

Dynamical process impact on the CBC background

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Stochastic background presentation

Definition

Signal composed by the superposition of every non-resolved gravitational wave.

Stochastic background sources

- Astrophysical background : From phenomena after the stellar activity like compact binaries coalescences.
- Cosmological background : From phenomena from early universe.

Characterization

$$\Omega_{gw}(f) = \frac{f}{\rho_c} \frac{d\rho_{GW}}{df}$$

Theoretical aspects

Ω_{GW} calculation

$$\Omega_{gw}(f) = \frac{f}{c\rho_c} \phi(f), \quad (1)$$

$$\phi(f) = T^{-1} \sum_{k=1}^N \frac{1}{4\pi r^2} \frac{dE_{gw}^k}{df}(f), \quad (2)$$

Energy density from a CBC k

$$\frac{1}{4\pi r^2} \frac{dE_{gw}^k}{df}(f) = \frac{5}{48G} \frac{\left[G\mathcal{M}_k^{(z)}\right]^{5/3}}{\pi^{1/3} d_L^2(z)} \Gamma_k(f, \chi_{eff}) F_\nu \quad (3)$$

Inspiral merger and ringdown waveforms.

Ajith et al. 2011

$$\Gamma(f, \chi_{eff}) \propto \begin{cases} f^{-1/3} & \text{si } f < f_{\text{merg}} \\ f^{2/3} & \text{si } f_{\text{merg}} \leq f < f_{\text{ring}} \\ L(f, f_{\text{ring}}, \sigma) & \text{si } f_{\text{ring}} \leq f < f_{\text{cut}} \end{cases} \quad (4)$$

Problematic of the study

Isolated binaries (50%)

Giacobbo et al. 2018

- $R_0^{BNS} = 283_{-75}^{+97} \text{Gpc}^{-3}\text{yr}^{-1}$, $R_0^{BBH} = 50_{-37}^{+71} \text{Gpc}^{-3}\text{yr}^{-1}$

Santoliquido et al. 2020

Young star clusters binaries (50%)

Di Carlo et al. 2020

Rastello et al. 2020

- Age < 100 Myr
- Density $\sim 10^3 \text{ star.pc}^{-3}$
- Original (*Orig*) and Exchanged (*Exch*) binaries
- $R_0^{BNS} = 151_{-38}^{+59} \text{Gpc}^{-3}\text{yr}^{-1}$, $R_0^{BBH} = 64_{-20}^{+34} \text{Gpc}^{-3}\text{yr}^{-1}$

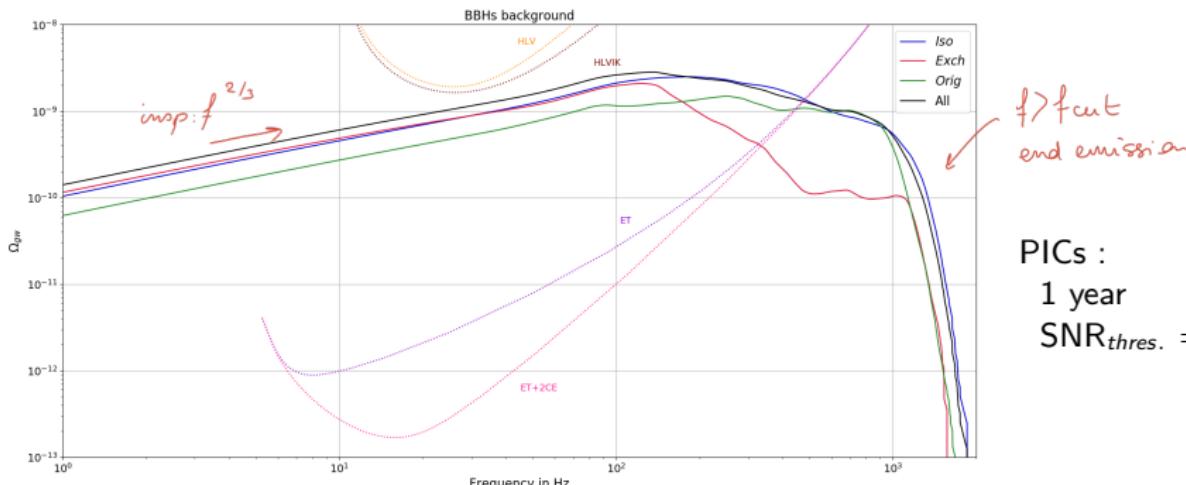
Santoliquido et al. 2020

LVK rates

LVK collaboration 2021

$$R_0^{BNS} = 320_{-240}^{+490} \text{Gpc}^{-3}\text{yr}^{-1}, R_0^{BBH} = 19_{-8}^{+18} \text{Gpc}^{-3}\text{yr}^{-1}$$

