Confusion Foreground from Compact Binaries*

Tania Regimbau

CNRS/ARTEMIS

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* (T.Regimbau & S.Hughes gr-qc/09012958)

Detection Isotropic Horizons*

- Detector sensitivity

	NS/NS	NS/BH
LIGO I/Virgo	15 Mpc	30 Mpc
Ad LIGO/Virgo	200 Mpc	420 Mpc
ET	~1	~2

- Gravitational lensing beyond z_{gl} ~1
- Confusion foreground of unresolved sources (z_{bg}?)

* distance at which the angle average SNR=8

Detection Regimes

Defined by the **duty cycle** i.e the ratio between the **average duration of the waveforms** and the **time interval between successive waveforms** (also the **average number of sources** present at the detector)

$$\Delta(z) = \int_0^z \underbrace{(1+z')\bar{\tau}}_{\bar{\tau}^o(z')} \underbrace{\frac{dR_c^o}{dz'}(z')}_{(\Delta t^o(z'))^{-1}} dz' \quad (1)$$

- Resolved sources at close redshifts

Sources separated by long stretches of silence

$\Delta(z) << 1$

- Popcorn background

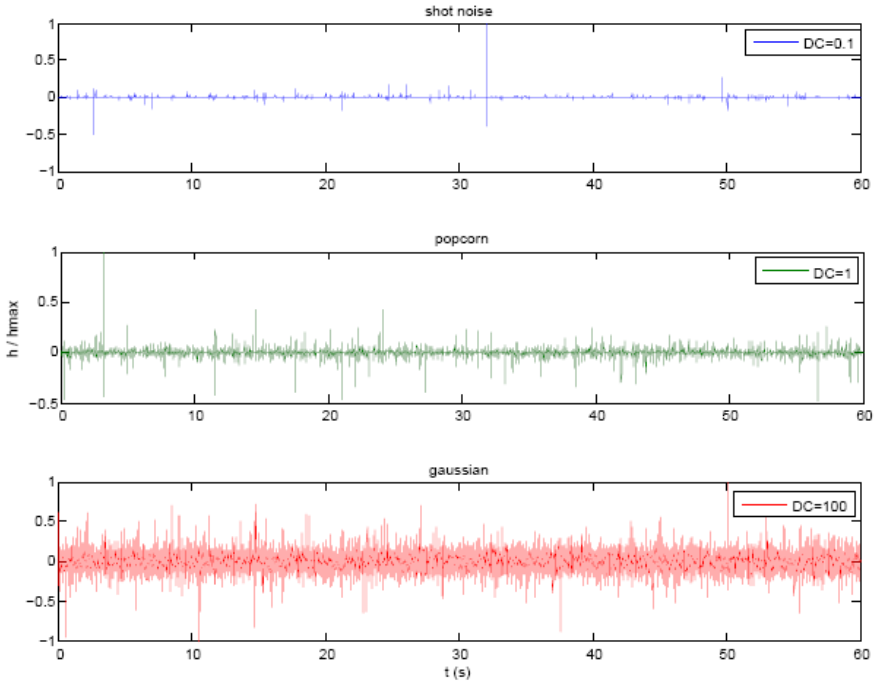
Sources start to overlap

$\Delta(z) \sim 1\text{-}10$

- Continuous stochastic background

Superposition of unresolved sources

$\Delta(z) >> 1$



Cosmic Coalescence Rate

Number of sources per redshift interval and unit of observer time:

$$\frac{dR_c^o}{dz}(z) = \dot{\rho}_c^o(z)\frac{dV}{dz}(z) \quad (2)$$

Number of sources per unit of comoving volume and unit of observer time:

$$\dot{\rho}_c^o(z) \propto \int \frac{\dot{\rho}_*(z_f)}{1+z_f} P(t_d)dt_d \quad (3) \text{ with } \dot{\rho}_c^o(0) = \dot{\rho}_0 (4)$$

$\dot{\rho}_0 = f n_{mw} R_{mw}$: local rate in $\mathrm{Mpc^{-3}Myr^{-1}}$

R_{mw} : Galactic rate in $\mathrm{Myr^{-1}}$

n_{mw} : number density of Milky Way like galaxies (~0.01-0.02 $\mathrm{Mpc^{-3}}$)

