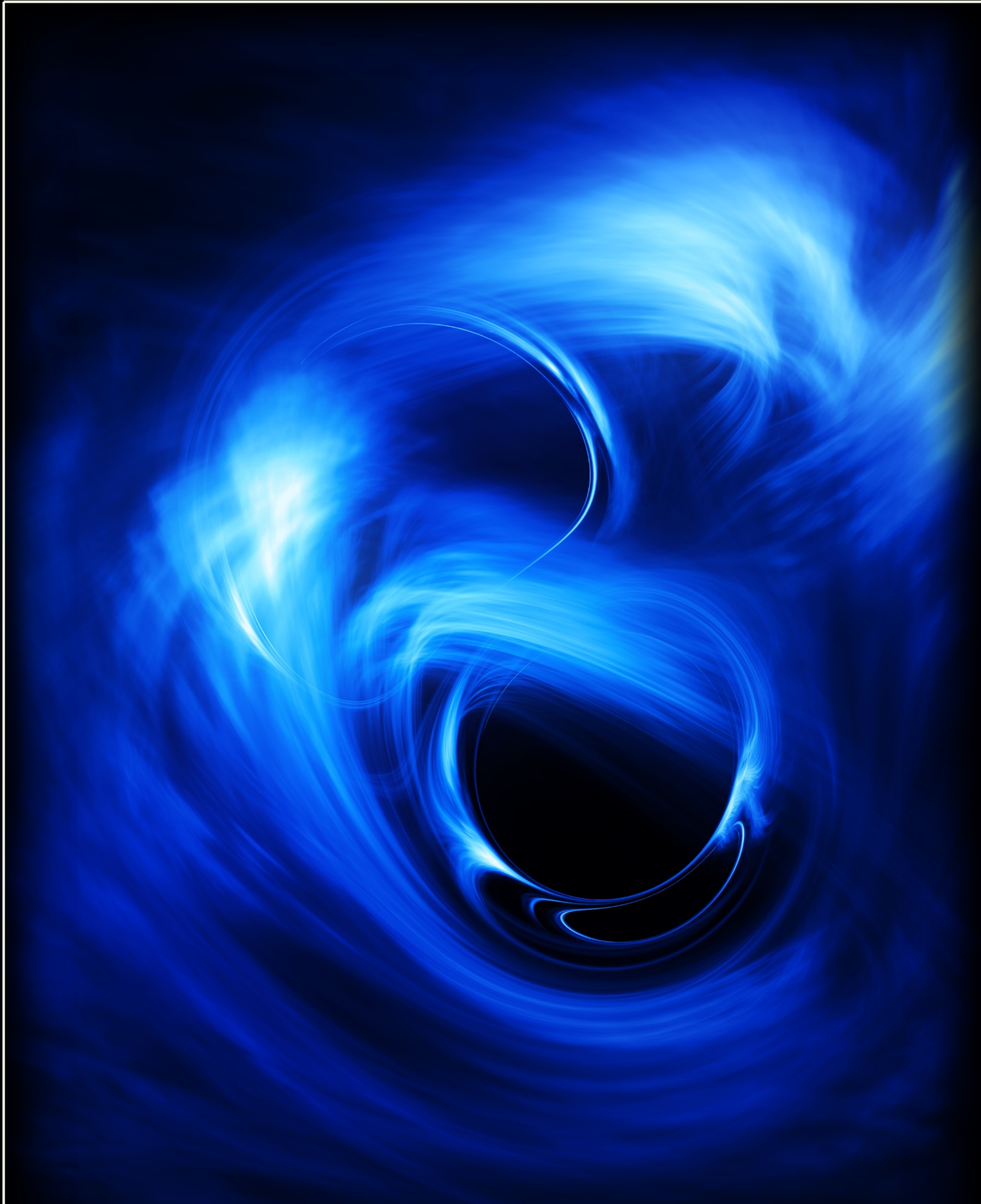


Numerical simulation of highly spinning black holes merging

Black Holes and Gravitational-Wave Cosmology

Grégoire Pierra

Postdoc Researcher
INFN, Sezione di Roma, Italy

Nov, 26th 2025

PhD Seminars

INFN Istituto Nazionale di Fisica Nucleare

LIGO VIRGO KAGRA

GravitySirens

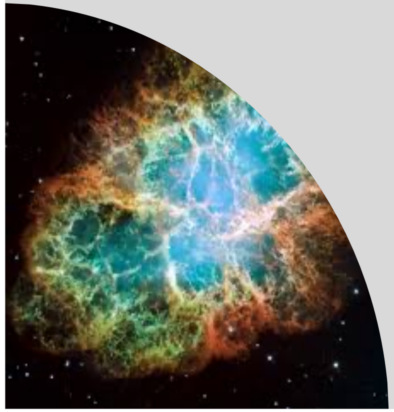
Funded by the European Union

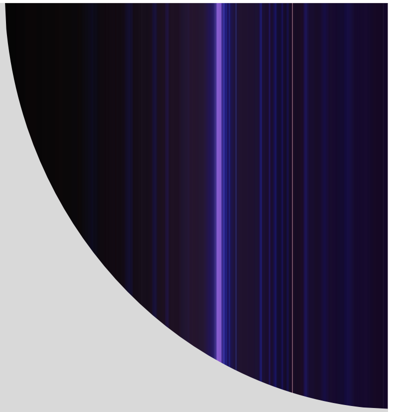
erc European Research Council
Established by the European Commission

Gravitational Waves Sources

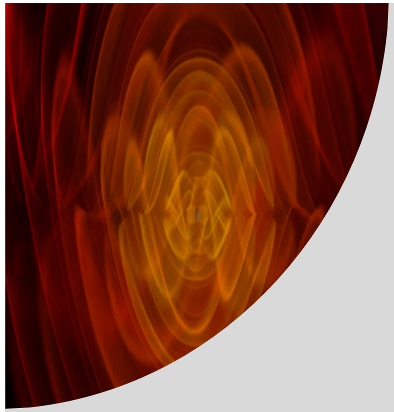
The cool ones

Too short (Bursts)





Too long (continuous source)

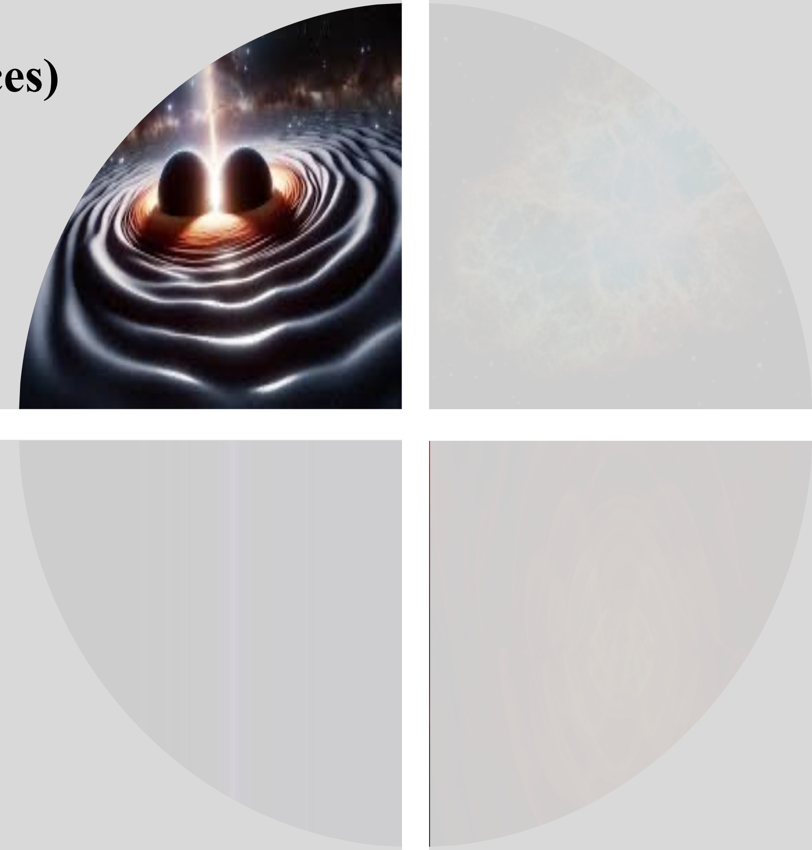


Too chaotic (stochastic background)

Gravitational Waves Sources

The cool ones
(Compact binary coalescences)

