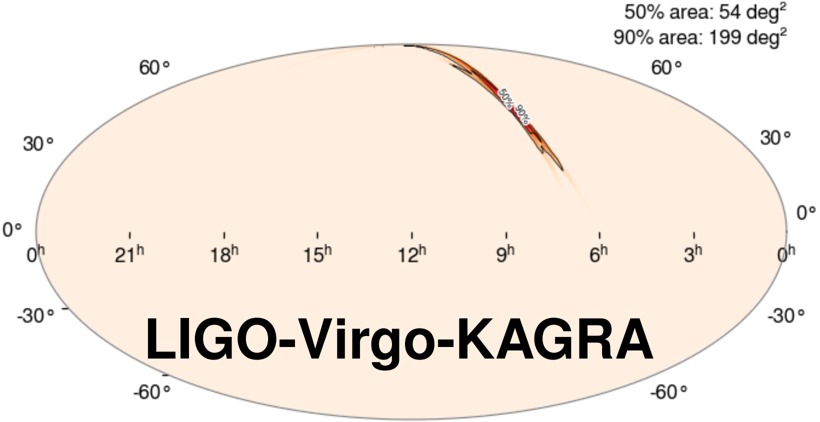
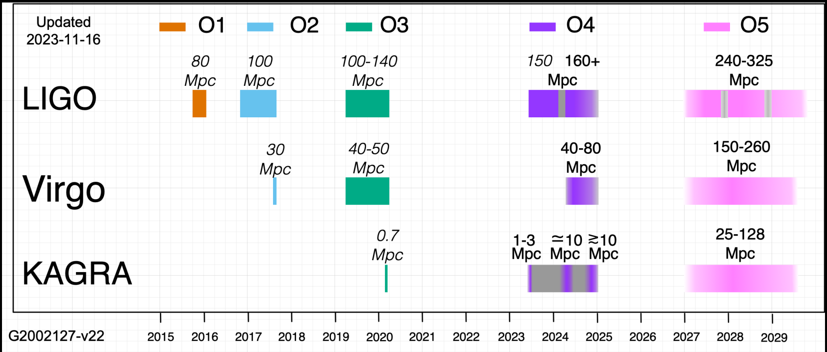


LIGO-Virgo-KAGRA

Michał Bejger, on behalf of the Virgo@CAMK group

Zjazd CAMK, 31.1.23

O4a run: 24 March 2023 - 16 January 2024



https://observing.docs.ligo.org/plan/

- ⋆ Almost 10 months of O4 (O4a), now two-months commissioning break
- ⋆ LHO: 130 Mpc, LHO: 170 Mpc BNS range. Duty cycle: LHO 69%, LLO 72%
- ⋆ Virgo: technical problems in reaching planned high sensitivity (best $\geq$ 50 Mpc BNS range, but $\approx$ 90% duty cycle)
- ⋆ KAGRA: bad luck (large earthquake on 1 Jan 2024)

→ Start of ER16 on 13 March 2024 and start of O4b on 27 March 2024.

O4a run: 24 March 2023 - 16 January 2024

LIGO/Virgo/KAGRA Public Alerts

- More details about public alerts are provided in the LIGO/Virgo/KAGRA Alerts User Guide.
- Retractions are marked in red. Retraction means that the candidate was manually vetted and is no longer considered a candidate of interest.
- Less-significant events are marked in grey, and are not manually vetted. Consult the LVK Alerts User Guide for more information on significance in O4.
- Less-significant events are not shown by default. Press "**Show All Public Events**" to show significant and less-significant events.

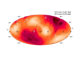
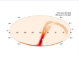
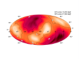
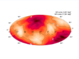
O4 Significant Detection Candidates: **81** (92 Total - 11 Retracted)

O4 Low Significance Detection Candidates: **1610** (Total)

Show All Public Events

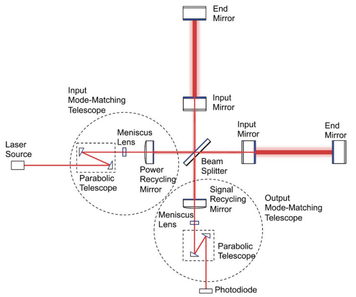
Page 1 of 7. next last »

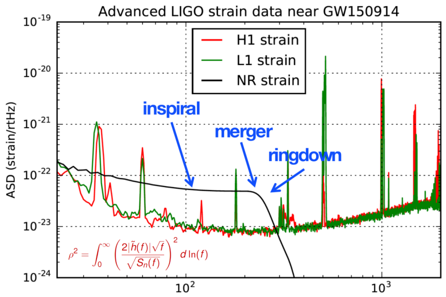
SORT: EVENT ID (A-Z)

