High-Energy Astrophysics in the Multi-Messenger Era

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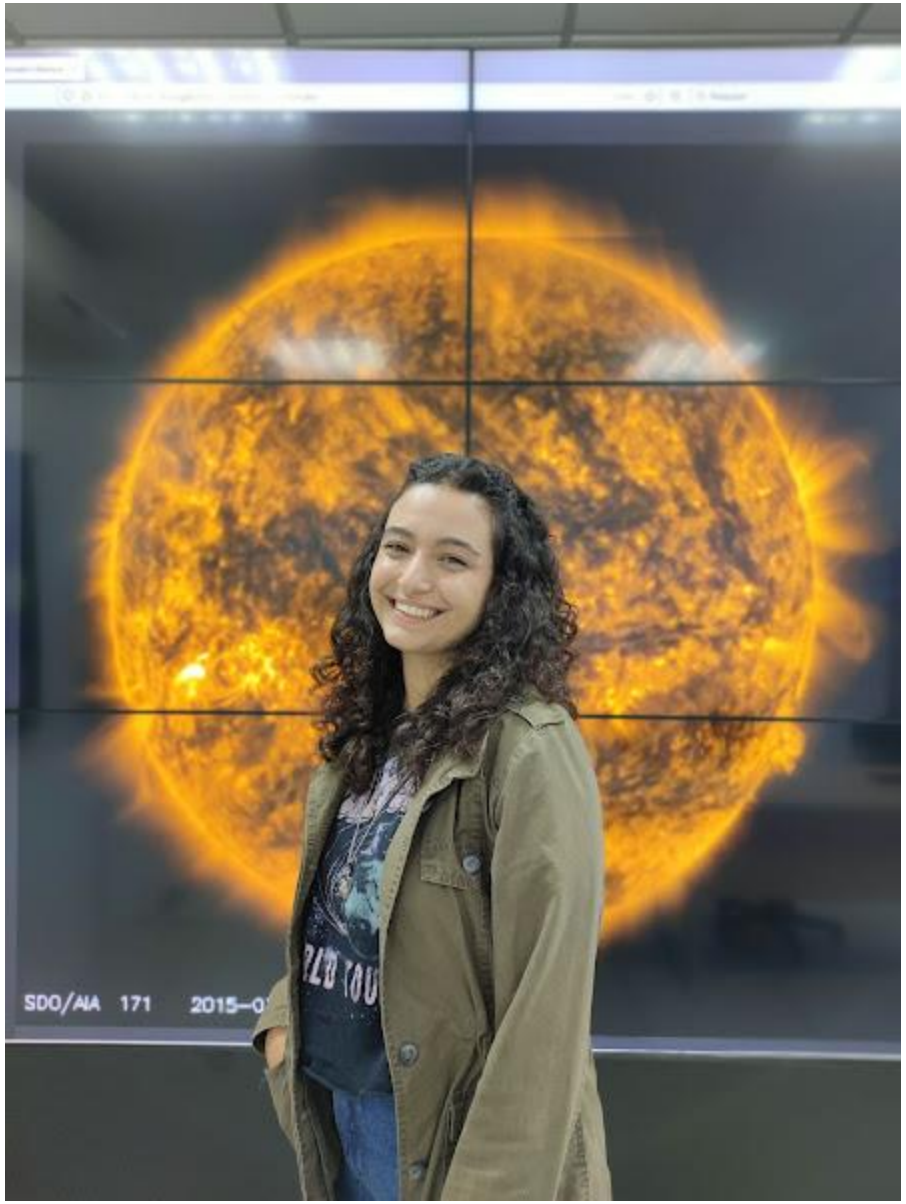
MINISTÉRIO DA CIÊNCIA,TECNOLOGIA E INOVAÇÃO

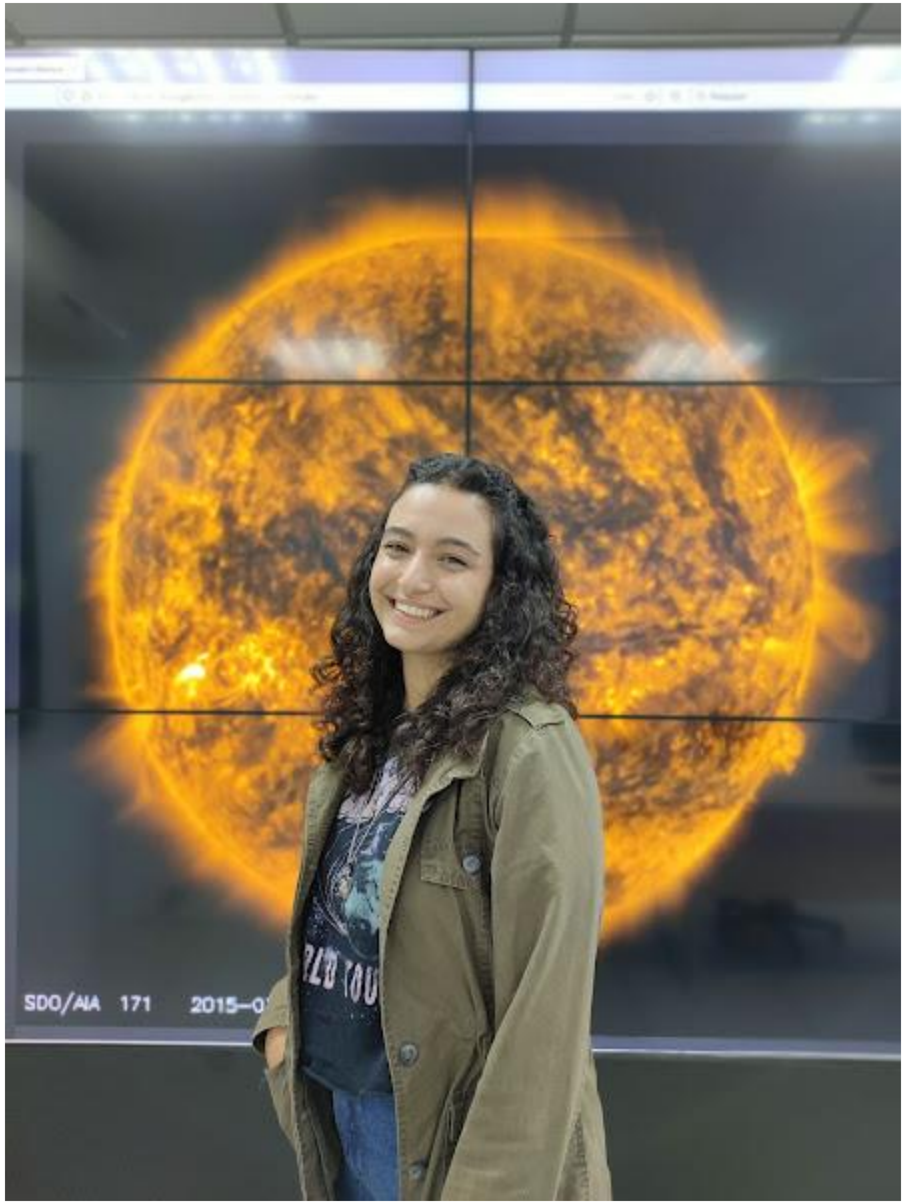
GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

About me



UEM

About me



UEM

BaO–reinforced SiO_2–Na_2O–Ca(O/F_2)–Al_2O_3 glasses for radiation safety: On the physical, optical, structural and radiation shielding properties

M.H. Pacheco [a b], M.S. Gibin [b], M.A. Silva [a b], G. Montagnini [b], R.C. Viscovini [a], A. Steimacher [c], F. Pedrochi [c], V.S. Zanuto [b], R.F. Muniz [a]

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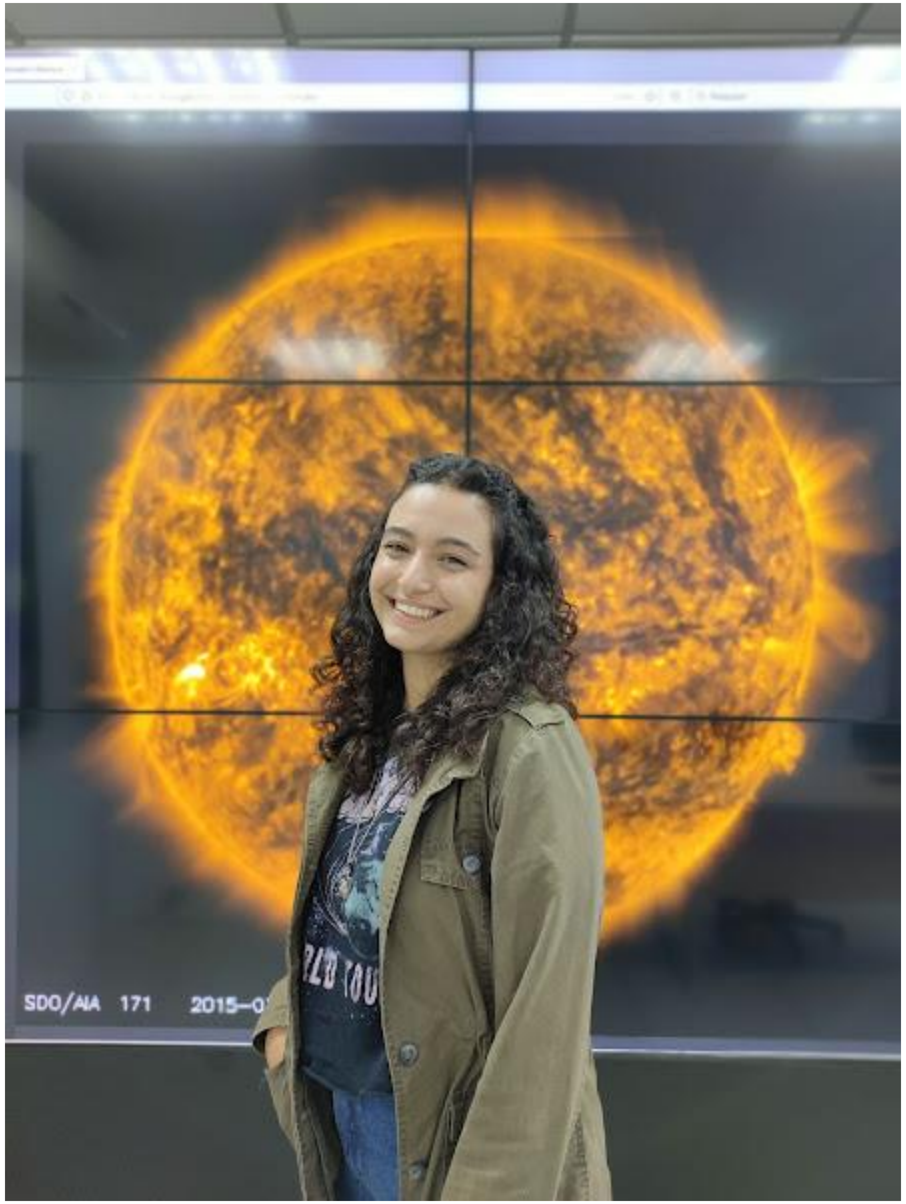

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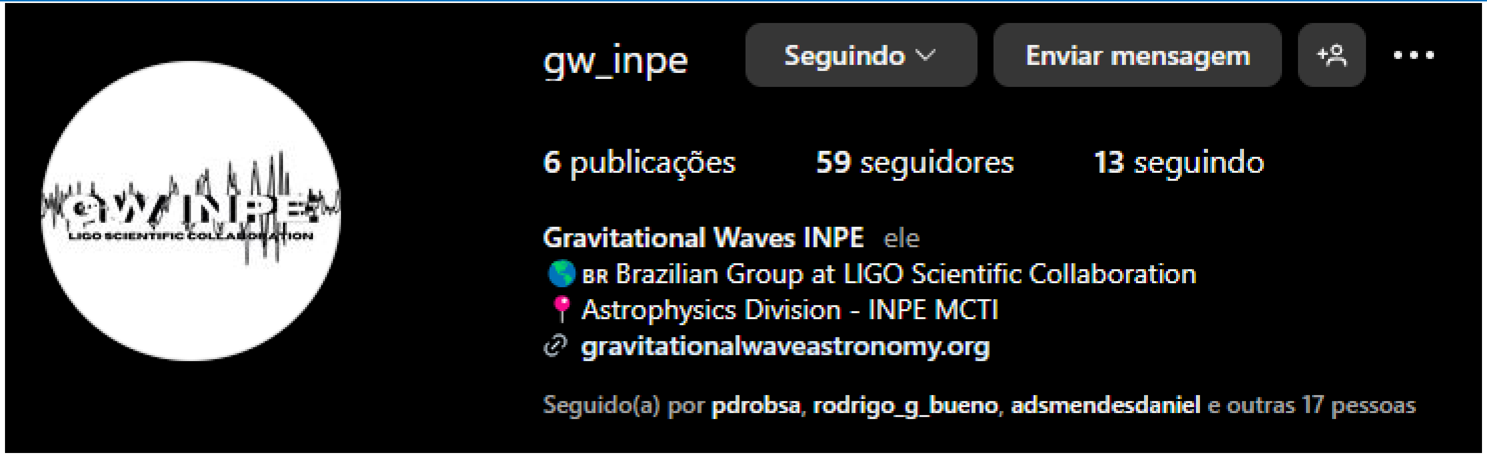
gw_inpe
Seguindo
Enviar mensagem
6 publicações
59 seguidores
13 seguindo
Gravitational Waves INPE ele
BR Brazilian Group at LIGO Scientific Collaboration
Astrophysics Division - INPE MCTI
gravitationalwaveastronomy.org
Seguido(a) por pdrobsa, rodrigo_g_bueno, adsmendesdaniel e outras 17 pessoas