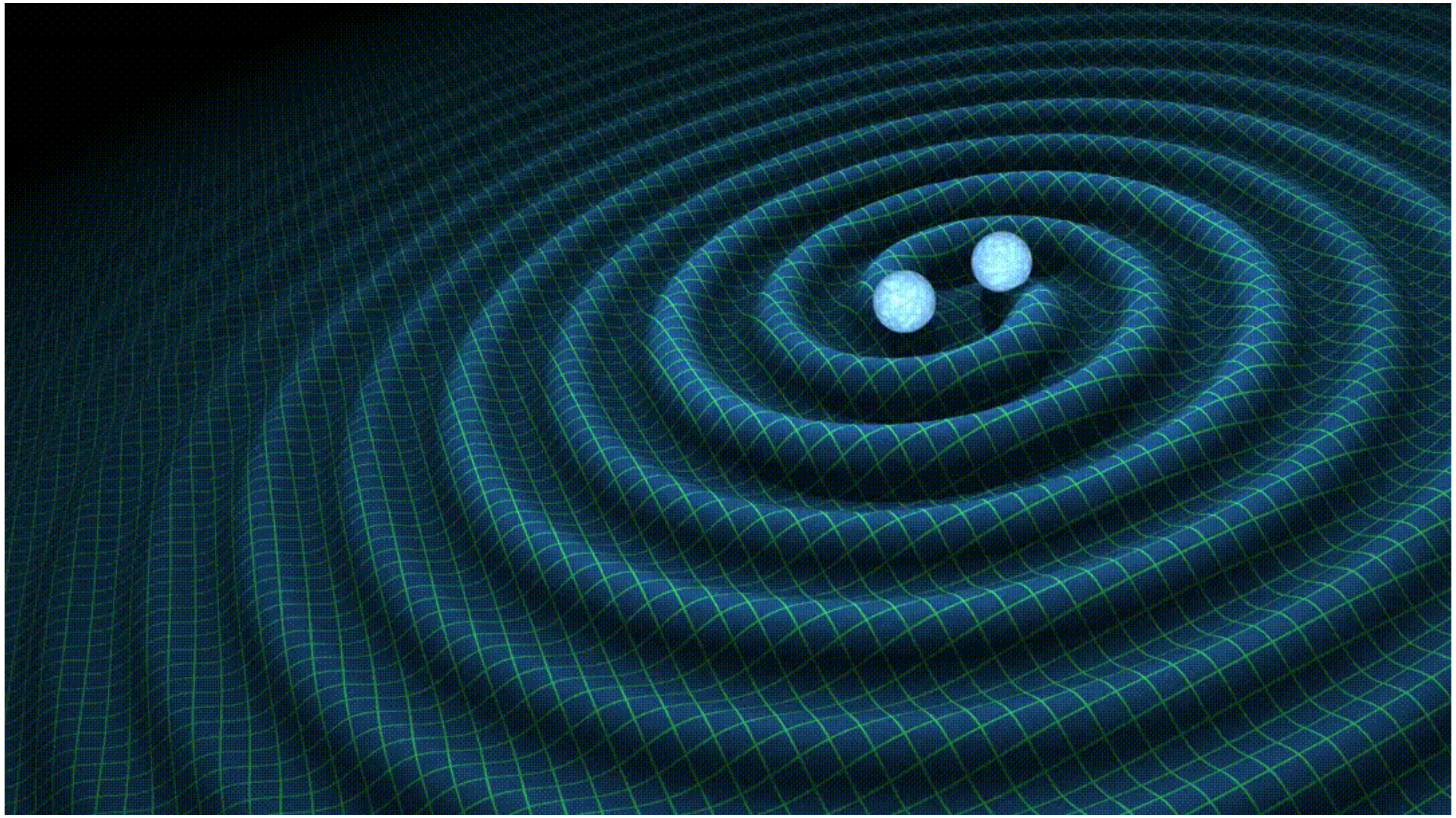
Too short
(Bursts)



Too long
(continuous source)

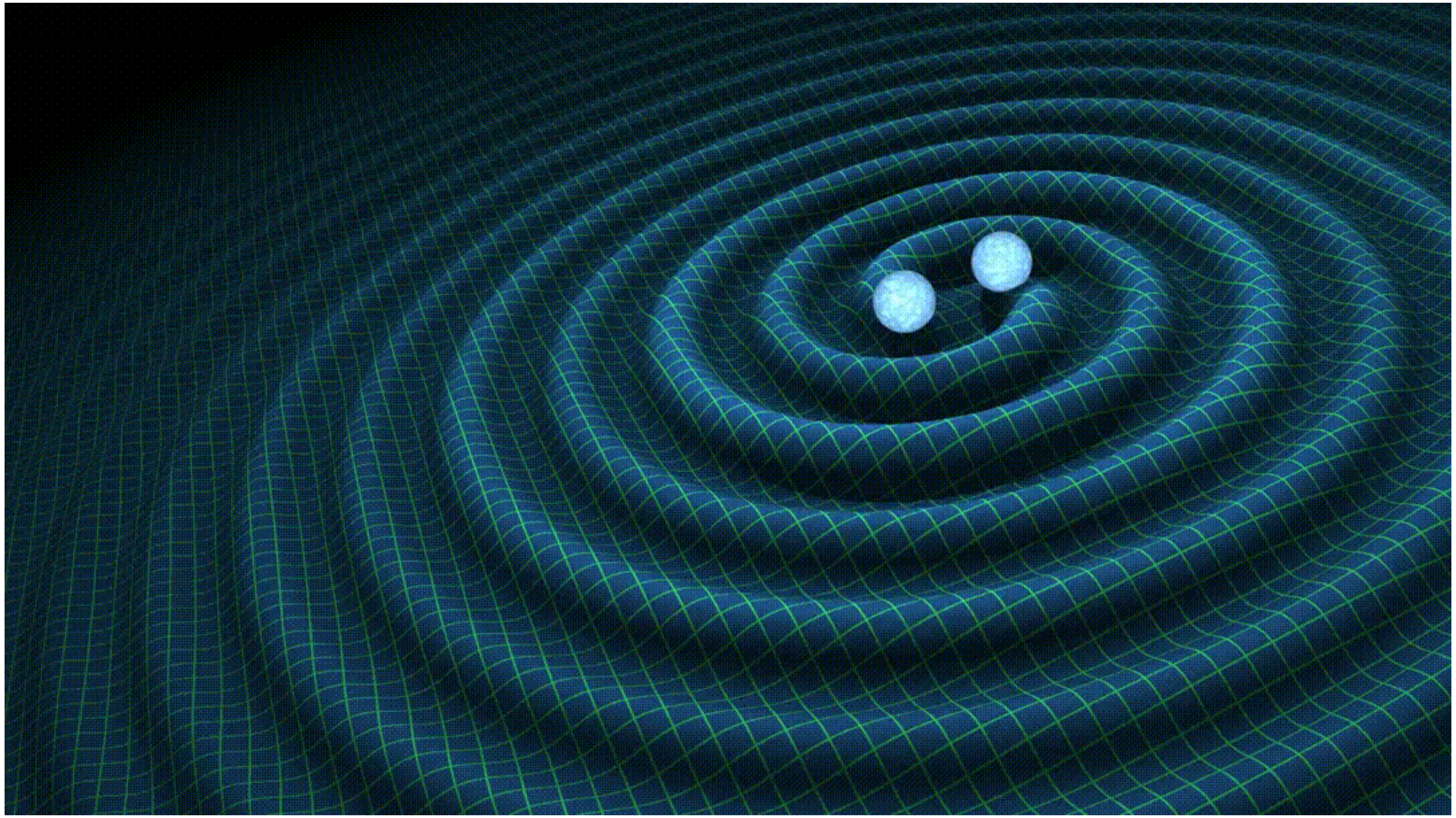
Too chaotic
(stochastic
background)

