Today's announcement on GW observational science:

We will join from AULA FORTUNA h19:00

New Pulsar Timing Array results !

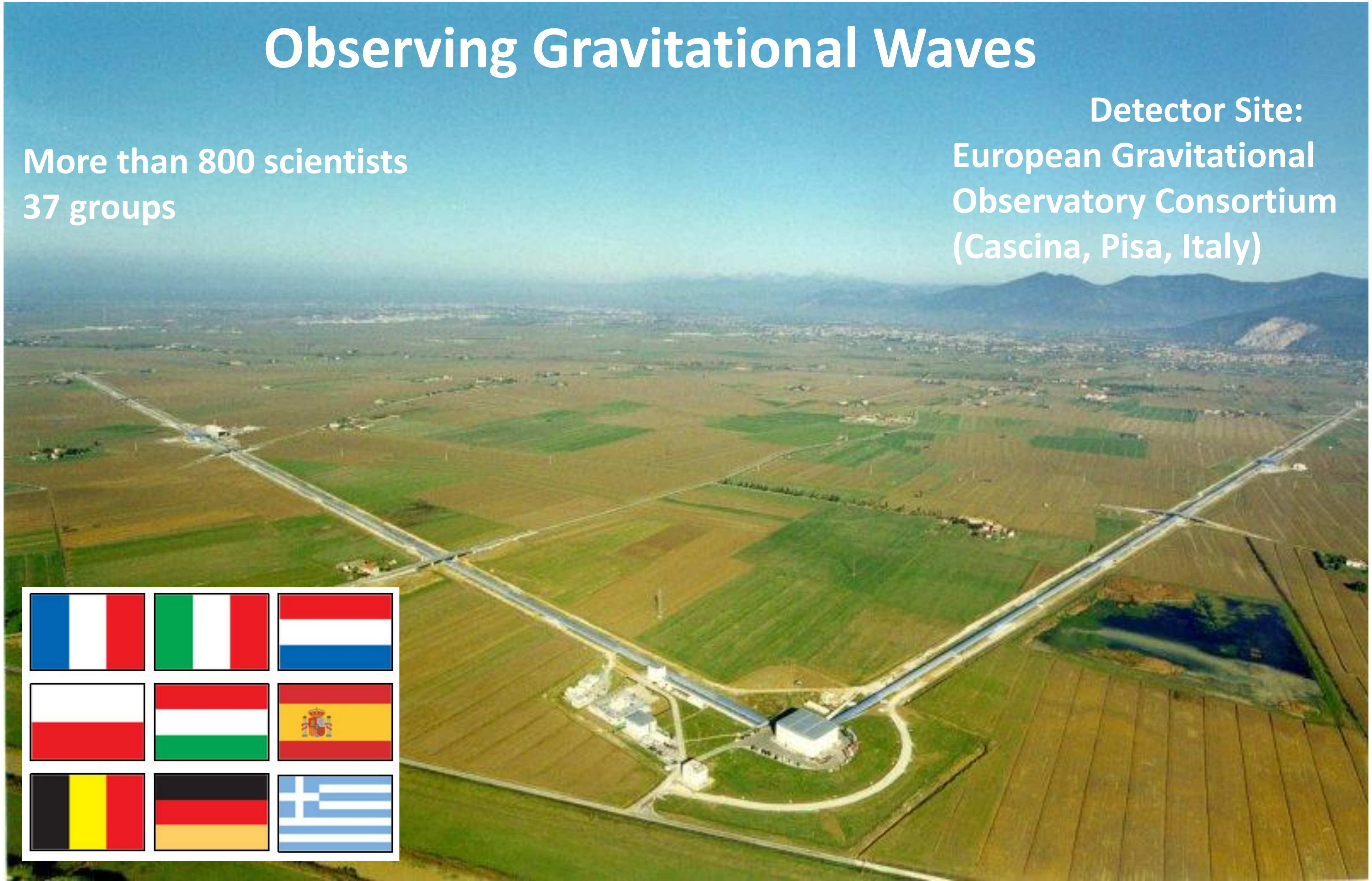
On June 29th, the North American Nanohertz Observatory for Gravitational Waves (**NANOGrav**) will be making a major announcement during a live-streamed event! This is in coordination with results being released by other PTAs around the globe.

We invite all interested members of the public to join our public announcement event on **Thursday, June 29, 2023 at 1:00 PM Eastern US Time.** The announcement will report results of the analysis of NANOGrav's 15-year data set, and interpretations of those results.

https://nanograv.org/news/2023Announcement
https://arxiv.org/abs/2306.16213

VIRGO

Observing Gravitational Waves



a large collaboration

LIGO & Virgo coordinating detector upgrades

Joined by **KAGRA collaboration (Japan)**

- joint strategies for observing runs and data analysis;
- prompt public alerts for multimessenger astronomy.
- Virgo detector expected to approach LIGO sensitivity across the entire spectrum in O4.

Current Virgo Group at TIFPA

Composition	FTE 4.7
Matteo Leonardi	0.4
Albino Perego	0.4
Antonio Perreca	**0.6**
Giovanni Prodi	**0.7**
Alessandro Martini	**1.0**
Andrea Miani	**0.8**
Sophie Bini	**0.8**
Gianmarco Puleo	**LM**
Damiano Avi	
Roberto Graziola	
Claudio Salomon	
Massimo Gennara	

activities:

- **Virgo Detector upgrade and commissioning**
  - implementation of signal recycling
  - instrument sensing and control
  - Mode Matching sensing and control for squeezed light injection
- **R&D in instrument science**:
  - optical mode matching devices
    - optical actuators
    - Study of Mode Matching control loop
  - squeezed light sources

- **Virgo LIGO KAGRA observational science**
  - transient gravitational waves
    - detection
    - characterization
  - interpretation of NS observations
- **R&D in data analysis and modeling of GW sources**

R&D activities have large overlap with **Einstein Telescope**

Virgo preventivi TIFPA 2024

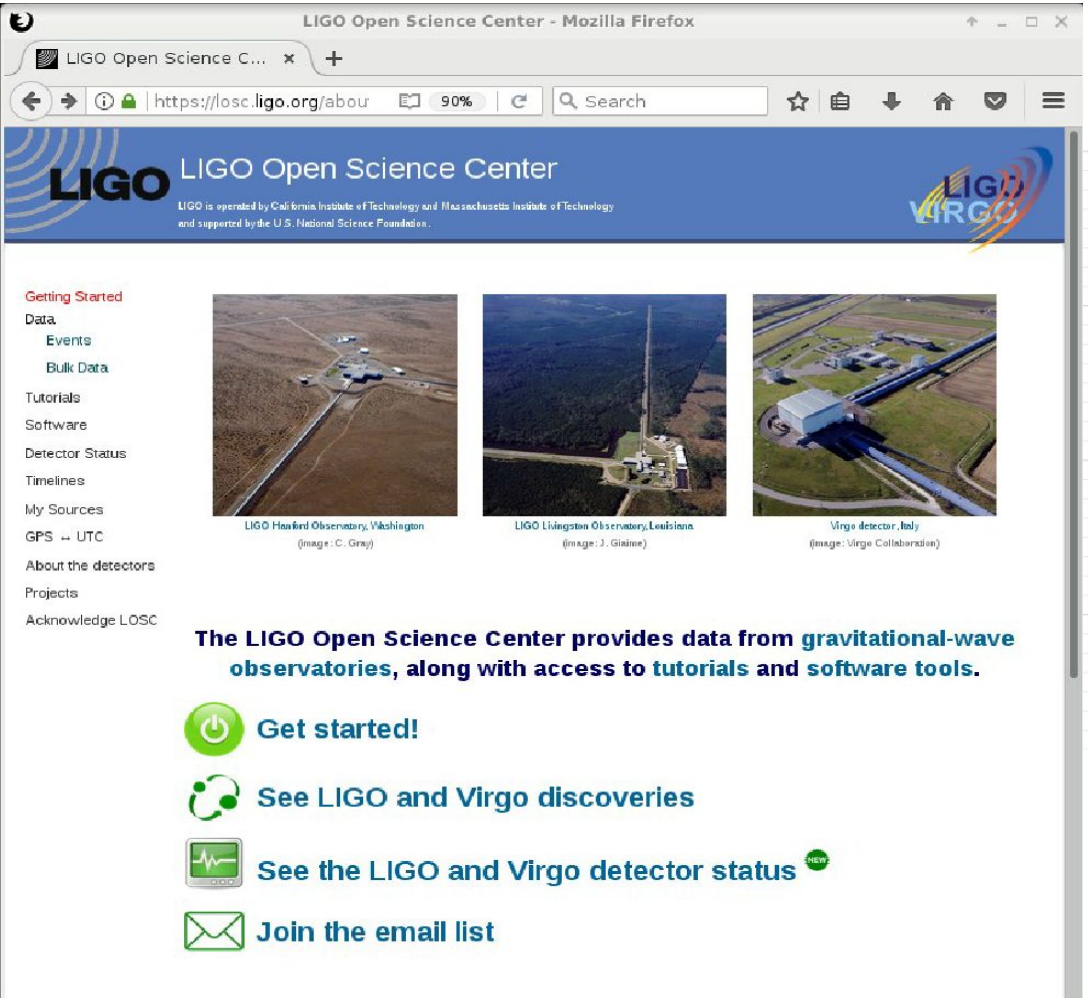
Non ancora definitivi, saranno richieste simili a quelle dell’anno scorso:

