*LCGT*と他の検出器を用いた背景重力波探索の検討

19aSV-3

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Outline

(I) Overview of searches for isotropic

Stochastic Gravitational Wave Background(SGWB)

(II) Sensitivity of Network searches for isotropic SGWB

(III) Search for Anisotropic SGWB

Introduction

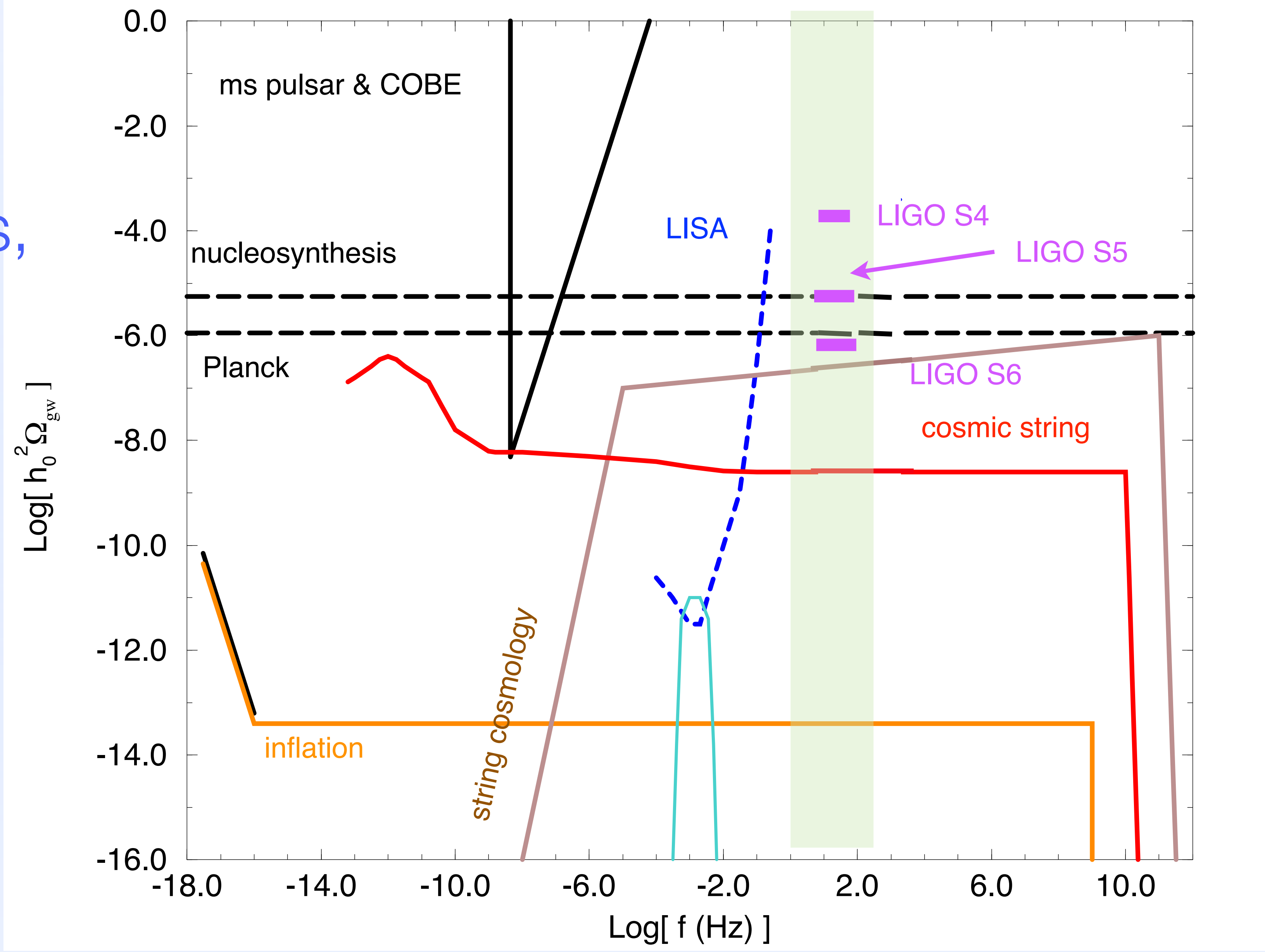
- SGWB

  superposition of weak, independent and unresolved GW sources.

- "Cosmological" sources include inflation, pre-big-bang, phase transitions, cosmic strings.

- "Astrophysical" sources include unresolved binaries, neutron star instabilities.

- The graph shows the observational constraints on SGWB.



M.Maggiore, gr-qc/0008027
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purple line is referd from

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- The intensity of SGWB is characterized by the dimensionless quantity,

$$\Omega_{gw}(f) \equiv \frac{1}{\rho_c}\frac{d\rho_{gw}}{d\log f}$$

where ρ_{gw} is energy density of gravitational radiation and ρ_c is critical energy density of the Universe.

↙ 2つの検出器のデータ

- Correlation $$S \equiv \int_{-T/2}^{T/2} dt \int_{-\infty}^{\infty} dt' s_1(t) s_2(t) Q(t-t')$$

Optimal filter
(SNRが最大になるようにとられる)

平均値 $\sigma^2 \equiv < S^2 > - < S >^2$

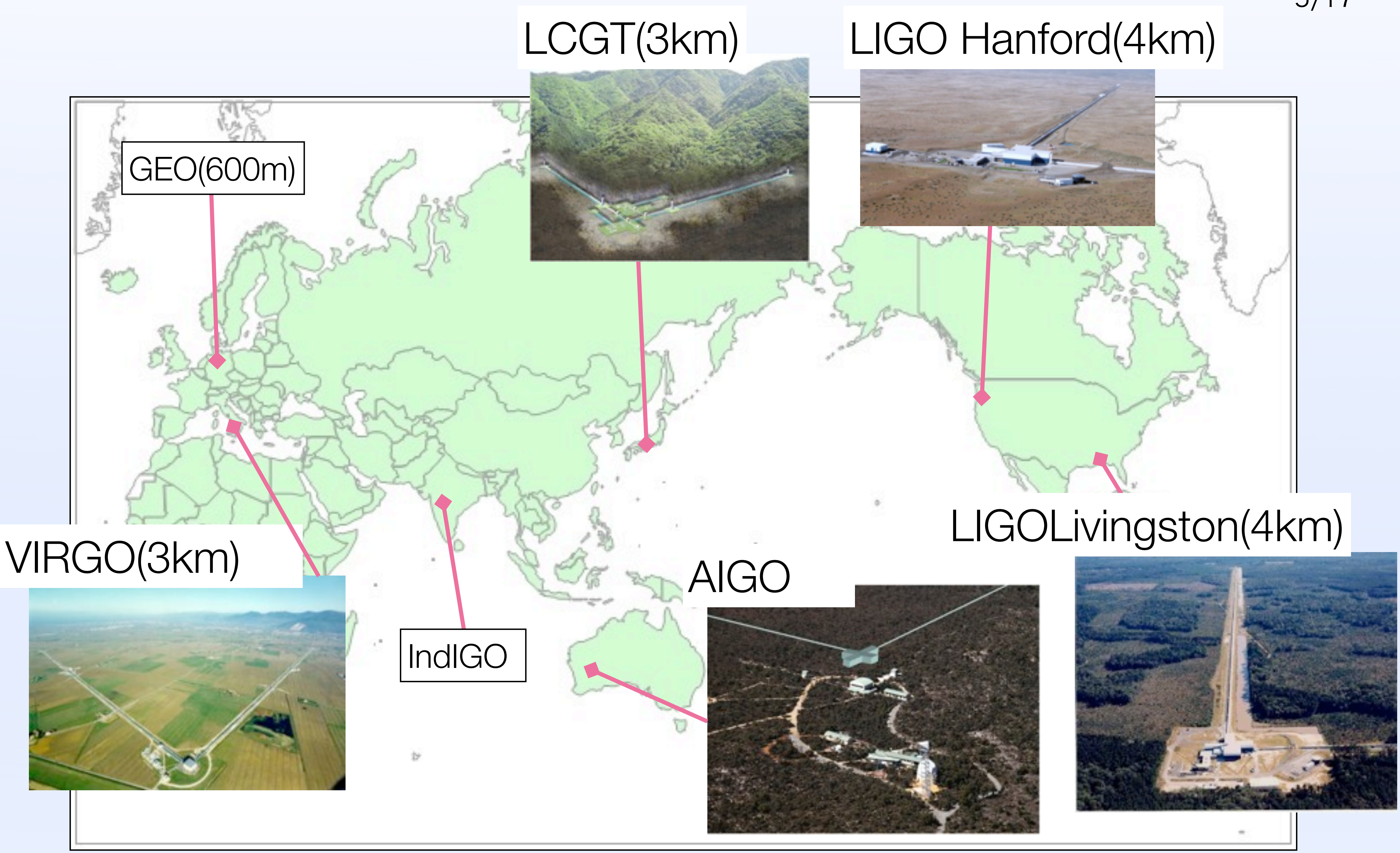
分散 $\mu \equiv < S >$

From this statistics, we can calculate

$$\mathrm{SNR} \equiv \frac{\mu}{\sigma}$$ and upper limit of $\Omega_{gw}(f)$

- We evaluate bounds expected with the network of detectors.

