

Latest LVK cosmological results from GWTC-5.0

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

GWTC-5.0: Constraints on the Cosmic Expansion Rate and Modified Gravitational-wave Propagation

Table of Contents



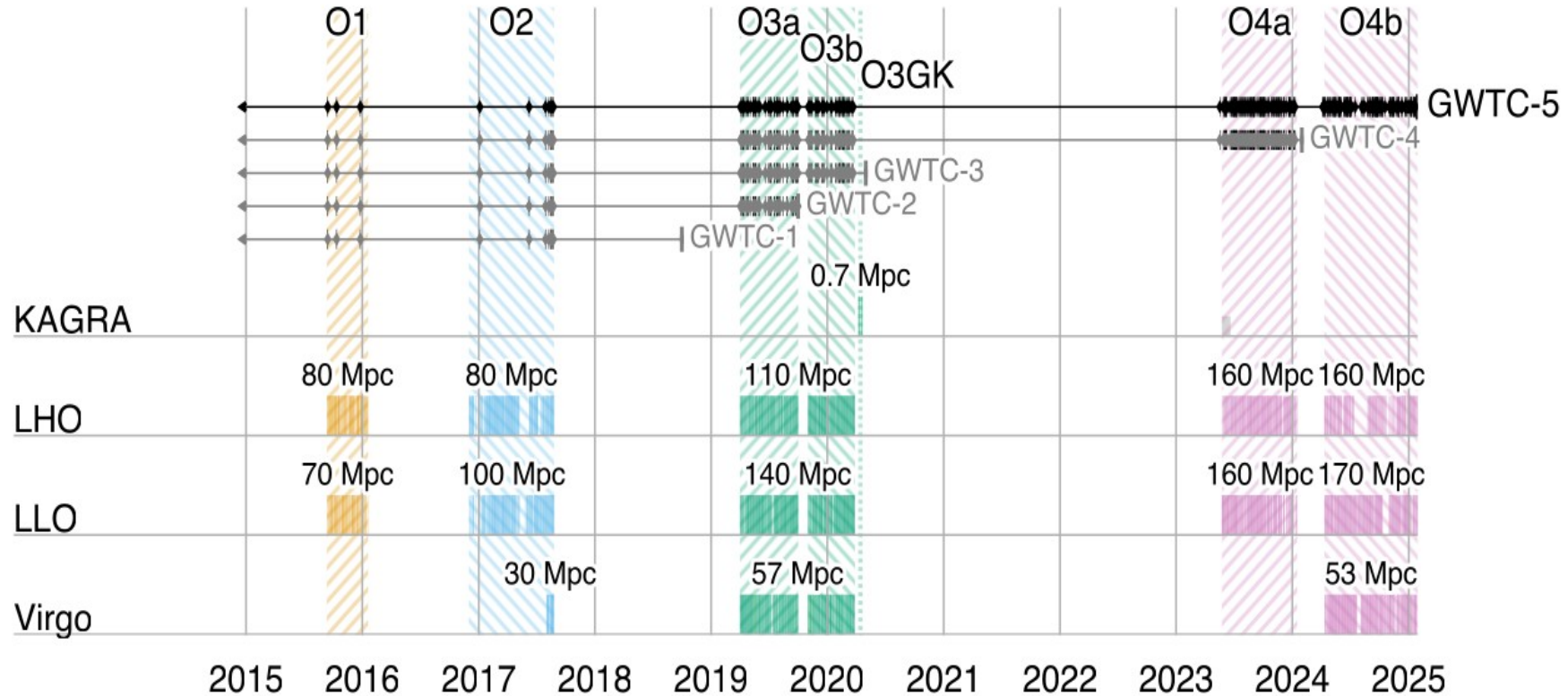
1/ The Gravitational Wave Transients Catalog 5.0

2/ From CBCs to cosmology

3/ Statistical Framework

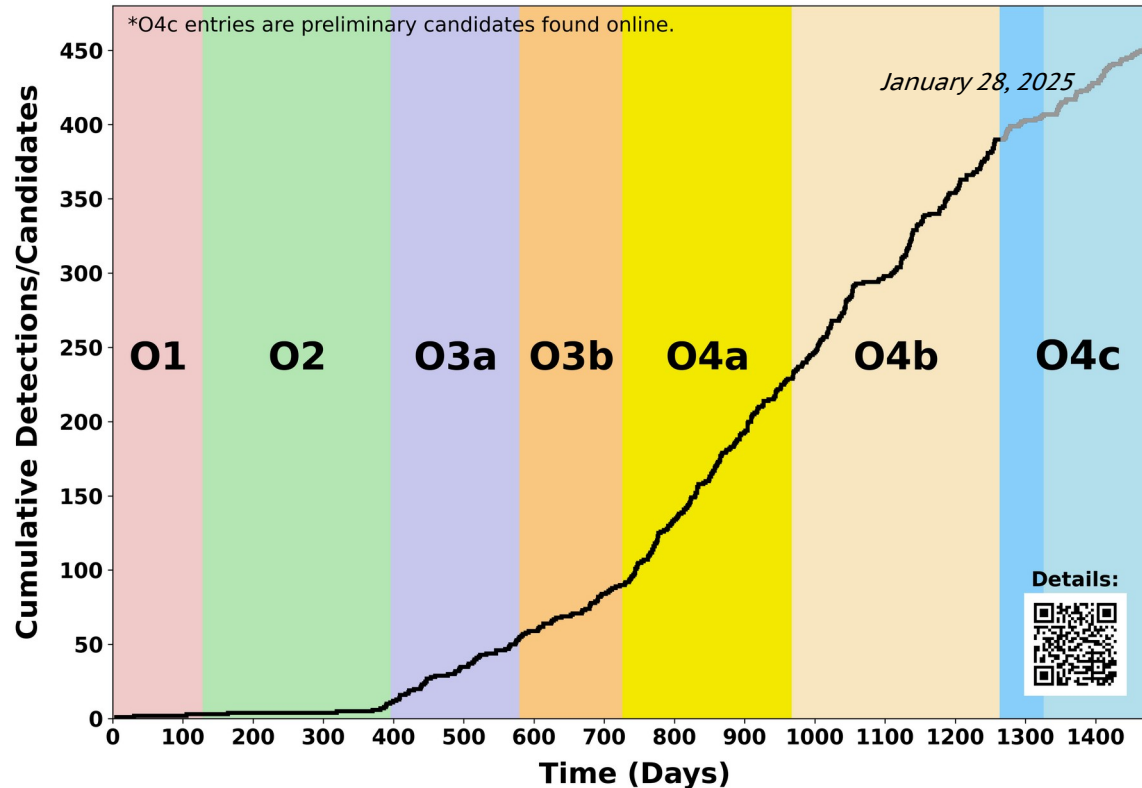
4/ Results of cosmological constraints using GWTC-5.0

GWTC-5.0 / CBC Detections



GWTC-5.0 / CBC Detections

O1 (3) + O2 (8) + O3a (44) + O3b (35) + O4a (139) + O4b (161) = 390, O4c* = 68, Total = 458



LIGO-G2302098 (f244d4f6), updated on 25 May, 2026

Credit: LIGO-Virgo-KAGRA Collaboration

390 events

(+161 compared to GWTC-4.0)

236 of which are used for
cosmological analysis after
the cut $i\text{FAR} > 4$ years

(+94 compared to GWTC-4.0)

From CBCs to cosmology

$$h_+(t, \iota, \varphi) = \frac{4}{D_L} \left(\frac{GM_c}{c^2} \right)^{5/3} \left(\frac{\pi f_{\text{GW}}}{c} \right)^{2/3} \frac{1 + \cos^2 \iota}{2} \cos(2\pi f_{\text{GW}} t_{\text{ret}} + 2\varphi)$$

$$D_L \approx \frac{cz}{H_0} \quad z \ll 1$$

Luminosity distance related to redshift and expansion rate.

