

# Cosmology with gravitational waves

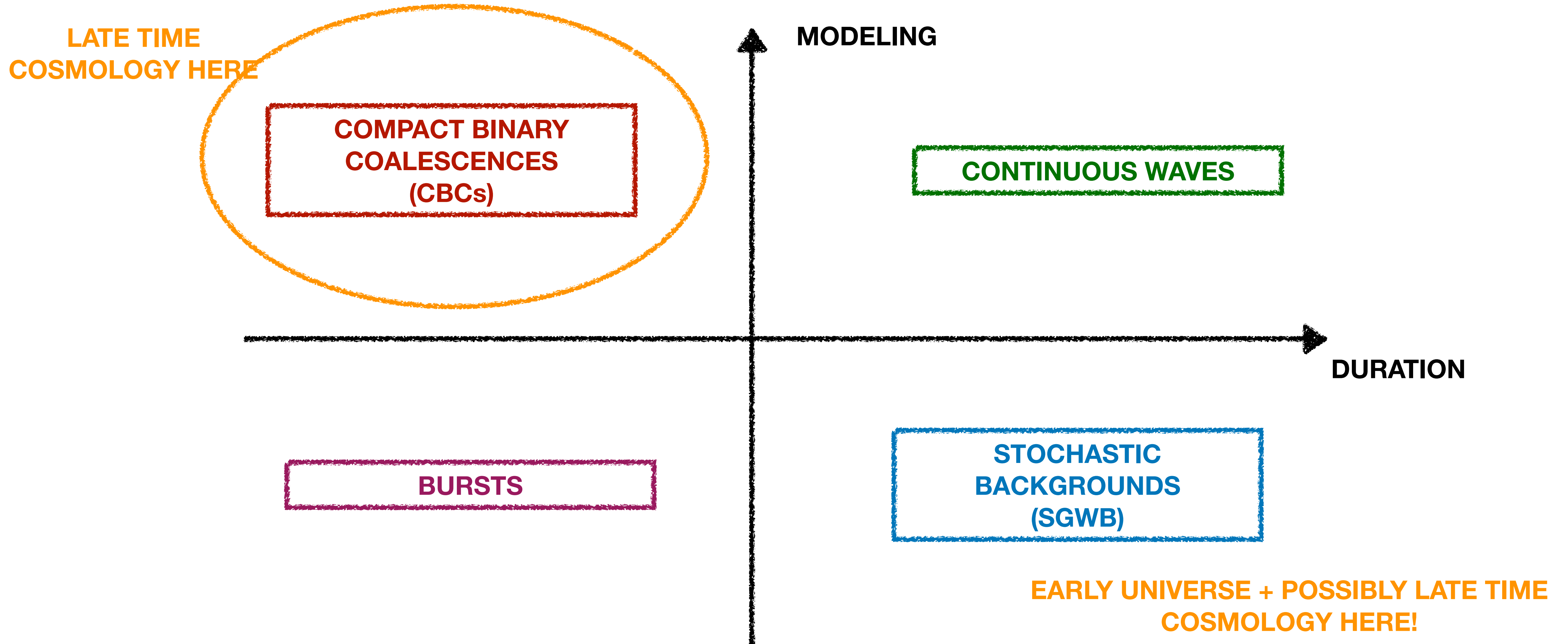
## Overview of GDR OG - cosmology



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On behalf of the GDR Ondes Gravitationnelles, Cosmology section

# Gravitational wave sources



# CBCs as Standard Sirens

Schutz 1986

Thanks to GR, GWs are “self-calibrated distance tracers”

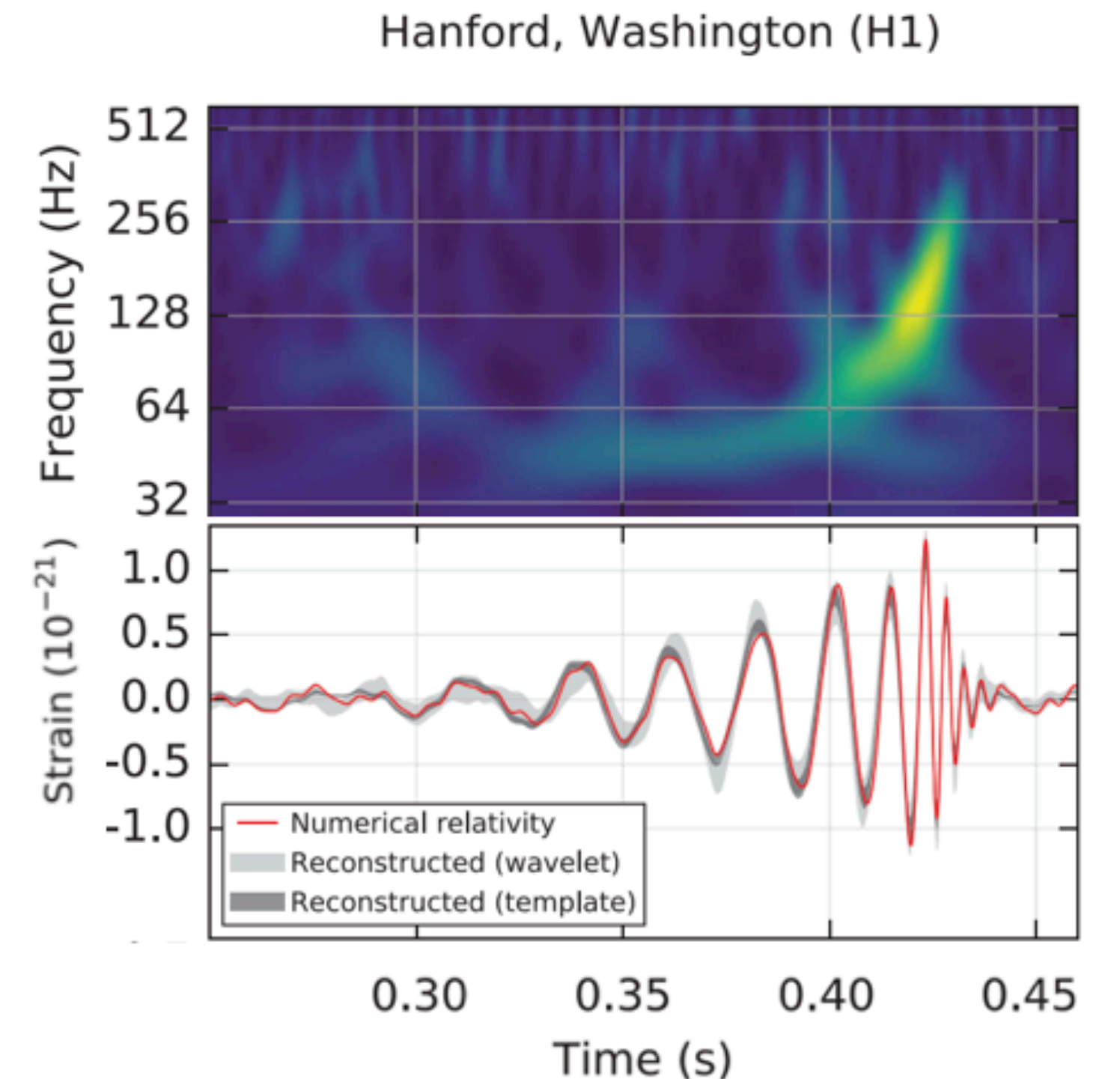
- Phase: **detector-frame chirp mass.**  
Redshift-mass degeneracy.

$$\dot{f}_{obs} \sim \mathcal{M}_z^{5/3} f_{obs}^{11/3} \quad \mathcal{M}_z \equiv \mathcal{M}_c \times (1+z)$$

- Amplitude: **Luminosity distance**

$$h \sim \frac{\mathcal{M}_z^{5/3} f_{obs}^{2/3}}{d_L} \longrightarrow d_L(z) = (1+z) \int_0^z \frac{c d\tilde{z}}{H_0 \sqrt{\Omega_m (1+\tilde{z})^3 + 1 - \Omega_m}} \approx \frac{z}{H_0}$$