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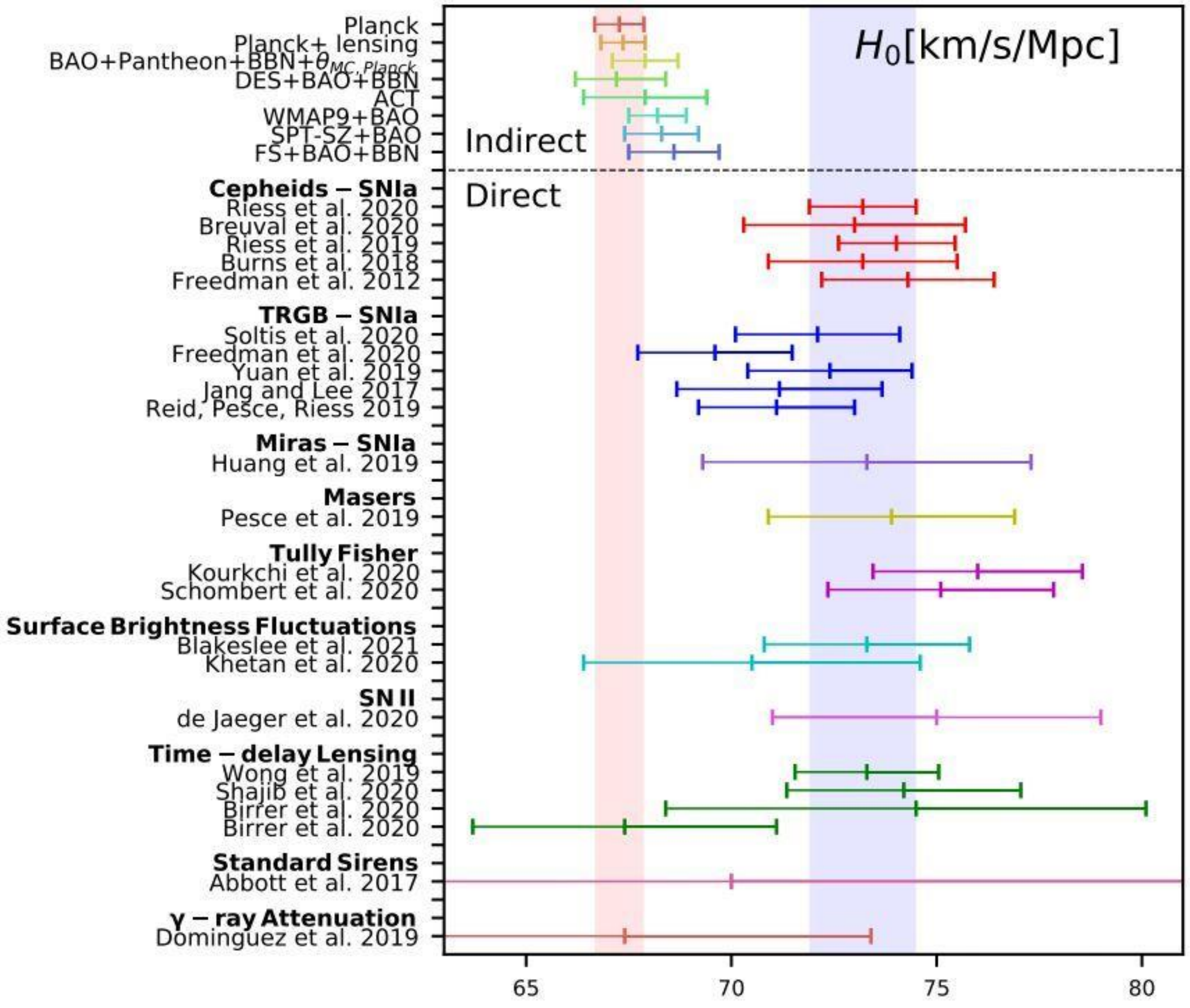
15 a 20 de janeiro de 2024 • ICTP-SAIFR

Determination of the Hubble Constant from Multi-messenger Astronomy Involving Gravitational Waves

Supervisors: Dr. Odylio Denys Aguiar (INPE)
Dr. Josiel Mendonça Soares de Souza (UFRJ)

Motivation



Hubble Tension:

The discrepancy between different measurements of the Hubble constant, particularly those derived from **observations of the cosmic microwave background (CMB)** $(z \approx 1100)$

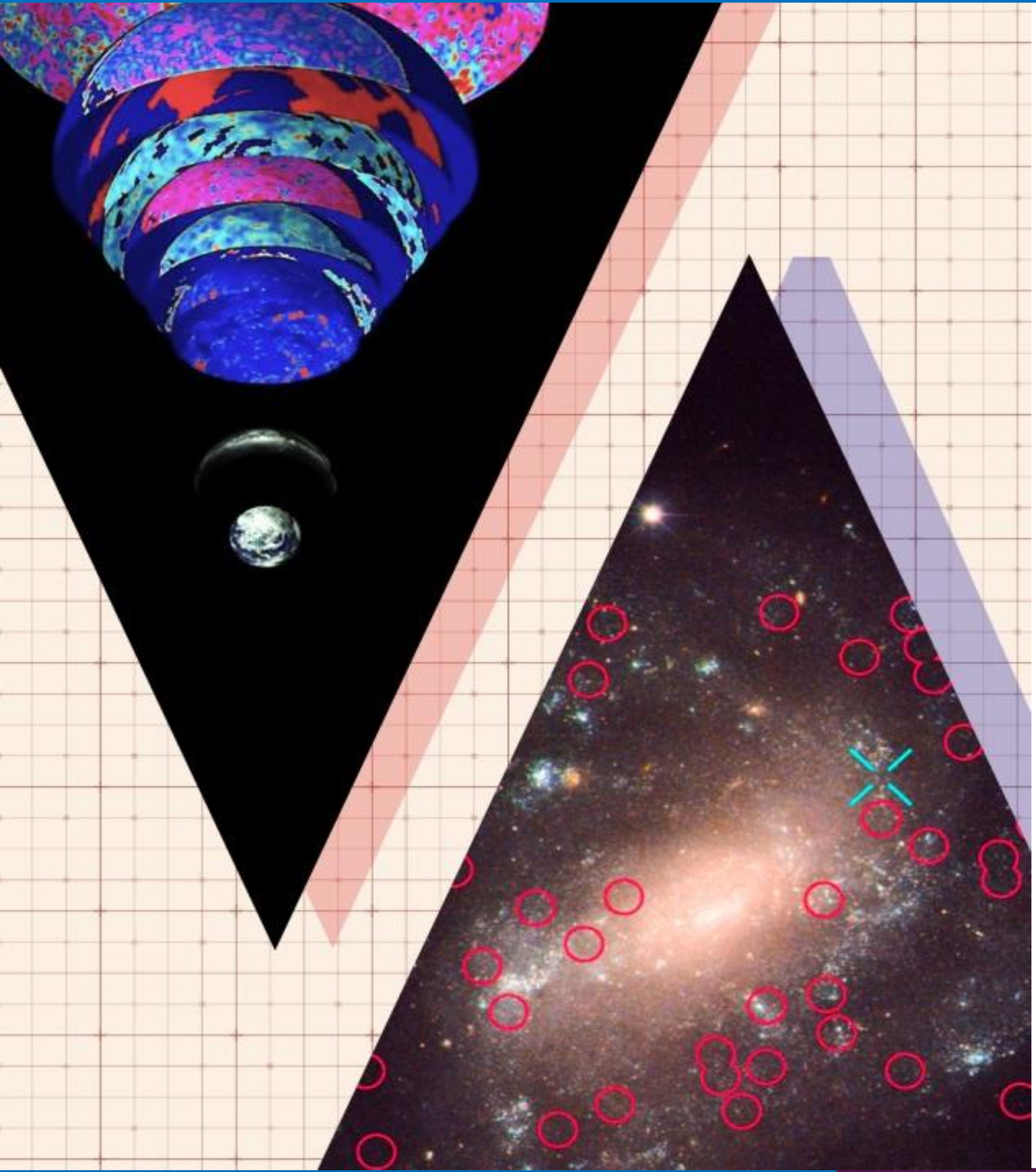
$$(67.4 \pm 0,5 km\ s^{-1} Mpc^{-1})$$

and **measurements with late time universe data** $(z \leq 2)$

$$(74.0 \pm 1,4\ km\ s^{-1} Mpc^{-1})$$

The discrepancy is $\sim\ 5\sigma - 6\sigma$ (Di Valentino et al. 2021; Riess et al. 2021)