We measure D_L : information on $z \rightarrow$ information on H_0

$$m_d = (1 + z)m_s$$

Chirp mass appear redshifted.

We measure m_d : if we can constrain $m_s \rightarrow$ information on z

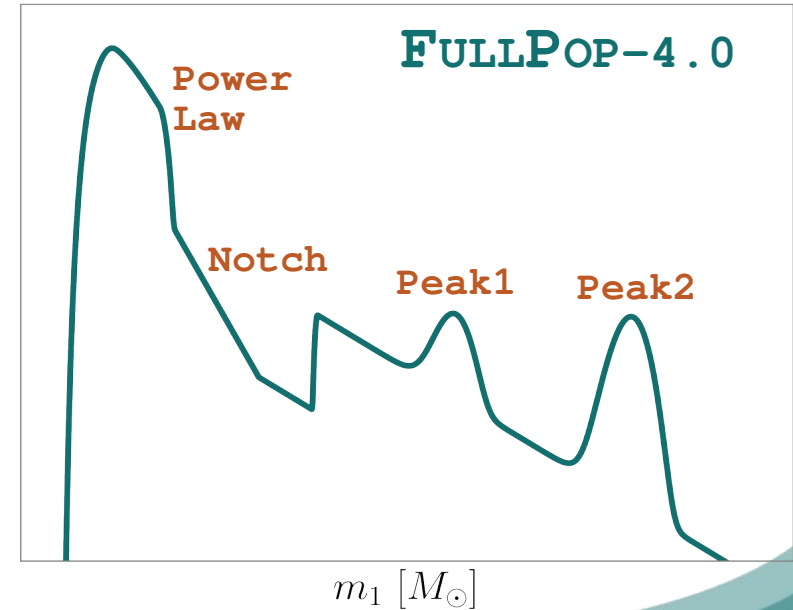
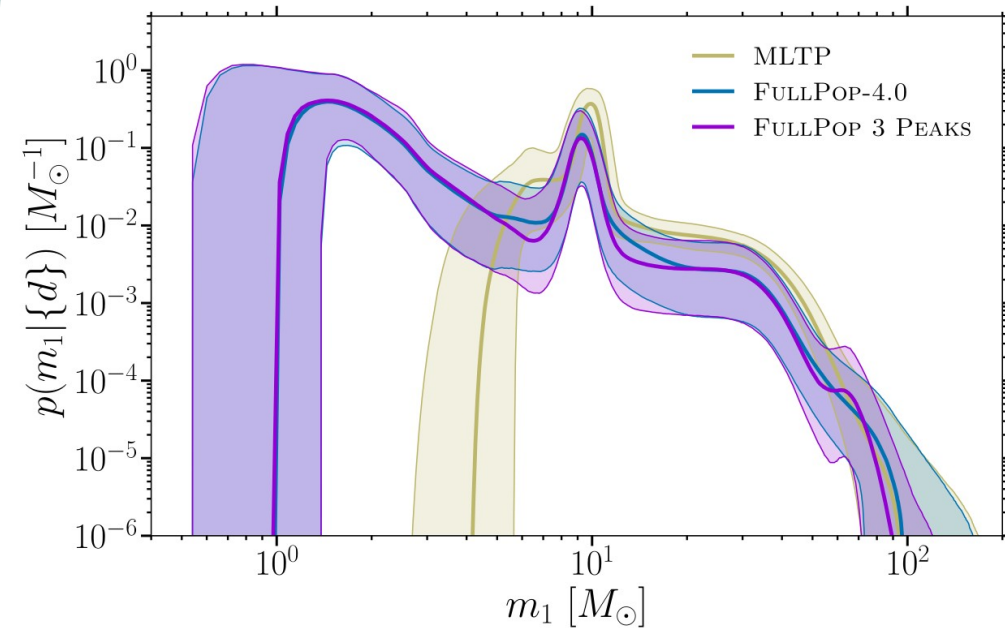
From CBCs to cosmology

/ Primary mass distribution

Inferred structures in source frame



Choice of structured model



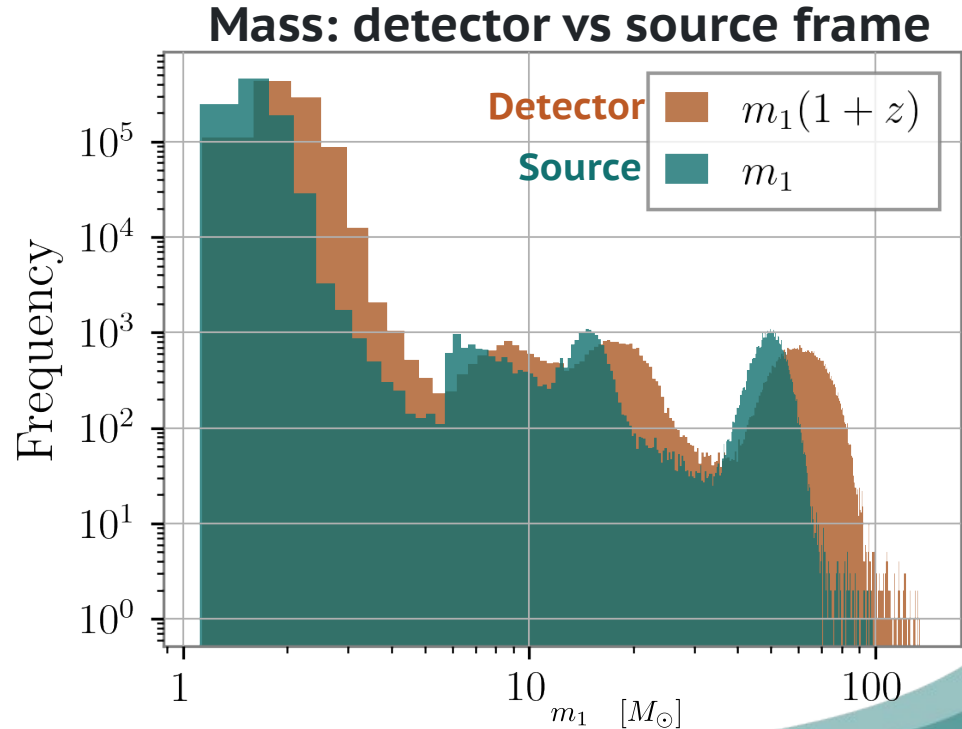
From CBCs to cosmology

/ Redshift inference from mass distribution

The mass spectrum has **certain structures**.