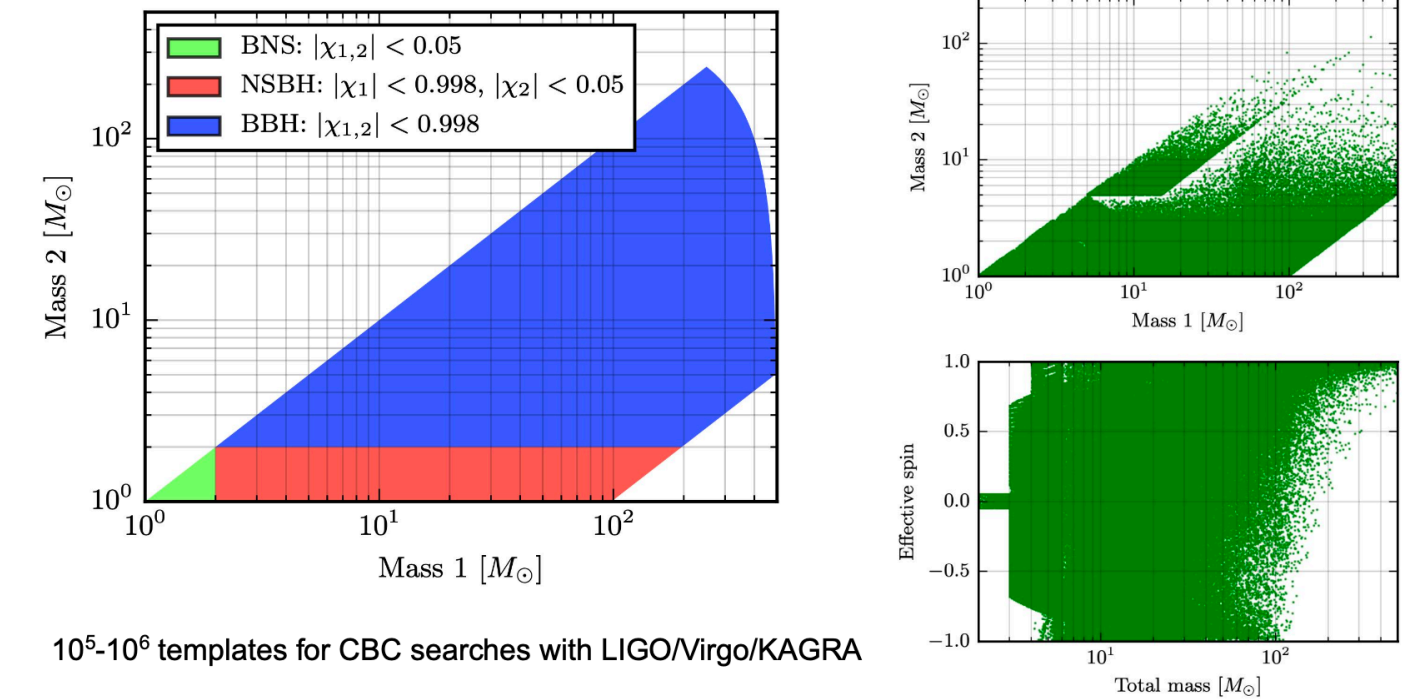
**No astrophysics, only GR**



# Workflow

Searches

matched filtering w. template banks  
glitch removal/vetoes  
ranking statistics  
consistency checks  
**False Alarm Rate** thresholds



Parameter Estimation

15-dimensional bayesian analysis  
Obtain single-event properties in the form of **posterior samples**

DET.-FRAME MASS AND  
LUMINOSITY DISTANCE HERE

<https://gwosc.org/> (catalogs)

Hierarchical analyses

Combine all events in catalog propagating uncertainty  
Correct for selection effects via **injections** campaigns  
Extract cosmology/astrophysics

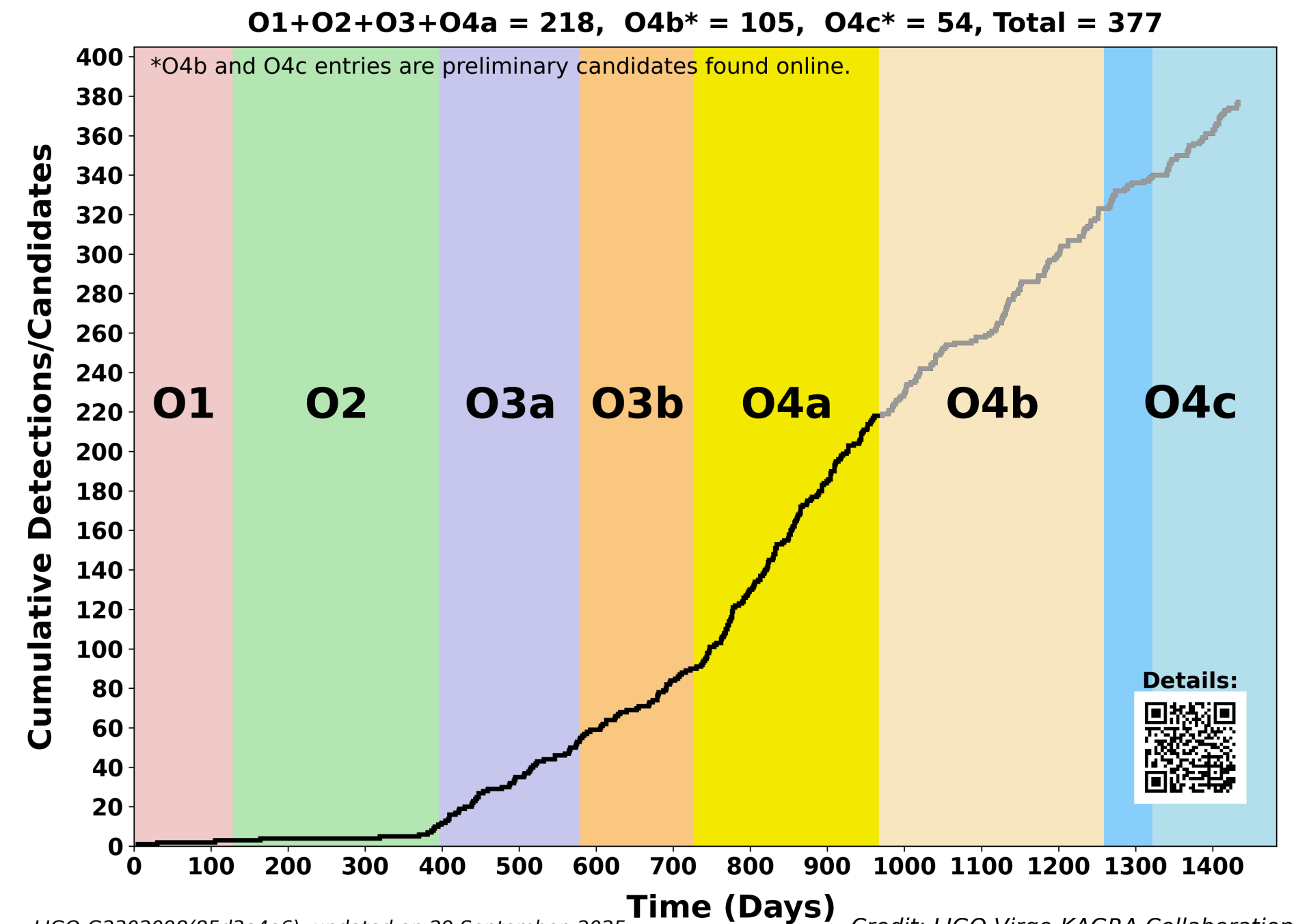
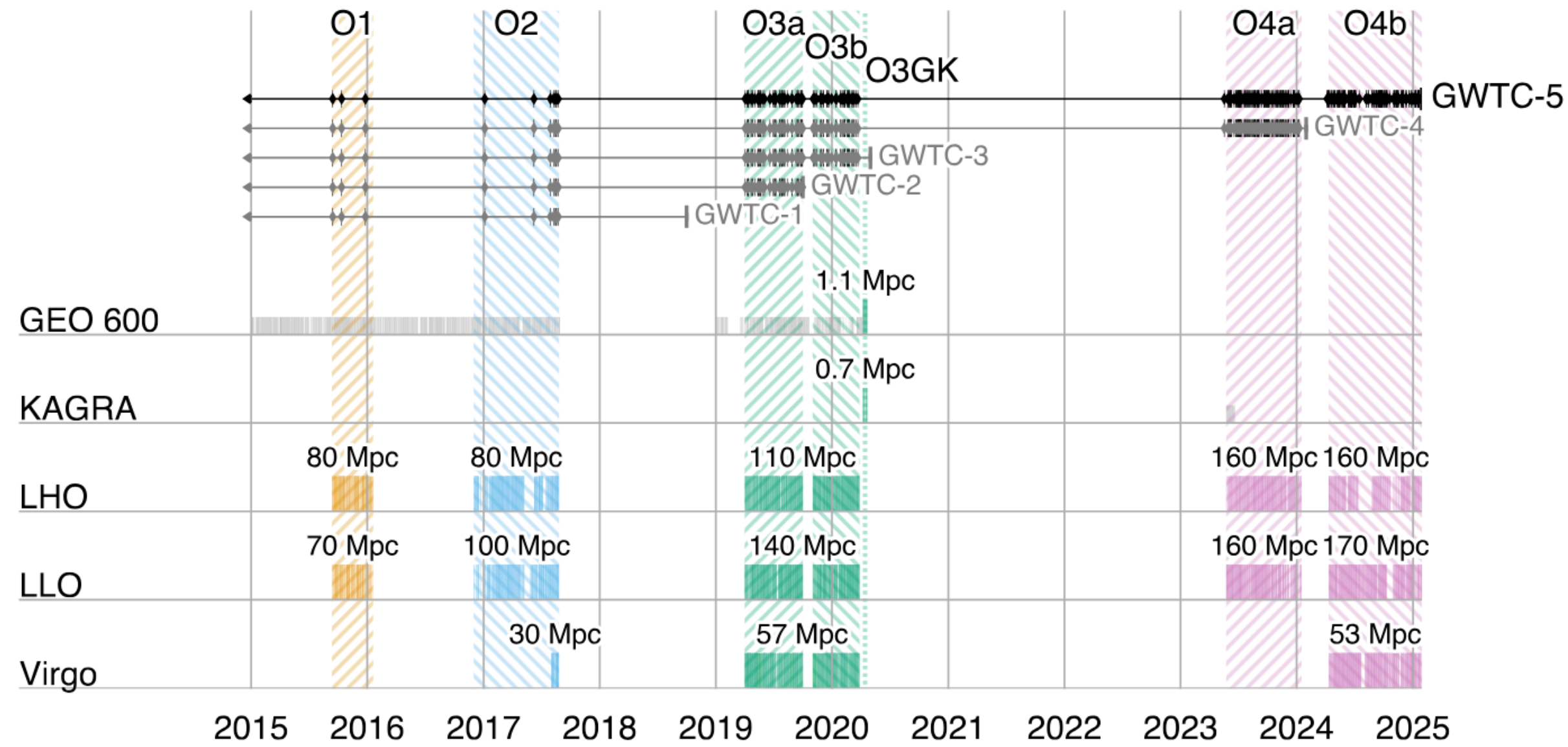
H<sub>0</sub> HERE