Gravitational Waves



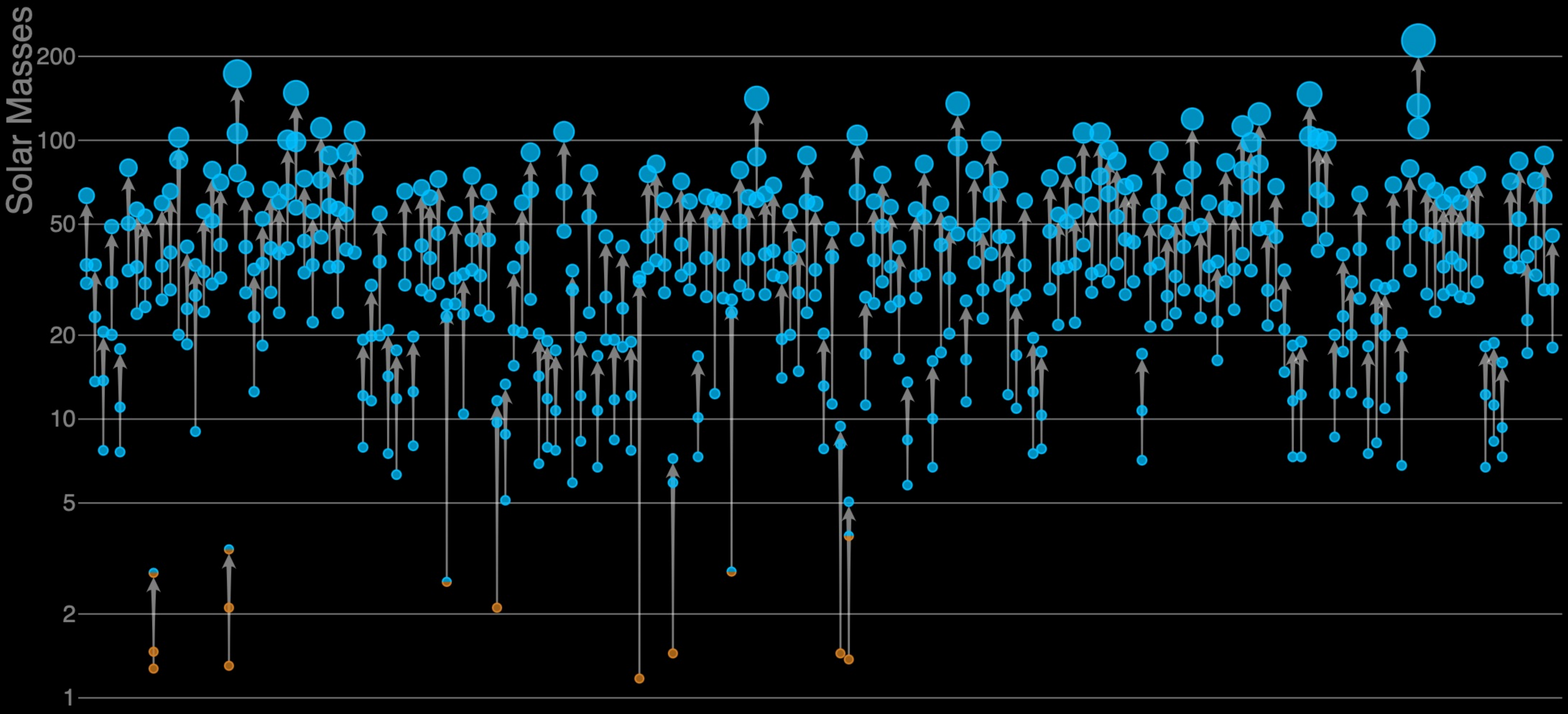
Ripples of the structure of space-time ⟶

Gravitational Waves



Ripples of the structure of space-time $\longrightarrow$ Detectable deformation on Earth.

As of today

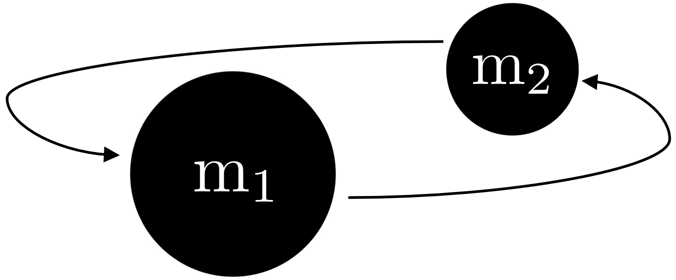


Aaron Geller - Northwestern

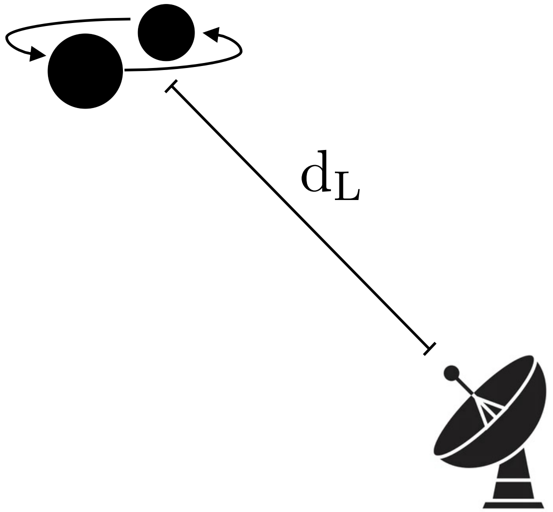
Properties of the source

From these detected signals, you can learn

How massive ?

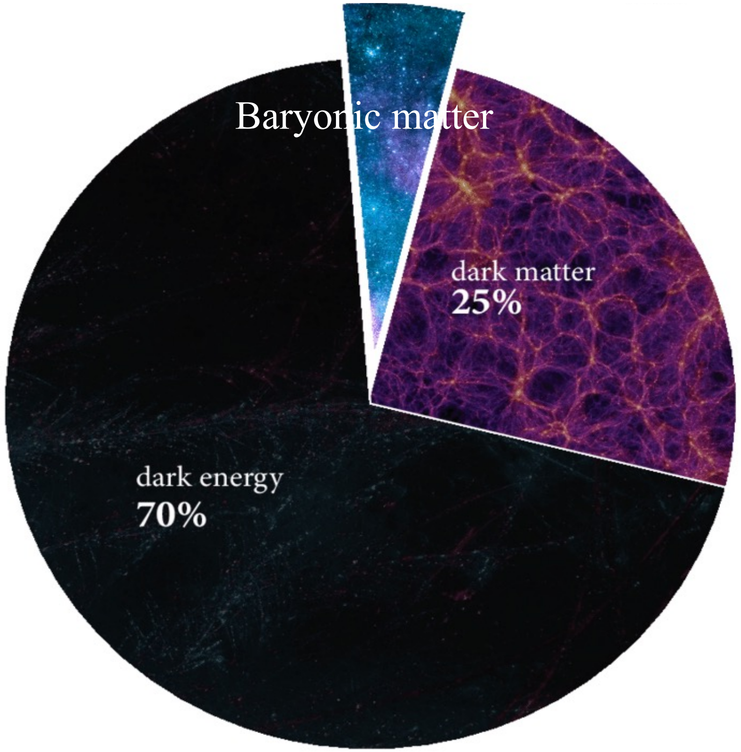


How far ?



Cosmology

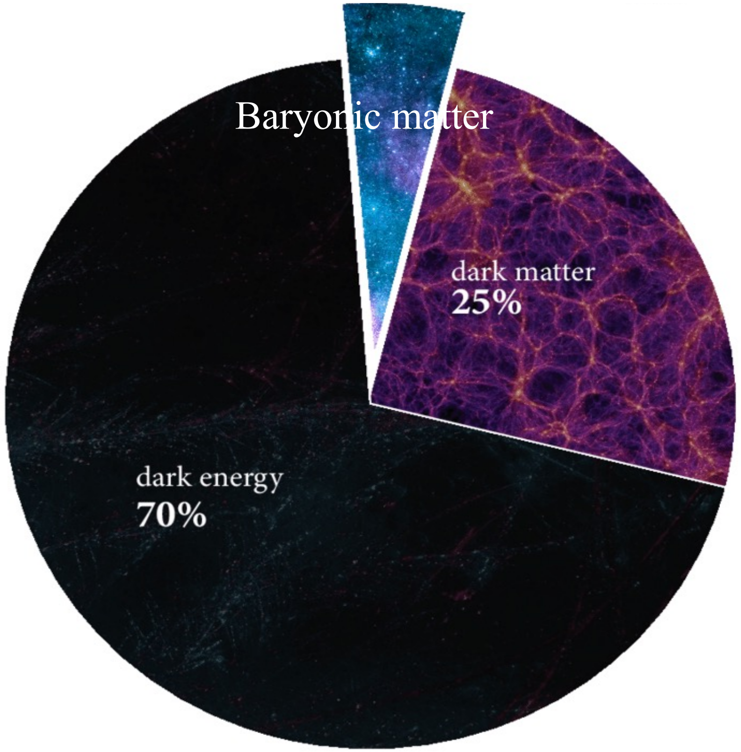
What about the Universe's content ?