- Hardware: ~ 20 k (inventariabile + consumo)

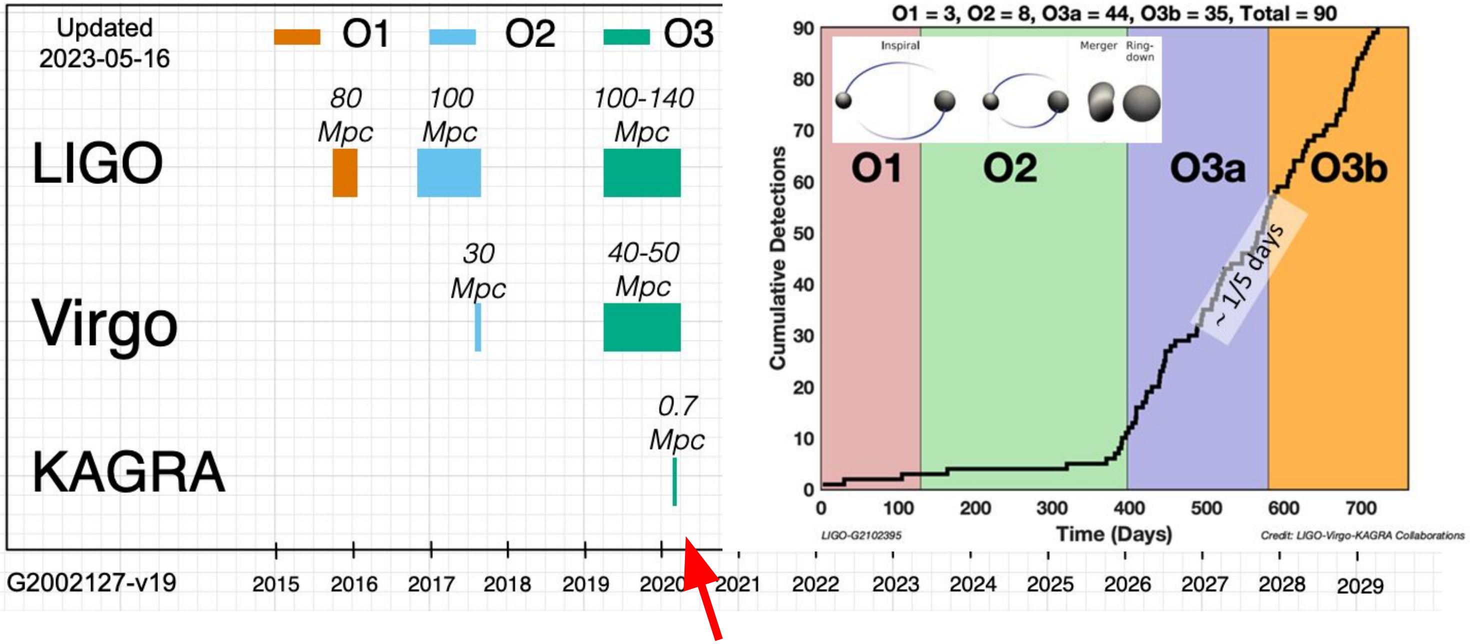
- Travel funds:
    - shifts at Virgo site: commissioning/noise hunting pre-O4 and operation O4
    - joint work with other LIGO-Virgo groups at their sites
    - topical f2f meetings when feasible and collaboration meetings
    -
    - Selected conferences

LIGO–Virgo **past** Gravitational Wave Surveys

- **Open data:**
- **LV** [10.1016/j.softx.2021.100658]
  LV *arXiv:2302.03676 (2023).*
  http://www.gw-openscience.org



First 5 years:
from GW detection to GW astronomy
nominal BNS ranges in Mpc
doi.org/10.1007/s41114-020-00026-9
LIGO-G2002127-v12



- **first observation by KAGRA and GEO600**
  Progress of Theor. and Exp. Phys. **2022**, 063F01 (2022)

LIGO–Virgo **past** observations' highlights

catalog.cardiffgravity.org

Yet to detect emissions different from Compact Binary Coalescences

90 confirmed detections of Compact Binary Coalescences

"…expect ~ 10% of false alarms"

\+ marginal and subthreshold candidates

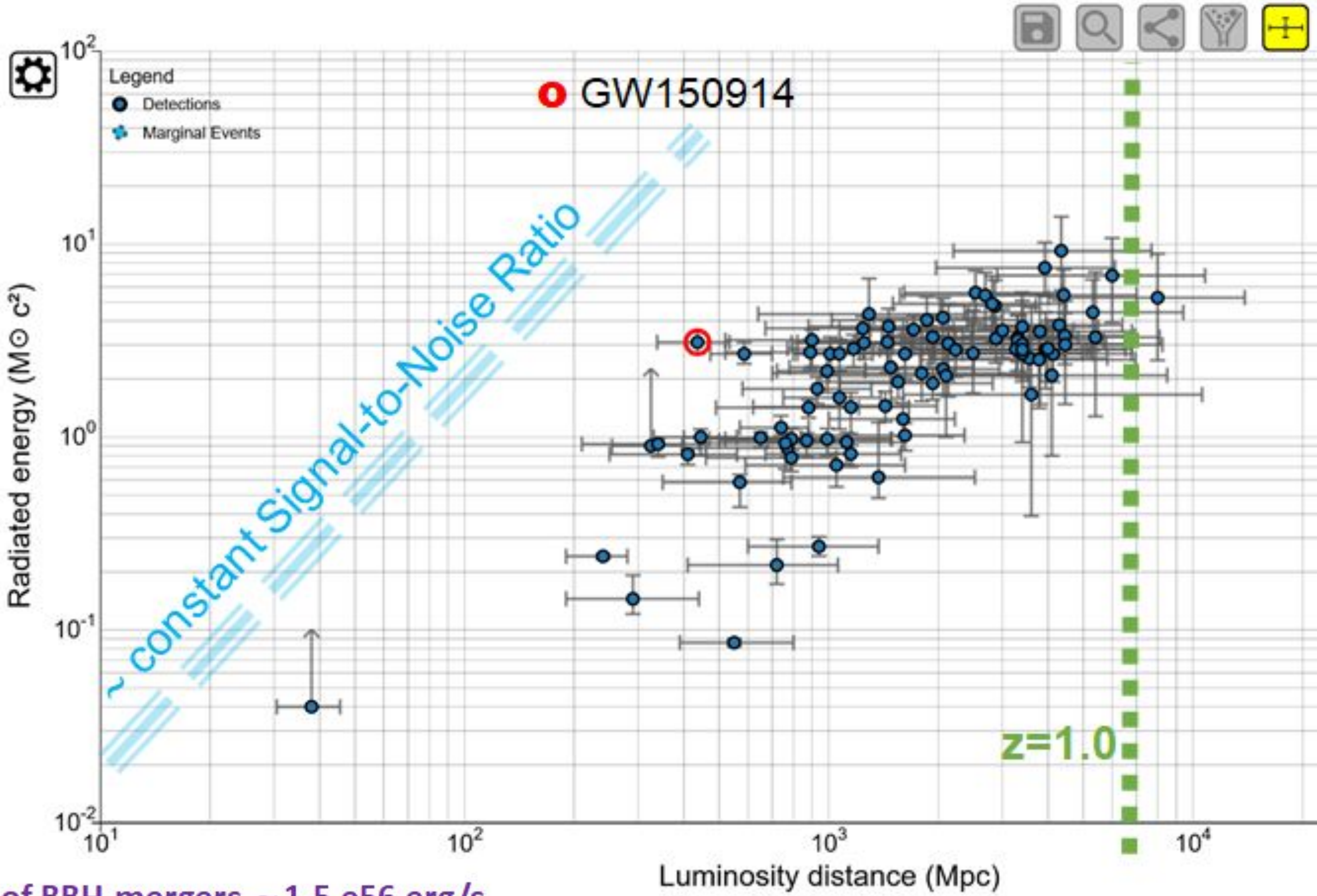
Radiated energy in GWs up to 10 solar masses

Distances up to z=1

GW Transient Catalogs:

GWTC-3 arxiv:2111.03606

GWTC-2.1 arxiv:2108.01045



Peak luminosity of BBH mergers ~1-5 e56 erg/s

~ 1e-3 of the upper limit set by GR (~ Planck Luminosity)

