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USING LISA AND ET TO EXPLORE COSMOLOGICAL GW BACKGROUNDS

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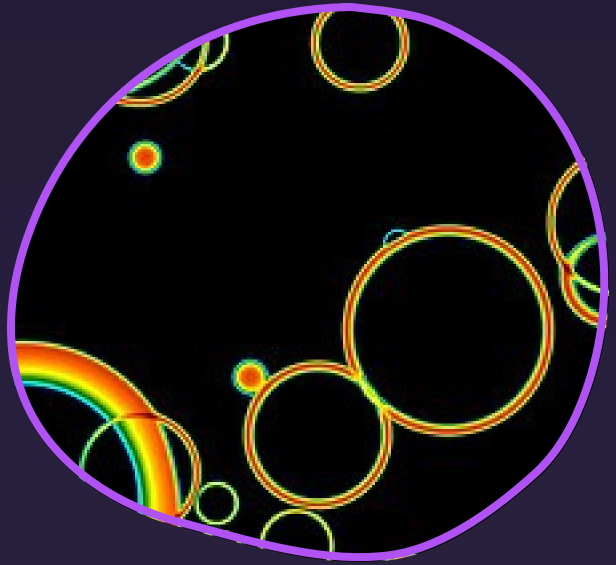
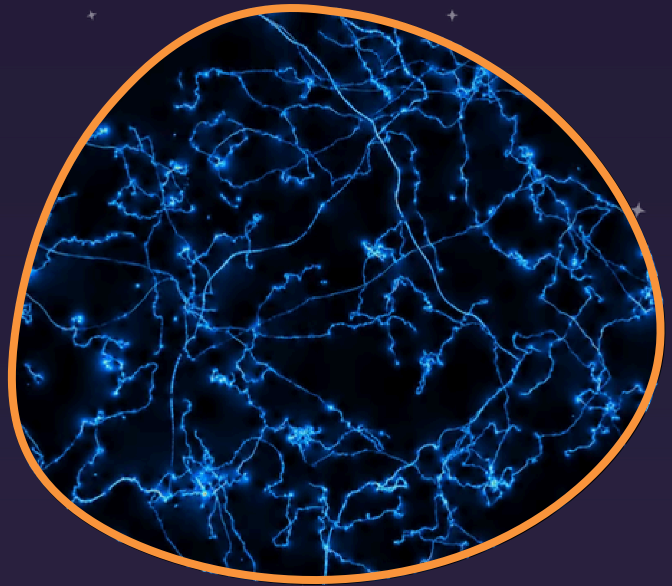
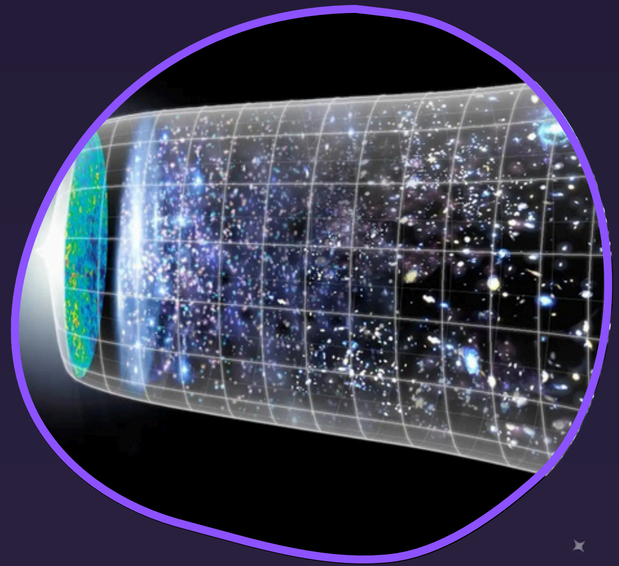
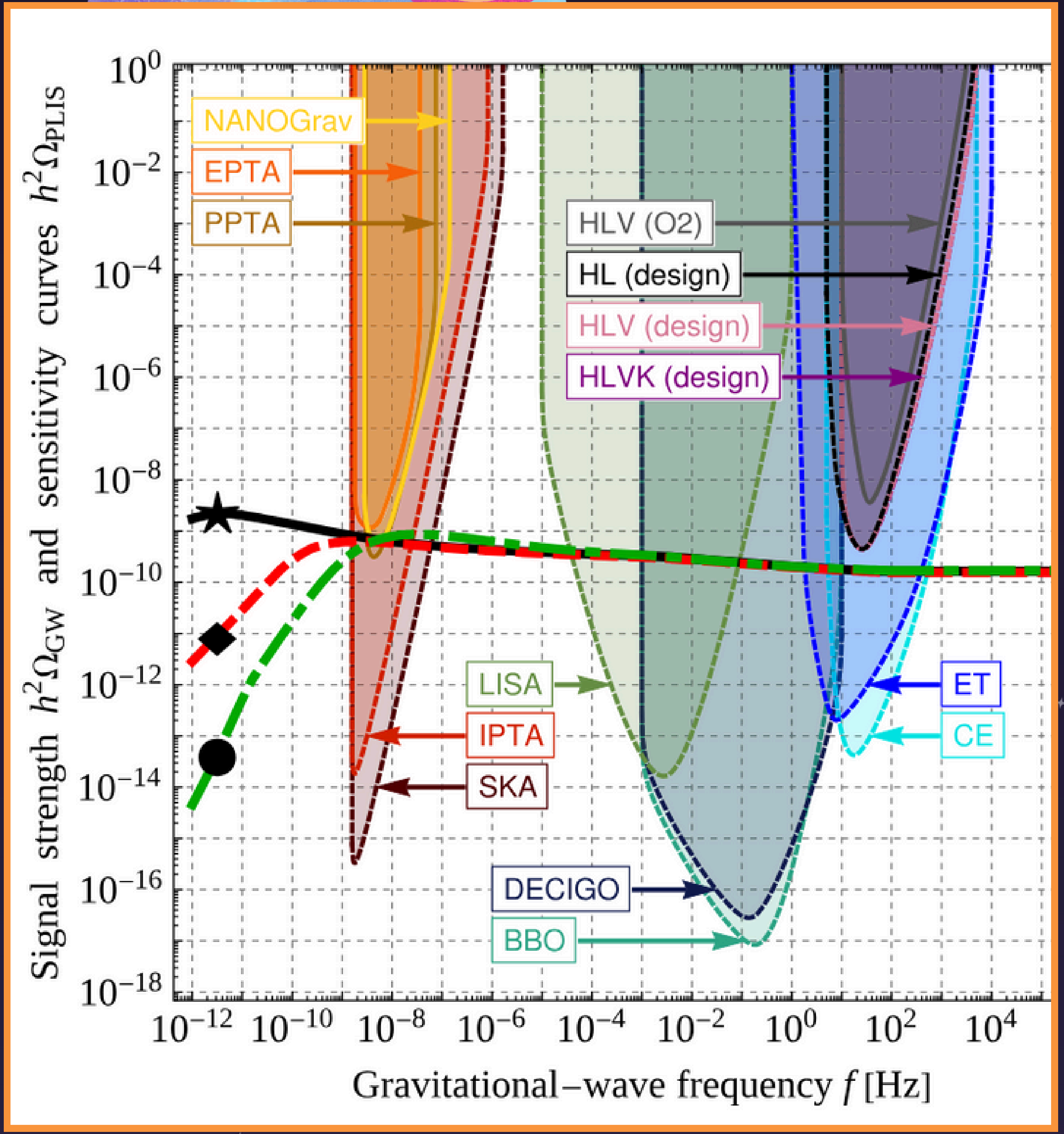
MOTIVATIONS