Event ID	Possible Source (Probability)	Significant	UTC	GCN	Location	FAR	Comments
S240109a	BBH (99%)	Yes	Jan. 9, 2024 05:04:31 UTC	GCN Circular Query Notices | VOE		1 per 4.3136 years	
S240107b	BBH (97%), Terrestrial (3%)	Yes	Jan. 7, 2024 01:32:15 UTC	GCN Circular Query Notices | VOE		1.8411 per year	
S240104bl	BBH (>99%)	Yes	Jan. 4, 2024 16:49:32 UTC	GCN Circular Query Notices | VOE		1 per 8.9137e+08 years	
S231231ag	BBH (>99%)	Yes	Dec. 31, 2023 15:40:16 UTC	GCN Circular Query Notices | VOE		1 per 3.7932e+06 years	

https://gracedb.ligo.org/superevents/public/O4

Virgo in O4a and O4b





- ⋆ Better sensitivity at high frequency thanks to the signal recycling, worst sensitivity at low and mid frequencies (80-200 Hz)
- ⋆ excess broadband noise in ”the bucket” impacts the BNS range. . .
- ⋆ Good news: 1.1 glitches/minute in O3b, now 0.15/minutes; many glitch families under control (subtracted/mitigated)

2023 management & coordination

Last year my roles were

- ⋆ LIGO-Virgo-KAGRA co-chair of one of 4 main working groups (CBC, Burst, CW, Stochastic - since July 2021),
- ⋆ Virgo Executive Committee member (since Nov 2022)
- ⋆ ~~Work group leader, COST action `G2Net` (Machine learning for GW astrophysics), 2018-2023~~

Other CAMK members' roles:

- ⋆ T. Bulik: Virgo Steering Committee (VSC), current OPUS NCN grant leader

2023 paper output

13 LVK or Virgo-only publications:

1. Abbott, R., et al., „GWTC-3: Compact Binary Coalescences Observed by LIGO and Virgo during the Second Part of the Third Observing Run", Physical Review X 13 041039 (2023)
2. Abbott, R., et al., „Search for Gravitational Waves Associated with Fast Radio Bursts Detected by CHIME/FRB during the LIGO-Virgo Observing Run O3a", The Astrophysical Journal 955 155 (2023)
3. Acernese, F., et al., „Virgo detector characterization and data quality: results from the O3 run", Classical and Quantum Gravity 40 185006 (2023)
4. F Acernese, et al., „Virgo detector characterization and data quality: tools", Classical and Quantum Gravity 40 185005 (2023)
5. Fletcher, C., et al., „A Joint Fermi-GBM and Swift-BAT Analysis of Gravitational-Wave Candidates from the Third Gravitational-wave Observing Run", arXiv e-prints arXiv:2308.13666 (2023)
6. Abac, A. G.,et al., „Search for Eccentric Black Hole Coalescences during the Third Observing Run of LIGO and Virgo", arXiv e-prints arXiv:2308.03822 (2023)
7. Abbott, R., et al., „Open Data from the Third Observing Run of LIGO, Virgo, KAGRA, and GEO", The Astrophysical Journal Supplement Series 267 29 (2023)
8. Acernese, F., et al., „Frequency-Dependent Squeezed Vacuum Source for the Advanced Virgo Gravitational-Wave Detector", Physical Review Letters 131 041403 (2023)
9. Abbott, R., et al., „Constraints on the Cosmic Expansion History from GWTC-3", The Astrophysical Journal 949 76 (2023)
10. Abbott, R., et al., „Search for gravitational-lensing signatures in the full third observing run of the LIGO-Virgo network", arXiv e-prints arXiv:2304.08393 (2023)
11. Acernese, F., et al., „The Advanced Virgo+ status", Journal of Physics Conference Series 2429 012039 (2023)
12. Abbott, R., et al., „Population of Merging Compact Binaries Inferred Using Gravitational Waves through GWTC-3", Physical Review X 13 011048 (2023)
13. Acernese, F., et al., „Advanced Virgo Plus: Future Perspectives", Journal of Physics Conference Series 2429 012040 (2023)

LVK-related short author list publications:

1. Królak, A., et al., „Search for postmerger gravitational waves from binary neutron star mergers using a matched-filtering statistic", Classical and Quantum Gravity 40 215008 (2023)
2. Haskell, B., & Bejger, M., „Astrophysics with continuous gravitational waves", Nature Astronomy 7 1160 (2023)
3. Pereira, J. P., Bejger, M., Haensel, P., & Zdunik, J. L., „Crustal Failure as a Tool to Probe Hybrid Stars", The Astrophysical Journal 950 185 (2023)

Machine Learning for GW astronomy

Various collaborations between LVK, CAMK/AstroCeNT, APC Paris and INFN:

- ⋆ Waveform prediction/recovery (with AstroCeNT)
- ⋆ GW events denoising (with APC),
- ⋆ Trigger generation & signal classification for one-detector period (with APC and INFN),

