SWG Gravitational Waves

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GW science (and its relation to Euclid)

The combination of GW and EM has proven to be crucial for cosmology and beyond

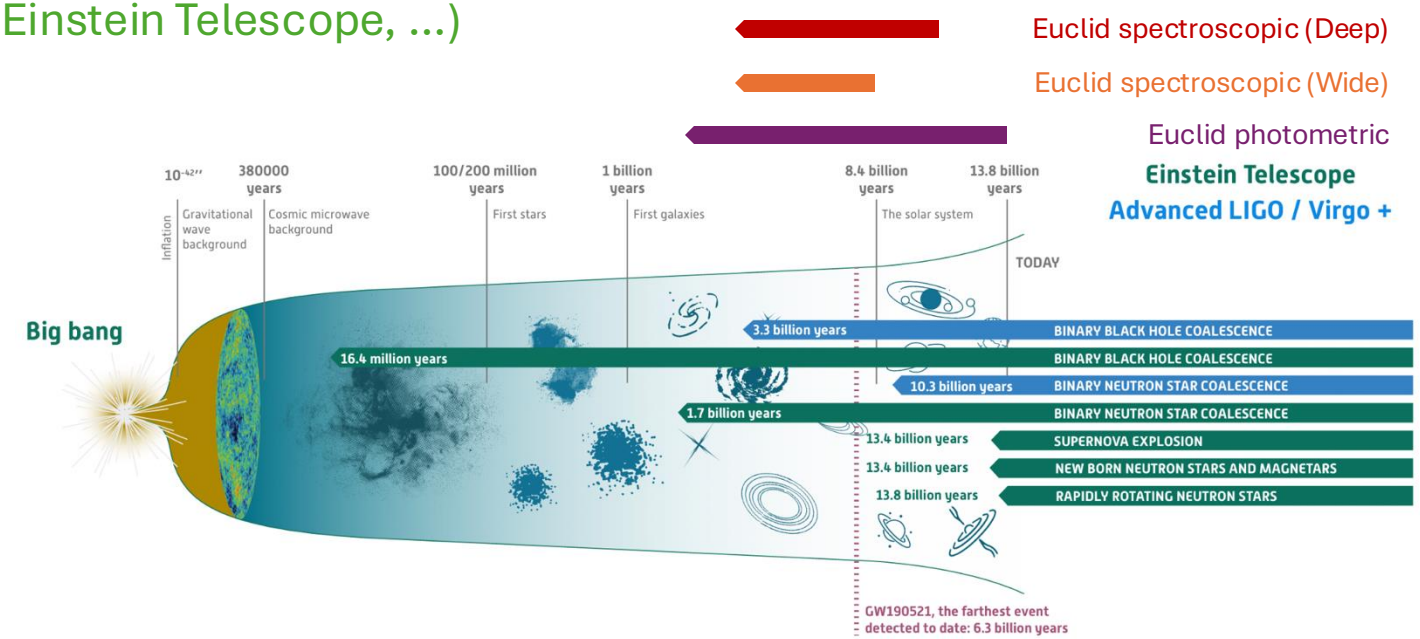
Euclid will provide a galaxy catalog with several extremely interesting applications, mapping on **all-sky** a range of **cosmic time** crucial for current and future GW observatories

- Having a **galaxy spectroscopic/photometric deep catalog** is crucial for GW cosmology

  → Euclid is in a unique position, and growing discussion about using it is ongoing in several GW collaborations (LVK, Einstein Telescope, …)

- Observing Run 4 for LVK is providing exquisite GW localizations (order of few square degrees) and DR1 is incoming