- We focus on early universe cosmological sources.
- These sources give signals in the LISA-ET band.
- We aim to measure all parameters with 10% accuracy
- Exploiting synergies allows us to probe frequencies in the range $$10^{-5} < f < 10^{2}$$



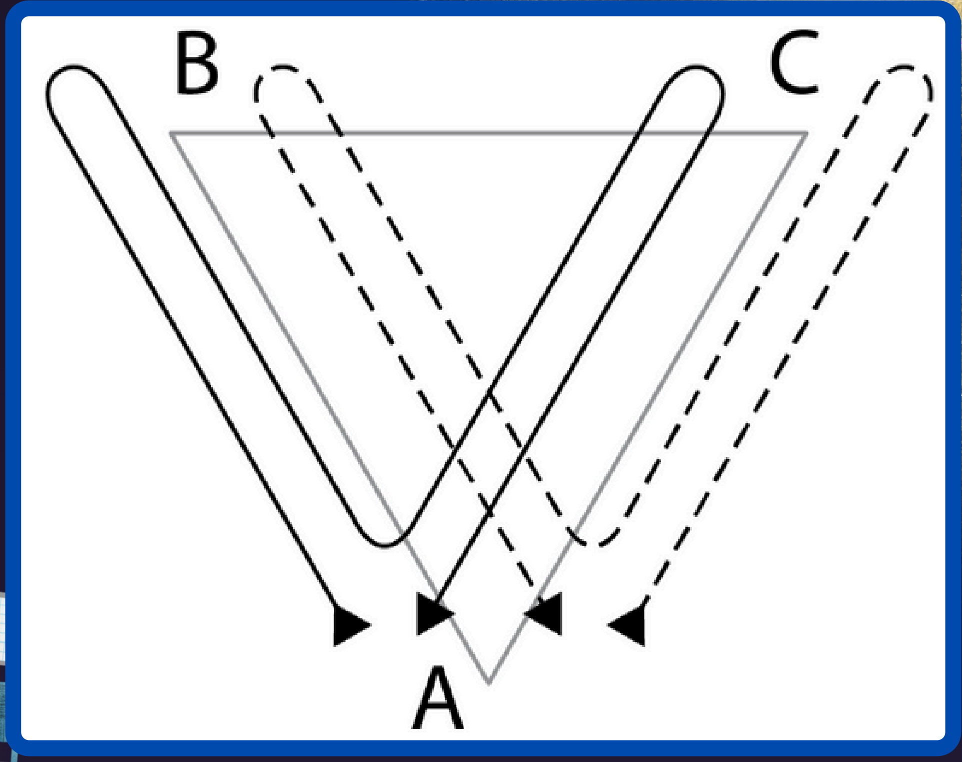






GRAPH FROM: 2009.06607

SYNERGIES BETWEEN THE TWO EXPERIMENTS



Phase difference at vertex A

$$\Phi_{A_{BC}} = \Delta\varphi_{A_{BC}} + n_{A_{BC}}$$

Two point function of the signal

$$\langle \Phi_{a_{bc}}(f)\Phi_{x_{yz}}(f')\rangle = \frac{\delta(f-f')}{2}\left[R_{a_{bc},\,x_{yz}}(f)\,I(f) + N_{a_{bc},\,x_{yz}}(f)\right]$$

$$\begin{pmatrix} C_1 & C_2 & C_2 & 0 & 0 & 0 \\ C_2 & C_1 & C_2 & 0 & 0 & 0 \\ C_2 & C_2 & C_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & C_3 & C_4 & C_4 \\ 0 & 0 & 0 & C_4 & C_3 & C_4 \\ 0 & 0 & 0 & C_4 & C_4 & C_3 \end{pmatrix}$$

Eigenmodes

Assumptions:

- No noise correlation between detectors
- No contaminations between detectors

Triangle config: 1908.00546

SNR

We're able to show that the signal-to-noise ratio for both interferometers is

$$\sum_{i=A^{\ell,e},E^{\ell,e}} \frac{S_i^2(f)}{N_i^2(f)} = \left[\left(\frac{R_{A^\ell}(f)}{N_{A^\ell}(f)}\right)^2 + \left(\frac{R_{E^\ell}(f)}{N_{E^\ell}(f)}\right)^2\right] I^2(f) + \left[\left(\frac{R_{A^e}(f)}{N_{A^e}(f)}\right)^2 + \left(\frac{R_{E^e}(f)}{N_{E^e}(f)}\right)^2\right] I^2(f)$$

