



Observatoire
de la CÔTE d'AZUR



Confusion Foreground from Compact Binaries: Consequences for ET

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Detection Horizons

➤ Detector sensitivity

	NS/NS	NS/BH
LIGO I/Virgo	20 Mpc	45 Mpc
Ad LIGO/Virgo	300 Mpc	650 Mpc
ET	2	5

➤ Gravitational lensing beyond $z_{gl} \sim 1$

➤ Confusion foreground of unresolved sources (z_{bg} ?)

Detection Regimes

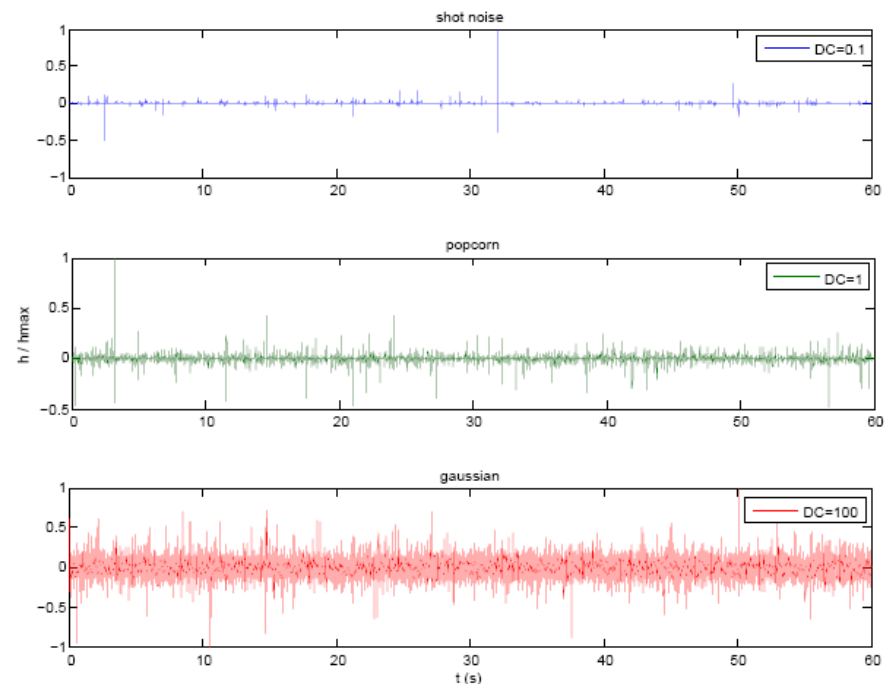
Defined by the **duty cycle** i.e the ratio between the **average duration of the GW signal** and the **time interval between successive waveforms** (also the **average number of sources** present at the detector)

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

➤ Resolved sources at close redshifts
Sources separated by long stretches of silence
 $D(z) \ll 1$

➤ Popcorn background
Sources start to overlap
 $D(z) \sim 1-10$

➤ Continuous stochastic background
Superposition of unresolved sources
 $D(z) \gg 1$