LIGO-Virgo **past** observations' highlights

catalog.cardiffgravity.org

Yet to detect emissions different from Compact Binary Coalescences

90 confirmed detections of Compact Binary Coalescences

+ marginal and subthreshold candidates

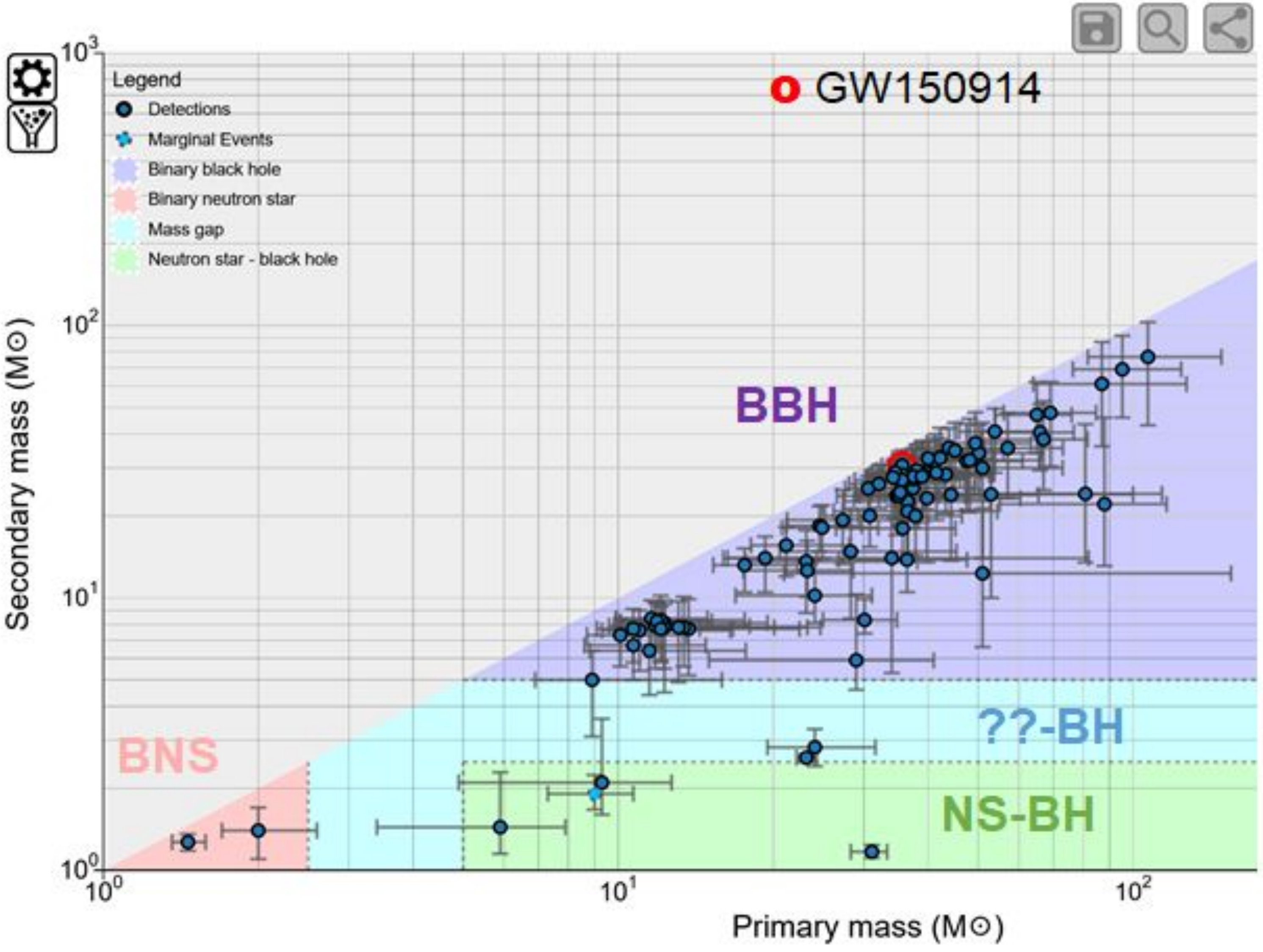
mostly binary BH mergers

2 Binary Neutron Star mergers

3 NS-BH mergers

2 ??-BH: ambiguous lighter object in-between known NS and BH mass ranges

3 intermediate mass BH



LIGO-Virgo-KAGRA Gravitational Wave Surveys

GraceDB Public Alerts Latest Search Documentation Login

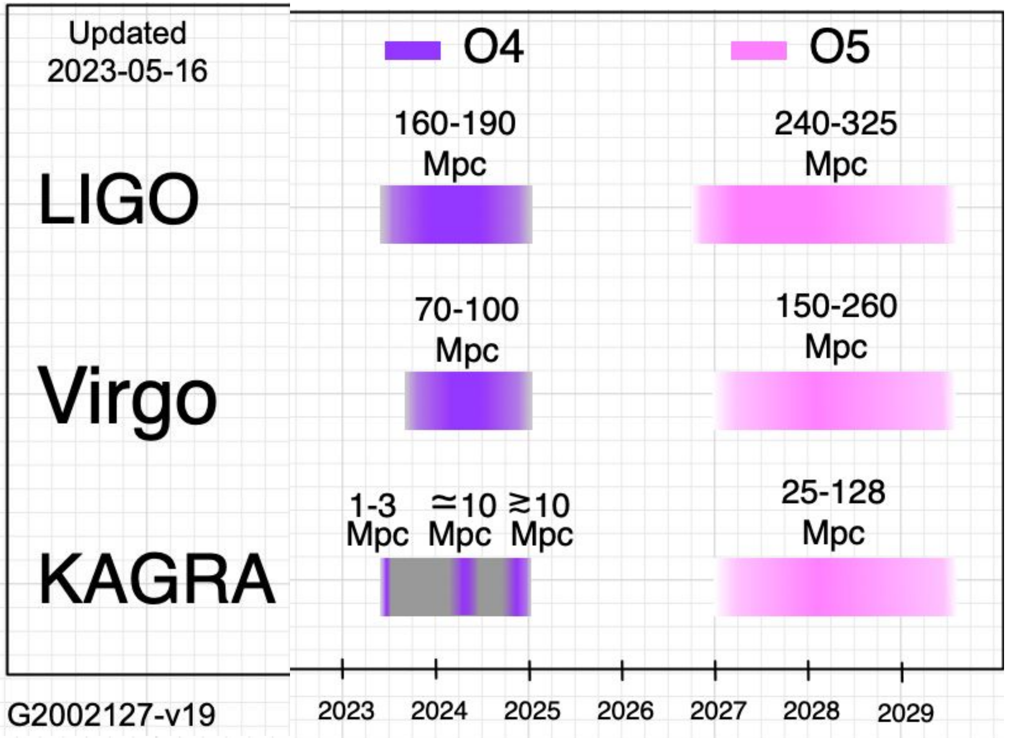
Please log in to view full database contents.

Event ID	Possible Source (Probability)	Significant	UTC	GCN	Location	FAR	Comments
S230628ax	BBH (>99%)	Yes	June 28, 2023 23:12:00 UTC	GCN Circular Query Notices | VOE		1 per 100.04 years	
S230627c	NSBH (49%), BBH (48%), Terrestrial (3%)	Yes	June 27, 2023 01:53:37 UTC	GCN Circular Query Notices | VOE		1 per 100.04 years	
S230624av	BBH (95%), Terrestrial (5%)	Yes	June 24, 2023 11:31:03 UTC	GCN Circular Query Notices | VOE		1 per 2.4372 years	
S230622ba	BBH (87%), Terrestrial (13%)	Yes	June 22, 2023 14:35:36 UTC	GCN Circular Query Notices | VOE		1.6345 per year	RETRACTED
S230609u	BBH (96%), Terrestrial (4%)	Yes	June 9, 2023 06:49:58 UTC	GCN Circular Query Notices | VOE		1 per 3.1557 years	
S230608as	BBH (>99%)	Yes	June 8, 2023 20:50:47 UTC	GCN Circular Query Notices | VOE		1 per 231.43 years	
S230606d	BBH (>99%)	Yes	June 6, 2023 00:43:05 UTC	GCN Circular Query Notices | VOE		1 per 2.7789 years	
S230605o	BBH (99%), Terrestrial (1%)	Yes	June 5, 2023 06:53:43 UTC	GCN Circular Query Notices | VOE		1 per 7.0086 years	
S230601bf	BBH (>99%)	Yes	June 1, 2023 22:41:34 UTC	GCN Circular Query Notices | VOE		1 per 1.8492e+07 years	
S230529ay	NSBH (62%), BNS (31%), Terrestrial (7%)	Yes	May 29, 2023 18:15:00 UTC	GCN Circular Query Notices | VOE		1 per 160.44 years	
S230524x	BNS (75%), Terrestrial (25%)	Yes	May 24, 2023 20:22:41 UTC	GCN Circular Query Notices | VOE		2.2799 per year	RETRACTED