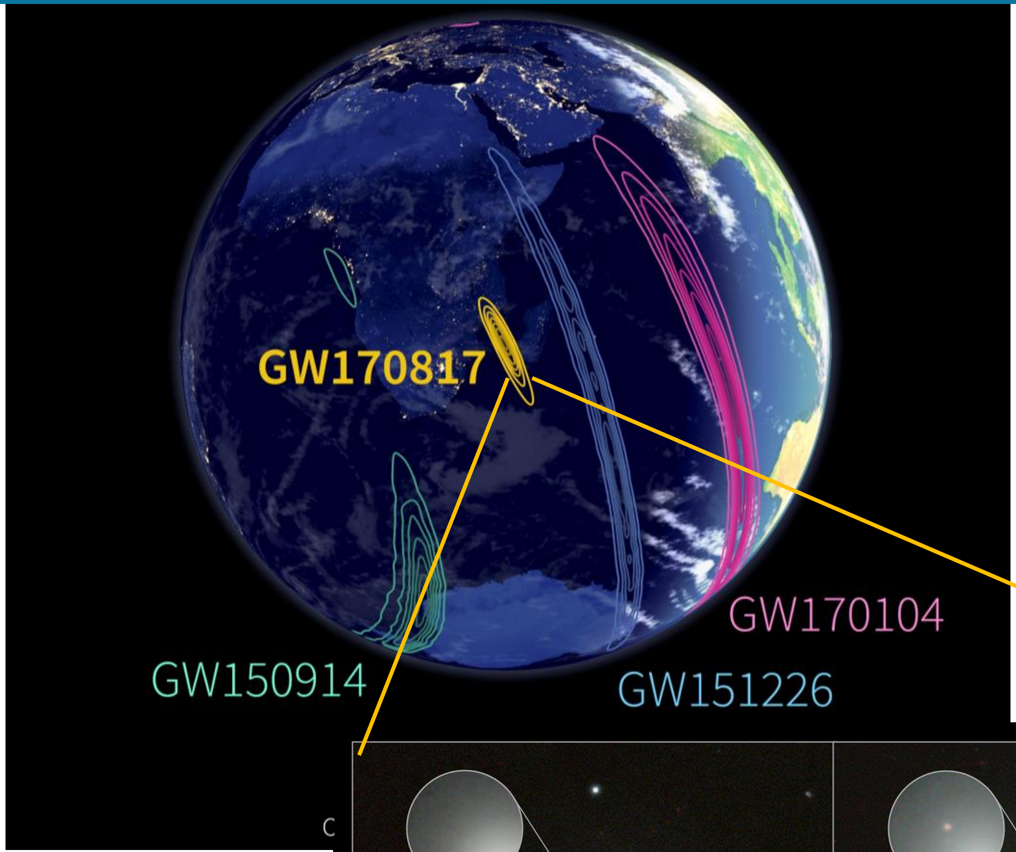
Motivation

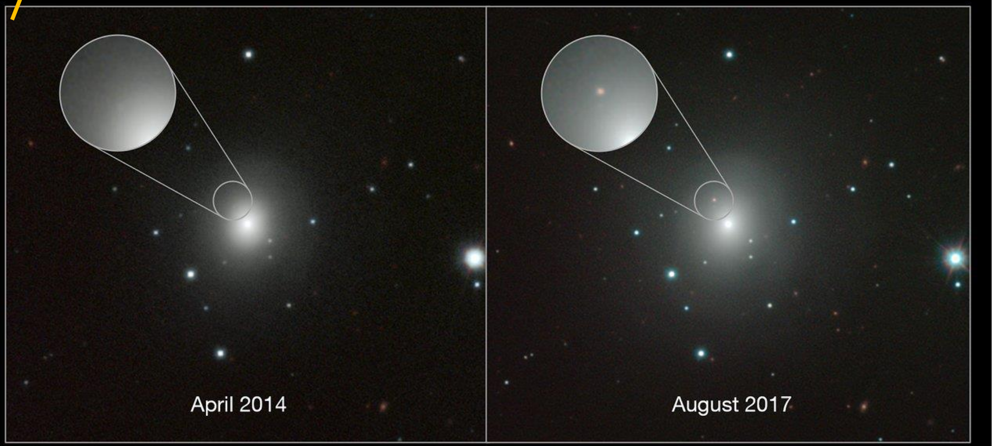


Besides expressing the universe's expansion rate…

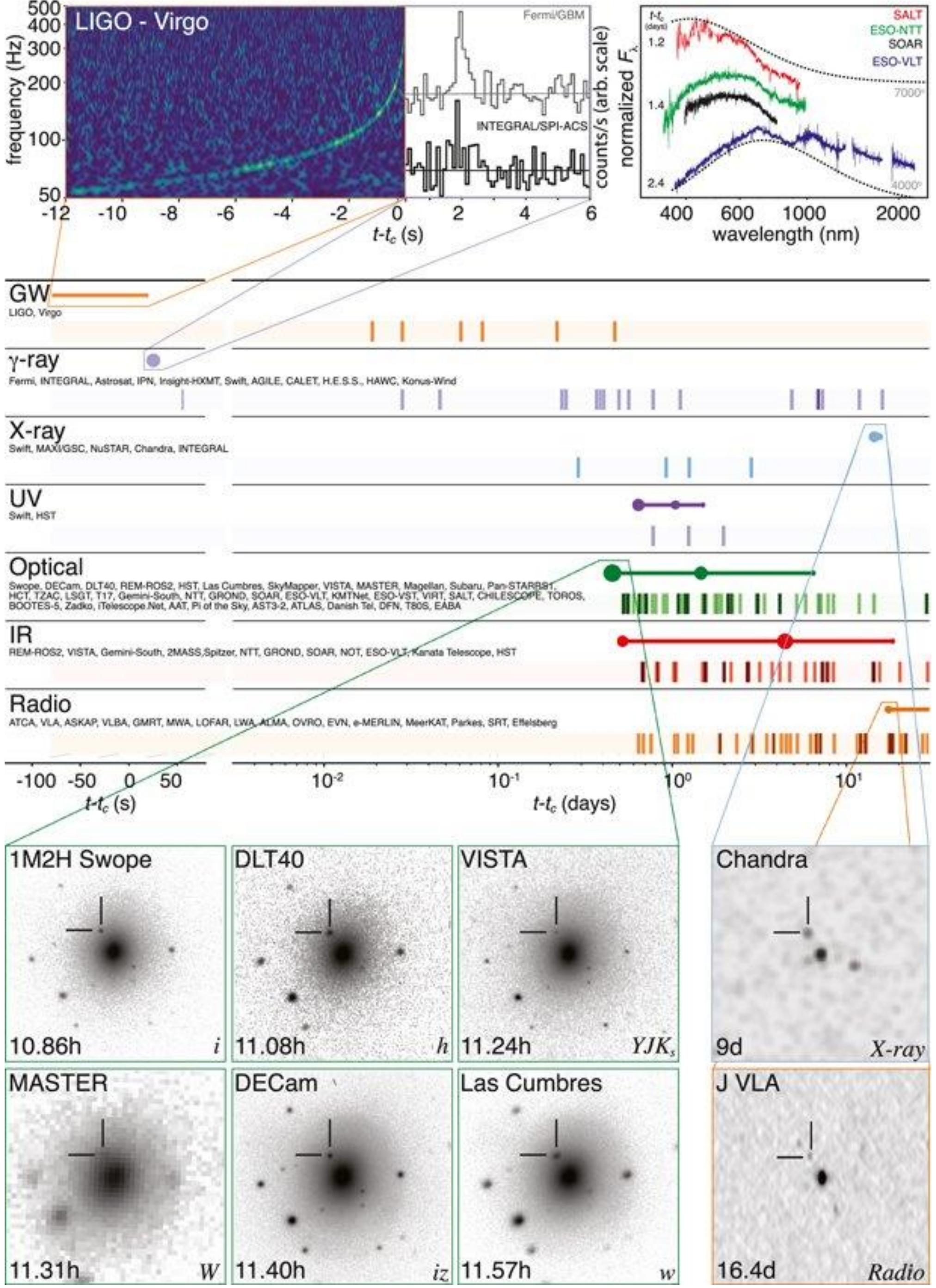
- the square of H_0 relates the total energy density of the universe to its geometry, as well as making it possible to calculate the age of the universe;
- the size of the observable universe, and its radius of curvature;
- for that H_0 is one of the most important parameters in Cosmology.

GW170817, GRB170817A and AT2017gfo

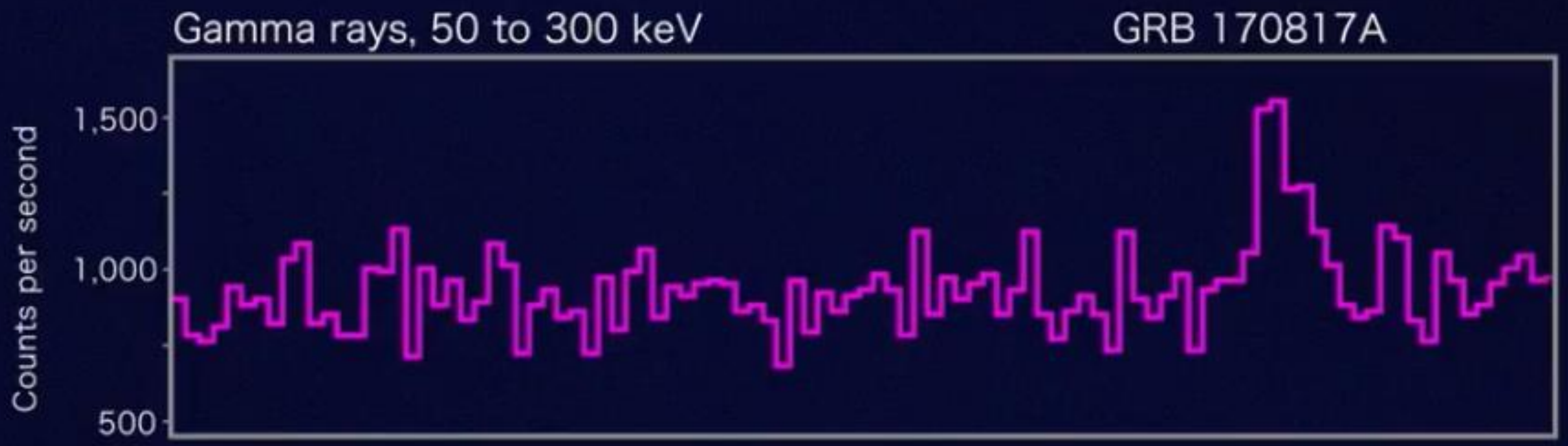




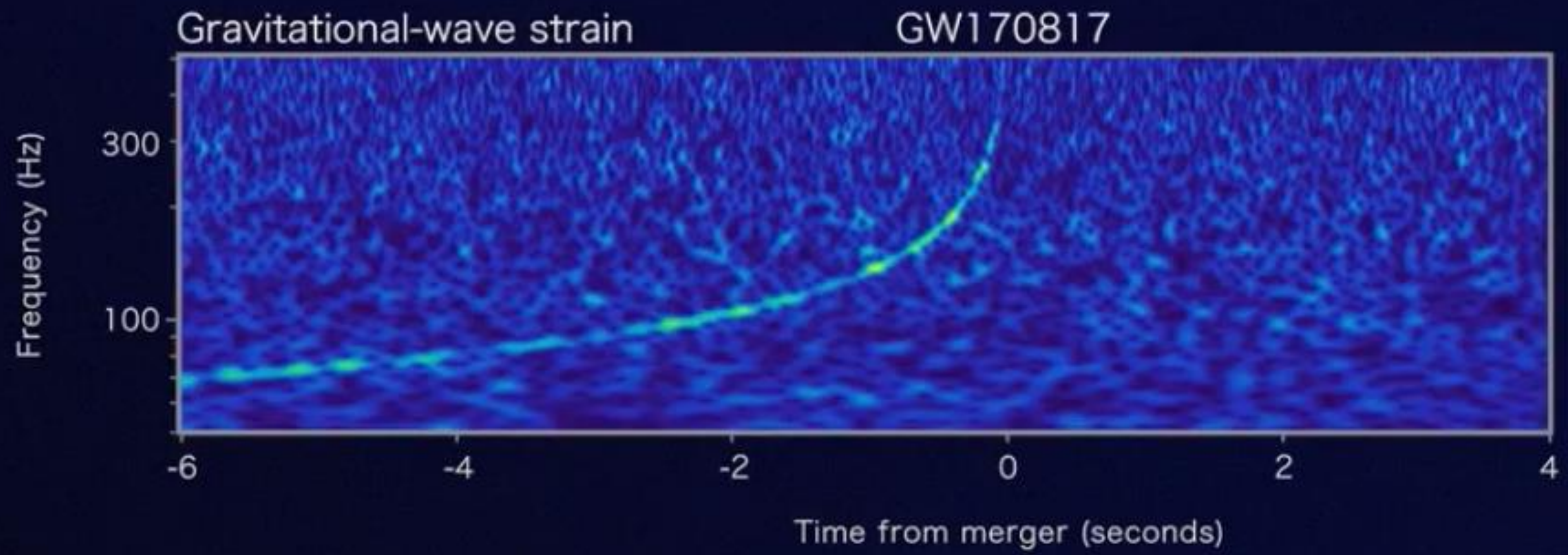
ESO/N.R. Tanvir, A.J. Levan and the VIN-ROUGE collaboration