Cosmic Coalescence Rate

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

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

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

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

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

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

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

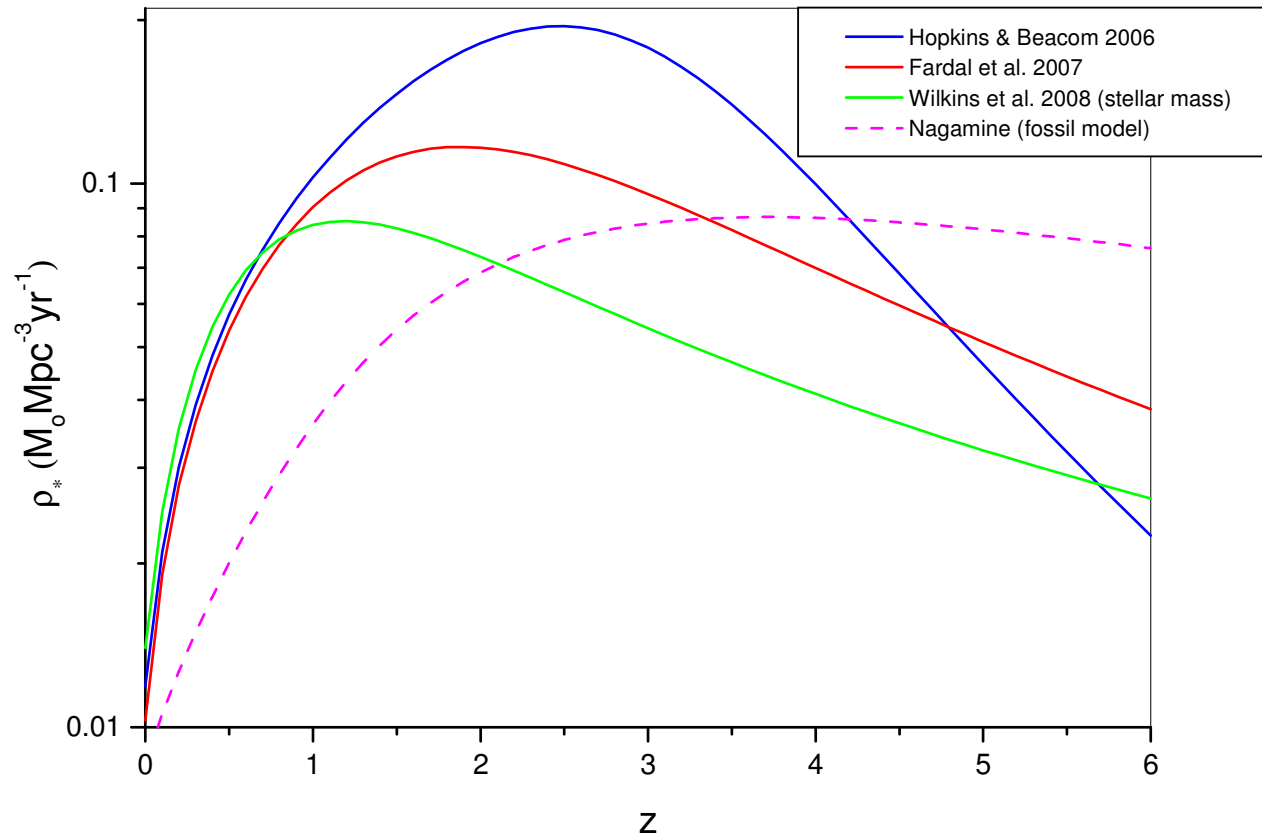
f : correction factor due to ellipticals ($\sim 1\text{-}2$)

$\dot{\rho}_*(z_f)$: cosmic star formation rate in $\text{M}_\odot \text{Mpc}^{-3} \text{yr}^{-1}$

