# ET Mock Data Challenge

ET Meeting – Budapest 23/11/10

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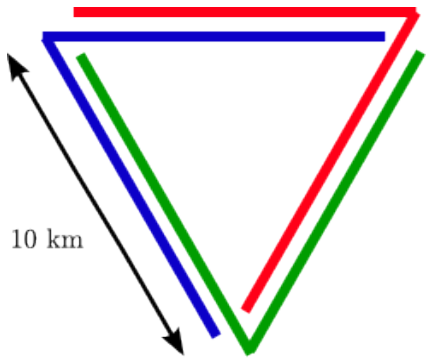
# ET Mock Data

Motivations: develop advanced DA strategies, able to perform accurate parameter estimation (cosmology) and extract single sources from the confusion noise.

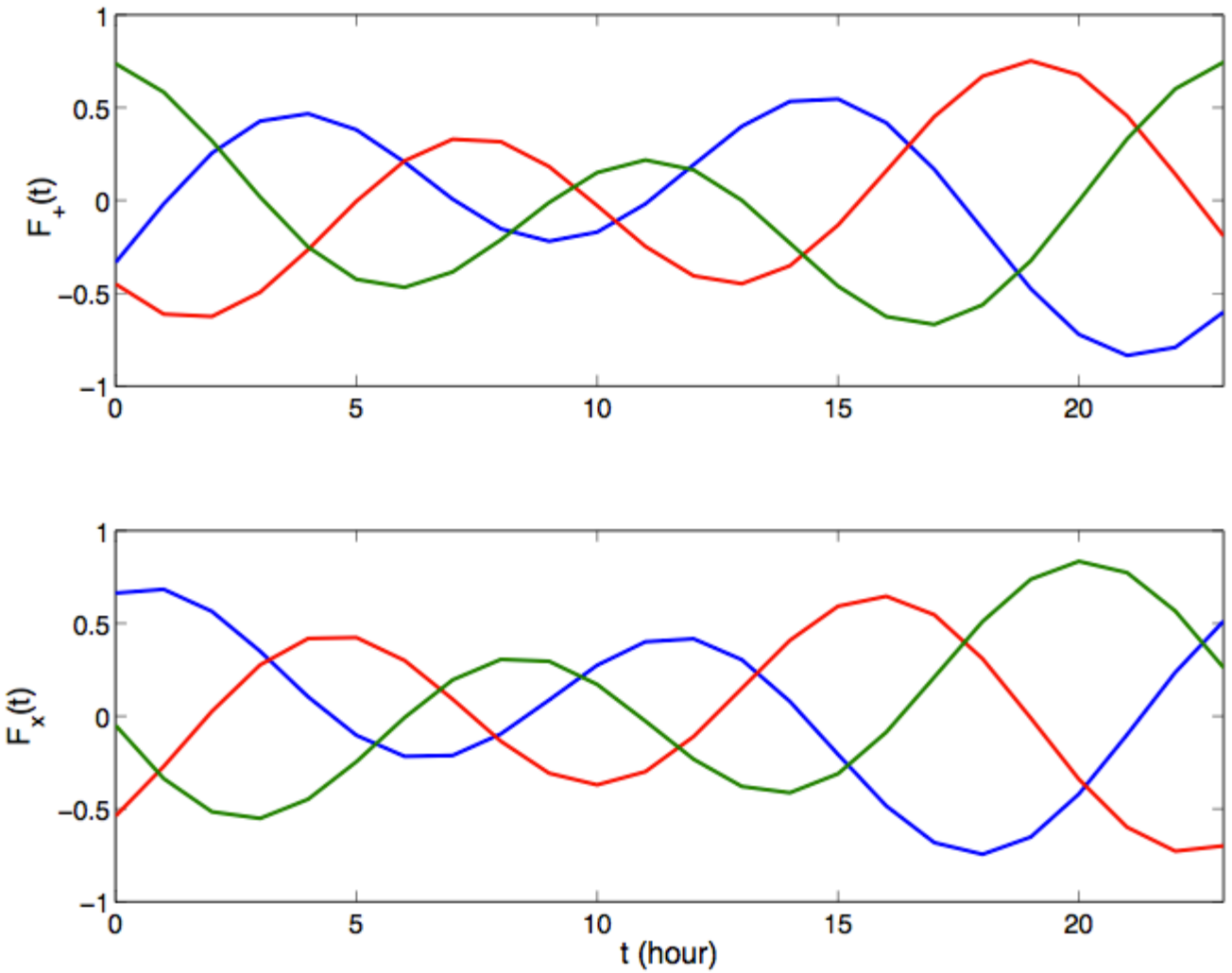
- time series at the detector outputs E1, E2, E3
- Noise : colored Gaussian noise based on ET-B sensitivity
- GW signal : extra galactic population of BNS
- ~1 month of data on Atlas