  → potential for significant discoveries



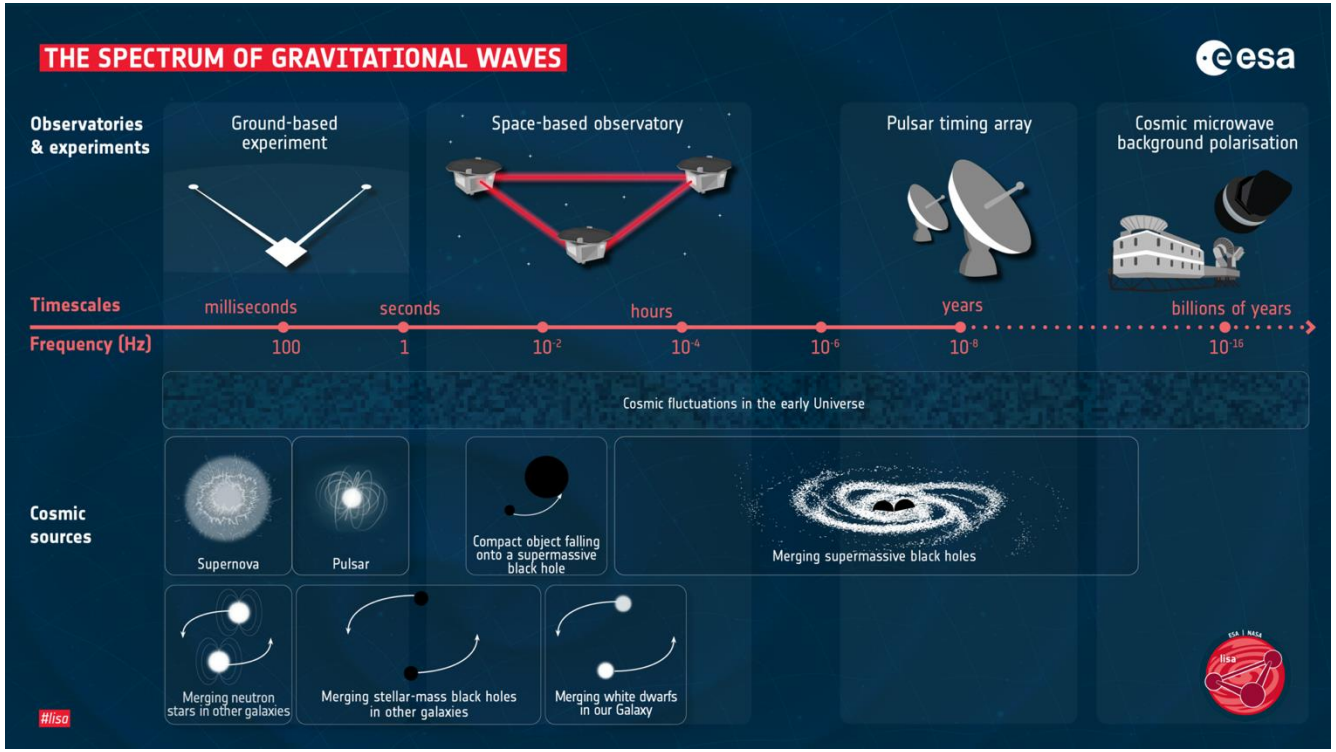
GW science (and its relation to Euclid)

Science now
Science in the future

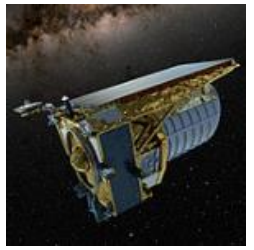
Several potential applications to be explored, both live or with future combinations:

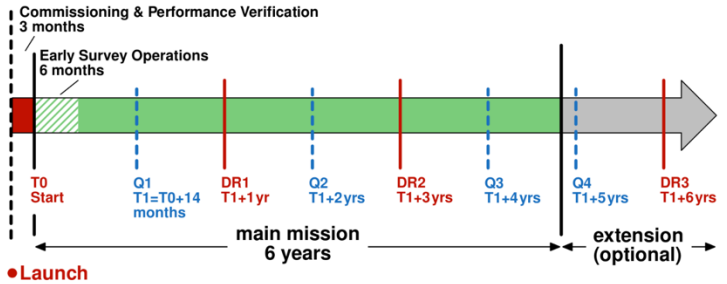
- **Dark siren analysis:** cross-correlation of galaxy catalogs with resolved GW events (LVK O3-O4-O5/ET/LISA + Euclid DR1/DR2/DR3)
- **Bright siren analysis:** detection of EM counterparts (LVK O3-O4 + Euclid DR1/DR2)
- **Cross-spectrum of galaxies and GWs:** combination at the level of statistics (LVK O3-O4-O5/ET + Euclid DR1/DR2/DR3)
- **Lensing:** explore combined information (LVK O3-O4-O5/ET + Euclid DR1/DR2/DR3)
- **Unresolved GW background:** x-correlation (LVK/Pulsar timing arrays + Euclid)