Total background from BBHs



PICs :
1 year
 $SNR_{thres.} = 2$

	StarTrack	Iso	Total
$\Omega_{gw}^{BBH}(25\text{Hz})$	7.27×10^{-10}	7.96×10^{-10}	1.04×10^{-9}

Table: Values of BBHs background $\Omega_{gw}^{BBH}(25\text{Hz})$. Comparison with StarTrack model.

Périgois et al. 2021

Revealing BBHs formation channels with the background shape

Parameters impacting the background

- Mass and redshift distributions.
- Stellar formation uncertainties.
- Proportion of dynamical binaries.

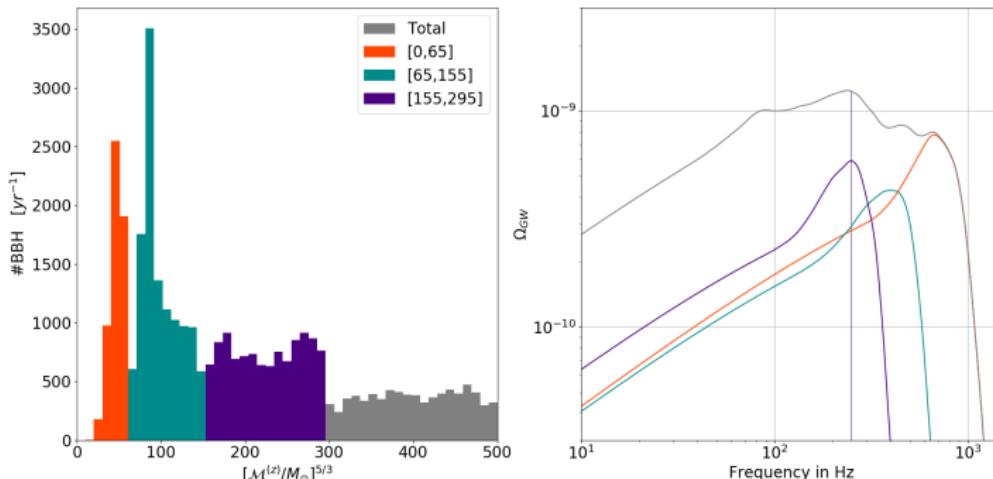
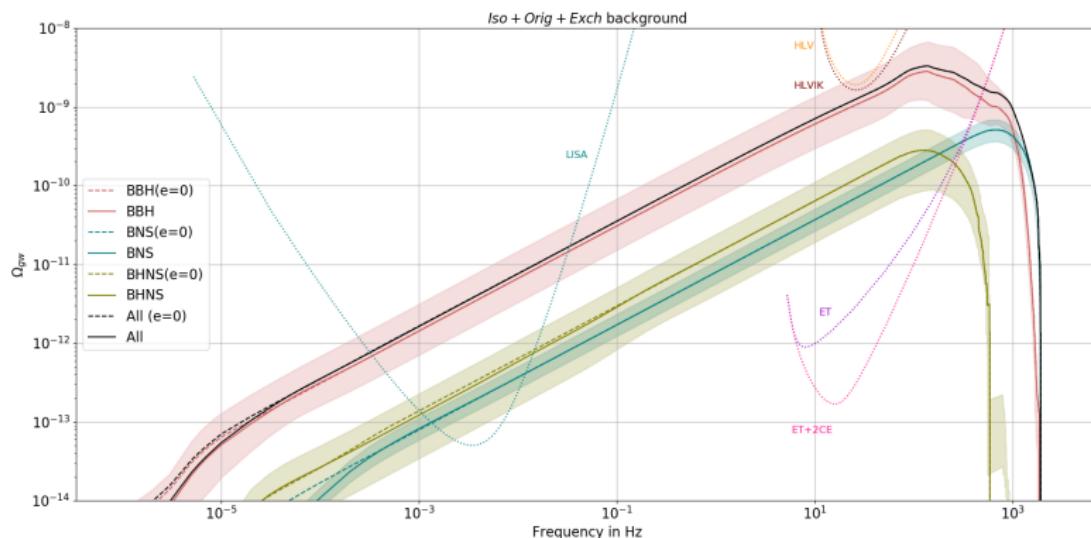


Figure: Impact of masses on original (Orig) BBHs background shape.