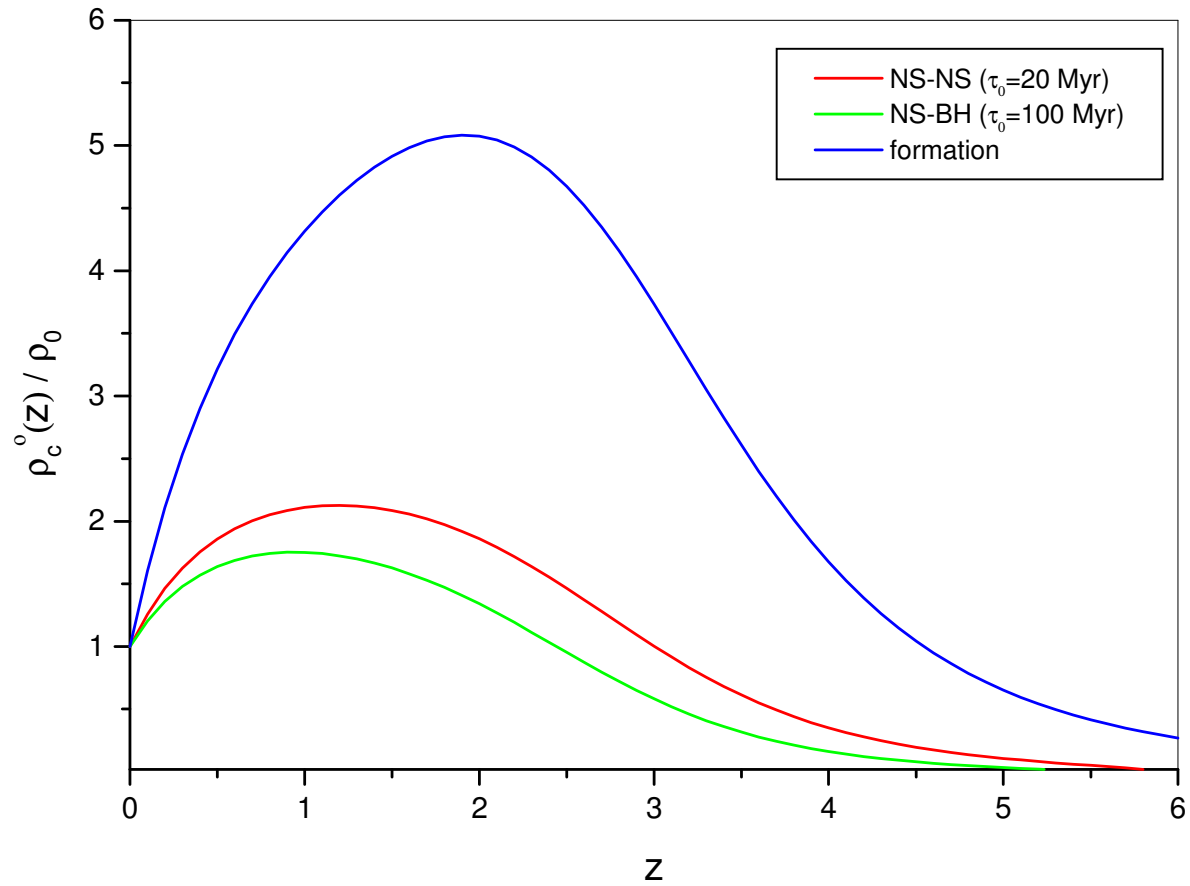
Probability distribution of the delay (evolution +merger):

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

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	
Belczynsky et al. (2007)	10-15	0.1
O'Shaughnessy et al. (2008)	30	3