# State of the art

## ► GWTC-5.0 catalog

<https://arxiv.org/abs/2605.27225>

<https://arxiv.org/pdf/2605.27223>



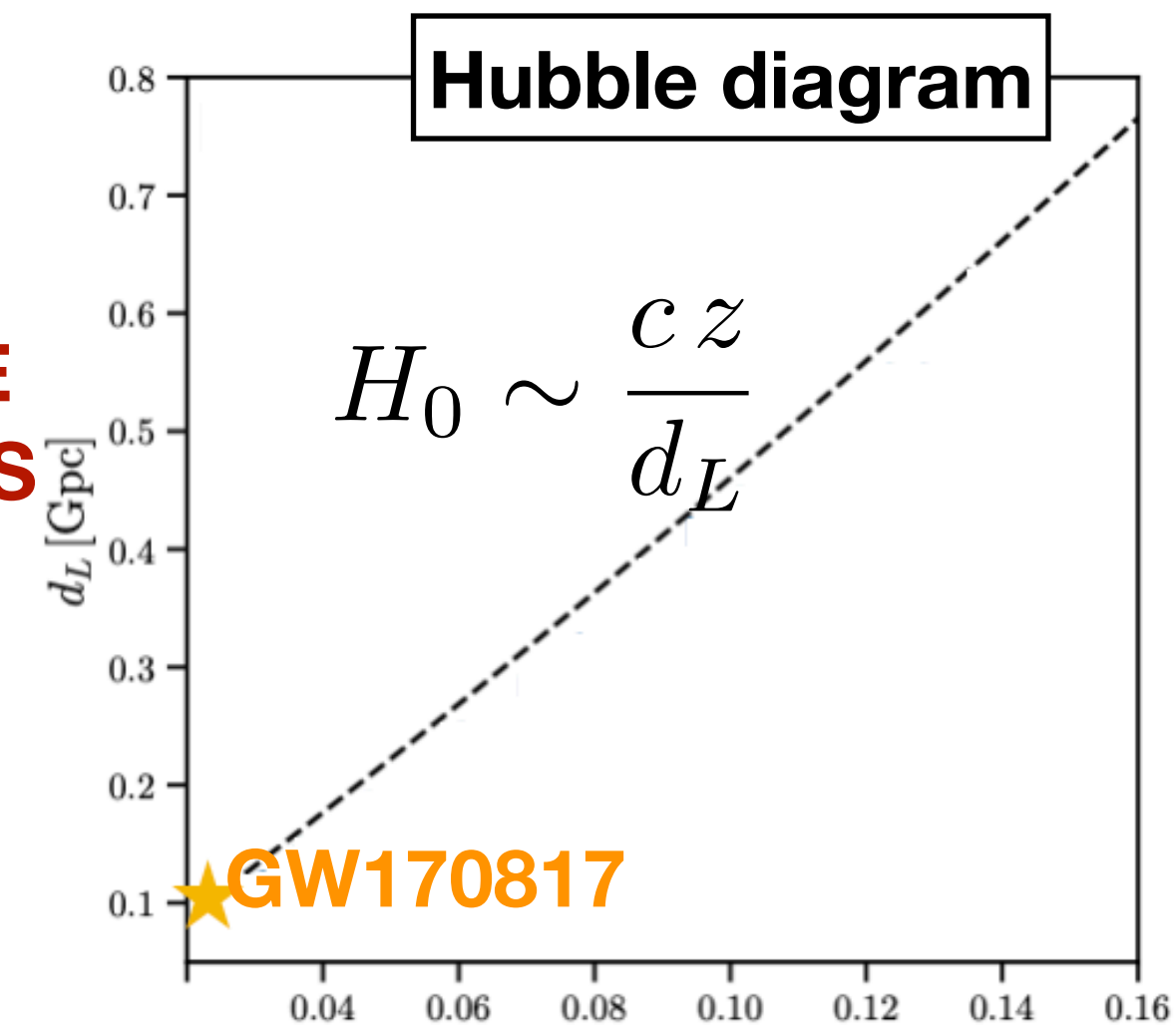
LIGO-G2302098(85d3a4e6), updated on 29 September, 2025 Credit: LIGO-Virgo-KAGRA Collaboration

# Redshift measurements

▶ “Bright sirens” : redshift of the source is known

- ◆ Multimessenger detection

**DISTANCE  
FROM GWS**



**REDSHIFT FROM HOST GALAXY IDENTIFICATION**

▶ “Dark sirens” : redshift of the source is not known

- ◆ Statistical association with galaxy catalogues
- ◆ Knowledge of source-frame mass properties from astroph.
- ◆ Clustering/two-point functions