DOI: 10.15488/12103

Cosmology

What about the Universe's content ?



Observations tell us: "You barely understand 5% of the Universe."

DOI: 10.15488/12103

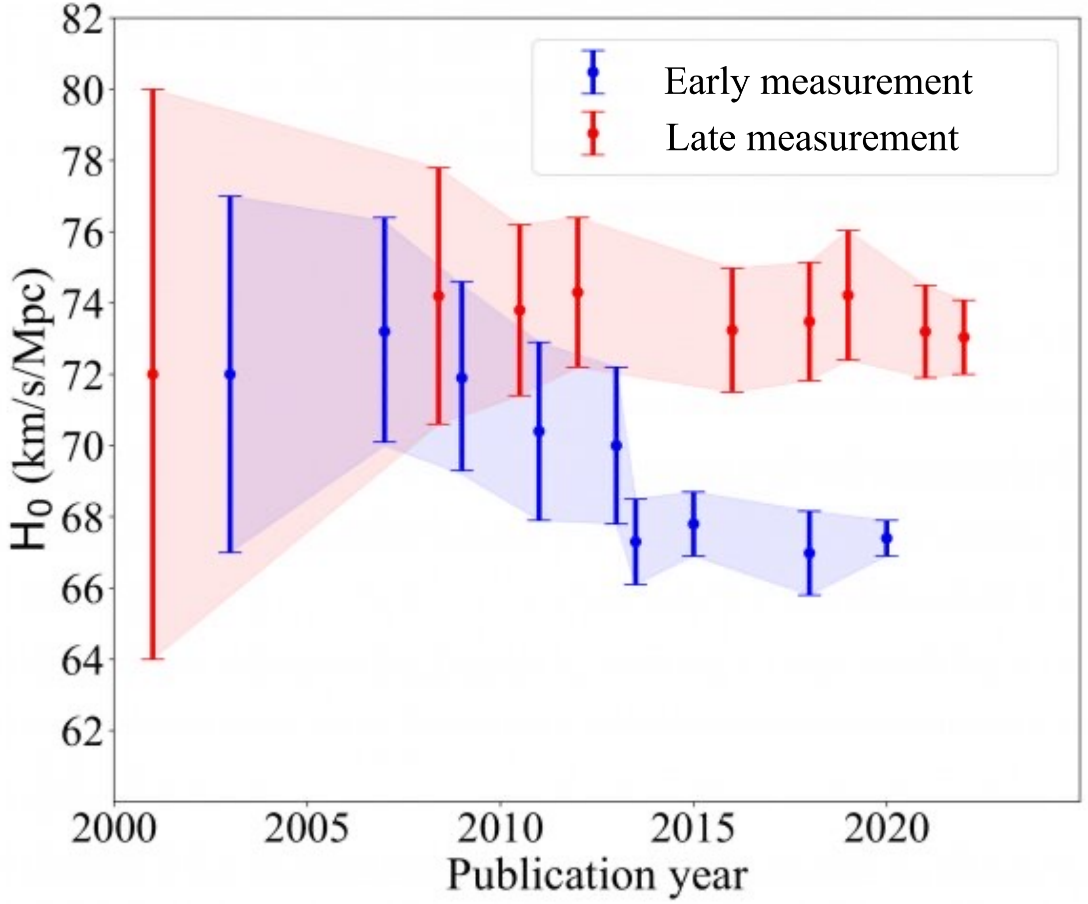
Cosmology

It’s dynamics maybe ?

Cosmology

H_0 : The Hubble constant – How fast the Universe is expanding today.

It's dynamics maybe ?

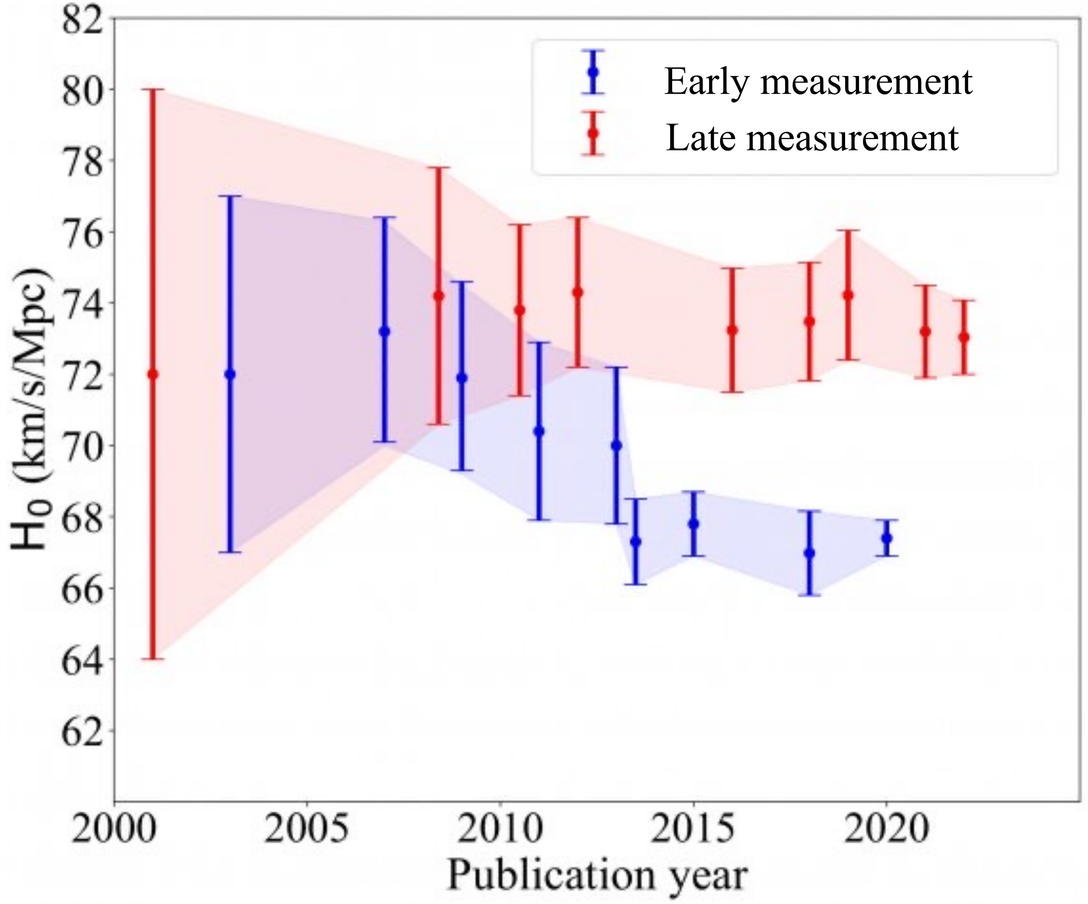


arXiv:2403.18902

Cosmology

H_0 : The Hubble constant – How fast the Universe is expanding today.

It's dynamics maybe ?