Using

$$\Omega_{\mathrm{GW}}(f) = \left(\frac{4\pi^2}{3\,H_0^2}\right) f^3 I(f)$$

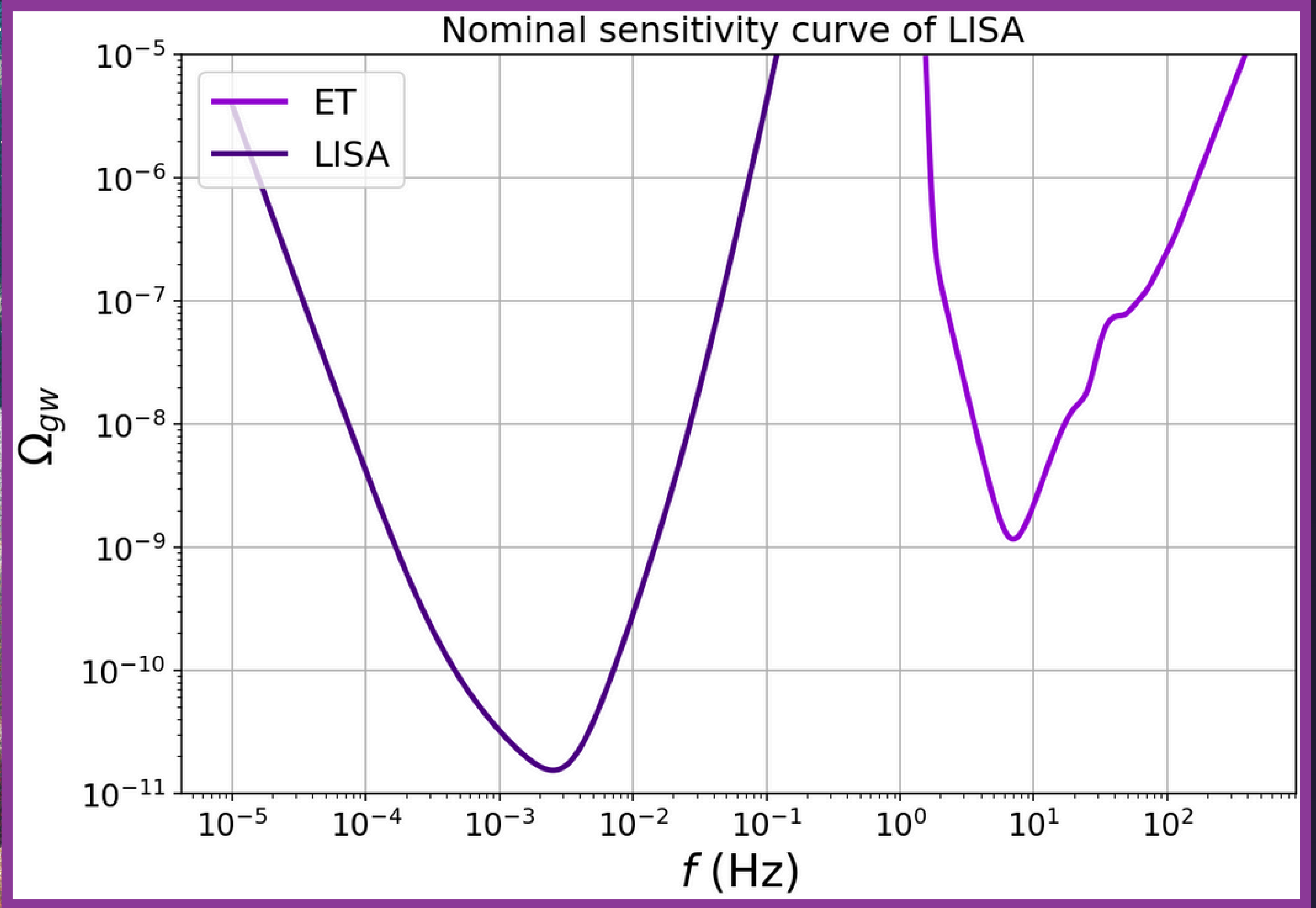
We can rewrite the SNR as

$$\mathrm{SNR}^2_{\mathrm{tot}} = \sum_{i=A^{\ell,e},E^{\ell,e}} \frac{S_i^2(f)}{N_i^2(f)} = \frac{\Omega^2_{\mathrm{GW}}(f)}{\Sigma^2_{\mathrm{LISA}}(f)} + \frac{\Omega^2_{\mathrm{GW}}(f)}{\Sigma^2_{\mathrm{ET}}(f)}$$

SNR

Where

$$\Sigma_{\mathrm{LISA}}(f) = \left(\frac{4\pi^2}{3\,H_0^2}\right) f^3 \left[\left(\frac{R_{A^\ell}(f)}{N_{A^\ell}(f)}\right)^2 + \left(\frac{R_{E^\ell}(f)}{N_{E^\ell}(f)}\right)^2\right]^{-1/2}$$



The key relation for our work is the SNR for the combined experiments:

$$\mathrm{SNR_{tot}} = \sqrt{T\int_0^\infty df\left[\frac{\Omega^2_{\mathrm{GW}}(f)}{\Sigma^2_{\mathrm{LISA}}(f)} + \frac{\Omega^2_{\mathrm{GW}}(f)}{\Sigma^2_{\mathrm{ET}}(f)}\right]} = \sqrt{\mathrm{SNR}^2_{\mathrm{LISA}} + \mathrm{SNR}^2_{\mathrm{ET}}}$$

$$\mathrm{SNR}_{\mathrm{tot}} = \sqrt{T \int_0^\infty df \left[\frac{\Omega^2_{\mathrm{GW}}(f)}{\Sigma^2_{\mathrm{LISA}}(f)} + \frac{\Omega^2_{\mathrm{GW}}(f)}{\Sigma^2_{\mathrm{ET}}(f)} \right]} = \sqrt{\mathrm{SNR}^2_{\mathrm{LISA}} + \mathrm{SNR}^2_{\mathrm{ET}}}$$