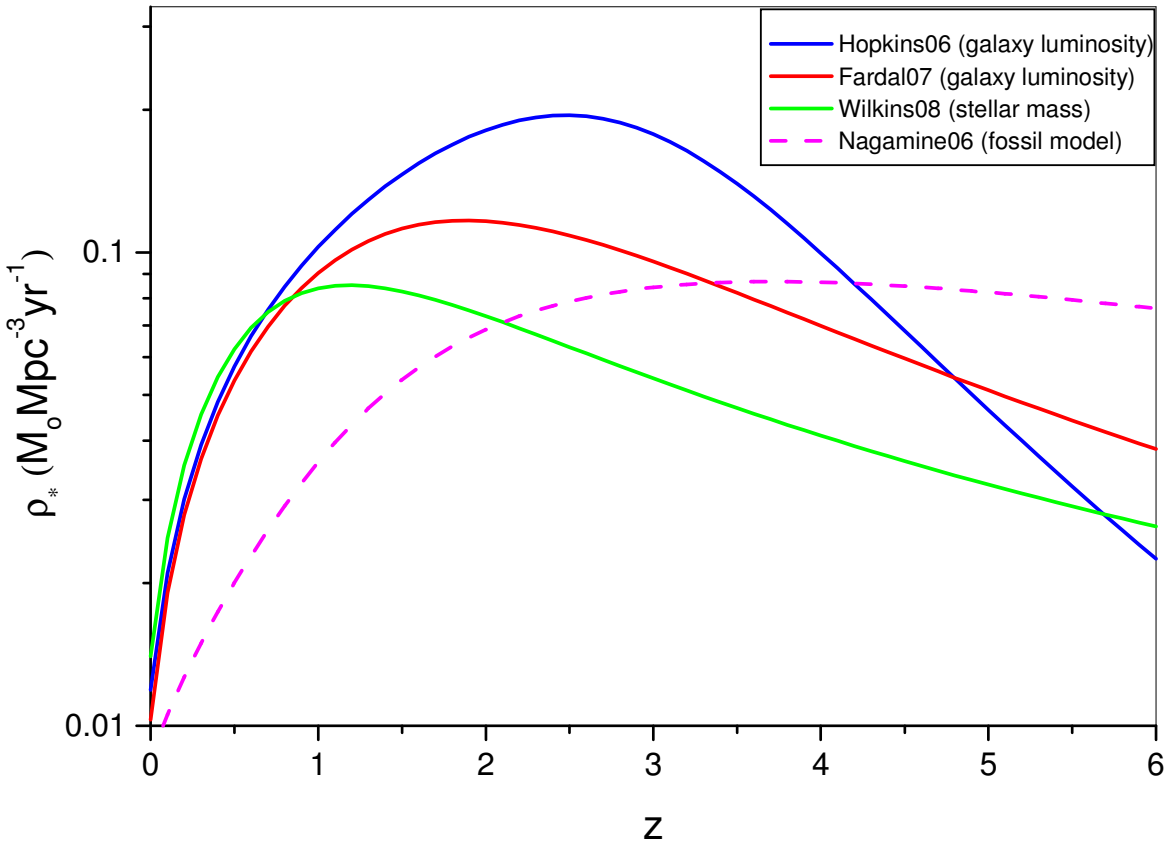
f : correction factor due to ellipticals (~1-2)

$\dot{\rho}_c(z_f)$: cosmic star formation rate in $\mathrm{M_\odot Mpc^{-3}yr^{-1}}$