… and many others…

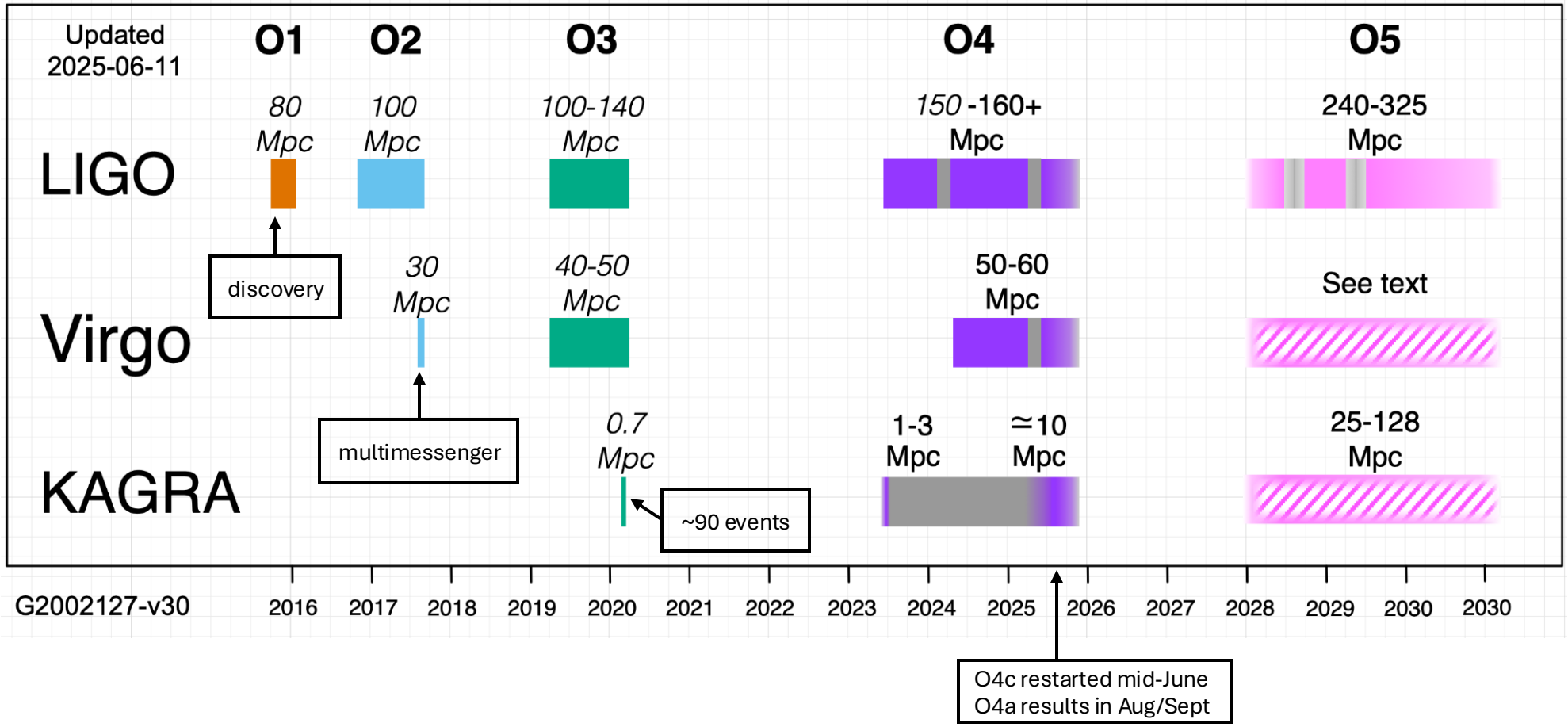


Timeline




Commissioning & Performance Verification
3 months
Early Survey Operations
6 months
T0
Start
Q1
T1=T0+14
months
DR1
T1+1yr
Q2
T1+2yrs
DR2
T1+3yrs
Q3
T1+4yrs
Q4
T1+5yrs
DR3
T1+6yrs
main mission
6 years
extension
(optional)
Launch