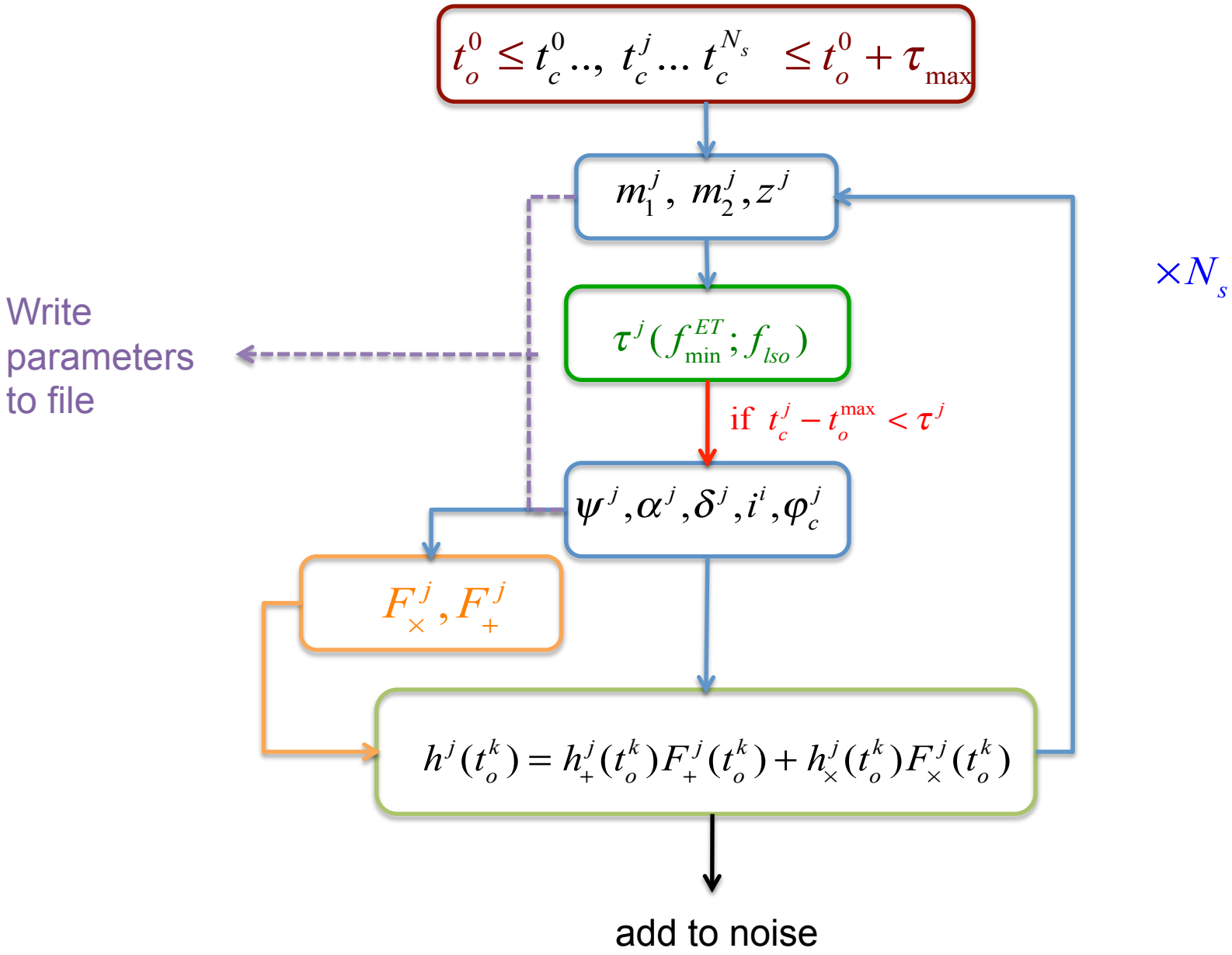
1182 frames :

- ✓duration 2048 s
- ✓sample rate 8192 Hz
- ✓$f_L$=10 Hz



# Beam Functions




$t_o^0 \le t_c^0 .., \; t_c^j ... \; t_c^{N_s} \; \le t_o^0 + \tau_{\max}$
$m_1^j, \; m_2^j, z^j$
$\tau^j(f_{\min}^{ET}; f_{lso})$
if $t_c^j - t_o^{\max} < \tau^j$
$\psi^j, \alpha^j, \delta^j, i^i, \varphi_c^j$
$F_\times^j, F_+^j$
$h^j(t_o^k) = h_+^j(t_o^k)F_+^j(t_o^k) + h_\times^j(t_o^k)F_\times^j(t_o^k)$
$\times N_s$
Write parameters to file
add to noise

# Distributions

- **coalescence time** (Poisson process):

$$p(\Delta t) \propto \exp(-\Delta t / \lambda) \text{ with } \lambda = \left[ \int_{z_{\min}}^{z_{\max}} \frac{dR_c^o}{dz}(z)\, dz \right]^{-1}$$

- **masses**: Gaussian distribution ($m_{min}, m_{max}, \mu, \sigma$)
- **redshift:** $p(z) \propto \frac{dR_c^o}{dz}(z)$
- **position in the sky:** uniform distribution
- **polarization:** uniform distribution
- **phase at the last stable orbit:** uniform distribution