This knowledge helps us **constrain the potential values of redshift** and **break the mass-redshift degeneracy**.

*This source of constraints is designated as the “**spectral**” information*



Statistical Framework / Bayesian inference

$$\underbrace{\mathcal{L}(x_{\text{GW}}|\Lambda)}_{\text{Individual CBC Likelihood of observed data given the hyper-parameters}} \propto \int \underbrace{\mathcal{L}(x_{\text{GW}}|\theta, \Lambda)}_{\text{Likelihood of observed data given the true parameters}} \underbrace{p(z|\Lambda)}_{\text{Redshift prior}} \underbrace{p(\theta|\Lambda)}_{\text{Other population models}} dz d\theta$$

**Individual CBC
Likelihood of observed
data given the hyper-
parameters**
(cosmo, mass model
parameters, etc)

⇒ H_0 Expansion Rate

**Likelihood of
observed data
given the true
parameters**
(from PE)

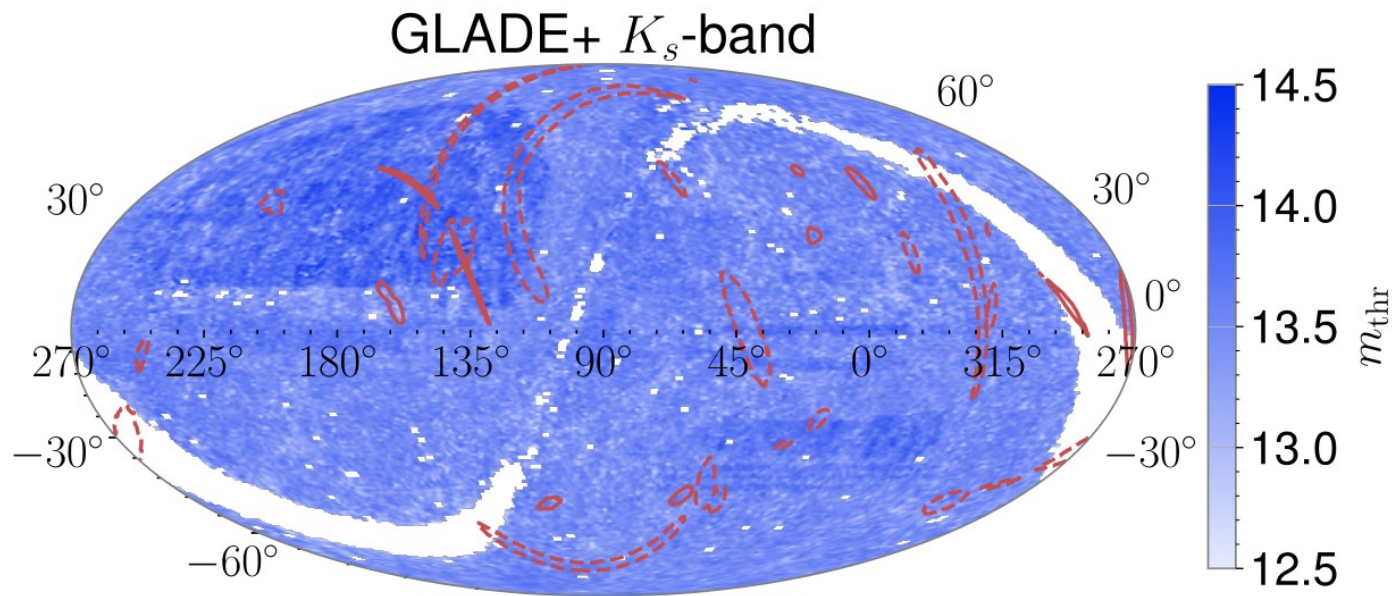
Redshift prior
(galaxy distribution,
merger rate)

⇒ Galaxy Catalog
information

**Other population
models**
(masses, spins...)

⇒ Spectral
information

Statistical Framework / Galaxy Catalogue



We can take the redshift prior uninformative (*uniform in comoving volume*) and only use the **spectral** information, or assume regions with **higher galaxy density are more likely to host CBCs**.

This is designated as the “dark sirens” information

Luminosity weighting for galaxies: $p(\text{CBC}|L) \propto L^\epsilon$

Results / analysis choices

236 CBCs selected with $i\text{FAR} > 4 \text{ yr}$

Mass models

- **MultiPeak** (*BBH Only*)
Power law + 2 peaks
- **FullPop-4.0** (*All CBCs*)
2 power laws + notch + 2 peaks
- **FullPop-3Peaks** (*All CBCs*)
2 power laws + notch + 3 peaks

Information included in $p(\theta|\Lambda)$

Redshift prior

Dark Sirens

- **GLADE+ K_s -band**
90% sky coverage. Low depth.
($9.9e5$ galaxies)
- **DES r -band**
13% sky coverage High depth.
($3.5e8$ galaxies)

Spectral Sirens

- **None**

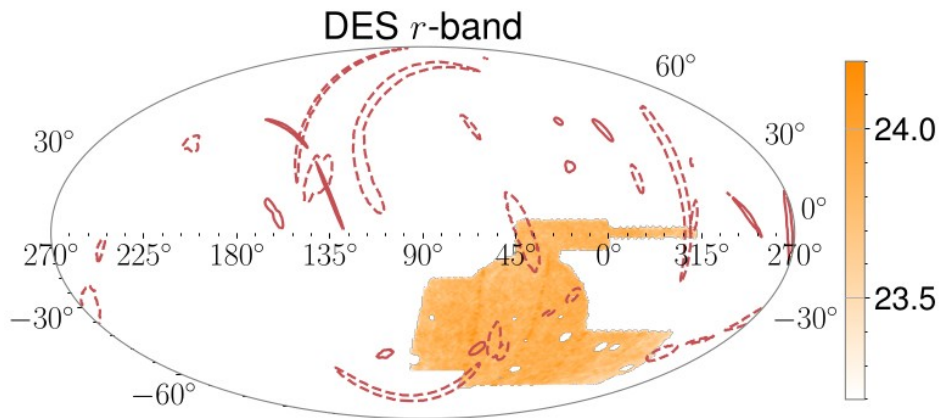
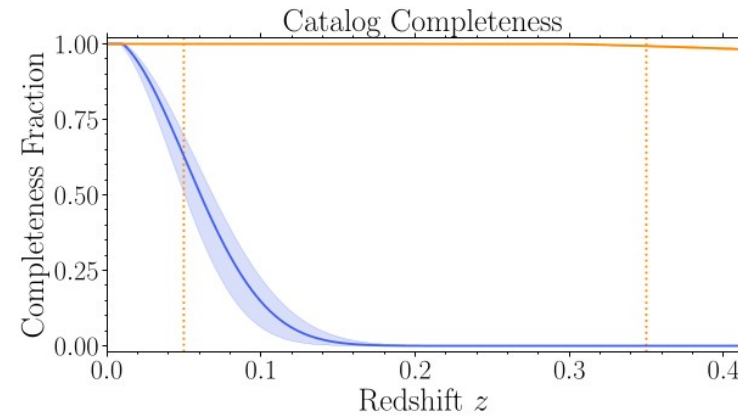
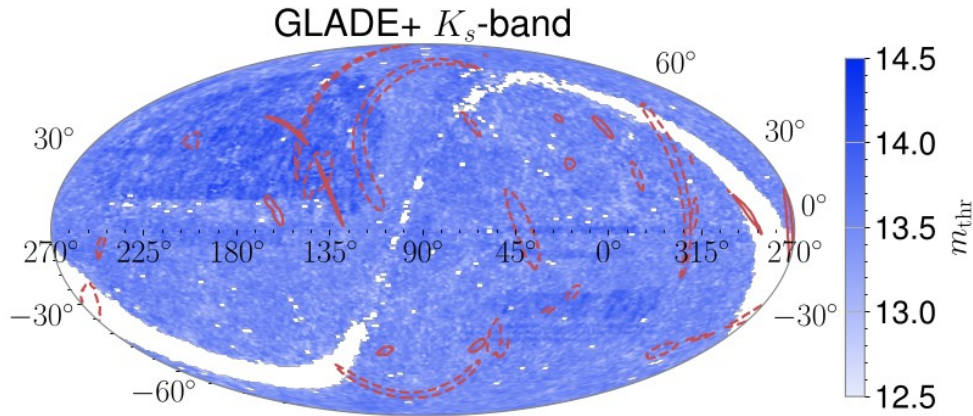
Uniform in comoving volume