Livingston
Hanford


Updated
2025-06-11
O1
O2
O3
O4
O5
LIGO
80 Mpc
100 Mpc
100-140 Mpc
150 -160+ Mpc
240-325 Mpc
discovery
Virgo
30 Mpc
40-50 Mpc
50-60 Mpc
See text
multimessenger
KAGRA
0.7 Mpc
1-3 Mpc
≃10 Mpc
25-128 Mpc
~90 events
G2002127-v30
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2030
O4c restarted mid-June
O4a results in Aug/Sept

Organization of the SWG

Leads: Michele Moresco (michele.moresco@unibo.it), Miguel Zumalacarregui (mzuma@aei.mpg.de)

Members (75 so far): Alessandra Silvestri, Alessandro Pedrotti, Andrea Francesco Maria Enia, Benjamin Granett, Carlos Martins, Carmelita Carbone, Chiara De Leo, Claudia Scarlata, Daniel Roberts, Divya Rana, Eliana Palazzi, Elsa Teixeira, Enrico Cappellaro, Enzo Branchini, Enzo Brocato, Eric KAJFASZ, Fabio Finelli, Federica Tarsitano, Filippo Mannucci, Francesco Pace, Gabriella De Lucia, Guillaume Mahler, Hubert Degaudenzi, Irene Salmaso, Jose M. Diego, Julien Bel, Kerry Paterson, Lauro Moscardini, Lorenzo Ulivi, Louis Legrand, Luca Izzo, Maria Teresa Botticella, Matteo Martinelli, Michele Cantiello, Michele Mancarella, Michele Moresco, Miguel Zumalacarregui, Nicola Borghi, Salvatore Quai, Sarah Ferraiuolo, Simone Mastrogiovanni, Stephanie Escoffier, Tessa Baker, Vincenzo Petrecca, Daniele Bertacca, etc...

Wikipage: https://euclid.roe.ac.uk/projects/swg-grav-waves/wiki/Wiki

Project page: https://euclid-projects.org/groups/374/overview/

Minutes: https://euclid.roe.ac.uk/projects/swg-grav-waves/wiki/SWG-GW_Telecons

Slack channel: https://euclidconsortium.slack.com/archives/C08CBHAN2G7

Regular telecon: third Monday of each month at 15:00 CEST -> Monday 21st July

WP structure

Given the areas of interest expressed at the kick-off telecon, for the moment we thought to open the following WPs. All of them refer to the combination of GW+Euclid data.

WP1: Dark Sirens (including cosmography, dark sirens analysis, lensing, GW x LSS, the use of clustering to assess the completeness of the sample, ...).
Co-lead: M. Mancarella + TBD

WP2: Bright Sirens (including GW transients with EM counterparts).
Co-lead: M.Zumalacarregui (ad interim) + TBD → Joint activity with SWG-SNe and Transients

WP3: Unresolved GW Foreground (PTA, stochastic, ...).
Co-lead: G. Domenech + TBD

WP4: Theory (test of DE, GR).
Co-leads: A. E. Romano, D. Bertacca → Joint activity with SWG-Theory

WP5: Simulations (N-body, galaxy catalogs, GW catalogs, could also provide sims to the group TBD).
Co-lead: C. Lovell + TBD

N.B. SWG-GW has been explicitly created to coordinate all activities related to GW, so anything related to GW has to be reported here. Joint activity is to ensure a better coordination.