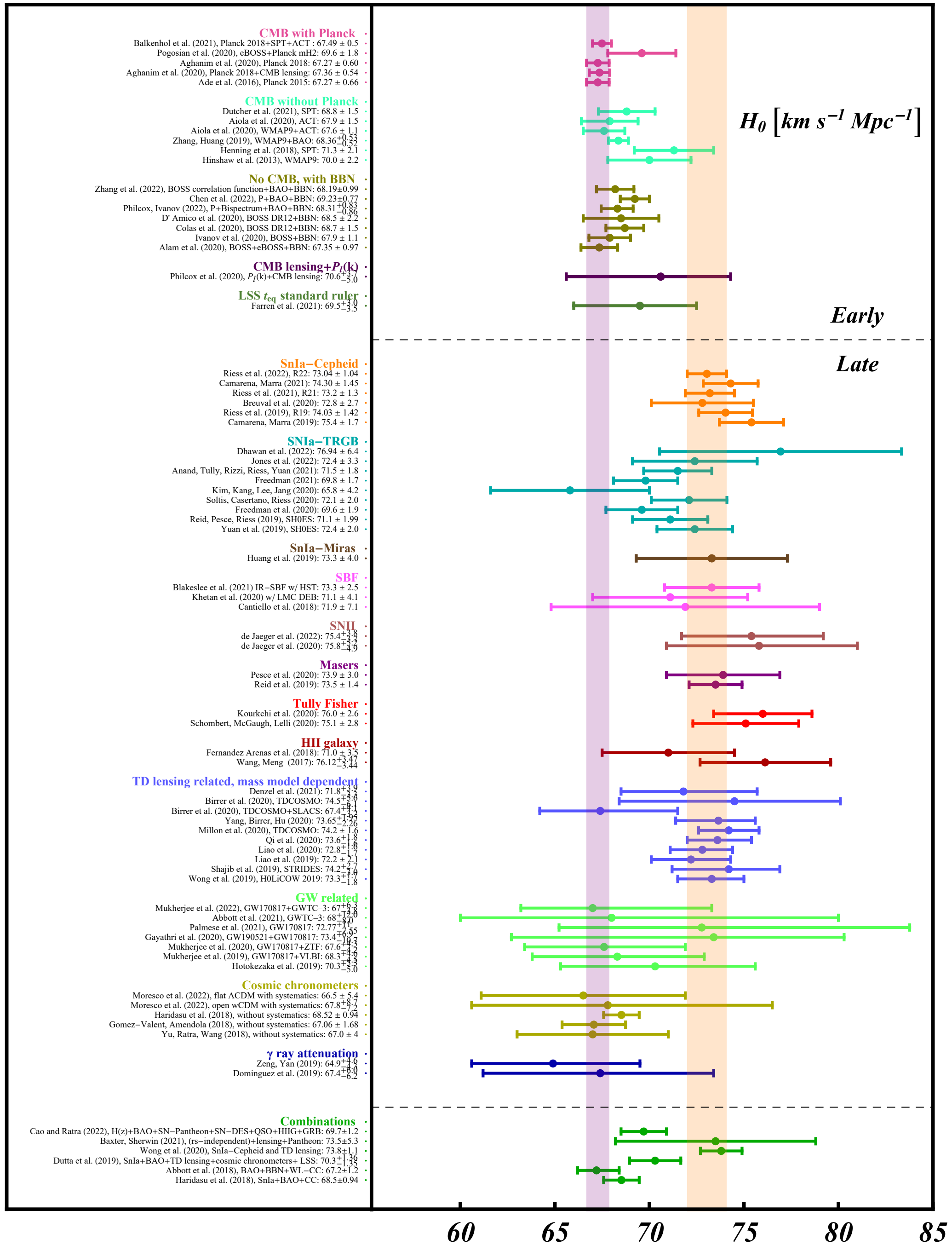


Observations tell us: "You can't even agree on that."

arXiv:2403.18902

Cosmology

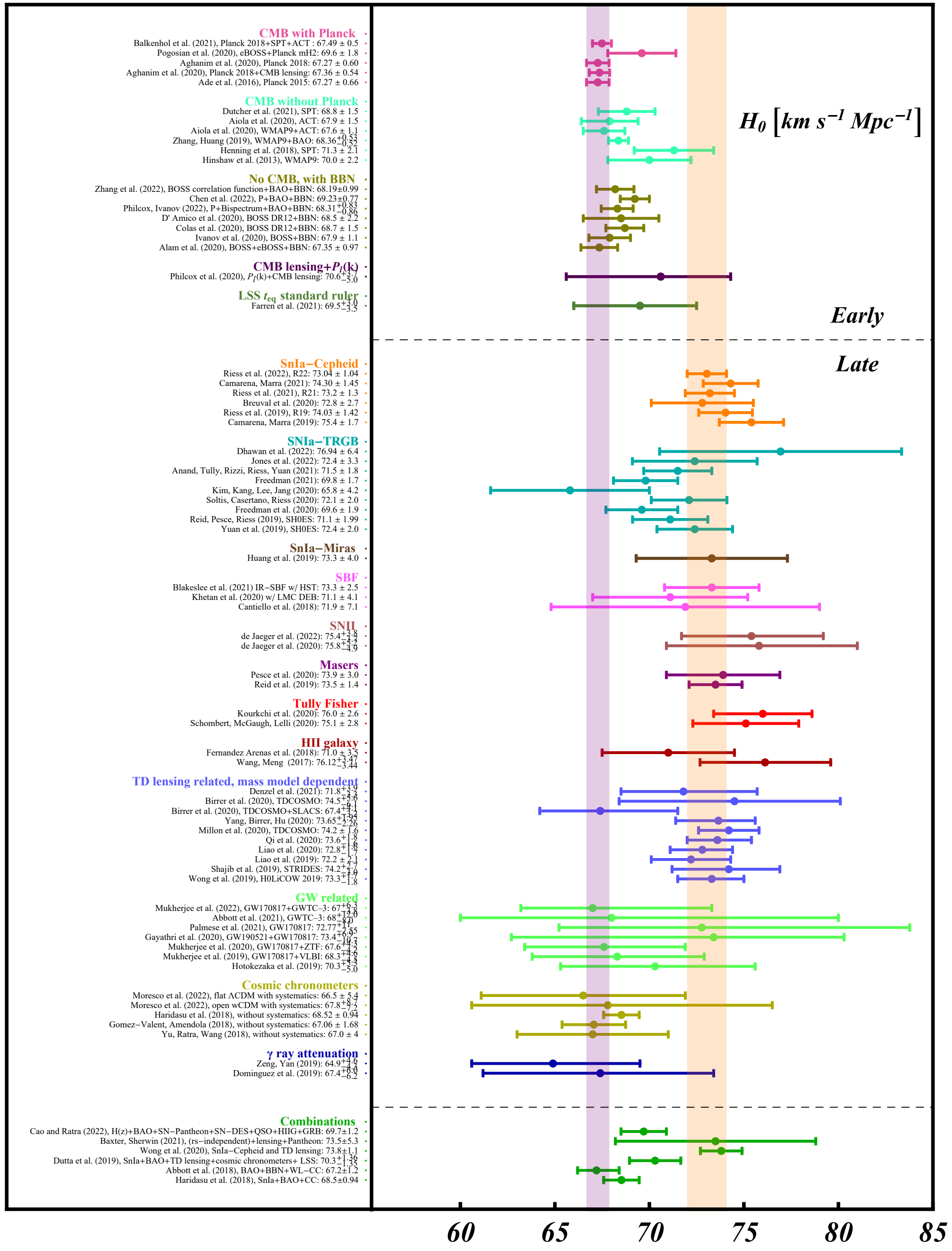
Actually, it's even worse...



arXiv:2105.05208

Cosmology

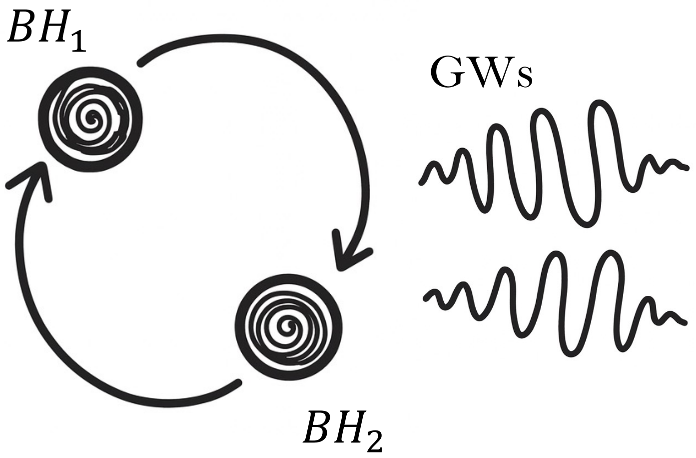
Actually, it's even worse...