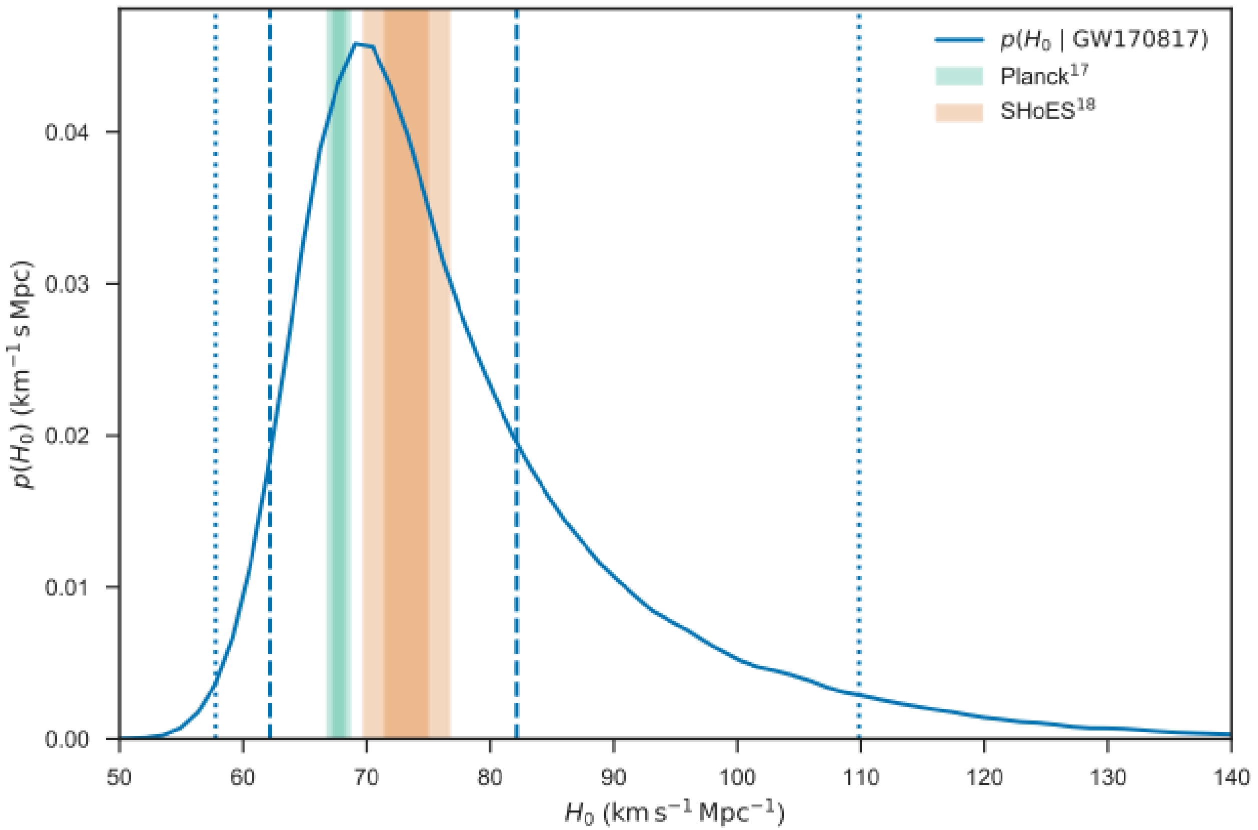


Fermi

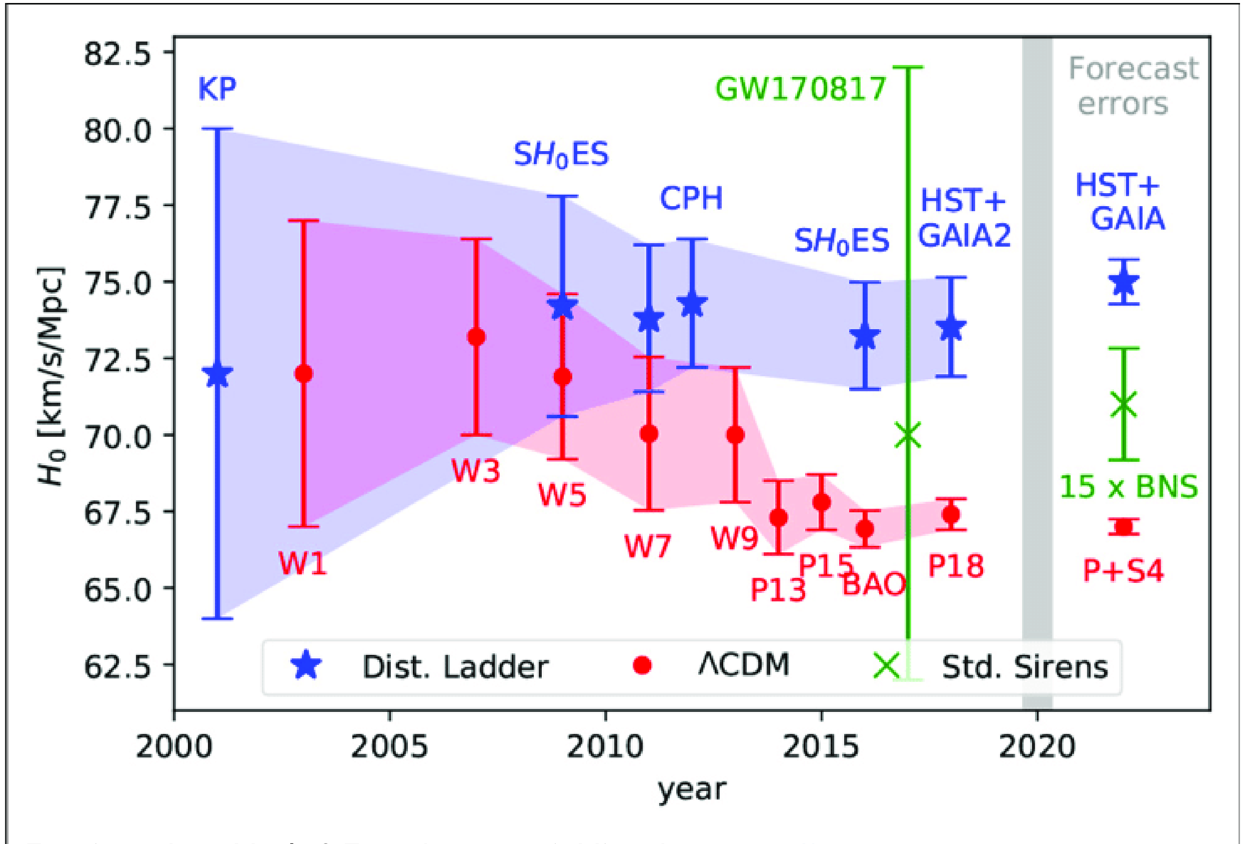

Gamma rays, 50 to 300 keV
GRB 170817A
Counts per second
1,500
1,000
500

LIGO


Gravitational-wave strain
GW170817
Frequency (Hz)
300
100
-6
-4
-2
0
2
4
Time from merger (seconds)



Abbott, B. P., et al. https://doi.org/10.1038/nature24471



Ezquiaga, Jose María & Zumalacarregui, Miguel. 10.3389/fspas.2018.00044

First measurement of H_0 with GW

About GW170817

- Luminosity Distance: $43.8^{+2.9}_{-6.9} Mpc$

15% uncertainty due to a combination of statistical measurement error from the noise in the detectors + instrumental calibration uncertainties

What do we know about AT2017gfo

- Host galaxy: NGC 4993
- Redshift: 0.00973

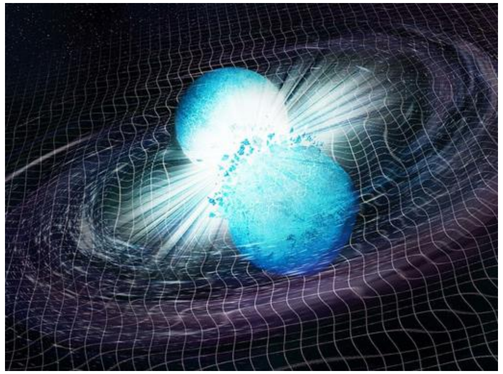
$$H_0 = 70.0^{+12.0}_{-8.0} km\ s^{-1} Mpc^{-1}$$

The Standard Siren

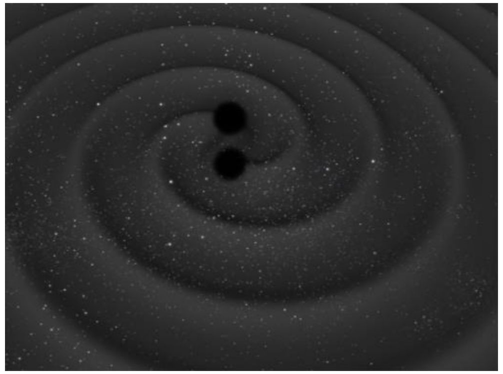
by Bernard Schutz, 1986

The use of GW signals to measure cosmic distances.

Bright Siren



Dark Siren



The quadrupole formula of general relativity predicts that the waves will have an amplitude (r.m.s averaged over detector and source orientations).

$$< h > = 1 \times 10^{-23} (m_T)^{2/3} \mu f^{2/3} d_L^{-1}$$

And that their frequency will change on a timescale

$$\tau = \frac{f}{\dot{f}} = 7.8 \; {m_T}^{-2/3} \mu f^{-8/3} s$$

$$d_L = 7.8 f^{-2} (< h_{23} > \tau)^{-1}$$

$$< h_{23} > = < h > \times 10^{-23}$$

independently of the masses of the stars.

Bright Sirens

When determining the H_0

- Estimate the distance through the GW signal
- Location of the source position in the sky
- Observing the electromagnetic counterpart of it

Bright Sirens

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- Estimate the distance through the GW signal
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$$d_L = 7.8 f^{-2} (< h_{23} > \tau)^{-1}$$

$$< h_{23} > = < h > \times 10^{-23}$$

without relying on any phenomenological relation or calibration at lower redshifts.