Information included in $p(z|\Lambda)$

Analysis pipeline

- **gwcsmo**
Gray et al, JCAP 12 (2023) 023
Gray et al, MNRAS 512 (2022) 1127
- **icarogw**
Mastrogiovanni et al, A&A 682 (2024) A167
Mastrogiovanni et al, PRD, 104, 062009

Results / galaxy catalogs



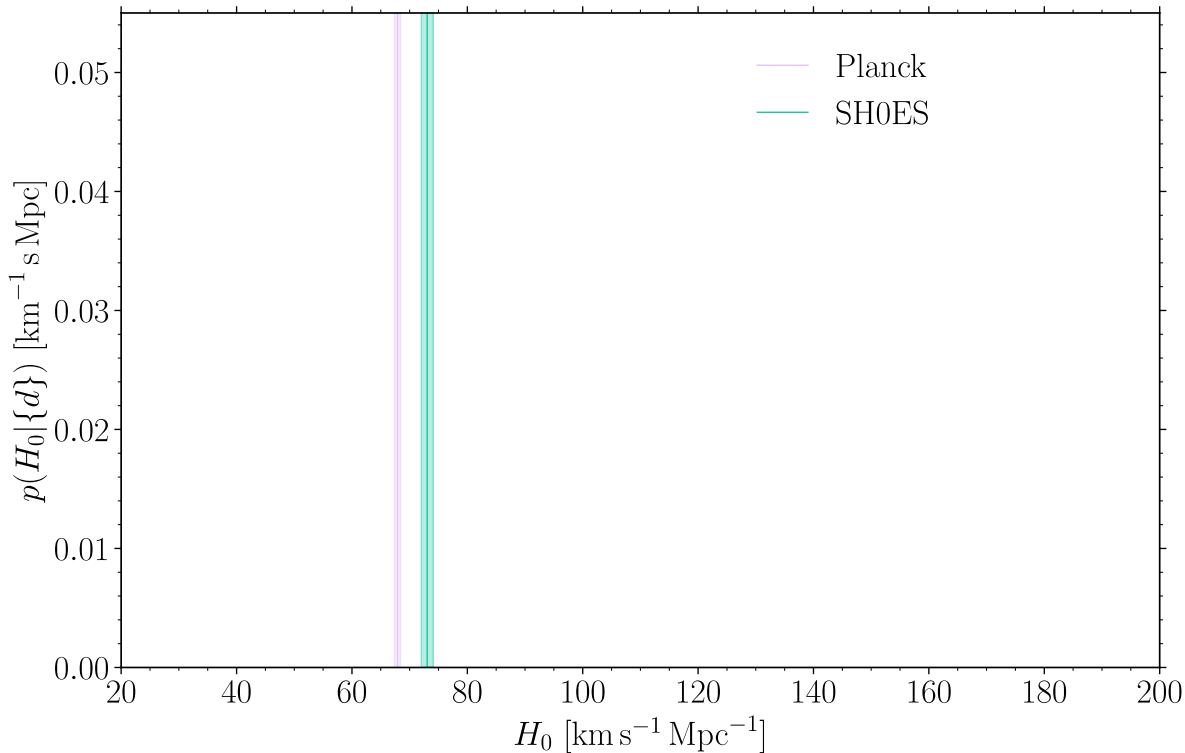
GLADE+ K_s -band

Better sky area coverage (90%), low depth.
Spectroscopic and photometric measurements.

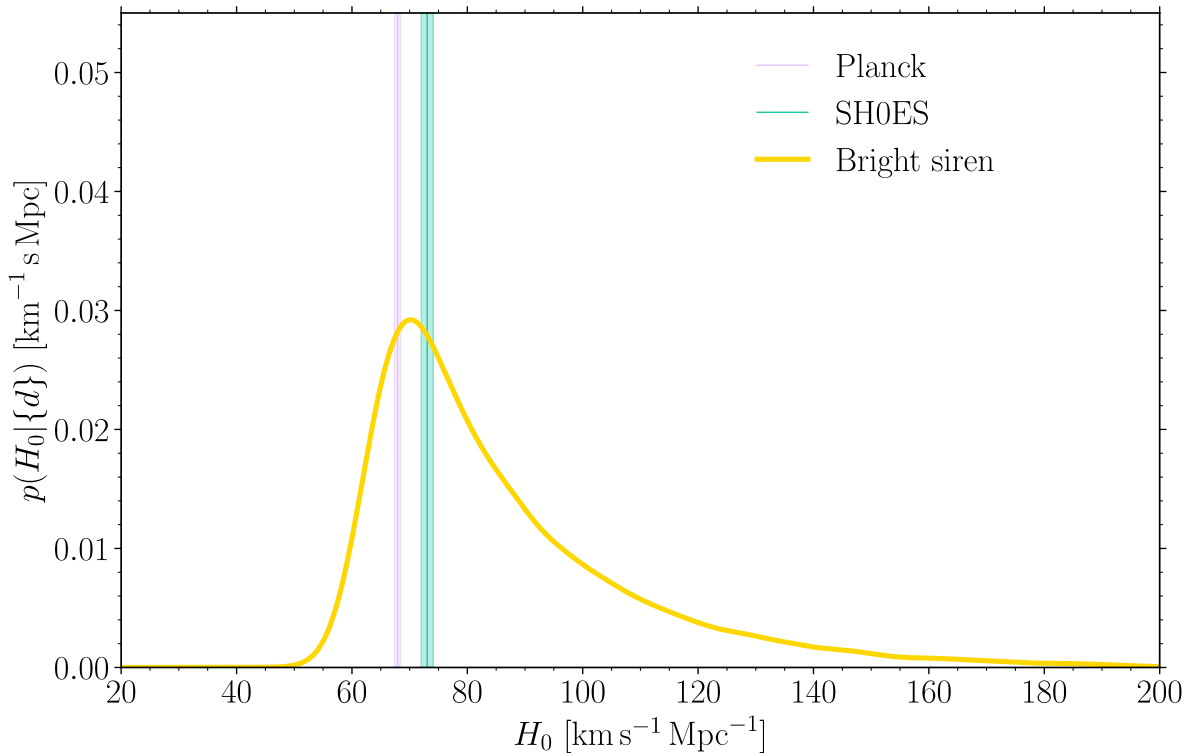
DES r -band

Small sky area coverage (13%), very deep.
Photometric measurements.