Total background



	BBH	BNS	BHNS (UL)	All (UL)
LVK	$5.0^{+1.7}_{-1.4} \times 10^{-10}$	$2.21^{+2.9}_{-1.6} \times 10^{-10}$	$< 8.4 \times 10^{-10}$	$< 3.4 \times 10^{-9}$
<i>Iso+Orig+Exch</i>	$1.04^{+1.26}_{-0.56} \times 10^{-9}$	$6.65^{+2.54}_{-1.85} \times 10^{-11}$	$1.03^{+0.99}_{-0.69} \times 10^{-10}$	$1.21^{+2.9}_{-1.6} \times 10^{-9}$

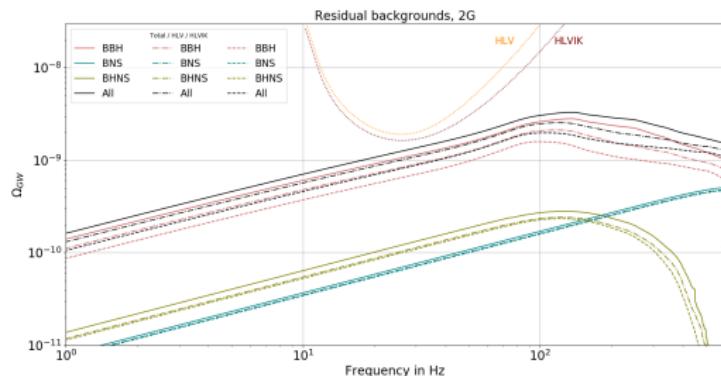
Table: Values background. Comparison with O3a. (UL) stands for upper limits from LVK observations.

LVK collaboration. 2021

Detectability and residual backgrounds

$$\text{SNR} = \frac{3H_0^2}{10\pi^2} \sqrt{2T} \left[\int_0^\infty df \sum_{i=1}^n \sum_{j>i} \frac{\gamma_{ij}^2(f) \Omega_{gw}^2(f)}{f^6 P_i(f) P_j(f)} \right]^{1/2} \quad (5)$$

Allen, Romano 1999

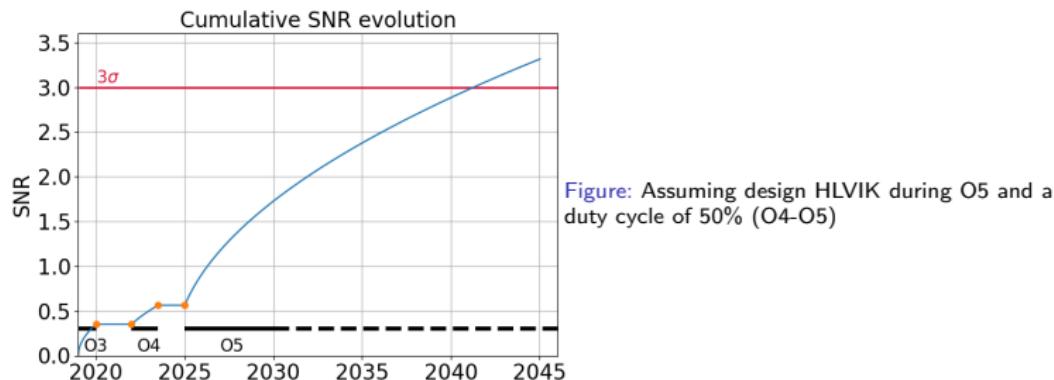


	HLV	HLVIK
Total	1.31	1.57
Residual	1.07	1.03

Table: SNR of total and residual backgrounds. $f_{Dyn} = 0.5$

		BBHs	BNSs	BHNSs	All
Total	Ω_{gw} N_{tot}	1.04×10^{-9} 106136	6.65×10^{-11} 275337	1.03×10^{-10} 151525	1.21×10^{-9} 532898
HLV	$\Omega_{gw}(r_\Omega)$ $\#N_{det}$	8.19×10^{-10} (78%) 617 (<1%)	6.47×10^{-11} (97%) 5 (~0%)	1.01×10^{-10} (97%) 6 (~0%)	9.85×10^{-10} (80%) 628 (~0%)
HLVIK	$\Omega_{gw}(r_\Omega)$ $\#N_{det}$	6.35×10^{-10} (61%) 3051 (~3%)	6.32×10^{-11} (95%) 20 (~0%)	9.73×10^{-11} (94%) 37 (~0%)	7.96×10^{-10} (65%) 3108 (<1%)

Detection scenario



Will be resolved with 3G detectors.