Detectors in the near future



Detectors in the near future

In the following paper, these 5 detectors is used.

Upgrade Planned and Noise of Detectors

Upgrade of Detectors is planned.

LIGO	->	aLIGO
VIRGO	->	Adv. VIRGO

h(f)[1/rtHz]

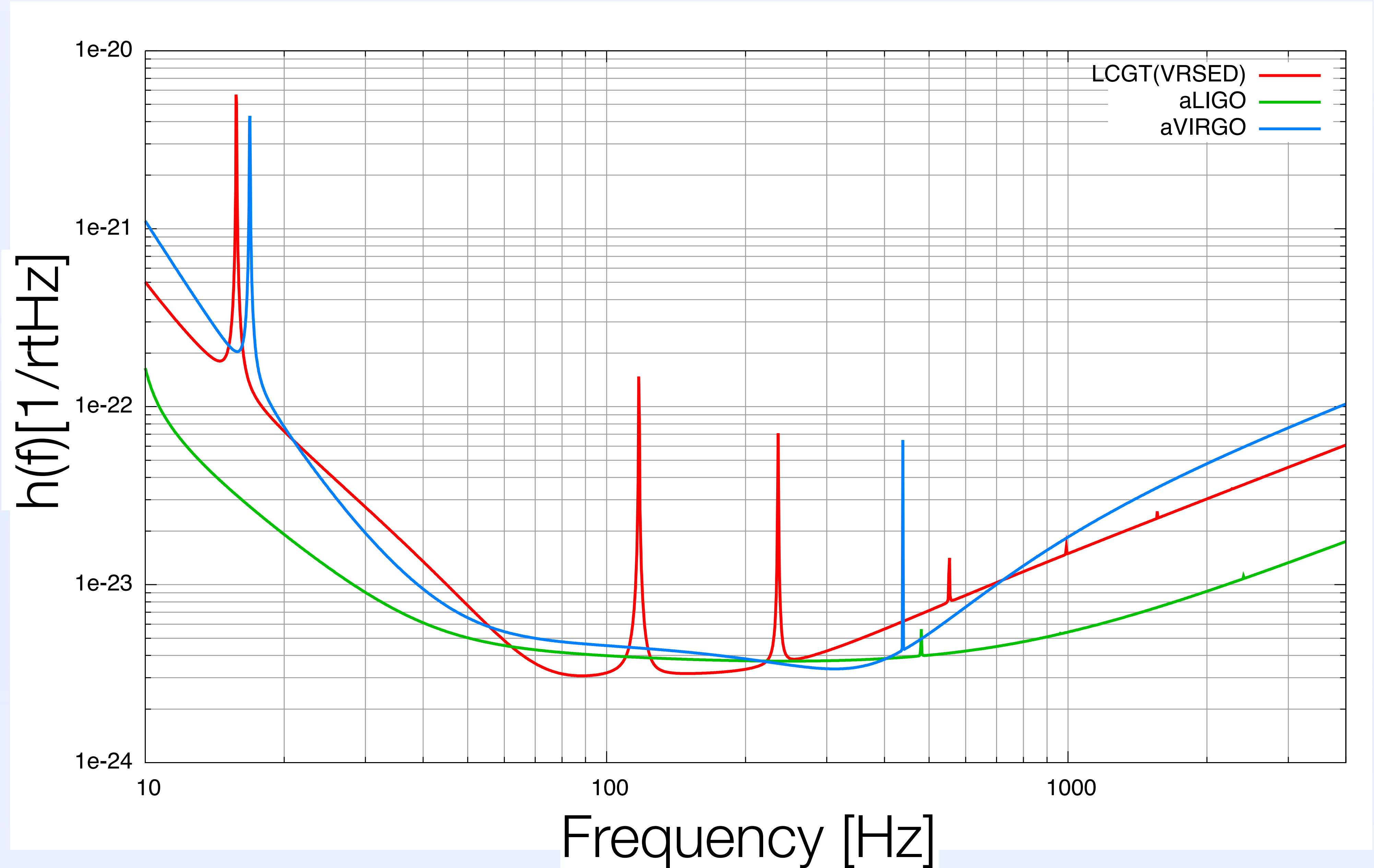
Frequency [Hz]

Upgrade Planned and Noise of Detectors

Upgrade of Detectors is planned.

LIGO	->	aLIGO
VIRGO	->	Adv. VIRGO

We assume that the noise of AIGO is same as aLIGO of noise.



Label and Locatioin of Detectors

In following paper, detectors are labeled.

	Label	location		
		Longitude	Latitude	Orientation
LCGT	J	137.30°E	36.42°N	75°
LIGO Livingston	L	90.77°W	30.56°N	242°
LIGO Hanford	H	119.41°W	46.4551°N	171°
VIRGO	V	10.50°E	43.63°N	115.6°
LIGO Australian	A	115.71°E	31.36°S	45°

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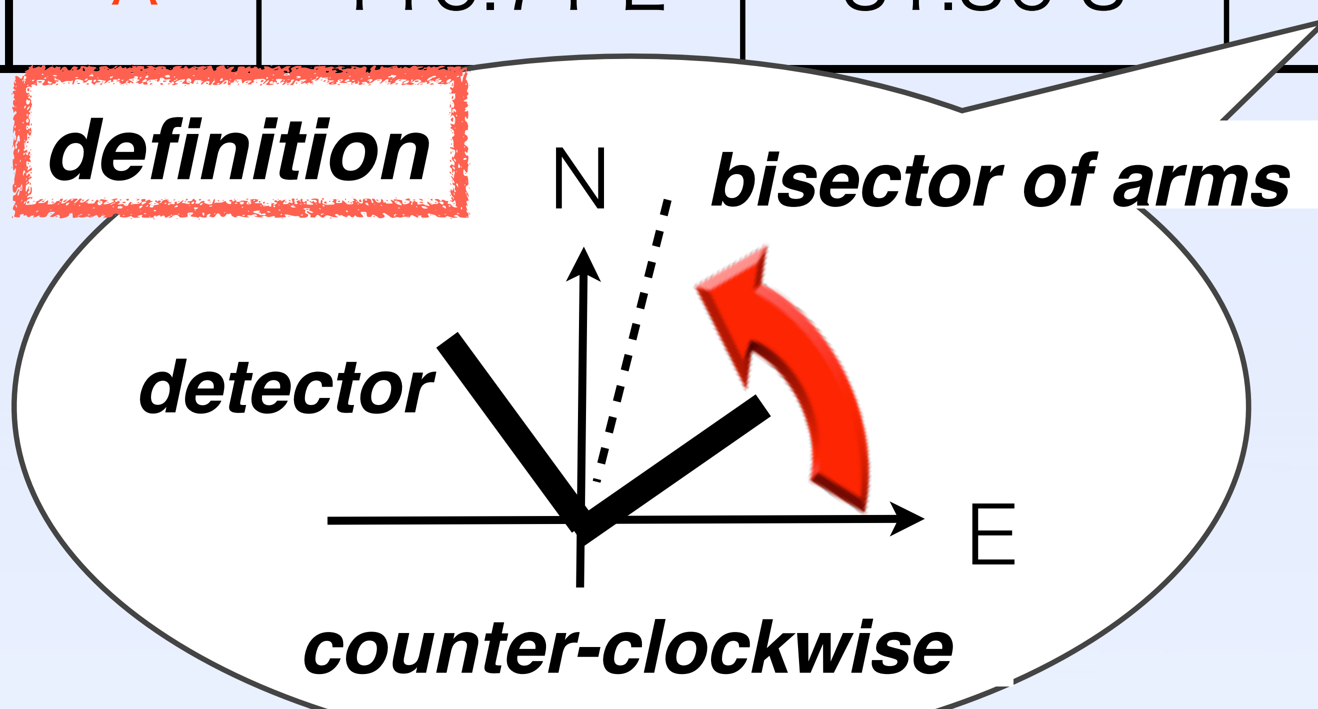


Overlap Reduction Function(1)

$$\gamma(f) = \frac{5}{8\pi} \sum_A \int_{S^2} d\hat{\Omega}\; e^{i2\pi f \hat{\Omega}\cdot\Delta\vec{x}/c} F_1^A F_2^A$$ [Bruce Allen et al,1999]

