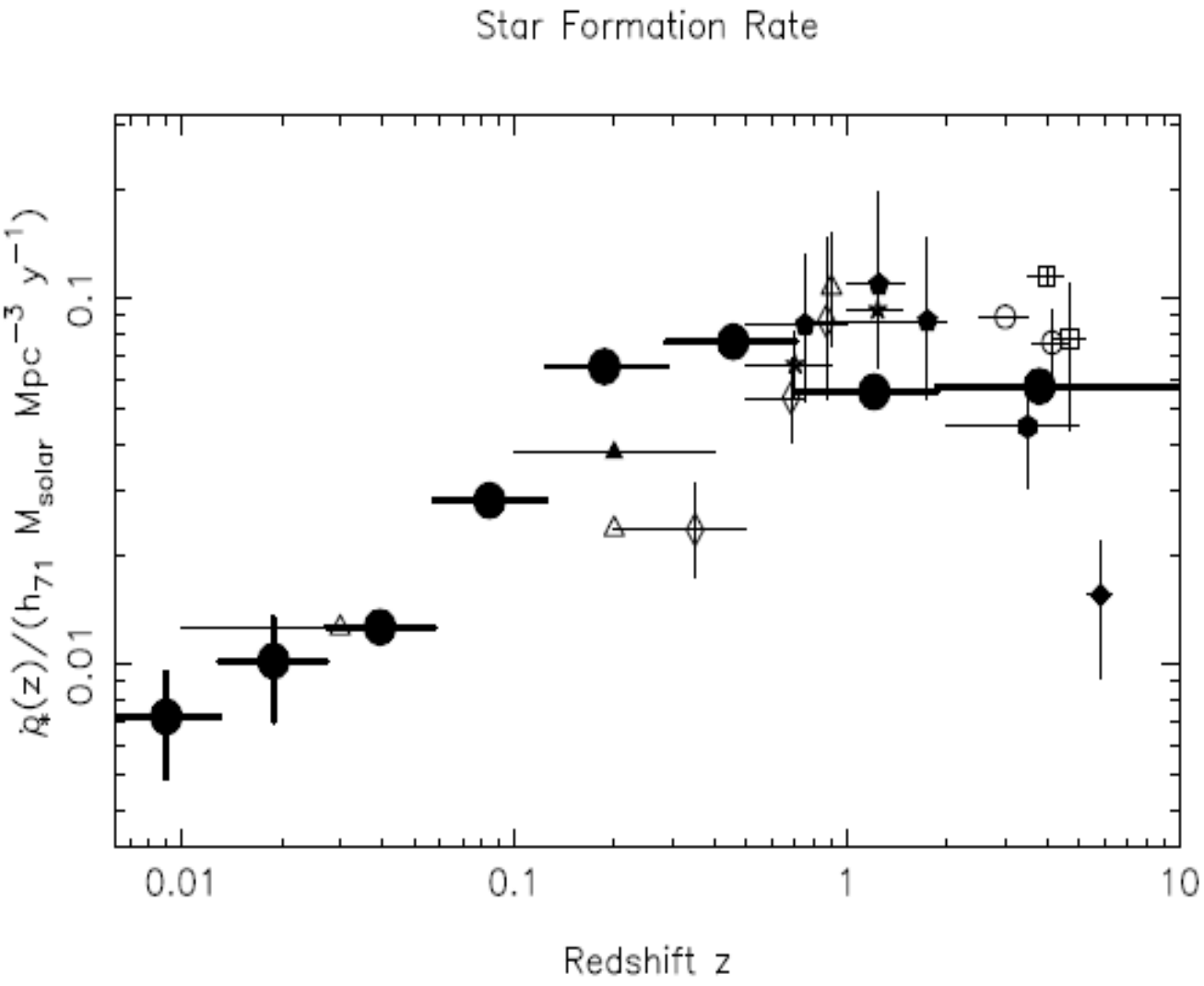
- Binary population synthesis

Population synthesis



Delay between formation and coalescence follows ~ 1/t distribution
Minimal delay – 10 to 100 Myrs.

Star formation history



Heavens et al. 2004

SFR consequences

- Binary formation rate increases with redshift
- BNS – short delays – increase of the coalescence rate with distance
- BBH and BHNS – possibly longer delays
- BBH – can we see the edge?