**Hierarchical bayesian inference  
in presence of selection effects.**

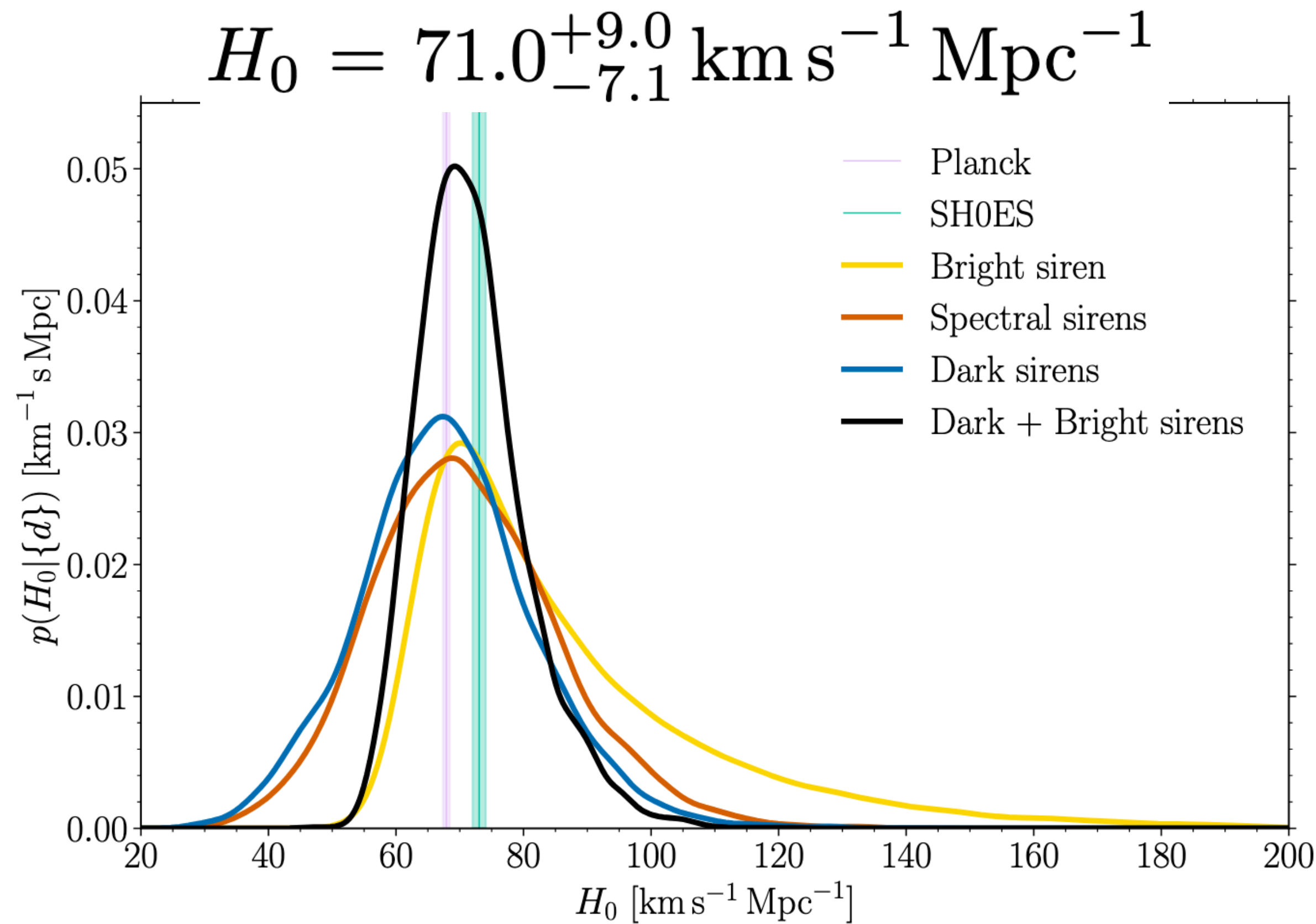
**Need to estimate reliably the  
detector sensitivity**

**+**

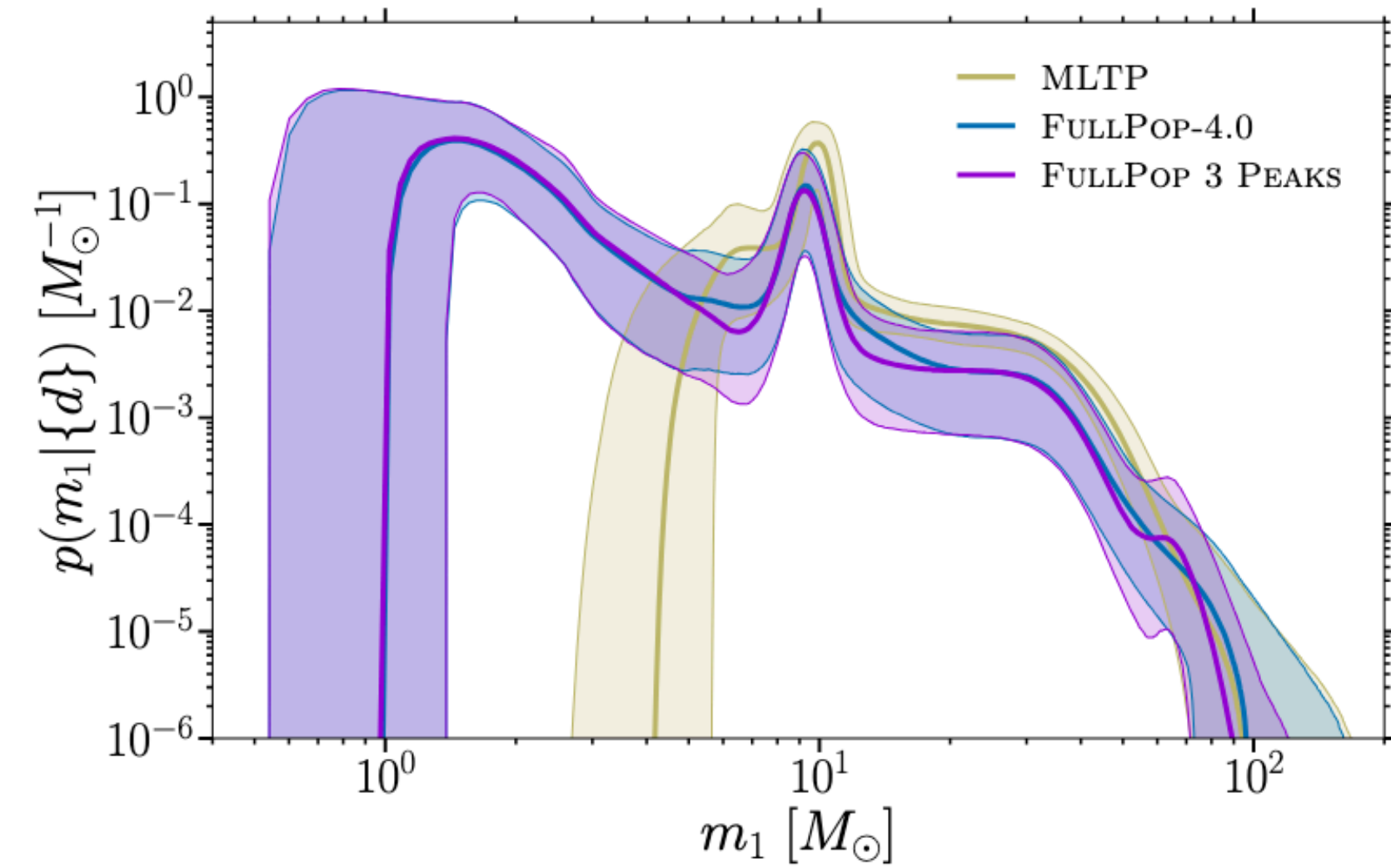
**astrophysical assumptions on  
GW source population**