- **Current survey: Observing run 4**

started on May 24, 2023

public alerts in low latency
https://gracedb.ligo.org



LIGO-Virgo-KAGRA Observing run 4

https://gwosc.org/detector_status/

GWOSC Calendar Today Yesterday O4 summary Previous Observing Runs

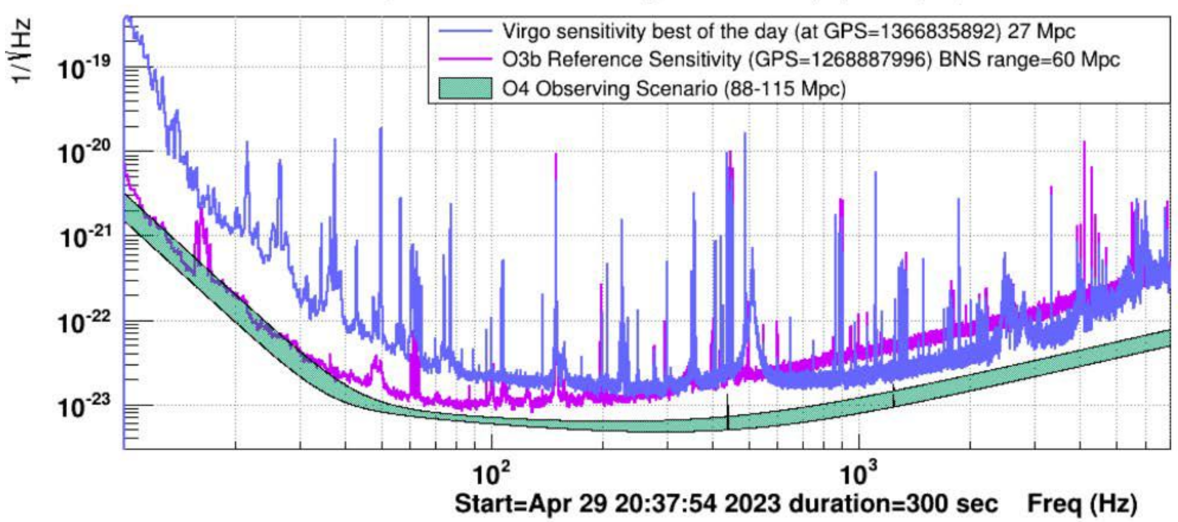
Gravitational-Wave Observatory Status

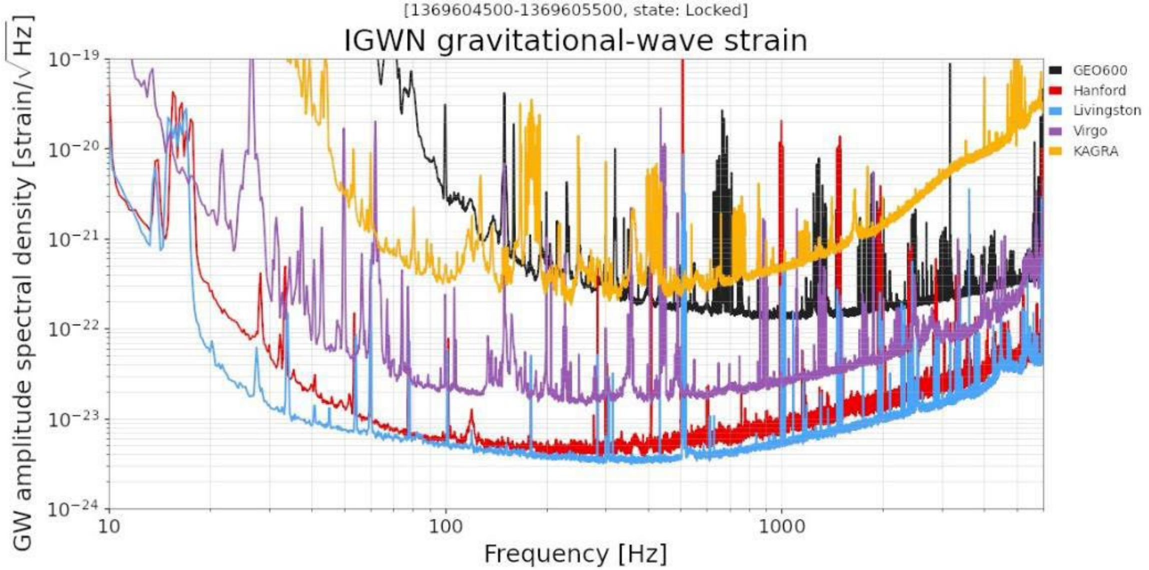
Please select a date from the calendar above to see archived or current status.

Information is available for dates after November 30, 2016. The Advanced LIGO and KAGRA detectors have begun the fourth observing run, known as O4, as of May 24, 2023. The entry of the Advanced Virgo detector into O4 has been postponed in order to continue detector commissioning activities and further increase the sensitivity of the detector. Summaries of the current observing run and previous observing runs are available in the menu above. For overviews of LIGO, Virgo, and KAGRA observing runs, see the arXiv:1304.0670.

- **Today's Summary Page**
- Current Status (GWISTAT)
- LIGO/Virgo Alerts (GraceDB)
- Hanford alog – Livingston alog – Virgo logbook – KAGRA klog
- LIGO Laboratory – Virgo – KAGRA Observatory – GEO600

Virgo sensitivity in April 2023:





Searches for transient gravitational waves @ Trento

Pursuing the most general search for transient gravitational waves

- Agnostic method wrt the signal morphology
- Phase-coherent analysis of the detector network
- All-sky, all-time, full frequency-band survey

LVK Collaborations Phys. Rev. D 104, 122004 (2021)