GW-SWG activities so far

- Started in February, kick-off telecon Mar 7th
  - overview of ongoing projects
  - ideas for directions, WPs…
- Regular monthly telecoms started in May (see wiki)
  - more in-depth presentation of each project
  - update on the status of Euclid surveys (photo and spectro)
- Defined WPs and started recruiting coordinators
- 1 Standard project “Predicting the Stochastic Gravitational Wave Background from Compact Binary Mergers” (+ others on their way)
- Development of visualization tools to monitor overlap of Euclid areas and GW events (in progress)
- Effort in putting Euclid in the radar of current/future GW facilities (e.g. talk at the ET Symposium)

GW-SWG science highlights

- Already 12 projects ongoing (+ additional presented when collecting interest in the preliminary phase before the creation of SWG-GW), both well advanced, ongoing or ideas

- Projects are divided between directly Euclid-related (based on observed/simulated data) vs Euclid-like (or generic stage-IV, also outside EC)

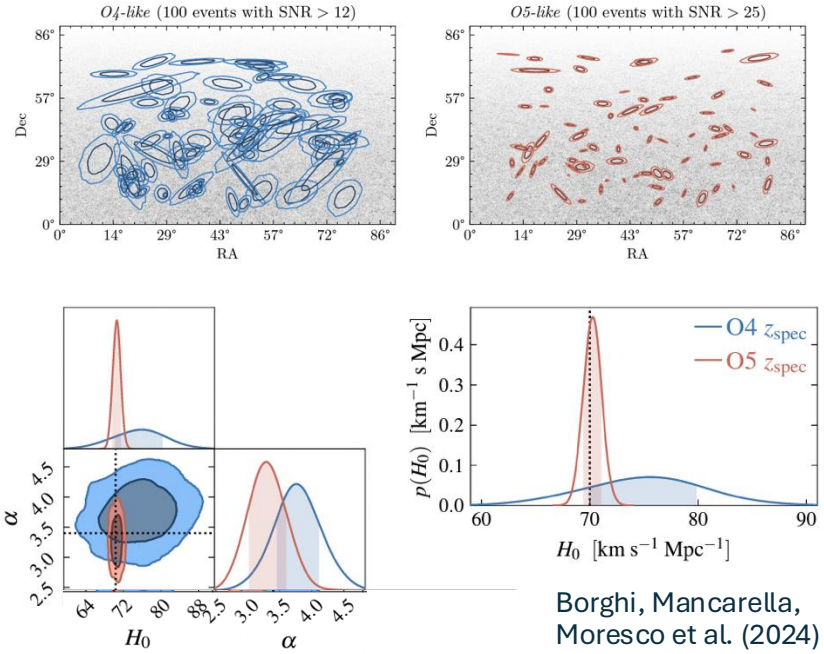
- Significant expertise within the SWG to perform the analysis, at the level of:
  - Simulations (multiple under development)
  - Analysis codes (at least 2/3 to do standard sirens analysis, but not only…)
  - Integration with other facilities (LVK, ET, LISA, …)

- The importance Flagship Simulations (inside and outside) → several requests are starting to arrive also from collaborations outside Euclid

GW-SWG science highlights

Dark siren analysis

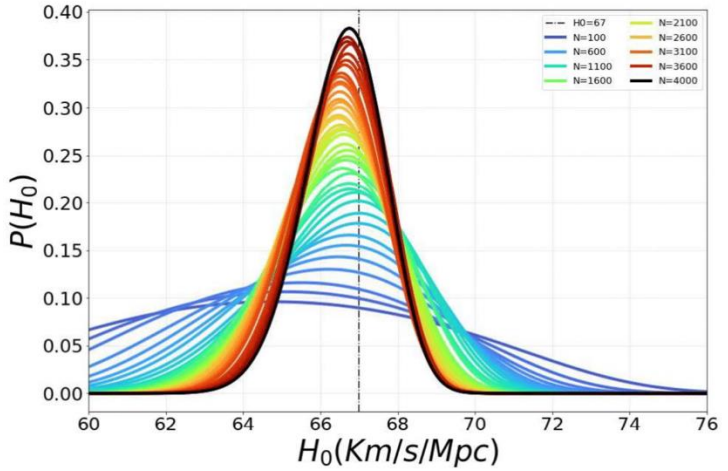
- Combination of GW events + Euclid galaxy catalog to constrain cosmological and astrophysical parameters
- Plan to explore several combinations: Euclid+ET (based on simulations), Euclid DR1+LVK O3-O4 (based on real data), Euclid EDS + LVK O5 (based on simulations), …
- Work ongoing in several groups
  Bologna (Borghi, Moresco, Cimatti), **Genova+Milano** (Ciancarella, Branchini, Carbone), **Roma+Marseille** (Ferraiuolo, Mastrogiovanni, Escoffier, …)