# State of the art

► GWTC-5.0 cosmology paper. ~250 LVK dark sirens + 1 bright siren + DES galaxies



<https://arxiv.org/abs/2605.27227>

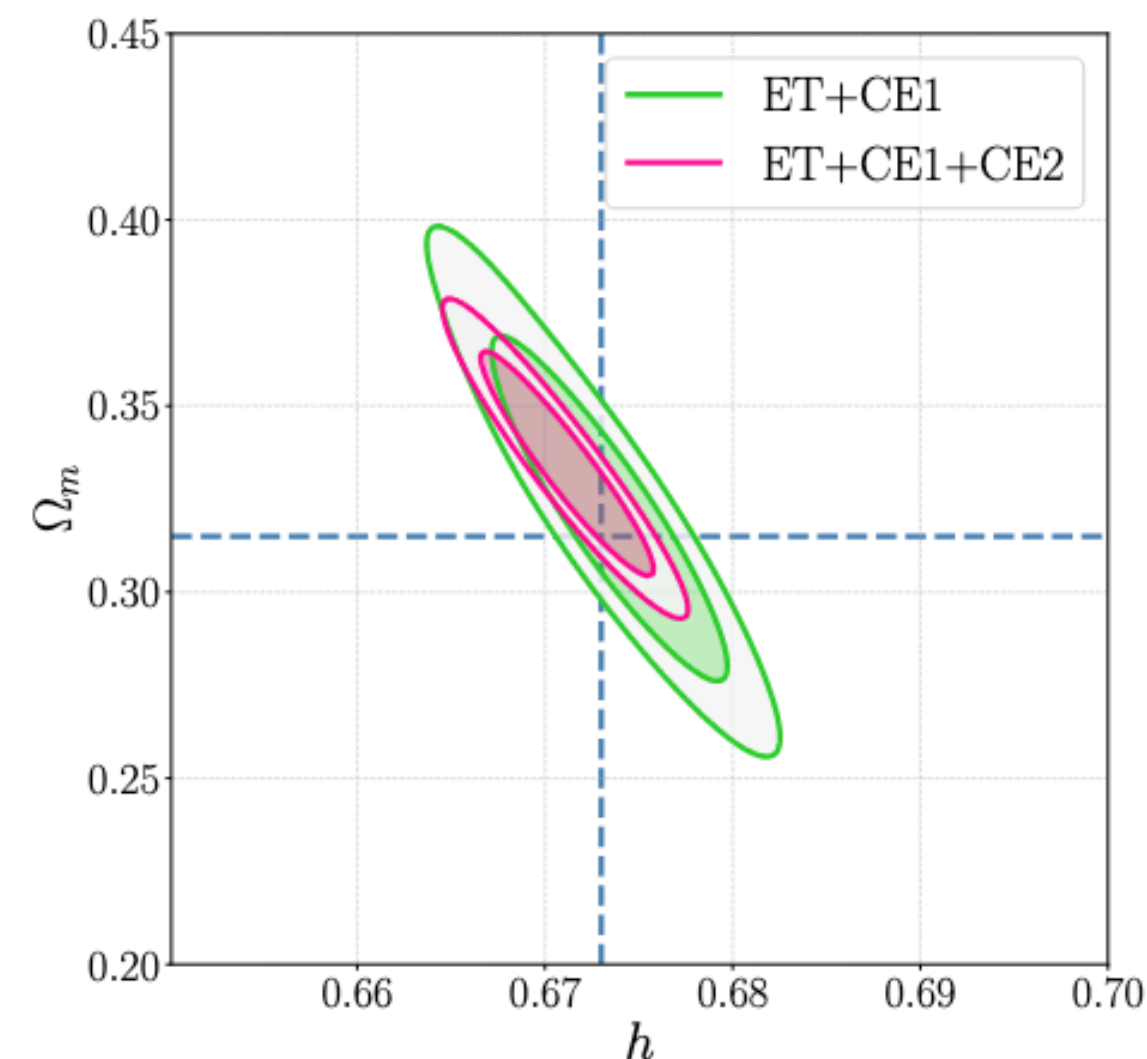


# “What do you need to solve the Hubble tension?”

~100 well-localised events in a complete spectroscopic catalog or ~tens of good bright sirens (+ control of numerical accuracy and systematic effects)

- ▶ Look at next generation observatories: **Einstein Telescope/LISA**
- ▶ Many other things **beyond  $H_0$** : dark energy/modified gravity, propagation tests, early Un.

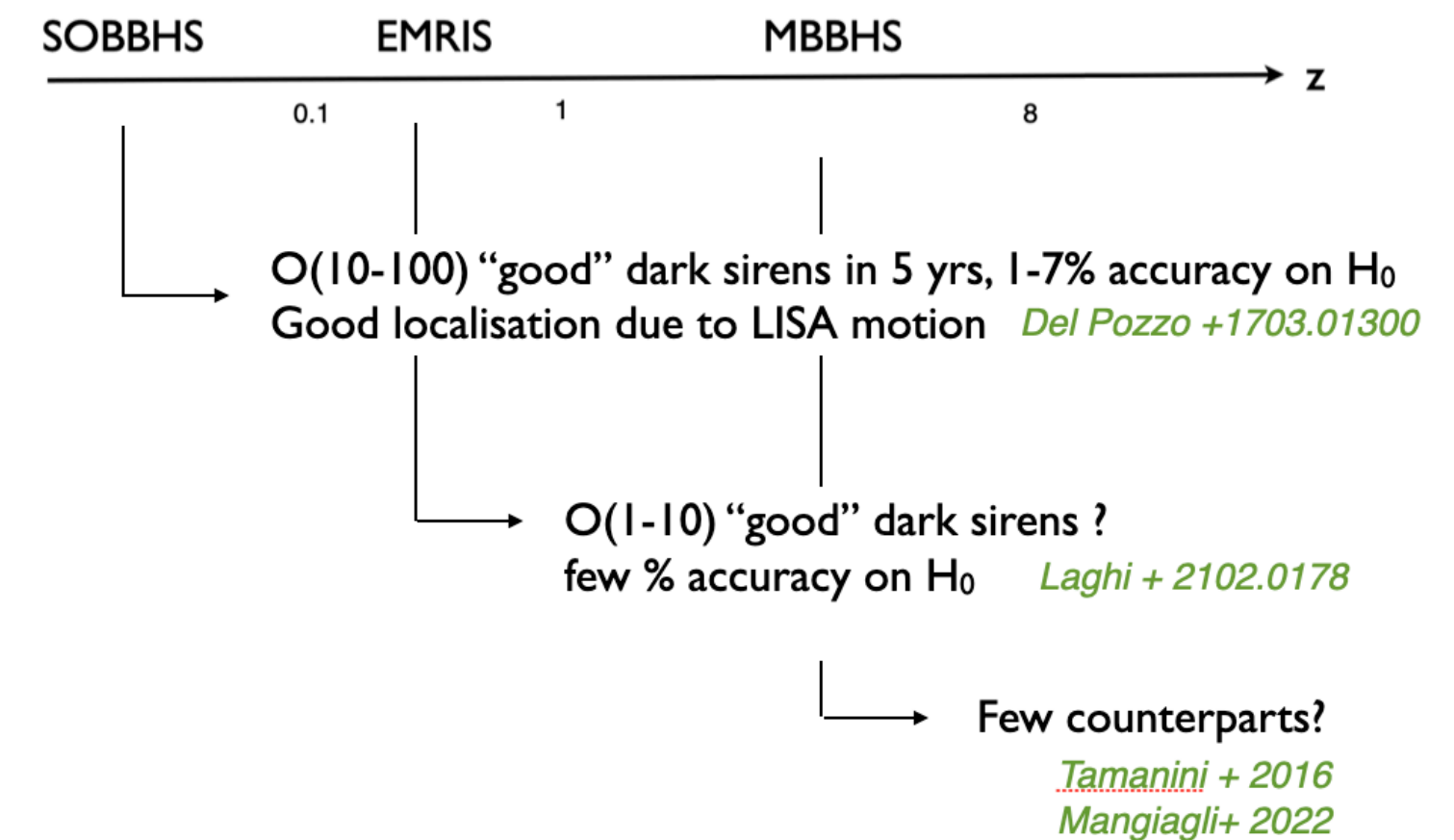
Einstein Telescope “Blue Book ”  
<https://arxiv.org/abs/2503.12263>