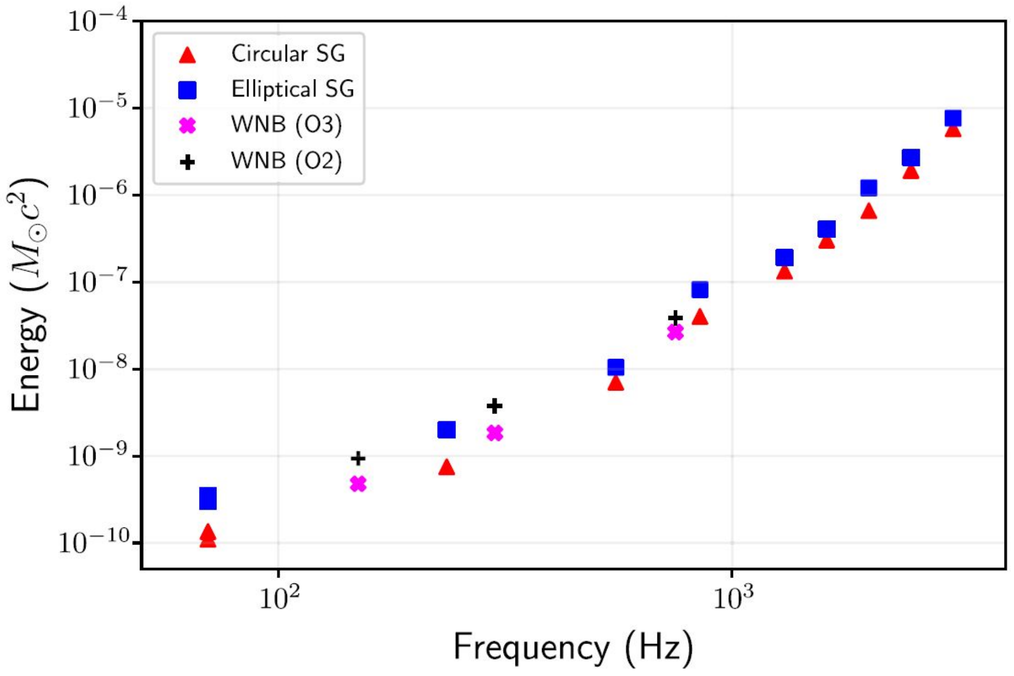
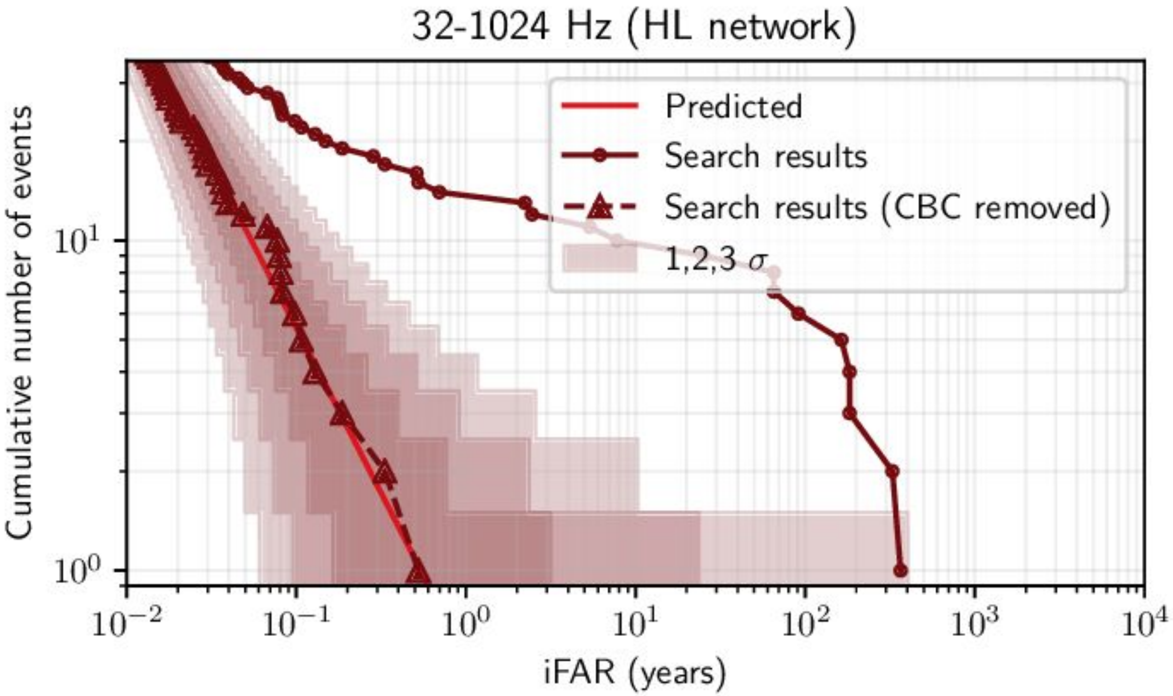
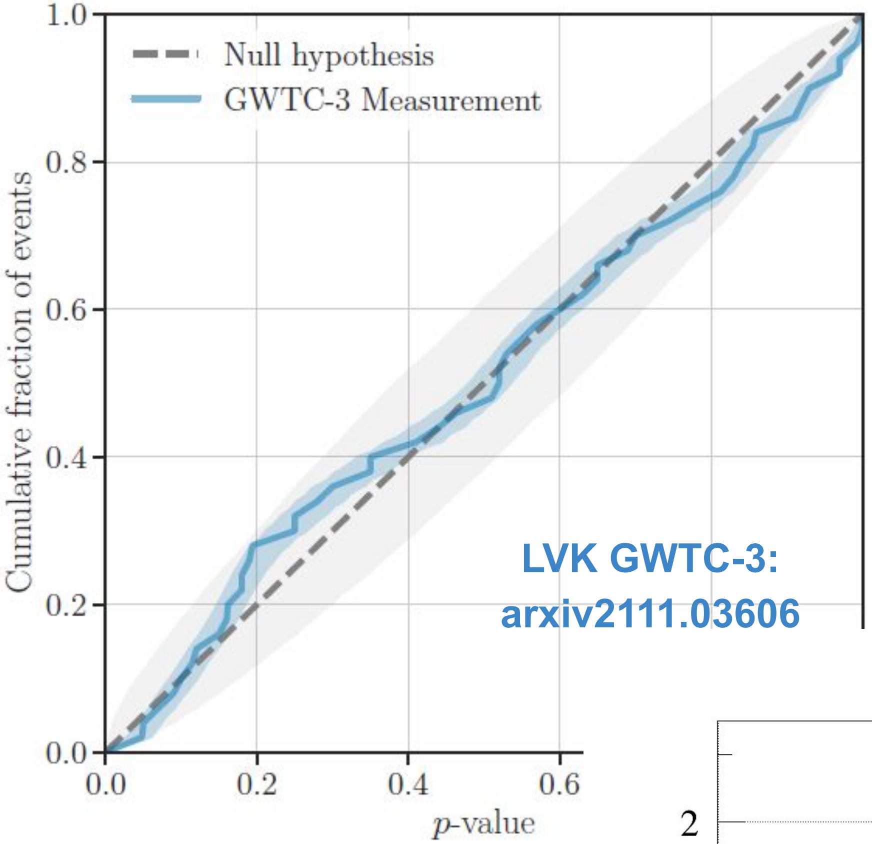


FIG. 5. The GW emitted energy in units of solar masses that correspond to a 50% detection efficiency at an IFAR of ≥ 100 years, for a source emitting at 10 kpc. The wave



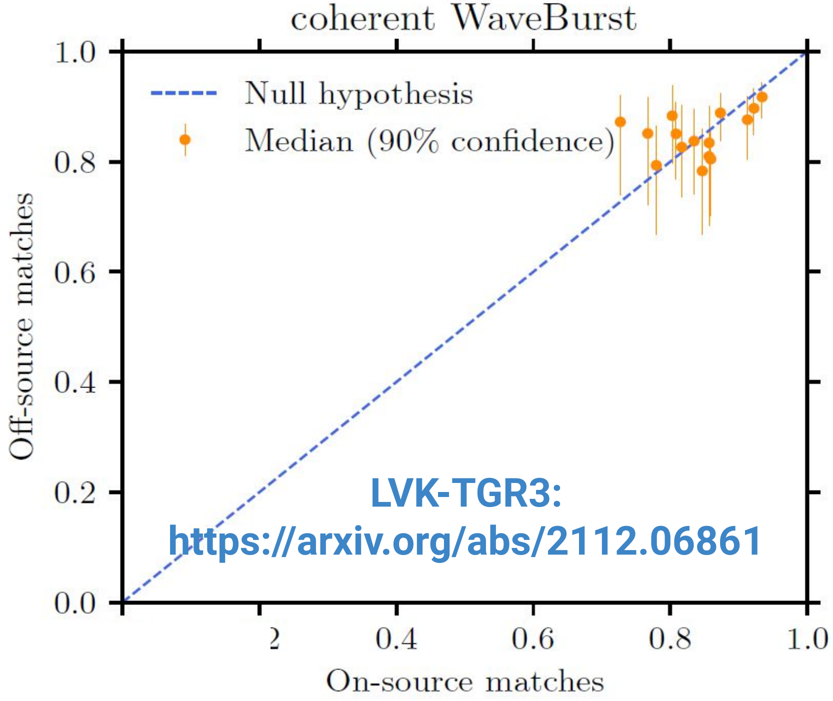
No other GW transients once Compact Binary Coalescences are excised

Unmodeled reconstruction vs GR models

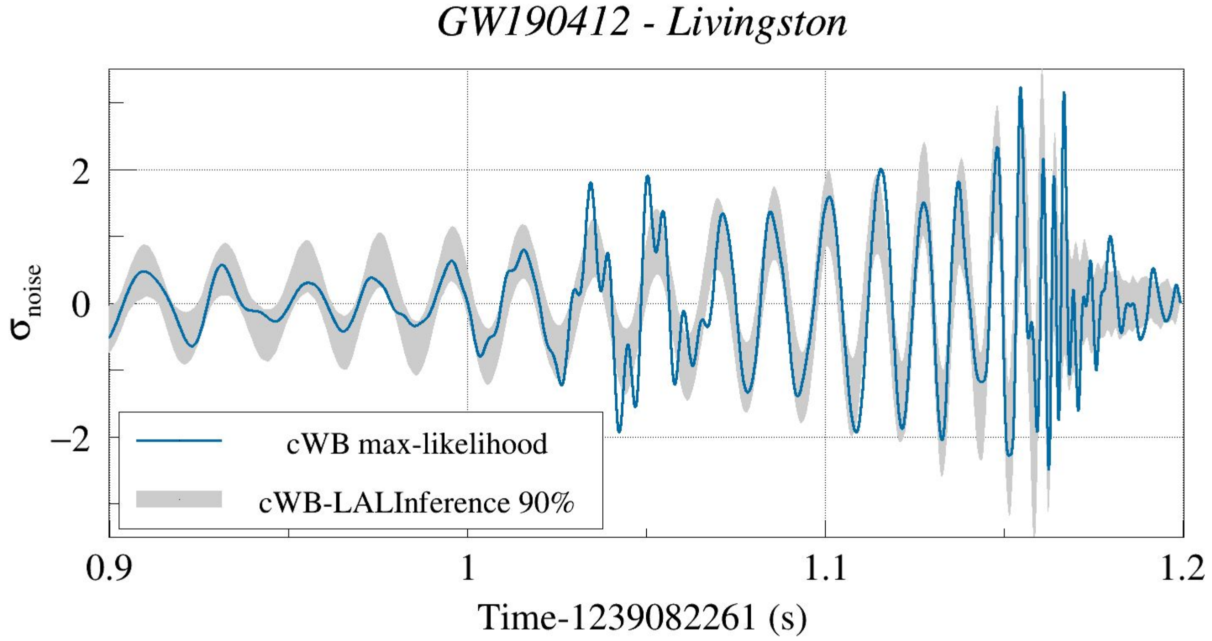


LVK GWTC-3:
arxiv2111.03606

check of consistency between preferred signal model and our data-driven agnostic reconstruction