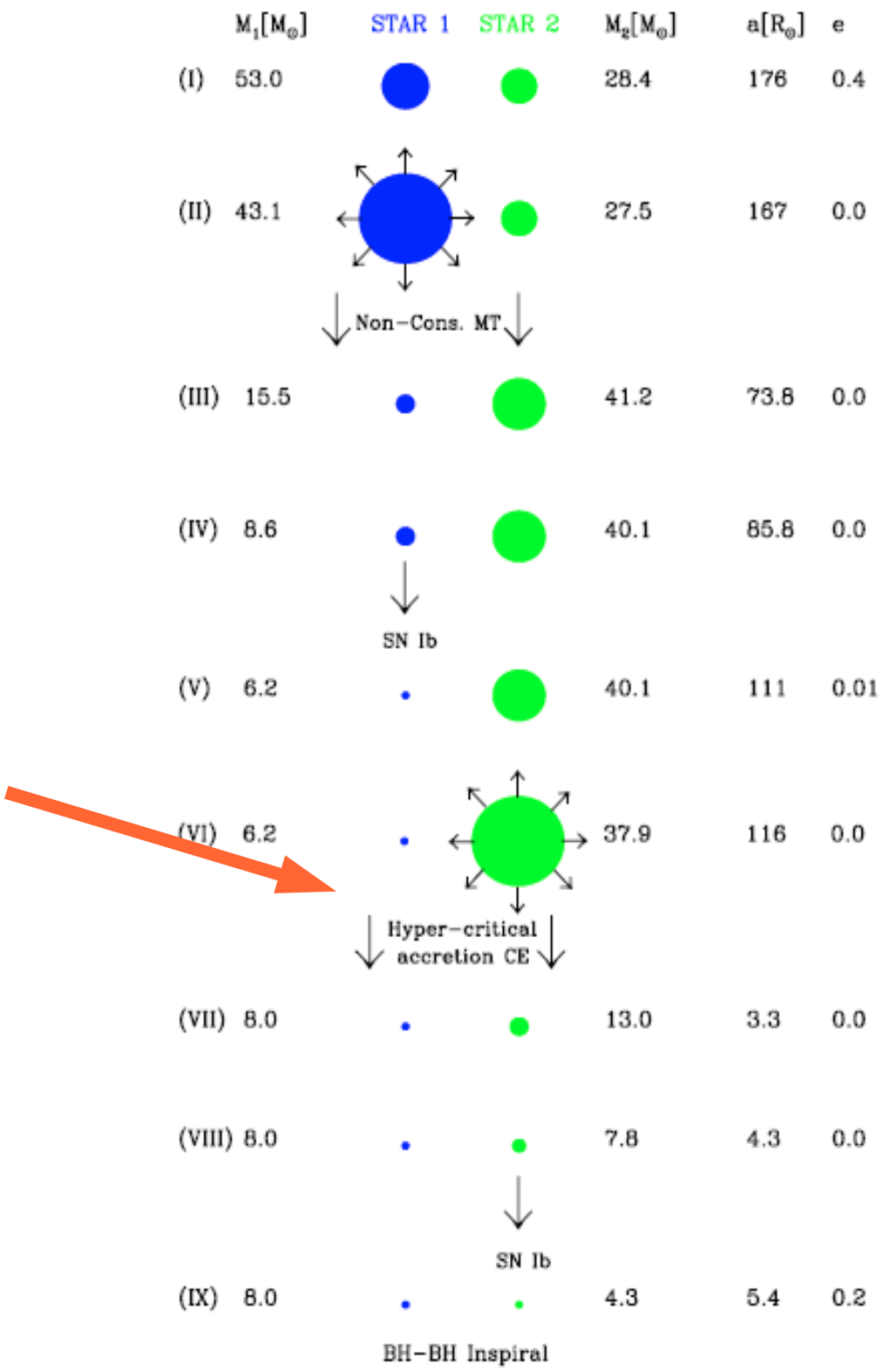
Metallicity evolution

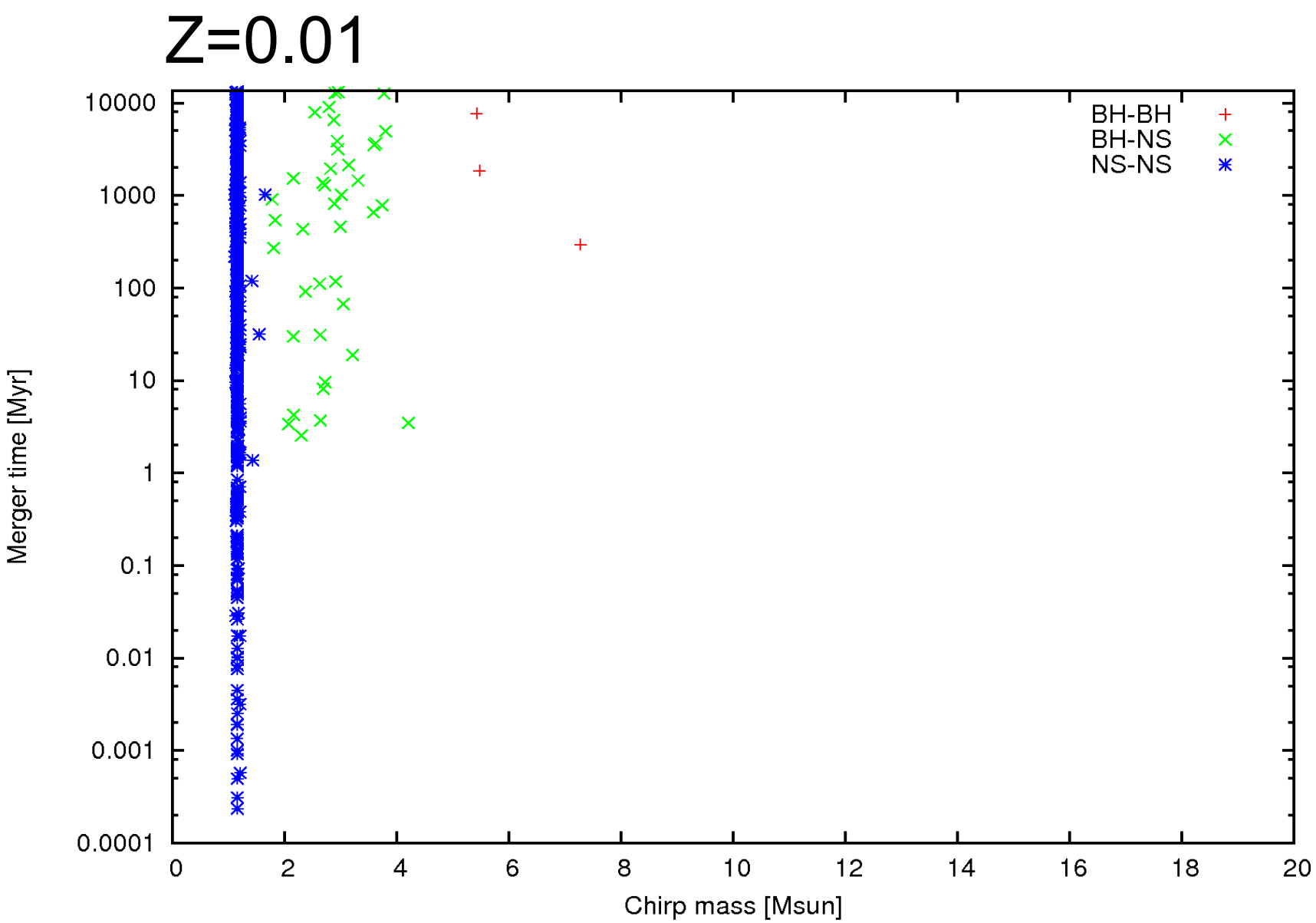
- Metallicity evolves from Z=0 to solar
- BH masses decrease with metallicity
- Profound consequences for binary evolution: mass loss rates, masses of compact objects, binary fraction, ...
- Formation of BBH binaries enhanced at low metallicity