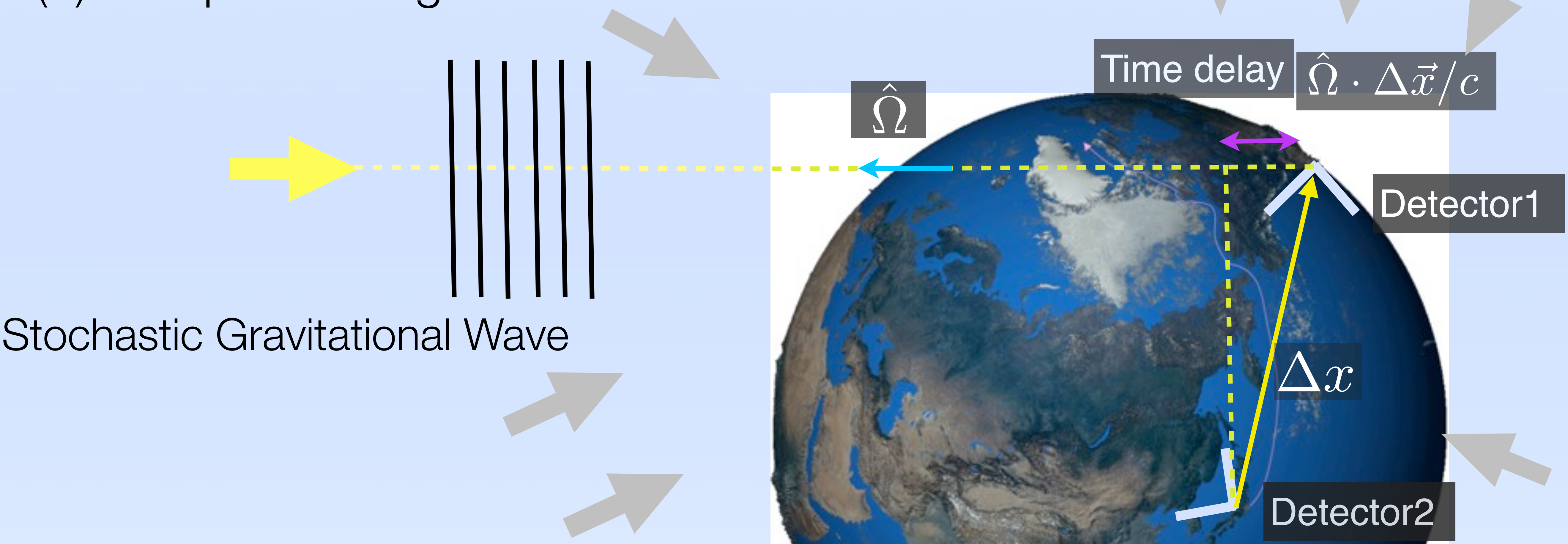
$F_i^A(\hat{\Omega})$ is the response of *i*-th(i=1,2) to the A = +,× polarization.

$\hat{\Omega}$ is a unit vector specifying a direction.

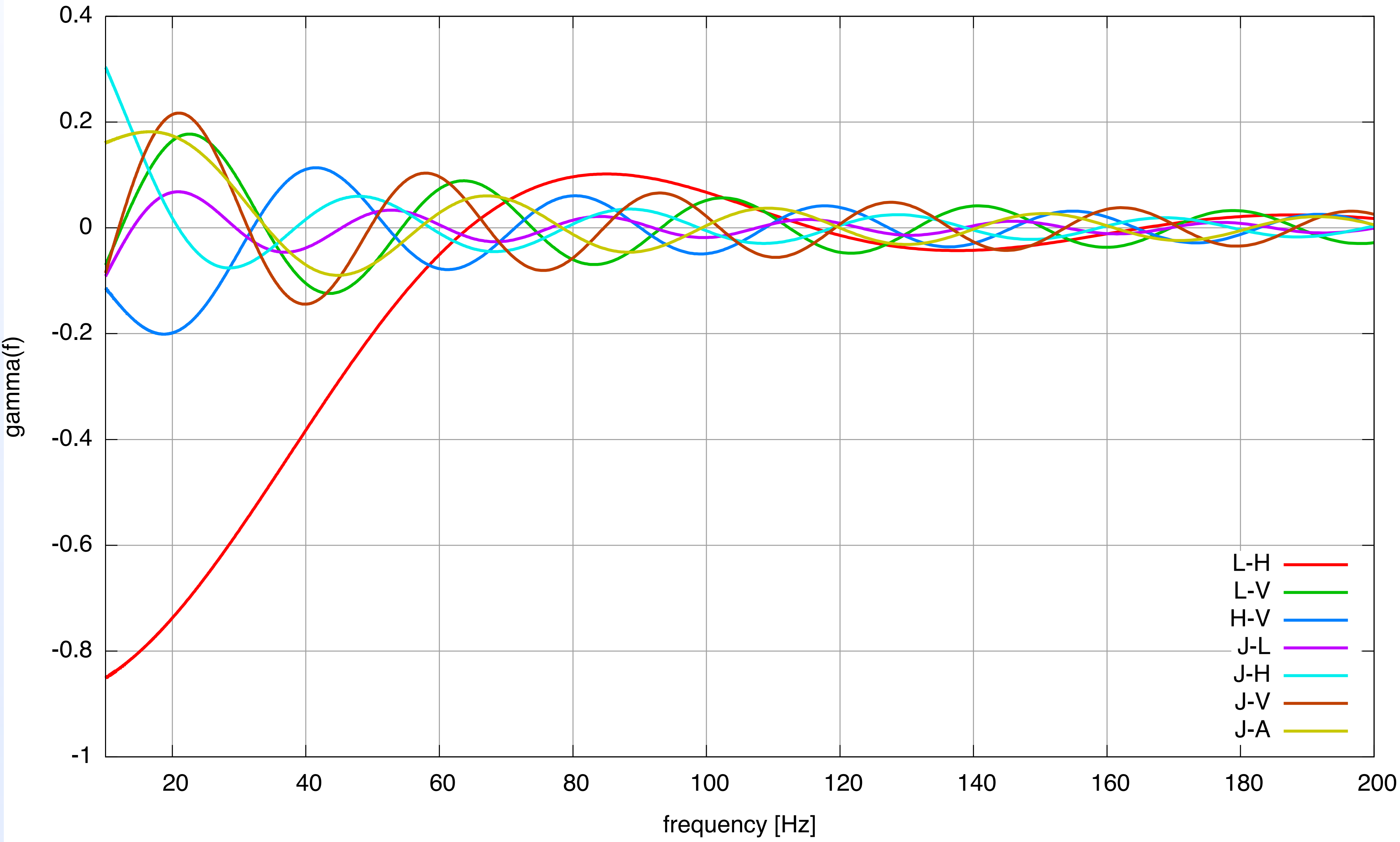
This function quantifies two effects:

(1) separation time delay between two detectors,

(2) non-parallel alignment of the detector arms.



Overlap Reduction Function(2)



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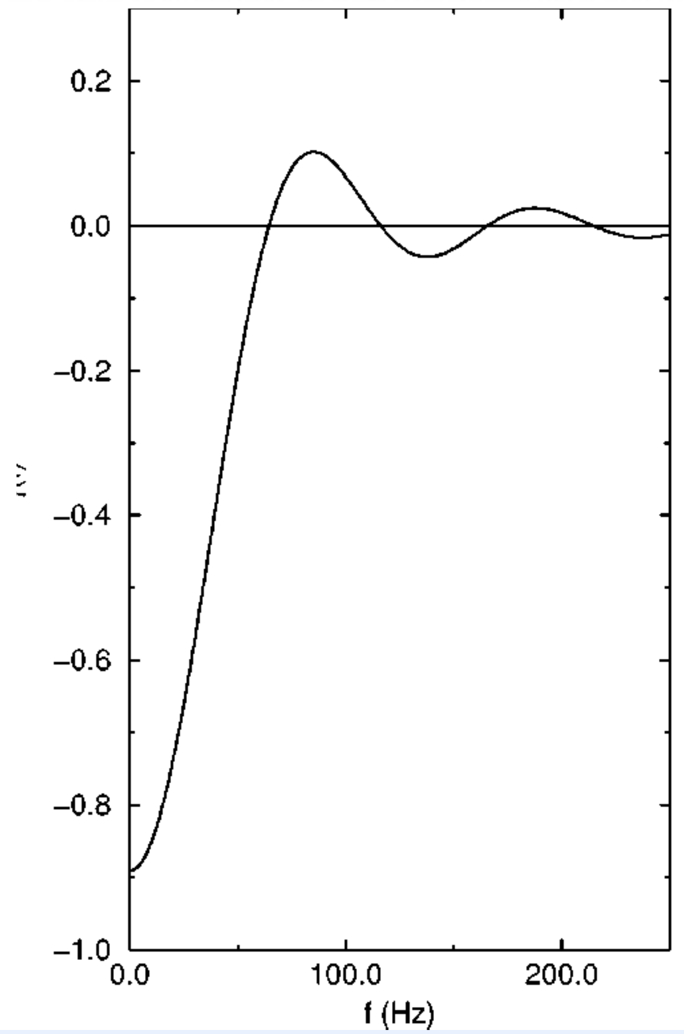


Pair of closer detectors (two LIGO) drops off fast at high frequency.
Pair of far detectors keeps at high frequency.