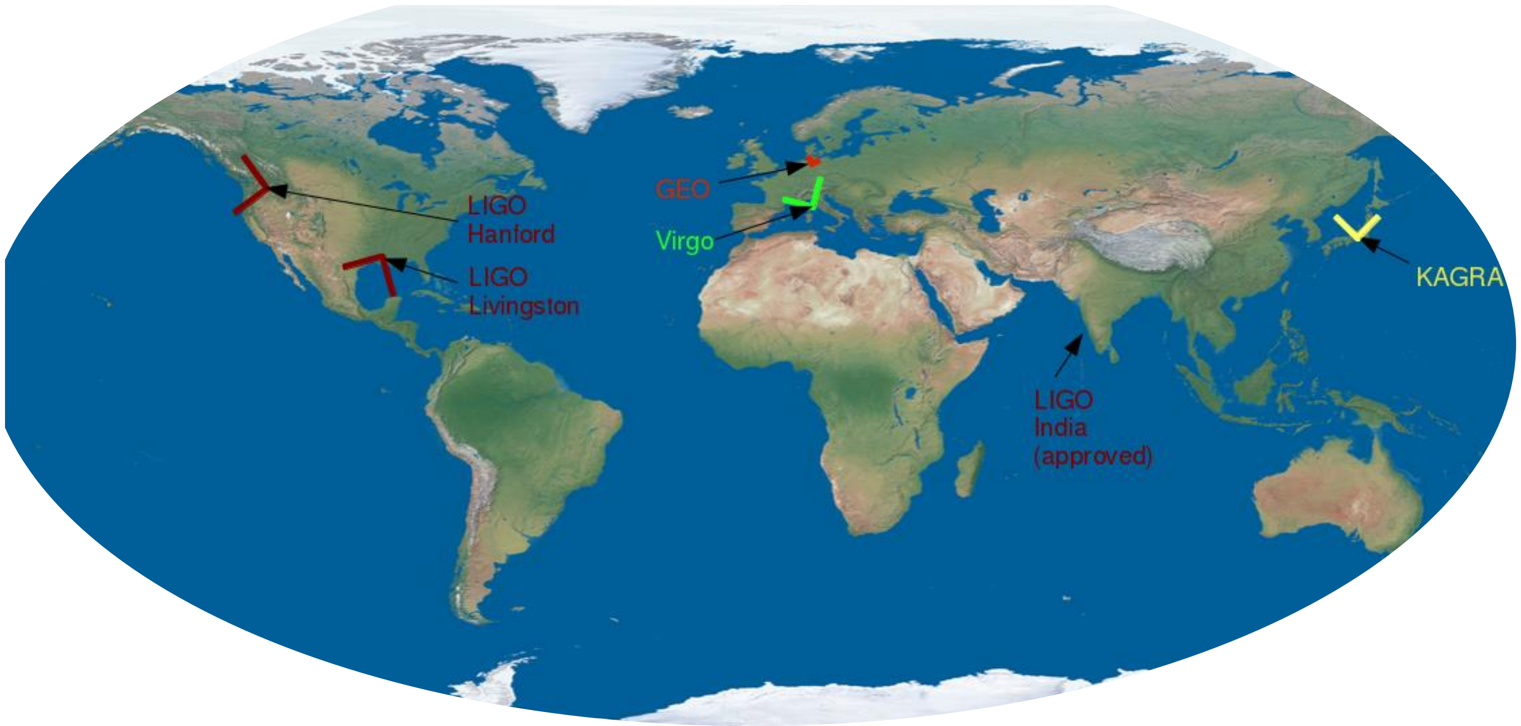
Bright Sirens

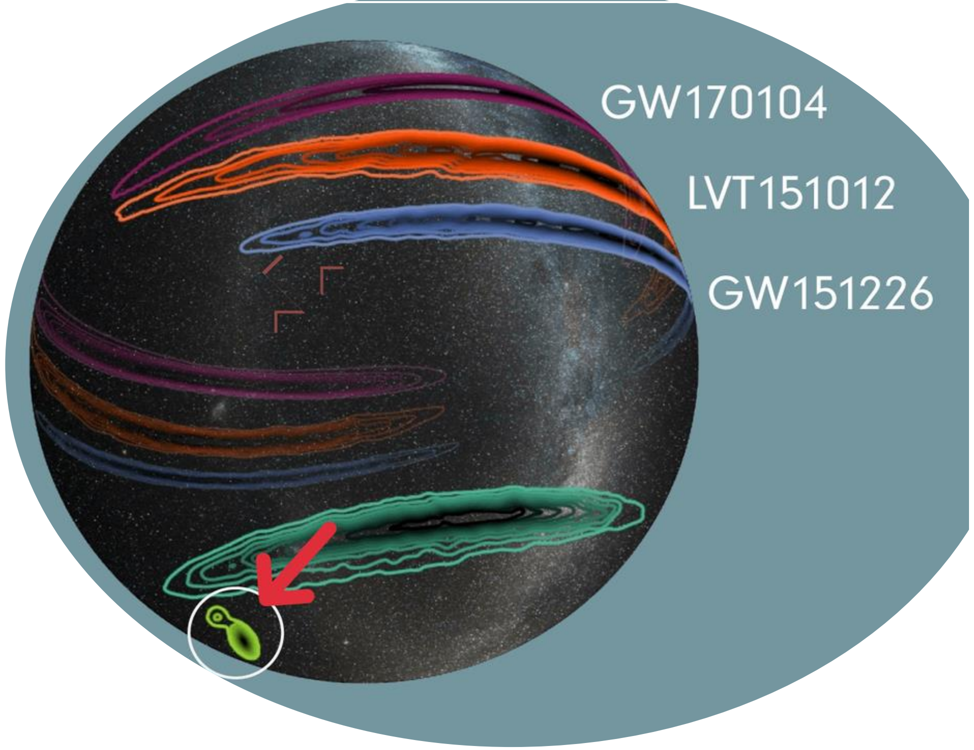
When determining the H_0

- Estimate the distance through the GW signal
- Location of the source position in the sky
- Observing the electromagnetic counterpart of it

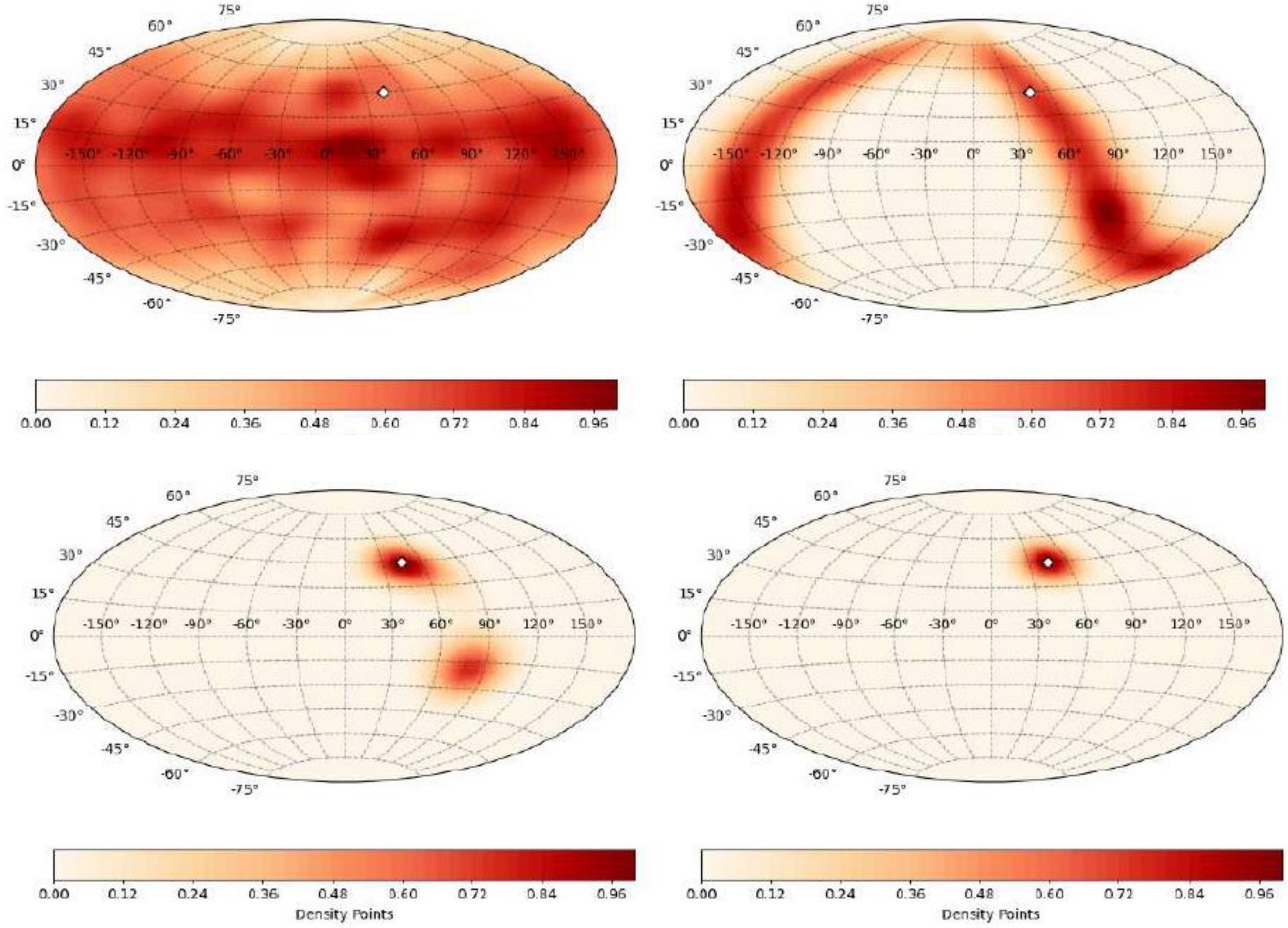
$$d_L = 7.8 f^{-2} (< h_{23} > \tau)^{-1}$$

$$< \boldsymbol{h_{23}} > = < \boldsymbol{h} > \times\ \mathbf{10^{-23}}$$





Three detectors are needed, preferably four, or more.



SOUZA, Josiel Mendonça Soares de. Late-time cosmology with third generation gravitational waves observatories. Orientador: Riccardo Sturani. 2023. 162f. Tese (Doutorado em Física) - Centro de Ciências Exatas e da Terra, Universidade Federal do Rio Grande do Norte, Natal, 2023.

Bright Sirens

When determining the H_0

- Estimate the distance through the GW signal
- Location of the source position in the sky
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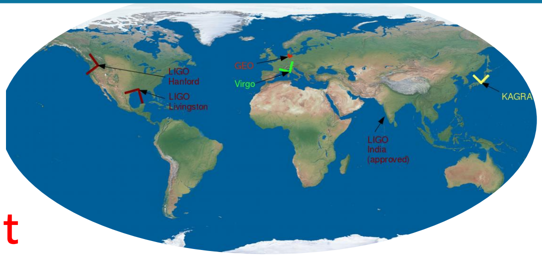


$$d_L = 7.8 f^{-2}(< h_{23} > \tau)^{-1}$$

$$< \boldsymbol{h_{23}} > = < \boldsymbol{h} > \times\, \mathbf{10^{-23}}$$

Transient High-Energy Sky and Early Universe Surveyor is a space telescope mission proposal by the European Space Agency that would study gamma-ray bursts and X-rays for investigating the early universe (z > 6)

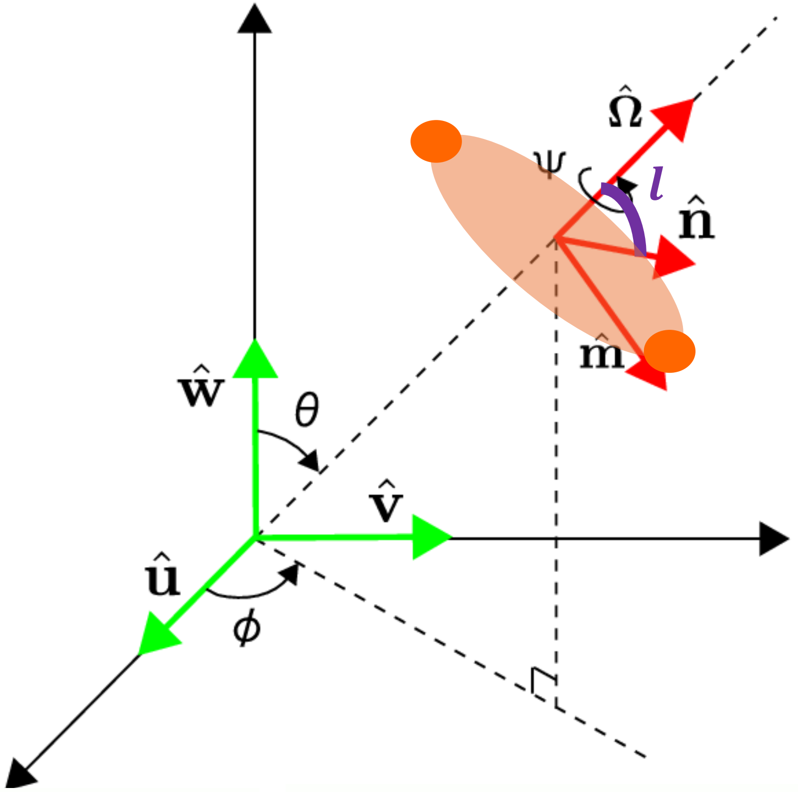
A network of robotic telescopes connected all over the world with both photometry and spectrometry capabilities for Time-domain Astronomy.

From General Relativity...

$$(dS)^2 = g_{\mu\nu} dx^\mu dx^\nu$$

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$(dS)^2 = -dt^2 + 2h_\times dxdt + (1 + h_+)dx^2 + (1 - h_+)dy^2 + dz^2$$



Polarizations

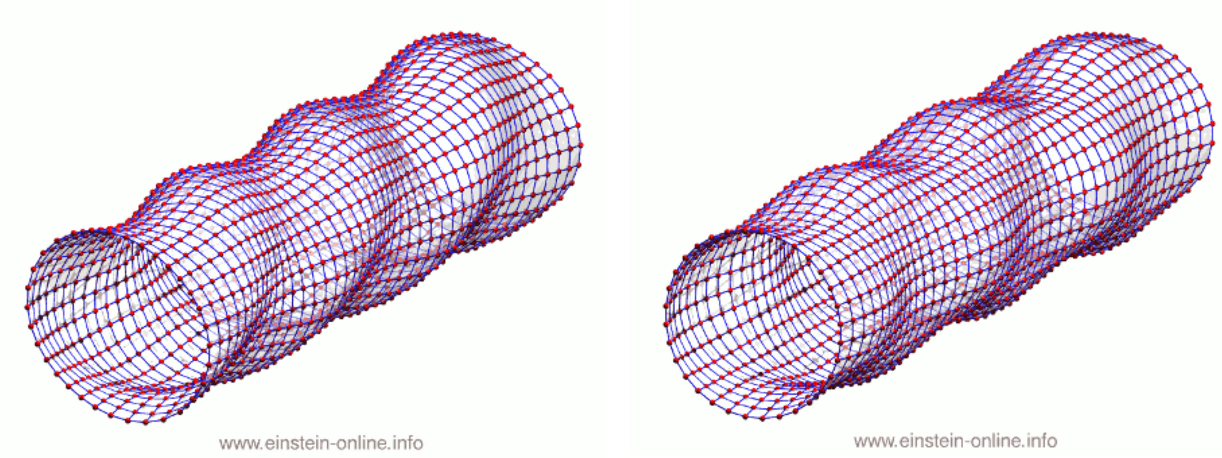
$$h(t) = F_+ h_+(t) + F_\times h_\times(t)$$

$$h_+ \propto \frac{1}{d_L}\left(\frac{1 + \cos^2 l}{2}\right)$$

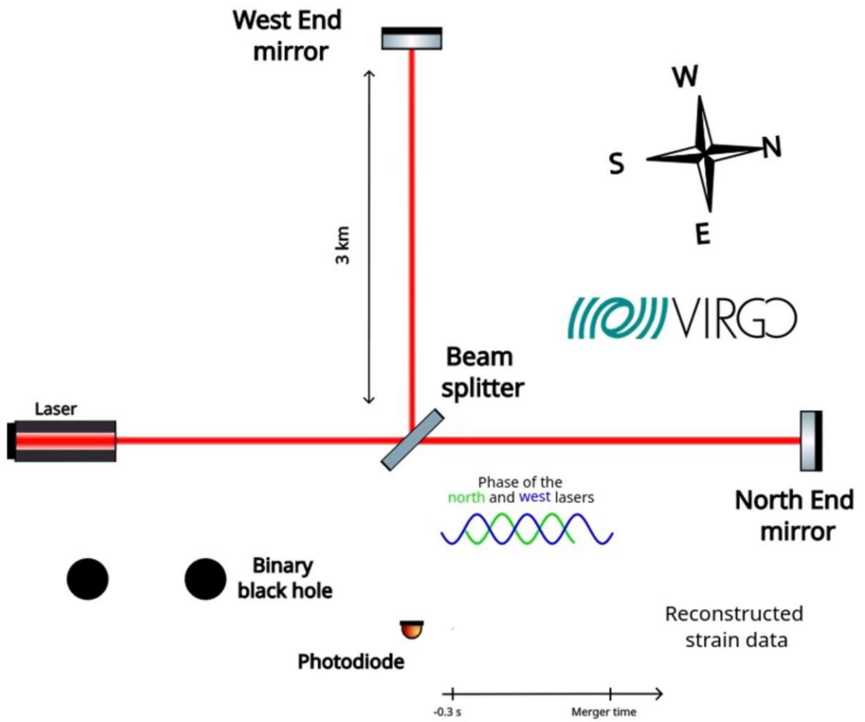
$$h_\times \propto \frac{1}{d_L} \cos l$$