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

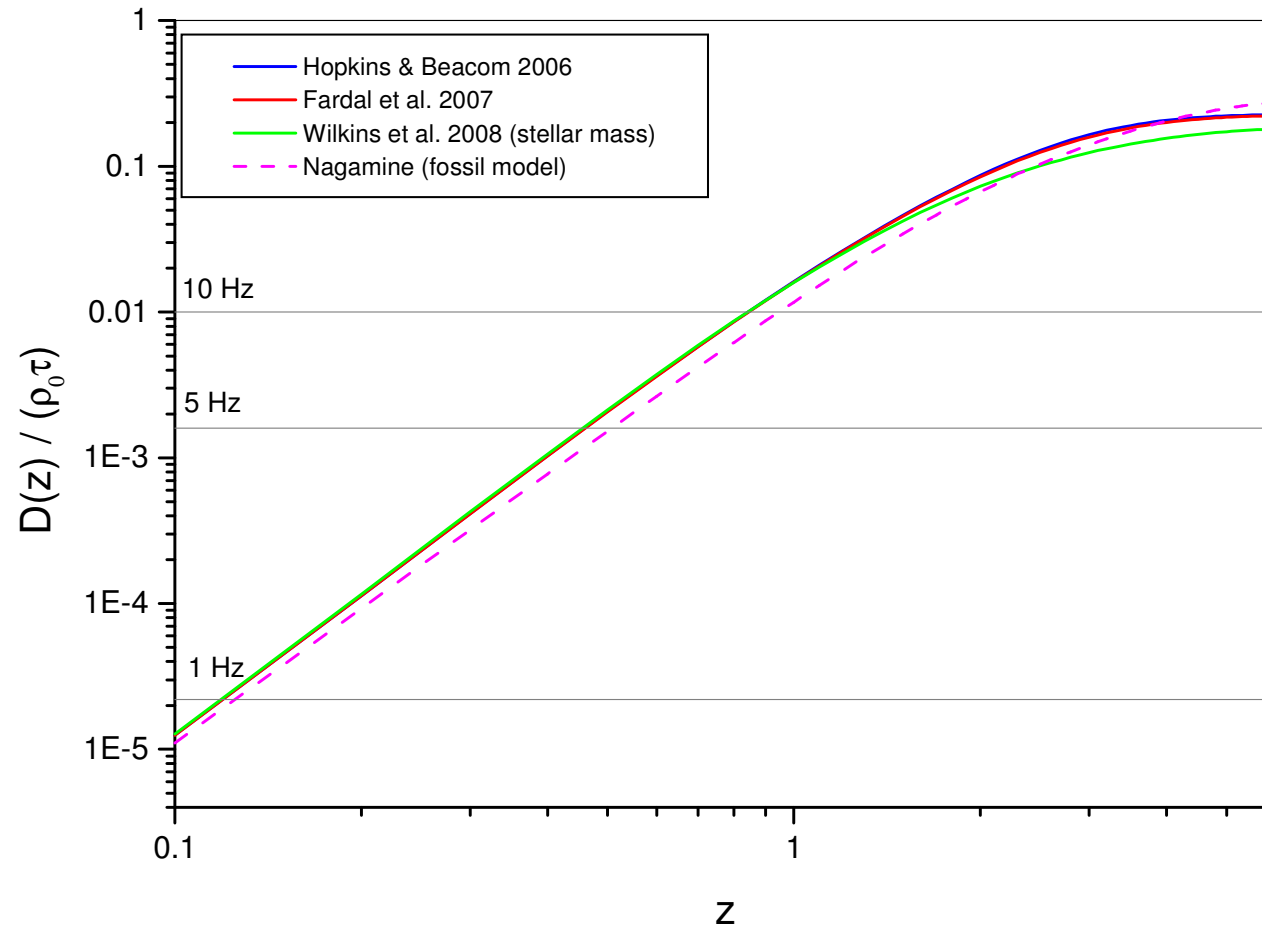
NS-BH: $\dot{\rho}_0 = 0.001-1 \text{ Myr}^{-1}\text{Mpc}^{-3}$, reference: 0.04