Results / H_0 posterior

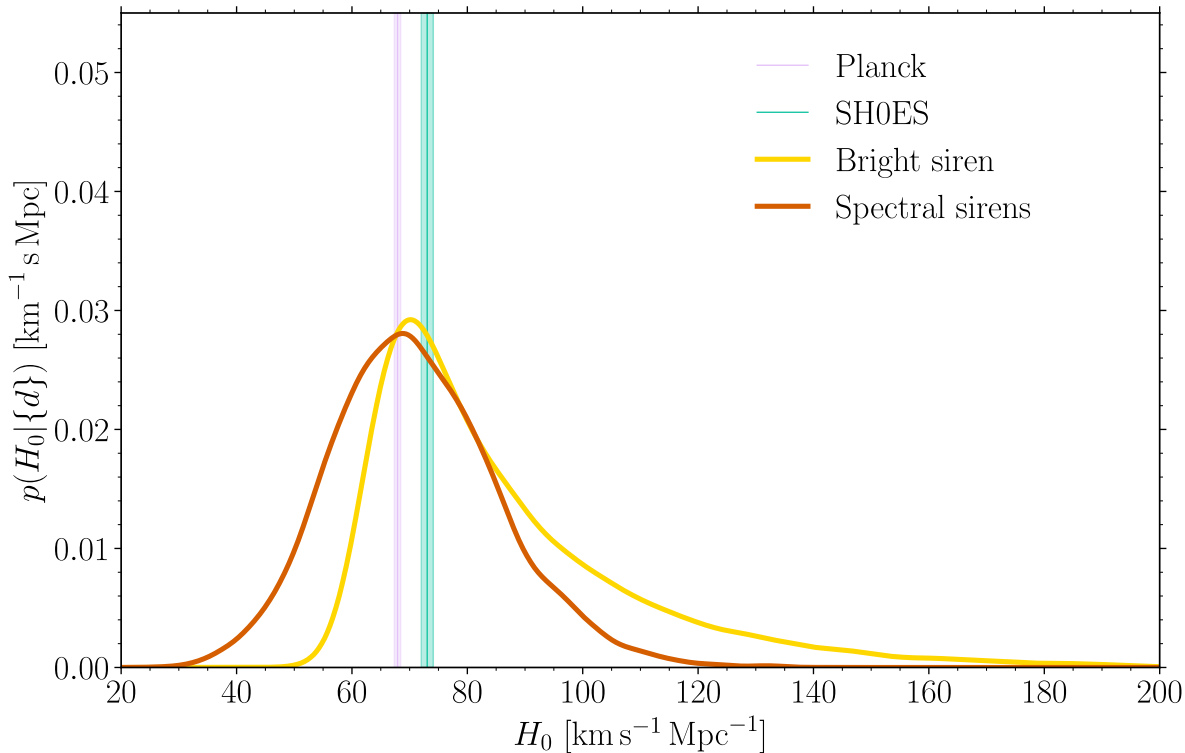


Results / H_0 posterior



$$H_0 = 79.1^{+27.6}_{-12.4} \text{ Bright Sirens}$$

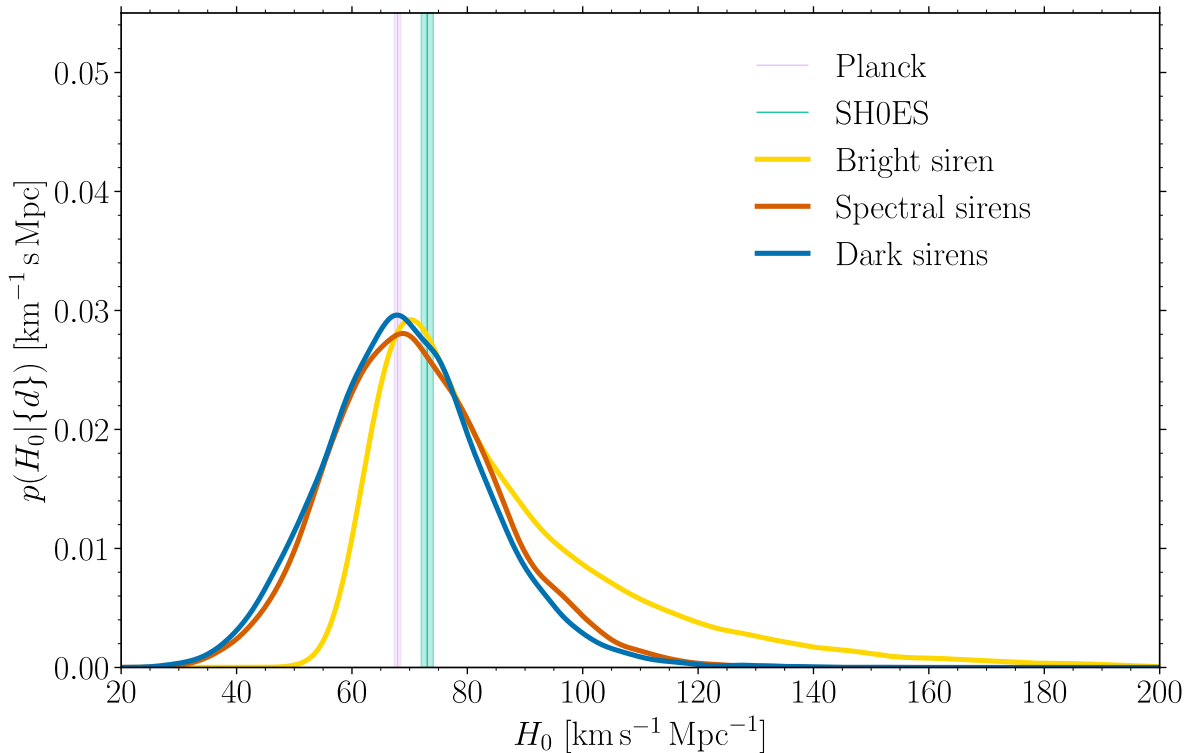
Results / H_0 posterior



$$H_0 = 68.8^{+14.2}_{-13.2} \text{ Spectral sirens}$$

$$H_0 = 79.1^{+27.6}_{-12.4} \text{ Bright siren}$$

Results / H_0 posterior

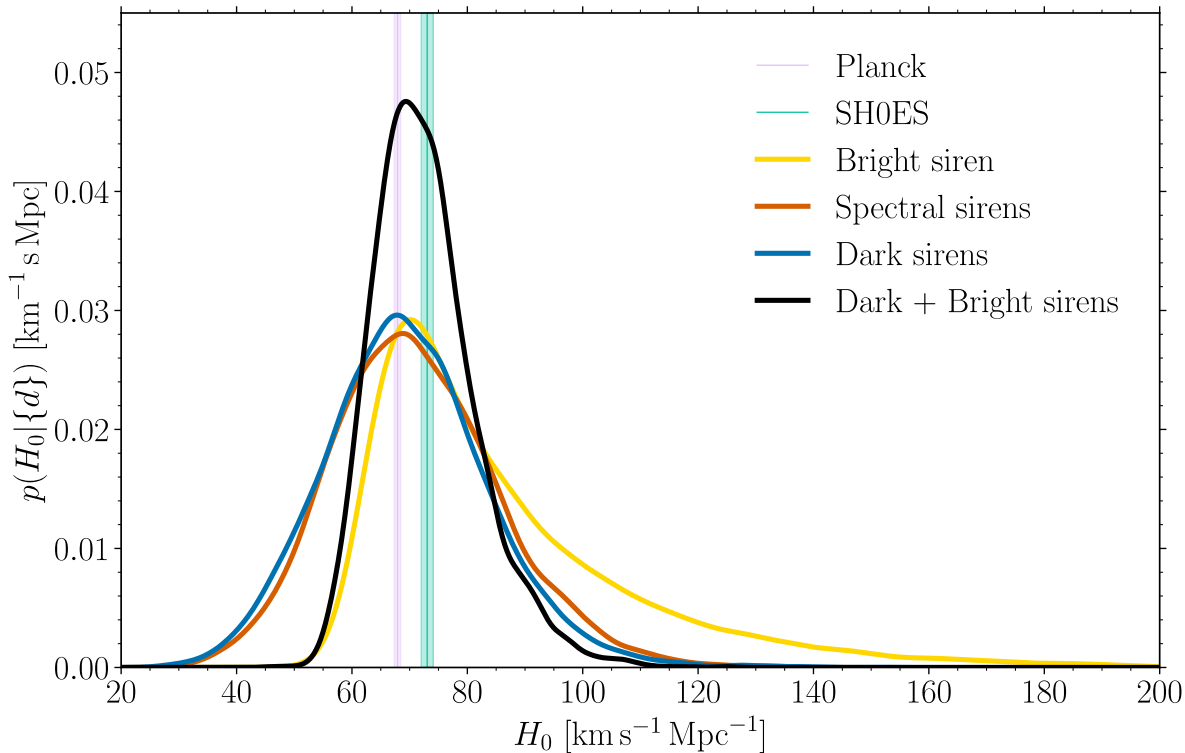