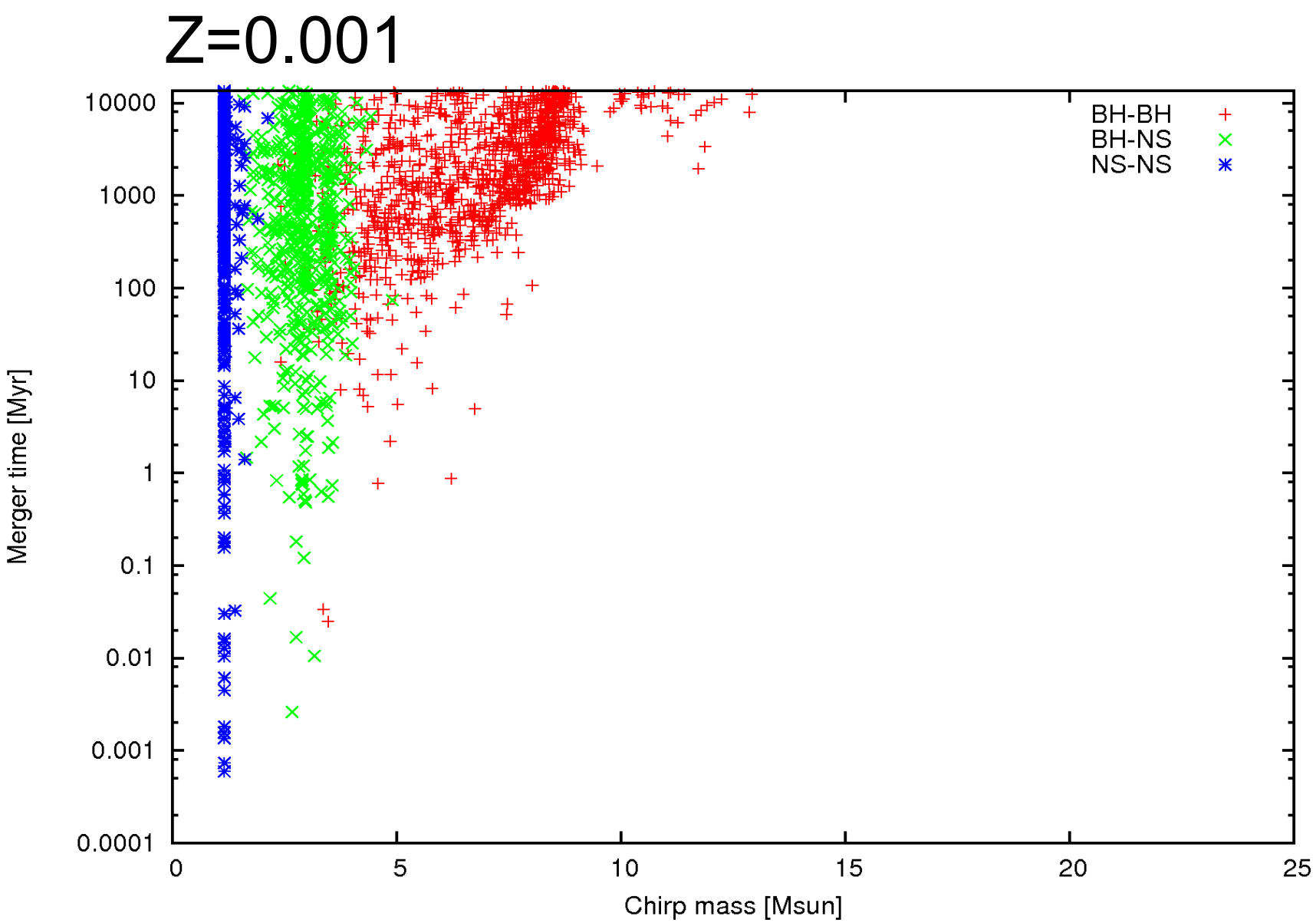
BBH formation is a challenge!