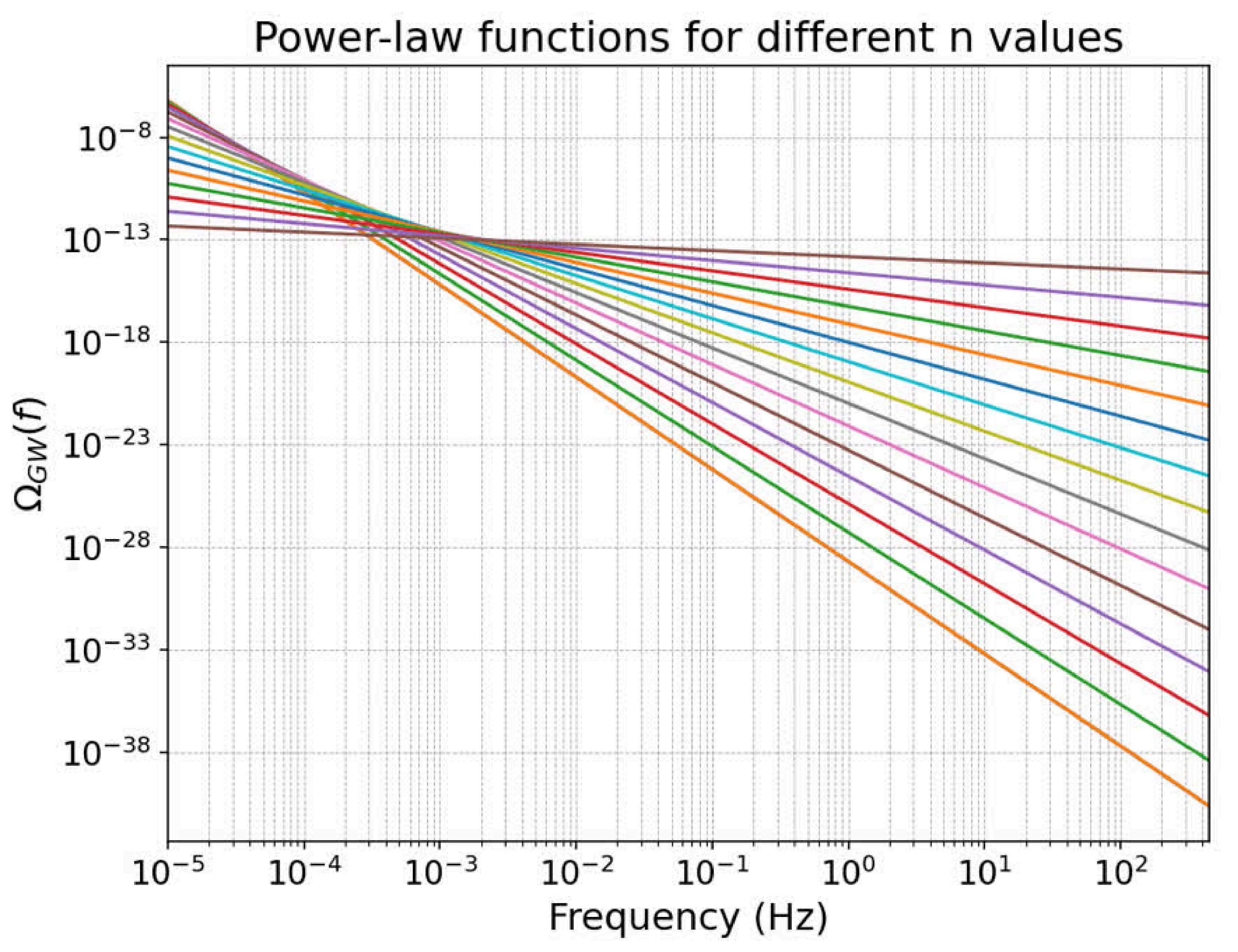
INTEGRATED SENSITIVITY CURVE

1. Substitute in the profile for the cosmological source: Ω_{GW}
2. Use time as (years): $\mathrm{T} = 3$
3. Choose desired SNR: $\mathrm{SNR} = 5$
4. Work backwards to find: $\Omega_\star$