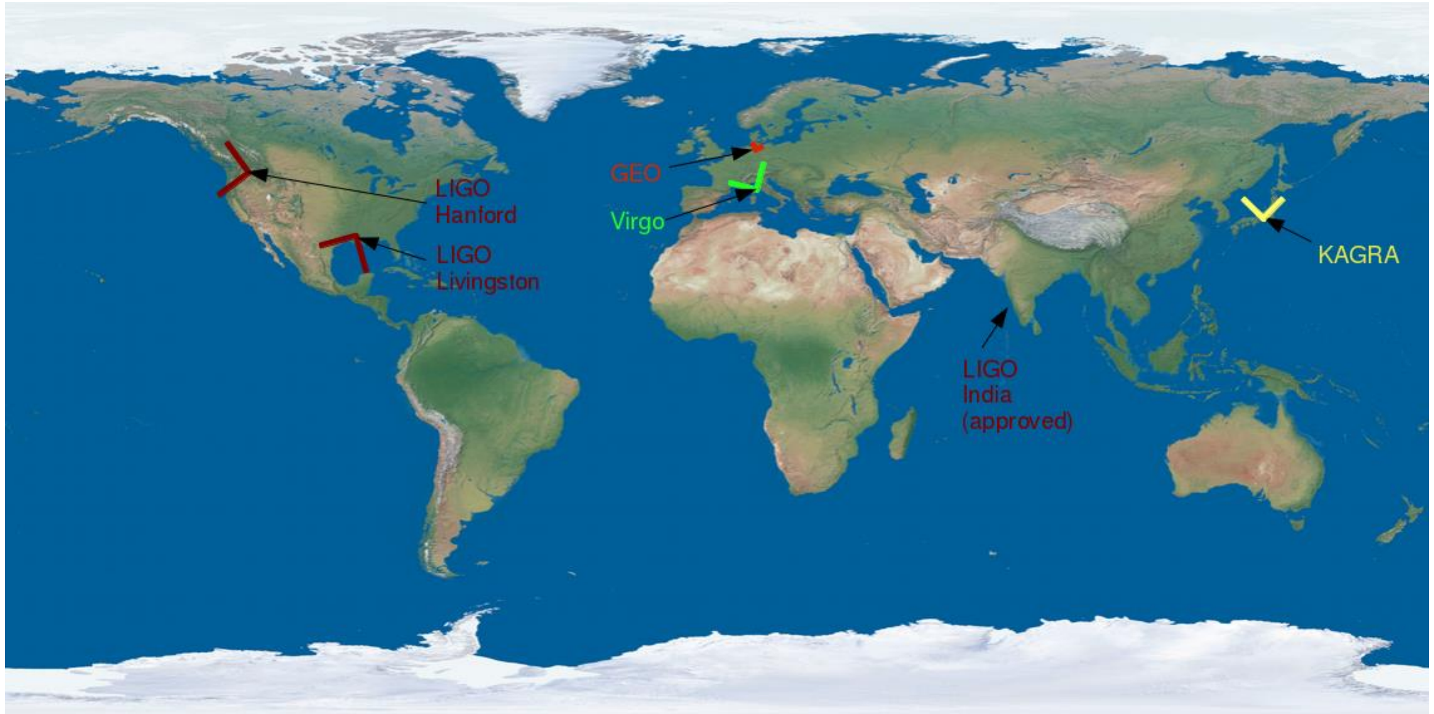
$$h \propto \frac{1}{d_L}$$

$$h \approx \frac{\Delta L}{L_0}$$



GW Detectors: 2G





LIGO Livingston = 4km

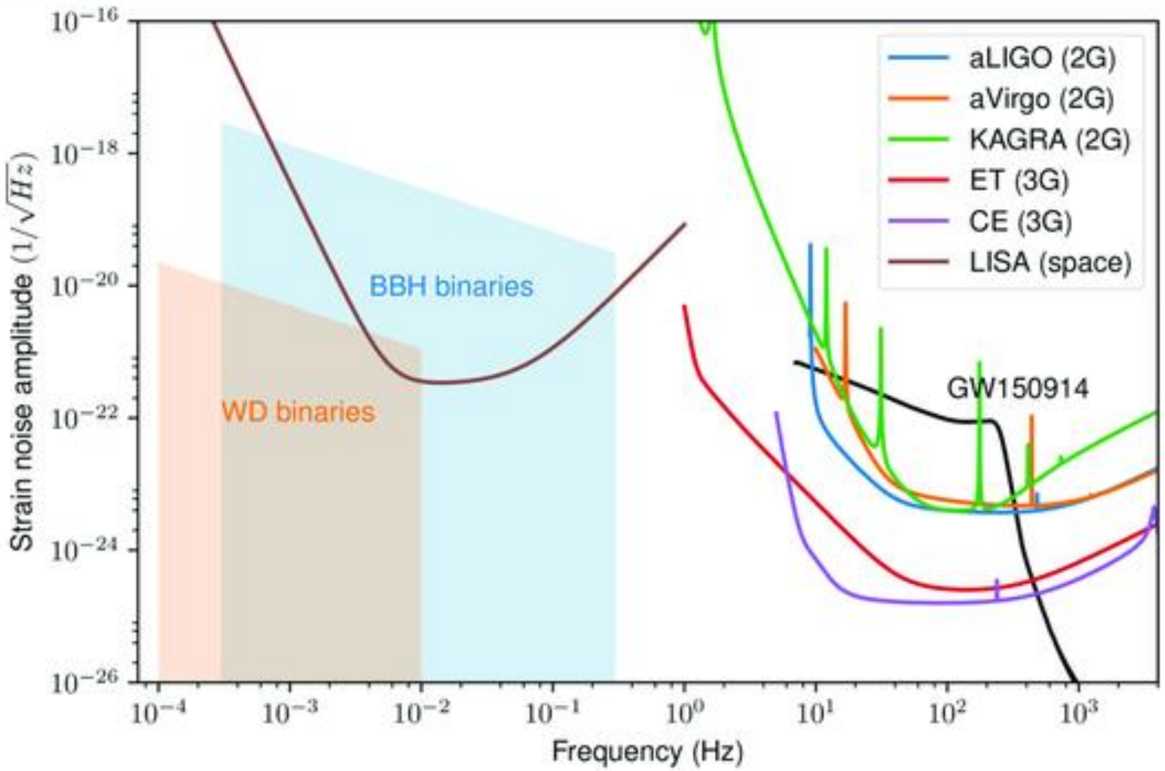
LIGO Hanford = 4km

Virgo = 3km

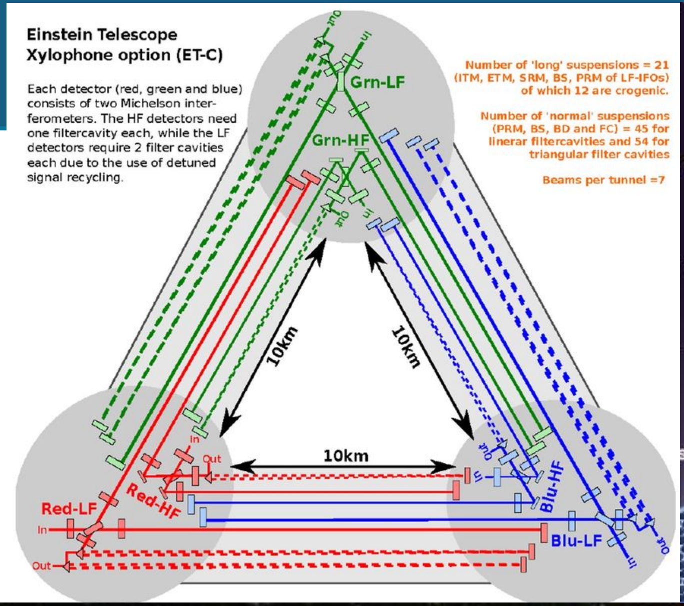
KAGRA = 3km

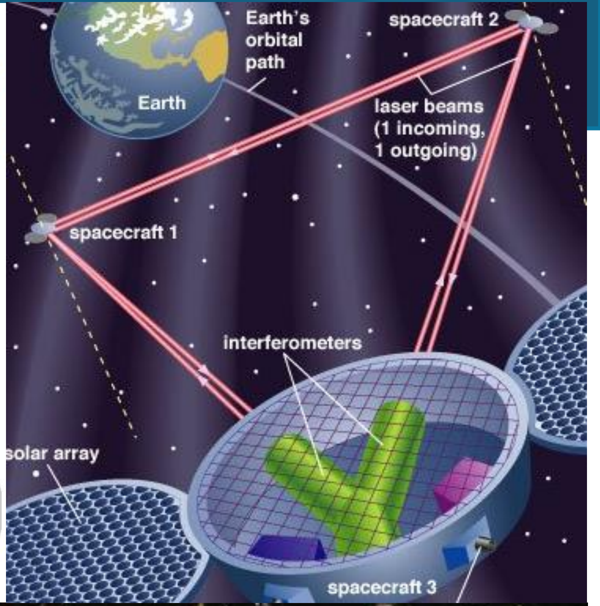
GW Detectors:
Ground 3G and Space 1G)

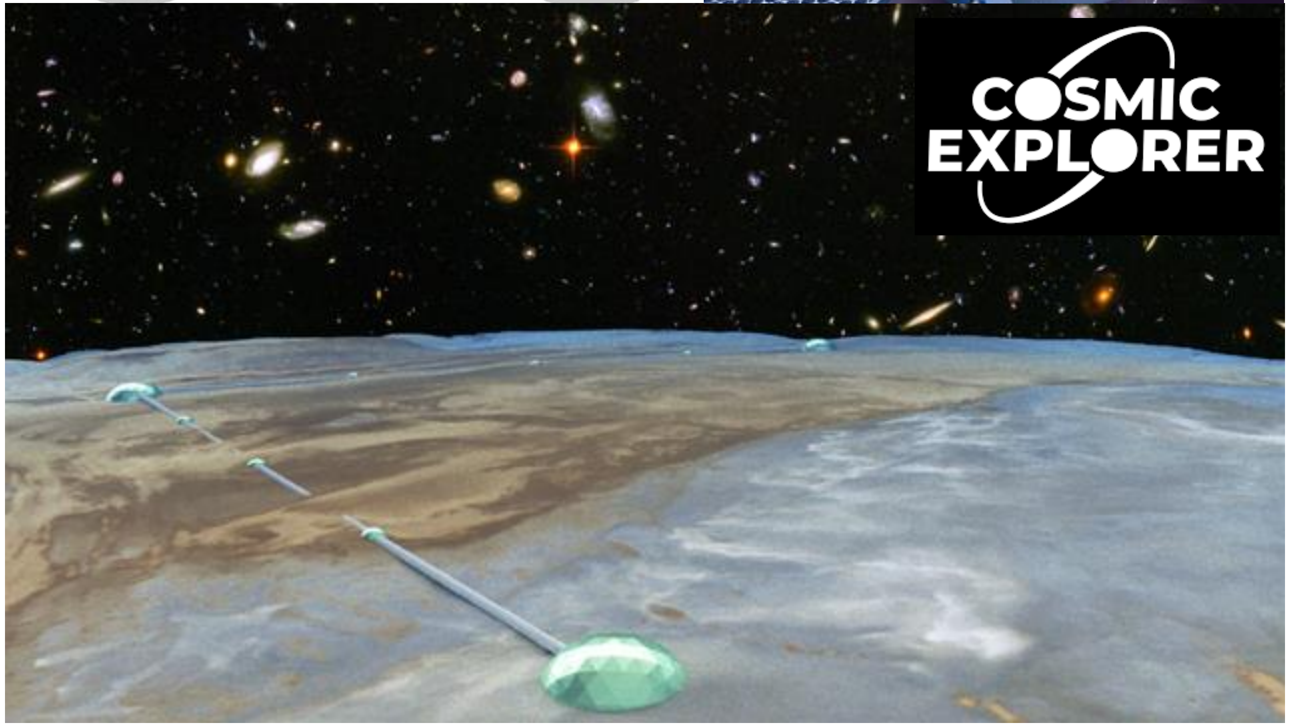
ET: $L = 10km$ CE: $L = 40km$ LISA: $L = 2.5 \times 10^6 km$