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



Confusion Horizon: NS-NS

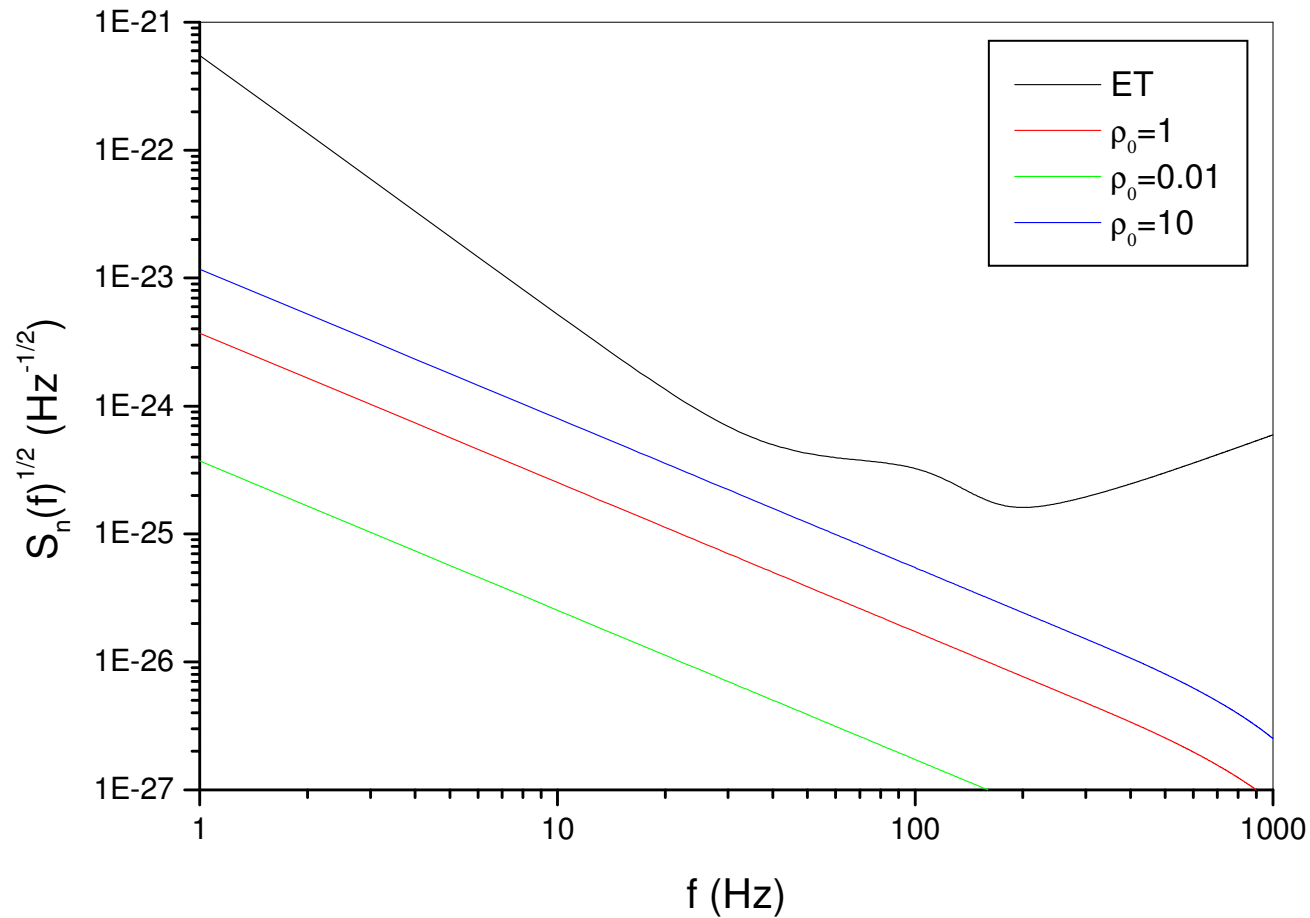
f_L (Hz)	ρ_o	z_* (D=1)	z_{**} (D=10)
10	0.01	>2	-
	0.4	0.5-0.6	1.2-1.3
	1	0.4	0.9
	10	0.2	0.4
5	0.01	1-1.1	>2.5
	0.4	0.3	0.6-0.7
	1	0.2	0.5
	10	0.1	0.2
1	0.01	0.25	0.5
	0.4	0.08	0.15
	1	0.06	0.03
	10	0.03	0.06

Confusion Horizon: NS-BH

f_L (Hz)	ρ_0	z_* (D=1)	z_{**} (D=10)
10	0.001	-	-
	0.04	>2.5	-
	1	0.6-0.7	1.6-1.7
5	0.001	-	-
	0.04	1.1-1.2	>3.5
	1	0.3-0.4	0.8
1	0.001	0.9	>2.4
	0.04	0.2-0.3	0.5-0.6
	1	0.08	0.2

Confusion Background NS-NS

no PN corrections, first harmonic in eccentricity



Conclusions and Future Plans

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 sirens to study dark energy
- Need to develop advanced DA techniques to separate the sources
- The foreground from NS-NS (and NS-BH) shouldn't affect the detection of other sources

What next:

- Redo the calculation including **PN corrections** and **higher harmonics in eccentricity** (Simona Birindelli)
- Develop DA techniques to detect individual sources (S. Birindelli, OCA Postdoc) and the popcorn regime (in progress S. Birindelli, S. Drasco (AEI), T. Regimbau)