Correlation and Upper Limit Expected

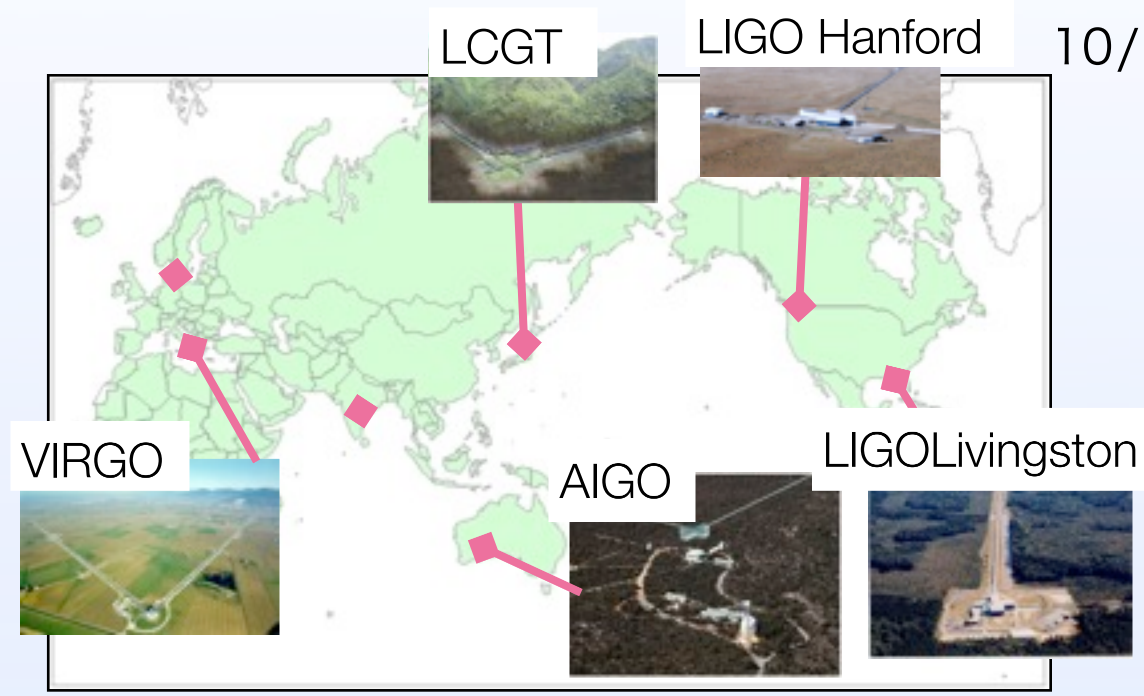
5 Detectors (L, H, V, J, A)

↓

(1) Take correlation between 2 detectors

↓

(2) Network of detectors



$$\Omega_{gw}(f) \geq \frac{1}{\sqrt{T_{tot}}} \frac{10\pi^2}{3H_0^2} \left[\frac{\gamma^2(f)}{f^6 P_1(f) P_2(f)}\right]^{-1/2} \times \sqrt{2}[\mathrm{erfc}^{-1}(2\alpha) - \mathrm{erfc}^{-1}(2\gamma)]$$

[Bruce Allen et al,1999]

where

H_0 is a Hubble constant.

$\gamma(f)$ is overlap reduction function.

$P_i(f)$ is the noise power spectra.

α is a false alarm rate.

γ is a desired detection rate. (not overlap reduction function)

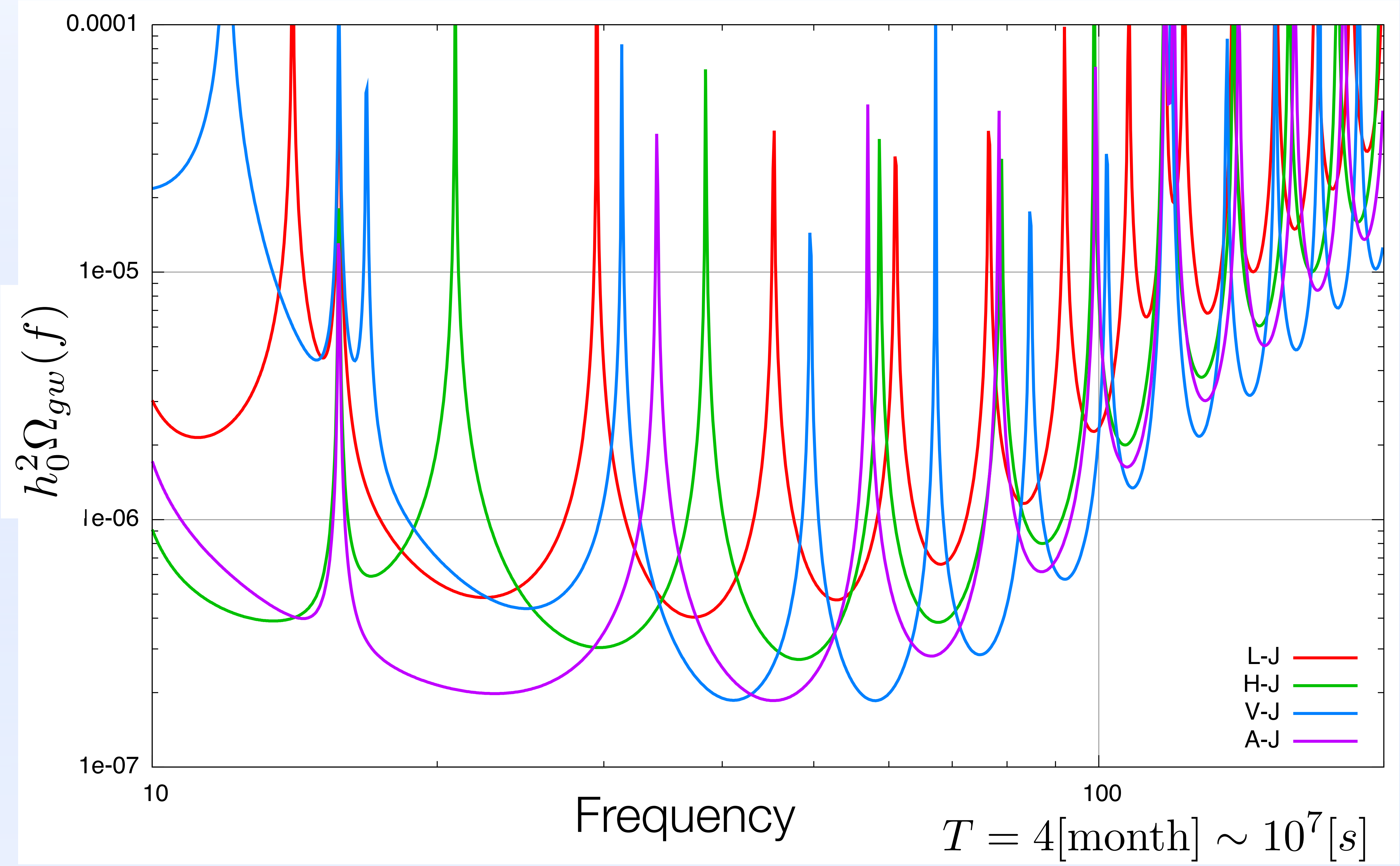
Here, we fix α=5% and γ=95%.

From these relation, calculate $h_0^2 \Omega_{gw}^{95\%,5\%}(f)$, upper limit expected.

Calculation of Upper Limit

Upper limit of $h_0^2\Omega_{gw}(f)$ between LCGT and other detectors.

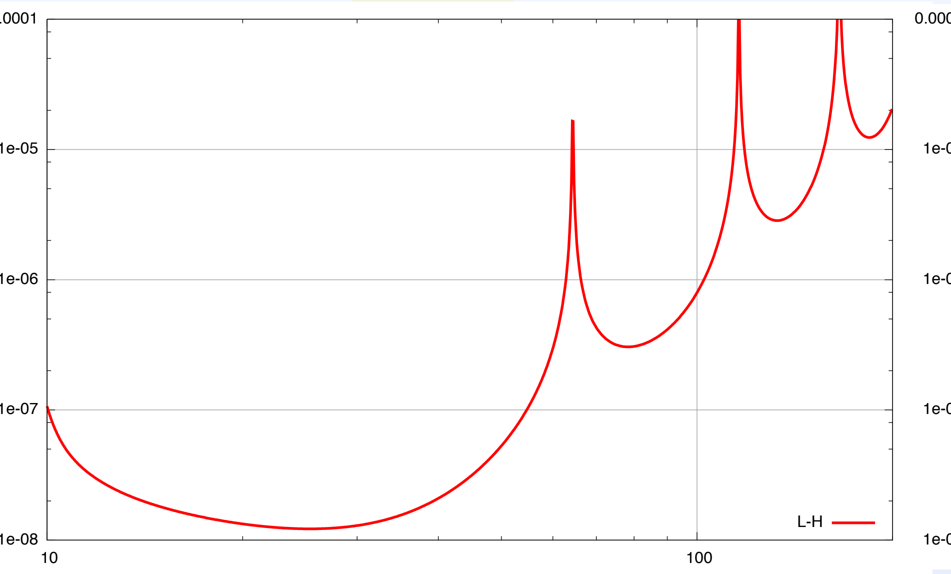
The peak has bad sensitivity.