$$H_0 = 70.1^{+15.1}_{-13.3} \text{ Dark sirens DES}$$

$$H_0 = 68.8^{+14.2}_{-13.2} \text{ Spectral sirens}$$

$$H_0 = 79.1^{+27.6}_{-12.4} \text{ Bright siren}$$

Results / H_0 posterior



$$H_0 = 71.7^{+9.4}_{-7.5} \text{ km/s/Mpc}$$

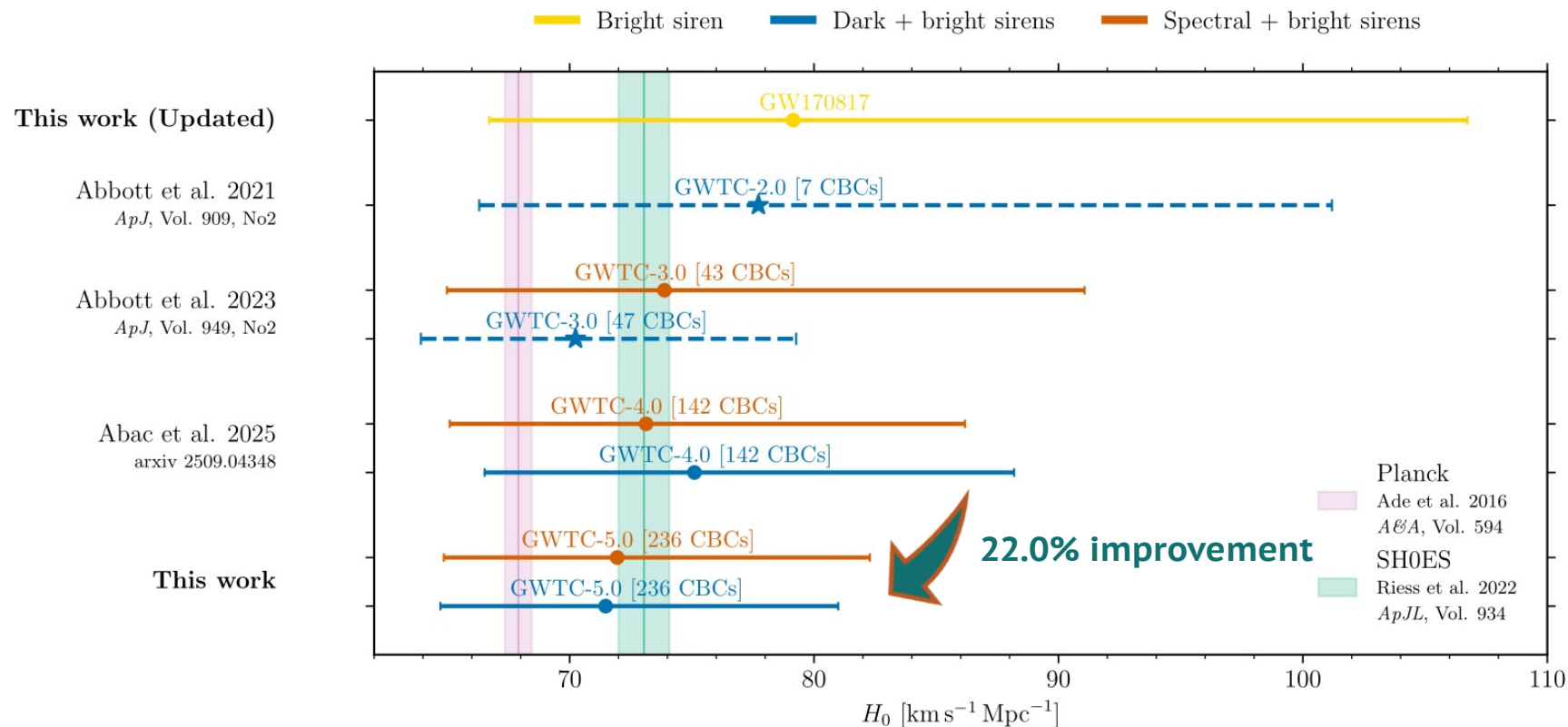
When combining the ***bright siren and the dark sirens with DES r-band galaxy catalogue***