Lisa cosmology white paper  
<https://arxiv.org/abs/2204.05434>

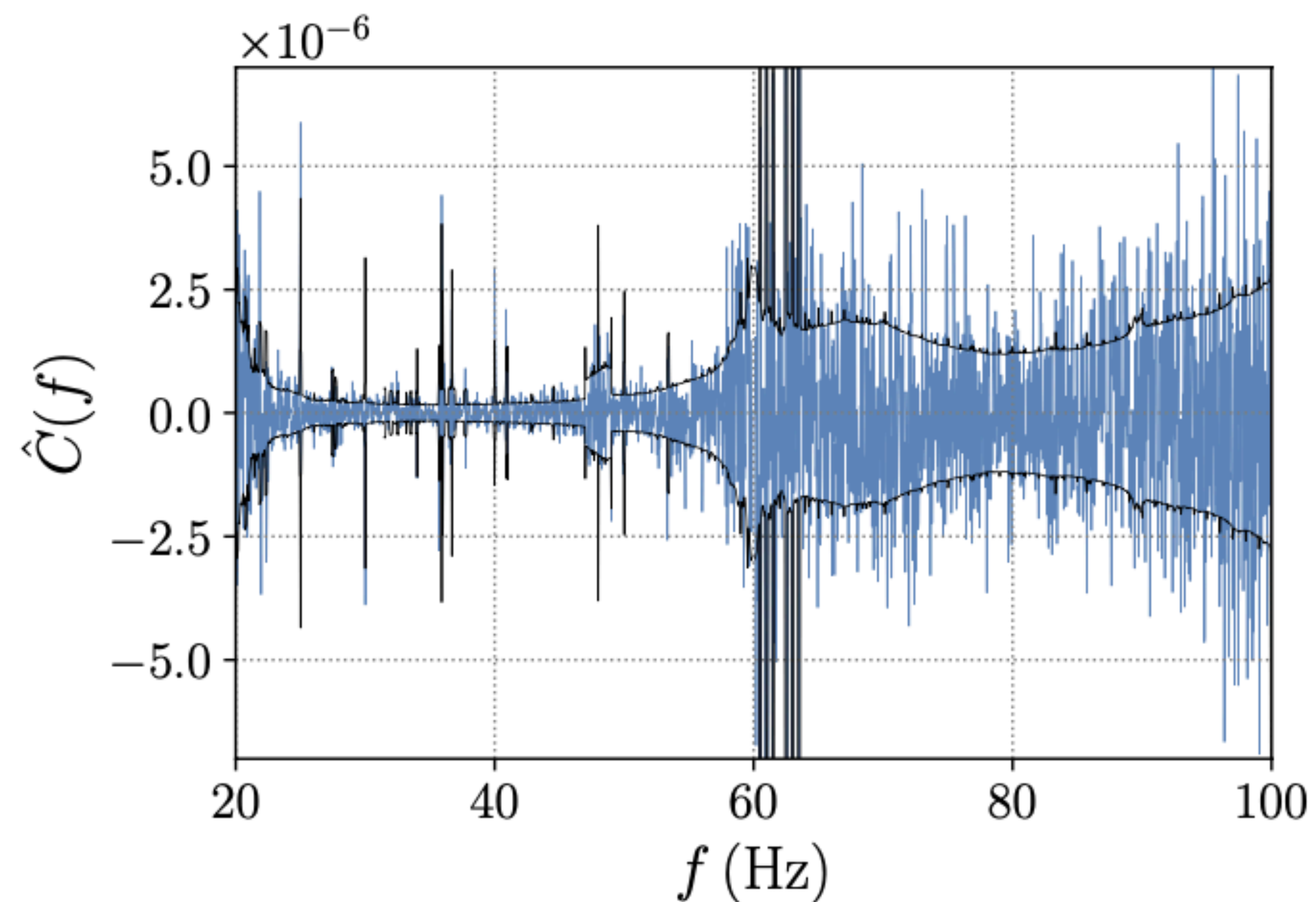
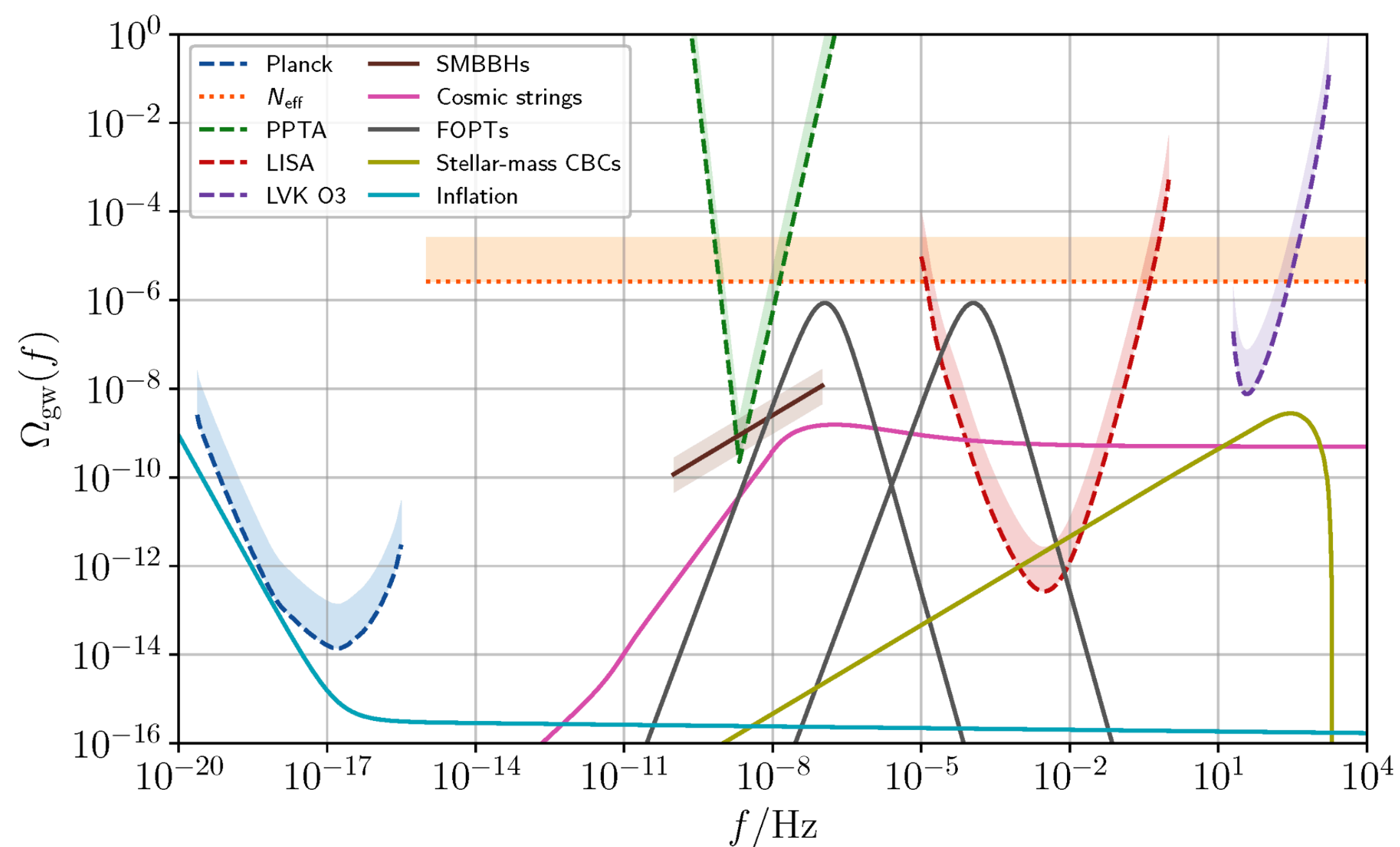