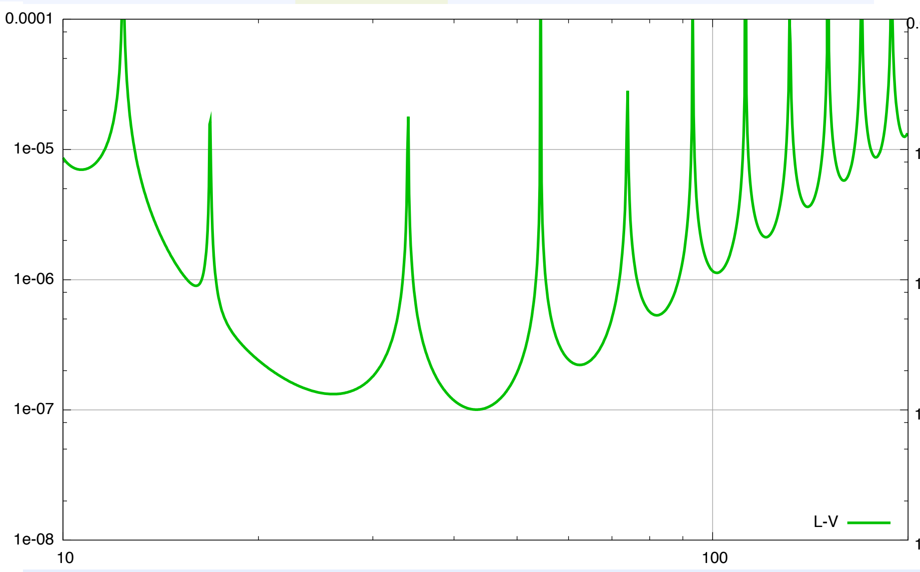
Network to Increase Sensitivity

In case of L-H-V, $T = 4[\mathrm{month}] \sim 10^7[s]$

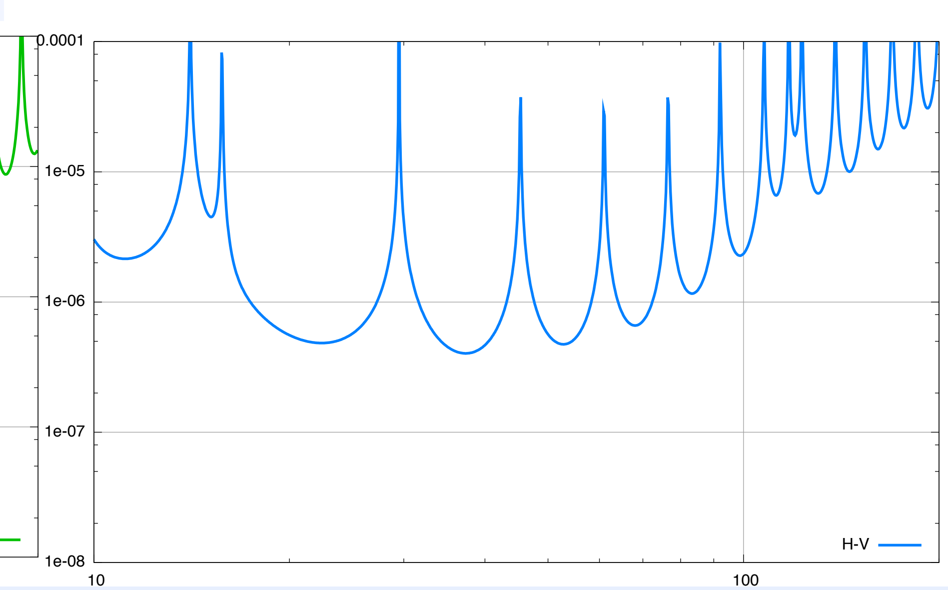
L-H



L-V



H-V



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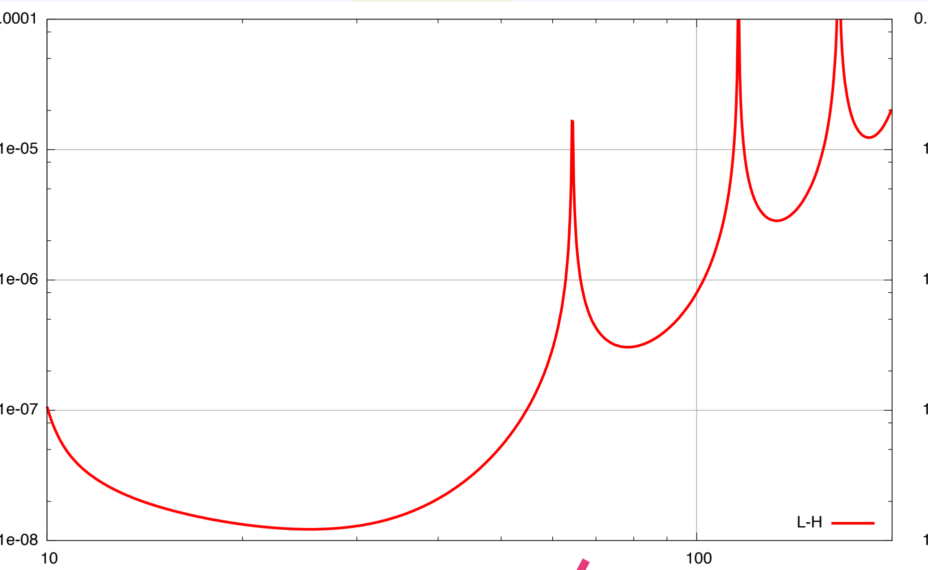
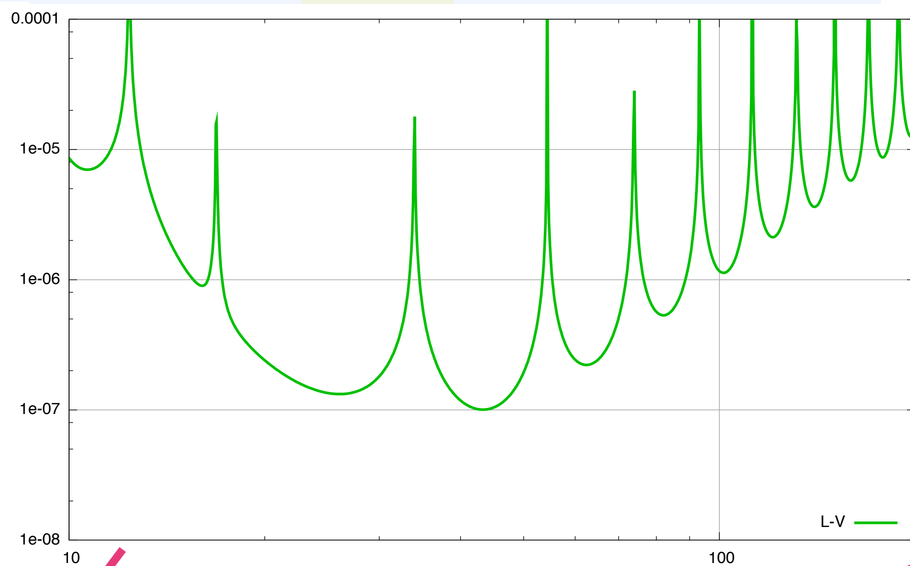
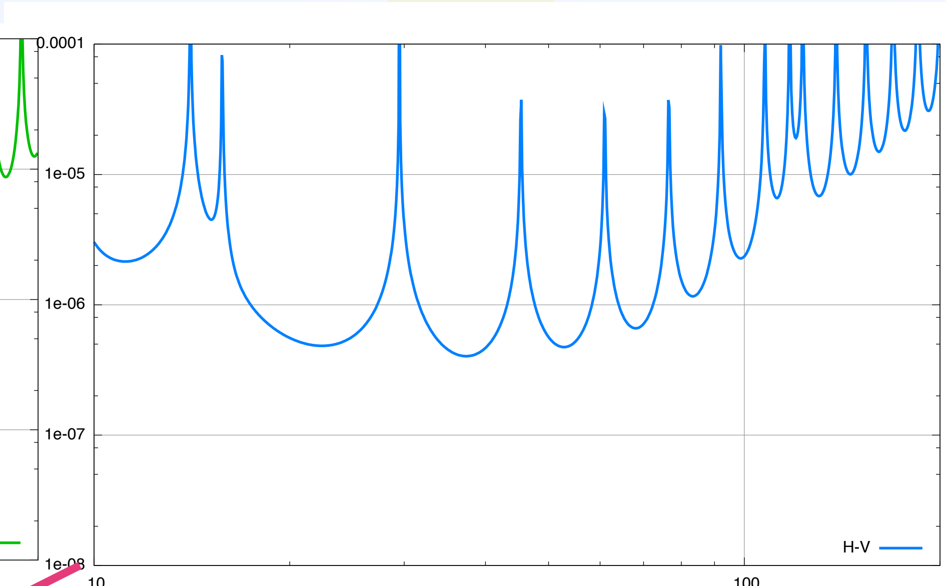
L-H