Borghi, Mancarella, Moresco et al. (2024)

Bright siren analysis

- Identification of EM counterpart of binary neutron star or neutron star-black hole binary (kilonova)
- Work ongoing also in SWG- SNe and Transients
  INAF (L. Izzo, M.T. Botticella, E. Cappellaro, V. Petrecca, I. Salmaso, E. Brocato, F. Mannucci) + (INFN, UNIROMA1, GSSI, UNINA – IT)



Ciancarella, Branchini, Carbone et al. (in prep)

GW-SWG science highlights

Stochastic background

- Cross-correlate stochastic GW background with galaxy counts to predict the signal from LVK binaries using Euclid data
  Minnesota (K. Yang, C. Scarlata, V. Mandic)

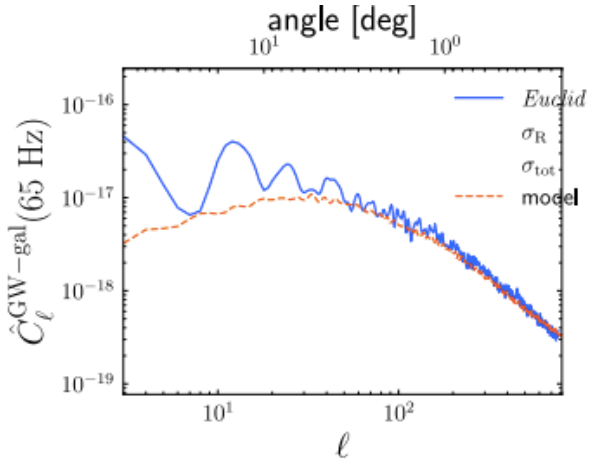
Cross-Correlations of GWs and LSS

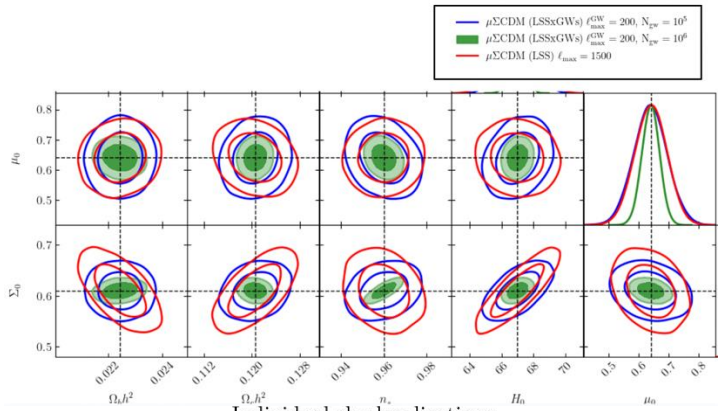
- Forecast the detectability of Modified Gravity signatures with the combination of future GW (ET+CE) and LSS (Stage IV) data
  ESA + Lorentz Institute + Rome Observatory (C. De Leo, M. Martinelli, G. Cañas-Herrera, A. Balaudo, A. Silvestri, T. Baker)