# Coalescence Rate

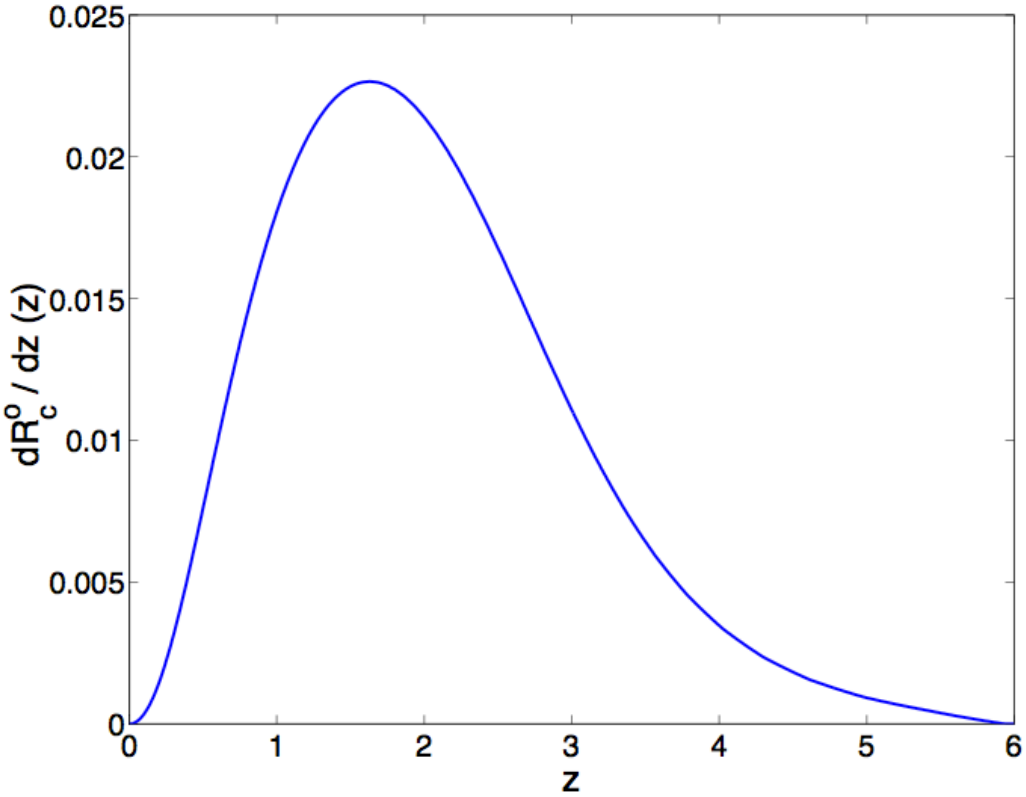
$$\frac{dR_c^o}{dz}(z) = \dot{\rho}_c^o(z)\frac{dV}{dz}(z) \quad \text{with } \dot{\rho}_c^o(z) \propto \int \frac{\dot{\rho}_*(z_f)}{1+z_f} P(t_d)\, dt_d$$

for:

$$\begin{cases} \text{SFR of Hopkins \& Beacom 2006} \\ H_0 = 0.7,\ \Omega_m = 0.3 \text{ and } \Omega_\Lambda = 0.7 \end{cases}$$

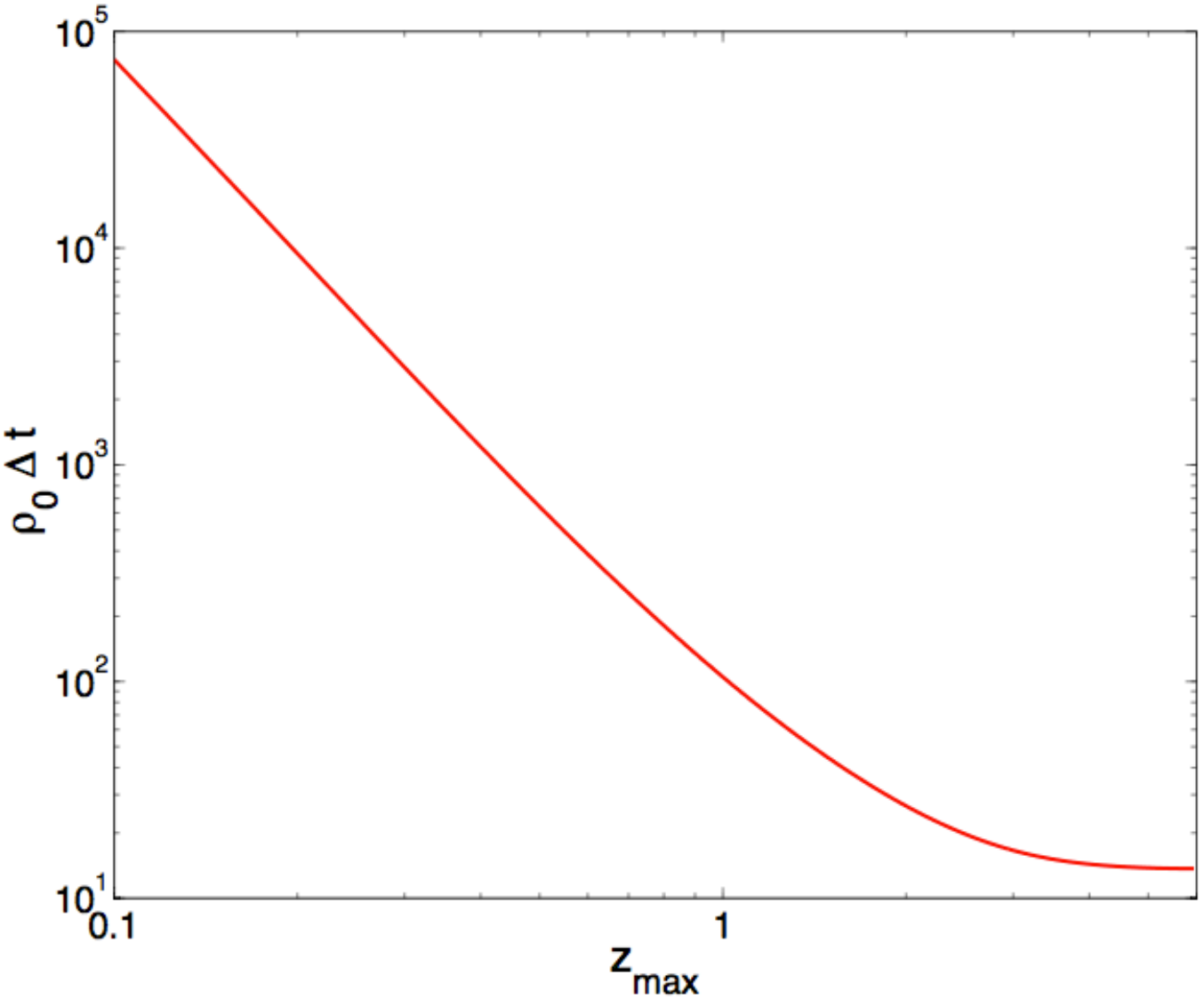
and (BNS):

$$\begin{cases} \dot{\rho}_c^o(0) = 1\ \text{Myr}^{-1}\text{Mpc}^{-3}\ * \\ P(t_d) \propto 1/t_d \text{ with } t_d > 20\ \text{Myr} \end{cases}$$