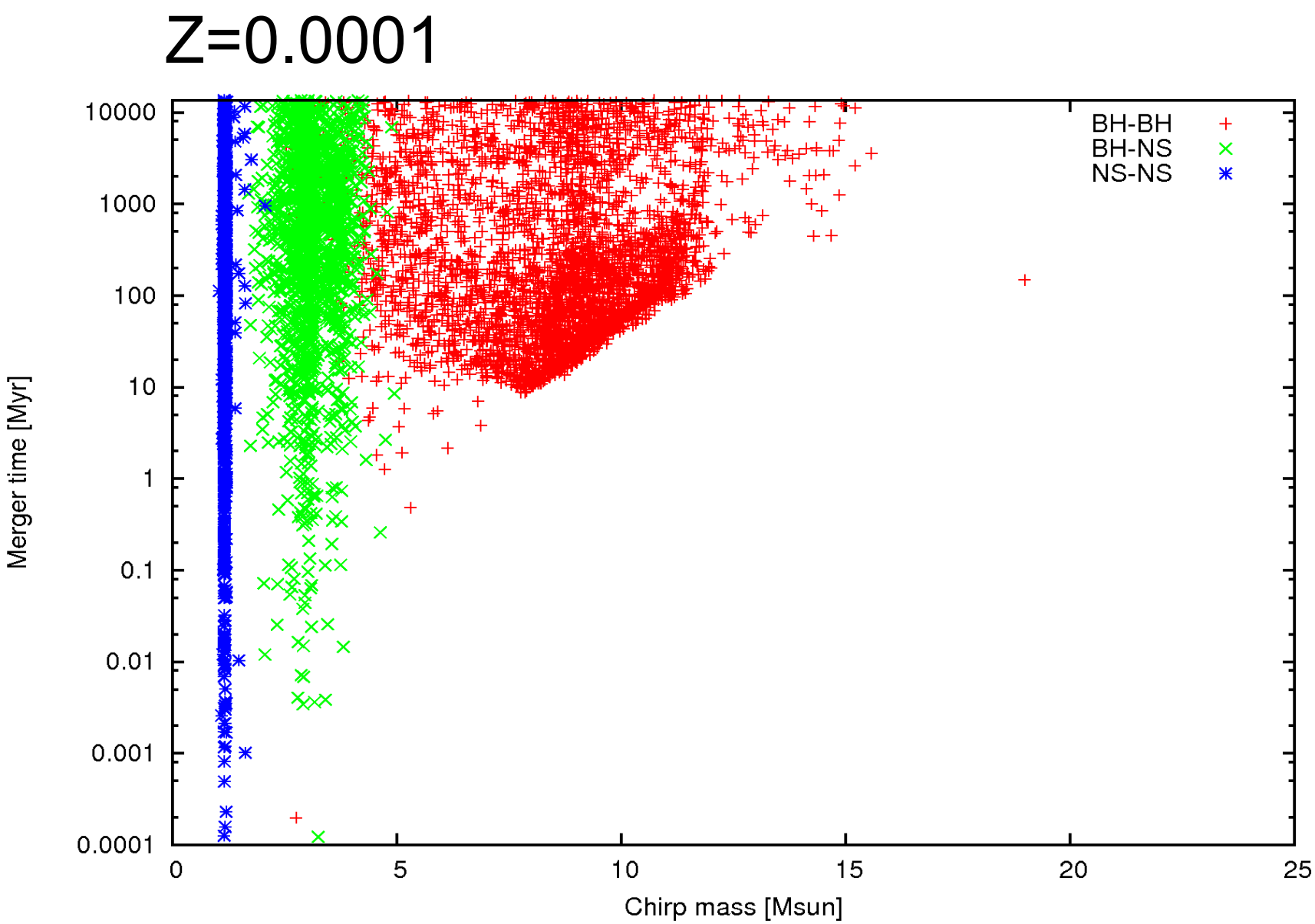
unstable mass transfer leads to merger before formation of BBH

Can be avoided if BH masses are large




Z=0.01
BH-BH
BH-NS
NS-NS
Merger time [Myr]
Chirp mass [Msun]
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0
2
4
6
8
10
12
14
16
18
20


Z=0.001
Merger time [Myr]
Chirp mass [Msun]
BH-BH
BH-NS
NS-NS
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0
5
10
15
20
25


Z=0.0001
Merger time [Myr]
Chirp mass [Msun]
BH-BH
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0.0001
0
5
10
15
20
25

IC 10 X-1

- X and optical observations
- Binary: WR star with massive BH
- Orbital period ~ 30h
- Low metallicity Z~0.006!

TABLE 2
DERIVED BLACK HOLE MASS ($M_\odot$)

Inclination (deg)	Wolf-Rayet Mass ($M_\odot$)		
	17	25	35
90	23.1 ± 2.1	27.7 ± 2.3	32.7 ± 2.6
60	29.3 ± 2.8	34.8 ± 3.1	40.7 ± 3.5
45	42.4 ± 4.4	49.2 ± 4.8	56.6 ± 5.3

Future evolution

Mass transfer – stable, formation of coalescing BBH!