L-V



H-V



$$\frac{1}{(h_0^2\Omega_{gw})^2} = \frac{1}{(h_0^2\Omega_{12})^2} + \frac{1}{(h_0^2\Omega_{13})^2} + \frac{1}{(h_0^2\Omega_{14})^2}$$

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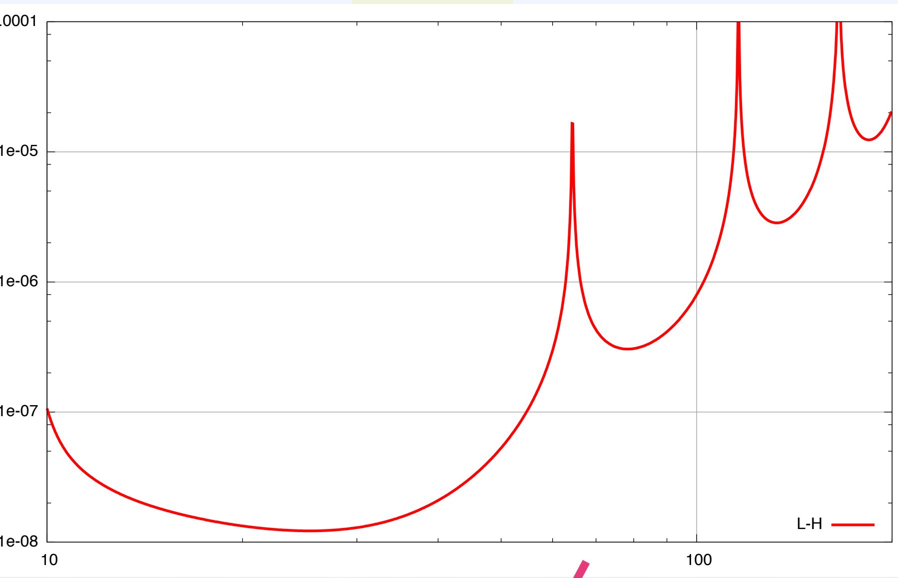
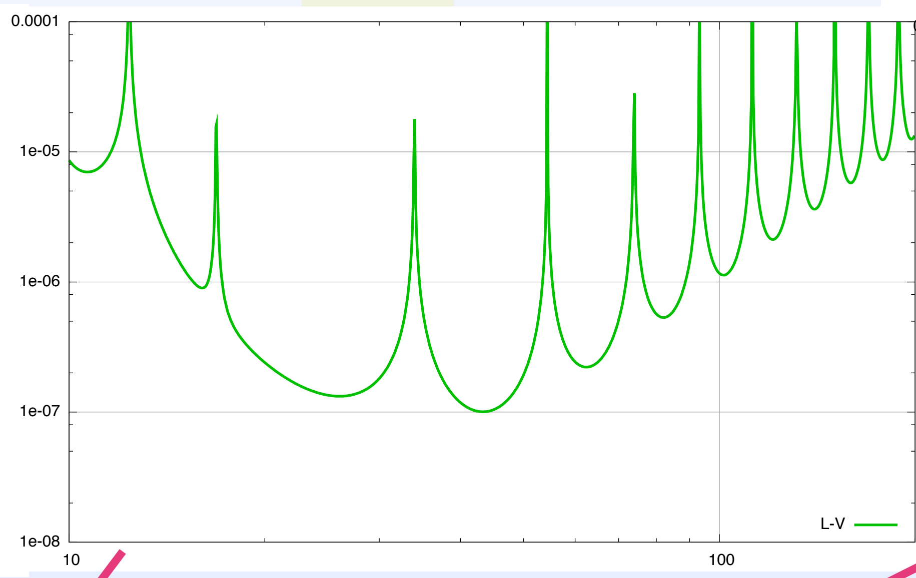
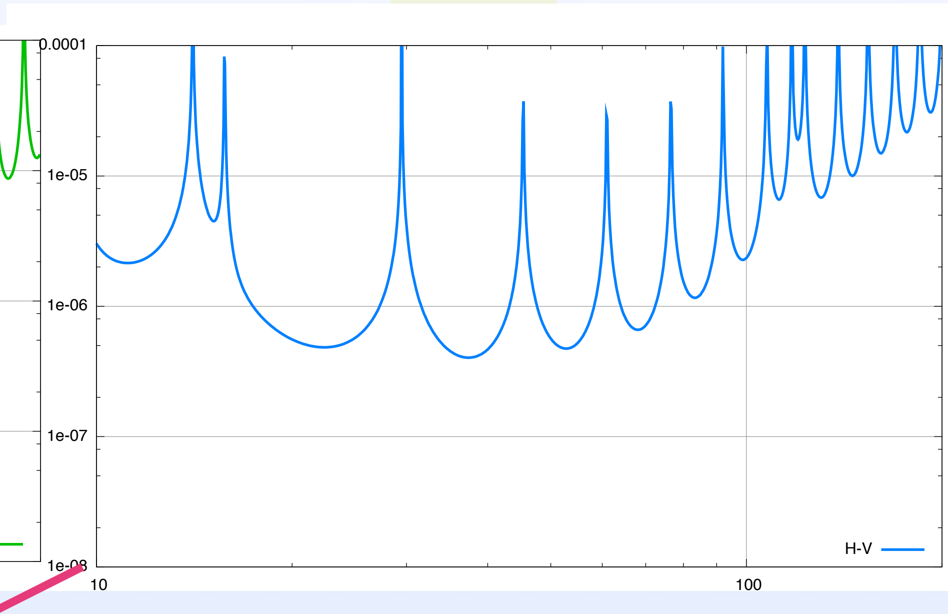