* 'realistic' rate from the LIGO rate paper

# average time step



# Detection Regimes

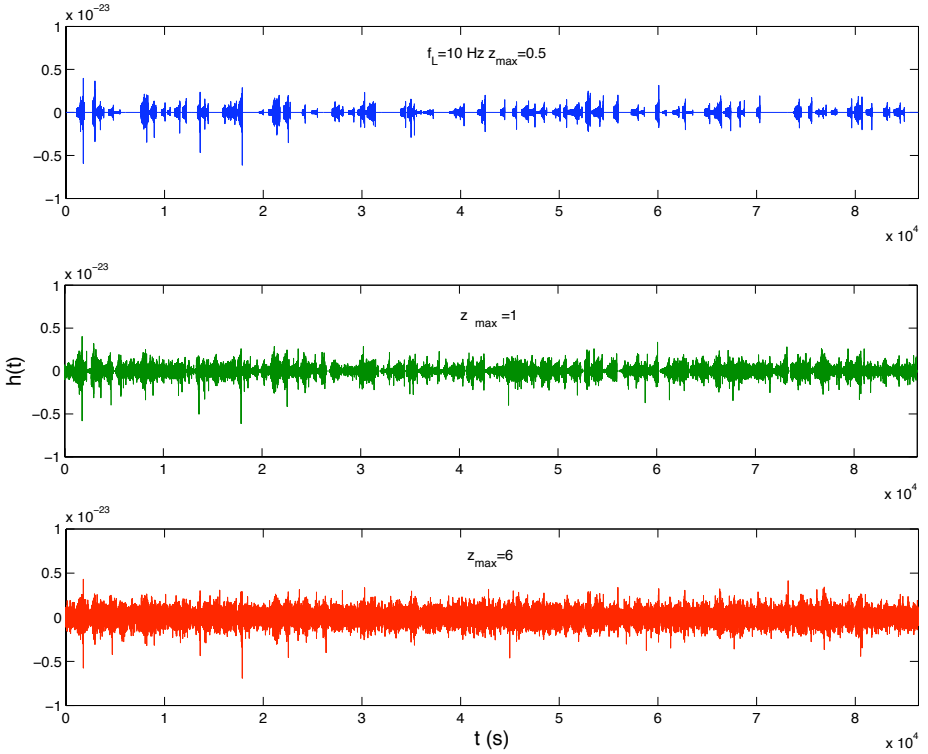
Defined by the duty cycle i.e the ratio between the average duration of the waveforms and the time interval between successive waveforms (also the average number of sources present at the detector)

$$\Delta(z) = \int_0^z (1+z')\bar{\tau}\,\frac{dR_c^o}{dz'}(z')dz'$$

- Resolved sources at close redshifts
  Sources separated by long stretches of silence