1. Bacon, P., Trovato, A., & Bejger, M., „Denoising gravitational-wave signals from binary black holes with a dilated convolutional autoencoder", Machine Learning: Science and Technology 4 035024 (2023)
2. Trovato, A., Chassande-Mottin, É., Bejger, M., Flamary, R., & Courty, N., „Neural network time-series classifiers for gravitational-wave searches in single-detector periods", arXiv:2307.09268 (2023)

Detecting GWs with ML (`arXiv:2307.09268`)

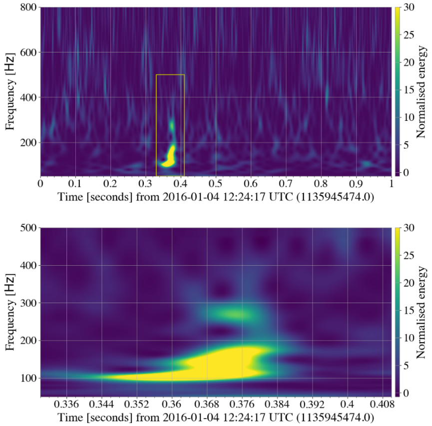


Figure 8. Time-frequency representation of the segment at 2016-01-04 12:24:17 UTC (GPS=1135945474 s) recorded by the LIGO Livingston detector. The top panel shows the entire segment. The bottom panel is a detailed view that focuses on the transient signal at $t \sim 0.37$ s. This representation is obtained through a constant-Q transform [55] with quality factor $Q = 12$. To facilitate comparison, the dynamic range is fixed, following a similar approach as described in [36], and the colormap is saturated at a maximum value of 30 for the normalized energy.

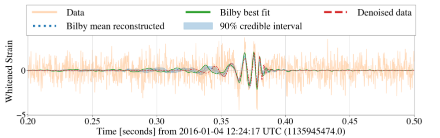


Figure 9. Comparison of the whitened L1 data (orange line) with the reconstructed waveform obtained from the posterior mean (dotted blue line), and from the maximum likelihood fit (solid green line) both computed using `Bilby`, and the 90% credible interval (blue) along with the ML denoising convolutional autoencoder neural network described in [81] (dashed red line).

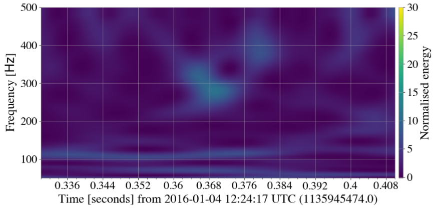


Figure 10. Time-frequency representation of the residual after the subtraction of the maximum likelihood fit waveform obtained with `Bilby` (green line in Fig. 9) from the data segment at 2016-01-04 12:24:17 UTC (GPS=1135945474 s). This representation adheres to the same settings as in Fig. 8, utilizing a constant-Q transform with a quality factor $Q = 12$ and the dynamic range is capped at a maximum of 30 for normalized energy, aligning with [36] to facilitate comparison. No excess power is visible in this plot.

Virgo@CAMK in LVK O4, O5 and beyond

- ⋆ Recent OPUS NCN "Science with Gravitational Waves in the Era of LIGO-Virgo-KAGRA Discoveries" (CAMK: 1.6M out of 4.4M total funding)

WP1. **Improvements of the Virgo detector sensitivity**

WP2. **GW data analysis and algorithms**

WP3. **Astrophysical modeling and interpretation of the data**

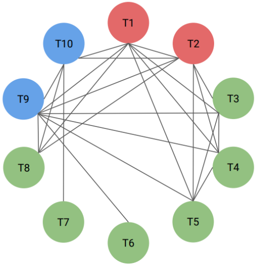


Figure 4: Synergies between the research tasks planned in this project. Tasks T0 and T11 are omitted in this diagram, as they are naturally connected to all other tasks.

Distribution of personpower between tasks:

CAMK: Bejger (T3-T6, T9), Ciecieląg (T3, T11), Haskell (T5, T9), Suchenek (T1), PhD-student1 (T3-T5, T9), post-doc1 (T3-T6, T9)

IMPAN: Królak (T3, T4, T6, T11), Tinto (T6)

NCBJ: Dorosh (T3, T5), Królak (T5, T11), Zadrożny (T7)

UwB: Jaranowski (T3, T4, T6, T11), Pisarski (T3, T4, T6)

UJ: Kubisz (T2), Ostrowski (T2, T11), Stawarz (T2, T11)

UW: Bulik (T0, T1, T2, T10, T11), Rosińska (T1, T8, T10, T11), Szczepańczyk (T8, T10), PhD student2 (T1, T2, T8,T10), post-doc2 (T1, T2, T10)

- ⋆ Application for financial resources for the implementation of the project under the "Support for the participation of Polish research teams in international research infrastructure projects" program (Ministry of Science)