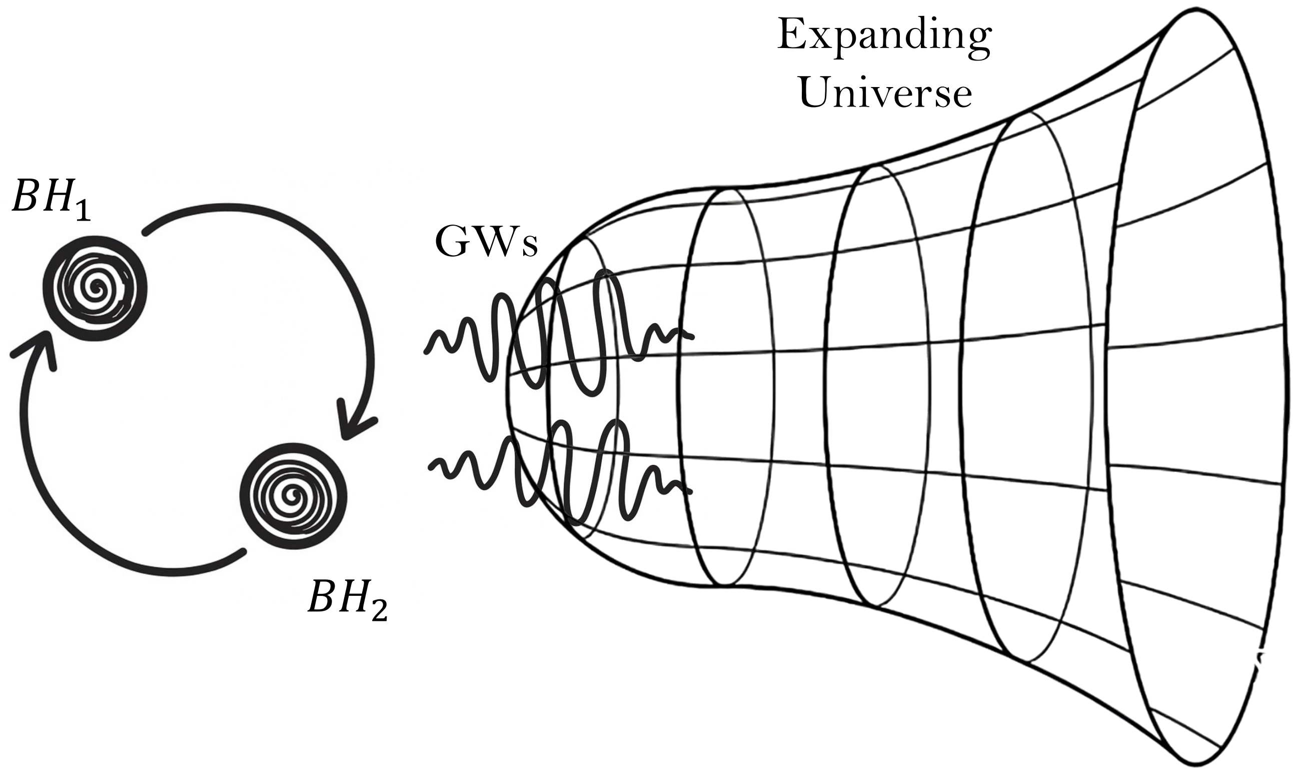


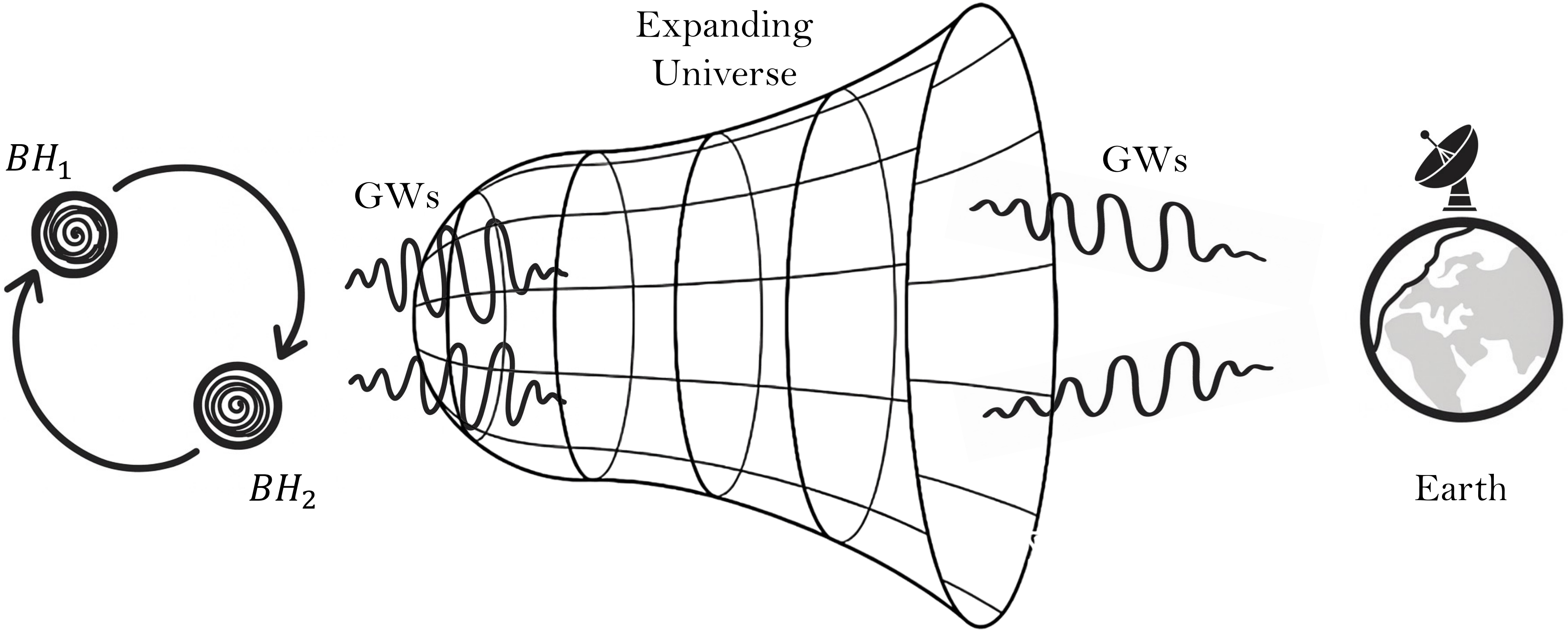
The Hubble tension

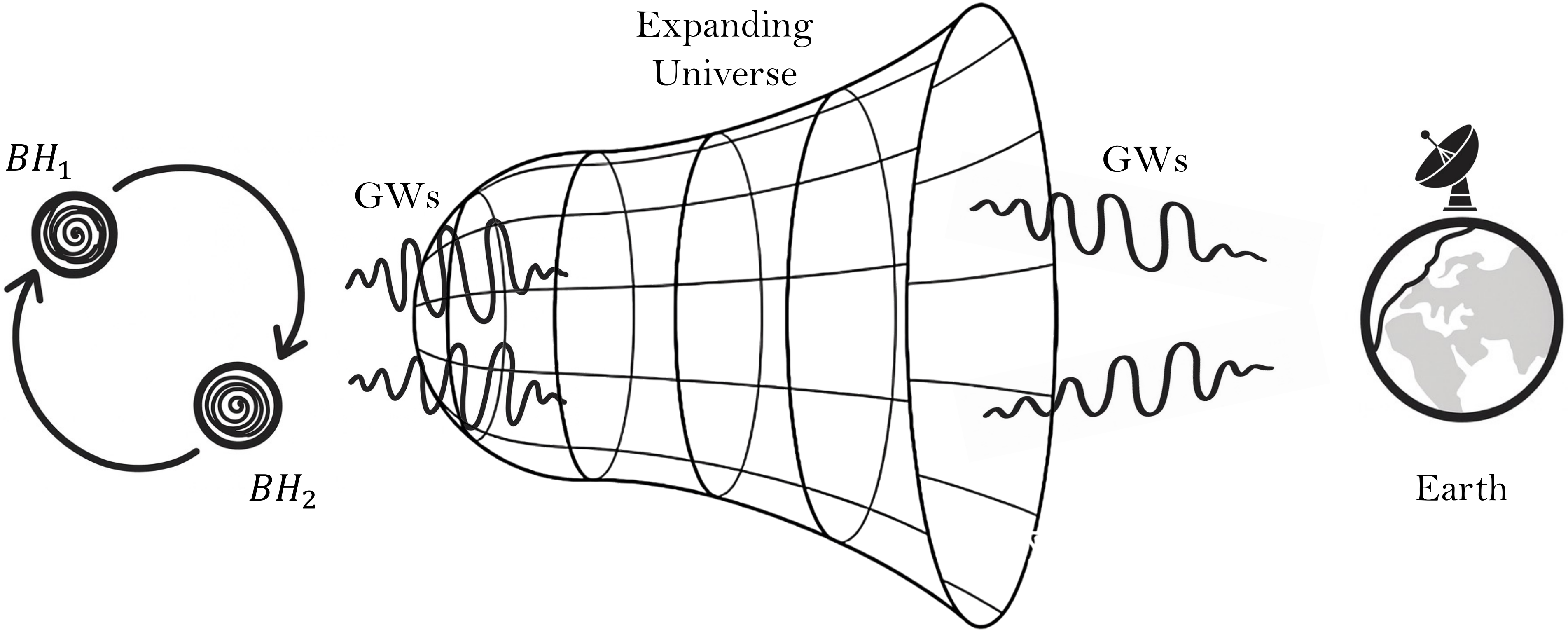
arXiv:2105.05208

Can we learn something new from GWs ?