L-V



H-V



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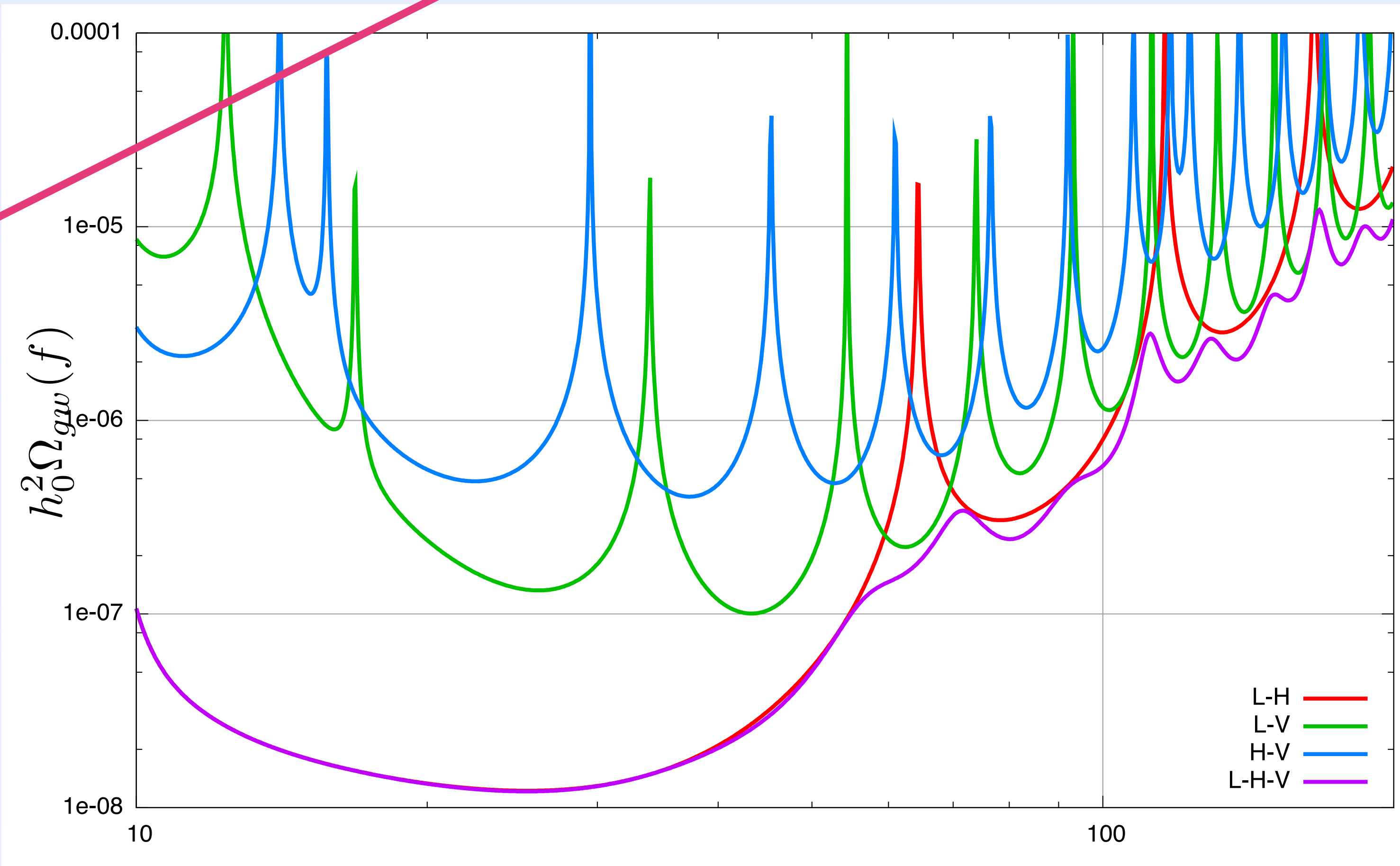
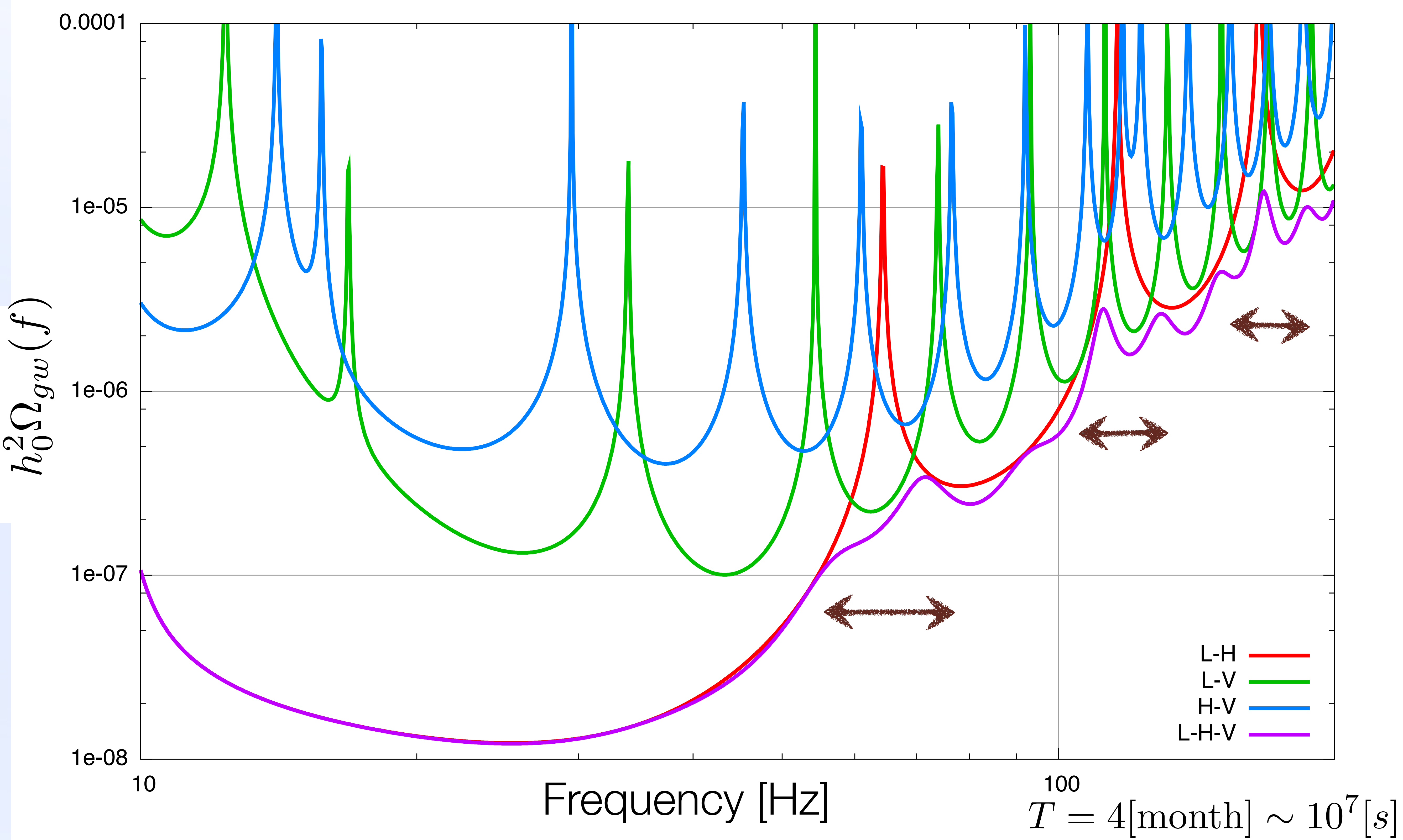
Taking combination will increase upper limit.



Merit of Network

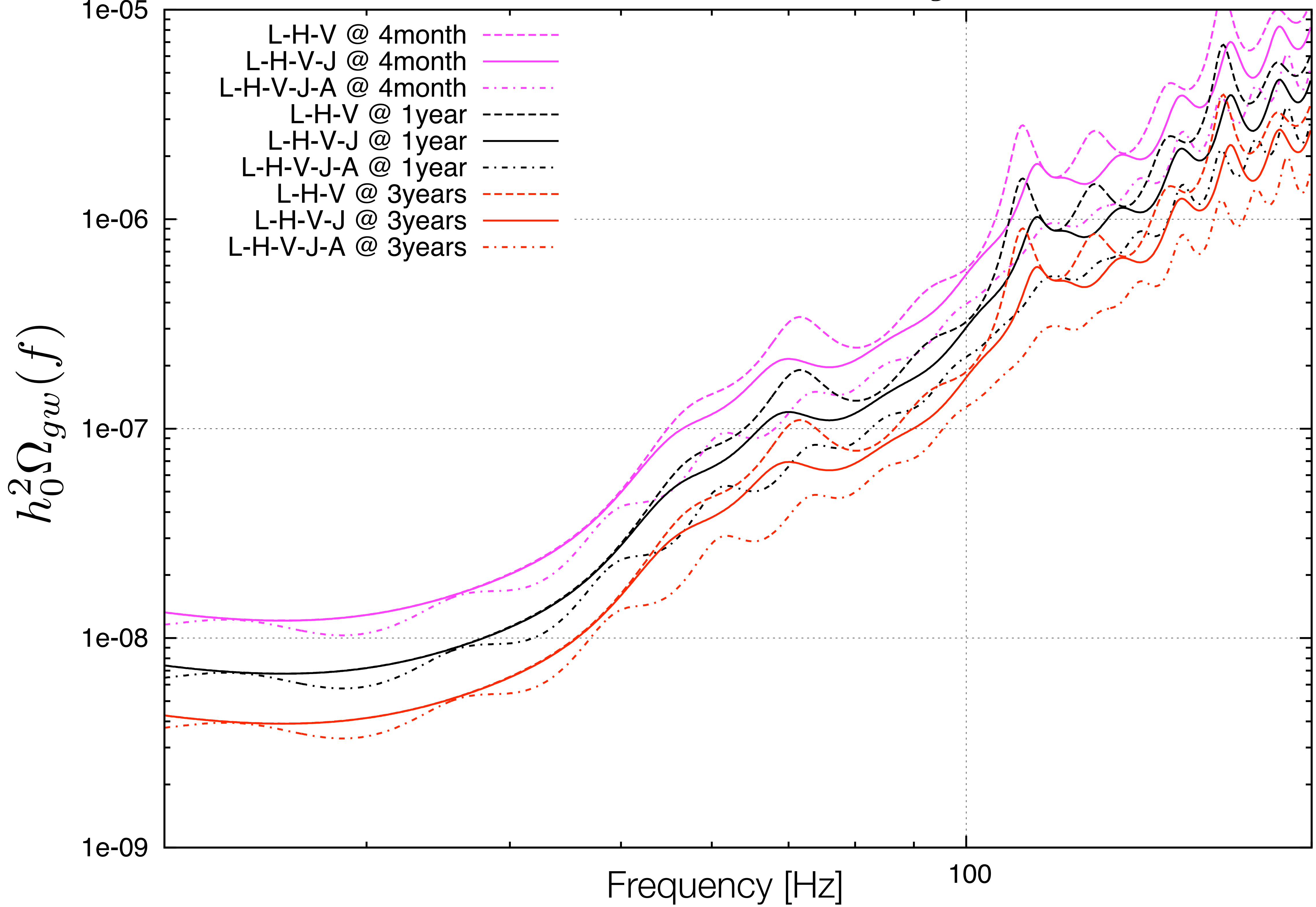
Network covers loss sensitivity of other detectors pair. (Brown arrow)