- Popcorn background
  Sources start to overlap

- Continuous stochastic background
  Superposition of unresolved sources

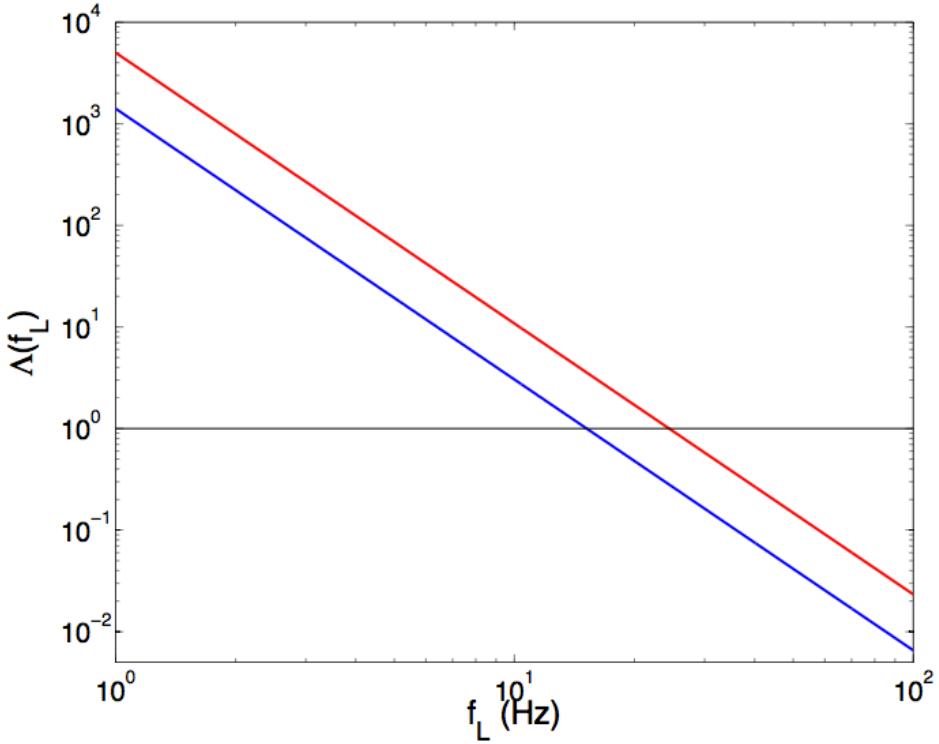


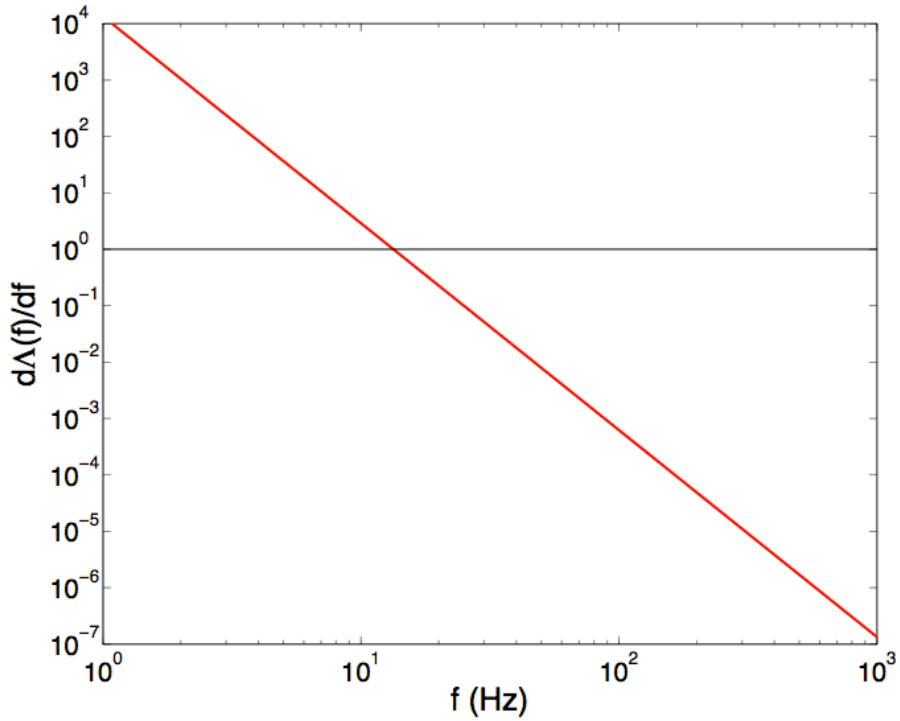
# Signal Duration

$$\tau(day) \sim 5.4\left(\frac{M_c^{-5/3}}{1.22\,M_\odot}\right) f_L^{-8/3}$$

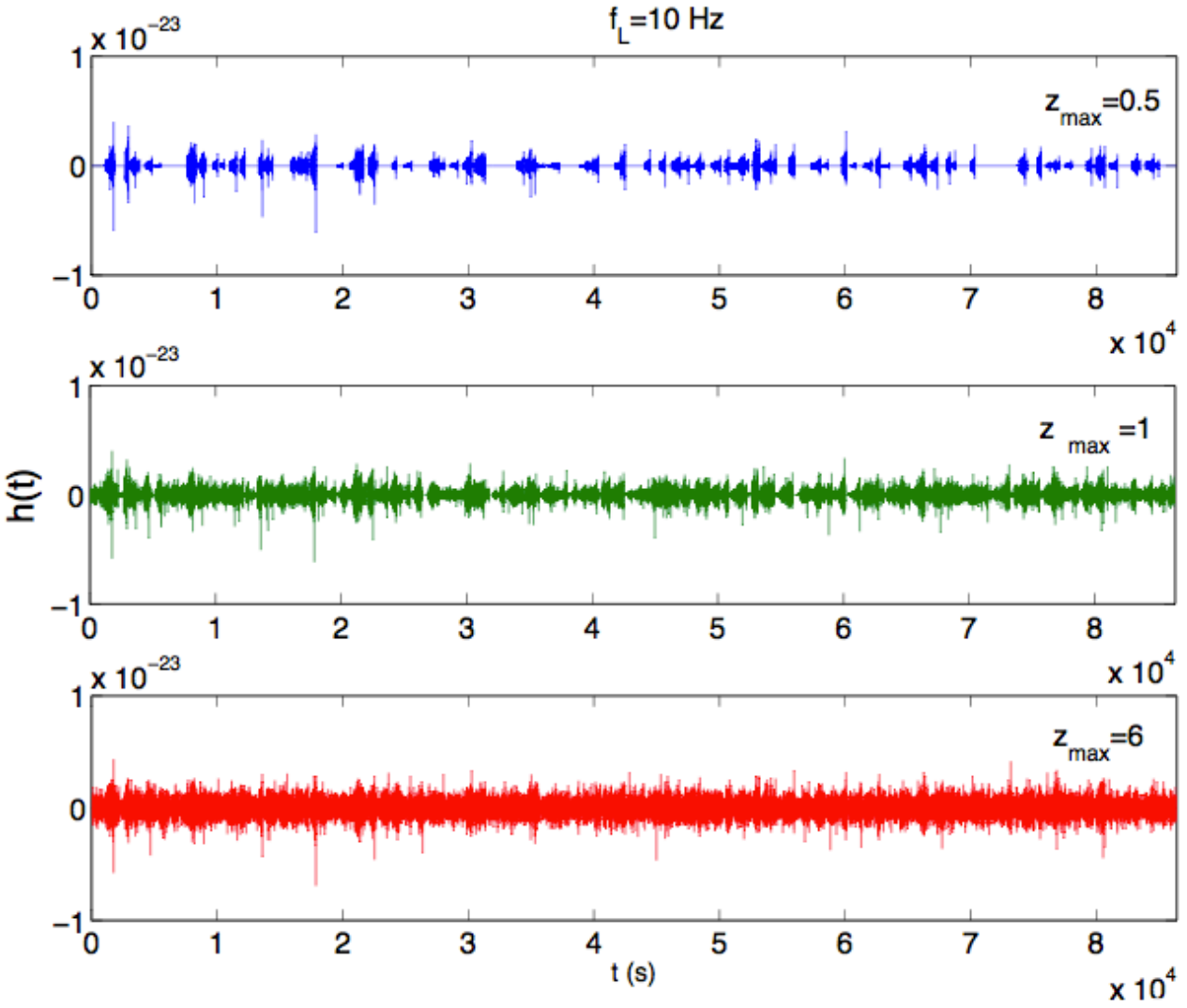
| $f_L$ (Hz) | NS-NS (1.4+1.4) | NS-BH (1.4+10) |
|---|---|---|
| 40 (initial) | 25 s | 5.8 s |
| 10 (Ad LIGO) | 16.7 m | 3.9 m |
| 5 (Ad Virgo) | 1.8 h | 24.6 m |
| 3 (possible ET) | 6.9 h | 1.6 h |
| 1 (planned ET) | 5.4 d | 1.2 d |