BH_1
GWs
BH_2


Expanding
Universe
BH_1
GWs
BH_2

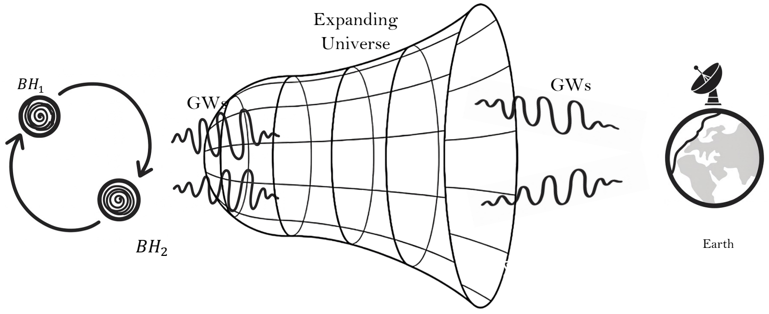

BH_1
BH_2
GWs
Expanding
Universe
GWs
Earth



What we detect is not exactly what was emitted, it’s been **redshifted** by the Universe’s expansion.

$$\mathrm{m}^{\mathrm{det}} = (1 + \mathrm{z})\mathrm{m}^{\mathrm{source}}$$

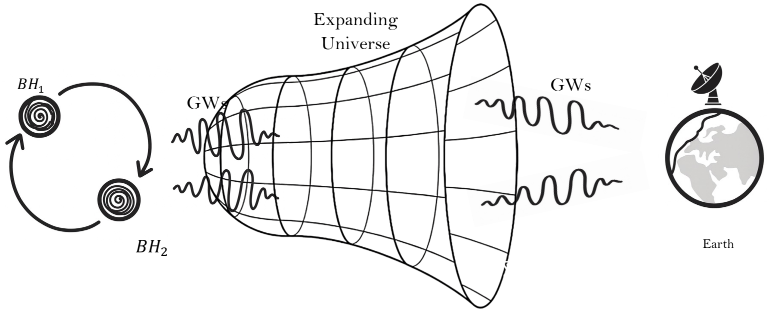
GW cosmology



$$\mathrm{m}^{\mathrm{det}} = (1+\mathrm{z})\mathrm{m}^{\mathrm{source}}$$

GW cosmology

From the standard model of cosmology



$$\mathrm{m}^{\mathrm{det}} = (1+\mathrm{z})\mathrm{m}^{\mathrm{source}}$$

Measured from the GW signal

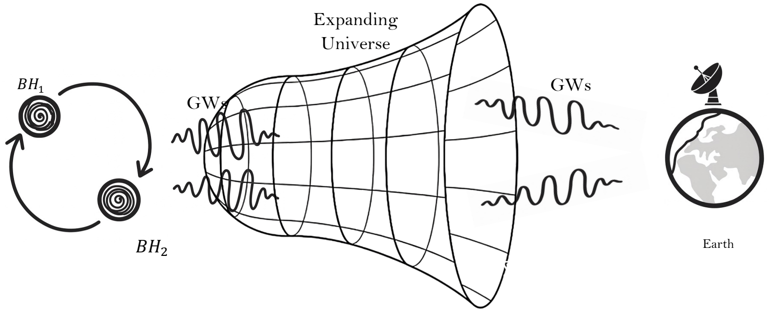
$$\boxed{d_{\mathrm{L}} \simeq \frac{c}{H_0} z}$$

Obtained from the mass-redshift relation

Speed of the Universe expansion

GW cosmology

From the standard model of cosmology



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Measured from the GW signal

$$\boxed{d_{\mathrm{L}} \simeq \frac{c}{H_0} z}$$

Obtained from the mass-redshift relation

Speed of the Universe expansion

"Spectral Siren" approach

Results

With 142 detected GW signals, from black-hole coalescences

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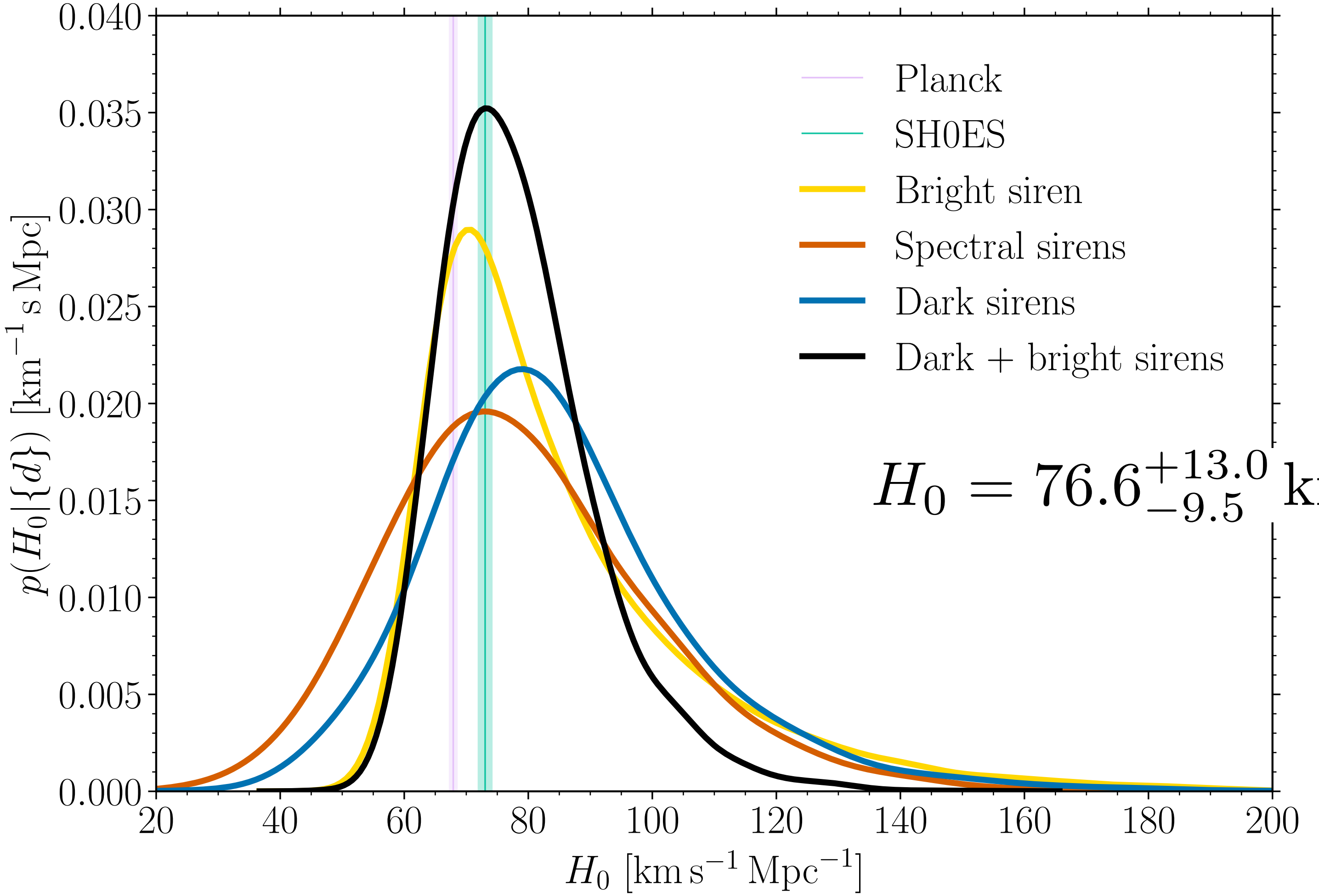
With 142 detected GW signals, from black-hole coalescences



$$H_0 = 76.6^{+13.0}_{-9.5}\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$$

(68% symmetric credible interval)

arXiv.2509.04348

Results

- Spectral sirens are at the center of GW cosmology.