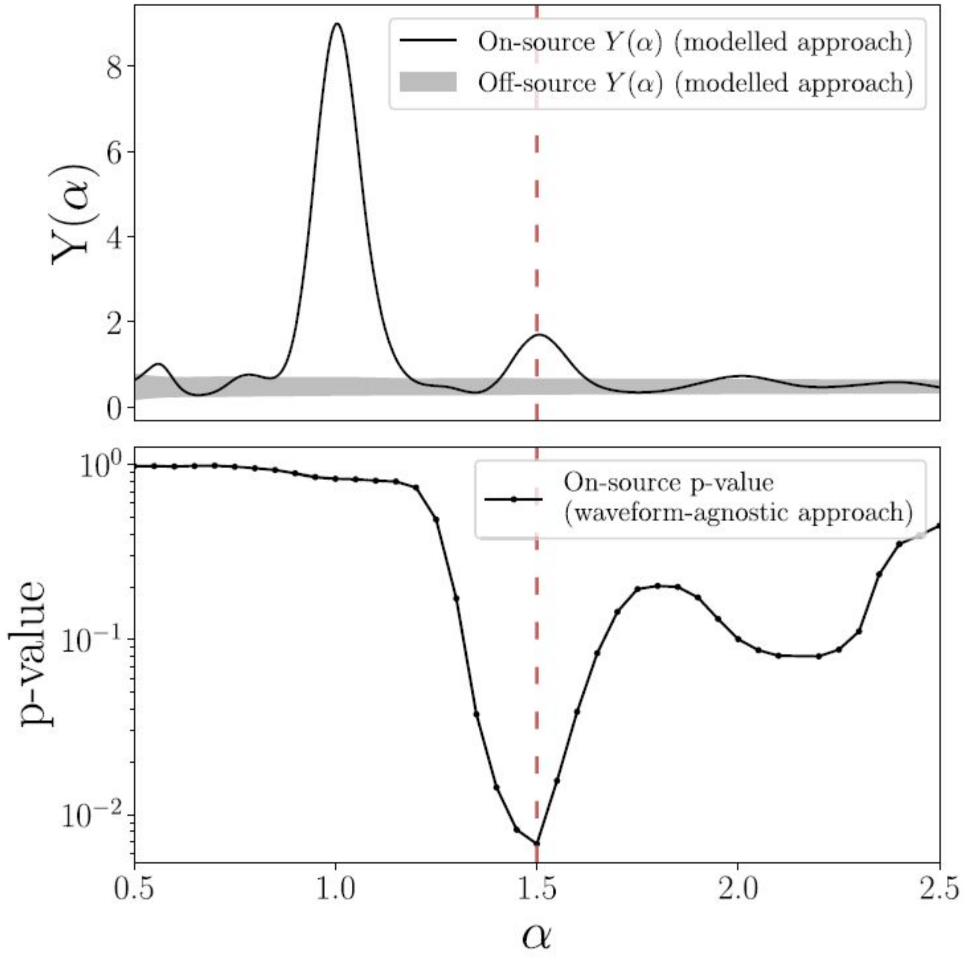


LVK-TGR3:
https://arxiv.org/abs/2112.06861

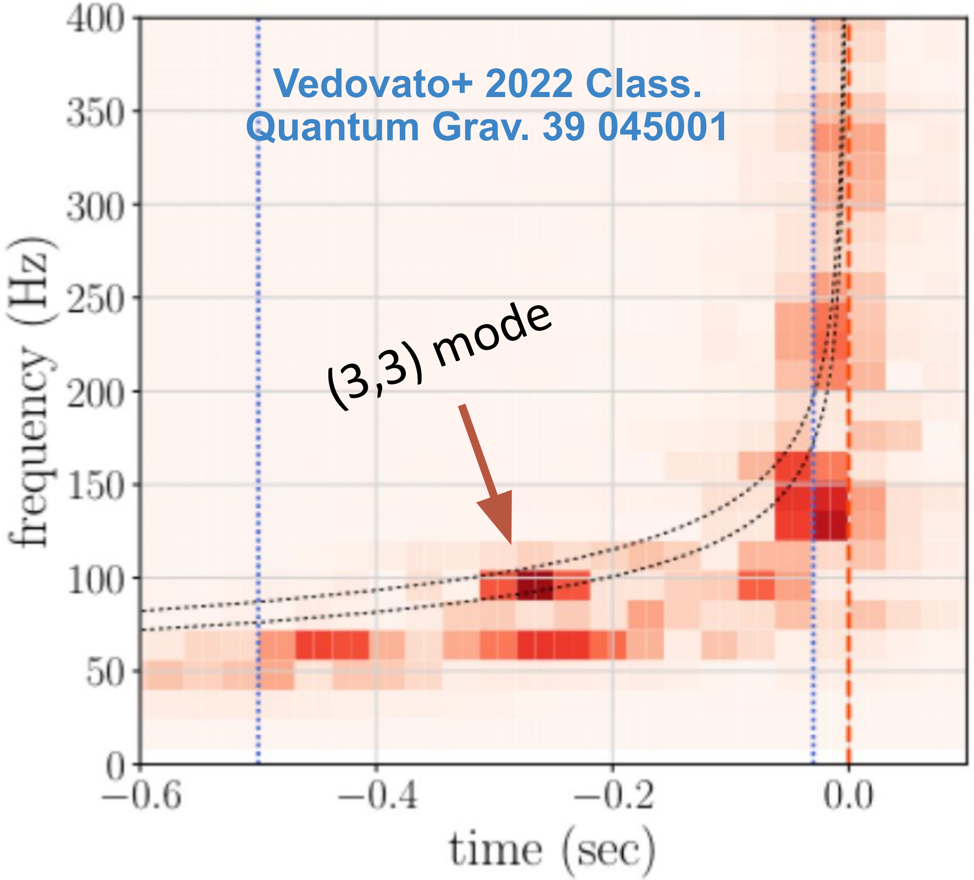


Unmodeled reconstruction vs GR models

Characterization of the signal waveform and detection of weak features



LVK GW190814: APJ896L44



Detection of l=3, |m|=3 higher order multipole in the inspiral of GW190814 at 1.5 * freq. of quadrupolar mode

Improving the most general search for GW transients

- Discrimination from noise
- Characterization of event properties

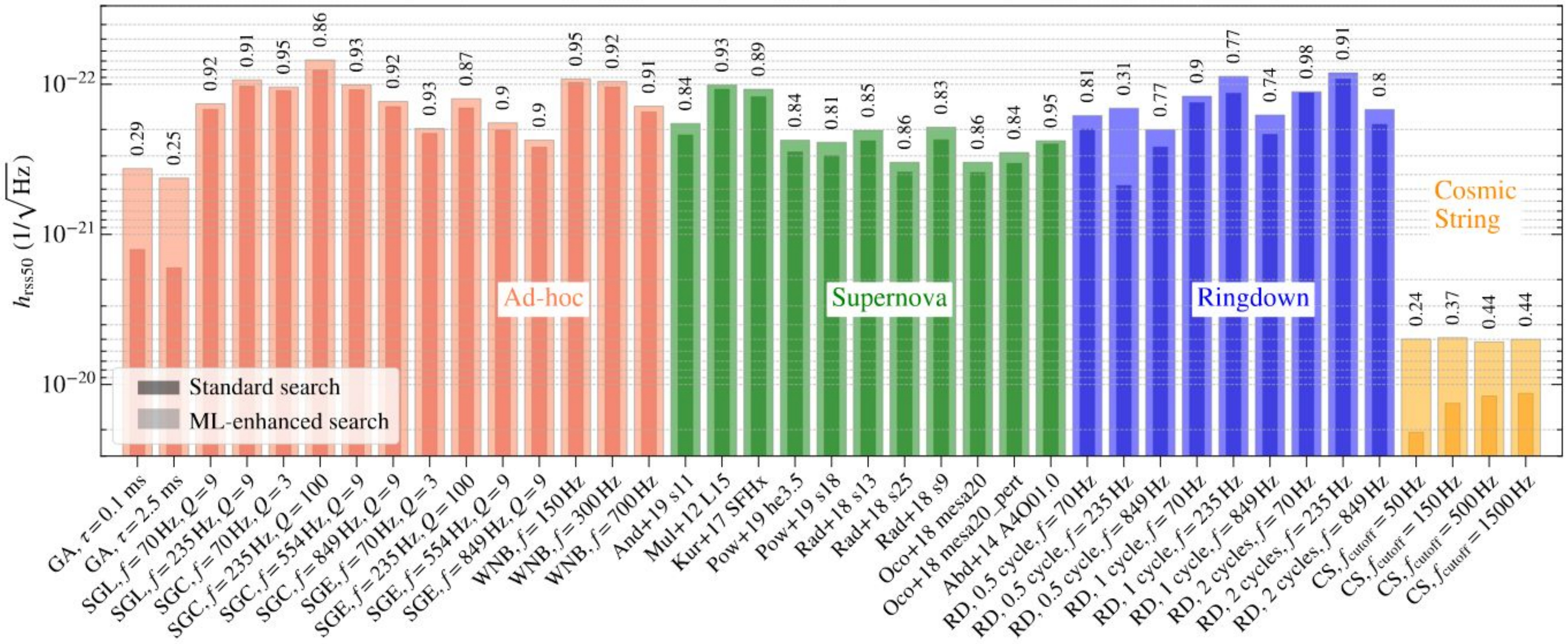


FIG. 2: Resulting h_{rss50} achieved with cWB with standard post-production veto procedure (darker colors) and with ML-enhanced cWB (lighter colors) for the HL network on full O3 and at iFAR$\geq$ 100 years. The waveforms reported are a subset of those listed in Table I: ad-hoc signals ordered according to central frequency (red), core-collapse supernovae (green), ringdown waveforms (blue), and cosmic strings (yellow). The values on the top show the reduction factor on h_{rss50} with respect to the standard search; h_{rss50} ordinate scale decreases going upwards.