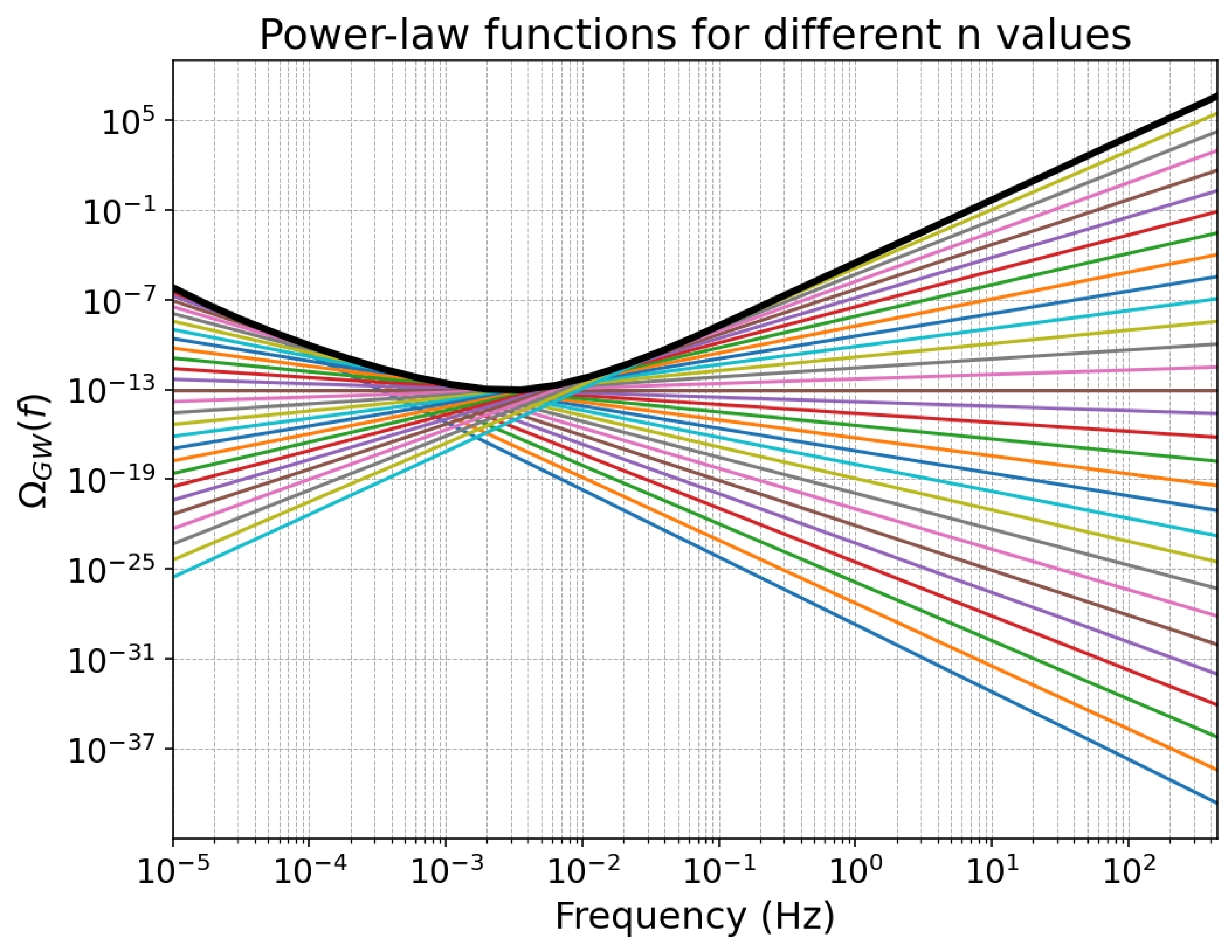
In this example we use

$$\Omega_{\mathrm{GW}} = \Omega_\star (f/f_\star)^n$$

INTEGRATED SENSITIVITY CURVE

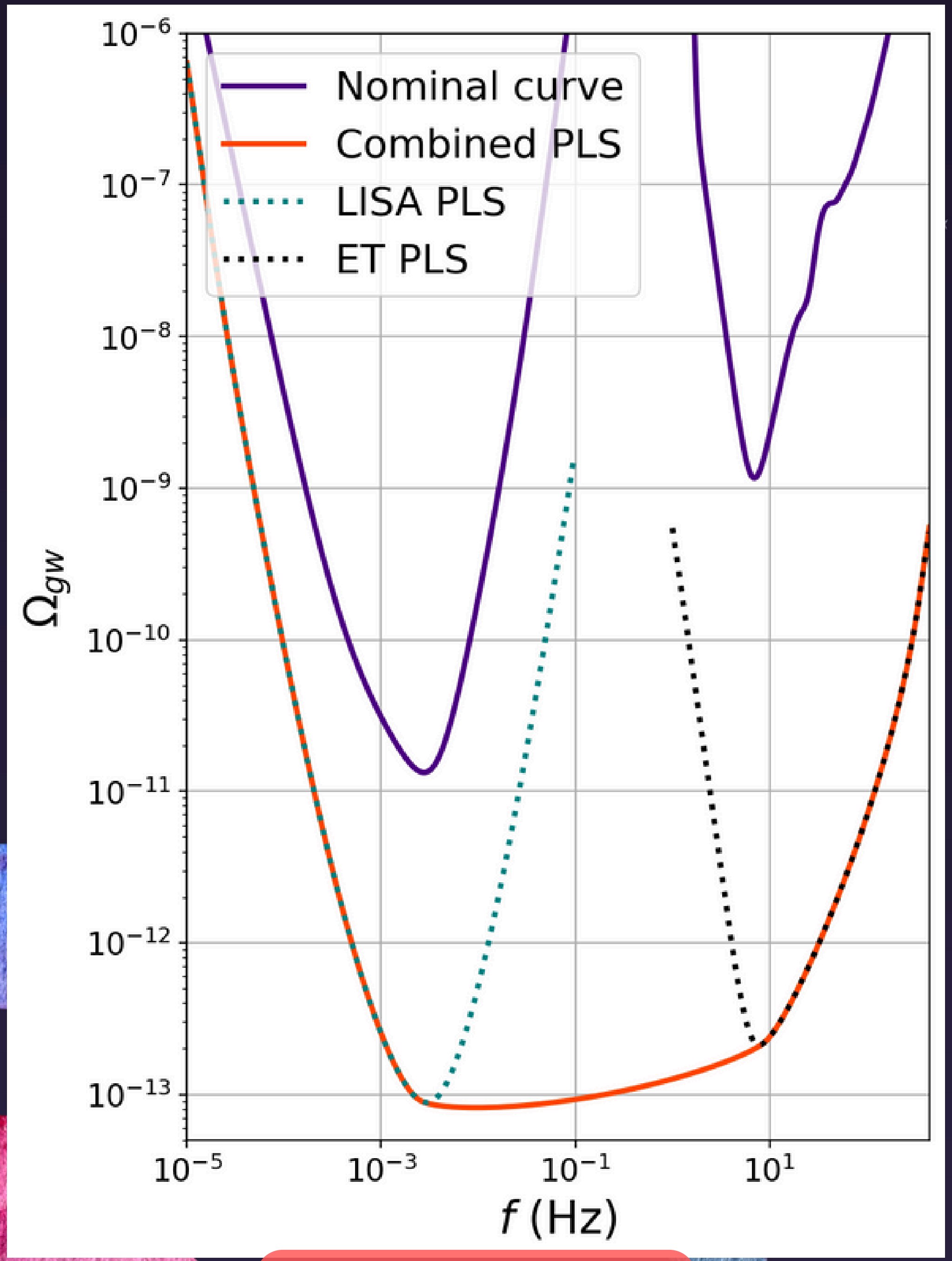


INTEGRATED SENSITIVITY CURVE