- CBCs background will reflect formation channels of binaries.
- Subtracting this background, we may highlight other contributions.



Impact of mass distribution

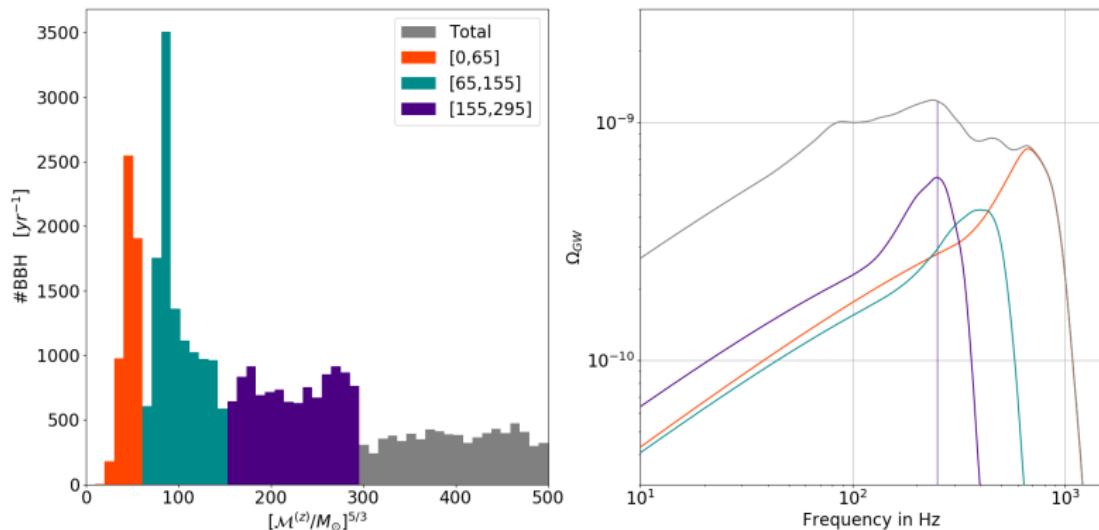


Figure: Impact of masses on original BBHs background shape.