Szczepańczyk, M. J., Salemi, F., Bini, S., et al. (2022).
All-sky search for gravitational-wave bursts in the third Advanced LIGO-Virgo run with coherent WaveBurst enhanced by Machine Learning.
Phys. Rev. D 107, 062002 (2023) https://doi.org/10.1103/PhysRevD.107.062002

Improving glitch discrimination

An autoencoder neural network learns transient noises morphologies from GW time-series. → Improving sensitivity to generic GW transients and binary black hole mergers

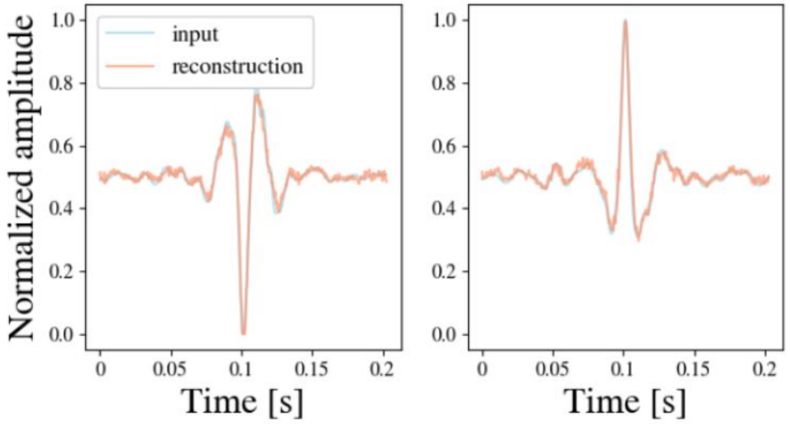


Figure 2. Two examples of blip time-series according to the GravitySpy classification detected by cWB in LIGO Hanford. In blue the autoencoder inputs x_i, that are cWB reconstructed waveforms windowed and normalized as described in Section 4.2). In orange the autoencoder reconstructions $g_D(f_E(x_i))$.

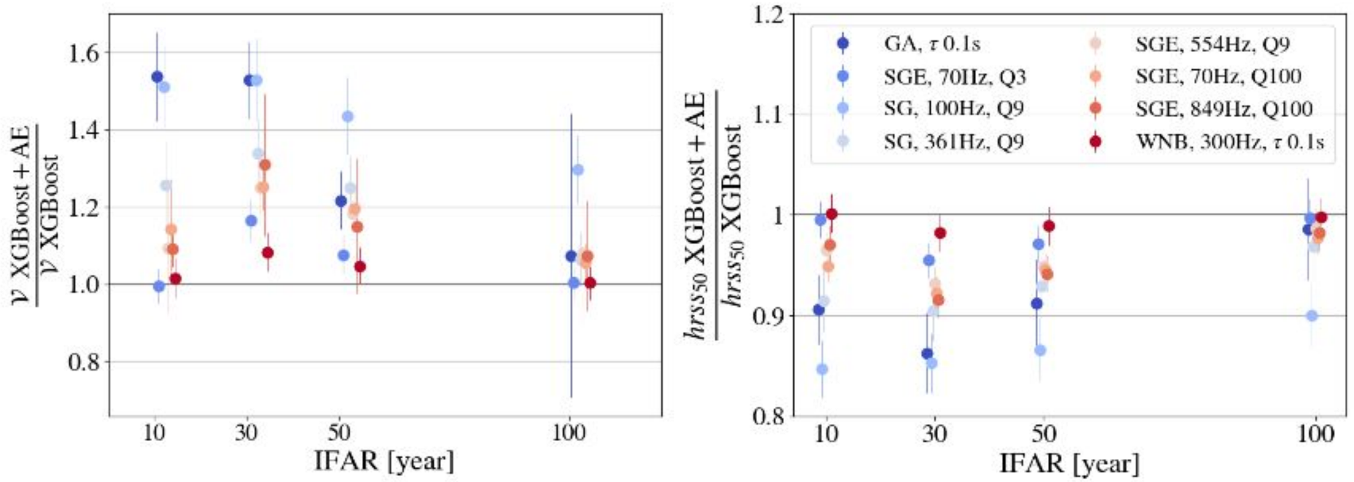


Figure 5. Ratio between the sensitivity volume $\mathcal{V}$ (left) and h_{rss50} (right) obtained including the autoencoder (`XGBoost + AE`) and without using it (`XGBoost`), at different IFAR thresholds (10, 30, 50, 100 years) for a subset of ad-hoc waveforms (data points are slightly shifted around the IFAR thresholds to avoid overlaps).The ad-hoc waveforms are: Gaussian Pulse (GA) characterized by the duration τ, then Sine Gaussian (SG) characterized by central frequency f, and the quality factor Q and White Noise Burst (WNB) with bandwidth Δf, duration τ and lower frequency bound f.

part of Sophie Bini's PhD thesis

S. Bini *et al* 2023 *Class. Quantum Grav.* **40** 135008
10.1088/1361-6382/acd981

Searches for Black Hole mimickers: post-merger echoes

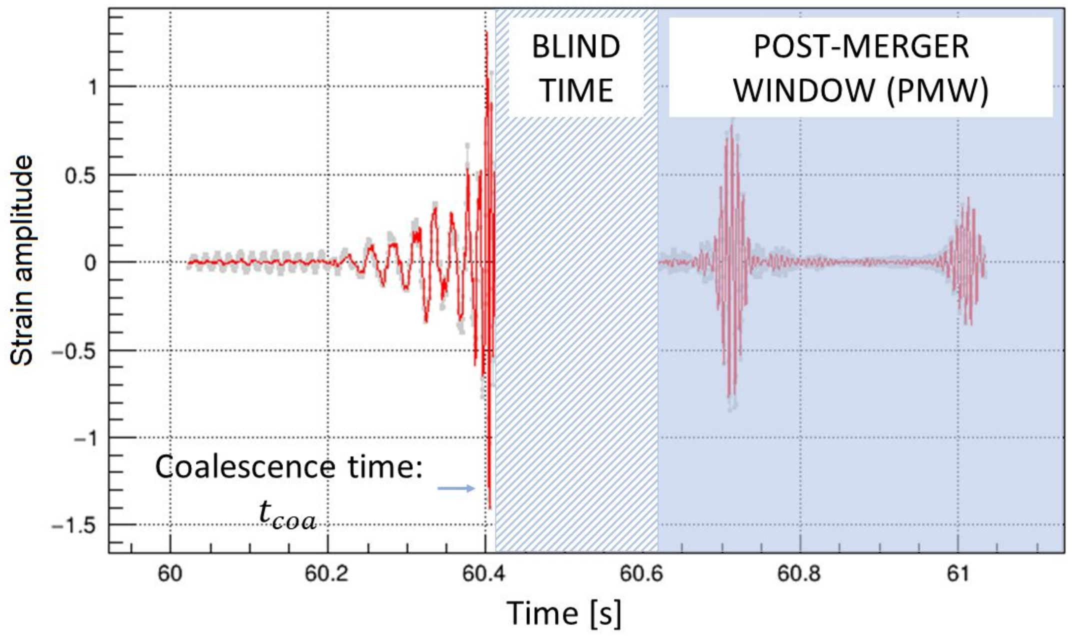
Echoes: repeated GWs pulses, after merger of binary of compact objects, ONLY IF remnant IS NOT a GR BH.

General method to search for weak GW features…

- **any exotic properties of matter at extreme densities (exotic compact objects)** ?
- **Solution of the BH information paradox ?**
- violations of the no-hair theorem for Black Holes ?