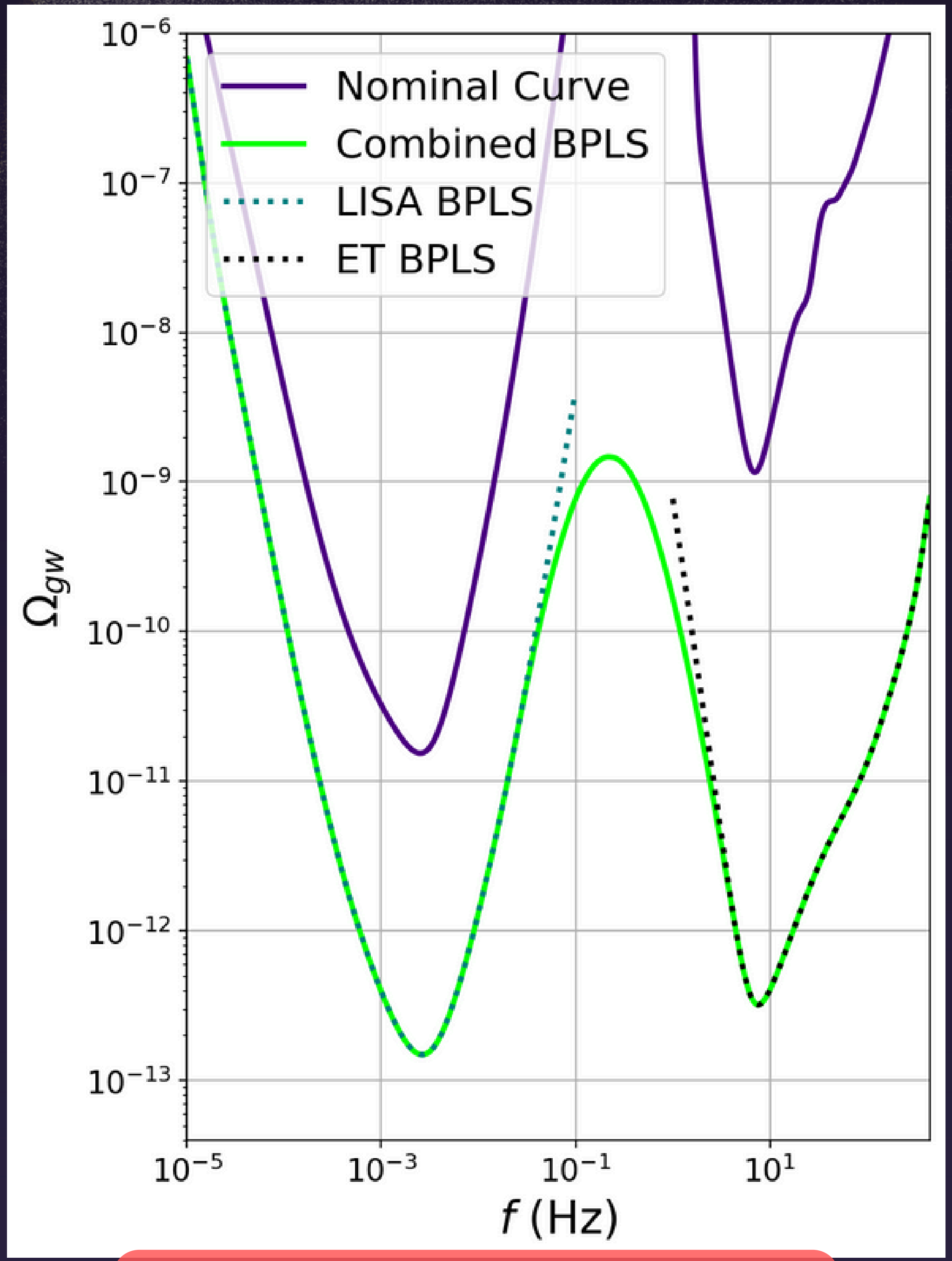


FREQUENCY PROFILES

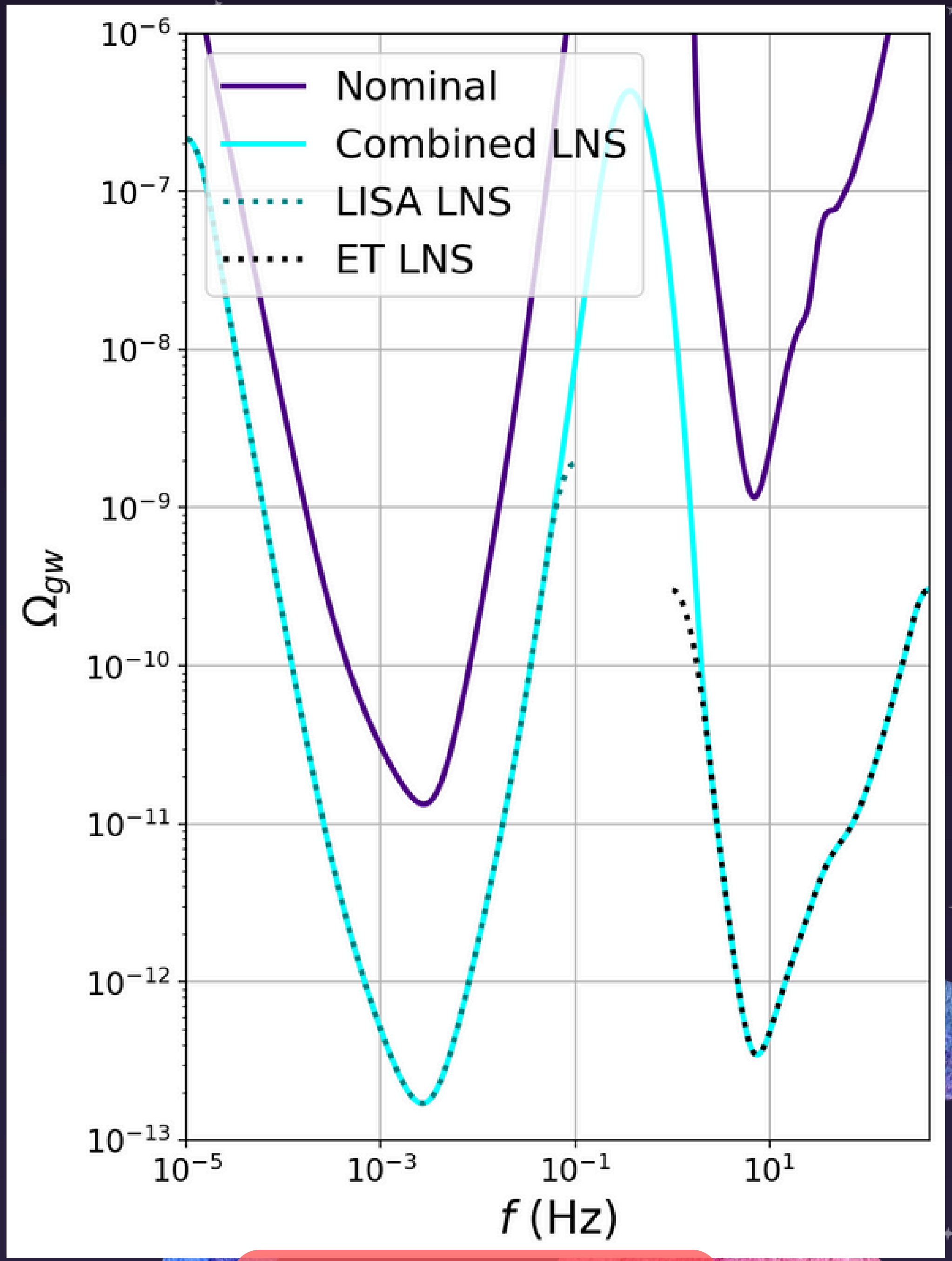
Profiles produced by Cosmic Strings (both PL and BPL), Phase Transitions (BPL), and Cosmological Inflation(LNS).