Impact of star formation rate and metallicity

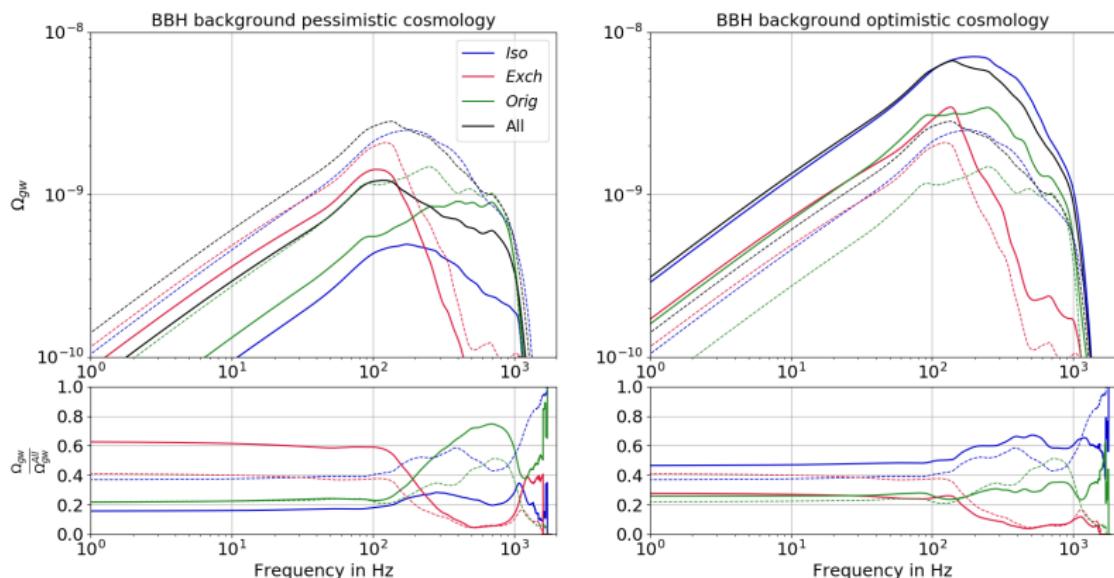


Figure: Pessimistic(left) and optimistic(right) catalogues stands for upper and lower quartile of SFR/redshift and metallicity/redshift relations. Bottom : Contribution proportions for the different channels. Dashed lines : Fiducial catalogue.

Proportion of dynamical binaries f_{Dyn}

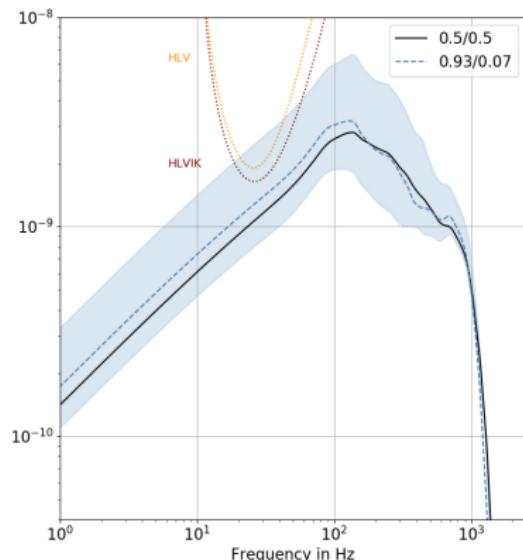
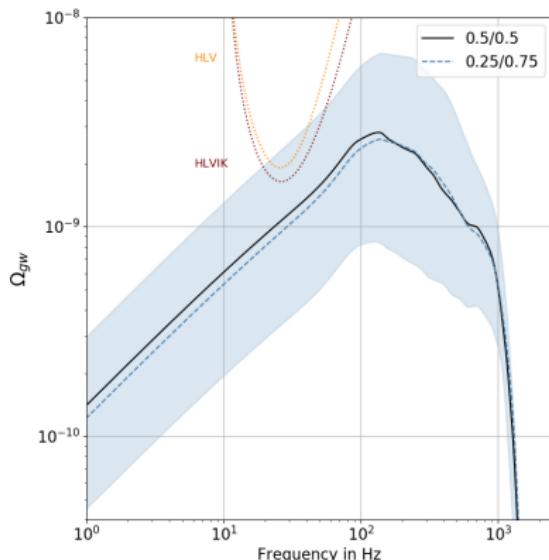


Figure: Left (Right) : BBH Energy density for $f_{Dyn} = 0.25$ (0.93). Extreme proportions from GWTC-2.
LIGO-Virgo collaboration. 2020

Stellar formation uncertainties

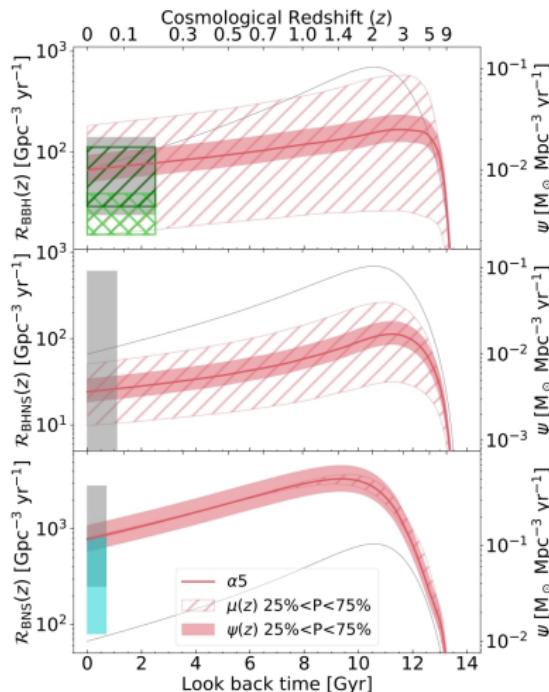


Figure: Merger rate uncertainties from SFR/redshift and metallicity/redshift relations.

Santoliquido et al. 2020