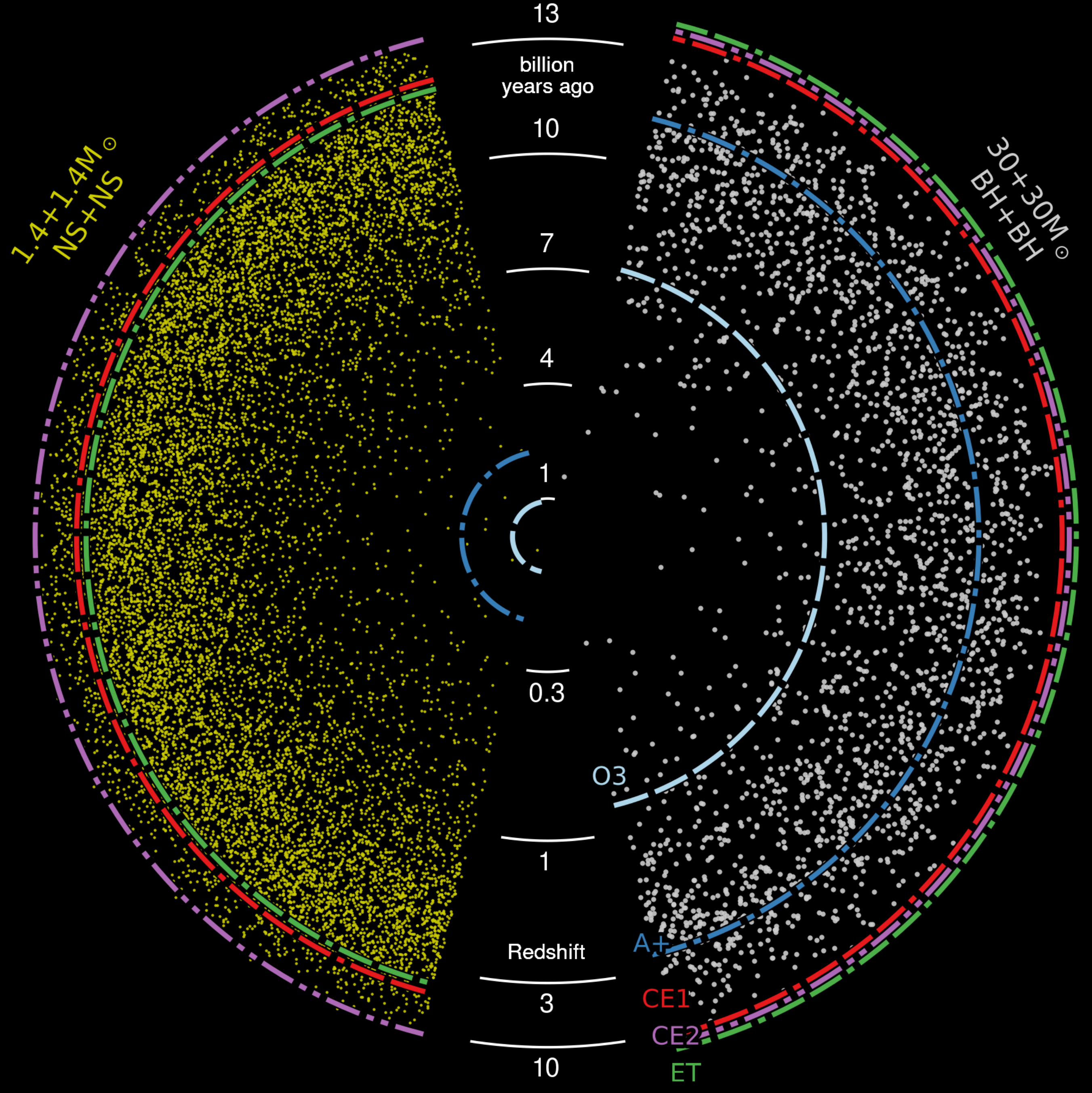


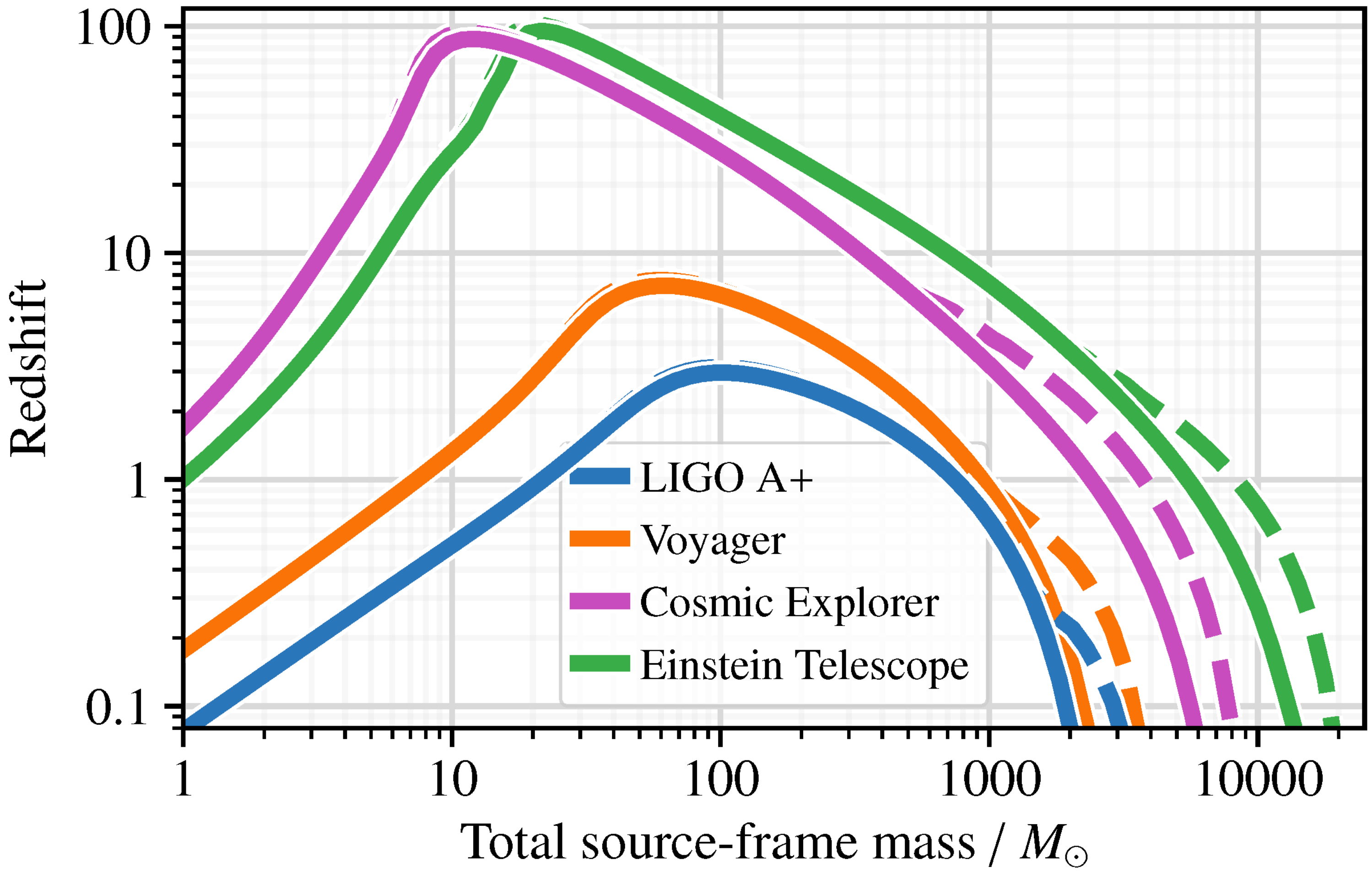
Frontiers in Astronomy and Space Sciences. 5. 10.3389/fspas.2018.00044.

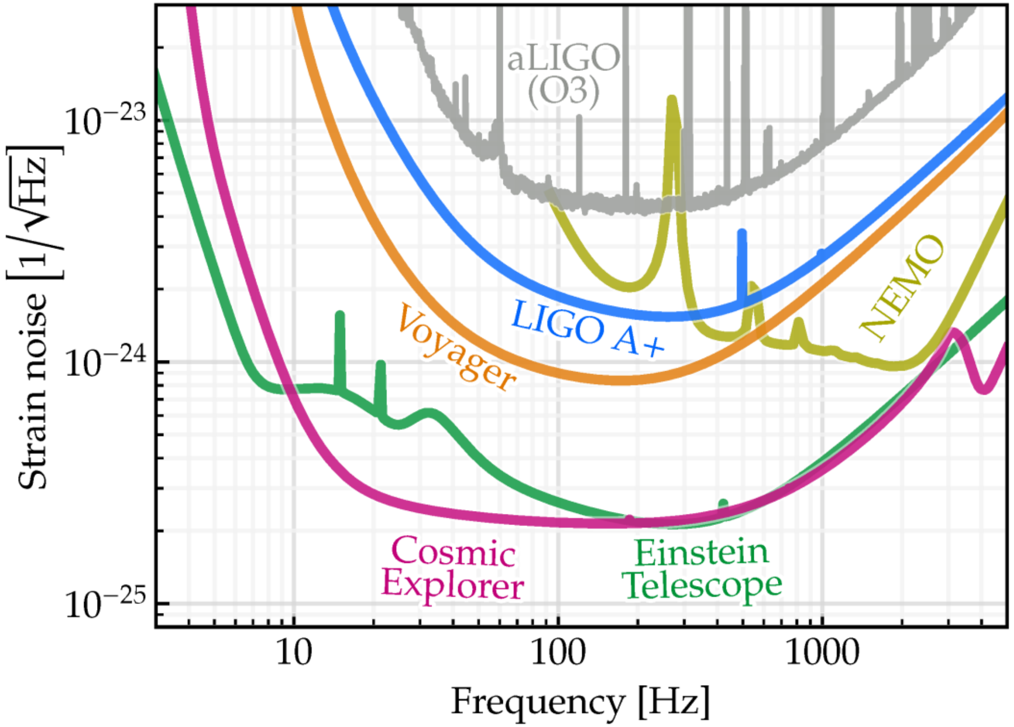







13
billion
years ago
10
7
4
1
0.3
1
Redshift
3
10
1.4+1.4M☉
NS+NS
30+30M☉
BH+BH
O3
A+
CE1
CE2
ET