Power law



Broken Power law



Log Normal

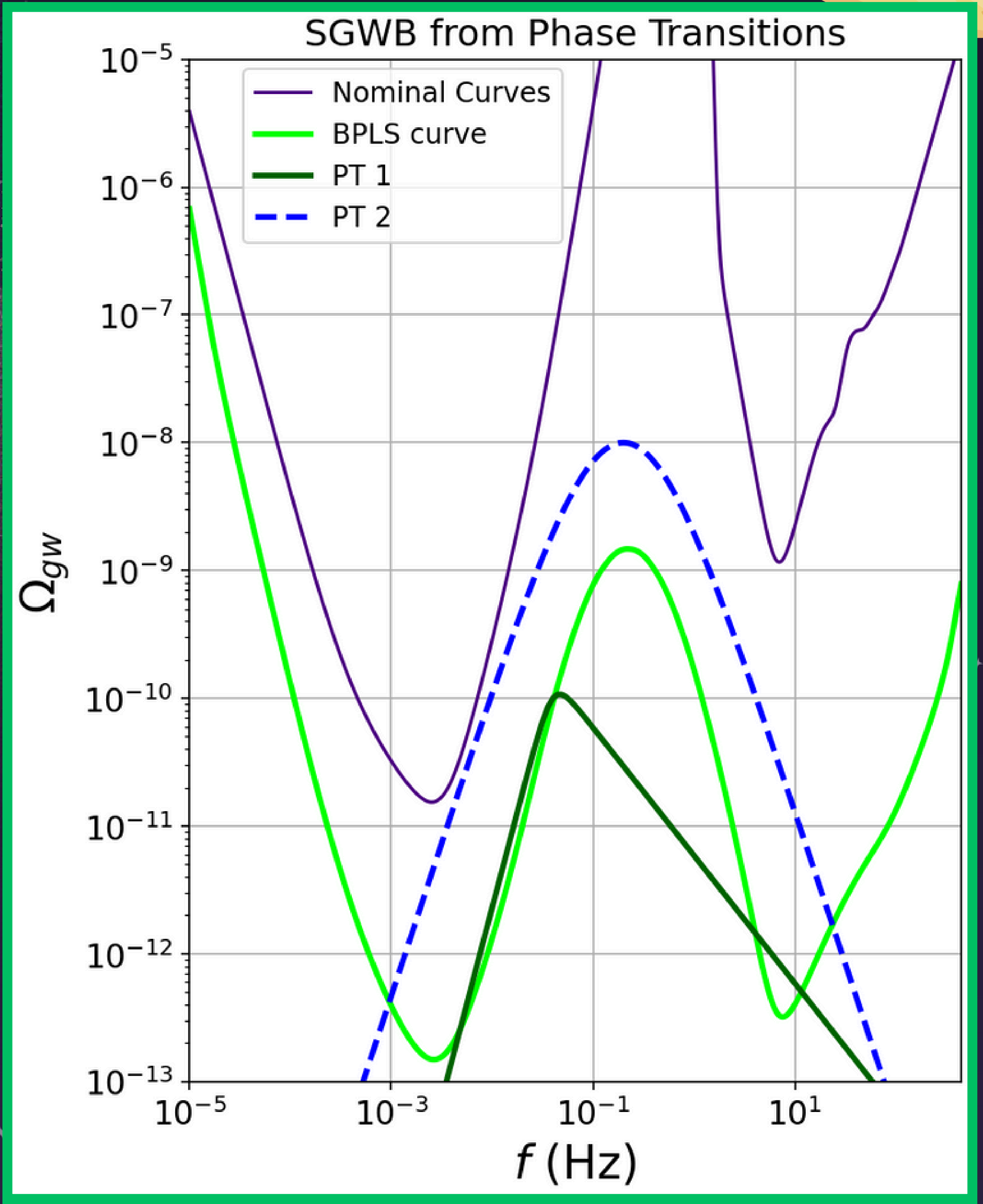
PHASE TRANSITIONS

In the case of phase transitions, we choose the following benchmark scenarios:

$$\Omega_{\rm GW}(f) = \Omega_\star \left(\frac{f}{f_\star}\right)^{n_1} \left[\frac{1}{2} + \frac{1}{2}\left(\frac{f}{f_\star}\right)^{\sigma}\right]^{\frac{n_2-n_1}{\sigma}}$$

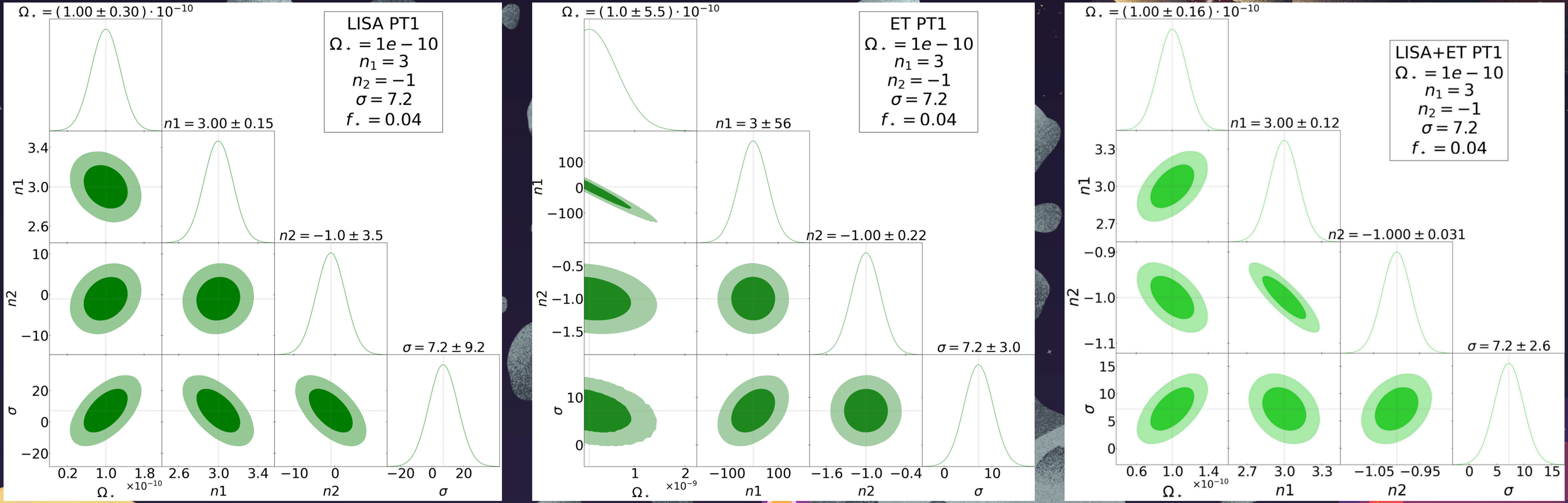
We need to measure both spectral indeces: n_1, n_2

	$\Omega_\star$	n_1	n_2	σ	$f_\star$
PT1	1×10^{-10}	3	-1	7.2	0.04
PT2	1×10^{-8}	2.4	-2.4	1.2	0.2



PT FISHER FORECAST

The third plot demonstrates how advantageous combining the two experiments is.