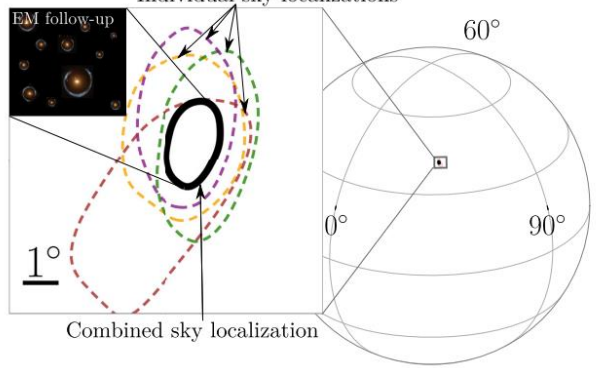
Lensing + GW

- Improve the identification of lensed GWs by cross-correlating with known lenses (e.g. Euclid galaxy & clusters
  AEI (M. Zumalacarregui)

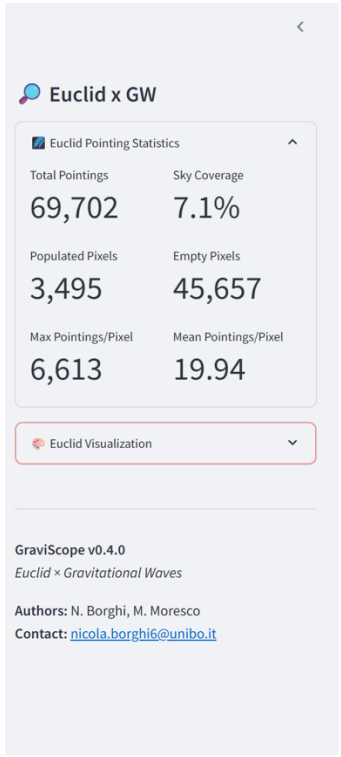
+ many others…



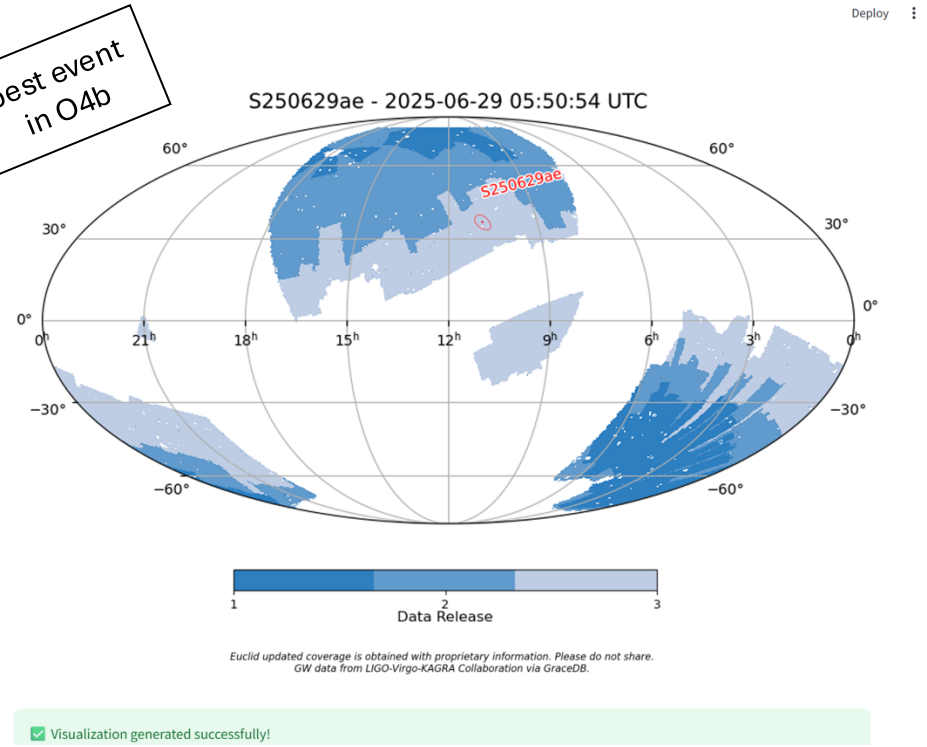


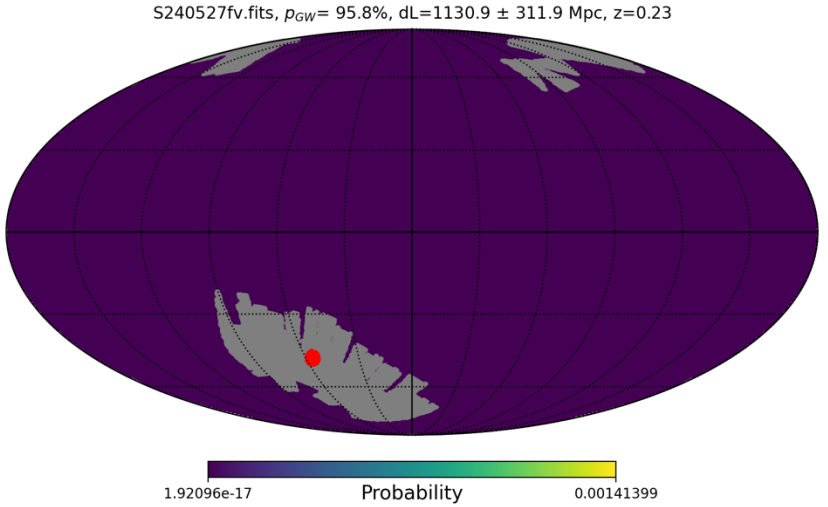


Euclid X GW visualization tools

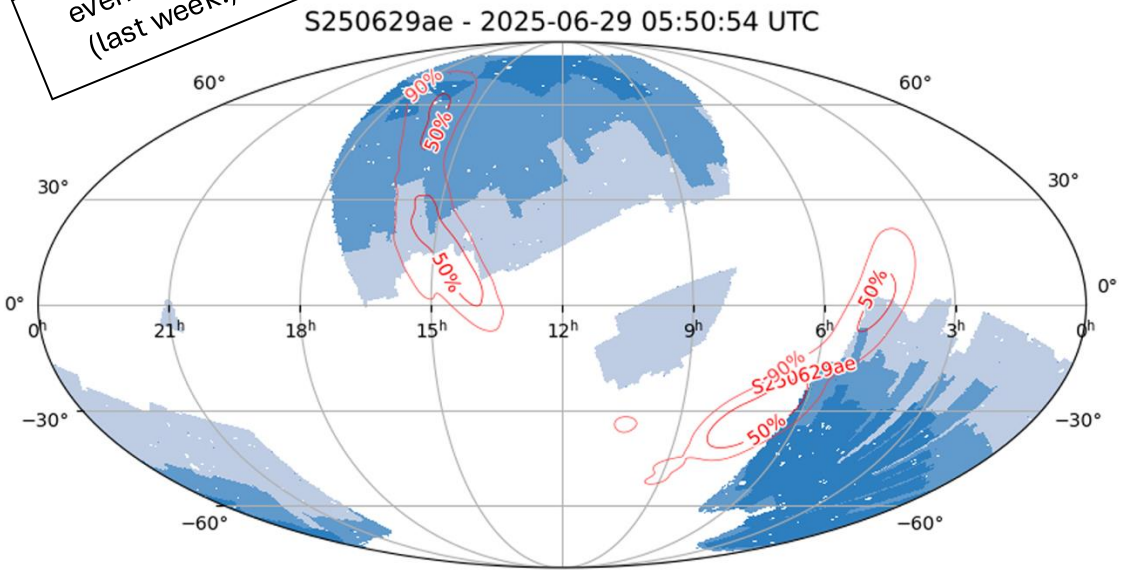


best event in O4b





event in O4c (last week!)



Possibility to explore in real time overlap of events

work ongoing by N. Borghi and Sarah Ferraiuolo (see next SWG-GW telecon)

Next steps

- Investigate MOU with LVK
- Continue overview of ongoing projects, and open associated Standard Projects
- Extend interaction with other SWG (e.g. SWG-Sne and Transients)
- Re-open a call for missing WP coleads
- Monitor the overlap of GW events with Euclid DR1
- Create a framework for GW simulations in Euclid

If you are interested, send us an email!

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