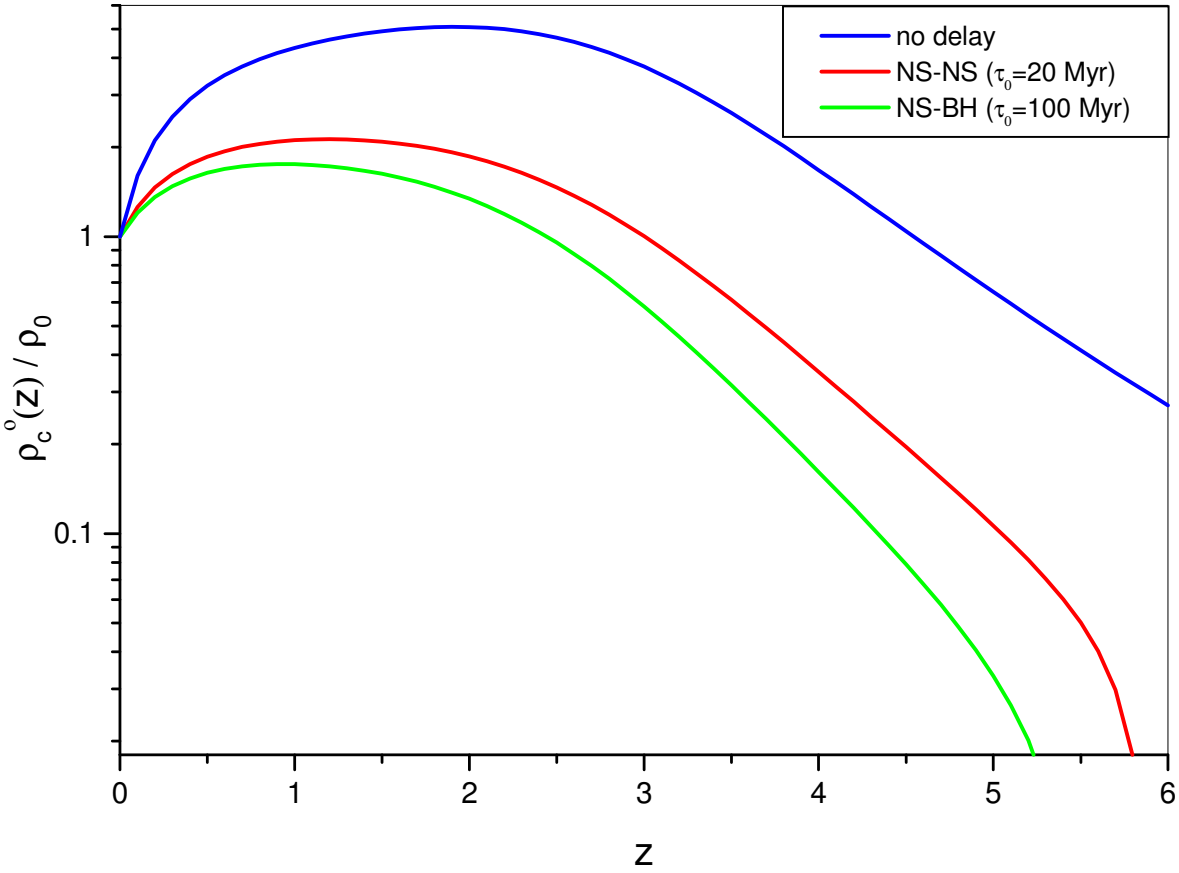
Probability distribution of the delay (evolution +merger):

$$P(t_d) \propto 1/t_d \text{ with } t_d > \tau_0 \quad (5)$$

Star Formation Rate



Coalescence Rate



Local Coalescence Rate

authors	NS-NS (Myr^{-1})	NS-BH (Myr^{-1})
statistics:		
Kalogera et al. (2004)	83 (17-292)	
pop. synthesis:		
Tutunov & Yungelson (1993)	300	20
Lipunov et al. (1997)	30	2
Potergies Zwart & Yungelson (1998)	20	1
Nelemans et al. (2001)	20	4
Voss & Tauris (2003)	2	0.6
O'Shaughnessy et al. (2005)	7	1
de Freitas Pacheco et al. (2006)	17	
Belczinsky et al. (2007)	10-15	0.1
O'Shaughnessy et al. (2008)	30	3

NS-NS: $\dot{\rho}_0 = 0.01 - 10\ \mathrm{Myr}^{-1}\mathrm{Mpc}^{-3}$, reference: 0.4 (pop synthesis) and 1 (statistics)