- not limited to GW echo signals
  - extendable to any post-merger features
  - morphological reconstruction
    - detector noise characterisation

Simulated Echoes

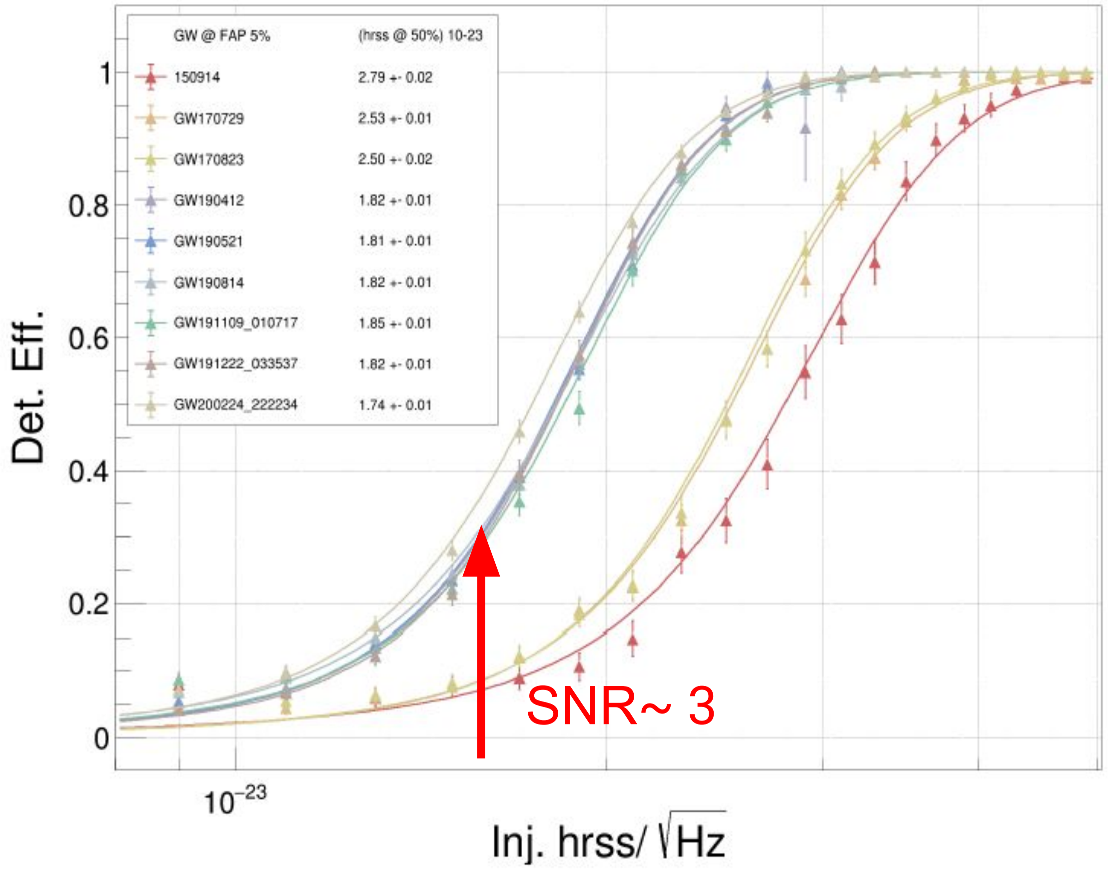


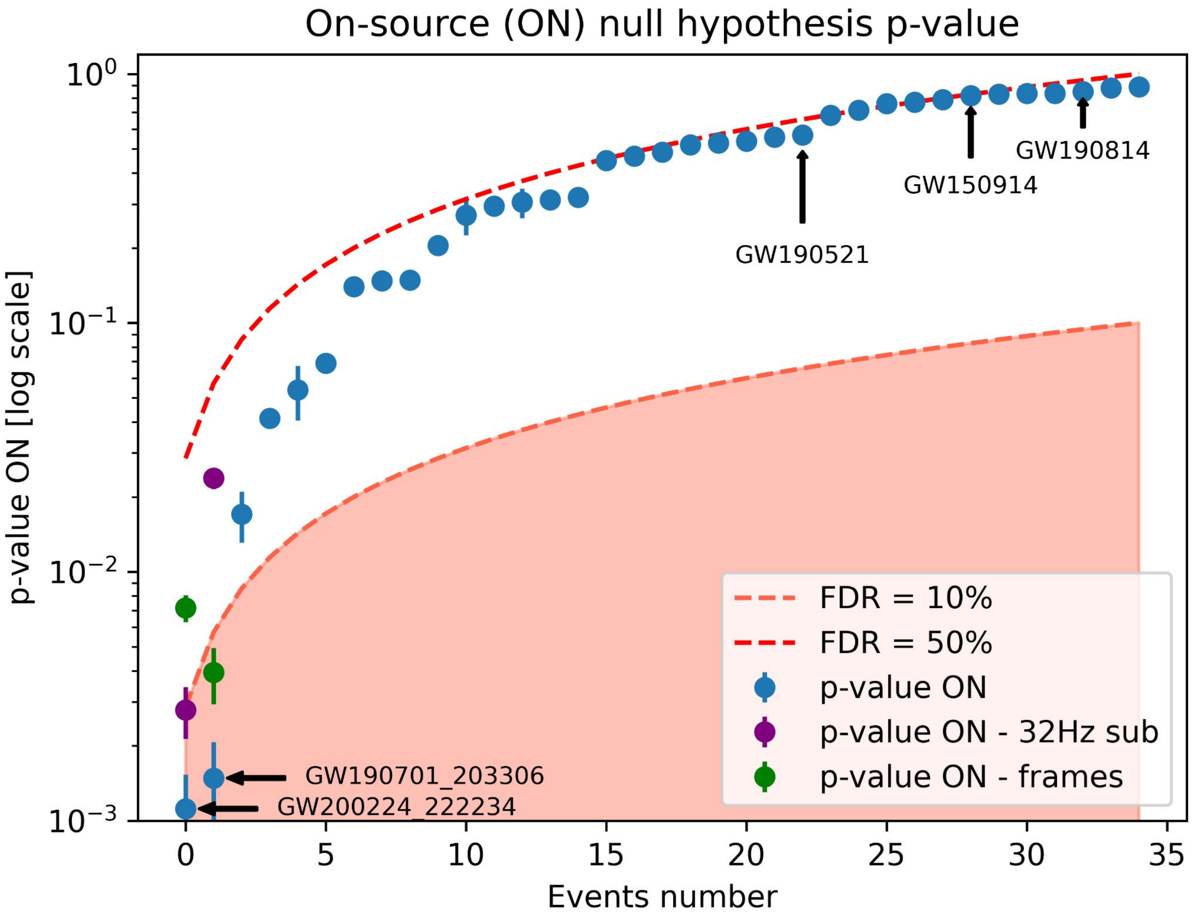
Andrea Miani's PhD thesis

A.Miani et al , arXiv:2302.12158

Searches for Black Hole mimickers: post-merger echoes

RESULTS





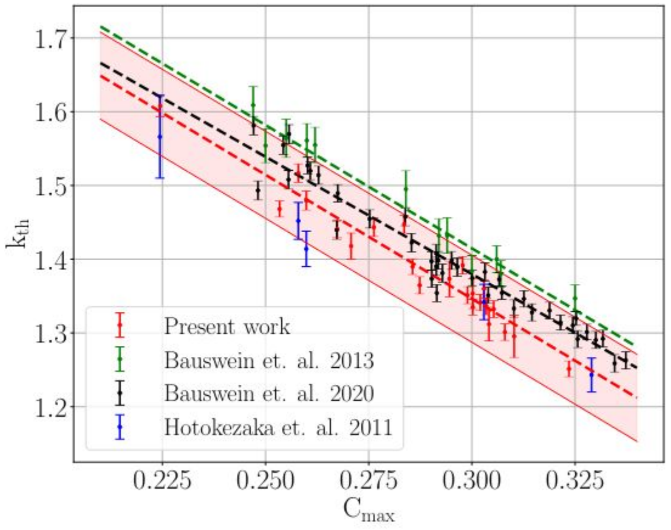
+

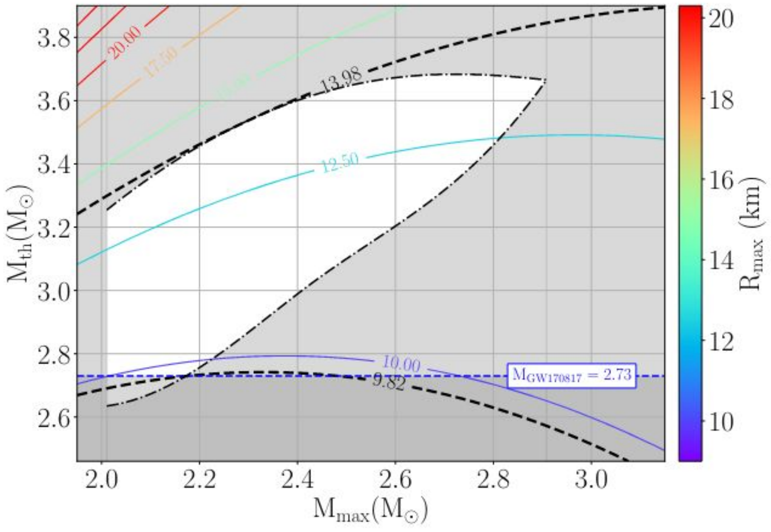
morphological reconstruction of subtreshold signals

Prompt collapse in BNS mergers

Detailed analysis of **prompt collapse** phenomenology in BNS mergers through the largest set of simulations (>400) in numerical relativity

- **EoS-insensitive relations** and **empirical constraints** for NS radii and tidal deformability from **symmetric** BNSs
- **constraints on nuclear EoS** from prompt collapse of **asymmetric** BNSs





up: Kashyap *et al, (2022) PRD*, bottom: Perego *et al*. PRL accepted