# Duty Cycle

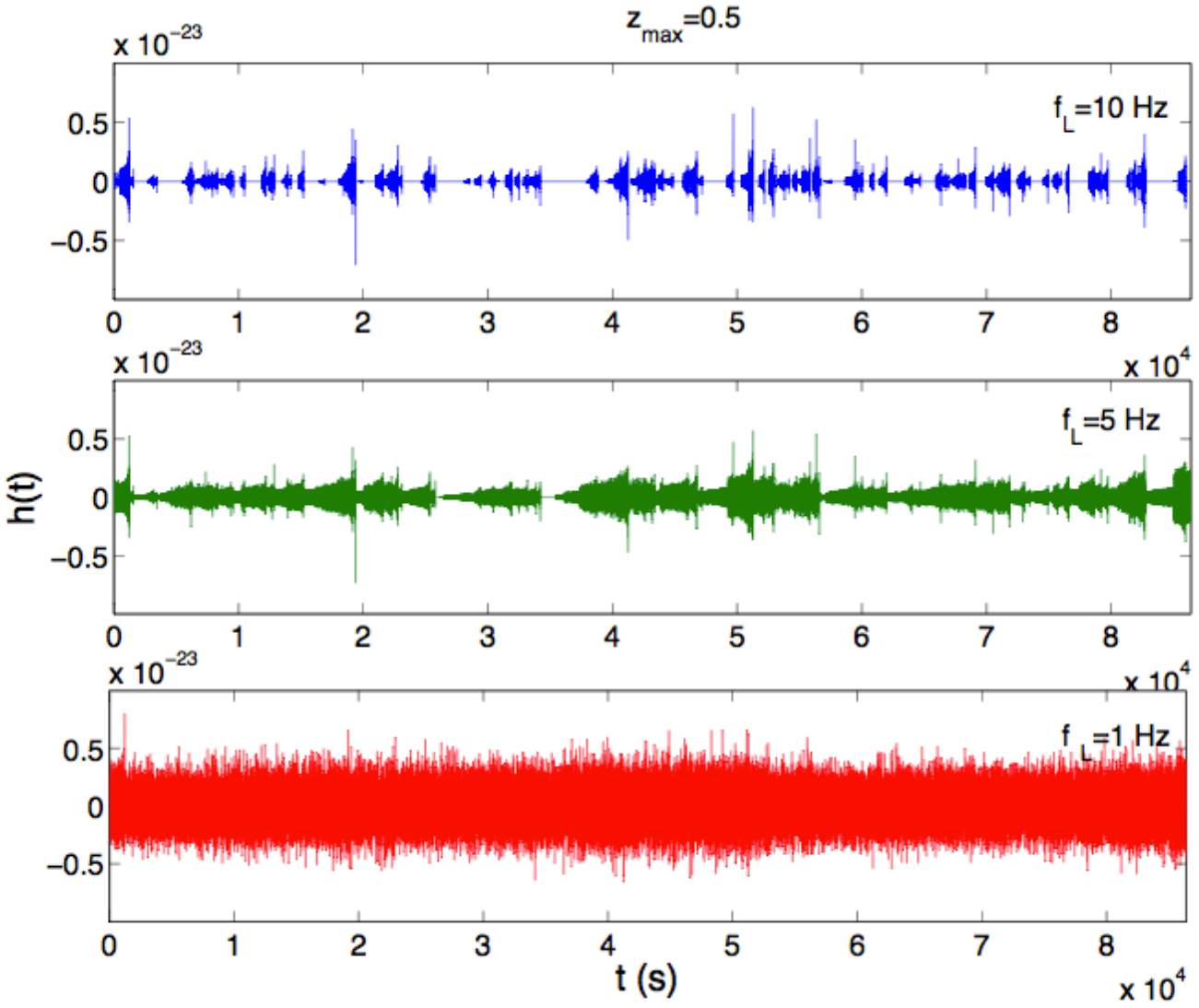

$10^4$
$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
$10^{-2}$
$\Lambda(f_L)$
$10^0$
$10^1$
$10^2$
$f_L$ (Hz)


$10^4$
$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$d\Lambda(f)/df$
$10^0$
$10^1$
$10^2$
$10^3$
f (Hz)