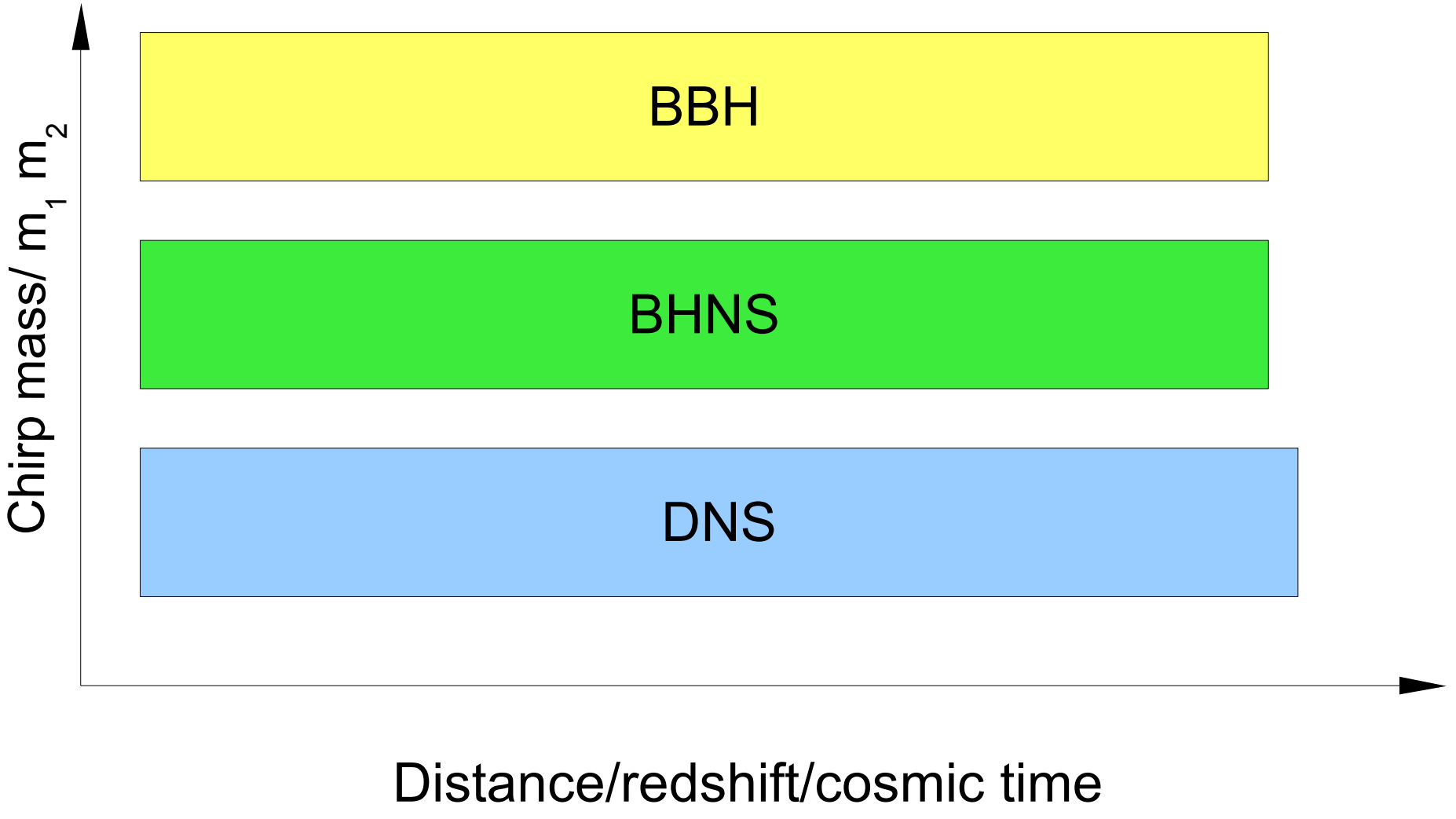
$$R = 0.63 \left(\frac{4\pi}{\Omega_s}\right) \left(\frac{M_{chirp}}{18 M_\odot}\right)^{5/2} \left(\frac{r_{BNS}}{18\mathrm{Mpc}}\right)^3 \left(\frac{2\mathrm{Mpc}}{r_s}\right)^3 \left(\frac{10^6\,\mathrm{yr}}{t_{obs}}\right) \mathrm{yr}^{-1}$$

Can be detected by current interferometers!