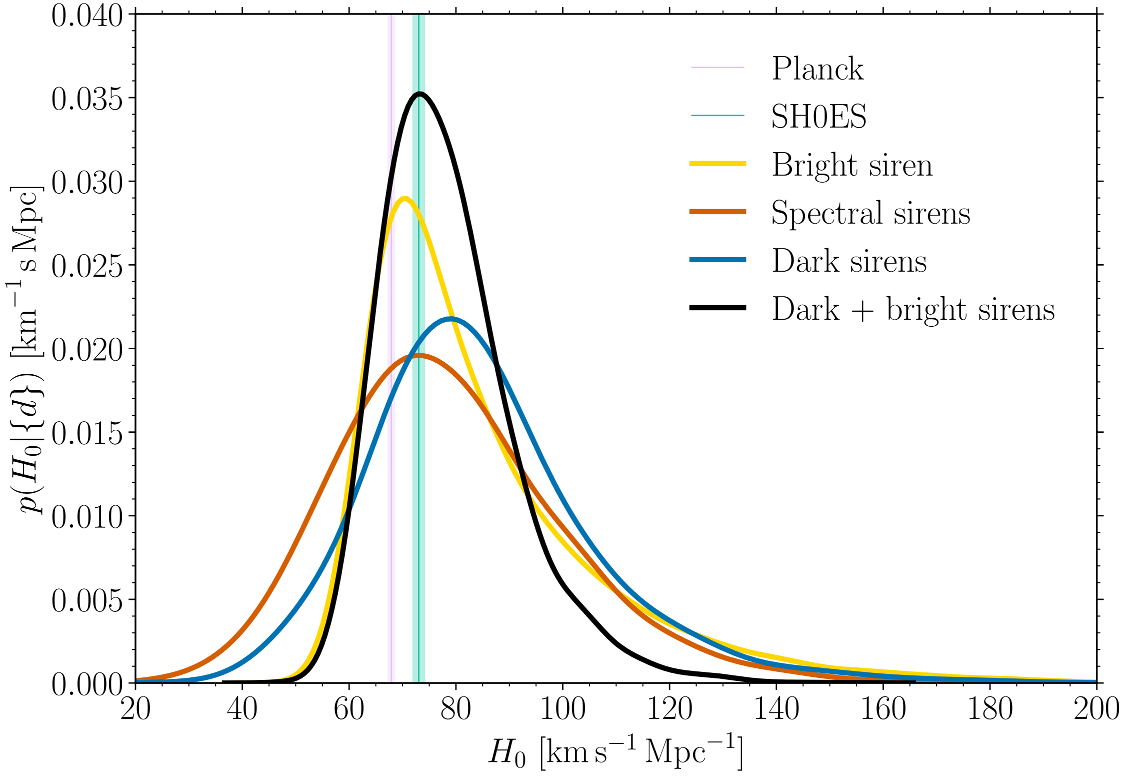
- Best H_0 constraint to date

$$H_0 = 76.6^{+13.0}_{-9.5}\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$$

- Not competitive for the "Hubble Tension"

- 60% improvement w.r.t to previous values

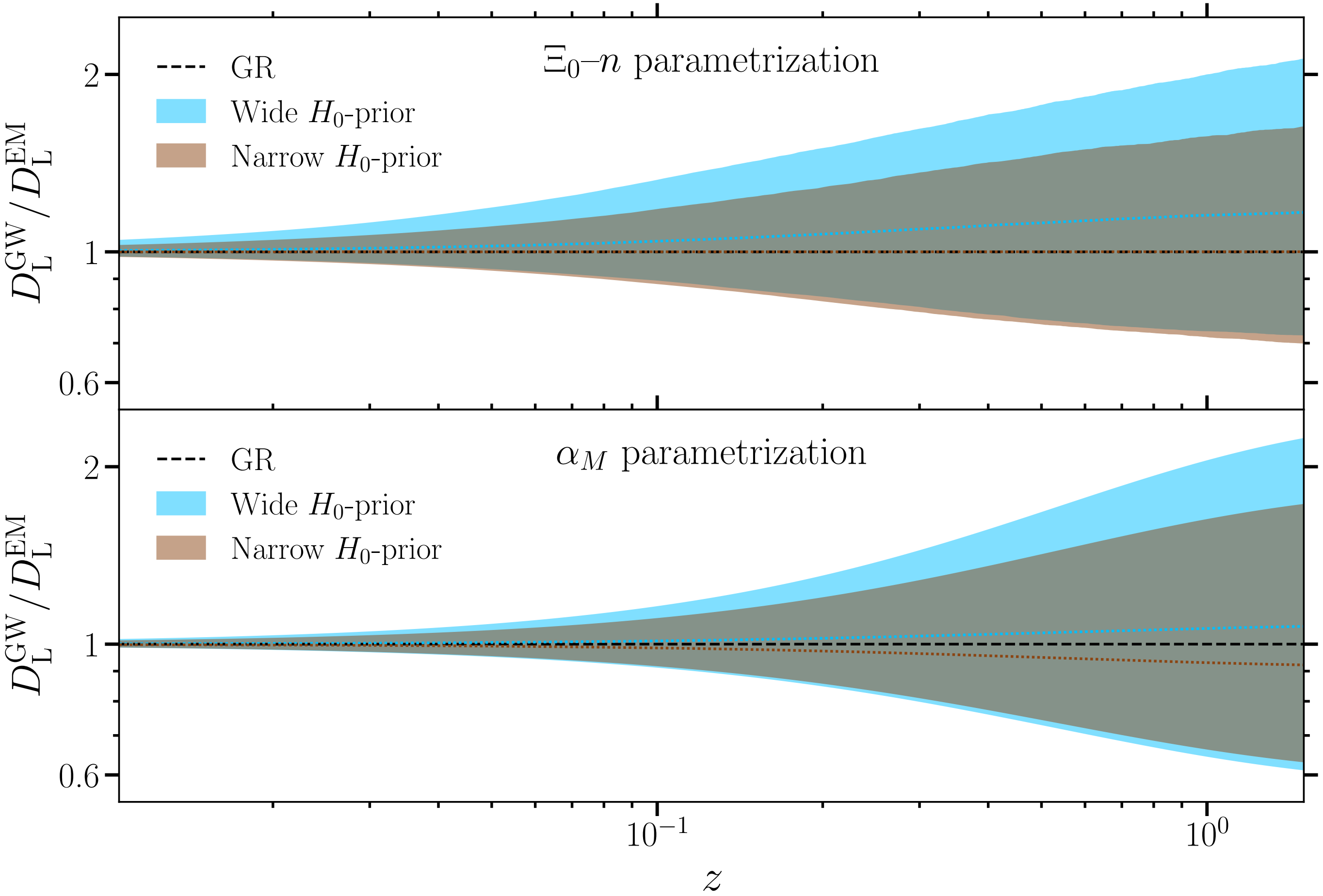
Coolest plot imo



arXiv.2509.04348

Any sign of modified gravity ?

Modification of the GW propagation $\longrightarrow$ modification of the estimated distance of the GW source $\longrightarrow$ $\dfrac{D_{\mathrm{L}}^{\mathrm{GW}}}{D_{\mathrm{L}}^{\mathrm{EM}}} \neq 1$



Phenomenological model

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

Horndeski gravity

$$D_{\mathrm{L}}^{\mathrm{GW}} = D_{\mathrm{L}}^{\mathrm{EM}} \exp\left(\frac{1}{2} \int_0^z \frac{\mathrm{d}z'}{1+z'} \frac{\Omega_\Lambda(z')}{\Omega_{\Lambda,0}} c_{\mathrm{M}} \right)$$

arXiv.2509.04348

Super cool papers to learn more

1. ”Gravitational-wave cosmology: an introduction”, Pierra+ (2025)

2. ”Constraints on the cosmic expansion and modified gravity”, LVK+ (2025)

3. ”Gravitational-waves as standard sirens”, Mastrogiovanni+ (2023)

I’ve changed the titles they were too long sorry.

This work is supported by ERC grant GravitySirens 101163912. Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council Executive Agency. Neither the European Union nor the granting authority can be held responsible for them. This material is in part based upon work supported by NSF’s LIGO Laboratory which is a major facility fully funded by the National Science Foundation.