Combination of 5 detectors

Take combination of L-H-V-J-A for 4month / 1year / 3years

LCGT raise upper limit totally. $\Omega_{gw} \sim 10^{-8} - 10^{-9}$



Cosmological landscape

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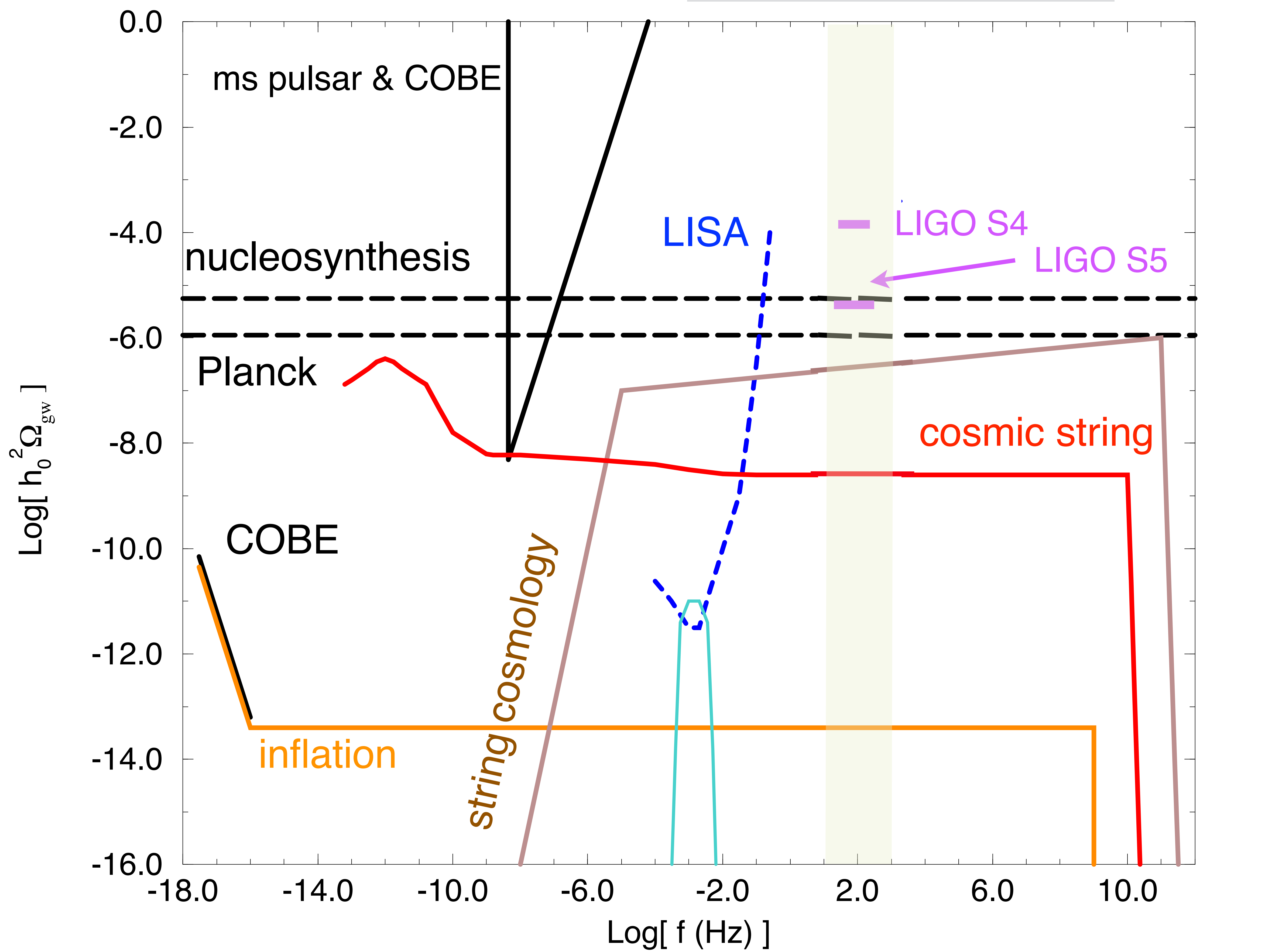

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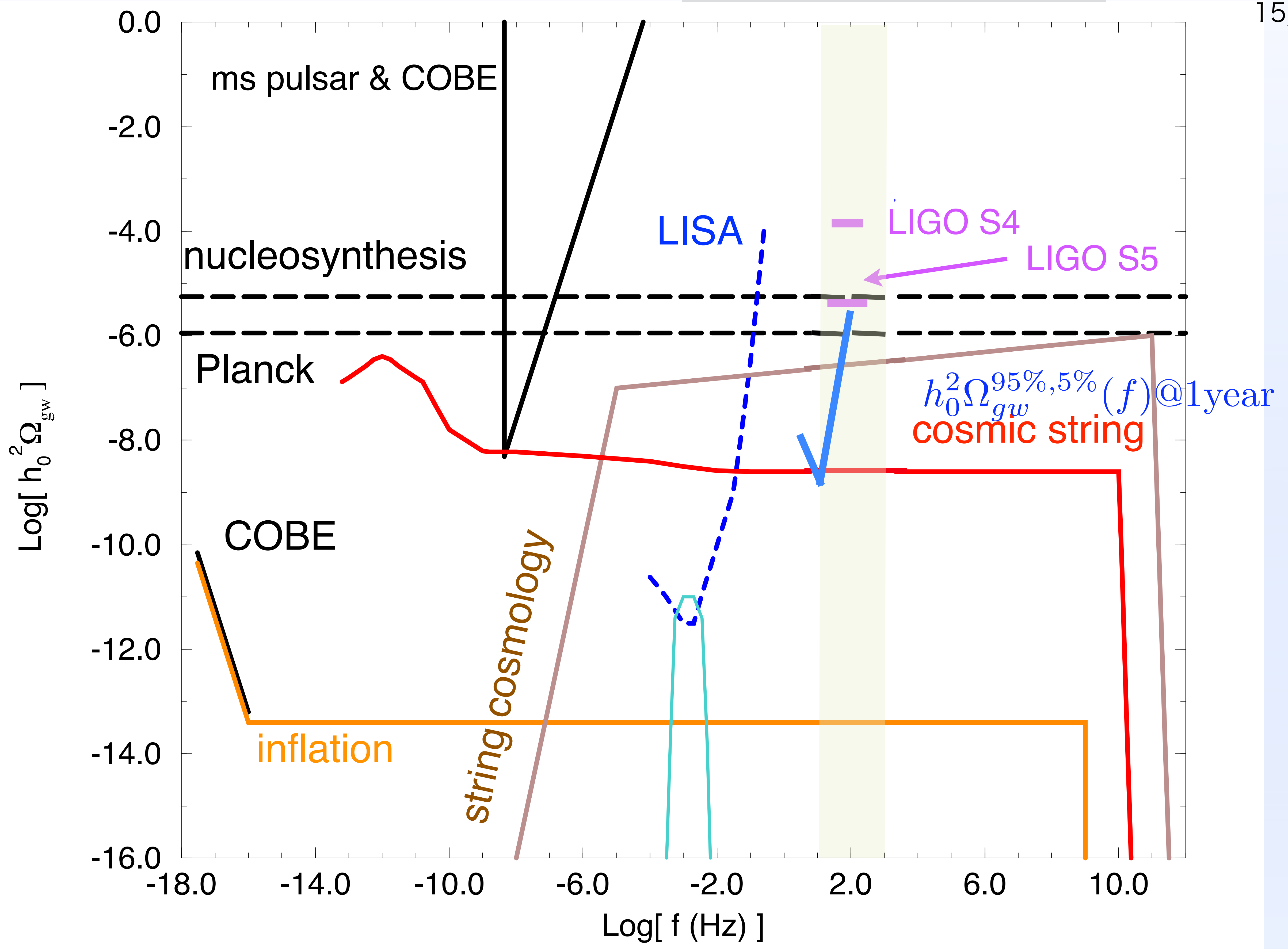

Anisotropic SGWB

Anisotropic SGWB has the different intensity by the direction.
It is expressed by $\mathcal{P}(\hat{\Omega})$, angular distribution function.

Spherical harmonic decomposition

$$\mathcal{P}(\hat{\Omega}) \equiv \sum_{lm} p_{lm} Y_{lm}(\hat{\Omega})$$

[Bruce Allen et al.1997]

$Y_{lm}(\hat{\Omega})$: Spherical harmonics function

p_{lm} : multipole moment

Anisotropic SGWB needs different way to evaluate overlap reduction function, SNR and $\Omega_{gw}(f)$ with spherical harmonic.

Summary

- We estimate the upper limit $h_0^2\Omega_{gw}(f)$ for isotropic SGWB by the correlation between two detectors and the network of detectors.

- We might detect SGWB from Cosmic String.

Future

- We evaluate the upper limit expected for anisotropic SGWB.

- We acquire how to analysis for SGWB.