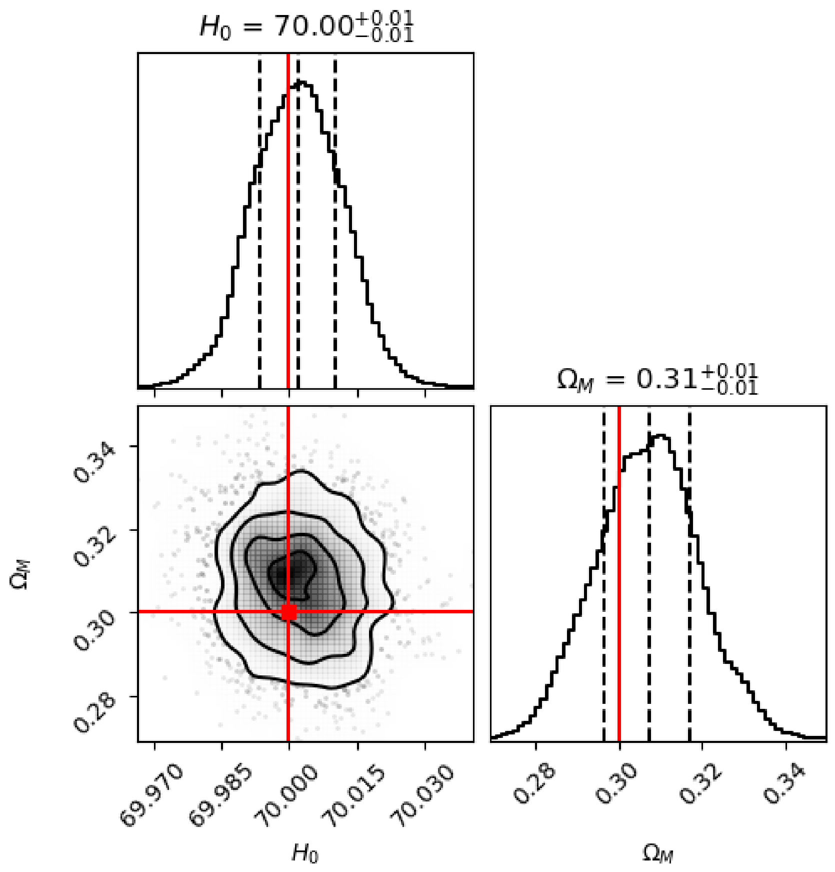
Galaxies 2022, 10(4), 90; https://doi.org/10.3390/galaxies10040090

In this work

- Considering the 3G of ground interferometers and.
- Use the GWDALI software to estimate GW parameters from compact objects coalescence (CBC) via Gaussian (Fisher Matrix formalism) and Beyond-Gaussian approximation of GW likelihoods.
- To determine H_o we are going to use the Cosmography approach (still on discussion)

```
def DL_model(z,H0,Om):
    cosmo = FlatLambdaCDM(H0,Om)
    return cosmo.luminosity_distance(z).value # Mpc
```

```
class Cosmo_Lilikelihood( bilby.Likelihood ):
    def __init__(self,args):
        self.Data = args[0]
        self.Err  = args[1]

        aux = {'H0':None, 'Om':None}
        super().__init__(aux)

    def log_likelihood(self):
        H0 = self.parameters['H0']
        Om = self.parameters['Om']

        Data = self.Data
        Err  = self.Err

        Model = DL_model(z,H0,Om)

        chi2 = np.sum( (Data-Model)**2/Err**2 )

        loglike = -0.5*chi2

        if(np.isnan(loglike)): return -1.e10
        else: return loglike
```



Thank you for your attention!

mayara.pacheco@inpe.br

Dark Siren/ Statistical Method

If no EM counterpart can be detected, other methodologies are nevertheless used to gather redshift information complementary to a GW binary signal.

- Suppose H_0 is less than some $H_{máx}$
- Na error box can be surveyed for bright galaxies with velocities below $H_{máx} d_L$
- In this box error, each cluster redshift gives a candidate value for H_0

HOW

Crossmatching the sky localization error volume, sometimes simply called volume error-box, of the GW source with galaxy catalogs collected by EM surveys.

MNRAS 000, 1–12 (2023) Preprint 2 November 2023 Compiled using MNRAS LATEX style file v3.0
FERMILAB-PUB-23-550-LDRD-PPD

A dark siren measurement of the Hubble constant using gravitational wave events from the first three LIGO/Virgo observing runs and DELVE

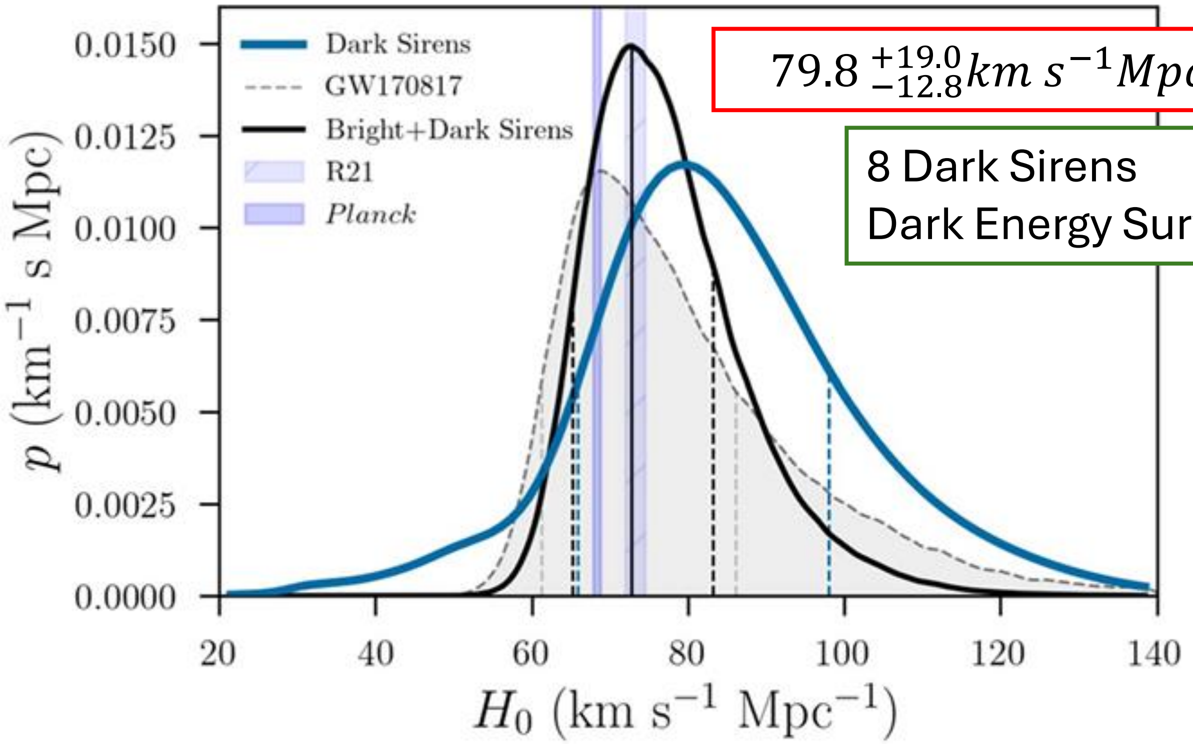
V. Alfradique[1⋆], C. R. Bom[1,2], A. Palmese[3], G. Teixeira[1], L. Santana-Silva[1], A. Drlica-Wagner[4,5,6], A. H. Riley[7], C. E. Martínez-Vázquez[8], D. J. Sand[9], G. S. Stringfellow[10], G. E. Medina[11], J. A. Carballo-Bello[12], Y. Choi[13], J. Esteves[14], G. Limberg[5,6,15], B. Mutlu-Pakdil[16], N. E. D. Noël[17], A. B. Pace[3], J. D. Sakowska[18], J. F. Wu[19,20]

Dark siren cosmology with binary black holes in the era of third-generation gravitational wave detectors

Niccolò Muttoni[1, 2, *] Danny Laghi[1] Nicola Tamanini[1] Sylvain Marsat[1] and David Izquierdo-Villalba[3, 4]
[1]Laboratoire des 2 Infinis - Toulouse (L2IT-IN2P3), Université de Toulouse, CNRS, UPS, F-31062 Toulouse Cedex 9, France
[2]Département de Physique Théorique and Gravitational Wave Science Center, Université de Genève, 24 quai Ernest Ansermet, 1211 Genève 4, Switzerland
[3]Department of Physics G. Occhialini, University of Milano - Bicocca, Piazza della Scienza 3, 20126 Milano, Italy
[4]INFN, Sezione di Milano-Bicocca, Piazza della Scienza 3, 20126 Milano, Italy
(Dated: September 6, 2023)

The Hitchhiker's Guide to the Galaxy Catalog Approach for Dark Siren Gravitational-wave Cosmology

Jonathan R. Gair[1], Archisman Ghosh[2], Rachel Gray[3], Daniel E. Holz[4], Simone Mastrogiovanni[5], Suvodip Mukherjee[6], Antonella Palmese[7,8,32], Nicola Tamanini[9], Tessa Baker[4], Freija Beirnaert[2], Maciej Bilicki[10], Hsin-Yu Chen[11,12], Gergely Dálya[2], Jose Maria Ezquiaga[13], Will M. Farr[14,15], Maya Fishbach[16], Juan Garcia-Bellido[17], Tathagata Ghosh[18], Hsiang-Yu Huang[19], Christos Karathanasis[20], Konstantin Leyde[21], Ignacio Magaña Hernandez[22], Johannes Noller[23,24], Gregoire Pierra[25], Peter Raffai[26], Antonio Enea Romano[27,28], Monica Seglar-Arroyo[20], Danièle A. Steer[29,30], Cezary Turski[2], Maria Paola Vaccaro[20], and Sergio Andrés Vallejo-Peña[27]



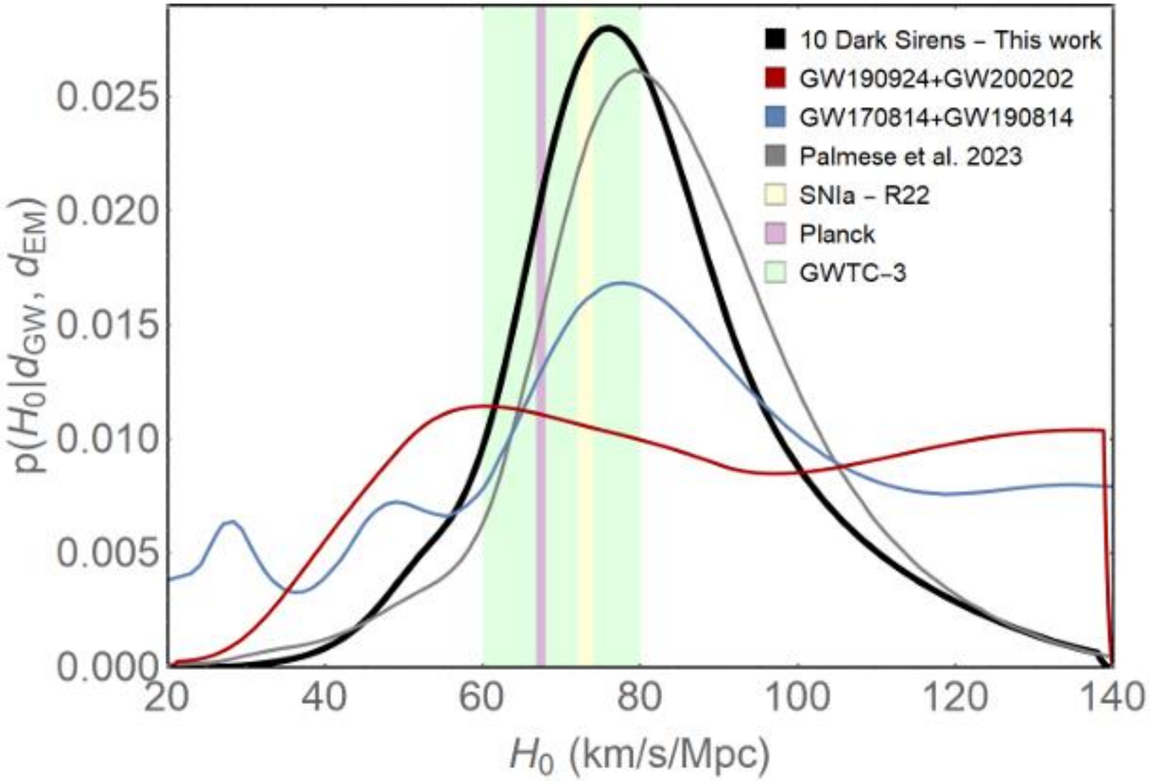
$79.8^{+19.0}_{-12.8} km\ s^{-1} Mpc^{-1}$

8 Dark Sirens
Dark Energy Survey (DES)

A. Palmese *et al* 2023 *ApJ* **943** 56

A single dark siren BBH provides a measure of H0 with a precision of 48% for GW170814 and 55% GW190814. Recently, Palmese et al. (2023) demonstrated that 8 dark sirens well localized in the sky are able to provide a measurement as accurate as that obtained with a single bright siren GW170817 (about 20% against 18%0

The photometric redshifts of the possible host galaxies of these two events are acquired from the DECam Local Volume Exploration Survey (DELVE) carried out on the Blanco telescope at Cerro Tololo in Chile.



arXiv:2310.13695