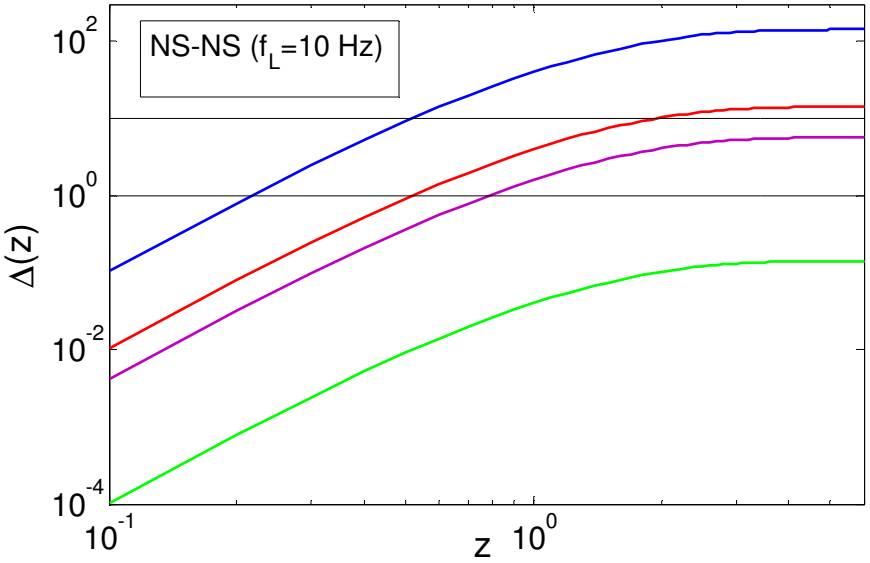
NS-BH: $\dot{\rho}_0 = 0.001 - 1\ \mathrm{Myr}^{-1}\mathrm{Mpc}^{-3}$, reference: 0.04

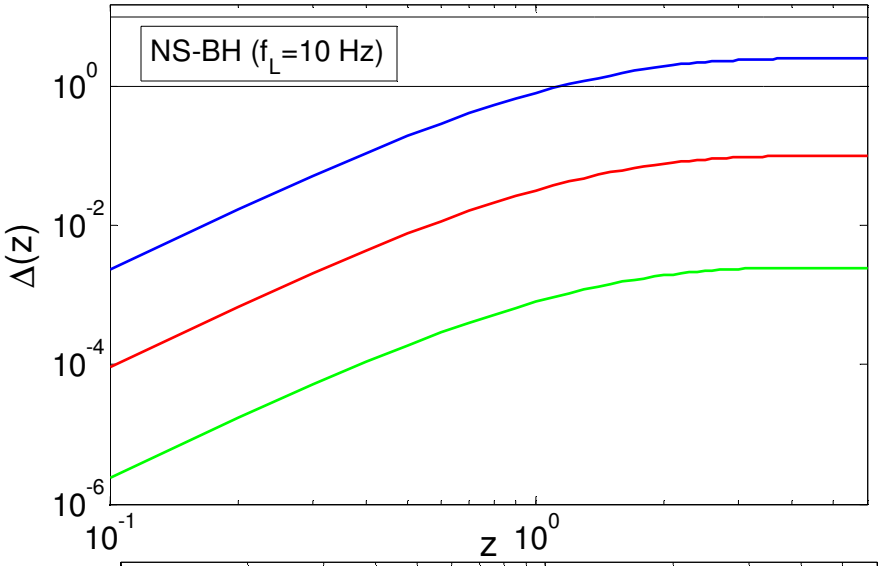
Signal Duration

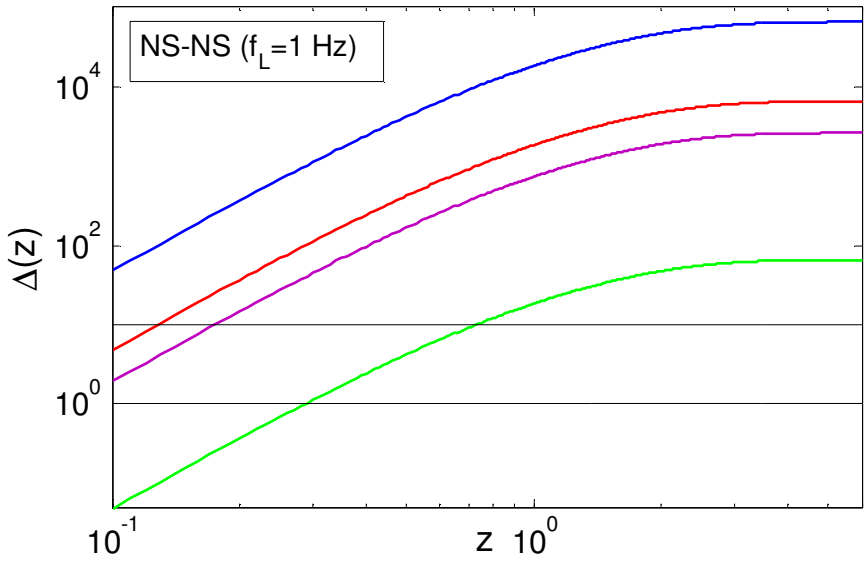
$$\tau \sim \frac{5c^5}{265\pi^{8/3}G^{5/3}} \underbrace{\frac{(m_1+m_2)^{1/3}}{m_1 m_2}}_{M_c^{-5/3}} f_L^{\,-8/3}$$