$$H_0 = 70.1^{+15.1}_{-13.3} \text{ *Dark sirens DES*}$$

$$H_0 = 68.8^{+14.2}_{-13.2} \text{ *Spectral sirens*}$$

$$H_0 = 79.1^{+27.6}_{-12.4} \text{ *Bright siren*}$$

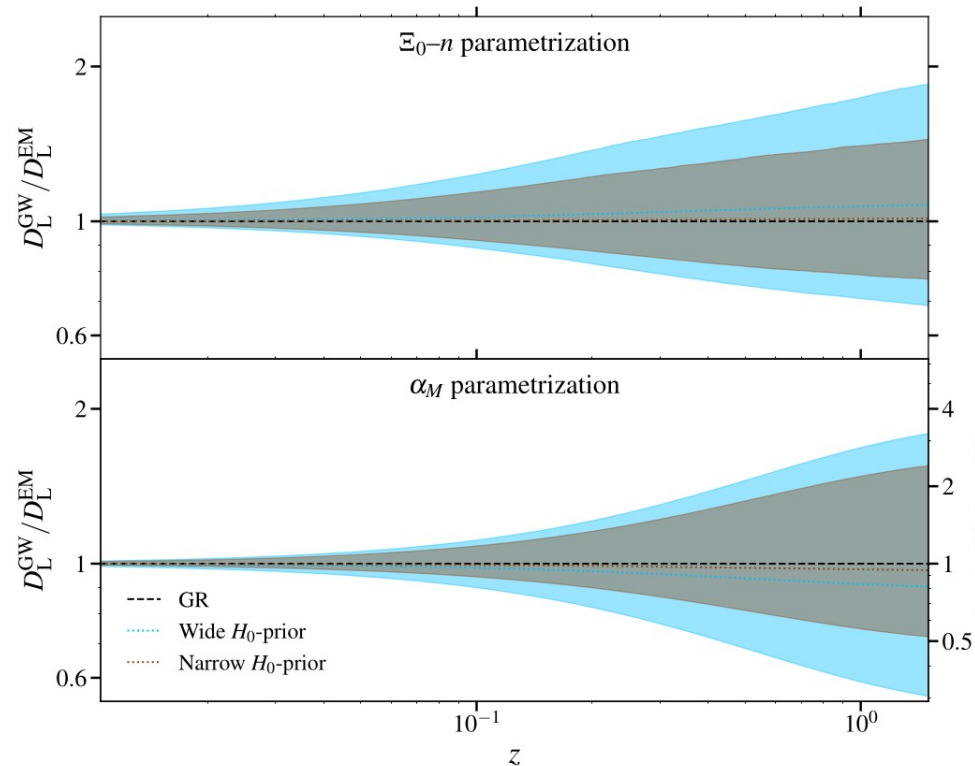
Results / H_0 posterior



Results / modified gravity

Modified gravity models predict different propagation for GW.
Therefore, GW do not propagate the same way than EM.

2 models:



$$D_L^{GW} = D_L^{EM} \left(\Xi_0 + \frac{1 - \Xi_0}{(1+z)^n} \right)$$

$$\Xi_0 = 1 \Leftrightarrow \text{GR}$$

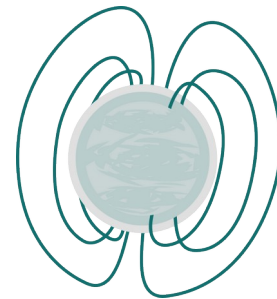
Horndeski, G. W. 1974, Int. J. Theor. Phys., 10, 363

$$D_L^{GW} = D_L^{EM} \exp \left(\frac{1}{2} \int_0^z \frac{dz'}{1+z'} \alpha_M \right)$$

$$\alpha_M = 0 \Leftrightarrow \text{GR}$$

Belgacem, E., et al. 2019b, JCAP, 07, 024

Conclusions



- **Fiducial mass model is** **FULLPOP-4.0** *(covering all CBCs, best constraint)*
- **Best constraint:** $H_0 = 71.7_{-7.5}^{+9.4} \text{ km/s/Mpc}$ *(22.0% improvement w.r.t. GWTC-4.0)*
- **No significant departure from General Relativity**
- **Next observing run: IR1 starting in November**

The background features a series of concentric, light gray circles centered on the text. Scattered around these circles are five stylized celestial objects: two black holes with accretion disks (one in the top-left and one in the bottom-right), two spiral galaxies (one in the top-center and one in the bottom-left), and one pulsar with concentric magnetic field loops (in the top-right).

Thank you

LIGO

LIGO Scientific Collaboration



This material is in part based upon work supported by NSF's LIGOLaboratory which is a major facility fully funded by the National Science Foundation

Cosmo parameters / mass model

FULLPOP-4.0		
Parameter	Description	Prior
α_1	Spectral index of the power law before b	$U(-4, 12)$
α_2	Spectral index of the power law after b	$U(-4, 12)$
β_1	Spectral index of the pairing function before m_{break}	$U(-4, 12)$
β_2	Spectral index of the pairing function after m_{break}	$U(-4, 12)$
m_{min}	Minimum primary and secondary mass [$M_{\odot}$]	$U(0.4, 1.4)$
m_{max}	Maximum primary and secondary mass [$M_{\odot}$]	$U(50, 200)$
$\delta_{\text{m}}^{\text{min}}$	1st smoothing parameter of the low mass [$M_{\odot}$]	$\text{LU}(10^{-2}, 1)$
$\delta_{\text{m}}^{\text{max}}$	2nd smoothing parameter of the low mass [$M_{\odot}$]	$\text{LU}(10^{-3}, 10)$
$\mu_{\text{g}}^{\text{low}}$	Location of the first peak [$M_{\odot}$]	$U(5, 150)$
$\sigma_{\text{g}}^{\text{low}}$	Width of the first peak [$M_{\odot}$]	$U(0.4, 10)$
$\mu_{\text{g}}^{\text{high}}$	Location of the second peak [$M_{\odot}$]	$U(5, 150)$
$\sigma_{\text{g}}^{\text{high}}$	Width of the second peak [$M_{\odot}$]	$U(0.4, 15)$
λ_{g}	Fraction of sources in peaks	$U(0, 1)$
$\lambda_{\text{g}}^{\text{low}}$	Fraction of sources in the first peak	$U(0, 1)$
$m_{\text{d}}^{\text{low}}$	Left side of the dip [$M_{\odot}$]	$U(1.5, 3)$
$m_{\text{d}}^{\text{high}}$	Right side of the dip [$M_{\odot}$]	$U(5, 9)$
$\delta_{\text{d}}^{\text{min}}$	Smoothing of the left side of the dip [$M_{\odot}$]	$\text{LU}(0.01, 2)$
$\delta_{\text{d}}^{\text{max}}$	Smoothing of the right side of the dip [$M_{\odot}$]	$\text{LU}(0.01, 2)$
A	Amplitude of the dip ($A = 1$; completely empty gap)	$U(0, 1)$

From GWTC-5.0: Constraints on the Cosmic Expansion Rate and Modified Gravitational-wave Propagation,

THE LIGO SCIENTIFIC COLLABORATION
THE VIRGO COLLABORATION ,
THE KAGRA COLLABORATION,
2026

arXiv:2605.27227v2

Cosmo parameters / merger rate model

Merger rate model

Parameter	Description	Prior
γ	Slope of the power law before the point z_p	$U(0, 12)$
κ	Slope of the power law after the point z_p	$U(0, 6)$
z_p	Redshift turning point between the power laws	$U(0, 4)$