Cosmology with the Laser Interferometer Space Antenna



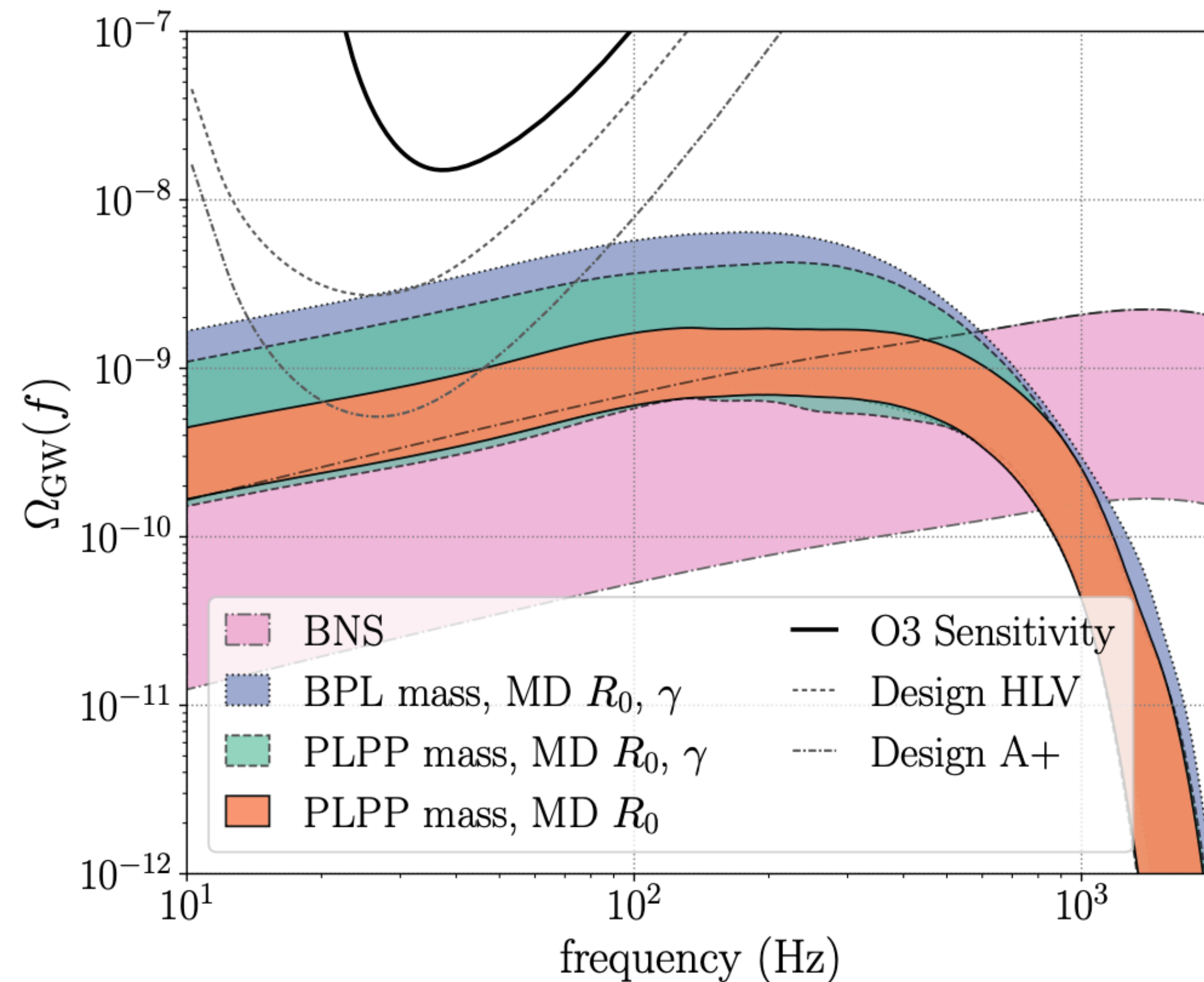
# “What do you need to solve the Hubble tension?”

- ▶ Looks like correlated noise with some predictable spectral shape
- ▶ No evidence so far