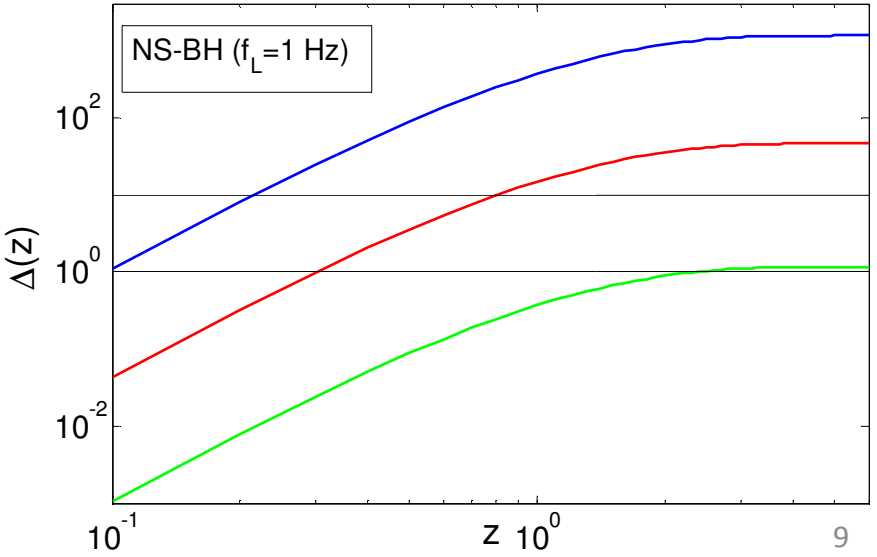
f_L (Hz)	NS-NS (1.4+1.4)	NS-BH (1.4+10)
40 (initial)	25 s	5.8 s
10 (Ad LIGO)	16.7 m	3.9 m
5 (Ad Virgo)	1.8 h	24.6 m
3 (possible ET)	6.9 h	1.6 h
1 (planned ET)	5.4 d	1.2 d