From GWTC-5.0: Constraints on the Cosmic Expansion Rate and Modified Gravitational-wave Propagation,

THE LIGO SCIENTIFIC COLLABORATION
THE VIRGO COLLABORATION ,
THE KAGRA COLLABORATION,
2026

arXiv:2605.27227v2

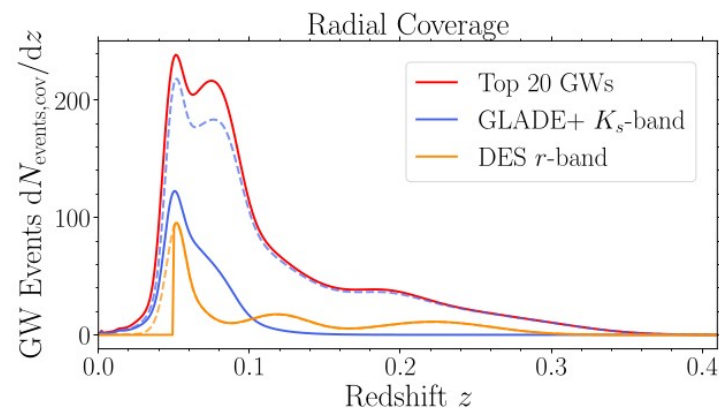
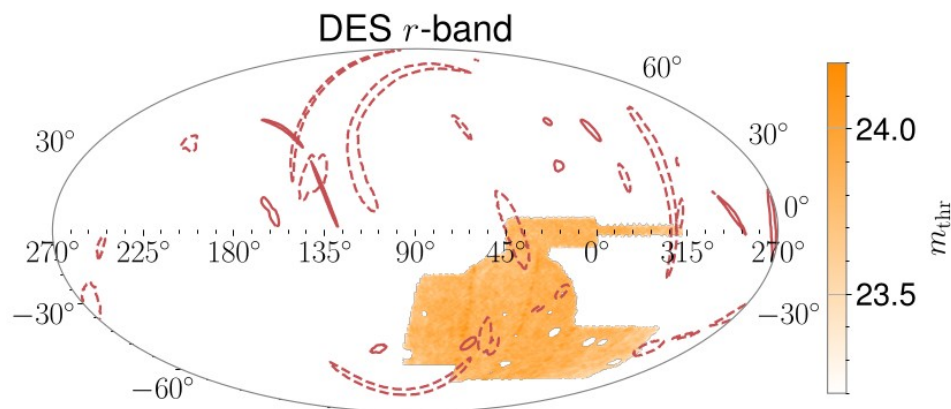
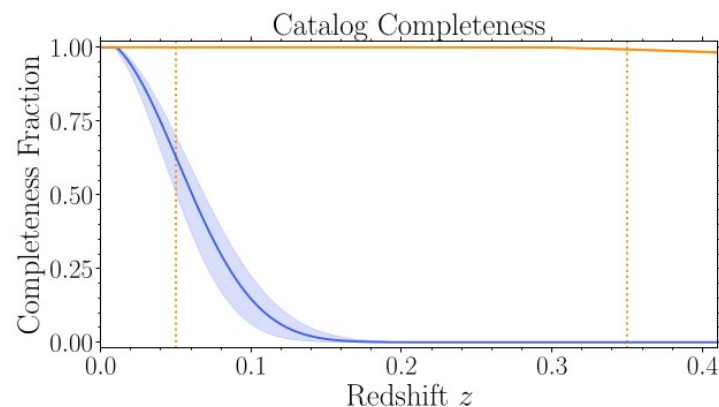
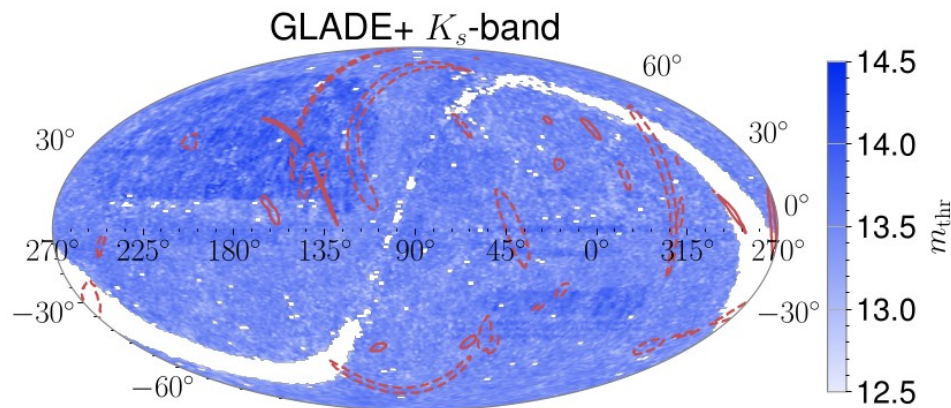
Statistical Framework / Bayesian inference

$$\mathcal{L}(x_{GW}|\Lambda) \propto \int \mathcal{L}(x_{GW}|\theta, \Lambda) p(z|\Lambda) p(\theta|\Lambda) dz d\theta$$

$$p(\Lambda|\{x_{GW}\}) \propto p(\Lambda) p(N_{det}|\Lambda) \prod_i^{N_{det}} \mathcal{L}(x_{GW_i}|\Lambda)$$



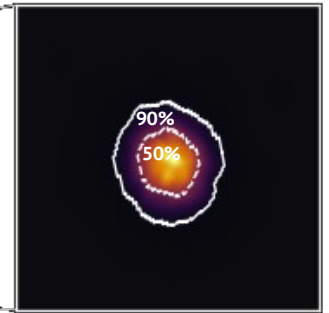
Statistical Framework / galaxy catalog



GWTC-5.0 / notable events

GW240615_113620

90% credible interval:
 6.24 deg^2



Best GW-only sky localization so far

$$m_1 = 34.0^{+5.4}_{-3.7} M_{\odot} \quad m_2 = 26.4^{+4.0}_{-4.8} M_{\odot} \quad D_L = 1.56^{+0.29}_{-0.45} \text{ Gpc} \quad SNR = 23.8^{+0.1}_{-0.2}$$

GWTC-5.0 / notable events

GW250114_082203: loudest event ever measured

$$m_1 = 33.76_{-0.9}^{+1.28} M_{\odot} \quad m_2 = 32.26_{-1.47}^{+0.96} M_{\odot} \quad D_L = 400_{-70}^{+80} \text{ Mpc} \quad SNR = 62.9_{-1.1}^{+1.0}$$

GW241011_233834: unequal mass BH and closest event of O4b

$$m_1 = 19.5_{-2.0}^{+2.6} M_{\odot} \quad m_2 = 5.96_{-0.58}^{+0.58} M_{\odot} \quad D_L = 210_{-40}^{+40} \text{ Mpc} \quad SNR = 35.8_{-0.1}^{+0.1}$$

Impact of analysis choices