# “What do you need to solve the Hubble tension?”

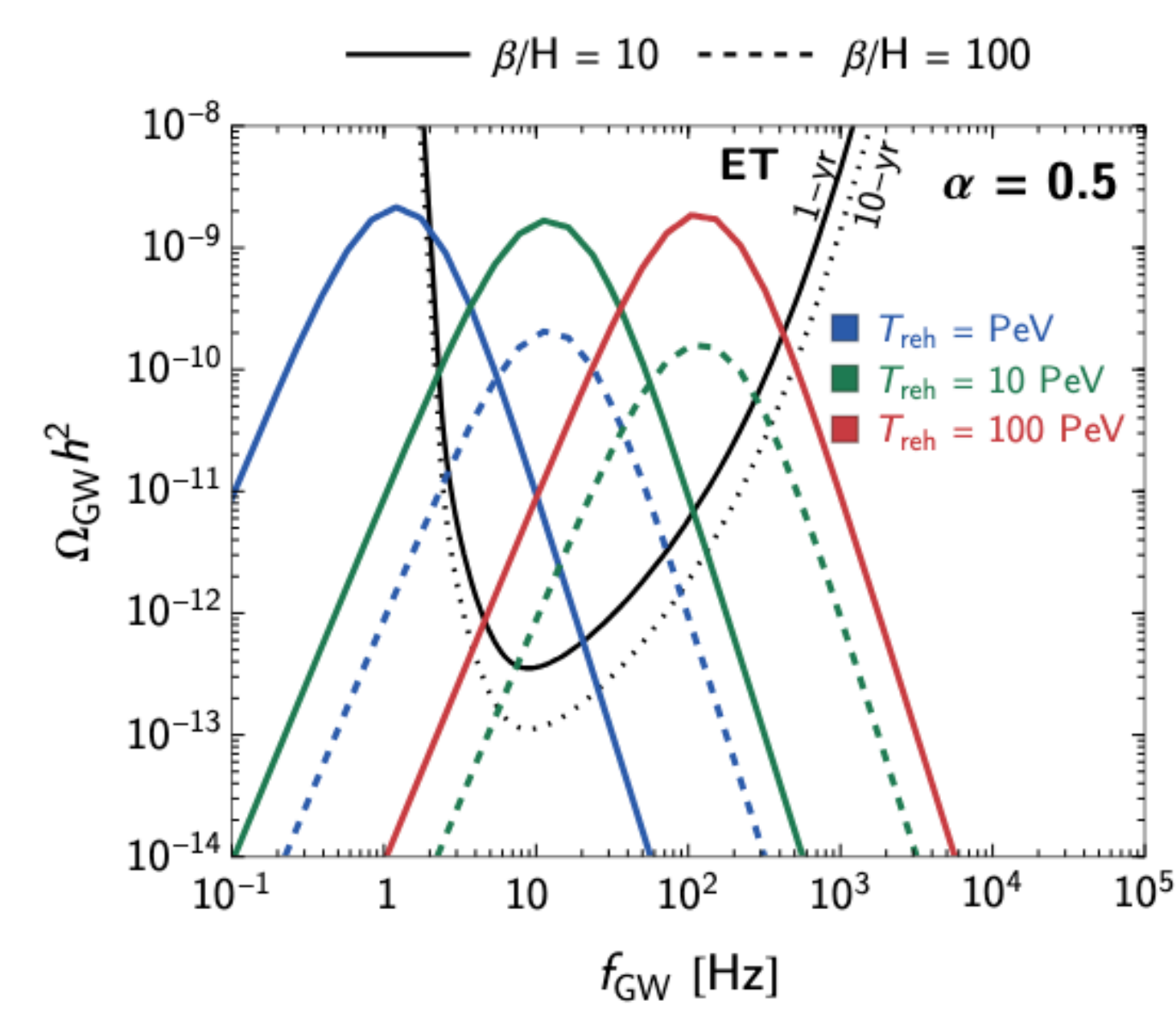
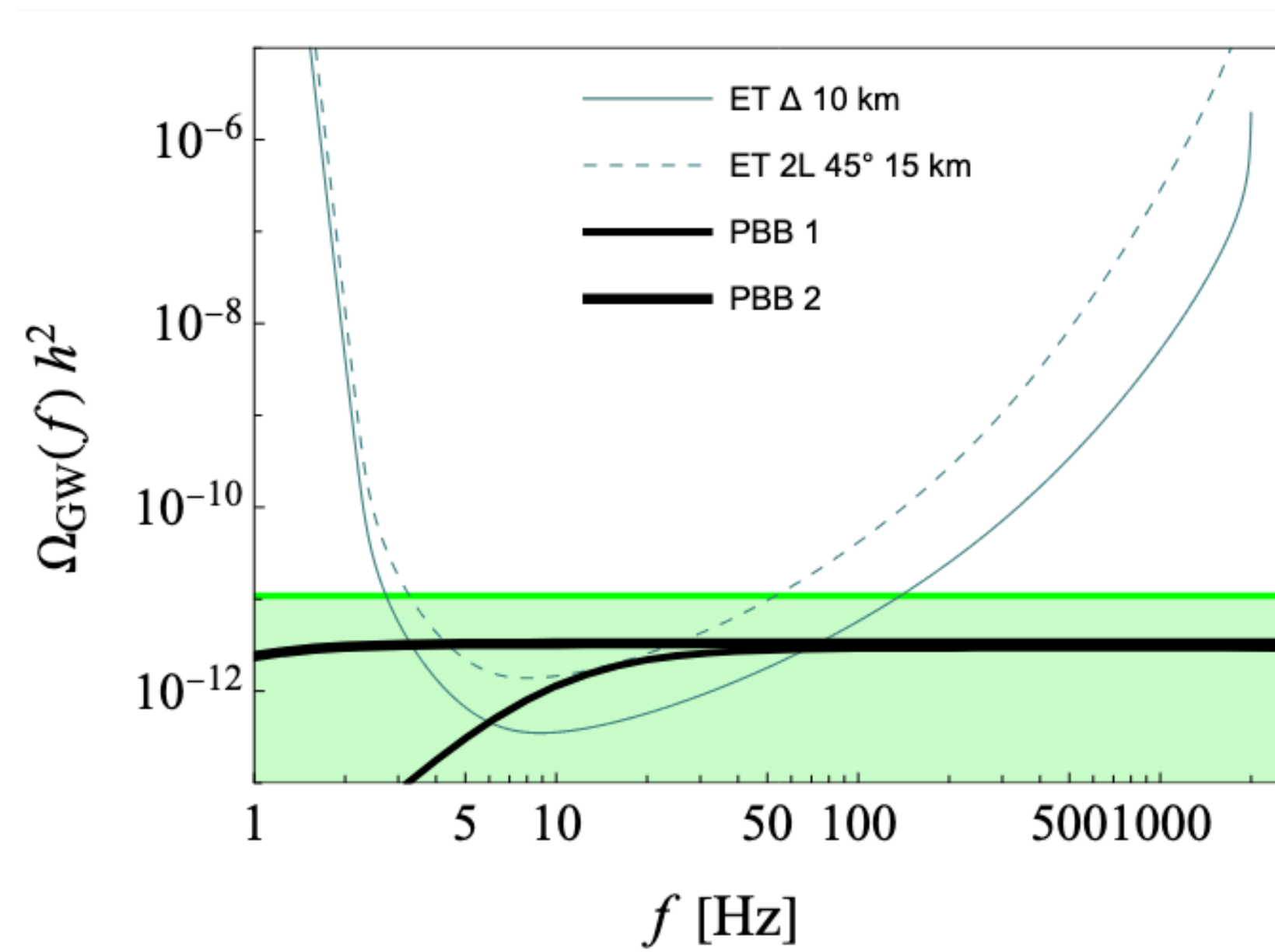
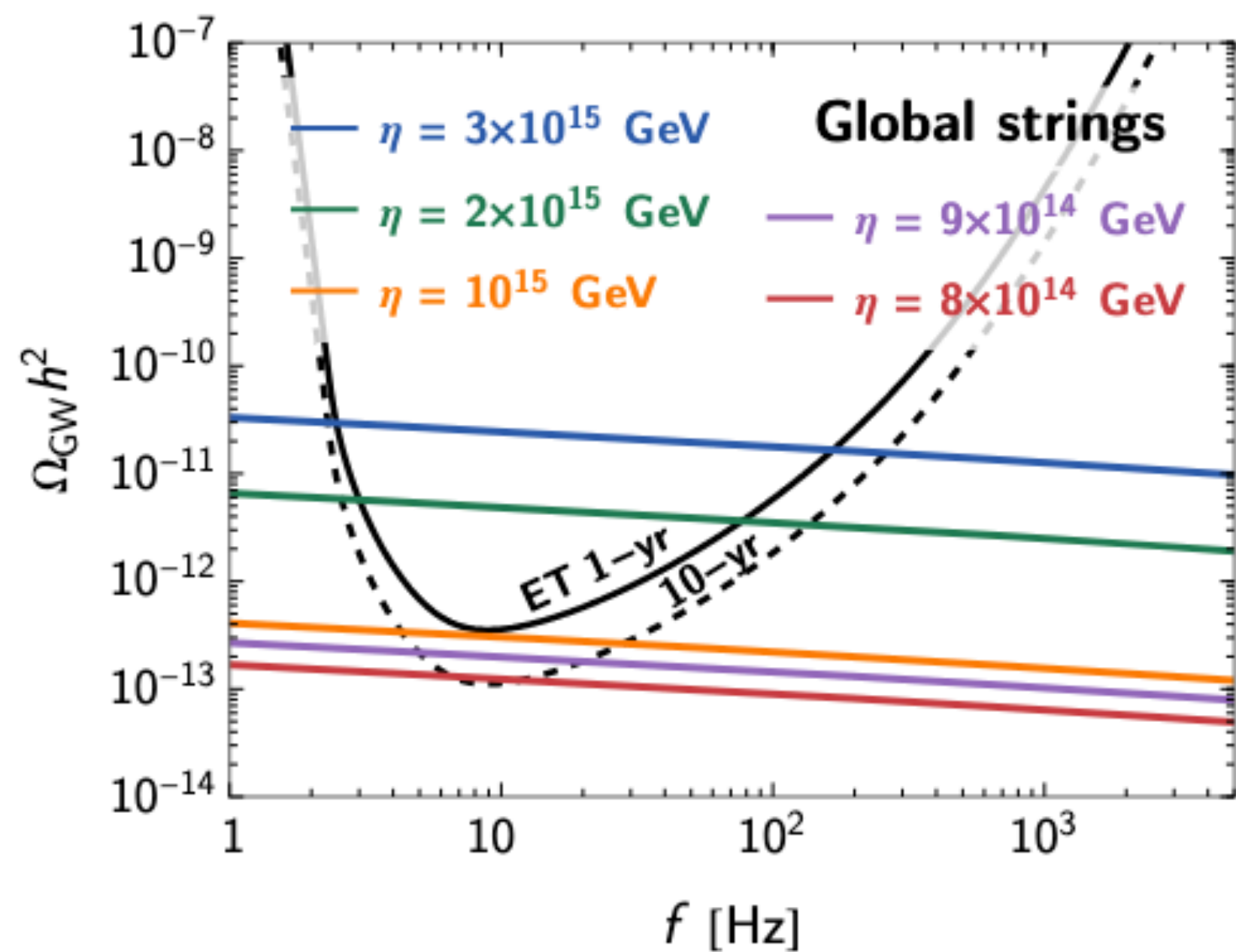
- Cosmology masked by astroph. foreground . Detectable at O5 !



<https://arxiv.org/pdf/2407.03742>

# Stochastic BG of primordial origin beyond slow-roll

► Subtraction of foreground may leave space for detecting early Universe physics



# The future of GW observatories