Duty Cycle


NS-NS (f_L=10 Hz)
10^2
10^0
10^{-2}
10^{-4}
Δ(z)
10^{-1}
z
10^0


NS-BH (f_L=10 Hz)
10^0
10^{-2}
10^{-4}
10^{-6}
Δ(z)
10^{-1}
z
10^0


NS-NS (f_L=1 Hz)
10^4
10^2
10^0
Δ(z)
10^{-1}
z
10^0


NS-BH (f_L=1 Hz)
10^2
10^0
10^{-2}
Δ(z)
10^{-1}
z
10^0

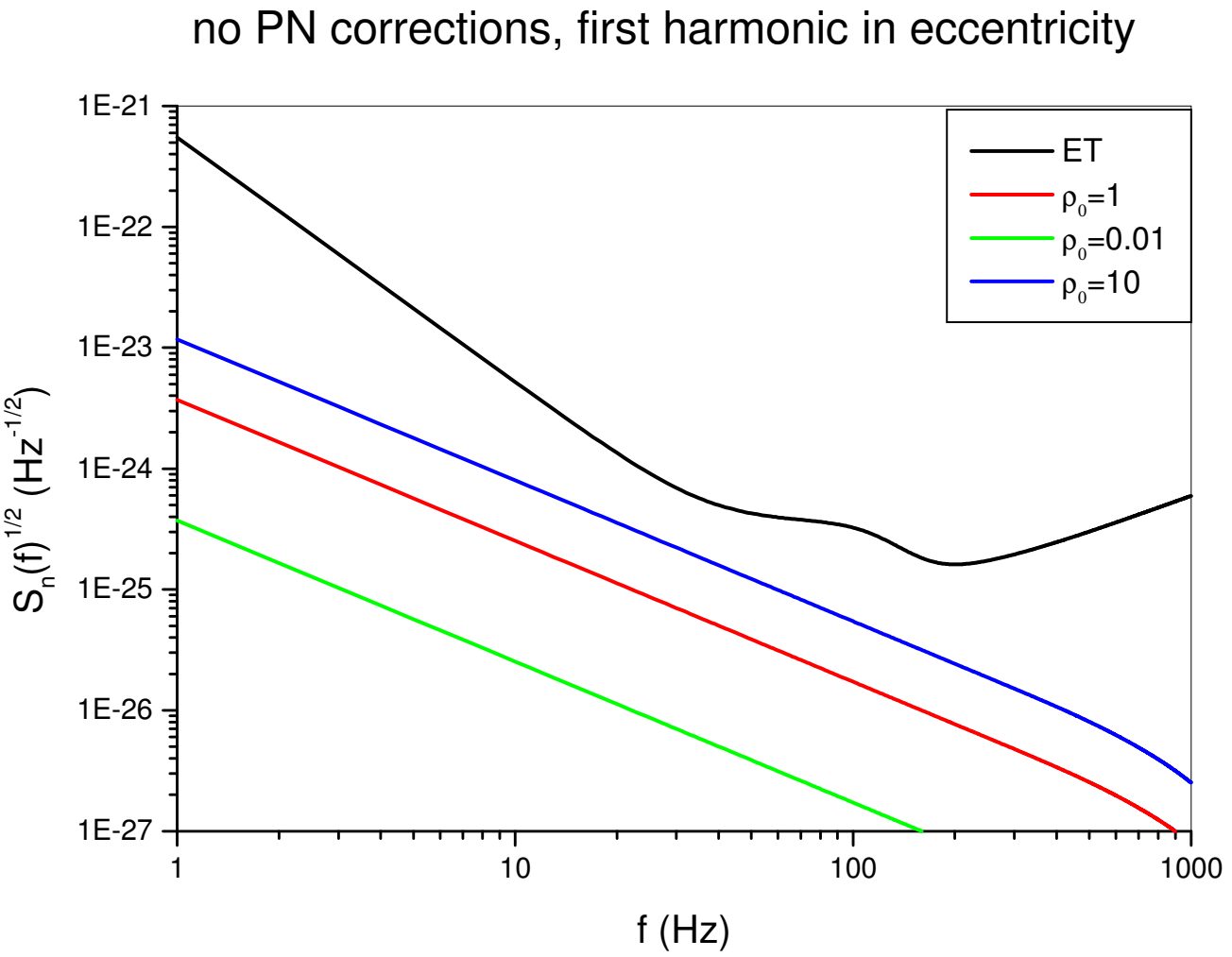
Confusion Horizon: NS-NS

f_L (Hz)	ρ_o	z_* (Δ=1)	z_{**} (Δ=10)
10	0.01 0.4 1 10	- 0.8-0.9 0.5-0.6 0.2	- - >2 0.5-0.6
5	0.01 0.4 1 10	- 0.4 0.25 0.1	- 1-1.2 0.6-0.7 0.25
1	0.01 0.4 1 10	0.3 0.08 0.06 0.03	0.8 0.2 0.13 0.06

Confusion Horizon: NS-BH

f_L (Hz)	ρ_o	z_* (Δ=1)	z_{**} (Δ=10)
10	0.001 0.04 1	- - 1.1-1.4	- - -
5	0.001 0.04 1	- - 0.5	- - >1.6
1	0.001 0.04 1	>2.3 0.3 0.1	- 0.8-0.9 0.2

Confusion Background NS-NS



Summary

- Compact binaries are likely to create a **background of unresolved sources** before the horizon of ET, especially between 1-10 Hz

- The background may degrade the quality of compact binaries as standard sirenes to study dark energy

- Need to develop advanced DA techniques to separate the sources (see Mock LISA challenge)

- The foreground from NS-NS (and NS-BH) shouldn't affect the detection of other sources