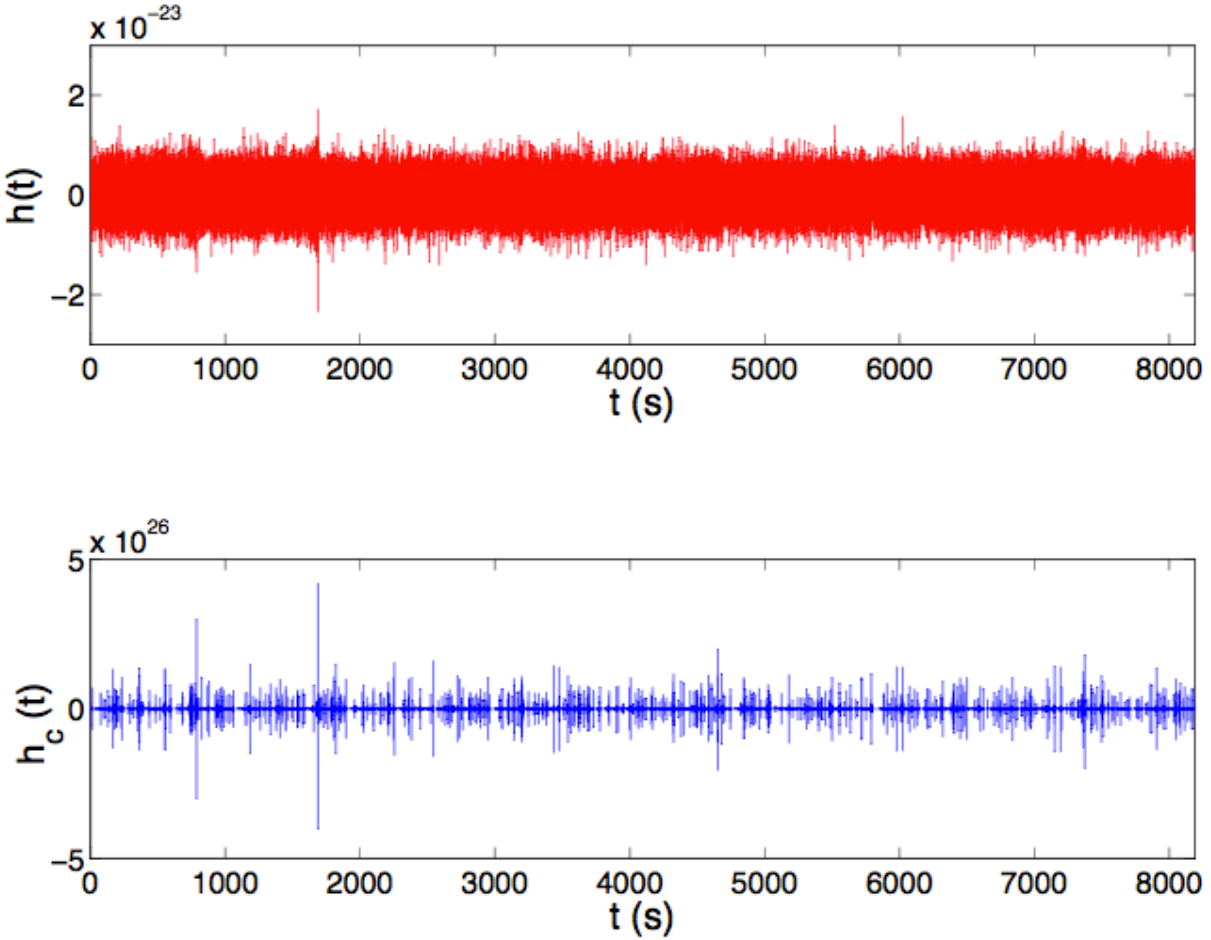
# Evolution with $z_{max}$



# Evolution with $f_L$



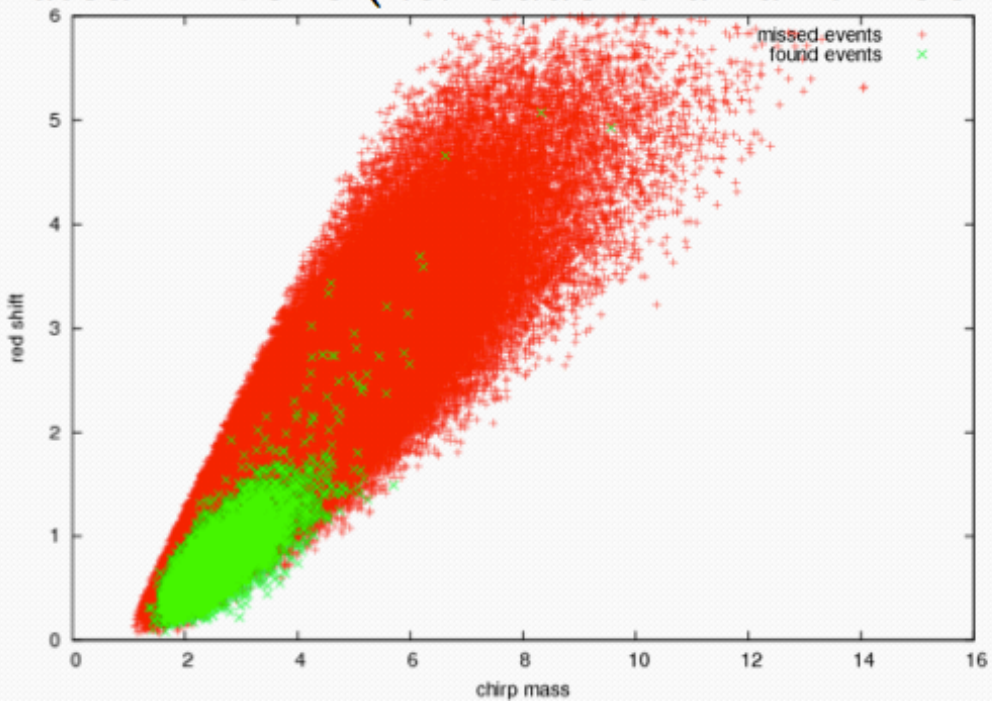
# Filter


x 10^−23
2
0
−2
h(t)
0
1000
2000
3000
4000
5000
6000
7000
8000
t (s)
x 10^26
5
0
−5
h_c (t)
0
1000
2000
3000
4000
5000
6000
7000
8000
t (s)