Population III binaries

- Extreme Z=0 metallicity
- High masses
- Binary fraction unknown
- Should be detectable by current instruments in the ringdown phase
- Stochastic background from LISA
- Limits on binary fraction and properties of first stars

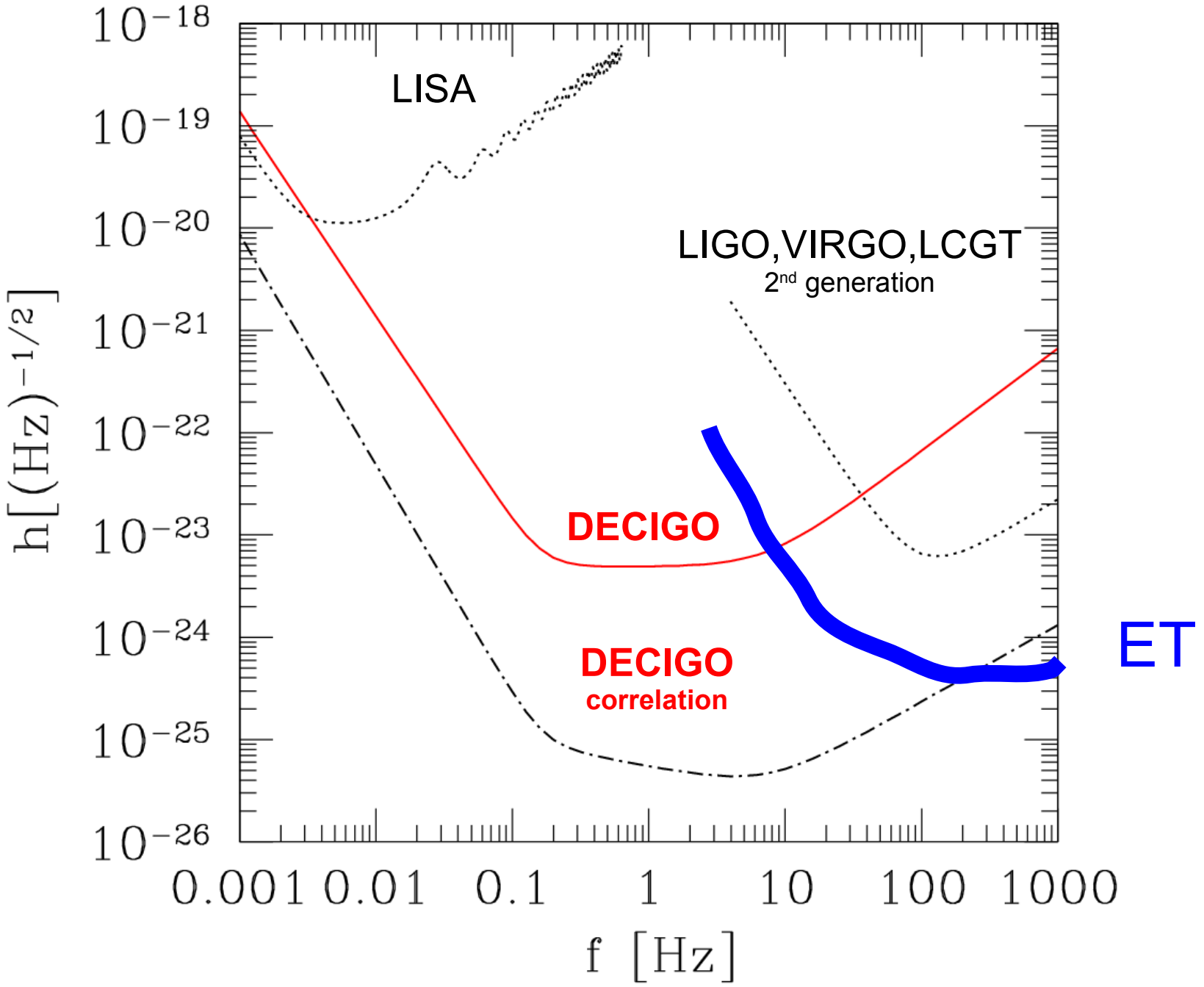
What do we want ?



Summary

- Rates: a convolution of SFR, metallicity evolution and delays
- Rates: confusion ?
- Mapping the coalescence rate density in the Universe
- Tracing mass function of compact objects binaries
- Detection of coalescences of Pop III binaries

DECIGO and ET



Seto, 2008, presented at 1st LISA-DECIGO Workshop