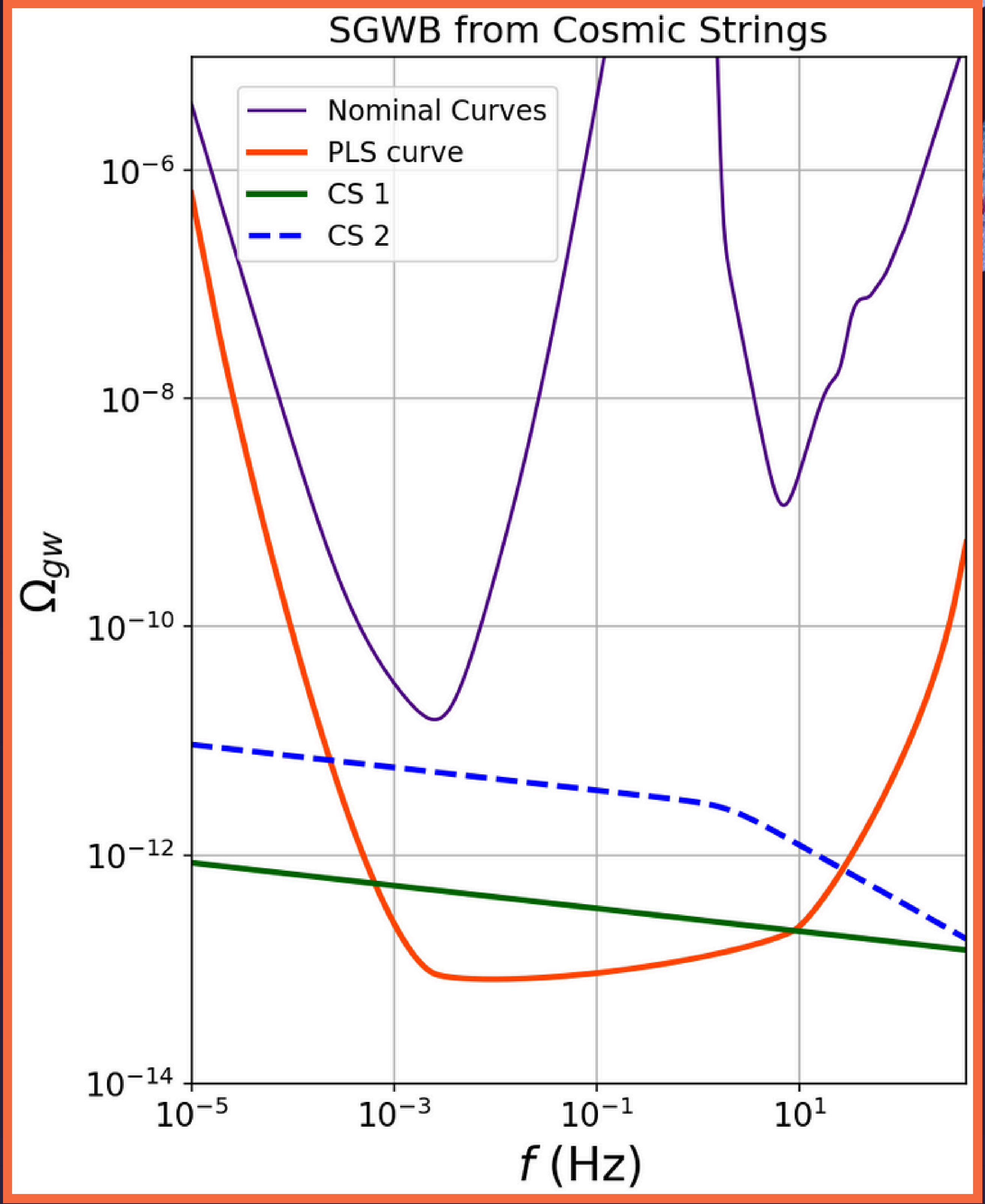
COSMIC STRINGS

In the case of cosmic strings, we choose the following benchmark scenarios:

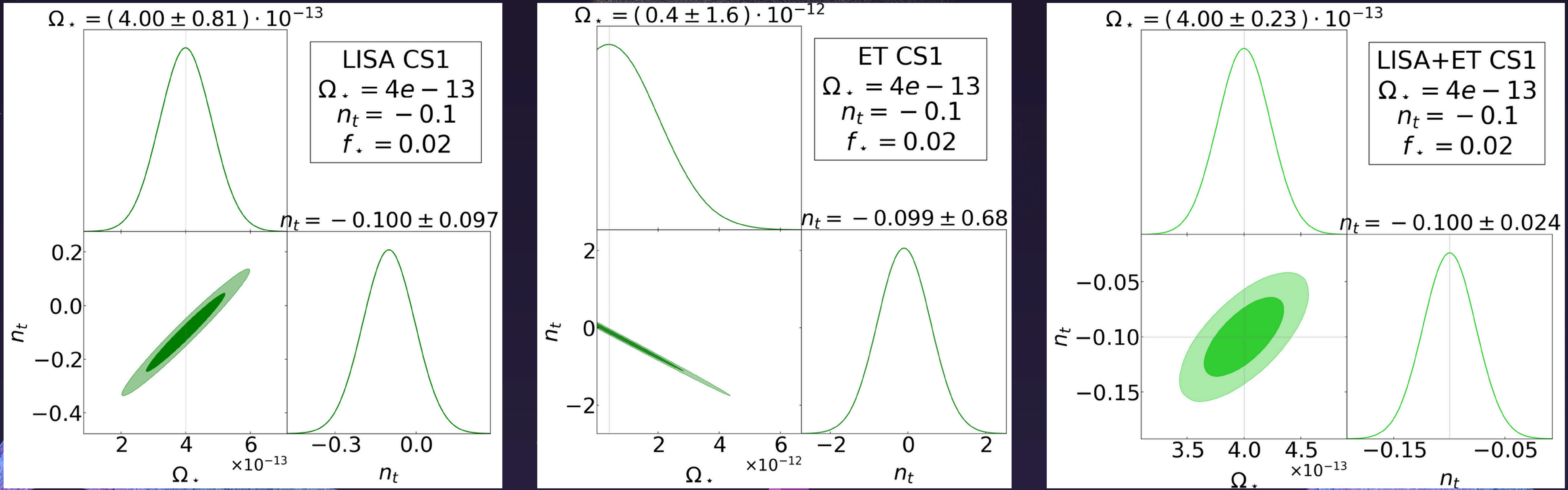
$$\Omega_{GW}(f) = \Omega_\star \left(\frac{f}{f_\star}\right)^{n_1}$$

Our Aim is to measure the spectral indeces, and other parameters

	$\Omega_\star$	n_1	n_2	σ	$f_\star$
CS1	4×10^{-13}	-0.1	-0.1	$-$	0.02
CS2	2.5×10^{-12}	-0.1	$-\frac{1}{2}$	3	2



CS FISHER FORECAST



CONCLUSION

- Only in synergy can the two experiments measure every parameter with 10% accuracy.
- The work demonstrates that LISA and ET together will have the opportunity to detect distinct features of GWs produced by the same cosmological source.
- The two experiments operating in tandem can be sensitive to features of early universe cosmic expansion before big-bang nucleosynthesis, which affect the SGWB frequency profile.
- For future research it will be important to consider the astrophysical case; and the case where ET is not an equilateral triangle.