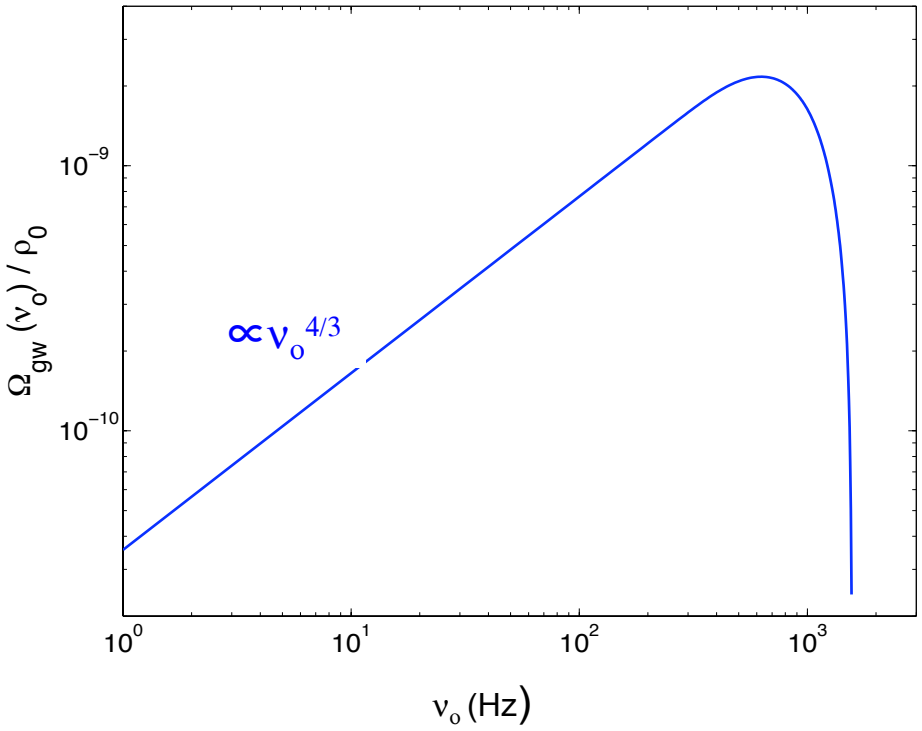
# CBC Analysis (Craig R.)

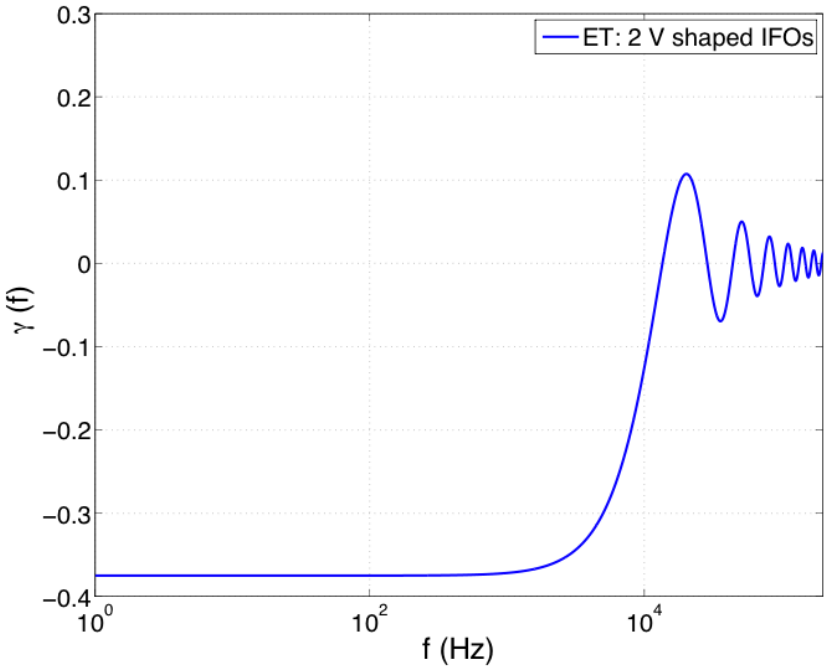
## Results

- The simulated ET data included 180062 injections
- We managed to find 4953 unique events with estimated FAR of 0 (i.e. louder than all time slides)



# Stochastic analysis




| | E1-E2 | E2-E3 | E1-E3 |
|---|---|---|---|
| $\Omega_{est}$ @100 Hz | 7.8 $10^{-10}$ | 8.4 $10^{-10}$ | 6.8 $10^{-10}$ |
| error | 6.5 $10^{-11}$ | 6.6 $10^{-11}$ | 6.6 $10^{-11}$ |

# Future Work

- extend to larger masses (NS-BH, BH-BH)
- … and to other source
- improve the model (distributions derived from binary evolution codes)
- generate data down to 1 Hz and for a year
- run data analysis
- test advanced DA methods

# Spectral Density